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Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level BIOLOGY

Paper 3

Wednesday 18 June 2025

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in **Section A**.
- Answer **one** question from **Section B**.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for the questions are shown in brackets.
- The maximum mark for this paper is 78.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
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6	
7	
TOTAL	



J U N 2 5 7 4 0 2 3 0 1

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Section A

Answer **all** questions in this section.

You are advised to spend no more than 1 hour and 15 minutes on this section.

0 1 . 1 Describe binary fission in bacteria.

[3 marks]

First the single circular DNA molecule replicates, so that each daughter cell will receive a copy.

The plasmids are also replicated, so copies can go into both cells.

The cell then divides: the cytoplasm divides and a new cell-surface membrane (and cell wall) forms across the middle of the cell, producing two genetically identical daughter cells.

Question 1 continues on the next page

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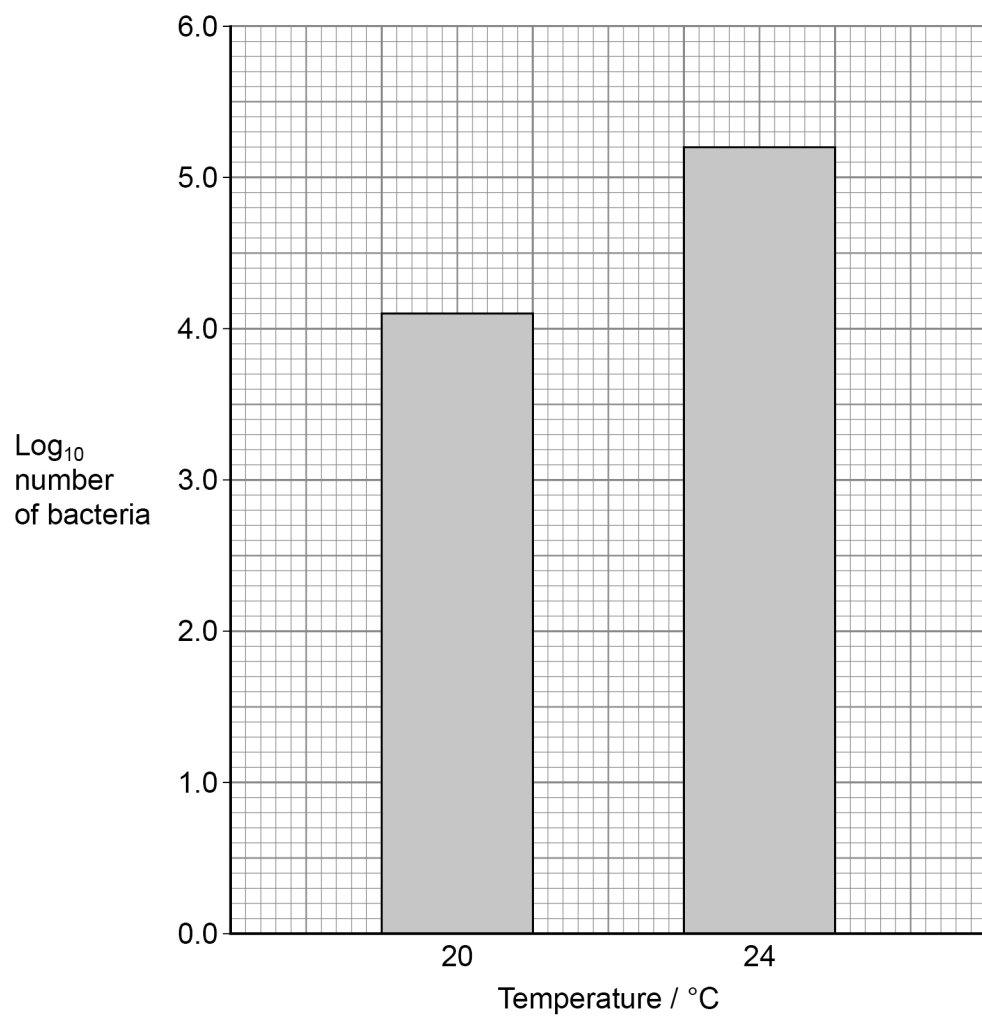
0 1 . 2

Microbiologists investigated the effect of two temperatures on the population growth of a species of bacterium.

They grew separate bacterial cultures in identical nutrient media at 20 °C and 24 °C for 8 hours.

Figure 1 shows the estimated final population size of each culture.

Figure 1



The bacterial population at 24 °C is larger than that at 20 °C

Calculate this difference as a percentage increase.

The actual number of bacteria can be calculated from the $\log_{10}$ value by using the 10^x button on your calculator.

Give your answer to the nearest whole number.

Show your working.

[2 marks]

$$24\text{ }^{\circ}\text{C: } 10^{5.2} = 158\,489\text{ bacteria} \quad 20\text{ }^{\circ}\text{C: } 10^{4.1} = 12\,589\text{ bacteria}$$

$$\text{Increase} = 158\,489 - 12\,589 = 145\,900$$

$$\% \text{ increase} = (145\,900 \div 12\,589) \times 100 = 1158.97\ldots$$

$$\text{Percentage increase} = \underline{1159\%}$$

0 1 . 3

Bedaquiline is a drug that inhibits ATP synthase in mycobacteria by stopping hydrogen ion (proton) movement.

Explain how bedaquiline can kill these bacteria.

[3 marks]

Bedaquiline stops protons (H^+) diffusing through ATP synthase, so there is no chemiosmosis.

Without the flow of protons there is no energy to add phosphate to ADP, so no ATP is formed by oxidative phosphorylation.

The bacteria die because there is not enough ATP to provide energy for metabolic processes such as active transport, DNA replication and protein synthesis.



0 2 . 1

Table 1 shows four statements and the names of four parts of a nephron.

Put a tick (✓) in each box where the statement is true for that part of the nephron.

[2 marks]

Table 1

Statement	Part of the nephron			
	Glomerulus	Proximal convoluted tubule	Distal convoluted tubule	Collecting duct
ADH receptors are present			✓	✓
Water can be absorbed from the filtrate		✓	✓	✓
Blood is under high pressure	✓			
Glucose is absorbed from the filtrate		✓		

0 2 . 2

Protein is **not** normally present in the urine of a person.

Explain why.

[2 marks]

Plasma proteins are too large to be filtered out of the blood in the glomerulus.

They cannot pass through the basement membrane (between the capillary endothelium and the Bowman's capsule), so they stay in the blood and do not enter the filtrate.



0 2 3

Glomerular sclerosis (GS) is a type of kidney damage that can cause protein to be present in the urine.

High-protein diets are linked to GS in adults.

Scientists investigated the development of GS in underweight, 5-day-old rats.

They fed:

- 14 rats a high-protein milk diet
- 14 rats a normal-protein milk diet.

From day 21, they fed both groups of rats the **same** diet of solid food. At 160 days old, they examined nephrons in the rats' kidneys for GS.

They identified the number of nephrons with GS for each group of rats.

Rats fed a high-protein diet had a larger number of nephrons with GS than rats fed a normal-protein diet. The scientists performed a statistical test on these data and they calculated $P < 0.01$

A journalist reported on this investigation and stated 'feeding high-protein milk to underweight human babies could cause kidney damage in adults'.

Use all of the information provided to evaluate this statement.

[5 marks]

The statement is partly supported: $P < 0.01$, so there is a probability of less than 0.01 (1%) that the increase in GS is due to chance, so the difference is significant. Rats and humans are both mammals, so their kidneys are similar.

However, the investigation was only done on rats, not on humans, so the result may not apply to human babies.

We do not know if 160-day-old rats count as adults.

Only 14 rats were used in each group (28 in total), a small sample, so the results may not be representative.

Only two diets were used (high and normal protein) and we are not told the protein content or the types of protein in the milks.

Only GS was studied, and other types of kidney damage, or other factors such as genetics, could also cause kidney damage.



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0 3

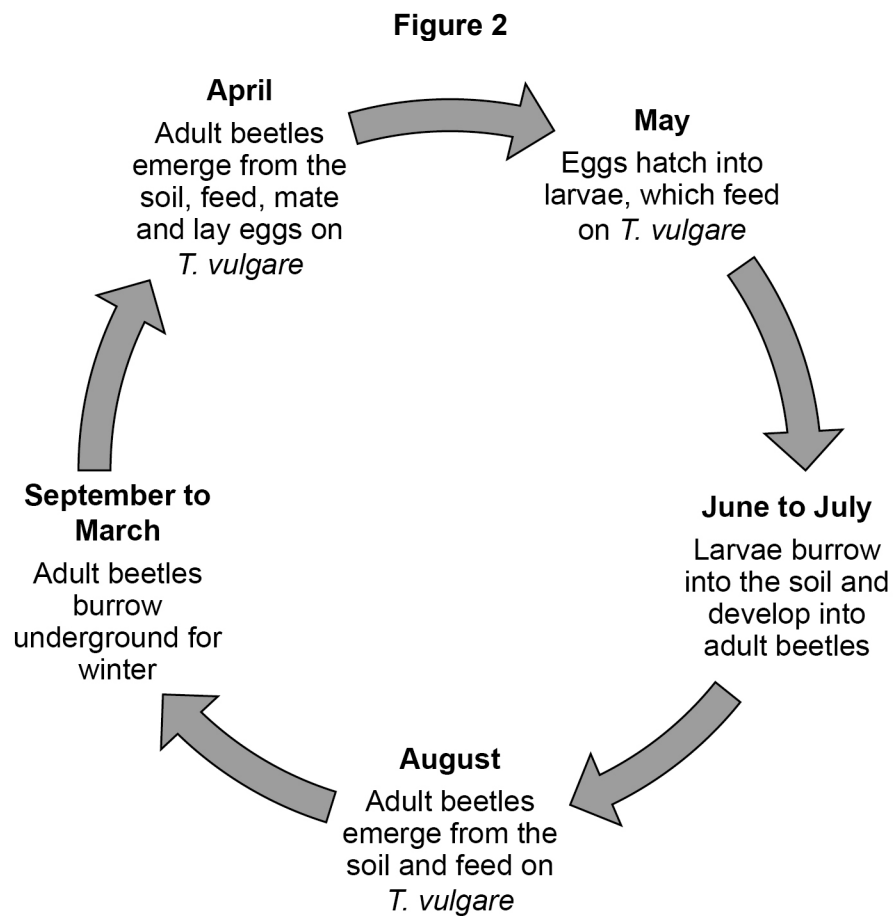
Tansy, *Tanacetum vulgare*, is a plant that grows in dense patches. The tansy beetle, *Chrysolina graminis*, feeds on, and completes its life cycle on *T. vulgare*.

C. graminis is 8–10 mm long and green in colour.

Two other green beetles can also be found in the same habitat.

- The dock beetle, *Gastrophysa viridula*, which is 4–7 mm long.
- The mint leaf beetle, *Chrysolina herbacea*, which is 6–10 mm long.

Figure 2 shows the life cycle of *C. graminis*.



0 3

1

How many different genera of beetles are there in the information provided?

[1 mark]

2 (*Chrysolina* and *Gastrophysa*)

Question 3 continues on the next page

Turn over ►



Ecologists investigated the population size of *C. graminis* using the mark-release-recapture method.

Table 2 shows the ecologists' results.

Table 2

Number of <i>C. graminis</i> captured and marked in first sample	Number of unmarked <i>C. graminis</i> captured in the second sample	Number of marked <i>C. graminis</i> captured in the second sample
405	248	124

0 3 . 2

The ecologists captured and marked the first sample of beetles during the second week of August. They identified the species of beetle before marking them.

Use the information provided to suggest:

[3 marks]

two reasons why the first sample of beetles was captured during the second week of August

1 *By then the adult beetles have emerged from the soil, so they are not still underground in burrows and can be caught.*

2 *It gives the beetles time to randomly distribute and be recaptured before they burrow underground in September, and it avoids mating and egg laying, so the population size does not change.*

one reason why the beetles had to be identified before being marked.

1 *The other two beetles are also green and a similar length, and only the *C. graminis* population is being investigated.*



0 3 . 3

Use the data provided in **Table 2** to estimate the population size of *C. graminis*.

Show your working.

[2 marks]

$$\text{Total in second sample} = 248 + 124 = 372$$

$$\text{Population} = (405 \times 372) \div 124$$

$$= 150\,660 \div 124 = 1215$$

Answer = 1215 beetles

0 3 . 4

The ecologists repeated the investigation over a five-year period to monitor the population size of *C. graminis*.

State **two** precautions they would have taken each year to obtain comparable data.

[2 marks]

1 Collect the samples at the same time of year each year (the second week of August) and from the same location / habitat.

2 Use the same method each year, with a mark that is not toxic, is not rubbed off and does not affect survival or predation (and use a different mark each year).

8

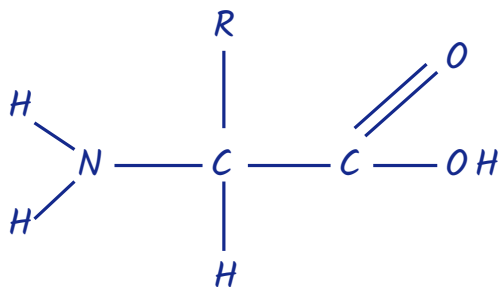
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0 4 . 1 Draw the **general** structure of an amino acid.

[1 mark]



0 4 . 2 Which statement describing protein structure is correct?

Tick (✓) **one** box.

[1 mark]

Proteins with a quaternary structure have one or more polypeptide chains.

☐

Disulfide bridges are present in all proteins with a tertiary structure.

☐

The secondary structure of a protein is maintained by ionic and hydrogen bonds.

☐

The primary structure of a protein is the sequence of amino acids joined by peptide bonds.

☒


0 4 . 3

Antibodies are proteins produced and secreted by plasma cells.

Once activated, a single B cell divides and produces 4000 plasma cells.

Each one of these plasma cells produces 2000 molecules of antibody **Q** per second.

A human male has a blood volume of 5.4 dm^3

Calculate the total number of molecules of antibody **Q** per cm^3 of blood 24 hours after the production of these plasma cells.

[2 marks]

$$\text{Seconds in 24 hours} = 60 \times 60 \times 24 = 86\,400$$

$$\text{Total} = 4000 \times 2000 \times 86\,400 = 6.912 \times 10^{11} \text{ molecules}$$

$$5.4 \text{ dm}^3 = 5400 \text{ cm}^3$$

$$6.912 \times 10^{11} \div 5400 = 1.28 \times 10^8$$

Answer = 1.28×10^8 molecules of antibody **Q** per cm^3 of blood

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0 4 . 4

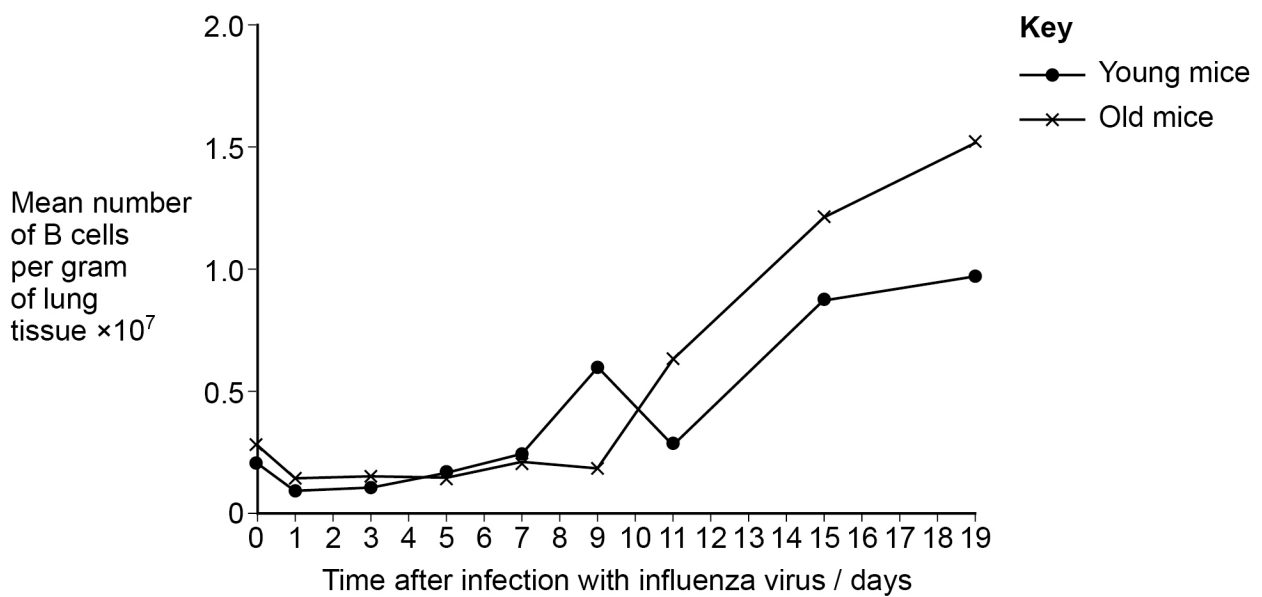
Scientists investigated the effect of age on the immune response in healthy female mice.

The scientists used the following method.

1. Infected a large number of young and old mice with the same strain of influenza virus.
2. Removed the lungs from 6 young and 6 old mice on the day of infection (day 0).
3. Repeated step 2 on 8 different days after infection.
4. Determined the mean number of B cells present per gram of lung tissue for young and old mice.

Figure 3 shows the scientists' results.

Figure 3



The scientists decided that further investigations would be required to conclusively determine the effect of age on the immune response in healthy female mice.

Using all the information provided, suggest **three** reasons for the scientists' decision.

Do **not** refer to statistical tests, repeats or sample size in your answer.

[3 marks]

1 *They only measured the number of B cells, so there is no data on the T cell (cell-mediated) response, only the humoral response.*

2 *They only looked at the lungs and only at one virus (influenza), so the response in other organs or to other pathogens is unknown.*

3 *The day 9 results do not fit the pattern (anomalous), and there are no data between days 11 and 15 or after day 19; we also do not know the ages of the young and old mice.*

7

Turn over for the next question

Turn over ►



0 5

Cleft lip and palate (CLP) is a split in the upper lip and/or the roof of the mouth. CLP is present from birth.

CLP can be caused by various genetic and environmental factors.

CDH1 is a gene involved in lip and mouth development in a fetus before a baby is born.

Scientists hypothesised that CLP is caused by a 'two-hit' model:

- a 'genetic hit' through loss of *CDH1* function
- an 'environmental hit' leading to *CDH1* methylation caused when inflammation affects a fetus.

Inflammation can result from the mother having an infection or diabetes.

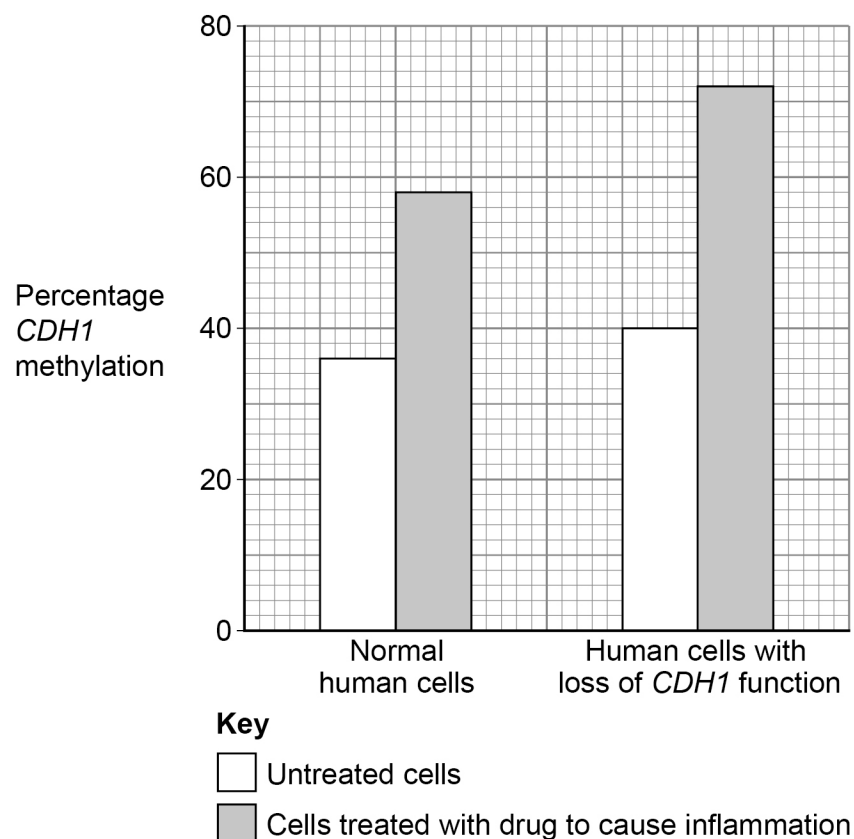
Scientists investigated the 'two-hit' model using human cells grown *in vitro*.

They:

- grew normal cells and cells with a loss of *CDH1* function
- treated some of each type of cell with a drug to cause inflammation and left some of each type of cell untreated
- measured the percentage *CDH1* methylation of the cells.

Figure 4 shows the scientists' results.

Figure 4



0 5 . 1

The frequency of live births with CLP is 1 in 700

Despite knowing this frequency, the Hardy–Weinberg equation **cannot** be used to estimate **any** allele frequencies for CLP.

Suggest **two** reasons why.

[2 marks]

1 *CLP is not caused by a single gene; various genetic factors are involved and new mutations occur.*

2 *Environmental factors (such as inflammation causing methylation) are involved, and human populations are not isolated because people migrate.*

0 5 . 2

Describe **one** effect methylation could have on *CDH1*

[1 mark]

*Methylation could prevent transcription factors (and RNA polymerase) binding to the promoter, so *CDH1* is not transcribed and less *CDH1* protein is produced.*

0 5 . 3

Suggest **and** explain **three** reasons why the data in **Figure 4** might **not** provide evidence for the ‘two-hit’ model.

[3 marks]

1 *Inflammation alone may be the cause, since both types of treated cells have increased methylation (58% and 72%).*

2 *Loss of *CDH1* function might not have an effect, as both untreated cell types have similar methylation (36% and 40%); also a drug was used, which may not be the same as infection or diabetes.*

3 *The cells were grown in vitro, so may not respond the same as in a fetus, and they did not develop into a lip or mouth, so we do not know if they would develop CLP.*

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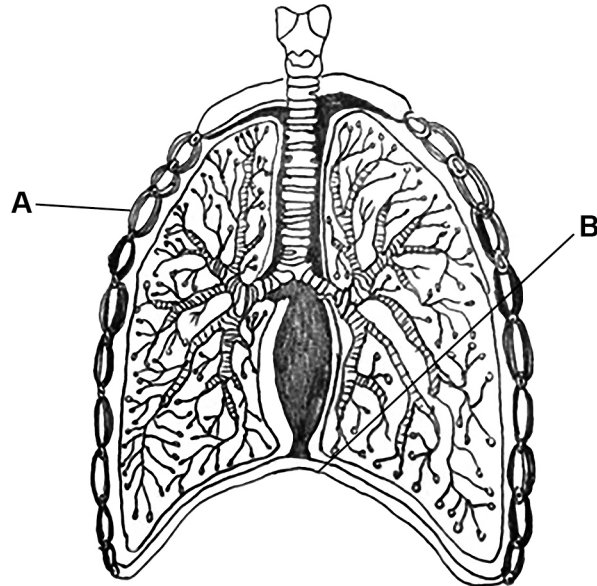


0 6

A student completed a dissection of an animal gas exchange system.

Figure 5 shows the scientific drawing he produced from his observations.

Figure 5



0 6 . 1

Suggest **two** ways the scientific drawing in **Figure 5** could be improved.

Do **not** refer to adding labels or using a sharp pencil in your answer.

[2 marks]

1 *Remove the shading / hatching and draw only the outlines of the tissues, simplifying the bronchioles and alveoli.*

2 *Use single continuous lines with no sketching, make the ribs the same number and size on each side, and add a scale bar.*



0 6 . 2

Describe the role of structures **A** and **B** in increasing the volume in the thoracic cavity. [2 marks]

A (the external intercostal muscles) contracts, pulling the ribs up and out.

B (the diaphragm) contracts and flattens, moving down. Together these increase the volume of the thoracic cavity.

0 6 . 3

Lung volume can be determined with a spirometer using the helium dilution method.

The lung volume (V_2) is calculated using the equation:

$$V_2 = \frac{V_1(C_1 - C_2)}{C_2}$$

where

C_1 = the initial concentration of helium in the spirometer

C_2 = the helium concentration in the spirometer when equal with the lungs

V_1 = volume of gas in the spirometer.

A student used a spirometer with a volume of 3250 cm^3 and an initial concentration of 10% helium. They found C_2 was 3.78%

Use the equation to calculate this student's lung volume in dm^3

Show your working.

[2 marks]

$$V_2 = 3250 \times (10 - 3.78) \div 3.78$$

$$= (3250 \times 6.22) \div 3.78 = 20\,215 \div 3.78$$

$$= 5347.9 \text{ cm}^3 = 5.35 \text{ dm}^3$$

Lung volume = 5.35 dm^3

Question 6 continues on the next page

Turn over ►



Asbestos is a fibrous mineral. If asbestos is inhaled, it can cause a lung disease called asbestosis.

The latency period of a disease is the time between exposure to the cause of the disease and the symptoms occurring. The latency period for asbestosis is 15 to 40 years.

Asbestosis can be diagnosed using a biopsy. This is where a sample of lung cells is removed from a patient and examined with a microscope.

Asbestosis can also be diagnosed without a biopsy. To diagnose asbestosis without a biopsy, five conditions must be met. Three of these are given below.

1. A scan of the lungs showing fibrous scar tissue.
2. Reduced gas exchange.
3. Shortness of breath.

These three conditions are also present in many other lung diseases.

0 6 . 4

Using the information provided, suggest the other **two** conditions that must be met before a diagnosis of asbestosis can be made.

[2 marks]

1 *The patient must have had known contact with / exposure to asbestos.*

2 *The symptoms must have appeared after a long latency period, at least 15 years (15 to 40 years) after exposure.*

0 6 . 5

Suggest **two** advantages of diagnosing asbestosis **without** a biopsy.

[2 marks]

1 *It is less invasive and less painful, as no surgery is needed, and there is less risk of infection or further lung damage / scar tissue.*

2 *It is cheaper and quicker, so results are obtained faster and there is no recovery time.*



Question 6 continues on the next page

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Idiopathic pulmonary fibrosis (IPF) is a lung disease similar to asbestosis. Both diseases cause:

- the death of alveolar epithelial cells due to DNA damage
- dead cells to be replaced by inelastic, fibrous scar tissue.

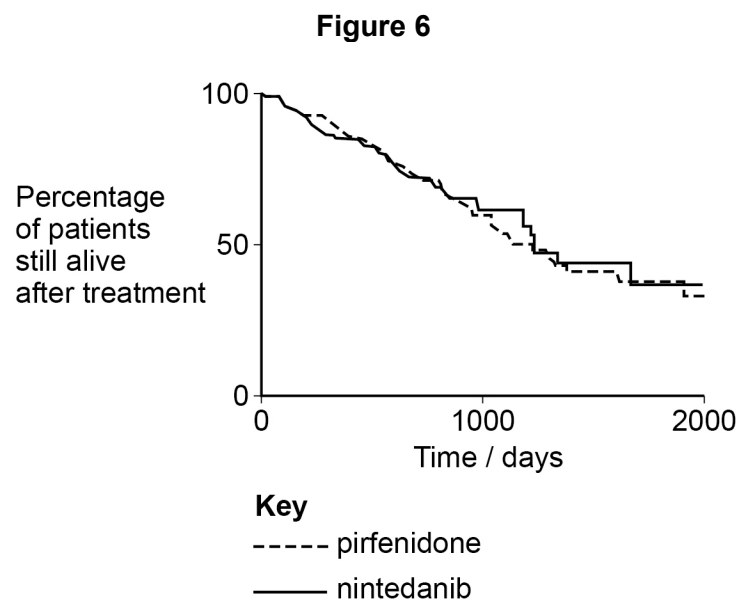
Currently, there is no cure for asbestosis and no effective treatment to slow its progression. There is also no cure for IPF. However, the drugs nintedanib and pirfenidone can slow the formation of scar tissue and slow the progression of IPF.

In two **separate** clinical trials, doctors investigated the effect of nintedanib and pirfenidone on 263 IPF patients.

- 124 patients were treated with nintedanib. 7 of these patients had to stop treatment due to side effects.
- 139 patients were treated with pirfenidone. 14 of these patients had to stop treatment due to side effects.

The doctors recorded how many days each patient lived after treatment.

Figure 6 shows their results.



0 6 . 6 Suggest why neither clinical trial had a control group.

[1 mark]

*It would be unethical not to treat patients with IPF (a fatal disease)
by giving a control group no drug or a placebo.*



0 6 . 7

The doctors concluded that both drugs increased life expectancy in patients with IPF compared with survival data for previous patients with IPF.

Using all the information, evaluate whether nintedanib and pirfenidone should be considered as treatments for **asbestosis**.

[4 marks]

For: both diseases involve DNA damage and the formation of inelastic scar tissue, with similar symptoms, and both drugs slow scar tissue formation and the progression of IPF. Both drugs were equally effective in humans over a long study (2000 days).

Against: neither drug is a cure; they only slow scar tissue formation and do not affect the cause (DNA damage). They were only tested in IPF, not asbestosis, where scarring may differ.

There was no control group, so we do not know what percentage would be alive without treatment, and side effects stopped treatment in 7 of 124 and 14 of 139 patients.

15

Turn over for Section B

Turn over ►



Section BAnswer **one** question.

You are advised to spend no more than 45 minutes on this section.

0 7Write an essay on **one** of the topics below.**Either****0 7 . 1**

The importance of condensation and hydrolysis reactions in biological systems.

[25 marks]**Or****0 7 . 2**

The importance of responses to changes in the internal and external environment of organisms.

[25 marks]

07.1 The importance of condensation and hydrolysis reactions in biological systems

A condensation reaction joins two molecules together with the formation of a chemical bond and the removal of a molecule of water. A hydrolysis reaction breaks a chemical bond using a molecule of water. These two reactions are essential because almost all biological polymers, including polysaccharides, proteins and nucleic acids, are built from monomers by condensation and broken back down into monomers by hydrolysis. This allows organisms to store, transport and use materials and energy, and to build the molecules that make up their cells.

In carbohydrates, monosaccharides are joined by glycosidic bonds formed in condensation reactions. Two alpha-glucose molecules form maltose, glucose and fructose form sucrose, and glucose and galactose form lactose. Many alpha-glucose molecules are joined by 1,4 and 1,6 glycosidic bonds to form starch in plants and glycogen in animals. These are important energy stores because they are large and insoluble, so they do not affect the water potential of cells, and they are compact. Glycogen



is highly branched, so it can be hydrolysed rapidly at many ends to release glucose for respiration when it is needed. In the liver, insulin stimulates glycogenesis, the condensation of glucose to glycogen, while glucagon and adrenaline activate enzymes that hydrolyse glycogen (glycogenolysis), so condensation and hydrolysis are central to controlling blood glucose concentration. Beta-glucose molecules are joined by condensation to form cellulose, where every other molecule is inverted, giving long straight chains linked by hydrogen bonds into microfibrils. This gives plant cell walls their strength, so cells do not burst when turgid.

Lipids are also formed by condensation. A triglyceride forms when three fatty acids each join to glycerol, forming three ester bonds and releasing three molecules of water. Triglycerides are an important energy store because they have a high ratio of carbon-hydrogen bonds, so they release more energy than carbohydrates, and they are insoluble so do not affect water potential. Phospholipids are formed in a similar way with a phosphate group replacing one fatty acid, and these form the bilayer of all cell membranes.

Proteins are made when amino acids are joined by peptide bonds in condensation reactions between the amine group of one amino acid and the carboxyl group of another. The sequence of amino acids is the primary structure, which determines the tertiary structure and therefore the function of enzymes, antibodies, channel proteins and hormones such as insulin. During translation, the ribosome moves along the mRNA, tRNA molecules bring the specific amino acids, and peptide bonds form between them by condensation, using ATP. Without this, cells could not produce the enzymes that catalyse almost every reaction in metabolism.

Turn over ►



Digestion depends on hydrolysis. Large insoluble food molecules cannot be absorbed, so they are hydrolysed into small soluble molecules. Amylase hydrolyses starch to maltose, and membrane-bound disaccharidases such as maltase, sucrase and lactase in the ileum hydrolyse disaccharides into monosaccharides, which are absorbed by co-transport with sodium ions. Lipase hydrolyses the ester bonds in triglycerides to give monoglycerides and fatty acids, helped by bile salts which emulsify lipids into micelles, increasing the surface area. Endopeptidases hydrolyse peptide bonds within a polypeptide, exopeptidases hydrolyse bonds at the ends, and membrane-bound dipeptidases hydrolyse dipeptides into amino acids. Without hydrolysis animals could not absorb the monomers they need to make their own polymers and to respire.

Nucleic acids are also polymers made by condensation. Nucleotides are joined by phosphodiester bonds formed between the phosphate group of one nucleotide and the deoxyribose of another. In semi-conservative DNA replication, DNA helicase breaks the hydrogen bonds between bases, free nucleotides pair with complementary bases and DNA polymerase catalyses condensation reactions to join adjacent nucleotides. This allows genetic information to be copied accurately before mitosis, so that daughter cells are genetically identical, which is essential for growth and repair.

Hydrolysis is also important in gene technology: restriction endonucleases hydrolyse phosphodiester bonds at specific recognition sequences, leaving sticky ends, and DNA ligase then joins the gene into a plasmid vector by condensation. This is used to produce human insulin in bacteria.

Restriction enzymes are also used in genetic fingerprinting to cut DNA into fragments that can be separated by electrophoresis.

ATP is the immediate energy source of cells. It is formed by the



condensation of ADP and inorganic phosphate, catalysed by ATP synthase, during photophosphorylation in photosynthesis and oxidative phosphorylation in respiration, as protons diffuse through ATP synthase by chemiosmosis. ATP hydrolase then hydrolyses ATP to ADP and P_i , releasing a small, manageable amount of energy. This energy is used for active transport, such as the sodium-potassium pump that maintains the resting potential of neurones, for muscle contraction, where myosin heads hydrolyse ATP to detach from actin and return to their original position, and for protein synthesis. The P_i released can also phosphorylate other compounds, such as glucose at the start of glycolysis, making them more reactive. Because ATP is constantly hydrolysed and reformed, cells only need a small amount of it.

Hydrolysis is also important in nerve impulse transmission. At a cholinergic synapse, acetylcholine binds to receptors on the postsynaptic membrane and causes depolarisation. Acetylcholinesterase then hydrolyses acetylcholine into ethanoic acid (acetate) and choline, which diffuse back to the presynaptic neurone and are recombined by condensation using ATP. If acetylcholine were not hydrolysed, sodium ion channels would stay open and the postsynaptic neurone or muscle would be continuously stimulated, so hydrolysis allows separate impulses to be transmitted.

In ecosystems, saprobionts secrete enzymes onto dead organisms and waste and hydrolyse proteins, nucleic acids and polysaccharides by extracellular digestion, absorbing the products. This releases ammonium ions and phosphate ions, which nitrifying bacteria and plants can then use, so hydrolysis is essential for the recycling of nitrogen and phosphorus in nutrient cycles. Plants then use these ions to make amino acids, nucleotides and ATP by condensation.

Turn over ►



Beyond the specification, lysozyme, an enzyme found in tears, saliva and in the lysosomes of phagocytes, hydrolyses the glycosidic bonds between the sugars in the peptidoglycan (murein) cell walls of bacteria. This weakens the wall so the bacterium bursts by osmotic lysis, which protects the body from infection. Similarly, penicillin works by preventing the cross-links in peptidoglycan from forming, so the walls are weakened. Another example is HIV, which makes its proteins as one long polypeptide that must be hydrolysed by the viral enzyme HIV protease before new viruses can mature; protease inhibitor drugs block this hydrolysis and slow the progression to AIDS.

Water itself is important in all of these reactions, since it is a metabolite in both condensation and hydrolysis, and as a solvent it allows the enzymes and substrates to move and collide. Enzymes are essential because they lower the activation energy of these reactions, so they occur fast enough at body temperature.

In conclusion, condensation reactions allow organisms to build the polymers that form their structure, store energy and carry genetic information, while hydrolysis reactions allow them to digest food, release stored energy from glycogen, starch, triglycerides and ATP, transmit nerve impulses and recycle nutrients. The balance between the two is fundamental to life at every level, from the molecule to the ecosystem.



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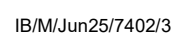
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