

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level BIOLOGY

Paper 2

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.
- 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 91.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	



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

0 1 . 1

Describe the process of glycolysis.

[4 marks]

Glycolysis happens in the cytoplasm. First, glucose is phosphorylated using ATP (2 ATP are used), forming glucose phosphate / hexose bisphosphate, which then splits into two molecules of triose phosphate. Each triose phosphate is oxidised to pyruvate by the removal of hydrogen. The hydrogen is used to reduce NAD, forming reduced NAD (NADH). 4 ATP are produced per glucose, but 2 were used, so there is a net gain of 2 ATP.

0 1 . 2

Malonate inhibits a reaction in the Krebs cycle.

Explain why malonate would decrease the uptake of oxygen in a respiring cell.

[2 marks]

Fewer reduced coenzymes (reduced NAD and reduced FAD) are produced, so fewer hydrogens / electrons are passed to the electron transfer chain. Oxygen is the final electron acceptor in the chain, so less oxygen is used to combine with electrons and protons to form water.



0 2 . 1

Explain how a resting potential is maintained across the axon membrane in a neurone.

[3 marks]

The sodium-potassium pump actively transports sodium ions out of the axon and potassium ions in (3 Na⁺ out for every 2 K⁺ in), using ATP.

This gives a higher concentration of potassium ions inside and a higher concentration of sodium ions outside the neurone.

The membrane is more permeable to potassium ions than to sodium ions (most sodium channels are closed), so potassium ions diffuse back out faster than sodium ions diffuse in. The inside therefore stays negative relative to the outside.

0 2 . 2

Explain why the speed of transmission of impulses is faster along a myelinated axon than along a non-myelinated axon.

[3 marks]

The myelin sheath provides electrical insulation, so depolarisation cannot occur where the axon is myelinated.

In a myelinated axon, depolarisation only happens at the nodes of Ranvier, so the action potential jumps from node to node (saltatory conduction).

In a non-myelinated axon, depolarisation has to occur along the whole length of the axon, which takes longer.

Question 2 continues on the next page

Turn over ►



0 2 . 3

A scientist investigated the effect of inhibitors on neurones. She added a respiratory inhibitor to a neurone. The resting potential of the neurone changed from -70 mV to 0 mV.

Explain why.

[3 marks]

The respiratory inhibitor means that no / less ATP is produced.

*So there is no active transport: the sodium-potassium pump is inhibited,
so Na^+ ions are not moved out and K^+ ions are not moved in.*

*The ions then move by facilitated diffusion down their gradients until
the concentrations of sodium and potassium ions are the same on both
sides, so the electrochemical gradient is not maintained and there is no
net movement of ions, giving 0 mV.*

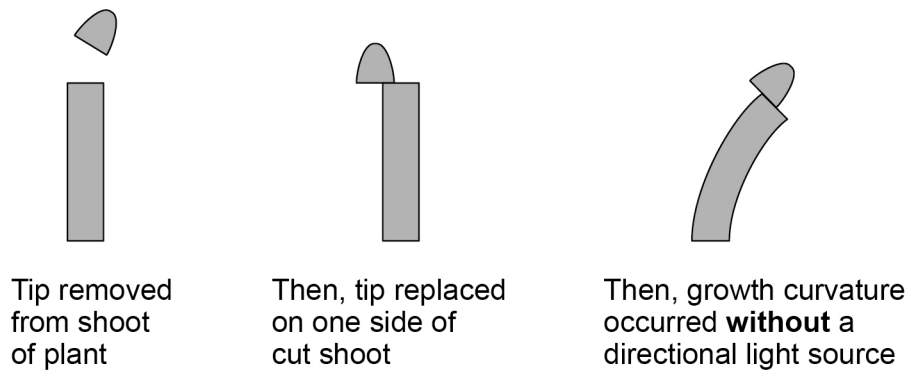
9



0 3

Figure 1 shows an investigation into growth factors in plants.

Figure 1



0 3 1

Use your knowledge of indoleacetic acid (IAA) to explain the growth curvature shown in **Figure 1**.

[3 marks]

The shoot tip produces IAA.

When the tip is placed on one side of the cut shoot, IAA diffuses down into the shoot on that side only.

IAA causes elongation of the cells, so the cells on the side under the tip (the left side) elongate more than the cells on the other side, so the shoot bends / curves.

Question 3 continues on the next page

Turn over ►



A bioassay is a method to determine the concentration of a substance by its effect on living tissues.

Figure 2 shows the practical procedure used in a growth curvature bioassay to determine the concentration of IAA in shoot tips.

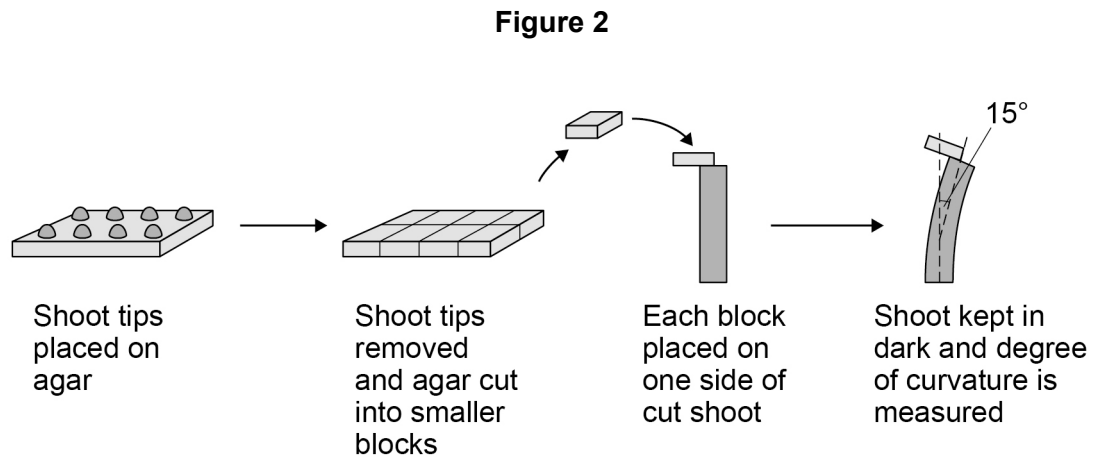
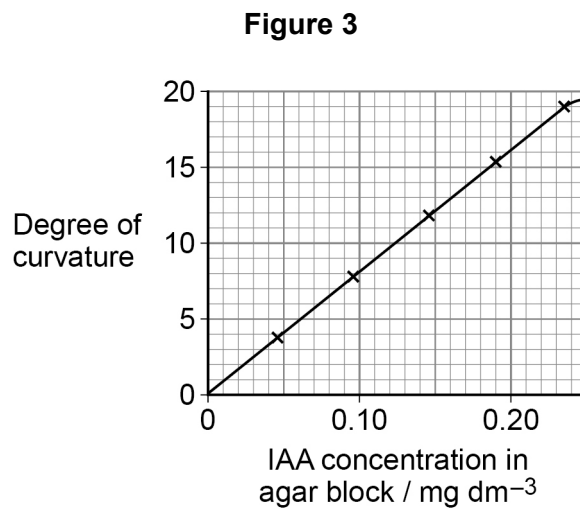


Figure 3 shows the calibration curve for this growth curvature bioassay.



0 3 . 2

Using the procedure in **Figure 2** and the calibration curve in **Figure 3**, describe how you could compare the IAA concentration in shoot tips from two different plant species.

In your answer you should refer to all the variables that should be controlled to produce a valid comparison.

[5 marks]

Cut the tips from shoots of each species and place them on agar blocks, then place each agar block on one side of a decapitated shoot, as in Figure 2, and measure the degree of curvature.

To make the comparison valid I would control: the size of the shoot tips, the number of shoot tips on each block, the size and type of agar block, the stage of growth (age) of the shoots, the time the tips are left on the agar and the time the block is left on the cut shoot (kept in the dark), and the temperature.

I would repeat this several times for each species and calculate a mean degree of curvature.

I would then read off the IAA concentration for each mean curvature from the calibration curve and compare them: the higher the degree of curvature, the higher the IAA concentration.

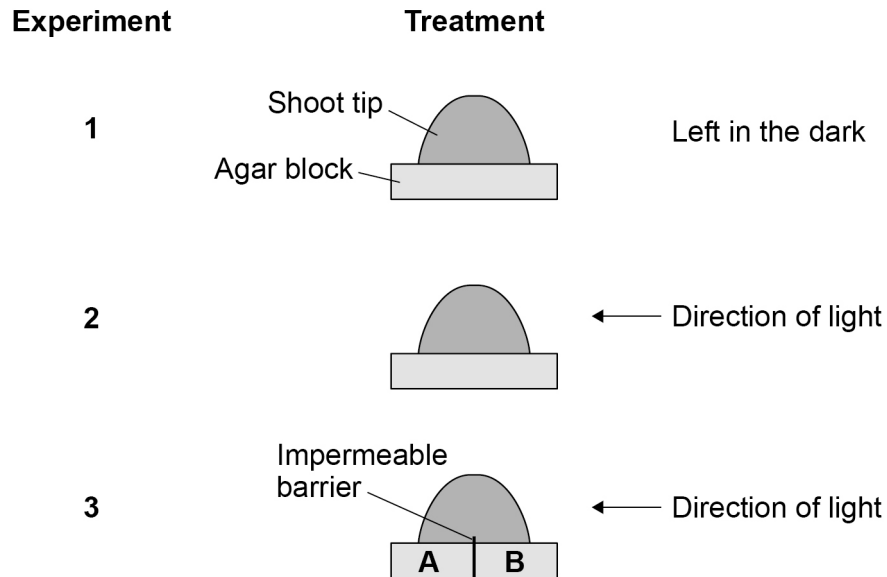
Question 3 continues on the next page

Turn over ►



A scientist investigated the effect of a directional light stimulus on the distribution of IAA in shoot tips. The scientist set up three experiments as shown in **Figure 4**. All variables were controlled apart from exposure to light.

Figure 4



She then used the growth curvature bioassay to compare the IAA concentrations in the agar blocks from:

- experiment 1
- experiment 2
- experiment 3 section A
- experiment 3 section B.

Table 1 shows the scientist's results.

Table 1

Experiment	Degree of curvature in Bioassay / degrees
1	17.69
2	17.61
3A	11.22
3B	6.50



0 3 . 3

State **two** conclusions about IAA that you can make from the results shown in Table 1.

[2 marks]

- 1 *Light does not affect IAA production / IAA is not broken down by light, as experiments 1 and 2 are the same.*
- 2 *IAA moves away from the light, to the shaded side of the shoot tip.*

10

Turn over for the next question

Turn over ►



0 4

In fruit flies, males have the sex chromosomes XY and the females have XX.
In fruit flies, a gene for eye colour is carried on the X chromosome. The allele for red eyes, **R**, is dominant to the allele for white eyes, **r**.

0 4 . 1

Male fruit flies are more likely than female fruit flies to have white eyes.

Explain why.

[2 marks]

Males have only one X chromosome, so they only have one allele and only need one recessive allele (r) to have white eyes.

Females need two recessive alleles (must be homozygous recessive, rr). A female with one R allele is heterozygous and is a red-eyed carrier.

0 4 . 2

A female fruit fly with white eyes was crossed with a male fruit fly with red eyes to produce a large number of offspring.

Tick (✓) **one** box next to the statement which correctly describes the phenotypes produced from this cross.

[1 mark]

All offspring red-eyed

☐

All females red-eyed, all males white-eyed

☒

All males red-eyed, all females white-eyed

☐

All males white-eyed, females red-eyed and females white-eyed

☐


In fruit flies, the genes for body colour and for wing development are **not** on the sex chromosomes. The allele for grey body colour, **G**, is dominant to the allele for black body colour, **g**. The allele for long wings, **L**, is dominant to the allele for short wings, **l**.

A geneticist carried out a cross between fruit flies with grey bodies and long wings (heterozygous for both genes) and fruit flies with black bodies and short wings.

Table 2 shows the results of this cross.

Table 2

Phenotype of offspring	Number of offspring
Grey body and long wings	223
Black body and short wings	218

0 4 . 3 Explain the results in **Table 2**.

[3 marks]

The two genes are linked: they are on the same (autosomal) chromosome, with G and L on one chromosome and g and l on the other in the heterozygous parent.

The genes are close together, so no crossing over occurred between them.

So the heterozygous parent only produced GL and gl gametes, and no Gl or gL gametes, so there are no Ggll or ggLl offspring (no grey short-winged or black long-winged flies).

Question 4 continues on the next page

Turn over ►



0 4 . 4

The **first** generation of a population of fruit flies had 50 females.

Calculate how many female fruit flies would be produced from this population in the **fifth** generation.

You can assume:

- each female produces 400 offspring each generation
- half the offspring produced each generation are female
- there is no immigration or emigration
- no flies die before reproducing.

Show your working.

Give your answer in standard form.

[3 marks]

Each generation, females increase by $400 \div 2 = 200$ times

Generation 1 to 5 = 4 generations of multiplying

$$50 \times 200 \times 200 \times 200 \times 200 = 50 \times 200^4$$

$$= 50 \times 1.6 \times 10^9 = 80\,000\,000\,000$$

Answer 8×10^{10}

9



0 5 . 1

Neonatal diabetes is a disease that affects newly born children. The disease is caused by a change in the amino acid sequence of insulin.

This change prevents insulin binding to its receptor. Explain why this change prevents insulin binding to its receptor.

[2 marks]

The change in amino acid sequence changes the primary structure, so

the hydrogen, ionic and disulfide bonds form in different places,

changing the tertiary structure (3D shape) of insulin.

So insulin is no longer complementary to its receptor and cannot bind.

Question 5 continues on the next page

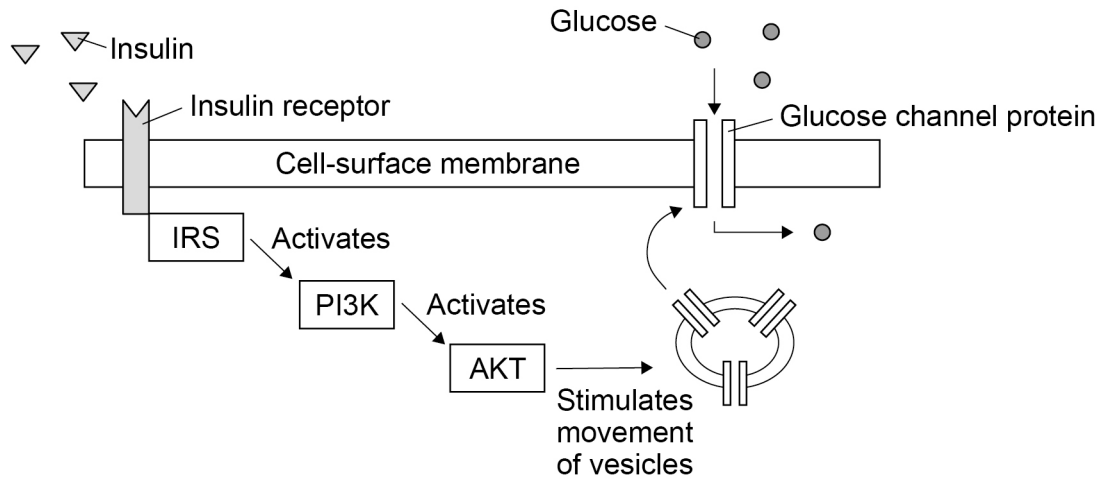
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Phosphoinositide 3-kinase (PI3K) is an enzyme in several metabolic processes.

Figure 5 shows the role of PI3K in the control of blood glucose concentration.

Figure 5



0 5 . 2 A decrease in the activity of PI3K can cause type II diabetes.

Use **Figure 5** to explain why.

[3 marks]

With less PI3K activity, less AKT is activated.

So fewer vesicles move to and fuse with the cell-surface membrane, so there are fewer glucose channel proteins in the membrane.

So less glucose diffuses into the cells by facilitated diffusion, so blood glucose concentration stays high, even though insulin is binding to its receptors.



0 5 . 3

Using your knowledge of the kidney, explain why glucose is found in the urine of a person with untreated diabetes.

[3 marks]

In untreated diabetes there is a high concentration of glucose in the

blood, so there is a high concentration of glucose in the filtrate.

Glucose is reabsorbed in the proximal convoluted tubule by co-transport with sodium ions, using carrier (co-transport) proteins.

These carrier proteins are working at their maximum rate (saturated), so not all of the glucose is reabsorbed and the rest stays in the filtrate and ends up in the urine.

8

Turn over for the next question

Turn over ►



0 6

Myelodysplastic syndromes (MDS) are a group of malignant cancers. In MDS, the bone marrow does not produce healthy blood cells.

Haematopoietic stem cell transplantation (HSCT) is one treatment for MDS. In HSCT, the patient receives stem cells from the bone marrow of a person who does not have MDS. Before the treatment starts, the patient's faulty bone marrow is destroyed.

0 6 . 1

For some patients, HSCT is an effective treatment for MDS.

Explain how.

[3 marks]

The transplanted stem cells divide (by mitosis) in the patient's bone marrow.

They then differentiate to produce healthy, normal blood cells.

Because the faulty bone marrow was destroyed, no MDS / cancerous blood cells are produced, only healthy ones.

0 6 . 2

MDS can develop from epigenetic changes to tumour suppressor genes. In some patients, the drug AZA has reduced the effects of MDS. AZA is an inhibitor of DNA methyltransferases. These enzymes add methyl groups to cytosine bases.

Suggest and explain how AZA can reduce the effects of MDS in some patients.

[3 marks]

AZA inhibits DNA methyltransferases, so it reduces methylation of the DNA (cytosine bases) of tumour suppressor genes.

So the tumour suppressor genes can be transcribed and expressed, so the tumour suppressor protein is formed.

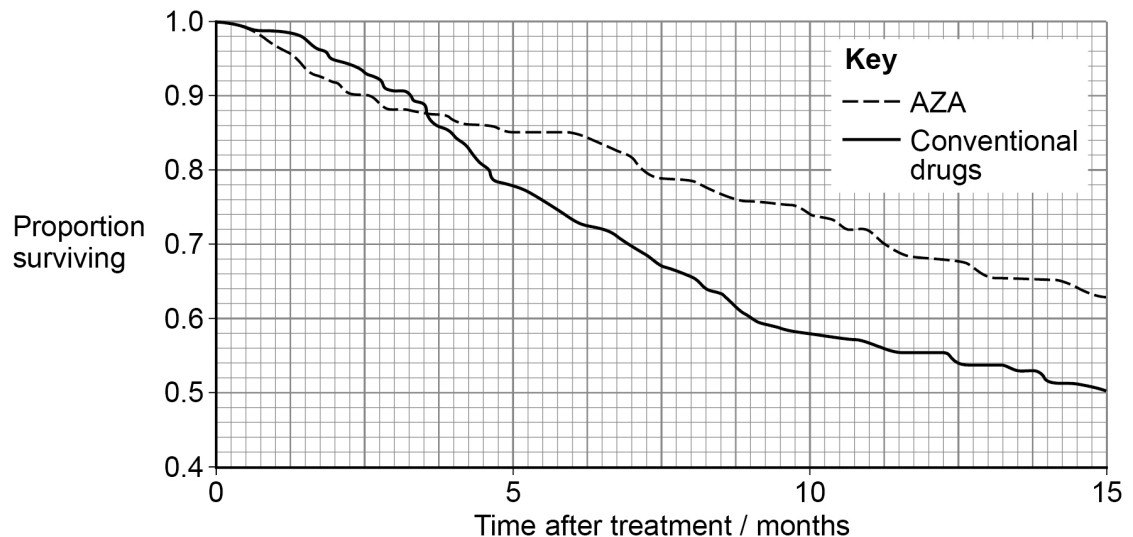
This slows down / controls cell division, preventing rapid, uncontrollable cell division.



Scientists investigated the effectiveness of AZA in patients with MDS. A total of 360 patients were randomised in the ratio of 1:1 to receive AZA or conventional drugs (control).

Figure 6 shows the scientists' results.

Figure 6



0 6 . 3

The control patients were treated with conventional drugs.

Give **two** reasons why.

[2 marks]

- 1 *So that the effect of AZA can be compared with the effect of existing treatment, to see if AZA is better.*
- 2 *It would be unethical not to treat the control patients, as MDS is a malignant cancer.*

0 6 . 4

Use **Figure 6** and the information provided to calculate the difference in the number of patients surviving at 10 months after treatment with AZA compared with conventional drugs.

[2 marks]

$$\text{Each group} = 360 \div 2 = 180 \text{ patients}$$

$$\text{AZA: } 0.74 \times 180 = 133.2 \quad \text{Conventional: } 0.58 \times 180 = 104.4$$

$$\text{Difference} = 133.2 - 104.4 = 28.8$$

Answer 29

10

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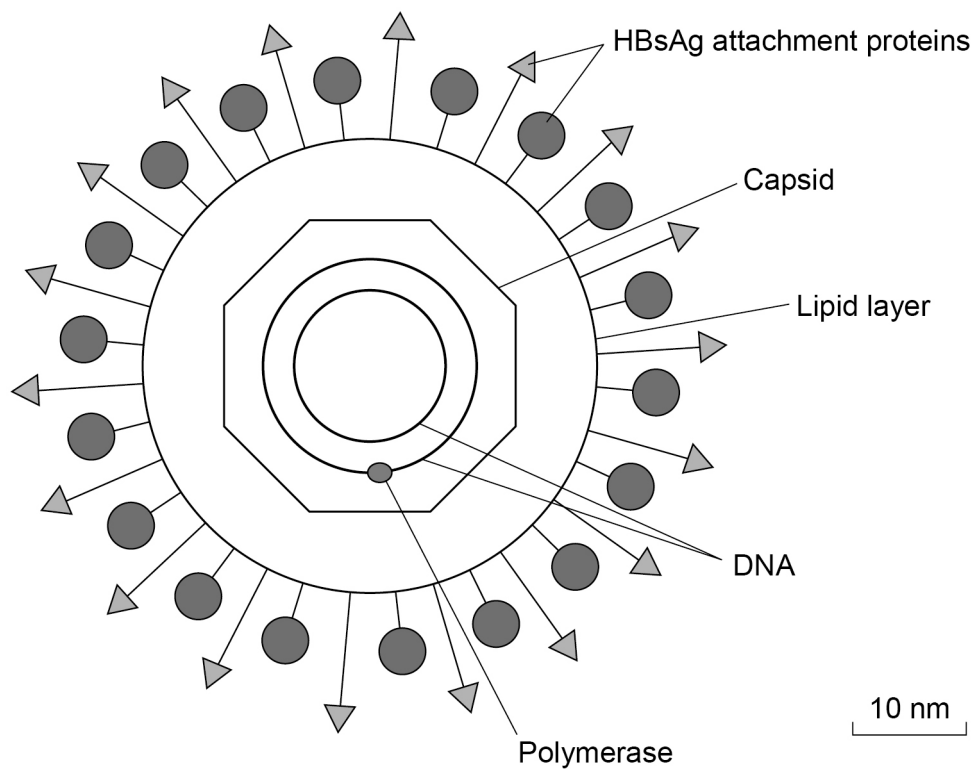


0 7

Hepatitis B is a life-threatening liver infection caused by the hepatitis B virus (HBV).

Figure 7 shows the structure of HBV.

Figure 7



0 7

1

HBV infects a liver cell. The liver cell is $25\mu\text{m}$ in diameter.

Use **Figure 7** to calculate how many times larger in diameter this cell is than HBV. You should use the lipid layer to measure the diameter of HBV.

[2 marks]

$$\text{Diameter of lipid layer} = 4 \times \text{scale bar} = 4 \times 10 \text{ nm} = 40 \text{ nm}$$

$$25 \mu\text{m} = 25\,000 \text{ nm}$$

$$25\,000 \div 40 = 625$$

Answer 625 times larger



Scientists investigated the effectiveness of two types of RNA interference (RNAi) molecules on reducing HBV replication. These molecules were:

- short hairpin RNA (shRNA)
- long hairpin RNA (lhRNA).

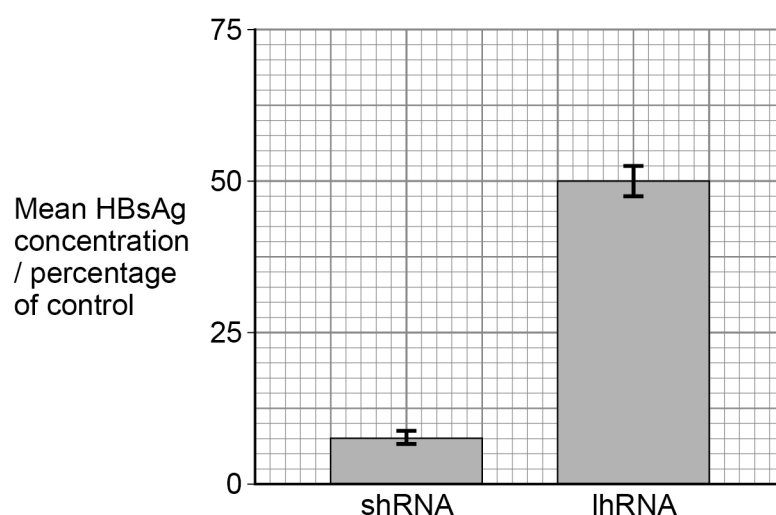
The scientists infected mouse liver cells with HBV and transferred either shRNA or lhRNA into these cells. Then they determined the concentration of the attachment proteins, HBsAg, in these cells.

The concentration of HBsAg is a measure of HBV replication.

Figure 8 shows the scientists' results.

The error bars represent ± 2 standard deviations from the mean, which includes over 95% of the data.

Figure 8



0 7 2

One method of transferring RNAi molecules into cells involves combining these molecules with a lipid. Suggest why this increases uptake of RNAi molecules into cells.

[1 mark]

Cell-surface membranes are made of a phospholipid bilayer, so the lipid lets the RNAi molecules cross the membrane without needing channel or carrier proteins.

Question 7 continues on the next page

Turn over ►



07.3

Using all the information provided, evaluate the use of the two types of RNAi in treating hepatitis B in humans.

Do **not** refer in your answer to how RNAi reduces HBV replication.

[5 marks]

Both types of RNAi reduced HBsAg concentration and so reduced HBV replication compared with the control. shRNA was more effective, reducing HBsAg to about 7.5% of the control compared with 50% for lhRNA (a 42.5% difference).

The error bars (± 2 standard deviations) do not overlap, so the difference between shRNA and lhRNA is significant and not likely to be due to chance.

However, neither reduced HBsAg (replication) to zero, so they would not cure the infection.

The investigation was done in mouse cells, not in humans, and in vitro (in isolated liver cells), not in vivo in a whole organism, so the results may be different in people.

There is no indication of the sample size, no statistical test was carried out, and the long-term effects or side effects (e.g. toxicity) are not known.

8



0 8 . 1

Describe and explain how the polymerase chain reaction (PCR) is used to amplify a DNA fragment.

[4 marks]

The DNA fragment is mixed with DNA polymerase (Taq polymerase), free DNA nucleotides and primers.

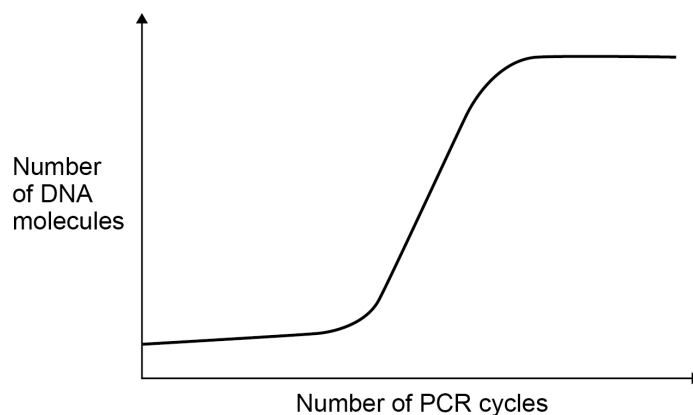
The mixture is heated to 95 °C to break the hydrogen bonds between the bases, separating the two strands.

The temperature is reduced to about 55 °C so that primers bind (anneal) to the complementary bases at the ends of the DNA strands.

The temperature is increased to 72 °C so DNA polymerase joins nucleotides to form new complementary strands. The cycle is repeated many times.

Figure 9 shows the number of DNA molecules produced using a PCR.

Figure 9



0 8 . 2

Explain the shape of the curve in **Figure 9**.

[2 marks]

At first the number of DNA molecules is low but it doubles every cycle, giving an exponential increase.

The curve then plateaus because the nucleotides and primers run out (and the polymerase may eventually denature).



0 9

A coral reef is an underwater ecosystem formed as a ridge of mainly calcium carbonate deposits. Algae are photosynthesising organisms. Some algae grow on coral reefs. Succession results in a wide variety of fish living on coral reefs.

0 9 . 1

Describe a method that could be used to determine the mean percentage cover of algae on a coral reef.

Do **not** include information on the difficulties of using your method underwater.

[3 marks]

Lay out a grid over the area of reef and place quadrats at random

coordinates, chosen using a random number generator.

Use a large number of quadrats (e.g. at least 30) and estimate the percentage cover of algae in each one.

Add up all the percentage cover values and divide the total by the number of quadrats to get the mean.

0 9 . 2

Explain how succession results in a wide variety of fish living on coral reefs.

Do **not** describe the process of succession in your answer.

[2 marks]

Succession increases the variety / diversity of species of algae and other organisms on the reef.

This provides more different habitats and niches and a greater variety of food sources, so many different fish species can live there.



Ecologists investigated the effect of two fish species, the redband parrotfish and the ocean surgeonfish, on algal growth on an artificial reef. They made this artificial reef by submerging many large concrete blocks at a depth of 16–18 metres off the coast of Florida. They attached four large wire cages, **A**, **B**, **C** and **D**, to each block and populated the cages as shown.

A – No fish

B – Two redband parrotfish

C – Two ocean surgeonfish

D – One redband parrotfish and one ocean surgeonfish

After 34 weeks, the ecologists measured the mean percentage cover of all algae within each set of wire cages. The ecologists used a statistical test to find out whether the mean for each set of cages was significantly lower than the mean for set **A**.

Table 3 shows the probability (*P*) values that the ecologists obtained using this statistical test.

Table 3

Set of cages	<i>P</i> value
B	=0.841
C	<0.001
D	=0.634

0 9 . 3

Using all the information, evaluate the effect of the two fish species on algal growth on coral reefs.

[5 marks]

Only C (ocean surgeonfish) significantly reduced algal cover compared with A ($P < 0.001$, below 0.05), so the difference is not due to chance.

B and D ($P = 0.841$, 0.634) were not significantly different from A, so parrotfish had no significant effect.

But algal species are not known, and it was only done off Florida, at 16 to 18 m, for 34 weeks. The artificial concrete reef may affect growth and other animals may enter the cages.

10

Turn over ►



1 0

Read the following passage.

Lake Malawi in East Africa has more species of fish than any other lake in the world. Many of these species have evolved from a common ancestor. Lake Malawi is one of the largest lakes in the world and was formed several million years ago. Since then, the water level has fluctuated greatly. As a result, what is now a large lake was at one time many smaller, separate lakes. 5

The country of Malawi has a total area of 118 000 km². The actual land area is only 94 080 km², because approximately one-fifth of the country is Lake Malawi.

In December 1990, forests covered 41.4% of the actual land area of Malawi. In December 2016, forests covered 26.4% of the actual land area of Malawi. 10

Deforestation and farming along the shores of Lake Malawi have caused increased soil erosion and loss of nutrients into the lake. This has resulted in a decrease in some fish populations. The mark-release-recapture method can be used to estimate the size of a fish population. However, this method can produce unreliable results in very large lakes. 15

Use the information in the passage and your own knowledge to answer the following questions.

1 0 . 1

Lake Malawi in East Africa has more species of fish than any other lake in the world (line 1).

Suggest and explain how this speciation may have occurred.

[4 marks]

When the water level fell, the lake split into many smaller separate lakes, so populations of the common ancestor were geographically isolated (allopatric speciation).

Variation arose in each population due to mutations. The smaller lakes had different environmental conditions, so different selection pressures.

Each population was reproductively isolated, so there was no gene flow and the gene pools stayed separate. Different alleles were selected and passed on, so allele frequencies changed differently in each lake.

Eventually the populations became so different they could no longer interbreed to produce fertile offspring, so they were different species.



1 0 . 2

The percentage of forest cover in Malawi decreased between December 1990 and December 2016 (lines 9–10).

Calculate the mean loss of forest cover in km² per week during this time period.

[2 marks]

$$\text{Loss} = (41.4 - 26.4)\% \times 94\,080 = 0.15 \times 94\,080 = 14\,112 \text{ km}^2$$

$$\text{Time} = 26 \text{ years} \times 52 = 1352 \text{ weeks}$$

$$14\,112 \div 1352 = 10.4$$

Answer 10.4 km² per week

1 0 . 3

Loss of nutrients **into** Lake Malawi has resulted in a decrease in some fish populations (lines 12–13).

Explain why.

[4 marks]

The extra nutrients (nitrates and phosphates) cause rapid growth of algae (an algal bloom) at the surface, which blocks light.

So plants under the water cannot photosynthesise and they die.

Saprobiotic microorganisms decompose the dead plants and algae, and their populations increase. They respire aerobically, using up oxygen from the water.

So there is less dissolved oxygen for the fish to respire aerobically, so some fish die and their populations decrease.

Turn over ►



1 0 . 4

The mark-release-recapture method can be used to estimate the size of a fish population (lines 13–14).

Explain how.

[4 marks]

Capture a sample of fish, e.g. with nets, count them, mark them and release them back into the lake.

The marking must not harm the fish or affect their survival (e.g. not toxic, and not making them more visible to predators).

Allow time for the marked fish to distribute randomly through the population before collecting a second sample, and count how many of these are marked.

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

1 0 . 5

Suggest why the mark-release-recapture method can produce unreliable results in very large lakes (lines 14–15).

[1 mark]

In a very large lake there is less chance of recapturing marked fish, because they are unlikely to distribute randomly / evenly and may stay in one area.

15

END OF QUESTIONS



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