

Please write clearly in block capitals.

Centre number

Candidate number

Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL BIOLOGY (9610)

Unit 5 Synoptic paper

Thursday 21 January 2021 07:00 GMT Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a pencil
- 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.
- In Question 6, 2 marks will be awarded for the quality of your written communication. You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use specialist vocabulary where appropriate.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
TOTAL	



Answer **all** questions in the spaces provided.

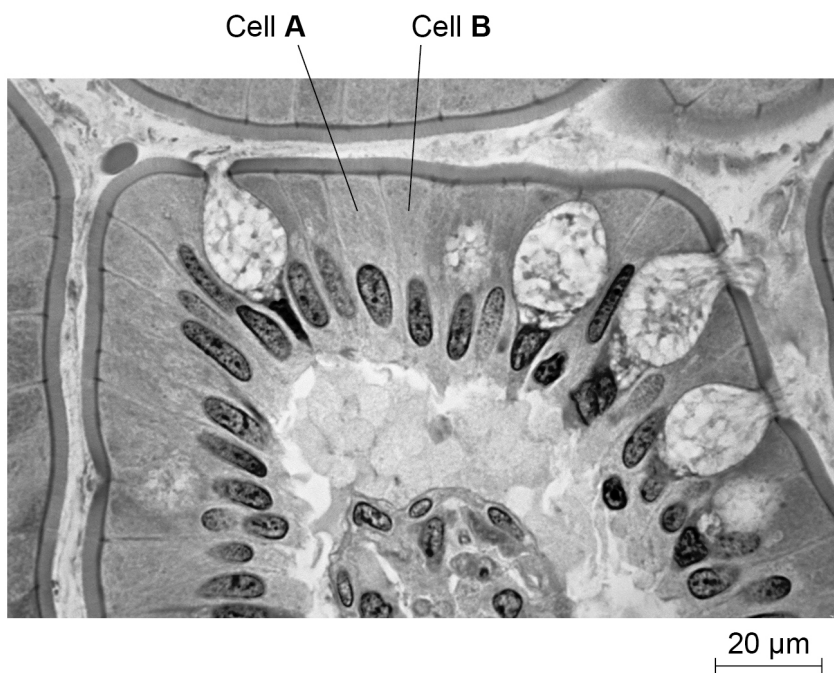
0 1

The inner surface of a mammal's small intestine is covered in villi.

Figure 1 shows the tip of a villus in the ileum, viewed through the high power objective lens of a light microscope.

The scale bar represents a distance of 20 μm

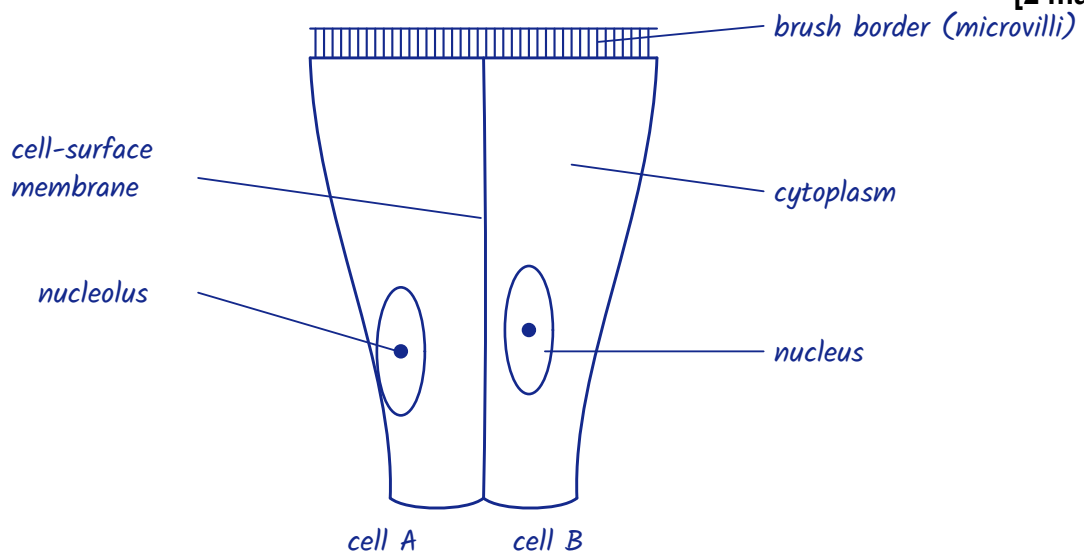
Figure 1



0 1 . 1

Draw a diagram of cells **A** and **B** from **Figure 1**.

[2 marks]



0 1 . 2 The scale bar in **Figure 1** represents 20 μm

Calculate the length of cell **A**.

Give your answer in micrometres to the nearest whole micrometre.

[2 marks]

length of cell A on Figure 1 = 27 mm; scale bar = 14 mm

length = $(27 \div 14) \times 20 = 38.6 \mu\text{m}$

Length of cell **A** = 39 μm

The resolution of the light microscope is approximately 250 nanometres (nm).

0 1 . 3 Define the term **resolution**.

[1 mark]

The minimum distance apart that two points (objects) can be and still be distinguished (seen) as separate points.

0 1 . 4 A typical mitochondrion measures 2 $\mu\text{m} \times 1 \mu\text{m}$

In theory, mitochondria should be visible when viewing these cells with this light microscope.

Suggest **one** reason why **no** mitochondria are visible in cells **A** and **B** in **Figure 1**.

[1 mark]

The mitochondria are not stained (differently from the rest of the cytoplasm), so they cannot be seen; or no mitochondria lie in the plane of the section.

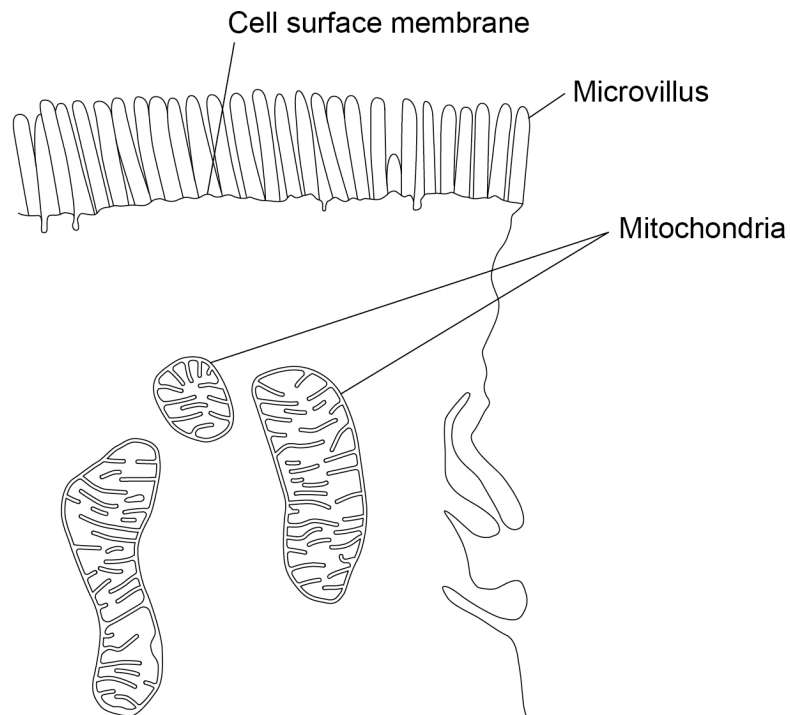
Question 1 continues on the next page

Turn over ►



Figure 2 shows part of cell **A** from Figure 1 in more detail.

Figure 2



The microvillus labelled in **Figure 2** has a length of $1.5\ \mu\text{m}$ and a width of $0.25\ \mu\text{m}$

If there were no microvilli, the cell-surface membrane on the free edge of cell **A** would have a length of $8\ \mu\text{m}$

There are 28 microvilli visible on the free edge of cell **A**.

0 1 . 5

Calculate by how many times the free surface of cell **A**, as shown in **Figure 2**, is increased by having microvilli.

Assume that each microvillus is a rectangle and that all the microvilli are the same size.

Give your answer to 2 significant figures.

[2 marks]

$$\text{membrane round one microvillus} = 1.5 + 1.5 + 0.25 = 3.25\ \mu\text{m}$$

$$\text{total} = 3.25 \times 28 = 91\ \mu\text{m}$$

$$\text{increase} = 91 \div 8 = 11.375 = 11\ (2\ \text{s.f.})$$

Surface of cell **A** is increased 11 times



One function of the cells lining the ileum is to absorb the products of digestion.

Cell **A** has many microvilli and many mitochondria.

0 1 . 6

The increase in surface area produced by many microvilli helps the ileum to absorb large amounts of digested food.

Give the reason why.

[1 mark]

More carrier and channel proteins (for facilitated diffusion and active transport), and more disaccharidases to convert disaccharides to monosaccharides for absorption.

Question 1 continues on the next page

Turn over ►



01.7

Cyanide is a poison that prevents the transfer of electrons to oxygen in mitochondria.

Scientists investigate the rates of absorption of monosaccharides by the ileum of rats with or without treatment with cyanide.

Table 1 shows the scientists' results.

Table 1

Monosaccharide	Relative rates of absorption	
	Without cyanide	With cyanide
Glucose	1.00	0.33
Galactose	1.10	0.53
Xylose	0.30	0.31
Arabinose	0.29	0.29

Discuss the relative importance of diffusion and active transport in the absorption of each of the different monosaccharides.

Use information from **Table 1**.

[3 marks]

Glucose and galactose are absorbed mainly by active transport

(co-transport with Na^+ , Na^+ pumped out), as their rate is reduced with cyanide, since less ATP is made.

Glucose depends more on active transport than galactose, as its rate decreases more with cyanide (1.00 to 0.33, not 1.10 to 0.53).

Some glucose and galactose are still absorbed with cyanide, so some is by diffusion (or electron transfer is not fully inhibited).

Xylose and arabinose are absorbed by diffusion, as cyanide has no effect.

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Turn over for the next question

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0 2

Most adults have a resting heart rate between 60 and 100 beats per minute.

A student made the hypothesis

‘Fitter people have lower resting heart rates.’

0 2

1

Plan an investigation to find out if the student’s hypothesis is correct.

[5 marks]

Measure the fitness of each volunteer using a standard test, e.g. the level reached in a multistage fitness (bleep) test.

Use a large number of volunteers, at least 30, covering a wide range of fitness levels.

Match the volunteers for age, sex and BMI, and use only non-smokers; all should have eaten at the same time beforehand and had no caffeine.

Define "at rest": measure the heart rate first thing after waking, or after the volunteer has lain down quietly for a set time of 30 minutes.

Measure the resting pulse rate by counting the pulse at the radial (wrist) artery for 60 seconds, or with a heart-rate monitor.

Repeat the measurement three times for each person and calculate the mean resting heart rate for each person.

Plot mean resting heart rate against fitness level and look for a negative correlation.



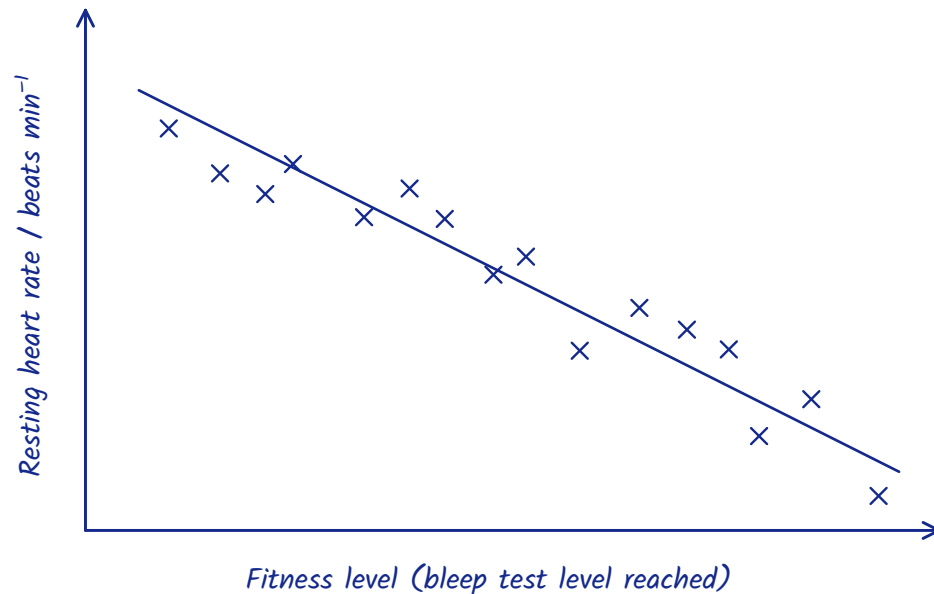
0 2 . 2

Draw a sketch graph to show the pattern of results you would expect from the investigation you planned in Question 02.1.

Assume the student's hypothesis is correct.

Give **one** reason for the type of graph you have drawn.

[3 marks]



Reason A scatter graph, because I am looking for a correlation between two continuous variables (fitness level and resting heart rate).

0 2 . 3

Name a statistical test you could use to analyse your results.

Give a reason for your choice.

[2 marks]

Statistical test Spearman's rank correlation coefficient

Reason To see if there is a significant (negative) correlation between resting heart rate and fitness level, i.e. to find the probability that the correlation is due to chance.

10

Turn over ►



0 3

In fruit flies (*Drosophila melanogaster*), eye colour is an inherited characteristic.

Wild-type *Drosophila* have red eyes. A mutation causes the flies to have white eyes.

Drosophila are easy to breed in the laboratory as they are small, have a life cycle of only 14 days and produce large numbers of offspring.

0 3 . 1

Explain why the production of large numbers of offspring is useful in genetic investigations.

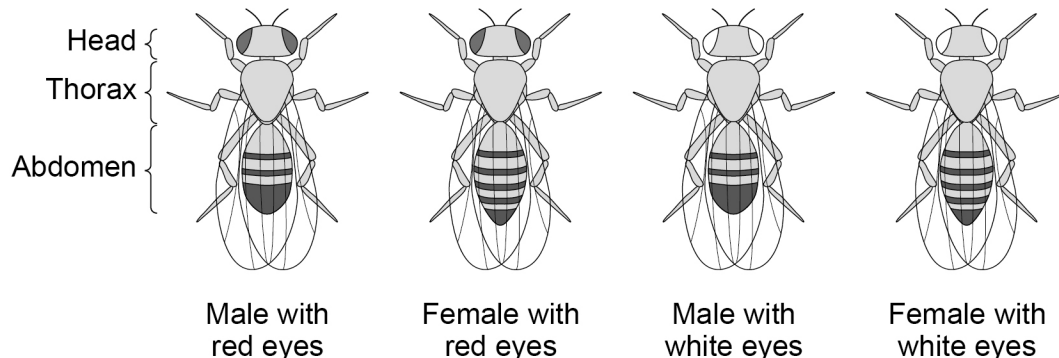
[2 marks]

Fertilisation is random, so you only see the expected (representative) ratios if large numbers are produced; this reduces the effect of chance variation and anomalies.

Large numbers also allow a statistical test (e.g. χ^2) to be used on the results.

Figure 3 shows male and female red-eyed and white-eyed *Drosophila*.

Figure 3



0 3 . 2

When choosing *Drosophila* for a genetic cross, it is important to identify which flies are males and which flies are females.

Use information from **Figure 3** to describe **two** ways that the abdomen of the male is different from the abdomen of the female.

[2 marks]

1 *The tip of the male abdomen is rounded (the female's is pointed).*

2 *The male abdomen is shorter, with a larger black region at the tip and fewer stripes (3 compared with 5).*



Question 3 continues on the next page

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Students cross red-eyed *Drosophila* with white-eyed *Drosophila*.

The results are different, depending on whether:

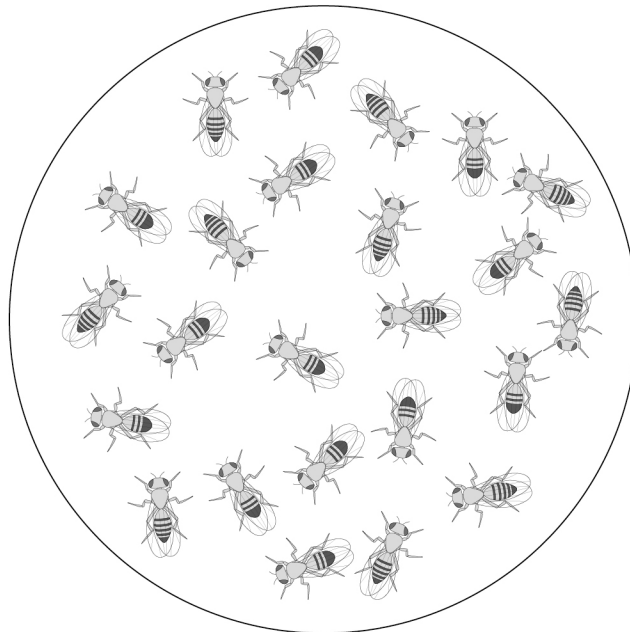
- a white-eyed male is crossed with a red-eyed female
- a red-eyed male is crossed with a white-eyed female.

Figure 4 shows the offspring produced in each cross.

Figure 4

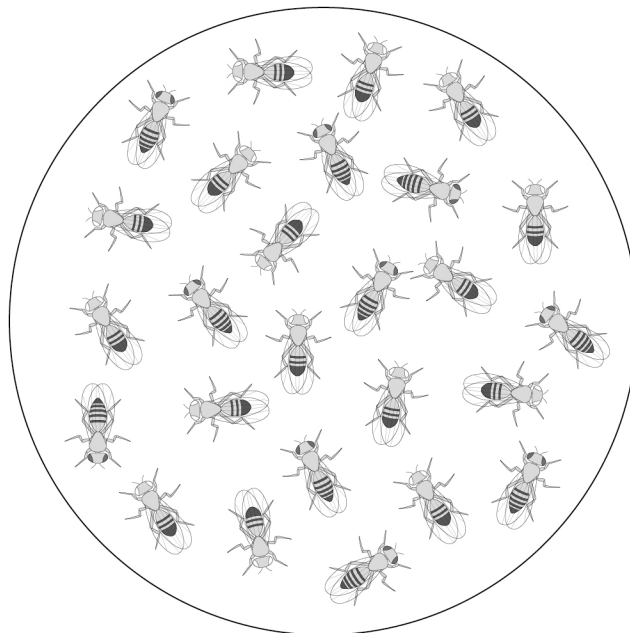
Experiment 1

White-eyed male $\times$ red-eyed female



Experiment 2

Red-eyed male $\times$ white-eyed female



0 3 . 3 Complete **Table 2** to show the numbers of each type of fly in **Figure 4**.

[2 marks]

Table 2

Phenotype of fly	Number of flies	
	Experiment 1	Experiment 2
Red-eyed male	13	0
Red-eyed female	11	10
White-eyed male	0	16
White-eyed female	0	0

In *Drosophila*, sex is determined in the same way as in humans.

0 3 . 4 Draw **two** genetic diagrams to explain the results in **Table 2**.

Include expected ratios of phenotypes for the offspring in each of experiments 1 and 2.

[4 marks]

Use the following symbols:

X^R = an X chromosome carrying the allele for red eyes

X^r = an X chromosome carrying the allele for white eyes

Y = a Y chromosome.

Experiment 1

White-eyed male × red-eyed female

Parents: $X^rY \times X^RX^R$

Gametes: X^r , Y and X^R

Offspring:

X^RX^r	X^RY
red-eyed female	red-eyed male

1 : 1

Ratio of offspring phenotypes 1 red ♀ : 1 red ♂

Experiment 2

Red-eyed male × white-eyed female

Parents: $X^RY \times X^rX^r$

Gametes: X^R , Y and X^r

Offspring:

X^RX^r	X^rY
red-eyed female	white-eyed male

1 : 1

Ratio of offspring phenotypes 1 red ♀ : 1 white ♂

Question 3 continues on the next page

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0 3 . 5 The students used the χ^2 (chi-squared) test to analyse their results.

The students calculated a value of $\chi^2 = 1.38$ for experiment 2.

Table 3 gives probability values for different values of χ^2 .

Table 3

Degrees of freedom	Probability value					
	0.99	0.95	0.10	0.05	0.01	0.001
1	0.0002	0.0039	2.71	3.84	6.63	10.83
2	0.020	0.103	4.61	5.99	9.21	13.82
3	0.115	0.352	6.25	7.81	11.34	16.27
4	0.297	0.711	7.78	9.49	13.28	18.47

Explain if the students' results fit the expected ratio for experiment 2.

Use the calculated value of $\chi^2 = 1.38$ and data from **Table 3**.

[3 marks]

Yes, the results fit the expected 1 : 1 ratio.

There are 2 classes so there is 1 degree of freedom; the critical value at $P = 0.05$ is 3.84.

The calculated $\chi^2 = 1.38$ is less than 3.84 (it is closest to 2.71, so $P > 0.10$, which is greater than 0.05).

So the difference between the observed and expected results is not significant and is due to chance; the null hypothesis is accepted.



0 3 . 6

A red-eyed female *Drosophila* could be homozygous or heterozygous for eye colour.

Describe how you could find out if a red-eyed female *Drosophila* was homozygous or heterozygous for eye colour.

[3 marks]

Cross the red-eyed female with a white-eyed male (X^rY) and record the eye colour of the offspring.

If the female is homozygous (X^RX^R) all the offspring, males and females, will be red-eyed; no white-eyed flies are produced.

If the female is heterozygous (X^RX^r) there will be red-eyed males and females and also white-eyed males and females (about 1 : 1 red : white), so some white-eyed flies are seen.

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Turn over for the next question

Turn over ►



04

Some parts of the human body, such as the skin and the lining of the digestive system, have cells that continue to divide to replace damaged cells.

Cell division requires DNA replication.

Mistakes are sometimes made when the DNA replicates. Some of these mistakes in DNA replication occur in genes that control the rate of cell division.

A gene called MLH1 codes for a DNA-repair protein.

The MLH1 gene contains 57 496 base pairs.

04.1

Calculate the number of amino acids you would expect the MLH1 protein to have.

[1 mark]

$$57\,496 \div 3 = 19\,165.3$$

Number of amino acids = 19 165

04.2

The actual number of amino acids in the MLH1 protein is 756.

State what causes the difference between this number of amino acids and the number you calculated in Question 04.1.

[1 mark]

The gene contains introns (non-coding base sequences), which are removed from pre-mRNA, so only exons are in the functional mRNA.

Methylation of the promoter region of the MLH1 gene can cause uncontrolled cell division and the formation of a tumour.

The promoter region of a gene is the point where RNA-polymerase attaches to the gene.

04.3

Explain how methylation of the promoter of the MLH1 gene could cause the formation of a tumour.

[3 marks]

RNA polymerase cannot attach to the promoter, so the MLH1 gene cannot be transcribed (no mRNA is synthesised).

So the MLH1 repair protein cannot be synthesised.

So errors in the DNA of tumour suppressor genes and (proto-)oncogenes cannot be corrected, so cell division is uncontrolled.



0 4 4

Doctors can treat tumours using surgery and chemotherapy. Chemotherapy uses chemicals that inhibit DNA replication.

A man has a large tumour in his colon.

The man's doctor considers **two** options:

1. Use chemotherapy to reduce the size of the tumour and then remove the tumour surgically.
2. Remove the tumour first and then use chemotherapy to destroy any remaining tumour cells.

Suggest why the doctor chooses option 2.

[3 marks]

Removing the tumour first means a smaller dose of chemotherapy, for a shorter time, is needed; option 1 would need a higher dosage for longer to shrink a large tumour.

Chemotherapy also inhibits DNA replication and cell division in healthy cells in other parts of the body, e.g. the skin and the lining of the gut. So a high dose would damage these body cells, which could not be replaced or repaired.

Early removal of the tumour also reduces the chance of metastasis, i.e. of tumour cells spreading to form secondary tumours elsewhere.

8

Turn over ►



0 5

Students investigate the diversity of small animals that live among stones at the bottom of a shallow river.

The students collect samples of the animals at two sites:

Site **P** 50 metres downstream from a sewage outlet.

Site **Q** 800 metres downstream from the sewage outlet.

The students:

- use square quadrat frames, 50 cm × 50 cm, and nets to take their samples
- put the samples of the small animals into shallow trays of water
- identify and count each different type of animal.

0 5 . 1

Describe how the students could collect a representative sample of the small animals living at each of sites **P** and **Q**.

[4 marks]

At each site place the quadrats randomly, e.g. use a random number generator to give coordinates on a grid marked out along the riverbed (or place quadrats at set intervals along a transect).

Use a standardised sampling technique: hold the net just downstream of the quadrat and disturb (kick) the stones inside the quadrat for the same time, e.g. 30 seconds, so the animals are washed into the net.

Take a suitable number of repeat samples, e.g. at least 10 quadrats at each site, at the same depth and flow rate.



Table 4 shows the students' results.

Table 4

Animal	Total number of animals	
	Site P	Site Q
<i>Tubifex tubifex</i>	80	2
<i>Chironomus thummi</i>	35	8
<i>Asellus aquaticus</i>	10	55
<i>Gammarus pulex</i>	5	75
<i>Baetis fuscatus</i>	0	15
Index of diversity	2.20	2.72

The students calculate an index of diversity for the animals at each of sites **P** and **Q**.

The students use the following equation:

$$d = \frac{N(N-1)}{\sum n(n-1)}$$

where d = index of diversity

N = total number of animals at the site

n = number of animals of each species

0 5 2 **Table 4** gives the index of diversity for site **P**.

Calculate the index of diversity for site **Q**.

[2 marks]

$$N = 2 + 8 + 55 + 75 + 15 = 155$$

$$\sum n(n-1) = 2 + 56 + 2970 + 5550 + 210 = 8788$$

$$d = (155 \times 154) \div 8788 = 23\,870 \div 8788 = 2.716$$

Index of diversity, d , for site **Q** = 2.72

Question 5 continues on the next page

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0 5 . 3

Suggest why the index of diversity at site **Q** is larger than the index of diversity at site **P**.

[3 marks]

At site P saprophytic bacteria decay the organic matter in the sewage, using up oxygen in their aerobic respiration.

So few species (only tolerant ones like Tubifex) survive.

At site Q more oxygen enters the water from the air, and from photosynthesis by plants and algae.

So there is sufficient oxygen for the respiration of more species of animals, giving a higher index of diversity.

9



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You are reminded that **2** marks will be awarded for the quality of your written communication in **Question 6**.

0 6

Life would not be possible without water and enzymes.

0 6 . 1

Describe how plants and animals use water.

[6 marks]

Water is a solvent, so it transports ions (e.g. nitrate) and organic molecules (e.g. glucose, sucrose and urea) in xylem, phloem and blood plasma, and removes waste substances.

As a solvent, water is the medium for chemical (metabolic) reactions in the cytoplasm.

Water is used in hydrolysis reactions, e.g. digestion of starch and proteins, mobilising stored food in seeds, and hydrolysis of ATP to release energy for active transport and synthesis.

In photosynthesis, water is split by photolysis in the light-dependent reaction, providing electrons, H^+ and oxygen; this produces reduced NADP and ATP for the Calvin cycle.

Turgor (water pressure inside vacuoles pushing against the cell wall) provides support for non-woody plants and opens and closes stomata.

Evaporation of water cools organisms, e.g. sweating in mammals and transpiration in leaves, because water has a high latent heat of vaporisation.

In mammals tissue fluid and blood plasma, which are mainly water, provide a constant internal environment, so homeostasis maintains their temperature and water potential.



0 6 . 2

Explain how enzymes can act as specific catalysts of metabolic reactions.

[6 marks]

Enzymes are biological catalysts: they lower the activation energy of a reaction by forming an enzyme-substrate complex.

So metabolic reactions occur rapidly at the moderate temperatures (e.g. 37°C) found in cells.

Enzymes are proteins (globular) with a specific tertiary structure, so each has an active site with a specific 3-D shape, determined by the sequence of amino acids (primary structure).

Only a substrate with a complementary shape fits (binds to) the active site, forming a specific enzyme-substrate complex (induced fit: the active site moulds around the substrate).

So each type of enzyme only combines with one type of substrate, and each type of reaction has a different enzyme.

Examples: condensation reactions such as DNA synthesis by DNA polymerase and protein synthesis; RuBisCO fixing CO₂; hydrolysis reactions in digestion, e.g. amylase hydrolyses starch.

Competitive inhibitors have a similar shape to the substrate and block the active site; non-competitive inhibitors bind elsewhere, changing the shape of the active site, so end-product inhibition regulates metabolic pathways.

Coenzymes such as NAD, NADP and coenzyme A help some enzymes to catalyse reactions.

Turn over ►



0 6 . 3

Different varieties of maize produce grains (fruits) that store different forms of starch.

Waxy maize grains store starch that is 98% amylopectin.

Non-waxy maize grains store starch that is over 90% amylose.

The enzyme α -amylase catalyses the complete hydrolysis of amylose to reducing sugars. α -amylase will only partially hydrolyse amylopectin.

Design an experiment, using α -amylase, to investigate whether a new variety of maize has waxy or non-waxy grains.

[6 marks]

Grind equal masses of grains of the new variety, of a known waxy variety and of a known non-waxy variety.

Suspend each in equal volumes of water (or pH buffer) to make starch suspensions.

Add the same volume of the same concentration of α -amylase to each.

Keep all the tubes at a constant temperature in a water bath, e.g. 37°C.

At intervals (e.g. every 2 minutes) remove same-size samples and test for reducing sugars by heating with the same volume of Benedict's reagent (or test with the same volume of iodine solution).

Compare the intensity of the colour, e.g. using a colorimeter, and plot a graph of colour intensity against time, with the three lines on common axes.

Non-waxy grains give more red (orange) precipitate as amylose is completely hydrolysed; waxy grains give less precipitate (and iodine stays blue-black for waxy, turning brown or yellow for non-waxy).

If the new variety matches the waxy control it is waxy; if it matches the non-waxy control it is non-waxy.

Repeat each test three times and calculate the mean intensity for each type of grain.



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Quality of written communication [2 marks]

END OF QUESTIONS



There are no questions printed on this page

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