AQA

Please write clearly in block capitals.

Centre number		Candidate number	

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

I declare this is my own work.

A-level
BIOLOGY
Paper 3

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	

Do not write outside the box

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 In one species of squirrel, *Sciurus carolinensis*, fur colour is controlled by one gene, with two codominant alleles. C^G represents the allele for grey fur colour, and C^B represents the allele for black fur colour.

Table 1 shows the three possible phenotypes.

Table 1

Genotype	Phenotype	
C^GC^G	Grey fur	- 16
C^GC^B	Brown-black fur	- 16
C^BC^B	Black fur	- 2

0 1 . 1 In a population of 34 *S. carolinensis*, 2 had black fur.

Use the Hardy–Weinberg equation to estimate how many squirrels in this population had brown-black fur. Show your working.

[2 marks]

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

$p = C^GC^G$
$pq = C^GC^B$
$q^2 = C^BC^B$

$q^2 = \text{black} = \frac{2}{34} = 0.058823\ldots$

$q = \sqrt{0.58823} = 0.2425\ldots$

$p = 1 - q = 1 - 0.2425 = 0.75746$

$p^2 = (0.75746)^2 = 0.57375$

$2pq = 1 - p^2 - q^2 =$ ~~1 - 0.58823 - 0.2425~~

$= 1 - 0.058823 - 0.57375$

$= 0.367\ldots$

$37\% \times 34$

$= 12.49$

$\Rightarrow 12$

Answer 12

Do not write outside the box

0 1 . 2 The actual number of squirrels in this population that had brown-black fur was 16.

Use all of the information to calculate the **actual** frequency of the C^G allele.

Do **not** use the Hardy–Weinberg equation in your calculation.

Give your answer to 2 decimal places.

[1 mark]

$$\frac{(16 \times 2) + (16 \times 1)}{34 \times 2} = 0.70588...$$

$$\Rightarrow 0.71$$

Answer 0.71

0 1 . 3 *S. carolinensis* were first introduced to the UK from North America in the 1870s. They are now widely distributed across the UK.

S. carolinensis from both North America and the UK show exactly the same genotypic and phenotypic variation. An identical mutation causing black fur has also been found in several other species closely related to *S. carolinensis*.

Use this information to deduce which **one** of the following conclusions is most likely true.

Tick (✓) **one** box.

[1 mark]

A	The mutation that caused black fur happened after *S. carolinensis* was introduced to the UK from North America.	☐
B	The mutation that caused black fur happened in a common ancestor of *S. carolinensis* and other closely related species.	✓
C	The mutation that caused black fur happened independently in *S. carolinensis* and all other closely related species.	☐
D	The phenotypic variation shown in *S. carolinensis* and other closely related species is caused by genetic drift.	☐

Question 1 continues on the next page

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The mutation that caused the C^B allele was due to a 24 base-pair deletion from the C^G allele.

0 1 . 4 The protein coded for by the C^B allele is 306 amino acids long.

Calculate the percentage reduction in size of the protein coded for by the C^B allele compared with the protein coded for by the C^G allele.

Give your answer to 3 significant figures and show your working.

[2 marks]

$\frac{24}{3} = 8$ $306 + 8 = 314$ $\frac{306}{314} \times 100 = 97.4522$

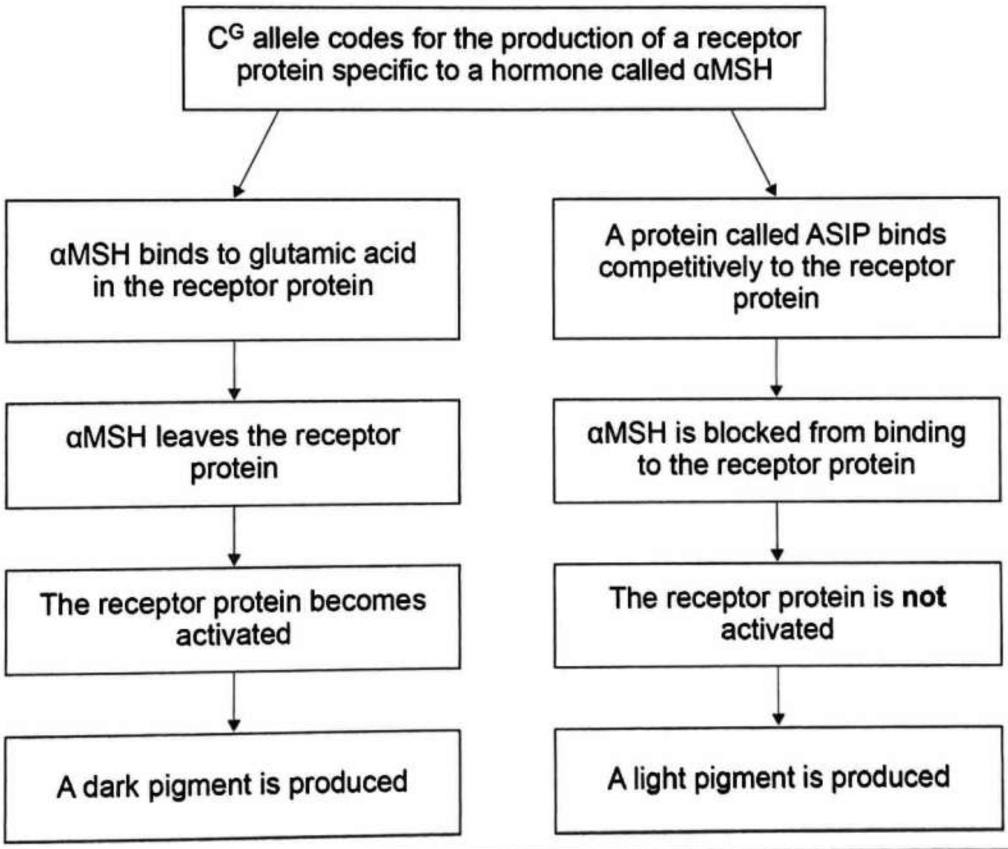
$100 - 97.4522 = 2.5477...$

~~$\frac{314}{306} = 1.02614... \Rightarrow 1.02614 \rightarrow 1 - 0.02614$~~

Answer 2.55 %

In *S. carolinensis*, fur colour depends on the distribution and relative amounts of light pigments and dark pigments in the hairs of the fur. **Figure 1** shows how the protein produced from the C^G allele can result in the production of a light pigment or a dark pigment.

Figure 1



The deletion mutation in the C^B allele results in the production of a receptor protein that does not have glutamic acid. The lack of glutamic acid in the receptor protein has the same effect as αMSH leaving the receptor protein.

0 1 . 5 Use **Figure 1** and this information to suggest why *S. carolinensis* with the genotype C^BC^B have black fur rather than grey fur.

[3 marks]

The lack of glutamic acid leaves the receptor activated permanently. So the receptor doesn't need the binding of αMSH to become activated. Therefore, ASIP may not be able to bind to the receptor protein. So, only the dark pigment is produced.

9

Turn over for the next question

0 2 . 1 Describe how the human immunodeficiency virus (HIV) is replicated **once inside** helper T cells (T_H cells).

[4 marks]

The RNA excreted into the cytoplasm gets converted to DNA by the enzyme reverse transciptase. This DNA then gets inserted into the genome of the T cell. DNA inserted into the genome gets transcribed into mRNA, which then gets translated to new viral proteins used to assemble viral particles.

Do not write outside the box

HIV-1 is the most common type of HIV. HIV-1 binds to a receptor on T_H cells called CCR5.

Current treatment for HIV-1 involves the use of daily antiretroviral therapy (ART) to stop the virus being replicated. Only 59% of HIV-positive individuals have access to ART.

Scientists have found that two HIV-1-positive patients (**P** and **Q**) have gone into remission (have no detectable HIV-1). This happened after a blood stem cell transplant (BSCT).

- Patient **P** was given **two** BSCTs, and patient **Q** was given **one** BSCT.
- All BSCTs came from a donor with T_H cells **without** the CCR5 receptor.
- In addition, patient **P** had radiotherapy, and patient **Q** had chemotherapy. Both of these treatments are toxic.
- **Both** patients (**P and Q**) stopped receiving ART 16 months after BSCT.

18 months after stopping ART, **both** patients had **no** HIV-1 RNA in their plasma, **no** HIV-1 DNA in their T_H cells and **no** CCR5 on their T_H cells.

0 2 . 2 Use the information given to evaluate the use of BSCT to treat HIV infections.

[5 marks]

For: As there is no trace of HIV-1 RNA in them detected it could have been an effective form of treatment.

The patients got transplant without CCR5 receptor so wont get HIV-1 in the future

For patient Q only 1 transplant was enough, so don't even need 2 like P.

Against:

Several treatments mixed so cant conclude the effectiveness of them seperately.

Treatment found to be sucessfull for only HIV-1 strain.

Treatment relies on donors, which there may not be enough to treat many patience

9

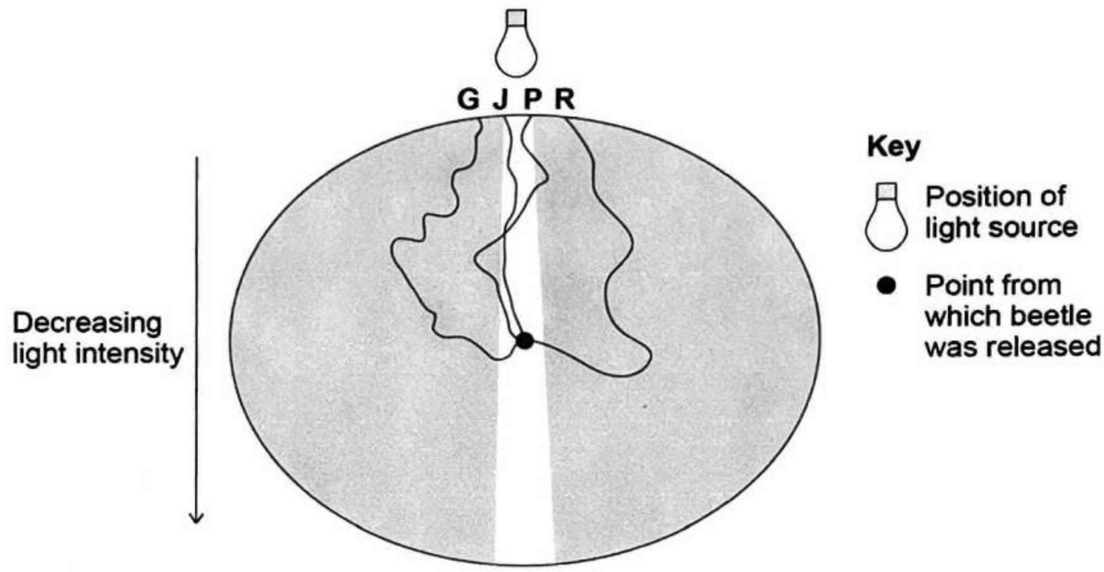
Do not write outside the box

0 3 Scientists investigated movement in adult pine beetles. Adult beetles emerge from cracks in tree bark.

The scientists released a newly emerged adult beetle, **G**, from the centre of a sample area that had a single light source coming from one direction. They made a drawing of the beetle's path of walking. They repeated this with three more beetles, **J**, **P** and **R**.

Figure 2 shows the scientists' results.

Figure 2



0 3 . 1 Name the type of behaviour shown by beetles **G**, **J**, **P** and **R**, and suggest **one** advantage to adult beetles of the type of behaviour shown.

[2 marks]

Behaviour Positive photo taxis

Advantage to find a mate

Do not write outside the box

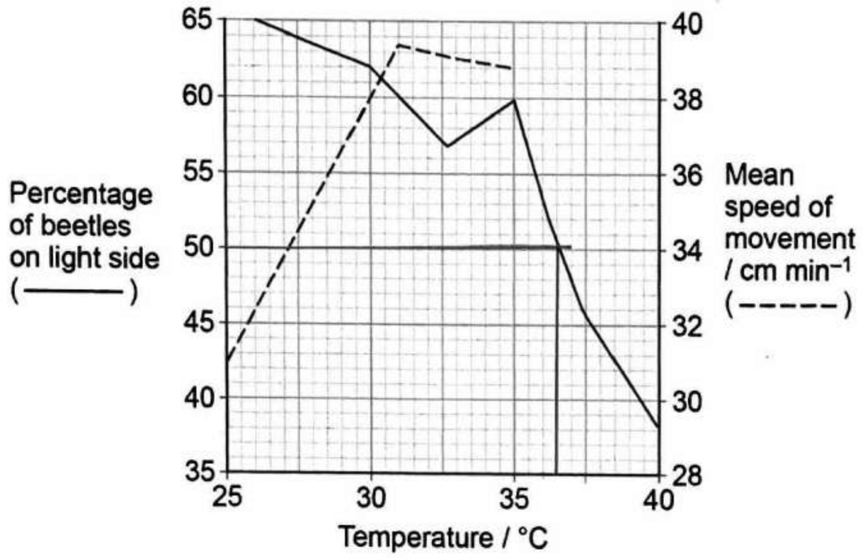
At higher temperatures and higher light intensities, adult pine beetles normally

- move more
- fly rather than walk.

When preparing to fly, these adult beetles walk slowly. The scientists investigated the movement of adult beetles at different temperatures, and in the light and the dark. They created a box that was half in the light and half in the dark. They released an adult beetle at the midpoint of the central dividing line between light and dark areas. They recorded the path of the beetle's movement and its location after 5 minutes. From this, they calculated the mean speed of movement. They repeated the experiment with many beetles and at several temperatures.

Figure 3 shows the scientists' results.

Figure 3



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0 3 . 2 After studying these experiments, a student concluded:

- there is a significant change in movement between 35 °C and 37.5 °C
- between 35 °C and 37.5 °C, more beetles move away from the light
- between 35 °C and 37.5 °C, more beetles have a slower walking speed.

Suggest reasons why these conclusions might **not** be valid.

[3 marks]

There was no statistical analysis so cant conclude if results are significant.
Even after 35°C all the way to 36.5°C 50% of the beetles ~~are on the light~~ or more are on the light side still.
There cant be any conclusion of speed above 35°C as there is no data for speed above 35°C.

5

Turn over for the next question

0 4 Freshwater marshes have one of the highest rates of gross primary production (*GPP*) and net primary production (*NPP*) of all ecosystems.

Carbon use efficiency (*CUE*) is the ratio of *NPP:GPP*. Freshwater marshes have a high *CUE*.

0 4 . 1 Use your knowledge of *NPP* to explain why freshwater marshes have a high *CUE* **and** the advantage of this.

Do **not** refer to abiotic factors in your answer.

[2 marks]

Explanation low level of respiration

Advantage more growth and biomass gain.

0 4 . 2 Freshwater marsh soils are normally waterlogged. This creates anaerobic conditions.

Use your knowledge of the nitrogen cycle to suggest why these soils contain relatively high concentrations of ammonium compounds and low concentrations of nitrite ions and nitrate ions.

[2 marks]

More denitrifying bacteria will be involved in denitrification, converting nitrates back to atmospheric nitrogen.

Do not write outside the box

A student investigated the growth rate of a freshwater marsh plant.

The growth rate (R) of a plant can be determined using this equation.

$$R = \frac{(\ln W_2 - \ln W_1)}{t}$$

Where
ln = natural logarithm
t = duration of the investigation in days
W_1 = plant biomass at the start of the investigation
W_2 = plant biomass at the end of the investigation

The student used the equation above; however, she substituted height for biomass. This was because she did not want to destroy the plants to measure their biomass.

0 4 . 3 State the assumption the student has made **and** suggest why this assumption might **not** be valid.

[2 marks]

Assumed height is directly proportional to biomass, not considering other aspects, like roots add to biomass but dont add to height.

0 4 . 4 At the end of the investigation, the student noted the freshwater marsh plant had grown 268 mm in height, and now measured 387 mm. She calculated the rate of growth (R) to be 0.097 mm m^{-1} day^{-1}

Use this information and, **substituting height for biomass**, use the equation to calculate the duration of the student's investigation.

Give your answer to the nearest full day. Show your working.

[2 marks]

$$R = \frac{(\ln(387mm) - \ln(119 mm))}{t}$$

$$t = \frac{5.95842... - 4.77912}{0.097} = 12.1577$$

$\Rightarrow$ 12 days

12 days

8

Do not write outside the box

0 5 . 1 The action of endopeptidases and exopeptidases can increase the rate of protein digestion. Describe how.

[2 marks]

endopeptidases hydrolise peptide bonds at the middle of polypeptides, while exopeptidases hydrolyse peptide bonds at the ends. As endopeptidases cut up polypeptide more ends get exposed for exopeptidases to cleave off from.

0 5 . 2 As humans age, there is a decrease in body protein.

Give the name of **one** body protein that could have resulted in:

[2 marks]

reduced muscle power actin

reduced immunity antibodies

Scientists investigated the effect of two types of dietary protein on the ability of old men to produce body proteins.

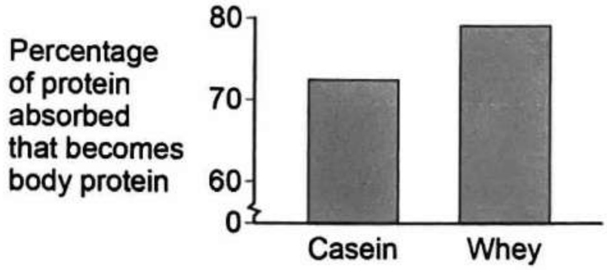
Table 2 shows information about the two types of dietary protein investigated.

Table 2

Physiological factor	Name of dietary protein	
	Casein	**Whey**
Rate of absorption of dietary protein / mmol dm^{-3} amino acids in blood plasma h^{-1}	3.05	4.33
Stimulation of protein synthesis	Higher rate	Lower rate
Breakdown of body proteins	No effect	Inhibitory effect

Figure 4 shows the percentage of protein absorbed that becomes body protein in old men following a meal of casein or whey.

Figure 4



A statistical test confirmed that the difference between the results shown in **Figure 4** was significant.

0 5 . 3 Suggest which type of dietary protein would be better for old men to eat to cause a **net** gain of body proteins. Use the information provided to explain your answer.

[3 marks]

Whey as it has the faster rate of absorbtion, while still stimulates protein synthesis. But it also inhibits the breakdown of body protein, while casein doesn't.
Significantly more of it becomes body protein

7

0 6 Plants transport sucrose from leaves to other tissues for growth and storage. SUT1 is a sucrose co-transporter protein.

Scientists investigated whether the cells of tobacco plant leaves used SUT1 to transport sucrose to other tissues.

0 6 . 1 The scientists used a radioactively labelled DNA probe to show that the cells of tobacco plant leaves contained the *SUT1* gene.

Describe how they would do this.

Do **not** include PCR in your answer.

[4 marks]

Extract DNA from the sample and combine it with restriction endonuclease enzyme. The enzyme will cut the DNA into fragments at specific places. Seperate out these fragments by electrophoresis. ~~Thea~~ Treat DNA to seperate the double strands, exposing the nuclear bases. Probe is then able to bind only to ~~base~~ base pairs coding for SUT1 gene. Then ~~create~~ use autoradiography to identify if probe is bonded to sample or not.

0 6 . 2 To study the role of SUT1 in tobacco plants, scientists reduced the expression of the *SUT1* gene.

When the *SUT1* gene is transcribed, the SUT1 mRNA produced is called 'sense' SUT1 mRNA. The scientists genetically modified plants by inserting an **extra** gene so that this **also** allowed the production of 'antisense' SUT1 mRNA.

The scientists had two types of tobacco plants:

- type **A** – plants that were genetically modified
- type **B** – plants that were **not** genetically modified.

Suggest how the production of 'antisense' SUT1 mRNA in type **A** plants would reduce the expression of the *SUT1* gene.

[4 marks]

'antisense' mRNA is complementary to the 'sense' mRNA so it would bind to each other to form a double strand. Ribosomes cant bind to double strand RNA, so translation is prevented. So less SUT1 protein is produced.

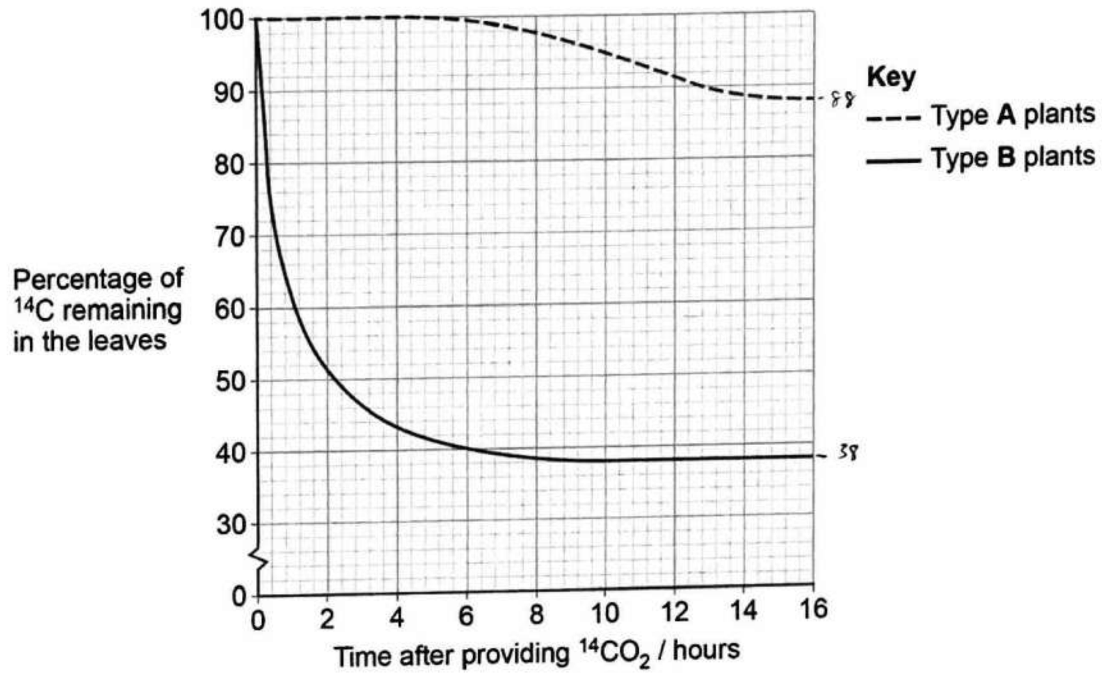
Question 6 continues on the next page

0 6 . 3 The scientists hypothesised that lower rates of sucrose transport from leaves would cause reduced growth.

To test this hypothesis, the scientists provided leaves of type **A** and type **B** plants with labelled carbon dioxide ($^{14}CO_2$). To estimate sucrose transport out of leaves, they measured the percentage of ^{14}C remaining in the leaves for 16 hours.

Figure 5 shows their results.

Figure 5



Calculate the ratio of percentage of ^{14}C remaining in leaves of type **B** to type **A** plants 16 hours after providing $^{14}CO_2$

[1 mark]

B - 38%
A - 88%

÷88 38 : 88 ÷88
0.4318 : 1

0.4318 = 0.4

Answer 0.4

0 6 . 4 In type **B** plants, the percentage of ^{14}C remaining in the leaves does not reach zero per cent, as shown in **Figure 5**.

Suggest **two** reasons why.

[2 marks]

1 Some of the $^{14}CO_2$ gets converted to starch that is stored in the leaf.

2 Not all $^{14}CO_2$ will be fixed in photosynthesis

Question 6 continues on the next page

The scientists measured physiological differences between type **A** plants and type **B** plants.

Table 3 shows the scientists' results as they presented them.

Table 3

Physiological factor	**Type of tobacco plant**	
	Type A	**Type B**
Rate of sucrose transport from leaf cells / µmol m^{-2} s^{-1}	0.1	3.7
Leaf sucrose concentration / mmol m^{-2}	22	4
Ratio of shoot:root dry mass	6:1	2:1
Rate of photosynthesis / µmol glucose m^{-2} s^{-1}	4	14

Do not write outside the box

Sucrose is able to inhibit the production and activity of rubisco in leaves of a plant. Type **A** plants have decreased dry mass compared with type **B** plants.

0 6 . 5 Use all the information to suggest **and** explain how the physiological factors in **Table 3** would contribute to the decreased dry mass observed in type **A** plants.

[4 marks]

In Type A there is less SUT1 expression, so less protein SUT1, so less sucrose is exported from leaf cells. This leads to a build up of its concentration. The increased concentration inhibits rubisco, so less $^{14}CO_2$ gets fixed into GP.
Less sucrose is transported to the roots ~~and the shoots~~ from the leaf so less growth and development will happen there shifting it to a larger shoot to root dry mass ratio. Less growth in roots means less minerals extracted from soil, limiting the plants growth rate. Reducing the plants overall growth rate.

15

Turn over for Section B

Section B

Answer **one** question.

You are advised to spend no more than 45 minutes on this section.

0 7 Write an essay on **one** of the topics below.

Either

DNA protein → enzyme, hormone → immune system

0 7 . 1 The importance of complementary shapes of molecules in organisms

[25 marks]

Or

0 7 . 2 The importance of ions in metabolic processes

[25 marks]

A lot of biological processess are quite specific, requiring specific 'machinery' to make them work. To achive this complementary shapes are common, to allow these processes to be distinct and specific for their function.

Lets take for instance proteins. They are involved in many processes, but maybe the best known of all are enzymes, that help to catalyse chemical metabolic reactions. ~~The~~ Each different enzyme has a specific active site that is complementary to the shape of the substrate, as suggested by the lock and key theory. This enables it to be a specialised catalys for a certain type of reaction. An example of this is Rubisco an enzyme involved in the light independent reaction of photosynthesis.

Do not write outside the box

Rubisco ~~[illegible]~~ has a complementary shape to bind RuBP, combining it with CO_2 and facilitating its conversion to 3PG. This is a vital step in the Calvin cycle, which produces sugars necessary for plants to grow and repair themselves.

However, proteins dont only show their specificity as enzymes. Hormones are also ~~enzymes that fit~~ proteins that fill in a specific function in the ~~[illegible]~~ body, due to their specific shape. ~~This s~~ Hormones get produced by glands and they travel as chemical messengers in the blood to ~~[illegible]~~ their target organs. They can stimulate change to the functioning of the target organ thanks to their complementary shape to receptors found on the surface of it. An example of this would be insulin binding to insulin receptors on liver and muscle cells, regulating ~~the~~ blood glucose levels. The binding to receptors is possible as the receptor has a complementary shape to the shape of insulin. The receptor is a protein that spans the plasma membrane of the cell, so as it binds to insulin its shape changes on the inside of the cell membrane. This action exposes another receptor site that is complementary to adenyl cyclase, which then gets stimulated by this specific action causing ~~more~~ eventually more glucose to be taken up by these cells. Hence complementary binding of hormones and

Turn over ▶

Do not write outside the box

specific receptors allow the regulation of blood glucose levels in the body.

Another aspect where complementary shapes are important in biology is one with gene replication and expression. The complementary base pairings in a DNA molecule, keep DNAs structure stable and replicatable, on which both sexual and asexual reproduction depend on. The complementary pairing of A to T and C to G allow each strand of the double helix to be used as a template strand, of genetic information needs to be replicated for cell division. While in expression specific regulatory factors can bind to DNA to up or down regulate the expression of a certain gene. This can happen as they are complementary to the sequence of base pairs found on the DNA strands

Furthermore, the complementary pairing of a codon on the mRNA to the anti codon on the tRNA allows ribosomes to translate the sequence of the mRNA base pairs, into a specific sequence of amino acids.

Lastly but not the least, complementary shapes are used by the immune system and cell recognition. Every cell, phatogen, virus have

a unique set of antigens on its surface, These are often glycoproteins or glycolipids and specific to a given type of cell. This enables for cells of the same body to recognise each other, as they have receptors that are complementary to these antigens. This allows adhesion between cells.
Another key process is done by T lymphocytes, which search the body for invading ~~phatogens~~ pathogens. They can recognise them by antigens on the surface of these phatogens which is complementary to the receptors on the surface of T cells. Hence bringing about a specific immune response.