

Victorian Certificate of Education  
Year

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER	<input type="text"/>	Letter	<input type="text"/>						
----------------	----------------------	----------------------	----------------------	----------------------	----------------------	----------------------	----------------------	--------	----------------------

**BIOLOGY**  
**Written examination**

Day Date

Reading time: \*.\*.\* to \*.\*.\* (15 minutes)

Writing time: \*.\*.\* to \*.\*.\* (2 hours 30 minutes)

**QUESTION AND ANSWER BOOK****Structure of book**

Section	Number of questions	Number of questions to be answered	Number of marks
A	40	40	40
B	10	10	80
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners and rulers.
- Students are **NOT** permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.
- No calculator is allowed in this examination.

**Materials supplied**

- Question and answer book of 40 pages
- Answer sheet for multiple-choice questions
- Additional space is available at the end of the book if you need extra space to complete an answer.

**Instructions**

- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

**At the end of the examination**

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

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

## SECTION A – Multiple-choice questions

### Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

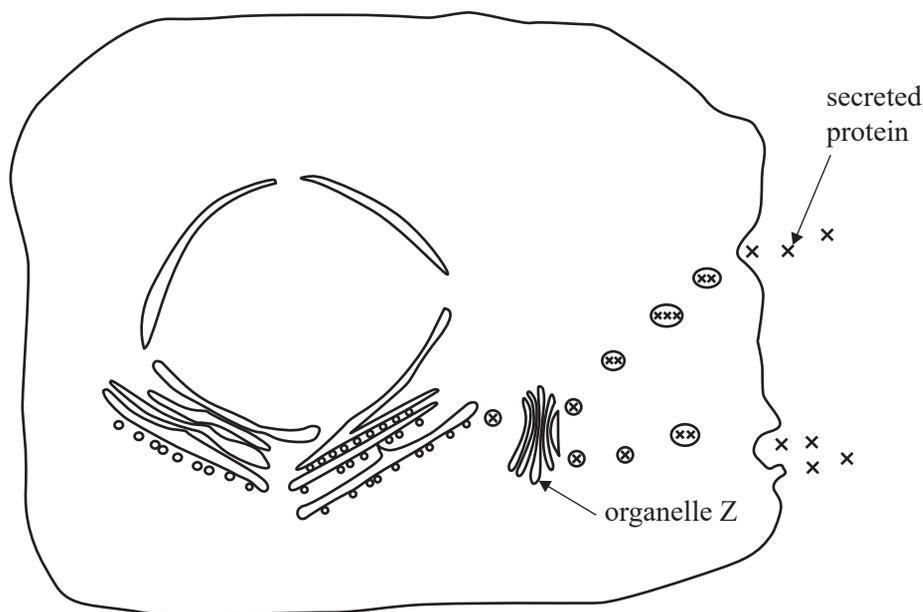
Marks will **not** be deducted for incorrect answers.

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.

### Question 1

The diagram below represents a human cell secreting protein molecules.



The role of organelle Z is to

- A. produce energy for protein production.
- B. transport protein through the cytosol.
- C. synthesise protein for secretion.
- D. package protein into vesicles.

### Question 2

Which one of the following molecules carries amino acids to the site of protein synthesis within a cell?

- A. DNA
- B. mRNA
- C. rRNA
- D. tRNA

Use the following information to answer Questions 3 and 4.

The owners of a young dog want to verify the parentage of their dog. They obtained a DNA profile for their young dog and compared it with the profiles of four older dogs. The profiles were made using many short tandem repeat (STR) markers, each marker having alleles of different lengths. The size of an STR marker is measured by the number of base pairs in the marker. The results for four of the STR markers are shown in the table below.

STR marker	Base pairs per allele				
	Young dog	Dog 1	Dog 2	Dog 3	Dog 4
1	110, 125	110, 120	110, 120	125, 130	125, 130
2	153, 155	150, 153	150, 155	155, 160	150, 160
3	100, 100	100, 105	100, 107	100, 109	100, 100
4	234, 248	200, 234	200, 234	200, 248	200, 248

### Question 3

Based on the information given, the parents of the young dog could be

- A. Dog 1 and Dog 2.
- B. Dog 1 and Dog 3.
- C. Dog 2 and Dog 3.
- D. Dog 3 and Dog 4.

### Question 4

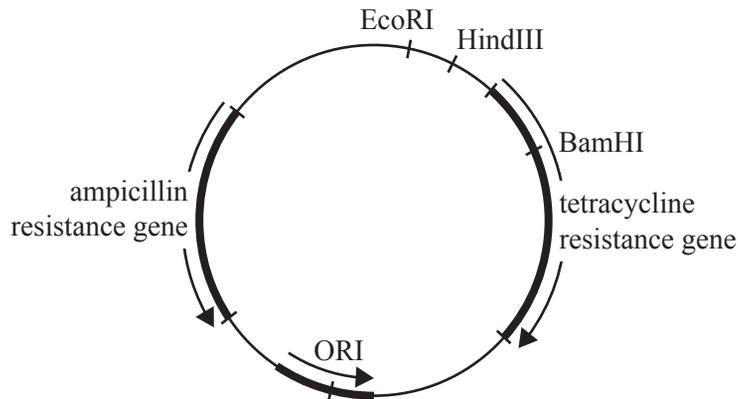
Which of the STR markers is the least useful in verifying the parents of the young dog?

- A. STR marker 1
- B. STR marker 2
- C. STR marker 3
- D. STR marker 4

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 5 and 6.

A particular bacterial plasmid contains recognition sites for three endonucleases: EcoRI, HindIII and BamHI. The plasmid also contains two antibiotic resistance genes – ampicillin resistance gene and tetracycline resistance gene – and an origin of replication (ORI). The diagram below shows the positions of these plasmid components.



Scientists used this plasmid to produce *Escherichia coli* (*E. coli*) cells containing the gene coding for human insulin. The following procedure was carried out:

- Step 1 – An endonuclease was used to help insert a gene coding for human insulin into these plasmids, making them recombinant.
- Step 2 – These recombinant plasmids were mixed with *E. coli* cells.
- Step 3 – The *E. coli* cells were placed in an electric field, which enabled some cells to take up the plasmids.
- Step 4 – *E. coli* cells containing the recombinant plasmids were then identified. The cells were grown on agar plates. An *E. coli* cell has been successfully transformed if it can grow on an agar plate containing ampicillin but not on an agar plate containing tetracycline.

#### Question 5

Which one of the following is a correct statement about the procedure?

- A. The endonuclease BamHI would have been used to cut the plasmids.
- B. The human insulin gene would have been joined to the plasmids using DNA polymerase.
- C. The recognition site for EcoRI would have the same base sequence as the recognition site for HindIII.
- D. Bacterial cells containing the human insulin gene would be resistant to both ampicillin and tetracycline.

#### Question 6

The *E. coli* cells that had been successfully transformed were isolated and then transferred to a nutrient solution. Exposure to particular environmental conditions resulted in the production of insulin by these cells.

Which one of the following is a true statement about insulin?

- A. Insulin is an enzyme.
- B. Nucleotides are the monomers of insulin.
- C. The tertiary structure of the insulin molecule is critical for its functioning.
- D. The secondary structure of the insulin molecule is the sequence of the monomers in the molecule.

DO NOT WRITE IN THIS AREA

**CONTINUES OVER PAGE**

**SECTION A – continued**  
**TURN OVER**

Use the following information to answer Questions 7 and 8.

DNA samples were collected from four people. DNA fragments in each sample were amplified using the polymerase chain reaction.

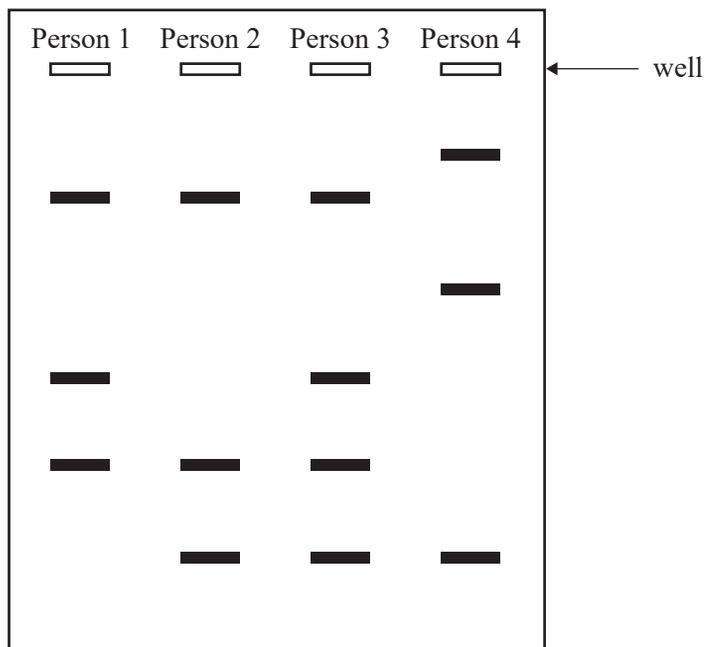
**Question 7**

Which one of the following is a correct statement about the polymerase chain reaction?

- A. A ligase is used to synthesise DNA.
- B. Primers anneal to single-stranded DNA.
- C. All steps are carried out at the same temperature.
- D. Several days are required to produce enough DNA fragments for analysis.

**Question 8**

The amplified DNA fragments were separated using gel electrophoresis. The results are shown below.



Which one of the following conclusions can be made based on the results shown?

- A. Person 4 could be the father of Person 1.
- B. Person 2 could be the mother of Person 3.
- C. Person 4 and Person 2 are identical twins.
- D. Person 1 is not a biological brother of Person 3.

*Use the following information to answer Questions 9 and 10.*

A student decided to investigate the movement of DNA fragments using gel electrophoresis. The DNA fragments were all 1000 base pairs in size. The distance that each DNA fragment moved over a period of 50 minutes was recorded. The student repeated the experiment five times, changing the voltage applied to the gel each time.

**Question 9**

The independent variable in this experiment is the

- A. voltage applied to the gel.
- B. length of the DNA fragments.
- C. distance the DNA fragments moved.
- D. time taken by the DNA fragments to move.

**Question 10**

The student realised that the electric current running through the gel could give them an electric shock.

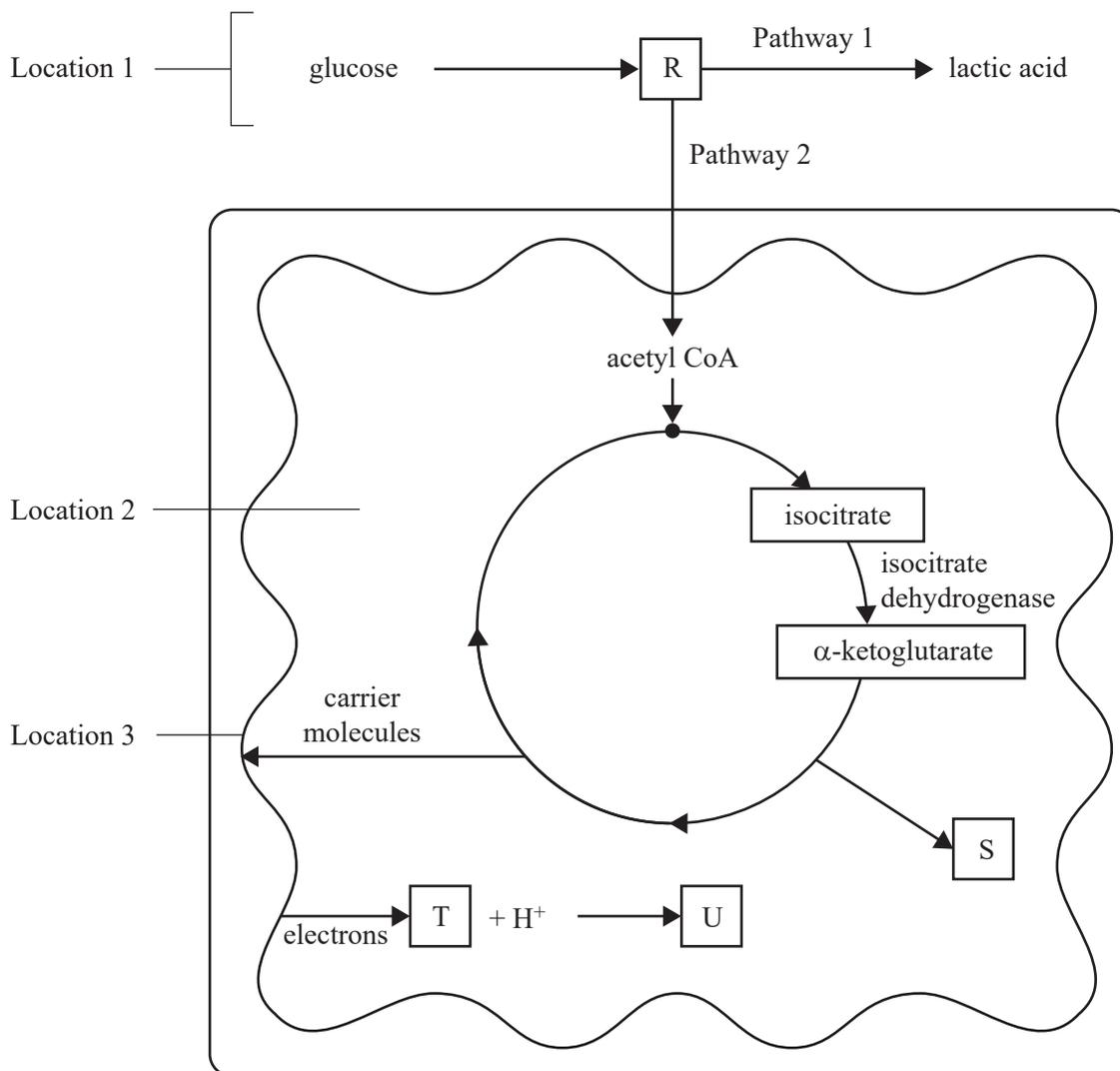
The student kept themselves safe from an electric shock by removing

- A. the lid of the tank used in the gel electrophoresis before turning off the electrical supply.
- B. any spilt buffer solution on the bench before turning on the electrical supply.
- C. the gel from the buffer solution with wet hands.
- D. books and food from the workstation.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 11–15.

The diagram below outlines the general biochemical pathways in cellular respiration in an animal cell.



**Question 11**

Biochemical pathways 1 and 2 are similar in animal cells because they

- A. create a high yield of ATP.
- B. cycle the coenzyme  $NAD^+$ .
- C. occur in the mitochondrion.
- D. produce carbon dioxide gas.

DO NOT WRITE IN THIS AREA

**Question 12**

Assume that oxygen levels are maintained.

If glucose supply to this animal cell were to

- A. decrease, then the movement of molecule R into Location 2 would increase.
- B. increase, then the production of molecule S would decrease.
- C. increase, then the production of lactic acid would increase.
- D. decrease, then ATP yield would decrease.

**Question 13**

Consider the conversion of isocitrate into  $\alpha$ -ketoglutarate. When ATP is produced in excess amounts for the needs of this cell, some ATP attaches to isocitrate dehydrogenase.

The role of the ATP that attaches to isocitrate dehydrogenase is to act as a

- A. catalyst.
- B. coenzyme.
- C. source of hydrogen ions.
- D. non-competitive inhibitor.

**Question 14**

Which of the following correctly states an input, an output and the ATP yield for Location 3?

	Input 'T'	Output 'U'	ATP yield
A.	oxygen	water	26–28
B.	NAD <sup>+</sup>	oxygen	26–28
C.	carbon dioxide	water	26–28
D.	NAD <sup>+</sup>	carbon dioxide	30–32

**Question 15**

As the concentration of glucose increased within this animal cell, the concentration of an unknown molecule (not shown on the diagram on page 8) measured at Location 1 was decreasing.

The unknown molecule is likely to be

- A. ADP.
- B. NADH.
- C. ethanol.
- D. pyruvate.

DO NOT WRITE IN THIS AREA

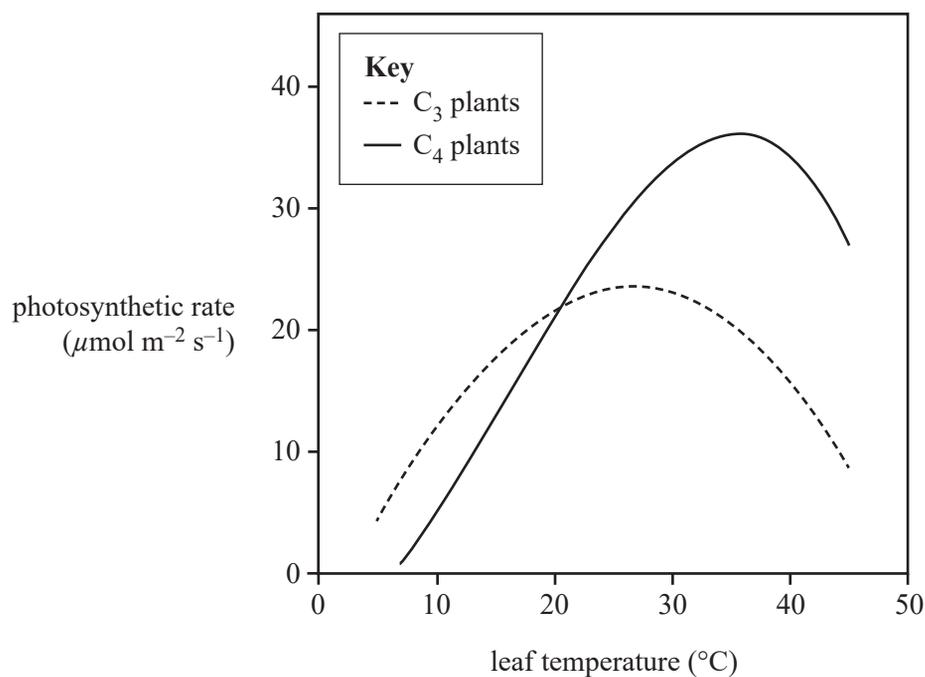
**Question 16**

During photosynthesis in  $C_3$  plants, which molecules would be produced within the thylakoid membrane?

- A. NADPH and carbon dioxide
- B.  $NADP^+$  and water
- C. oxygen and ATP
- D. ADP and oxygen

**Question 17**

The graph below shows the effect of leaf temperature on the rate of photosynthesis in  $C_3$  and  $C_4$  plants.



Source: adapted from W Yamori, K Hikosaka and DA Way, 'Temperature response of photosynthesis in  $C_3$ ,  $C_4$  and CAM plants: temperature acclimation and temperature adaptation', *Photosynthesis Research*, (2014) 119: 101–117, <<https://doi.org/10.1007/s11120-013-9874-6>>; licensed by CCC-Rightslink (USA) with permission from Springer-Nature

This graph shows that

- A.  $C_4$  plants have a higher photosynthetic rate than  $C_3$  plants across all temperatures.
- B. maximum enzyme efficiency occurs at the same temperature in  $C_3$  and  $C_4$  plants.
- C. the optimum temperature for photosynthesis in  $C_3$  plants is 35  $^{\circ}\text{C}$ .
- D. the photosynthetic rate of  $C_3$  and  $C_4$  plants is the same at 20  $^{\circ}\text{C}$ .

DO NOT WRITE IN THIS AREA

**CONTINUES OVER PAGE**

**SECTION A – continued  
TURN OVER**

Use the following information to answer Questions 18–20.

A field study of a rock pool was conducted by a Biology student to explore factors that could affect marine animals. Data was collected from two locations (Location A and Location B) 50 km apart over the same seven-week period, as outlined in the tables below. It was predicted that there would be less species diversity in the rock pools in the urban coastal area (Location A) compared to the rural coastal area (Location B).

**Table 1. Location A – An urban coastal area**

Variable	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Average
air temperature (°C)	28.6	22.8	26.4	25.1	29.1	25.8	26.5	26.3
atmospheric carbon dioxide (ppm)	414	415	414	413	414	414	415	414
dissolved oxygen (mg/L)	7.1	6.9	7.0	7.2	7.1	7.0	7.2	7.1
average number of rock pool animal species per square metre	12	17	22	13	19	7	14	15

**Table 2. Location B – A rural coastal area**

Variable	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Average
air temperature (°C)	22.8	15.2	19.5	18.9	23.1	19.9	20.0	19.9
atmospheric carbon dioxide (ppm)	410	410	411	409	410	409	409	410
dissolved oxygen (mg/L)	7.2	6.9	7.2	7.3	7.4	7.3	7.1	7.2
average number of rock pool animal species per square metre	26	28	6	25	19	20	17	20

DO NOT WRITE IN THIS AREA

**Question 18**

Which one of the following is true regarding this investigation?

- A. This is a correlational study between environmental factors and species diversity.
- B. The student conducted a controlled experiment since they recorded measurements at regular intervals.
- C. The student could conclude that carbon dioxide levels do not affect the rate of cellular respiration in rock pool animals.
- D. There is a causal relationship between dissolved oxygen levels and the average number of rock pool animal species per square metre.

**Question 19**

The data collected suggests that

- A. there are several outliers in the measurements for dissolved oxygen.
- B. the measurements for atmospheric carbon dioxide for both locations are imprecise.
- C. the measurements for dissolved oxygen show a high level of repeatability for Location B only.
- D. both air temperature and atmospheric carbon dioxide levels were higher in Location A than in Location B.

**Question 20**

It could be inferred that, compared to rock pool animals from Location A, those at Location B would have a

- A. higher rate of anaerobic respiration based on the dissolved oxygen levels.
- B. lower rate of aerobic respiration based on the dissolved oxygen levels.
- C. higher rate of aerobic respiration based on the carbon dioxide levels.
- D. lower rate of aerobic respiration based on the air temperatures.

**Question 21**

A new drug to treat malaria is being trialled by scientists.

To apply the concept of non-maleficence to their research, the scientists should ensure that

- A. any harm to the participant resulting from the trial is not disproportionate to the benefits obtained from using the new drug.
- B. data that shows the new drug is ineffective is not published.
- C. consent is obtained from all of the participants in the trial.
- D. the participants experience only the benefits of the trial.

**Question 22**

For a drug to be effective against a pathogen the correct dose must be given. Analysis at the end of the first trial for a drug found that each dose given to participants contained only 25% of the required compound.

This is considered to be

- A. a systematic error.
- B. a personal error.
- C. a random error.
- D. an outlier.

DO NOT WRITE IN THIS AREA

**Question 23**

Precision medicine can be used to develop anticancer drugs that target and silence the gene or genes that cause a particular cancer. The government does not provide funding for many of these drugs and patients may need to spend upwards of \$100 000 for one course of the treatment, when many courses of the treatment are likely to be needed to prolong life. This leads to unequal access to these lifesaving drugs in society.

In terms of bioethics, this situation shows a lack of

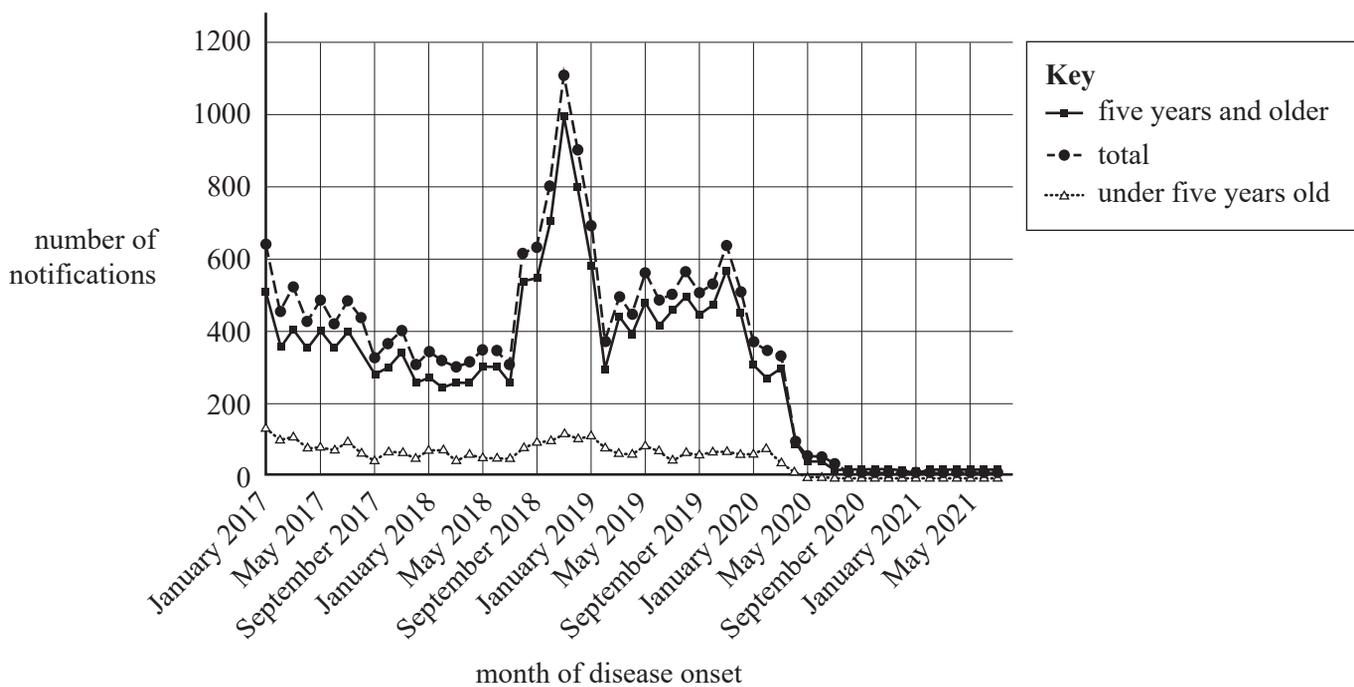
- A. care.
- B. justice.
- C. respect.
- D. integrity.

*Use the following information to answer Questions 24–26.*

Whooping cough (pertussis) is caused by the *Bordetella pertussis* bacterium. The bacteria are spread from one person to another when someone with the infection coughs and fine droplets containing the bacteria are transmitted. When pertussis infections are detected, the health department of the relevant state government must be notified.

The following graph shows the pertussis notifications in the state of New South Wales by month of disease onset and age group.

**Pertussis notifications in NSW residents by month of disease onset and age group, January 2017 to July 2021**



Source: NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health, <[www1.health.nsw.gov.au/IDD/#/PERT/periodandagegroup](http://www1.health.nsw.gov.au/IDD/#/PERT/periodandagegroup)>; CC-BY 4.0; © State of New South Wales, NSW Ministry of Health; for current information go to <[www.health.nsw.gov.au](http://www.health.nsw.gov.au)>

DO NOT WRITE IN THIS AREA

**Question 24**

At which of the following points in the graph is the total number of pertussis notifications most similar?

- A. July 2018 and February 2019
- B. September 2017 and May 2019
- C. May 2020 and September 2020
- D. January 2017 and November 2019

**Question 25**

It is recommended that pregnant women get vaccinated in the last three months of their pregnancy to provide protection against pertussis in the first six weeks of their newborn baby's life.

The type of immunity that a baby would gain from this process would be

- A. active natural.
- B. passive natural.
- C. active artificial.
- D. passive artificial.

**Question 26**

Which of the following gives the best combination of procedures to stop the transmission of *B. pertussis* between unvaccinated people?

A.	cleaning surfaces with disinfectant	physical distancing
B.	wearing masks	physical distancing
C.	washing hands	closing windows
D.	wearing masks	closing windows

**Question 27**

In an innate immune response, which one of the following cells directly destroys virally infected cells?

- A. plasma cells
- B. helper T cells
- C. cytotoxic T cells
- D. natural killer cells

**Question 28**

The rhizosphere is made up of a variety of microorganisms that interact with the roots of plants. One of the roles carried out by the microorganisms within the rhizosphere is to protect plants against plant pathogens.

An equivalent role in humans would be

- A. intact skin acting as a physical barrier.
- B. stomach acid digesting foodborne bacteria.
- C. bacteria in the gut outcompeting foodborne pathogens.
- D. lysozyme in tears breaking down bacteria that make contact with the surface of the eye.

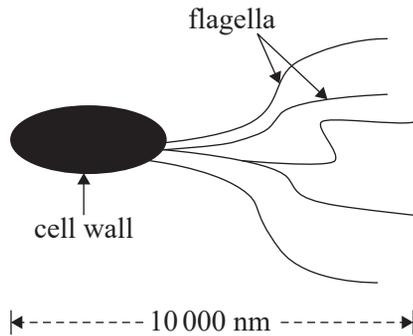
**Question 29**

Higher than normal levels of eosinophils are commonly associated with

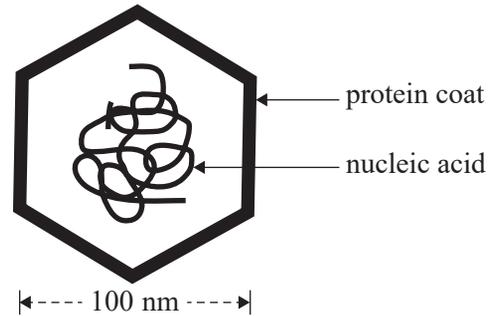
- A. presentation of antigens to lymphocytes in the lymph nodes.
- B. conditions such as parasitic infections and allergic asthma.
- C. viral invasion of host cells.
- D. swelling due to bruising.

**Question 30**

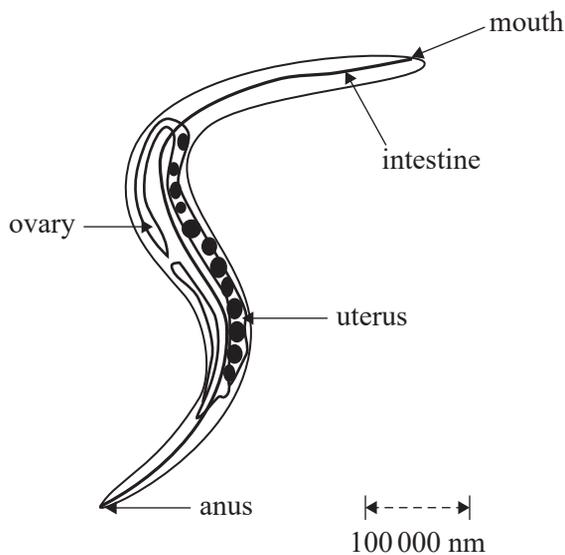
The following diagrams represent various types of plant and mammal pathogens. The approximate size of each pathogen is indicated by a scale bar.



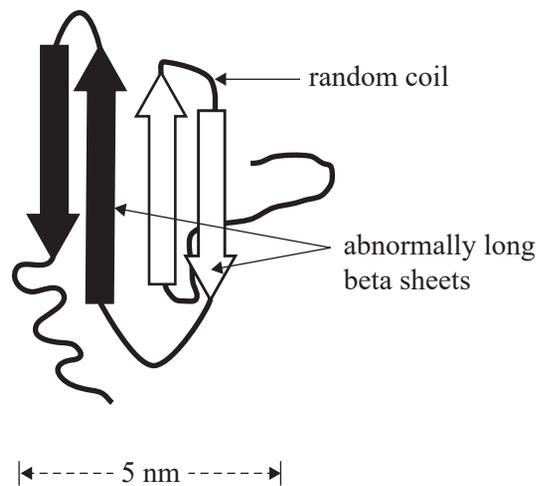
Pathogen W



Pathogen X



Pathogen Y



Pathogen Z

Which of the pathogens above are considered to be cellular?

- A. W, X and Y
- B. X, Y and Z
- C. W and Y
- D. X and Y

DO NOT WRITE IN THIS AREA

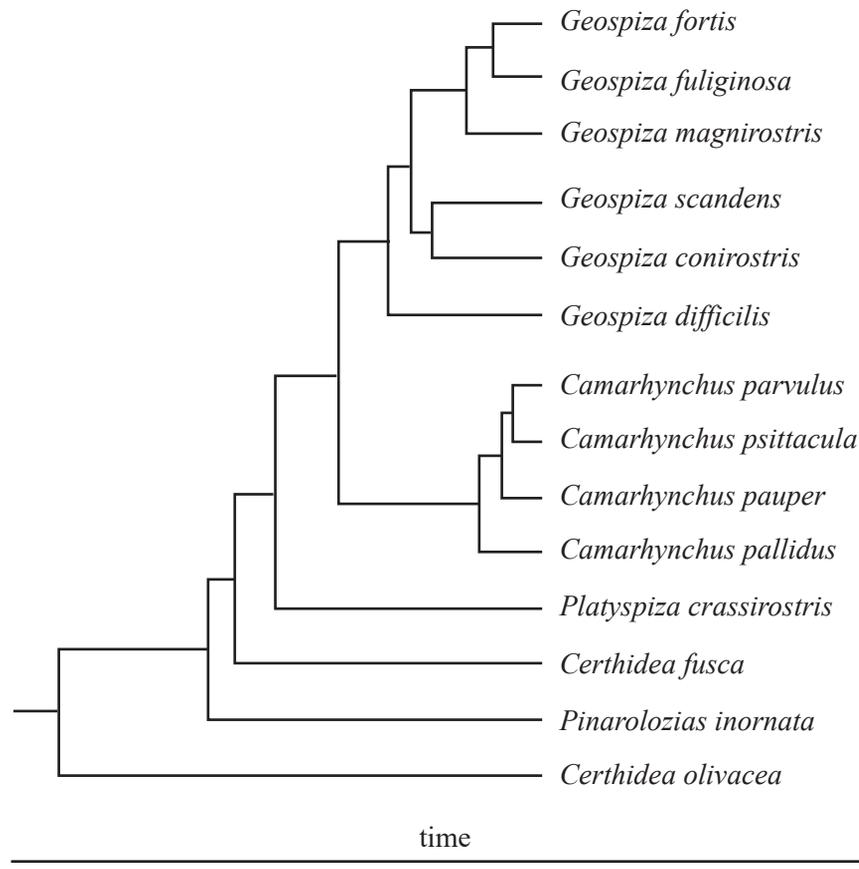
DO NOT WRITE IN THIS AREA

**CONTINUES OVER PAGE**

**SECTION A – continued  
TURN OVER**

Use the following information to answer Questions 31–33.

There are 14 species of Darwin’s finches inhabiting the Galápagos Islands. These finch species share a common ancestor, the dull-coloured grassquit, which is found on mainland South America. The finch species are similar in body size, shape and colour, with noticeable differences observed in their beak shape and size. The phylogenetic tree below shows divergence from the finches’ grassquit ancestor.



Source: adapted from MK Skinner, C Gurerrero-Bosagna, MM Haque, EE Nilsson, JAH Koop, SA Knutie and DH Clayton, ‘Epigenetics and the evolution of Darwin’s finches’, *Genome Biology and Evolution*, vol. 6, issue 8, August 2014, <<https://doi.org/10.1093/gbe/evu158>>, <<https://academic.oup.com/gbe/article/6/8/1972/569028>>; licensed CC-BY-NC

The *Howea* palms are native to Lord Howe Island, a small volcanic island approximately 600 km north-east of Sydney. Around five million years ago, the ancestral palms grew in both neutral and acidic soil. At one point, seeds from these ancestral palms spread to more alkaline soil. The resulting palms had different reproductive cycles, which led to the formation of new species.

### Question 31

Refer to the phylogenetic tree displaying the divergence of Darwin’s finches.

Which of the following pairs of finches share a more recent common ancestor?

- A. *C. fusca* and *C. olivacea*
- B. *G. scandens* and *G. conirostris*
- C. *P. inornata* and *C. olivacea*
- D. *C. pauper* and *C. pallidus*

**Question 32**

Which one of the following factors was necessary for the speciation of the 14 species of Darwin's finches, but was not necessary for the speciation of *Howea* palms on Lord Howe Island?

- A. natural selection
- B. non-random mating
- C. similar environmental food sources
- D. ancestral species dispersed across different environments

**Question 33**

In these examples, allopatric speciation gave rise to new species of Darwin's finches and sympatric speciation gave rise to new species of *Howea* palms. These speciation events are different, but also have some similarities.

Which one of the following is a similarity between the two types of speciation?

- A. The emergence of new species relies on the presence of a geographical barrier.
- B. The new species can produce viable and fertile offspring with the ancestral species.
- C. Both occur through the reproductive isolation of individuals in a population.
- D. The new species are identical to the ancestral species.

**Question 34**

The Australian Sheep Breeding Values is a genetic selection program aimed at improving traits such as growth rate, wool quality, fibre diameter and parasite resistance.

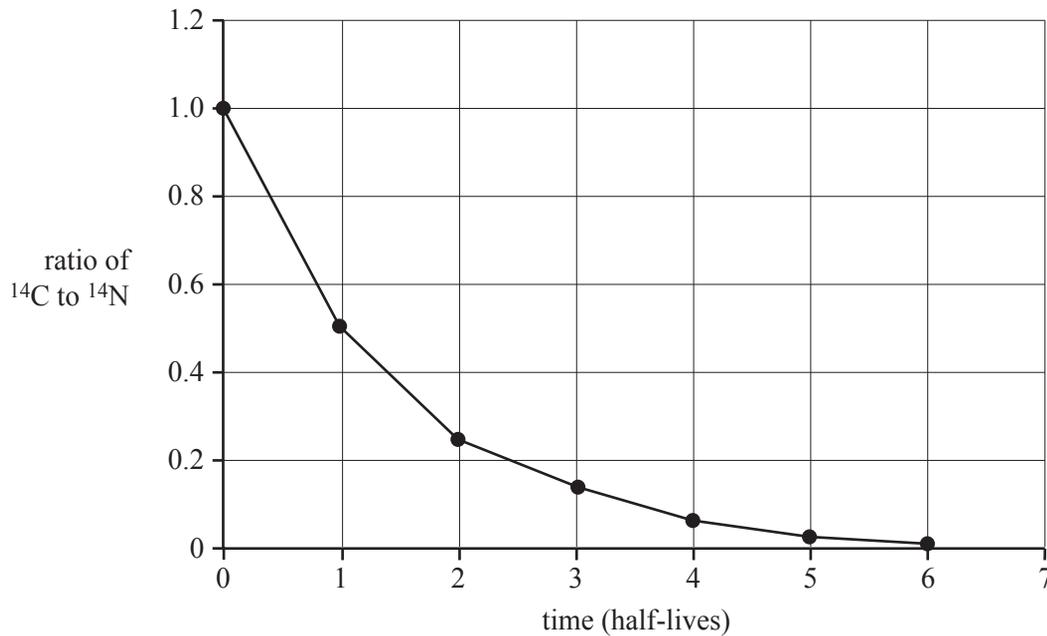
The effect of selective breeding programs such as this one on the genetic variation of a population over time is best explained by

- A. an increase in the gene pool through the selection of alleles that enhance the survival of a population.
- B. a decrease in the gene pool of the population through the selection of particular alleles by humans.
- C. no change to the allele frequency due to the bottleneck event taking place within this population.
- D. an increase in gene flow leading to an increase in the variety of alleles.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 35 and 36.

One method for dating fossils uses carbon-14 ( $^{14}\text{C}$ ). When an organism dies, the unstable  $^{14}\text{C}$  atoms begin to break down into nitrogen-14 ( $^{14}\text{N}$ ) atoms. The graph below shows the ratio of  $^{14}\text{C}$  to  $^{14}\text{N}$ . The half-life of  $^{14}\text{C}$  is approximately 6000 years.



**Question 35**

If the ratio of  $^{14}\text{C}$  to  $^{14}\text{N}$  in a fossil is 0.2, approximately how old would the fossil be?

- A. 6000 years
- B. 12000 years
- C. 15000 years
- D. 18000 years

**Question 36**

Palaeontologists regularly refer to this graph when attempting to date fossilised remains of plant and animal matter. Which of the following correctly indicates the type of dating method used, the type of data represented in this graph and the data in the radioactive decay curve, as used by palaeontologists?

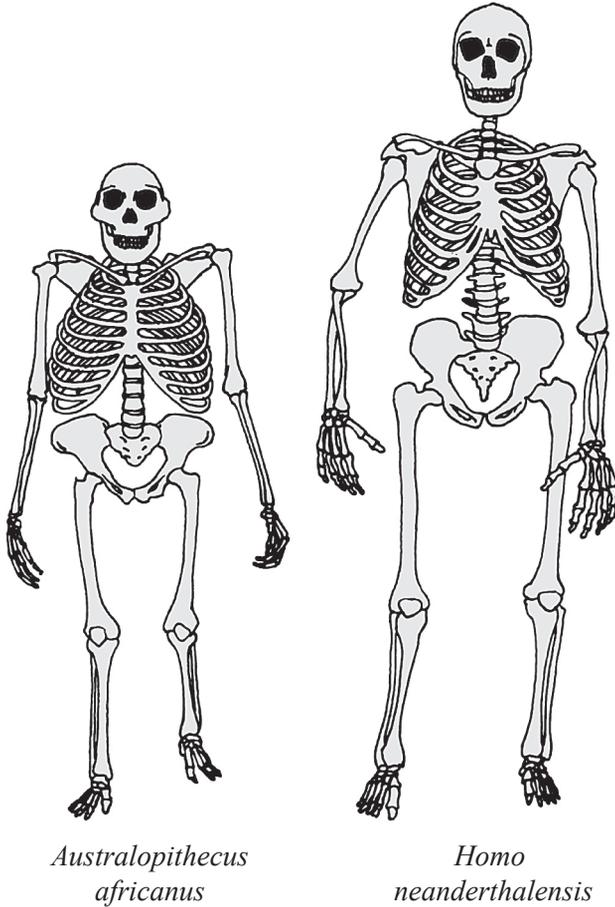
	Type of dating method	Type of data	Data as used by palaeontologists
A.	absolute	quantitative	primary
B.	absolute	quantitative	secondary
C.	relative	qualitative	primary
D.	relative	quantitative	secondary

DO NOT WRITE IN THIS AREA

**Question 37**

A feature that is shared by both hominins and primates but not by all mammals is

- A. bipedal stature.
- B. five cusps on the molar teeth.
- C. narrow and protruded rib cages.
- D. relatively larger brains compared to overall body size.

**Question 38**

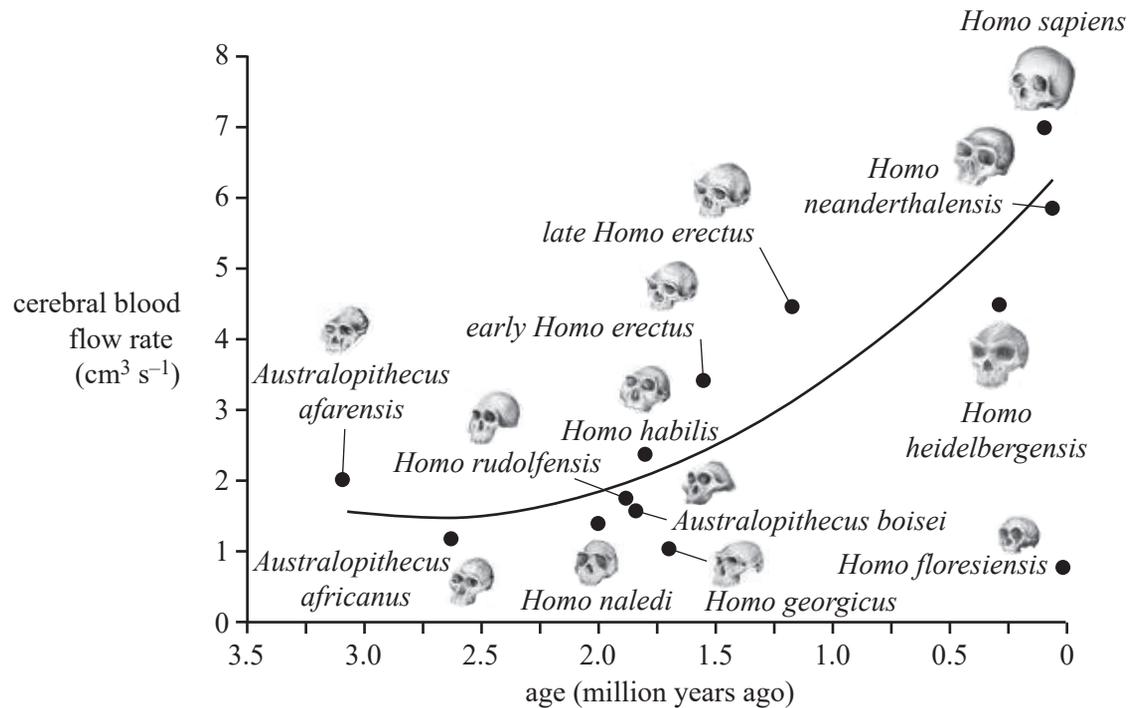
The diagram above shows the skeletons of *Australopithecus africanus* and *Homo neanderthalensis*.

Based on the limb structures of each skeleton, which one of the following is a feature that would confirm both species moved by bipedal locomotion?

- A. size of the heel bone
- B. length of the femur and tibia
- C. longer arm-to-leg length ratio
- D. alignment of the big toe with the other toes

Use the following information to answer Questions 39 and 40.

The graph below compares the cerebral blood flow rate of hominins. The cerebral cortex is associated with many higher-order brain functions, including memory and voluntary physical actions.



Source: adapted from RS Seymour, V Bosiocic and EP Snelling, 'Fossil skulls reveal that blood flow rate to the brain increased faster than brain volume during human evolution', *Royal Society Open Science*, vol. 3, issue 8, August 2016, <<https://doi.org/10.1098/rsos.160305>>; article and original diagram licensed CC-BY 4.0

### Question 39

Which one of the following correctly identifies why the line graph does not connect each of the points representing different species?

- A. The curved line represents the average cerebral blood flow rate of every fossilised skull discovered for each species.
- B. The curved line represents the average cerebral blood flow rate for each of the species present in a given time period.
- C. The curved line is the line of best fit comparing the estimated geological age of each species with the cerebral blood flow rate.
- D. The curved line is the line of best fit comparing the average size of the brain in each species shown.

### Question 40

Which one of the following once-putative species is an outlier to the general trend in cerebral blood flow rate for their time of existence?

- A. *H. habilis*
- B. *A. africanus*
- C. *H. floresiensis*
- D. *H. neanderthalensis*

DO NOT WRITE IN THIS AREA

**CONTINUES OVER PAGE**

**TURN OVER**

**SECTION B**

**Instructions for Section B**

Answer **all** questions in the spaces provided.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

**Question 1** (10 marks)

Gene regulation is the process of turning genes on or off in a particular cell.

- a.** State **two** advantages for an organism of being able to turn genes on or off in particular cells. 2 marks

---

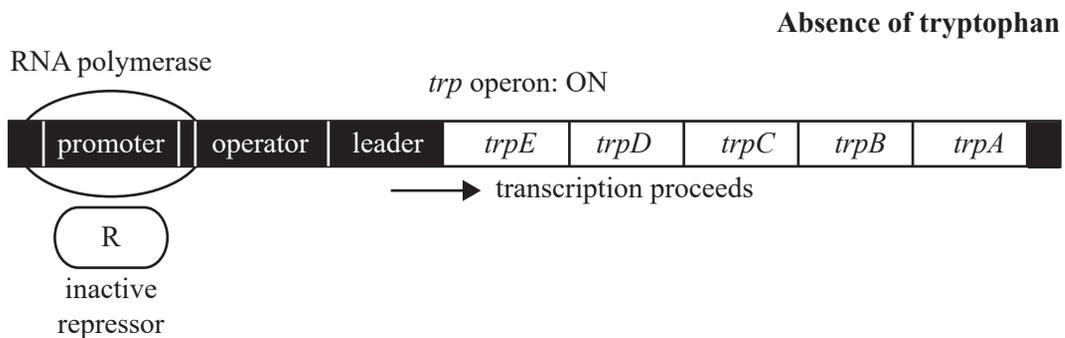
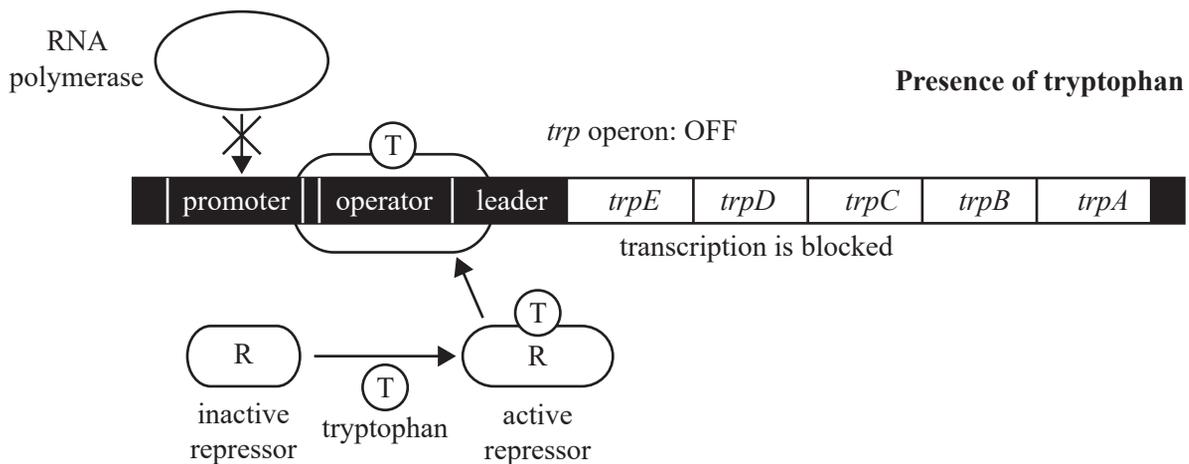


---



---

In *Escherichia coli* (*E. coli*) bacteria, the five genes that code for the enzymes involved in the synthesis of the amino acid tryptophan are regulated. The five genes are grouped together in an operon referred to as the *trp* operon. The diagrams below illustrate how the genes are regulated.



Source: adapted from Meletios Verras/Shutterstock.com

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

- b. Describe how changes to the level of tryptophan in the cell changes the level of transcription of these five genes. Refer to the role of both the promoter and the operator in your response. 5 marks

---

---

---

---

---

---

---

---

---

---

- c. *E. coli* have another method to regulate the genes in the *trp* operon. This method is referred to as attenuation. In this method, when levels of tryptophan are high, RNA polymerase begins transcription but then stops when it reaches the leader section (as shown in the diagram on page 24).  
In this case, will the enzymes for tryptophan synthesis be produced? Justify your response. 3 marks

---

---

---

---

---

**Question 2** (13 marks)

Gene editing refers to modifications made to the genome of a living organism. CRISPR-Cas9 is one method that is frequently used to edit genes. This method relies on clustered regularly interspaced short palindromic repeats (CRISPR) and the endonuclease protein Cas9, which occur naturally in bacteria.

- a. Describe the function of the endonuclease protein Cas9 in bacteria. 2 marks

---

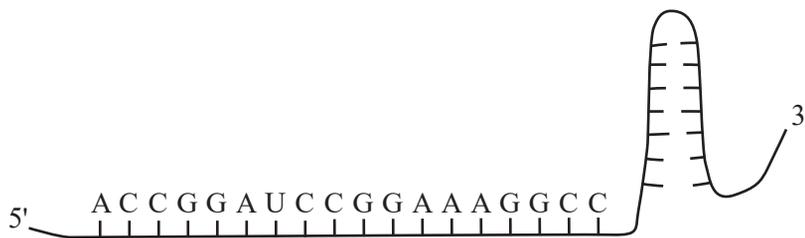


---



---

- b. Gene editing with CRISPR-Cas9 relies on the Cas9 protein and single guide RNA (sgRNA) molecules. A molecule of sgRNA synthetically produced by scientists is shown below.



- Describe the role played by the Cas9 protein in the editing of the gene. Refer to the sgRNA molecule in your response. 2 marks

---



---



---

CRISPR-Cas9 has been used to edit genes in many plant species. In tomato plants, CRISPR-Cas9 was used to stop the expression of the gene controlling flower production. The resulting tomato plants flowered rapidly and produced fruit earlier than tomato plants that were not edited.

- c. Suggest **three** advantages to humans of editing the gene controlling flower production in tomato plants. 3 marks

---



---



---

DO NOT WRITE IN THIS AREA

Two applications of CRISPR-Cas9 in tomato plants are described in the table below.

**Applications of CRISPR-Cas9 in tomato plants**

Target gene	Role	Edit/Modification	Target trait
<i>SIJAZ2</i>	important repressor in a metabolic signalling pathway key regulator of stomatal opening during biotic stresses	gene insertion	bacterial resistance
<i>SIMLO1</i>	confers susceptibility to fungi, causing powdery mildew disease	gene disruption (48 base pairs deletion)	powdery mildew resistance

d. Pathogens such as bacteria and fungi can affect the stems, leaves, roots or fruit of tomato plants.

Explain how genetic editing of *SIJAZ2* and *SIMLO1* can increase tomato plant yields.

2 marks

---



---



---

e. The editing of plant genomes raises a range of ethical issues. For example, there are concerns about the risk of inducing ‘off-target’ mutations and adverse immune responses to the Cas9 protein.

Discuss how a consequences-based approach and beneficence could apply to the use of CRISPR-Cas9 to edit the genomes of plants from the perspective of a research scientist.

4 marks

---



---



---



---



---

DO NOT WRITE IN THIS AREA

**Question 3** (8 marks)

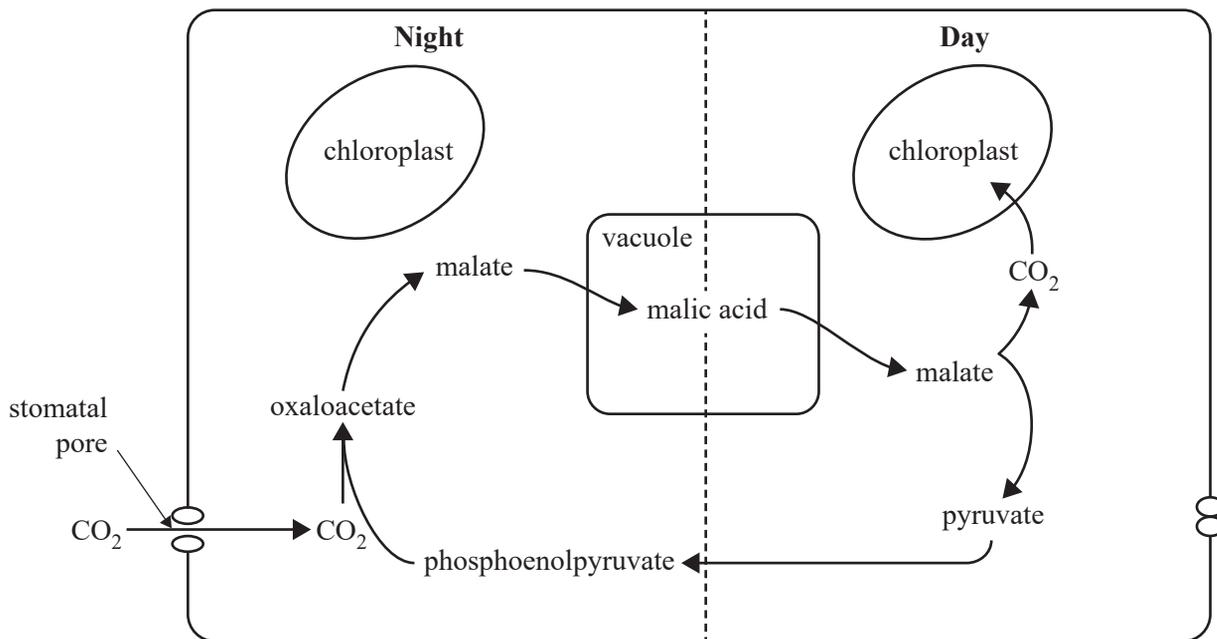
*Agave* is a genus of about 200 plant species that are adapted to dry environments. The photograph below shows some of these plants.



Source: Jesus Cervantes/Shutterstock.com

Agave plants use the CAM pathway to carry out photosynthesis. Several of the key steps in this pathway are outlined in the diagram below.

**A simplified overview of the CAM pathway in an agave leaf cell**



Source: adapted from IN Forseth, 'The ecology of photosynthetic pathways', *Nature Education Knowledge*, 3(10):4, Figure 6

- a. What primary advantage does an agave plant have in using the CAM pathway compared to  $C_3$  plants? 1 mark

---



---

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

- b. In recent years, agave crops have been grown in northern Queensland to explore their potential for bioethanol production. Yeast cells are used to ferment agave biomass to produce bioethanol.

Explain how yeast cells can produce bioethanol and outline the benefits of producing bioethanol from agave biomass.

3 marks

---



---



---



---

- c. In contrast to the CAM pathway used by agave plants, rice uses the C<sub>3</sub> pathway (C<sub>3</sub> rice). Scientists have been attempting to engineer rice that includes components of the C<sub>4</sub> pathway (C<sub>4</sub> rice). Consider the information presented in the tables below.

**Table 1. A comparison of traits in C<sub>3</sub> and C<sub>4</sub> rice**

Trait	C <sub>3</sub> rice	C <sub>4</sub> rice
photosynthetic efficiency	low	high
carbon dioxide interaction with Rubisco	low	high
chloroplast volume	low	high
water usage	high	medium

**Table 2. Predicted changes to the Australian climate in the 21st century**

Environmental factor	Predicted direction of change
atmospheric carbon dioxide concentration	increase
mean surface air temperature	increase
cool season rainfall	decrease

Assess the suitability of developing C<sub>4</sub> rice as a food source in Australia.

4 marks

---



---



---



---



---

**Question 4** (9 marks)

Smallpox was one of the deadliest human viral diseases. People who survived this disease were often badly scarred, blinded or both. In April 1789, 15 months after the British arrival to Australia, a major smallpox outbreak occurred. In terms of the number of infected individuals and subsequent deaths, the outbreak affected the Indigenous population to a greater extent than the British population.

- a. The British population and the Indigenous population were both exposed to the smallpox virus.

Suggest **one** reason why the Indigenous population was affected to a greater extent than the British population. Explain your response.

3 marks

---

---

---

---

- b. In an infected individual, the smallpox virus will come into contact with components of the innate immune system, including various antigen-presenting cells.

Describe the role of antigen-presenting cells in the activation of the adaptive immune response against the smallpox virus.

3 marks

---

---

---

---

- c. Adaptive immunity consists of responses to intracellular and extracellular threats.

Explain how the adaptive immune system responds to an intracellular pathogen.

3 marks

---

---

---

---

DO NOT WRITE IN THIS AREA

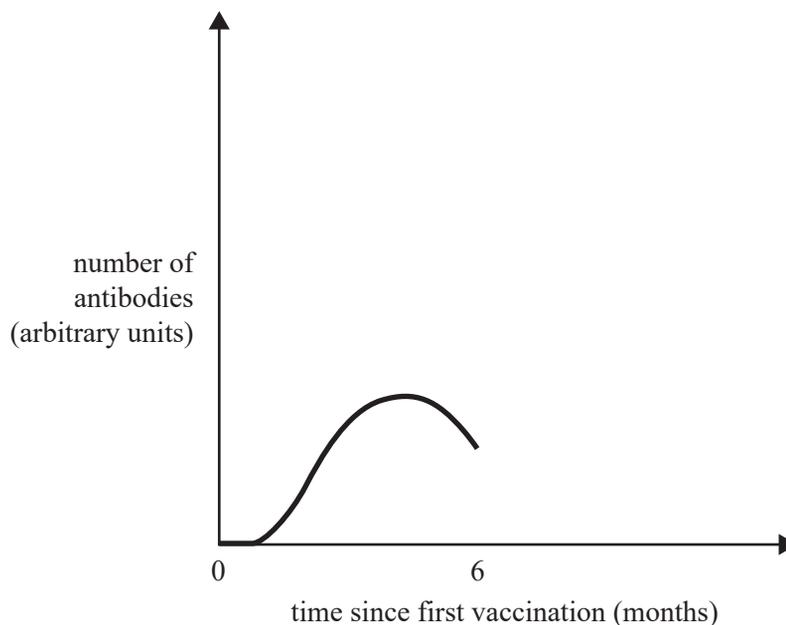
**Question 5** (3 marks)

Measles is a highly contagious viral disease. Measles can be prevented by vaccination.

- a. The graph below shows the number of antibodies produced by someone who has had the first dose of the measles vaccine and is due to receive their second dose in six months.

On the graph, draw what would happen to the number of antibodies circulating in this person's bloodstream during the month following their second dose.

1 mark



- b. Explain why you have drawn the graph in the way that you have in **part a**.

2 marks

---

---

---

DO NOT WRITE IN THIS AREA

**Question 6** (4 marks)

Monoclonal antibodies such as adalimumab and alemtuzumab can be used in the treatment of both autoimmune diseases and cancer.

Adalimumab is a monoclonal antibody used in the treatment of the autoimmune disease rheumatoid arthritis. Adalimumab reduces inflammation by blocking the protein called tumour necrosis factor (TNF).

Alemtuzumab is a different monoclonal antibody and it is used in the treatment of the cancer chronic lymphocytic leukaemia. Alemtuzumab attaches to the cancer cells and sends signals to cells of the immune system that then bring about the death of the cancer cells.

- a. State **two** structural features that adalimumab and alemtuzumab monoclonal antibodies would have in common. 2 marks

---



---



---

- b. Some monoclonal antibodies act by stimulating the immune response, others suppress the immune response and some have no effect on the immune response.

Consider the mode of action of adalimumab and alemtuzumab and complete the table below. 2 marks

Monoclonal antibody	Mode of action – Stimulating, suppressing or no effect on immune response?	Justification for your response
adalimumab		
alemtuzumab		

**Question 7** (7 marks)

*Staphylococcus aureus* (*S. aureus*) is a bacterium that causes skin infections, resulting in swelling and redness at the site of infection.

- a. Describe what happens to cause the swelling and redness at the site of infection. 2 marks

---

---

---

- b. Occasionally, *S. aureus* infections can spread to the blood and bone. This requires immediate treatment. Some antibiotics are effective against such infections; however, a mutation in a single bacterium can result in resistance to one or more of these effective antibiotics.

With reference to natural selection, explain why hospitals would be concerned about a mutation in this bacterium and outline **two** strategies hospitals would need to implement to help prevent more *S. aureus* bacteria becoming antibiotically resistant. 5 marks

---

---

---

---

---

---

---

---

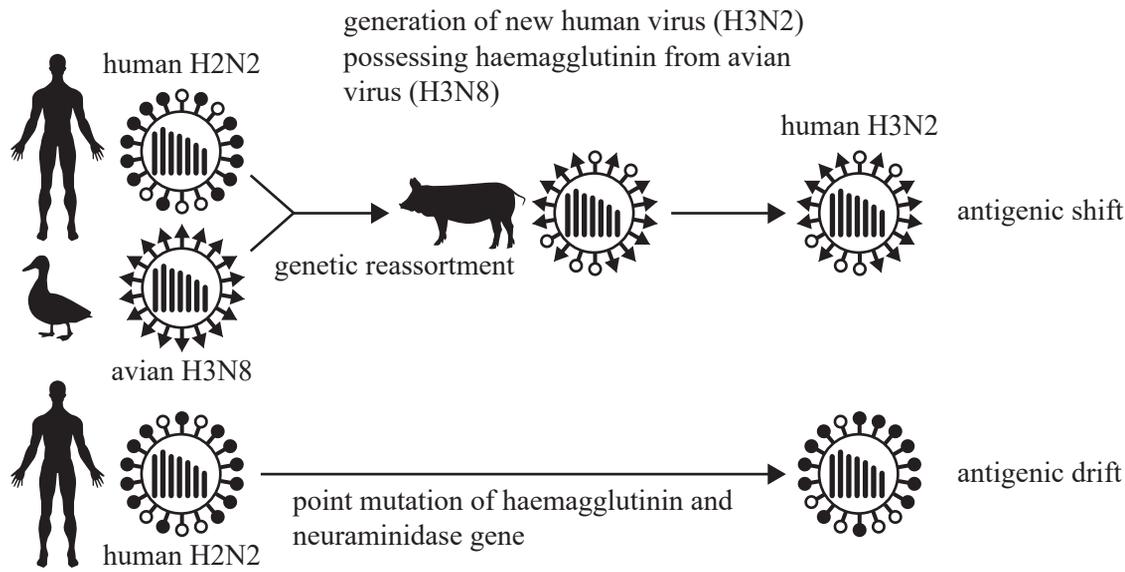
---

---

DO NOT WRITE IN THIS AREA

**Question 8** (5 marks)

Influenza viruses have two surface antigens referred to as haemagglutinin (H) and neuraminidase (N). These antigens can be modified in two distinct ways, as shown in the diagram below.



Source: adapted from Y Suzuki (2000), 'Influenza virus and its glycoreceptor: Host range variation of human and animal influenza viruses', Glycoforum 4, A7(Glycoword GD-A06), <[www.glycoforum.gr.jp/article/04A7.html](http://www.glycoforum.gr.jp/article/04A7.html)>; reproduced by permission

- a. Which form of viral modification would provide more concern for scientists? Justify your response using evidence from the diagram above. 3 marks

---



---



---



---

- b. As part of a vaccine development program, scientists must first ensure they either isolate a specific antigen or construct a weakened version of the pathogen. Prior to the approved use of the vaccine, several stages of clinical testing and trials are undertaken.

Identify **two** controlled variables that the scientists would need to consider as part of the clinical trials using human patients. 2 marks

---



---



---

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

**CONTINUES OVER PAGE**

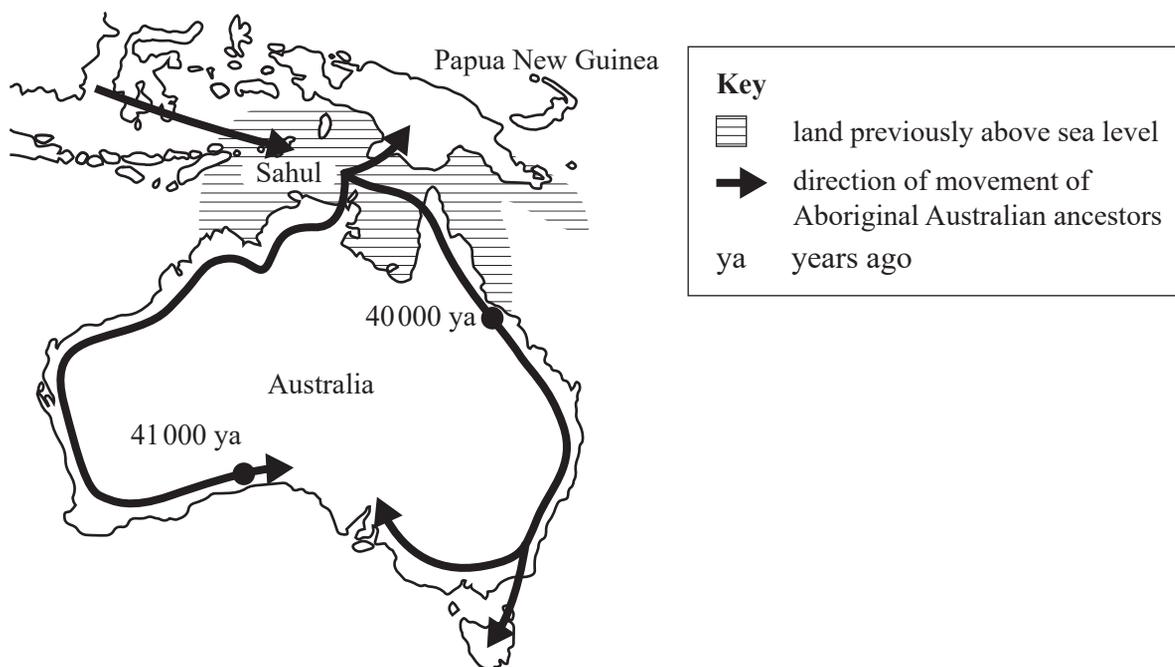
**SECTION B – continued**  
**TURN OVER**

**Question 9** (10 marks)**50 000 years of Aboriginal regionalism in Australia**

Research is currently being conducted on bone, plant, soil and other biological specimens found worldwide in an effort to determine the phylogenetic relationships between ancient human remains. Mitochondrial DNA (mtDNA) comparisons have enabled the tracking of past migrations of Indigenous populations, including the movements of Aboriginal Australian ancestors. Aboriginal Australians have one of the longest continuous cultural complexes known.

Scientists are conducting three lines of inquiry. Firstly, they are hoping to complete the first Aboriginal genome and to map the variation between different Indigenous Australian populations using DNA sequencing of hair samples. Current reporting suggests 111 mitochondrial genomes exist. Secondly, scientists are exploring the biological impacts of rapid environmental and cultural changes, such as climate change, farming, disease and colonialism. Thirdly, they are investigating the genetic records of people of Sahul, the landmass previously connecting New Guinea with Australia until the rise in sea levels around 9000 years ago. This research has been used to predict the route of arrival of Aboriginal Australian ancestors approximately 50 000 years ago.

The second wave of hominin migration was predicted to have begun 60 000 years ago, coinciding with the arrival of the ancestors of Aboriginal Australians in Australia 50 000 years ago. Key fossils from this time period include *Homo erectus* and *Homo floresiensis* in Indonesia. Indigenous Australians and current populations in Indonesia and Papua New Guinea share approximately 4–6% similar nuclear DNA with *Homo denisova*. All other currently known ancestral hominin species do not share similar nuclear DNA with Indigenous Australians.



While there is little currently known about Aboriginal Australian movement once in Australia, their migration is believed to have occurred rapidly via the pathways indicated on the map above. The history and knowledge held by Aboriginal Australians is interwoven with the varied and changing Australian landscape through their connection to Country. This is evidenced by the limited dispersal of Aboriginal Australian lineages over time, as well as songlines and Dreaming narratives.

Reference: R Tobler, A Rohrlach, J Soubrier et al., 'Aboriginal mitogenomes reveal 50 000 years of regionalism in Australia', *Nature*, vol. 544, 13 April 2017, <[www.nature.com/articles/nature21416](http://www.nature.com/articles/nature21416)>

DO NOT WRITE IN THIS AREA

- a. Which currently known hominin species is most likely the ancestor of Aboriginal Australians? Explain your response by referring to the different species and other information presented in the article. 3 marks

---

---

---

---

---

- b. Comparisons of genomes of Aboriginal Australian populations on the west coast and east coast suggest that there were two distinct pathways of migration across Australia.  
Using supporting evidence from the article, explain likely reasons for the differences seen in the genomes of the populations. 2 marks

---

---

---

- c. Analysis of mtDNA from Aboriginal Australians and phylogeographic patterns support the contention that there was a continuous presence of distinct populations in discrete geographic areas for up to 50 000 years.
  - i. Identify **two** types of artefacts that may be found in a particular geographic area if Aboriginal Australians had lived in that area for long periods of time (thousands of years)? 2 marks

---

---

---

- ii. Explain how mtDNA phylogeny provides evidence for the continuous presence of Aboriginal Australian populations in discrete geographic areas. 3 marks

---

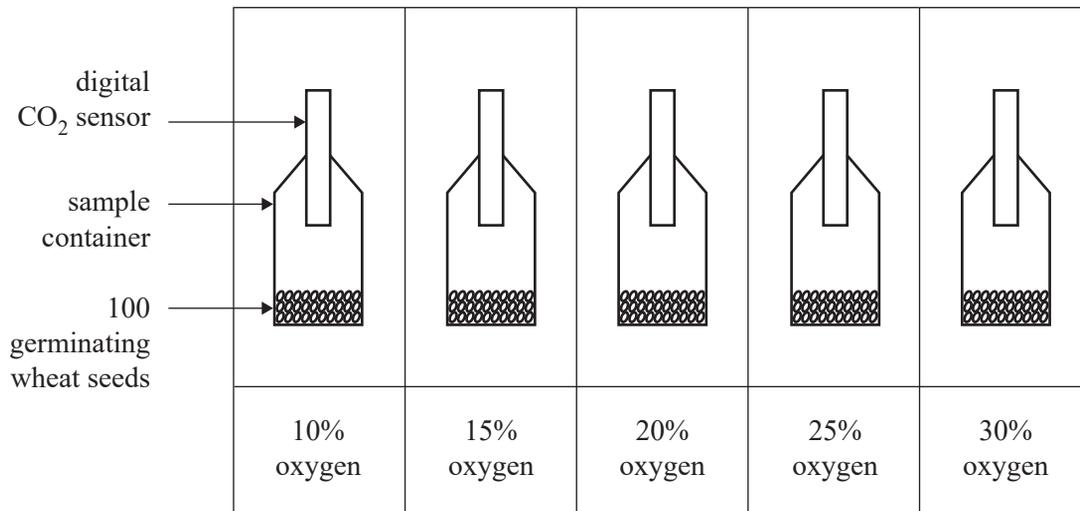
---

---

---

**Question 10** (11 marks)

For their VCE Biology practical investigation, a student investigated cellular respiration in germinating wheat seeds. The experimental set-up recorded in their logbook is shown below.



The temperature, the number and species of wheat seeds, and the size of the sample container were all kept the same in each set-up. All containers were kept in the dark. The level of carbon dioxide in each container was recorded every 10 minutes over a period of 60 minutes.

- a. State a hypothesis that the student may have formulated. 2 marks

---



---

- b. Was the concentration of glucose a controlled variable? Explain your response. 2 marks

---



---

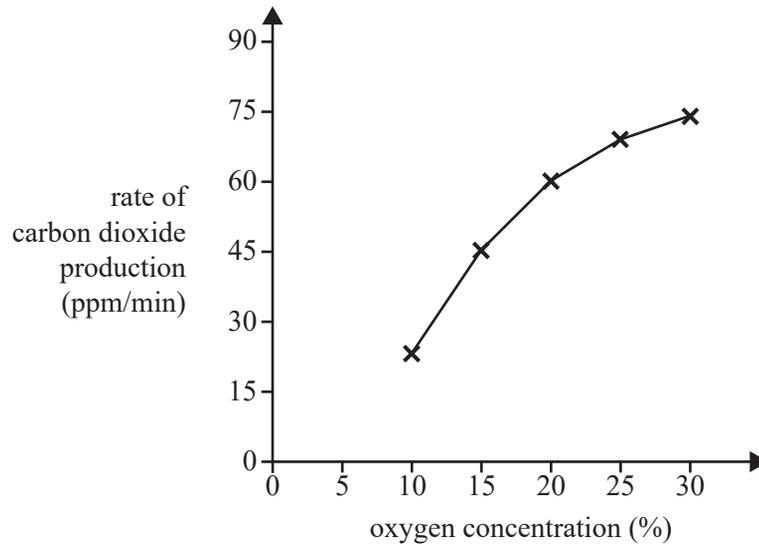


---

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

c. The results of the investigation are shown in the graph below.



Analyse the results of the student's experiment.

3 marks

---

---

---

---

---

d. The student then modified the investigation by including an additional sample container, which was supplied with a very low concentration of oxygen (less than 1% oxygen). The student predicted that the rate of carbon dioxide produced for this set-up would be close to zero. However, results collected from this low-oxygen set-up showed a consistent and relatively high initial rate of carbon dioxide production. After a period of time, the rate of carbon dioxide production decreased. Repeating the investigation with this set-up three more times produced the same results.

Account for the results of this set-up (very low concentration of oxygen), providing a plausible explanation for the results recorded by the student.

4 marks

---

---

---

---

---



**Answers to multiple-choice questions**

Question	Answer
1	D
2	D
3	B
4	C
5	A
6	C
7	B
8	B
9	A
10	B
11	B
12	D
13	D
14	A
15	A
16	C
17	D
18	A
19	D
20	D

Question	Answer
21	A
22	A
23	B
24	D
25	B
26	B
27	D
28	C
29	B
30	C
31	D
32	D
33	C
34	B
35	C
36	B
37	D
38	D
39	C
40	C