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INTERNATIONAL A-LEVEL BIOLOGY (9610)

Unit 3 Populations and Genes

Thursday 4 January 2024 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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TOTAL	



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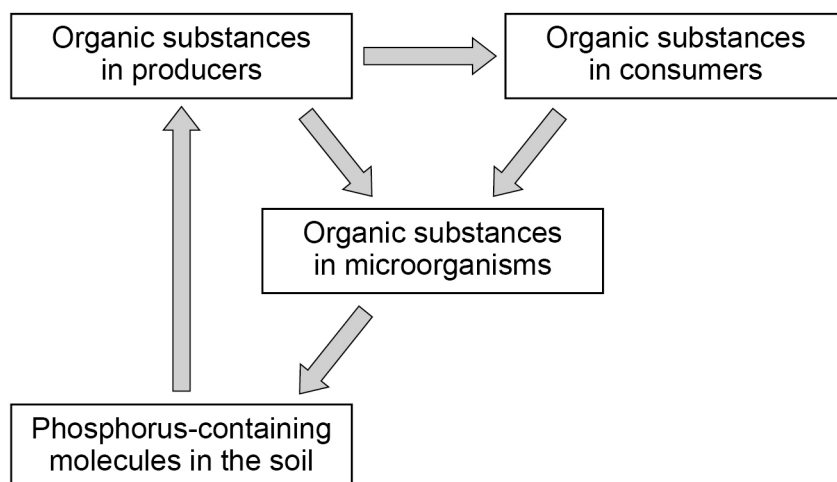
Answer **all** questions in the spaces provided.

0 1

Phosphorus is a chemical element found within organic substances in living organisms.

Figure 1 shows part of the phosphorus cycle.

Figure 1



0 1 . 1

Describe how phosphorus from organic substances in producers becomes part of organic substances in consumers.

[2 marks]

Consumers feed on the producers (plants) and digest the large phosphorus-containing molecules (eg DNA, ATP, phospholipids) into smaller soluble molecules.

These molecules are absorbed and assimilated: they are made into the consumer's own phosphorus-containing biological molecules, eg phospholipids, DNA, RNA and ATP.



0 1 . 2

Describe the role of microorganisms in making phosphorus from consumers available to producers.

[3 marks]

Decomposers (saprobionts, eg saprophytic bacteria and fungi) hydrolyse (digest) the phosphorus-containing biological molecules in dead organisms and waste.

This releases the phosphorus into the soil (environment) as ions, eg phosphate ions, or simple inorganic molecules.

The phosphate ions are absorbed (taken up) by plant roots and incorporated into organic molecules, eg DNA, ATP and phospholipids.

5

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0 2

Glycolysis is a process that happens in both aerobic and anaerobic respiration.

0 2 . 1

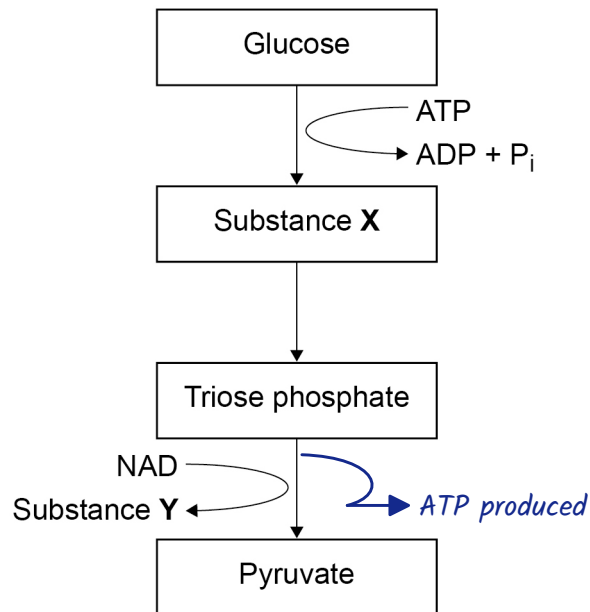
Name the part of a cell where glycolysis happens.

[1 mark]

Cytoplasm

Figure 2 shows some of the stages of glycolysis.

Figure 2



0 2 . 2

Name substances **X** and **Y**.

[1 mark]

Substance **X** Glucose phosphate (phosphorylated glucose)

Substance **Y** Reduced NAD (NADH)

0 2 . 3

Add an arrow and a label to **Figure 2** to show where ATP is produced.

[1 mark]

Question 2 continues on the next page

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0 2 . 4 There is a net gain of ATP in glycolysis.

Define **net gain**.

[1 mark]

More ATP is produced than is used: 4 ATP are produced and 2 ATP are used, so there is an overall gain of 2 ATP (per glucose).

Scientists investigate the effect of lactate on the contraction force generated by muscle from a rat.

The scientists:

- put a muscle in a control solution at 30 °C for 15 minutes
- put another muscle in a test solution of 20 mmol dm⁻³ lactate at 30 °C for 15 minutes
- after 15 minutes, stimulate each muscle using electrodes
- measure the contraction force in newtons (N) every 30 seconds for 5 minutes
- repeat the investigation 9 times and calculate the mean contraction force for each muscle for the control solution and for the test solution.

0 2 . 5 The scientists use a statistical test to analyse their results.

Name the statistical test the scientists should use.

Give the reason for your choice.

[2 marks]

Name of statistical test *Standard error and 95% confidence limits*

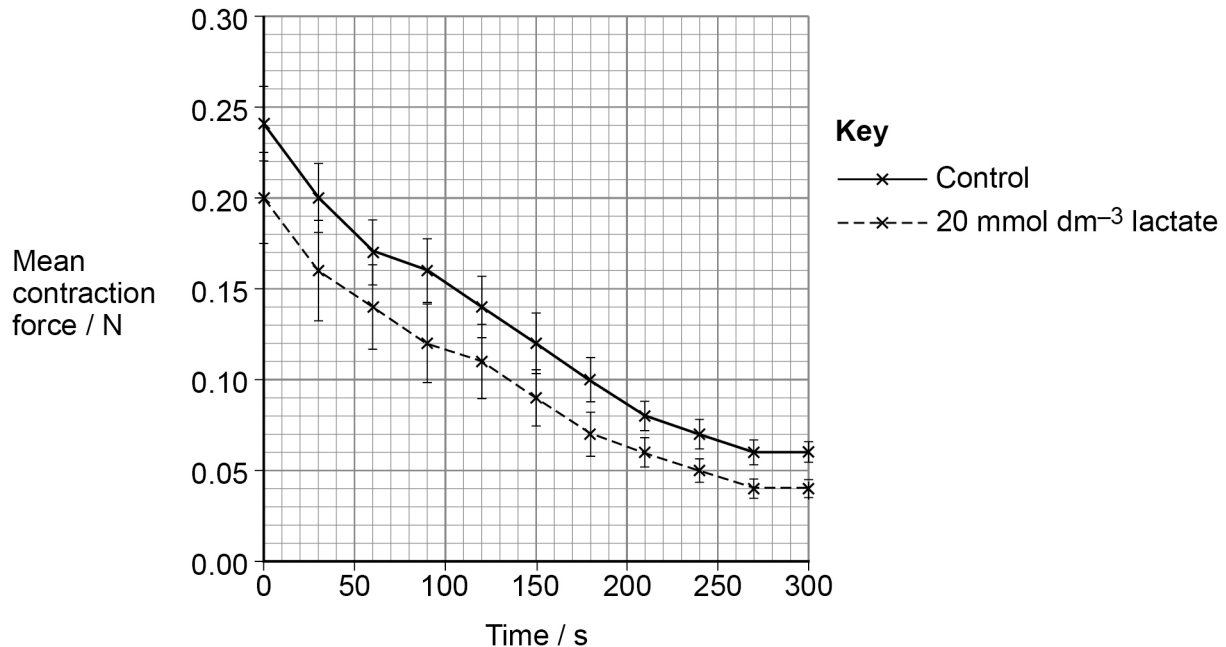
Reason for choice *Because the scientists are comparing two means (of continuous data).*



Figure 3 shows the scientists' results.

The values show the mean contraction force $\pm$ standard error.

Figure 3



0 2 . 6

A student concludes that lactate decreases the contraction force of muscle in animals.

Give **three** reasons why the student's conclusion may **not** be valid. Use the scientists' method and the results from **Figure 3**.

[3 marks]

1 *The standard error bars overlap at most times (eg at 0 s, 30 s and 60 s), so the difference is not significant at these times.*

2 *Only one concentration of lactate (20 mmol dm⁻³) was used, and only rat muscle was used, not muscle from other animals.*

3 *Isolated muscles were used, so it might be different in a living organism, and other animals have a body temperature higher than 30 °C.*

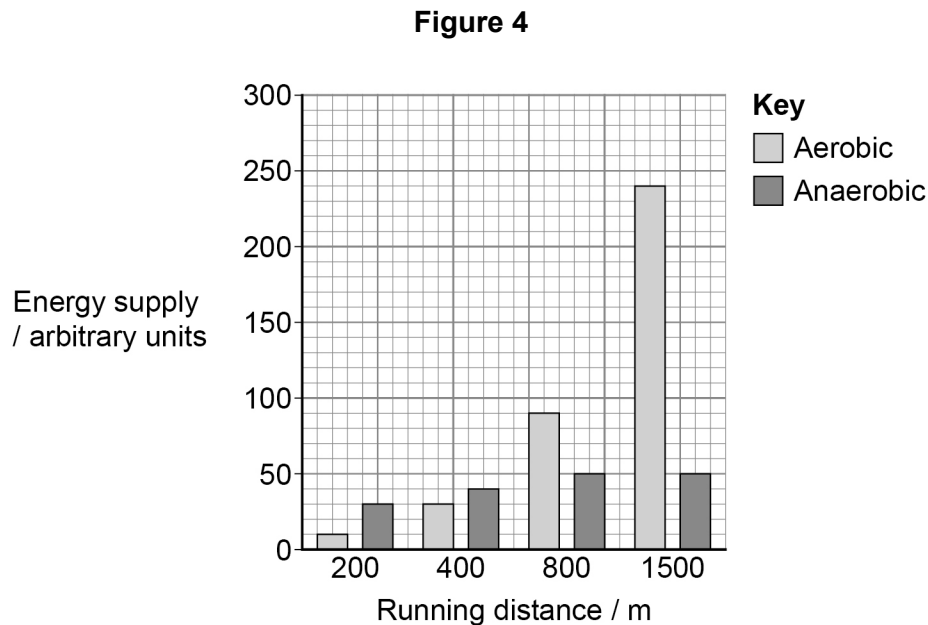
Question 2 continues on the next page

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A sports scientist investigates the contribution of aerobic and anaerobic respiration to the total energy supply for athletes running different distances.

Figure 4 shows the scientist's results.



0 2 . 7 Describe the trends the scientist's results show.

Use data from **Figure 4**.

[3 marks]

Aerobic energy supply increases as running distance increases: from 10 arbitrary units at 200 m to 240 arbitrary units at 1500 m.

Anaerobic energy supply increases slightly from 30 at 200 m to 50 at 800 m, then plateaus (stays at 50 at 1500 m), so it stays fairly constant.

Anaerobic respiration supplies more of the energy at shorter distances (30 compared with 10 aerobic at 200 m), but aerobic supplies more at longer distances (240 compared with 50 at 1500 m).



0 2 . 8

Calculate the ratios of aerobic to anaerobic respiration at 200 m **and** at 800 m.**[2 marks]***200 m: aerobic = 10, anaerobic = 30* *$10 \div 30 = 0.3$* *800 m: aerobic = 90, anaerobic = 50* *$90 \div 50 = 1.8$* Ratio at 200 m 0.3 : 1Ratio at 800 m 1.8 : 1

0 2 . 9

During a 200 m race, athletes run very quickly.

Explain why most of the energy supply is from anaerobic respiration during the 200 m race.

[2 marks]*Running very quickly means the rate of muscle contraction and the force of contraction are high, so the respiration rate (ATP demand) is very high.**Oxygen cannot be supplied to the muscle cells quickly enough for aerobic respiration, so most ATP comes from anaerobic respiration.*

16

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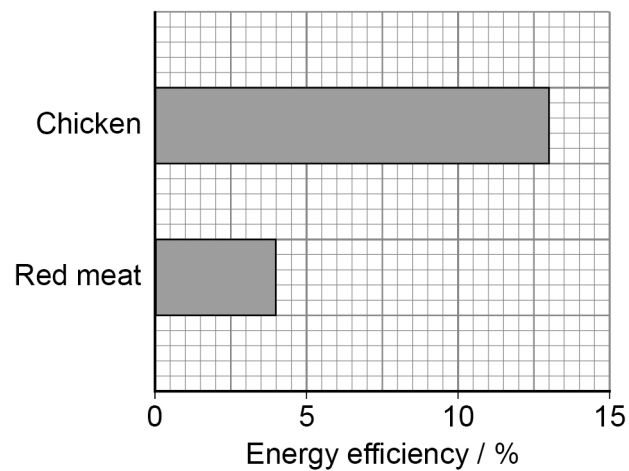
0 3

The energy efficiency of meat production is calculated from the energy input of food that is converted to animal product.

Figure 5 shows the energy efficiency of meat production for two different types of meat:

- chicken
- red meat.

Figure 5

**0 3 . 1**

Calculate how many times more efficient chicken production is than red meat production.

Use data from **Figure 5**.

[1 mark]

Chicken = 13%, red meat = 4%

$13 \div 4 = 3.25$

Times more efficient = 3.25

0 3 . 2

Chickens are often kept indoors.

Suggest **one** reason why this makes chicken production more efficient.

[1 mark]

*Indoors there is less heat loss and less movement (muscle contraction),
so less energy is lost in respiration and more is converted into chicken.*

Turn over ►



Land use for agriculture leads to deforestation and loss of biodiversity.

Scientists study the effect of five different types of diet on global land use.

Table 1 shows the five diets.

✓ = included in diet

X = **not** included in diet.

Table 1

Diet	Red meat	Dairy (milk-based)	Chicken	Eggs	Fish	Plant products
A	✓	✓	✓	✓	✓	✓
B	X	✓	✓	✓	✓	✓
C	X	X	✓	✓	✓	✓
D	X	X	X	✓	✓	✓
E	X	X	X	X	X	✓

Figure 6 shows the scientists' results.

1 hectare is 10 000 m²

Figure 6

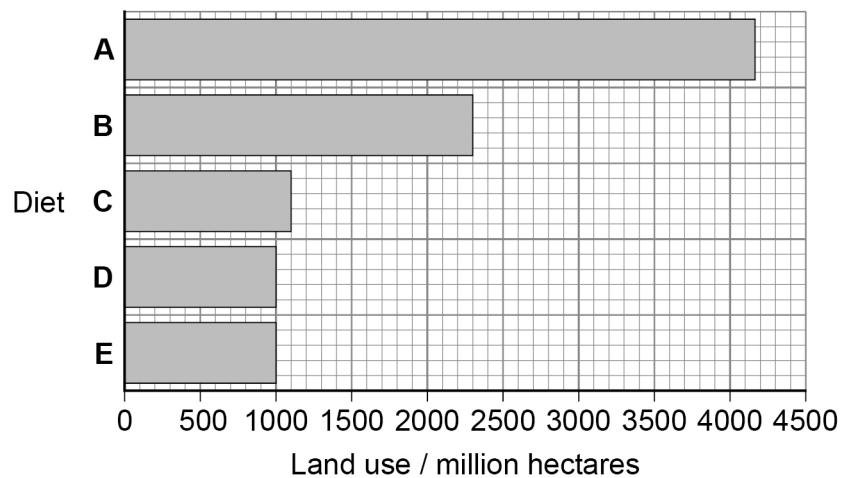
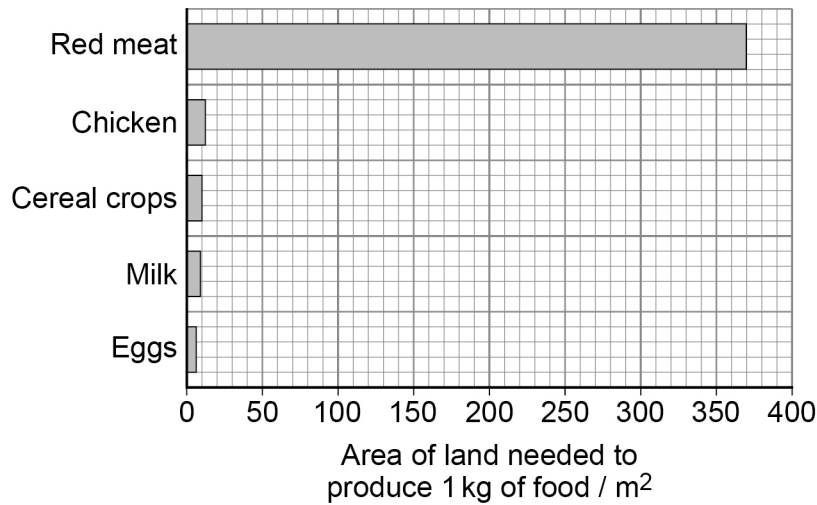


Figure 7 shows the area of land needed to produce 1 kilogram of five different food products.

Figure 7



0 3 . 3

One conclusion from the scientists' study is that everyone should eat diet **E** (only plant products) rather than diet **A** (current global diet).

Evaluate this conclusion using information from **Table 1**, **Figure 6** and **Figure 7**.

[4 marks]

Supports: diet E uses the least land (about 1000 million hectares

compared with about 4150 million hectares for diet A), so there would be less deforestation and less loss of biodiversity.

Against: diet D (with eggs and fish) has the same land use as diet E, and diet C (with chicken) has similar land use (about 1100 million hectares).

Not everyone wants to eat a plant-only diet, eg for cultural reasons, and diet E may contain less protein, vitamins and minerals.

Figure 7 shows cereal crops need more land than eggs and the same area of land as milk, and there is no information about land needed for plant crops other than cereals.

6

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0	4
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Alpacas are hairy mammals that can be found in South America.

Figure 8 shows an alpaca.

Figure 8



The hair colour of alpacas is controlled by a number of different genes.

Two genes controlling the hair colour of alpacas are **ASIP** and **MC1R**.

Alleles of ASIP are:

A = allele for yellow pigment

a = allele for no yellow pigment.

Alleles of MC1R are:

E = allele for black pigment

e = allele for no black pigment.

Black alpacas are homozygous recessive at the ASIP locus, and homozygous dominant or heterozygous at the MC1R locus.

Brown alpacas are homozygous dominant or heterozygous at the ASIP locus, and heterozygous at the MC1R locus.



0 4 . 1

Define **locus**.

[1 mark]

The position of a gene (allele) on a chromosome.

0 4 . 2

Give the **two** possible genotypes of a black alpaca.

[1 mark]

aa EE

and

aa Ee

0 4 . 3

A brown alpaca has the genotype Aa Ee.

Give **all** the possible gametes this alpaca could produce.

[1 mark]

AE, Ae, aE and ae

Question 4 continues on the next page

Turn over ►

0 4 . 4

A different gene affects the amount of pigment in alpaca hair.

The dominant allele of this gene, **G**, produces grey hair by reducing the amount of black pigment.

Some genotypes are lethal and an organism with this genotype will die at an early stage of development.

Genetic crosses between heterozygous grey alpacas with genotype **Gg** result in a ratio of 2 grey : 1 black offspring.

Explain how this ratio shows that the inheritance of the homozygous dominant genotype is lethal.

Only include the alleles **G** and **g** in your answer.

[3 marks]

A cross between Gg and Gg should give GG, Gg, Gg and gg: a ratio of 3 grey : 1 black.

Black offspring are still produced (1 in the ratio), so gg survives.

The 2 grey offspring must both be Gg, so the GG offspring die (GG is lethal), giving 2 grey : 1 black instead of 3 : 1.



0 4 . 5

Alpacas have two different lengths of hair caused by a single gene.

The dominant allele causes long hair and the recessive allele causes short hair.

The frequency of the recessive allele in a population is 0.295

Calculate the percentage of the population that are heterozygous for hair length.

Use the Hardy–Weinberg equation.

[3 marks]

$$q = 0.295, \text{ so } p = 1 - 0.295 = 0.705$$

$$\text{Heterozygotes} = 2pq$$

$$2pq = 2 \times 0.705 \times 0.295 = 0.41595$$

$$0.41595 \times 100 = 41.6\%$$

Percentage of the population that are heterozygous = 41.6 %

9

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0 5

A student investigates the effect of competition on the growth of carrot plants.

The student:

- plants different numbers of carrot seeds outside in 1 m² areas of soil
- grows the carrot plants for 12 weeks
- measures the dry mass of the carrot plants after 12 weeks.

0 5 . 1

Name the type of competition the student is investigating.

[1 mark]

Intraspecific (competition)

0 5 . 2

Give **two** variables the student should control.

[2 marks]

Control variable 1 *The variety (type) of carrot*

Control variable 2 *The volume of water added to each area of soil*

0 5 . 3

Give the reason why the student measures the dry mass of the carrot plants instead of the fresh mass.

[1 mark]

Fresh mass includes the water content of the plants, which can vary, so dry mass is a more reliable measure of growth.



Question 5 continues on the next page

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Table 2 shows the student's results.

Table 2

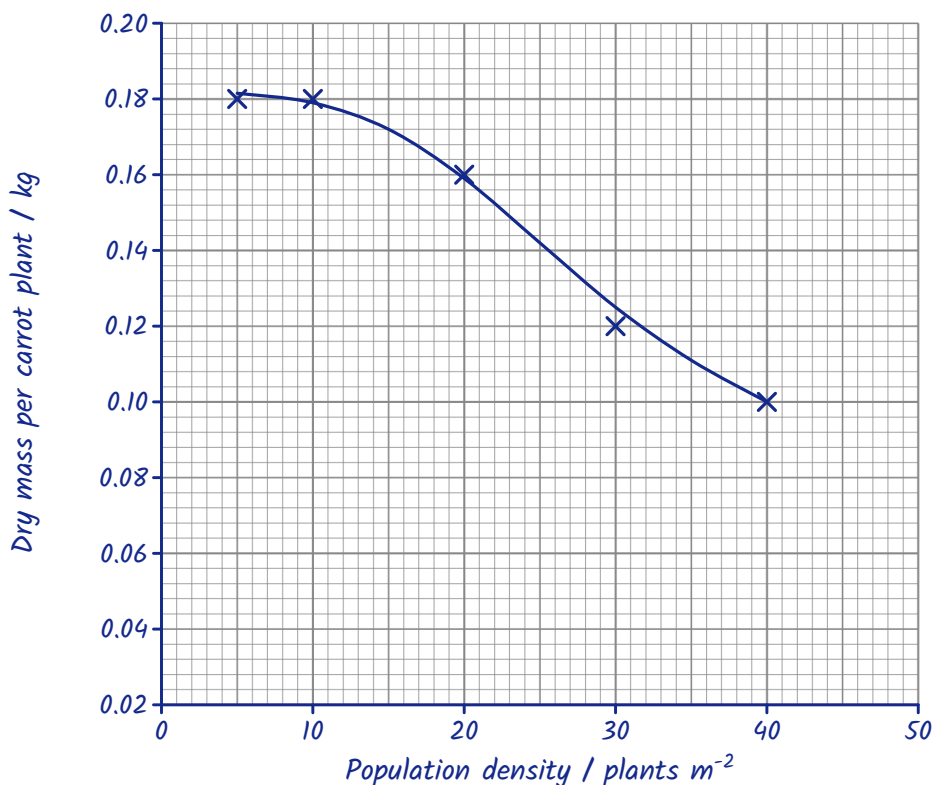
Population density / plants m^{-2}	Dry mass of carrot plants / kg m^{-2}	Dry mass per carrot plant / kg
5	0.9	0.18
10	1.8	0.18
20	3.1	0.16
30	3.7	0.12
40	3.8	0.10

- 0 5 . 4** Complete **Table 2** by calculating the dry mass per carrot plant for population densities of 20 plants per square metre **and** 30 plants per square metre. **[2 marks]**

- 0 5 . 5** Plot a graph of the student's results to show the relationship between **population density** and the **dry mass per carrot plant**.

Draw a line of best fit on your graph.

[4 marks]



0 5 . 6

The student concludes that the optimum population density for growing carrots is 10 plants per square metre.

Evaluate the student's conclusion.

Use information from the student's method and results.

[4 marks]

10 plants per m^2 gives the highest recorded dry mass per plant (0.18 kg), which supports the conclusion.

But 5 plants per m^2 gives the same dry mass per plant, and there is no density between 10 and 20 plants per m^2 . 10 plants per m^2 does not give the highest dry mass per m^2 (1.8 compared with 3.8 $kg\ m^{-2}$ at 40).

Dry mass of the whole plant is measured rather than crop yield, with no measure of carrot size or quality.

Only one plot was used for each density (no repeats) and no statistical test was done, so there may be no significant difference. Plants were only grown for 12 weeks; competition increases as plants get bigger.

14

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0 6

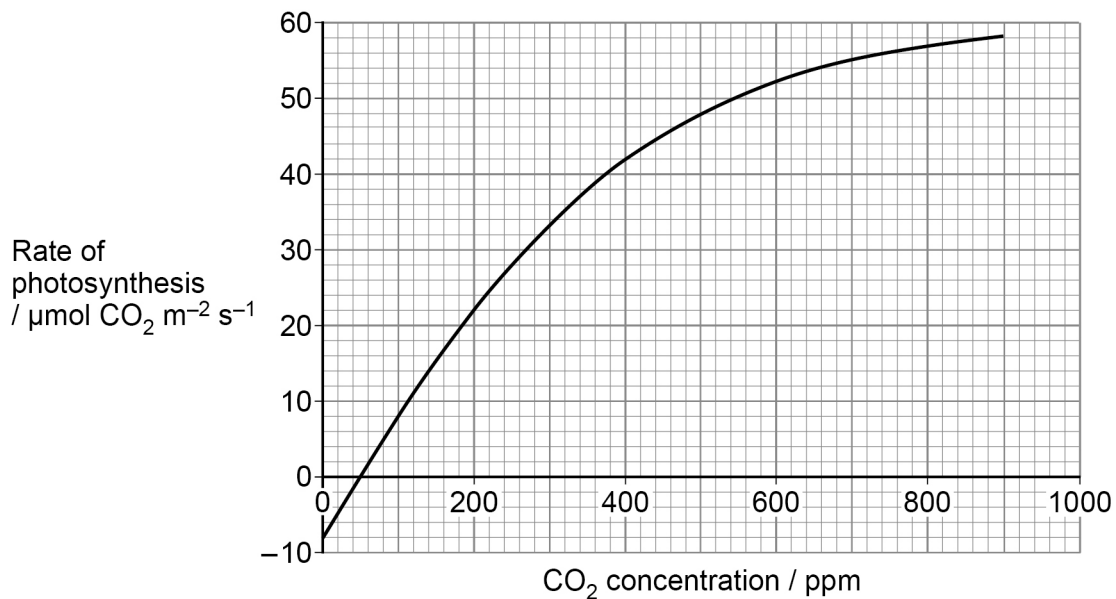
Scientists investigate the effect of carbon dioxide concentration in the air on the rate of photosynthesis by a plant.

The scientists use the amount of carbon dioxide fixed per leaf area per second as a measure of the rate of photosynthesis.

The scientists measured the carbon dioxide concentration in parts per million (ppm).

Figure 9 shows the scientists' results.

Figure 9



0 6 . 1

Figure 9 shows a negative value for the rate of photosynthesis at carbon dioxide concentrations below 50 ppm

Explain why.

[2 marks]

Below 50 ppm the rate of respiration is greater than the rate of photosynthesis.

So there is a net release of carbon dioxide: more CO₂ is released by respiration than is fixed by photosynthesis.



0 6 . 2

Explain how increasing the carbon dioxide concentration would increase the production of organic substances in a plant.

Use your knowledge of the light-independent reaction.

[4 marks]

With more carbon dioxide, more CO_2 is available to combine with RuBP (catalysed by rubisco).

So more glycerate 3-phosphate (GP) is formed.

More GP is reduced to triose phosphate, using reduced NADP and ATP from the light-dependent reaction.

So more triose phosphate is converted to organic substances, eg glucose, starch, amino acids and lipids, and more is used to regenerate RuBP to fix more CO_2 .

0 6 . 3

Calculate the percentage change in the rate of photosynthesis from 100 to 200 ppm

Use data from **Figure 9**.

[2 marks]

Rate at 100 ppm = 8, rate at 200 ppm = $22 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$

Change = $22 - 8 = 14$

$14 \div 8 \times 100 = 175\%$

Percentage change in rate = 175 %

Question 6 continues on the next page

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06.4

The percentage change in the rate of photosynthesis between 800 and 900 ppm is 1.75%

This value is much lower than the percentage change in rate between 100 and 200 ppm

Explain why.

[2 marks]

Between 100 and 200 ppm, CO₂ concentration is the limiting factor, so increasing the concentration increases the rate of photosynthesis a lot.

Between 800 and 900 ppm, another factor such as light intensity or temperature is limiting, so increasing CO₂ concentration does not increase the rate much.

10



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Mitochondria are the sites of aerobic respiration.

0	7	.	1
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Describe how ATP is synthesised inside mitochondria during aerobic respiration.

[5 marks]

In the matrix, the Krebs cycle generates ATP by substrate-level phosphorylation.

The Krebs cycle also generates reduced coenzymes (reduced NAD and reduced FAD).

The reduced coenzymes transfer electrons to the electron transfer chain on the inner mitochondrial membrane.

The electrons pass down the electron transfer chain and energy is released.

This energy is used to pump (actively transport) protons (H^+) into the intermembrane space.

The protons diffuse back across the inner mitochondrial membrane into the matrix through ATP synthase, which makes ATP from ADP and P_i (oxidative phosphorylation).

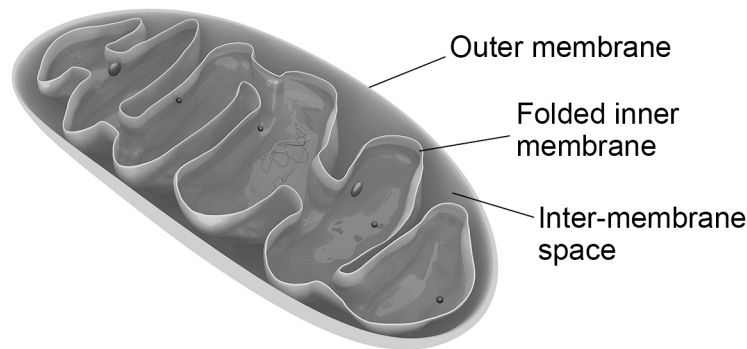
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Figure 10 shows the structure of a mitochondrion.

Figure 10



0 7 . 2

Explain how each of the following features helps a mitochondrion to function:

- inter-membrane space
- folded inner membrane
- pyruvate carrier proteins in the membranes.

[6 marks]

Inter-membrane space: the double membrane allows a high concentration of H^+ to build up in the inter-membrane space, so a proton gradient is established.

So H^+ can diffuse back into the matrix through ATP synthase, and the outer membrane stops H^+ diffusing out of the mitochondrion.

Folded inner membrane: the folds (cristae) provide a large surface area, for the attachment of more proteins (enzymes) of the electron transfer chain and more ATP synthase, so more ATP is made.

Pyruvate carrier proteins: these allow pyruvate (from glycolysis) to be transported into the matrix of the mitochondrion, because the membranes are impermeable to pyruvate (pyruvate cannot diffuse across), and the link reaction occurs in the matrix, so acetyl coenzyme A can be produced from pyruvate.



07.3

Cytochrome c is a protein involved in aerobic respiration in mitochondria.

The molecular structure of cytochrome c varies in different species.

Describe how a difference in the molecular structure of cytochrome c could become more frequent in a small, geographically isolated population.

[4 marks]

A mutation in the gene (DNA) for cytochrome c causes a change to the structure of the protein.

Individuals with the changed cytochrome c structure have a selective advantage, eg more efficient aerobic respiration in that environment.

These individuals are more likely to survive and reproduce, so they have more offspring and pass on the allele.

The allele frequency increases over time (over many generations). In a small population with no gene flow from other populations, genetic drift also makes the allele more frequent quickly.

15

END OF QUESTIONS



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