GradeMax

Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0736965576

BIOLOGY **9700/42**

Paper 4 A Level Structured Questions **February/March 2024**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **32** pages. Any blank pages are indicated.

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1 **(a)** Fig. 1.1 is a diagram of a nephron.

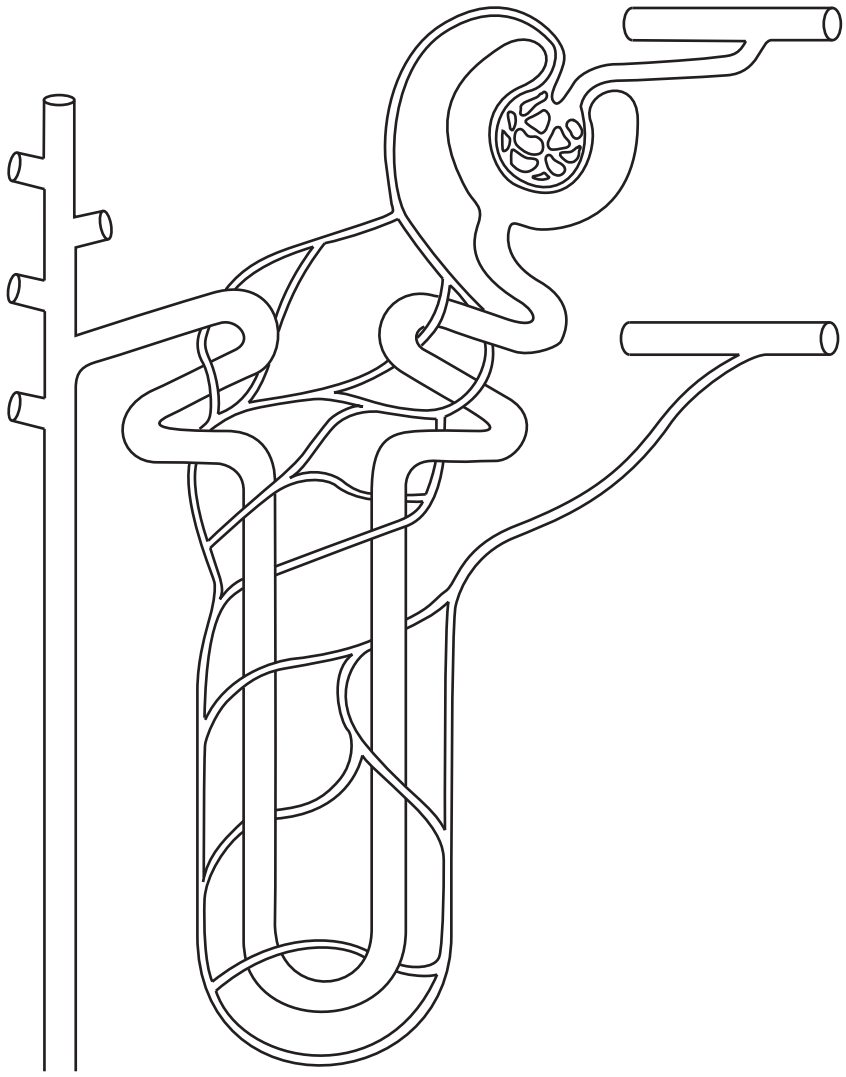

Fig. 1.1

Label Fig. 1.1 using:

- one labelling line and the letter **A** to identify a region that contains urine
- one labelling line and the letter **B** to identify a region that contains podocytes
- one labelling line and the letter **C** to identify a region of the nephron that is within the medulla of the kidney
- one labelling line and the letter **D** to identify the afferent arteriole.

[4]

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(b) The cells of the proximal convoluted tubule are adapted to carry out selective reabsorption.

Describe **and** explain how these cells are adapted to carry out selective reabsorption.

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[Total: 8]

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2 The scientist Gregor Mendel investigated differences in the length of the stem in the pea plant, *Pisum sativum*. In 1866, he published the results of his investigation into this trait (characteristic).

Fig. 2.1 shows a diagram of a pea plant.

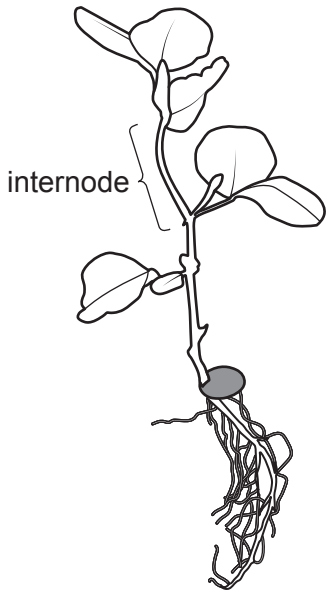

Fig. 2.1

Mendel observed that the pea plants he grew either had tall stems or dwarf (short) stems. In his investigation, Mendel carried out crosses using pea plants with these two phenotypes.

(a) From the results of these crosses, Mendel demonstrated that tall stems were dominant to dwarf stems in pea plants.

It is now known that the stem length trait in pea plants is controlled by one gene that has two alleles:

- a dominant allele, *Le*
- a recessive allele, *le*.

Describe a cross that could be carried out **and** how the results of the cross could be analysed to determine the genotype of a pea plant with a tall stem.

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(b) The scientists P W Brian and H G Hemming identified that the difference in the length of the stem in pea plants was associated with the presence or absence of gibberellin. They published their findings in 1955.

(i) Gibberellin leads to a response in plant cells by binding to specific receptor molecules.

State the term used to describe a molecule, such as gibberellin, that binds to specific receptor molecules and leads to a response in cells.

..... [1]

(ii) Suggest the response of the cells in the internode region of the stem, as labelled in Fig. 2.1, to the presence of gibberellin **and** describe how this response affects the trait investigated by Mendel.

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3 Cystic fibrosis is an autosomal recessive genetic disease. People with cystic fibrosis have a homozygous recessive genotype.

(a) Explain the meaning of the terms homozygous and recessive.

homozygous .....

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recessive .....

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[2]

(b) **(i)** In 2020:

- there were 10 800 people with cystic fibrosis in the UK
- the UK population was estimated to be 67 100 000 people.

A proportion of people in the UK population are heterozygous for the gene that causes cystic fibrosis and do **not** have symptoms of the disease.

Use the Hardy–Weinberg principle to calculate the number of people in the UK population who are expected to be heterozygous for the gene that causes cystic fibrosis.

The two equations for the Hardy–Weinberg principle are provided.

equation 1

$$p + q = 1$$

equation 2

$$p^2 + 2pq + q^2 = 1$$

p = frequency of the dominant allele
q = frequency of the recessive allele
p^2 = frequency of the homozygous dominant genotype
$2pq$ = frequency of the heterozygous genotype
q^2 = frequency of the homozygous recessive genotype

The first stage of the calculation has been completed for you.

$$q^2 = \frac{10\,800}{67\,100\,000}$$

q =

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p =

$2pq$ =

number of people in the UK expected to be heterozygous for the gene = ... [3]

(ii) The Hardy–Weinberg principle provides a useful estimate of the number of people in the UK who are heterozygous for cystic fibrosis. However, the estimate is lower than the actual number. This underestimation occurs because **not** all the conditions of the Hardy–Weinberg principle apply.

In the UK in 2020, the mean life expectancy of:

- people with cystic fibrosis was approximately 50 years
- **all** people was approximately 80 years.

Explain how this information accounts for the underestimation of the number of people in the UK that are heterozygous for cystic fibrosis.

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(c) A screening programme for cystic fibrosis was introduced in 2007 for all children born in the UK. Children are tested within seven days of their birth. Children identified from the screening programme as being at high risk of having cystic fibrosis can have a genetic test to confirm whether they have the disease.

(i) Table 3.1 shows the median predicted life expectancy for people born in the UK who have cystic fibrosis. Predictions are shown for people born in 2008, 2012, 2016 and 2020.

Table 3.1

year of birth	median predicted life expectancy / years
2008	38.8
2012	43.5
2016	47.0
2020	50.6

Describe the trend shown in Table 3.1 **and** outline how early screening for cystic fibrosis may have contributed to this trend.

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(ii) In many countries, a genetic test for cystic fibrosis is available to **adults** who do **not** have cystic fibrosis but have a family member who either has cystic fibrosis or is heterozygous for the gene that causes cystic fibrosis.

These adults include partners, parents, offspring, brothers and sisters of the family member. The aim is to find out if any of **these adults** are heterozygous for the gene that causes cystic fibrosis.

Discuss the ethical and social considerations of making a genetic test for cystic fibrosis available to these adults.

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4 Holstein Friesian cattle are a breed of cattle used by dairy farmers in many countries of the world for the high milk yield of their cows.

Fig. 4.1 shows Holstein Friesian cattle.



Fig. 4.1

Milk yield in Holstein Friesian cattle is affected by heat stress. Heat stress occurs when homeostatic mechanisms are **not** enough to keep the body temperature down to normal levels.

One of the factors that contributes to heat stress is air temperature.

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Fig. 4.2 shows:

- the mean daily air temperature in Central Europe
- the mean monthly milk yield per cow of Holstein Friesian cattle in Central Europe.

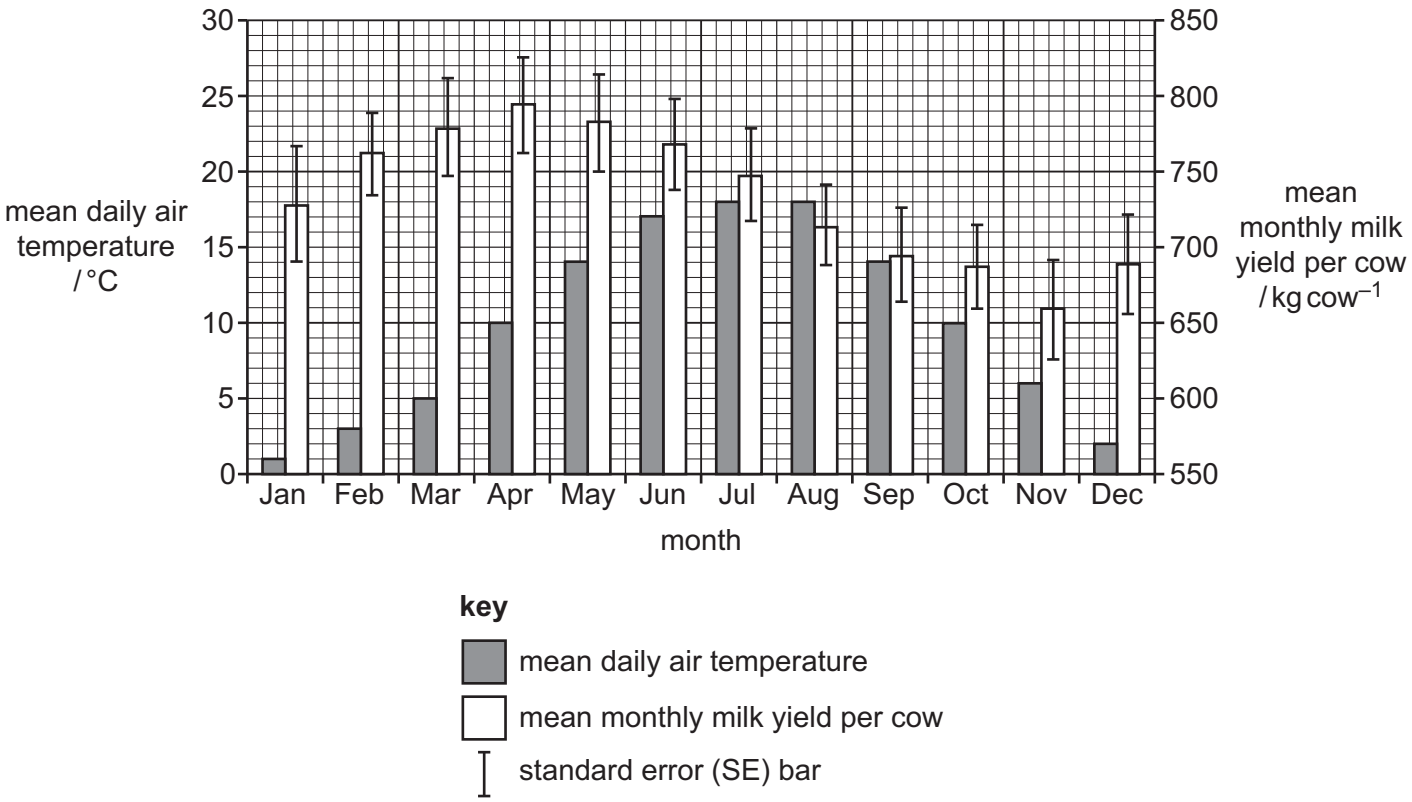

Fig. 4.2

(a) With reference to Fig. 4.2, describe the trends in air temperature and milk yield from April to August.

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(b) Many dairy farmers in tropical regions use cattle breeds that are tolerant to heat stress (heat-tolerant cattle). These heat-tolerant cattle:

- can tolerate higher air temperatures than Holstein Friesian cattle before heat stress occurs
- have milder symptoms of heat stress than Holstein Friesian cattle for the same high air temperatures.

Where heat stress does **not** occur, heat-tolerant cattle produce a lower milk yield than Holstein Friesian cattle under the same conditions.

Scientists compared DNA sequences of Holstein Friesian cattle and heat-tolerant cattle for a number of genes known to have an effect on body temperature.

Twenty genes were found that had alleles associated **only** with heat-tolerant cattle.

With reference to the information provided, including the data in Fig. 4.2:

- state the type (pattern) of phenotypic variation shown by milk yield in cattle
- identify factors that cause phenotypic variation in milk yield in cattle.

In each case, give a reason for your choice.

type (pattern) of phenotypic variation and reason for choice .....

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factors that cause phenotypic variation and reason for each choice .....

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[3]

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(c) The scientists found that one of the genes studied, *PRLR*, has a dominant allele known as *SLICK*. The *SLICK* allele was identified in Senepol cattle, a heat-tolerant breed, and is **not** found in Holstein Friesian cattle.

Cattle with the *SLICK* allele have short hair due to reduced hair growth.

Scientists have used selective breeding to introduce the *SLICK* allele into Holstein Friesian cattle. The milk yields of normal Holstein Friesian cattle and Holstein Friesian cattle with the *SLICK* allele are shown in Fig. 4.3, during:

- March, when the mean daily air temperature is 5 °C.
- September, when the mean daily air temperature is 14 °C.

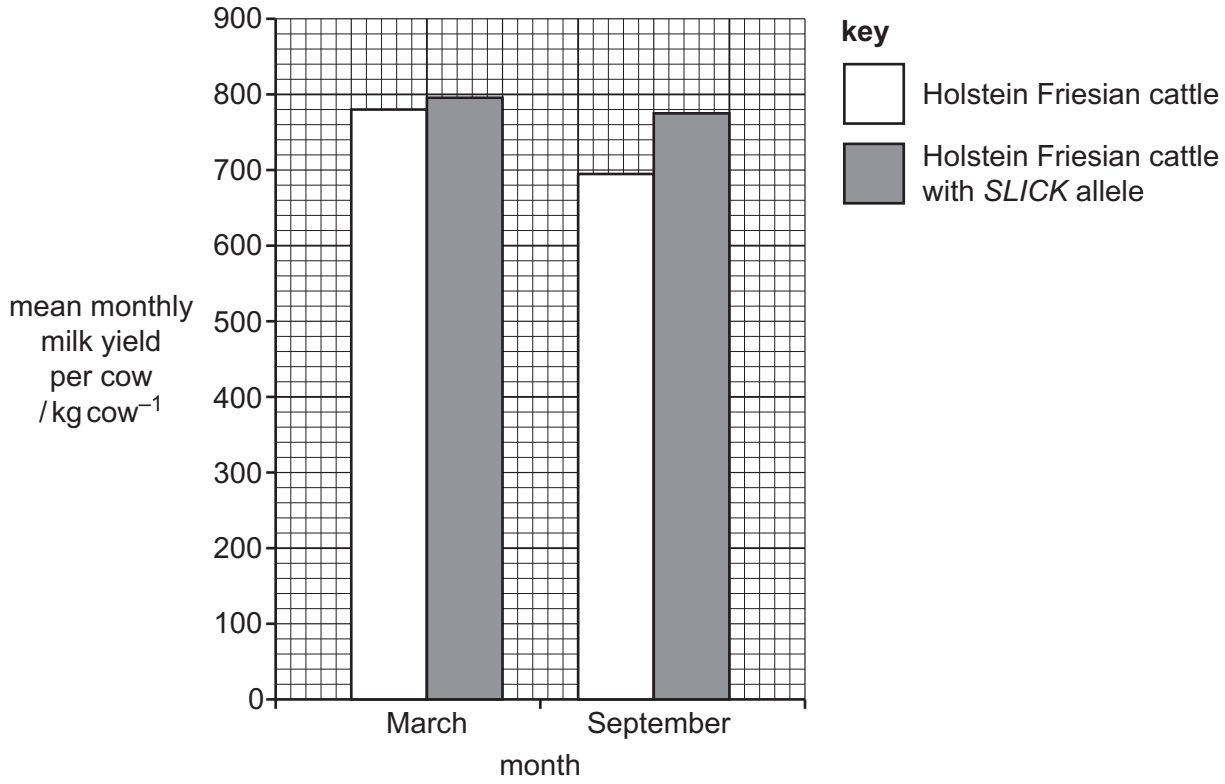

Fig. 4.3

With reference to Fig. 4.3, describe the effect of the *SLICK* allele on milk yield in Holstein Friesian cattle.

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(d) The *SLICK* allele differs from the recessive allele by a single nucleotide deletion. This results in a frameshift mutation and introduces a premature stop codon in the *PRLR* gene.

Scientists can use gene editing to replicate this mutation in Holstein Friesian cattle. This provides a way to introduce the *SLICK* allele into Holstein Friesian cattle without selective breeding.

Compare gene editing and selective breeding for introducing the *SLICK* allele into Holstein Friesian cattle.

Include similarities **and** differences in your answer.

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5 Complete the following paragraphs using the most appropriate word or words.

The theory of evolution describes a process that can lead to the formation of new species from pre-existing species over ..... .

DNA sequence data of different species can be compared to show evolutionary relationships. Two species that have a more recent common ancestor share more ..... in the DNA nucleotide sequences of their genomes than two species that are more distantly related.

Mitochondrial DNA can also be used in the study of evolutionary relationships. Mitochondrial DNA is inherited only from the female gamete, and its nucleotide sequence is unaffected by ..... during the production of gametes.

DNA sequence data can be stored in large biological ..... , allowing faster comparison of the nucleotide sequences of genomes using computer software. DNA sequence data can also be used to predict the ..... sequences of proteins produced by a species.

A ..... can be used to detect many different mRNA molecules at the same time in studies that compare gene expression between different species.

[6]

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6 A respirometer is a piece of apparatus that can be used to measure the rate of respiration of living tissue such as germinating peas.

A simple respirometer is shown in Fig. 6.1.

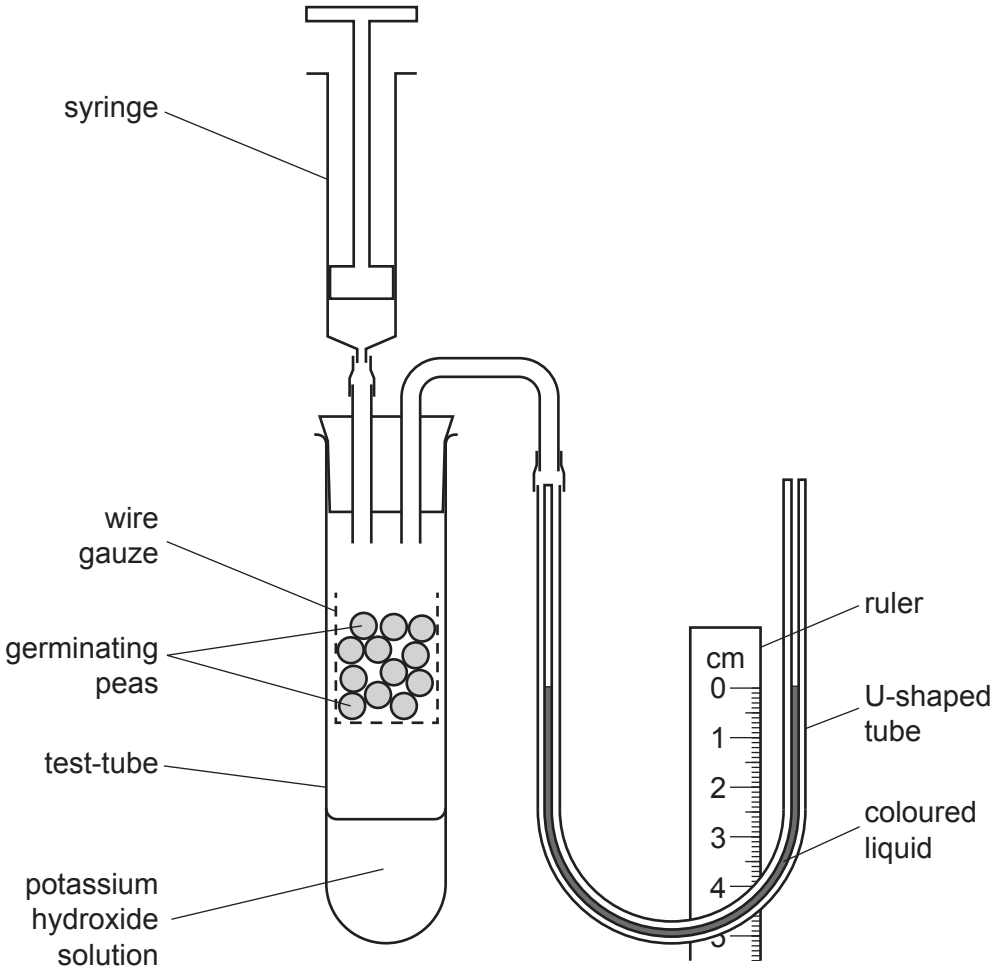

Fig. 6.1

A student carried out an investigation to determine the effect of temperature on the rate of respiration of germinating peas.

- The student set up the respirometer as shown in Fig. 6.1 and placed the respirometer in a water-bath at 10 °C.
- After five minutes, the student used the syringe to adjust the position of the coloured liquid in the right-hand side of the U-shaped tube so that it lined up with 0 cm on the ruler. The student immediately started a timer.
- The germinating peas used up oxygen, causing the coloured liquid in the U-shaped tube to move.
- The student measured the distance moved by the coloured liquid after 20 minutes.
- The student repeated the experiment at temperatures of 20 °C, 30 °C, 40 °C and 50 °C.

(a) State the function of the potassium hydroxide solution used in the investigation.

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(b) Suggest how the validity of the results could be assessed.

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(c) Explain why the respirometer was left in the water-bath for five minutes before starting the experiment.

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(d) The rate of movement of the coloured liquid in the U-shaped tube, calculated from the results, is shown in Table 6.1.

Table 6.1

temperature / °C	rate of movement / mm min^{-1}
10	0.40
20	0.70
30	1.30
40	1.15
50	0.60

Plot a graph of the results shown in Table 6.1 on the grid in Fig. 6.2. Draw a curved line of best fit.

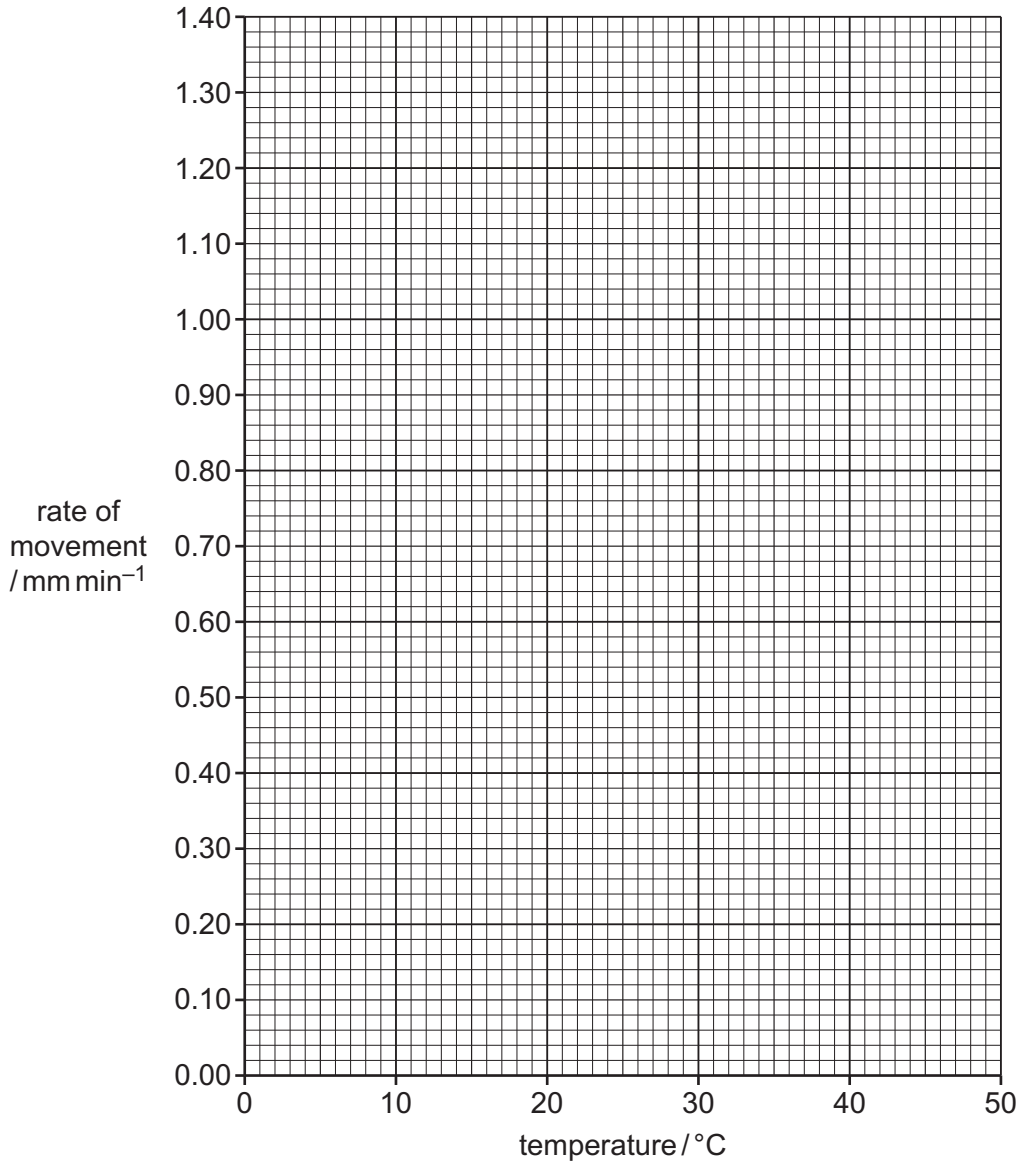

Fig. 6.2

[2]

(e) The rate of movement of the coloured liquid is related to the rate of respiration.

Explain the effect of temperature on the rate of respiration shown in Table 6.1 and Fig. 6.2.

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[Total: 9]

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7 **(a)** The light-dependent stage of photosynthesis occurs within chloroplasts. In this stage, electrons are emitted from the chlorophyll *a* molecules and passed to electron acceptors.

If a redox indicator, such as DCPIP, is added to a suspension of illuminated chloroplasts, electrons will be transferred to DCPIP, causing the colour of the DCPIP to change from blue to colourless.

A student investigated the effect of the wavelength of light (colour of light) on the rate of photosynthesis.

- DCPIP was added to three colorimeter tubes, each containing a suspension of chloroplasts. The chloroplast suspensions were kept in the dark until required.
- The colorimeter tubes were each exposed to light of a different colour: red, blue or green. The intensity of light was the same for all tubes, and each was exposed to light for four minutes. All other conditions were kept the same.
- The absorbance of each chloroplast suspension was measured at one-minute intervals using a colorimeter.

The results are shown in Fig. 7.1.

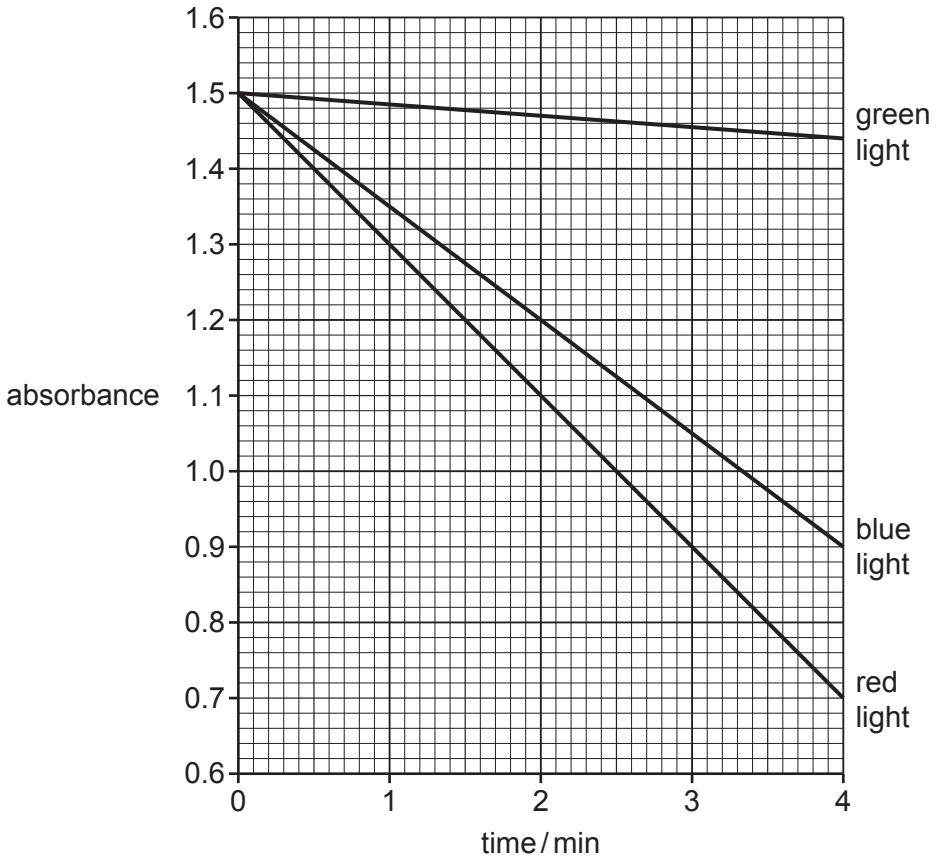

Fig. 7.1

(i) Explain why the chloroplast suspensions were kept in the dark until required.

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(ii) Describe the results shown in Fig. 7.1.

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(iii) With reference to the light-dependent stage of photosynthesis, explain the differences between the results shown in Fig. 7.1 for red light and for green light.

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(b) Changes in the atmospheric carbon dioxide concentration, light intensity and temperature can affect the rate of photosynthesis. These three factors directly affect different processes of photosynthesis.

Complete Table 7.1 using a tick (✓) to identify the processes that can be **directly** affected by each factor or a cross (✗) to identify the processes that are **not directly** affected by each factor.

Indirect effects where a change in the rate of one process affects the rate of a different process should **not** be considered.

A tick or a cross must be placed in the final column of every row.

Table 7.1

factor	process	✓ or ✗
carbon dioxide concentration	Calvin cycle	.....
	photophosphorylation	.....
light intensity	Calvin cycle	.....
	photophosphorylation	.....
temperature	Calvin cycle	.....
	photophosphorylation	.....

[3]

[Total: 10]

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8 **(a)** Approximately 2×10^9 people in the world are currently infected with the bacterial disease tuberculosis (TB) caused by *Mycobacterium tuberculosis*. Early diagnosis is important so that treatment can begin.

APOPO is a non-profit organisation that has trained African giant pouched rats, *Cricetomys gambianus*, to use their sense of smell to detect *M. tuberculosis*. They do this by sniffing a sample of thick mucus from the lungs of people who may have TB. The African giant pouched rats are able to detect the presence of *M. tuberculosis* with an accuracy of 87–93%.

Fig. 8.1 shows an African giant pouched rat.



Fig. 8.1

(i) The type of receptor cell used by African giant pouched rats to detect *M. tuberculosis* is the same as that used in human taste buds.

Name this type of receptor cell.

..... [1]

(ii) Suggest why African giant pouched rats trained to detect *M. tuberculosis* may also be able to detect other species of *Mycobacterium* that cause TB.

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(b) The African giant pouched rat belongs to the kingdom Animalia in the domain Eukarya.

Complete Table 8.1 to show the full classification of the African giant pouched rat.

Table 8.1

kingdom	Animalia
.....	Chordata
class	Mammalia
.....	Rodentia
family	Nesomyidae
.....	.....
species	*gambianus*

[2]

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(c) Differences between members of the domain Eukarya and members of the domain Bacteria include the presence or absence of particular membrane-bound cell structures.

Outline **other** differences in the characteristic features of members of the domain Eukarya and members of the domain Bacteria.

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(d) Describe, with reference to the structure of viruses, how viruses are classified.

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9 **(a)** An investigation was carried out to study the effect of different intensities of blue light on the percentage germination of barley seeds. Barley seeds were exposed to blue light for a period of seven days. All other variables were kept constant.

The results are shown in Table 9.1.

Table 9.1

light intensity / arbitrary units (au)	percentage germination
0 (dark)	98.0
36	76.9
48	45.0
57	14.7

The effect of blue light on the concentration of abscisic acid (ABA) was also investigated. ABA concentration was measured at intervals over seven days in barley seeds exposed to blue light at an intensity of 57 arbitrary units.

The results are shown in Table 9.2.

Table 9.2

day	concentration of ABA / arbitrary units (au)
0	100
1	90
3	350
5	351
7	381

For comparison, in the dark the concentration of ABA in barley seeds fell from 100 au at the start (day 0) to 45 au on day 1 and did **not** increase from day 1 to day 7.

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ABA is thought to affect gibberellin synthesis or activity.

Using the information in Table 9.1 and Table 9.2, describe the effect of blue light on the germination of barley seeds **and** suggest an explanation for this effect.

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(b) After germination, auxin is important in the growth of barley plants.

Describe **and** explain the role of auxin in cell elongation.

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10 **(a)** Striated muscle is composed of myofibrils. Myofibrils contain several structural proteins including troponin, tropomyosin, actin and myosin.

Outline the roles of these four structural proteins in the contraction of a sarcomere.

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(b) Drugs that cause muscle paralysis (paralytic drugs) are used during surgery to stop the patient moving. One commonly used paralytic drug is succinylcholine, which works by preventing contraction of muscles. Succinylcholine is able to prevent muscles contracting because it has a similar shape to acetylcholine.

Suggest how succinylcholine is able to prevent muscles contracting.

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(c) Duchenne muscular dystrophy (DMD) is a genetic disease that is caused by a single gene. DMD affects striated muscle, and symptoms of the disease first appear at an early age.

A fibrous protein, dystrophin, stabilises muscle fibres during contraction. A person with DMD produces non-functioning dystrophin or no dystrophin at all. The disease occurs in about four in 100 000 people and mainly affects boys.

Suggest **and** explain why boys are more likely to have DMD than girls.

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