

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names
Centre Number	Candidate Number	

Pearson Edexcel Level 3 GCE

Wednesday 5 June 2024

Afternoon (Time: 1 hour 45 minutes)

Paper reference **9BI0/01**

Biology B

Advanced

PAPER 1: Advanced Biochemistry, Microbiology and Genetics

You must have:
Scientific calculator, HB pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- In question(s) marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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Answer ALL questions.

Some questions must be answered with a cross ☒. If you change your mind about an answer, put a line through the box ☐ and then mark your new answer with a cross ☒.

- 1** Blood is pumped around the body in blood vessels to supply cells with nutrients and oxygen.

- (a) Which box in each row of the table shows where endothelial cells and valves are found?

(2)

Features of blood vessels	Type of blood vessel			
	both capillaries and veins	capillaries only	veins only	neither capillaries nor veins
Endothelial cells	☒	☐	☐	☐
Valves	☐	☐	☒	☐

- (b) Nutrients and oxygen pass into cells from tissue fluid.

Explain how tissue fluid is formed.

(2)

At the arterial end of the capillary there is a high hydrostatic pressure, because the blood has come from the arteries and the vessels narrow into arterioles and capillaries. This forces fluid (plasma) out of the blood through the gaps (pores) in the capillary wall, forming tissue fluid.

(Total for Question 1 = 4 marks)



2 Glucose is a monosaccharide that is found in sucrose, amylose and amylopectin.

(a) Sucrose is made from glucose and one other molecule.

Which row of the table gives the name of this molecule and the type of reaction that joins the two molecules together?

(1)

	Name of molecules	Type of reaction
☒ A	fructose	condensation
☐ B	fructose	hydrolysis
☐ C	galactose	condensation
☐ D	galactose	hydrolysis

(b) Compare and contrast the structure of amylose and amylopectin.

(3)

Similarities: both are made of α -glucose monomers, and both contain glycosidic bonds formed by condensation.

Differences: amylose has only 1-4 glycosidic bonds, but amylopectin has both 1-4 and 1-6 glycosidic bonds.

Amylose is unbranched and coiled into a helix, but amylopectin is branched.

(Total for Question 2 = 4 marks)



3 Viruses can replicate using the lytic cycle.

Viruses can be grown in a laboratory by culturing them with appropriate cells.

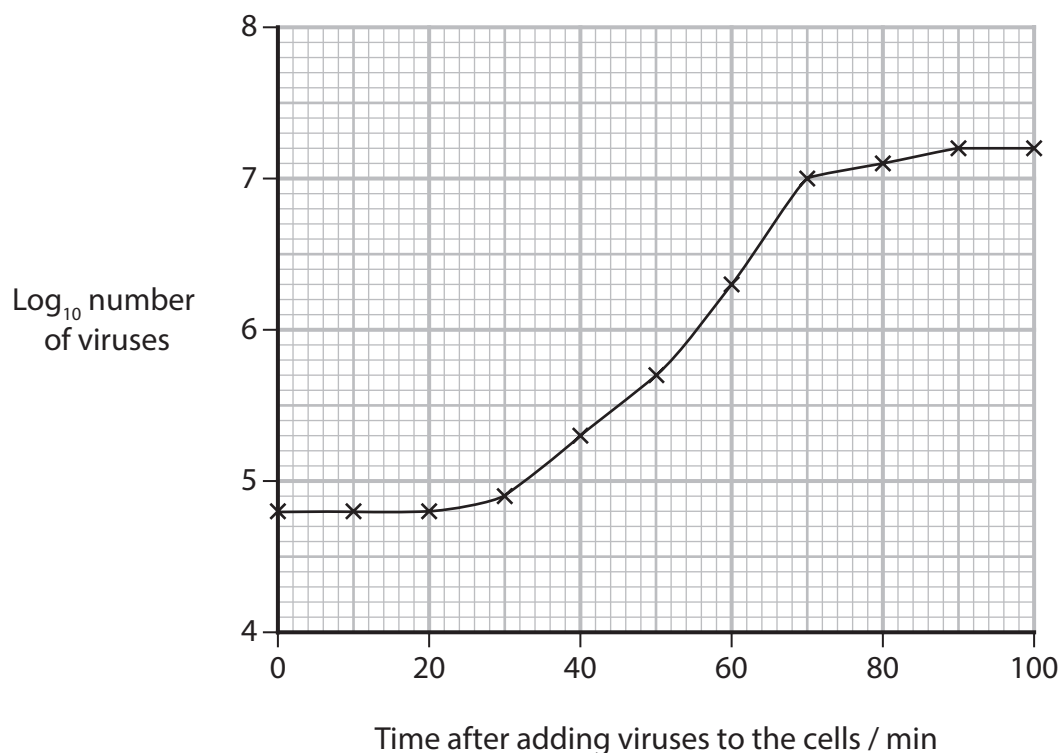
(a) Explain why viruses have to be cultured with 'appropriate cells'.

(2)

Viruses can only bind to a specific type (a limited number of types) of host cell, because the attachment proteins on their capsid must fit specific receptors on the surface of the cells.

Viruses cannot replicate without a host cell.

(b) The graph shows the changes in the number of viruses after they had been added to the cells.



- (i) Explain why the number of viruses did not start to increase until after 20 minutes.

(3)

Time is needed for the viral genetic material (DNA or RNA) to enter the host cell.

Time is then needed for nucleic acid and protein synthesis (transcription and translation of viral genes) to make new viral nucleic acid and capsid proteins.

Time is needed for the assembly of new viruses.

The numbers only increase once the host cells have been lysed and the new viruses are released.

- (ii) Calculate how many more viruses are present at 70 minutes than at 50 minutes.

Give your answer to **three significant figures**.

(2)

at 70 min: $\log_{10} = 7.0$, so $10^7 = 10\,000\,000$

at 50 min: $\log_{10} = 5.7$, so $10^{5.7} = 501\,187$

$10\,000\,000 - 501\,187 = 9\,498\,813$

Answer *9 500 000*

(Total for Question 3 = 7 marks)



P 7 8 6 6 3 A 0 5 3 2

4 Photosynthesis results in the production of GALP. This molecule is used by plants to produce glucose and other organic molecules.

(a) Glucose consists of the elements of carbon, hydrogen and oxygen.

Name the inorganic molecules that supply these elements for photosynthesis.

(2)

Carbon *carbon dioxide*

Hydrogen *water*

Oxygen *carbon dioxide*

(b) Light is essential for photosynthesis. It is needed for photolysis and for the excitation of electrons in the photosystems.

Which row in the table shows where photolysis and the excitation of electrons occurs?

(1)

		Photolysis	Excitation of electrons
☐	A	stroma	stroma
☐	B	stroma	thylakoid membrane
☐	C	thylakoid membrane	stroma
☒	D	thylakoid membrane	thylakoid membrane



- (c) Scientists have developed an experimental technique that uses artificial photosynthesis.

Electricity generated from solar panels was used to convert carbon dioxide and water into the organic compound acetate.

Plants were then able to grow in the dark using the acetate.

- (i) Explain why these plants were able to grow in the dark.

(3)

Carbon dioxide has already been fixed, because the acetate was made from carbon dioxide and water using electricity, so no light-dependent reaction is needed.

The plants use the acetate to form GALP, glucose and other organic molecules such as amino acids and proteins.

These organic molecules are stored as biomass, so the plants grow.

The acetate can also be used in respiration to release energy (ATP) for growth.

- (ii) The scientists hope that this technique will be able to produce plant-based food.

State **one** advantage of using this method.

Give a reason for your answer.

(1)

The food can be grown anywhere (indoors), at any time of year, because there is no need for sunlight, so yields are higher.

(Total for Question 4 = 7 marks)



5 Septicaemia is a life-threatening condition that can arise from bacterial infection.

- (a) In one year, 245 000 people were diagnosed with septicaemia and 49 735 of these people died as a result.

Which percentage of people **survived** septicaemia in this year?

(1)

- ☐ A 20.3%
- ☐ B 25.5%
- ☐ C 39.3%
- ☒ D 79.7%

- (b) Two types of bacteria that cause septicaemia are *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*).

E. coli is Gram negative and *S. aureus* is Gram positive.

- (i) Which of the following statements about the cell walls of these bacteria are correct?

(1)

1. Both bacteria have peptidoglycan (murein) in their cell walls.
2. *S. aureus* has an outer membrane (lipopolysaccharide layer).
3. The cell wall of *E. coli* is thinner than that of *S. aureus*.

- ☐ A 2 only
- ☐ B 3 only
- ☐ C 1 and 2 only
- ☒ D 1 and 3 only



(ii) Both *E. coli* and *S. aureus* produce toxins.

E. coli produces the same type of toxin as *Salmonella* bacteria.

Which of the following statements about the toxins produced by these bacteria are correct?

(1)

1. *E. coli* produces endotoxins.
2. The toxins produced by *S. aureus* are released only once the bacteria die.
3. The toxins produced by *S. aureus* are components of their cell wall.

- ☒ **A** 1 only
- ☐ **B** 2 only
- ☐ **C** 1 and 2 only
- ☐ **D** 1, 2 and 3

(c) Vaccines against bacteria are not always effective. The antigens they contain stimulate only a weak immune response.

Which of the following types of immune response is stimulated by a vaccine?

(1)

- ☒ **A** artificial active
- ☐ **B** artificial passive
- ☐ **C** natural active
- ☐ **D** natural passive



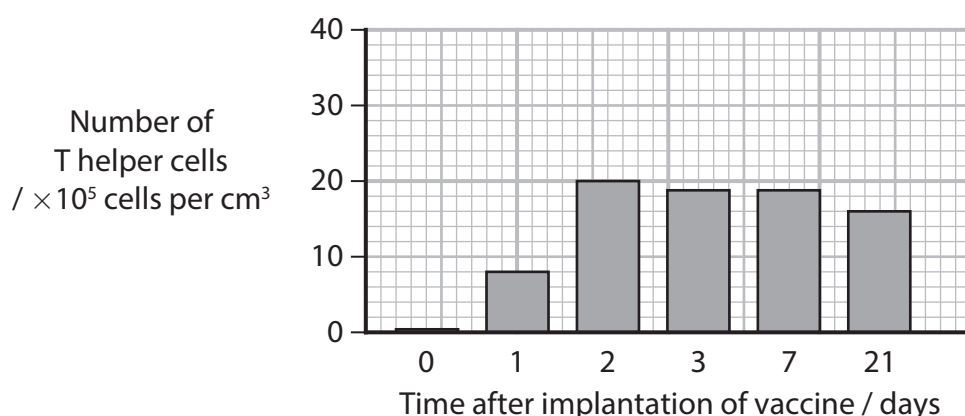
- (d) There are currently no vaccines for either *E. coli* or *S. aureus*.

Scientists are developing vaccines against *E. coli* and *S. aureus* which can be implanted under the skin.

The bacterial antigens are held in a mesh that contains chemicals to attract tissue macrophages.

The effect of implantation of these vaccines on the immune response in mice was investigated.

- (i) The graph shows the number of T helper cells in the lymph nodes that drain the part of the body where the vaccine was implanted.



Explain the results shown in the graph.

(3)

At day 0 there are very few T helper cells, because there is a delay while the antigen is taken up and presented by the macrophages.

By day 1 some T helper cells are present, as they have been activated (clonal selection) and are beginning to divide.

By day 2 there is a large number of T helper cells, due to clonal expansion by mitosis.

The number drops by day 21, as the T helper cells have died or moved out of the lymph nodes.

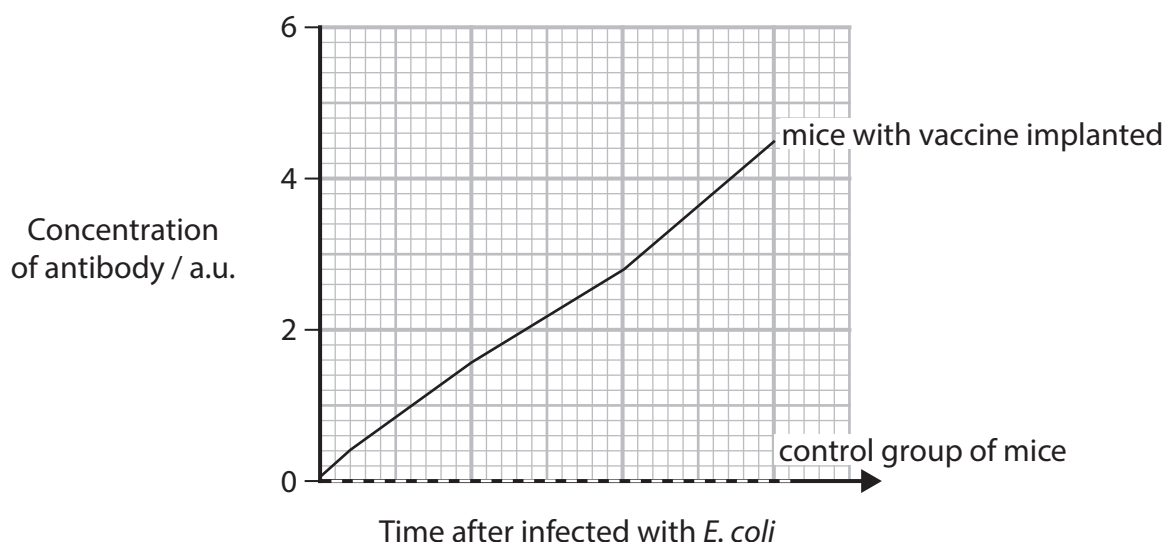


- (ii) In part of this investigation, mice had the vaccine implanted 35 days before being infected with *E. coli*.

A control group that had not received the vaccine was also infected with *E. coli*.

The levels of antibody in the blood of both groups of mice were determined.

The graph shows these results.



Explain the results shown in the graph.

(3)

There are no antibodies in the control mice at first, as they had not been exposed to the antigen before, so they must undergo a primary immune response, which takes time.

In the vaccinated mice there is an immediate, rapid increase in antibodies, due to a secondary immune response.

This is because they had memory cells present as a result of the vaccine.

Therefore there is a rapid increase in plasma cells, which release antibodies.

(Total for Question 5 = 10 marks)

6 In a cell, DNA is found in both the nucleus and the mitochondria.

(a) Where is DNA found in mitochondria?

(1)

- ☐ A cytoplasm
- ☐ B intermembrane space
- ☒ C matrix
- ☐ D nucleus

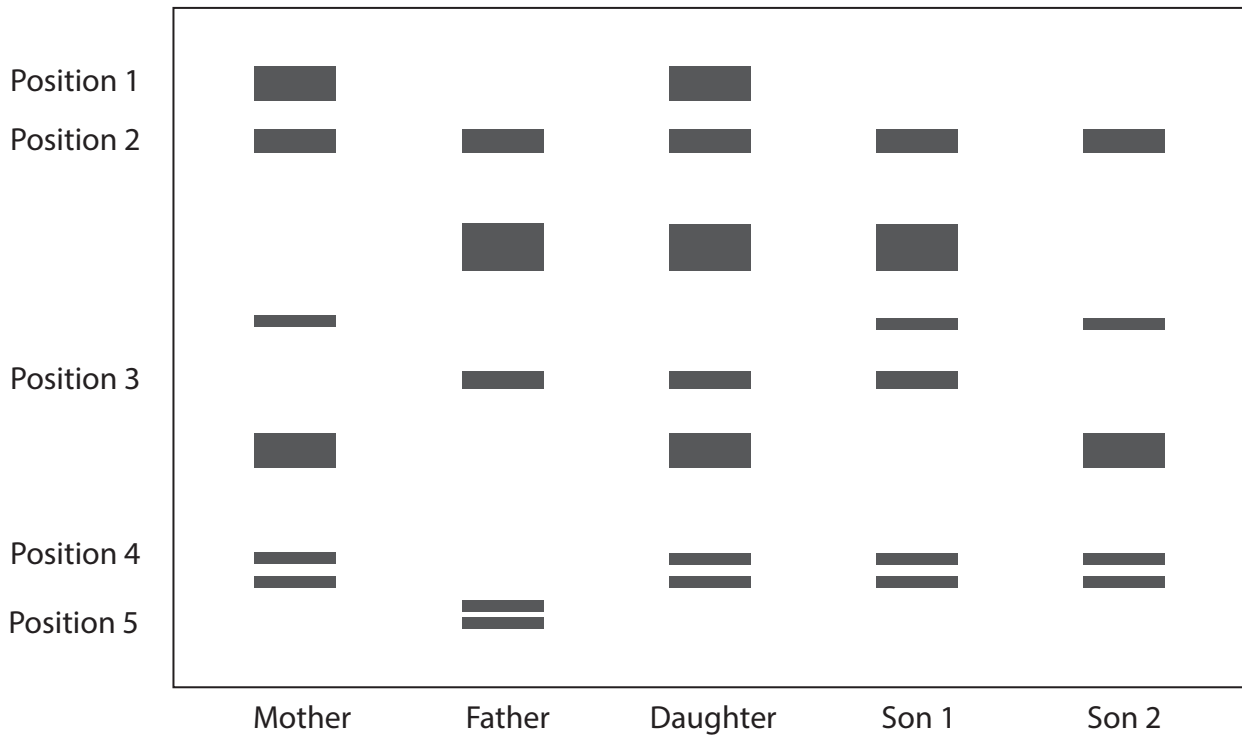
(b) Which row of the table describes DNA found in the mitochondria?

(1)

	Shape	Ratio of phosphodiester bonds : pentose sugars
☒ A	circular	higher than nuclear DNA
☐ B	circular	lower than nuclear DNA
☐ C	linear	higher than nuclear DNA
☐ D	linear	lower than nuclear DNA

(c) Gel electrophoresis can be used to analyse the DNA of a person.

The diagram shows some of the bands produced when the DNA of a family was analysed using gel electrophoresis.



Analyse the information to explain the bands found at positions 1 to 5 in this family.

(4)

Position 1: only the daughter has inherited this DNA from the mother.

Position 2: this DNA (and the genes located in it) is common to all people, so it is found in everyone in the family.

Position 3: the daughter and son 1 have inherited this DNA from their father, but son 2 has not.

Position 4: this could be mitochondrial DNA, as it is found in the mother and all of the children (mitochondria are inherited from the mother).

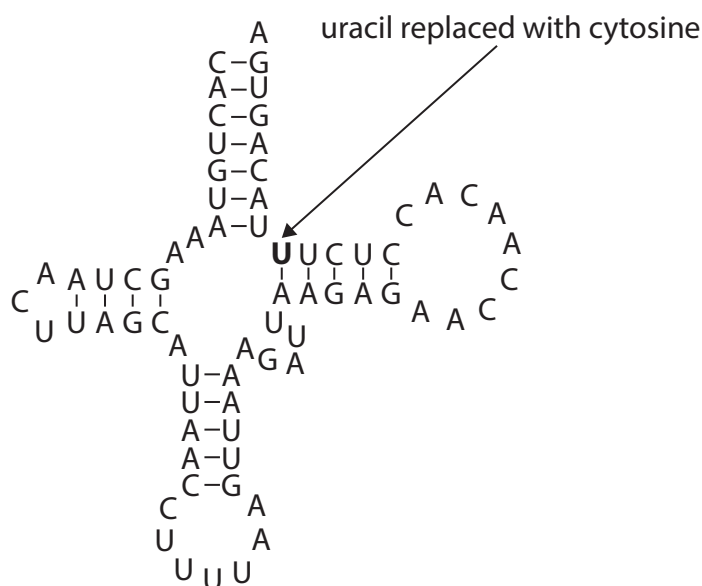
Position 5: this could be the mitochondrial DNA of the father, as it is not present in any of the children.



P 7 8 6 6 3 A 0 1 3 3 2

- (d) A mutation in the tRNA^{Lys} gene in the mitochondria replaces one uracil with a cytosine in the resulting tRNA molecule.

The diagram shows the position of the uracil that is replaced with cytosine in a tRNA^{Lys} molecule.



- (i) Name this type of mutation.

(1)

Substitution (transition).

- (ii) Explain how this mutation could affect the structure of the tRNA^{Lys} molecule shown in the diagram.

(2)

The cytosine will not bind with the adenine opposite it, so the hydrogen bonds between these bases will not form.

So the left-hand loop will open up (or other bonds may form), and the tRNA will be a different shape.



(iii) Explain how this mutation could affect the role of the tRNA^{Lys} molecule.

(2)

The tRNA^{Lys} may not be able to bind to the ribosome, because of its different shape.

Therefore it will not hold the amino acid lysine in place, so lysine cannot be added to the polypeptide.

(Total for Question 6 = 11 marks)

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- 7 Coal tits, blue tits and great tits are three species of bird found in the UK all year round.

The photograph shows a blue tit.



(Source: © Andrew_Howe/Getty Images)

These birds all have mitochondria in their red blood cells.

- (a) More than 90% of ATP is produced by mitochondrial respiration.

- (i) Describe how the remaining ATP is produced.

(2)

The remaining ATP is produced during glycolysis (anaerobic respiration) in the cytoplasm.

Glucose is converted to pyruvate, producing ATP by substrate-level phosphorylation.



- (ii) In the mitochondria, ATP is synthesised on the inner mitochondrial membrane.

Leakage of protons (H^+) across the inner mitochondrial membrane reduces ATP synthesis and generates more heat. This is called leaked respiration.

Explain why leakage of protons reduces ATP synthesis.

(3)

Leakage of protons back across the inner membrane means the proton (electrochemical) gradient would be shallower.

So protons would flow through ATP synthase more slowly.

Therefore there is less energy for the phosphorylation of ADP, so less ADP + P_i is converted to ATP.

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(b) The table shows some information about adult coal tits, blue tits and great tits.

Species of bird	Length from head to tail / cm	Wing span / cm	Mass / g
Coal tit	11	19	11
Blue tit	12	18	11
Great tit	14	24	18

(i) Calculate the magnification of the photograph of the blue tit.

Measure from the top of the head to the tip of the tail.

(1)

$$\text{length on photo} = 41 \text{ mm} = 4.1 \text{ cm}$$

$$\text{magnification} = 4.1 \div 12$$

Answer $\times 0.34$

(ii) Calculate the length from head to tail : mass ratio for the **great tit**.

Give your answer to **one decimal place**.

(1)

$$14 : 18 = 0.78 : 1$$

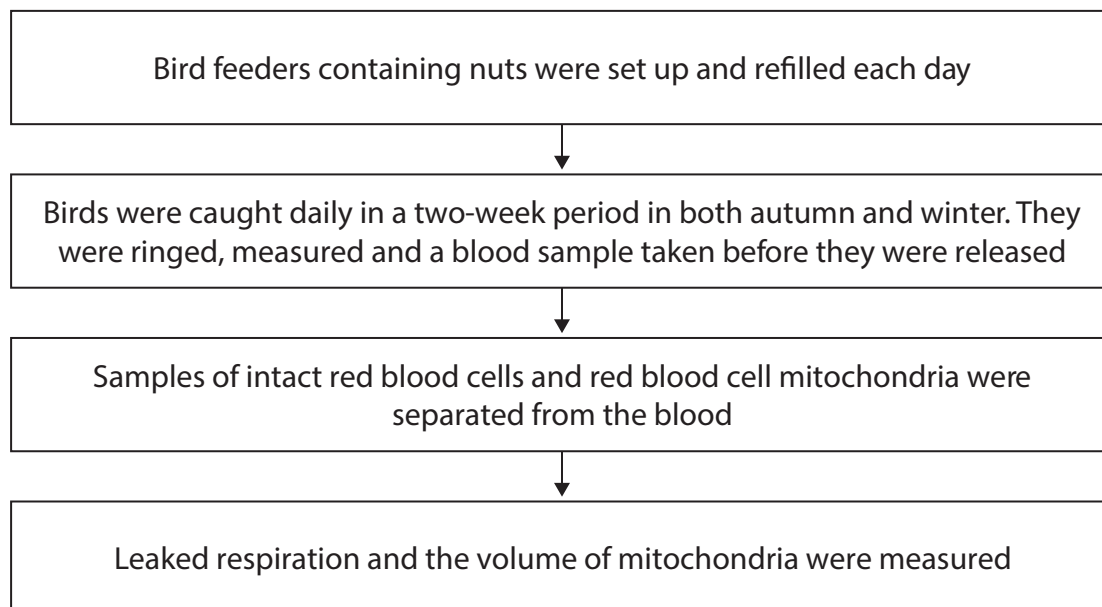
Answer $0.8 : 1$



- (c) The generation of heat by red blood cell mitochondria in these birds in autumn and winter was investigated.

The mean air temperature in autumn was 10.7 °C and in winter 7.2 °C.

The flowchart shows some of the stages in this investigation.



- (i) Explain why well-stocked bird feeders containing nuts were available throughout this investigation.

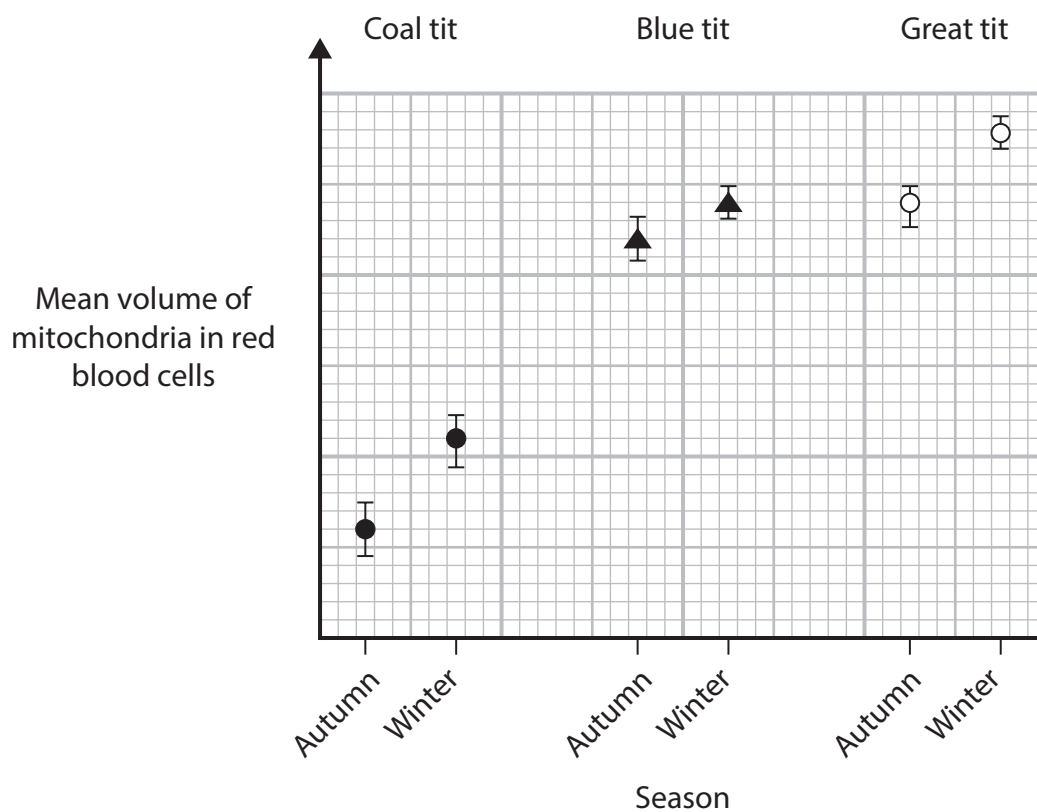
(2)

To attract the birds to the feeders so that they could be caught.

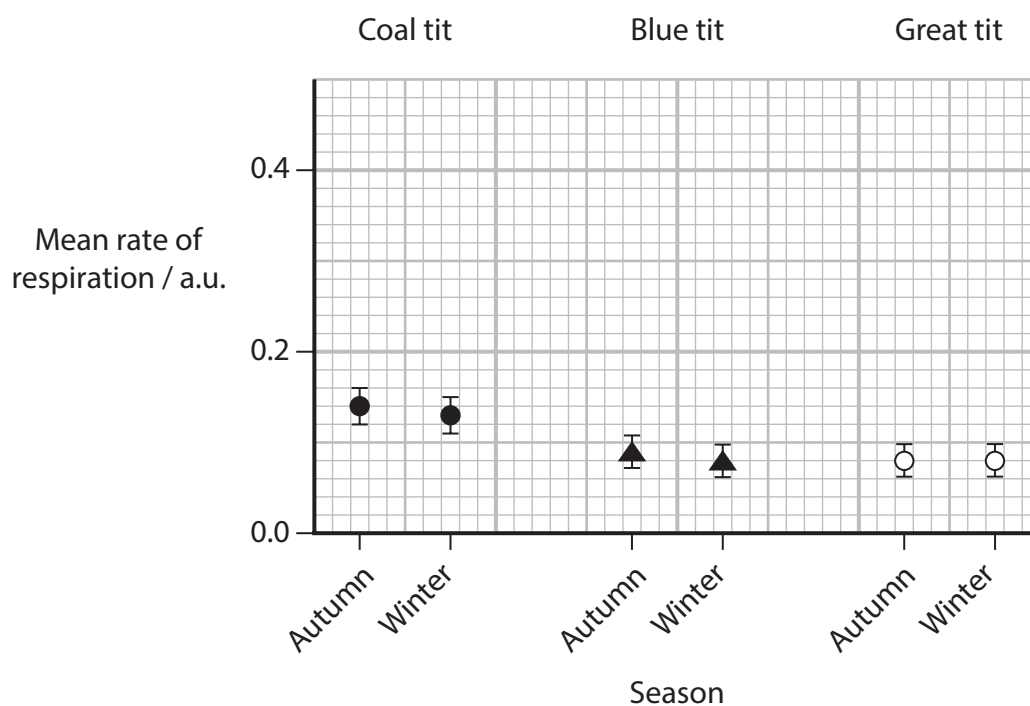
So that all birds had plenty to eat, so their respiration would not be limited by the energy source, making the investigation valid.

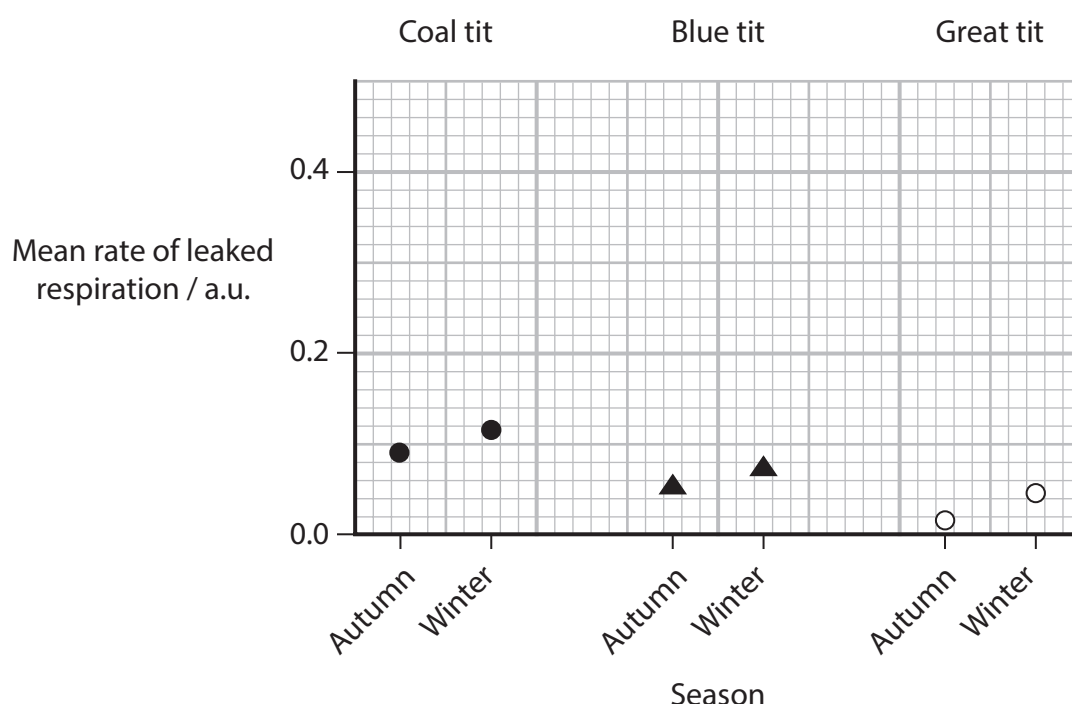
*(ii) The graphs show the results of this investigation.

Graph 1: volume of mitochondria



Graph 2: respiration producing ATP



Graph 3: leaked respiration

Explain the results of this investigation.

Use all the information in the question to support your answer.

(6)

Graph 1: great tits have the largest volume of mitochondria, then blue tits, then coal tits. Bigger birds need to produce more ATP for flying, while coal tits are smaller so need less ATP. All three species increase their volume of mitochondria in winter, by division of mitochondria. The error bars between autumn and winter do not overlap, so these differences are significant. A greater volume is needed in winter because more heat must be generated to keep warm in the colder season, by more leaked respiration.

Graph 2: coal tits respire (produce ATP) faster than blue tits and great tits, even though they have fewer mitochondria. There is no significant difference between blue tits and great tits, as the error bars overlap. Great tits show no difference between autumn and winter, but the rate decreases slightly in winter in blue tits and coal tits, because they switch to leaked respiration to produce more heat. With leaked respiration the proton gradient is smaller, so less ATP is made.

Graph 3: the rate of leaked respiration is faster in all three species in winter, because leaked respiration produces more heat. It is fastest in coal tits, then blue tits, then great tits, as smaller birds have a larger surface area : volume ratio and therefore lose more body heat. There are no error bars on graph 3, so we cannot say if these differences are significant.

(Total for Question 7 = 15 marks)



- 8 Changes must occur to mammalian sperm cells as they pass through the female reproductive tract, if successful fertilisation is to take place.

Capacitation results in changes to the sperm cell membrane and increased motility.

The acrosome reaction (AR) must follow capacitation but not too soon nor too late.

- (a) Explain why the timing of the AR is important for successful fertilisation.

(3)

If the AR happens too early, the enzymes in the acrosome will have been released

before the sperm reaches the egg, so they will not be available for fertilisation.

So the sperm will not be able to digest through the zona pellucida (jelly coat).

If the AR happens too late, the egg (or sperm) may have died, or the sperm may have

swum past the egg.



(b) A protein is involved in the timings of capacitation and the AR.

This protein exists in two forms: protein G and protein G-P.

Protein G-P results in the stimulation of capacitation and protein G results in the inhibition of the AR.

Protein G-P is located in the midpiece (neck) and flagellum of the sperm.

Protein G is located in the head region of the sperm.

The levels of these two forms of protein change just before capacitation, during capacitation and just before the AR.

Complete the table to show which form of protein is present and which is absent.

If the protein is present put a tick (✓) in the box and if the protein is absent put a cross (✗) in the box.

(4)

Event	Presence of protein G		Presence of protein G-P	
	Head region	Midpiece and flagellum	Head region	Midpiece and flagellum
Just before capacitation	✓	✗	✗	✓
During capacitation	✓	✗	✗	✓
Just before the AR	✗	✗	✓	✓

(c) In some infertile males, the gene coding for protein G is methylated.

Explain why DNA-methylation of this gene could result in infertility.

(3)

DNA methylation is a form of epigenetic modification that silences (switches off) the gene.

The methyl groups prevent transcription factors (RNA polymerase) binding to the DNA, so the gene cannot be transcribed and no protein G will be produced.

Without protein G the AR is not inhibited, so the timings of capacitation and the AR will be wrong: the AR will happen too soon, so fertilisation cannot take place.



(d) Scientists have used 'knockout' mice to investigate the effect of protein G on fertility.

(i) State the meaning of the term 'knockout' mice, as used in this context.

(2)

Genetically modified laboratory mice,

in which the gene coding for protein G has been inactivated (knocked out) or replaced,

so protein G is not expressed.

(ii) In an investigation, female mice and 'knockout' mice were housed together.

Describe how this investigation should be designed to confirm that protein G affects fertility.

(3)

All the female mice must be fertile, e.g. have already produced offspring.

Set up a control group of fertile male mice that have not had the gene modified,

housed with the same number of fertile females.

Use mice of the same species, strain and age, kept on the same diet and conditions.

Measure the pregnancy rate (the number of offspring produced) in each group over the

same time and compare them.

(Total for Question 8 = 15 marks)

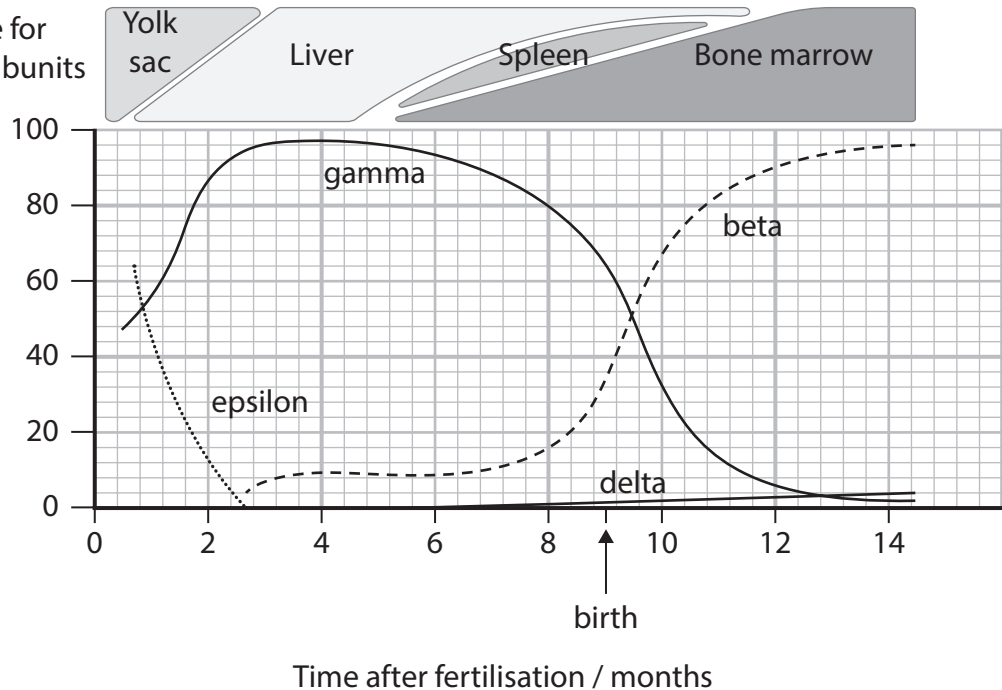


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9 The structure of haemoglobin changes as the embryo develops into a fetus and after the child is born.

(a) The graph shows the changes in the synthesis of four globin subunits (beta, gamma, delta, epsilon) during these stages of development.

Structures responsible for synthesising globin subunits



(i) Explain why there is no synthesis of globin subunits in the first few days after fertilisation.

(3)

In the first few days the embryo is increasing in cell number by mitosis.

All the cells are unspecialised (have not differentiated), so they have no genes switched on to produce the globin subunits.

Also, no yolk sac has developed yet, so there is no structure to synthesise globin subunits.

- (ii) Analyse the data to describe conclusions that can be made about globin subunit synthesis during the 14 months following fertilisation.

(4)

The structure responsible for synthesising the globin subunits changes with time after fertilisation: yolk sac, then liver and spleen, then bone marrow.

The yolk sac is responsible for synthesis of epsilon globin, while the liver synthesises mainly gamma globin (and some beta).

The embryo and fetus contain gamma globin plus either epsilon or beta globin (and some delta), so mainly gamma is made before birth.

After birth the baby has increasing levels of beta (and delta) globin and decreasing levels of gamma globin, as the bone marrow synthesises both components of adult haemoglobin (beta and delta).

- (iii) Calculate the rate of decrease in percentage of gamma globin subunit synthesis from 7.6 to 10 months after fertilisation.

Give your answer to **two decimal places** with appropriate units.

(2)

at 7.6 months = 84%, at 10 months = 32%

$(84 - 32) \div (10 - 7.6) = 52 \div 2.4 = 21.666...$

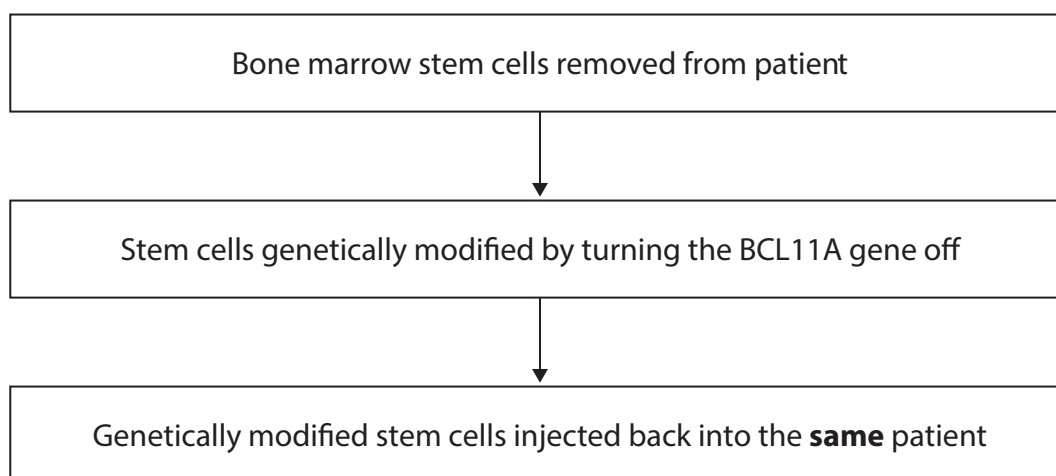
Answer *21.67 % month⁻¹*



(b) Sickle cell disease (SCD) is an inherited disorder.

A new treatment for SCD is being developed that involves genetic modification.

The flowchart shows some of the stages in this process.



- (i) There are approximately 67 million people in the UK, 15 000 of these people are affected by SCD.

Calculate the ratio of the number of people **without** SCD to the number of people **with** SCD in the UK.

Express your answer in **whole numbers**.

(2)

$$67\,000\,000 - 15\,000 = 66\,985\,000$$

$$66\,985\,000 : 15\,000 = 4465.67 : 1$$

Answer **4466 : 1**



- * (ii) The product of the BCL11A gene regulates the switch from the synthesis of fetal to adult globin subunits.

Analyse all the information in this question to discuss how this approach could provide a cure for SCD and the ethical issues surrounding this treatment.

Use your own knowledge to support your answer.

(6)

SCD is caused by a mutation in the gene coding for the beta globin subunit, which causes red blood cells to change to a sickle shape and reduces the oxygen supply to body cells. Fetal haemoglobin contains gamma globin, which is switched to beta globin around birth.

This switch is due to the product of the BCL11A gene. If BCL11A is switched off there is no transcription, so the BCL11A product is not produced. Therefore gamma globin will still be produced, so fetal haemoglobin is made, which is not defective and has a higher affinity for oxygen. So the red blood cells will no longer be sickle shaped. Bone marrow stem cells are used as they produce haemoglobin after birth. They divide by mitosis to produce genetically identical cells that all contain the modified BCL11A gene, giving a long-term cure. The patient's own cells have no foreign antigens, so there is no immune response or rejection and no immunosuppressants are needed.

Ethics: this is a new technology, so there is little evidence that it will work in the long term or that there are no unanticipated changes, and the long-term effects of GM are not known. Modified cells may become cancerous. The treatment is expensive, so who will it be available to? Extracting bone marrow is painful and young children cannot consent. However, the cells are taken from the patient, not an embryo, the changes will not be inherited, and the treatment would save lives.

(Total for Question 9 = 17 marks)

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