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I declare this is my own work.

INTERNATIONAL AS BIOLOGY (9610)

Unit 2 Biological Systems and Disease

Monday 13 January 2025 07:00 GMT Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- 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).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 75.

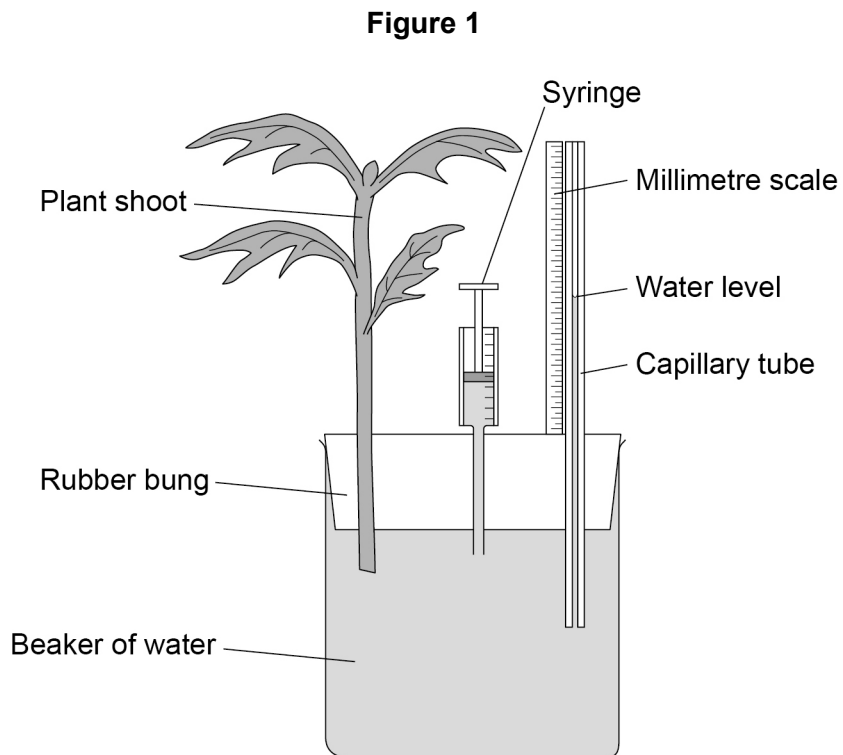
For Examiner's Use	
Question	Mark
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A student uses a potometer to investigate the rate of water uptake from two different plant species.

Figure 1 shows the potometer the student uses.



The student uses several practical techniques in the method to make sure that the results are as accurate as possible.



0 1 . 1

Describe **three** practical techniques the student uses when setting up the potometer to make sure that the results are accurate.

Give the reason for each practical technique.

[6 marks]

1 *Seal all the joints with petroleum jelly (Vaseline), and make sure the base of the stem fits tightly in the hole in the rubber bung.*

Reason *So the potometer is air-tight and prevents air from entering (and no water leaks or evaporates out).*

2 *Set up the potometer submerged under water, filling the capillary tube under water.*

Reason *To prevent air bubbles (air locks) and make sure that the capillary tube is completely filled with water.*

3 *Cut the stem of the shoot while it is submerged in water.*

Reason *To prevent air entering the xylem, as air bubbles in the xylem would stop the movement of water.*

Turn over ►



0 1 . 2

Give the function of the syringe shown in **Figure 1**.

[1 mark]

*To return the water level in the capillary tube to the start of the scale
(to refill the capillary tube) so further measurements can be taken.*

The student records the results for the first plant shoot (species **A**).

The student repeats the investigation on a different day using a shoot from a different plant (species **B**).

The student calculates the rate of water uptake for species **A** and species **B**.

Table 1 shows the student's results.

Table 1

Time interval / min	Rate of water uptake / $\text{mm}^3 \text{min}^{-1}$	
	Species A	Species B
0–15	0.30	0.24
15–30	0.31	0.23
30–45	0.32	0.24
45–60	0.31	0.24



0 1 . 3

Describe how the student calculates the rate of water uptake in $\text{mm}^3 \text{min}^{-1}$ for each time interval.

[3 marks]

Record the distance the water level moves along the capillary tube in each 15 minute time interval, using the millimetre scale.

Measure the diameter of the capillary tube and use $\pi r^2 \times \text{length}$ to calculate the volume of water taken up (mm^3).

Calculate the rate by dividing the volume of water by the time taken, 15 minutes.

0 1 . 4

Suggest **two** reasons for the lower rate of water uptake by species B.

[2 marks]

1 *Lower temperature on the day species B was tested (or lower light intensity, so fewer stomata open).*

2 *Species B has fewer or smaller leaves, so a lower surface area (or fewer stomata).*

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0 2

Immunity is the ability of an organism to resist infection.

0 2 . 1

Define **active** and **passive** immunity.

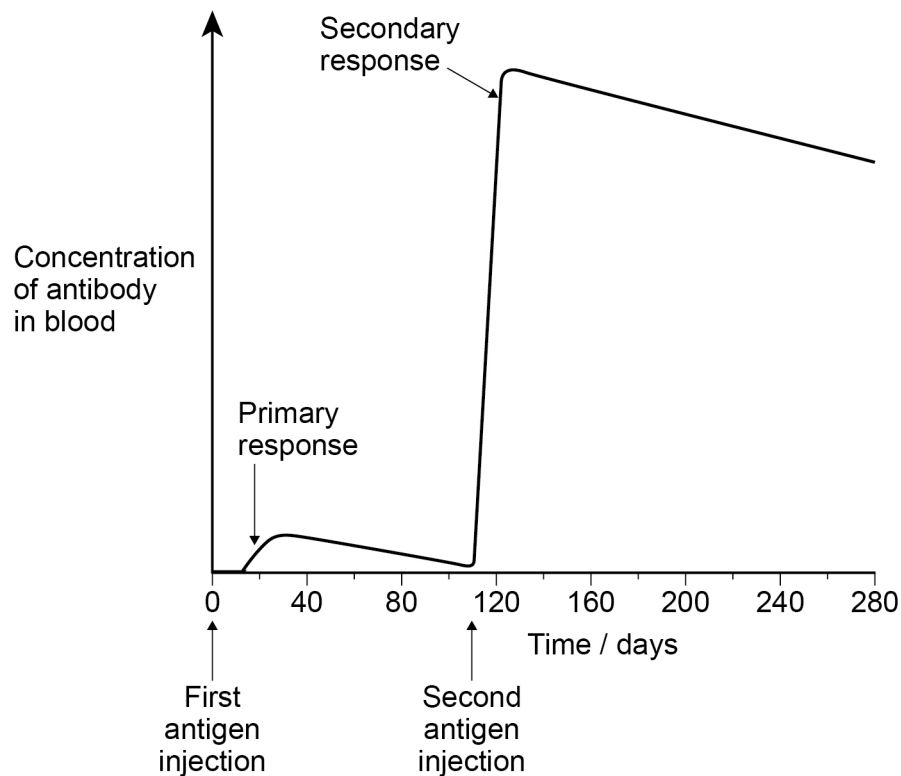
[2 marks]

Active immunity Stimulation of the production of its own antibodies (and memory cells) after exposure to the antigen.

Passive immunity Introduction of antibodies from another source, e.g. across the placenta or by injection.

Figure 2 shows the primary and secondary response to the injection of the same antigen as part of a vaccination programme.

Figure 2



0 2 . 2

Suggest a suitable unit of measurement for the 'concentration of antibody in blood' axis in **Figure 2**.

[1 mark]

mg cm⁻³



0 2 . 3

Describe and explain **two** ways that the secondary response in **Figure 2** is different from the primary response.

[4 marks]

Difference 1 *The secondary response is faster: antibody is produced sooner after the injection.*

Explanation *Clonal selection has already occurred, as memory cells for this antigen are present.*

Difference 2 *The secondary response produces a much higher concentration of antibody, maintained for longer.*

Explanation *More clonal expansion: memory cells divide rapidly by mitosis into many plasma cells, so more antibody is produced.*

Question 2 continues on the next page

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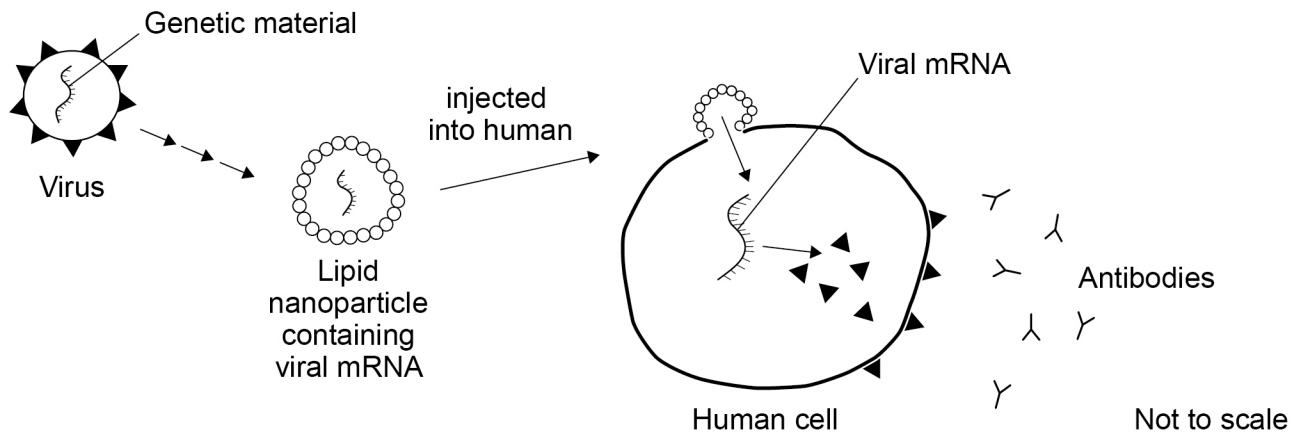


There are many different types of vaccine. One type of vaccine uses mRNA molecules within lipid nanoparticles.

A nanoparticle is a small particle between 1 to 100 nanometres in size.

Figure 3 shows an **outline** of the process of the production and use of the vaccine. Not all the stages are shown.

Figure 3



0 2 . 4 Suggest which part of the virus the mRNA is coding for.

[1 mark]

Spike (attachment) proteins on the virus surface, the antigen.

0 2 . 5 Suggest why the viral mRNA is put into a lipid nanoparticle.

[1 mark]

So the viral mRNA can pass through the cell surface membrane (phospholipid bilayer) and enter the human cell; the lipid also protects the mRNA from being broken down.

0 2 . 6 Name the type of human cell shown in **Figure 3**.

[1 mark]

Antigen-presenting cell (e.g. a dendritic cell or macrophage)

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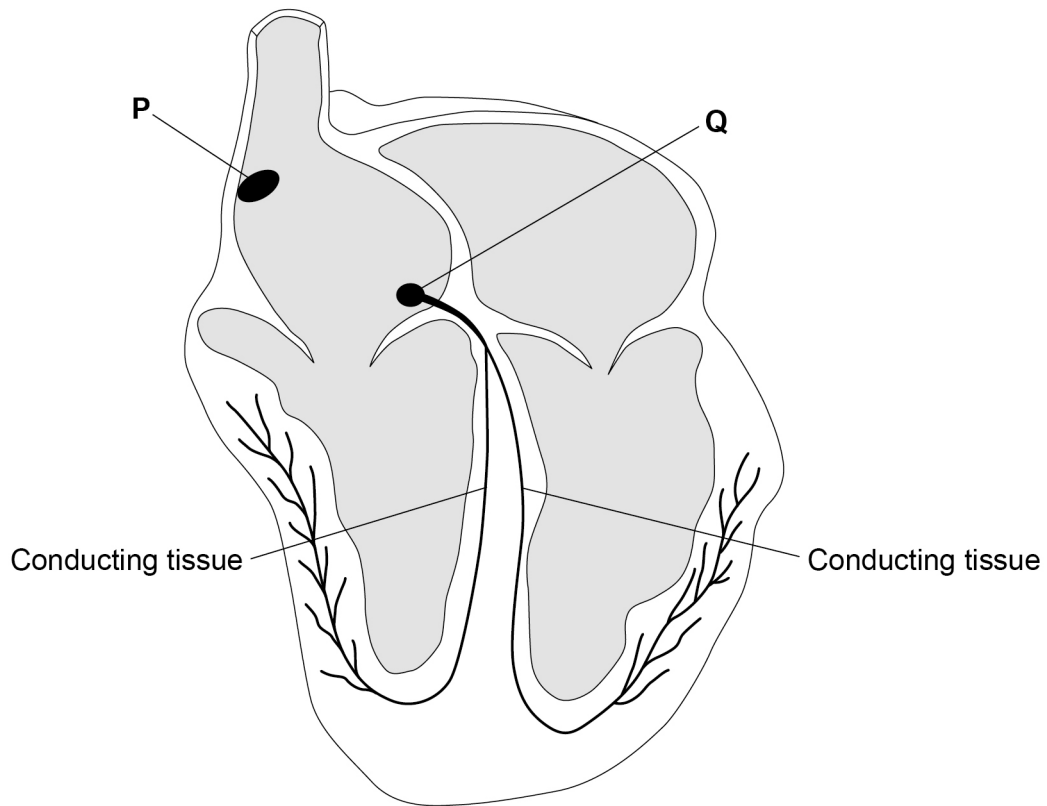


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Figure 4 shows some of the internal structures of the human heart.

Figure 4



Structure **P** starts the contraction of the heart muscle.

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Name the chamber of the heart containing structure **P**.

[1 mark]

Right atrium



The contraction of the heart muscle is delayed briefly at structure **Q** before the lower chambers contract.

0 3 . 2 Suggest why the delay at structure **Q** is important.

[1 mark]

To allow the atria to empty and the ventricles to fill with blood before the ventricles contract.

0 3 . 3 Explain why it is important that the contraction of the lower chambers starts at the base of the heart.

[2 marks]

So the ventricles contract from the base upwards, squeezing the blood upwards and out of the heart (no blood is left at the bottom), into the aorta and pulmonary artery, which leave from the top of the ventricles.

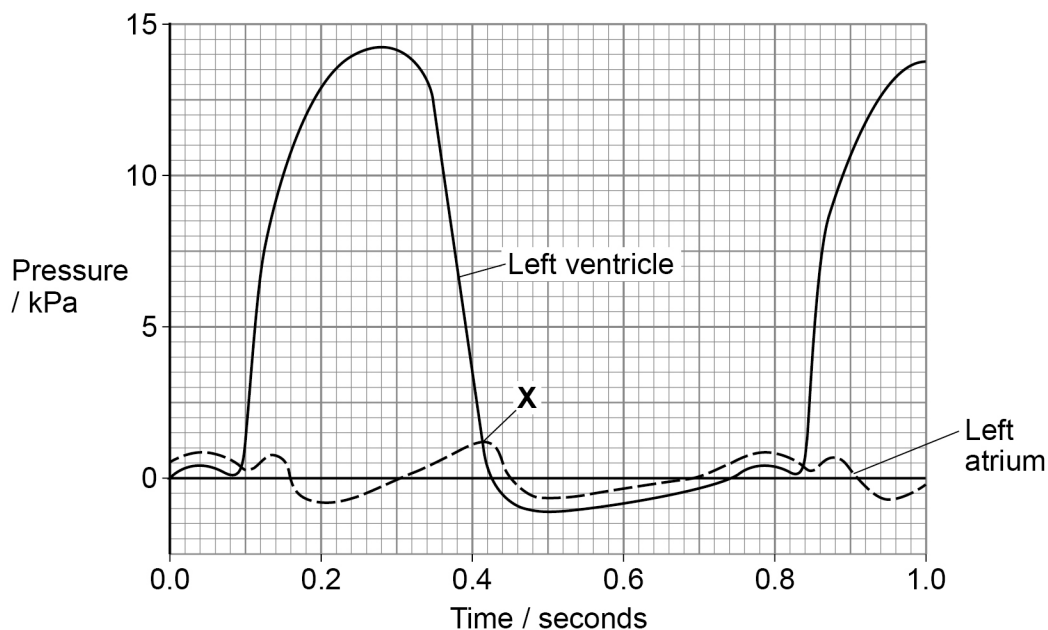
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Figure 5 shows the pressure changes in the left side of the human heart.

Figure 5



0 3 . 4

Use Figure 5 to calculate the heart rate in beats per minute (bpm).

[1 mark]

Start of one contraction = 0.09 s, start of the next = 0.83 s

One cardiac cycle = 0.83 - 0.09 = 0.74 s

Heart rate = 60 ÷ 0.74 = 81 bpm

Heart rate 81 bpm



0 3 . 5

The cardiac output was measured as $5.6 \text{ dm}^3 \text{ min}^{-1}$

Use the equation for cardiac output to calculate the stroke volume for this individual in cm^3

[2 marks]

$$\text{Cardiac output} = \text{stroke volume} \times \text{heart rate}$$

$$5.6 \text{ dm}^3 \text{ min}^{-1} = 5600 \text{ cm}^3 \text{ min}^{-1}$$

$$\text{Stroke volume} = 5600 \div 81 = 69.1 \text{ cm}^3$$

Stroke volume 69 cm^3

0 3 . 6

Describe **and** explain what is happening at point **X** on **Figure 5**.

Include the name of the **valve** involved in your answer.

[2 marks]

At X the atrioventricular (bicuspid / mitral) valve opens.

This is because the pressure in the left atrium is now higher than the pressure in the left ventricle, so blood flows from the left atrium into the left ventricle.

0 3 . 7

What causes the maximum pressure in the ventricle to be much **higher** than the maximum pressure in the atrium?

[2 marks]

The ventricle walls have a much thicker muscle layer than the atrium walls,

so the ventricle contracts with greater force (a stronger contraction).

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0 4

The human immunodeficiency virus (HIV) is a retrovirus containing the enzyme reverse transcriptase.

0 4 . 1

Explain why HIV needs reverse transcriptase to produce viral proteins.

[2 marks]

HIV contains RNA (not DNA) as its genetic material.

Reverse transcriptase is needed to synthesise cDNA (DNA) from the viral RNA; this DNA is inserted into the host DNA and transcribed to mRNA, which is translated into viral proteins.

HIV binds to receptors on helper T-cells.

0 4 . 2

Describe the role of helper T-cells in defending the body against HIV.

[2 marks]

Helper T cells stimulate B cells to divide and form plasma cells that produce antibodies (and memory cells).

They also activate cytotoxic T cells and stimulate phagocytes to engulf the virus.

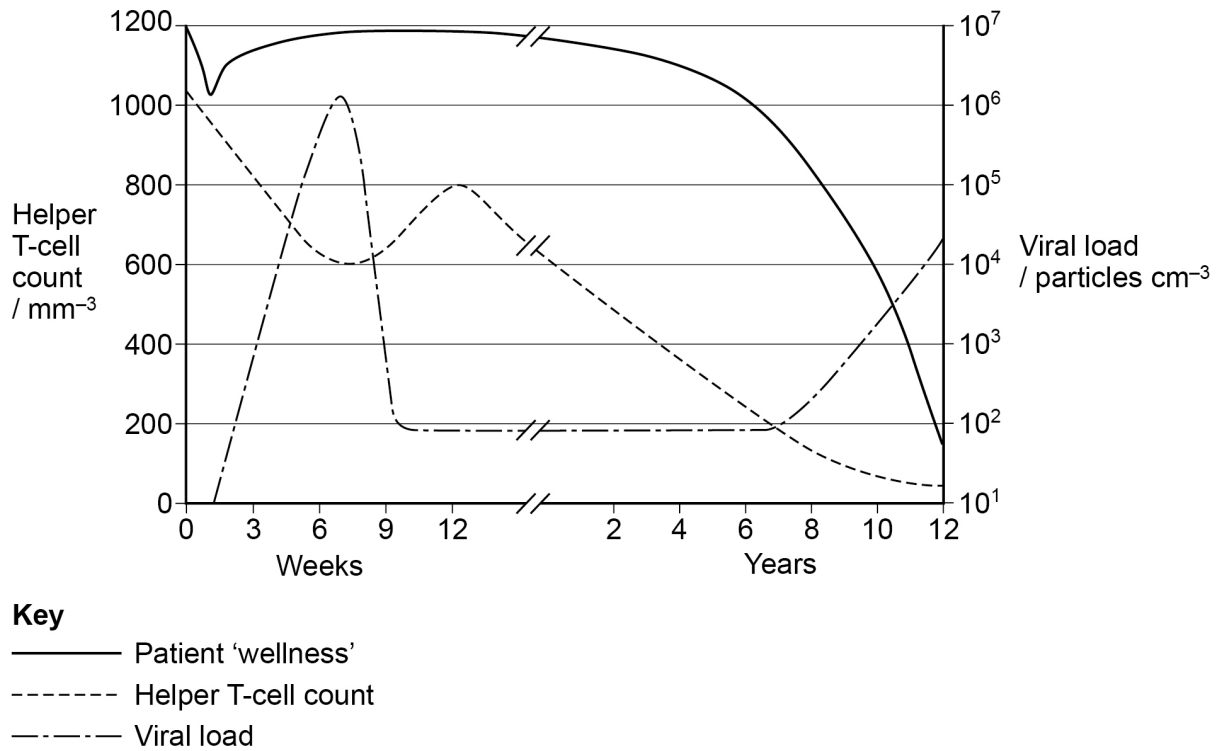
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Figure 6 shows the stages of a typical untreated HIV infection.

Figure 6



0 4 . 3

Describe the trend in the viral load between years 1 to 12 shown in **Figure 6**.

[1 mark]

The viral load stays stable (level) from year 1 until about year 7, then increases rapidly up to year 12.



0 4 . 4

'Patient wellness' is a measure of how well a patient is feeling.

Suggest a method scientists could have used to measure patient wellness **and** the reason why their measure of patient wellness might be inaccurate?

[2 marks]

Method for measuring patient wellness Patient questionnaire (survey) asking how well they feel.

Reason for inaccuracy in measuring patient wellness It is subjective: each patient judges how they feel differently.

0 4 . 5

The viral load was 9.9×10^1 at the end of the first year and 3.5×10^4 at the end of 12 years.

Calculate the percentage change in the viral load.

Give your answers to the **nearest whole number**.

[2 marks]

$$\begin{aligned}\% \text{ change} &= (3.5 \times 10^4 - 9.9 \times 10^1) \div (9.9 \times 10^1) \times 100 \\ &= (35000 - 99) \div 99 \times 100 = 35253.5\end{aligned}$$

Percentage change in the viral load = 35254 %

0 4 . 6

Patients in the final stage (9–12 years) of untreated HIV are more likely to die from cancer and diseases caused by pathogens.

Use information in **Figure 6** to explain why untreated HIV patients are more likely to die from these diseases.

[2 marks]

The helper T cell count decreases to a very low level (below 200 mm^{-3}), so fewer B cells produce antibodies, fewer cytotoxic T cells are activated and there is less phagocytosis, so pathogens and cancer cells are not killed.



0 5

Bacteria are prokaryotic cells. Prokaryotic cells and eukaryotic cells divide using different processes to produce new cells.

0 5 . 1

Name the type of cell division in prokaryotic cells and the type in eukaryotic cells.

[1 mark]

Prokaryotic cells Binary fission

Eukaryotic cells Mitosis

0 5 . 2

Give **two** ways that cell division in prokaryotic cells is different from cell division in eukaryotic cells.

[2 marks]

1 Prokaryotic cells replicate circular DNA (and plasmids), but eukaryotic cells replicate linear DNA (chromosomes).

2 Prokaryotic cells do not use spindle fibres, and there is no breakdown of a nuclear envelope.

0 5 . 3

In a culture of bacteria, each cell can divide every 30 minutes.

The original number of cells in the population of bacteria is 1.15×10^5

Calculate the number of cells after 24 hours.

None of the bacterial cells die during this time.

Give your answer in standard form.

[2 marks]

$$\text{Number of divisions} = 24 \times 60 \div 30 = 48$$

$$\text{Cells} = 1.15 \times 10^5 \times 2^{48} = 3.237 \times 10^{19}$$

$$\text{Number of cells after 24 hours} = \underline{3.24 \times 10^{19}}$$



A scientist investigates how effective an antibiotic called vancomycin is in killing a species of bacterium called *Staphylococcus aureus*.

The scientist:

- puts an equal volume of a culture of *S. aureus* into five containers
- adds the same volume of different concentrations of vancomycin solution to each of four of the containers
- adds the same volume of water instead of vancomycin solution to the fifth container
- keeps the containers at 35 °C for 3 hours
- estimates the number of living bacteria in each container.

Table 2 shows the scientist's results.

Table 2

Concentration of vancomycin / $\mu\text{g cm}^{-3}$	Estimated number of living bacteria remaining after 3 hours ($\times 10^6$)
0	100
5	57
10	48
50	37
100	36

0 5 . 4 Describe the results shown in **Table 2**.

[2 marks]

The number of living bacteria decreases as the concentration of vancomycin increases.

There is a large decrease from 0 to 50 $\mu\text{g cm}^{-3}$ (100 to 37×10^6), but the number levels out at and after 50 $\mu\text{g cm}^{-3}$ (37 to 36×10^6).

Question 5 continues on the next page

Turn over ►



0 5 . 5

Give **one** limitation of the method used in this investigation.**[1 mark]**

*It was only done once (no repeats), so the results are not reliable; also
only 4 concentrations were used, with large intervals.*

Scientists discovered that some cells of *S. aureus* have a gene for resistance to the antibiotic vancomycin.

Scientists had previously identified this same resistance gene in a different species of bacterium called *Enterococcus faecalis*.

0 5 . 6

Describe how the resistance gene could have passed from *E. faecalis* to *S. aureus*.**[2 marks]**

*By horizontal gene transmission: the plasmid (DNA) containing the
resistance gene is replicated in *E. faecalis*,
and a copy is transferred to *S. aureus* by conjugation, through a pilus.*



0 6

Mutagens can cause damage to DNA.

Damage to the DNA in a cell activates a tumour suppressor gene to code for a protein called p53

The p53 protein activates another gene to produce a protein called p21

The p21 protein can either repair the DNA or stop the cell cycle.

0 6 . 1

Explain how a mutation in a tumour suppressor gene could cause cancer to develop.

Use your own knowledge and the information provided.

[3 marks]

The mutation means the p53 protein is faulty (or not produced), so the p21 gene is not activated.

So p21 protein is not produced, so the DNA is not repaired and cells with damaged DNA continue to divide.

So cell division is not stopped, leading to uncontrolled cell division and a tumour.

Question 6 continues on the next page

Turn over ►

Chemotherapy drugs are used to treat cancer.

The drugs work by causing damage to the DNA in cancer cells.

This damage causes the cancer cells to die.

Chemotherapy drugs damage DNA most if they are given in the stage of the cell cycle where DNA replication occurs.

0 6 . 2

Name the stage of the cell cycle that a chemotherapy drug is likely to cause the **most** damage to DNA.

[1 mark]

S phase (synthesis phase of interphase)

Chemotherapy drugs can sometimes cause tumour cells to go into an inactive state called senescence.

Cells in senescence are alive but are no longer able to divide.

Scientists can identify the cells that are in senescence by adding ^3H -labelled thymine to a tissue section from a tumour.

^3H is a radioactive isotope of hydrogen.

0 6 . 3

Suggest how the use of ^3H -thymine could distinguish between cells in senescence and cells **not** in senescence.

[2 marks]

Cells not in senescence can divide, so they take up the ^3H -thymine and use it to make new DNA (DNA replication).

So only the cells not in senescence become radioactive; senescent cells do not replicate DNA, so they are not radioactive.



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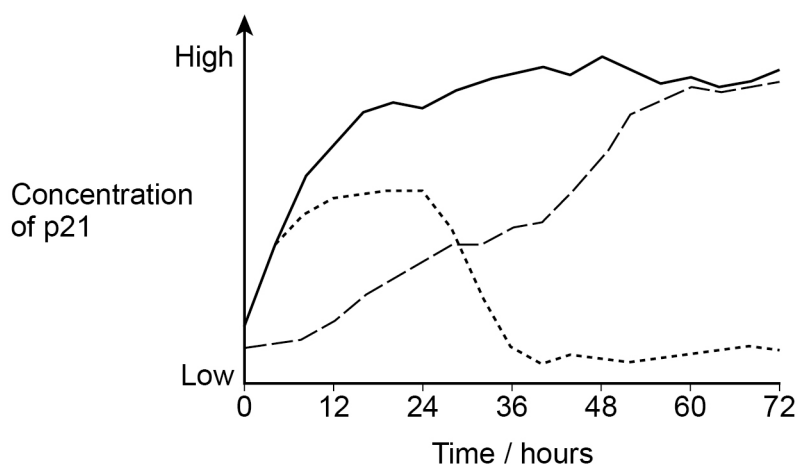
Scientists investigate the effect of a chemotherapy drug on the concentration of p21 in human lung cancer cells.

The scientists:

- isolate and culture a large number of lung cancer cells and divide them into two groups
- add the chemotherapy drug to the cancer cells in one group before the cells replicate their DNA
- add the chemotherapy drug to the cancer cells in the other group after the cells have replicated their DNA
- measure the concentration of the p21 protein in the cells from both groups at regular intervals for 72 hours
- analyse a large number of cells from each group to determine if they are in senescence.

Figure 7 shows the scientists' results.

Figure 7



Key

Chemotherapy drug added

Group 1: Before cells replicate DNA

Group 2: After cells replicate DNA

Condition of cells

—— Cells in senescence

..... Cells continue dividing

--- Cells in senescence



0 6 . 4

A journalist states:

'This investigation shows that future chemotherapy treatments should happen before DNA replication. This would increase the chances of successful treatment of cancerous tumours.'

Evaluate the journalist's statement.

Use the information provided and **Figure 7**.

[5 marks]

Support: group 1 (drug before DNA replication) had a faster rise in the concentration of p21 and had the highest concentration of p21 over the 72 hours. It might be successful if the decrease in p21 (after 24 hours) can be stopped.

Against: in group 1 the p21 concentration in some cells decreased and these cells continued to divide, whereas group 2 (after replication) showed an increase in p21 and resulted in cells that were only in senescence.

It was only conducted on isolated lung cancer cells (in vitro), only once, with only one type of chemotherapy drug, and only for 72 hours.

Tumours contain a mixture of cells at different stages of the cell cycle, so the drug cannot be timed for all cells, and p21 might not be the only measure of success.

11

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Food is digested and absorbed in the human digestive system.

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Describe how **proteins** are digested in humans.

Include the names of the enzymes involved **and** the locations of the enzymes in the digestive system.

[5 marks]

Proteins are digested by the hydrolysis of peptide bonds.

The stomach secretes an endopeptidase, pepsin, which breaks peptide bonds within the polypeptide, producing shorter polypeptides.

The pancreas secretes more endopeptidases (trypsin, chymotrypsin) and also exopeptidases, which operate in the small intestine (duodenum).

Exopeptidases break peptide bonds at the ends of the polypeptides, producing dipeptides and amino acids.

Membrane-bound dipeptidases in the cell surface membrane of the epithelial cells of the ileum hydrolyse dipeptides into amino acids.



07.2

Pathogens, including cholera bacteria, may also be ingested with food and water.

Describe how cholera bacteria cause severe dehydration.

[5 marks]

Cholera bacteria produce a toxin (a protein).

*The toxin binds to complementary receptors on the cell surface
membrane of the epithelial cells lining the small intestine.*

*It opens chloride ion channels, so chloride ions move out of the cells
into the lumen of the small intestine.*

*The chloride ions lower the water potential in the lumen of the small
intestine.*

*So water leaves the epithelial cells and enters the lumen by osmosis,
down a water potential gradient.*

*The increased water in the lumen leads to severe diarrhoea, so a lot of
water is lost from the body, causing dehydration.*

10

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