BIOLOGY

Paper 9700/11
Multiple Choice

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

General comments

Questions 6, **10**, **11**, **18**, **23**, **25**, **30**, **31** and **39** focused on knowledge and understanding and were found to be relatively straightforward. **Questions 3**, **4**, **5**, **9**, **13**, **27** and **33** were more challenging and the most difficult of these required candidates to draw together different pieces of information and apply their knowledge, sometimes to unfamiliar contexts.

Comments on specific questions

Question 3

Most candidates answered this question correctly, selecting option **A**. The most popular incorrect answer was option **D**. These candidates knew that rough endoplasmic reticulum and mitochondria contained nucleic acids and needed to consider nucleic acids such as tRNA and mRNA that are in the cytoplasm.

Question 4

Slightly more candidates selected option **D**, rather than the correct answer, option **C**. Capsids, found only in viruses, was the only option that was not associated with genetic material. Very few candidates thought that introns (option **A**) or telomeres (option **B**) were found in bacterial cells, suggesting a good knowledge of some aspects of the bacterial genetic material. Many candidates needed to apply their understanding of transcription and protein synthesis to realise that bacterial cells would transcribe RNA from a template strand.

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Question 5

About one fifth of the cohort selected the correct option, **D** (four hydrogen bonds), with slightly more candidates suggesting that there was a maximum of two hydrogen bonds (option **B**) between a single water molecule and other water molecules. This question required candidates to think about the three-dimensional structure of a water molecule in the liquid state, where one hydrogen bond can form between each of its hydrogen atoms and other water molecules, and two other water molecules can form hydrogen bonds with the two lone pairs associated with its oxygen atom.

Question 9

Slightly more candidates calculated the correct mass of haemoglobin from the data as 64.5 kDa (option **D**) than those who incorrectly calculated it as 31.6 kDa (option **A**). Candidates who chose option **A** thought that there was only one each of the α–globin chain, β–globin chain and the haem group in a haemoglobin molecule. Very few candidates who had accounted for both α–globin and β–globin chains made the error of only adding one haem group in their calculation (option **C**).

Question 13

Many candidates found this applied question on the cotransporter mechanism difficult. Candidates were required to compare their knowledge of the cotransporter mechanism in phloem with a diagram of a cotransporter moving nicotine and protons in and out of the blood plasma. Although slightly more candidates opted for the correct answer, option **B**, similar numbers of candidates selected each of the three other options.

Question 15

This question on osmosis required candidates to apply their knowledge in a practical context to the observations of two microscope slides that contained some blood cells and different concentrations of salt. Approximately half the cohort correctly identified the explanations for the results on the two microscope slides (option **B**), with no clear pattern in the incorrect options selected by the other candidates.

Question 17

Although most candidates knew that stems cells can give rise to phagocytes, only half of the candidates also realised that stem cells cannot repair cells (option **D**). Any damaged cells would need to be replaced.

Question 27

This challenging question required candidates to identify two points on a graph of the volume in the ventricles during the cardiac cycle and connect this information with the opening and closing of the valves. Slightly more candidates selected the correct option (**A**) than chose the next most popular options, **B** or **C**. Very few candidates suggested that both valves would be open at the transitions between the systole and diastole (option **D**).

Question 33

Almost all candidates knew that a continual supply of deoxygenated blood by the pulmonary artery helps to maintain the concentration gradient of gases in the lungs. Slightly more candidates incorrectly suggested that the recoil of elastic fibres in the walls of the alveoli is not involved (option **B**), than correctly attributed this mechanism to the maintenance of the gradient (option **A**).

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Paper 9700/12
Multiple Choice

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

General comments

Questions 1, **2**, **3**, **5**, **6**, **8**, **14**, **19**, **33** and **35** were found to be straightforward. In contrast, candidates found **Questions 4**, **7**, **11**, **12**, **13**, **26**, **31** and **39** relatively difficult. Some of the least challenging questions came from the topic of cell structure, whereas some of the more challenging questions were associated with protein structure, or the properties of specific proteins including enzymes, haemoglobin, and antibodies. Other questions where many candidates did not select the correct option required particularly careful reading or precision of knowledge about the topic.

Comments on specific questions

Question 4

Many candidates answered this correctly, selecting option **C**. Some candidates chose the incorrect options **B** and **D**, and needed to have read the key for the cross more carefully.

Question 7

Many candidates answered this correctly, selecting option **D**. Of the candidates who answered incorrectly, many selected option **A**. These candidates were able to identify that statement 3 was true and needed to be more familiar with the role of tRNA during translation.

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Question 11

This question required candidates to determine the affinity of three enzymes for their substrates from an enzyme kinetics graph. Nearly half of the cohort knew how to find K_m and knew that a lower K_m corresponded to a higher affinity for the substrate, so correctly selected option **B**. Some candidates confused K_m with V_{max} and selected option **C**. A similar proportion thought that the gradient of the initial curve showed enzyme affinity, and so selected option **A**.

Question 12

A common misconception identified in this question was that candidates believed that hydrogen bonds are strong bonds within the tertiary and quaternary structure of a protein, with a considerable number of candidates opting for **A**, over the correct option, **B**.

Question 13

Many candidates also found this question on the structure and function of haemoglobin difficult. Candidates needed to read the descriptions in the rows carefully.

Question 16

Many candidates correctly selected option **C**. A considerable number of candidates selected option **B**; although they were familiar with the process of osmosis, they had not observed that the red blood cell labelled in the photomicrograph was shrivelled because that option correctly described the movement of water when blood cells swell and burst.

Question 26

Option **C** proved to be a strong distractor in this question on the movement of solutes in the symplast pathway. These candidates were not aware that mineral ions dissolve in water readily or that the apoplast pathway is not selective.

Question 27

A number of candidates incorrectly selected option **A**. Although this option was a correct statement, it did not explain why water molecules are forced to move through xylem vessel elements as a consequence of transpiration.

Question 31

Many candidates found this question on determining the minimum number of times a carbon dioxide molecule crosses a cell surface membrane a challenge. Some candidates needed to take more careful note of the information provided to them in the stem of the question.

Question 39

Some candidates incorrectly selected options **B** or **C** for this question on antibodies, statements that were not relevant to the properties of the antigen-antibodies binding sites.

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Paper 9700/13
Multiple Choice

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

General comments

Questions 6, **8**, **13**, **15**, **16**, **18**, **22**, **31** and **33** were found to be relatively straightforward and came from a range of topics across the syllabus. They used a range of question styles, from a list of options relying on knowledge and understanding to some applied questions with graphical information. **Questions 4**, **5**, **9**, **12**, **23**, **24** and **27** were more challenging and required very careful reading of the options, particularly where it was necessary to select a combination of correct and relevant statements from a list.

Comments on specific questions

Question 4

This question required candidates to draw together their knowledge of the functions of the four cells listed with the cell structures that would be necessary to carry out those functions. Almost half of the candidates correctly selected the goblet cell (option **B**), realising that it would have many cell structures bound by a single membrane, including secretory vesicles, rough endoplasmic reticulum, and Golgi bodies. A significant number of candidates opted for the red blood cell (option **C**).

Question 5

A few candidates read this question carefully and correctly attributed the cause of the polarity of phosphate heads to them becoming ionised in water (option **C**). A considerable number of candidates incorrectly selected option **A**. Although this is a true statement, it does not answer the question.

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Question 6

Although many candidates identified that only statement 2 described a feature of cellulose that contributes to its function (option **D**), a number of candidates incorrectly thought that statement 3 was also correct (option **C**).

Question 9

Many candidates knew that the quaternary structure of a protein depends on the primary structure of the polypeptides (option **C**). Options **A** and **D** were both popular incorrect answers.

Question 12

The precise detail of the Michaelis-Menten constant was correctly understood by approaching half of the cohort (option **B**). The popular incorrect answers highlighted a common misconception about K_m (option **C**) and a confusion between K_m and V_{max} (option **D**).

Question 23

Almost all candidates selected statement 1 as a description of translation. Although this was the only correct statement (option **C**), many of these candidates incorrectly thought that either statement 2 or 3 (options **A** and **B**, respectively) were also correct and relevant. Questions where candidates must make a choice between different combinations of options, require very careful reading of each statement to check for its relevance and accuracy. In this case, statement 2 is not relevant because it is describing part of transcription, not translation, and statement 3 is incorrect because hydrogen bonds, not peptide bonds, form between anticodons and codons.

Question 24

Very few candidates selected options **B** or **D**, and hence did not confuse the pairing of adenine with thymine and uracil. A considerable number of responses confused the template strand with the non-transcribed strand and chose option **A** rather than the correct option, **C**.

Question 27

Many candidates found this question on drawing and labelling a sieve tube element from an electron micrograph challenging. The majority correctly selected option **C**. A similar number of responses selected either option **A** or **D**, suggesting that some candidates did not observe the cytoplasm seen adjacent to the side walls, or incorrectly thought that the dark stained structures in the centre of the sieve tubes were mitochondria.

Question 29

Half of the cohort correctly identified arrow **B** as the atrial systole on the graph showing the pressure changes during two cardiac cycles. Some candidates realised that the pressure in the atria is much lower than the pressure in the ventricles and opted for arrow **C**, whereas others confused atrial systole with ventricular systole and opted for arrow **A**.

Question 40

Almost all candidates correctly identified statement 1 as an explanation as to why it is possible to have influenza more than once. Some candidates did not realise that both statements 2 and 3 are also correct explanations for this phenomenon. These candidates incorrectly selected either option **B** or **C** rather than the correct option, **A**.

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Paper 9700/21
AS Level Structured Questions

Key messages

Candidates should take care when writing units; in **Question 1(a)(i)**, nm often looked like μm. Writing the full compound unit in descriptions of the rate of transpiration in **Question 5(a)** gave many candidates problems as they did not write out the unit in full as mmol m^{-2} s^{-1}.

There were several questions on this paper that required candidates to make comparisons. In **Question 2(c)(ii)**, the structure of a muscular artery had to be compared with the structure of an arteriole visible in the transmission electron micrograph of a cross-section of an arteriole. **Question 5(a)** asked candidates to compare transpiration rates of two plants shown in a graph. These questions did not specifically ask for similarities and/or differences and so candidates were free to give similarities and differences that could be credited. Candidates must give a response where a comparison is obvious: in **Question 2(c)(ii)**, many gave statements about muscular arteries, such as they are thick walled, without making their comments comparative. Candidates who gave strong answers in **Question 5(a)**, looked for patterns and/or trends and made sure that each statement they made was comparative.

Responses to **Question 6(a)(i)** highlighted that some candidates needed a clearer understanding of the difference between the mode of action of antibodies and the mode of action of enzymes. Candidates wrote about active sites and substrates rather than antigen-binding sites and antigens. Many also included the term 'lock and key' in these answers, showing that they appreciated the importance of molecular shape in the formation of antigen-antibody complexes, but then used the wrong terms for the two structures that bind together.

General comments

Candidates should check that they are answering all of the questions, as some on this paper missed **Question 1(b)(i)**. They should look down the right-hand side of the paper to find the mark allocations as a way to check that they have answered each question.

Candidates who had carefully read the stimulus material accompanying **Question 3(b)** were able to use the information provided to understand that there were two aspects of the inhibition of reverse transcription by the drug tenofovir. Many left this question unanswered or provided vague responses, showing that they had not assimilated the information given.

In **Question 3(b)**, the term 'stop codon' was often used incorrectly. Some thought that the role of tenofovir as an inhibitor meant that it acted as a stop codon.

In **Question 3(c)(ii)**, which was based on the transmission of HIV, many candidates wrote about precautions that are more suitable for reducing transmission of respiratory diseases rather than HIV. A number of answers suggested making sure everyone received a vaccine, when there is no vaccine currently available for HIV. It was also common to find candidates stating that people with HIV should be placed into quarantine, when this too is not appropriate.

Questions are often set in specific contexts. Some candidates thought that **Question 4(c)** was about stem cells so gave information about their role, rather than concentrate on the function of centrioles in cell division as required by the question. Others wrote a lot of information about mitosis, describing the movement of chromosomes instead of the way centrioles control the spindle fibres to bring about this movement.

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Comments on specific questions

Question 1

(a) (i) The most popular answer for the thickness of the membrane in **Fig. 1.1** was 7 nm. Any answer between 5 nm and 10 nm was accepted, as were ranges of measurements, such as 6–8 nm. Some candidates gave 7 but followed it with the wrong unit, usually μm.

(ii) Many candidates completed **Table 1.1** correctly, often with considerable detail. When facilitated diffusion was not given as the answer to row 1 there was often a suitable description of the process. Many candidates chose **C** rather than **A** in the first row: **C** is a carrier protein, not a channel protein. The simplest answer for the phospholipids in row 2 was 'forms a bilayer', and many referred to their role in forming a barrier to the movement of water-soluble substances. Glycoproteins and glycolipids were accepted for the receptor for cell signalling. Some candidates gave **B** and **D** in the final column for the receptor. This was accepted if both glycoprotein and glycolipid were given in the first column in the same order. Common answers for cholesterol in row 4 were providing stability and maintaining fluidity of the membrane. Many also stated that cholesterol regulates or maintains 'cell fluidity'. Many described the phospholipid molecule rather than describing its function in the cell surface membrane.

(b) (i) Many candidates drew recognisable drawings of the three organelles. Errors included: showing ribosomes inside the cisternae of the rough endoplasmic reticulum or across the membrane; drawing a mitochondrion with three membranes, not two; and showing the cisternae of both rough endoplasmic reticulum and smooth endoplasmic reticulum as single lines. Some labelled one of the drawings of chloroplasts as a mitochondrion instead of following the instruction to draw the organelle.

(ii) Most candidates correctly gave the answer as Golgi body. 'Golgi' on its own did not gain credit, but Golgi apparatus or Golgi complex was acceptable. There were many good answers for the function of this organelle, including glycosylation of proteins. Quite a few gave the incorrect answer 'protein synthesis' as the function.

Question 2

(a) This question focused on two properties of water that make it suitable as the main component of blood. Most candidates stated that water is a good solvent and listed some of the substances that are transported in solution in the blood, such as glucose, albumen, and hydrogencarbonate ions. Some candidates only stated that water was a solvent and could gain credit if they explained that ions and polar molecules are dissolved in water. A few gave an example of a substance transported in solution in the plasma and linked it with a reason. The other property that is relevant to blood is the high specific heat capacity of water. Many related this to the importance of maintaining the constant temperature of the blood. Credit was not given to those who omitted 'specific' and only stated that water has a 'high heat capacity'. It was not relevant in this question to refer to the latent heat of vaporisation. Some candidates wrote about cohesion and adhesion, which is relevant to transport in the transpiration stream, but not in the blood stream.

(b) (i) Most candidates stated the aorta for **P** and the vena cava for **Q** and most spelled these correctly. Venae cavae was also accepted. The most common error was to label **P** as pulmonary artery and **Q** as pulmonary vein.

(ii) Most candidates stated that the aorta (**P**) carries oxygenated blood to the organs or to the body. It was taken that this referred to the systemic circulation and did not include the lungs, although it is ideal for candidates to write 'to the body except to the lungs'. Most stated that the vena cava (**Q**) carries deoxygenated blood to the heart. Candidates who referred to the blood pressure in these vessels rather than to the degree of oxygenation gained credit. Candidates should be aware that arteries and veins do not pump blood.

(iii) The great majority of candidates gained full credit by explaining why the mammalian circulation is described as a closed, double circulation. Some lost credit by writing simply 'blood flows through the heart twice' without further qualification that this happens in each circulation or circuit of the body.

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(c) (i) Many candidates did not realise that they needed to explain why blood pressure decreased as it flows through arterioles because it then flows through capillaries. Good answers explained that capillaries have walls composed of a single layer of cells which is very thin and would burst at the pressure of blood as it enters the arterioles. A common error was to write about the 'cell walls' of the capillaries. Another very common error was to write 'capillaries are one cell thick'. Candidates also pointed out that blood flows more slowly through capillaries to allow more time to achieve the efficient exchange of substances. Those candidates who wrote about arterioles bursting had not answered the question.

(ii) Candidates were asked to compare the structure of a muscular artery with the arteriole shown in the transmission electron micrograph in **Fig. 2.2**. Credit was available for similarities between the two blood vessels as well as differences; answers that only dealt with the differences could gain full credit. Many candidates made three correct statements. The most common were the wider lumen and thicker wall of the muscular artery and its larger quantity of smooth muscle. Many candidates omitted the word smooth so did not gain credit. Candidates also stated that the muscular artery has more collagen and elastic fibres. Both blood vessels have a folded or 'crinkly' endothelium or tunica intima; some candidates stated that the endothelium of the arteriole was 'crinkly', but this was not accepted as a difference between the two. Some candidates referred to 'elastic muscle' rather than to smooth muscle.

Question 3

(a) Candidates needed to complete the flow chart in **Fig. 3.1**. Details of malaria were better known than the others. Species names were spelled correctly by many and were required for credit to be awarded. The most common spelling errors for *Mycobacterium* were Myobacterium and Microbacterium. A number spelled *Vibrio* as Vibro and/or *cholerae* as cholera. Most of the candidates who named *Mycobacterium bovis* as the causative species for tuberculosis correctly referred to transmission in contaminated meat or contaminated milk. The full binomial species names were required so those who only gave the first letter of the genus did not gain credit.

(b) This question on one of the drugs used to treat people living with HIV was made clearer and easier for those who considered all of the information provided, including the structure of tenofovir and deoxyribose adenosine monophosphate shown in **Fig. 3.2**. Those who noticed the similarity between these two molecules gained credit for stating that tenofovir acts as a competitive inhibitor. Some correctly deduced that the phosphorylated form of tenofovir does not simply occupy the active site of reverse transcriptase, it also takes part in the reaction, being added to a lengthening DNA strand. More observant candidates worked out that tenofovir has no pentose and thus no –OH group attached to a 3' carbon so a phosphodiester bond cannot form and no further nucleotides can be added. This proved a challenging question for many and only the strongest candidates gave clear explanations.

(c) (i) The only answer accepted was 20. The question asked for a whole number so any answer with decimal places, such as 20.16 or 20.2, did not gain credit. Many candidates did not use the information provided in the question correctly so that there were often answers well above 100%.

(ii) In this question, candidates were asked to state and explain how health authorities can reduce the transmission of HIV. Overall, the candidates identified about nine or ten different strategies employed by health authorities. These included providing sterile needles and syringes to intravenous drug abusers; making sure that all instruments used in medical procedures are sterilised; providing testing facilities for those at risk of being infected with HIV and carrying out contact tracing. Many candidates mentioned providing information to those at risk and to the general population about transmission and also the treatments that are available. To gain full credit, candidates had to have at least one example of a strategy and at least one suitable explanation in terms of reducing the transmission of HIV. Many candidates only wrote about measures that individuals can take, which does not answer the question.

Question 4

(a) (i) Many candidates identified cell **A** in **Fig. 4.1** as a ciliated epithelial cell. A common error was to give the tissue, ciliated epithelium, rather than name the type of cell. More candidates correctly identified cell **B** as a goblet cell, although there were many who incorrectly stated 'mucous gland', which is not a cell type and would not be visible on the scanning electron micrograph in **Fig. 4.1** as the location of mucous glands is beneath the epithelium.

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(ii) There were many good descriptions of the role of the ciliated epithelium in protecting the gas exchange system from particulate matter, including pathogens. Good answers explained that goblet cells secrete mucus and that this covers the ciliated epithelium to trap material such as dust, pollen, bacteria and viruses. The function of ciliated epithelial cells was described as possessing cilia to move mucus towards the throat or mouth. The direction taken by the mucus was often described as 'upwards' and this was accepted. Fewer showed an understanding that, to protect all cells and prevent pathogens reaching cells, mucus covers the epithelium to trap pathogens. Some wrote that mucus prevented pathogens reaching the gas exchange system, forgetting that the ciliated epithelium shown in **Fig. 4.1** is in the gas exchange system. Many wrote that the cilia move pathogens and omitted to state that cilia move the mucus with trapped material. Weak responses stated that cilia provide a large surface area for gas exchange.

(b) (i) Many stated that the internal appearance of structure **X**, a cilium, is a 9+2 arrangement of microtubules. Some of these gave a comprehensive account by including further detail. Weaker responses suggested that cilia are made of microfilaments rather than microtubules.

(ii) The answer, clearly visible in **Fig. 4.2**, is that each cilium is surrounded by a cell surface membrane. Many candidates needed to look more carefully at the transmission electron micrograph (TEM) of cross sections of the cilia from the surface of the epithelial cell. A number of candidates stated that the structures were surrounded by a membrane or double membrane, rather than the cell surface membrane, or simply suggested that they were inside a cell. Some candidates attempted to justify their answer in terms of the magnification of **Fig. 4.2** or just wrote about the magnification of the image in the TEM.

(c) Good answers to this question described the function of centrioles in mitosis. These answers often began by stating that centrioles organise microtubules into spindle fibres for the movement of chromosomes. The term microtubular (or microtubule) organising centre (MTOC) was frequently seen. Candidates also described the replication or duplication of centrioles during the S phase and/or G2 phase of the cell cycle and their movement to the poles during prophase. Imprecise descriptions of moving to 'opposite sides of the cell' were infrequently seen. There were a few descriptions of named stages and the process of microtubules being assembled to lengthen spindle fibres or disassembled to shorten the fibres. Movement of chromosomes during mitosis was frequently included in responses, but this was not relevant to the question posed.

Question 5

(a) **Fig. 5.1** showed the transpiration rates of two plants. As in **Question 2(c)(ii)**, credit was available for identifying similarities and differences, in this case between the results for the two species. It was clear that some candidates had used a ruler to help them analyse the graph and take appropriate data points to illustrate their answer. Other candidates simply gave a list of transpiration rates for the two species without making any descriptive comments. Very few candidates stated that there was no transpiration in either species when the leaf vapour pressure deficit (LVPD) was 0 kPa. Many stated that the rates of transpiration increased as LVPD increased. However, some of these went on to state that both species reached a point at 2.5 kPa when the rate remained constant, or reached a plateau, when clearly this only applied to *Helianthus annuus*. A number of candidates were more precise and stated that the rate of transpiration for *Nerium oleander* decreases slightly at 3.0 kPa. Many also stated that the rate of transpiration of *Helianthus annuus* is higher at all values of LVDP, and a high proportion of these gave a comparative data quote in support. Many also noted the steeper gradient for *H. annuus*.

Some candidates could have gained more credit by using units with numerical data or by writing the unit for rate of transpiration in full. When writing the units some candidates included the solidus, which was not necessary. Some candidates wrote about V_{max} and K_m. These are appropriate for a graph showing rates of enzyme action at different concentrations of substrate, not for a graph of transpiration rates.

(b) In the information at the start of **Question 5**, candidates were told that *N. oleander* was adapted to grow in hot, dry conditions. In this question, candidates were able to deduce that the leaf of *Nerium* would have xerophytic adaptations so that rates of transpiration would be reduced. To gain full credit, the stated adaptation identified in **Fig. 5.3** and then in **Fig. 5.4**, had to be accompanied by a suitable explanation in terms of reducing water vapour loss from the leaves. The most common adaptation noticed by the candidates in **Fig. 5.3** was the location of stomata in cavities or

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chambers on the lower surface of the leaf. There were other acceptable descriptions for this stated adaptation. For **Fig. 5.4** candidates noticed the thick cuticle and the presence of trichomes. A common error was to state that the stoma in **Fig. 5.4** was sunken. This was only accepted for **Fig. 5.3** where stomata can be seen in the cavity on the lower surface. Some candidates thought the trichomes were root hairs and others referred to a waxy cuticle without qualifying their answer with the word 'thick'.

Question 6

(a) (i) Many were able to explain how the structure of antibodies makes the antigen-binding sites specific for a particular antigen by writing about the complementary shapes of the antigen and antibody binding site. The strongest responses also drew on knowledge of the levels of organisation of proteins. They made accurate references to the sequence of amino acids and/or to the folding to form secondary and tertiary structures of the variable regions, with some explaining the effect of the specific R groups that form the binding sites. Some candidates misused the term epitope, which is not a term that is required knowledge, to refer to the antibody instead of the antigen.

(ii) Many candidates stated that the hinge region provides flexibility but did not continue their answer to say why this is an advantage. Strong answers stated that it gives the flexibility to bind to antigens that are various distances apart on the surface of a pathogen. A common answer that did not gain credit was 'to hold the polypeptide chains together'.

(iii) A number of candidates were able to suggest an appropriate advantage of having antibodies binding to receptors on macrophages. These receptors are for the constant regions of antibodies and so facilitate the binding of a macrophage to a pathogen that already has antibodies bound to its surface. Many others stated that this was related to antigen presentation or to the activation of T-lymphocytes. Some candidates' answers could have been made clearer if they had sketched a diagram of an antibody bound at one end to a receptor on a macrophage and at the other end to an antigen on a pathogen.

(b) This question relied on an understanding of RNA splicing during post-transcriptional modification. Many candidates included removal of introns in their answers, but most of these then stated that exons would be joined together. A number explained that to form the great variety of antibodies the exons could be joined in different orders or that some of the exons are not used at all. A few mentioned alternative splicing, which is the name for the process that produces variation in proteins at this stage in their production. A common incorrect answer was mutation, and some candidates referred to changes that occur after translation, not after transcription.

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Paper 9700/22
AS Level Structured Questions

Key messages

Acceptable acronyms DNA, RNA and ATP are given in the AS syllabus and may be used instead of the longer full names of these molecules. For other scientific terms, candidates should write out the full term the first time they use it, to show that they have the correct knowledge of the term, before they shorten it by using an acronym, abbreviation or symbol. For example, in **Question 1(c)(i)** and **Question 1(c)(ii)**, where reference to red blood cells, rather than rbc, was required; in **Question 2(a)(i)** where the cell structure smooth endoplasmic reticulum should have been given, rather than SER or smooth ER; and in **Question 3(a)** where enzyme-substrate complex rather than ESC should have been used when labelling the drawn diagram.

Candidates need to be clear about the difference between vaccines and vaccination programmes. **Question 2(c)** gave some information about vaccination programmes and introduced features of the BCG vaccine, which is used to prevent tuberculosis. Even though the question asked about advantages of using the BCG vaccine, some candidates only wrote about advantages of a vaccination programme.

Some questions involved making comparisons. **Question 3(b)** asked for similarities and differences, which meant that if only differences were given, it would not be possible to gain full credit. In **Question 4(d)**, only differences were required. Credit could not be given if only the rate of nitrate uptake for 5.0 mmol dm^{-3} or only the rate of nitrate uptake for 2.0 mmol dm^{-3} was described. Similarities that were stated in responses did not gain credit.

General comments

Candidates who gave a good all-round performance were knowledgeable of the syllabus topics and showed confidence when answering questions that required some analysis and deduction. They were careful to address command terms and instructions in questions and used available information to help plan their responses. There were occasions where some candidates, including those who had a good grasp of the syllabus and who were clearly prepared for the examination, could have benefited from re-reading a question before answering. This was evident in **Question 2(a)(i)** and **Question 2(a)(ii)** where candidates were given guidance to help them complete **Fig. 2.1** that was also helpful for the completion of **Table 2.1**. Checking answers against the question after finishing a response is also advisable. Scientific terms were generally used appropriately, with correct spellings.

Some candidates could have improved their answers by having a broader understanding of scientific terms and using them more in their responses. Some answers showed understanding, but at a level that was too basic to be creditworthy.

Many candidates used valuable time including irrelevant points in some of their responses. It may help some candidates to take the time before responding to analyse exactly what is being asked in the question.

For **Question 4(a)**, some candidates showed a lack of understanding of what constitutes a cellulose molecule. Many wrote about how cellulose molecules contribute to a cellulose cell wall by becoming part of cellulose microfibrils. These candidates will have lost time writing about irrelevant subject matter and sometimes giving information that was contradictory, meaning that associated correct ideas could not be credited.

In **Question 5(b)**, some candidates described metaphase when, with more careful reading, they should have realised that their response needed to be limited to the structure of chromosomes as they appear at metaphase of mitosis.

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Question 6(a) asked candidates to give the full term for HIV. Candidates must be able to spell correctly the species names for the pathogens causing tuberculosis, malaria and cholera and must be able to spell correctly the name of the virus that is the cause of HIV/AIDS.

Comments on specific questions

Question 1

(a) Most candidates understood that smooth muscle cells present in the walls of the bronchiole were able to contract and relax. Stronger answers explained how this allowed the control of airflow by causing the lumen of the bronchiole to decrease or increase in width. Some incorrectly stated that contraction would widen, and relaxation would narrow the airway or stated that smooth muscle cells helped the bronchiole to contract and relax. Good answers gave sensible examples, such as explaining the need for relaxation to allow the airway to remain wide and allow maximum air into and out of the alveolar area during exercise. It was not correct to relate contraction and relaxation to the process of breathing in and out. Some used the terms vasoconstriction and vasodilation, which are used when describing changes in lumen diameter for blood vessels.

(b) (i) Most of the candidates who gave the correct answer, stage micrometer, also used the correct spelling. A few stated 'stage micrometre'. Many incorrectly named the type of microscope used to calibrate the eyepiece graticule, so there were numerous responses that stated 'light microscope' or 'electron microscope'. Incorrect answers trying to describe the stage micrometer included 'microscope slide', 'micrometer slide',

(ii) There were two steps that needed to be carried out correctly to answer this question. The first was to show a correct conversion calculation and the second was to use the answer to decide whether a candidate would be able to see a cell of length 250 μm if their vision allowed them to see a length of 0.2 mm. Many did this successfully to gain credit. Some made the correct calculation but did not think through the situation carefully enough and stated that it was not possible for the candidate to see the cell. Others stated 'Yes' and needed to explain their reasoning with calculated values and units. Those candidates who correctly converted both given measurements to metres were also credited.

(c) (i) The most common correct observations made by candidates were the red blood cells orientated in a single line within the blood vessel and the fact that a single red blood cell filled the available space. This indicated the lumen diameter of the cell was similar to a red blood cell diameter. Although many could see on **Fig. 1.1** that the capillary wall did not have the tunica media and tunica externa present in other blood vessels, only a proportion correctly described a thin wall or a one cell thick layer of endothelial cells. Many wrote about a thin membrane or stated that the capillary was one cell thick, which was not precise enough to describe the capillary wall. Some candidates incorrectly referred to the capillary wall as the cell wall.

(ii) The strongest answers identified one or more substances that would be in the blood delivered by the capillaries to smooth muscle cells and/or taken up from the cells, and then went on to describe and explain the structural features that allowed efficient functioning. It required a more precise answer to explain that, with a thin capillary wall, substances only had a short distance to travel, rather than stating it was 'easier' or 'faster'. Statements relating to the small size of the capillaries needed to be related to the ability to reach all muscle cells rather than just to state they went close to tissues, because the latter would also apply to other types of blood vessel. Some wrote about the structure of the capillary and red blood cells and needed to go on to explain the benefit, which is the delivery of oxygen to the cells. Some of the weaker responses wrote about contraction and relaxation of muscle cells.

(d) (i) Many candidates had learnt the definition and gained full credit for stating this explanation of a gene mutation from the syllabus. Others explained that there would be a change in the sequence of nucleotides or base pairs in DNA and needed to explain that this may result in an altered polypeptide. Some did not state that the change was in DNA. There were many who named the different types of mutation or stated that mutations were caused by mutagens or gave examples of mutagens, none of which were relevant to the question. Common misconceptions were that amino acids form part of the DNA sequence, or that nucleotides form part of the polypeptide chain.

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(ii) To do well in this question, candidates needed to have noted the information provided to them about the two forms of caldesmon and have an outline understanding of how the primary transcript is modified to produce mRNA. Some knew that introns are removed and do not have a role in the translation process, but many others incorrectly thought that differences that occur in RNA splicing could be due to leaving some introns in the final mRNA produced. A number of candidates showed an understanding that exon joining could be different and a few remembered that the information provided stated that H-caldesmon had a repeating sequence, so suggested that exons in this area could have been removed. Incorrect responses suggested mutation or gave suggestions that were more to do with differences that could have occurred during transcription or translation, rather than immediately after transcription.

(iii) Many were able to suggest that the binding sites of the two forms of caldesmon could have similar shapes or that the tertiary structures could be similar. Some stated that the amino acid sequence of the tertiary structure would be the same but this would produce the same proteins. References to active site were ignored because the proteins were not enzymes. Some candidates did not focus on the proteins and gave explanations in terms of DNA or mRNA and explained how different primary structures could have occurred.

Question 2

(a) (i) Many completed Table **2.1** with the correct cell structures, spelled correctly, to match the stated function. The most common incorrect structures given instead of the nucleolus were the nucleus, the ribosome and the rough endoplasmic reticulum. The Golgi body and rough endoplasmic reticulum were quite frequently given incorrectly for the smooth endoplasmic reticulum. The stimulus of 'pair of…' helped many arrive at the correct answer of centrioles. Centrosomes, which are not included in the expected knowledge of cell structure for this syllabus, was the most frequent incorrect response.

(ii) The majority followed instructions to draw the three named cell structures from **Table 2.1** into **Fig. 2.1**. There were some excellent attempts. Many gave very good drawings of the pair of centrioles and knew that they tended to be located close to the nucleus. Of the three, these were credited the least and some unsuccessfully drew them as two ovals or as stick-like structures that were parallel to each other, rather than at right angles. Quite a few responses labelled the diagram, which was not required.

(b) (i) Most were able to give a reasonable description of how a phagocytic vacuole is formed. For full credit, an event occurring either before or after the engulfing of the bacterial cells needed to be described. It was not enough to state 'detected' as this was already given in the question text. Many were familiar with receptor binding and others described antibody-marked bacterial cells or chemotaxis. Fewer wrote about how the macrophage cell surface membrane fused once the bacterial cells had been fully engulfed. Events occurring after the formation of the vacuole were not asked for and so did not gain credit. Candidates who did not describe endocytosis gave an outline of functioning of B-lymphocytes or T-lymphocytes, which was not appropriate for the question.

(ii) Almost all candidates named lysosomes as the cell structures that fuse with the phagocytic vacuole. Correct spelling was required and those not gaining credit usually wrote 'lysozomes' or 'lyzosomes' or, on occasion, 'T-lymphocytes'.

(c) High-quality responses addressed the advantages of stated features of the BCG vaccine and added information about how long-term immunity could be gained from the vaccine. Many suggested appropriate advantages of using a freeze-dried vaccine. Some erroneously thought that this meant the vaccine needed to be kept in freezers or cold conditions. A small number of candidates deduced that a live vaccine would give a stronger primary immune response because of a high quantity of non-self antigen (resulting from bacterial replication in the body). Some realised that this meant boosters would not be needed. A few more explained that a person would not become ill with tuberculosis if a weakened bacterium was used.

Many knew that memory cells were important in long-term immunity, and here it was important to explain that they are formed as a result of the primary immune response and not just to state that the body has memory cells. The production of antibodies in the primary immune response was frequently included but was not relevant in this question. A significant number of candidates could

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have used more scientific terms when referring to memory cells in immunity and avoided phrases such as the body or memory cells 'remembering' and 'fighting' the infection. Some suggested that antibodies served as memory cells or that antibodies remained in the circulatory system for a secondary immune response. A very few candidates recognised that a live vaccine meant that more antigen would be present, so that this would provide a stronger immune response.

Question 3

(a) Many candidates drew very clear, labelled diagrams of the lock and key hypothesis of enzyme action. Most produced one or more diagrams, and a high proportion of these gained full credit by adding a label or annotation to link the diagrams to the specific example of the action of lysozyme on peptidoglycan. Some of the weaker responses labelled peptidoglycan as the enzyme or lysozyme as the substrate and some thought the active site was part of the peptidoglycan. Others annotated their diagrams with descriptions of the induced fit model and could only gain credit for drawing and labelling an enzyme-substrate complex.

(b) Candidates who knew that penicillin is an antibiotic and who had outline knowledge of the mechanism of action of penicillin were able to gain full credit in this question. Not all knew that the peptidoglycan referred to in the question text is a molecule forming the cell wall of bacteria, as evidenced by responses that stated that lysozyme acts within the cell. A common misconception was that penicillin creates 'holes' in the cell wall rather than it prevents the action of the enzyme that forms cross bridges (after autolysins create the gaps to allow more cell wall material to be added to growing cells). Others suggested that penicillin acts directly on peptidoglycan.

Question 4

(a) There were many well-expressed descriptions of a cellulose molecule that included more than enough features to gain maximum credit. Almost all who knew that the molecule was composed of beta-glucose monomers, either wrote out the term or gave the correct β symbol rather than writing the letter B or b, which did not gain credit. A large proportion gave irrelevant details about cellulose microfibrils or cellulose fibres, even though the question had clearly asked about a molecule. Some misunderstood the question and gave properties of cellulose or the cell wall. Very weak responses described a collagen molecule, amylose or amylopectin.

(b) (i) To gain credit, candidates needed to be more detailed than just stating that more protein or more polypeptide would be produced. This is because the question asked about an increase in mRNA specific to gene *NR* and candidates were provided with the information that this gene coded for an enzyme, nitrate reductase. Some focused on the enzyme reaction and stated that more nitrite would be produced from nitrate, which was acceptable. Some responses were too general, for example, stating that plant growth would increase or that there would be more photosynthesis, without explaining why this would occur.

(ii) Candidates needed to suggest why using a colorimeter would improve the method to detect nitrite. Many explained the increased accuracy compared to a subjective by eye judgment of colour. Fewer were able to give a second relevant suggestion. Stronger responses included the idea of the equipment being able to provide quantitative results, and a few showed an understanding of the benefit of constructing calibration curves. Some explained that the intensity of colour obtained would be a measure of the concentration of nitrite: others understood this idea but did not express themselves well enough to gain credit, stating 'different' or 'changing' colours rather than 'intensity'. Some thought that the measurements obtained were different wavelengths of light rather than different absorbance or transmission values using the same light wavelength. Others incorrectly suggested a benefit was the ability to compare with colour charts.

(c) (i) For this question, candidates needed to assimilate the essential piece of information provided that amino acid transport into a companion cell occurred in the same way to that of sucrose. Many well-written responses were seen, points were organised in a sequential manner and relevant explanations were given. Some showed a very good understanding of the process and included all the expected points. Others missed out detail, such as stating that protons ended up in the cell wall or apoplast of the companion cell after being pumped out of the cell. Some could have been clearer that in the cotransport of amino acids, it is only the protons that move through the cotransporter by facilitated diffusion. Some incorrectly described the movement of amino acids as active transport. Responses that did not gain credit attempted to explain other transport

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mechanisms. Others gave suggestions of how amino acids could be transported across the apoplast in the leaves or in roots (even though the location of transport was stated as in the leaf).

(ii) Most realised that amino acids could move through the plasmodesmata into the phloem sieve tubes or deduced that a concentration gradient would exist that would allow diffusion into the sieve tube. Incorrect responses referred to transport through membrane proteins, with facilitated diffusion stated on a number of occasions.

(d) Candidates needed to refer to **Fig. 4.1** and describe differences between 5.0 mmol dm^{-3} and 0.2 mmol dm^{-3} in the rate of uptake of nitrate ions between 2 h and 5 h only. This meant that any comparisons between 0 to 2 h and with 1.0 mmol dm^{-3} were disregarded. As this question was about rate of uptake and not uptake values at each time period, candidates needed to consider the quantity of nitrate taken up over a set time. Very few candidates extracted values to work out actual rates, and some of those who did omitted to include the correct units. Many thought that quoting values extracted directly from the graph were the equivalent to rates. To see the difference in overall rate between the two concentrations, candidates needed to compare gradients within the time period, and many noted that the 5.0 mmol dm^{-3} was a steeper gradient and hence had a higher rate of uptake of nitrate ions. The second noticeable difference stated by a proportion of candidates was the change in rate that occurred in the 5.0 mmol dm^{-3} concentration in the 3 hours, with a decrease in rate between 3h to 5 h. This compared to the constant rate shown by the straight line for the 0.2 mmol dm^{-3} concentration. Some needed to check their answer carefully as they referred to 0.5 mmol dm^{-3} when they meant 5.0 mmol dm^{-3}.

(e) The strongest responses used the data in **Table 4.1** to deduce the mechanism by which nitrates are taken up and compared the result for each experiment with the result for the control to suggest one or more explanations as to how each factor had an effect on uptake. Weaker responses just described the results, which was only a minor part of a complete response. Some omitted to compare each experiment with the control and compared the experiments instead. Many could have gained further credit by supporting their points with data extracted from **Table 4.1**, including units. A small number of candidates showed an understanding that adding antibacterial compound produced results, which suggested that the presence of bacteria had a (slightly) beneficial effect on uptake.

Question 5

(a) Most knew what happened to chromatin so that chromosomes become visible during mitosis. A few gave contradictory responses such as ‘it uncoils and condenses’ or stated that the chromatin needed to be stained to make the chromosome visible.

(b) Candidates who did not make the error of describing metaphase, usually stated two or three correct features of the structure of a chromosome at metaphase, most often by describing two identical or sister chromatids and the centromere joining the two, plus stating in some way that telomeres are located at the ends of chromatids. A few gave comprehensive accounts to gain full credit and described a DNA molecule for each chromatid and/or the complex formed with histone proteins. Some could have gained further credit by noting that the chromatids were identical or were called sister chromatids; others needed to state that there were two of them. A few remembered the important point that the chromosome contained DNA but stated that each chromatid had a DNA strand rather than a molecule. Some responses used the term ‘centrosome’ instead of the centromere or stated that the centromere joined chromosomes together.

Question 6

(a) The majority of candidates knew the full term for HIV and many knew the correct spelling. Most spelling errors occurred with the ‘immunodeficiency’ part of the term and the most common of these were: ‘immune deficiency’, ’imunodeficiency’, ‘immunodefficiency’ and ‘imminodeficiency’. A few candidates misspelled human (hunman) or virus (virius), while others stated ‘human immunodeficiency disease’.

(b) Candidates who gained full credit usually explained the beneficial effect ART was likely to have on the immune system and qualified this further by explaining that opportunistic infections would be prevented or less likely to occur. Fewer suggested that the treatment would reduce viral numbers or would maintain the numbers of T-lymphocytes. Many candidates could have improved their answer by taking a positive approach and explaining how treatment with ART would help people

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with HIV/AIDS. If no mention of ART was made or if the detail about ART was not creditworthy, candidates were given partial credit for responses that explained that a person with HIV/AIDS had a weakened immune system, a lower T-lymphocyte count and a greater susceptibility to opportunistic diseases. Others needed to use more scientific terminology to gain credit. Some misread the question and wrote about how ART would benefit people who were not living with HIV or who were living with HIV but did not have HIV/AIDS. Some candidates had no understanding of what anti-retroviral therapy was, stating, for example, that ART was a drug to treat the opportunistic infections or was an approach, such as better education or a control method, such as quarantining.

(c) (i) A small proportion of candidates placed a cross on **Fig. 6.1** in the correct place to show an area of the right coronary artery that was bypassed by the great saphenous vein. Many placed a cross at the junction of the great saphenous vein and the right coronary artery, which was not credited but showed that they had worked out the correct side of the heart for the location of the artery. The most frequent incorrect placement of a cross was in the great saphenous vein, or past the junction of the two blood vessels. There were numerous incorrect placements, some of which were written on the heart muscle itself and not within a blood vessel.

(ii) The majority realised that the vein would need to become thicker to cope with the increase in blood pressure. Some stronger answers went on to qualify this with an explanation that there would need to be more smooth muscle, or elastic fibres, or cartilage. A few continued to explain how these tissues would allow the vein to act as a replacement for a coronary artery. Some wrote that the vein had to 'withstand pressure', which was not detailed enough to be credited.

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Paper 9700/23
AS Level Structured Questions

Key messages

In this syllabus, it is acceptable to use the acronyms DNA, RNA and ATP instead of the longer full names of the molecules. For other scientific terms, it is good practice for candidates to write out the full term the first time it is used, to show that they have the correct knowledge of the term, before they shorten the term by using acronyms, abbreviations or symbols. For example, in **Question 3(b)(ii)**, where reference to haemoglobin, rather than hb or Hb was required and in **Question 6(a)**, when comparing RNA and DNA structure, the names of the bases uracil and thymine were credited, rather than U and T.

Question 1(d)(i) asked how giving a vaccine could lead to the development of long-term immunity, whereas **Question 1(d)(ii)** asked about how a vaccination programme could limit the spread of a disease. Candidates needed to be clear about the difference between vaccines and vaccination programmes. Some were unable to distinguish between the two and introduced concepts about vaccination programmes in **Question 1(d)(i)** and wrote about the events occurring in an immune response in **Question 1(d)(ii)**.

There were questions that involved making comparisons. **Question 1(c)** asked for similarities and differences, which meant that if only differences were given, it would not be possible to gain full credit. In **Question 6(a)** only differences were required. It was important to choose three distinct structural differences between messenger RNA and DNA and give a comparative statement. Credit could not be given if only mRNA or only DNA structure was stated. Similarities that were stated did not gain credit.

General comments

Some candidates showed a very good grasp of the syllabus topics and could also apply their knowledge and understanding with confidence to questions introducing unfamiliar material. Generally, scientific terms were spelled correctly and used appropriately.

Other candidates could have introduced more scientific terminology in their answers and give more detail to match the available credit for the part questions that were being answered. A proportion of candidates had large gaps in their knowledge and for this reason could not access many of the part questions in this paper.

Question 1 used a theme of Zika virus and Zika virus disease to assess a number of different syllabus topics. In **Question 1(d)(i)**, which was assessing knowledge about the immune response that leads to long-term immunity, phrases such as ‘fight the disease’, ‘remember the disease’, ‘learns about the virus’ should be avoided as they are not specific enough to be creditworthy.

The ability to make the distinction between a collagen molecule and a collagen fibre was critical in gaining credit in **Question 2(a)**. Here, some candidates may have benefitted from planning their answer and organising their ideas into logical sections, while others needed to read their answer and consider whether the facts stated were in the appropriate section. There were correct statements about collagen molecules that appeared in the collagen fibre section and vice versa.

Question 3(b)(ii) was an example where candidates needed to think carefully about what was required in their answer. Although based on knowledge of transport in mammals and gas exchange, there was a precise focus on oxygen and the ability to maintain a steep concentration gradient in the lungs. This meant that candidates needed to think about the most relevant points to answer the question, which some did to good effect. Others relied on ideas seen in previous mark schemes about gas exchange and so did not answer the question asked.

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Candidates needed to give an extended response for **Question 4(a)**, which asked about two different polymers, lignin and suberin. The strongest answers addressed each polymer in separate sections, describing clearly their location and features and explaining how these were relevant to the transport of water. These contrasted with responses that either tried to mention both polymers in the same sentence or gave a number of statements where suberin or lignin appeared in no apparent order. Candidates who did this may have benefitted from planning their answer more carefully.

In **Question 5(c)(i)** candidates were asked to identify the correct inhibitor that would result in two different outcomes, a high concentration of mitochondria and two chromatids per chromosome. To gain full credit, the inhibitor needed to be stated together with an explanation for each of the two outcomes. Candidates should always attempt to address all bullet points in questions such as these.

In **Question 6(a)**, it was evident that many had not read the instruction to give differences in structural features between messenger RNA and DNA. Some differences were about location, the process of transcription and post-transcriptional modification. As this was not an extended response and candidates were limited to describing only three differences, a non-structural difference could not be credited and counted as one of the three.

Comments on specific questions

Question 1

(a) (i) The more scientific term capsid was more commonly seen than protein coat. Some candidates correctly stated capsomeres. A very wide variety of incorrect responses were given and the most frequent incorrect answers were protein capsule, nuclear envelope, nuclear membrane, cell surface membrane, epithelium and endothelium.

(ii) Most candidates suggested either DNA or RNA. Either was acceptable as candidates were not expected to know that Zika virus is an RNA virus. Some did not note that the question asked for the name of the molecule and gave nucleic acid as the type of molecule. Naming one of the three types of RNA, such as messenger RNA (mRNA) was not accepted.

(b) (i) The measurement of **X**–**Y** was usually correct. Most measured the length as 1 cm or 10 mm and used a correct formula to obtain the actual diameter of the Zika virus. A proportion of candidates went on to multiply by the correct conversion factor to obtain a calculated value of 50 nm. Many obtained an answer of 5 as they had measured 1 cm and omitted to multiply by 10 to obtain millimetres before multiplying by 1000. Candidates who clearly used a correct formula but who did not obtain a correct final value were given partial credit.

(ii) Many gave precise and concise descriptions of what is meant by resolution. Others were more vague and wrote about detail and clarity. Weak responses suggested that resolution meant an ability to obtain high magnifications.

(c) Most knew that Zika virus disease and malaria are transmitted by a mosquito vector; there was more confusion about the details of transmission, with a proportion believing that the mosquito was also affected by taking blood from an infected person. Fewer candidates explained that there was a difference in the vector and named *Anopheles* as the mosquito that transmits malaria. It was not enough to state that transmission of malaria was using another species or type of mosquito. Weak responses did not specify that malaria is a blood-borne disease and described the mosquito taking up the pathogen from water or food.

(d) (i) There were some very comprehensive accounts of the events that can lead to the development of long-term immunity against Zika virus disease. The strongest of these gave details in clear sentences and in a sequential approach, as well as making very clear the difference between a primary immune response and a secondary immune response. The small proteins from the Zika virus were correctly identified as non-self or foreign antigens. Some candidates who had a fairly good grasp of the subject matter could have improved their response by focusing more on the importance of the memory cells. Many of these wrote about plasma cells and antibody production in the primary immune response, which was not pertinent to the question. A common error in weaker responses was to assume that antibodies represented immunological memory and antibodies rather than memory cells are long-lived, or that circulating antibodies recognised antigens on second exposure.

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(ii) Some candidates had correct knowledge of the term herd immunity and used the term or explained it in enough detail to gain some credit. Fewer explained the benefits of vaccination programmes to people who are not vaccinated or who do not have immunity against the Zika virus. A number of responses used ideas from **Question 1(d)(i)** and gave examples of events occurring in an immune response, which was not required in this question about a vaccination programme.

Question 2

(a) Candidates found it easier to write about the structure of a collagen molecule than a collagen fibre. Many knew that a collagen molecule was composed of three polypeptides that together formed the collagen triple helix. Some noted that the polypeptides were tightly wound and had a repeating pattern involving glycine. Fewer noted that hydrogen bonds linked the polypeptide and some explained the ability of glycine to form hydrogen bonds. It was not correct to state that a polypeptide was an alpha helix or to state that glycine formed covalent bonds with other amino acids in the other polypeptides. Candidates gave few details about the structure of a collagen fibre, the most common correct feature stated was the cross links or covalent bonds between molecules. Some also had additional knowledge about collagen fibrils to gain credit. There were also some extremely muddled answers that collectively gave many correct features of a collagen molecule and a collagen fibre. However, these intertwined facts were frequently in the wrong section, and so could not gain credit as they were contradictory.

(b) (i) Many were precise, as instructed, and gave the correct response of alpha glucose or α-glucose when identifying monosaccharide **D**. 'Glucose' on its own, or 'a-glucose' did not gain credit. Incorrect answers included sucrose and fructose.

(ii) There was flexibility in where the label **G** was placed on **Fig 2.1** and credit was given for any label in the vicinity of the oxygen connecting the two monosaccharides. The most frequent incorrect location was around the oxygen connecting the disaccharide portion to the R group.

(iii) Fewer were able to identify the R group of hydroxylysine. Many placed a circle around the top NH_2 group or around this and the connecting CH_2 group, or around the NH next to the amino acid in the chain. Although candidates had been told that the disaccharide had been bonded to hydroxylysine, some drew a large circle around the R group and the disaccharide.

(c) Many gained full credit here. The most common examples chosen were skin, blood vessels and tendons. Responses not credited simply stated a structure, without any qualification to show how the structure was affected, or they just wrote about the effect on 'the tissue' and did not give an example. Some who gained partial credit gave a correct example and continued to give a vague answer, such as 'doesn't work properly' or 'can fail'.

Question 3

(a) The majority followed the instruction to use ticks and crosses to complete **Table 3.1**. There were many who demonstrated sound knowledge of the structure of the named blood vessel types to gain full credit. Lack of knowledge that the artery and/or vein possessed an endothelium was a common error.

(b) (i) Almost all candidates knew the direction of movement of oxygen and carbon dioxide and labelled this correctly on **Fig. 3.1**. There were a few who drew arrows without naming the respiratory gas, some who got the direction the wrong way round, and others who drew arrows going up and down within the area between the alveolar wall and the capillary wall or within one of the two different structures.

(ii) The important point to note in this question was the reference to the 'steep' oxygen concentration gradient. Candidates needed to suggest and explain how this was maintained in the lungs. Some of the strongest answers gave precise locations, noting the alveolar space and the capillary lumen and referred to deoxygenated blood flowing into the alveolar capillary network and oxygenated blood flowing away. The importance of haemoglobin binding to oxygen as the red blood cells passed through the capillary was also stated. The most complete responses explained the importance of ventilation in maintaining the steep gradient. Some understood what was required and needed to give more details, such as mentioning the alveoli and the capillary blood flow, rather

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than just stating 'the lungs' and 'blood coming from the heart'. Ideas about ventilation were frequently too vague to be credited. Some candidates termed ventilation 'respiration' and wrote about 'air coming in and going out', or similar. Many incorrectly interpreted the question as asking for an account of gas exchange in the lungs, or of the features of a good gas exchange surface, or about the carriage of carbon dioxide and how reactions that occur in the red blood cell would allow the uptake of oxygen.

(c) The passage required careful reading before attempting to fill the three gaps. Many knew that the pulmonary vein carries blood to the left atrium. Some erroneously gave the vena cava or simply wrote 'vein'. For the second gap, candidates who had noted the phrase 'two large arteries' in the previous sentence, gave semi-lunar as their answer to cover both valves or named the two valves, aortic and pulmonary, whereas some only stated 'aortic'. A number gave bicuspid or atrioventricular. The final gap was the least well-known answer and frequent incorrect suggestions for the coronary arteries were pulmonary, cardiac and systemic.

Question 4

(a) Some candidates were very knowledgeable about the two polymers lignin and suberin and gave very full responses. Apart from these, a wide range of quality of response was seen. Many candidates needed to identify the waterproof nature of the polymers. Knowledge of suberin as part of the Casparian strip in endodermal cells was generally evident, and a number explained the link to the change of water pathway from the apoplast to the symplast. When writing about lignin, some candidates could have been more precise in stating the location of the polymer, as many answers did not identify that it formed part of the cell walls of xylem vessel elements or the walls of xylem vessels. A common error was to state that lignin is involved in the adhesion of water molecules because it is hydrophilic, rather than to explain that the adhesion occurred with hydrophilic parts of lignin. Some were correct in stating that the strength of lignin and the structural support it provided prevented collapse of xylem vessels, while others incorrectly thought that the flow of water created outward pressures. Weak accounts demonstrated a gap in knowledge of these polymers and ideas stated tended to suggest that both were hydrophilic and had some effect on helping water to move within the plant.

(b) Most candidates were able to use **Fig. 4.1** to help them answer this extended response question about the mode of action of laccase. The majority deduced from the diagram that this was an example of induced fit and a good proportion of candidates did very well by bringing together descriptions of binding with explanations of how this was achieved, and to give more sequential details of enzyme-substrate complex formation and product release, with explanations about lowering the activation energy and the role of the copper ions. Some candidates suggested that the copper ions were cofactors or gave sensible suggestions as to how they may be involved in the reaction.

Question 5

(a) Most began their answer with binding of the ligand to a receptor. Details of events occurring within a cell are not required at AS level, but many stated enough detail to gain credit for an appropriate event that occurred to cause a specific response. Fewer candidates mentioned release of the ligand from a secreting cell or transport to the target cell. Some candidates incorrectly described antigens on the receptors or receptors entering the cell.

(b) Many candidates gained full credit. The term allosteric site was frequently used and most stated that binding caused a change in the shape of the active site, rather than simply that there is a change to the active site. Some only stated that the enzyme changed shape and were able to gain full credit if they continued to explain how this would prevent the substrate binding to the active site.

(c) (i) Many correctly identified one of the two inhibitors, p21Cip1 and palbociclib, that would result in a cell containing one chromatid per chromosome. The majority of these gave sufficiently accurate explanations to gain full credit. It was important to show an understanding that DNA replication occurs in S phase, rather than just to imply that there is an increase in DNA in this phase, because the concept of replication explains how sister chromatids occur. Some incorrectly thought that sister chromatids formed by the splitting of the chromosome. A number stated the name of the CDK rather than the CDK inhibitor.

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(ii) Some correctly identified RO-3306 as the CDK inhibitor that resulted in a cell with many mitochondria and two chromatids. Fewer were able to give a sufficiently detailed explanation to gain credit. A number explained that S phase had occurred to produce the two chromatids. To gain credit, this information needed to be coupled with the fact that mitosis would not occur (to allow separation of the chromatids). Some were more successful in explaining the high concentration of mitochondria, stating that these would be produced in G_2 (in preparation for cytokinesis).

(d) Many showed an understanding that the synthetic CDK inhibitors should act to prevent cell division. A high proportion also noted that cancerous tumours resulted from uncontrolled mitosis of cells and that this would also be prevented with the use of inhibitors. Weaker responses wrote about cell growth rather than cell division.

Question 6

(a) This straightforward question allowed many to gain full credit. Strong answers made it clear whether they were giving a fact about the structure of mRNA or a fact about the structure of DNA. Some candidates could have improved by stating both molecules, as per the instruction given, and ensuring that their answer gave a structural comparison. If a candidate chose to note the difference in the base or nucleotide, then the spelling of uracil and thymine needed to be correct.

(b) (i) Candidates were expected to identify the bases with a double ring structure. If the correct answer of **P** and **B** was not given, it was usually because the candidate had incorrectly thought a purine was a single ring base and so **Z** and **S** were stated.

(ii) Many candidates correctly stated cytosine and guanine as the base pair most similar to the synthetic base pairs. Some candidates needed to go on to explain that this was because three hydrogen bonds were present between the two bases. Others noted the three bonds but did not state that these were hydrogen bonds.

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Paper 9700/31
Advanced Practical Skills 1

Key messages

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

Candidates should be encouraged to observe fine detail when viewing slides under a microscope or on a photomicrograph and include such detail when producing diagrams, such as the shapes of epidermal cells in high power diagrams and the proportion of the tissues in a plan diagram. They should be reminded that although epidermal cells have the same common structures, the fine detail of these structures may vary.

Candidates need to think carefully about the investigation they have carried out and apply their knowledge about the topic when explaining their results.

The wording of a question often indicates how the candidate should respond. In **Question 1(a)(iv)**, where the question stated: 'Explain, in terms of water potential, your observations for slide **U1**', the candidate needed to use their observations of the cells on slide **U1** which they had drawn and explain their observations in terms of water potential rather than the theory of osmosis.

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

General comments

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

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

The majority of candidates demonstrated that they could skilfully carry out an investigation, record the results in an appropriate table and estimate the concentration of starch in **R1** and **R2**. Candidates were able to identify how the procedure could be improved so that a more accurate estimate of the concentration of starch in **R1** and **R2** could be obtained.

Comments on specific questions

Question 1

(a) (i) The majority of candidates organised their results clearly by presenting a ruled table and included a suitable heading for the independent variable, such as sodium chloride solution, and the heading for number of cells showing plasmolysis. Most candidates gained credit for recording the highest number of cells showing plasmolysis in solution **U1** and for recording the lowest number of cells showing plasmolysis in solution **U2**.

(ii) The majority of candidates used their results from **Question 1(a)(i)** to correctly identify the concentration of sodium chloride in solutions **U1**, **U2** and **U3**.

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(iii) 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 gained credit for carefully following the instructions to draw a group of onion cells with each cell touching at least two of the other onion cells and with double lines representing the onion cell walls. The stronger candidates drew the correct shape of the onion cells and showed the state of plasmolysis observed in slide **U1**. Most candidates used a label line to correctly identify the cell membrane of one onion cell. The most common errors were to draw lines that did not meet up precisely and to draw a single line for the cell wall in plasmolysed cells.

(iv) Many candidates who had drawn plasmolysed cells in **Question 1(a)(iii)** correctly explained that **U1** had a lower water potential than the onion tissue. The stronger candidates explained that water moved out of the onion tissue from a higher water potential in the onion cells, to a lower water potential in solution **U1**. Most candidates stated that the movement of water was by osmosis and a few candidates explained that due to plasmolysis the cell membrane pulled away from the cell wall. Credit was not awarded for explaining that a higher concentration of sodium chloride solution was present in **U1** than in the onion cells and that the movement of water occurred from a low concentration to a high concentration. Candidates who had not drawn plasmolysed cells in **Question 1(a)(iii)** were given credit for explaining that **U1** had a higher water potential than the onion tissue and for the correct explanation for the movement of water in terms of water potential for their observations. The most common error was for candidates to explain the theory of osmosis in terms of water potential but not use their observations of the onion cells on slide **U1**.

(b) (i) The majority of candidates correctly calculated the percentage change in mass of the potato piece soaked in 0.2 mol dm^{-3} sucrose solution.

(ii) The majority of candidates correctly calculated the mean percentage change in mass of the potato piece soaked in 0.2 mol dm^{-3} sucrose solution.

(iii) The majority of candidates drew the graph, using the headings given in the table to correctly label sucrose concentration / mol dm^{-3} on the *x*-axis and mean percentage change in mass on the *y*-axis. Many of the candidates used scales of 0.2 mol dm^{-3} to 2 cm for the *x*-axis and 2.0% to 2 cm for the *y*-axis, and plotted the points exactly with a dot in a circle or a small cross. Some candidates drew a sharp, clear ruled line of best fit. The most common errors were using only a positive scale on the *y*-axis so that the points could not be accurately plotted and drawing lines plot to plot.

(iv) Most of the candidates correctly used the graph to read off the value for the concentration of sucrose solution that would result in no change in mass of the potato pieces.

Question 2

(a) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The majority gained credit for carefully following the instructions and drawing the whole root. Stronger candidates gained credit for drawing the layer of tissue below the epidermis and a double line for the endodermis and for showing the correct proportion of the vascular tissue to the whole root. Most candidates used a label line to correctly identify the xylem tissue.

(b) (i) The majority of candidates were able to show how to prepare a serial dilution of 1.0% starch suspension, with the correct concentration below each beaker (0.1%, 0.01%, 0.001% and 0.0001%) and showing the transfer of 1 cm^3 of the previous concentration to the next beaker and the addition of 9 cm^3 of distilled water to each beaker. A few candidates showed different volumes of 1.0% starch suspension below each beaker showing the different concentrations made by proportional dilution.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. Some candidates included the heading for percentage concentration of starch (**S**) and the heading symbol. The majority of candidates gained credit for recording symbols for all of the concentrations of starch made, and recording results which showed that the highest concentration had a greater number of symbols than the lowest concentration. A few candidates did not record 1.0% starch suspension and a few recorded colours instead of symbols.

(iii) The majority of candidates correctly stated that the colour observed was the dependent variable.

(iv) The majority of candidates correctly recorded a higher number of symbols for **R1** than for **R2**.

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(v) The majority of candidates used their results in **Question 2(b)(ii)** and **Question 2(b)(iv)** to correctly estimate the concentration of starch in **R1** and **R2**.

(vi) The majority of candidates suggested at least one improvement to the procedure so that a more accurate estimate of the concentration of starch in **R1** and **R2** could be obtained. Most responses suggested using a colorimeter or repeating the experiment and calculating a mean. Some responses correctly described using concentrations with narrower intervals.

(vii) Many candidates used the information given and their estimates in **Question 2(b)(v)** to correctly identify which root extract was taken in the summer and explained that less starch was present in roots during the summer.

(c) The majority of responses identified at least two observable differences between **Fig. 2.4** and **Fig. 2.5**. Many stated that the vascular bundle in **Fig. 2.4** was smaller than the vascular bundle in **Fig. 2.5** and that **Fig. 2.5** had root hairs whereas **Fig. 2.4** did not. Many candidates stated that in **Fig. 2.4** the xylem vessels were in a cross shape whereas in **Fig. 2.5** the xylem vessels were arranged in a circular shape. Some candidates stated that the cortex in **Fig. 2.4** was larger than the cortex in **Fig. 2.5** and that the cortex cells were smaller in **Fig. 2.4** than in **Fig. 2.5**.

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Paper 9700/32
Advanced Practical Skills 2

Key messages

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

The majority of candidates demonstrated that they could skilfully carry out an investigation, record the results in an appropriate table and estimate the concentration of protease in **U**. Candidates could improve by practising techniques for how a procedure can be modified to obtain a more accurate estimate of an unknown concentration, such as that of protease in **U** in **Question 1(a)(viii)**.

The wording of a question often indicates how candidates should respond. The word 'explanation' may imply reasoning or some reference to theory, depending on the context. Where the question stated 'Use the data in **Table 1.3** and your graph in **Fig. 1.2** to explain the effect of pH on the activity of protease', candidates needed to make sure that they stated why the activity of protease changes rather than just describing the change in activity of the enzyme. For example, candidates could refer to the formation of more enzyme-substrate complexes between pH 1.8 and pH 6.1 and explain that this is because the pH is getting closer to the optimum pH for the enzyme, so the active site becomes more complementary to the substrate. Candidates could also explain why the activity decreases after pH 6.1, such as, the shape of the active site changes so the substrate is unable to bind with the active site resulting in less enzyme-substrate complexes.

General comments

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

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates selected four additional concentrations of protease that were evenly spaced between 100% and 0.0% concentration of protease and completed **Table 1.2** with the correct volumes of **P** and **W** to prepare the additional concentrations. Some candidates only selected three concentrations between 100% and 0.0% but gained credit for the correct volumes of **P** and **W** to prepare the stated concentrations. A few candidates incorrectly selected concentrations made by serial dilution instead of proportional dilution, which did not gain any credit.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of protease (**P**) and the heading for time and seconds. They gained credit for recording two times for all the concentrations of protease made, and

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recorded results which showed that the time for clots to appear for the highest concentration of protease was shorter than the time for clots to appear for the lowest concentration of protease. Most of the candidates gained credit for recording time in whole seconds.

(iii) Most of the responses correctly suggested one source of error in the procedure described in step 6 of the investigation as the difficulty in judging when the clots first appear. A few candidates incorrectly suggested that it was difficult to stop the timer when the clots appeared.

(iv) Many candidates suggested that the procedure was repeated to improve the accuracy of the results. The most common incorrect suggestion was to calculate a mean.

(v) Some candidates correctly stated 1 cm^3 as the volume of fruit extract **U** to use.

(vi) Most candidates recorded a time for **U** longer than the time recorded for 100% protease and included units.

(vii) Most candidates used their results from **Question 1(a)(ii)** and **Question 1(a)(vi)** to correctly estimate the concentration of protease in fruit extract **U**.

(viii) Most candidates suggested how to modify the procedure to obtain a more accurate value for the concentration of protease in fruit extract **U**. Many responses correctly described using concentrations with narrower intervals with the stronger candidates using their estimate in **Question 1(a)(vii)** to state concentrations around the estimate for **U.** The most common error was to use the estimate in **Question 1(a)(vii)** as the upper or lower value in the suggested range of concentrations.

(b) (i) The majority of candidates drew the graph, using the headings given in the table to correctly label pH on the *x*-axis and protease activity / $\mu mol\ min^{-1}\ mg^{-1}$ on the *y*-axis. Most of the candidates used scales of 2 pH units to 2 cm for the *x*-axis and 5 $\mu mol\ min^{-1}\ mg^{-1}$ 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 (the pH value to be plotted) on the *x*-axis so that the points could not be accurately plotted and drawing a curve that did not accurately connect the points.

(ii) The majority of the candidates used the data in **Table 1.3** and the graph in **Fig. 1.2** to describe the effect of pH on the activity of protease. These could not gain credit as the question required candidates to explain the effect of pH on the activity of protease. Credit was awarded to those candidates who stated an optimum pH. A few responses explained that the protease activity increased between pH 1.8 and pH 6.1 because the shape of the active site became more complementary to the substrate, so more enzyme-substrate complexes were formed. Some candidates went on to state that the maximum number of enzyme-substrate complexes were formed at the optimum pH. Some answers described the increase in protease activity as the pH increased and then correctly explained that after the optimum pH the activity decreased due to a change in the shape of the active site of protease, resulting in fewer enzyme-substrate complexes.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided, with no shading. The majority of the candidates gained credit for carefully following the instructions and drawing the region of the leaf indicated in **Fig. 2.1**. The stronger candidates gained credit for drawing the layer of tissue under the epidermis of each fold containing trichomes and a vascular bundle in each fold. The majority of candidates used a label line to correctly identify a vascular bundle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines which joined up precisely and used most of the space provided. Many candidates gained credit for carefully following the instructions to draw a group of three epidermal cells and one trichome, with each cell touching at least one other cell and with double lines representing the cell walls. The stronger candidates drew the correct shape of the trichome. Most candidates used a label line to correctly identify the wall of the trichome. The most common errors were drawing lines that did not meet up precisely and an epidermal cell with a small narrow protrusion.

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(iii) The majority of candidates correctly stated an observable feature that suggested the leaf is from a plant that is a xerophyte. Suitable features included: rolled leaf, thick epidermis/cuticle, sunken stomata and hinge cells. The most common incorrect answer was trichomes which was given in the stem of the question.

(b) (i) The majority of candidates used appropriate units to correctly measure the width of the paired guard cells and the width of the stoma in **Fig. 2.2**, using the lines **P–Q** and **R–S**. Most candidates correctly showed the division of the width of the stoma by the width of the paired guard cells and multiplied the answer by 100. Most candidates recorded the answer to two significant figures. The most common error was calculating the percentage change in width using the width of the paired guard cells minus the width of the stoma, divided by the width of the stoma and multiplied by 100.

(ii) The majority of candidates identified at least two observable differences between **Fig. 2.3** and **Fig. 2.4**. The majority of candidates stated that there were more stomata or guard cells on **Fig. 2.4** than on **Fig. 2.3** and that the stomata were larger on **Fig. 2.3** than on **Fig. 2.4**. Many candidates stated that the epidermal cells on **Fig. 2.3** were larger than on **Fig. 2.4** or that the stomata were further apart on **Fig. 2.3** than they were on **Fig. 2.4**. A common error was to include a structure that was not observable, for example vascular bundle, or to refer to the epidermal cells as epithelial cells.

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Paper 9700/33
Advanced Practical Skills 1

Key messages

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

Candidates should be given the opportunity to draw both line graphs and bar charts. In this paper, a bar chart was required. The bars should be plotted accurately and drawn exactly along the horizontal lines with a ruled line. All the lines, both vertical and horizontal, should be unbroken. When drawing the bar chart, consideration should be given to how to arrange the bars and in this case, each of the bars should have been separated from each other.

General comments

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

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates correctly drew two lines on test-tube **S**, one line at the top of the test-tube at the same height as the line at the top of test-tube **R** and a line below with the label sediment. Weaker candidates omitted the label or gave an incorrect label.

(ii) Many candidates correctly stated at least three additional concentrations of ethanol and stated the correct volumes of ethanol and water for each concentration.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger responses included the heading for percentage concentration of ethanol and the heading for depth of sediment / mm. Many candidates gained credit for recording a depth for each concentration stated in **Question 1(a)(ii)** and the depth of sediment in test-tube **C**, for every 4 minutes. The stronger candidates recorded the depth of sediment at 20 minutes for all the concentrations of ethanol and recorded all the depths as whole millimetres.

(iv) Successful responses gave a conclusion about the effect of the concentration of ethanol on the sedimentation of yeast cells according to their results.

(v) Many candidates stated whether their results supported or rejected the hypothesis and explained how their results provided evidence for their choice. The stronger candidates explained that if

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there was sedimentation in test-tube **C**, the hypothesis had to be rejected as there was no ethanol in test-tube **C**, therefore ethanol was not needed for sedimentation of yeast cells to occur.

(vi) Some candidates correctly stated the percentage concentration of ethanol that caused the most sedimentation according to their results and correctly suggested that the procedure could be modified by using concentrations of ethanol either side of the concentration stated and using narrower intervals close to this concentration.

(vii) Some answers correctly identified a source of error and stated that the test-tubes were not left for the same length of time.

(viii) Some candidates correctly completed **Table 1.3** by stating that the type of error was systematic and that there would be no effect on the trend.

(b) (i) The majority of candidates drew the bar chart, with the label 'source of carbohydrate' on the *x*-axis and the label 'percentage ethanol per 100 g of carbohydrate' on the *y*-axis. The stronger candidates ensured that all five bars were separated and of the same width, and used a scale for the *y*-axis of 1.0 to 2 cm. Many candidates plotted the horizontal line at the top of each bar exactly with a thin straight line. The most common errors were not including a full axis label for each axis and not labelling the scale on the *y*-axis every 2 cm.

(ii) Many candidates correctly suggested that the optimum pH and the optimum temperature for *Schizosaccharomyces pombe* was not the same as for *Saccharomyces cerevisiae* and so the percentage of ethanol produced by *Schizosaccharomyces pombe* was lower than that for *Saccharomyces cerevisiae*.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing the whole section of the stem. Many responses gained credit for drawing at least four layers of tissue and drew the epidermis as a double line. Most candidates used a label line and label to correctly identify the cortex.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin lines which joined up precisely and used most of the space provided. Many were able to draw four adjacent cortex cells with each cell touching at least two other cells, with double lines representing the cell walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many responses were credited for drawing the correct shape of the cortex cells. Most candidates used a label line to identify the cell wall of one cortex cell.

(b) Many candidates recorded three observable differences between the section on **L1** and the section in **Fig. 2.1**. The higher-achieving responses recorded three features as shown below:

feature	L1	Fig. 2.1
number of vascular bundles	fewer	more
size of vascular bundles	all the same size	different sizes
vascular bundles	joined together	separate

(c) Many candidates correctly determined the mean actual diameter of the stem by showing a minimum number of measurements of the diameter with the appropriate units, showing the addition of these measurements and the division by the number of measurements taken and then division by the value of the magnification (×40).

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Paper 9700/34
Advanced Practical Skills 2

Key messages

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

Candidates should be aware that the wording of questions indicates how they should respond. The words 'using the data and your graph' imply that candidates are required to quote figures included in the table. Where the question instruction was 'describe the change in concentration between 60 minutes and 240 minutes', the candidate needed to make sure that they not only stated that the concentration decreases but used the data in the table to support this, such as the concentration decreases from 65.5 to 31.5 $\mu g\,mL^{-1}$.

General comments

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

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates correctly stated at least three additional concentrations of salicylic acid and the correct volumes of salicylic acid and water for each concentration.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for percentage concentration of salicylic acid and the heading for colour intensity. Many gained credit for recording symbols for each concentration stated in **Question 1(a)(i)**. The stronger candidates recorded the correct trend as the greater the salicylic acid concentration the more intense the colour.

(iii) The majority of candidates correctly recorded the intensity of colour for samples **S1** and **S2**.

(iv) Some candidates correctly used their results in **Question 1(a)(ii)** and **Question 1(a)(iii)** to estimate the percentage concentration of salicylic acid.

(v) Many responses correctly stated the sample with the highest concentration of salicylic acid was from the person's blood as the salicylic acid entered the blood and circulated in the bloodstream.

(vi) Some answers correctly stated that the independent variable was the concentration of salicylic acid.

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(vii) Many candidates correctly identified an error when carrying out step 6 and step 7 as the difficulty of judging the intensity of colour and suggested that using a colorimeter would be an improvement to reduce the error.

(b) (i) Most candidates correctly labelled the *x*-axis as time / minutes and the *y*-axis as concentration of salicylic acid / $\mu g\,mL^{-1}$. Some candidates labelled the incorrect axis or gave incomplete headings. The stronger candidates used a scale of 30 to 2 cm for the *x*-axis and 10 to 2 cm for the *y*-axis. Many candidates plotted the five points accurately and joined the points with a thin line. The most common errors were not including a full axis label for each axis, omitting the units for the *y*-axis, not labelling the scale every 2 cm and drawing lines which were too thick.

(ii) Many candidates correctly showed a line crossing the *x*-axis at 105 minutes and correctly estimated the percentage concentration of salicylic acid.

(iii) Some candidates correctly stated that the concentration of salicylic acid decreased at 60 minutes, from 65.5 $\mu g\,mL^{-1}$ to 31.5 $\mu g\,mL^{-1}$ at 240 minutes.

(iv) Many candidates correctly stated that the aspirin acted as an inhibitor of the enzyme-controlled reactions, changing the shape of the active site of the enzyme, resulting in fewer enzyme-substrate complexes.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing a section of the plant that included four vascular bundles. Many candidates gained credit for drawing each epidermis as double lines. Most candidates used a label line and label to correctly identify a 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. Some candidates were able to draw four adjacent cells in the lower epidermis, with each cell touching at least one other cell and all the cells in a line, and with double lines representing the cell walls. The stronger candidates drew the correct shape of the epidermal cells. The most common error was to draw lines that did not meet up precisely or were too thick. Most candidates used a label line to identify the cell wall.

(b) Many candidates recorded three observable differences between the section on **M1** and the section in **Fig. 2.2**. The higher-achieving candidates recorded three features as shown below:

feature	M1	Fig. 2.2
number of vascular bundles	fewer	more
location of vascular bundles	at the centre of the leaf	around the centre of the leaf
presence of trichomes	absent	present

(c) (i) Many candidates correctly measured the width of the stem section and the width of the central region with the appropriate units.

(ii) Many answers gave the correct ratio of the width of the whole stem section to the width of the central region.

(iii) Many candidates correctly stated that to determine the mean width of the central region of the stem, more measurements should be taken of the central region, and then the mean could be calculated.

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Paper 9700/35
Advanced Practical Skills 1

Key messages

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

Within an investigation, candidates should be able to decide which variables need to be standardised and how to standardise them. Variables that are expected to have a minimal effect, such as variation between test-tubes of the same type, do not need to be standardised.

Candidates should also be able to identify systematic or random errors from using apparatus in an investigation and understand that systematic errors do not affect the trend in results, whereas a random error, for example, due to variability of biological material, may affect the trend and accuracy.

General comments

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

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates correctly stated at least three additional concentrations of ethanol and stated the correct volumes of ethanol and water for each concentration.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for percentage concentration of ethanol and the heading for colour intensity. Many candidates gained credit for recording symbols for each concentration stated in **Question 1(a)(i)** and recording the correct trend.

(iii) The stronger candidates correctly described the trend as the greater the ethanol concentration the more intense the colour.

(iv) Some responses correctly explained that the effect of low concentrations of ethanol on the cell membranes was that the phospholipids were dissolved, and at high concentrations of ethanol the proteins within the membrane were denatured resulting in the membrane becoming more permeable and eventually breaking down.

(v) The majority of candidates correctly stated that the dependent variable was the intensity of colour.

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(vi) Some candidates correctly stated a variable that was standardised as the volume of ethanol put into each test-tube which was standardised by using a syringe to measure 10 cm^3. Other variables that were acceptable were the amount of beetroot used and a set time for the reaction.

(vii) Many responses correctly identified an error in the investigation as the difficulty of judging the final colour or that the beetroot discs were not all exactly 2 mm thick.

(viii) Some candidates correctly stated that the procedure could be modified to investigate the effect of temperature on the permeability of cell membranes by using one ethanol concentration and placing the beetroot discs in the ethanol at five different temperatures.

(b) (i) Most candidates correctly labelled the *x*-axis as time after drinking / minutes and the *y*-axis as difference in mean blood pressure compared to control group / kPa. Some labelled the incorrect axis or gave incomplete headings. Stronger candidates used a scale of 50 to 2 cm for the *x*-axis and –0.2 to 2 cm for the *y*-axis. Many candidates plotted the six points accurately and joined the points with a thin line. The most common errors were not including a full axis label for each axis, omitting the units for the *y*-axis, not labelling the scale every 2 cm, and drawing lines which were too thick.

(ii) Many candidates correctly showed a line crossing the *x*-axis at 100 minutes and read off from the graph the difference in mean blood pressure then took this figure away from 15.79 kPa.

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 a section of the leaf that included four vascular bundles. Many candidates gained credit for drawing at least three layers of tissue and drawing at least one large air space. Most candidates used a label line and label to correctly identify a 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. Some candidates were able to draw two guard cells and two adjacent epidermal cells, with each cell touching at least one other cell and all the cells in a line, and with double lines representing the cell walls. The most common error was to draw lines that did not meet up precisely or were too thick. Stronger candidates were credited for drawing both guard cells smaller than the adjacent cells. Most candidates used a label line to identify the cell wall of one guard cell.

(b) (i) Many candidates drew an appropriate table to record three observable differences between the leaf section on **N1** and the leaf section in **Fig. 2.1**. The stronger candidates recorded three features as shown below:

feature	N1	Fig. 2.1
number of vascular bundles	more	fewer
size of vascular bundles	larger	smaller
palisade mesophyll	single layer present	double layer present

(ii) Many candidates correctly calculated the actual thickness of the leaf by measuring the length of the scale bar and the length of line **A**–**B** with the appropriate units, and then dividing the length of **A**–**B** by the length of the scale bar and multiplying by 100.

(iii) Many candidates correctly calculated the magnification by dividing the length of **A**–**B** by the answer to **Question 2(b)(ii)** and giving their answer to two significant figures.

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Paper 9700/41
A Level Structured Questions

Key messages

Candidates who performed most strongly were able to integrate question paper information with their pre-existing knowledge in a logical way. Careful reading of the question and targeted shaping of the answer was a feature of the strongest answers. Weaker responses showed a lack of understanding of what a question was asking and instead discussed the scientific terms in the question in a general way.

General comments

Most candidates finished the paper without leaving blank spaces. Candidates performed best on AO1 recall questions, particularly if they used subject-specific terminology accurately and scientific conventions (e.g. ion symbols) correctly and were precise and unambiguous in their answers. Many of the questions on the paper presented novel contexts in which candidates had to apply their knowledge and think more deeply, and these AO2 questions allowed the candidates with the most highly developed analytical and creative thinking skills to differentiate themselves from candidates who relied on rote learning and who had limited understanding of the principles and conceptual framework of Biology.

Comments on specific questions

Question 1

(a) The majority of candidates were able to identify the locations of different stages of aerobic respiration on a micrograph of a mitochondrion. The location that was identified the least was for oxidative phosphorylation where some candidates chose the outer rather than the inner mitochondrial membrane.

(b) The reason why ATP synthesis by oxidative phosphorylation stops in anaerobic conditions was explained well by many, especially by those who realised that they needed to answer in terms of the normal events that will not happen or will happen less in this context. Some answers stated that NADH, instead of NAD, would not be regenerated.

(c) Most candidates listed events that will not happen if the enzyme that catalyses the last step of lactate fermentation is inhibited, although some simply described lactate fermentation as it does happen, without addressing the context of the enzyme being inhibited. Successful candidates identified lactate dehydrogenase as the relevant enzyme and realised that less pyruvate would be converted to lactate, and therefore less NAD would be regenerated. Some candidates described less ATP production, which was stated in the question, without adding the information that there would be less substrate-level phosphorylation.

Question 2

(a)(i) Most candidates gave the similarity that both paracrine and endocrine signalling use a chemical, but fewer answers gave the difference that the signalling molecule travels in the blood in the endocrine system. A common error was for candidates who did mention the bloodstream to state that molecules diffuse through the blood, whereas the purpose of a circulatory system is faster transport by mass flow.

(ii) Many candidates stated that acetylcholine can be considered as a paracrine signalling molecule as it diffuses a short distance across the synaptic cleft.

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(b) The majority of candidates attempted to describe the results shown on **Fig. 2.1**, which was not required. The most successful candidates followed the instruction to consider the cell signalling molecule and to deduce conclusions about it from the data; for example, its site of origin (palmitate-exposed cells), its chemical nature (it does not denature at high temperature so is not a protein, and it is lipid-soluble) and its effects (switching on stress genes in new muscle cells).

(c) Strong answers named the proteins in a muscle cell whose production would be lessened by stress gene products inhibiting translation, stating that there would be less actin and myosin for example. Weaker responses struggled to explain the significance of protein translation in the specific context of a muscle cell and did not make reference to the named proteins typical of a muscle cell.

Question 3

(a) Many candidates were well prepared in describing how stomata open in sunlight. Some candidates omitted to specifically identify guard cells as the location of the mechanism. A few answers lost credit as all points made were about ion and water movements to and from stomata instead of to and from cells. It is essential that candidates realise that a stoma is a hole between two guard cells.

(b) (i) The majority correctly described the relationship between the concentration of abscisic acid in the xylem sap and stomatal conductance. Data points needed to be read accurately to within half a grid square from **Fig. 3.1**, either from the crosses or from the line of best fit. Most candidates who gave figures from two points on the graph used correct units. Those who tried to distinguish between the steeply decreasing part of the curve and the plateau often did not recognise that the steepest decrease in conductance only occurred until around 150 $\mu mol\, m^{-3}$.

(ii) Explanations for the pattern shown on the graph were good. Most linked a rise in ABA with stomatal closure. Many knew that calcium ions enter the guard cells as a result of ABA increase, and that potassium ions leave the cells. Relatively few described ABA binding to receptors on guard cells. As with **Question 3(a)**, some candidates incorrectly used the term stomata instead of guard cells.

(c) Most answered this correctly and identified DNA or promoter as the place where transcription factors bind. Incorrect answers included RNA polymerase and operator.

Question 4

(a) Candidates were asked how the North American crayfish *Pacifastacus leniusculus* became resistant to a pathogen. Some candidates did not appreciate that a mutation for resistance would have occurred in one or a few individuals, rather than in the species as a whole. Good answers were focussed at the genetic level and linked selective advantage to having this new allele for resistance. Most answers identified the disease as the selection pressure. Errors included inappropriately using the term gene instead of allele and stating that the mutation occurred because of the presence of the disease rather than randomly. Some candidates mentioned that frequency of the beneficial allele changed but did not state that it increased. Many candidates realised that resistance evolved due to natural or directional selection, but some contradicted this by also mentioning genetic drift.

(b) (i) Candidates were generally confident in describing the stages of PCR, although some did not state the appropriate temperature at which each stage occurs. The question required answers to outline the stage (e.g. the temperature) and to explain what happens to the DNA at this stage. Answers described denaturation and the annealing of primers relatively well, but some did not fully explain the role of the polymerase in making the new strand of DNA. Many referred to repeating the cycles but few explained why, to increase the amount of DNA. Some answers suggested that different reagents (e.g. primers, Taq polymerase, nucleotides) were added at successive stages during the process rather than that all the necessary reagents are present in the reaction tube from the start, with the temperature changes allowing different reactions to occur. One error that occurred was candidates writing probes instead of primers.

(ii) Many candidates correctly named use of a database or bioinformatics as a way to discover suitable sequences for the primers. The commonest wrong answer was microarrays.

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(c) (i) This question challenged candidates to understand the principle of DNA doubling through the interpretation of a graph showing the concentration of DNA after cycles of PCR. Most candidates opted for **A** or **D** as the highest concentration of DNA. The correct answer, **A**, was given by those who identified the sample which reached the threshold after the lowest number of PCR cycles.

(ii) Candidates found this question challenging and gave a wide range of incorrect responses. The data from **Fig. 4.1** needed for the calculation was given in the stem of the question to help candidates. Some calculated the difference in concentration between **C** and the *Austropotamobius pallipes* DNA as 3 cycles (28–25), and needed to go on to relate this to the quantity of DNA doubling in each of the three cycles of PCR. A few responses gave the correct answer of $2^3 = 8$.

(d) (i) Knowledge of the genetic modification of bacteria so that they fluoresce was tested. Many identified a plasmid or vector as the component that must be taken up by normal bacteria to transform them, and many answers stated that this plasmid would contain the gene for green fluorescent protein and a promoter. The major misconception was candidates suggesting that the fluorescence was due to a dye or to fluorescently labelled DNA. Others stated that the green fluorescent protein would be added, with no reference to the gene or DNA.

(ii) Most candidates realised that the gene for green fluorescent protein is a marker gene that allows scientists to identify which bacteria have taken up and are expressing the desired gene. Some incorrectly suggested that the transferred gene can be identified, rather than the bacteria which possess it.

Question 5

(a) (i) Most candidates identified **A** as the stroma but many did not know the term for area **B**, which is the thylakoid space or thylakoid lumen. Errors included reversing the answers, confusing **B** with the intermembrane space of a mitochondrion or referring to the thylakoid alone.

(ii) Most candidates recognised and named **E** as ATP synthase and the strongest candidates read the question and studied **Fig. 5.1** carefully enough to deduce that the biochemical process occurring at the named components was cyclic photophosphorylation. A serious misconception was shown by candidates who wrote oxidative phosphorylation for this thylakoid membrane process.

(iii) Almost all candidates identified reduced NADP and most mentioned its role in producing triose phosphate. Some omitted to state that GP is reduced in this process, some incorrectly suggested GP was oxidised and some gave the name for GP incorrectly, for example glycerol or glucose phosphate rather than glycerate 3-phosphate.

(b) (i) Candidates were presented with a graph showing rates of energy transfer in different ecosystems. This question asked about limiting factors affecting the three forest ecosystems only. Many candidates wrote about grasslands and desert as well, which are not relevant. Most candidates stated that tropical forests had the highest rate of energy transfer (or that snow forests had the lowest) and supported this by a data quote from two of the forests. Strong answers explained that temperature and light intensity were higher in tropical forests, hence allowing more photosynthesis or energy transfer. Some weaker answers listed the limiting factors of photosynthesis without reference to the question context. Carbon dioxide concentration was not relevant to this real ecosystem, as opposed to a laboratory or glasshouse context.

(ii) The lower rate of energy transfer by photosynthesis in grasslands and desert (compared to forests) was difficult for candidates to explain. Successful answers reasoned that there are fewer plants and less light absorbed in these ecosystems, and that stomatal closure leads to less carbon dioxide being available for photosynthesis. Ideas that did not gain credit were that water acts directly as a limiting factor on the rate of the photosynthesis reactions and that enzymes are denatured by high temperatures in desert plants.

Question 6

(a) (i) Most candidates were able to identify a shared feature of the homologous chromosomes. They identified that homologous chromosomes were the same length, shape or had their centromeres in the same position. Some candidates needed to read the question more carefully as they missed

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out on credit by referring to genetic features. The word similar was not an acceptable alternative to the same or equal.

(ii) Many candidates identified that a homozygous recessive phenotype would lead to faulty or no tyrosinase enzyme. Some recalled the steps of the metabolic pathway catalysed by tyrosinase and needed to go further and state that in the absence of functioning tyrosinase each step would not happen; these answers showed recall of knowledge and needed application of that knowledge within the specific question context. Weak responses did not give any biochemical detail but tried to explain what is meant by the term homozygous recessive.

(b) Most candidates were able to gain credit for completing the genetic cross in the Punnett square provided. For full credit, all sixteen phenotypes needed to be written into the Punnett square, as well as the genotypes; a significant proportion of candidates did not do this. Abbreviations or symbols for phenotypes can be used if a key explaining what each symbol means is given. The final ratio needs to state the phenotypes and not just be presented as a series of numbers.

Question 7

(a) (i) Candidates were asked to describe a relationship between two variables, mutation rate and lifespan, from a table of data. Most answers succeeded in describing the overall trend that as one variable increased the other decreased.

(ii) More able candidates understood that evolutionary adaptation occurs in a population over generations and scored well; weaker candidates did not understand this and wrote in terms of individual animals surviving. An example of an incorrect answer of this type would be that humans can adapt faster as they have more time to adapt because they live longer. Correct reasoning centred on the higher likelihood of beneficial alleles arising in a species with a higher mutation rate, leading to a greater chance of, or faster rate of, adaptation, for example in the house mouse. Some answers also reasoned that a shorter lifespan means more new generations per year so more new variants for selection to act upon.

(b) (i) Most answers stated that a longer time is needed for selective breeding as it occurs over many generations, or that its key elements (selection and breeding) must be repeated. Many candidates wrongly envisaged genetic engineering as a one-day event without appreciating that the laboratory manipulation of embryos is only part of the process and that modified embryos still undergo the normal gestation period within surrogate mother cows.

(ii) Most candidates could suggest two features of dairy cattle that could be improved through genetic engineering: the quantity or yield of milk produced and some aspect of the quality of the milk or the dairy cow. Despite the term ‘dairy’ appearing on the syllabus, some candidates did not understand that this relates to milk and wrote about ‘improving the quantity of dairy’ or about meat production.

Question 8

(a) Candidates were confused about the nature of the IUCN. Errors included referring to active conservation measures like zoos and captive breeding programmes and the activities of CITES in establishing trading laws. Accurate ideas about the role of the IUCN included assessing conservation status, the Red list, education and global influence on governments.

(b) The syllabus lists the biological, ecological and morphological species concepts that were asked for in this question. Most answers did not mention these. Some candidates stated what these meant from recall but did not attempt to answer the question, which was to select the relevant points from the information given, to combine this with knowledge of the tenets of the species concepts and to decide in each case whether two types of bears were members of the same species or whether they represented two different species. The commonest points to gain credit were describing the lack of reproductive isolation between the grizzly and polar bears and the differences in mass, colour, habitat and diet between them. Points were written without sound reasoning as to what these observations meant. Ambiguous use of the word ‘species’ (the same in the singular and in the plural) and ‘they’ without specifying the two types of bears, limited credit in some answers.

(c) (i) Most candidates filled in **Table 8.1** with correctly calculated figures stated to the same number of decimal places as the other values in the table and arrived at a correct value for Simpson’s Index of Diversity, equal to 0.728. Occasional errors were missing out the final stage of subtracting the total

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from 1, and not including the calculated value for *Gaultheria hapalotricha* in summing the final column.

(ii) A high proportion scored credit and were able to explain that a higher *D* value meant more diversity. Some answers did not address the question and instead referred to significant difference.

Question 9

(a) Some candidates found it difficult to put the differences between continuous and discontinuous patterns of variation into words to answer this recall question. Some wrote about the genetic basis of the patterns. Some answers gave a feature of one type of variation without a valid matching comparison to the other. Many answers referred to quantitative and qualitative data but in both cases the number of individuals showing each phenotype would need be counted.

(b) The introductory paragraph stated that colour variation in this ladybird was discontinuous. Some candidates gave this as their only answer point, suggesting a lack of understanding of what the question asked them to do and poor reading of the question information. Knowledge of the genetic basis of discontinuous variation was poor. The most commonly stated correct points were that it is controlled by one or two genes and that different alleles at a single locus have large effects. Some candidates reasoned that codominance or epistasis could be involved.

(c) Most answers scored credit for food availability or temperature, and the more able candidates integrated their ideas with the question information and explained that these factors would make their impact on final adult size through their effect on growth at the larval stage.

Question 10

Strong candidates could describe all parts of the sequence of events from depolarisation of the chemoreceptor cell to neurotransmitter release, events at the synapse, and the stimulation of an action potential in the postsynaptic sensory neurone. Weaker candidates did not distinguish between the presynaptic chemoreceptor cell and the postsynaptic sensory neurone. Candidates were strongest in their knowledge of events at a synapse, although some made the error of stating that vesicles leave a cell by exocytosis. Strong answers referred to ions and used their correct symbols, used the terms ligand-gated and voltage-gated appropriately, used correct terms in describing the mechanisms of ion movements, and did not make the mistake of stating that ions enter membranes.

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Paper 9700/42
A Level Structured Questions

Key messages

- It is essential that candidates are confident in using basic technical terms, such as gene, allele and phenotype, correctly.
- Candidates should remember to state whether a membrane is a cell surface membrane, plasma membrane, luminal membrane, presynaptic membrane or postsynaptic membrane, as appropriate. It is insufficient to refer simply to a 'membrane'.
- Acceptable abbreviations for biological terms are given in the syllabus. Candidates should be discouraged from using their own abbreviations.

General comments

Many candidates scored well on this paper, conveying knowledge, articulating ideas and effectively analysing data. Very few candidates did not complete the paper or left questions unanswered. Candidates achieved across the full range of possible marks.

Comments on specific questions

Question 1

(a) (i) The majority of candidates identified the hypothalamus as the location of the osmoreceptors. Incorrect responses tended to refer to a part of the kidneys, or gave a generic answer such as cell surface membrane.

(ii) Most candidates appreciated that the osmoreceptors would detect a change in water potential of the blood. A few used incorrect terms, such as water concentration or water level, and references to the water potential of the body were not credited.

(iii) Many candidates recognised that the pituitary gland was responsible for the secretion of ADH into the bloodstream; some needed to specify that it would be the posterior pituitary, and a few mentioned the anterior pituitary.

(b) (i) The calculation of the percentage decrease in the rate of production of urine was correctly performed by most, and only rarely were answers given to more than one decimal place. The most common mistake was to divide by the incorrect denominator.

(ii) There were some very good explanations of the relationship between the concentration of ADH in the blood and the rate of urine production in the kidney. Stronger candidates had a good understanding of the mechanism of action of ADH at the collecting duct, beginning their response by stating that ADH would bind to its receptor on the cell surface membrane, initiating a cascade of reactions resulting in the fusion of vesicles containing aquaporins with the luminal membrane. Some went on to provide further detail of the phosphorylation of the vesicles and the effect of more aquaporins on membrane permeability. Many appreciated that more water would then be reabsorbed, although weaker candidates did not mention that reabsorption would increase, or simply stated that water would be absorbed without mention of its re-entry into the blood stream or tissue fluid. Most appreciated that the urine concentration would then increase or that its volume

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would decrease. The most frequent error was to describe the graph without explaining the consequences of ADH secretion.

Question 2

(a) Many candidates correctly stated that the phenotype was affected by both environmental and genetic factors. Few were able to go on to mention that the interaction of genetic and environmental factors was important.

(b) (i) Many candidates did not gain full credit for this question as they focused their answer on full descriptions of the process of natural selection. Most were able to state that this was a process that occurred over time or generations. Some candidates used the term organism instead of species and vice versa.

(ii) Good answers clearly stated what would be compared and how this would relate to the evolutionary relationship between species. However, some referred to two species with similar DNA sequences having a common ancestor, rather than a more recent common ancestor. Many responses described the processes of how the sequences would be prepared, with some very detailed descriptions of gel electrophoresis and PCR, which was not the focus of the question.

Question 3

(a) The question asked for an explanation for the involvement of multiple alleles in the given context of colour pattern in tortoise beetles. To answer correctly, in context, required an explanation that gene ***L*** has four alleles or to list the four alleles. Credit was available for a generic definition of multiple alleles, namely more than two alleles for a single gene, although few candidates gave this idea.

Most candidates had the correct idea but usually missed out on the credit for not specifying how many alleles were involved, or if they said there were more than two alleles, they often missed out the reference to a gene.

Some candidates used the term 'multiple alleles' as their description – this was in the stem of the question and did not explain as requested. Many candidates simply repeated the phenotypes rather than referring to alleles. A few candidates linked the different phenotypes to more than just one allele.

There were a large number of very general descriptions given, some including comments on additive effects.

(b) The majority of candidates were able to present a clear and correct response. The main errors were not clearly linking the offspring genotypes and phenotypes, not writing descriptions of phenotypes in the correct order for the ratio given and having the superscript the same size as the letter for the allele, e.g. **LR** instead of $\mathbf{L^R}$.

(c) Most candidates identified the codominant alleles correctly and only a few identified $\mathbf{L^T}$ and $\mathbf{L^R}$ as being codominant in the order of hierarchy in the second part of the question.

A few candidates incorrectly gave phenotypes or genotypes instead of the alleles. A significant number of candidates wrote all four alleles for codominance or were not able to write in the correct format.

(d) (i) This question proved challenging for some candidates, although many gained some credit. While the majority of responses for cross 1 were correct, a minority of candidates made errors in writing the correct order of female/male genotypes or did not label them.

It was difficult to distinguish between $\mathbf{L^V}$ and $\mathbf{L^r}$ on many scripts. Students should consider their presentation carefully when attempting genetics questions as ambiguous responses cannot be credited.

(ii) This question discriminated very well with only the highest ability candidates being awarded the credit. Some were able to describe the number of males and females for each phenotype to be

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similar, or female metallic offspring being produced. Many candidates, however, discussed the ratio of phenotypes.

(iii) Most answers named the chi-squared test. The most common incorrect response was the *t*-test, and a few named Pearson's or made an unsuccessful attempt at remembering a name.

Question 4

(a) Many candidates were able to explain the relationship between a gene, a protein and a phenotype using haemophilia as an example. A good number of responses achieved full credit.

It was not uncommon for the *F8* gene and the factor VIII protein to be mixed up, referring to the factor VIII gene or the *F8* protein.

Many candidates recognised the condition to be sex-linked or that the gene was located on the X chromosome but relatively few referred to it being a recessive allele. Weaker responses discussed inheritance of recessive genes, not alleles.

A large number of responses mentioned that the factor VIII protein would be non-functioning or in lesser quantity or not there at all and most gained credit for stating that it results in excessive bleeding. There were a large number of responses which gave the idea that the gene is not coded for when they needed to state that the factor VIII protein is non-functional due to mutation. The *F8* gene will always be present but it is which version, namely which allele is present, that will determine what type of gene product is produced.

The main incorrect responses for a minority of candidates was to describe sickle cell anaemia or abnormal haemoglobin. A few responses detailed gene mutation and effects on primary structure with a minimal link to haemophilia.

(b) This question was generally well answered, with many candidates understanding that there is no active gibberellin produced, even if they missed out the non-functional enzyme step. There were some very detailed explanations for the lack of cell elongation. Relatively few responses referred to the genotype being homozygous recessive.

Some responses were not clear and the scientific terminology was not used correctly. Some responses did not answer the question, but included details about the functions of gibberellin or details that would have answered **Question 4(c)**. Many also made the link to germination rather than stem elongation.

(c) Many candidates performed well in this question, providing clear statements as to the sequence of events involving DELLA acting as a repressor.

Some candidates confused the context of plants with repressor proteins in prokaryotes with the binding of repressor proteins to the operator.

Other errors included describing DELLA proteins binding to promoter regions directly, mentioning lack of gene expression but not realising this was in the stem of the question, and giving a response about the role of gibberellin in the breakdown of DELLA to cause gene expression.

Question 5

(a) Very few candidates linked the reasons for genetic testing to be due to having a family history of breast cancer. The majority stated that this would be so that individuals can prepare for treatments or to start treatment early. Most candidates could then describe the result of the mutation resulting in DNA not being repaired and many stated that this would lead to uncontrolled mitosis or cell division.

(b) The majority of candidates were able to state that PCR amplifies the DNA sample. Many went on to describe the process, missing out on the credit available for linking it to only having a small sample in the first place.

(c) Many candidates made the correct calculation but then lost credit as they did not give their answer in standard form.

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(d) This question was attempted well, and most candidates scored credit. The most common errors were reading the figures on the graph incorrectly or not quoting what the labels on the axis showed. Very few candidates referred to the lack of statistical testing.

Question 6

(a) A significant number of candidates did not answer this question, while many mistakenly put the arrow through the membrane proteins. Another common mistake was that candidates did not show the complete journey of oxygen asked for in the question, so their arrows would, for example, show half the journey or would not start or finish in the right places. This was a diagram that should have been familiar to candidates, although many had difficulty understanding that it was showing the membranes between the cytoplasm and the mitochondrial matrix, even with the labels provided.

(b) A large number of candidates were able to demonstrate their accurate and thorough knowledge of oxidative phosphorylation, giving complete answers. Common errors included identifying **A**, **B** and **C** just as carrier proteins, or sometimes proton pumps, rather than electron carriers or the electron transport chain, and not distinguishing whether the movement of hydrogen ions was by active transport or diffusion. Some good answers mistakenly stated that energy was lost or produced, as electrons moved along the electron transport chain, instead of being released.

(c) Many candidates found it difficult to apply their knowledge of mitochondrial structure to the production of the proteins that a mitochondrion might need. Most common correct responses included ATP synthase, membrane or channel proteins and electron transport chain proteins. A few candidates were able to suggest the production of ribosomes. A large minority of answers included irrelevant information about the role of the mitochondrial DNA in replicating the mitochondrion as well as how it is used to trace female ancestry and make evolutionary links.

Question 7

(a) (i) The graph was well described by the majority, although some candidates missed the instruction and described both of the lines on the graph, while others focused on the small decrease in oxygen production at higher temperatures and found it difficult to find the correct words to explain that the rate was low/constant. Many candidates knew that light intensity was the limiting factor, although a significant proportion lost out on the credit by referring only to 'light'.

Many who had correctly described the rate of photosynthesis as being low or constant, and that light intensity was limiting, were unable to effectively explain the consequences of this. A lot of responses incorrectly explained that no light was absorbed or that no photolysis, photoactivation or photophosphorylation was taking place despite stating that oxygen production was constant earlier.

(ii) This was a high-scoring question with the majority of candidates gaining full credit. A significant number of responses included irrelevant information relating to the situation before 30 °C. When quoting data from the graph, many candidates read values incorrectly and therefore lost credit. A significant minority gave figures for the rate of oxygen production but made no reference to the temperatures. Enzymes being denatured was a very common creditworthy point, with fewer referring to the change in active site.

(b) Most candidates understood about photolysis and what was produced during the process, so were able to access full credit. Knowledge of photosystems and the oxygen-evolving complex was much more limited. Many candidates were unsure where light absorption took place, and others were inaccurate in listing the products of photolysis, giving incorrect equations or stating hydrogen instead of hydrogen ions or O instead of O_2.

Question 8

(a) (i) Most candidates were able to name cell **A** as a receptor.

(ii) A majority of candidates correctly named the cell that forms a synapse with structure **B** as a relay or intermediate neurone. Motor neurone was also accepted. Dendrite or axon were given by many who had not focused on the word 'cell' in the question.

(iii) Most candidates identified the Schwann cell as forming the myelin sheath.

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(b) Generally, this question was answered well. Most were able to state that the impulse in a myelinated neurone would travel faster than in an unmyelinated neurone. Good answers then went on to describe the insulating effect of the myelin that resulted in action potentials only occurring at the nodes of Ranvier. This would lead to longer local circuits and so the action potential would have to jump from node to node. A common error was to state that impulses would jump from node to node; the credit for this point could still be gained if the candidate then referred to saltatory conduction.

(c) (i) Those candidates who knew the difference in function of the two ion channels as well as which ion passes through were rewarded. There were lots of attempts based on where the ion channels were positioned in the diagram. Many candidates only described the location of the two ion channels. Many gained credit for correctly stating that channel **A** allowed calcium ions to pass into the neurone and sodium ions passed through channel **B**. Some mistakenly stated that these ions were released through the channels. Credit was not given if a candidate used the symbol Ca^{+} instead of Ca^{2+}. Fewer candidates managed to correctly compare the method of opening of the channels, for example voltage-gated and ligand-gated.

(ii) This question was well attempted by many candidates who noted that calcium ions would not enter the neurone and so not trigger the movement of vesicles to the presynaptic membrane to result in exocytosis of acetylcholine. Credit was only awarded if reference was made to the specific membrane. Some lost credit by stating that calcium ions would not move into the membrane or that the vesicles would not bind to the presynaptic membrane. Strong candidates went on to state that there would be no binding of acetylcholine to receptors on the postsynaptic membrane causing no influx of sodium ions. Many missed out on credit by mentioning that the postsynaptic neurone would not be depolarised rather than the postsynaptic membrane.

(iii) Candidates often found this challenging, and a common error was to describe the inside of the cell as becoming negative rather than more negative. Strong candidates who gained credit for this idea then explained that the threshold would be harder to reach and so action potentials may not be generated.

Question 9

(a) Many candidates achieved all of the credit available for suggestions as to how the Asian common toad might affect the ecosystem of Madagascar, although some missed out by repeating the information they had been given in the stem of the question without supplying any further detail. Nevertheless, many understood that its fast reproduction would result in a rapid increase in the Asian common toad population and that its ability to travel several kilometres per year would allow it to spread to other parts of Madagascar. While candidates appreciated that the toad would have a detrimental effect on the ecosystem and food chains, this was not always well expressed, and credit was lost for vague statements such as animals would die. Stronger candidates understood that potential predators would be killed by the toxins in the skin and that native species would be predated, reducing their populations. Many recognised that the Asian common toad would compete with native species for resources such as food, or introduce new diseases, both of which could lead to possible extinction of some species and a reduction in biodiversity.

It is important that candidates avoid using neutral terms like ‘affects’. For example, ‘this affects the food web’ is not creditworthy because there is no indication if the effect is positive or negative.

(b) Most candidates were able to give an outline of IVF and the strongest successfully gained full credit. Good responses stated that hormones, often identified as FSH, would be administered to the female rhino to trigger superovulation or stimulate the maturation of several oocytes. Most commented that the eggs would then be extracted from the ovaries, often describing the use of fine needles and ultrasound, then mixed with sperm for fertilisation to take place. Higher-achieving candidates recognised that the embryo would be implanted into the uterus of either the original rhino or a surrogate, while weaker answers simply stated that it would be introduced into the female. Few mentioned embryo testing or screening, although some understood that the embryos could be frozen and stored, or cryopreserved. Common errors were to refer to semen instead of sperm, or to implant the zygote, rather than the embryo, into the female. There was rarely a mention of obtaining sperm from genetically distant males.

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Question 10

(a) Many candidates incorrectly stated homeostasis instead of negative feedback.

(b) In this question, candidates were asked to explain the graph. Many were able to show that a drop in blood glucose concentration would result in glucagon being released which would act on liver cells. The result would be the processes of glycogenolysis and gluconeogenesis and an increase in blood glucose concentration. Candidates need to take care when spelling names that are similar. Some responses gave descriptions of the graph rather than explanations. Misreading the command word often resulted in the loss of credit. Likewise, some explained the whole graph rather than what was occurring between 15 minutes and 70 minutes.

(c) (i) This question was quite well answered, although some candidates struggled with the spelling of gluconic acid.

(ii) Many were able to score full credit. The accuracy and the ability to reuse a biosensor were the most common correct answers.

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Paper 9700/43
A Level Structured Questions

Key messages

- Acceptable acronyms for biological terms are given in the syllabus. Candidates should be discouraged from using their own abbreviations.
- Candidates should be reminded that energy is not made or destroyed, so phrases such as 'energy is lost' or 'energy is made' are not be creditworthy. These phrases were common in answers to **Question 7(b)** and **Question 8(b)(ii)**.

General comments

There was a wide spread of marks awarded across the cohort on this paper.

Most candidates had difficulty recalling knowledge from syllabus area 19.1 Principles of genetic technology, in **Question 4(a)(i)**, **Question 4(a)(ii)**, **Question 5(c)(i)** and **Question 5(c)(ii)**. Many candidates demonstrated misconceptions from the syllabus area 16.3 Gene control in **Question 3(a)(iv)**.

A common misconception was that a gene is not coded for if both alleles present are recessive, instead of non-functional gene products being made after protein synthesis involving recessive alleles. This was evident in **Question 3(b)** where some wrote that a mutation in the *F8* gene cannot code for factor VIII, instead of a mutation in the *F8* gene resulting in the factor VIII protein made being non-functional or that less or none is made in translation. Many candidates confused gene regulation in prokaryotes (operons and an operator) with gene regulation in eukaryotes (no operons or operator).

Comments on specific questions

Question 1

(a) The majority of candidates correctly named G protein, cyclic AMP and aquaporin as the three structures.

(b) Many responses mentioned dehydration or sweating during exercise or hot weather. Fewer candidates were able to obtain further credit by referring to the ingestion of salty food or by an increase in solute concentration of the blood.

(c) Many candidates again mentioned dehydration, due to the loss of much water in the urine, which may lead to tiredness or fatigue. A few misunderstood the question and described the symptoms of diabetes mellitus.

(d) Many candidates scored full credit by stating that few or no aquaporins would be added to the membrane and this would lead to the membrane becoming less permeable to water. No credit was given to those who mentioned that the membrane would become impermeable to water or that no osmosis would occur. Some responses incorrectly suggested that the membrane structure would change or made errors about aquaporins no longer binding to the membrane (instead of fusing) or that aquaporins were no longer open.

(e) Candidates found this question more challenging. Most were able to show that a man with NDI could not inherit the condition from his father as it was sex linked and so he would receive an

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X chromosome from his mother. He would inherit a Y chromosome from his father. Imprecise statements about a mother passing on the condition were not creditworthy.

Question 2

(a) The most common error was for the second description, which was caused by environmental factors only because the strawberry plants were produced by asexual reproduction and therefore genetically identical. The first description was also difficult for some who gave the answer of environmental only. However, the description included the information that seventeen genes are associated with yield, indicating a genetic cause too.

(b) The spontaneous and random event occurring inside cells that can be a source of phenotypic variation is mutation. Common incorrect responses included independent assortment and crossing over, which are not spontaneous as they occur in fixed stages of meiosis.

(c) For this question the most able candidates described all three events of meiosis that cause genetic variation. Many also described that after meiosis random mating and random fusion of gametes would also contribute to genetic variation.

Question 3

(a) (i) **T**his question was answered well by most candidates.

(ii) Most candidates added up the numbers of genotypes that resulted in non-blue and blue petals and wrote this as a ratio. Many were successful, with a minority getting the correct ratio but writing it the other way around without indicating that they had changed to blue to non-blue petals. Many incorrect ratios did not add up to sixteen, the number of genotype boxes in the Punnet square, and so demonstrated a misunderstanding of what was required.

(iii) Candidates found this question very challenging with few giving the correct answer of epistasis for the type of gene interaction that had caused the ratio.

(iv) A few responses achieved full credit and most gained some of the credit available. Most candidates did not focus on the roles of the proteins coded for by the two genes or consider how the presence of a dominant allele would be different to having two recessive alleles present. Some incorrectly mentioned a dominant gene instead of a dominant allele. Other incorrect responses referred to repressor proteins acting on operators and operons, despite this being a plant and therefore an example of eukaryotic gene control, and that the gene product would be a protein that coded for malvidin even though it was a metabolic pathway and so the gene product for gene ***T/t*** would be an enzyme. Many candidates believed that if recessive alleles were present, it would mean that the gene was not coded for instead of the gene product being non-functional.

(b) Many candidates recognised the condition to be sex-linked or that the gene was located on the X chromosome but relatively few referred to it being a recessive allele. Weaker responses discussed inheritance of recessive genes not alleles. A large number of responses stated that the factor VIII protein would be non-functioning or in less quantity or not there at all. Most candidates gained credit for stating that it resulted in excessive bleeding. There were many responses which had the idea that the gene is not coded for instead of the idea that the factor VIII protein is non-functional due to the mutation. The ***F8*** gene will be always present but it is which version, namely which allele is present, that will determine what type of gene product is produced. Few candidates were able to sufficiently link the phenotype to the genotype and most did not include alleles and sex chromosomes for the genotype part. For the phenotype part, many did not include both sex phenotypes and whether they would have haemophilia or not. The main incorrect responses for a minority of candidates was to describe sickle cell anaemia or abnormal haemoglobin.

Question 4

(a) (i) Many candidates either could not recall the role of the enzymes or made errors in their attempt. The main error for the restriction enzyme role was to describe it cutting mRNA and not DNA. Many candidates described how DNA ligase made phosphodiester bonds but did not mention plasmids. Many outlines for DNA polymerase missed the idea that the strand of DNA made would be a complementary strand. There were many candidates writing that reverse transcriptase 'converts' mRNA into cDNA instead of it using mRNA to make cDNA.

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(ii) Some candidates knew that the promoter was the site for RNA polymerase and transcription factors to bind to, to allow the gene to be transcribed. Common incorrect responses mentioned DNA polymerase or polymerase binding, or the promoter allowing a gene to be 'produced' or to include an operator in the control.

(b) This question was well answered by most candidates. Some missed credit where they did not comment on whether the polypeptide would be produced or if they did not explain their reason clearly.

Question 5

(a) The information given in the stem of the question described a double-stranded piece of DNA breaking and that the protein BRCA2 was responsible for repairing the damage along with an enzyme. Candidates were asked to state the event in meiosis that is initiated as a result of double-stranded DNA breaks. A minority of candidates were able to think synoptically to give the correct answer of crossing over.

(b) (i) Candidates needed to interpret the information given to suggest and explain how a specific named mutation was responsible for a very high percentage of breast cancer cases in Iceland compared to the general global population. Many candidates found this achievable and gave good accounts of this specific mutation occurring a long time ago when the original population was small thus showing a founder effect and, due to a small gene pool in an isolated population, the frequency of this mutation increased a lot. Common errors were to use the term 'gene' instead of 'mutation' or to only explain that the mutation frequency had 'changed' and not 'increased'. A few candidates misinterpreted the isolated population and decided incorrectly that allopatric speciation had occurred, disregarding the human context.

(ii) Stronger candidates were often able to suggest two advantages of genetic screening and a minority were able to achieve full credit. Credit was often not awarded for weak descriptions of preventative measures, such as 'allowing gene therapy to be carried out' or 'preventing getting the mutation'.

(iii) This 'suggest' question focused on an advantage to a country of a screening programme for specific mutations in *BRCA2* in the population. Very few candidates used the information about there being hundreds of mutations in *BRCA2* and that not all of these mutations will increase the risk of cancer. This was the stimulus material for the conclusion that because screening programmes are very expensive it would be more cost effective to only screen for mutations that are known to occur in a high frequency in the country's population and that you only need to identify mutations that are known to increase the risk of breast cancer. For this question, a minority of candidates were awarded the credit.

(c) (i) Candidates found this question challenging and only a very small number of candidates were able to draw on their knowledge to achieve credit. The main error was to suggest that the whole gene was deleted and then the correct gene inserted.

(ii) Candidates did not score well on this question. A small number of responses focused on gene editing affecting only very specific sequences on the target DNA which would only be found in the named gene *Lcn2*.

Question 6

(a) An explanation as to why stomata needed to open and close according to environmental conditions was required. The strongest explanations identified that stomata needed to open for the named gas, carbon dioxide, for the process of photosynthesis. Many candidates needed to be more specific and add the name of the gas and/or the process. Most responses identified that stomata must close to prevent water loss and named an environmental cause of this, e.g. drought conditions. Some answers went on to explain that stomata close at night when no photosynthesis could occur, and a few candidates mentioned that stomata close to prevent water loss by transpiration.

(b) Many candidates were able to cover all mark points in very clear, logical descriptions of the mechanism that occurs in guard cells to open the stomata. Common errors were to get the direction of ion movement or water movement the wrong way around or to get the name of the ion

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that is moving wrong. Some were muddled about the type of moving, e.g. pumping of K^+ or diffusion of H^+. Candidates must take care to use water potential terminology when describing the movement of water by osmosis. It is incorrect to describe water moving down a concentration gradient.

Question 7

(a) (i) Candidates were presented with the outline of an experiment on photosynthesis and a table of results from that experiment. They were asked to complete the table by adding a calculated rate of photosynthesis and this was successfully achieved by the vast majority to achieve the correct answer.

(ii) Many candidates successfully drew a curve of the table of results to show the effect of light intensity on the rate of photosynthesis. The very small minority of candidates who drew the curve without adding any plots of data points, or added additional incorrect plots, could not be awarded full credit.

(iii) The curve should have been shown to level off in **Question 7(a)(ii)**, and candidates were asked to give reasons for this. Most were able to state that light intensity was no longer limiting and that either temperature or the concentration of carbon dioxide was becoming limiting. Credit was not given to responses that mentioned just light or light energy or omitted to state carbon dioxide concentration, and this reduced the level of achievement for some.

(b) Strong answers described the emission of electrons which then travelled along the electron transfer chain to release energy and that this energy was used to pump protons into the thylakoid space or lumen. This would create a proton gradient and so the protons could diffuse through ATP synthase into the stroma. Some incorrectly referred to protons being pumped into the thylakoid membrane and that the enzyme involved was ATPase. Another error was to describe energy being produced or generated instead of energy release coupled to electron movement.

Question 8

(a) Strong answers stated that the inner membrane was the site of the electron transfer chain where energy released from electron movement was used to pump protons into the intermembrane space and that it was also the location of ATP synthase which produced ATP. Some went on to describe the folding of the inner membrane allowing more electron transfer chain and ATP synthase molecules to be present because of an increased surface area. Many weaker responses stated that the inner membrane was the site of oxidative phosphorylation and chemiosmosis. A few strong candidates were able to show that the entry of pyruvate was to be used in the link reaction or that the exit of carbon dioxide was from the Krebs cycle. A few candidates commented on the impermeability of the inner membrane to protons to maintain the proton gradient or that having membranes allowed compartmentalisation.

(b) (i) Only some candidates mentioned that more mitochondria would be needed in cells with high energy needs or those about to carry out cell division. Some also suggested that they would replace damaged mitochondria, as described in **Question 8(c)**.

(ii) A small number of candidates were able to say that GTP would be suitable as a source of energy because it could be hydrolysed easily like ATP. This was another example of where some candidates incorrectly wrote that energy would be 'produced' when the bond was broken.

(c) A minority of candidates were able to state that they would be broken down by lysosomes and a few answers mentioned that the breakdown components would be used to make new mitochondria.

Question 9

(a) (i) Candidates were given a graph and were asked to calculate the percentage increase between 340 000 years ago and the year 2020. Most were able to correctly give the figure of 36.7%. To gain full credit, candidates needed to follow the instruction to give their answer to one decimal place.

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(ii) The graph showed that a large increase in carbon dioxide concentration has occurred. The impact of this on the environment and biodiversity was well described by many. Strong answers explained that global warming would lead to rising sea levels and habitat destruction. Some good examples of habitat destruction were given. Food webs would be disrupted and this would lead to a reduction in biodiversity and eventually, in some case, extinction. Lower-scoring responses often focused on one point in a lot of detail instead of presenting a variety of different suggestions.

(b) The reasons for maintaining plant diversity were well described by many. All marking points were seen. Strong answers referred to aesthetic, cultural or ethical reasons. Many described the importance of plants for medicine, as resource materials and enabling soil stability. Ecotourism was frequently mentioned along with the need to maintain stability in ecosystems and genetic diversity.

Question 10

(a) The majority were able to correctly identify potassium ions and ATP on a diagram of a part of a neurone membrane.

(b) Many candidates were able to accurately describe the events that occur during an action potential. Most mentioned an influx of sodium ions leading to depolarisation of the membrane. If a threshold potential is reached, the action potential would occur and then the potassium ions would exit the neurone leading to repolarisation of the membrane followed by hyperpolarisation of the membrane before the resting potential is restored. Common errors were to mention sodium or potassium rather than their ions. It is important for candidates to note that membranes are depolarised and not neurones or axons. A number of responses described the propagation of an action potential instead of the events during one action potential. Candidates should make sure that the symbol given for an ion is correct, e.g. Na^+ and not NA^+ or Na^{2+}. A small number of answers incorrectly suggested that Na^+ ions moved out and K^+ ions moved in during an action potential and referred to voltage gated Na^+ channels as sodium pumps.

(c) Candidates found this question to be slightly more challenging than the other part questions in **Question 10**. Many were able to state that myelination and large axon diameters led to faster transmission speeds and a few went on to explain that myelination had the greater effect. Strong candidates were able to explain the reason for the increase in speed of myelinated neurones due to saltatory conduction. Few were able to show that a large axon diameter would have a large surface area or lower resistance. Candidates should take care not to write that an action potential is faster but that the transmission of the action potential (impulse transmission) is faster. It is not the impulse that jumps from node to node in saltatory conduction, but the action potential that jumps from node to node. It is also incorrect to link speed to the number of action potentials occurring. The term ‘signal’ is not creditworthy. The correct term is either action potential or impulse.

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Key messages

When planning an investigation, it is important to set out the work in a logical way and not repeat details that are provided. For example, in **Question 1(a)(ii)**, where the question states 'Details of how to set up the apparatus shown should not be included', no credit is awarded for repeating the details provided.

Candidates should be encouraged to highlight and annotate the information provided in each question. Identifying key points and looking for trends in data will help promote understanding.

General comments

Candidates need to use precise terminology such as volume and concentration; 'amount' is never an appropriate term in this context.

It is important that candidates always show their working for calculation questions as credit may be awarded, even if the final answer is incorrect.

When making conclusions using statistical data, as in **Question 2(d)(iii)**, candidates should focus only on the relevant probability threshold. Those candidates who gave conclusions for every critical value in **Table 2.4** did not gain full credit.

It is important that candidates understand the difference between the control for an investigation and variables that need to be standardised, as in **Question 3(a)(i)**.

Comments on specific questions

Question 1

(a) (i) Most candidates correctly identified the independent variable as the wind speed.

(ii) This question was well answered, and many candidates were able to describe a suitable method to investigate the effect of wind speed on the rate of transpiration. Several candidates developed clear and appropriate plans that addressed all of the key aspects of the method.

Changing the setting of the fan was the most common approach to achieve varying wind speeds. The fan should be placed at the same distance from the plant if different settings are used. Some candidates suggested other valid methods to vary wind speed, such as placing a fan on a medium setting at different distances from the plant. At least five different wind speeds should be tested so that a meaningful graph can be plotted showing the relationship between wind speed and rate of transpiration. Strong responses included consideration of how the different wind speeds could be measured, for example by using an anemometer or a digital wind speed meter.

Most candidates considered the variables that would need to be controlled in this investigation, such as temperature and light intensity. Candidates are always asked to give a method that is 'set out in a logical order' and is 'detailed enough to allow another person to follow it'. Therefore, candidates should be encouraged to specify the method used: for example, a thermostatically controlled room and using a lamp at a fixed distance from the plant. Not all suggestions were practicable, e.g. some candidates suggested that temperature could be controlled using a water-

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bath. This would not be a feasible option for the apparatus shown in **Fig. 1.1**. No credit was given for repeating information that had been provided on page 2.

The methods planned by the majority of candidates stated the measurements that would need to be taken. Candidates should measure the initial mass of the plant and container and then measure the final mass after a set time interval. It is not possible to measure a 'decrease in mass'. Leaving the plant for only 5 minutes would not give sufficient time for transpiration to take place. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. Some responses were imprecise, referring to calculation of averages rather than means. Credit was only given to those candidates who stated that a minimum of three measurements should be used to calculate a mean for each wind speed.

The strongest responses included details of how to acclimatise the plant to each new wind speed before taking measurements. It is also appropriate to replace the water lost from the plant before each new measurement; ideally this would be adding the same mass of water as the measured decrease in mass of the plant. The majority of responses incorporated some form of risk assessment. Where potential hazards were identified, most responses clearly indicated how associated risks could be reduced. For example, the plant might cause an allergic reaction and gloves should be worn.

(iii) Most responses correctly stated that as wind speed increases the rate of transpiration also increases. Stating that the mass of the plant will decrease as the wind speed increases was insufficient to gain credit; a reference to rate or time was also required.

(b) (i) The majority of candidates were able to correctly calculate the rate of transpiration to three significant figures as 26.3 h^{-1}. Answers given to three decimal places did not gain credit. A few candidates did not use the information provided in **Fig. 1.3** and attempted to convert units unnecessarily.

(ii) Candidates were asked to state one change that could be made to the method to improve the validity of the results. A few candidates suggested using the same sized piece of cobalt chloride paper. Some candidates considered the subjectivity of judging the end-point by eye. Candidates should be aware of the importance of using colour standards when judging colour changes. A colorimeter would not be suitable for this investigation.

Using a greater number of leaves was already stated as an improvement, so references to taking repeat measurements or using more plants were not creditworthy. Measuring at different positions on the lower surface of the leaf would be appropriate, although measuring the upper surface of the leaf would not improve upon the current measurements. Additionally, a systematic method could be used to select each leaf; for example, always choosing the third leaf down from the top of the stem.

Question 2

(a) Candidates were asked to state three environmental conditions that should be standardised in the glasshouse, other than the temperature of the glasshouse. Creditworthy responses included standardising the light intensity, humidity or the type of soil. Whilst many candidates identified water, carbon dioxide or mineral ions as variables to be standardised, a common error was to refer only to the amount of these variables. References to the volume of water and the concentration of carbon dioxide or mineral ions, and not just 'amount', were required.

(b) Most candidates used **Fig. 2.1** to correctly state that a high mean temperature leads to a decreased mean stomatal conductance. Credit was only awarded if they also stated that this happened in both isohydric and anisohydric tree species.

(c) This question challenged candidates' ability to organise and apply a large amount of information. Annotating **Fig. 2.1** with information from the text and **Table 2.2** would help candidates to reflect more easily on what the data was showing. Many candidates compared groups **3** and **4** using **Table 2.2** to correctly state that the difference in mean stomatal conductance for anisohydric species was not significant. These candidates then compared groups **3** and **4** using **Table 2.2** for isohydric species, noting that the difference was significant. Credit was given where candidates also noted from **Fig. 2.1** that isohydric species exposed to water stress and a high temperature show an increase in mean stomatal conductance. Lengthy discussions of the *p* values given in

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Table 2.1 were not required. The term 'insignificant' should not be used when discussing statistical data.

Some candidates compared group **1** with group **3** using **Fig. 2.1** to correctly state that water stress leads to a lower mean stomatal conductance. To gain credit, candidates also needed to state that the decrease occurred in both isohydric and anisohydric species. A few then gained further credit by explaining that the lower stomatal conductance would reduce water loss from the trees. Most candidates found it easier to suggest conclusions than to explain them. The cooling effect of increased transpiration in isohydric species exposed to water stress and a high temperature was rarely stated.

Comparing isohydric species to anisohydric species within the same group gained no credit. Several candidates were able to give a suitable data quote to support their conclusion. It is important to take care to read graphs accurately when quoting data.

(d) (i) Candidates were often able to state the null hypothesis in an appropriate way. One of the most common errors was to state that there was no correlation or no relationship between the data sets for isohydric and anisohydric tree species, rather than no difference between the means. Some candidates incorrectly expressed the null hypothesis in terms of the difference between the mean number of leaves that were dead, rather than the mean percentage.

(ii) Candidates were usually able to correctly calculate the value of t as 1.883. For credit to be awarded, the answer should be given to the same number of significant figures as the value given in the question, so $t = 1.9$ was not credited.

(iii) Many candidates recognised that the relevant probability threshold to consider was that of $p = 0.05$. The strongest responses stated that the calculated value of t was less than the critical value of 2.011. Therefore, the null hypothesis is accepted and there is no significant difference. Some candidates selected the wrong critical value of 1.667 (for $p = 0.10$). The ability to recognise and select the correct critical value was required for credit to be awarded.

Question 3

(a) (i) Many candidates recognised the principle that a suitable control method would involve the human volunteer and no insect repellent.

(ii) Most candidates were able to identify a risk to the scientists carrying out the investigation and indicate the precaution that should be taken. For example, the mosquitoes might take a blood meal from the scientist or transmit pathogens, and suitable PPE should be worn. Some candidates suggested using mosquito repellent as a precaution; as this would impact on the results of the investigation, no credit was given. Answers that focussed on the risk to the human volunteer were not creditworthy.

(b) The majority of candidates were able to use the data in **Table 3.1** to state that 98% DEET was an effective mosquito repellent. Further credit was gained by candidates who went on to state that 40% DEET was less effective. A common error was in not distinguishing between the two concentrations of DEET. Several candidates gained credit by noting the absence of a statistical test. Stating that there were no repeats did not gain credit.

Ideas relating to the overlap of standard error for 98% DEET and lemon eucalyptus oil were valid. The strongest responses stated that this overlap indicated that there was no significant difference between these repellents. Several candidates stated correctly that lemon eucalyptus oil might be a better choice as it contained a lower concentration of chemical and therefore might be safer. References to the size of the standard error and to reliability did not gain credit.

Strong responses also considered whether the procedure supported the student's decision to use a mosquito repellent that contained DEET. The limitation of only testing mosquito repellents on one human volunteer was noted by some candidates. Candidates were sometimes confused by the procedure and thought the mosquitoes were killed by the spray. The investigation only measured the attraction of mosquitoes to the human volunteer. A few candidates noticed that some mosquitoes were still attracted to the human volunteer, even when 98% DEET was used. Several candidates realised that the mosquitoes used in the investigation, *Aedes aegypti*, do not transmit malaria. Stating that the procedure did not use *Anopheles* mosquitoes was creditworthy.

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Key messages

An aim of any experimental procedure should be to generate reliable data. Accurate data is not the same as reliable data and is produced with the use of precision equipment and not by repeating the experimental process.

The term volume is not an alternative term for mass. The term 'amount' is not accepted as it is not specific.

Repeating a procedure is not carried out to find anomalies, although repeating a procedure can be used to reduce the impact of any anomalies. In large data sets any anomalies may be excluded.

The inclusion of full working for each process in calculation questions enables credit to be given for some processes even if the final answer is incorrect.

General comments

The spelling of terms is important, particularly when the misspelt word has a different meaning, for example, in **Question 1(b)**, 'quadrant' was not credited as it has a different meaning to 'quadrat'.

In **Question 1(b)** and **Question 2 (b)(vi)**, it was important for candidates to study the stem of the question carefully and tailor their answers to the specific requirements of the scenario. In **Question 1(b), c**andidates needed to be familiar with both belt transects and Simpson's index of diversity (*D*). This was challenging as the standard responses, e.g. repeating three times and calculating a mean and controlling abiotic factors, were not relevant to the investigation described.

Comments on specific questions

Question 1

(a) (i) Most candidates demonstrated full understanding of independent and dependent variables. These candidates were able to identify the tree species as the independent variable. Some candidates wrote a full sentence beginning with 'The undergrowth'; this identified the undergrowth as the independent variable and so could not gain credit. Weaker responses often only referred to alien species or indigenous species, without reference to trees.

(ii) Many clear answers were seen which indicated that the candidates had read the information carefully. The most common responses gave the number of the plantations and the area of the plot as variables that had been standardised. Weaker responses did not make a clear distinction between the plot area within each plantation and the area of the whole plantation, or described environmental conditions that cannot be controlled. It should be noted that the term 'area' can mean a unit of measurement or a location so responses such as 'the size of the area' were too vague. A few candidates gave the use of a belt transect as the method used to collect data.

(b) Some excellent answers were seen, gaining full credit. Many candidates described how to lay out and use a belt transect clearly and concisely. Weaker responses did not distinguish between the plot and the plantation, or described transects that extended beyond the plot area. Quadrat was misspelt by some candidates.

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Credit for the collection of data required careful wording to include a statement about counting the numbers of each plant species in each quadrat. Some candidates showed knowledge of the Simpson's Diversity Index formula, which was not required. References to the ACFOR scale and general references to abundance as an alternative to number were too vague. Weaker responses counted trees rather than plant species in the undergrowth and described the use of random sampling and systematic sampling. The strongest responses recognised and fully described appropriate safety precautions. Weaker answers were often vague, e.g. 'wear gloves to prevent allergies' without reference to the cause of the allergy. Candidates should be aware that there is only a limited amount of credit available for safety and providing a full description of all possible hazards would not gain extra credit. Candidates should be aware of the distinctions between systematic sampling using a belt transect and random sampling methods to estimate abundance. Candidates should also be aware of the distinction between area and length.

(c) This question required two elements in the answer - a statement and a matching explanation based on specific data from named species. The data that could have been used was either the mean data for each named species or the biodiversity, *D* values for each named species, for each month. The strongest responses used correct data from named tree species to justify supporting or not supporting the hypothesis. Many candidates made general statements about alien or indigenous species without naming the specific species.

(d) (i) Most candidates correctly described a simple dilution using distilled water. Their accounts were clear and would produce the final required concentrations with the appropriate volumes and units for both the stock solution and the distilled water. Some responses used the formula $C_1V_1 = C_2V_2$ and needed units or clear descriptions of what the C and V figures referred to for credit to be awarded. Weaker responses contained incorrect units or no units or described a correct procedure for one dilution and then stated 'repeat the opposite' for the second dilution. The question required responses to contain a description of both dilutions. The use of distilled water to dilute the stock solution was expected.

(ii) Many candidates gained credit for clear, correct calculations and writing their answer to 3 significant figures. Fewer recognised and stated that the percentage change was a decrease, –13.1%. Weaker responses had calculations which used an incorrect numerator or denominator.

(e) This question challenged candidates to fully process the information provided in the written method and the data. Each mark point could be gained by identifying one improvement and how that specific improvement would improve confidence in the results. Strong candidates wrote clear responses describing the use of repetition as a way to achieve a clearer trend or to reduce the impact of anomalies. The use of statistical analysis was suggested, often with limited reference to what this would achieve in terms of judging the significance of any differences. It should be noted that repeats to calculate means are not undertaken to identify or check for anomalies. Some suggestions were not feasible, for example: measuring all the roots or measuring the roots at different times during the growth period. A common answer described using seeds from the same packet or flower; this does not remove the impact of genetic differences, only the use of clones would do that.

(f) This question was answered well by many candidates. These candidates recognised that the number of microorganisms might vary with distance from the roots and that the mass of the soil removed during sampling was important. Weaker responses implied that the soil was taken from the environment rather than the container or they gave standard answers that could be applied to many different investigations about controlling environmental factors.

Question 2

(a) Many candidates counted the eyepiece units correctly and produced clear calculations using the information provided in the stem of the question. Most understood that the magnification was not needed as the size of an eyepiece graticule division in nm was provided. Correct conversion to μm was seen on most scripts along with the answer of 8.96.

(b) (i) This question was about how the process of measuring of the nuclear diameter could be carried out to obtain valid comparisons. Few candidates recognised the need to measure the same aspect of the nucleus, namely the longest or widest part of the nucleus. Repeating measurements and

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calculating a mean would not generate valid data. Some candidates assumed that using the same microscope magnification or same graticule would be sufficient.

(ii) The majority of responses gained credit for reference to the use of the thyroid gland. The magnification of the microscope was also seen. Few candidates mentioned the fact that one scientist had carried out all of the measurements or that the scientist did not know whether the cells were malignant or benign.

(iii) The correct wording of a null hypothesis was understood by many candidates. Weaker responses were too lengthy and confused. Candidates should understand that correlations or relationships are not appropriate in this context. It was important to include the term 'mean nuclear diameter', without which the response would indicate that the diameter of the cell was being measured.

(iv) Few candidates recognised that the null hypothesis could be accepted. Careful attention to the reference to probability in the question stem was required.

(v) This was a challenging question that required candidates to write a comparative statement about the mean nuclear diameters of malignant and benign cells and then provide the evidence to support the statement. An explanation that was limited to data quotes was insufficient. A very small number of candidates mentioned the overlapping means but without +/– 2 SE.

(vi) This question required candidates to explore the disadvantages of the sampling procedure and having only one scientist measuring the diameters of hundreds of nuclei. The responses had to include aspects of the procedure and why each aspect identified was a disadvantage. Most candidates were able to identify disadvantages; the most common disadvantage given was that the procedure was time consuming. Relatively few considered the impact on patients or its use in a large-scale programme. It was expected that candidates would review all aspects of this specific procedure and not simply recall stock responses about the lack of statistical tests. Many recognised the potential for human error and a few put this into the context of taking small measurements and a large number of measurements.

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Key messages

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

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

Candidates should be given opportunities to evaluate a variety of experimental techniques and make use of statistical data to support their answers.

General comments

It is important that candidates develop the skill of determining variables in preparation for this paper.

When repeating and determining a mean, as in **Question 1(a)(ii)**, candidates need to focus on what should be repeated and how, and also how many means should be calculated. At least three replicates should be carried out and a mean should be calculated, in this instance for each type of blood vessel. The term 'average' should not be used.

In **Question 2(a)**, where candidates needed to describe how to produce a specific concentration of solution, dilutions should always be carried out with distilled water.

The use of 95% CI and checking whether they overlap is a key skill for statistical analysis, as required in **Question 2(e)**.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to identify the independent and dependent variables correctly, although some wrote them the wrong way around.

(ii) Many candidates were able to achieve full credit with a clear method to determine the mass required to break an artery and a vein. Stronger responses stated the equipment and techniques needed for each step of the method. For example, a scalpel should be used to cut the blood vessel. Credit was given for standardising the length of each blood vessel by using a ruler. The source of the blood vessels should be standardised. It would also be appropriate to discard any samples that were damaged or not healthy.

The majority of candidates added 10 g masses to the mass hanger, as shown in **Fig. 1.1**, until the blood vessel broke. The highest-achieving responses measured the total mass when each blood vessel broke, including the mass of the mass hanger in this total. An excellent refinement of the investigation would involve repeating the procedure with smaller mass intervals near to breaking mass as this would give a more precise breaking mass.

Risk assessments should include a hazard, the risk associated with that hazard and the precaution that should be taken. For example, blood vessels are a biohazard due to the pathogens that might be present, and gloves/PPE should be worn.

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(b) (i) The majority of candidates correctly completed **Table 1.1** with the percentage change in length. It is important to follow the convention within the table in terms of the number of decimal places. Devising the method used to derive the examples already given would help candidates answer questions of this type.

(ii) Many answers here were generalised; for example, the percentage change was calculated so that results can be compared. Further qualification was required in terms of the likelihood that the initial lengths of the veins would vary, so percentage change in length would make the comparisons more valid.

(iii) Most correctly plotted the mass added against the percentage increase in length. Some candidates used the length of the ring of vein as their *y*-axis data, although it is preferable to use percentage increase in length of vein for the *y*-axis, as calculated in **Question 1(b)(i)**. It is important to include all data points (including the origin) and so a truncated *y*-axis should be avoided in this case. When constructing a graph, it is important to draw a line connecting all data points.

(iv) Most candidates were able to sketch the curve they would predict for the muscular artery, starting at the same point and remaining below the line of the vein. Candidates needed to use percentage increase in length of vein for the *y*-axis in **Question 1(b)(iii)**, as otherwise the starting point for the sketched line was unclear. Full credit was only given to candidates who used percentage increase in length of vein for the *y*-axis and started their sketched line at zero.

(v) Many candidates were able to make use of their knowledge of the structural differences between veins and muscular arteries to explain their sketch in **Question 1(b)(iv)**. It was important to be specific about which feature is thicker in the artery; for example, muscular arteries have more smooth muscle or a thicker wall. Stating that arteries are stronger without giving a reason was not sufficient. The strongest responses noted that muscular arteries withstand more blood pressure and therefore stretch less than veins.

(vi) Most candidates gave only one suggestion for a method to improve the quality of the results. Many focussed on the need to add smaller masses to the mass hanger. A few candidates standardised the width of the blood vessel or suggested that the range of masses added could be extended by adding more masses. Adding a pointer to the blood vessel and measuring at eye level would allow more accurate length measurements to be recorded.

Question 2

(a) Several candidates described a correct dilution, adding 1 cm^3 of stock solution to 149 cm^3 of distilled water. The relative magnitudes of the concentrations, with their values being given in standard form, caused difficulties for some candidates. The strongest candidates were able to give a correct dilution factor of 150; describing the dilution as 1 to 150 or 1/150 was also creditworthy.

(b) Many candidates were able to suggest methods to standardise the measurement of the stem with most opting to straighten the stem while measuring. Holding a piece of string along the stem, and then measuring its length would also be appropriate. Some candidates maintained the environmental conditions for the growth of the plant or when measuring; candidates need to be aware that some plant measurements will not require a standardised environment.

(c) (i) Most candidates correctly calculated the rate of stem elongation for the low concentration GA_3 as 1.9 $cm\,day^{-1}$. The answer should follow the decimal point convention used in **Table 2.1**.

(ii) Many answers stated the need for statistical analysis and some identified the anomalies between day 14 and day 16 for the high concentration GA_3. A very few answers referred to the problem with the resolution of the measurements given; the stem length was only measured to the nearest cm.

(iii) More candidates were able to suggest modifications to the investigation to increase confidence in the results than were able suggest shortcomings. Most answers referred to increasing the duration of the study or increasing the number of seedlings. Those candidates who noted the anomalies in **Table 2.1** could gain credit by suggesting that the high concentration GA_3 experiment should be repeated.

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(d) A very well-answered question with the majority of responses following the convention in the other examples given in **Table 2.3**.

(e) Candidates found this question challenging. Many made a direct comparison between both types of gibberellins when a comparison between the different wavelengths of light and the concentrations of gibberellins was the focus of the question. Use of the correct language when describing the concentration of gibberellin was important and it is always advisable to use the language given in the question in such cases.

Several candidates concluded correctly that the highest concentration of GA_8 was with red light and the highest concentration of GA_1, was in the dark. Understanding that gibberellins are produced and not grown in response to the different wavelengths of light was important. The strongest responses then compared the effect of the different wavelengths of light on the concentration of either gibberellin, for example noticing that there is a higher concentration of GA_8 for all of the wavelengths of light when compared to darkness. Effective use of available statistical analysis when making conclusions gained credit. Using **Table 2.3**, 95% confidence intervals (95% CI) do not overlap for a higher concentration of GA_8 at all of the wavelengths of light, so there is a significant difference.

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