

Please write clearly in block capitals.

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 19 June 2024

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	
5	
6	
7	
TOTAL	



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

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 In the following passage, each numbered space can be filled with a biological term.

Each type of cell has specific molecules on its _____ (1) _____ that identify it. An antibody is a _____ (2) _____ with two _____ (3) _____ binding sites. Antibodies are made and released by _____ (4) _____ cells.

Vaccines can provide protection for individuals and populations against disease. The response to a vaccine is an example of _____ (5) _____ immunity.

_____ (6) _____ immunity occurs when a large proportion of a population becomes immune to a disease.

Write the correct biological term beside each number below that matches the space in the passage.

[3 marks]

- 1 (Cell-surface) membrane
- 2 Protein (immunoglobulin)
- 3 Antigen
- 4 Plasma
- 5 Active
- 6 Herd

0 1 . 2 There is currently no effective vaccine available for HIV.

Suggest **one** reason why.

[1 mark]

HIV has a high rate of mutation, so its antigens keep changing
(antigenic variability) and antibodies / memory cells made in response to
a vaccine would no longer be complementary.



0 1 . 3 Table 1 shows the action of two antibiotics.

Table 1

Antibiotic	Action of antibiotic
Ciprofloxacin	Causes double-stranded DNA to break apart
Penicillin	Prevents formation of crosslinks between murein chains

Using the information in **Table 1**, explain why each antibiotic is **not** effective against HIV.

[2 marks]

Ciprofloxacin *HIV has RNA as its genetic material, not DNA, so there is no double-stranded DNA for ciprofloxacin to break apart.*

Penicillin *HIV is a virus with no cell wall, so it does not contain murein and there are no crosslinks for penicillin to prevent.*

6

Turn over for the next question

Turn over ►

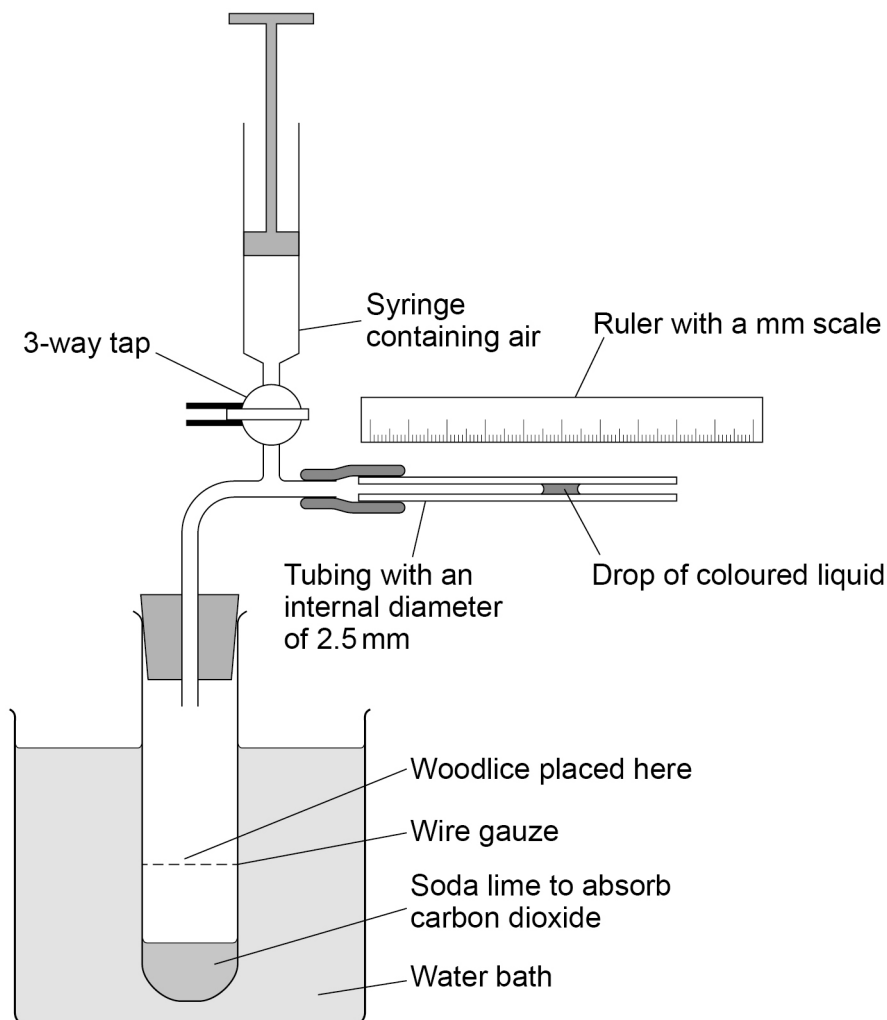


0 2

A student investigated the effect of temperature on the rate of aerobic respiration in woodlice.

Figure 1 shows the apparatus they used.

Figure 1



The student altered the temperature of the water bath and measured how far the drop of coloured liquid moved every minute for 5 minutes.

0 2

. 1

Other than those stated, suggest **two** variables the student should have kept constant in this investigation.

[1 mark]

1 Volume / mass of soda lime

2 Mass (and number) of woodlice



0 2 . 2

Describe how the student used the apparatus in **Figure 1** to reset the drop of coloured liquid back to the **right-hand** end of the tubing.

[2 marks]

I would open the 3-way tap so that the syringe is connected to the tubing.

Then I would push the syringe plunger down, pushing air into the apparatus so that the drop moves back to the right-hand end, and then close the tap again.

0 2 . 3

The student also set up a control experiment.

Suggest a suitable control experiment **and** explain why it was necessary.

[2 marks]

Control experiment *The same apparatus with no woodlice (or glass beads of the same volume), with all other conditions the same.*

Explanation *To show that it is the respiring woodlice taking up the oxygen that causes the drop to move, and that no other factor (e.g. temperature changing the volume / pressure) is causing it.*

Question 2 continues on the next page

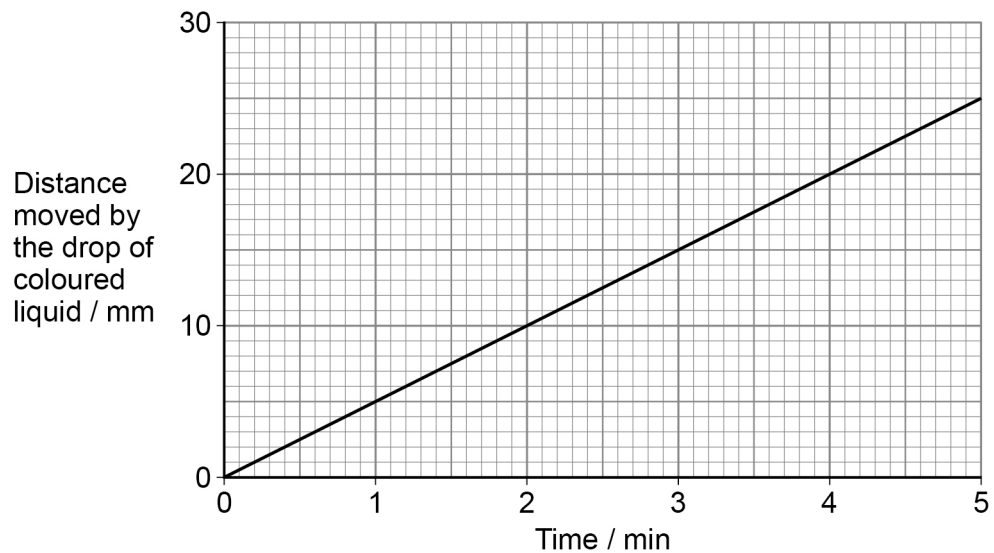
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0 2 . 4

Figure 2 shows the student's results at 25 °C

The mass of the woodlice in the tube was 3.78 g

Figure 2

Use **Figure 1** (on page 4) and **Figure 2** to calculate the mean rate of oxygen uptake by the woodlice in $\text{mm}^3 \text{s}^{-1} \text{g}^{-1}$

The formula for the volume of the capillary tubing is $\pi r^2 l$.

Use $\pi = 3.14$ in your calculation.

Show your working **and** give your answer to 2 decimal places.

[3 marks]

Distance moved in 5 min = 25 mm; radius = $2.5 \div 2 = 1.25 \text{ mm}$

Volume of O_2 = $3.14 \times 1.25^2 \times 25 = 122.66 \text{ mm}^3$

Rate = $122.66 \div (5 \times 60) = 0.409 \text{ mm}^3 \text{s}^{-1}$

Per gram = $0.409 \div 3.78 = 0.108 \text{ mm}^3 \text{s}^{-1} \text{g}^{-1}$

Answer 0.11 $\text{mm}^3 \text{s}^{-1} \text{g}^{-1}$

8



03.1

Describe **and** explain the relationship between surface area to volume ratio of the human body and metabolic rate.

[3 marks]

As the surface area to volume ratio increases, the metabolic rate increases, so a person with a large surface area to volume ratio has a high metabolic rate.

This is because a larger surface area to volume ratio means more heat is lost (faster) from the body surface.

A higher rate of metabolism / respiration releases more heat, which replaces the heat lost and maintains body temperature.

Question 3 continues on the next page

Turn over ►



Table 2 shows the height and mass of two adults.

Table 2

Person	Height / cm	Mass / kg
A	181	90.90
B	149	62.62

The surface area of a person is estimated using the following formula:

$$\text{Surface area in m}^2 = \sqrt{\frac{\text{height in cm} \times \text{mass in kg}}{3600}}$$

The volume of a person is estimated using the following formula:

$$\text{Volume in m}^3 = \frac{\text{mass in kg}}{1010}$$

0 3 . 2

Using suitable calculations, deduce which person has the smaller surface area to volume ratio.

Show your working **and** complete the sentence below.

Give your answer to 3 significant figures.

[3 marks]

$$A: SA = \sqrt{(181 \times 90.90 \div 3600)} = 2.14 \text{ m}^2; \quad V = 90.90 \div 1010 = 0.09 \text{ m}^3$$

$$A: SA : V = 2.14 \div 0.09 = 23.75 = 23.8 : 1$$

$$B: SA = \sqrt{(149 \times 62.62 \div 3600)} = 1.61 \text{ m}^2; \quad V = 62.62 \div 1010 = 0.062 \text{ m}^3$$

$$B: SA : V = 1.61 \div 0.062 = 25.97 = 26.0 : 1$$

23.8 is smaller than 26.0, so person A has the smaller ratio.

Person A has the smaller surface area to volume ratio which = 23.8 : 1



0 3 . 3

Which is **not** a possible explanation for the difference in surface area to volume ratio between person **A** and person **B**?

Tick (✓) **one** box.

[1 mark]

Person **A** and person **B** have different body shapes.

☐

Person **A** has a higher mass than person **B**.

☒

Person **A** is taller than person **B**.

☐

0 3 . 4

Name **two** structural features of the gills of a fish that increase their surface area.

[1 mark]

1 *Many gill filaments*

2 *Many lamellae (on each filament)*

8

Turn over for the next question

Turn over ►



0 4

Osteoarthritis (OA) is a disease resulting in joint damage which causes stiffness.

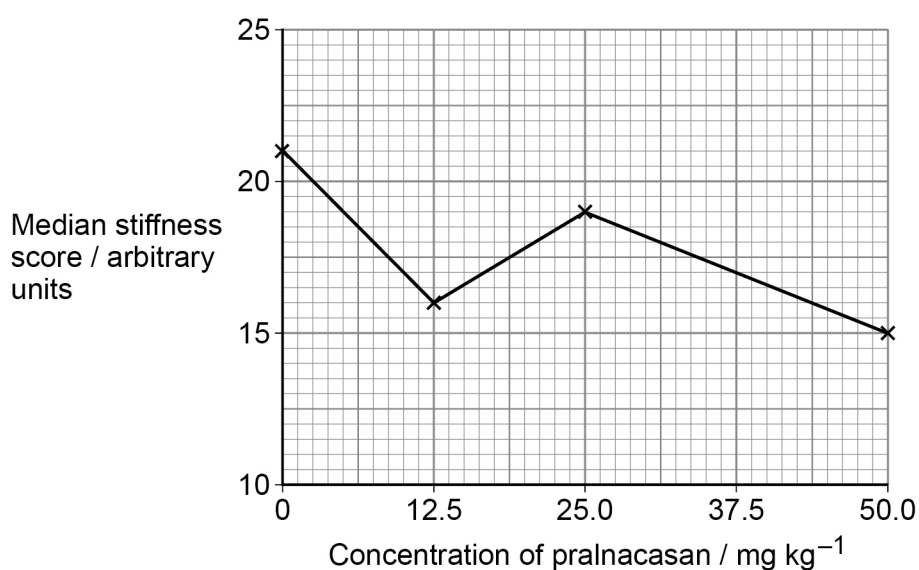
Scientists investigated the use of a drug called pralnacasan to treat OA in 80 mice.

The scientists:

- injected the knee joints of mice with an enzyme to cause joint damage
- split the mice randomly into 4 equal groups
- fed each group with food containing a different concentration of pralnacasan
- after 6 weeks, assessed the stiffness of the knee joints of the mice and scored them using an arbitrary scale.

Figure 3 shows their results.

Figure 3



0 4 . 1

Describe how the scientists determined the median of the stiffness scores.

[1 mark]

They put the stiffness scores for each concentration in order from smallest to largest and found the middle value.



0 4 . 2

Using all the information, evaluate the use of pralnacasan as an effective treatment for OA in humans.

[5 marks]

For: all concentrations of pralnacasan reduced the median stiffness score compared with 0 mg kg⁻¹ (from about 21 to 15 at 50.0 mg kg⁻¹), and reduced stiffness could mean less joint damage / pain and better mobility.

Against: only medians are shown, so there is no idea of the range or standard deviation, and no statistical test was done, so we do not know if the differences are significant or just due to chance.

There is no result for 37.5 mg kg⁻¹, and 25.0 gave more stiffness than 12.5, so there is no clear dose response.

All the mice still had stiffness, so it only reduced the stiffness and did not cure it.

The joint damage was caused by an injected enzyme, which may not be the same as OA. The study was done in mice, not humans, only lasted six weeks so long-term effects are unknown, and had a small sample of only 20 mice in each group.

6

Turn over for the next question

Turn over ►



0 5

Leigh syndrome (LS) is a rare, recessive, inherited condition.

LS is caused by a mutation in any one of more than 75 different genes coding for proteins involved in oxidative phosphorylation.

In 80% of people with LS, these mutations occur in nuclear DNA. In 20% of people with LS, these mutations occur in mitochondrial DNA (mtDNA).

15% of the nuclear DNA mutations that cause LS occur in the *SURF1* gene. A mutated *SURF1* gene codes for a shorter polypeptide than a non-mutated *SURF1* gene.

0 5**1**

Name **one** type of *SURF1* gene mutation and explain how this mutation could lead to production of a shorter polypeptide.

[2 marks]

Type of mutation Substitution (of a base)

Explanation The substitution could change a codon (triplet) into a premature stop codon, so translation stops early and fewer amino acids are joined, giving a shorter polypeptide.



Globally, the frequency of LS is 1 in 40 000

In the Faroe Islands, which are 18 isolated islands, the frequency of LS is 1 in 1700

0 5 . 2 The population of the Faroe Islands is 49 053

Estimate the number of people in the Faroe Islands with LS caused by a mutation in the *SURF1* gene.

Use information in this question and the information on page 12.

Give your answer to the nearest whole number.

Show your working.

[3 marks]

$$\text{People with LS} = 49\,053 \div 1700 = 28.85$$

$$\text{Nuclear DNA mutations} = 28.85 \times 0.80 = 23.08$$

$$\text{SURF1 mutations} = 23.08 \times 0.15 = 3.46$$

Answer 3 people

0 5 . 3 The frequency of LS is higher in the Faroe Islands than globally.

Suggest and explain **one** reason why.

[2 marks]

The Faroe Islands are isolated, so there is inbreeding within the population and little or no interbreeding with other populations (the people may share a common ancestor / founder effect).

So there is a small gene pool with little gene flow, so the frequency of the LS alleles is higher and there is a higher chance of inheriting two recessive alleles.

Turn over ►



0 5 . 4

LS usually causes death within the first three years of life.

Using all the information in this question, evaluate whether all people should be genetically screened for LS.

[3 marks]

Yes: screening could identify people who are heterozygous carriers, allowing informed decisions about having children and preventing suffering / death of children. It might be worth it in families with a history of LS or in the Faroe Islands (1 in 1700).

No: LS is rare globally (only 1 in 40 000), and it can be caused by mutations in any one of more than 75 genes, so many probes would be needed, making it too expensive to screen everybody.

10



0	6	.	1
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Define the biological term **population**.**[2 marks]**

*A group of organisms of the same species living in a particular area
(habitat) at a particular time,
which can interbreed to produce fertile offspring.*

Question 6 continues on the next page**Turn over ►**

Ecologists monitored the biodiversity of birds in a protected woodland.

They recorded the number of bird species breeding in the woodland on the same day, every year for a 30-year period.

Figure 4 shows their results.

Figure 4

Figure 4 not reproduced here due to third-party copyright restrictions

The figure is taken from the following website:

Figure 1a. Anne E. Magurran, Stephen R. Baillie, Stephen T. Buckland, Jan McP. Dick, David A. Elston, E. Marian Scott, Rognvald I. Smith, Paul J. Somerfield, Allan D. Watt, Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time, Trends in Ecology & Evolution, Volume 25, Issue 10, 2010, Pages 574-582, ISSN 0169-5347, <https://doi.org/10.1016/j.tree.2010.06.016>.

0 6 . 2 Which statement correctly represents the species richness of the woodland?

Tick (✓) **one** box.

[1 mark]

The number of all species present in the woodland

☒

The number of all species present in the woodland and their habitats

☐

The number of animal and plant species present in the woodland

☐

The number of bird species present in the woodland

☐


0 6 . 3

A student studying the information in this question concluded that all woodlands should be protected to increase the biodiversity of birds.

Evaluate the student's conclusion.

[4 marks]

In support, the number of bird species breeding in the protected woodland increased over the 30 years, and this was a long-term study.

However, the number of species did not increase every year; in some years it decreased / fluctuated.

We do not know when the protection started or whether its aim was to protect birds or increase biodiversity.

There is no comparison with (control) woodland that was not protected, and only one woodland was studied, so protection may not have the same effect in all woodlands.

Only breeding birds were recorded on one day each year, so species that breed at other times or migrate would be missed. The number of individuals of each species is not known, so a diversity index cannot be calculated, and the data is old.

0 6 . 4

It is **not** possible to extrapolate the data for the number of bird species recorded breeding each year beyond 1979.

Explain why.

[1 mark]

The relationship is not linear; the data fluctuates from year to year, so we cannot predict how the number of species will change.

Turn over ►



In this woodland, the ecologists measured the similarity in the bird community by comparing each year to 1949 using an index of similarity.

This index ranges from 1.0 for total similarity to 0.0 for total dissimilarity.

Figure 5 shows their results.

Figure 5

Figure 5 not reproduced here due to third-party copyright restrictions

The figure is taken from the following website:

Figure 1b, Anne E. Magurran, Stephen R. Baillie, Stephen T. Buckland, Jan McP. Dick, David A. Elston, E. Marian Scott, Rognvald I. Smith, Paul J. Somerfield, Allan D. Watt,
Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time,
Trends in Ecology & Evolution, Volume 25, Issue 10, 2010, Pages 574-582, ISSN 0169-5347, <https://doi.org/10.1016/j.tree.2010.06.016>.

0 6 . 5

Suggest how the changes in the index of similarity in the bird community provide evidence for the process of succession.

[2 marks]

The index of similarity decreases over time, so the bird community

becomes less similar to (more dissimilar from) the 1949 community.

This suggests the biodiversity / species of birds changed, due to changes

in the woodland, e.g. changes in the habitat, food sources, competition

and predation as the plant community changed over time, as happens in

succession.



06.6

In **Figure 5**, the index of similarity for the last 10 years remains fairly constant.

Name the stage of a succession this represents.

Suggest **one** reason why the index of similarity is **not** absolutely constant.

[2 marks]

Stage of succession Climax community

Reason why the index of similarity is not absolutely constant Even in a climax
community, the bird species present change slightly from year to year,
e.g. due to migration, or the arrival or loss of a species.

Question 6 continues on the next page

Turn over ►



The Living Planet Index (LPI) is an index designed to monitor the state of the world's biodiversity.

The LPI is arbitrarily scaled to be 1.0 in 1970, the baseline year.

Figure 6 shows the LPI from the Living Planet Report, 2008. The dotted lines represent ± 2 standard deviations from the mean, which includes over 95% of the data.

Figure 7 shows an alternative version of **Figure 6** published on a news website.

Figure 6

Figure 7

Figures 6 and 7 not reproduced here due to third-party copyright restrictions

The figures are taken from the following website:

Figure 2a and 2b, Anne E. Magurran, Stephen R. Baillie, Stephen T. Buckland, Jan McP. Dick, David A. Elston, E. Marian Scott, Rognvald I. Smith, Paul J. Somerfield, Allan D. Watt,

Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time, Trends in Ecology & Evolution, Volume 25, Issue 10, 2010, Pages 574-582, ISSN 0169-5347, <https://doi.org/10.1016/j.tree.2010.06.016>.



0 6 . 7

The news website published the headline:

The LPI shows human activities cause significant decrease in biodiversity.

Suggest **three** reasons why this headline is **not** valid.

Use all the information provided.

[3 marks]

1 *The values in Figure 6 stay within the ± 2 standard deviation lines, so there is no significant decrease, and the changes could be due to chance / natural variation.*

2 *There is no data or evidence about human activity, so we do not know that humans caused the change; it could be due to other factors such as disease or natural disasters.*

3 *Figure 7 has an altered (stretched) vertical scale which makes the change in the LPI look much worse (more dramatic) than it really is.*

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**

Phosphorus-containing substances and their importance in biological systems.

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

The mechanisms and importance of transport within organisms.

[25 marks]*07.2 The mechanisms and importance of transport within organisms*

Every living cell needs a supply of substances such as oxygen, glucose, amino acids and water, and needs to remove waste products such as carbon dioxide and urea. In single-celled organisms, diffusion over a short distance is enough, but multicellular organisms have a small surface area to volume ratio and a long diffusion distance, so they have evolved mechanisms of transport, both across membranes and by mass flow over long distances.

At the level of the cell, transport across the cell-surface membrane is essential. The membrane is a phospholipid bilayer, so small, non-polar molecules such as oxygen and carbon dioxide diffuse straight through it down their concentration gradient. Polar and charged substances such as glucose and ions cannot pass through the hydrophobic core of fatty acid tails, so they move by facilitated diffusion through specific channel and carrier proteins. Water moves by osmosis from a higher to a lower water potential, partly through aquaporins. Active transport uses carrier proteins



and ATP, which is hydrolysed to ADP and P_i , to move substances against their concentration gradient. For example, in the ileum, sodium ions are actively transported out of epithelial cells into the blood, which keeps the sodium concentration in the cell low. Sodium ions then diffuse into the cell from the lumen through a co-transporter protein, bringing glucose with them against its concentration gradient. Glucose then moves into the blood by facilitated diffusion. This co-transport is important because it allows all of the glucose produced by digestion to be absorbed, providing the respiratory substrate needed for ATP production in every cell. Microvilli increase the surface area for absorption, and many mitochondria provide ATP for the active transport.

Transport is also important inside cells. In protein synthesis, mRNA is transcribed in the nucleus and leaves through the nuclear pores to the ribosomes. Proteins made on the rough endoplasmic reticulum are transported in vesicles to the Golgi apparatus, where they are modified, for example by adding carbohydrate to form glycoproteins, and then packaged into vesicles that fuse with the cell-surface membrane, releasing the proteins by exocytosis. This is how plasma cells secrete antibodies and how digestive enzymes are released. In mitosis, spindle fibres pull the sister chromatids to opposite poles of the cell, so that each daughter cell receives an identical copy of the genetic information. Mass transport in mammals is carried out by the circulatory system. The heart pumps blood at high pressure through arteries, which have thick walls with elastic tissue that stretches and recoils to smooth out the flow, and muscle to control blood flow. The cardiac cycle is controlled by the sinoatrial node, which sends a wave of electrical activity across the atria, and by the atrioventricular node and bundle of His, which pass it

Turn over ►



to the base of the ventricles so that they contract from the bottom up.

Heart rate is altered by the medulla oblongata in response to chemoreceptors detecting a rise in carbon dioxide during exercise, so that more oxygen is delivered to the respiring muscles. In the capillaries, the walls are one cell thick, giving a short diffusion pathway. At the arteriole end, the high hydrostatic pressure forces tissue fluid out, and at the venule end water returns by osmosis because the water potential of the blood has been lowered by plasma proteins, with excess fluid returned in the lymph.

Haemoglobin is a protein with quaternary structure, made of four polypeptide chains each with a haem group containing iron. In the lungs, where the partial pressure of oxygen is high, haemoglobin has a high affinity for oxygen and loads it, with cooperative binding making it easier for each oxygen molecule to bind once the first has changed the shape of the molecule. In respiring tissues, where the partial pressure of oxygen is low and carbon dioxide is high, the affinity is reduced (the Bohr effect), so oxygen unloads where it is most needed for aerobic respiration. Gas exchange in the alveoli depends on this transport: ventilation and blood flow maintain a steep concentration gradient across the thin alveolar epithelium, and in fish, the counter-current flow of blood and water over the gill lamellae maintains a gradient along the whole length of the lamella.

Plants also depend on mass transport. Water enters root hair cells by osmosis and travels across the root to the xylem. Transpiration from the leaves lowers the water potential in the mesophyll, so water is pulled up the xylem as a continuous column, because water molecules are held together by hydrogen bonds (cohesion) and stick to the walls of the



xylem vessels (adhesion). This cohesion-tension mechanism is important because it supplies water for photosynthesis, keeps cells turgid for support, and carries mineral ions such as nitrate for making amino acids. Organic substances such as sucrose are moved in the phloem by mass flow. At the source, sucrose is actively loaded into the sieve tubes, lowering the water potential so water enters by osmosis from the xylem, which raises the hydrostatic pressure. At the sink, such as respiring roots or growing fruits, sucrose is removed and used, so the pressure is lower and the solution flows from source to sink. Transport of the plant hormone IAA is also important: in phototropism, IAA moves to the shaded side of a shoot, where it causes cell elongation, so the shoot bends towards the light, maximising photosynthesis.

Transport of ions across membranes is essential for coordination. A resting potential of about -70 mV is maintained by the sodium-potassium pump, which actively transports three sodium ions out for every two potassium ions in. When a neurone is stimulated, voltage-gated sodium ion channels open and sodium ions diffuse in, causing depolarisation, followed by repolarisation as potassium ions diffuse out. At a synapse, calcium ions diffuse into the presynaptic knob, causing vesicles to move to and fuse with the membrane, releasing acetylcholine by exocytosis, which diffuses across the cleft to receptors on the postsynaptic membrane. In skeletal muscle, the action potential causes calcium ions to be released from the sarcoplasmic reticulum; they bind to tropomyosin, moving it so that myosin heads can bind to actin, and ATP hydrolysis allows the power stroke. Without this transport of ions, animals could not respond to stimuli or move.

Hormones are transported in the blood, which allows homeostasis by

Turn over ►



negative feedback. When blood glucose rises, insulin is secreted by beta cells and travels in the blood to liver and muscle cells. It binds to receptors and causes vesicles containing glucose transporter proteins to fuse with the cell-surface membrane, increasing the uptake of glucose by facilitated diffusion. In type 2 diabetes, cells respond less to insulin, so glucose remains high in the blood. In the kidney, glucose is reabsorbed from the proximal convoluted tubule by co-transport with sodium ions, so it is not lost in urine. The loop of Henle creates a low water potential in the medulla by actively transporting sodium and chloride ions out of the ascending limb, and ADH, released from the posterior pituitary when the water potential of the blood is low, causes more aquaporins to be inserted into the membranes of the collecting duct, so more water is reabsorbed by osmosis. This keeps the water potential of the blood constant, preventing cells from bursting or shrinking.

Beyond the specification, cystic fibrosis shows what happens when transport fails. It is caused by a mutation in the CFTR gene, most commonly a deletion of three bases ($\Delta F508$), so one amino acid, phenylalanine, is missing from the CFTR protein. The protein folds incorrectly and is not transported to the cell-surface membrane, so chloride ions cannot be moved out of epithelial cells. Less water leaves the cells by osmosis, so the mucus in the lungs and pancreatic ducts becomes thick and sticky, leading to lung infections and poor absorption of digested food. New drugs called CFTR modulators, such as ivacaftor, help the faulty protein reach the membrane and hold its channel open, restoring chloride transport.

In conclusion, transport mechanisms range from diffusion, osmosis, facilitated diffusion, active transport and co-transport across membranes,



to mass flow in the blood, xylem and phloem. They are important because they supply every cell with the substrates it needs for respiration, photosynthesis and protein synthesis, remove waste, allow cells to communicate through nerve impulses and hormones, and maintain a constant internal environment.

Turn over ►



[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

25



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ANSWER IN THE SPACES PROVIDED**



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Question number	Additional page, if required. Write the question numbers in the left-hand margin.
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