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Candidate surname <i>StemUp Model Solution</i>		Other names
Centre Number	Candidate Number	

Pearson Edexcel Level 3 GCE

Time 2 hours	Paper reference	9BN0/01
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Biology A (Salters Nuffield)

Advanced

PAPER 1: The Natural Environment and Species Survival

You must have: Ruler, pencil and calculator	Total Marks
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Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- **Show all your working out** in calculations and **include units** where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

P67090RA

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Q:1/1/1/1



Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Mineral ions are required for plant growth.

(a) (i) Nitrate ions are required for the synthesis of

(1)

- ☒ **A** amino acids
- ☐ **B** cellulose
- ☐ **C** starch
- ☐ **D** sucrose

(ii) Phosphate ions are required for the synthesis of

(1)

- ☐ **A** cellulose
- ☐ **B** chlorophyll
- ☒ **C** nucleic acids
- ☐ **D** sucrose

(iii) Magnesium ions are present in the structure of

(1)

- ☐ **A** amino acids
- ☐ **B** cellulose
- ☒ **C** chlorophyll
- ☐ **D** starch

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(b) Mineral ions enter the plant through the roots.

Mineral ions in the soil are in lower concentrations than in the vacuoles of root hair cells.

Describe how mineral ions are taken up by root hair cells.

(3)

Mineral ions are taken up by active transport, because they move against their concentration gradient, from a lower concentration in the soil to a higher concentration in the root hair cell.

The ions bind to specific carrier proteins (protein pumps) in the cell surface membrane, which change shape to move the ions into the cell.

This requires energy from ATP, produced by aerobic respiration in the root hair cell.

(Total for Question 1 = 6 marks)



P 6 7 0 9 0 R A 0 3 3 2

2 Anthropogenic activities are contributing to global warming.

Scientists from the IPCC (Intergovernmental Panel on Climate Change) say that changes to diet can have a major impact on greenhouse gas emissions. The method of farming affects the level of impact.

The Paris Agreement of 2015 committed countries to reduce carbon emissions.

(a) How many of the following statements about global warming are correct?

(1)

- global warming is caused by a reduction in greenhouse gases
- deforestation may contribute to global warming
- global warming is leading to the melting of sea ice
- global warming may lead to a change in rainfall patterns
- global warming is affecting only the ice caps

☐ **A** 2

☒ **B** 3

☐ **C** 4

☐ **D** 5



- (b) The table shows the mass of greenhouse gas released in the production of one serving of a variety of sources of protein.

Source of protein	Mass of greenhouse gas released in the production of one serving of the protein / kg
Beef	7.0
Lamb	5.0
Chicken	2.5
Cheese	2.0
Tofu (from soya beans)	1.0
Nuts	0.5

- (i) Explain why a diet based on plant protein produces lower greenhouse gas emissions than a diet based on animal protein.

(3)

Plants photosynthesise, so they remove carbon dioxide from the atmosphere and use it to make organic compounds such as glucose, starch and protein (biomass), so plants are close to carbon neutral.

Animals respire, releasing carbon dioxide, and energy is lost at each trophic level, so much more plant material is needed to make each serving of animal protein.

Also, some animals such as cattle and sheep produce methane, a potent greenhouse gas.

- (ii) Beef cattle are traditionally reared by grazing on natural pastures (grassland).

In recent years, large areas of rainforest have been cleared to produce beef.

Explain why the farming of beef cattle on deforested land produces more greenhouse gas emissions than from those reared on natural pastures.

(3)

Deforestation cuts down trees, which are carbon sinks (stores of carbon).

The trees are usually burned or left to decompose, which releases carbon dioxide into the atmosphere.

Without the trees there is less photosynthesis, so less carbon dioxide is removed from the atmosphere. Natural pasture was never forest, so this extra carbon dioxide is not released.

(Total for Question 2 = 7 marks)



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- 3 Peat bogs are formed over millions of years from the remains of plants and animals.

Waterlogging and acidic conditions prevent the decomposition of plants and animals in peat bogs.

The photograph shows peat being cut from a peat bog.



(Source: © Reimar/Shutterstock)

- (a) (i) State how the age of the layers in a peat bog can be determined.

(1)

By carbon-14 (radiocarbon) dating of the remains in each layer; the deeper the layer, the older it is.

- (ii) Explain why the conditions in peat bogs prevent decomposition.

(3)

Waterlogging means the peat is anaerobic, because there is very little oxygen in the water.

So decomposers such as bacteria and fungi carry out less aerobic respiration, so there is little decomposer activity.

The acidic conditions (low pH) denature the decomposers' enzymes, changing the shape of the active site so the substrate no longer fits.

Therefore the enzymes cannot digest (break down) the organic material in the dead plants and animals.



(b) In the 1980s, there was a scheme to plant trees in areas of peat bog.

This dries out the bog and allows it to decompose, releasing the carbon dioxide locked in the peat bog.

Conservationists are cutting down trees and raising the water level to recreate the peat bog. It is estimated that the peat bogs will recover in 15 years.

The photograph shows sphagnum moss that grows on the surface of peat bogs and helps their formation.



(Source: © Jan Holm/Shutterstock)

Devise a procedure to measure the rate of recovery of the peat bog.

(4)

Mark out an area of the bog and lay a grid using two tape measures at right angles.

Use a random number table (or random number generator) to give coordinates for random sampling.

Place a 1 m × 1 m quadrat at each coordinate and record the percentage cover of sphagnum moss in the quadrat (or count the number of squares containing sphagnum).

Sample several quadrats (e.g. 20) and calculate the mean percentage cover.

Repeat the sampling at regular time intervals, e.g. every year in the same month, for 15 years.

Plot mean percentage cover against time and calculate the rate of recovery as the change in sphagnum cover per year (gradient of the graph).

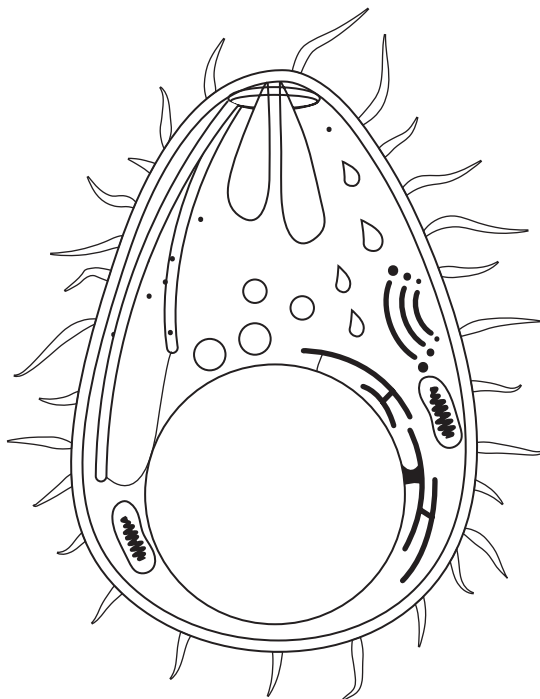
(Total for Question 3 = 8 marks)

4 Malaria is a disease that kills more than 400 000 people every year.

It is caused by *Plasmodium*, a single-celled organism that lives in the blood.

Plasmodium is transmitted by mosquitoes.

The diagram shows a *Plasmodium* organism.



(a) State and justify two structures shown in the diagram that indicate that *Plasmodium* is a eukaryotic organism.

(2)

Nucleus: it has a nucleus surrounded by a nuclear envelope, and prokaryotes have no nucleus.

Mitochondria (and Golgi apparatus): these are membrane-bound organelles, which prokaryotes do not contain.

- (b) Malaria can be controlled by killing the mosquitoes that transmit the disease.

Scientists are genetically modifying *Metarhizium pingshaense*, a fungus that infects mosquitoes.

The genetically modified (GM) fungus contains a gene from a species of spider. This gene codes for a protein that kills mosquitoes.

- (i) The GM fungus transcribes and translates the gene for this protein.

Describe the primary structure of a protein.

(2)

The primary structure is the sequence of amino acids in the polypeptide chain.

The amino acids are joined together by peptide bonds, formed in condensation reactions.

- (ii) The primary structure of this protein is then converted into a tertiary structure and modified by organelles in the cell.

Describe the role of the organelles involved in these processes.

(5)

The polypeptide made on ribosomes on the rough endoplasmic reticulum (rER) enters the rER, where it is folded into its tertiary structure.

Bonds form between the R groups of the amino acids, such as hydrogen bonds, ionic bonds and disulfide bridges, holding the 3D shape.

The rER then packages the protein into vesicles, which pinch off and transport the protein to the Golgi apparatus.

The vesicles fuse with the Golgi apparatus, where the protein is modified (processed), e.g. carbohydrate (sugar) groups are added to form a glycoprotein, or a prosthetic group is added.

The Golgi apparatus then packages the protein into vesicles for secretion by exocytosis.

(Total for Question 4 = 9 marks)



- 5 Porphyria is a life-threatening genetic disease. It is caused by a mutation in the gene coding for an enzyme involved in the production of haem.

In people with porphyria, haem cannot be produced.

- (a) Explain why this mutation may prevent the enzyme involved in the production of haem from functioning correctly.

(4)

A mutation changes the sequence of bases in the DNA of the gene (the triplet code).

This changes a codon in the mRNA, so a different amino acid may be coded for (or a STOP codon may be produced), changing the sequence of amino acids in the enzyme.

Different amino acids have different R groups, so different bonds (hydrogen, ionic, disulfide) form between the R groups and the tertiary structure of the enzyme changes.

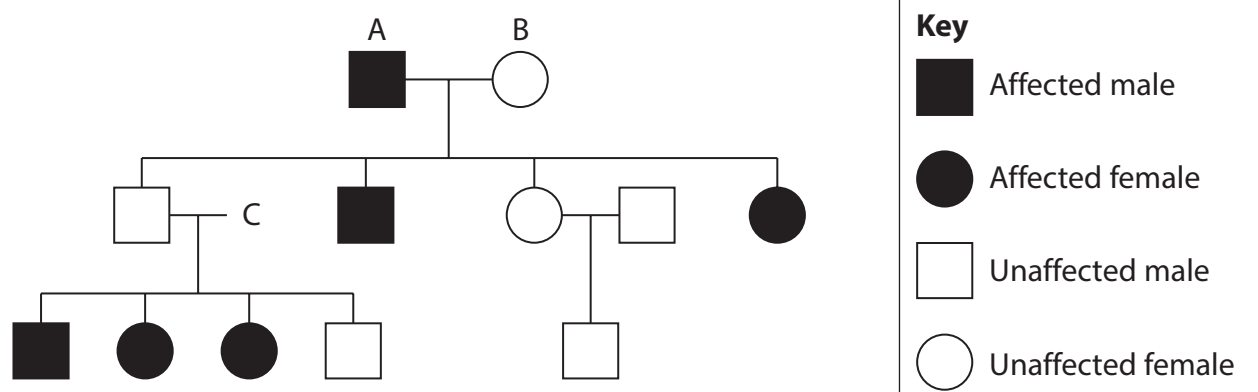
Therefore the shape of the active site is changed, so the substrate no longer fits (is not complementary to) the active site.

Enzyme-substrate complexes cannot form, so the reaction in haem production is not catalysed.



(b) Porphyria is caused by a dominant allele and may not develop until later in life.

The pedigree diagram shows a family in which some individuals have porphyria.



(i) State the genotype and phenotype of person C.

(1)

Genotype: heterozygous, Pp. Phenotype: affected (has porphyria).

(ii) Person A and Person B have one son with porphyria. What was the probability of them having a child that was male and had porphyria?

(1)

- ☐ A 0.00
- ☒ B 0.25
- ☐ C 0.50
- ☐ D 1.00

- (c) A new technique known as gene silencing has been developed to treat this disease.

Molecules known as small interfering RNA (siRNA) combine with mRNA to prevent translation.

Deduce how siRNA may be used to prevent the development of porphyria.

(4)

The siRNA has a base sequence complementary to part of the mRNA transcribed from the mutated (dominant) allele, so it binds to this mRNA by complementary base pairing.

The mRNA cannot then bind to the ribosome, and tRNA molecules cannot bind to the mRNA codons, so amino acids are not brought to the mRNA.

Therefore translation does not occur and the faulty enzyme (polypeptide) is not synthesised.

The normal (recessive) allele is still transcribed and translated, so functioning enzyme is made, haem can be produced and porphyria does not develop.

(Total for Question 5 = 10 marks)

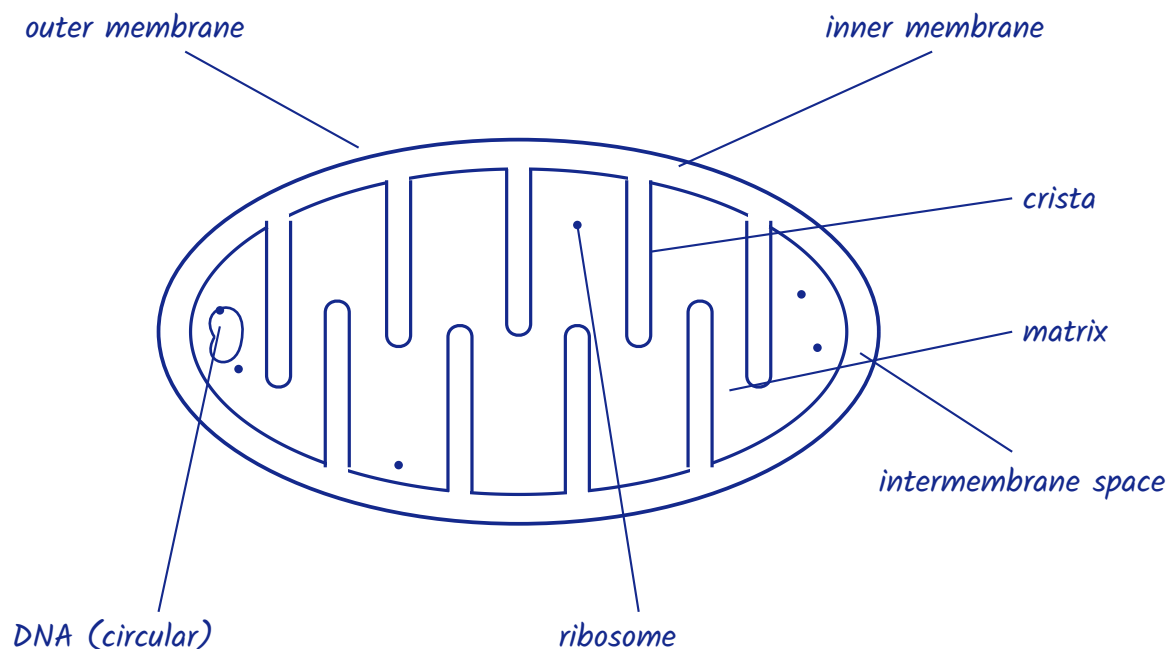


6 Leigh syndrome is a disease of the nervous system that affects the brain.

It is caused by a mutation in the DNA present inside mitochondria.

(a) Draw and label a mitochondrion.

(2)



(b) Mitochondrial diseases such as Leigh syndrome are passed on by the mother during fertilisation.

Explain why a fertilised egg cell will contain only maternal mitochondria.

(2)

During fertilisation only the nucleus (head) of the sperm enters the egg cell; the mitochondria in the sperm's midpiece do not enter the egg.

Therefore all the mitochondria in the fertilised egg come from the egg cell (the mother).



- (c) Using IVF, it is possible to produce an embryo that does not have the mitochondrial disease.

The nucleus is removed from a donor egg cell from another individual.

The nucleus from a fertilised egg from a mother with the mutation is then placed in the egg cell from the donor.

- (i) Explain why the resulting embryo does not develop mitochondrial disease.

(2)

All the mitochondria in the egg, and so in the embryo, come from the donor egg cell;

only the nucleus came from the mother's fertilised egg.

The donor's mitochondria do not carry the mutation in their mitochondrial DNA, so the embryo does not develop the disease.

- (ii) Comment on the inheritance of parental characteristics in offspring produced in this way.

(3)

The DNA (chromosomes) in the nucleus comes from the sperm and egg of the two parents.

So characteristics determined by nuclear DNA, which is almost all characteristics, will be inherited from the parents.

However, any characteristics controlled by mitochondrial DNA will be inherited from the donor, so the child has genetic material from three people (though mitochondrial DNA codes for only a few proteins).

(Total for Question 6 = 9 marks)



7 Measles is a contagious disease that can be controlled by vaccination.

Not all parents choose to have their children vaccinated.

The table shows the number of cases of measles and the percentage of children vaccinated in the UK between 2012 and 2017.

Year	Number of cases of measles	Percentage of children vaccinated (%)
2012	1564	91.2
2013	1855	92.3
2014	135	92.7
2015	71	92.3
2016	556	91.9
2017	216	91.6

- (a) (i) Calculate the percentage change in the number of cases of measles from 2013 to 2014.

Give your answer to three significant figures.

(2)

$$1855 - 135 = 1720$$

$$(1720 \div 1855) \times 100 = 92.72...$$

$$= 92.7 \% \text{ decrease (3 s.f.)}$$

..... 92.7 %



- (ii) One conclusion from the data is that it takes time for an increase in vaccination rate to reduce the number of cases of measles in children.

Explain why this is a valid conclusion.

(4)

As the percentage of children vaccinated increases, the number of cases of measles decreases, but the fall is seen in the following year.

For example, vaccination rose from 91.2% in 2012 to 92.3% in 2013, but cases still rose from 1564 to 1855; cases then fell to 135 in 2014 and 71 in 2015. Vaccination fell from 92.7% in 2014 to 92.3% in 2015, and cases rose the year after, to 556 in 2016.

The delay is because it takes time for B cells to be activated and to produce antibodies and memory cells.

It also takes time for herd immunity to develop, when enough people are immune that the virus cannot spread.



(b) The incidence of measles has risen by 300% worldwide in recent years.

A study has found that some B memory cells and antibodies are destroyed by the measles virus.

(i) Antibodies are released into the blood when

(1)

- ☐ A B cells are activated to become killer cells
- ☒ B B cells are activated to become plasma cells
- ☐ C macrophages are activated to become B cells
- ☐ D plasma cells are activated to become memory cells.

(ii) Vaccinations are carried out against many serious diseases.

Vaccination leads to the production of antibodies and memory cells.

Which kind of immunity is provided by this type of vaccination?

(1)

- ☒ A active artificial
- ☐ B active natural
- ☐ C passive artificial
- ☐ D passive natural

(iii) Explain why, following a measles infection, it may be advisable for children to repeat other vaccinations they have had.

(3)

The measles virus destroys some of the memory cells (and antibodies) made by previous vaccinations.

Without these memory cells there is no secondary immune response if the child meets those pathogens again, so antibodies cannot be produced quickly.

Therefore the child has less immunity and could catch diseases they were previously immune to.

Repeating the vaccinations produces new memory cells, restoring immunity.

(Total for Question 7 = 11 marks)

8 Tuberculosis (TB) is a disease that affects the lungs. It is caused by the bacterium *Mycobacterium tuberculosis*. When these bacteria enter the body an immune response is triggered.

(a) The initial response when bacteria enter the body is a

(1)

- ☐ A non-specific response and bacteria are destroyed by antibodies
- ☒ B non-specific response and bacteria are destroyed by phagocytes
- ☐ C specific response and bacteria are destroyed by antibodies
- ☐ D specific response and bacteria are destroyed by phagocytes.

(b) *M. tuberculosis* bacteria can remain dormant in the body after infection.

Explain why these dormant bacteria are not destroyed by the immune system.

(3)

The dormant bacteria are inside macrophages (phagocytes) that engulfed them, so they are hidden from antibodies.

M. tuberculosis has a thick waxy cell wall, so it resists digestion.

Lysosomes cannot fuse with the phagocytic vacuole, so the bacteria are not destroyed by lysosomal enzymes.

The infected macrophages are walled off inside tubercles in the lungs, where the bacteria survive.



- (c) The Human Immunodeficiency Virus (HIV) affects the immune system. People infected with HIV are more likely to develop TB.

A study investigated the relationship between TB infections and HIV status.

In 2008, the number of people in the world estimated to have TB was 9.4 million.

The table shows the percentage of these people who were either HIV positive or HIV negative. The estimated number of deaths due to TB is also shown in the table.

HIV status	Percentage of people with TB in 2008 (%)	Estimated number of patients with TB who died in 2008	Percentage of deaths due to TB (%)
HIV positive	15	521 700	
HIV negative	85	1 278 400	16

- (i) Calculate the percentage of TB patients infected with HIV who died of TB.

(2)

$$TB \text{ patients with HIV} = 15\% \times 9.4 \text{ million} = 1\,410\,000$$

$$(521\,700 \div 1\,410\,000) \times 100 = 37.0$$

..... 37.0 %

- (ii) Describe the effect of HIV on the number of deaths from TB.

(2)

A greater percentage of TB patients with HIV die from TB (37%) than TB patients without HIV (16%).

However, the total number of TB cases and deaths from TB is greater in people without HIV (1 278 400 deaths compared with 521 700).



*(iii) There are increased numbers of deaths from TB as a result of HIV infection.

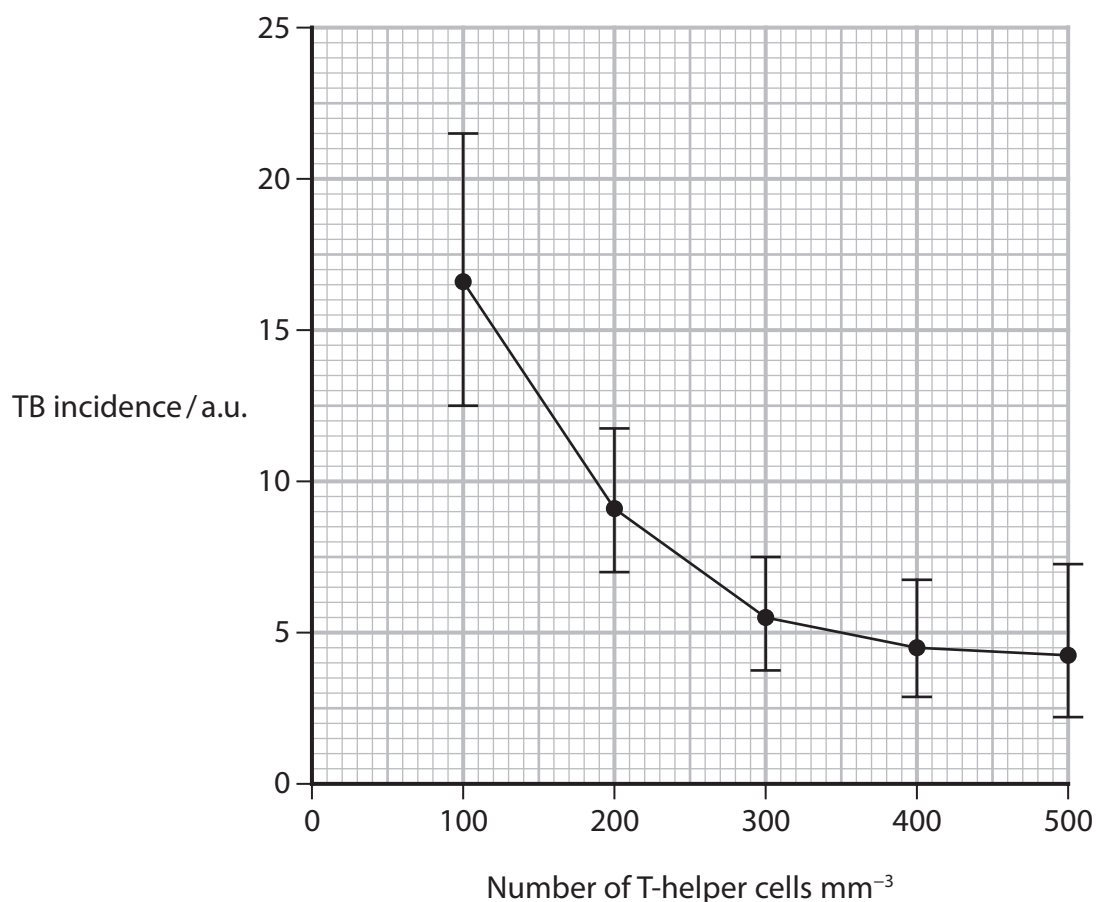
The table shows data for deaths worldwide from HIV and TB in 2016.

Type of infection	Number of deaths
TB only	1 300 000
HIV only	826 000
TB and HIV	374 000

Treatment of HIV with anti-viral drugs has reduced the incidence of TB associated with HIV infection.

The replication of HIV reduces the T-helper cell count. These anti-viral drugs reduce the replication of the virus in the body.

The graph shows the effect of this on the incidence of TB.



Explain the effect of using anti-viral drugs to treat HIV on the number of deaths from TB.

(6)

HIV makes TB more likely to develop and to kill: in 2016, 374 000 people died with both TB and HIV. HIV binds to CD4 receptors on T-helper cells and enters them. It replicates inside the T-helper cells and destroys them as the new viruses burst out, so the T-helper cell count falls.

The graph shows TB incidence is highest (about 17 a.u.) at 100 T-helper cells mm^{-3} and falls to about 4.5 a.u. at 400 to 500 cells mm^{-3} ; the error bars overlap above 300 cells mm^{-3} , so there is probably no significant difference above this.

T-helper cells release cytokines that activate B cells to divide into plasma cells that make antibodies, and activate T killer cells. With few T-helper cells there is little immune response when *M. tuberculosis* enters the body, so the bacteria multiply and the patient develops TB.

Anti-viral drugs reduce HIV replication, so fewer T-helper cells are destroyed and the count rises. The immune system can then stop TB developing, so TB incidence falls and fewer people with HIV die from TB.

However, most TB deaths (1 300 000) are in people without HIV. Anti-viral drugs do not kill bacteria, so they only reduce TB deaths in people also infected with HIV.

(Total for Question 8 = 14 marks)



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9 A biodiversity hotspot is a region that is both highly diverse and threatened with destruction.

(a) Biodiversity can be measured by the number of

(1)

- ☐ A different genes in a population.
- ☒ B different species in a habitat.
- ☐ C homozygotes in a habitat.
- ☐ D individuals in a population.

(b) Biodiversity hotspots have at least 1500 endemic plant species.
These hotspots have lost at least 70% of their natural vegetation.

Explain how protection of these hotspots can affect global biodiversity.

(2)

Endemic species are only found in that one location, so if a hotspot is destroyed these species become extinct.

Protecting hotspots prevents the extinction of many endemic species, so it prevents a large reduction in global biodiversity.



- (c) A population of white-tailed deer *Odocoileus virginianus* was introduced from North America into Finland in 1934. There were four females and one male. The population has since increased rapidly.

A study in 2012 compared the genetic diversity of the population in Finland with the population in North America.

Ten genes were compared from 72 deer in each population. The allele richness (number of alleles in the population) of each gene was measured.

A χ^2 test was carried out to compare the two populations.

- (i) The null hypothesis for this investigation is

(1)

- ☐ **A** the allele richness in the population from Finland is higher than the USA.
- ☐ **B** the allele richness in the population from the USA is higher than Finland.
- ☐ **C** the population in the USA is more genetically diverse than the population in Finland.
- ☒ **D** there is no difference in allele richness between the two populations.



- (ii) The values from the population in the USA can be taken as the expected values and a χ^2 test can be carried out.

Gene	Allele richness (Finland population) X (observed)	Allele richness (USA population) Y (expected)	X – Y	(X – Y) ²	(X – Y) ² / Y
1	6	14	8	64	4.57
2	4	5	1	1	0.2
3	7	13	6	36	2.77
4	7	15	8	64	4.27
5	6	6	0	0	0
6	8	12	4	16	1.33
7	2	3	1	1	0.33
8	4	4	0	0	0
9	4	9	5	25	2.78
10	3	4	1	1	0.25

Complete the table to calculate the χ^2 value, using the formula

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

(3)

$$\begin{aligned}\chi^2 &= 4.57 + 0.2 + 2.77 + 4.27 + 0 + 1.33 + 0.33 + 0 \\ &\quad + 2.78 + 0.25 \\ &= 16.50\end{aligned}$$

Answer 16.50.....



- (iii) The table shows the critical values of chi-squared at different levels of probability.

Degrees of freedom	Probability	
	p=0.10	p=0.05
1	2.706	3.841
2	4.605	5.991
3	6.251	7.815
4	7.779	9.488
5	9.236	11.070
6	10.645	12.592
7	12.017	14.067
8	13.362	15.507
9	14.684	16.919
10	15.987	18.307

Deduce the effect of a small founder population on the allele richness in the population of white-tailed deer in Finland.

(3)

There are 10 genes, so degrees of freedom = $10 - 1 = 9$, and the critical value at $p = 0.05$ is 16.919.

The chi-squared value of 16.50 is below the critical value, so there is no significant difference in allele richness between the two populations at $p = 0.05$; the null hypothesis is accepted.

So the small founder population has had little or no effect on allele richness.



- (d) The table shows the heterozygosity index for each population of white-tailed deer.

Heterozygosity index for Finland population	Heterozygosity index for North American population
0.692	0.742

Climate change may affect the habitat of both populations of deer.

Explain which population is more likely to adapt to changing conditions.

(4)

The North American population is more likely to adapt, because it has a higher heterozygosity index (0.742 compared with 0.692), so it is more genetically diverse.

With more different alleles in the gene pool, it is more likely that some individuals have an allele that gives an advantage in the changed conditions.

These individuals are more likely to survive and breed, passing on the advantageous allele to their offspring.

So the frequency of that allele increases in the population over generations by natural selection.

(Total for Question 9 = 14 marks)

10 Some plants are adapted to grow in shady conditions.

A study was carried out to compare the effect of growing in different light intensities on rates of photosynthesis of plants.

The plants are rated for levels of shade tolerance.

Plant seedlings of nine species were grown in either 25% or 5% of full sunlight. All other abiotic factors were controlled.

These seedlings were grown for six weeks and then exposed to full sunlight for 15 minutes. The rate of photosynthesis was measured during the exposure to full light.

The table shows the results of this investigation for four species of plant.

Species	Shade tolerance	Rate of photosynthesis / a.u.	
		Seedlings grown in 25% of full sunlight	Seedlings grown in 5% of full sunlight
A	Intolerant	410	415
B	Intermediate	300	275
C	Tolerant	180	210
D	Very tolerant	150	215

- (a) (i) Determine which species had the greatest percentage change in rate of photosynthesis when grown in lower light intensities.

(2)

$$A: (415 - 410) \div 410 \times 100 = +1.2\%$$

$$B: (275 - 300) \div 300 \times 100 = -8.3\%$$

$$C: (210 - 180) \div 180 \times 100 = +16.7\%$$

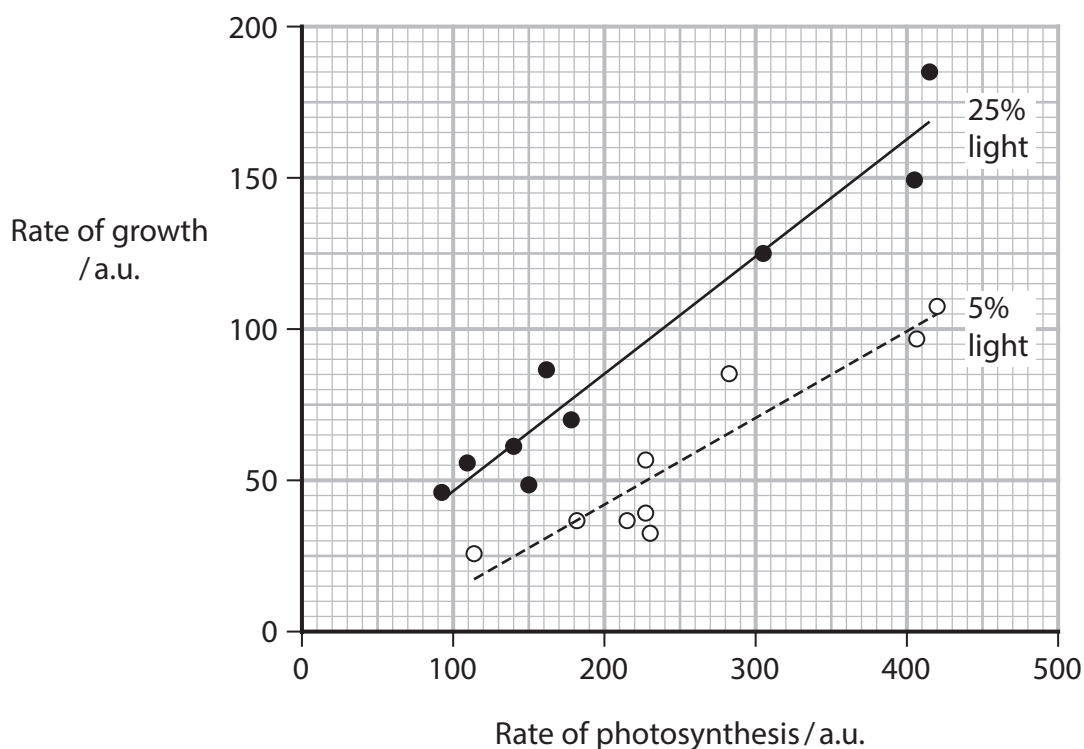
$$D: (215 - 150) \div 150 \times 100 = +43.3\%$$

Answer Species D (43.3%)



(ii) The rate of growth for all nine species of plant was also measured.

The graph shows the effects of the rate of photosynthesis on the rate of growth of these plants.



Explain the effect of light intensity during the first six weeks of growth on the growth rate of these species of plant.

(4)

There is a positive correlation: the rate of growth increases as the rate of photosynthesis increases.

At the same rate of photosynthesis, growth rate is higher for plants grown in 25% light than in 5% light, so higher light intensity in the first six weeks gives faster growth.

Light is absorbed by chlorophyll in the light-dependent reactions, causing photolysis of water and photophosphorylation, producing ATP and reduced NADP for the Calvin cycle.

So more photosynthesis means more glucose (carbohydrate) is produced, giving more glucose for respiration to release energy for growth, and for making cellulose and proteins for new cells.



- *(b) Differences in the rate of photosynthesis may be due to the light-dependent reactions in chloroplasts.

Devise an investigation to compare the rate of the light-dependent reaction in shade tolerant and shade intolerant plants grown at different light intensities.

(6)

Grow seedlings of a shade tolerant and a shade intolerant species (e.g. C and A) in 5% and 25% of full sunlight for six weeks, keeping temperature, humidity, water and minerals the same.

Take the same mass of leaves (e.g. 10 g) from each group and grind with the same volume of ice-cold isolation medium for the same time. Filter through muslin, centrifuge, and resuspend the pellet of chloroplasts in isolation medium.

Add equal volumes of chloroplast suspension to equal volumes of DCPIP and illuminate at 5% and at 25% light intensity (lamp at a fixed distance), in a water bath at 25 °C. Keep a control in the dark.

DCPIP is a blue electron acceptor that is reduced to colourless by electrons from the light-dependent reaction, so time how long the DCPIP takes to decolourise (or use a colorimeter). Rate = $1/\text{time}$. Repeat 3 times and find the mean.

A faster colour change means more electrons are released from photolysis of water, so the rate of the light-dependent reaction is higher.

If the difference is due to the light-dependent reaction, chloroplasts from shade tolerant plants will decolourise DCPIP faster at low light intensity, and shade intolerant plants faster at high light intensity. Use a t-test to see if the difference in mean rates is significant.

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 100 MARKS

