

STUDENT NUMBER

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BIOLOGY

Written examination

Friday 29 October 2021

Reading time: 9.00 am to 9.15 am (15 minutes)

Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	40	40	40
B	11	11	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 39 pages
- Answer sheet for multiple-choice questions

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.

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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

Cells synthesise different molecular chains using distinct monomers, as shown in the two examples below.

	Monomer	Molecular chain
Example 1	$\begin{array}{c} \text{R} \\ \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array}$	
Example 2		

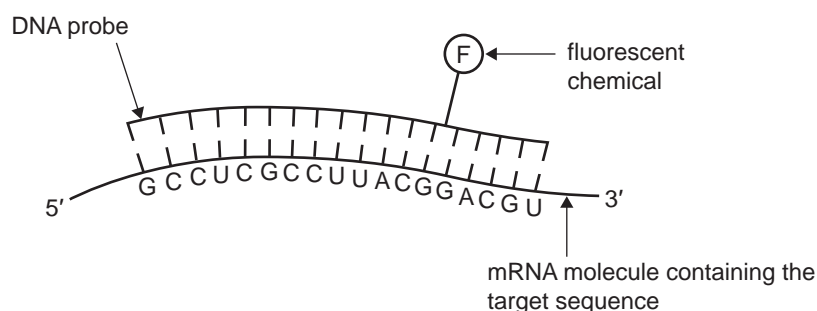
The formation of chemical bonds X and Y

- requires a water molecule as a reactant.
- involves condensation polymerisation.
- releases energy for use in the cell.
- occurs in the Calvin cycle.

Use the following information to answer Questions 2–4.

One method that is used to identify and measure quantities of mRNA molecules is called fluorescence in situ hybridisation (FISH).

The fluorescent chemical is attached to the DNA probe. When the DNA probe binds to the target mRNA sequence, as shown in the diagram below, the fluorescent chemical allows the mRNA molecule to be visualised.



Source: adapted from LVJC Mannack, S Eising and A Rentmeister, 'Current techniques for visualizing RNA in cells', F1000 Research, 5:F1000 Faculty Rev-775, 28 April 2016, <<https://doi.org/10.12688/f1000research.8151.1>>

Question 2

To make the mRNA molecule containing the target sequence, a cell must

- A. synthesise DNA polymerase.
- B. attach a poly-A tail to the 3' end of the gene.
- C. create a nucleotide chain with a ribose-phosphate backbone.
- D. have a ready supply of the N-containing bases adenine, thymine, guanine and cytosine.

Question 3

The mRNA molecule identified by FISH is used by the cell to produce a new type of molecule.

Which one of the following statements correctly describes one aspect of the production of this new molecule?

- A. The rRNA and its associated proteins create a binding site for the mRNA.
- B. The tRNA delivers and attaches a nucleotide to the new growing molecule.
- C. The mRNA anticodons are complementarily matched with the tRNA codons.
- D. The mRNA attaches to the smaller sub-unit of the ribosome to initiate transcription.

Question 4

Using the information provided in the diagram above and your own knowledge of genetic coding, which of the following is correct? Assume that there are no STOP codons in the target mRNA sequence.

	Probe sequence	Number of amino acids coded by the mRNA target sequence
A.	3' GCAGGCAUCCGAUCCGA 5'	5
B.	3' CGGAGCGGAATGCCTGCA 5'	5
C.	3' CGGAGCGGAAUGCCUGCA 5'	6
D.	3' CGGAGCGGAATGCCTGCA 5'	6

Question 5

Consider the process of photosynthesis.

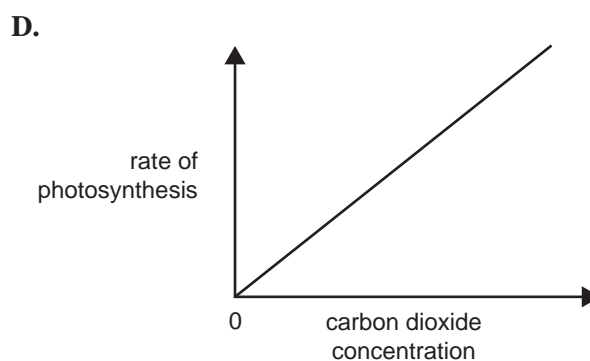
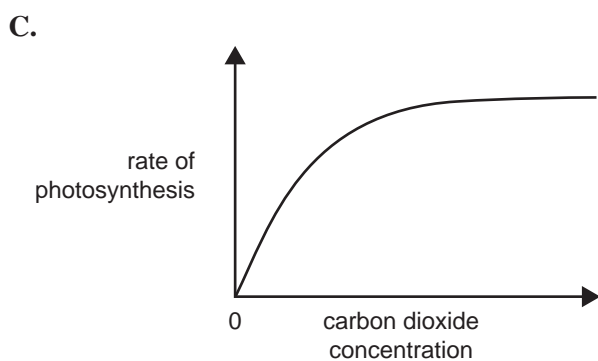
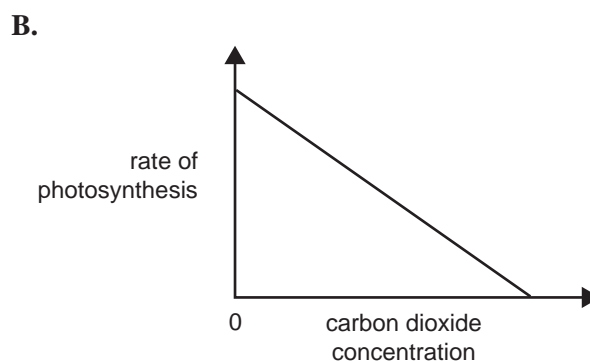
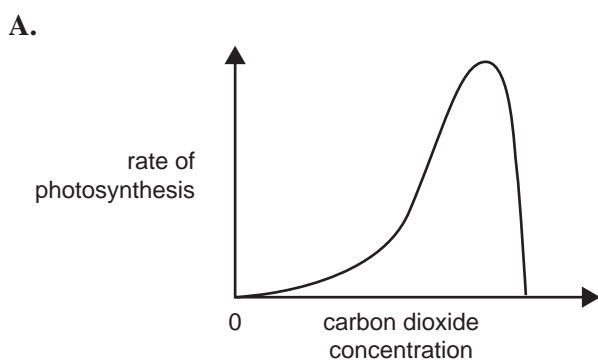
Which of the following shows correct information about each of the two stages of photosynthesis?

	Light-dependent stage	Light-independent stage
A.	produces oxygen	produces carbon dioxide
B.	requires water	requires NADH
C.	occurs in the stroma	occurs in the grana
D.	energy is provided by light	energy is provided by ATP molecules

Question 6

In a series of experiments, the rate of photosynthesis in plant cells was measured in environments with different concentrations of carbon dioxide. All other variables were kept constant.

Which one of the following graphs reflects the trend that would be shown by the results of these experiments?

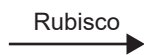


Question 7

Ribulose biphosphate carboxylase/oxygenase (Rubisco) is an enzyme found in green plants. Rubisco is important in two reactions. These reactions are shown below.

Reaction 1

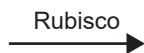
ribulose 1,5-bisphosphate + oxygen



2 phosphoglycolate + 3 phosphoglycerate

Reaction 2

ribulose 1,5-bisphosphate + carbon dioxide



3 phosphoglycerate

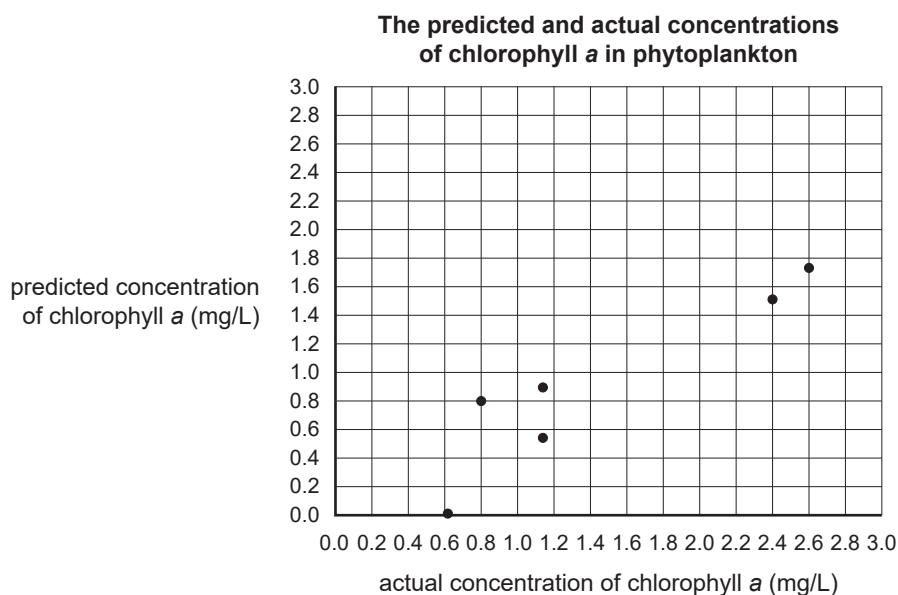
A Biology student hypothesised that the same active site on Rubisco is used in Reaction 1 and Reaction 2.

Which one of the following observations would support this hypothesis?

- A. The rate of Reaction 2 increases when the temperature is increased.
- B. The rate of Reaction 2 decreases when the concentration of oxygen is increased.
- C. The rate of both reactions decreases when the concentration of Rubisco is increased.
- D. The rate of Reaction 1 increases when the concentration of carbon dioxide is increased.

Question 8

The graph below shows the relationship between the predicted and actual concentrations of chlorophyll *a* in phytoplankton.



Source: Fairouz Binti Johan et al, 'Chlorophyll *a* concentration of fresh water phytoplankton analysed by algorithmic based spectroscopy', *Journal of Physics: Conference Series*, 1083 (2018) 012015, <<https://iopscience.iop.org/article/10.1088/1742-6596/1083/1/012015/pdf>>; licensed CC-BY 3.0 <<https://creativecommons.org/licenses/by/3.0/>>

From the graph, it can be inferred that

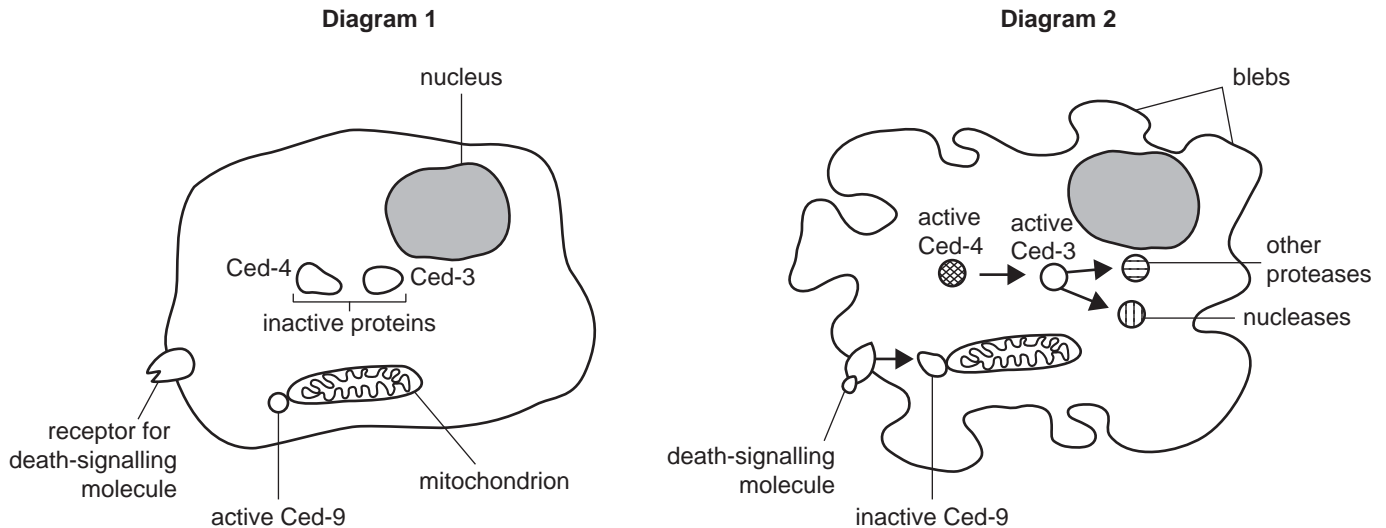
- A. the actual concentration of chlorophyll *a* was lower than the predicted concentration in all recorded measurements.
- B. at 2.4 mg/L actual concentration of chlorophyll *a*, the predicted concentration of chlorophyll *a* was 2 mg/L.
- C. at 0.8 mg/L, the predicted concentration and the actual concentration of chlorophyll *a* were the same.
- D. at zero predicted concentration of chlorophyll *a*, photosynthesis did not occur.

Use the following information to answer Questions 9–11.

Scientists studied cells in the embryos of the nematode worm *Caenorhabditis elegans*. They identified three proteins, Ced-3, Ced-4 and Ced-9, that are involved in programmed cell death.

When no death-signalling molecule was detected by an embryonic cell, Ced-9 inhibited the action of Ced-3 and Ced-4, as shown in Diagram 1.

When a death-signalling molecule was detected, Ced-9 changed shape and became inactive. Ced-3 and Ced-4 were no longer inhibited and their activity resulted in the changes shown in Diagram 2.



Question 9

The cell in Diagram 2 is undergoing

- A. apoptosis.
- B. exocytosis.
- C. plasmolysis.
- D. endocytosis.

Question 10

The Ced-3 protein is most likely to be a

- A. mitochondrial protein.
- B. transcriptional factor.
- C. coenzyme.
- D. caspase.

Question 11

The purpose of most of the programmed cell deaths in *C. elegans* embryos is to

- A. remove ageing, worn-out cells.
- B. destroy pathogen-infected cells.
- C. eliminate abnormal cells that could cause cancer.
- D. ensure appropriate formation of developing organs.

Use the following information to answer Questions 12–14.

Growth hormone (GH) is a peptide hormone that is made by cells in the pituitary gland. GH is transported to the plasma membrane of the cells in the pituitary gland and then released into the blood. Liver cells respond to GH by secreting another hormone called insulin-like growth factor (IGF-1). IGF-1 stimulates muscle cells to increase in size and bone cells to produce mineralised bone. Fat cells respond to GH by breaking down triglycerides into fatty acids and glycerol.

Question 12

Which organelle transports GH to the plasma membrane of cells in the pituitary gland?

- A. vesicle
- B. ribosome
- C. Golgi apparatus
- D. endoplasmic reticulum

Question 13

The receptors that are responsible for detecting GH in liver cells and fat cells are located

- A. in the cytosol.
- B. within the nucleus.
- C. on the plasma membrane.
- D. on the nuclear membrane.

Question 14

In this scenario, the secretion of IGF-1 by liver cells is called

- A. signal reception.
- B. a cellular response.
- C. signal transduction.
- D. a stimulus-response model.

Question 15

Neutrophils

- A. secrete complement proteins.
- B. migrate to the site of infection and engulf invading pathogens.
- C. increase the diameter of blood vessels to make them more permeable.
- D. release histamine following the binding of the antigen to receptors on the neutrophil's surface.

Question 16

In humans, an example of a chemical barrier that prevents the entry of pathogens into the internal environment would be

- A. histamine.
- B. interferons.
- C. lysozymes.
- D. complement proteins.

Question 17

The role of the lymphatic system in an immune response includes

- A. carrying mast cells to the site of infection.
- B. activation of platelets to help heal wounds.
- C. transport of antigen-presenting cells, including dendritic cells.
- D. delivery of injected monoclonal antibodies to specific target cells.

Question 18

One method of assessing the progress of multiple sclerosis (MS) in patients detects fragments of the protein NfL. These protein fragments are released into spinal fluid and blood when nerves are damaged.

It can be expected that patients with progressive MS will have

- A. an increased number of T helper lymphocytes.
- B. lower levels of the NfL protein in the blood.
- C. thicker myelin sheaths around nerves.
- D. lower levels of antibodies.

Question 19

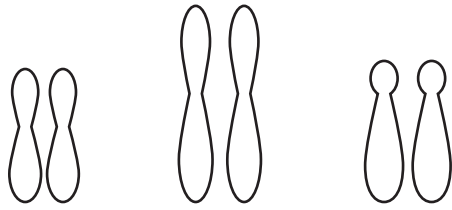
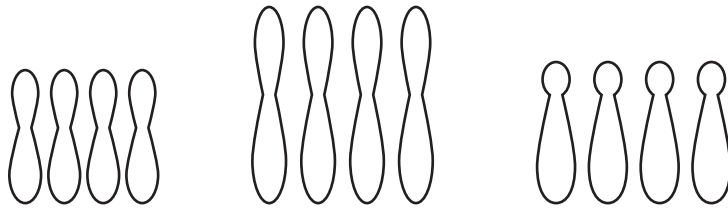
A new treatment for some cancers includes the use of conjugated monoclonal antibodies, which have an anti-cancer drug attached.

The main advantage of using conjugated monoclonal antibodies in this new cancer treatment is that they

- A. decrease the amount of the anti-cancer drug delivered to cancerous cells.
- B. reduce the effects of the anti-cancer drug on non-cancerous cells.
- C. cause an increase in the number of memory T cells.
- D. stimulate B cells to produce antibodies.

Question 20

The diagram below shows the chromosomes from two different but related plant species.

Plant species 1**Plant species 2**

Compare the chromosomes of the two plant species.

The differences seen in the chromosomes of Plant species 2 compared to the chromosomes of Plant species 1 can be described as

- A. aneuploidy.
- B. polyploidy.
- C. triploidy.
- D. trisomy.

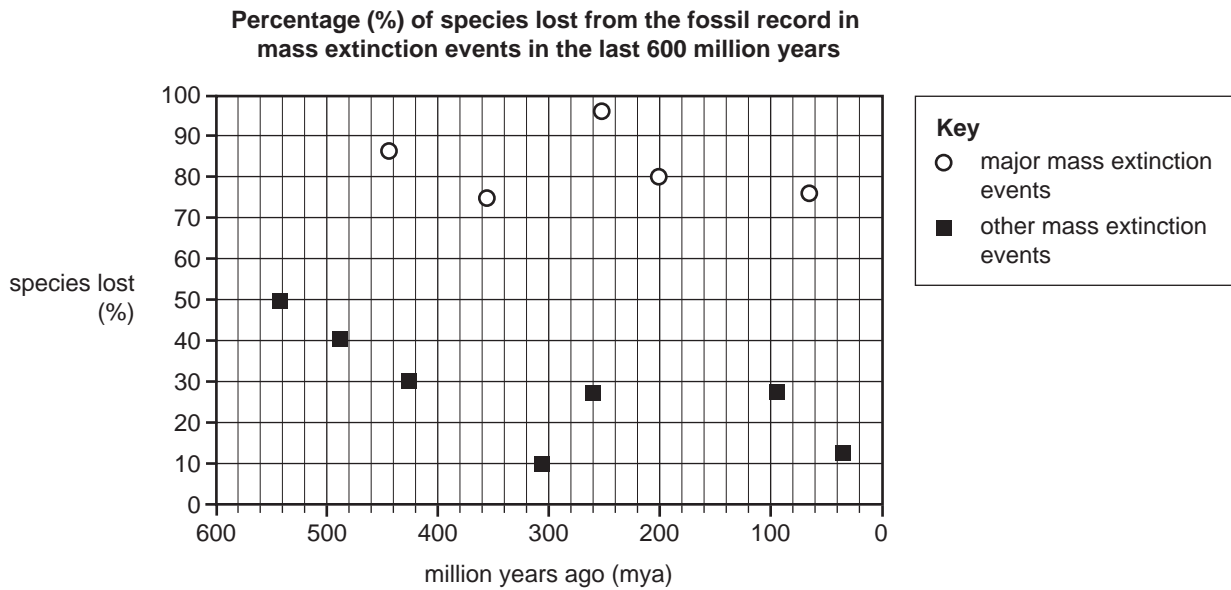
Question 21

Which of the following shows some of the organisms on the fossil record in the correct order in which they first appear?

- A. fish, green algae, mammals, flowering land plants
- B. green algae, fish, flowering land plants, mammals
- C. fish, mammals, green algae, flowering land plants
- D. green algae, fish, mammals, flowering land plants

Question 22

The graph below shows when the five major mass extinction events and several other mass extinction events occurred. It also shows the percentage of species that were lost in each event.



According to the graph, to be classified as a major mass extinction event, the percentage of species that are lost has to be at least

- A. 10%
- B. 50%
- C. 74%
- D. 97%

Question 23

Mass extinction events

- A. allow new species to evolve to occupy available niches.
- B. allow all species that survive to recover and diverge.
- C. result from a constant global climate.
- D. affect all species equally.

Question 24

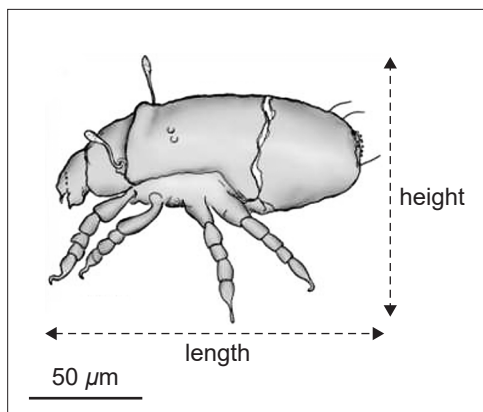
Sea stars are soft-bodied marine animals that have survived periods of mass extinction. The oldest sea star fossils have been dated to 480 million years ago. The number of sea star fossils found is relatively low.

One reason why the number of sea star fossils found is relatively low is that sea stars

- A. are easily eroded from rock layers after exposure to wind.
- B. live in seawater that fluctuates widely in temperature.
- C. are unlikely to be covered in sediment after death.
- D. have bodies that decompose quickly.

Question 25

Below are two photographs (Image A and Image B) of arthropod fossils found in tree resin (amber) and a drawing of an arthropod (Image C). Each image has a scale in micrometres (μm).

Image A**Image B****Image C**

Sources: Ernie Cooper/Shutterstock.com (Image A); Bjoern Wylezich/Shutterstock.com (Image B); JD Stilwell, A Langendam, C Mays et al, 'Amber from the Triassic to Paleogene of Australia and New Zealand as exceptional preservation of poorly known terrestrial ecosystems', *Scientific Reports*, 10, 5703 (2020), <<https://doi.org/10.1038/s41598-020-62252-z>> (Image C), licensed CC-BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>

From the images shown, it can be concluded that the arthropod

- A. fossils are examples of trace fossils.
- B. in Image C is less than $90 \mu\text{m}$ in height.
- C. fossil in Image A is greater than $100 \mu\text{m}$ in length.
- D. that was fossilised in Image B was buried in sediment before it was surrounded by amber.

Question 26

Until May 2019, Denisovan fossils had been found in only two locations: Siberia and Tibet. Since then, Denisovan DNA has been discovered in some present-day populations. These populations are found on several continents, including Australia.

This suggests that the ancient Denisovan hominin group was or its descendants were

- A. only fossilised in Siberia and Tibet.
- B. genetically identical to *Homo sapiens*.
- C. extinct prior to the presence of Neanderthals.
- D. more widespread than fossil evidence suggests.

Question 27

The BMP4 gene in African cichlid fish is responsible for

- A. the great range of colours and scale patterns observed in adult fish of different species.
- B. the amount of bone laid down in the jaws of cichlid fish embryos.
- C. convergent evolution between different species of cichlids.
- D. sex determination in cichlid fish living in African lakes.

Question 28

Small amounts of DNA can be collected from items such as cigarette butts and hair follicles that are found at crime scenes. This DNA can be replicated for analysis and used as evidence in court cases.

Which of the following identifies the method of DNA replication and the enzyme used?

	Method	Enzyme used
A.	polymerase chain reaction	<i>Taq</i> polymerase
B.	DNA profiling	DNA ligase
C.	polymerase chain reaction	DNA ligase
D.	DNA profiling	<i>Taq</i> polymerase

Question 29

A four-month investigation was undertaken in the classrooms of a large number of Year 2 and Year 3 students from four primary schools. For the first two months, half of the classes from each school used an antimicrobial gel hand sanitiser, while the other half used soap and water for regular hand hygiene. The students then switched hand-cleaning methods for the final two months. No significant differences in illness were observed between the groups.

The purpose of this investigation was most likely to

- A. reduce water use in schools.
- B. encourage students to wash their hands more often.
- C. reduce the number of students who are away from school due to illness.
- D. decide if purchasing antimicrobial gel hand sanitiser for students was worthwhile.

Use the following information to answer Questions 30–33.

The short-beaked echidna (*Tachyglossus aculeatus*) can be found in Australia and New Guinea. This species is sometimes a target of the illegal wildlife trade.



Source: Kristian Bell/Shutterstock.com

A university Biology student set out to compare DNA from four different short-beaked echidnas living in four different locations. The student aimed to determine the country of origin of each echidna. This was achieved using primers that amplified a 430 base pair (bp) sequence from the echidna's mitochondrial genome.

A flow chart of the steps taken by the student is shown below.

Step 1 – Isolate mitochondrial DNA (mtDNA) from the short-beaked echidna's quills (spines).



Step 2 – Amplify the mtDNA at a precise location.



Step 3 – Verify that mtDNA amplification was successful using gel electrophoresis.



Step 4 – Sequence the mtDNA fragments from the gel and compare the samples.

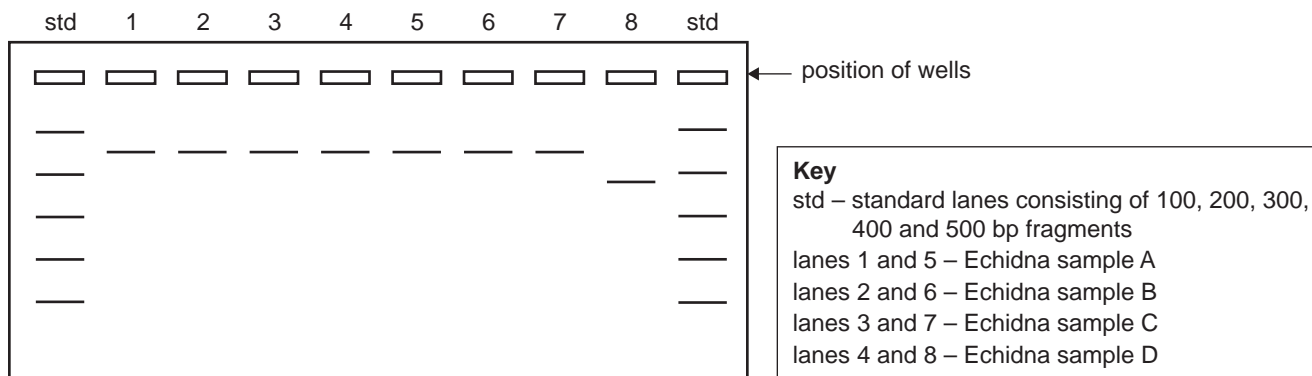
Question 30

Which one of the following would be a requirement of either Step 1 or Step 2?

- A. Step 2 would require the use of a thermocycling machine to maintain the temperature at 37 °C.
- B. Step 1 would require the quill samples to have been stored at a very high temperature.
- C. Step 1 would require the extraction of DNA from the nuclei of quill epithelial cells.
- D. Step 2 would usually require a reaction mixture containing two primers.

Use the following **additional** information to answer Questions 31 and 32.

Results from Step 3 – Verification that DNA amplification was successful



Question 31

In order for the student's experiment to be valid, the student would need to

- A. ensure the amplified DNA region is from the correct locus of the echidna's mitochondrial genome.
- B. be able to have the same set of results replicated by a different observer at a different time.
- C. demonstrate that the results from the amplified samples were precise.
- D. repeat the experiment a minimum of three times.

Question 32

Attempts to reach a conclusion based on these electrophoresis results may be affected by

- A. an unidentified systematic error.
- B. the presence of several outliers in the results.
- C. a degree of uncertainty in the results for Echidna sample D.
- D. a random error causing the position of the DNA sample in lane 7.

Question 33

The results from Step 4 are shown in the table below. They compare a sequence of 20 bases between the echidna samples. Of the four samples, three were determined to be from Australia and one was determined to be from New Guinea.

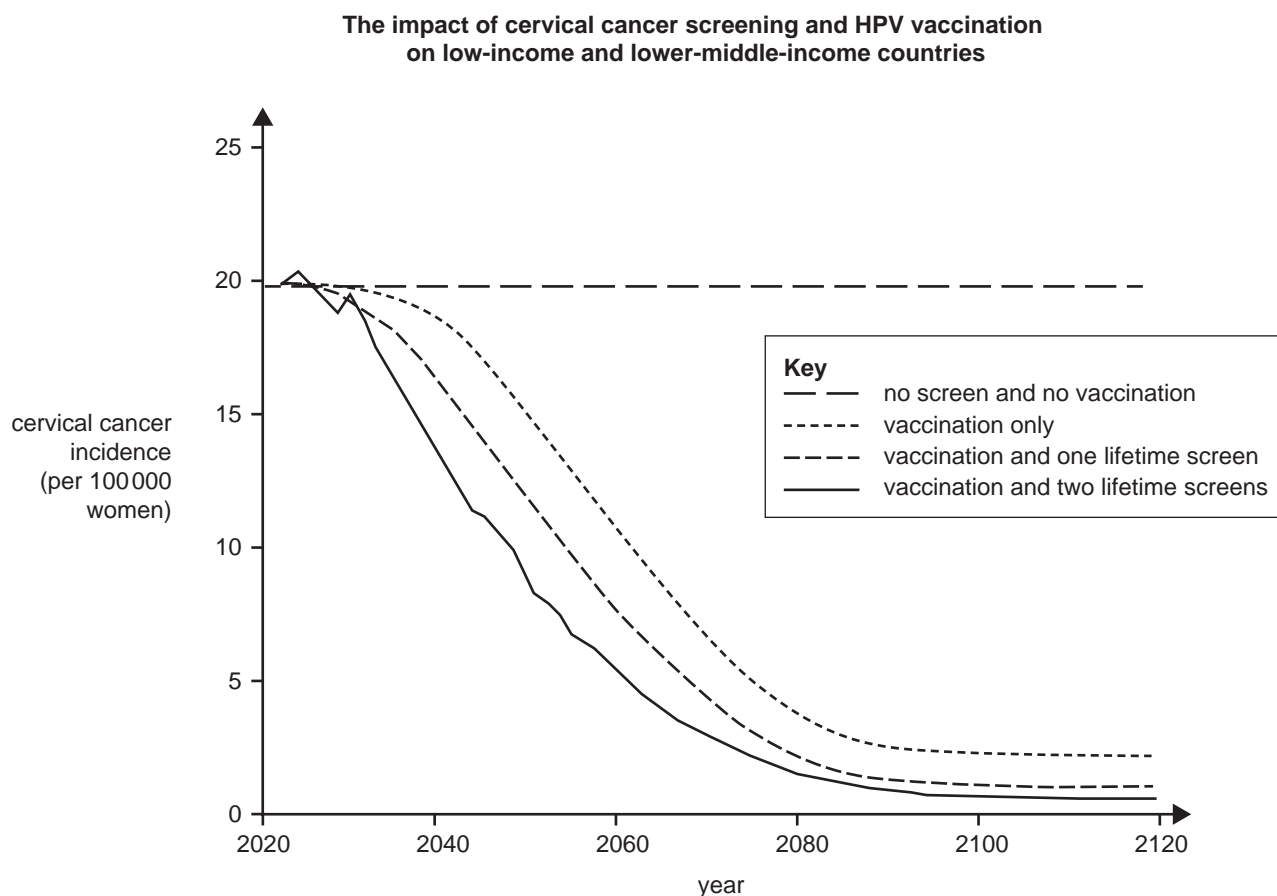
Echidna sample	Mitochondrial DNA sequence
A	... ATAGGCATTGCTCTGGGAAT ...
B	... ATTGGCATGGCTCTCGGATT ...
C	... ATAGGCATTGCTCTGGCAAT ...
D	... ATAGGCATTGCTCTGAGAAT ...

Considering the information provided, which echidna sample is most likely to be from New Guinea?

- A. Echidna sample A
- B. Echidna sample B
- C. Echidna sample C
- D. Echidna sample D

Question 34

The World Health Organization (WHO) runs a campaign to eliminate cervical cancer globally. In response to this campaign, a study was conducted to model the impact of cervical cancer screening along with a human papillomavirus (HPV) vaccination program in low-income and lower-middle-income countries. HPV is the cause of most cervical cancers. The results of the modelling are shown below.



Source: adapted from M Brisson et al, 'Impact of HPV vaccination and cervical screening on cervical cancer elimination: A comparative modelling analysis in 78 low-income and lower-middle-income countries', *The Lancet*, vol. 395, 22 February 2020, <[https://doi.org/10.1016/S0140-6736\(20\)30068-4](https://doi.org/10.1016/S0140-6736(20)30068-4)>

Which one of the following conclusions is supported by the data in the graph?

- A. The incidence of cervical cancer would be unaffected by a cervical cancer screening program.
- B. The largest factor in reducing the incidence of cervical cancer in the long term is vaccination.
- C. With vaccination only, it is possible to achieve fewer than 10 cervical cancer cases per 100 000 women by 2050.
- D. Vaccination and one lifetime screen would be more effective than vaccination and two lifetime screens by 2070.

Question 35

Prior to modern human pregnancy test kits, *Xenopus* frogs were used. Urine samples from women were injected into the legs of female frogs. The frogs were then placed back into water tanks and, the following day, the tanks were checked for eggs. If a female frog had laid eggs, the woman who had provided the urine sample was diagnosed to be pregnant.

Which one of the following factors may result in a false diagnosis of pregnancy?

- A. using male frogs instead of female frogs
- B. maintaining an optimum tank temperature
- C. replacing the water in the tanks with fresh water each day
- D. female frogs laying eggs naturally around the time of the injection

Question 36

A study assessed the effectiveness and safety of a drug called doxycycline. One hundred and fifty adults hospitalised with malaria were involved. These adults were randomly placed into two groups of equal size. One group received doxycycline in addition to standard care. The other group received standard care only.

The group receiving standard care only was the

- A. control group.
- B. variable group.
- C. unsupported group.
- D. experimental group.

Question 37

Viruses can be detected in sewage. Human faecal matter is the main source of pathogenic viruses in sewage. Infected individuals shed viral particles in their faeces.

Which one of the following is an advantage of testing sewage for viral particles in order to control possible virus outbreaks?

- A. Infected individuals can be prevented from shedding the virus.
- B. Infection in a community can be rapidly identified.
- C. Infected individuals can be located quickly.
- D. Sewage can be treated for the virus.

Question 38

Middle East respiratory syndrome (MERS) is caused by a virus that does not encode any neuraminidase proteins.

This means that the antiviral drug Relenza would

- A. reduce the number of MERS viral particles released from infected cells.
- B. be useful to consider as a prevention method against MERS infections.
- C. be unlikely to improve the recovery of MERS-infected patients.
- D. target other cell surface proteins of MERS-infected cells.

Use the following information to answer Questions 39 and 40.

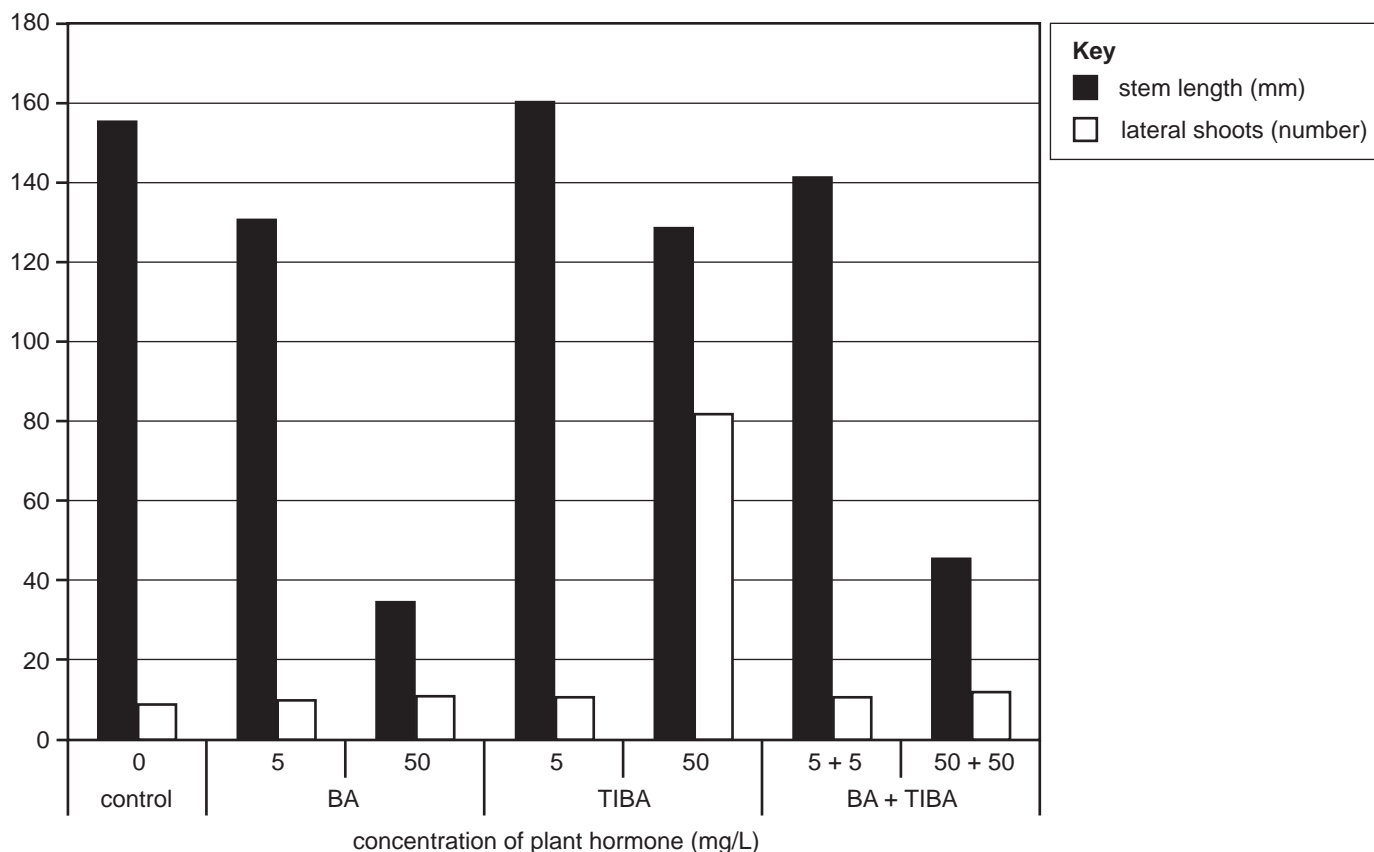
An experiment investigated the effect of two plant hormones, BA and TIBA, on seedlings of the Douglas fir tree, *Pseudotsuga menziesii*.

There were three treatment groups of one-month-old *P. menziesii* seedlings. Each group was sprayed with a buffered detergent solution containing BA or TIBA or BA + TIBA.

The solutions were sprayed onto the seedlings once a week for 12 weeks. The seedlings were kept in the same greenhouse under identical temperature and light conditions during the experiment.

The stem length of each seedling was measured and lateral shoots were counted at the start and end of the 12-week period. The average results for each group are displayed in the graph below.

Effect of BA and TIBA on stem length and number of lateral shoots when applied weekly to leaves of one-month-old *P. menziesii* seedlings for 12 weeks



Source: adapted from LG Nickell (ed.), *Plant Growth Regulating Chemicals*, volume II, 1st reprint edition, CRC Press, 2018, p. 45

Question 39

An appropriate treatment for the control group of seedlings would be

- spraying with buffered detergent solution at the same intervals as the treatment group.
- spraying with distilled water at the same intervals as the treatment group.
- spraying with tap water at the same intervals as the treatment group.
- not spraying at all during the 12-week period.

Question 40

Which one of the following conclusions can be drawn from this data with respect to the growth of *P. menziesii* seedlings?

- A. BA in low concentrations promotes stem elongation but has no significant effect on the number of lateral shoots.
- B. The stems of seedlings exposed to high concentrations of BA grow to one-third of the length of the stems of non-treated seedlings.
- C. TIBA reduces the effect of BA on the number of lateral shoots when both BA + TIBA are applied at high concentrations.
- D. TIBA in high concentrations inhibits stem elongation but increases the number of lateral shoots when compared to the seedlings in the control group.

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SECTION B

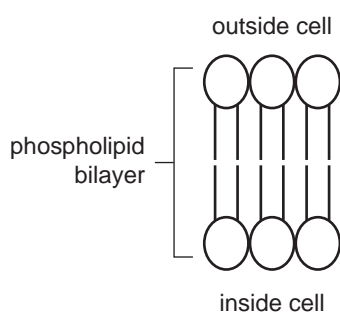
Instructions for Section B

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

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

Question 1 (5 marks)

The diagram below shows a small part of a cross-section of the plasma membrane of a cell.



Some substances can move directly through the phospholipid bilayer.

- a. Complete the table below by naming one small hydrophilic substance and one small hydrophobic substance that can move through the phospholipid bilayer. Provide an example of a situation when each small substance would move through the phospholipid bilayer. The first row has been completed for you.

2 marks

Name of small substance	Hydrophilic or hydrophobic	Example of situation when substance moves through phospholipid bilayer
<i>oxygen</i>	hydrophobic	<i>Oxygen diffuses out of a photosynthetic plant cell.</i>
	hydrophilic	
	hydrophobic	

- b. Some very large substances and/or large particles that do not dissolve in the phospholipid bilayer can still move into or out of a cell.

Using **one** example, explain how the phospholipid bilayer transports these very large substances and/or large particles without the use of channel or carrier proteins **either** into a cell **or** out of a cell.

Select a direction of transport for your response by ticking (✓) the box beside it:

into a cell

out of a cell

3 marks

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SECTION B – continued
TURN OVER

Question 2 (9 marks)

Baker's yeast (*Saccharomyces cerevisiae*) is a unicellular, eukaryotic organism. Biologists have studied its proteome. A single yeast cell contains approximately 6000 different proteins.

- a. Consider the 6000 different proteins. The concentration of each protein may change with a change in environmental conditions.

Give **one** example of a **type** of protein within a yeast cell that may change in concentration and explain why this change is necessary.

3 marks

- b. There are several cellular activities that directly alter the number of proteins within a yeast cell. These include transcription, RNA processing, translation and breakdown of protein.

For each cellular activity listed in the table below, state the immediate end product of the activity.

2 marks

Cellular activity	Immediate end product
transcription	
RNA processing	
translation	
breakdown of protein	

- c. Four *S. cerevisiae* genes and the functions of their gene products are outlined in Table 1 below.

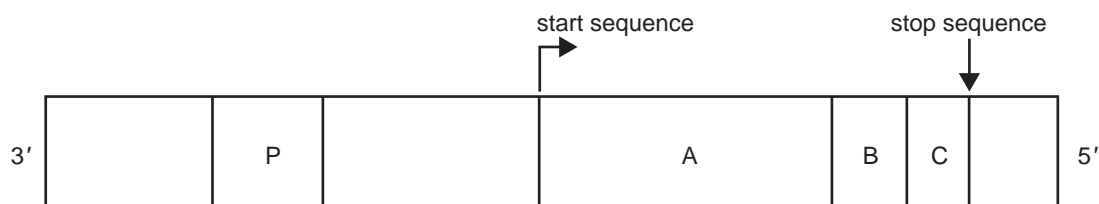
Table 1. *S. cerevisiae* genes and the functions of their gene products

Gene	Function of gene product
HSP82	active on the plasma membrane to pump protons out of cell
ADR1	binds to DNA and acts as a transcriptional factor
GCN4	controls the activity of RNA polymerase
AQY1	a water channel in the plasma membrane

Identify the regulatory genes in Table 1 and justify your response.

2 marks

- d. One particular *S. cerevisiae* protein, PFY1, assists with the organisation of a cell's cytoskeleton. In the diagram below, the gene for the PFY1 protein is shown with a promoter region (labelled P), start and stop transcription sequences, and a single intron (labelled B).



Give the general name of the sections labelled A and C, and outline the function of these sections.

2 marks

Question 3 (6 marks)

Scientists measured the metabolic activity of mammalian cells by measuring the uptake of glucose into the cells. The cells were maintained at 37 °C with a pH of 7.4 and suspended in a nutrient solution containing glucose. The uptake of glucose into the cells was recorded for the next 30 minutes.

- a. Explain why the uptake of glucose into the cells could be used to measure the metabolic activity of the cells. 2 marks

- b. The scientists repeated the experiment. They kept all conditions the same as for the first experiment, except that the cells were kept in low-oxygen conditions.

Would the uptake of glucose into the cells be expected to be higher, lower or the same as for the first experiment? Justify your response. 4 marks

Question 4 (10 marks)

Varicella (chickenpox) is a highly contagious disease caused by the varicella zoster virus. A live, attenuated varicella zoster virus vaccine is recommended for children at age 18 months. In Australia, this vaccine is provided free of charge under the National Immunisation Program.

- a. Once the varicella zoster virus vaccine is injected into the arm of a child, an immune response occurs.

Summarise the immune response that occurs within the child to result in long-term protection from chickenpox.

5 marks

- b. If a person has not been vaccinated and is older than 14 years, it is recommended that this person has two doses of the varicella zoster virus vaccine. The second dose should be given at least four weeks after the first dose.

What is the benefit of having two doses instead of one dose? Justify your response.

2 marks

- c. Outline similarities and/or differences in active and passive ways of acquiring immunity.

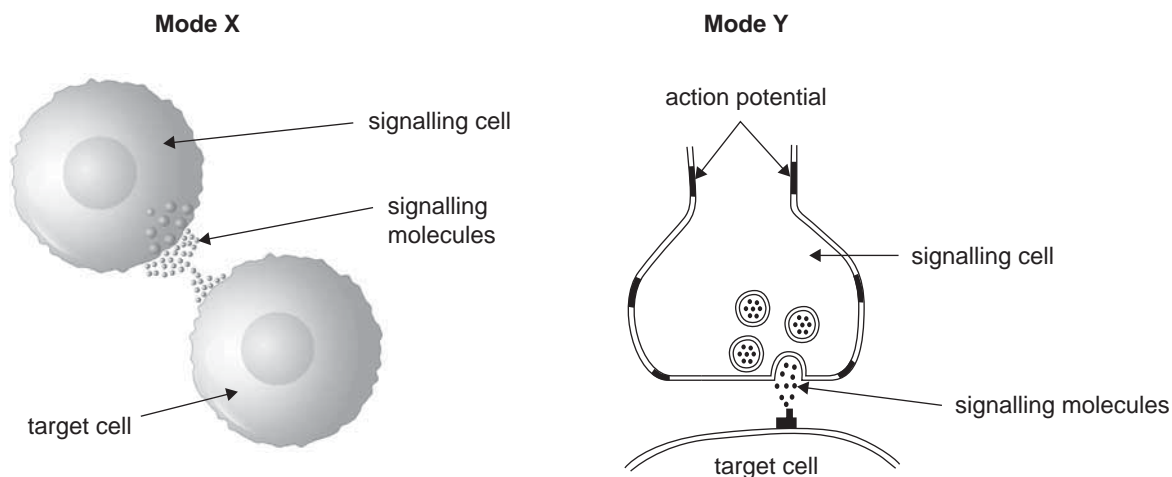
3 marks

Question 5 (6 marks)

a. Outline what is meant by the term ‘cell signalling’.

2 marks

b. The diagrams below show two different modes of cell signalling that occur over short distances.



Sources: adapted from Art of Science/Shutterstock.com (Mode X); adapted from Excellent Dream/Shutterstock.com (Mode Y)

Complete the table below by naming an example of the signalling molecule and target cell for each mode of cell signalling shown above.

2 marks

Mode of cell signalling	Example of signalling molecule	Example of target cell
X		
Y		

DO NOT WRITE IN THIS AREA

- c. Cell signalling has been observed in honey bees (*Apis mellifera*) that live in large colonies in hives (nests). If a hive is disturbed, guard bees secrete a substance that smells like bananas from sting glands in their abdomens. The guard bees stand at the entrance of the hive, and raise their abdomens to expose the glands and release the secretion, while moving their wings like fans.

Name the type of signalling molecule secreted by *A. mellifera* that causes this banana-like smell and give a reason why the guard bees fan their wings.

2 marks

DO NOT WRITE IN THIS AREA

Question 6 (6 marks)

Many species of octopus can be found in the oceans surrounding Australia and New Zealand. Populations of octopus can be found on both the east and west coasts of Australia and on the north coast of New Zealand. The distribution of the populations is shown shaded on the map below.



Source: adapted from MD Amor, MD Norman, HE Cameron and JM Strugnell, '... within a cryptic species complex of Australasian octopuses', *PLOS ONE*, vol. 9, issue 6, e98982, June 2014, <<https://doi.org/10.1371/journal.pone.0098982>>

- a. Scientists investigated whether the octopus populations on Australia’s east coast are a separate species from the populations on the west coast. After analysing both molecular and morphological results, the scientists concluded that all populations share a distant common ancestor. They also concluded that the populations of octopus on the east coast of Australia are a distinct species from the populations of octopus on the west coast of Australia.

Describe the process that may have led to the formation of the two distinct species of octopus from the distant common ancestor.

4 marks

DO NOT WRITE IN THIS AREA

- b. The scientists also compared the populations of east Australian octopus with the populations of the New Zealand octopus. No significant genetic differences between these populations of the New Zealand octopus and east Australian octopus were found. It is known that young octopi can be carried long distances by water currents. Occasionally, adult octopi have been seen on pieces of floating wood.

Give **two** reasons that may account for the lack of genetic diversity between the populations.

2 marks

DO NOT WRITE IN THIS AREA

Question 7 (10 marks)

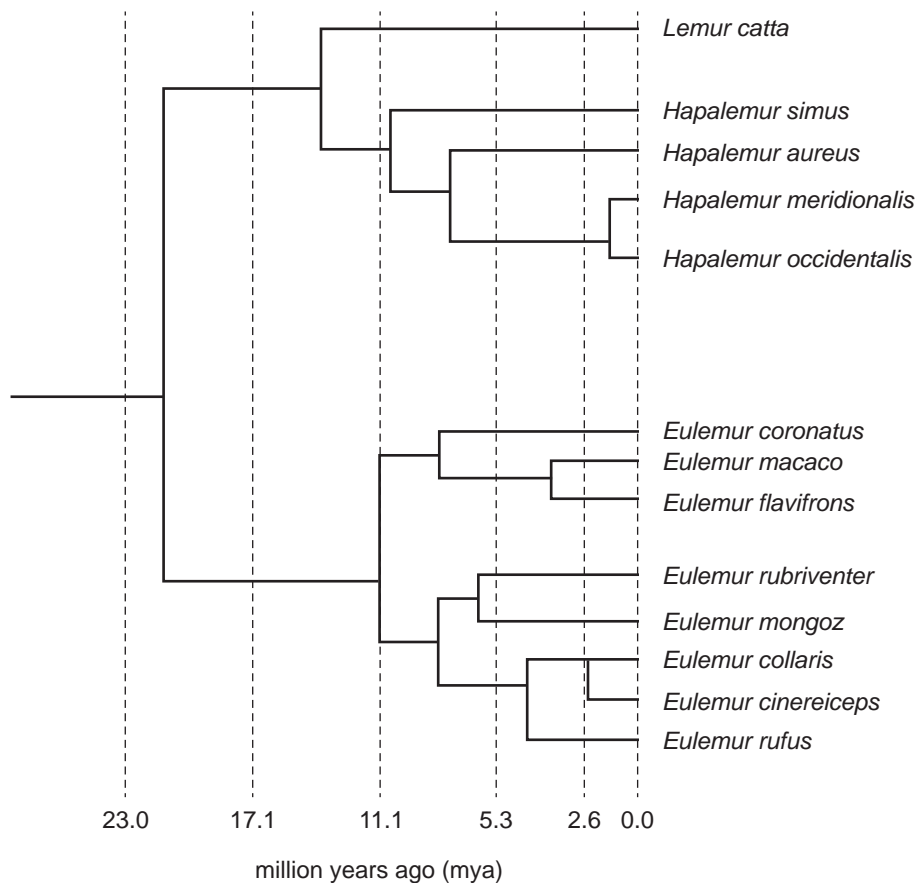
Lemurs belong to the order Primates and are found in the wild only on the African island of Madagascar.

- a. Identify **two** structural features that are common to most primates and that distinguish them from other mammal groups. 2 marks

A team of biologists combined morphological data from extinct and living lemur species, along with genetic data, to produce a phylogenetic tree for lemurs. The biologists used published sequences from mitochondrial DNA (mtDNA) as a molecular clock.

- b. Give **two** advantages of using mtDNA as a molecular clock. 2 marks

A small part of the phylogenetic tree for lemurs, constructed by the biologists, is shown below.



Source: adapted from JP Herrera and LM Dávalos, 'Phylogeny and divergence times of lemurs inferred with recent and ancient fossils in the tree', *Systematic Biologists*, 65(5), 2016, p. 781

- c. Describe the phylogenetic relationships between *Lemur catta*, *Eulemur coronatus* and *Eulemur flavifrons*, as shown in the phylogenetic tree on page 30.

2 marks

- d. Biologists isolated DNA from different species of present-day lemurs and performed DNA hybridisation.

Outline the main steps in the process of DNA hybridisation and explain how DNA hybridisation supports the relationships shown in the phylogenetic tree on page 30.

4 marks

DO NOT WRITE IN THIS AREA

Question 8 (6 marks)

Ancient cave drawings contribute evidence of cognitive changes that are unique to modern humans, *Homo sapiens*. Biologists argue that these unique cognitive changes in *H. sapiens* allowed cultural evolution that would have been impossible in other hominin species.

- a. Describe how ancient cave drawings contribute evidence of cultural evolution in *H. sapiens*. 2 marks

Cave drawings depicting animals have been found on stalagmites in the Ardales Cave in south-west Europe. A stalagmite is a rock formation that grows upwards from a cave floor, as shown in the image below. Over a long period of time, water, containing minerals, dripped from the cave roof, solidified and formed a transparent layer on top of the drawings on the stalagmites.



stalagmite

Source: lapas77/Shutterstock.com

- b. A team of scientists dated the mineral deposits in the solid, transparent layer using uranium–thorium dating. They found that some of the mineral deposits are 65 000 years old.

What conclusion can be made about the age of the ancient drawings on the stalagmites? Justify your response. 2 marks

- c. The table below shows the arrival dates of some hominin species to the European continent as well as their extinction dates. The dates are the best estimates based on fossil evidence from multiple sites and genetic data.

Hominin species	First appearance in Europe (years before present)	Time of extinction (years before present)
<i>Homo sapiens</i>	45 000	not extinct
<i>Homo neanderthalensis</i>	130 000	30 000
<i>Homo heidelbergensis</i>	800 000–600 000	400 000–200 000
<i>Homo erectus</i>	1 200 000–600 000	143 000

How does the discovery of the drawings in the Ardales Cave challenge the view that the art of cave drawing first arose in *H. sapiens*? In your response, refer to the evidence provided in the table above and the information on page 32.

2 marks

Question 9 (6 marks)

The following table provides information on three commonly grown genetically modified (GM) crops in Australia.

Crop	Genetic modification	Characteristic given by modification
GM cotton	several bacterial genes inserted	insect resistance and herbicide tolerance
GM canola	two genes from two different bacterial species inserted	tolerance to several herbicides
GM safflower	a selection of genes silenced within the safflower genome	elevated levels of oleic acid in its seeds

- a. Select **one** of the GM crops in the table above and justify whether or not this crop could be described as transgenic.

1 mark

Crop selected _____

- b. One issue with GM canola is the accidental release, during transport, of seeds along roadsides. Usually, unwanted plants that grow on the side of the road are killed using the herbicide glyphosate. However, GM canola is resistant to glyphosate.

Suggest **one** practical solution for treating GM canola that is found growing along roadsides.

1 mark

- c. A new GM canola crop has been approved for use in Australia. It contains increased levels of omega-3 fatty acids, which are important, in humans, for building healthy cell membranes and for general growth and development, and also protect against a wide variety of diseases.

Omega-3 has traditionally been sourced from fish. Due to the growing demand for sources of omega-3, bioengineers have been encouraged to continue developing GM canola crops as a sustainable alternative.

Discuss one social implication and one biological implication of using GM canola with increased levels of omega-3. Use a different implication in each response.

4 marks

Social implication _____

Biological implication _____

DO NOT WRITE IN THIS AREA

Question 10 (7 marks)**The path to human insulin**

In the 1970s, recombinant deoxyribonucleic acid methods for cloning and expressing genes in the bacteria *Escherichia coli* were under intense development. An important question that arose at the time was: Can humans design and chemically synthesise genes that function in bacteria? This question was answered in the late 1970s with the successful expression of human insulin using *E. coli*. For the first time, this provided a practical source of recombinant human insulin for the treatment of diabetes. Prior to this, insulin was isolated from either cows or pigs.

When recombinant human insulin was first developed, researchers had knowledge of the amino acid sequence and the structure of insulin. Researchers investigated cloning the human insulin gene using plasmids found in *E. coli*. They knew of the presence of an EcoRI recognition site (GAATTC) within these plasmids.

When research began, the safety of recombinant plasmids was being actively discussed. Safety regulations were put in place to identify, evaluate, minimise and manage the risks involved. Researchers tested the first recombinant human insulin in cell cultures in the laboratory and in live animals. This was followed by clinical trials where information was gained about the effectiveness and side effects of using this insulin to treat diabetes.

The first recombinant human insulin that was produced and tested established that the use of recombinant plasmids was successful. Facilities were built for recombinant plasmid research and the commercial production of recombinant human insulin. One of insulin's first researchers, Arthur Riggs, stated, 'It is interesting to think about how much progress has been made since [the 1970s]. For example, in 2020, the genes for insulin can be made in a few hours by automated instruments, then cloned and expressed by a single person in about a week'.

Reference: AD Riggs, 'Making, cloning, and the expression of human insulin genes in bacteria: The path to humulin', *Endocrine Reviews*, vol. 42, issue 3, June 2021, pp. 374–380, <<https://doi.org/10.1210/edrev/bnaa029>>; licensed CC-BY-NC-ND 4.0 <<https://creativecommons.org/licenses/by-nc-nd/4.0/>>

- a. What is meant by recombinant deoxyribonucleic acid in the context of this article? 1 mark

- b. The article states that the researchers knew the structure of insulin and the amino acid sequence before they created the recombinant human insulin in the laboratory.

How would the researchers have used this information to genetically engineer a human insulin gene and how might this engineered insulin gene have differed from a natural insulin gene isolated from human DNA? 2 marks

- c. Outline the steps that are required for the human insulin gene to be cloned and expressed in bacteria in 2020.

3 marks

- d. What ethical response would have been expected from the researchers in the 1970s if, during their clinical trials, they discovered that the recombinant human insulin was significantly more effective than using insulin from either cows or pigs?

1 mark

DO NOT WRITE IN THIS AREA

Question 11 (9 marks)

Two students designed an experiment to investigate antibiotic resistance in *Escherichia coli* bacteria. They began with an *E. coli* culture. The following procedure was conducted in a filtered air chamber using aseptic techniques:

- On Day 0, spread 1 mL of *E. coli* culture onto a nutrient agar plate containing 0 $\mu\text{g}/\text{mL}$ (micrograms per millilitre) of the antibiotic ampicillin. Spread 1 mL of the *E. coli* culture onto a separate nutrient agar plate containing 1 $\mu\text{g}/\text{mL}$ of ampicillin. Cover each plate with an airtight lid.
- On Day 1, transfer a sample of bacteria from one of the Day 0 plates to one of the Day 1 plates containing 2 $\mu\text{g}/\text{mL}$ of ampicillin. Transfer a sample of bacteria from the other Day 0 plate to the other Day 1 plate, which also contains 2 $\mu\text{g}/\text{mL}$ of ampicillin. Cover as before.
- On Day 2, transfer a sample of bacteria from one of the Day 1 plates to one of the Day 2 plates containing 4 $\mu\text{g}/\text{mL}$ of ampicillin. Transfer a sample of bacteria from the other Day 1 plate to the other Day 2 plate, which also contains 4 $\mu\text{g}/\text{mL}$ of ampicillin. Cover as before.
- On Day 3, transfer a sample of bacteria from one of the Day 2 plates to one of the Day 3 plates containing 6 $\mu\text{g}/\text{mL}$ of ampicillin. Transfer a sample of bacteria from the other Day 2 plate to the other Day 3 plate, which also contains 6 $\mu\text{g}/\text{mL}$ of ampicillin. Cover and seal the plates.

All plates were incubated at 37 °C for each 24-hour period. Used plates were refrigerated until the end of the experiment. They were then photographed to compare the amount of bacterial growth and disposed of safely.

The students drew a diagram (Figure 1) to help explain the experimental design and to show their predicted results in each condition at the end of each day.

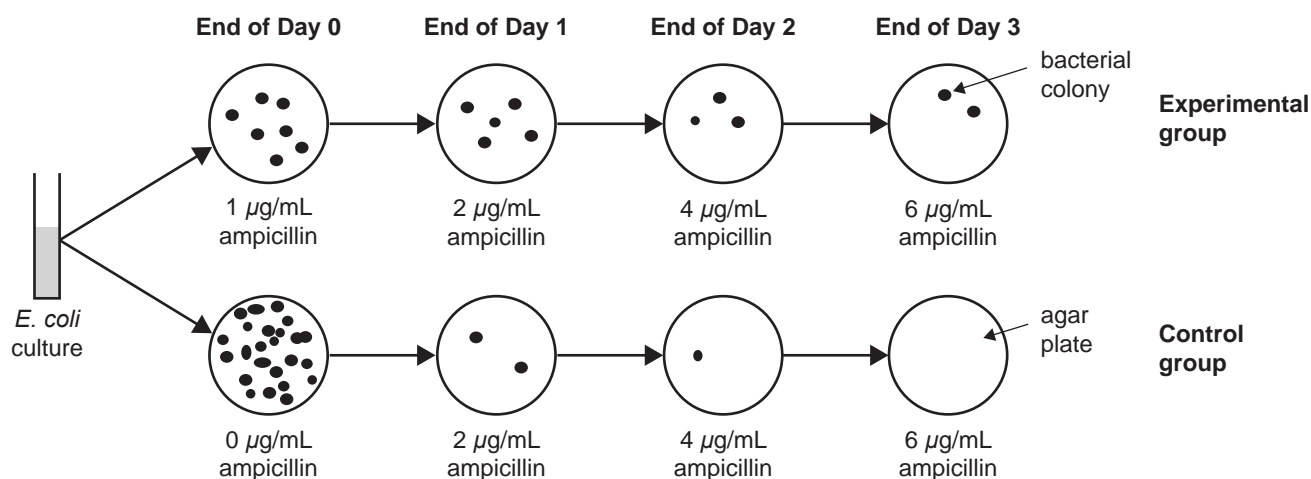


Figure 1

- a.** Identify any **two** controlled variables for this experiment.

2 marks

- b.** Write a suitable hypothesis for this experiment.

2 marks

The refrigerated plates kept from Days 0, 1, 2 and 3 of the experiment were photographed. The diagrams in Figure 2 represent the bacterial growth seen in the photographs.

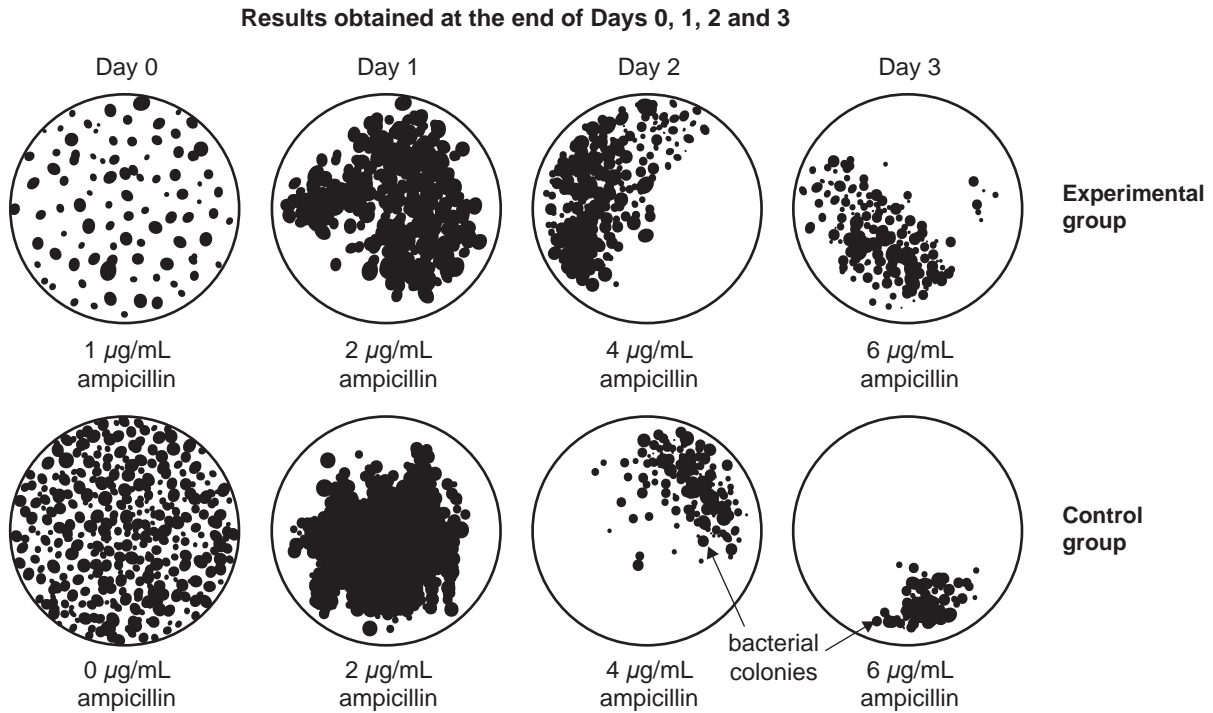


Figure 2

- c. i. Analyse the results of the experiment shown in Figure 2.

3 marks

- ii. Explain whether the results of the students' experiment shown in Figure 2 support the predicted results shown in Figure 1.

2 marks
