

Please check the examination details below before entering your candidate information

Candidate surname

StemUp Model Solution

Other names

Centre Number

--	--	--	--	--

Candidate Number

--	--	--	--

Pearson Edexcel Level 3 GCE

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.
- Show your working in 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 ►

P67087A

©2022 Pearson Education Ltd.

1/1/1/1/1/




Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. 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 pathogenic effects of bacteria can be due to the toxins they release.

(a) Endotoxins are released by Gram negative bacteria.

(i) Name **one** type of Gram negative bacteria that releases endotoxins.

(1)

Salmonella (or E. coli)

(ii) Give **one** difference between the structure of Gram negative bacteria and Gram positive bacteria.

(1)

Gram negative bacteria have a thinner peptidoglycan cell wall, surrounded by an outer membrane of lipopolysaccharide.

(b) Endotoxins are usually less toxic than exotoxins.

(i) The LD₅₀ value is the mass of the chemical per kg of body mass that would kill half the number of rodent animals.

The LD₅₀ value can be used to indicate how toxic a chemical is.

One endotoxin has an LD₅₀ value of 11 ng kg⁻¹.

The mean body mass of a group of rodents is 28 g.

Calculate the mass of endotoxin given to each rodent that would kill half of the rodents in this group.

(1)

$$LD_{50} \text{ for one rodent} = 11 \text{ ng kg}^{-1} \times 0.028 \text{ kg}$$

$$= 0.308 \text{ ng}$$

Answer *0.308* ng



(ii) State **two** differences, other than toxicity, between endotoxins and exotoxins.

(2)

Endotoxins are lipopolysaccharides (from the outer membrane), whereas exotoxins are proteins.

Endotoxins are released only from Gram negative bacteria when the bacteria die and break down, whereas exotoxins are released from living Gram negative and Gram positive bacteria.

(Total for Question 1 = 5 marks)



P 6 7 0 8 7 A 0 3 3 2

2 A zygote is formed when gametes fuse at fertilisation.

(a) Explain how meiosis results in genetic variation in the gametes.

(2)

Meiosis results in new combinations (recombination) of alleles.

This is due to independent assortment, as the pairs of homologous chromosomes line up randomly on the equator in meiosis I.

It is also due to crossing over, where genetic material is swapped between non-sister chromatids of homologous chromosomes.

(b) Describe how the process of fertilisation results in the formation of a zygote from the gametes in humans.

(3)

When the sperm makes contact with the secondary oocyte (zona pellucida), the acrosome reaction occurs: digestive enzymes are released from the acrosome.

The sperm cell membrane fuses with the oocyte membrane and the sperm nucleus enters, which triggers the oocyte to complete meiosis II.

The cortical reaction takes place: cortical granules release their contents, which harden the zona pellucida (fertilisation membrane) so no more sperm can enter.

The sperm nucleus fuses with the nucleus of the ovum, forming a diploid zygote.

(Total for Question 2 = 5 marks)



3 Malaria is a serious and sometimes fatal disease.

Scientists are constantly looking for new ways of controlling this disease.

- (a) Which row of the table shows the name of the pathogen that causes malaria, and its classification group?

(1)

	Name of pathogen	Classification group
☒ A	<i>Plasmodium</i>	genus
☐ B	<i>Plasmodium</i>	species
☐ C	<i>Puccinia</i>	genus
☐ D	<i>Puccinia</i>	species

- (b) One group of scientists has genetically modified a fungus to produce a spider toxin that kills mosquitoes.

Describe how a fungus could be genetically modified to produce spider toxin.

(3)

The gene (DNA) coding for the toxin is isolated from the spider, e.g. by making it from the mRNA using reverse transcriptase.

The gene is cut out using restriction enzymes (restriction endonucleases), and a vector such as a plasmid is cut with the same restriction enzyme.

The spider gene is inserted into the fungus using the vector (or a gene gun), sealed in with ligase.

The genetically modified fungi are identified, e.g. using marker genes, and then cloned and cultured.



- (c) Another group of scientists has discovered a type of fungus that completely protects mosquitoes from infection by the pathogen that causes malaria.

This fungus does not kill the mosquitoes.

Explain why this approach is less controversial than the approach used by the scientists who are developing the genetically-modified fungus.

(3)

It is not unethical, because the mosquitoes are not killed.

There is no risk of other organisms being harmed by the toxin or of the inserted gene transferring into other organisms (no unknown risks).

Organisms that feed on mosquitoes do not lose their food supply, so the food chain is not disrupted and biodiversity is maintained.

Also, some people believe that modifying DNA is wrong, so no genetic modification is involved.

(Total for Question 3 = 7 marks)



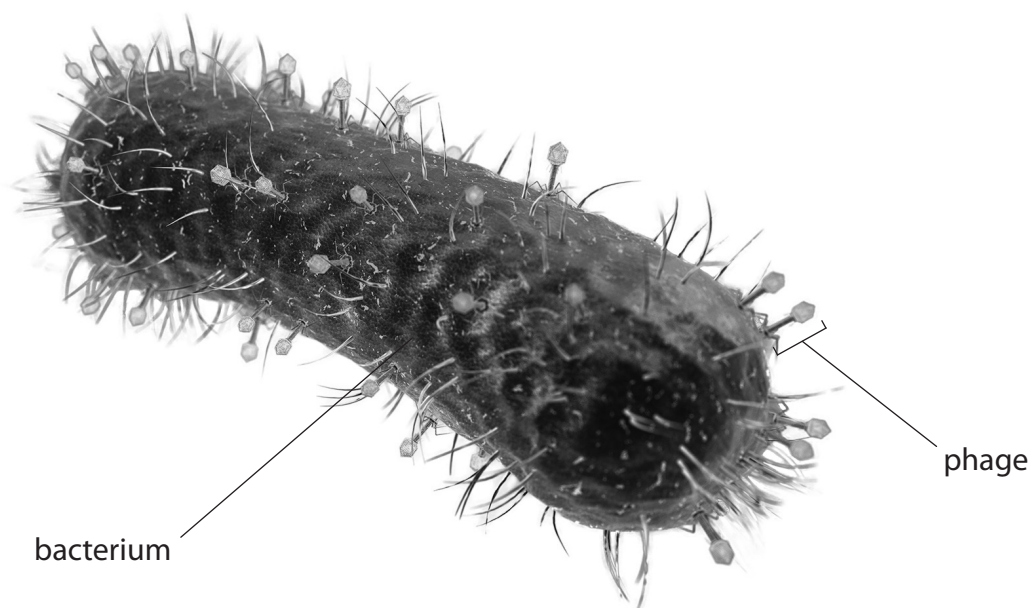
4 Bacteria are the host cells for λ (lambda) phage viruses.

(a) Which is a description of a λ phage?

(1)

- ☒ **A** DNA virus with a complex protein capsid
- ☐ **B** DNA virus with a helical protein capsid
- ☐ **C** RNA virus with a complex protein capsid
- ☐ **D** RNA virus with a helical protein capsid

(b) The image shows phage viruses attacking a bacterium.



(Source: © nobeastsofierce Science/Alamy Stock Photo)

The length of this bacterium is $1.7\text{ }\mu\text{m}$.

Calculate the length of the labelled phage.

Give your answer in nanometres (nm).

(2)

$$\text{length of bacterium in image} = 102\text{ mm} = 102\,000\text{ }\mu\text{m}$$

$$\text{length of phage in image} = 7.5\text{ mm} = 7500\text{ }\mu\text{m}$$

$$\text{magnification} = 102\,000 \div 1.7 = 60\,000$$

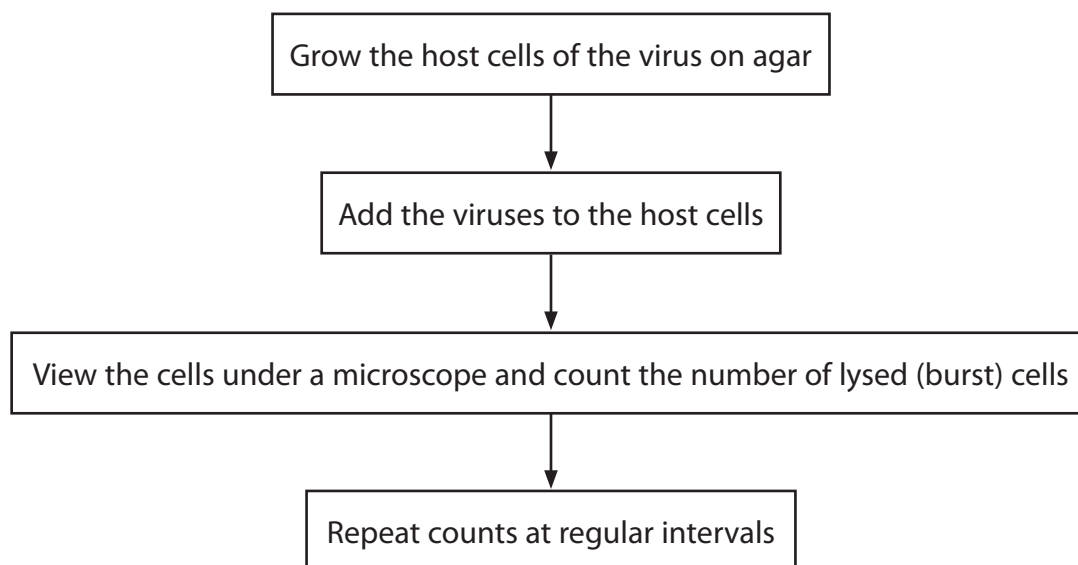
$$\text{actual length} = 7500 \div 60\,000 = 0.125\text{ }\mu\text{m} = 125\text{ nm}$$

Answer 125..... nm

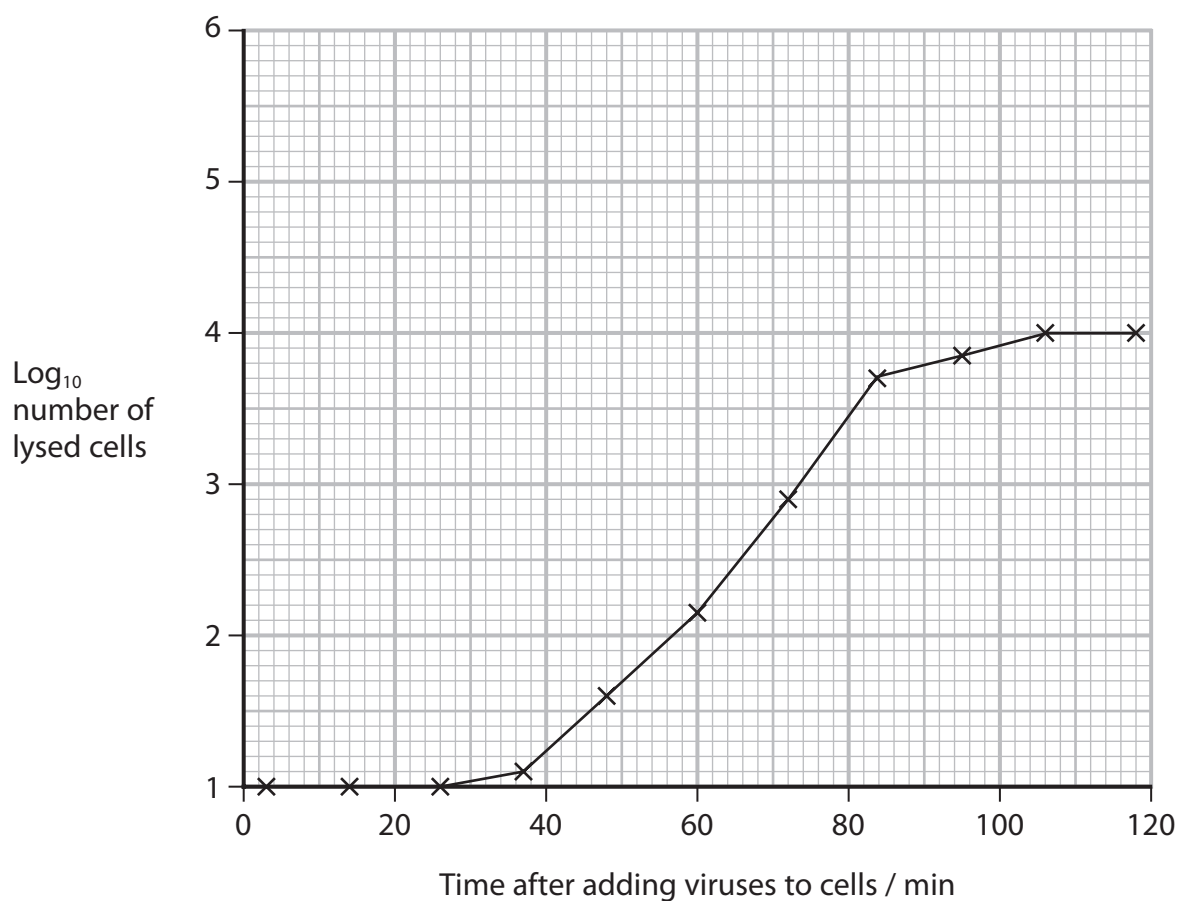


(c) Viruses can be cultured and a growth curve can be produced.

The flow chart shows how this can be done.



The graph shows a growth curve for viruses.



- (i) Explain why there was a delay before the number of lysed cells started to increase.

(3)

First the virus must attach to the host cells and inject its genetic material (DNA) into the host cell.

Then the viral DNA must be replicated (synthesis of DNA) using the host cell's enzymes and nucleotides.

The viral genes must be transcribed and translated (protein synthesis) to make capsid proteins, tail fibres and enzymes such as lysozyme.

Finally the new viruses must be assembled before the host cell lyses (bursts).

- (ii) Calculate the mean rate of increase in the actual number of lysed cells between 50 minutes and 90 minutes.

(2)

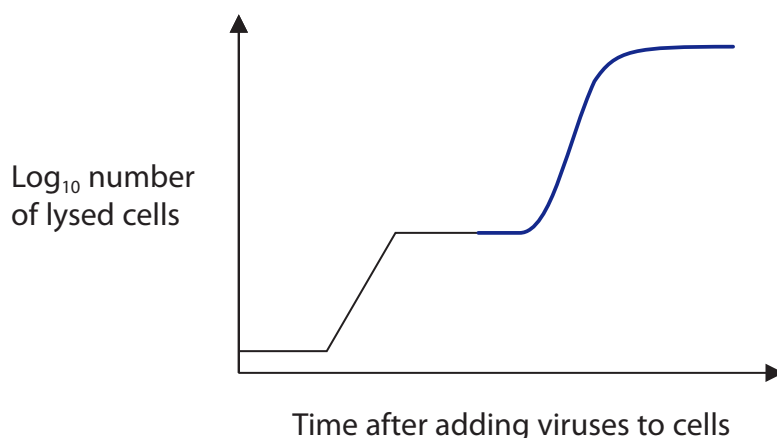
at 50 min: $\log = 1.7$, number = $10^{1.7} = 50$

at 90 min: $\log = 3.8$, number = $10^{3.8} = 6310$

rate = $(6310 - 50) \div 40 = 156$

Answer 156 cells min^{-1}

- (iii) A sketch has been made of this growth curve.



Complete this sketch to predict the shape of the growth curve after 120 minutes, assuming there is an excess of host cells.

(2)

(Total for Question 4 = 10 marks)



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

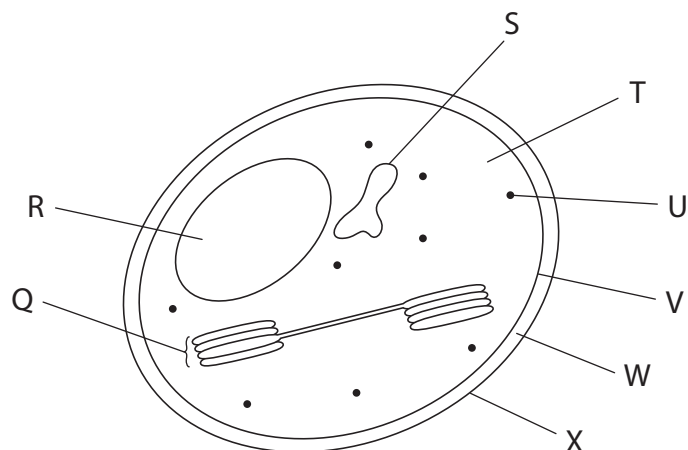
BLANK PAGE



- 5 The light-dependent stage and the light-independent stage of photosynthesis both take place in the chloroplast.

The rate of photosynthesis is affected by a number of different factors, including carbon dioxide concentration and temperature.

- (a) The diagram shows a chloroplast.



- (i) Where does the light-dependent stage take place?

(1)

- ☒ **A** Q
☐ **B** T
☐ **C** V
☐ **D** X

- (ii) The light-dependent stage produces hydrogen ions.

Where do these hydrogen ions accumulate?

(1)

- ☒ **A** Q
☐ **B** R
☐ **C** S
☐ **D** W

- (iii) Where does translation take place?

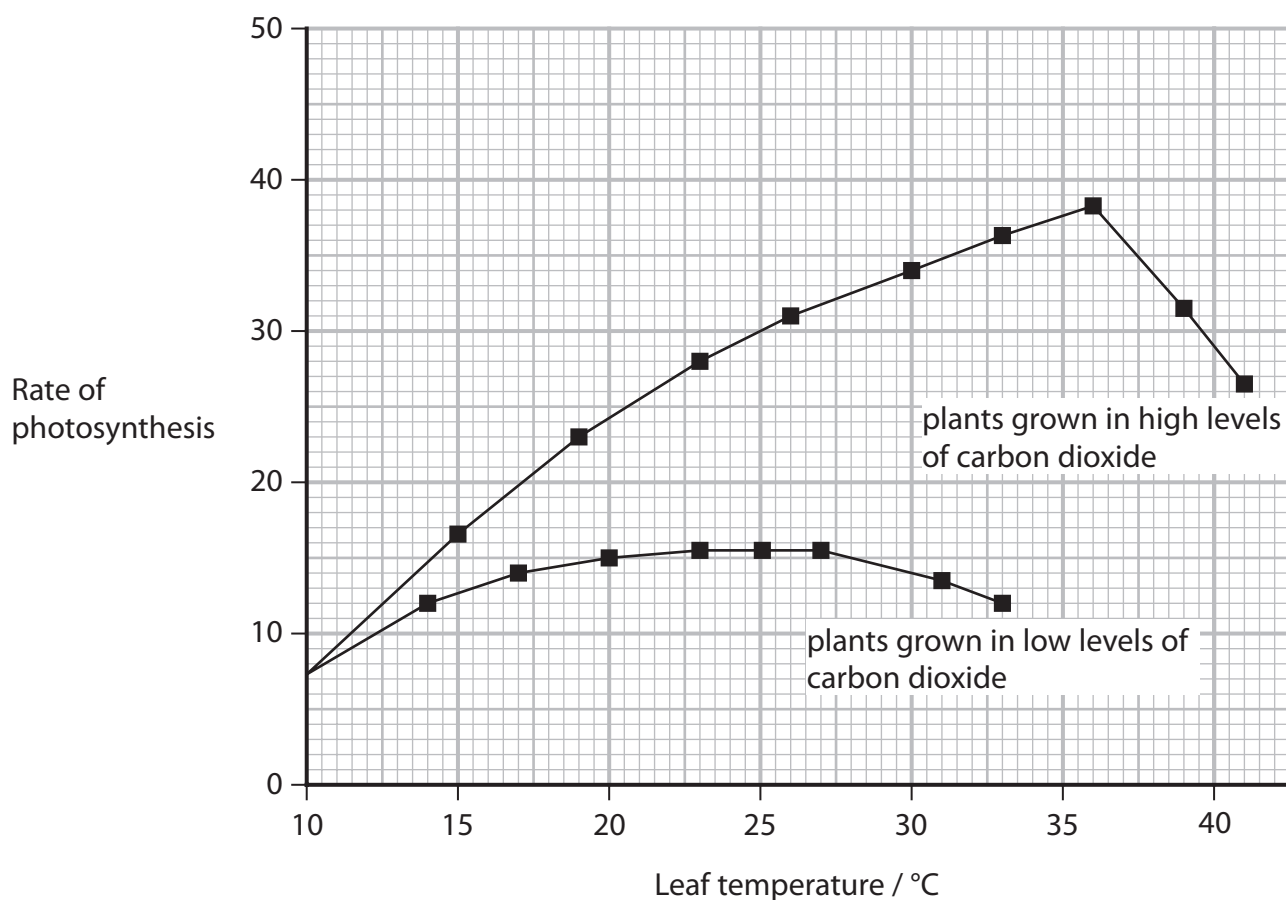
(1)

- ☐ **A** Q
☐ **B** R
☐ **C** S
☒ **D** U



- (b) Scientists measured the effect of two different concentrations of carbon dioxide on the rate of photosynthesis at different leaf temperatures, in one species of plant.

The results are shown in the graph.



- (i) Which units are suitable for measuring the rate of photosynthesis in leaves?

(1)

- ☐ A $\mu\text{mol m}^{-1} \text{sec}^{-1}$
- ☐ B $\mu\text{mol m}^{-1} \text{sec}^{-2}$
- ☒ C $\mu\text{mol m}^{-2} \text{sec}^{-1}$
- ☐ D $\mu\text{mol m}^{-2} \text{sec}^{-2}$



- (ii) Analyse the data to identify **three** conclusions that can be made from this graph.

(3)

As leaf temperature increases, the rate of photosynthesis increases, up to an optimum.

The rate of photosynthesis is faster in plants grown in high levels of carbon dioxide than in low levels, at all temperatures above 10°C.

The optimum temperature for photosynthesis is higher in high carbon dioxide (36°C) than in low carbon dioxide (about 25°C).

So the optimum conditions are high levels of carbon dioxide and a temperature of 36°C.

- (iii) Explain the effects of carbon dioxide concentration and temperature on the rate of formation of GALP.

(4)

More carbon dioxide and higher temperatures (below the optimum) mean more GALP is formed.

A higher carbon dioxide concentration means more carbon dioxide is available for carbon fixation in the light-independent stage (Calvin cycle), so carbon dioxide combines with RuBP faster.

Higher temperatures mean RUBISCO can catalyse carbon fixation faster, because the molecules have more kinetic energy, so there are more successful collisions and more enzyme-substrate complexes form.

Therefore more GP is formed, which is reduced (using ATP and reduced NADP) and converted into GALP. Above the optimum temperature RUBISCO denatures, so less GALP forms.

(Total for Question 5 = 11 marks)



- 6 The lipid content of the cell membranes of prokaryotic organisms changes in response to changes in the environmental temperature.

(a) Phospholipids form a bilayer in the cell membranes of bacteria.

Describe the structure of a phospholipid.

(2)

A phospholipid is made of one glycerol molecule attached to two fatty acids by ester bonds.

A phosphate group is attached to the third carbon of the glycerol, forming a hydrophilic head with two hydrophobic fatty acid tails.

- (b) The cell membranes of most organisms belonging to the domain Archaea are lipid monolayers.

The lipid that forms this monolayer is a bipolar lipid.

Explain why a bipolar lipid is a suitable molecule to form the cell membrane.

(2)

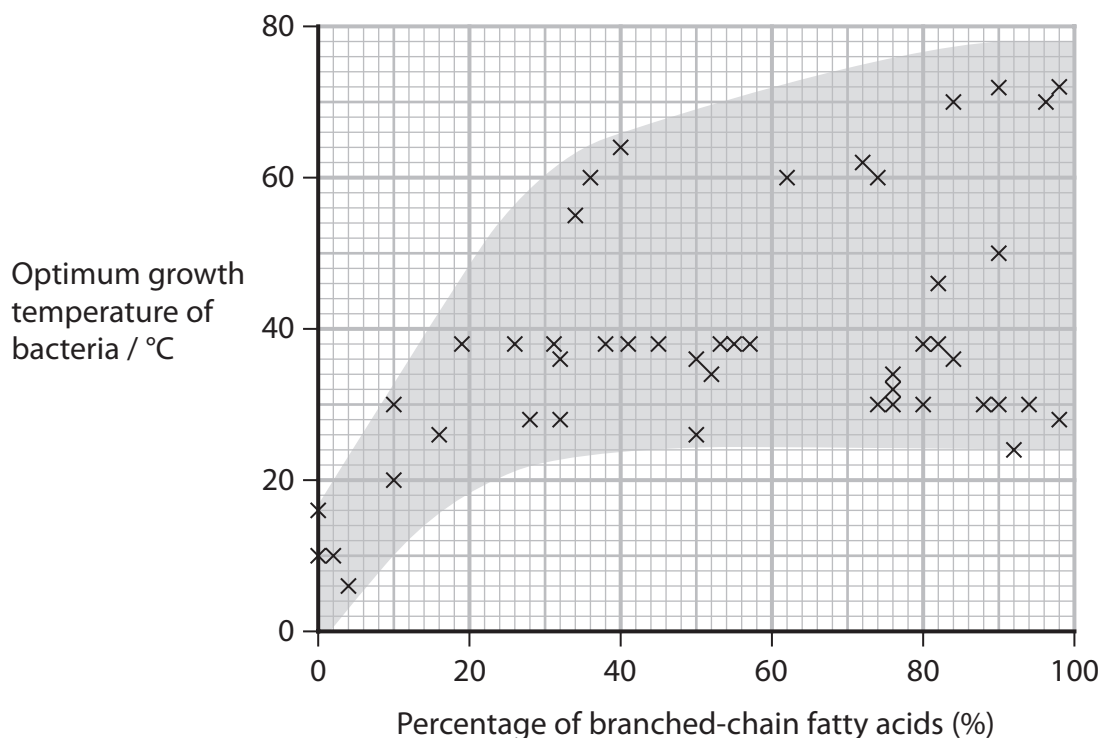
The two polar (hydrophilic) groups at each end interact with the aqueous environment on each side of the membrane, forming hydrogen bonds with water.

The non-polar middle of the molecule forms a hydrophobic layer inside, which acts as a barrier to water-soluble substances.



- (c) The percentage of branched-chain fatty acids in membranes of bacteria that have different optimum growth temperatures was investigated.

The graph shows the results of this investigation.



- (i) Calculate the mean percentage of branched-chain fatty acids in bacteria whose optimum growth temperature is $<20^{\circ}\text{C}$.

(1)

$$(0 + 0 + 2 + 4) \div 4 = 1.5$$

Answer 1.5 %

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

(2)

There is a positive correlation: bacteria with higher optimum growth temperatures have

a greater percentage of branched-chain fatty acids.

Bacteria with an optimum growth temperature above 40°C need at least 30%

branched-chain fatty acids.



- (d) A change in temperature can affect the permeability and fluidity of the membrane.

Explain why it is important that the lipid composition of the membrane of prokaryotic organisms changes if the temperature changes.

(3)

Membranes control permeability (what can enter and leave the cell), and at higher temperatures membranes become more fluid and leaky.

So changing the lipid composition keeps the permeability constant, allowing the uptake of nutrients and oxygen and the removal of waste products to be controlled.

Membranes also need to stay fluid (not too rigid at low temperatures) for movement and cell division.

(Total for Question 6 = 10 marks)



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

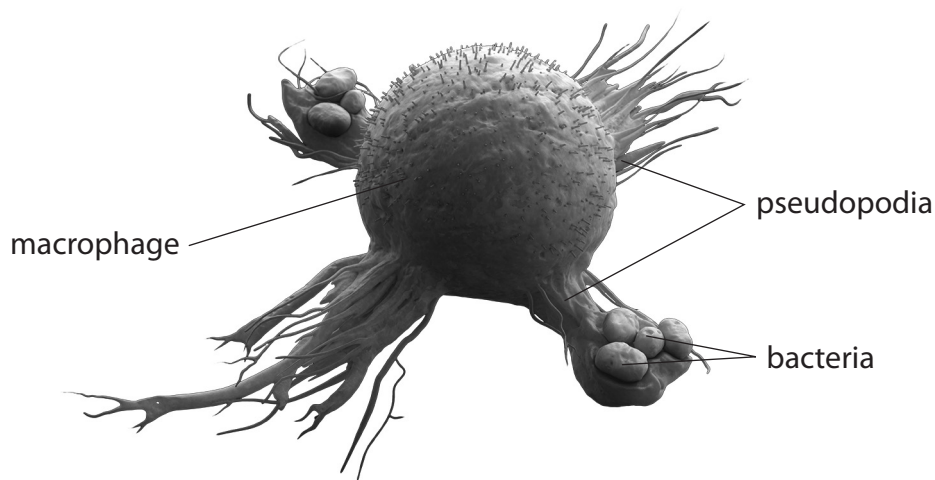
BLANK PAGE



7 Macrophages are involved in response to infection.

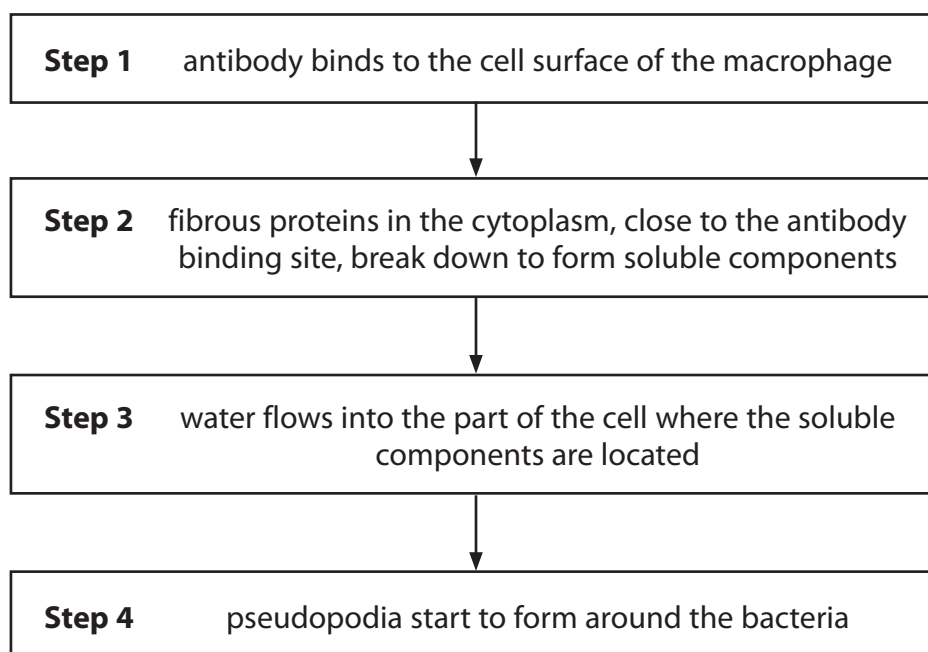
(a) Macrophages engulf bacteria by surrounding the bacteria with pseudopodia.

The image shows a macrophage forming pseudopodia around some bacteria.



(Source: © urfin/Shutterstock)

The flow chart shows one theory for the formation of pseudopodia.



- (i) Which diagram shows one antibody binding to the surface of a macrophage (**Step 1**)?

(1)



- (ii) Actin is a fibrous protein.

Which row of the table describes the breakdown of actin (**Step 2**)?

(1)

	monomer formed	process by which bond is broken
☐ A	amino acid	condensation
☒ B	amino acid	hydrolysis
☐ C	nucleotide	condensation
☐ D	nucleotide	hydrolysis

- (iii) Explain why water flows into the part of the cell where the soluble components are located (**Step 3**).

(2)

Water flows in by osmosis.

The soluble components lower the water potential (more negative osmotic potential) of the cytoplasm there, so water moves from a higher water potential to a lower water potential.



(iv) Describe the events that take place resulting in T helper cell activation, following the formation of pseudopodia by the macrophages (**Step 4**).

(3)

The bacteria are engulfed into a phagosome, which fuses with a lysosome, and the bacteria are digested (broken down) by enzymes.

The bacterial antigens are attached to MHC antigens (proteins) and displayed on the macrophage cell surface membrane.

So the macrophage becomes an antigen-presenting cell.

The CD4 receptor of a T helper cell with a complementary receptor binds to the antigen-MHC complex, activating the T helper cell.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

BLANK PAGE



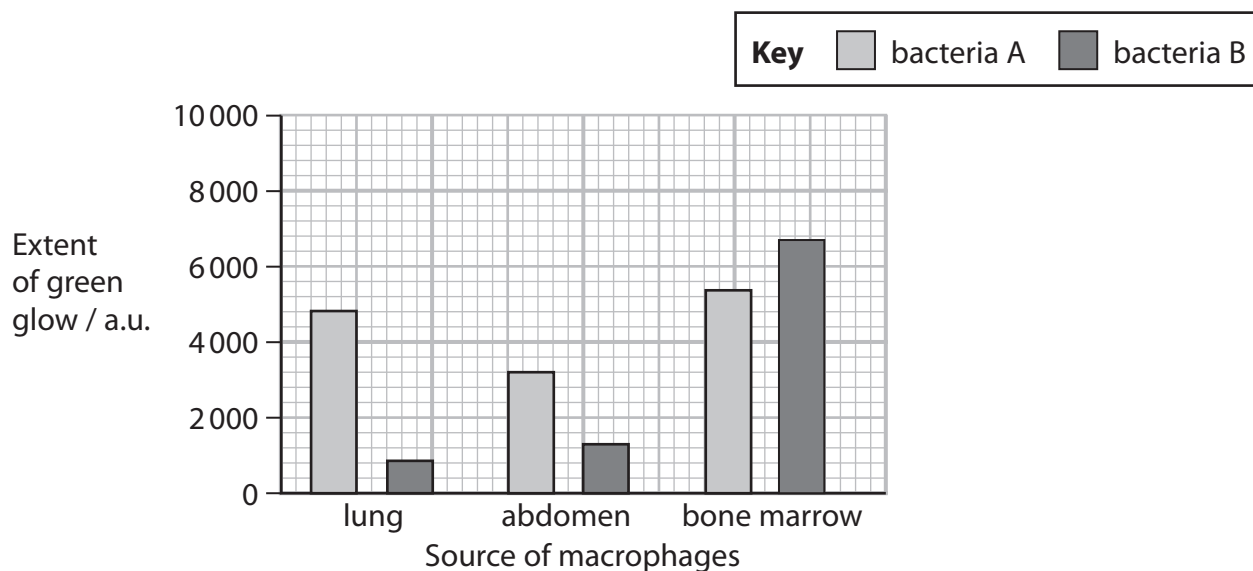
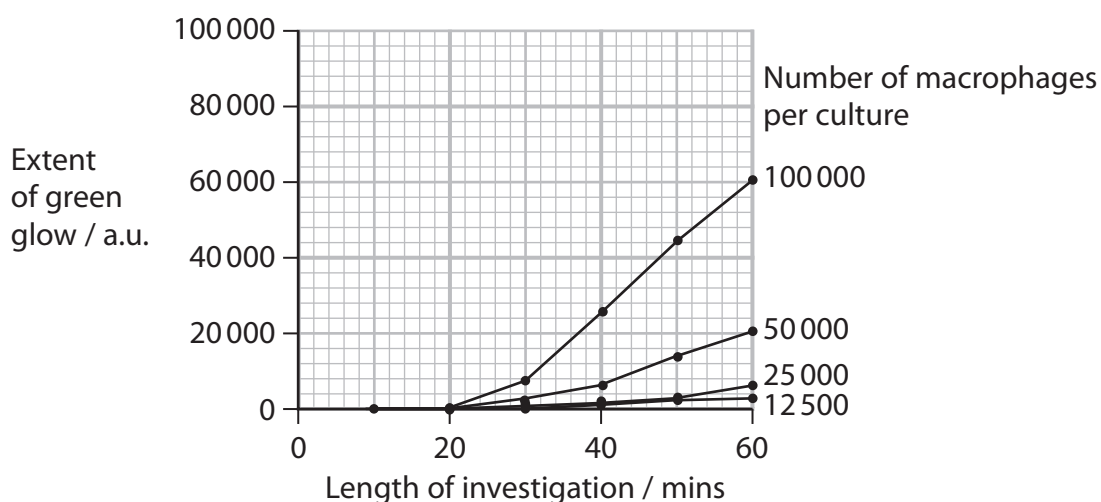
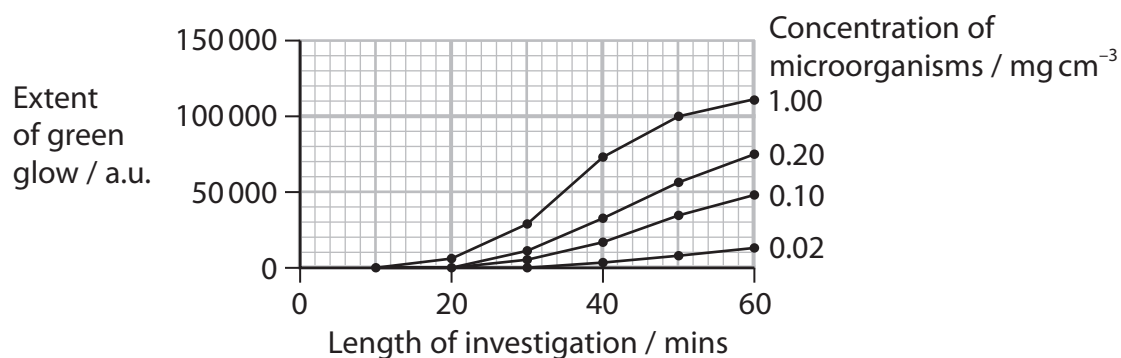
*(b) Phagocytosis by macrophages is affected by a number of factors.

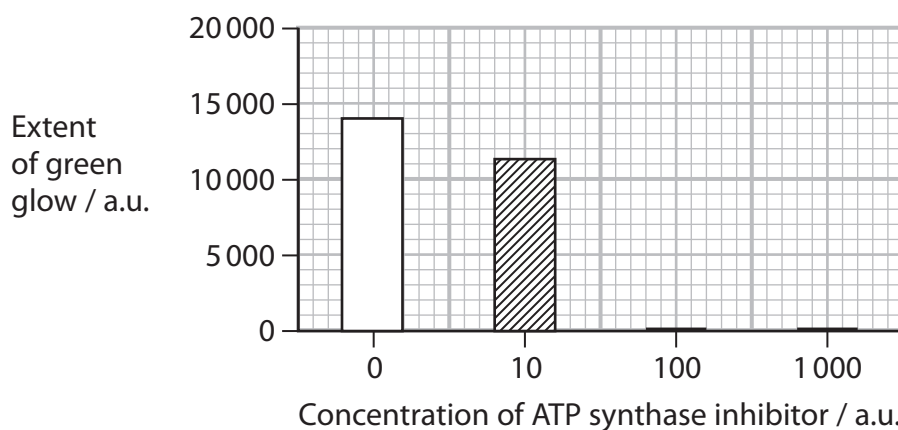
Microorganisms with a fluorescent green dye attached to them were used to measure phagocytosis by macrophages.

The microorganisms were added to the macrophages and incubated. The macrophages were then washed and the extent to which they glowed green was determined.

The extent of the green glow is proportional to the number of microorganisms engulfed by the macrophages.

The graphs show the results of investigations into phagocytosis by macrophages.





Analyse the data to discuss the factors that affect phagocytosis by macrophages.

(6)

Concentration of microorganisms: as the length of the investigation increases, the number of microorganisms engulfed increases. The higher the concentration of microorganisms, the more phagocytosis there is, but this is not proportional to the number present, and the effect is only seen after 10 minutes, as macrophages first need time to bind and engulf them.

Number of macrophages: the more macrophages per culture, the more microorganisms are engulfed, as there are more cells to carry out phagocytosis. However, the difference is only marked with 100 000 macrophages present, and the effect is only seen after about 30 minutes.

Source of macrophages: macrophages from bone marrow take up the most of both types of bacteria. The type of bacteria also matters: lung and abdomen macrophages engulf many more of bacteria A than B, so a combination of source and type of bacteria affects uptake.

ATP synthase inhibitor: increasing inhibitor concentration reduces uptake, because less ATP is available for phagocytosis (pseudopodia formation needs energy), but large differences are only seen at 100 a.u. and above.

(Total for Question 7 = 13 marks)



8 Hypoxia is an inadequate supply of oxygen to tissues and cells that restricts their function.

(a) The normal partial pressures of oxygen vary from tissue to tissue.

The table shows the normal partial pressure of oxygen in two tissues.

Tissue	Partial pressure of oxygen / kPa
Pulmonary arterial blood	5.3
Other arterial blood	13.3

(i) Calculate the ratio of the partial pressures of oxygen in these two tissues. Give your answer to one decimal place.

(1)

$$13.3 \div 5.3 = 2.5$$

Answer 2.5 : 1

(ii) Explain why the partial pressures of oxygen in these two tissues are different.

(2)

The pulmonary artery carries deoxygenated blood from the body (right ventricle) to the lungs, so its partial pressure of oxygen is low.

Other arterial blood is oxygenated, as it has just been through the lungs, and carries oxygen to the body tissues, so its partial pressure is high.



- (b) The body responds to hypoxia by releasing hypoxia-inducible transcription factors (HIF).

Investigations have shown that one effect of HIF is an increase in the rate of glycolysis in the affected cells.

- (i) Explain how HIF could result in an increase in the rate of glycolysis.

(2)

HIF can switch on genes (increase gene expression) by binding to the promoter region, stimulating transcription and protein synthesis.

This produces more of the enzymes involved in glycolysis.

- (ii) Explain why cells need to respond to hypoxia with an increase in the rate of glycolysis.

(4)

Under hypoxic conditions there is not enough oxygen available to act as the terminal electron acceptor.

Therefore the electron transport chain will not operate.

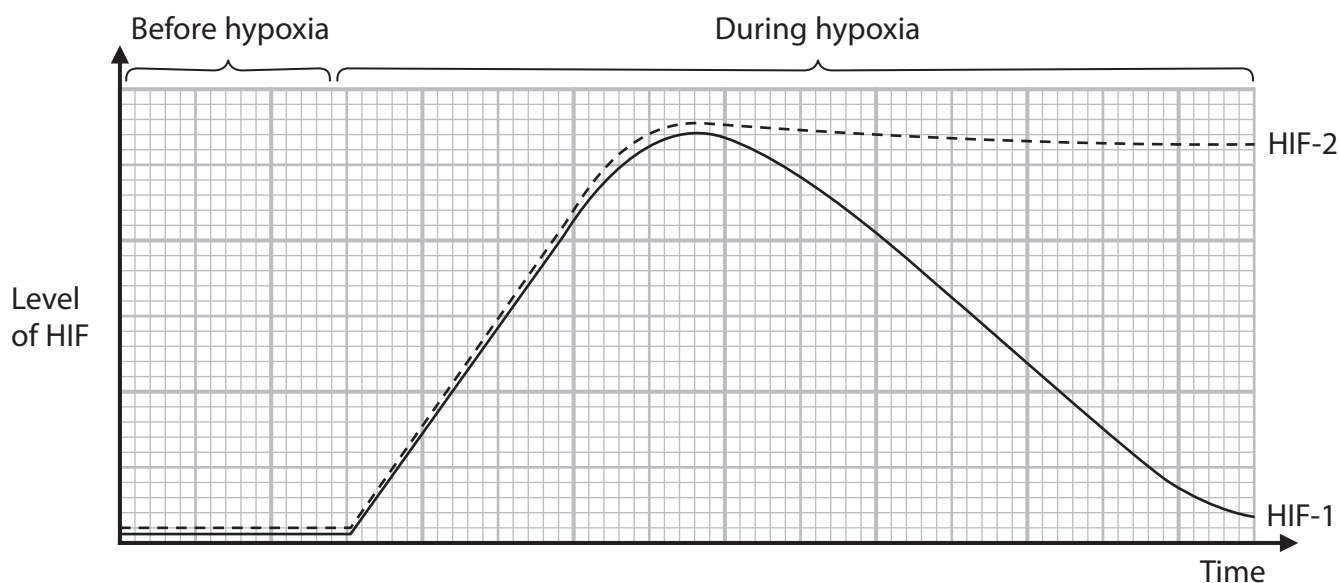
So ATP production by oxidative phosphorylation is reduced.

ATP can still be produced directly by substrate-level phosphorylation in glycolysis under these anaerobic conditions, so a faster rate of glycolysis is needed to supply enough

ATP.



- (iii) The graph shows the changes in levels of two HIFs, HIF-1 and HIF-2, before and during hypoxia.



Compare and contrast the changes in the levels of HIF-1 and HIF-2 during hypoxia.

(2)

Both HIF-1 and HIF-2 increase at the same rate at the start of hypoxia.

However, the level of HIF-2 then remains high (after a small decrease), whereas the level of HIF-1 falls back to its original level.

- (iv) Explain the changes in levels of HIF-1 and HIF-2 during hypoxia.

(2)

HIF-1 and HIF-2 switch on different genes, and the products of both are needed in the early stages of hypoxia.

The products of genes switched on by HIF-2 are needed for longer periods of hypoxia, to sustain glycolysis.

(Total for Question 8 = 13 marks)



9 Plants and animals are adapted for gas exchange.

(a) (i) Which row of the table describes gas exchange in the root of a plant?

(1)

	Net movement of carbon dioxide	Net movement of oxygen
☐ A	in only	out only
☒ B	out only	in only
☐ C	in and out	in and out
☐ D	neither in nor out	neither in nor out

(ii) Which is the gas exchange surface in the stem of a woody plant?

(1)

- ☒ A lenticel
☐ B pit
☐ C plasmodesmata
☐ D stomata



- (b) Spiracles are small openings in the exoskeletons of insects that allow air to enter the respiratory system.

Water can evaporate out of the spiracles when they are open. The insect can close the spiracles to reduce water loss.

In an investigation, the water loss from insects in air with different humidities was measured.

The insects were kept in air with 80% humidity and then moved into air with a lower humidity. Water loss was then measured.

The investigation was repeated in air high in carbon dioxide to keep the spiracles open.

The table shows the results of this investigation.

Percentage humidity (%)	Water loss from insects / mg hr^{-1}	
	Insects in air	Insects in air high in carbon dioxide
0	0.10	0.90
20	0.13	0.68
40	0.15	0.50
60	0.13	0.35
80	0.07	0.07

- (i) State how the water loss could have been measured in this investigation.

(1)

Weigh the insects before and after the investigation and calculate the difference in mass.

- (ii) Calculate the percentage increase in water loss from the insects kept in air at 0% humidity compared with those kept at 80% humidity.

Give your answer to two decimal places.

(1)

$$(0.10 - 0.07) \div 0.07 \times 100$$

$$= 42.857 = 42.86\%$$

Answer **42.86** %



(iii) Explain why the insects were kept in air with 80% humidity at the start of this investigation.

(2)

To act as a standard for comparison, so the effects of lower humidities can be seen.

To prevent water loss (dehydration) before the start of the investigation, as 80% is the highest humidity they can tolerate.

(iv) Explain the results of this investigation.

(3)

Water loss increases as humidity decreases, because there are fewer water molecules in the air, so there is a steeper water vapour concentration gradient.

In normal air, water loss is less at low humidity (0% and 20%) because the spiracles close.

Water loss is much greater in air high in carbon dioxide because the ventilation (breathing) rate is faster and the spiracles stay open.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

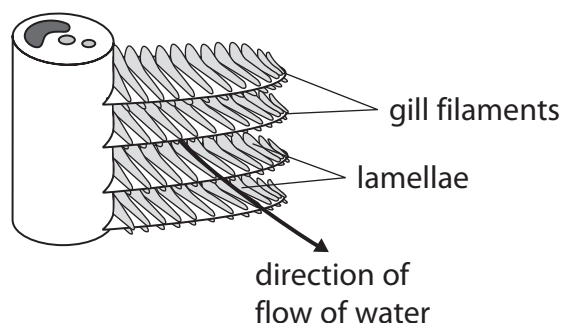
DO NOT WRITE IN THIS AREA



P 6 7 0 8 7 A 0 2 9 3 2

(c) The gas exchange surfaces of fish are the gills.

The diagram shows part of the structure of a gill.



Fish can be divided into two groups: species of fish that are active and species of fish that are inactive.

The table shows some information about some species of fish and their gills.

Species of fish	Mass of fish / g	Total number of gill filaments	Number of lamellae on each side of filament per mm	Surface area of gills / cm ² per g of fish	Diffusion distance between water and blood / μm
Active species					
<i>Trachurus</i>	26	1665	39	7.8	2.2
<i>Lucioperca</i>	70	1811	15	18.0	no data
<i>Salmo</i>	394	1606	19	2.0	6.4
<i>Katsuwonus</i>	3258	6066	32	13.5	0.6
<i>Thunnus</i>	26600	6480	24	8.9	no data
Inactive species					
<i>Callionymus</i>	39	478	16	2.1	no data
<i>Ictalurus</i>	239	no data	10	1.2	no data
<i>Opsanus</i>	251	660	11	1.9	5.0
<i>Tinca</i>	268	1764	22	1.8	2.5



- (i) Lamellae are present on both sides of the gill filaments.

The mean length of a gill filament is 25 mm.

Calculate the total number of lamellae on the gill filaments of *Thunnus*.

Express your answer in standard form.

(1)

$$6480 \times 24 \times 25 \times 2$$

$$= 7\,776\,000$$

Answer 7.78×10^6

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



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

- *(ii) Analyse the data to explain the relationships between the activity of these fish and the structure of their gills.

(6)

Active fish generally have a greater number of gill filaments than inactive fish, e.g.

Thunnus has 6480 compared with 660 in Opsanus, although Tinca is an exception.

There may be a weak correlation with mass in active fish.

Active fish generally have more lamellae on each filament (e.g. 39 per mm in

Trachurus compared with 10 to 22 in inactive fish), but this does not correlate with mass.

Active fish have a greater surface area of gills per gram than inactive fish of similar mass (e.g. Trachurus 7.8 cm² per g compared with Callionymus 2.1 cm² per g).

There is little data on diffusion distance, but active fish seem to have a smaller diffusion distance (0.6 µm in Katsuwonus compared with 5.0 µm in Opsanus).

More filaments, lamellae and a larger surface area, with a shorter diffusion distance, increase the rate of gas exchange, so more oxygen diffuses into the blood for aerobic respiration. Therefore more ATP is generated for the contraction of the muscles needed for the movement of active fish.

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

