

Victorian Certificate of Education
2018

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

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BIOLOGY
Written examination

Wednesday 30 May 2018

Reading time: 10.00 am to 10.15 am (15 minutes)

Writing time: 10.15 am to 12.45 pm (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	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.

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.

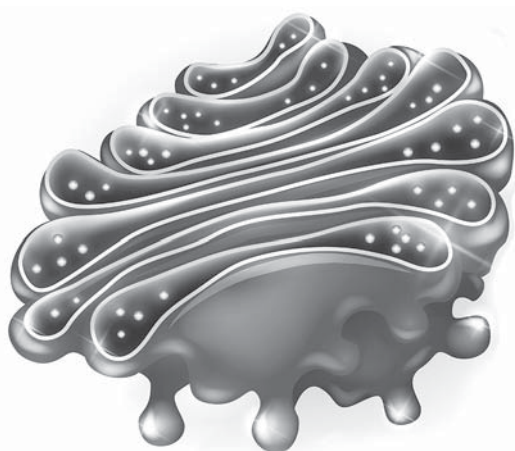
Marks will **not** be deducted for incorrect answers.

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 shows the structure of an organelle in a cell.



Source: Tefi/Shutterstock.com

The organelle would

- A. synthesise most of the ATP molecules required by a cell.
- B. modify and package proteins into secretory vesicles.
- C. transport proteins throughout the cytosol of a cell.
- D. assemble amino acids into proteins.

Question 2

Molecules can move across a plasma membrane in various ways.

Which of the following molecules are most likely to cross a plasma membrane by passing between the phospholipid molecules within the membrane?

- A. carbon dioxide molecules
- B. molecules of an enzyme
- C. hydrophilic molecules
- D. molecules of mRNA

Question 3

Consider the production of ATP molecules in a eukaryotic cell.

The majority of ATP molecules are produced

- A. during glycolysis.
- B. in the Krebs cycle.
- C. during anaerobic respiration.
- D. by the electron transport chain.

Question 4

The enzymes that are required for the Krebs cycle in cellular respiration are found

- A. in the cytosol of the cell.
- B. in the mitochondrial matrix.
- C. on the plasma membrane of the cell.
- D. on the outer membrane of the mitochondria.

Question 5

NADH is a coenzyme.

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

- A. NADH is a carrier of electrons and protons between reactions in a cell.
- B. NADH is not produced in the glycolysis stage of aerobic respiration.
- C. NADH is the immediate source of energy for cellular activity.
- D. NADH is required in aerobic respiration but not in anaerobic respiration.

Question 6

Transcription of a structural gene can be initiated by the

- A. presence of DNA polymerase.
- B. arrival of mRNA at a ribosome.
- C. increase in concentration of amino acids in the cytosol of a cell.
- D. absence of a protein that is usually attached to an operator for that structural gene.

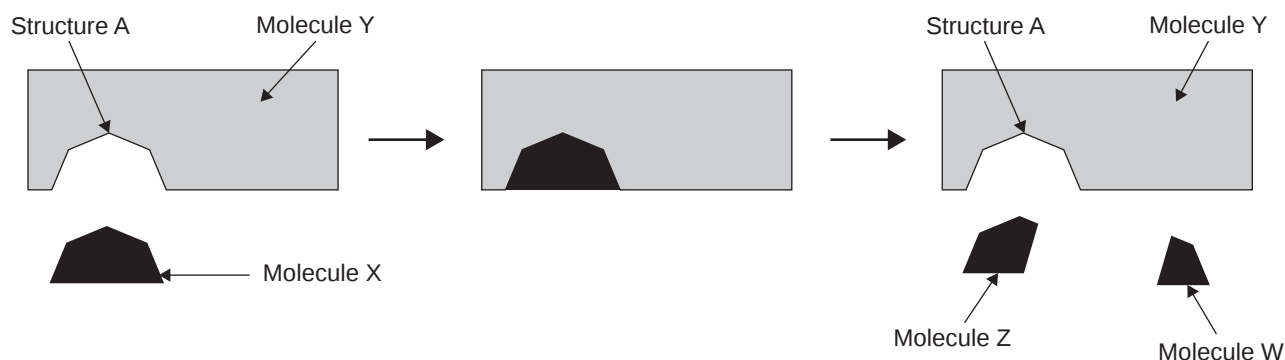
Question 7

When a bacterial pathogen penetrates the physical barrier of skin, an immediate immune response is the

- A. stimulation of the adaptive immune system.
- B. migration of phagocytic cells to the entry site.
- C. differentiation of T cells into T cytotoxic cells in the bloodstream.
- D. activation of complement proteins to engulf the bacterial pathogen.

Use the following information to answer Questions 8 and 9.

The diagram below represents a generalised biochemical process.



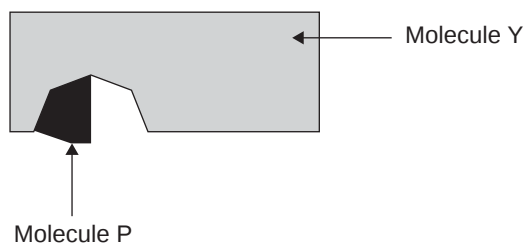
Question 8

Which one of the following statements is correct?

- A. Molecule Y represents the substrate.
- B. Molecule X represents an enzyme.
- C. Structure A is an active site.
- D. Molecule Z is a reactant.

Question 9

Another molecule, Molecule P, can bind to part of Structure A of Molecule Y, as shown below.



Consider a mixture containing molecules of X, molecules of Y and molecules of P. The rate of production of Molecule Z and Molecule W is measured and found to change in the presence of Molecule P. In the presence of Molecule P, increasing the concentration of Molecule X increases the rate of production of Molecule Z and Molecule W.

Which one of the following statements is correct?

- A. Molecule X changes shape in the presence of Molecule P.
- B. Molecule P is considered a reversible inhibitor.
- C. Molecule Y is denatured by Molecule P.
- D. Molecule P is made from monomers of nucleotides.

Use the following information to answer Questions 10–14.

Tetanus is caused by the bacterium *Clostridium tetani*. When a person is infected with *C. tetani*, the bacterial cells secrete a highly poisonous toxin called tetanospasmin. The toxin affects the central nervous system, preventing neurotransmitter release and causing muscle paralysis.

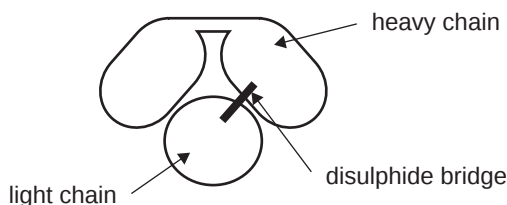
Question 10

A neurotransmitter

- A. stimulates or inhibits a target cell after diffusing across the synaptic gap.
- B. can be released into the external environment of an organism.
- C. binds to receptors found inside the target cell.
- D. is secreted by an endocrine cell.

Question 11

The toxin tetanospasmin is lethal even in extremely small amounts. A simplified representation of the structure of the toxin is shown below.



Source: Dr AK Rana

A new preparation of the tetanus vaccine uses just the heavy chain segment of tetanospasmin.

From the information given above, it is correct to conclude that

- A. an injection of only the light chain segment still results in the disease tetanus.
- B. the quaternary structure of the original tetanospasmin is still intact in the vaccine.
- C. after vaccination, specific antibodies will agglutinate the heavy chain segment of tetanospasmin.
- D. during manufacture of the vaccine, the primary structure of tetanospasmin is altered so that the toxin is unable to cause the disease tetanus.

Question 12

Being injected with the tetanus vaccine results in

- A. artificially acquired passive immunity.
- B. naturally acquired passive immunity.
- C. artificially acquired active immunity.
- D. naturally acquired active immunity.

Question 13

The tetanus vaccination schedule for children includes five doses of the vaccine spread over several years of a child's life. The graph below shows the antibody levels of a child if the vaccination is given and if it is not given at that time.

Due to copyright restrictions,
this material is not supplied.

Source: adapted from MH Roper, JH Vandelaer and FL Gasse, 'Maternal and neonatal tetanus',
The Lancet, vol. 370, December 2007, p. 1951

Using the information from the graph above, it is reasonable to conclude that a child would

- A. have a higher antibody count at 16 years of age than at nine years of age when fully immunised.
- B. no longer be immune at six years of age if the child is not given the fourth vaccination.
- C. have a tetanus antibody count of 1 arbitrary unit (AU) at three years of age.
- D. have inherited tetanus antibodies from its mother while in the womb.

Question 14

The most likely reason for the tetanus vaccination schedule requiring so many vaccine injections is that

- A. memory B lymphocytes need to be activated to maintain high levels of tetanus antibodies.
- B. antibodies injected during each vaccination are unable to remain in the bloodstream for more than two months.
- C. the vaccine acts like a self-antigen in the immune system and is destroyed before it can trigger a large immune response.
- D. lymphocytes in the human immune system are unable to differentiate into the specific plasma B lymphocytes and memory B lymphocytes for the tetanospasmin toxin.

Use the following information to answer Questions 15 and 16.

Chemicals control the development of eggs in female goldfish and, often, these chemicals leak out of their gills and into the water. It is hypothesised that ancestral male goldfish were unable to detect the chemical in the water but that goldfish evolution has resulted in present-day male goldfish being able to detect the female goldfish chemical.

Due to copyright restrictions,
this material is not supplied.

Source: adapted from T Wyatt, 'How animals communicate via ...',
American Scientist, March–April 2015, vol. 103, no. 2

Question 15

Based on this information, in present-day goldfish the chemical released into the water is acting as a

- A. protein hormone.
- B. neurohormone.
- C. lipid hormone.
- D. pheromone.

Question 16

Which one of the following would most likely explain present-day male goldfish being able to detect the female goldfish chemical?

- A. convergent evolution
- B. natural selection
- C. genetic drift
- D. speciation

Question 17

Cells of the bacterium *Pseudomonas fluorescens* each have a flagellum that enables them to move. Scientists removed a master gene in *P. fluorescens* that controls the expression of genes responsible for the formation of the flagellum. Removal of the master gene produced a strain of the bacterium that did not grow flagella and was unable to move. These bacteria were placed in the centre of a dish with a supply of food. Initially only the food immediately next to the bacteria was consumed. After four days, the scientists noticed that the food further from the bacteria had been consumed and that almost all bacteria in the dish had flagella.

Which one of the following best explains these observations?

- A. Natural selection caused the bacteria to mutate and grow flagella.
- B. Due to the lack of food, the bacteria had to adapt by growing flagella.
- C. Mutations in a gene enabled it to function as the master gene for flagella growth.
- D. Each of the genes involved in producing the flagella mutated so that they were expressed without the master gene.

Question 18

Unlike many domesticated animal species, sheep have a diverse gene pool. The Merino breed of sheep is particularly diverse.

This means that the Merino breed of sheep

- A. has been through a genetic bottleneck.
- B. will be very susceptible to infectious disease.
- C. will show a high frequency of genetic disorders.
- D. has a good chance of surviving environmental change.

Question 19

Scientists conducted an experiment to test a hypothesis about the evolution of multicellular organisms. In the experiment, the scientists took a single-celled organism – yeast – that included a ‘multicellular’ form in which eight or more single cells clumped together. The scientists mixed the single-celled form and the ‘multicellular’ form in a container with a predator. They then observed the change in the proportion of single-celled and ‘multicellular’ yeast. They noted an increase in the proportion of ‘multicellular’ yeast.

Which one of the following hypotheses is being tested in this experiment?

- A. Predators cause multicellularity to occur.
- B. Natural selection favours multicellular predators.
- C. Predators that eat multicellular organisms are at a selective advantage.
- D. Predators act as a selective pressure in the evolution of multicellular organisms.

Question 20

With respect to the classification of ancestors and relatives of modern humans, it is true to say that

- A. all primates are bipedal.
- B. the genus *Homo* includes all hominoids and hominins.
- C. hominoids include gorillas, chimpanzees and *Homo sapiens*.
- D. hominins include gibbons, *Homo erectus* and *Australopithecus afarensis*.

Question 21

Scientists have been studying the genomes of groups of present-day *Homo sapiens*. Most of the DNA in these present-day groups is the same as the DNA found in *Homo heidelbergensis*, suggesting that *H. heidelbergensis* is the direct ancestor of *Homo sapiens*. The scientists found that there were traces of DNA in these present-day groups from three *Homo* species, indicating earlier crossbreeding.

The table below provides information about eight species of *Homo*.

Species	When this species lived	Where this species lived
<i>Homo rudolfensis</i>	2.1–1.8 million years ago	eastern Africa
<i>Homo habilis</i>	1.9–1.4 million years ago	eastern and southern Africa
<i>Homo erectus</i>	1.9 million – 100 000 years ago	Africa and Asia
<i>Homo antecessor</i>	approximately 1.2 million years ago	Spain
<i>Homo heidelbergensis</i>	700 000–200 000 years ago	Africa, Europe and possibly Asia
<i>Homo neanderthalensis</i>	500 000–40 000 years ago	western Eurasia (as far east as Siberia)
<i>Homo denisova</i>	100 000 years ago	Siberia
<i>Homo sapiens</i>	approximately 180 000 years ago to present	worldwide

Data: D Lewis, 'Where did we come from?
A primer on early human evolution', *Cosmos*, issue 75, winter 2017

Two of the species that crossbred were identified as *Homo neanderthalensis* and *Homo denisova*. Which species of *Homo* shown in the table above could have been the third species to crossbreed?

- A. *H. rudolfensis*
- B. *H. antecessor*
- C. *H. erectus*
- D. *H. habilis*

Question 22

Russian scientists have been running a long-term experiment since the 1950s to simulate the domestication of dogs by ancient humans. The scientists started with a group of wild silver foxes and, over time, bred foxes with traits typical of domesticated dogs.

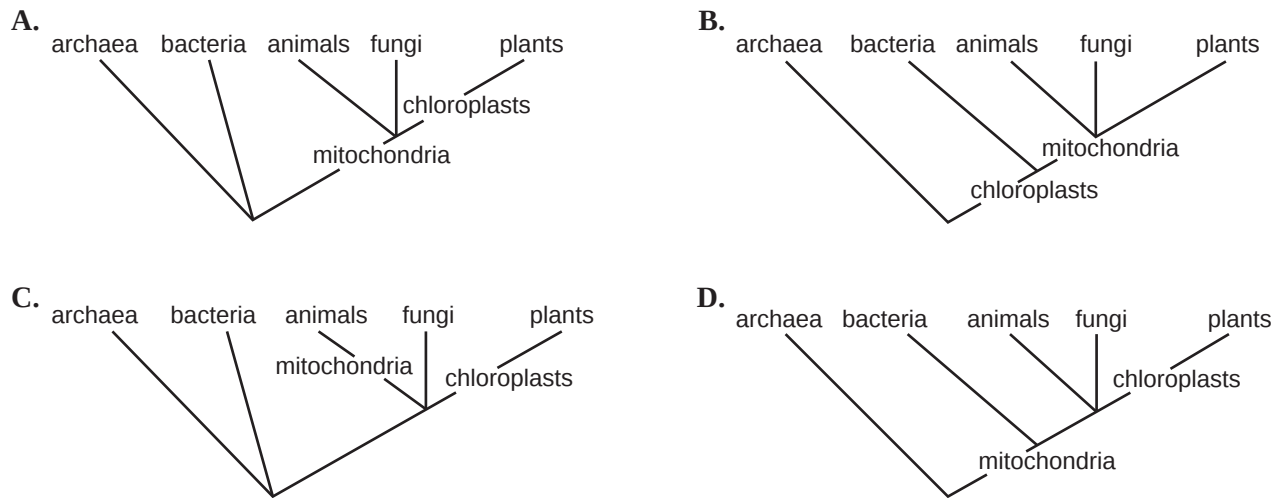
During the experiment, the scientists would have

- A. observed that the appearance of the foxes bred in the experiment remained unchanged from the wild population.
- B. noted that the genetic make-up of the foxes bred in the experiment was becoming more diverse.
- C. selected quieter, friendly foxes for breeding.
- D. kept the foxes isolated from humans.

Question 23

Consider the theory of the evolution of mitochondria and chloroplasts.

Which one of the following diagrams correctly represents this theory?

**Question 24**

Which one of the following characteristics of *Homo sapiens* has enabled cultural evolution?

- A. bipedal locomotion
- B. binocular vision
- C. a grasping hand
- D. a large brain

Question 25

Scientists analysed DNA markers from four seal species. They compared these DNA markers to DNA extracted from the remains of a common ancestor using gel electrophoresis.

Electrophoresis gel of seal species

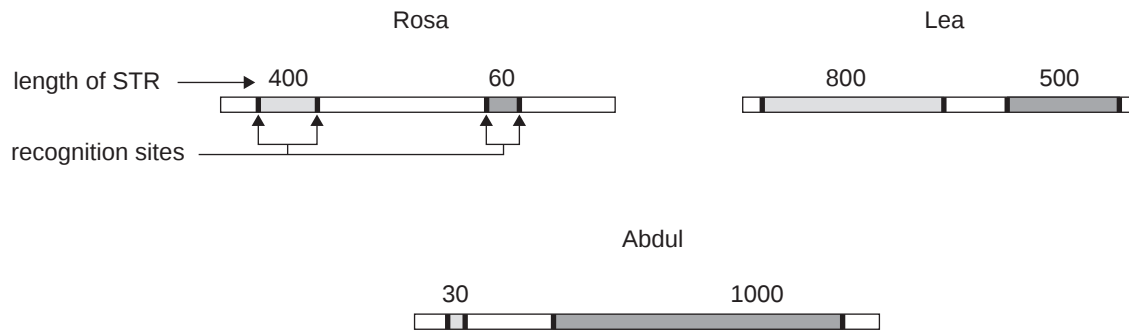
Seal species				
1 (common ancestor)	2	3	4	5
■■■■		■■■■		■■■■
■■■■		■■■■		■■■■
■■■■	■■■■	■■■■	■■■■	■■■■
■■■■	■■■■		■■■■	■■■■
	■■■■	■■■■	■■■■	■■■■
■■■■		■■■■	■■■■	■■■■
■■■■		■■■■	■■■■	■■■■

Which seal species is most closely related to the common ancestor (Seal species 1)?

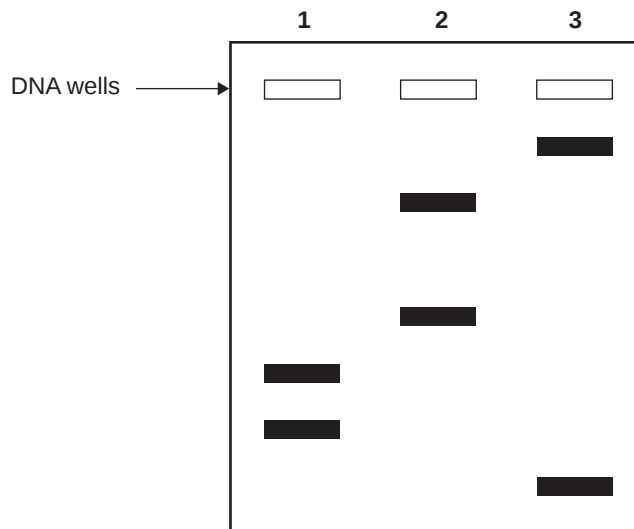
- A. Seal species 2
- B. Seal species 3
- C. Seal species 4
- D. Seal species 5

Question 26

Scientists analysed the DNA samples of three students, Rosa, Lea and Abdul. Short tandem repeats (STRs) that are unique to each individual were investigated. Each student's DNA was digested using a restriction enzyme. The length of each STR for each student is shown in the diagram below.



The DNA of each student was separated using gel electrophoresis and the positions of the STRs were observed. STRs were marked with a florescent probe and were the only visible bands in the gel. The results are shown in the diagram of the electrophoresis gel below.



From the results and the information provided for each student, it can be concluded that the DNA in wells 1, 2 and 3 respectively belong to

- A. Abdul, Lea and Rosa.
- B. Lea, Rosa and Abdul.
- C. Rosa, Abdul and Lea.
- D. Rosa, Lea and Abdul.

Question 27

Doctors tested a new medication, Medi-X, that controls blood pressure in pregnant women.

A hundred pregnant women aged between 25 and 35 years were divided into two groups of 50 patients:

- Group A received a pill containing Medi-X.
- Group B received a pill containing sugar.

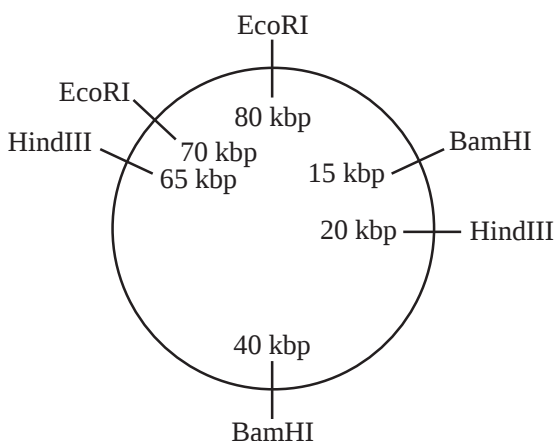
Each patient was given one pill per day. All pills were blue and of equal mass.

The independent variable in this experiment was

- the composition of the given pill.
- the pregnant women aged 25–35 years.
- the blood pressures of the pregnant women.
- being given a pill of the same mass each day.

Question 28

Consider the following plasmid that has a total length of 80 kbp. The recognition sites for three restriction enzymes are shown.



The plasmid above was treated with both restriction enzymes EcoRI and BamHI.

How many fragments of DNA would be produced and what would be the respective lengths of these fragments?

	Number of fragments	Lengths (kbp)
A.	4	5, 15, 25, 40
B.	4	10, 15, 25, 30
C.	6	15, 20, 40, 65, 70, 80
D.	6	5, 10, 15, 20, 25, 30

Question 29

The Zika virus is spread by the bite of the *Aedes aegypti* female mosquito. *A. aegypti* males do not bite and so cannot spread the virus.

Scientists have been studying ways of preventing the spread of the Zika virus by controlling reproduction in *A. aegypti*. Approval has been given to release genetically modified (GM) *A. aegypti* males. These GM males each carry a gene that makes their offspring die before reproductive age. The scientists expect the GM males will mate with wild females that carry the Zika virus.

The scientists' reasoning in this strategy for reducing the spread of the Zika virus is that

- A. wild male mosquitoes will be more successful at mating with females than the GM male mosquitoes.
- B. humans bitten by one of the GM male mosquitoes will be protected from the Zika virus.
- C. there will be a decrease in the number of *A. aegypti* mosquitoes.
- D. the gene will be transferred to wild adult female mosquitoes.

Question 30

An experiment was conducted to measure the effect of a hormone on oxygen consumption in liver cells at different temperatures. Two liver cell samples were prepared in the following way:

- Sample A – 10 g of liver cells in a nutrient solution
- Sample B – 10 g of liver cells in a hormone and nutrient solution

The results of the experiment are shown in the table below.

Temperature (°C)	Consumption of oxygen (mL/hour)	
	Sample A	Sample B
10	4.1	8.0
20	7.8	15.5
30	10.1	21.0
40	6.7	13.4
50	1.5	3.1

Which one of the following hypotheses is supported by these results?

- A. As the temperature increases from 10 °C to 30 °C, the effect of the hormone on the oxygen consumption of the liver cells decreases.
- B. Enzymes in the liver cells that assist the hormone to work are denatured at lower temperatures.
- C. An increase in temperature from 30 °C to 50 °C will result in an increase in oxygen consumption in both samples.
- D. The liver cells in the hormone and nutrient solution consume approximately double the amount of oxygen that is consumed by the liver cells in the nutrient solution.

Question 31

All genetically modified organisms

- A. possess at least one gene obtained from another species.
- B. have at least one section of their DNA that has been altered by scientists.
- C. produce at least one protein that is not naturally produced in that species.
- D. have at least one gene that is removed or prevented from being transcribed.

Question 32

Amoxicillin is used against a number of infections in humans. Amoxicillin prevents the synthesis of the cell walls of bacteria.

From this information, it is correct to state that amoxicillin is

- A. a DNA polymerase.
- B. an antiviral drug.
- C. an antibiotic.
- D. a vaccine.

Use the following information to answer Questions 33–35.

In the United States of America (USA) genetic screening of newborn babies is conducted for around 60 conditions. In the United Kingdom (UK), nine conditions are screened for and in the state of Victoria in Australia, 25 conditions are screened for. The table below provides data on the most frequent genetic conditions identified from screening newborn babies in the USA, the UK and Victoria, Australia.

Genetic condition	Incidence (no. of babies born with condition : total no. of babies born)		
	USA	UK	Victoria, Australia
phenylketonuria (PKU)	1 : 10 000–15 000	1 : 10 000	1 : 12 000
galactosaemia	1 : 30 000–60 000	not screened	not screened
primary congenital hypothyroidism (CH)	1 : 2000–4000	1 : 3000	1 : 2200
sickle-cell disease (SCD)	1 : 500 African Americans	1 : 2000	not screened
congenital adrenal hyperplasia (CAH)	1 : 15 000	not screened	not screened
cystic fibrosis (CFTR)	1 : 2500–3500 Caucasians	1 : 2500	1 : 3300

Data: Genetics Home Reference, <<https://ghr.nlm.nih.gov>>; National Health Service, <www.nhs.uk/pages/home.aspx>; Victorian Clinical Genetics Services, <www.vcgs.org.au>

Question 33

From this information it can be concluded that

- A. CAH is not present in Australian newborn babies.
- B. the frequency of PKU and CFTR has risen in all countries of the world.
- C. the most frequent genetic condition that affects Victorian newborn babies is CH.
- D. cystic fibrosis in newborn babies is more prevalent in Victoria than in the UK.

Question 34

The main purpose of screening programs for newborn babies is to

- A. construct an individual DNA profile for each baby.
- B. enable early treatment of conditions to improve the health of many babies.
- C. allow parents to make informed choices on whether to continue with a pregnancy.
- D. supply blood and DNA for research into genetic conditions and possible treatments.

Question 35

SCD is caused by a mutation in the HbS gene that codes for the beta-globin sub-unit of haemoglobin. A person with two copies of the mutated form of the HbS gene makes a rigid type of haemoglobin, causing abnormally shaped red blood cells. SCD is most frequent in West Africa, where 25% of people carry the mutated HbS gene.

SCD is screened for in the USA and in the UK, but not in Victoria.

A factor that would influence the decision by the Victorian state government health department to not carry out screening for SCD is that

- A. there is a low incidence of SCD in the Victorian population.
- B. the genetic screening test for SCD in newborn babies is too unreliable to use in Australia.
- C. the heel prick test to obtain blood for screening is difficult to conduct on newborn babies.
- D. Victoria's warm air temperatures denature the rigid form of HbS haemoglobin.

Question 36

The effect of different concentrations of sucrose solution on the average height of groups of bean plants was tested. Six groups containing 40 plants were left to grow for 20 days. Each plant had an initial height of approximately 2 cm. Each group was watered daily. The concentration of sucrose solution for each group is shown in the table below. The heights of the plants were measured and averaged for each group. The results are summarised below.

Effect of sucrose solution on the height of bean plants

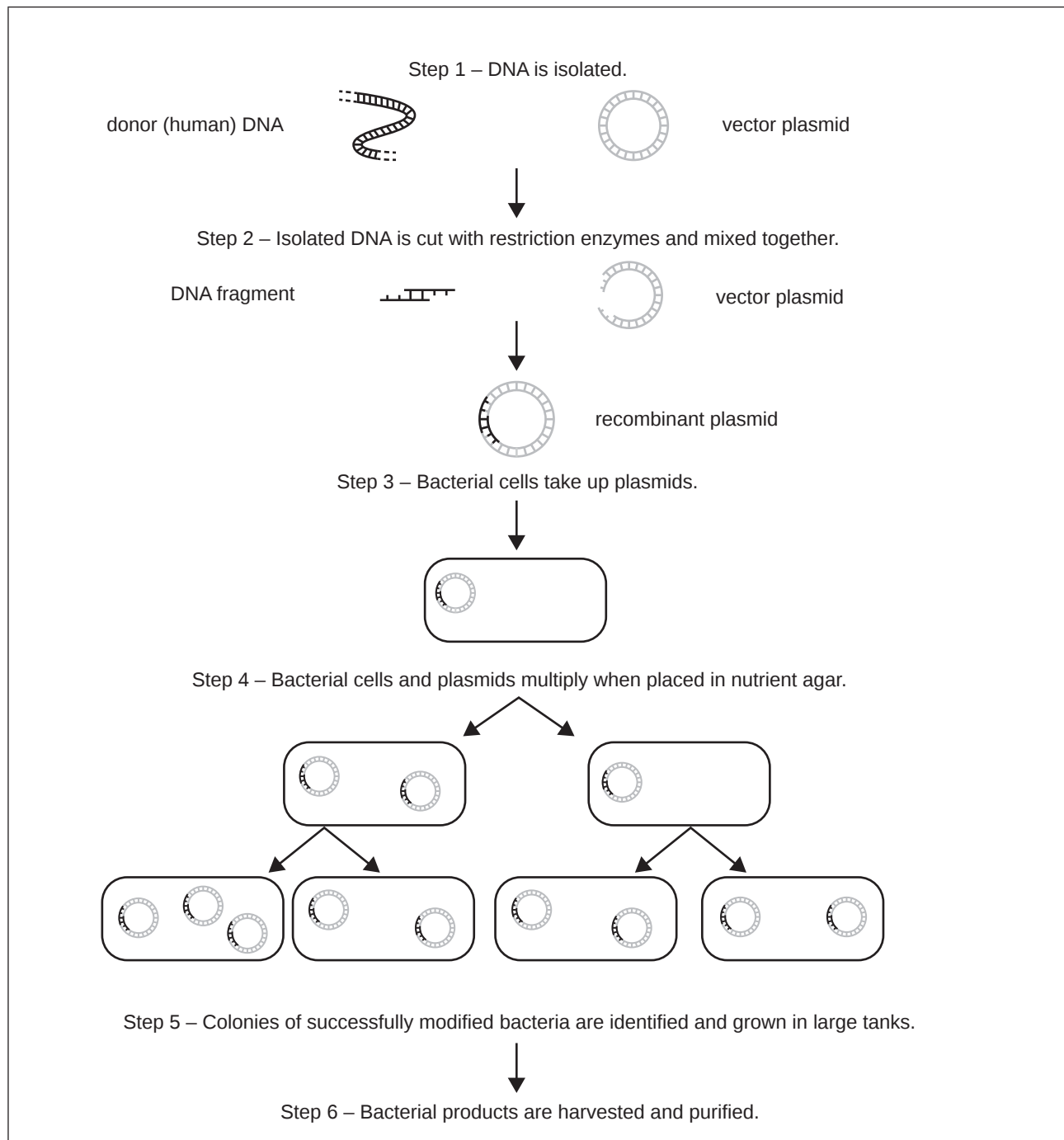
Plant group	Percentage of sucrose solution (%)	Average final height (cm)
A	0	40
B	5	30
C	10	20
D	15	15
E	20	5
F	25	2

It would be reasonable to conclude that

- A. plants grown in 5% sucrose solution had an average final height that was six times greater than the average final height of plants grown in 15% sucrose solution.
- B. plants grown in 20% sucrose solution had an average final height that was a quarter of the average final height of plants grown in 10% sucrose solution.
- C. plants grown in 15% sucrose solution grew 10 cm on average over the 20 days of the experiment.
- D. overall plant growth is inhibited if there is no sucrose present in the watering solution added to the soil.

Use the following information to answer Questions 37 and 38.

A molecular biologist performed the procedure outlined in the flow chart below.



Source: adapted from P Ladiges, B Evans, R Saint and B Knox,
Biology: An Australian Focus, 3rd edition, McGraw Hill Australia,
 NSW, 2008, p. 273

Question 37

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

- A. In Step 1 both donor DNA and the vector plasmid are isolated from the same human cell.
- B. In Step 2 different restriction enzymes are used to cut the DNA fragment and the plasmid.
- C. The process of transcription is shown in Step 3.
- D. In Step 4 multiple copies of donor DNA are being made.

Question 38

One way in which the bacterial products from Step 6 could be used is in the

- A. modification of viruses to transport healthy genes into the cells of people with cystic fibrosis.
- B. growing of human heart tissue and possibly a whole heart from human stem cells.
- C. production of commercial quantities of human insulin or human growth hormone.
- D. breeding of mice with human cancer genes in order to test cancer treatments.

Use the following information to answer Questions 39 and 40.

Citrus greening is a disease that affects citrus trees, such as orange trees. The disease is caused by the bacterium *Candidatus Liberibacter asiaticus*. These bacteria are transferred to the trees when insects called psyllids feed on the sap in leaves. The bacteria live in the plants' nutrient-conducting tissues (phloem), causing slow death of the trees.

A solution to this disease uses a gene from a spinach plant, which codes for a defensins protein. The defensins protein binds to and punches holes in the bacteria, breaking them apart.

Genetic engineers have inserted the defensins gene into a viral vector. The viral vector is a modified form of a virus that normally infects citrus trees. The genetically engineered viral vectors were placed in many orange trees through small incisions in the trees' bark. After several years' growth, all of the treated trees were very healthy while all of the untreated trees nearby were affected by citrus greening.

Question 39

The role of the viral vector in this genetic engineering solution is to

- A. infect and kill the *Candidatus Liberibacter asiaticus* bacteria living in the phloem of the orange trees.
- B. kill psyllids while they are feeding on the sap of the orange trees' leaves.
- C. deliver viral DNA with the defensins gene into the cells of the orange trees.
- D. invade spinach leaves and incorporate the defensins gene into the viral genome.

Question 40

One advantage of using a genetic engineering solution to prevent citrus greening is that it will

- A. improve the nutritional content of oranges.
- B. remove the need to increase insecticide applications in orange orchards.
- C. produce spinach-flavoured orange juice as an innovative consumer food.
- D. avoid public concern about the possible risks of genetically modified foods.

SECTION B**Instructions for Section B**

Answer **all** questions in the spaces provided. Write using blue or black pen.

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

Question 1 (7 marks)

Two students noticed bubbles forming on the submerged leaves of an *Elodea* plant growing in an aquarium. The bubbles seen on the leaves were the result of a gas formed within the cells of the leaves. The photograph below shows the appearance of these bubbles.

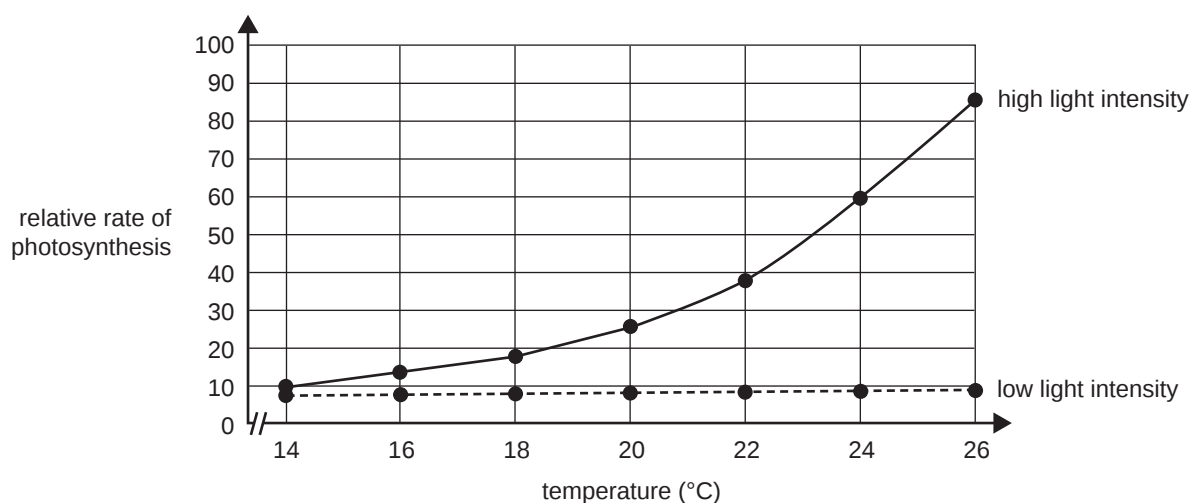
Due to copyright restrictions,
this material is not supplied.

Source: PH Raven, RF Evert and SE Eichhorn, *Biology of Plants*, 4th edition,
Worth Publishers, Inc., New York, p. 97

There was a bright light shining on the aquarium. The bright light was not affecting the temperature of the water.

- a. Describe what occurs within the cells of the leaves to result in the formation of these bubbles. 3 marks

- b. The students investigated the rate of photosynthesis in the leaves of the *Elodea* plant. The graph of their results is shown below.



- i. Name the two stages of photosynthesis.

2 marks

- ii. Consider the relative rates of photosynthesis at a temperature of 20 °C. Explain the difference observed in the relative rates of photosynthesis when the *Elodea* plant was exposed to light of low intensity compared to when it was exposed to light of high intensity. Refer to both stages of photosynthesis in your answer.

2 marks

Question 2 (6 marks)

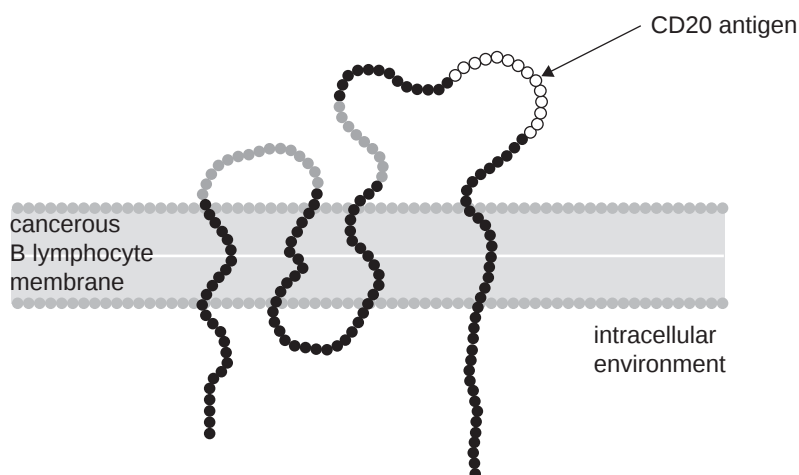
Dendritic cells are one type of cell circulating within the lymph and lymph nodes of humans.

- a. Describe how dendritic cells perform their function within the human immune system. 2 marks

Non-Hodgkin lymphoma is a type of cancer. In most patients with non-Hodgkin lymphoma, the B lymphocytes multiply uncontrollably and are unable to differentiate. The patient can develop recurring infections from normally non-pathogenic bacteria such as *Staphylococcus epidermidis*.

- b. Explain why a non-Hodgkin lymphoma patient's immune system would find it difficult to eliminate an infection by *S. epidermidis*. 2 marks

- c. One effective treatment against non-Hodgkin lymphoma is the use of monoclonal antibodies to target the cancerous B lymphocytes. The monoclonal antibodies target the CD20 antigen, which is a unique self-antigen found on cancerous B lymphocytes, as shown in the diagram below.



Source: adapted from S Cang, N Mukhi, K Wang and D Liu, 'Novel CD20 monoclonal antibodies for lymphoma therapy', *Journal of Hematology & Oncology*, 5:64, 2012; licensed via BioMed Central, Creative Commons Licence (CC-BY 2.0)

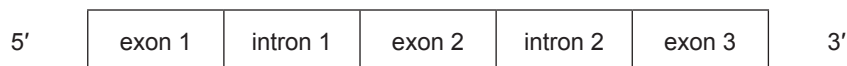
- Explain how monoclonal antibodies can be used to treat cancerous B lymphocytes. 2 marks

Question 3 (5 marks)

Alpha-globin is one of the polypeptides in a human haemoglobin molecule. The HBA1 gene codes for the production of alpha-globin.

Molecule X is produced when the HBA1 gene is transcribed.

The diagram below shows the relative positions of the two introns and the three exons in Molecule X.



- a. Outline the steps that occur within the nucleus of a cell to produce Molecule X. 4 marks

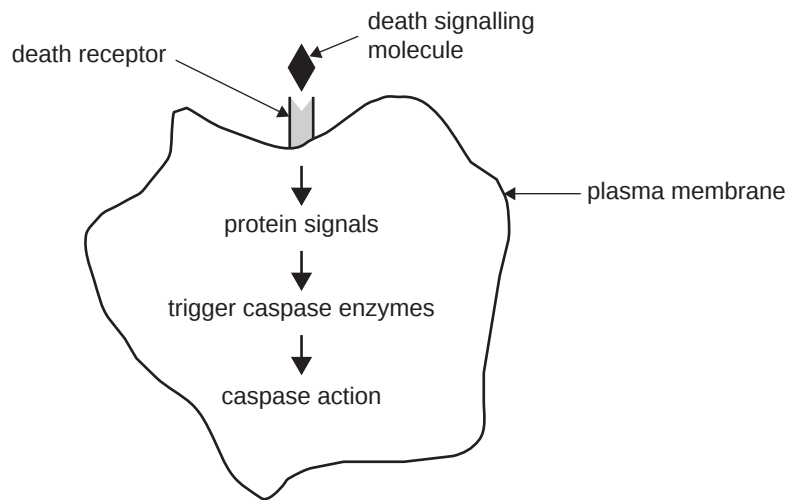
- b. Alpha-globin is a polypeptide consisting of 141 amino acids.

In which parts of Molecule X would the codons for these amino acids be found?

1 mark

Question 4 (3 marks)

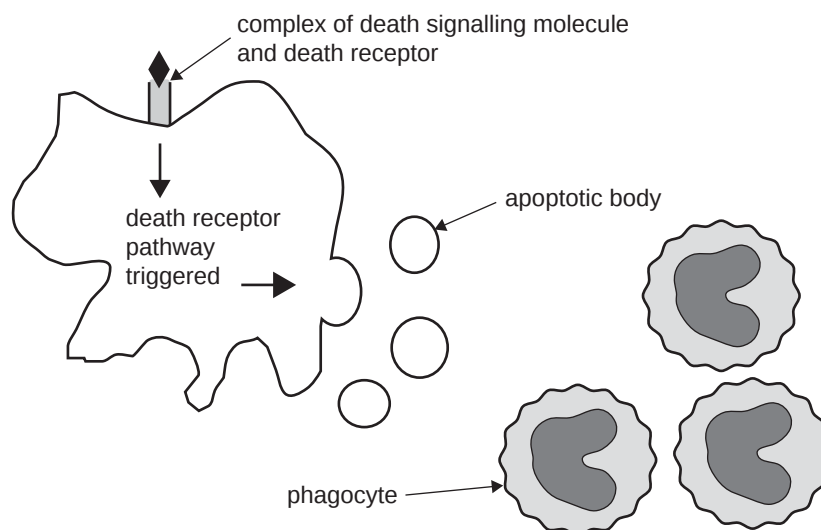
A cell can be stimulated to undergo apoptosis after receiving an external signal that binds to a specific receptor on the plasma membrane. Below is a simplified diagram that shows how an external signal for the death receptor pathway begins to stimulate apoptosis.



- a. What action is carried out by the caspase enzymes during apoptosis?

1 mark

- b. Once caspases have carried out their action, the plasma membrane of the apoptotic cell forms apoptotic bodies. Phagocytes are attracted to the area, as shown below.

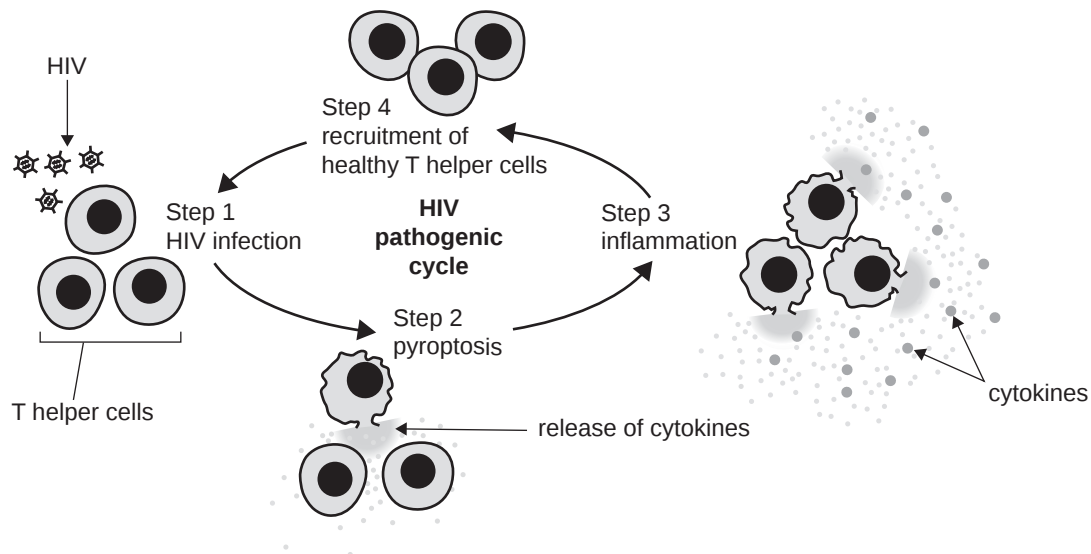


Explain how the phagocytes shown in the diagram above perform their role.

2 marks

Question 5 (5 marks)

The human immunodeficiency virus (HIV) infects T helper cells. Scientists have discovered that 95% of infected T helper cells undergo a process called pyroptosis. During pyroptosis, the plasma membrane bursts, releasing cytokines. This release of cytokines results in constant inflammation.



Source: adapted from G Doitsh, NLK Galloway, Xin Geng, et al., 'Pyroptosis drives CD4 T-cell depletion in HIV-1 infection', *Nature*, 505 (7484), 23 January 2014; from National Center for Biotechnology Information website, <www.ncbi.nlm.nih.gov/>

In the diagram above, Step 3 shows inflammation.

- a. Explain why the recruitment of healthy T helper cells (Step 4) would be harmful for an HIV patient. 2 marks

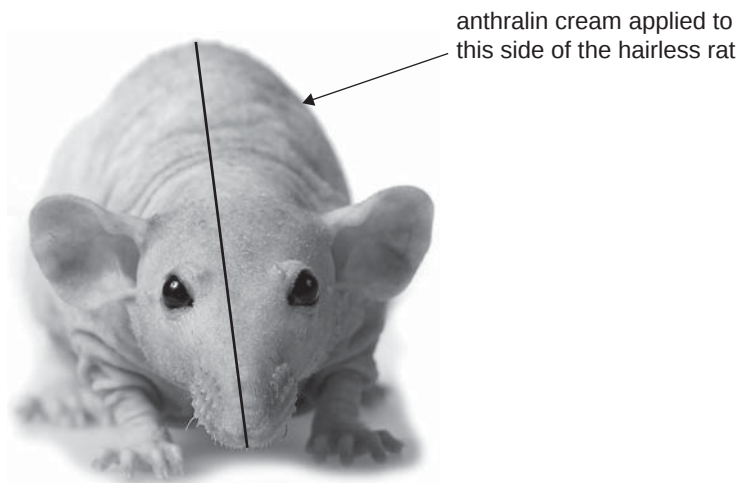
- b. i. Other than the recruitment of healthy T helper cells, the release of cytokines and the migration of phagocytes to the site, state **two** changes that occur during an inflammatory response. 2 marks

- ii. Describe how constant inflammation could affect HIV patients. 1 mark

Question 6 (9 marks)

Alopecia areata is an autoimmune disease that causes loss of body hair. Scientists wanted to study a treatment for alopecia areata using a cream called anthralin.

The scientists selected a breed of rat that develops alopecia areata at the age of four months. From 0–4 months of age, these rats had a normal coat of hair. Sixteen rats that had lost their hair were selected for the experiment and anthralin cream was applied to one half of each rat every day for 10 weeks.



Source: Sergey Lavrentev/Shutterstock.com

The scientists hypothesised that if they applied the cream to one half of each of the 16 rats and left the other half untreated, they would only see the treated side regrow hair.

The results showed that all 16 rats regrew a full coat of hair on the treated half and remained hairless on the untreated half.

- a. Suggest a reason why the scientists decided to treat only one half of each rat while leaving the other half untreated.

1 mark

- b. The scientists kept the rats in identical environments and gave them the same mass of food and volume of water at regular intervals.

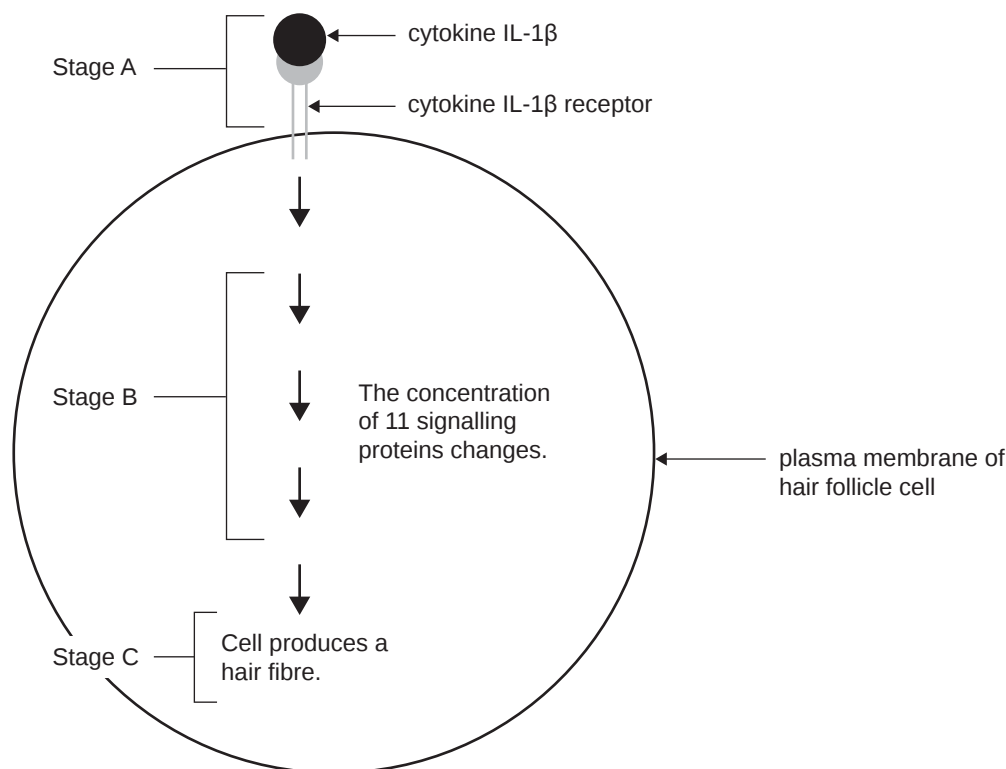
State **two** other variables the scientists would have had to keep constant during the experiment.

2 marks

Cytokines play an important role in signalling either the destruction or survival of hair follicle cells in the rats. The scientists measured the levels of cytokines present in the untreated skin and compared these with the levels of cytokines present in the treated skin. It was found that the treated skin had a significant increase in the level of cytokine IL-1 β .

The scientists then tested the effect of cytokine IL-1 β on hair follicle cells. They found that 11 different signalling proteins within the cytoplasm changed in concentration in the presence of cytokine IL-1 β .

A simplified cytokine IL-1 β cell signalling pathway found in a hair follicle cell is shown below.



- c. What evidence suggests that cytokine IL-1 β is a hydrophilic molecule? 1 mark

- d. Name the three stages labelled A, B and C in the cell signalling pathway shown above. 3 marks

Stage A _____

Stage B _____

Stage C _____

- e. The table below shows the relative concentrations of the 11 different signalling proteins that were found in the cells of the untreated skin compared to the concentrations that were found in the cells of the treated skin. The concentrations were measured in arbitrary units (AU).

Signalling proteins	Untreated skin	Treated skin
	Protein concentration (AU)	Protein concentration (AU)
1	16.0	9.8
2	6.4	3.9
3	7.6	3.7
4	3.8	2.2
5	7.1	3.3
6	14.2	10.2
7	0.0	4.7
8	2.8	4.3
9	0.0	2.6
10	12.1	21.0
11	2.8	4.3

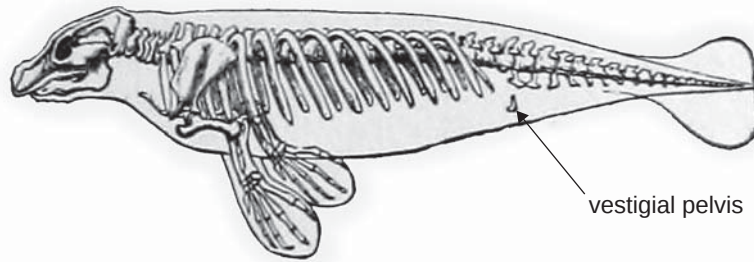
Summarise the results shown in the table above.

2 marks

Question 7 (5 marks)

Manatees are aquatic mammals with flipper-like forelimbs and tail, but no hind limbs.

The diagram below shows the skeleton of a female manatee. A vestigial pelvis is shown.



Scientists have studied a 50-million-year-old fossil of an ancient animal called *Pezosiren portelli*. They believe *P. portelli* shared a recent common ancestor with present-day manatees. The diagram below shows the skeleton of *P. portelli*.

Due to copyright restrictions,
this material is not supplied.

Source: DP Domning, 'The earliest known fully quadrupedal sirenian',
Nature, vol. 413, 11 October 2001, p. 626

- a. How does the presence of a vestigial pelvis provide evidence that present-day manatees possibly evolved from animals similar to the *P. portelli* fossil? 1 mark

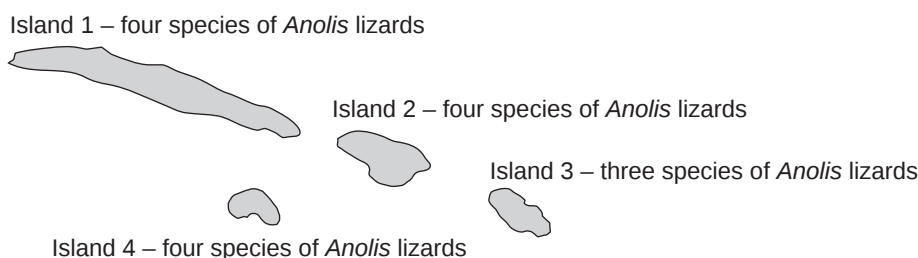
The scientists justified that the *P. portelli* fossil is 50 million years old by referring to fossils of several ancient molluscs (shellfish).

- b. Explain how scientists would have calculated the absolute age of the ancient mollusc fossils. 2 marks

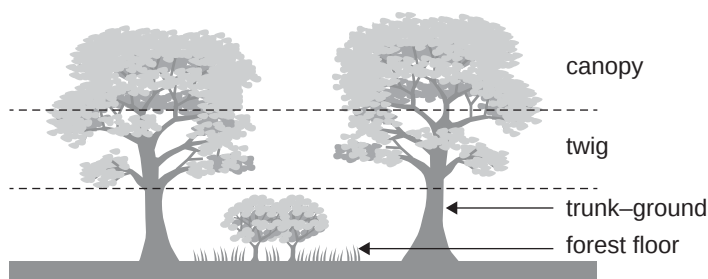
- c. How can the absolute age of the ancient mollusc fossils be used to estimate the age of the *P. portelli* fossil? 2 marks

Question 8 (11 marks)

Scientists studied 15 species of lizards of the genus *Anolis* on four islands in the Caribbean Sea. On each island, there were up to four different species of these lizards.



Each island is covered with large areas of forest. In the forests, there are four distinct habitats, as shown in the diagram below and described in the table. The habitats correspond to different layers of the forest, from the canopy down to the forest floor. The scientists noticed that each of the habitats on each island was inhabited by just one of the species of lizards found on that island. Lizards found in similar habitats on different islands showed similar body structures.



The table below shows the relationship between the characteristics of the lizards and the habitat in which they are found.

Habitat	Characteristics common to <i>Anolis</i> species living in each habitat
canopy (leafy section at the top of the tall trees)	large body, large toe pads, able to climb on the surface of broad leaves
twig (part-way up the trees, on thin branches)	small body, very short legs, moves slowly, able to cling to twigs
trunk–ground (the trunks of the trees and the ground around the trunks)	chunky body, long legs, able to move very fast
forest floor (grassy areas and bushes between the trees)	long tail, slender body, short legs, able to cling to grasses and thin branches

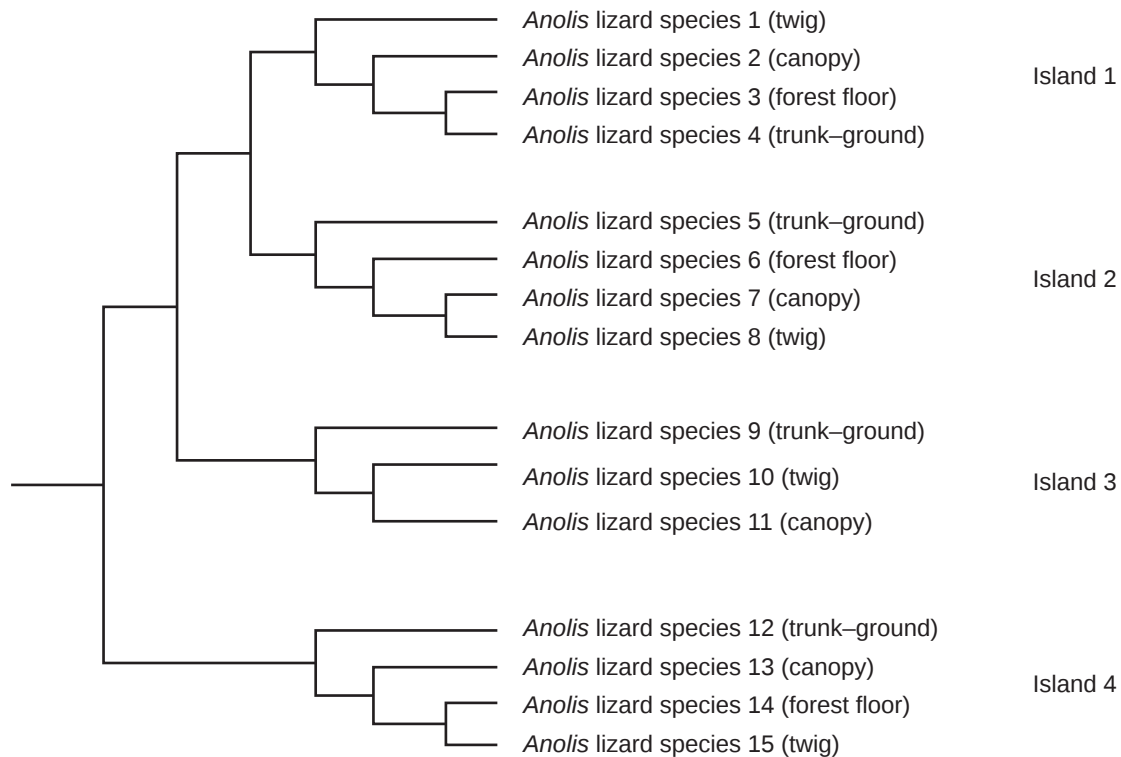
- a. Choose **one** characteristic from the table on page 28 and suggest how this characteristic provides a selective advantage to lizards living in the corresponding habitat. 1 mark

- b. Outline the process by which different lizard species of the genus *Anolis* have evolved to occupy the different habitats. 3 marks

The scientists sequenced the genomes of the *Anolis* lizard species on each island. Using their results, they constructed a phylogenetic tree.

- c. Explain how the scientists would have decided where to place each lizard species on the phylogenetic tree. 2 marks

The phylogenetic tree constructed by the scientists is shown below.



- d. Use the phylogenetic tree to justify whether *Anolis* lizard species 8 is more closely related to *Anolis* lizard species 1 or *Anolis* lizard species 5.

2 marks

- e. One hypothesis is that *Anolis* lizard species with characteristics suitable for living in the canopy of the forest have evolved separately on four occasions.

Explain how the phylogenetic tree supports this hypothesis.

3 marks

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SECTION B – continued
TURN OVER

Question 9 (9 marks)

A group of scientists is seeking approval to edit the DNA of human embryos to discover which genes play a key role during an embryo's first week of development. The scientists plan to use only one-day-old embryos donated for research purposes. A total of 25 embryos will be required for the study.

- a. A similar study in another country used fewer than 10 embryos.

What is the advantage of using 25 embryos instead of 10 embryos?

1 mark

- b. The scientists will edit (target and change) genes in the embryos by switching off genes that are thought to be involved with the earliest stages of development. Embryo growth will then be observed over the next three days.

What results would support the hypothesis that is being tested by the scientists?

1 mark

The CRISPR technique is a gene editing method. It involves a protein called Cas9 and a short piece of guide RNA (gRNA). The gRNA leads Cas9 to a gene in the DNA that scientists wish to edit. Cas9 is an endonuclease that acts in a similar way to a restriction enzyme.

- c. What action is Cas9 expected to perform?

1 mark

DNA ligase is required for the next stage of the editing process.

- d. What role would DNA ligase play?

1 mark

The CRISPR technique can be used to insert new genes or to delete sections of a gene.

While some scientists have recognised the potential benefits of using the CRISPR technique to edit genes in the future, other scientists have expressed concern.

- e. State one potential benefit some scientists may have recognised and one concern other scientists may have had.

2 marks

Benefit _____

Concern _____

- f. The scientists will need to make multiple copies of gRNA to place into each embryo. Polymerase chain reaction (PCR) will be performed to produce many copies of the DNA template sequence that is used to create the gRNA molecules.
Two different primers are used in the copying process.

Explain the role played by primers and why it is necessary to have two different primers.

3 marks

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Question 10 (10 marks)**Is Tamiflu a waste of money?**

On 19 March 2014 the journal *Lancet Respiratory Medicine* published a study showing that the influenza drugs Tamiflu and Relenza save lives. On 14 April 2014, another journal, the *British Medical Journal* (*BMJ*), published a review saying these influenza drugs do not save lives.

The *Lancet* researchers focused on the 2009 H1N1¹ global swine flu pandemic that claimed up to 575 400 lives worldwide. They asked whether Tamiflu and other neuraminidase inhibitor drugs prevented deaths during the pandemic. Looking at data from over 29 000 patients in hospital, they concluded the drugs saved lives. A comparison between patients who received the drug early, and those who received it late, suggested early treatment halved the death rate.

The *BMJ* researchers looked at general populations recovering from mild to moderate seasonal influenza. In their study the same drugs had only a minor effect, reducing the length of illness from seven to six-and-a-half days. There was no reduction in hospital admissions but there was an increased risk of side effects from using these drugs.

The *BMJ* study limited itself to the data obtained from randomised control studies. They carefully allocated comparable groups of people to receive either the real drug or a placebo. The *Lancet* study observed what took place in hospitals during the pandemic; observational studies like this are generally more open to criticism. But randomised control studies cannot be done during a pandemic on hospitalised patients at risk of dying from influenza.

Source: adapted from E Finkel, 'Is Tamiflu a waste of money?', *Cosmos*, 14 April 2014, <<https://cosmosmagazine.com/biology/tamiflu-waste-money>>

¹**H1N1** – the name of the swine flu virus; refers to haemagglutinin (H) and neuraminidase (N) proteins

- a. What is meant by the term 'pandemic'? 1 mark

- b. The two groups of scientists who contributed to the two journals mentioned in the article have reached opposite conclusions on whether neuraminidase inhibitors, such as Tamiflu and Relenza, save lives.

Explain how both conclusions can be correct. 2 marks

- c. Using evidence from the article, justify your own opinion on whether the government should spend hundreds of millions of dollars stockpiling neuraminidase inhibitors to prepare for a possible flu pandemic.

2 marks

- d. The surface of the influenza virus has a unique structure that distinguishes it from other viruses. The virus is covered in two types of protein spikes: haemagglutinin (H) and neuraminidase (N). Neuraminidase allows newly formed viruses to be released from the host cell. The drug Relenza is a neuraminidase inhibitor that was developed using the techniques of rational drug design.

Explain, at a molecular level, how Relenza was designed to prevent the spread of the influenza virus.

3 marks

- e. Complete the table below by circling the correct answers to show how an antiviral drug, such as Relenza, acts differently from the influenza vaccine. The first row has been completed as an example.

2 marks

Aspect of treatment or prevention method	Relenza	Influenza vaccine
when it is administered	before a person becomes ill <u>when a person is ill</u> after a person recovers	<u>before a person becomes ill</u> when a person is ill after a person recovers
duration of effect	long acting short acting no effect	long acting short acting no effect
chance of herd immunity being achieved	high low none	high low none

Question 11 (10 marks)

A group of students wanted to investigate the activity of an enzyme that catalyses the breakdown of hydrogen peroxide into water and oxygen.

The students measured oxygen concentration using an oxygen sensor. The oxygen sensor fits into the top of a conical flask, as shown in the photograph below.



The students set up three conical flasks with the contents listed in the table below.

Flask	Contents of flask
1	50 mL of 3% hydrogen peroxide solution 2 mL of enzyme solution 50 mL of pH neutral distilled water
2	50 mL of 3% hydrogen peroxide solution 2 mL of enzyme solution 50 mL of high pH buffer solution
3	50 mL of 3% hydrogen peroxide solution 2 mL of enzyme solution 50 mL of low pH buffer solution

The buffer solutions and the distilled water did not react with the hydrogen peroxide.

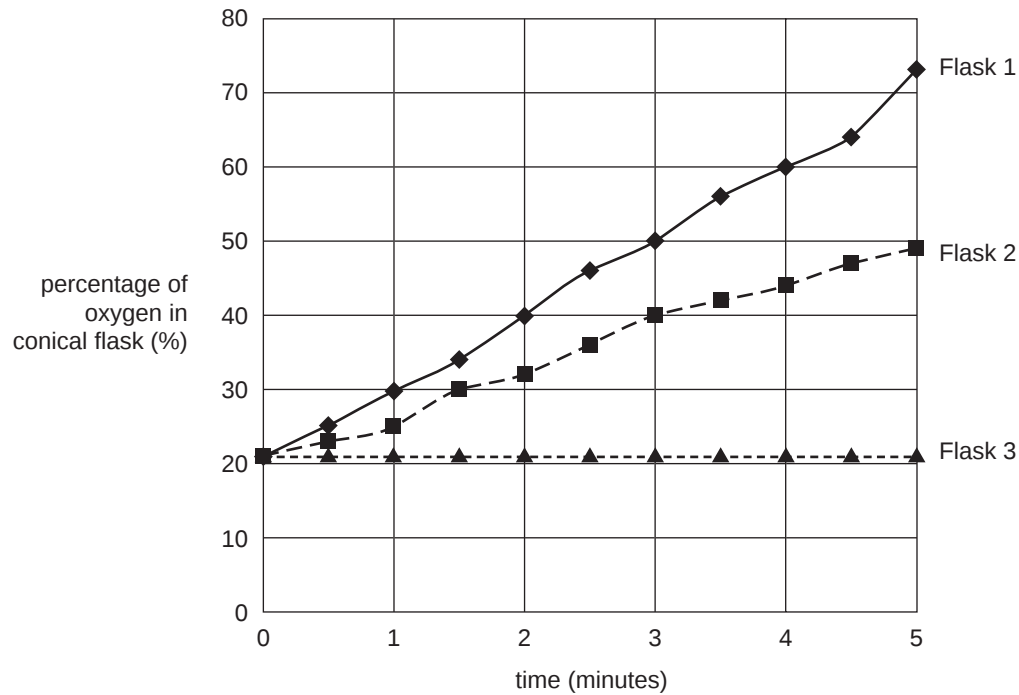
All three conical flasks were at room temperature.

The students recorded the concentration of the oxygen over a five-minute period.

- a. State a hypothesis that the students could be testing with this experiment.

1 mark

- b. The results of the experiment are shown below.



Explain the differences in the results that the students obtained for the three different flasks. 3 marks

- c. After completing the experiment, the students decided they could improve their experimental design by adding another conical flask that contained the following.

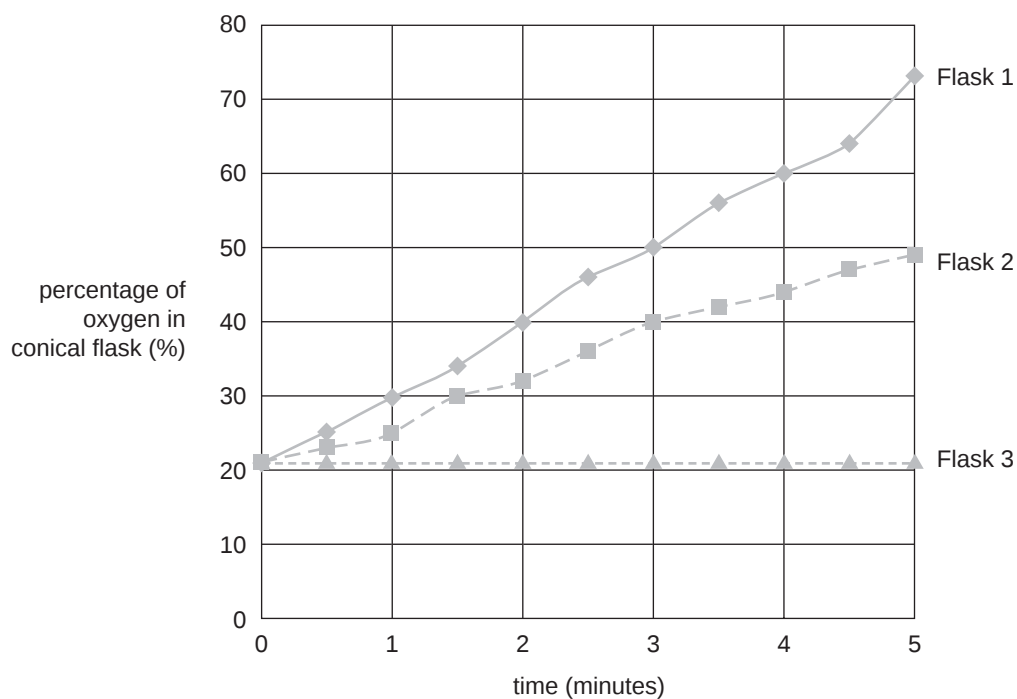
Flask	Contents of flask
4	50 mL of 3% hydrogen peroxide solution 52 mL of distilled water

- i. Explain how this additional flask could improve their experimental design.

2 marks

- ii. Draw on the graph below the results that would be expected for the production of oxygen in Flask 4.

1 mark



- d. Suggest **one** further improvement that could be made to the students' experimental design. Justify your suggestion.

1 mark

- e. Consider any experiment. Explain the difference between the accuracy and precision of measurements.

2 marks
