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Candidate surname

StemUp Model Solution

Other names

**Pearson Edexcel
Level 3 GCE**

Centre Number

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Candidate Number

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Thursday 6 June 2019

Morning (Time: 1 hour 45 minutes)

Paper Reference **9BI0/01**

Biology B

Advanced

**Paper 1: Advanced Biochemistry,
Microbiology and Genetics**

You must have:

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.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- You may use a scientific calculator.
- In questions 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.

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.*

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.

Write your answers in the spaces provided.

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 The nucleic acids, DNA and mRNA, are polymers.

(a) The table shows some components that may be found in a molecule of these nucleic acids.

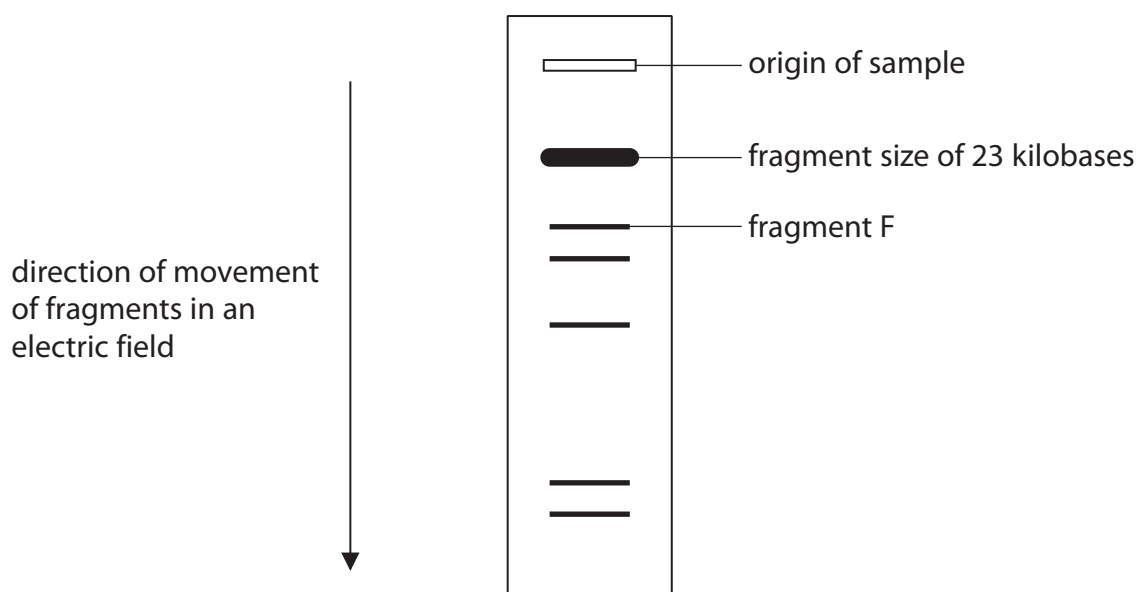
For each component, put **one** cross ☒ in the appropriate box, in each row, to show where these components can be found.

(4)

Component	Component found in a molecule of			
	both DNA and mRNA	DNA but not mRNA	mRNA but not DNA	neither DNA nor mRNA
Adenine	☒	☐	☐	☐
Hydrogen bonds	☐	☒	☐	☐
Pentose sugar	☒	☐	☐	☐
Uracil	☐	☐	☒	☐

(b) Fragments of DNA can be separated by gel electrophoresis to produce a DNA profile.

The diagram shows an example of a DNA profile.



- (i) Explain why fragments of DNA can be separated by gel electrophoresis.

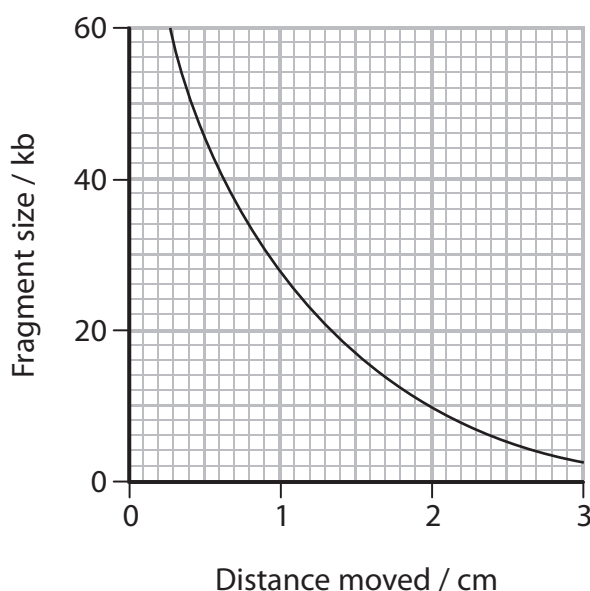
(2)

DNA fragments are negatively charged because of their phosphate groups.

So when a potential difference is applied, the fragments move through the gel towards the positive electrode (anode).

Smaller (lighter) fragments move further through the gel than larger (heavier) fragments, so the fragments separate by size.

- (ii) The graph shows the relationship between the distance moved in a gel and the fragment size.



Determine the size of fragment F.

(1)

Answer 8 kb

(Total for Question 1 = 7 marks)



2 Bacteria were cultured in two different types of medium.

One medium contained glucose as the energy source and the other contained sucrose.

The same molar concentrations of glucose and sucrose were used.

(a) Which row of the table identifies these sugars?

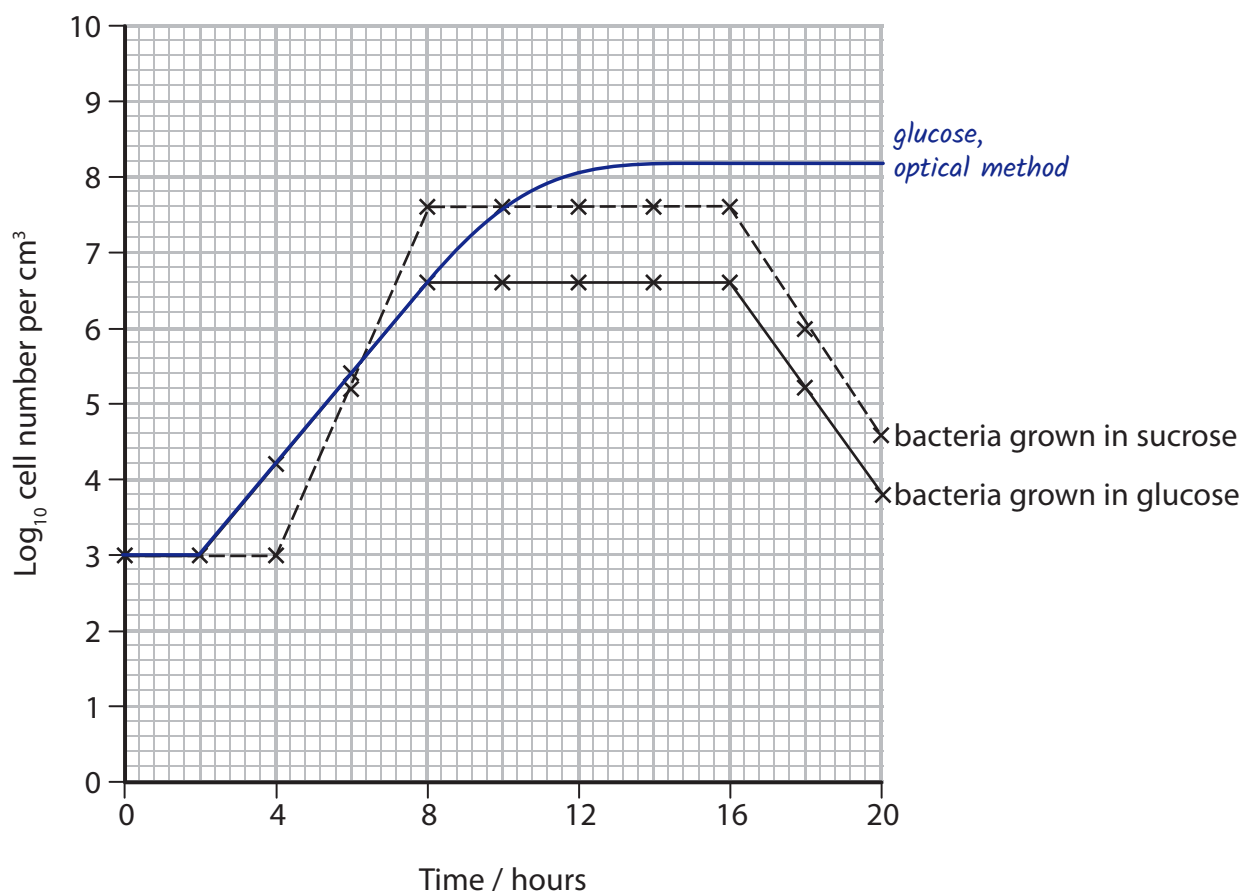
(1)

	Glucose	Sucrose
☐ A	monosaccharide	monosaccharide
☒ B	monosaccharide	disaccharide
☐ C	disaccharide	disaccharide
☐ D	disaccharide	monosaccharide

(b) Bacteria were grown in each medium for 20 hours.

Every two hours, the numbers of bacteria were determined using dilution plating and an optical method (turbidity).

The graph shows the results from the dilution plating.



- (i) Calculate how many times faster the bacteria in sucrose reproduce than the bacteria in glucose, during the log phase.

(2)

Log phase, 4 to 8 hours:

$$\text{sucrose: } (10^{7.6} - 10^{3.0}) \div 4 = (39\,810\,717 - 1000) \div 4 \\ = 9\,952\,429 \text{ cells per hour}$$

$$\text{glucose: } (10^{6.6} - 10^{4.2}) \div 4 = (3\,981\,072 - 15\,849) \div 4 \\ = 991\,306 \text{ cells per hour}$$

$$9\,952\,429 \div 991\,306 = 10.04$$

Answer 10 times

- (ii) Analyse the data to explain why the growth curve for sucrose is different from the growth curve for glucose.

(2)

The lag phase is longer in sucrose because sucrose has to be broken down (hydrolysed) first, so the enzyme sucrase had to be synthesised.

Reproduction is then faster in sucrose because sucrose is a disaccharide (glucose + fructose), so it provides more monosaccharides (energy) per molecule.

- (iii) On the graph, draw a curve to show the number of bacteria grown in glucose as determined by the optical method.

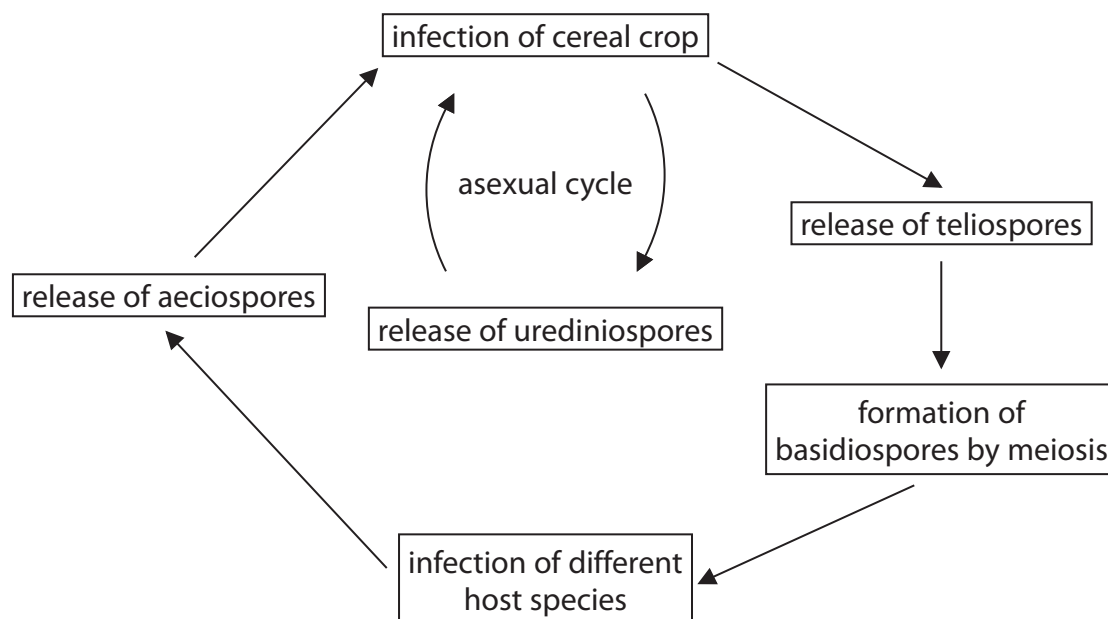
(1)

(Total for Question 2 = 6 marks)



3 The stem rust fungus is responsible for destroying cereal crops and reducing grain yield.

The diagram shows some stages in the life cycle of the stem rust fungus.



(a) Which genus does the stem rust fungus belong to?

(1)

- ☐ A *Plasmodium*
- ☒ B *Puccinia*
- ☐ C *Salmonella*
- ☐ D *Staphylococcus*



(b) Explain how stem rust fungus results in a reduction in grain yield.

(3)

The stem rust fungus takes up (uses) nutrients from the plant, such as glucose and amino acids.

So there is less glucose to form starch and fewer amino acids to form protein in the grain, and less glucose for respiration by the plant.

The fungus also interferes with (damages) the vascular tissue (xylem and phloem).

So less sucrose is transported to the grain and fewer magnesium ions reach the leaves for chlorophyll, and the stems are weakened.

(c) Cereal crops have been genetically modified (GM) to produce plants that are resistant to stem rust fungus.

Analyse the diagram to deduce why the formation of basidiospores and urediniospores can produce a stem rust fungus to which these GM plants are no longer resistant.

(3)

Basidiospores are formed by meiosis (sexual reproduction), which results in genetically different fungi (variation).

This is because of crossing over and independent assortment of chromosomes during meiosis.

A mutation in the DNA may also produce a fungus that the GM plants are not resistant to.

The asexual cycle (production of urediniospores) then produces many clones of this fungus, so more stem rust fungus that the plants are not resistant to spreads.

(Total for Question 3 = 7 marks)



4 (a) Photographs **P** and **Q** are electron micrographs of mitochondria.

Each photograph was taken using a different electron microscope.

Photograph **P**



Sourced from: <http://book.bionumbers.org/how-big-are-mitochondria/>

Photograph **Q**



Source: Cellupedia

(i) What is the structure labelled **S**?

(1)

- ☐ **A** crista
- ☒ **B** matrix
- ☐ **C** stroma
- ☐ **D** thylakoid

(ii) Explain the difference in appearance of the parts labelled **C** using the two different electron microscopes.

(2)

The resolution of the microscope used for P is lower (worse) than for Q.

So in P the small distance between the two membranes cannot be distinguished, whereas in Q the inner and outer membranes are seen as separate structures (two lines with the intermembrane space between them).



- *(b) The table shows the protein : lipid ratio of the inner and outer membrane of a mitochondrion.

Membrane of mitochondrion	Protein : lipid ratio
inner	3:2
outer	1:1

Explain the difference in the protein : lipid ratio of the inner and outer membrane of a mitochondrion.

(6)

Both membranes are made of a phospholipid bilayer with embedded proteins. The lipid content is the phospholipid bilayer, which provides fluidity and compartmentalisation. In the outer membrane the protein content equals the lipid content (1 : 1). Its proteins include channel proteins that allow pyruvate to pass through into the mitochondrion.

The inner membrane has a higher protein : lipid ratio (3 : 2), so it has more protein compared to lipid, because it is the site of oxidative phosphorylation (chemiosmosis), which synthesises ATP.

It contains the proteins of the electron transport chain. Reduced NAD and reduced FAD release electrons, which pass along these electron carriers, releasing energy. This energy is used to pump protons (H^+) from the matrix into the intermembrane space, producing a proton gradient.

The inner membrane also contains many ATPase (ATP synthase) channel proteins.

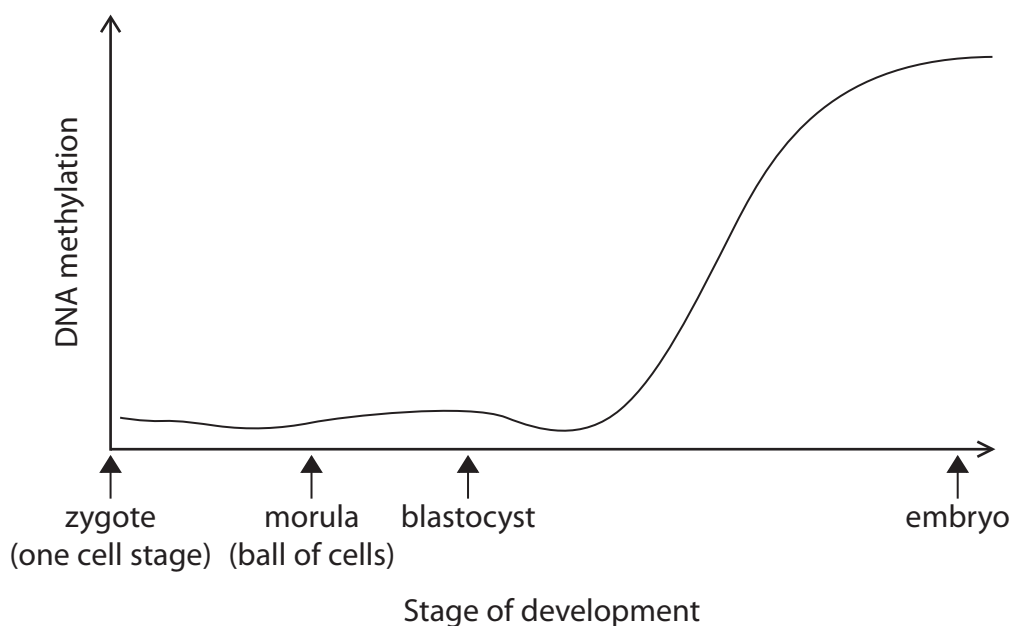
Protons diffuse back through the ATPase channels into the matrix, and this movement of protons results in ATP formation from ADP and P_i . Oxygen is the final electron acceptor, combining with electrons and protons to form water.

(Total for Question 4 = 9 marks)



5 (a) Epigenetic modifications are involved in the development of an embryo.

The graph shows the changes in DNA methylation during the development of an embryo from a zygote.



(i) State the meaning of the term DNA methylation.

(1)

A methyl group (CH_3) is added to a base in DNA, usually cytosine (at a CpG site).

(ii) Describe the differences between totipotent, pluripotent and multipotent stem cells during the development of an embryo.

(3)

The zygote and the cells of the morula are totipotent stem cells, because they can give rise to all cell types (including extra-embryonic tissue).

The inner cell mass of the blastocyst contains pluripotent cells, which give rise to most cell types, i.e. the cells of the embryo but not the extra-embryonic tissue.

Cells in the developing embryo are multipotent, as they can only become some cell types (e.g. blood cells).

(iii) Analyse the graph to explain why DNA methylation is involved in the development of an embryo.

(2)

The level of DNA methylation stays low until the blastocyst stage and then increases after the blastocyst stage.

Methylation switches off (silences) genes, so they cannot be transcribed or expressed.

This causes the cells to become specialised (differentiated) as the embryo develops.

(b) Explain why some cells are not able to become other cell types.

(2)

Because they are fully differentiated (specialised) cells.

Therefore the genes needed for other cell types are permanently switched off (silenced), so the proteins needed by other cell types cannot be produced.

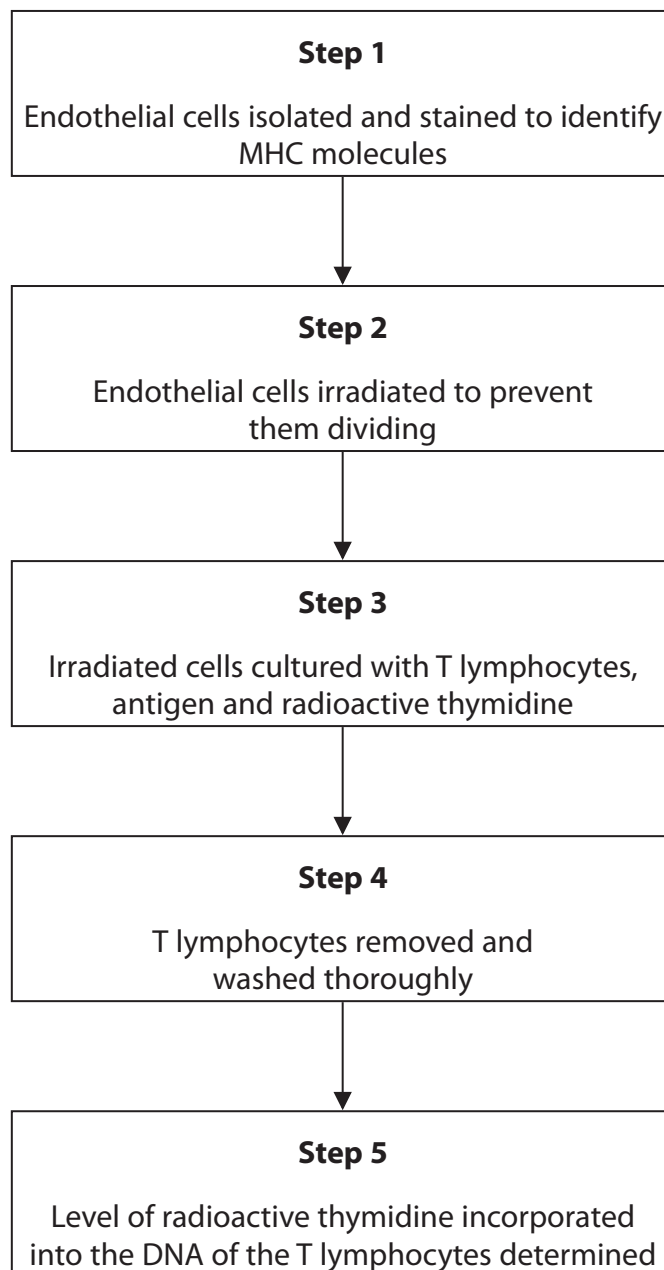
(Total for Question 5 = 8 marks)



- 6 Cell division can be measured using radioactive thymidine. This molecule is used in the synthesis of new DNA molecules.

A scientist investigated the ability of endothelial cells to present antigens.

The flow chart shows some of the steps involved in this investigation.



- (a) Explain why the scientist looked for the presence of MHC molecules on the endothelial cells, in Step 1.

(2)

MHC molecules are needed if the endothelial cells are to present antigen (be antigen presenting cells), as antigen binds to MHC molecules.

The MHC-antigen complex binds to the CD4 receptor on T helper cells, activating them.

- (b) Irradiation prevents cells from dividing.

Explain why the endothelial cells were irradiated in Step 2, before they were cultured with T lymphocytes and antigen.

(2)

Irradiation stops DNA replication in the endothelial cells, because dividing cells take up the radioactive thymidine for DNA synthesis.

So any radioactive thymidine uptake will be by the T cells only, and only T cell division is measured.

- (c) Explain why the T lymphocytes needed to be washed thoroughly in Step 4.

(2)

To remove any radioactive thymidine that was not taken up into the DNA of the T lymphocytes.

Otherwise this would result in an overestimate of the thymidine present (and the number of T cells), giving an inaccurate result.

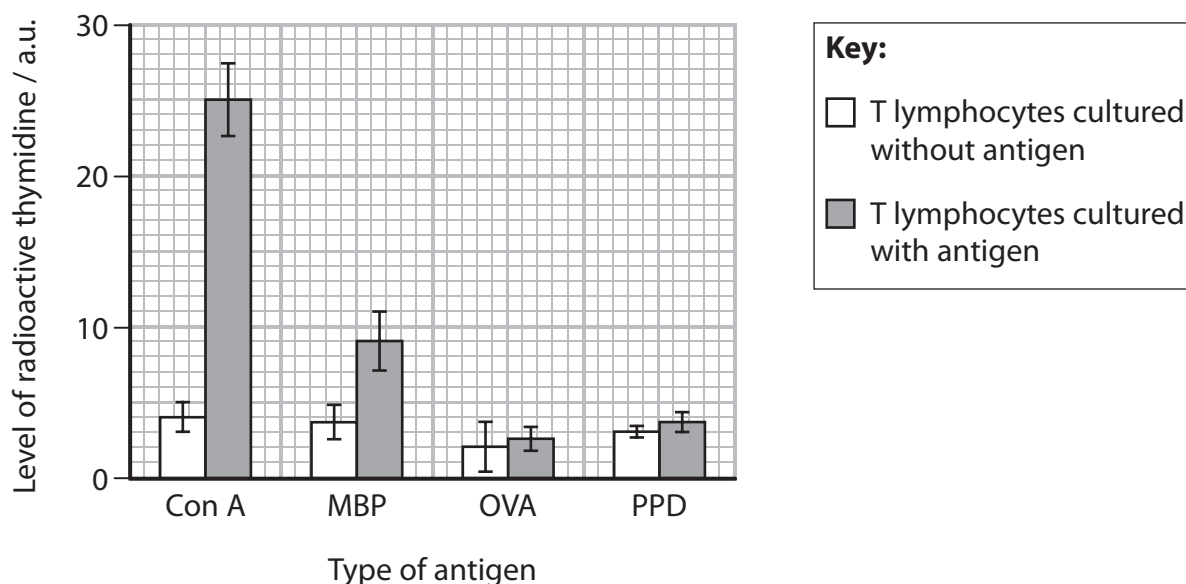


- (d) In this investigation, the ability of the endothelial cells to present four different types of antigen was assessed.

T lymphocytes were cultured with endothelial cells and antigen.

This was repeated using T lymphocytes cultured with endothelial cells and no antigen.

The graph shows the results of this investigation.



- (i) Explain why T lymphocytes were cultured with and without the antigen.

(2)

Without antigen, it determines any passive uptake of radioactive thymidine, i.e. whether T cells take up thymidine without antigen present.

Comparing with and without antigen shows that the antigen is stimulating the T cells to divide.

- (ii) Analyse the data to explain the conclusions that can be drawn from this investigation.

(3)

Endothelial cells are best at presenting Con A and MBP: these have the highest level of thymidine and their error bars do not overlap with the control (no antigen).

Endothelial cells are least effective at presenting OVA and PPD, which are not presented.

This is because there is very little difference between antigen and no antigen (control), and their error bars overlap with the control.

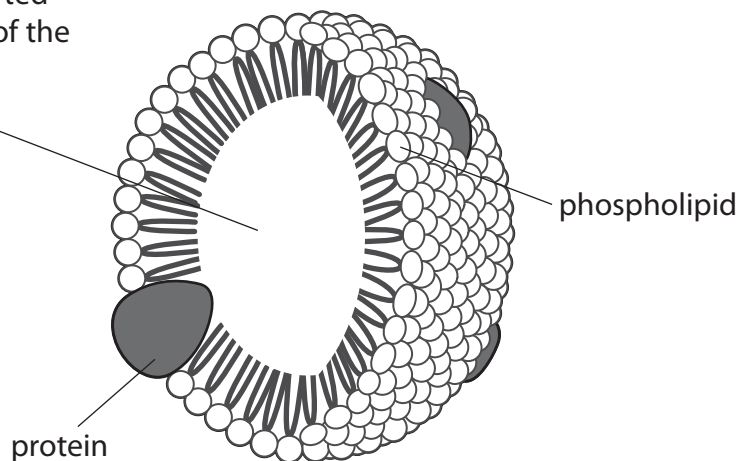
(Total for Question 6 = 11 marks)



- 7 High density and low density lipoproteins are spherical structures that transport cholesterol and fatty acids in the bloodstream.

The diagram shows a lipoprotein.

cholesterol and fatty acids transported in the centre of the lipoprotein



- (a) Explain why the properties of lipoproteins enable cholesterol and fatty acids to be transported in the bloodstream.

(3)

Cholesterol and fatty acids are hydrophobic (non-polar), so they cannot be carried dissolved in the blood plasma.

The phospholipid tails are hydrophobic, so cholesterol and fatty acids can be carried inside the lipoprotein.

The protein and the phospholipid heads on the outside of the lipoprotein are hydrophilic (polar), so the lipoprotein can be transported in the bloodstream.



(b) The table shows some information about two types of lipoprotein, high density lipoprotein (HDL) and low density lipoprotein (LDL).

Information about lipoproteins	HDL	LDL
density range / g cm ⁻³	1.063 to 1.210	1.019 to 1.063
typical diameter / nm	8	22
typical volume / nm ³	268	5572
percentage of protein (%)	50	20

(i) Complete the table to show the volume of a typical LDL using the formula:

$$\frac{4}{3}\pi r^3 \quad \text{where } \pi = 3.14$$
(2)

$$r = 22 \div 2 = 11 \text{ nm}$$

$$V = \frac{4}{3} \times 3.14 \times 11 \times 11 \times 11 = 5572.45$$

$$V = 5572 \text{ nm}^3$$

(ii) Analyse the information to explain why LDLs have a lower density range than HDLs. (2)

In the LDL there is less protein (20% compared with 50%) contained in a larger volume, and protein is denser than phospholipid.

So the LDL has fewer molecules in relation to its size (a larger hole in the middle).



(iii) Explain why raised levels of LDLs may increase the risk of heart disease.

(4)

Cholesterol is a risk factor for heart disease, as LDLs transport cholesterol from the liver to the body cells.

So raised LDLs mean more cholesterol in the blood.

Cholesterol builds up in the walls of the coronary arteries, forming an atheroma (plaque), which narrows the lumen.

This reduces the flow of blood to the heart tissue (cells).

Therefore there is a lack of oxygen for aerobic respiration in the heart muscle cells, which can cause a heart attack (myocardial infarction).

(Total for Question 7 = 11 marks)

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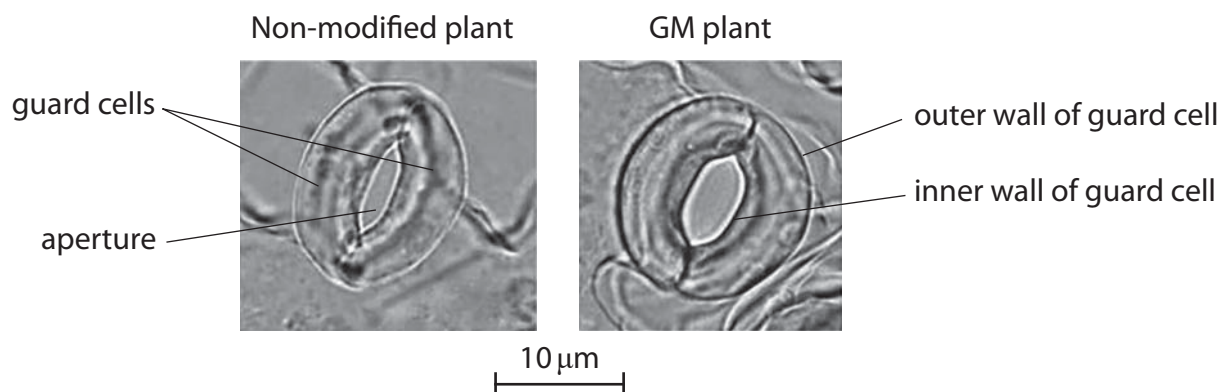
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- 8 Genetically modified (GM) crop plants have been produced that have stomata with a wider aperture than non-modified crop plants.

This difference in the width of the aperture is only evident in daylight.

The photographs show the appearance of each type of stoma in daylight.



Sourced from: http://www.aip.nagoya-u.ac.jp/en/public/nu_research/images/Wang_f1.jpg

- (a) (i) Calculate the magnification of the GM plant photograph using the scale bar.

Give the answer in standard form.

(2)

$$\text{length of scale bar} = 17 \text{ mm} = 17\,000 \mu\text{m}$$

$$\text{magnification} = 17\,000 \div 10 = 1700$$

Answer 1.7×10^3

- (ii) Calculate how many times wider the aperture of the stoma of the GM plant is compared with the stoma of the non-modified plant.

(1)

$$\text{GM aperture width} = 6 \text{ mm}, \text{ non-modified} = 3.5 \text{ mm}$$

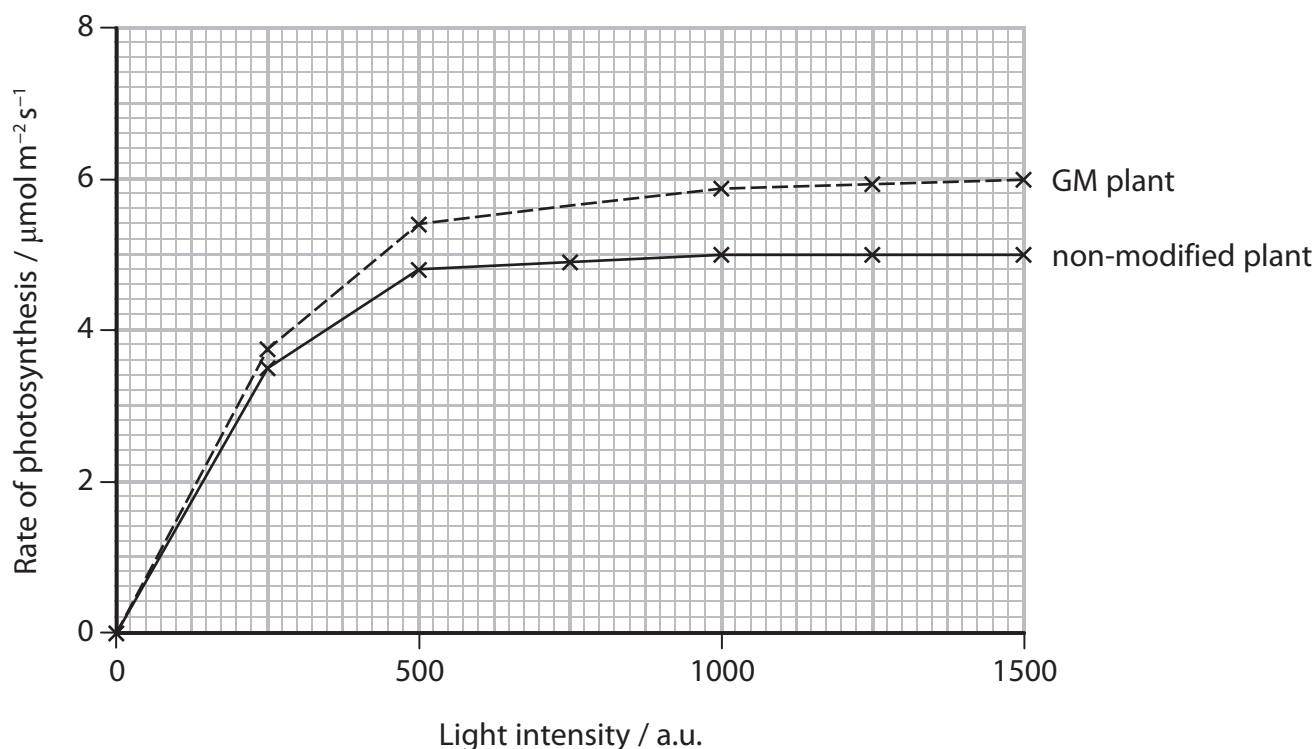
$$6 \div 3.5 = 1.7$$

Answer 1.7



- (b) An investigation was carried out to compare the effect of light intensity on the rate of photosynthesis in GM plants with the effect in non-modified plants.

The graph shows the results of this investigation.



- (i) The rate of photosynthesis is expressed as $\mu\text{mol m}^{-2} \text{s}^{-1}$.

Describe what was measured to find the rate of photosynthesis.

(3)

The number of μmol of carbon dioxide used (taken up), or of oxygen produced, by the leaf.

m^{-2} : per square metre, the area of the leaf.

s^{-1} : per second, e.g. measure the amount of carbon dioxide used over 120 seconds and divide by 120.



(ii) Explain the results of this investigation.

(3)

As light intensity increases, the rate of photosynthesis increases, and the GM plants photosynthesise faster than the non-modified plants.

The increase is greater in GM plants because the wider stomatal aperture results in more gas exchange (uptake of carbon dioxide).

Therefore the light-independent reactions (Calvin cycle, carbon fixation) are faster, as carbon dioxide is not limiting.

The rate levels off when another factor, such as carbon dioxide concentration or temperature, becomes rate limiting.

(c) Explain why the wider stomata in GM crop plants could increase their yield.

(3)

Faster photosynthesis results in more GALP (glucose) being produced.

This is used to form plant molecules such as starch, cellulose, proteins and lipids, increasing biomass.

The transpiration stream will also be faster through the wider stomata.

Therefore more mineral ions are taken up, e.g. magnesium ions for chlorophyll and nitrates for proteins.

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(d) The flow chart shows some of the steps involved in opening the aperture of a stoma.

Hydrogen ions actively transported out of the guard cells



Potassium ions diffuse into the guard cells



Starch broken down into malate



Water moves into the guard cells



Aperture of the stoma widens

(i) What happens when hydrogen ions are actively transported out of the guard cells? (1)

- ☐ A ADP and phosphate ions are converted into ATP by a hydrolysis reaction
- ☐ B ADP and phosphate ions are converted into ATP by a condensation reaction
- ☐ C ATP is broken down into ADP and phosphate ions by a condensation reaction
- ☒ D ATP is broken down into ADP and phosphate ions by a hydrolysis reaction

(ii) Which of the following explains why water moves into the guard cells? (1)

- ☒ A malate lowers the water potential of the cytoplasm
- ☐ B malate raises the water potential of the cytoplasm
- ☐ C starch lowers the water potential of the cytoplasm
- ☐ D starch raises the water potential of the cytoplasm



(iii) Which of the following explains why the aperture of the stoma widens?

(1)

- ☐ **A** The guard cells become smaller and the inner wall of the guard cell is more flexible than the outer wall
- ☐ **B** The guard cells become smaller and the inner wall of the guard cell is less flexible than the outer wall
- ☐ **C** The guard cells become larger and the inner wall of the guard cell is more flexible than the outer wall
- ☒ **D** The guard cells become larger and the inner wall of the guard cell is less flexible than the outer wall

(Total for Question 8 = 15 marks)

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9 Doxorubicin (Dox) is a drug used to treat cancer.

(a) Cancer is caused when cells divide uncontrollably.

This drug works in two ways:

- it becomes inserted into the DNA and holds the two strands together.
- it binds to an enzyme that repairs DNA.

Explain how Dox prevents cancer cells from dividing.

(5)

DNA synthesis (replication) is needed for mitosis (cell division). Without it the cell remains in interphase.

Dox holds the two strands together, so it prevents the DNA strands separating and prevents DNA synthesis, because the strands are not available for free nucleotides to align (pair).

Dox also prevents transcription, as RNA polymerase and transcription factors cannot bind (to promoters), so mRNA cannot be made and no proteins are synthesised.

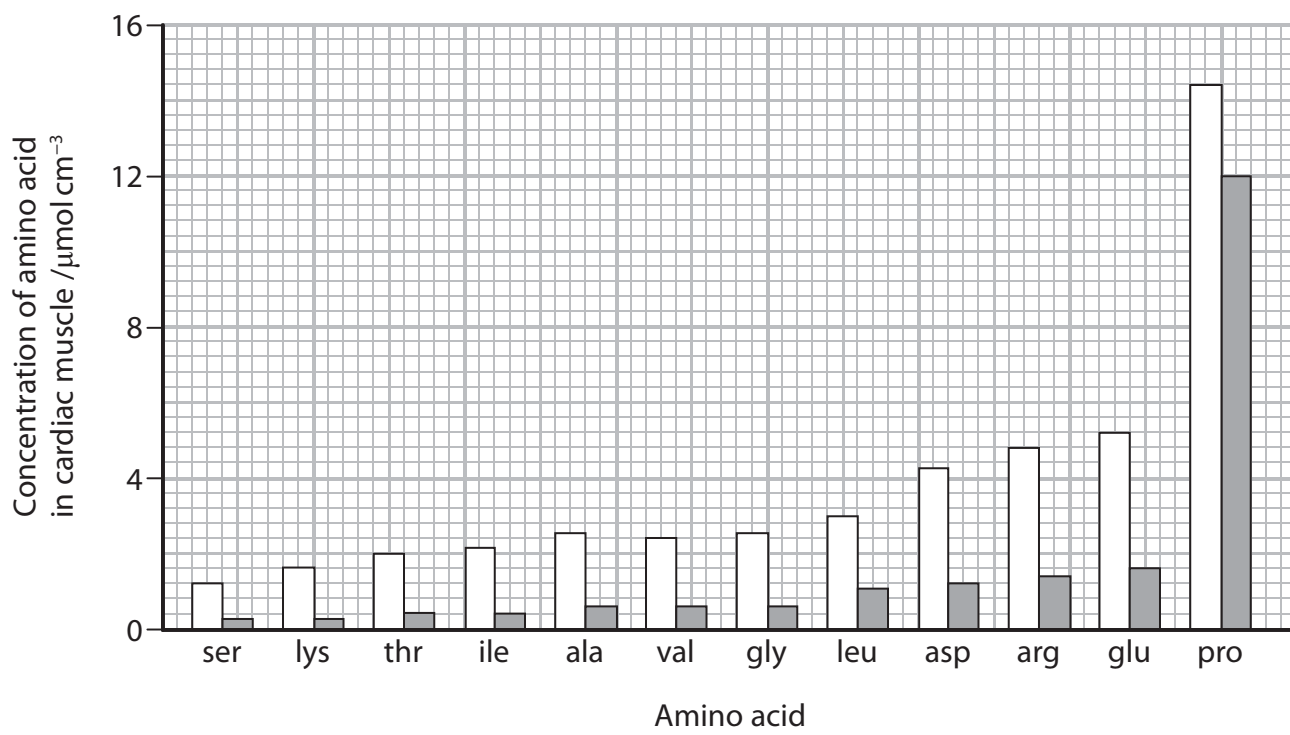
Dox binds to the repair enzyme, so the repair enzyme will not be able to remove the drug, and the damaged DNA is not repaired, so the cell cycle stops (the cells are destroyed).



(b) Weakening of the cardiac muscle is one side effect of using Dox.

The effect of Dox on the concentration of several amino acids in cardiac muscle was investigated.

The graph shows the results of this investigation.



Key:

- before treatment with Dox
 ■ after treatment with Dox

The table shows some non-polar and polar amino acids.

Type	Amino acids
non-polar	ala, gly, ile, leu, pro, val
polar	arg, asp, glu, lys, ser, thr

- * (i) Analyse the information to determine the effect of Dox on the concentration of these types of amino acid in cardiac muscle.

(6)

Dox decreases the concentration of all the amino acids shown in cardiac muscle, both polar and non-polar, although data are not available for all amino acids.

The largest actual decrease is for glu, $5.2 - 1.6 = 3.6 \mu\text{mol cm}^{-3}$, and the smallest actual decrease is for ser, $1.2 - 0.3 = 0.9 \mu\text{mol cm}^{-3}$.

Polar amino acids are affected most: their total decrease is $13.8 \mu\text{mol cm}^{-3}$ (mean 2.3) compared with $11.7 \mu\text{mol cm}^{-3}$ (mean 1.95) for the non-polar amino acids.

Within the polar group the actual decrease varies widely, from 0.9 (ser) to 3.6 (glu), but the percentage decrease is high for all, from 69% (glu) to 81% (lys).

Within the non-polar group the actual decrease is in a narrower range, 1.8 to $2.4 \mu\text{mol cm}^{-3}$, but the percentage decrease has a wider range: the least is pro, $2.4 \div 14.4 \times 100 = 17\%$, and the greatest is ile, 81%.

So Dox has a greater effect on polar amino acids, except that pro has the largest concentration and is least affected.



- (ii) Explain why a change in the concentration of amino acids results in the weakening of cardiac muscle.

(2)

A decrease in some amino acids means that certain proteins cannot be formed (less protein is made).

If these are structural proteins of heart muscle, such as actin, myosin or collagen, the muscle will be weaker, and proteins such as myoglobin and cytochromes affect heart muscle function.

- (iii) Explain how weakening of the cardiac muscle could affect a person.

(3)

The heart will not be able to pump (contract) as well, so the cardiac output falls.

So less oxygenated blood (oxygen) will be delivered to the cells, tissues and organs such as skeletal muscle, and less carbon dioxide is removed.

So there is less aerobic respiration, causing a build-up of lactic acid, fatigue and breathlessness.

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

