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INTERNATIONAL A-LEVEL BIOLOGY (9610)

Unit 3 Populations and genes

Tuesday 5 June 2018

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.
- 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
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	



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

0 1

Lemmings are small herbivorous mammals. A population of lemmings lives in the Arctic ecosystem.

0 1 . 1

Give the meaning of the terms:

[2 marks]

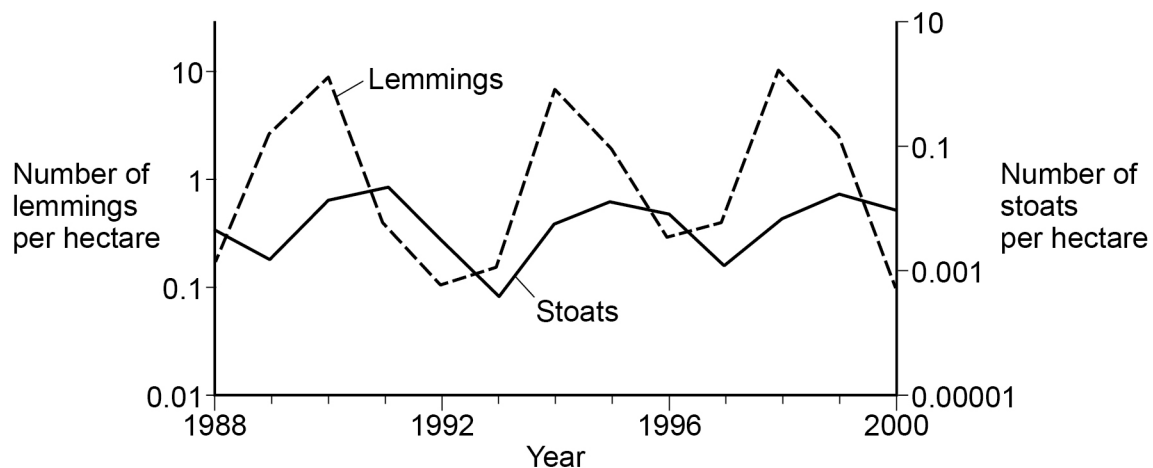
Population All the organisms of one species in a habitat (area).

Ecosystem All the populations of different species (the community) and the non-living components: all the interacting biotic and abiotic factors in an area.

Stoats are carnivorous mammals that feed almost exclusively on lemmings.

Figure 1 shows the changes in the numbers of lemmings and stoats in one region from 1988 to 2000.

Figure 1



0 1 . 2

Give the reason why logarithmic scales have been used on the y-axes in **Figure 1**.

[1 mark]

There is a large range of values (numbers), so a log scale fits them all on the axes.

0 1 . 3

Describe the relationship between the number of lemmings and the number of stoats.

Use information from **Figure 1**.

[2 marks]

The number of lemmings is always higher than the number of stoats.

When lemmings increase, stoats then increase; when stoats increase, lemmings then decrease. Both follow 4 year cycles (lemming peaks 1990, 1994, 1998).

0 1 . 4

Lemmings feed on leaves, shoots, roots and bulbs. Predators of lemmings include stoats, owls and foxes.

A student suggests that an increase in the stoat population causes a decrease in the lemming population.

Evaluate this statement.

Use the information provided above and in **Figure 1**.

[4 marks]

Supports: the lemming population decreases when stoats are high; lemmings start to decrease about a year before the stoat population peaks.

Against: in some years (1989 to 90, 1993 to 94, 1997 to 98) both populations increase.

There is a correlation, but this does not mean cause.

Lemmings could decrease due to lack of food (leaves, roots, bulbs), disease, or an increase in other predators (owls, foxes).

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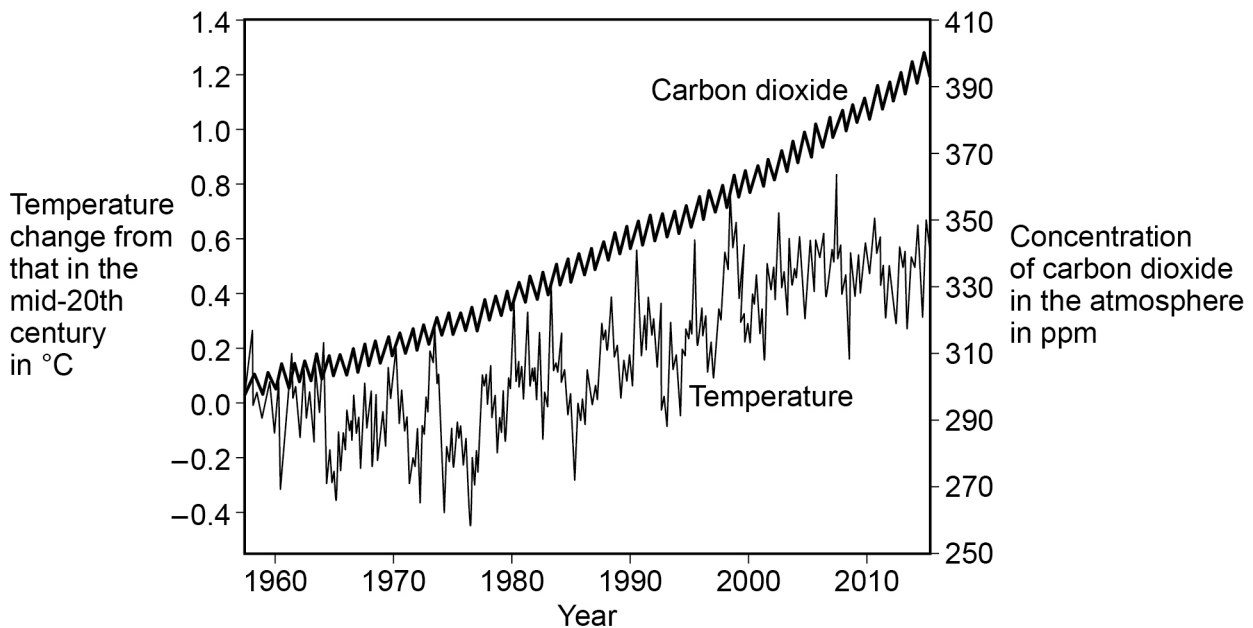
0 2

The Mauna Loa Observatory in Hawaii has been collecting and monitoring data about climate change since 1956.

The equipment and techniques used to collect the data have remained unchanged during the monitoring period.

Figure 2 shows changes in atmospheric carbon dioxide concentration and in air temperature since 1956.

Figure 2



0 2 1

Give **one** reason why the equipment and techniques used to collect the data shown in **Figure 2** have been kept the same.

[1 mark]

To allow comparison of the data over the years; new techniques could give different readings that could not be compared.



0 2 . 2

Figure 2 shows a regular fluctuation in the carbon dioxide concentration every year.

Suggest **one** reason for the fluctuation.

[2 marks]

The CO₂ concentration rises in winter (cold weather), when there is a lower rate of photosynthesis, so less CO₂ is taken in by plants, because there is less vegetation (leaf fall), lower temperature, shorter days and less light.

0 2 . 3

Do the data in **Figure 2** support the idea that an increase in atmospheric carbon dioxide concentration has caused an increase in global temperature?

Explain your answer.

[3 marks]

Yes; both CO₂ concentration and temperature show an overall increase.

No; temperature fluctuates a lot, sometimes dropping while CO₂ rises; the rise could be due to chance or methane; correlation is not causation; CO₂ measured at one location only; the temperature rise is very small, no SD or statistical test.

6

Turn over for the next question

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0 3

Flower colour in the *Salvia* plant is controlled by two genes.

One gene determines the production of a pigment. The other gene determines the colour of the pigment. The two genes are not linked.

Each gene has two alleles.

The dominant allele **A** causes a pigment to be produced. Plants with the genotype **aa** will produce no pigment and the flowers will be white.

The dominant allele **B** produces a plant with purple flowers. Plants with the genotype **bb** will have pink flowers.

0 3 . 1

Name the interaction between the two genes for flower colour.
Give a reason for your choice.

[2 marks]

Interaction (Recessive) epistasis

Reason Gene A allows the expression of the other gene (B/b); aa plants make no pigment so are white, whatever alleles of gene B they have.

0 3 . 2

Give **all** possible genotypes of a pink-flowered plant.

[1 mark]

AAbb and Aabb



0 3 . 3

A plant breeder crossed a purple-flowered plant heterozygous for both genes with a white-flowered plant homozygous recessive for both genes.

The plant breeder expected pink, purple and white flowers in the ratio 1 : 1 : 2

Draw a genetic diagram to show how this ratio of phenotypes can be produced.

[3 marks]

Parent phenotypes Purple flowers White flowers

Parent genotypes $AaBb$ $aabb$

Gametes AB, Ab, aB, ab ab

	AB	Ab	aB	ab
ab	$AaBb$	$Aabb$	$aaBb$	$aabb$

Offspring genotypes $AaBb$ $Aabb$ $aaBb$ $aabb$

Offspring phenotypes *Purple* *Pink* *White* *White*

Ratio pink : purple : white = 1 : 1 : 2

Question 3 continues on the next page

Turn over ►



0 3 . 4

The plant breeder counted the number of plants with each flower colour and compared them with the expected ratio.

The plant breeder completed a statistical test to see if the difference in the observed and expected ratio was due to chance.

Table 1 shows values for χ^2 (chi squared) at different probability levels and for different degrees of freedom.

Table 1

Degrees of freedom	Probability, p				
	0.2	0.1	0.05	0.02	0.01
1	1.64	2.71	3.84	5.41	6.64
2	3.22	4.61	5.99	7.82	9.21
3	4.64	6.25	7.82	9.84	11.35
4	5.99	7.78	9.49	11.67	13.28
5	7.29	9.24	11.07	13.39	15.09

The value of χ^2 was calculated and found to be 4.73.

Explain what the results of the χ^2 test show about the difference between the observed and expected ratio.

Use **Table 1** and the calculated value of χ^2 .

[2 marks]

Critical value at $p = 0.05$ for 2 degrees of freedom (3 phenotypes) is

5.99.

4.73 is less than 5.99, so there is no significant difference between the observed and expected ratio; the difference is due to chance ($p > 0.05$).



0 3 . 5

A population of *Salvia* plants contains 49% white flowers.

Calculate the percentage of this population that you would expect to be heterozygous for the production of pigment gene.

Use the Hardy-Weinberg equation.

[2 marks]

$$aa = \text{white, so } q^2 = 0.49$$

$$q = \sqrt{0.49} = 0.7$$

$$p = 1 - 0.7 = 0.3$$

$$\text{Heterozygous } Aa = 2pq = 2 \times 0.3 \times 0.7 = 0.42$$

Answer = 42%

10

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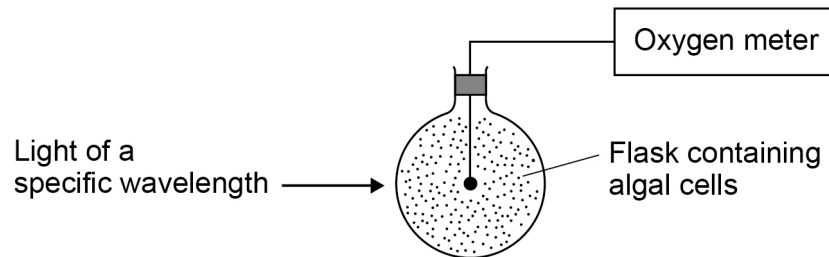
0 4

A student investigates the effect of different wavelengths of light on the rate of photosynthesis.

The student:

- uses photosynthesising algal cells
- sets up the apparatus shown in **Figure 3**
- shines different wavelengths of light onto the flask
- takes measurements to determine the rate of photosynthesis.

Figure 3



0 4 . 1

What **two** measurements should the student take to determine the rate of photosynthesis?

[1 mark]

Oxygen concentration (the reading on the oxygen meter) and time.

0 4 . 2

The student controls the temperature, pH and carbon dioxide concentration.

Give **two** other factors that the student should keep constant during this investigation.

[2 marks]

1 *Light intensity (distance between the light and the flask).*

2 *Mass (or number) of algae / photosynthesising cells.*



0 4 . 3

The student adds a reagent to the suspension of photosynthesising algal cells.

The reagent is blue when oxidised and is colourless when reduced.

The blue colour disappears when the suspension of algal cells is exposed to light.

Explain why.

Use your knowledge of the light-dependent reaction of photosynthesis.

[2 marks]

Light excites electrons in chlorophyll, which are lost, and reduced NADP is formed.

Hydrogen (electrons) from water and chlorophyll reduce the dye, so it changes from blue to colourless.

0 4 . 4

Some purple bacteria can photosynthesise, but use hydrogen sulfide instead of water. The hydrogen sulfide has a similar role to water in photosynthesis.

Suggest how the bacteria use hydrogen sulfide.

[3 marks]

Hydrogen sulfide is a source of hydrogen ions (protons) and electrons.

The protons (hydrogen) are used to reduce NADP, forming reduced NADP.

The electrons replace the electrons lost from chlorophyll.

The protons are also used to generate ATP.

0 4 . 5

Suggest how the products of the light-dependent reaction in purple bacteria would be different from those in photosynthetic algae.

[1 mark]

Sulfur is produced instead of oxygen.



0 5

Modern farming practices increase productivity in animals reared for meat and eggs.

A scientist investigates the effect of temperature on the rate of chicken growth and the efficiency of food conversion to biomass. The scientist uses the same breed of chicken for each temperature.

Table 2 shows the results of the investigation.

Table 2

Temperature / °C	Mean growth rate / g per day	Efficiency of conversion of food to biomass / %
5	26	15
10	39	41
20	43	47
30	23	34
35	16	34

0 5**1**

How could the scientist calculate the efficiency of conversion of food to biomass?

[1 mark]

Efficiency = (growth rate in g per day ÷ mass of food eaten in g per day) × 100

0 5**2**

A student interprets the results in **Table 2** and concludes that 20 °C is the optimum temperature for chicken growth.

Evaluate this conclusion.

[2 marks]

Supports: 20 °C gives the highest mean growth rate (43 g per day) and the highest efficiency of conversion (47%).

Against: no intermediate temperatures (between 10 and 20 °C or 20 and 30 °C) were tested, so the optimum could be e.g. 15 or 25 °C.



0 5 . 3

Explain why there is a higher efficiency of conversion of food to biomass at 20 °C than at 5 °C.

[2 marks]

At 20 °C less energy is lost as heat, so less energy is needed to maintain a constant body temperature, so more energy is available for the production of biomass.

0 5 . 4

Suggest why the scientist did not use a temperature above 35 °C.

Use data from **Table 2**.

[2 marks]

Growth rate decreases above 20 °C (23 at 30 °C, 16 at 35 °C) and efficiency is the same at 30 and 35 °C (34%), so a higher temperature would not increase growth rate or efficiency; it would waste time and resources and could harm the chickens.

Question 5 continues on the next page

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Chickens are farmed for meat and egg production.

In some countries, chickens are kept in cages to increase the efficiency of conversion of food to biomass.

Figure 4 shows a typical cage system for intensively farmed chickens.

Figure 4

Dimensions of a chicken	Guidelines for typical cage system
Length of chicken = 30–45 cm Wing span = 45–60 cm Height = 35–45 cm	• cages should provide at least 750 cm² floor space per chicken • cage height should be at least 45 cm



0 5 . 5

Evaluate the use of cages for intensive chicken farming.

Use information from **Figure 4**.**[3 marks]**

For: the temperature can be kept at the optimum for maximum efficiency of conversion of food to biomass (less heat loss).

Reduced movement (less muscle use), so more energy is available for biomass; cages also protect against predators.

Against: 750 cm² is insufficient space: minimum length 30 cm and minimum wingspan 45 cm need at least $30 \times 45 = 1350 \text{ cm}^2$.

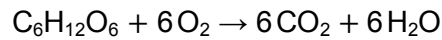
Animal welfare: prevents natural behaviour, causes stress and joint problems; chickens are close together so disease spreads easily, so antibiotics are added to food.

10

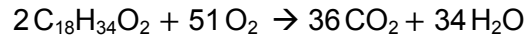
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0 6

Glucose is the main respiratory substrate used by cells.
The overall equation for the aerobic respiration of glucose is:



Oleic acid is a fatty acid. Fatty acids can be used as respiratory substrates.
The overall equation for the aerobic respiration of oleic acid is:

**0 6 . 1**

Calculate the ratio of the respiratory quotient (RQ) for the aerobic respiration of oleic acid to the RQ for the aerobic respiration of glucose.

[2 marks]

$$RQ = \text{CO}_2 \text{ produced} \div \text{O}_2 \text{ used}$$

$$\text{Oleic acid RQ} = 36 \div 51 = 0.71$$

$$\text{Glucose RQ} = 6 \div 6 = 1.0$$

$$\text{Ratio} = 0.71 \div 1.0$$

$$\text{Ratio} = \underline{0.71 : 1}$$

0 6 . 2

Suggest one reason why an experimental RQ value does not always indicate the type of substrate used in respiration.

[1 mark]

A mixture of substrates is respired (or some respiration is anaerobic), so the RQ is not that of one substrate.



Table 3 shows the relative energy values of carbohydrate and lipid.

Table 3

Respiratory substrate	Mean energy value / kJ g ⁻¹
Carbohydrate	15.8
Lipid	39.4

0 6 . 3

Glucose is a carbohydrate with the chemical formula C₆H₁₂O₆

Oleic acid is a breakdown product of lipids. The chemical formula for oleic acid is C₁₈H₃₄O₂

Explain why cells gain more energy from lipid than from carbohydrate.

Use your knowledge of aerobic respiration.

[3 marks]

Lipid contains more hydrogen: 34 H in oleic acid compared with 12 H in glucose.

More hydrogen (protons) means more reduced NAD and reduced FAD are formed,

so more electrons move down the electron transport chain and more protons move across the inner mitochondrial membrane,

so more ATP is produced (by ATP synthase).

Question 6 continues on the next page

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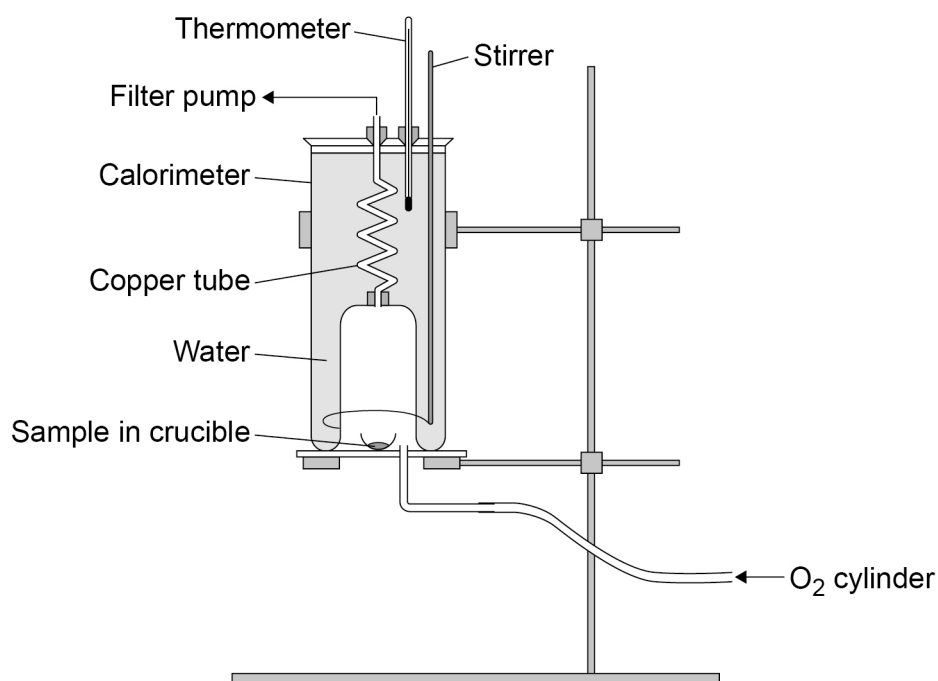


The energy value of a food can be found by burning the food and measuring the heat energy released.

A student uses a piece of equipment called a calorimeter to determine the mean energy value of glucose.

Figure 5 shows a calorimeter.

Figure 5



0 6 . 4

The student:

- adds a known mass of water to the calorimeter
- puts the glucose sample in the crucible
- sets the glucose on fire.

Suggest **two** measurements the student would take to determine the energy content of glucose in kJ g^{-1}

[2 marks]

1 *Mass of the glucose sample burned (in g).*

2 *Temperature change of the water (start and final temperature).*



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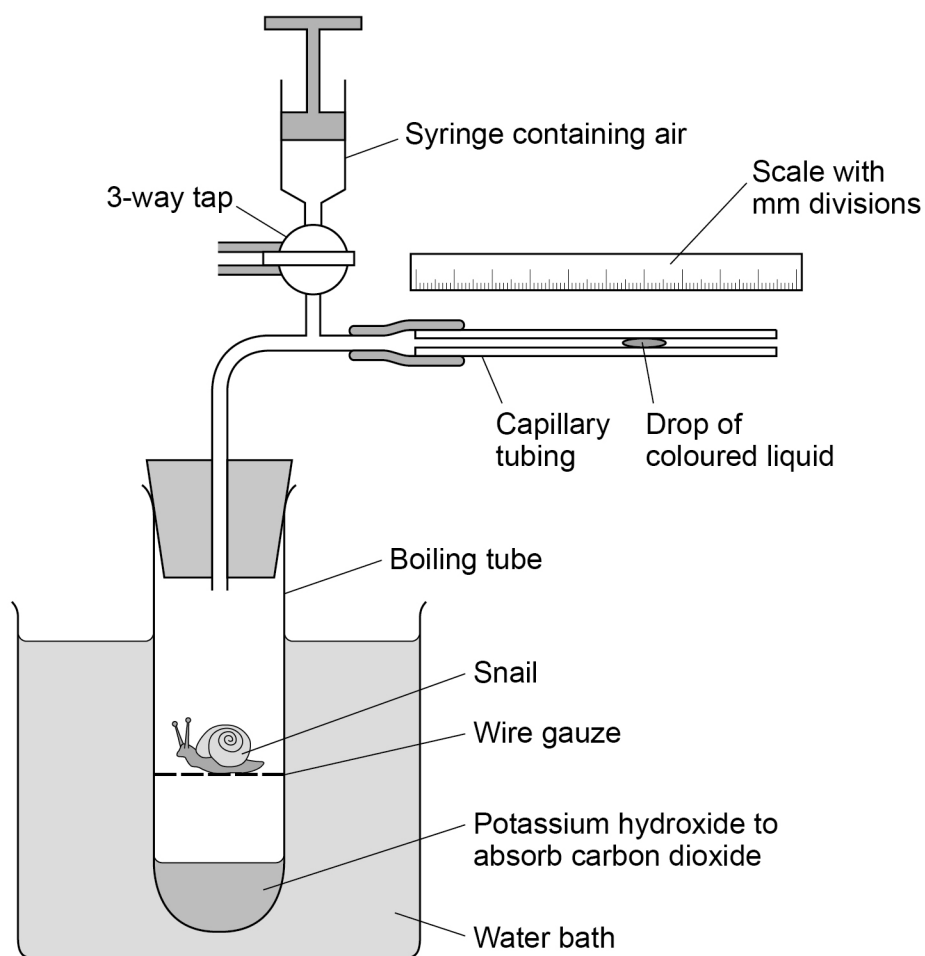
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07

A student investigates the effect of temperature on the rate of respiration of a snail. The student uses the apparatus shown in **Figure 6**.

Figure 6



07.1

Explain what would happen if the student replaced the potassium hydroxide with water.

[2 marks]

*The drop of coloured liquid would not move,
because CO_2 released is not absorbed, so the volume of CO_2 produced
equals the O_2 taken up; the pressure (volume) inside the tube would not
decrease.*



07.2

The internal diameter of the capillary tubing is 1 mm
The drop of coloured liquid moves 30 mm in 10 minutes
The snail has a mass of 7 g

Calculate the rate of oxygen uptake in $\text{mm}^3 \text{g}^{-1} \text{hour}^{-1}$

Volume of a cylinder = $\pi r^2 h$

Use $\pi = 3.14$. Give your answer to 3 significant figures.

[3 marks]

$$r = 1 \div 2 = 0.5 \text{ mm}$$

$$\text{Volume of } O_2 = 3.14 \times 0.5^2 \times 30 = 23.55 \text{ mm}^3 \text{ in 10 min}$$

$$\text{Per gram} = 23.55 \div 7 = 3.364 \text{ mm}^3 \text{ g}^{-1} \text{ per 10 min}$$

$$\text{Per hour} = 3.364 \times 6 = 20.19 \text{ mm}^3 \text{ g}^{-1} \text{ hour}^{-1}$$

Rate of oxygen uptake = 20.2 $\text{mm}^3 \text{g}^{-1} \text{hour}^{-1}$

Question 7 continues on the next page

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A student investigates the effect of temperature on the rate of oxygen uptake in seashore snails. Seashore snails are covered with sea water at high tide and exposed to the air at low tide.

The student:

- measures the oxygen uptake of snails kept at different temperatures in moist air
- repeats the experiment using the same snails in different temperatures of sea water
- calculates the means and standard deviations for each temperature.

The student's results are shown in **Table 4**

Table 4

	Mean oxygen uptake of snails / $\text{mm}^3 \text{g}^{-1} \text{h}^{-1}$ ($\pm$ standard deviation)	
Temperature / $^{\circ}\text{C}$	In moist air	In seawater
5	35 ± 2	28 ± 8
10	34 ± 6	32 ± 3
15	36 ± 3	35 ± 3
20	86 ± 8	52 ± 10
25	141 ± 13	96 ± 15
30	132 ± 14	108 ± 9
35	120 ± 16	79 ± 21



07.3

The student concludes that 25 °C is the optimum temperature for the rate of oxygen uptake.

Evaluate this conclusion.

[3 marks]

Supports: in moist air, oxygen uptake is significantly higher at 25 °C

(141 ± 13) than at 20 °C (86 ± 8); the SDs do not overlap.

Against: in seawater, oxygen uptake is not highest at 25 °C (96); it is highest at 30 °C (108).

There is no significant difference between 25, 30 and 35 °C in either experiment, as the SDs overlap (141 ± 13, 132 ± 14, 120 ± 16 in air; 96 ± 15, 108 ± 9, 79 ± 21 in seawater).

Temperatures between 20 and 25 °C or 25 and 30 °C were not tested, so the true optimum may be at another temperature.

8

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0 8

Open pit mining is a technique used to extract copper ore near the surface of the earth.

After mining finishes, the pit is filled in and the soil is replaced.

0 8 . 1

Over time, succession occurs and the ecosystem around an old copper mine changes.

Describe and explain these changes.

[6 marks]

The bare soil is first colonised by pioneer species, e.g. mosses, lichens and copper-tolerant grasses, which can survive the hostile conditions.

The pioneer species change the environment (abiotic conditions): when they die and decompose they add humus, producing deeper soil that holds more water and minerals.

So the environment becomes less hostile and abiotic conditions become more favourable for other species.

New species (herbs, then shrubs and trees) colonise, and the pioneer species are outcompeted, e.g. for light.

Biodiversity changes during succession: it increases from the early to mid stages, with more habitats and food sources, then decreases slightly as a few dominant species outcompete others.

The final stage of succession is a stable climax community, e.g. woodland.



0 8 . 2

Soil around old copper mines has a high concentration of copper ions. Copper ions are toxic to many plant species. Some species of grass have developed a high tolerance to copper ions and grow readily in the soil around copper mines.

Explain how natural selection could produce a population of copper-tolerant grass.

[4 marks]

There is genetic variation in the original grass population: random

mutation produced an allele for copper tolerance.

Copper-tolerant individuals are more likely to survive and reproduce in the soil with a high concentration of copper ions.

They pass on the copper tolerance allele(s) to their offspring (next generation).

Over many generations the frequency of the copper tolerance allele increases in the population.

Question 8 continues on the next page

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0 8 . 3

Copper-tolerant grass produces its flowers earlier in the year than non-tolerant grass of the same species.

Explain how this might produce two different species of grass.

[5 marks]

Different flowering times mean the populations are reproductively isolated: no interbreeding.

So there is no flow of alleles (genes) between the populations; they have separate gene pools, and different random mutations occur in each group.

There are different selection pressures on each population.

So the type and frequency of alleles change: the gene pools change.

Eventually members of the two populations are unable to interbreed and produce fertile offspring, so they are two different species.

15

END OF QUESTIONS



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