

Please write clearly in block capitals.

Centre number

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Candidate number

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A-level BIOLOGY

Paper 2

Tuesday 20 June 2017

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a calculator.

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 work 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 the questions are shown in brackets.
- The maximum mark for this paper is 91.

For Examiner's Use

Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	



J U N 1 7 7 4 0 2 2 0 1

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

0 1 . 1

Exercise causes an increase in heart rate.

Describe the role of receptors and of the nervous system in this process.

[4 marks]

During exercise the rate of respiration increases, so the concentration of CO_2 in the blood rises and the blood pH falls. This is detected by chemoreceptors in the aorta and carotid arteries (and in the medulla).

The chemoreceptors send more impulses along sensory neurones to the cardiac centre in the medulla oblongata.

The cardiac centre then sends more impulses along the sympathetic nervous system (sympathetic neurones) to the sinoatrial node (SAN).

So the SAN sends waves of excitation more frequently, increasing the heart rate. (Baroreceptors detecting a change in blood pressure also send impulses to the cardiac centre.)

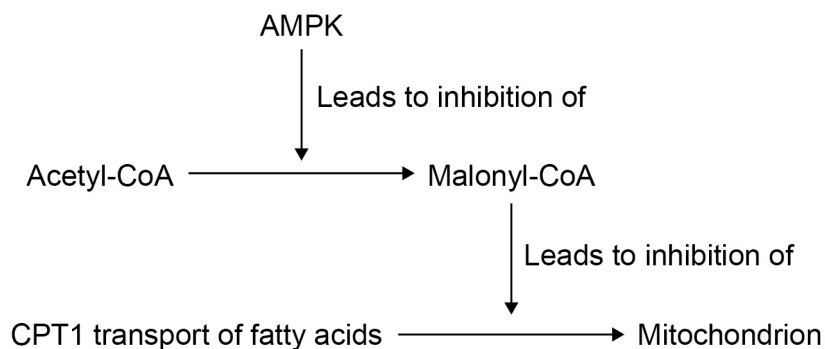


0 1 . 2

AMP-activated protein kinase (AMPK) is an enzyme that regulates a number of cellular processes. Exercise leads to activation of AMPK.

Figure 1 shows one effect of activation of AMPK during exercise.

Figure 1



CPT1 is a channel protein that transports fatty acids into mitochondria.

Using **Figure 1**, explain the benefit of activation of AMPK during exercise.

[3 marks]

Activated AMPK inhibits the conversion of acetyl-CoA to malonyl-CoA, so less malonyl-CoA is produced.

Malonyl-CoA normally inhibits CPT1, so with less malonyl-CoA, CPT1 is not inhibited and more fatty acids are transported into the mitochondria.

In the mitochondria the fatty acids are oxidised in aerobic respiration (via acetyl-CoA entering the Krebs cycle), which provides more ATP for muscle contraction during exercise.



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ANSWER IN THE SPACES PROVIDED**



0	2
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Dengue is a serious disease that is caused by a virus. The virus is carried from one person to another by a mosquito, *Aedes aegypti*. One method used to try to reduce transmission of this disease is the Sterile Insect Technique (SIT). This involves releasing large numbers of sterile (infertile) male *A. aegypti* into the habitat. These males have been made infertile by using radiation.

0	2
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 .

1

Explain how using the SIT could reduce transmission of dengue.

[2 marks]

The sterile males compete with the fertile males to mate with the females (intraspecific competition).

Females mating with sterile males do not reproduce, so the mosquito population falls and fewer mosquitoes carry the virus.

0	2
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 .

2

Describe how the mark-release-recapture method could be used to determine the population of *A. aegypti* at the start of the investigation.

[3 marks]

*Capture a sample of *A. aegypti*, count them and mark them in a way that does not harm them or affect their survival, then release them back into the habitat.*

Leave enough time for the marked mosquitoes to disperse and mix back into the population before taking a second sample, and count the number of marked (recaptured) mosquitoes in it.

Population = (number in first sample × number in second sample) ÷ number of marked mosquitoes in the second sample.

Question 2 continues on the next page

Turn over ►



0 2 . 3

The release of radiation-sterilised *A. aegypti* has not been very successful in controlling the transmission of dengue.

Suggest **one** reason why.

[1 mark]

The radiation reduces the survival / life span of the males or makes them less attractive to females in courtship.

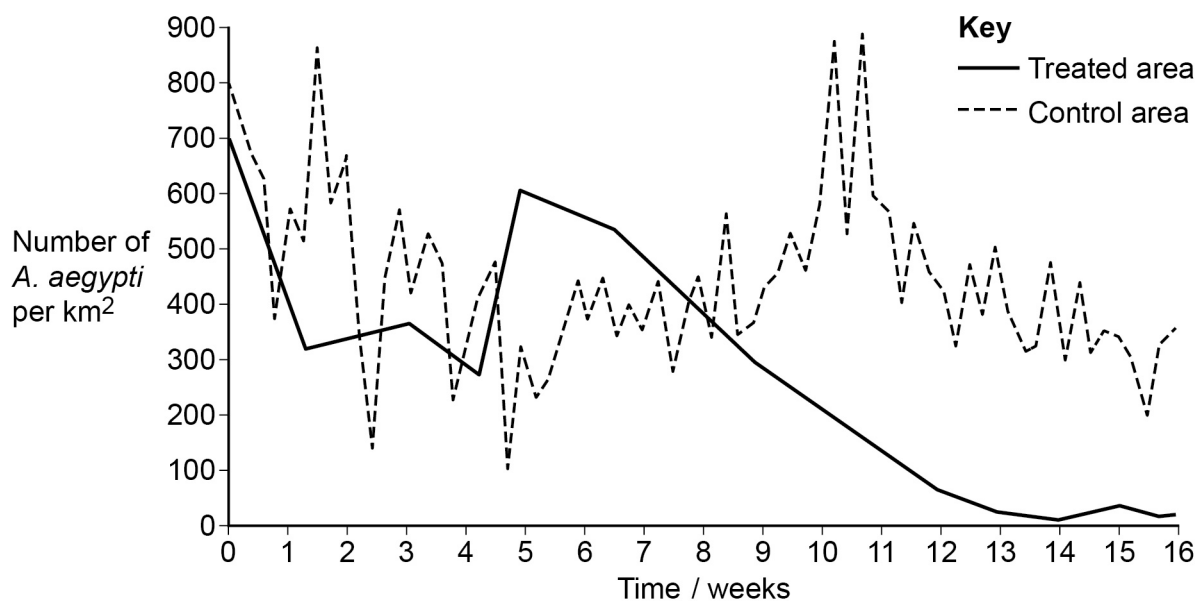
0 2 . 4

Recently a new method was developed to control *A. aegypti*. Scientists produced transgenic males carrying a 'lethal gene' which kills their offspring before they can reproduce.

The scientists released transgenic males every week in one area of a city in Brazil. At regular intervals they determined the number of *A. aegypti* per km² in the area where transgenic males were released and in a control area where no transgenic males were released.

Figure 2 shows their results.

Figure 2



Suggest why the scientists released more transgenic males every week.

[1 mark]

The transgenic males die / have a short life span, so more are released to replace them and maintain their number, so that they keep competing with wild males.



0 2 . 5

The release of transgenic males proved successful in reducing the number of *A. aegypti*.

Describe how the results in **Figure 2** support this conclusion.

[2 marks]

*After about 12 weeks the number of *A. aegypti* in the treated area was much lower than in the control area.*

For example at 14 weeks the treated area had about 10 per km², compared with about 450 per km² in the control area, and the number in the treated area stayed low up to 16 weeks.

9

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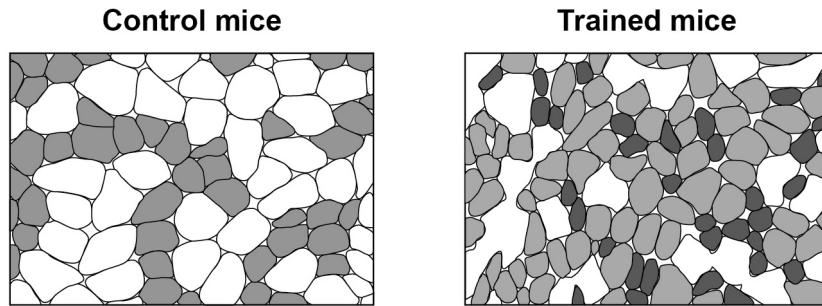


0 3

Scientists investigated the effect of regular exercise on skeletal muscle fibres in mice. The scientists compared the muscle fibres of mice after six weeks of regular exercise (trained mice) with those of mice that had not exercised (control mice). The scientists stained the muscle fibres from both sets of mice to show succinic acid dehydrogenase activity. The darker the stain the greater the succinic acid dehydrogenase activity.

Figure 3 shows a typical set of results they obtained.

Figure 3



0 3 . 1

Succinic acid dehydrogenase is an enzyme used in the Krebs cycle.

Suggest **one** reason for the difference in the staining between the muscle fibres of the control mice and the trained mice.

[1 mark]

The trained mice have more mitochondria in their muscle fibres (more slow fibres), so there is more aerobic respiration.



0 3 . 2

The scientists then compared the length of time that the control mice and the trained mice could carry out prolonged exercise. The trained mice were able to exercise for a longer time period than control mice.

Explain why.

[3 marks]

*The trained mice have more succinic acid dehydrogenase activity, so more aerobic respiration takes place in their muscles, which produces more ATP (and produces it faster).
So anaerobic respiration is delayed in the trained mice.
So less lactate (lactic acid) is produced, so muscle fatigue is delayed and they can exercise for longer.*

0 3 . 3

The scientists determined the mean diameter of muscle fibres in trained mice using an optical microscope to examine sections of muscle tissue. The circular area (πr^2) of one field of view was 1.25 mm^2 . The diameter of this area was equal to the diameter of 15 muscle fibres.

Using this information, calculate the mean diameter in μm (micrometres) of muscle fibres in this section of tissue.

[2 marks]

$$\pi r^2 = 1.25 \text{ mm}^2, \text{ so } r^2 = 1.25 \div 3.142 = 0.398, r = 0.63 \text{ mm}$$

$$\text{Diameter of field} = 2 \times 0.6308 = 1.26 \text{ mm} = 1261.6 \mu\text{m}$$

$$\text{Mean fibre diameter} = 1261.6 \div 15 = 84.1 \mu\text{m}$$

Answer = 84.1 μm

Question 3 continues on the next page

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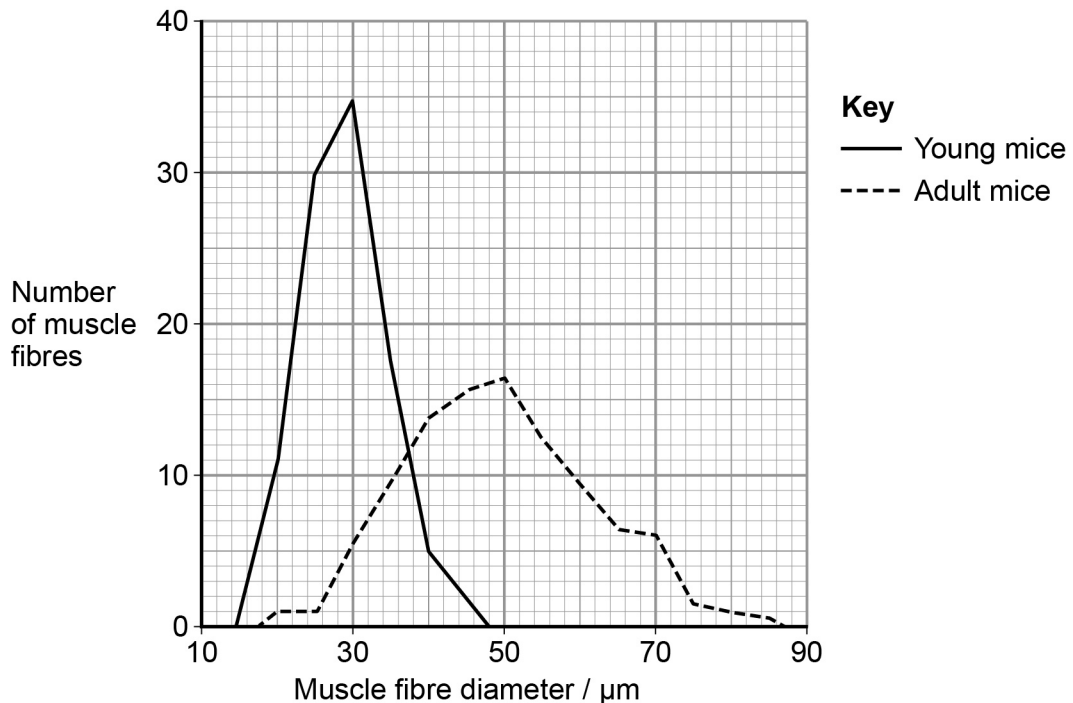


0 3 . 4

The scientists also compared the diameter of samples of muscle fibres taken from young mice and adult mice.

Some of their results are shown in **Figure 4**.

Figure 4



Describe **two** differences between these samples of muscle fibres.

[2 marks]

1 Adult fibres have a larger range of diameters, from about 17 to 87 μm , compared with young fibres, from about 15 to 48 μm .

2 The most common (modal) diameter is higher for adult fibres, at about 50 μm , compared with about 30 μm for young fibres.



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0 4

A student isolated chloroplasts from spinach leaves into a solution to form a chloroplast suspension. He used the chloroplast suspension and DCPIP solution to investigate the light-dependent reaction of photosynthesis. DCPIP solution is blue when oxidised and colourless when reduced.

The student set up three test tubes as follows:

- **Tube 1** – 1 cm³ of solution without chloroplasts and 9 cm³ of DCPIP solution in light.
- **Tube 2** – 1 cm³ of chloroplast suspension and 9 cm³ of DCPIP solution in darkness.
- **Tube 3** – 1 cm³ of chloroplast suspension and 9 cm³ of DCPIP solution in light.

The student recorded the colour of the DCPIP in each of the tubes at the start and after the tubes had been left at 20 °C for 30 minutes.

His results are shown in **Table 1**.

Table 1

Tube	Colour of DCPIP in tube	
	At start	After 30 minutes
1	blue	blue
2	blue	blue
3	blue	colourless

0 4 . 1

The solution that the student used to produce the chloroplast suspension had the same water potential as the chloroplasts.

Explain why it was important that these water potentials were the same.

[2 marks]

With equal water potentials there is no net movement of water into or out of the chloroplasts by osmosis.

So the chloroplasts do not burst (lyse) or shrivel, and they are not damaged.



0 4 . 2

Explain why the student set up **Tube 1**.**[2 marks]**

It is a control to show that light alone does not change the colour of (decolourise) the DCPIP.

So it shows that chloroplasts are required for the DCPIP to be decolourised.

0 4 . 3

Explain the results in **Tube 3**.**[2 marks]**

In the light, chlorophyll absorbs light energy and electrons are excited and released in the light-dependent reaction (photoionisation).

These electrons reduce the DCPIP, so it turns from blue to colourless.

0 4 . 4

The student evaluated the effectiveness of different chemicals as weed-killers by assessing their ability to prevent the decolourisation of DCPIP in chloroplast suspensions.

He added different concentrations of each chemical to illuminated chloroplast suspensions containing DCPIP. He then determined the IC_{50} for each chemical. The IC_{50} is the concentration of chemical which inhibits the decolourisation of DCPIP by 50%.

Explain the advantage of the student using the IC_{50} in this investigation.

[1 mark]

It provides a standard reference point, so the effectiveness of the different chemicals (weed-killers) can be compared, and it saves waiting for complete decolourisation.

Question 4 continues on the next page

Turn over ►

0 4 . 5

Explain how chemicals which inhibit the decolourisation of DCPIP could slow the growth of weeds.

[2 marks]

The chemicals inhibit the light-dependent reaction, so less ATP and less reduced NADP are produced.

So less GP is reduced to triose phosphate in the light-independent reaction, so less glucose and other organic substances are made for growth.

9



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0 5

Arbuscular mycorrhiza fungi (AMF) are fungi which grow on, and into, the roots of plants. AMF can increase the uptake of inorganic ions such as phosphate.

0 5 . 1

Suggest **one** way in which an increase in the uptake of phosphate could increase plant growth.

[1 mark]

Phosphate is used to make ATP (and DNA, RNA and phospholipids), which are needed for cell division and growth.

0 5 . 2

Suggest **one** way in which AMF may benefit from their association with plants.

[1 mark]

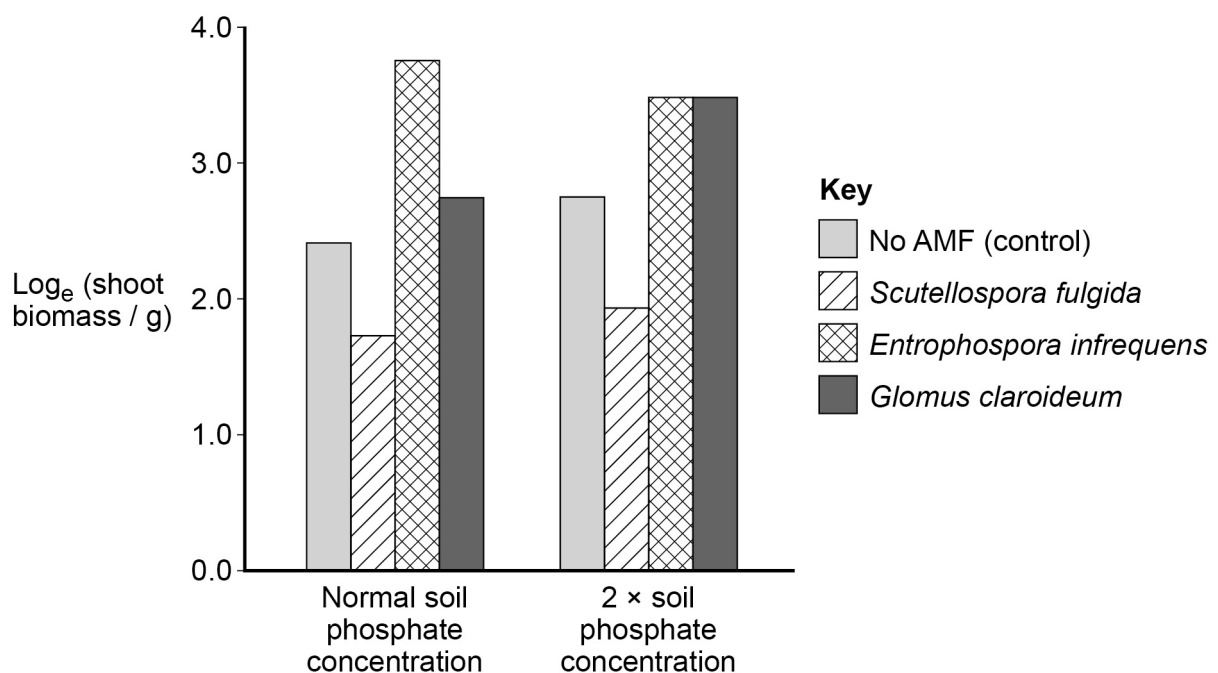
The fungi receive carbohydrates such as sugars (carbon-containing organic compounds) made by the plant in photosynthesis.

0 5 . 3

Scientists investigated the effects of different AMF species on the productivity of the plant community of a prairie grassland ecosystem when growing in/on soil containing different phosphate concentrations.

The scientists set up identical plots of prairie grassland soil containing seeds of the plant species found in the ecosystem. The scientists added different AMF species and different concentrations of phosphate to particular plots. Control plots without AMF species were also set up. After 20 weeks the scientists determined the shoot biomass for each plot.

The results the scientists obtained are shown in **Figure 5**.

Figure 5

Explain why an increase in shoot biomass can be taken as a measurement of **net** primary productivity.

[2 marks]

Shoot biomass represents the dry mass (mass of carbon) of the plant, which is the chemical energy stored in the plant.

This is what remains of the gross primary production after respiratory losses, and $NPP = GPP$ minus respiratory losses (R).

0 5 . 4

Using the data from **Figure 5**, evaluate the effect on plant productivity of adding AMF species and adding phosphate to the soil.

[4 marks]

*In the control, doubling the phosphate increases growth ($\log_e$ shoot biomass rises from about 2.4 to 2.75), and with *Glomus* it rises from about 2.75 to 3.5.*

*With *Entrophospora*, increasing the phosphate reduces growth slightly (from about 3.75 to 3.5).*

**Scutellospora* reduces growth compared with the control at both phosphate concentrations, whereas *Entrophospora* and *Glomus* increase growth compared with the control.*

However, there are no standard deviations / error bars and no statistical test, so we cannot tell if the differences are significant.

The plants only grew for 20 weeks, and only shoot biomass was measured, so root (underground) growth is not known.

Question 5 continues on the next page

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0 5 . 5

Using the e^x button on your calculator, determine the rate of shoot biomass production in grams per day for the control plot in soil with normal phosphate concentration.

[2 marks]

$$\text{Control, normal phosphate: } \log_e(\text{biomass}) = 2.4$$

$$\text{Biomass} = e^{2.4} = 11.02 \text{ g}$$

$$20 \text{ weeks} = 20 \times 7 = 140 \text{ days}$$

$$\text{Rate} = 11.02 \div 140 = 0.079 \text{ g day}^{-1}$$

Answer = 0.08 g day⁻¹

10

0 6 . 1

Each year, a few people with type I diabetes are given a pancreas transplant. Pancreas transplants are not used to treat people with type II diabetes.

Give **two** reasons why pancreas transplants are not used for the treatment of type II diabetes.

[2 marks]

1 *People with type II diabetes usually still produce insulin, so they do not need new insulin-producing cells.*

2 *Their cells / insulin receptors are less sensitive to insulin, and the condition can be controlled by diet, exercise and weight loss.*

0 6 . 2

The pancreas produces the hormone insulin.

Put a tick (✓) in the box next to the statement which describes **incorrectly** the action of insulin.

[1 mark]

Activates enzymes involved in the conversion of glucose to glycogen.

☐

Controls the uptake of glucose by regulating the inclusion of channel proteins in the surface membranes of target cells.

☐

Attaches to receptors on the surfaces of target cells.

☐

Activates enzymes involved in the conversion of glycerol to glucose.

☒

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0 6 . 3

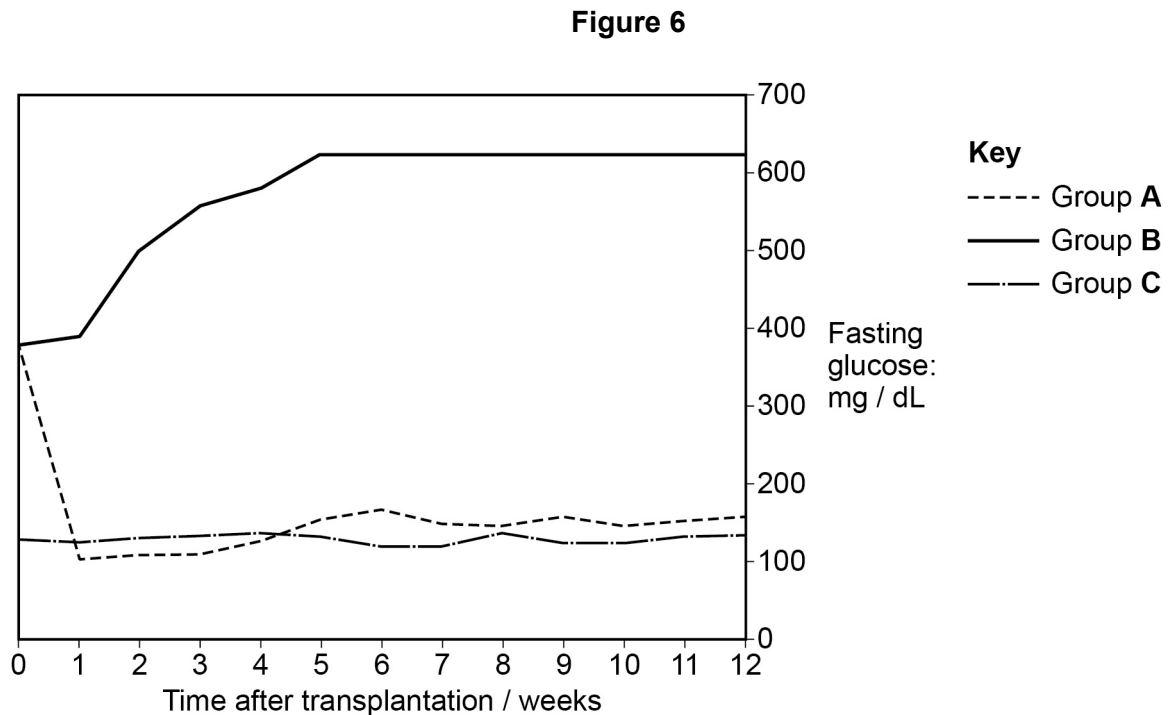
Scientists investigated the use of induced pluripotent stem cells (iPS cells) to treat type I diabetes in mice. The scientists used four transcription factors to reprogramme skin cells to form iPS cells. The scientists then stimulated the *in vitro* differentiation of iPS cells into pancreatic cells.

The scientists set up three experimental groups:

- Group **A** – 30 mice with type I diabetes received pancreatic cell transplants derived from iPS cells.
- Group **B** – 30 mice with type I diabetes were left untreated.
- Group **C** – 30 mice without diabetes were left untreated.

The scientists measured the blood glucose concentration of all the mice on a weekly basis for 12 weeks.

The results the scientists obtained are shown in **Figure 6**.



Suggest how transcription factors can **reprogramme** cells to form iPS cells.

[2 marks]

The transcription factors attach to the promoter regions of specific genes (DNA).

They stimulate (or inhibit) transcription by RNA polymerase, so genes that are switched off in skin cells are expressed again and the cells become pluripotent.



06 . 4

Using all the information provided, evaluate the use of iPS cells to treat type I diabetes in humans.

[4 marks]

For: the mice in group A that received the iPS-derived cells had a lower blood glucose concentration than the untreated diabetic mice in group B.

Also, the blood glucose of group A became similar to that of the non-diabetic mice in group C, so the treatment appears effective.

Against: the investigation was done on mice, not humans, so the results may not apply to humans.

The results only cover 12 weeks, so the long-term effects (e.g. whether the cells keep working or form tumours) are not known.

9

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07 . 1

What is meant by the term phenotype?

[2 marks]

The phenotype is the observable characteristics / appearance of an organism.

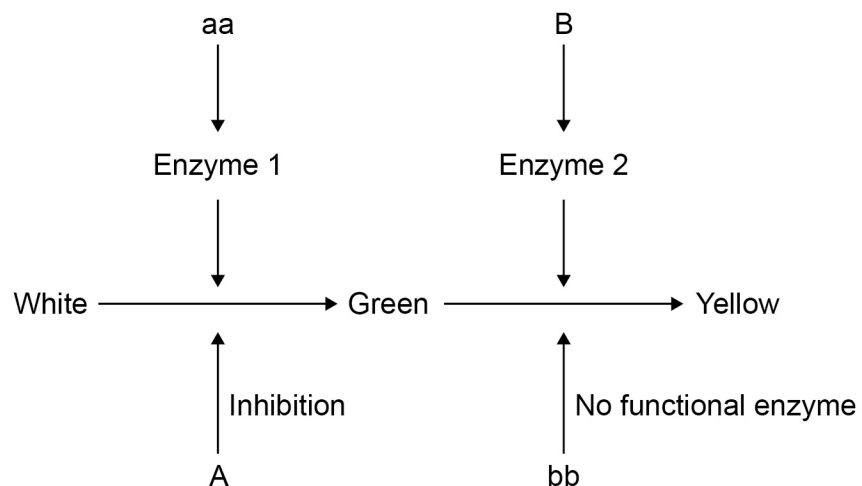
It results from the expression of its genotype (alleles) and the interaction with the environment.

07 . 2

The inheritance of fruit colour in summer squash plants is controlled by two genes, **A** and **B**. Each gene has two alleles.

Figure 7 shows the interaction of these two genes in controlling fruit colour in summer squash plants.

Figure 7



Name the type of gene interaction shown in **Figure 7**.

[1 mark]

Epistasis

07 . 3

What fruit colour would you expect the following genotypes to have?

[1 mark]

AAbb *White*

aaBB *Yellow*



07 . 4

Genes **A** and **B** are **not** linked.

Complete the genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

[3 marks]

Genotypes of parents **aabb** × **AaBb**

Gametes *ab* *AB, Ab, aB, ab*

Offspring: *ab × AB = AaBb, ab × Ab = Aabb,*
ab × aB = aaBb, ab × ab = aabb

Genotypes of offspring *AaBb, Aabb, aaBb, aabb*

Phenotypes of offspring *White, white, yellow, green*

Ratio of phenotypes *2 white : 1 yellow : 1 green*

07 . 5

A population of summer squash plants produced only green and yellow fruit. The percentage of plants producing yellow fruit in this population was 36%.

Use the Hardy-Weinberg equation to calculate the percentage of plants that were heterozygous for gene **B**.

[2 marks]

All plants are aa; green = bb = 100 - 36 = 64%

$q^2 = 0.64$, so $q = 0.8$ and $p = 1 - 0.8 = 0.2$

Heterozygous = $2pq = 2 \times 0.2 \times 0.8 = 0.32$

Answer = 32 %

9

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0 8

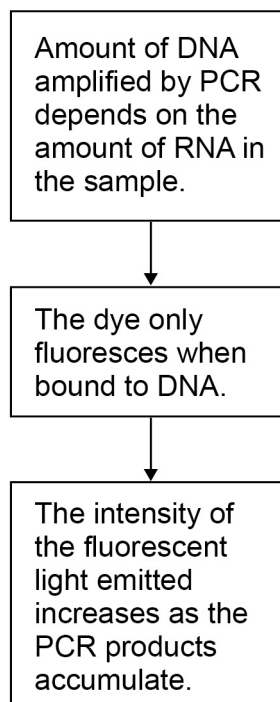
One way to detect and measure accurately the amount of RNA in a tissue sample is by RT-PCR (reverse transcriptase-polymerase chain reaction).

RT-PCR uses a reaction mixture containing:

- the sample for testing
- reverse transcriptase
- DNA nucleotides
- primers
- DNA polymerase
- fluorescent dye.

The principle behind this method is shown in **Figure 8**.

Figure 8

**0 8****. 1**

Explain the role of reverse transcriptase in RT-PCR.

[1 mark]

Reverse transcriptase produces (complementary) cDNA using the mRNA in the sample as a template.



08 . 2

Explain the role of DNA polymerase in RT-PCR.

[1 mark]

*DNA polymerase joins DNA nucleotides together to produce
complementary strands of DNA.*

08 . 3

Any DNA in the sample is hydrolysed by enzymes before the sample is added to the reaction mixture.

Explain why.

[2 marks]

*To remove (destroy) any DNA already present in the sample.
Otherwise this DNA would also be amplified / replicated in the PCR
and act as a template, so the measurement of RNA would not be
accurate.*

Question 8 continues on the next page

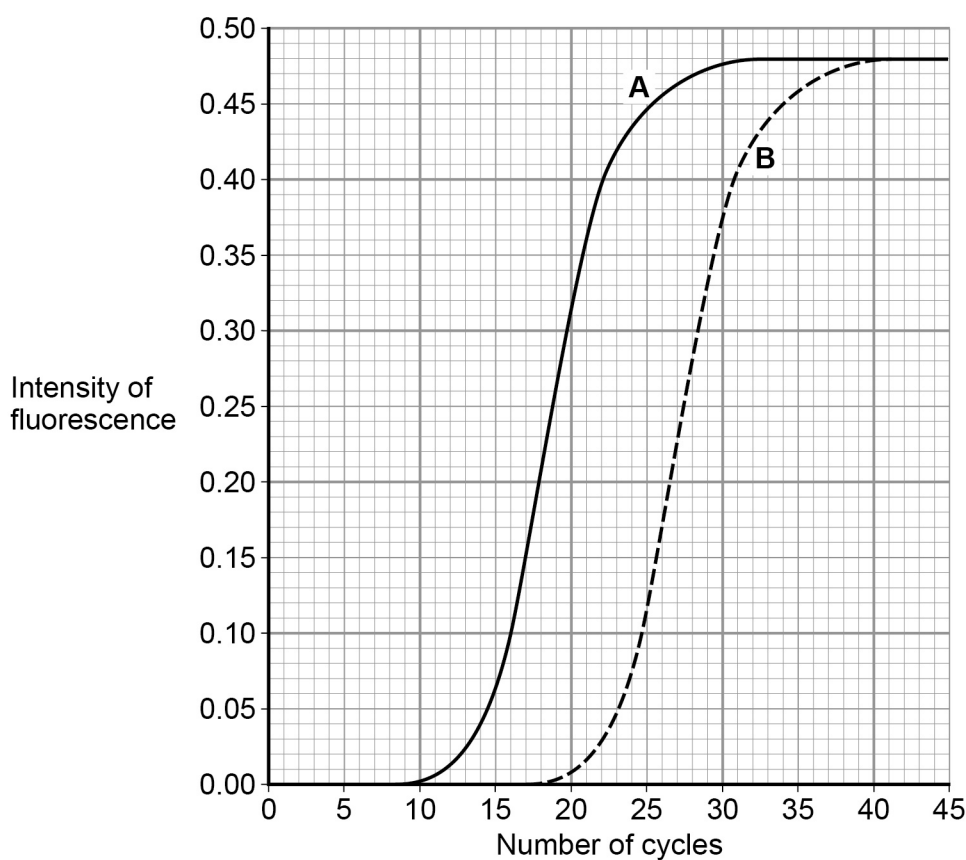
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0 8 . 4

Figure 9 shows the results from using RT-PCR to detect RNA in two different samples, **A** and **B**.

Figure 9



A quantitative comparison can be made of the amount of RNA in samples **A** and **B**. This involves determining the number of cycles required to reach 50% maximum concentration of DNA (**C**).

The amount of RNA in a sample can be measured as: $\frac{1}{C}$

Use this information to calculate the ratio for RNA content in sample **A** : RNA content in sample **B**.

[2 marks]

$$50\% \text{ of maximum} = 0.48 \div 2 = 0.24$$

$$C \text{ for A} = 19 \text{ cycles; } C \text{ for B} = 27 \text{ cycles}$$

$$A : B = 1/19 : 1/27 = 0.0526 : 0.0370$$

$$= 1.42 : 1$$

Answer = 1.42 : 1



0 8 . 5

Suggest **one** reason why DNA replication stops in the polymerase chain reaction.**[1 mark]**

*There is a limited number of primers and nucleotides, so they get
used up.*

0 8 . 6

Scientists have used the RT-PCR method to detect the presence of different RNA viruses in patients suffering from respiratory diseases.

The scientists produced a variety of primers for this procedure.

Explain why.

[2 marks]

*Different viruses have different base sequences in their RNA (and so
in the cDNA).
So different primers with complementary base sequences are required
to bind to each virus's sequence.*

9

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09 . 1

What is a gene pool?

[1 mark]

All the alleles of all the genes in a population.

09 . 2

Lord Howe Island in the Tasman Sea possesses two species of palm tree which have arisen via sympatric speciation. The two species diverged from each other after the island was formed 6.5 million years ago. The flowering times of the two species are different.

Using this information, suggest how these two species of palm tree arose by sympatric speciation.

[5 marks]

Sympatric speciation occurs in the same habitat (on the same island), with no geographical isolation of the population.

Mutations occurred that caused some palms to have different flowering times.

So palms flowering at different times could not cross-pollinate: there was reproductive isolation, so there was no gene flow and the gene pools remained separate.

Different alleles were then passed on and selected in each group, so the allele frequencies changed. This could be disruptive selection, favouring early and late flowering times.

Over 6.5 million years the two groups became so different that they could no longer interbreed to produce fertile offspring, so they became separate species.



1 0

Alzheimer's disease (AD) is a non-reversible brain disorder that develops over a number of years. At the start of 2014 the number of Americans with AD was estimated to be 5.4 million. Every 30 seconds another person in America develops AD.

In the brain of a person with AD there is a lower concentration of acetylcholine. This affects communication between nerve cells and initially results in memory loss and confusion. Some of the symptoms of AD that are associated with communication between nerve cells are reduced by taking the drug donepezil. Donepezil inhibits the enzyme acetylcholinesterase. 5

A gene mutation called E280A found on chromosome 14 causes early-onset AD at a mean age of 49 years. The age at which the E280A mutation is expressed to cause AD varies. 10

Yaramul is a town in a historically isolated region of the Andes Mountains. The population of this town has the highest frequency of the E280A mutation in the world. The origin of the E280A mutation in this population has been traced back to a common ancestor in the 17th century. Natural selection has not reduced the frequency of the E280A mutation in the population. 15

This autosomal dominant mutation involves a change in triplet 280 from GAA to GCA. Scientists analysed chromosome 14 from 102 individuals from Yaramul. They recorded a sample size of 204 and detected 75 E280A mutations but only 74 potential AD cases. The scientists identified individuals with the mutation by whole genome sequencing. They had decided that a DNA probe would not be a suitable method to detect the E280A mutation. 20

1 0 . 1

Assuming no one with AD died in 2014, calculate the annual percentage increase in AD cases in America for 2014 (lines 2–4).

[2 marks]

$$\begin{aligned} \text{New cases per year} &= 2 \text{ per minute} \times 60 \times 24 \times 365 \\ &= 1\,051\,200 \end{aligned}$$

$$\begin{aligned} \% \text{ increase} &= 1\,051\,200 \div 5\,400\,000 \times 100 \\ &= 19.47\% \end{aligned}$$

Answer 19.47 %

Question 10 continues on the next page

Turn over ►



1 0 . 2

Explain how donepezil could improve communication between nerve cells (lines 7–9).

[3 marks]

Donepezil inhibits acetylcholinesterase, so less acetylcholine is broken

down in the synaptic cleft and more acetylcholine remains.

So more acetylcholine attaches to the receptors on the postsynaptic membrane (and stays attached for longer).

So more sodium ions (Na^+) enter the postsynaptic neurone, causing depolarisation that reaches the threshold, so an action potential (impulse) is produced.

1 0 . 3

Suggest and explain **two** reasons why there is a high frequency of the E280A mutation in Yaramul (lines 13–15).

[2 marks]

1 *The town was isolated, so there was inbreeding (no interbreeding with other populations), giving a small gene pool.*

2 *The allele was inherited through many generations from a common ancestor who carried the mutation.*

1 0 . 4

Explain why natural selection has **not** reduced the frequency of the E280A mutation in the population (lines 16–17).

[2 marks]

AD develops late in life, at a mean age of 49 years.

So people with the mutation have usually already reproduced and passed the allele on to their children before the symptoms develop.



1 0 . 5

The age at which the E280A mutation is expressed to cause AD can vary (lines 11–12).

Suggest and explain **one** reason for this.

[2 marks]

Environmental (epigenetic) factors differ between people, e.g. diet, stress, smoking or alcohol.

These cause increased methylation of the gene (or decreased acetylation of histones), which inhibits transcription, so the mutation is expressed later.

1 0 . 6

One scientific study which analysed chromosome 14 involved 102 individuals. The scientists recorded a sample size of 204. In this sample they detected 75 E280A mutations but only 74 potential AD cases (lines 19–21).

Suggest explanations for the figures the scientists recorded.

[2 marks]

Each person is diploid, so has two copies of chromosome 14: $102 \times 2 = 204$ chromosomes in the sample.

There were 75 mutations but only 74 cases because one person was homozygous dominant, carrying two copies of the E280A allele.

1 0 . 7

Suggest why a DNA probe for the mutated triplet was **not** considered a suitable method for detection of the E280A mutation (lines 22–23).

[2 marks]

The triplet GCA is common and is found in many other places in the genome, so the probe would bind elsewhere.

So it would give false positives, and you would not know if it had bound to the mutated allele.

END OF QUESTIONS

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