# BIOLOGY

**Paper 9790/01**
**Structured**

## Key Messages

- Candidates should be prepared to re-read the stimulus material that introduces a whole question or covers a number of part questions. The relevance of some of the information often becomes clearer as progress is made through a question.

- This syllabus names some biological molecules within its Learning Outcomes, such as haemoglobin, keratin and collagen as examples of proteins. Candidates should be familiar with the level of detail set out in the Learning Outcomes for these molecules. In responding to questions on such molecules, it will not always be sufficient to apply knowledge of general features of the type of biological molecule concerned.

- Candidates should be well versed on the main events that occur throughout the mitotic and meiotic cell cycles. This includes being able to draw annotated diagrams clearly illustrating each stage.

## General Comments

A high proportion of candidates performed extremely well overall, demonstrating a high standard on all questions and displaying the ability to apply their syllabus knowledge expertly. Extensive use of scientific terminology was evident in the majority of responses.

Nearly all candidates attempted every question and appeared to have sufficient time to complete the paper. Some candidates would have benefited from structuring their responses more clearly and separating out their main ideas.

## Comments on Specific Questions

***SECTION A***

Questions **3**, **7**, **8**, **15** and **18** proved to be the most accessible questions. Questions **2**, **11**, **13**, **16**, **19** and **20** were the most challenging.

***SECTION B***

**Question 21**

In this question, candidates were presented with information and data from a study of *Geospiza fortis*, one of the species of Galapagos finches.

**(a) (i)** Most candidates gained full credit. The most effective responses gave clear sampling dates that were linked to correct numerical data for both aspects of seed supply referred to in the table, with the units for seed abundance being included. Some candidates calculated differences or percentage decreases; credit could not be given for vague statements such as "fell by approximately half". A number of candidates did not refer to the data given in Table 21.1; others only referred to one of the two aspects of seed supply shown in the table.

**(ii)** The majority of candidates gave a correct suggestion.

**(iii)** This was the most challenging part of this question. Candidates needed to place themselves in the position of the researchers when planning an investigation. Some gave excellent descriptions of the factors they would consider and included details of sampling methods, suggesting that they had gained their own practical experience of estimating abundance. Many realised that the time of the year for sampling was an important consideration and a number were able to write about a relevant sampling method. Fewer considered how to take samples within the shortest possible time period or the size of the area that should be sampled. Very few candidates noted the importance of identifying the seed species. Accounts which were limited to a discussion of results or a general discussion about factors that could affect the distribution of the seed-producing plants and the abundance of seeds did not address the question effectively. Some candidates mentioned standard experimental ideas, such as controlling variables or taking repeat measurements, but without qualifying this further and applying it to the question posed.

**(b) (i)** Most candidates calculated the percentage changes correctly. A few did not follow match the precision shown in the table and only gave the answer to one decimal place.

**(ii)** Generally, directional selection was identified correctly as the type of natural selection occurring, although a few candidates thought that this was adaptive radiation.

**(c)** An interesting and wide variety of approaches were taken by candidates, with a high proportion fully addressing the question. Some gave expertly written accounts that linked the events occurring within the *G. fortis* population to the theoretical points that summarise how natural selection operates; these points were presented in a logical and sequential manner and scientific terminology was used in a correct context. Responses that reiterated Darwin's ideas without contextualising the principles in the example given were much less effective.

A number of candidates thought that the birds with higher mass or bigger bills had arisen during the drought as a result of mutation; they had not appreciated that there was phenotypic variation within the population prior to the drought.

Some candidates did not show clearly the idea of differential survival by considering outcomes for birds with higher mass or larger bills together with outcomes for birds with lower mass or smaller bills.

**Question 22**

A number of candidates made good use of the information provided at the beginning of this question in order to help them formulate their responses. Most of the facts presented in the text and in the summary diagram of Fig. 22.2 were unlikely to have been known to candidates and so the information required careful consideration before candidates proceeded to write their answers.

**(a)** The most effective responses reflected an understanding of the different mechanisms of transport across the cell surface membrane and suggested a viable way for urushiol to enter the two different cell types. It was necessary to have noted from the introduction that urushiol was 'an oily substance' so that passive diffusion directly via the hydrophobic core of the phospholipid bilayer or an endocytotic mechanism could be suggested. Indeed, a number of candidates began by highlighting the oily nature of urushiol as an explanation for their choice of mechanism. The stated mechanism needed to be accompanied by a brief outline. Some of these outlines were too vague; for example, some candidates stated that endocytosis involved urushiol being inside a vesicle within the cell, rather than explaining that the vesicle was formed as a result of an invagination of the cell surface membrane.

Candidates who did not note that urushiol was oily often stated incorrectly that facilitated diffusion would be the method of uptake. Others considered a role for active transport or protein pumps. A number of candidates had not read the question correctly and repeated the information in the introduction about urushiol diffusing through the skin layers to reach the skin cells.

**(b) (i)** There were many well-expressed responses demonstrating knowledge and understanding of introns and exons. Some candidates only mentioned either introns or exons and a few incorrectly named the coding regions as introns.

**(ii)** Key to this question was the appreciation that cytokines are secreted from the cell. This information was provided to candidates in the introduction at the start of **Question 22** and could also have been deduced from syllabus knowledge of the immune system. Effective responses gave a correct sequence of events leading up to the export of cytokines from the keratinocytes and made clear links between ribosomes, endoplasmic reticulum and the Golgi apparatus. A number of candidates did not consider the final destination of cytokines and were therefore unable to fully address the question.

**(c) (i)** Most candidates took note of the fact that the immune response involved in poison ivy rash does not involve antibody production and so were able to rule out a humoral response.

A minority had carefully sifted through the information given at the start of the question and realised that the initial response to the presence of urushiol was only to prime the immune system cells. A noticeable response occurred on a subsequent exposure as a result of greater numbers of specific T-cells.

For candidates who had not realised this, other valid responses included details of antigen presentation, clonal selection, clonal expansion, the role of cytotoxic (killer) T-cells and the role of cytokines correctly applied to this example. There were some responses where the distinction between the two types of cell was not made clear. For example, a number of candidates considered that T-helper cells acted as killer cells or that killer cells released cytokines. Some incorrectly thought that cytokines were cytotoxic. Others thought that urushiol was equivalent to a pathogen and wrote about infected cells, incorrectly thinking that the poison ivy rash resulted as a direct result of urushiol entry into the cell.

**(ii)** This question was generally well done, with the majority of candidates showing an understanding of the nature of antigen presentation and suggesting that some people may lack quinone (hapten) receptors. Others gave valid suggestions involving an event in the cells that would result in no hapten appearing on the cell surface membrane. There were some vague responses that did not gain credit. Most of these were suggestions that the urushiol did not penetrate through the skin layers or that the urushiol was broken down, without any further detail being given. Suggestions that some people do not have an immune response required further qualification.

**(d)** Candidates needed to understand that the *x*-axis of the graph shown in Fig. 22.3 was substrate concentration, with urushiol as the substrate for the enzyme catechol oxidase. Many noticed that Fig. 22.3 showed a standard substrate concentration curve and that the curve for enzyme and red wine was similar to a theoretical curve for competitive inhibition. Many of the candidates who deduced this then gave good accounts, applying their knowledge of the effect of a competitive inhibitor on the rate of an enzyme-controlled reaction to gain full credit.

Other candidates thought that non-competitive inhibition was occurring. The evidence for this, with a curve still trending towards the enzyme-only curve, was far less convincing. However, candidates were still able to gain full credit with either a statement that fewer enzyme-substrate complexes would be formed or a data quote to highlight the differences between the two curves.

A fairly high proportion of candidates, including a number who performed well overall, considered that denaturation was occurring and gave descriptions of a loss of tertiary structure, caused by the breakage of bonds, affecting the shape of the active site. Stating that the enzyme could no longer function because of denaturation could not be supported by the graph. Nevertheless, some credit could still be gained for these candidates, for example, if they had used data from Fig. 22.3. However, many candidates did not extract data to show comparative results.

**(e)** The most effective responses considered a feasible pathway for glyphosate to reach the roots, beginning with an initial external application to the leaf. There were some excellent outline descriptions of the mass flow theory.

Many candidates stated that glyphosate would enter through the stomata, without considering that stomatal density is lower on the upper surface of leaves compared to the lower. In addition, such candidates often went straight on to consider transport in the phloem sieve tubes without considering that the herbicide would have been in the intercellular air spaces. Some responses gave suggestions that indicated that transport could be in either the phloem or xylem, without considering that transport in the xylem is a one-way pathway from the roots.

**Question 23**

This short question assessed understanding of the link between the light-dependent and light-independent stages of photosynthesis and between eukaryotic chloroplasts and photosynthetic prokaryotes. A small proportion of candidates gave sufficiently detailed answers to gain full credit. Most others gave a partial answer for part **(a)**, while many did not consider sufficiently carefully what they were being asked to explain in part **(b)**. Part **(c)** was very well done by the majority.

**(a)** Although candidates realised that the light-dependent reactions resulted in products that were required in the light-independent reactions, many did not name the products or give some qualification as to why the products are needed.

**(b)** This question was very well answered by some candidates, who gave concise, clear explanations of the statement. Some knew that the synthesis of photosynthates resulted from the Calvin cycle but were only able to state that the extra six carbon atoms could be used to make these compounds, without giving further details. Responses that simply gave an outline of the cycle without addressing the focus of the question could only achieve limited credit. Some candidates incorrectly stated that the loss of carbon atoms was as a result of the production of carbon dioxide.

**(c)** The most effective responses outlined the events that occurred in the progression from photosynthetic prokaryotes to chloroplasts of eukaryotic cells. Most candidates used the term 'endosymbiosis' within their response, but some wrote about prokaryotic cells incorporating photosynthetic prokaryotes without explaining how this could then lead to chloroplasts in eukaryotic cells.

**Question 24**

The emphasis of this question was mainly on biochemistry and molecular biology, but it also extended into the role of collagen in blood vessels.

**(a)** A few candidates used precise terminology and gave detailed explanations, focusing on the importance of glycine in the structure of collagen. Others did not give details of the structure of a collagen polypeptide or even the interaction between the polypeptides, instead writing about the collagen fibril, which was too far removed from glycine to be creditworthy. Many candidates did not appreciate the difference between the helical nature of the individual polypeptide and the term 'alpha helix', as assigned to protein secondary structure. A number misread the question and described general protein structure including details of the four levels of protein structure. Some of the weaker responses mentioned glycosidic bonds between strands.

**(b) (i)** Candidates needed to be confident about the general structure of an amino acid before tackling this question. Some drew out this structure in the space next to Fig. 24.2 for reference. Most candidates correctly identified the R-group, but there were some who left out the $CH_2$ or $CH_2$-$CH_2$ section and placed a box around the lower part of the R-group. Others only boxed in the first $CH_2$. Some candidates drew a box around the hydrogen of the alpha carbon atom.

**(ii)** This was well done by most candidates; some comparative statements of difference were very clear. Some candidates had not read the question carefully enough and framed their responses in terms of the differences between $\alpha$- and $\beta$-glucose.

**(c) (i)** The majority of candidates did well on this question. All expected suggestions were seen, with the most popular being the avoidance of immune response problems. Some candidates did not read the introduction sufficiently carefully and gave cost as a reason, not noticing that it had already been stated that the procedure was not always cost effective.

**(ii)** This was also very well answered by most candidates.

**(d)** Candidates who gave thorough responses included details about the structural features of collagen and linked these to the functions of the molecule. They continued their answers by applying these ideas to the symptoms of scurvy, explaining the symptoms in terms of the role of collagen in connective tissue and lack of tensile strength. Weaker responses included general facts about the levels of protein structure, which were not pertinent to the question, or simply repeated the symptoms already stated in the introduction. Only a few candidates stated that collagen was an important structural protein. Some candidates were precise in explaining the presence of collagen in the particular layers making up the walls of blood vessels. Other candidates were vague or gave confused or incorrect responses. For example, they stated that 'collagen is elastic tissue', forms the tunica intima or has an important role in blood capillaries. Some candidates clearly had a gap in their knowledge of this section of the syllabus.

**(e) (i)** Candidates who were confident in their knowledge and understanding of this topic had no problems in applying this to the investigation of *GULOP* using the rat cDNA probe. They gave a logical progression of relevant ideas in their answers. Some responses were poorly structured, often repeating the information given about the mutations present in *GULOP* and only touching upon an explanation of how the investigation supported the idea of *GULOP* once being an active gene.

**(ii)** Almost all of the candidates gained some credit here by explaining that a change in the primary structure of a protein alters its tertiary structure or that a change to the shape of the active site would lead to a loss of function of the protein. Fewer described correctly what the effect of a single base-pair insertion would be, but for those that did descriptions tended to be well-expressed and accurate. Only a few used the term 'frame shift' in their answers. Many candidates focused incorrectly on describing a base substitution mutation.

**(f)** This question was answered very well by most candidates.

**Question 25**

The most able candidates found this question to be straightforward, with only part **(c)** making them pause to work out the required details. Some gained full credit. Part **(a)** was a good opportunity for candidates of all abilities to do well providing that they had learned Section 3.6 of the syllabus thoroughly. Without this preparation, a number of candidates floundered. Fewer candidates were able to perform to a high standard on part **(b)**, highlighting the need to be clear about all stages of mitosis and meiosis. Part **(c)**, an exercise to deduce the number of chromosomal DNA molecules per cell at different stages of oogenesis, was particularly challenging and required clear thought in addition to sound knowledge.

**(a)** Well-organised responses gave a short introduction listing the hormones produced by the ovary and the anterior pituitary gland before outlining the role of each hormone in a sequential manner to show how they controlled the menstrual cycle. Weak responses included reversing the roles of progesterone and oestrogen and omitting to mention the effect of these hormones on the uterine lining. Some responses gave only vague links between the relevant hormones and the development of the follicle and/or corpus luteum. Some candidates went on beyond the menstrual cycle into pregnancy; this was not required.

**(b) (i)** Generally only those candidates who performed well overall knew the precise stage of meiosis that was shown in Fig. 25.1. Some gave metaphase, but did not state whether this was meiosis 1 or 2. Others stated prophase and anaphase, most commonly anaphase 1. Anaphase 1 begins when the homologues separate from each other and move towards opposite poles.

**(ii)** This was a good example of the importance of reading through a question carefully before attempting to formulate a response. Some candidates addressed the question effectively by writing only about chromosome behaviour before the stage shown in Fig. 25.1; they often drew diagrams that supported their descriptions. However, other candidates included extra information that was not relevant, such as the behaviour of the centrioles and/or spindle or descriptions of the state of the cell at interphase. Some gave details about DNA replication and there were a number who gave an outline account of all stages of meiosis 1 or who only described Fig. 25.1.

A number of candidates provided vague or inaccurate accounts. Some thought that chromosomes condensed at late interphase. Others stated that chromosomes replicated during prophase 1. A sizeable minority failed to mention the pairing of homologous chromosomes. Many candidates did not seem to appreciate that genetic material was exchanged between non–sister chromatids of homologous chromosomes and that alleles of the same genes were involved. Often the use of terminology appropriate to the standard required was lacking. Where credit was given to weaker responses, it tended to be for knowledge of chiasmata and crossing over although, even here, responses considering these aspects were often too vague or imprecise for credit to be awarded.

**(c)** Candidates needed to adopt a methodical approach to working through the information provided. Many would have benefited from going through this more than once and checking that their deductions were correct. Those who had performed well on **(b)** also tended to perform well here, which was to be expected since correct knowledge of prophase 1 is indicative of a candidate who has a good grasp of meiosis in general.

Part **(c)** was not well attempted by the majority, with often only the last row of Table 25.1 being completed correctly. DNA replication occurs during the S-phase of interphase so immediately before the onset of prophase 1 each of the chromosomes has two chromatids and thus two DNA molecules, giving 92 DNA molecules in total for the 46 chromosomes. This was the starting point for candidates to complete the second row of the table and continue carefully through each of the events.

**Question 26**

This question asked candidates to consider how the small and large intestines of a herbivore differ from that of a carnivore. Many of the most effective responses gained full credit with a few concise and succinct sentences providing a sequential account of the differences.

Some candidates did not read the question sufficiently carefully and began their response with details comparing the stomach of a carnivore with that of a herbivore. A number extended this to compare the stomachs of ruminant and non-ruminant herbivores. Such details, however accurate, were not relevant to the question. In a few cases, candidates did not go on to consider anything other than the stomach and therefore were unable to address any aspects of the question. Some candidates who did begin with the intestines also included details about the pancreatic enzymes, which were not required. Longer, vaguer responses were sometimes contradictory; for example, some candidates stated at the beginning of their response that the small intestine of the herbivore was shorter than that of a carnivore, but later on stated the opposite. Examples of this type highlight the need to carefully read the question and check that it is addressed by the answer, even if it is the last question on the question paper.

# BIOLOGY

**Paper 9790/02**
**Long Answer**

**Key Messages**

- Successful candidates show a detailed knowledge and understanding of the syllabus and are able to apply this in familiar and unfamiliar contexts.
- Candidates should be able to make a critical study of information provided and illustrate their answers with carefully chosen examples taken from data provided.
- Candidates should know which statistical methods are appropriate to different types of investigations and be prepared to carry out suitable calculations and then interpret the results.
- There are principles in this syllabus that have many applications and candidates should be able to identify contexts where these are relevant. One example is that of surface area to volume ratio, as found in **Question 2** in this paper.
- The essay and the case study provide opportunities to bring together several related topics in a balanced and integrated way and to demonstrate argumentation when developing a theme.

**General Comments**

The various parts of each question on the paper often share an underlying theme or interrelated themes; careful reading of each part question to identify the theme or themes often helps to answer the whole question.

There were numerous examples of good responses and the Examiners were pleased to note that many of the scripts were of a very high quality.

Many candidates did not realise that Simpson's index of diversity was relevant to the planning exercise in **Question 4**. Many showed a lack of clarity in explaining how data should be presented and analysed using statistics and this limited the credit gained on this question. The Examiners were, however, pleased to note that other aspects of the planning exercise showed a significant improvement on last year's performance.

Many candidates understood the mechanics of carrying out statistical tests but found it difficult to apply an understanding of probability in biological contexts. **Question 1 (b)** was an example of this.

There were many pleasing essays in ***Section C*** in which candidates displayed not only a detailed and balanced knowledge, but the ability to think synoptically and to develop effective argumentation.

All candidates attempted all parts to all questions and there was no indication that there was insufficient time to complete the paper.

## Comments on Specific Questions

### *SECTION A*

### Question 1

The theme for this question was the lactose molecule, its hydrolysis by lactase and lactose intolerance. This question tested Learning Outcomes 1.4 (i) and (j) and 2.2 (e) and (f). Part **(b)** tested the interpretation of the *t*-test in terms of probability. There were some good answers, but a significant number of candidates did not interpret the simple significance test clearly in part **(b)**.

**(a)** Many candidates lost credit through not correctly explaining the hydrolysis of a disaccharide into its component monosaccharides. Many did not add water to the equation, did not indicate what happened to the water after the bond broke and did not label the resulting glucose and galactose.

**(b) (i)** Many candidates were unable to identify clearly which difference was statistically significant and which was not, or to interpret the results in simple terms. It was apparent that lactose was the cause of the symptoms. Lactose-free milk offered lactose-intolerant people a viable alternative since it was no more likely to cause the symptoms in people who were lactose intolerant than was ordinary milk to people who were not.

**(ii)** Most candidates suggested at least one limitation of the experiment. Suggestions included that the sample size in the lactose-tolerant control group was too small, that the method of collecting data was too subjective and that variation within the sample might be reduced by restricting it to males or females or to specific age groups. Few candidates gained full credit.

**(c)** The practical application to produce low lactose milk is an example of an industrial process which uses hydrolytic enzymes. This part of the question enabled candidates to demonstrate their knowledge and understanding of the advantages of immobilised enzymes including reduced costs by facilitating continuous culture (as opposed to batch culture), reduced downstream processing and more efficient use of enzymes. Many candidates gained credit on this part of the question.

### Question 2

The unifying theme for this question was that of surface area to volume ratio and how this relates to maintenance of a constant body temperature in mammals, gaseous exchange in insects and the need for respiration to compensate for energy loss to the environment. Fig. 2.1 introduced the idea of adaptation to habitat and part **(b)** referred to environmental changes that have occurred over geological time. This question tested Learning Outcomes 3.1 (a) and (c) and 1.5 (a).

**(a)** Most candidates recognised that there was a negative correlation between body mass and environmental temperature and some suggested that mammals in cold places might be large because of their thick fur and fat reserves. However, many did not recognise that this had something to do with surface area to volume ratio.

**(b) (i)** Many candidates correctly described the gaseous exchange system of an insect in terms of spiracles and tracheoles and the breathing movements of the thorax and abdomen due to muscle action.

**(ii)** This part of the question was about the relationship between diffusion and surface area to volume ratio. Insects' bodies rely on diffusion of oxygen for respiration and the size of insects is therefore limited by the rate at which oxygen can diffuse into all of their cells. The result of the historic reduction in oxygen concentration given in the question was to reduce the diffusion gradient and so reduce the rate of diffusion of oxygen into cells. The maximum rate of aerobic respiration was therefore limited, leading to a decrease in the availability of ATP to provide energy for growth and movement (flight). The latter was particularly critical for the dragonflies with the largest wings. The only insects to survive this environmental change were the smaller ones.

**Question 3**

The theme here was investigating human evolution by comparison of a gene sequence from DNA extracted from modern humans, four species of modern primates and fossilised remains of Neanderthals. The question tested Learning Outcomes 2.2 (m), 1.7 (d) and (i), 2.4 (a), (c) and (e) and 1.6 (k).

**(a)** Most candidates had no difficulty with this question although all four nucleotide bases had to be given accurately. Misspelling a word like adenine can easily transform it into the name of a different substance.

**(b)** Most candidates had no difficulty in identifying the polymerase chain reaction as the answer.

**(c)** This question asked candidates to evaluate the application of the binomial *Homo sapiens* to Neanderthals. This required an understanding of the limited nature of the evidence. Many candidates gained full credit by recognising that the scientist was suggesting that Neanderthals and modern humans were the same species and going on to discuss the impossibility of directly testing whether they could interbreed and produce fertile offspring.

**(d)** This question required a detailed discussion involving references to DNA profiling, phylogenetic classification and consideration of limitations of the data (e.g. small sample size). Many candidates gained credit for recognising the principle that the fewer the number of differences between the species the more recently they shared a common ancestor, whilst appreciating that the data was based on a very small sample of DNA. However, few gained maximum credit. Not all candidates supported their answers by quoting selected data, for example, that a chimpanzee differed from humans by two bases but a macaque by ten. Only a few discussed the fact that cytochrome is a mitochondrial protein found in a very large range of species.

**(e)** The final section concerned the role of mutation in evolution. Credit was not available for simply listing possible causes of mutations such as substitution, deletion and insertion. Credit was only awarded if substitution was identified as the only possible mutation, since this is consistent with the data in Fig. 3.1. Further credit was available for considering a possible cause of the substitution in terms of incorrect pairing during DNA replication or suggesting a possible mutagenic agent.

**Question 4**

This question required knowledge of biodiversity and of the techniques to measure it from Learning Outcomes 5.2 (a) and (b), and Practical Learning Outcomes 5.2 (i) and (ii).

In the planning section, most candidates gained marking point P1 for a simple, plausible hypothesis. Most also gained P2 for suggesting a reasonable scientific rationale, such as stating that a mowing machine would cut everything including large prickly shoots, or that sheep are selective in their eating. Few candidates gained P3 for a more detailed discussion emphasising, for example, that this ancient vegetation type had been grazed by sheep for centuries and that their selectivity may have shaped the biodiversity. P4 required the identification of independent and dependent variables in the proposed investigation, such as mowing versus grazing (independent) and biodiversity (dependent). Marking point P5 required the identification of two variables which needed to be controlled. Most candidates suggested only one or outlined proposals that were not sufficiently specific to gain credit. Marking point P6 required the identification of a hazard and a suggestion about how to deal with it (relevant precaution). A great variety of possible responses was possible. For example, loss of control when using a heavy duty mower could damage someone's feet (hazard) and so wearing steel-capped shoes would be recommended (precaution). Many candidates made suggestions for P6 that were too general or imprecise to gain credit. For example, merely recommending wearing protective clothing against a vaguely stated threat was not enough.

Many candidates engaged effectively with the planning of this investigation and were able to suggest detailed methods. However, most did not mention Simpson's index of diversity from Practical Learning Outcome 5.2 (ii). Some candidates named it without giving a formula or explaining how to interpret the results. These omissions had consequences for planning the sampling procedure. This type of investigation requires records of the number of individuals for each species in each quadrat instead of just recording presence or absence. Some credit was awarded, as far as possible, for estimating simple species richness, but doing this, rather than working with Simpson's index, limited the scope for subsequently planning the statistical analysis of the outcomes and gaining further credit. Some candidates mentioned the *t*-test without explaining which means were being compared. The mean of (say) ten estimates of the Simpson's index of diversity value for the grazed area and the mean of ten estimates from the mown area would provide material for a bar chart (especially if it had error bars) followed by a *t*-test. These might be further compared with the mean Simpson's index of diversity with a control, such as a plot neither mowed nor grazed, or the mean at the start of the investigation so that the change in diversity could be estimated. Some candidates compared results of control plots that were left unmown and ungrazed with plots that were managed, or compared vegetation sampled before and after the mowing and grazing were carried out, to estimate change. Both approaches were credited.

***SECTION B***

This section is a case study based on data from several sources and requires candidates to apply their knowledge and understanding of syllabus content in unfamiliar synoptic contexts. In this case, the two interrelated questions explored aspects of the relationship between stomatal density and the environment.

**Question 5**

**(a)** Many candidates realised that the data in Fig. 5.1 were less than ideal but candidates were often too ready to reject everything out of hand without evaluating the information critically enough. Few appreciated that, despite its short comings, the study does in fact show that stomatal density in 23 BP is significantly less than in 3341 BP – the error bars do not overlap. The trend suggested is that stomatal density in this species has been constant for over 3000 years and that the decline in stomatal density is very recent. This perspective puts the numerous weaknesses of the data in context, including very large error bars, vague dating (one date is listed as '>2346 BP'), the fact that the sample from Tutankhamun's tomb was presumably very small and not very representative, and that a trend covering over 3000 years is represented by a mere 5 points with irregular time intervals between them. These data set the scene for what follows in this question and **Question 6**, where the possible effects of an increase in atmospheric carbon dioxide and global warming over the past century on stomatal density are explored. They also provide candidates with the opportunity to demonstrate their ability to critically evaluate data by extracting and using specific examples.

**(b) (i)** Many candidates did not consider the data to be very reliable since none of the points were on the line of best fit. This is suggestive of a limited understanding of scatter diagrams and correlation. The error bars merely reflected the fact that each point was a mean of several replicates and suggested that the variation about the mean represented by each point was much tighter than was the case in **Question 5 (a)**. The error bars for the temperatures at opposite ends of the range do not overlap and the means at these temperatures are therefore significantly different. A few candidates showed sound understanding by suggesting that were a Spearman's Rank correlation coefficient to be calculated it would probably be negative and significant.

**(ii)** This question required candidates to consider the balance in plants between minimising water loss by transpiration and maximising carbon dioxide uptake for photosynthesis. This assessed Learning Outcome 5.1 (e). Many good answers were seen in which candidates engaged positively with the information provided and demonstrated sound understanding of the principles involved.

**(c) (i)** This was a straightforward question testing understanding of the statistical term 'mode'. Almost all candidates were successful.

**(ii)** Most of the species included in Table 5.1 showed a reduction in stomatal density with an increase in carbon dioxide concentration. However, a significant minority showed increased stomatal density and, in a few cases, there was no change. This suggests that a variety of factors may be involved. Candidates who considered the result of the trade-off between carbon dioxide uptake and water loss by transpiration for plants growing in habitats with differing water availability were able to develop the fullest responses.

Many candidates were side-tracked into an often confused consideration of C3 versus C4 plants, photorespiration and CAM plants. They did not make the connections between different parts of the question.

**Question 6**

This question continued the same theme from the earlier part of ***Section B*** but the emphasis shifted from whole plant biology to the stomatal guard cells, covered in Learning Outcomes 4.1 (d) and (e).

**(a)** This question was well answered and many candidates demonstrated a sound understanding of the mechanism of stomatal opening and closing, allowing them to achieve full credit.

**(b)** Many candidates did well on this question, demonstrating sound understanding by explaining that if plasmodesmata were present in guard cells then these would allow water and ions to diffuse in and out and thus prevent the control of cell turgidity that is the basis of the stomatal mechanism. Some candidates referred correctly to the symplast route in their explanation.

**(c) (i)** There were many effective responses that displayed a real understanding of the microscopic world of a leaf surface.

**(ii)** The stem of this question introduced information that was almost certainly unfamiliar to the candidates. This concerned a possible mechanism to explain how changes in leaf stomatal density of a species can be a response to an environmental factor, in this case an increase in atmospheric carbon dioxide concentration. There was no single right answer to this question. Candidates were expected to use their knowledge of plant growth substances to suggest a possible explanation. This is relatively new research and very much work in progress, but the proposed mechanism, involving control of gene action, closely parallels the action of gibberellins in controlling cell elongation by causing the removal of repressor proteins (see Learning Outcomes 4.4 (c) and (d)). This was a demanding question but there were many thoughtful answers suggesting that increases in carbon dioxide concentration might suppress formation of, or destroy, TMM. This substance is, to some extent, equivalent to DELLA proteins (see Learning Outcome 4.4 (d)). Another suggestion was that TMM might activate the gene that produces brassinosteroids, which trigger epidermal cells to become guard cells. Some candidates suggested a combination of these two methods. Presumably there must be another mechanism operating in wet places where more carbon dioxide brings about an increase in stomatal density.

**(d)** This question directly tested Learning Outcomes 4.4 (c) and (d), but many answers were not expressed clearly enough to achieve full credit.

***SECTION C***

The essays in this section were generally of a good standard.

To do well in an essay candidates have to:

- choose the essay title which, for them, gives the greatest scope to write in full on all the aspects of the question,
- decide which areas of the syllabus are relevant to the essay so that sufficient breadth can be covered,
- identify the ‘big idea’ behind the question and ensure that each paragraph contributes to the development of this idea.

A good essay addresses each aspect of the topic in a balanced way, using selected information from the syllabus and beyond, to provide support and evidence for the main argument. Ten marks are awarded for balance, argumentation, communication skills and spelling and grammar.

**Question 7**

This essay required a clear and detailed comparative description of the social behaviour of the dunnock and red deer (Learning Outcome 5.1 (c)) and a named primate (Learning Outcome 3.3 (n)). The second aspect of the essay required integration of this material with genetic diversity, selective advantage and reproductive success (Learning Outcome 2.3 (c)). The third aspect was to discuss the nature of innate behaviour (Learning Outcome 3.3 (k)) and relate this to the examples in the essay. Effective answers tended to have some higher level argumentation about the nature of innate behaviour.

**Question 8**

This essay required a clear and detailed explanation of directional, stabilising and disruptive selection (Learning Outcome 2.3 (d)), illustrated by appropriate examples chosen to illustrate the underlying principles. The second aspect of the essay required integration of this material with the species concept (Learning Outcome 2.4 (a)), speciation (Learning Outcome 2.3 (g)) and adaptation (Learning Outcome 5.1 (a)). The most effective answers tended to have some higher level argumentation about whether disruptive selection was enough to bring about speciation without geographical isolation.

**Question 9**

This essay required a clear definition of homeostasis (Learning Outcome 3.4 (a)) and a discussion of its general features before going on to illustrate these principles with a detailed account of the control of blood glucose concentration (Learning Outcomes 3.4 (b) and (c)) and osmoregulation (Learning Outcomes 3.4 (e) and (f)). The second aspect of the essay required a discussion of the physiology of diabetes (Learning Outcome 3.4 (d)) in the light of the earlier discussion of the homeostatic control of blood glucose concentration. The most effective responses included detailed and balanced accounts of both blood glucose regulation and osmoregulation. They also demonstrated good skills of argumentation in discussing how the failure to control blood glucose concentrations disrupts the osmoregulatory system and produces symptoms of dehydration and excessive urine production. There were many very good attempts at this essay including some that achieved full credit.

# BIOLOGY

**Paper 9790/03**
**Practical**

## Key Messages

- Centres should check all the requirements for the examination. If any substitutions are needed they should make these clear in the Supervisor's Report. It is important that any slides supplied are checked carefully before the date of the examination. If any are not of suitable quality then Centres should contact Cambridge immediately for replacement.

- Prepared microscope slides are provided by Cambridge at the ratio of one slide for every two candidates. It is important that Centres organise the examination so that half of their candidates start the examination with the questions that require slides and the rest start with the questions that do not. It is unlikely that slides will be required for more than 30 minutes during the examination so candidates should have sufficient time to use them.

- In relation to the conduct of the examination, it should be stressed how important it is that Centres follow closely the directions provided in the Confidential Instructions.

- In ***Section A***, candidates should read the questions carefully before starting their practical work. They will always have decisions to make about how they implement the instructions and time is needed to consider these before they start any practical work.

- Candidates should anticipate questions on interpretation of data using knowledge of relevant learning outcomes. While carrying out the practical they should be thinking about the relevant topics and how to use them to interpret their results. This was especially true for **Question 1** in this examination.

## General Comments

There was an improvement in the overall standard with some candidates showing a wide range of skills and a detailed knowledge of the topics assessed on this paper.

It was very pleasing to find that Centres had taken note of the comment in this section of last year's report about making drawings from the microscope of prepared or temporary preparations. The quality of drawings for part **(a)(i)** of **Question 2** was very high; that for **(a)(ii)** was less so. Almost all candidates calculated the magnifications of their drawings in **(a)(ii)** and could explain their calculations in part **(iv)**. However, a few candidates simply gave the magnification that they had used to make their drawings, for example $\times 400$.

Candidates should consider their responses carefully and check that suggestions are sensible. For example, it should be apparent that there are no air spaces in the walls of blood vessels or the Bowman's capsule.

At the end of the examination, candidates should take time to read through their answers and make sure that they are complete. Several candidates left gaps in their answers to **Question 1 (a)**, presumably with the intention of completing these after part **(b)**. For example, on one script there was a blank space left for the chosen range of temperatures.

**Comments on specific questions**

***SECTION A***

**Question 1**

In this question, candidates were asked to investigate the effect of temperature on the rate of respiration of yeast using the downward displacement method. Candidates set up respirometers using syringes with glass tubing attached. This method has several disadvantages, not least the difficulty of keeping the yeast suspension at the target temperature throughout the time that readings are taken. All candidates gained results, although the disorganised presentation by some indicated a less than systematic approach to work at the laboratory bench.

**(a)** As suggested above, many candidates wrote their plans in continuous prose. There is no single approved method of writing plans, but candidates could save themselves time by using numbered points, as employed in previous papers and most practical protocols. In fact, a suitable way to prepare candidates for this paper and for the Planning Exercise in Paper 2 is to do this. One advantage of this approach is that it makes references to earlier steps much easier; for example, 'repeat step 5' is easy to incorporate into a description or a plan and avoids unnecessary repetition.

Candidates needed to show a suitable range and number of values for temperature and explain how they would determine the dependent variable and calculate their derived variable – the rate of respiration. Although the time taken to travel a set distance has a relationship to the rate this does not, however, allow easy comparison. For example, as the time increases the rate decreases. It is much better to calculate the speed of the meniscus down the tube or use 1/t. Some candidates suggested that rates could be calculated from the volume of gas collected, although none used their own results to do this by including a calculation of the cross-sectional area of the glass tube.

It was expected that candidates would choose a wide range of temperatures between 0 °C and 70–100 °C and then select three or four suitable temperatures within this range. Many did not choose a wide enough range as they rarely exceeded 40 °C and others did not state what temperatures they would use within their range.

Most candidates followed the hints in the question to incorporate controls. They decided to use the yeast in water and/or the glucose solution as controls although these decisions were rarely justified. No candidate used the results to adjust their results, for example by deducting any movement recorded for these controls.

Many candidates did not explain in their instructions whether they would use one respirometer for all their results or whether they would use several respirometers.

**(b)** Almost all candidates presented their results in tables that showed a logical sequence of columns and rows. Column headings were usually complete and units were rarely placed in the body of the table. Some candidates did not show any derived variable, such as rate / mm $s^{-1}$ or rate calculated as 1/t and expressed using the unit $s^{-1}$. Some candidates used two solidi in their column headings, for example 'rate of respiration / mm / s'. This is not the correct convention; they should have written 'rate of respiration / mm $s^{-1}$'.

Candidates mostly took care where to place headings, such as 'distance travelled by meniscus / mm' or 'time taken for meniscus to travel 20 mm / s' so that the column for the mean was included. The term 'mean' is preferred to 'average' and was used by most candidates.

Few candidates recorded *actual* temperatures. Instead, they simply gave the target temperatures in their tables. A very small number recorded the temperatures of their water-baths at the beginning and end of the equilibration period and used the mean temperature in their graph. This demonstrated a much more thoughtful approach.

Most candidates expressed their results to a suitable number of significant figures. They also used sensible numbers of significant figures when calculating means and rates. No candidate collected sufficient replicates to make calculations of standard deviation possible, although credit was available to reward this.

Some candidates either did not carry out the controls that they had planned in **(a)** or failed to record such results.

It is possible to present tables in landscape format by rotating the paper through 90°, if this is felt to better fit the data to be presented. Where this was done, the resulting table was particularly clear and effective.

Credit was available for showing the uncertainty in readings, be they for distance, time or temperature. None of the candidates gave this detail in their table. This concept is something expected in evaluations, but can also be included at this point in an investigation.

**(c)** All the graphs drawn were line graphs that followed the usual conventions. Some of the candidates who carried out controls included these results in their graphs. Where results for controls are plotted, the data points must be positioned appropriately to show the correct temperature and rate, rather than placed arbitrarily to one side of the experimental data.

The Examiners carried forward errors from part **(b)** when marking these graphs. For example, if rate had not been calculated, credit was awarded for labelling of the *y*-axis if this agreed with the table heading.

With insufficient data to draw a smooth line of best fit to show the effect of temperature, most candidates correctly joined points with straight lines. This had the advantage that candidates did not automatically take their line back to the origin if they had not used 0 °C as one of their temperatures or extrapolate beyond the highest temperature tested.

**(d) (i)** Some candidates explained that the movement of the meniscus in the glass tube was the result of oxygen collecting in the syringe. Few considered that the respiration was likely to be both aerobic and anaerobic. However, the great majority wrote about carbon dioxide, although only a few explained that this came from decarboxylase reactions during respiration – the link reaction, Krebs cycle or decarboxylation during alcoholic fermentation. Several candidates stated that respiration must be aerobic as ‘carbon dioxide is not produced in anaerobic respiration’ perhaps forgetting that they were investigating the respiration of yeast.

**(ii)** In most cases the graphs were straightforward to describe and credit was awarded both for those that showed a peak at around 40 °C and those that showed a steady increase to that temperature without a decrease at higher temperatures. A few candidates made reference to the temperature coefficient, $Q_{10}$, although no one calculated a value for this from their results. Explanations were often limited. Rarely did candidates use their knowledge of enzymes to explain the effect of temperature other than making references to kinetic energy and denaturation. Weaker candidates simply referred to yeast as if it were an enzyme, rather than giving any details expected from a study of sections 1.4 and 1.5 of the syllabus.

**(e)** The evaluations were generally much better than the explanations in **(d)(ii)**. When evaluating, candidates should endeavour to focus on aspects specific to the investigation in question, rather than just listing generic points such as ‘do more repeats’, ‘keep the temperature constant’ and ‘air bubbles in the syringe’. Sufficient relevant details should be included to clearly explain the limitation or proposed improvement. For example, some candidates stated that their method was likely to underestimate the rate of respiration and justified this with explanations. Credit was not given for criticisms and improvements that could easily have been taken account of while making decisions about how to carry out the investigation. So ‘widen the range of temperatures to include 80 °C’, for example, was not accepted since including temperatures up to and including 100 °C was perfectly possible. Including more intermediate temperatures was a valid improvement, because of the limited time available, as was testing a narrower range of temperatures around the temperature at which the rate was fastest. The latter improvements were more effective if specific temperatures were also stated.

Many candidates wrote about the difficulty of deciding ‘end-points’ as if they were looking for a colour change. Here they meant determining the time when the meniscus had reached a mark on the tube or how long it had taken to travel a set distance. Few made this clear.

Limitations will sometimes be related to the apparatus and materials provided. Possible improvements can therefore consider the use of additional resources. In this case, improvements could be made to the way in which the gas produced is measured. Some candidates suggested using graduated tubes to improve this method, while others suggested using gas syringes to collect the gas directly; both of these improvements gained credit.

One improvement that could easily be implemented is to record the distance travelled by the meniscus at short time intervals, instead of after a fixed time period. If these readings are plotted on a graph with distance as the *y*-axis and time as the *x*-axis, then results can continue to be taken until four points lie on a straight line. Since the gradient of the line is proportional to the rate of respiration this ensures that the rate of respiration has stabilised for each temperature.

Other points for consideration include:

- Taking replicate results does not increase the *accuracy* of the results. High concordance is an indication that the method is valid and the method has a high level of *repeatability*; however, there could well be a systematic error that has affected all the results.
- Candidates should use the data they have collected to support their answers; for example they could comment on the concordance between replicates or calculate the range in replicates as a percentage of the mean that they calculated for each temperature.
- pH cannot be controlled by using a pH meter alone.
- Temperature cannot be controlled by using a thermometer alone.

**(f)** There were many very good ideas about the advantages and disadvantages of using dip sticks to measure the uptake of glucose as an alternative or additional way of determining the rate of respiration of yeast. Many candidates recognised that until the glucose concentrations fall below $2\,g\,100\,cm^{-3}$, the result will always be the same.

Some candidates compared using dip sticks with the method that they had used in their investigation. Credit was only awarded for describing the advantages of using dip sticks, not for describing problems with the original method. Some candidates were concerned about putting dip sticks into reaction mixtures in case they influenced the reaction taking place. Since samples can be taken at intervals for testing, this is not a disadvantage.

## ***SECTION B***

### Question 2

The theme of this question was the relationship between the structure and function of blood vessels. The candidates were provided with slides of a renal artery (K1), an aorta (K2) and a vena cava (K3). The quality of answers was much improved compared to the previous year, although drawings from high power in **(a)(ii)** were not as good as expected.

**(a) (i)** Low-power plan drawings of the renal artery were uniformly good. All were drawn carefully with due attention to the width of the regions of the walls, using clear and continuous lines without any shading. Labelling was generally sound, although weaker candidates were not always sure what terms to use. They tended to confuse the layers of the intestine with those of blood vessels. There is no *muscularis mucosa* in the renal artery. Although not required, some candidates gave magnifications. All drawings made use of the available space, but candidates should be advised to use pencil, not ink, for their label lines and labels.

**(ii)** The high-power drawings of the wall of the renal artery were less successful. Most candidates drew a sector of the wall although sometimes these could not have resembled what was visible through the microscope as they showed no curvature. A few candidates drew details of each region as three separate drawings. Both approaches were credited, although drawing a sector is the best way to show high-power detail in cross-sections of blood vessels and other tubular structures. They also help with showing how measurements have been taken. The Examiners looked for the correct distribution of elastic fibres, collagen fibres and smooth muscle. Almost all candidates omitted any reference to the elastic laminae and to smooth muscle. If the muscle tissue was qualified, more often than not it was called striated muscle. Sarcomeres in smooth muscle are not visible in the light microscope. Many candidates labelled an endothelium, but whether one was present or not in the slides was open to question. This is so thin that usually only a few, if any, nuclei are visible. This layer was occasionally mislabelled as endodermis, epidermis or epithelium. Labelling rarely added more than was already given in **(a)(i)**.

**(iii)** Magnifications were generally appropriate for the size of the drawings. Some candidates did not convert units correctly resulting in a magnification that was one order of magnitude too large.

**(iv)** The explanations of the answers to **(iii)** were generally well expressed and almost all candidates made it clear where they had taken their measurements by putting lines across all or part of their drawings.

**(b)** There were some excellent answers to this question in which candidates compared the cross-sections of the three blood vessels. Some candidates took the hint from part **(a)** and included measurements of parameters, such as the total diameter, the diameter of the lumen and the thicknesses of the different layers of the wall of each vessel. There were also many qualitative comparisons, such as relative quantities of collagen and elastin. Almost all tables had direct comparisons across rows although not all included a column for the features compared. This can help to keep entries in the body of the table as concise as possible.

Choice of words was important for some comparisons. Instead of measuring the diameter of the lumen, some candidates indicated the rank order of the lumen diameters in the three blood vessels. This was much clearer than some other descriptions.

In some cases, it appeared that answers were recalled rather than made from direct observation. For example, candidates who wrote about valves and the strength or elasticity of blood vessels were taking their answers beyond what could be observed in the slides.

**(c)** Responses to this question that asked candidates to label and annotate the electronmicrograph of the glomerular capillary were much more variable than answers to other parts of **Question 2**. Some candidates did not recognise what they were looking at and thought that it was an image of a complete glomerulus, as they might have seen in diagrammatic form. As a result they labelled afferent and efferent arterioles either side of the endothelial nucleus. Stronger candidates identified the podocytes with their pedicels, but fewer labelled the endothelial cell and its fenestrations. Many candidates omitted the word ‘basement’ from the label of the relatively thick membrane between the endothelial cells and the podocytes. Some annotations suggested that the basement membrane is equivalent either to a cell membrane with a phospholipid bilayer or to a unicellular layer. It is neither of these. Very few explained in their annotations that the basement membrane is the only layer separating blood plasma from filtrate or stated that only substances with a relative molecular mass of less than about 69 000 can pass through this filter. Some candidates again took measurements and made calculations of actual sizes – for example, the width of the lumen of the capillary and the thickness of the basement membrane.

Most candidates gave annotations beneath their labels, but some wrote notes on ultrafiltration in the white spaces above and below Fig. 2.1 without relating these to structures visible in the electronmicrograph. Candidates should realise that podocytes are not responsible for ultrafiltration, but the slit pores between the secondary processes do facilitate the movement of filtrate into the lumen of the Bowman’s capsule.

**(d)** This question was a good test of candidates' understanding but the responses were less imaginative than those to **Question 1 (f)**, suggesting that candidates had not considered this aspect before. Effective answers referred to the appearance of valves, which cannot be seen clearly, if at all, in cross-section. There were also comments on the appearance of smooth muscle and the possibility of observing damage to the lining of the vessels, such as the development of atheroma. Some candidates seemed to assume that a longitudinal section would appear in three dimensions rather than two. Many stated that this type of section together with cross-sections would allow the build up of a three-dimensional view of these vessels. This latter idea was given credit.

*An Atlas of Histology* by Freeman and Bracegirdle, the standard animal histology text used by past generations of A Level candidates, is long out of print. There is no really suitable successor, although there are many histology texts at higher levels. Websites on medical histology rely almost exclusively on photomicrographs rather than drawings. *Comprehensive Practical Biology* by Salma Siddiqui (1999) has some drawings made from photomicrographs and is a suitable introduction to histology at this level. The book was written to support the Cambridge A Level Practical Examination and is still available.