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Write your **student number** in the boxes above. **Letter**

# Biology

## Question and Answer Book

### VCE Examination – Monday 3 November 2025

- Reading time is **15 minutes**: 9.00 am to 9.15 am
- Writing time is **2 hours 30 minutes**: 9.15 am to 11.45 am

### Materials supplied

- Question and Answer Book of 44 pages
- Multiple-Choice Answer Sheet

### Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

### Contents





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# **Section A** – Multiple-choice questions

## Instructions

- Answer **all** questions in pencil on your Multiple-Choice Answer Sheet.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

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**Question 1**

In an experiment investigating the effect of different temperatures on DNA structure, which one of the following is the independent variable?

**A.** rate of DNA denaturation

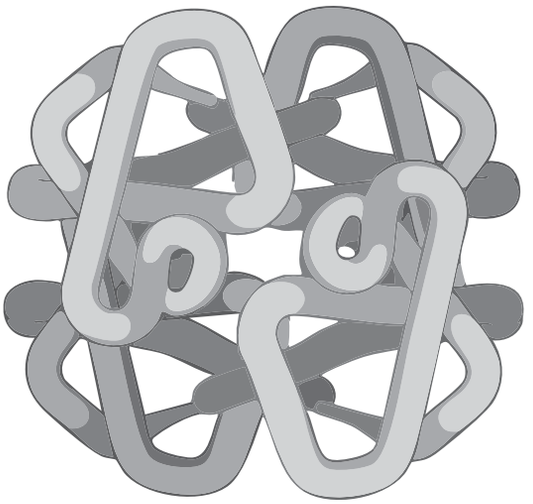
**B.** mass of DNA in the sample

**C.** number of nucleotide bases in the DNA sequence

**D.** temperatures at which the experiment is conducted

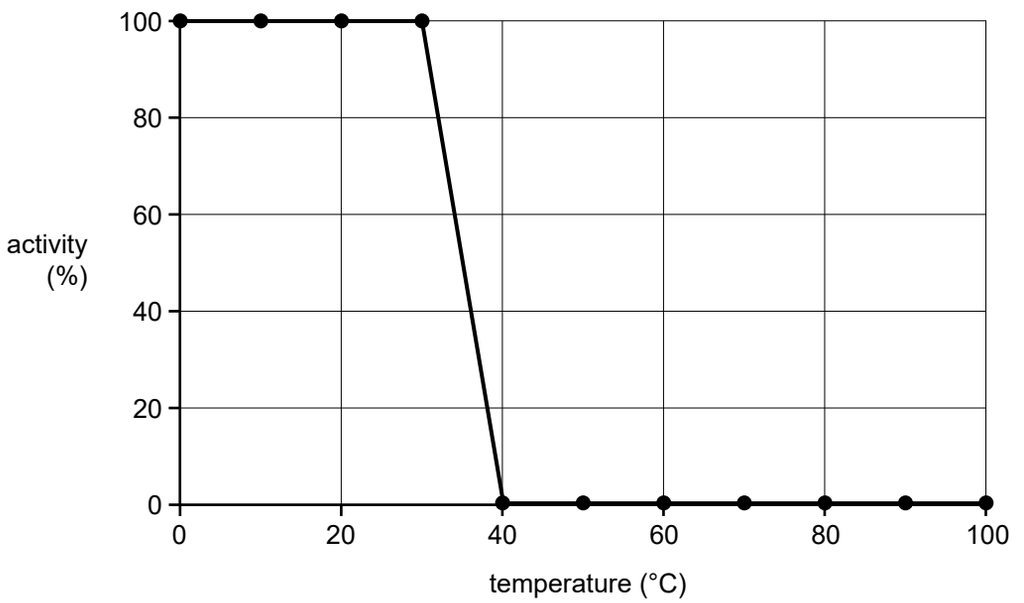
**Question 2**

The image below shows the structure of haemoglobin.



Source: Adapted from BioRender, <www.biorender.com/icon/hemoglobin>

The graph below shows the effect of temperature on the activity of haemoglobin.




Based on the graph, it can be concluded that at temperatures between

**A.** 0 °C and 30 °C the tertiary structure is unravelled.

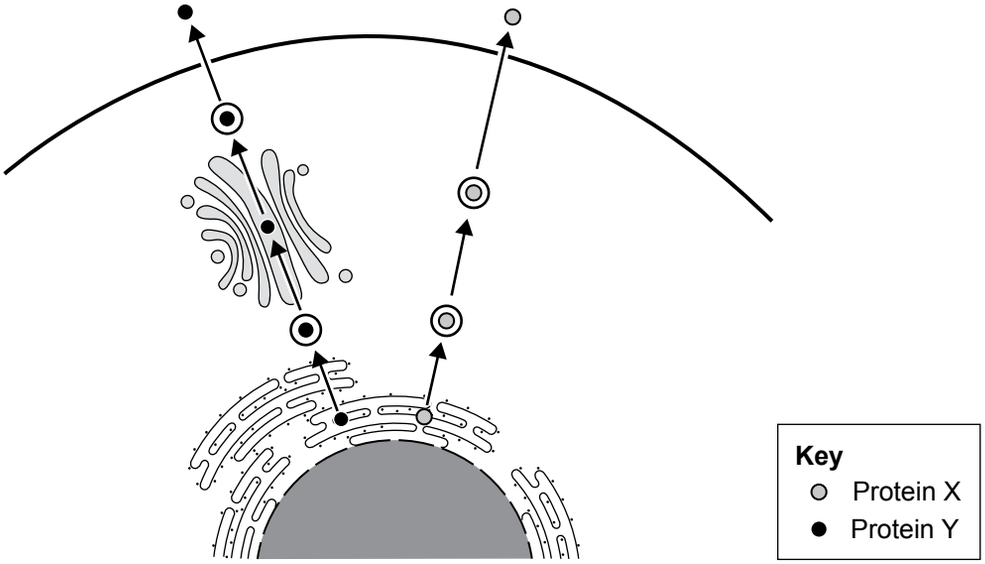
**B.** 0 °C and 30 °C the primary structure is changed.

**C.** 30 °C and 40 °C the quaternary structure is denatured.

**D.** 30 °C and 100 °C the secondary structure is unaffected.

**Question 3**

Protein X and Protein Y take different pathways to reach the plasma membrane. These two pathways are shown in the diagram below.




Source: Adapted from J Kim et al., 'Unconventional protein secretion – new insights into the pathogenesis and therapeutic targets of human diseases', *Journal of Cell Science*, vol. 131, 2018

The diagram demonstrates that

**A.** Protein X does not reach the plasma membrane without passing through the Golgi apparatus.

**B.** Protein Y is secreted directly from the rough endoplasmic reticulum without any further modifications.

**C.** Protein Y is the only one to be packaged into a vesicle for secretion.

**D.** Protein X does not undergo further modifications after leaving the rough endoplasmic reticulum.

**Question 4**

The DNA triplet GCA codes for an amino acid.

Which one of the following correctly identifies the corresponding tRNA anticodon for this triplet?

**A.** GCT

**B.** GCA

**C.** CGU

**D.** GCU

**Question 5**

During protein synthesis in a eukaryotic cell, which event marks the end of transcription?

**A.** All introns are removed from the pre-mRNA.

**B.** The ribosome reaches a stop codon on the mRNA.

**C.** The polypeptide chain is released from the ribosome.

**D.** RNA polymerase reaches a termination sequence on the DNA template.

**Question 6**

Four different sections of DNA are described below.

| Section | Description |
|---|---|
| Q | contains exons and introns, and requires splicing to form mature mRNA |
| R | a cluster of genes under the control of a single promoter, transcribed together into mRNA |
| S | has a promoter region for RNA polymerase binding and does not have introns |
| T | codes for proteins that control the expression of other genes |

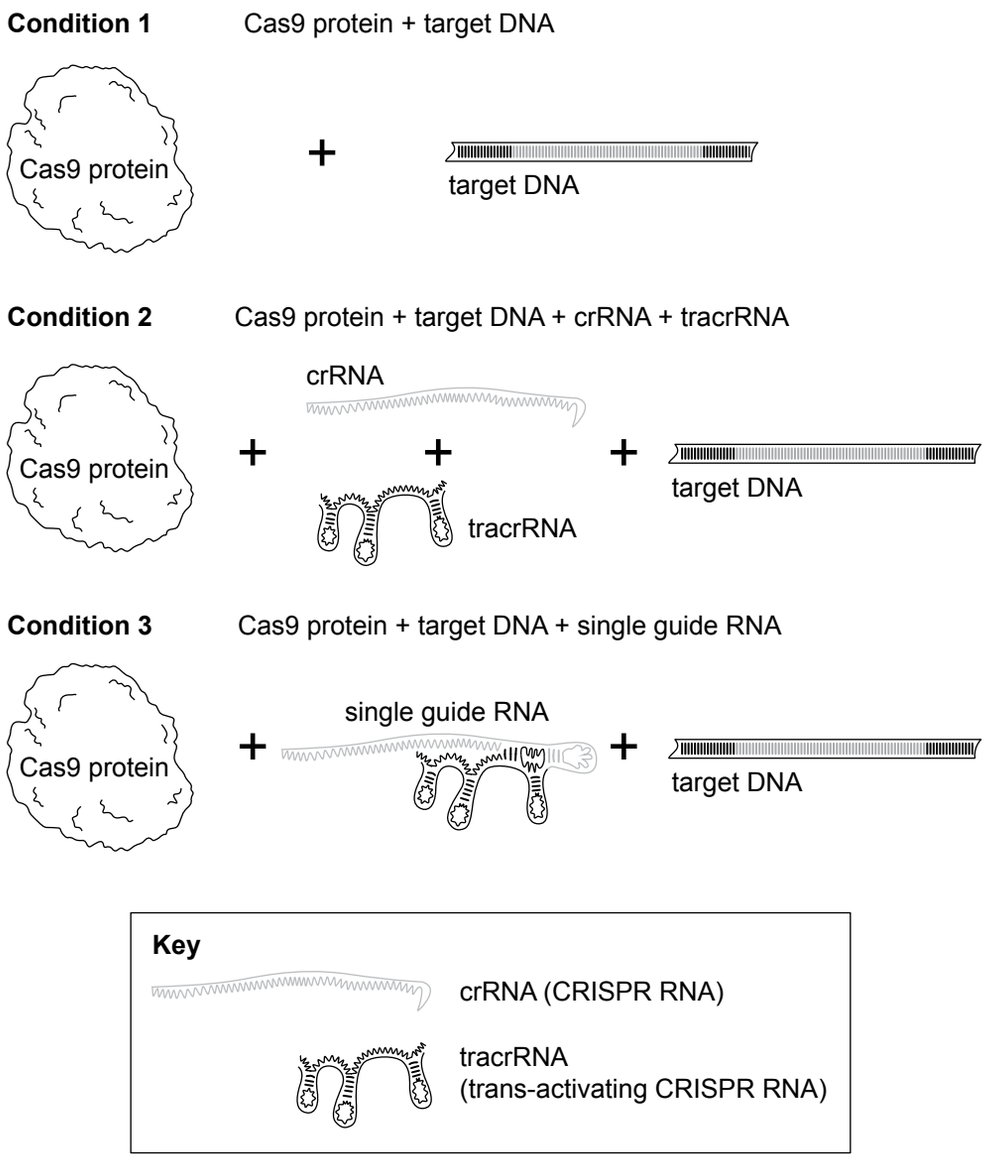
Based on the descriptions, which option correctly labels the four sections of DNA?

| | Prokaryotic gene | Operon | Eukaryotic structural gene | Regulatory gene |
|---|---|---|---|---|
| **A.** | T | S | R | Q |
| **B.** | S | R | T | Q |
| **C.** | S | R | Q | T |
| **D.** | R | T | Q | S |

**Use the following information to answer Questions 7–9.**

Emmanuelle Charpentier and Jennifer A Doudna won the Nobel Prize in Chemistry in 2020 for the discovery of CRISPR-Cas9 genetic scissors.

The diagram below shows three different conditions that the scientists tested. Condition 1 acted as the control group, and conditions 2 and 3 were the experimental groups.




Source: Adapted from Jennifer Doudna, Kevin Doxzen and Martin Jinek, 'CRISPR-Cas9: A Tool for Genome Editing'; XBio: The Explorer's Guide to Biology (Explorebiology.org); licensed CC-BY 4.0

**Question 7**

What is the purpose of single guide RNA?

**A.** to cut the target sequence

**B.** to create off-target editing

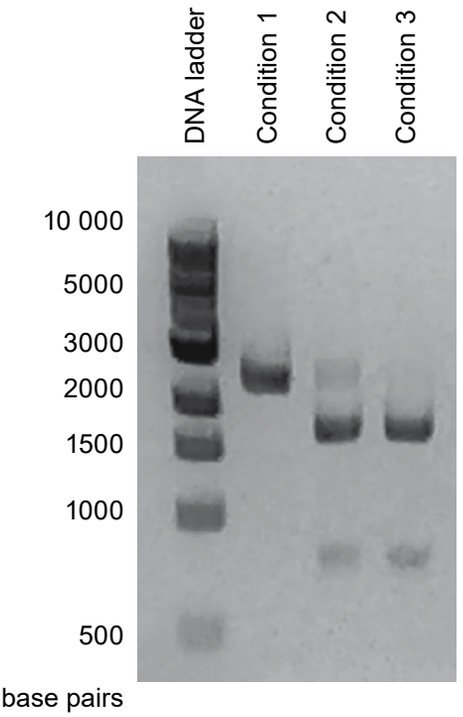
**C.** to direct the cutting of DNA

**D.** to repress the Cas9 protein

Do not write in this area.

**Question 8**

To view the outcomes of the three conditions, the scientists ran a gel electrophoresis. The results are shown below.




Source: Adapted from Jennifer Doudna, Kevin Doxzen, Martin Jinek, 'CRISPR-Cas9: A Tool for Genome Editing'; XBio: The Explorer's Guide to Biology (Explorebiology.org); licensed CC-BY 4.0

From the results, it can be concluded that CRISPR-Cas9 was functional in

**A.** conditions 1, 2 and 3.

**B.** conditions 2 and 3.

**C.** conditions 1 and 3.

**D.** condition 1 only.

**Question 9**

Which hypothesis would Charpentier and Doudna likely propose regarding CRISPR-Cas9 technology?

**A.** DNA cleavage depends entirely on the presence of crRNA without any modifications.

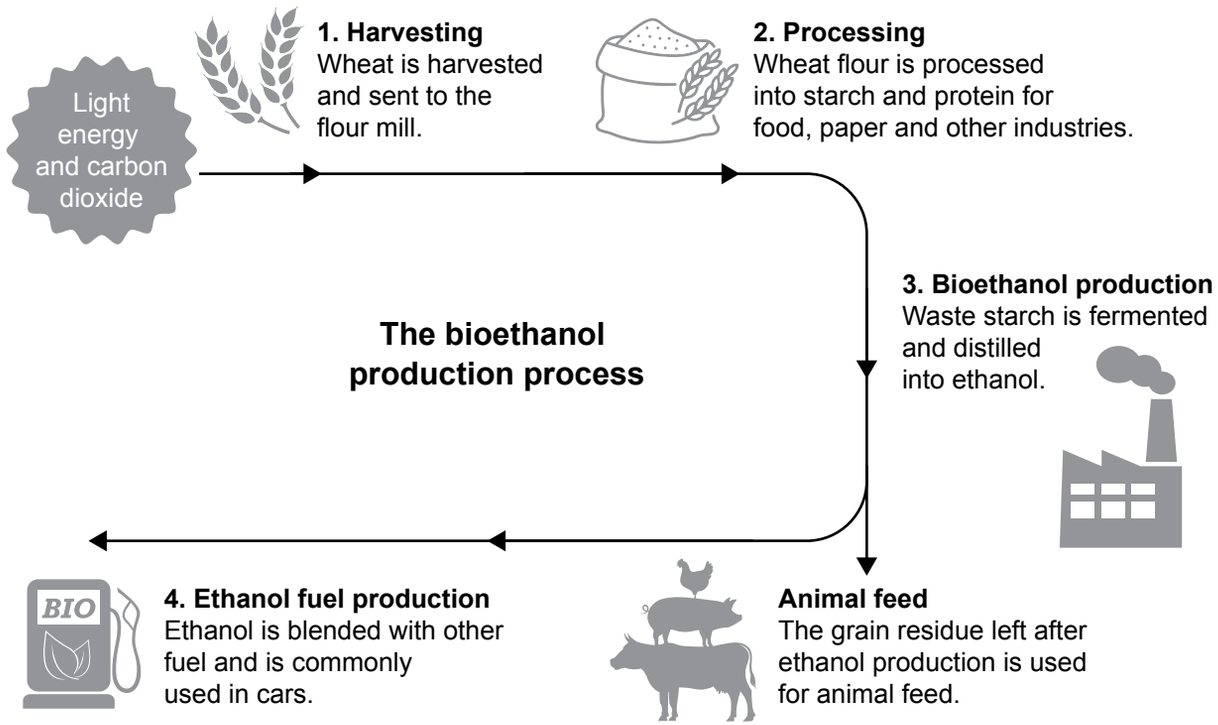
**B.** The Cas9 protein can target and cut DNA sequences without the need for guide RNA molecules.

**C.** The tracrRNA sequence is unnecessary for Cas9 to recognise and cut DNA sequences.

**D.** CRISPR-Cas9 can be guided to edit DNA by combining crRNA and tracrRNA into a single guide RNA.

**Question 10**

The infographic below shows the different stages involved in the fermentation of biomass for bioethanol production.



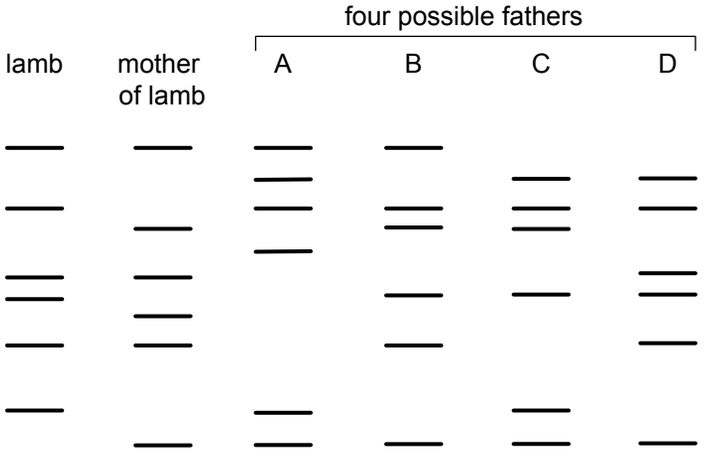

Source: Adapted from NSW Farmers, <https://nswfarmers.org.au>; Gilbert – Illustration/Shutterstock.com (wheat bag); Hunter Leader/Shutterstock.com (3 animals); SoleilC/Shutterstock.com (factory, fuel pump); stoker_1/Shutterstock.com (wheat)

Which option correctly identifies an output along with ethanol, and the environmental conditions needed for the production of high levels of ethanol?

| | Output along with ethanol | Environmental conditions needed |
|---|---|---|
| **A.** | oxygen | optimal temperature (25 °C) for yeast |
| **B.** | carbon dioxide | absence of oxygen |
| **C.** | oxygen | absence of carbon dioxide |
| **D.** | carbon dioxide | optimal temperature (10 °C) for yeast |

**Use the following information to answer Questions 11 and 12.**

The diagram below shows an example of DNA profiling used to help identify the possible father of a lamb.




**Question 11**

Which one of the following is likely to be the father of the lamb?

**A.** father A

**B.** father B

**C.** father C

**D.** father D

**Question 12**

Which one of the following assists in the movement of the DNA fragments through the gel once an electric current is applied to the gel?

**A.** the ribose sugar

**B.** the charge of the DNA molecule

**C.** the number of DNA fragments

**D.** the types of nitrogenous bases present

**Question 13**

The amplification of DNA through polymerase chain reaction includes

**A.** binding of RNA polymerase to the DNA template during the extension stage.

**B.** heating the DNA template to 72 °C during the annealing stage.

**C.** attachment of DNA primers during the denaturation stage.

**D.** repeating the cycle many times.

**Question 14**

A student notices that many plants grow in a way that reduces the overlap of their leaves.

This adaptation allows a faster rate of photosynthesis in the plants as the plants can absorb more

**A.** carbon dioxide into the bundle sheath cells.

**B.** glucose through the mesophyll cell wall.

**C.** oxygen from the air.

**D.** light on the grana.

**Question 15**

During cellular respiration

**A.** cells will consistently yield 36 or 38 molecules of ATP from each molecule of glucose.

**B.** there is a difference between the theoretical and actual ATP yields when cells break down glucose.

**C.** ATP is not produced in the cells in the roots of plants as these cells have no glucose source.

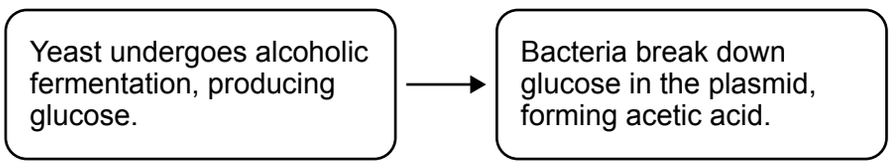
**D.** $C_4$ plants consistently produce more ATP from each glucose molecule compared to $C_3$ plants.

**Question 16**

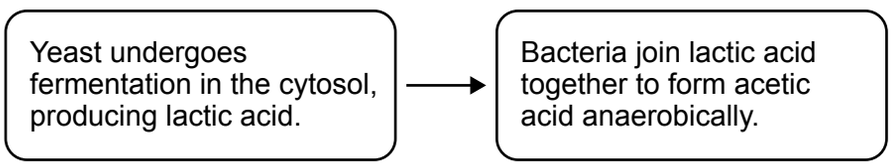
Acetic acid is a by-product of some bacterial biochemical pathways. Acetic acid gives vinegar its distinctive taste. Vinegar can be made using sugar, yeast and bacteria.

Which one of the following flow charts correctly summarises two of the steps in the process of making vinegar?

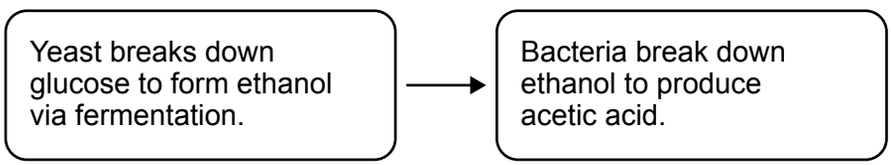
**A.**



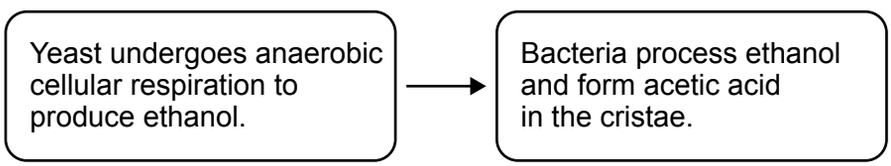

**B.**




**C.**




**D.**



**Use the following information to answer Questions 17–19.**

The table below shows some important stages, inputs and outputs of the biochemical pathways of photosynthesis or cellular respiration.

| Stage | Input | Output |
|---|---|---|
| S | water | NADPH |
| T | carbon dioxide | ATP |
| U | water | oxygen |
| V | glucose | ATP |
| W | carbon dioxide | oxygen |
| X | pyruvate | lactic acid |
| Y | glucose | ADP |
| Z | oxygen | ATP |

**Question 17**

Which one of the following correctly names two of the stages shown in the table above?

**A.** S is the light-dependent stage and T is the light-independent stage.

**B.** U is the light-dependent stage and V is glycolysis.

**C.** W is the light-independent stage and X is the Krebs cycle.

**D.** Y is glycolysis and Z is the Krebs cycle.

**Question 18**

Consider stage X.

Which one of the following statements is correct?

**A.** This stage occurs in animal cells.

**B.** The lactic acid is further broken down to ethanol.

**C.** Another possible output of this stage is carbon dioxide.

**D.** Pyruvate is broken down into lactic acid in the mitochondrial matrix.

**Question 19**

To investigate the rate of photosynthesis, a student could

**A.** complete fieldwork to determine the amount of Rubisco bound to oxygen in stage Z.

**B.** complete a literature review to identify the amount of NADPH produced in stage S.

**C.** conduct a controlled experiment to determine the amount of glucose used in stage Y.

**D.** design a computer model to predict the amount of carbon dioxide produced in the stroma during stage W.

**Question 20**

Three factors that affect the rate of photosynthesis in plants are stated below:

- Factor 1 – light intensity
- Factor 2 – carbon dioxide concentration
- Factor 3 – temperature

Scientific data consistently shows specific trends for each factor when other variables are controlled. Graphs were plotted showing the rate of photosynthesis against an increasing change in each factor.

If plotted over a large range, which of the following would show graphs with the same trend?

**A.** factors 1 and 2

**B.** factors 1 and 3

**C.** factors 2 and 3

**D.** factors 1, 2 and 3

**Question 21**

ATP synthase is an enzyme that is used in the formation of ATP.

A competitive inhibitor to ATP synthase is introduced into a cell.

The competitive inhibitor would initially

**A.** bind to the active site of ATP, blocking it from binding to ATP synthase.

**B.** reduce the number of ADP molecules available for moving cellular energy.

**C.** bind to the allosteric site of ATP synthase, preventing ADP from binding.

**D.** cause more ADP molecules to be present in the cell.

**Use the following information to answer Questions 22 and 23.**

Mint, shown below, is a popular garden herb.

Source: Paul Maguire/Shutterstock.com

The essential oils and phenolic compounds found within the cells of the mint plant protect the plant from pathogens such as bacteria, fungi, yeasts and viruses.

**Question 22**

When the essential oils and phenolic compounds are in the mint plant cells, they act as

**A.** antimicrobial agents inhibiting pathogen growth.

**B.** the first line of defence against pathogens.

**C.** a microbiota barrier to the pathogens.

**D.** a structural barrier to the pathogens.

**Question 23**

A group of students discussed the benefits of using the essential oils and phenolic compounds from mint to protect themselves from pathogens. Each student made a contribution as follows:

- Student 1 said that they could not make any decisions until they had completed a correlational study.
- Student 2 said that he thought the essential oils and phenolic compounds could protect them from bacterial pathogens.
- Student 3 recalled a scientific study about the use of the essential oils and phenolic compounds to cure yeast infections in young children.
- Student 4 recalled a time when her mother put the essential oils and phenolic compounds on a fungal infection she had on her feet.

Which one of the students contributed an anecdote to the discussion?

**A.** student 1

**B.** student 2

**C.** student 3

**D.** student 4

**Question 24**

Cellular pathogens, non-cellular pathogens and allergens can initiate an immune response.

Which of the following correctly provides an example of a cellular pathogen, non-cellular pathogen and allergen?

| | Cellular pathogen | Non-cellular pathogen | Allergen |
|---|---|---|---|
| **A.** | virus | fungus | prion |
| **B.** | bacterium | virus | dog hair |
| **C.** | fungus | bacterium | virus |
| **D.** | prion | dog hair | pollen |

**Question 25**

A student was feeling unwell and had a sore throat. She touched her neck area and could feel many small swollen lymph nodes.

Source: Doucefleur/Shutterstock.com

In the swollen lymph nodes

**A.** swelling is caused by an accumulation of red blood cells.

**B.** some of the lymphocytes undergo clonal selection and expansion.

**C.** macrophages present antigens to dendritic cells.

**D.** lymph fluid is filtered and lymphocytes are removed.

**Question 26**

In an inflammatory response

**A.** pathogens are engulfed by natural killer cells.

**B.** the number of white blood cells circulating in the blood is reduced.

**C.** the activation of the immune system is prevented to avoid internal damage.

**D.** blood flow is increased to the infection site, allowing more immune cells to reach the area.

**Question 27**

Many molecules are involved in an innate immune response.

Which of the following correctly matches the molecule with its characteristic and function?

| | Molecule | Characteristic | Function |
|---|---|---|---|
| **A.** | histamine | acts as an enzyme | causes vasodilation |
| **B.** | interferon | produced by viral infected cells | breaks down bacterial cell walls |
| **C.** | complement protein | circulates in an inactive form in the blood | once activated, can result in cell lysis |
| **D.** | lysozyme | produced by mast cells | signals to help protect adjacent cells |

**Question 28**

The primary function of plasma cells is to

**A.** produce antibodies that bind to specific antigens on the surfaces of pathogens.

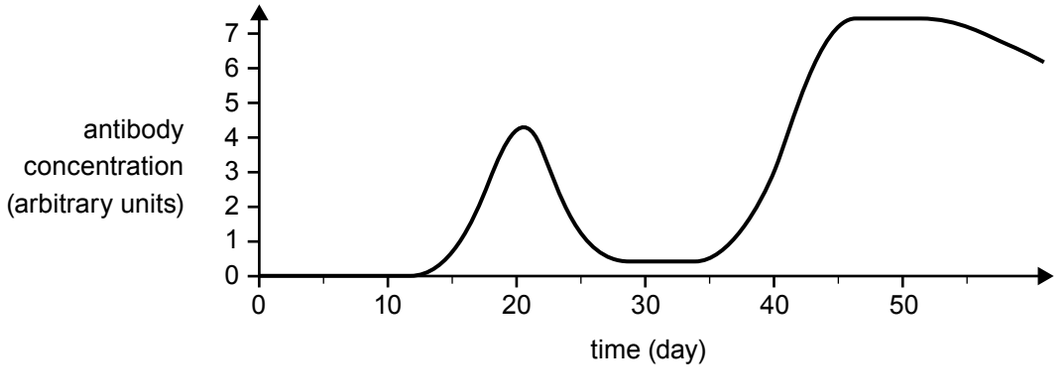
**B.** destroy virally infected cells through phagocytosis.

**C.** secrete cytokines to communicate with other immune cells.

**D.** present antigens to helper T cells.

**Use the following information to answer Questions 29 and 30.**

The following graph shows antibody concentration during two exposures a person had to the same antigen.




Source: Adapted from Namba et al., *Anatomy and Physiology* (University of Hawai'i, 2021); ch. 22, <https://pressbooks-dev.oer.hawaii.edu/anatomyandphysiology2021> licensed CC-BY 4.0

**Question 29**

On what day was the person most likely first exposed to the antigen?

**A.** 2

**B.** 13

**C.** 22

**D.** 30

**Question 30**

Which one of the following statements is correct?

**A.** On day 0, there is an absence of antibodies because cytotoxic T cells are inactive.

**B.** On day 10, T cells quickly differentiate into plasma cells.

**C.** On day 15, the antibody concentration is half that of day 35.

**D.** On day 33, activation of memory cells leads to the highest concentration of antibodies.

**Question 31**

In human populations, high vaccination rates

**A.** reduce the spread of pathogens between members of the population, protecting susceptible people.

**B.** create herd immunity by increasing transmission of the pathogen between vaccinated individuals.

**C.** create passive artificial immunity through exposure to the specific antigen.

**D.** prevent antigenic shift by removing all human hosts.

**Question 32**

In a particular human population, over a short period, there was a big increase in the number of people with symptoms caused by an infectious pathogen. The health authorities examined several factors associated with the population.

Which of the following correctly identifies the factor that influences whether the pathogen is new or re-emerging?

| | Factor associated with the population | New pathogen or re-emerging pathogen |
|---|---|---|
| **A.** | increased access to medical treatment | re-emergence of a known pathogen in the population |
| **B.** | a decline in immunisation rates in the population | emergence of a new pathogen in the population |
| **C.** | members of the human population travelling the world and returning home | emergence of a new pathogen in the population |
| **D.** | improved sanitation and living conditions for people in the population | re-emergence of a known pathogen in the population |

**Question 33**

A particular pathogenic change requires the immediate development of a new vaccine.

This change most likely involves

**A.** antigenic drift, leading to minimal structural change to the pathogen.

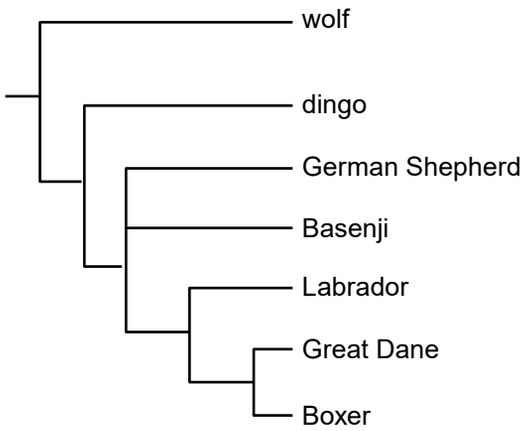
**B.** bacterial mutations, which can provide antibiotic resistance.

**C.** antigen mutations, with no change in antigen shape.

**D.** an antigenic shift, producing a new viral strain.

**Question 34**

An investigation compared the dingo genome with that of wolves and five breeds of domestic dogs (Great Dane, Boxer, German Shepherd, Basenji and Labrador). A phylogenetic tree showing these relationships was drawn.




Source: Adapted from MA Field et al., 'The Australian dingo...', *Science Advances*, vol. 8, no. 16, 22 April 2022

This phylogenetic tree suggests that

**A.** dingoes are not related to wolves or German Shepherds.

**B.** the differences in DNA sequences between Great Danes and Boxers are less than they are between Great Danes and dingoes.

**C.** the wolves, dingoes and five breeds of domestic dogs have no common ancestor.

**D.** Labradors are more closely related to Basenjis than to German Shepherds.

**Question 35**

Consider the image of the lemur below.

Source: meunierd/Shutterstock.com

Which characteristic seen in the image allows the lemur to be classified as a primate?

**A.** the presence of a tail

**B.** the presence of an opposable thumb

**C.** the presence of fur covering the body

**D.** the presence of side-facing eyes

**Question 36**

Scientists investigated the evolution of both reptiles and mammals. The fossil record indicates that reptiles were present before mammals. A fossil has been found that shows characteristics of both reptiles and mammals.

This fossil could be used to

**A.** determine the absolute age of the first mammal.

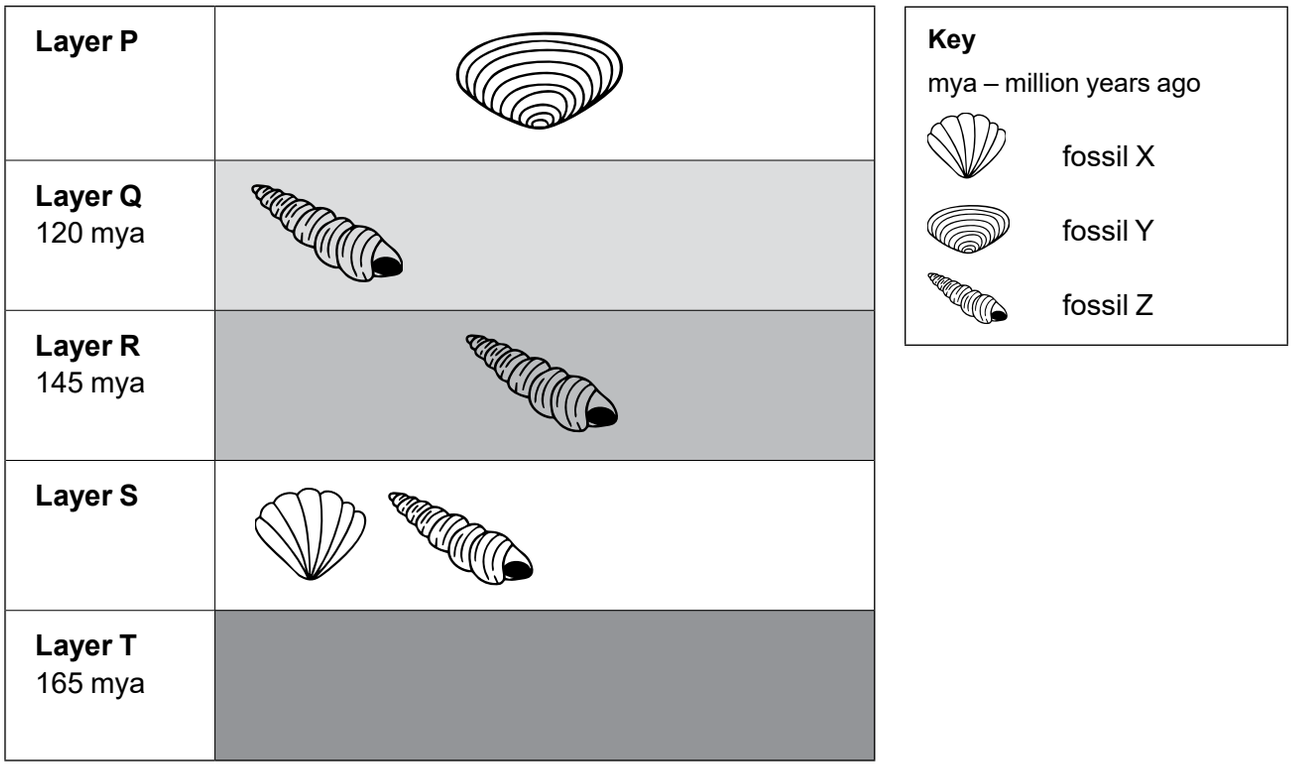
**B.** compare all characteristics of reptiles with those of mammals.

**C.** support the hypothesis that reptiles and mammals share a common ancestor.

**D.** show that reptiles were the most common animal living before the appearance of mammals.

**Question 37**

The following fossils have been located in rock layers, as shown below. The age of some of the layers has been determined.




Source: Adapted from Kristina Chistiakova/Shutterstock.com

Which one of the following can be inferred using the information in the diagram?

**A.** Fossil Z is an organism that went extinct 165 mya.

**B.** Fossil X is dated between 145 mya and 165 mya.

**C.** Fossil Z can be used as an index fossil.

**D.** Fossil Y is older than Fossil X.

**Question 38**

The pig-nosed turtle, *Carettochelys insculpta*, is a freshwater turtle. In Australia, the turtle is found only in the Northern Territory.

Source: Paulo Resende/Shutterstock.com

Scientists hypothesised that the pig-nosed turtle recently arrived in Australia from nearby countries. They are now reconsidering their hypothesis based on new evidence.

Which piece of evidence could the scientists now have that refutes their original hypothesis?

**A.** finding five-million-year-old fossilised remains of the pig-nosed turtle in Melbourne, Australia

**B.** noticing vestigial structures within the digestive system of the pig-nosed turtle

**C.** observing differences in mtDNA between individual pig-nosed turtles

**D.** recording homologous structures in a number of turtle species

**Use the following information to answer Questions 39 and 40.**

A Year 12 student conducts an investigation into the effects of different amounts of water on the growth of lettuce plants. The following table outlines some aspects of the investigation.

| Lettuce plant | Amount of water (mL/day) | Temperature (°C) | Light wavelength (nm) | Percentage increase in mass of lettuce (%) |
|---|---|---|---|---|
| 1 | 150 | 10 | 660 | 5 |
| 2 | 200 | 15 | 660 | 10 |
| 3 | 250 | 20 | 660 | 15 |
| 4 | 300 | 25 | 660 | 13 |

**Question 39**

The investigation is not considered valid because

**A.** it contains more than one dependent variable.

**B.** only lettuce is used in the investigation.

**C.** the light wavelength is set at 660 nm.

**D.** the temperature is different for each plant.

**Question 40**

Which one of the following would be the most likely qualitative data for this investigation?

**A.** the concentration of carbon dioxide in the air surrounding each plant

**B.** the number of chlorophyll molecules in each lettuce leaf

**C.** the shape of the lettuce leaves

**D.** the mass of minerals in the water

**End of Section A**

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Examination continues on the next page.

# Section B

## Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

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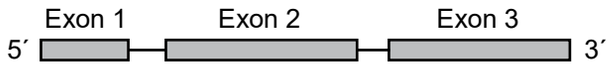
**Question 1** (5 marks)

Insulin is a hormone that helps regulate blood glucose levels. The insulin gene has three exons. The three exons within the gene are shown in the diagram below.




Source: Adapted from S Ataie-Ashtiani and B Forbes, 'A review of the biosynthesis and structural implications of insulin gene mutations linked to human disease', *Cells*, vol. 12, no. 7, 25 March 2023

**a.** Construct a diagram of an mRNA molecule in the space provided below to show the result of mRNA processing of the insulin gene. Label **three** modifications as a result of mRNA processing on the diagram. 3 marks

**b.** Recombinant DNA technologies are used to produce large quantities of human insulin to treat diabetes.

Shown below are some of the steps involved in one method used in the production of human insulin. Two steps are incomplete.

Complete step 4 and step 8 in the spaces provided below. 2 marks

Step 1 – Obtain genes coding for the two insulin amino acid chains A and B.

Step 2 – Isolate the plasmids, each of which contains an antibiotic resistance gene.

Step 3 – Some of these plasmids are mixed with genes coding for amino acid chain A. Remaining plasmids are mixed with genes coding for amino acid chain B.

Step 4 – DNA ligase _____

_____

_____

Step 5 – All bacteria are exposed to heat shock to take up the recombinant plasmids.

Step 6 – Bacteria are grown on nutrient plates containing antibiotics. Transformed bacteria will survive and express genes.

Step 7 – Isolate amino acid chains A and B from the bacteria.

Step 8 – Amino acid chains A and B _____

_____

_____

**Question 2** (11 marks)

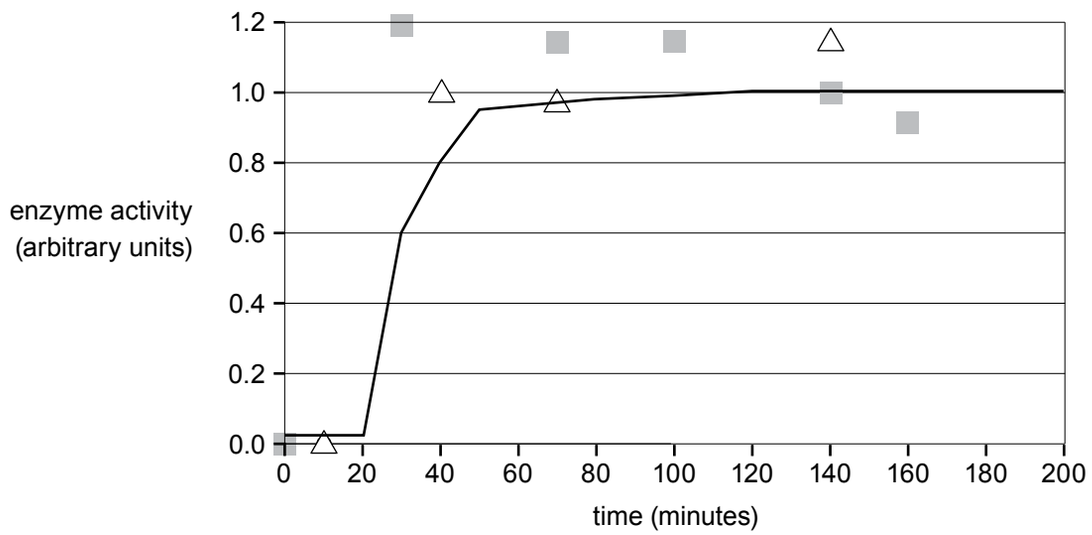
Tryptophan (*trp*) is one of the least common amino acids in proteins. When needed, some bacteria can synthesise *trp*. In these bacteria, the *trp* operon regulates the production of enzymes involved in *trp* synthesis.

**a.** Explain how enzymes such as those coded by the genes within the *trp* operon catalyse biochemical reactions. 2 marks

**Use the following information to answer part b and part c on page 27.**

The graph below shows the activity of the enzymes coded by the genes within the *trp* operon. At 20 minutes, the bacteria were shifted from an environment containing *trp* to an environment without *trp*.

The solid line represents a model simulation of enzyme activity, while the triangles and squares represent two sets of experimental data.




Source: Adapted from M Santillán and M Mackey, 'Dynamic regulation of the tryptophan operon: A modeling study and comparison with experimental data', *PNAS*, vol. 98, no. 4, 13 February 2001

**b.** Referring to the graph, explain why enzyme activity remains low between 0 and 20 minutes and why it remains steady after approximately 60 minutes. As part of your response, explain how the repression and attenuation mechanisms work together to regulate the production of enzymes coded by genes within the *trp* operon. 5 marks

**c.** The model simulation captures the general trend of enzyme activity but does not accurately replicate the experimental data, especially when the bacteria are first moved to a *trp*-free environment.

State **two** possible limitations of the model simulation that could account for the differences in the data from the simulation and the two experiments. 2 marks

**d.** In the past, bacteria had four stop codons, including UGG, and no codon for *trp*. The UGG codon in bacteria now codes for *trp*.

Identify a consequence for the bacteria of the UGG codon now coding for *trp*. Justify your response. 2 marks

**Question 3** (9 marks)

A Year 12 student knew that photosynthesis and photorespiration both occur in $C_3$, $C_4$ and CAM plants.

**a.** $C_3$, $C_4$ and CAM plants all use Rubisco in photosynthesis.

Place a cross (X) in the correct boxes in the following table to indicate the location of Rubisco activity for each plant type.

Place another cross (X) in the correct boxes to indicate the time of day when Rubisco activity is greatest for each plant type. 3 marks

| | **Location of Rubisco activity** | | **Time of day when Rubisco activity is greatest** | |
|---|---|---|---|---|
| | **Mesophyll cells** | **Bundle sheath cells** | **Daytime** | **Night-time** |
| **$C_3$** | | | | |
| **$C_4$** | | | | |
| **CAM** | | | | |

Do not write in this area.

**Use the following information to answer part b and part c below.**

The student read the following statement in their Biology textbook: 'The rate of photorespiration increases with an increase in temperature in $C_3$ plants.'

**b.** Explain why the rate of photorespiration increases with an increase in temperature in $C_3$ plants. 2 marks

**c.** The student wanted to test the statement by conducting a controlled experiment.

The student proposed that they would need to control the amount of sunlight and water that each plant received.

**i.** Describe how the student could control each of these variables. 2 marks

**ii.** The student proposed using the amount of glucose in the plant as the dependent variable. Their teacher suggested that this would not be an appropriate dependent variable for their experiment.

Describe **two** reasons why this would not be an appropriate dependent variable for their experiment. 2 marks

**Question 4** (4 marks)

Genetic engineering has been used to modify the traits of many plants.

The following table shows examples of genetic engineering in two agricultural crop plants: rice (*Oryza sativa*) and maize (*Zea mays L.*).

| Crop | Information |
|---|---|
| rice | The editing of the *OsHXK1* gene in rice using CRISPR-Cas9 technologies increases chlorophyll levels in the leaves of plants. |
| maize | Genes responsible for the production of toxins in the soil bacterium *Bacillus thuringiensis* were inserted into the genome of maize to kill corn rootworm larvae. |

**a.** Complete the table below, using the information provided, to determine whether each crop is transgenic, genetically modified or both. Justify each response. 2 marks

| Crop | Transgenic, genetically modified or both | Justification |
|---|---|---|
| rice | | |
| maize | | |

**b.** Explain how the editing of the *OsHXK1* gene in rice could result in an increased crop yield. 2 marks

**Question 5** (6 marks)

The bacterium *Neisseria meningitidis* causes meningococcal disease*. N. meningitidis* is contagious and transmitted between people via secretions of the nose and throat.

**a.** State **two** roles of neutrophils in an immune response to *N. meningitidis*. 2 marks

**b.** Contrast how the adaptive immune system responds to an extracellular pathogen, like *N. meningitidis*, and an intracellular pathogen, like the influenza virus. 4 marks

**Question 6** (10 marks)

Respiratory syncytial virus (RSV) is a common virus that can infect people of all ages. RSV can lead to the hospitalisation of infants. RSV is easily spread via respiratory droplets from those infected.

In late 2024, the Australian federal government announced an initiative for pregnant women to receive a vaccine to combat RSV. A single dose of the vaccine is recommended at between 24 and 36 weeks of pregnancy. The vaccine contains two different proteins normally found on the surface of RSV.

**a.** Identify the type of immunity given to the babies of mothers who have had this vaccination. Justify your response. 2 marks

**b.** Suggest **one** reason why pregnant women would be advised to receive a booster vaccine for RSV if they become pregnant again. 2 marks

**c.** Explain **one** economic benefit relevant to the vaccination of pregnant women. 2 marks

**d.** Nirsevimab is a monoclonal antibody that can be used to help prevent severe RSV infections. Injections containing these antibodies are given to infants born during high-risk RSV periods to unvaccinated mothers.

Explain how monoclonal antibodies work to reduce the severity of RSV in these infants. 2 marks

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**e.** Other than administering vaccination and nirsevimab, identify **one** way in which the spread of RSV could be reduced in the infants of unvaccinated mothers. Justify your response. 2 marks

**Question 7** (8 marks)

In 2007, a single colony of Asian honey bees (*Apis cerana*) was accidentally introduced into Australia via a port in Queensland. Honey bee queens typically mate with up to 10 males during a short period early in life and use the stored sperm to fertilise eggs over their lifetime. The queen in the introduced colony was already carrying sperm from matings in her native environment. Upon arrival, the queen continuously laid eggs, producing offspring. Other bees in the initial colony did not produce fertilised eggs. Over time, new colonies were established. The bees expanded to an estimated 10 000–50 000 colonies within a decade.

**a.** Scientists believe the introduction of the Asian honey bee into Australia is an example of the founder effect.

Referring to genetic changes, state what the founder effect is and why the scientists are correct. 2 marks

**b.** Compared to the initial colony, the bees in the new colonies showed an improved ability to gather food and organise their colonies. Scientists investigated their DNA and discovered 481 differences from the original colony of Asian honey bees that had been introduced into Australia.

Identify the process responsible for these DNA differences and explain how this process contributed to the successful expansion of the colonies. 3 marks

**c.** The introduction of the Asian honey bee has had serious ecological effects. The bees compete with native species for resources, take over important nesting sites and pose a threat to native honey bee colonies that are managed for agriculture. The introduction of the Asian honey bee could be an environmental selection pressure for the native bee population.

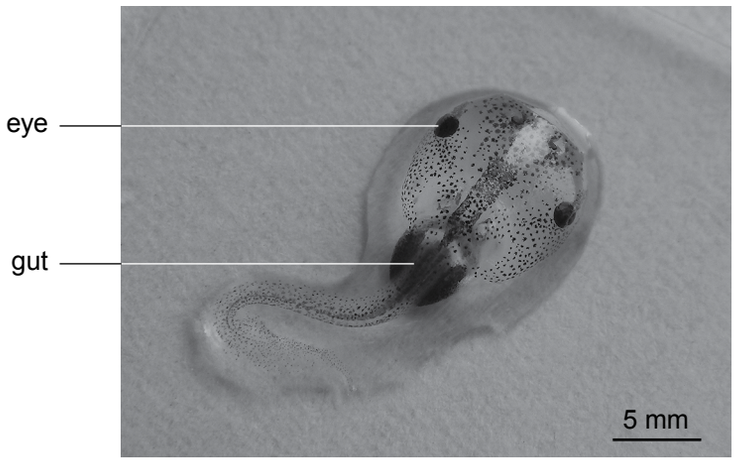
Explain the potential genetic change in the native bee population. 3 marks

**Question 8** (14 marks)

**Scientists are using microorganisms to restart brain activity in tadpoles**

Animal brains are made up of specialised cells called neurons. The activity of these cells relies on a constant supply of oxygen. When oxygen supply is too low (hypoxia), brain activity stops.

Scientists often use tadpoles during research. Tadpoles hatch from eggs that are laid in groups of thousands. Their skin can be transparent, as shown in the diagram below.

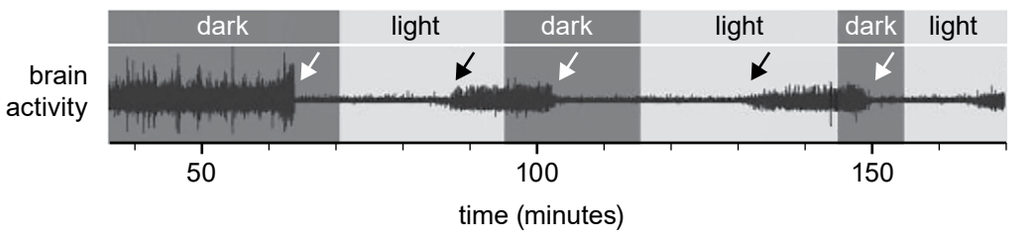



Source: TadeasH/Shutterstock.com

During the early stages of their development, tadpoles absorb dissolved oxygen from the water through their gills.

Researchers conducted an experiment using tadpoles. The experiment was approved by the ethical standards committee. The tadpoles were used to explore whether photosynthetic cyanobacteria could serve as an alternative oxygen source to that supplied in the water. Researchers injected cyanobacteria into the hearts of tadpoles. The cyanobacteria entered each tadpole's bloodstream and were transported to other parts of the body, including the brain.

After the injection, these tadpoles were placed in a dark, hypoxic environment. After about 65 minutes, brain activity stopped, indicated by the white arrowheads in the figure below. These tadpoles were then exposed to light. After 15–20 minutes in the light, brain activity restarted, indicated by the black arrowheads in the figure below.




In the future, this might provide a way to increase oxygen levels to humans during medical emergencies. However, a major challenge for a future use of injectable photosynthetic microorganisms is the potential activation of an immune response in people. Much more research is needed to ensure the safety of this potential treatment.

Source: Adapted from S Özugur et al., 'Green oxygen power plants in the brain rescue neuronal activity', *iScience*, vol. 24, 22 October 2021

**a.** Using information from the article, propose **two** reasons why tadpoles were chosen for this experiment. 2 marks

**b.** **i.** Other than enzymes, name **two** molecules the photosynthetic cyanobacteria would require to produce oxygen. 2 marks

**ii.** Describe the role of each of the molecules named in **part b.i** in the production of oxygen. 2 marks

**c.** Explain why the tadpoles' brain activity stopped when their neurons were exposed to a hypoxic environment for extended periods of time. 2 marks

**d.** Referring to a biochemical pathway, explain **one** reason for the delay in the restart of the tadpoles' brain activity. 2 marks

**Question 8** continues on the next page.

**e.** The electron transport chain occurs within the mitochondria.

Outline **two** events that occur along this chain. 2 marks

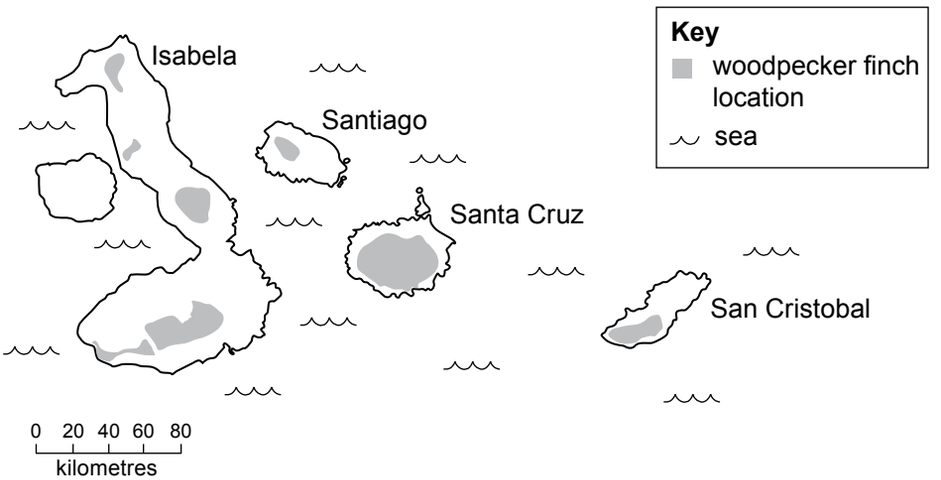
**f.** Two students noted that this research had been approved by the researchers' ethical standards committee:

- Student X thought this experiment was ethical as it met the principle of beneficence.
- Student Y thought this experiment was unethical as it did not meet the principle of non-maleficence.

State which student you agree with and justify your response using information from the article. 2 marks

**Question 9** (5 marks)

The Galápagos archipelago is a group of islands. The woodpecker finch (*Camarhynchus pallidus*) is found on four of the islands that comprise the Galápagos islands. The locations of populations of the woodpecker finch on these four islands are shown below.




Source: Adapted from LP Lawson et al., 'A hidden finch …', *Zoological Journal of the Linnean Society*, vol. 202, no. 4, December 2024

**a.** Scientists studied the different woodpecker finch populations using molecular homology.

Use **one** example to describe how molecular homology can be interpreted to determine the relatedness between the populations. 2 marks

**b.** Scientists concluded that the woodpecker finch populations on San Cristobal island may be considered to be a different species from the woodpecker finch populations on the three other islands shown on the map above.

Referring to the map, explain the type of speciation that has occurred. 3 marks

**Question 10** (8 marks)

A team of researchers has uncovered dozens of fossilised footprints at an archaeological site in Kenya. The sediments around the footprints were dated to about 1.52 million years old.

The researchers made two conclusions:

- Conclusion 1 – The footprints are from hominin species.
- Conclusion 2 – There are two separate hominin species rather than variation within the one species.

**a.** Describe the evidence that would support each conclusion. 2 marks

Conclusion 1 _____

_____

Conclusion 2 _____

_____

**Use the following information to answer part b below and part c on page 41.**

One species of hominins, *Homo neanderthalensis*, lived in Europe and west Asia for hundreds of thousands of years before disappearing about 40 000 years ago. Modern-day non-African *Homo sapiens* have inherited 1–2% of their DNA from *H. neanderthalensis*.

Evidence for interbreeding between *H. sapiens* and *H. neanderthalensis* has been obtained from two recent studies and is summarised in the table below. Each study analysed the genomes belonging to *H. sapiens* individuals of different ages.

| | **Number of genomes studied** | **Individuals studied and age** | **Conclusion made** |
|---|---|---|---|
| **Study 1** | 7 | 7 ancient individuals dated at approximately 45 000 years ago | interbreeding occurred between 49 000 to 45 000 years ago |
| **Study 2** | 334 | 275 present-day individuals and 59 ancient individuals dated from 45 000 to 2200 years ago | interbreeding occurred between 50 500 to 43 500 years ago |

**b.** Give **one** reason for the difference in the conclusion made in each study. Justify your response using information from the table above. 2 marks

_____

_____

_____

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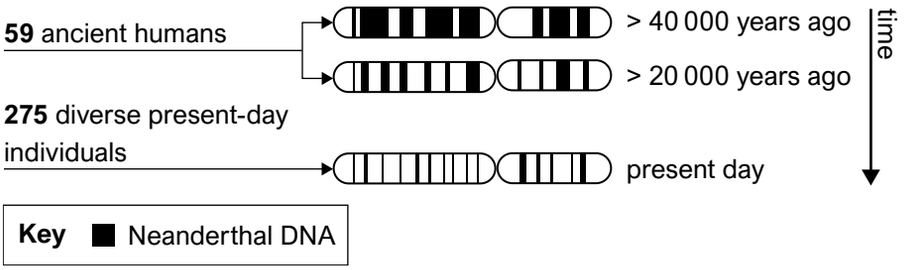
**c.** Study 2 also compared the percentage of Neanderthal DNA in the 59 ancient human individuals to the 275 present-day individuals. The diagram below summarises the findings.




Source: Adapted from LNM Iasi et al., 'Neanderthal ancestry through time: Insights from genomes of ancient and present-day humans', *Science*, vol. 386, issue 6727, 13 December 2024

Account for the change in the percentage of Neanderthal DNA found in ancient human individuals compared to present-day individuals. 2 marks

**d.** Fossils have been used to indicate where and at what time certain hominin species lived in the world. mtDNA has been used to provide evidence of how hominin species may have migrated across the world.

Outline **two** benefits of using mtDNA to help determine pathways hominin species may have taken. 2 marks

**End of examination questions**

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**Extra space for responses**

Clearly **number** all responses in this space.

Do not write in this area.

If you use any additional Question and Answer Books to complete your responses, write your **student number** on the front cover. At the end of the examination, place the additional Question and Answer Books inside the front cover of the first Question and Answer Book.