Candidate 2 evidence

1. **Read through the supplementary sheet for question 1 before attempting this question.**

   (a) Mammals have both specific and non-specific defences against parasites. Antibody production is a specific immune response.

   Describe how **one** non-specific defence protects against parasites. 1

   Physical barriers is an example as epithelial cells blocks entry of pathogens.

   (b) Refer to **Figure 1.**

   There is a positive correlation between total blood antibody concentration before and total blood antibody concentration after measles infection.

   What conclusion can be drawn about the effect of measles on the total antibody concentration in the blood? 1

   The effect of measels increases the total antibody concentration in the blood.

   (c) (i) Refer to **Figure 2.**

   Give a conclusion about the effect of infection with the measles virus on antibody diversity. 1

   Infection with the measles virus decreases the percentage change in total antibody hits (%) which reduces antibody diversity

MARKS

1. (c) (continued)

(ii) Refer to **Figure 2.**

The mean age of the control group and the measles infected groups was around eight years old, but the mean age of the group vaccinated against measles was less than two years old, as this is the normal age for measles vaccination.

Suggest why the antibody diversity might be expected to increase more in younger children compared to the control children. 1

As vaccine contain antigens that ilict an immune response and so this would create more antibodies.

(d) Refer to **Figure 3.**

(i) Calculate the percentage decrease in the proportion of antibodies still present between the medians of the control group and the severely affected measles group. 1

Space for calculation

$$0.89 - 0.6 = \frac{0.29}{0.89} \times 100 = 32.6$$

32.6%

(ii) Other than the differences in the median values, use the data to compare the effect of the severity of measles infections on the proportion of antibodies still present. 2

In the mild measels group it has a lowest value of 0.27 antibodies present and a highest value of 0.88. 25%. of the data is lower than 0.64 and 25%. was higher than 0.83. In the severe measels group, it has the lowest value of 0.38 and the highest value of 0.89. 25%. of the data is lower than 0.5 and 25%. of the data is higher than 0.74

(iii) Previous studies have suggested that loss of memory cells may contribute to the immune suppression observed after measles virus infection.

Explain how the data support this hypothesis. 1

As the range of values seen in those with severe and mild measels is much greater than the control group. The lower values are significantly lower than the control which suggests there is a lower proportion of antibodies present, suggesting lack of memory cells.

MARKS

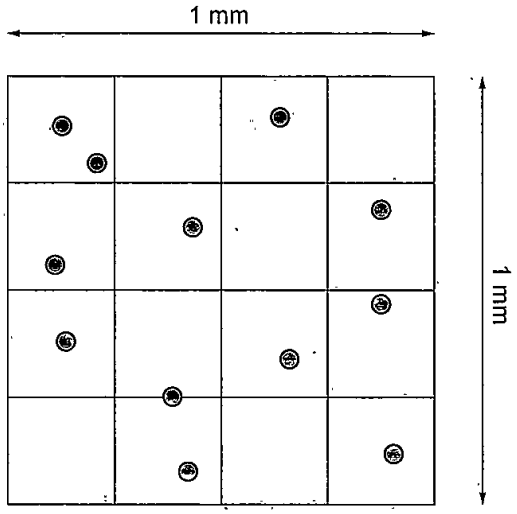
2. Many species of bacteria can be grown in liquid culture.

(a) State the importance of aseptic technique when culturing micro-organisms. 1

It allows for the elimination of unwanted microbial contaminants when culturing micro-organisms which may affect their growth.

(b) A haemocytometer can be used to estimate the number of bacterial cells in a liquid culture.

The figure represents bacterial cells from a culture, placed in a haemocytometer that has a depth of 0.1 mm.



Calculate the number of cells per cm^3 of the liquid culture. 1

Space for calculation

$0.01 \times 0.1 \times 0.1 = 1 \times 10^{-4}$

in 1×10^{-4} cm^3 → 12 cells

1 cm^3 → $\frac{12}{1 \times 10^{-4}} = 120,000$

120,000 cells per cm^3

MARKS

2. (continued)

(c) An experiment was carried out to compare the effects of two novel antimicrobial substances, compounds A and B, on the growth of the bacterium *E. coli*. Cultures of *E. coli* were grown in the presence of the compounds. Cell counts were carried out following vital staining with a dye that is only retained by non-viable cells.

Results from the experiment are shown in the table.

Antimicrobial compound in culture	Mean number of cells	
	Stained by vital stain	Not stained by vital stain
A	380	40
B	385	127

(i) State which of the antimicrobial compounds is more effective at killing bacterial cells and use the data to explain your choice. 1

Most effective antimicrobial A

Explanation As 380 cells are non-viable and only 40 are viable. A higher proportion is killed using A.

(ii) What method, other than vital staining, can be used to determine the number of viable bacterial cells in a liquid culture? 1

Plate them out in a serial dilution and count the number of colony-forming units.

(iii) Benzalkonium chloride is an antimicrobial compound found in products such as handwashes. It works by disrupting the interactions between the phospholipids of the cell membrane.

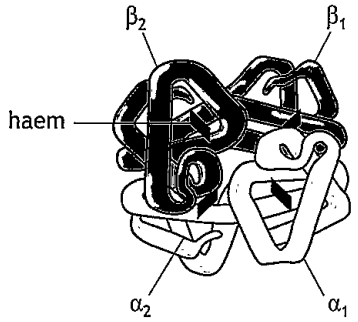
Suggest how this disruption could lead to cell death. 1

The receptors and ion channels on the cell membrane would not function correctly. This means also breaks the membrane down, so any molecule can move into the cell. This could result in the production of a cell death molecule, which triggers the death of the cell.

[Turn over

MARKS

3. Haemoglobin, the oxygen-carrying protein in the blood of vertebrates, consists of four subunits: two alpha (α) subunits and two beta (β) subunits. The α and β subunits have similar tertiary structure. Each subunit contains a haem group, which binds to oxygen to produce oxyhaemoglobin.



haemoglobin

(a) Within each haemoglobin subunit, a high proportion of the amino acids in the polypeptide form α-helices.

State the main force stabilising these regions. **1**

hydrogen bonding

(b) Explain why haem is described as a prosthetic group. **1**

As it is a non-protein unit that is bound to haemoglobin and is necessary for its ability to bind to oxygen

(c) Haemoglobin is affected by a number of allosteric interactions.

Allosteric interactions between the oxygen-binding sites result in co-operativity.

Explain what is meant by co-operativity in haemoglobin. **1**

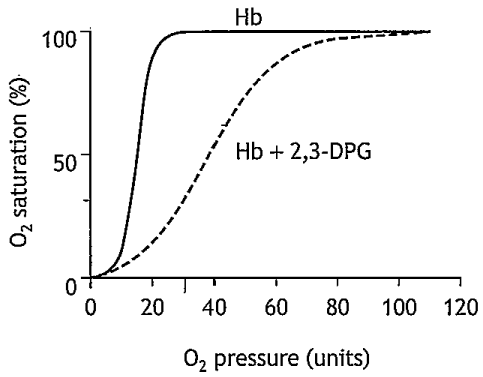
Changes in binding of oxygen at one subunit alters the affinity of the remaining subunits. If oxygen binds to one subunit, the affinity of the remaining subunits for oxygen increases

MARKS

3. (continued)

(d) The compound 2,3-diphosphoglycerate (2,3-DPG) is an allosteric modulator that binds haemoglobin (Hb).

The graph shows the effect of 2,3-DPG on the binding of oxygen.



(i) Explain how the data show that 2,3-DPG is acting as a negative modulator. 1

As at 30 units of oxygen pressure Hb has 100% O_2 saturation whereas Hb+2,3-DPG has a much lower value. It increases at a much slower rate.

(ii) The concentration of 2,3-DPG in the blood is normally 5 mmol per litre, but this rises to approximately 8 mmol per litre in individuals living at high altitude.

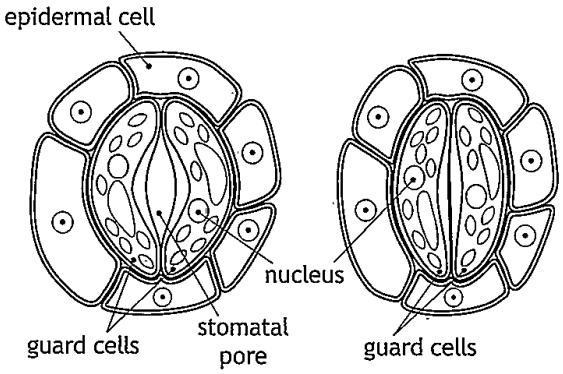
Explain how this increase in 2,3-DPG concentration at high altitude would help oxygen delivery to tissue. 1

As it is a negative modulator, an increased concentration of 2,3-DPG would bind to more haemoglobin, slowing how much oxygen can bind. If oxygen binding is reduced, this promotes increasing oxygen delivery to the tissue, that are actively respiring.

[Turn over

MARKS

4. Stomata are pores in the underside of the leaves of plants that allow gas exchange. Each pore (stoma) opens in response to high light intensity and humidity.



stoma open **stoma closed**

The opening mechanism begins with the active transport of positively charged hydrogen ions out of the guard cells via an ion pump.

(a) The hydrogen ion pump is known to be an ATPase.

Describe the chemical reaction that ATPases catalyse. **1**

The hydrolysis of ATP

(b) What name is given to ion channels that open or close in response to changes in ion concentration? **1**

Voltage-gated ion channels

MARKS

4. (continued)

(c) (i) Explain the meaning of the term electrochemical gradient. 1

It is created when the membrane potential and an electrical potential difference across a membrane combines, to form electrochemical gradient that determines the transport of a solute

(ii) The movement of hydrogen ions out of the guard cells causes the inside of the cell to become more negatively charged, which in turn results in the opening of potassium ion channels. The final event in the process is the movement of water molecules into the guard cells by osmosis, which results in opening of the stoma.

Explain why, after the potassium channels open, positive potassium ions move into the cell **against** the concentration gradient. 1

This is to restore the membrane resting potential as potassium ions add positive charges. Repolarises the membrane, as it has polarised to a much more negative value initially.

MARKS

5. Steroid hormones are a type of hydrophobic signalling molecule.
Describe how steroid hormones bring about a response in target cells. 5

Hydrophobic signalling molecules can diffuse directly through the phospholipid bilayer of membranes, and so bind to intracellular receptors. The receptors for hydrophobic signalling molecules are transcription factors. Transcription factors are proteins when bound to DNA can either inhibit or stimulate the initiation of transcription. The steroid hormones oestrogen and testosterone are examples of hydrophobic signalling molecules. Steroid hormones bind to specific receptors in the cytosol or the nucleus. The hormone-receptor complex moves to the nucleus where it binds to specific sites of DNA and affects gene expression. The hormone-receptor complex binds to specific DNA sequences called hormone response elements (HREs). Binding at these sites influences the rate of transcription with each steroid hormones affect the gene expression of many genes.

MARKS

6. The black mamba, *Dendroaspis polylepis*, is a large African snake whose bite is extremely venomous and usually fatal to humans. Its venom consists of a mixture of toxins that primarily affect the nervous system.

(a) One of these toxins binds to neurotransmitter receptors at synapses, preventing their activation.

Describe the process by which neurotransmitters released into a synapse initiate an action potential in a connecting cell. 3

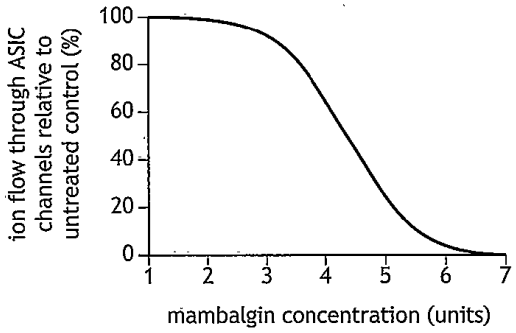
Depolarisation of a patch of the membrane influences neighbouring ~~other~~ patches of membrane to depolarise and go through the same cycle as adjacent voltage-gated sodium channels open. When the action potential reaches the end of the neuron, it triggers vesicles containing neurotransmitters to move to and fuse with the plasma membrane, releasing the neurotransmitter to initiate a response in a connecting cell. It would bind to its receptor in the connecting cell which is a ligand-gated ion channel and cause to cell to begin depolarisation

MARKS

6. (continued)

(b) *Acid sensing ion channels* (ASICs) are involved in the perception of pain and are activated by small changes in the pH of the surrounding cellular environment. *Mambalgin* is another toxin found in black mamba venom, which is known to be able to bind to ASICs.

The graph shows the effect of increasing the dose of mambalgin on the activity of ASIC ion channels.



(i) Describe the effect of mambalgin concentration on the activity of the ASIC channels. 1

As the mambalgin concentration increases, the activity of the ASIC channels decreases

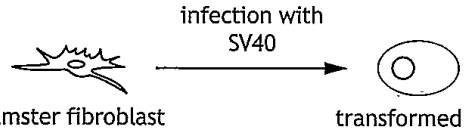
(ii) Laboratory experiments on mice show that mambalgin has a similar effect to that of a strong painkiller.

Suggest the mechanism by which mambalgin might work as a painkiller by preventing the generation of a nerve impulse. 1

As mambalgin binds to ASICs which are involved in pain perception, when it is bound, it decrease the activity of ASICs which decreases pain.

MARKS

7. Some viruses can deregulate cell division in cells and cause tumours. Simian virus 40 (SV40) is a virus that naturally infects some species of monkeys. SV40 infection rarely causes disease in its natural host, but it has been shown to be able to induce tumours in laboratory animals and transform rodent cells in culture by causing them to divide in an unregulated way.



(a) (i) Cells transformed with SV40 have features of tumour cells in culture.

State one way in which tumour cell lines differ from primary cell lines in culture. 1

Tumour cell lines can perform unlimited divisions while primary cell lines can only divide a limited number of times

(ii) Suggest one advantage of studying SV40 in laboratory animals rather than in cell culture. 1

As it allows for the effect of SV40 to be studied on the whole organism.

(b) Large T antigen (Tag) is a protein encoded by the SV40 genome. This protein is essential for SV40's tumour-forming capabilities. Tag has been shown to bind to and inactivate the tumour suppressor p53.

(i) Give one outcome of p53 activation in a normal cell. 1

stimulate cell repair

(ii) Tag has also been shown to bind to and inactivate the retinoblastoma protein (Rb).

Explain how the interaction of Tag with Rb would disrupt the normal control of cell division. 2

As when Tag binds to Rb, this would inhibit Rb. This allows the transcription of genes that code for proteins that regulate DNA replication. This would result in the cell cycle progressing* at an uncontrolled rate.

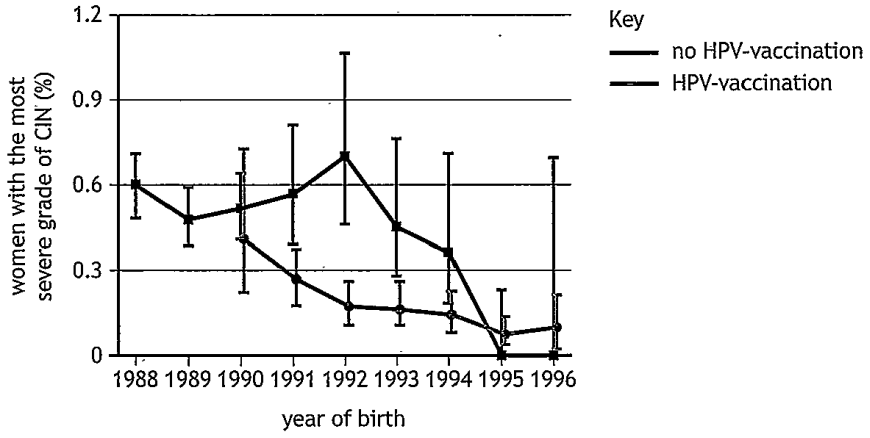
* from G1 to S phase

MARKS

7. (continued)

(c) Human papillomavirus (HPV) is another virus that has also been found to inhibit p53 and Rb. HPV can cause the development of cervical intraepithelial neoplasia (CIN), the abnormal growth of cells that line the cervix that can lead to the development of cervical cancer.

A recent study in Scotland assessed the impact of routine vaccination against HPV on the development of CIN in the first year of screening. The graph shows the effect of HPV-vaccination on the percentage of women found to have the most severe grade of CIN by cervical screening.



(i) What is the effect of HPV-vaccination on the incidence of CIN? 1

HPV – vaccination decreases the incidence of women with the most severe grade of CIN (%)

(ii) Explain how the data support the suggestion that vaccination against HPV could lead to herd immunity. 1

As in 1995 and 1996, the majority was vaccinated and this decreased the percentage of women with most severe grade of CIN.

MARKS

8. As bananas ripen, the insoluble starch in the cells is converted to soluble sugars giving a sweet taste.

A student wanted to estimate the changes in soluble carbohydrate content of bananas using colorimetry. They crushed peeled banana segments in distilled water and centrifuged the resulting extract. The supernatant was pipetted off into vials and tested with Anthrone reagent. Anthrone turns a blue-green colour with carbohydrates. This coloured solution was then tested in a colorimeter measuring absorbance at 620 nm. Five bananas attached together in a bunch were used. One banana from the bunch was taken and tested each day for 5 days.

The student prepared a range of concentrations of glucose solutions and tested these in the same way as the banana extract solutions.

(a) The student used information from a peer reviewed article to develop their method using Anthrone reagent.

Describe what happens during the peer review process. 1

Specialists from the same field read the article and assess it and may suggest changes to be made

(b) (i) Identify a positive control for this experiment. 1

glucose solutions

(ii) Suggest why it was important to use bananas originally attached in a single bunch rather than separate bananas. 1

As single bananas may have been grown under different conditions and may have differing quantities of sugars

(c) The student used data from the known glucose concentrations to construct a standard curve.

Describe the purpose of this standard curve. 1

To then compare the absorbance of the banana solutions to work out the concentration of carbohydrate (sugar) content.

MARKS

8. (continued)

(d) Anthrone reacts with both soluble and insoluble carbohydrates.

In the pilot study, the student did not use the centrifuge.

Explain why using the centrifuge is an improvement to this experimental procedure. 1

As this would allow for only the carbohydrates to be present in the resulting solution. And a centrifuge is the most effective way to seperate solutions of differing densities

(e) Describe a method that the student could have used when preparing the banana extract to ensure the concentration was controlled. 1

Use banana segments of known size, mass and volume, so the same amount of banana was added to make each solution.

(f) The student did not carry out an independent replicate of this experiment.

State one feature of an independent replicate for this experiment. 1

Replicate this experiment in the exact same method but using another banana from the same bunch and new solutions.

(g) Give one reason, other than the lack of independent replication, and the extract concentration, why any results achieved might be considered invalid. 1

As the student did not control any confounding variables which may have also had an effect on the results e.g. temperature

MARKS

9. Taxonomy is an essential tool for studies of biodiversity. It involves both the identification and classification of organisms, often based on their morphology.

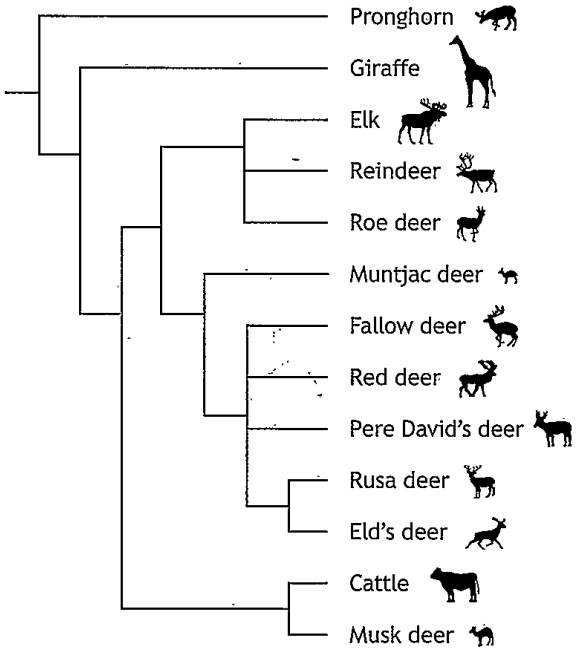
(a) (i) State one method that can be used to identify organisms in a sample during fieldwork. **1**

Using classification guides

(ii) What is meant by 'morphology'? **1**

Morphology is the physical structure and shape of the organisms and the changes of this that has occured during evolution.

(b) The figure is a phylogenetic tree showing the evolutionary history and relationships of a number of mammalian species.



(i) Other than morphology, give an example of heritable evidence that may be used to construct a phylogenetic tree. **1**

DNA sequences and protein structure

MARKS

9. (b) (continued)

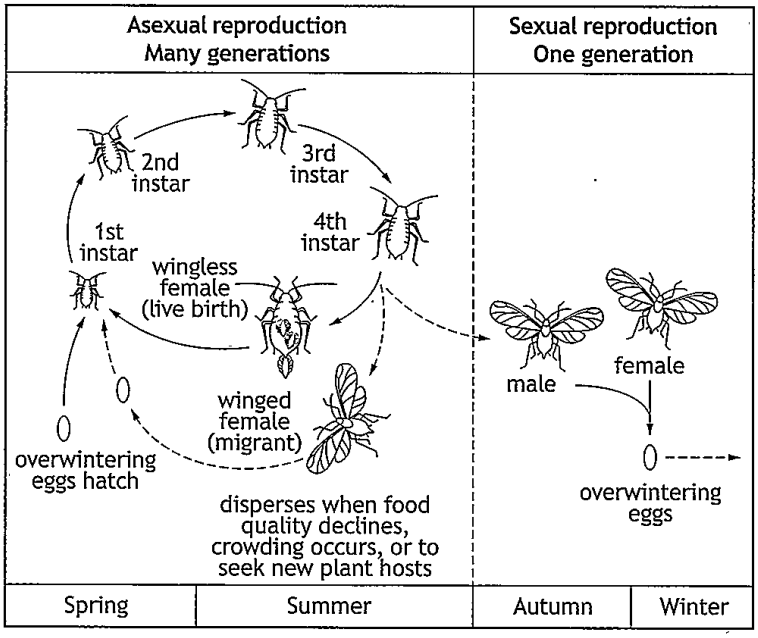
(ii) Tick (✓) the box to indicate which of the following statements is correct from the evidence shown. 1

Red deer are more closely related to reindeer than elk	
Cattle are closer relatives of fallow deer than giraffes	✓
Pere David's deer and red deer have evolved at the same rate	✓

MARKS

10. Aphids are small insects adapted to feed on plants by piercing and sucking sap from them. Many crop species are hosts of aphid species and the rapid reproduction rate of aphids represents a significant challenge to food crop production.

Aphids have complex life cycles as shown in the figure.



(a) The form of asexual reproduction carried out by aphids is called parthenogenesis.

State the meaning of the term parthenogenesis. 1

Parthenogenesis is the reproduction of female gametes without fertilisation

(b) Many invertebrates act as vectors for plant viruses.

Use the figure to explain how aphids may act as vectors for plant viruses. 1

As during summer if the food quality declines etc., the aphids become winged female (migrant) which means it can fly around and transmit plant viruses from one plant host to another.

MARKS

10. **(continued)**

The importance of aphids in food security has prompted research into how they are affected by climate change.

(c) In a study of 55 aphid species, it was found that over a period of many years all produced winged forms earlier in the year. Most species showed an increased duration of the flight season. These aphid flight trends follow trends in climate change associated with rising global temperatures.

(i) Predict with justification the effect of these trends on crop production. 1

The trends would decrease crop production as more aphids have longer flight so can have more plant hosts to infect.

(ii) Suggest one evolutionary benefit to aphid populations from increased sexual reproduction made possible by climate change. 1

sexual reproduction would increase the genetic variation of the aphid population, in this case, the increase in winged forms of aphids.

MARKS

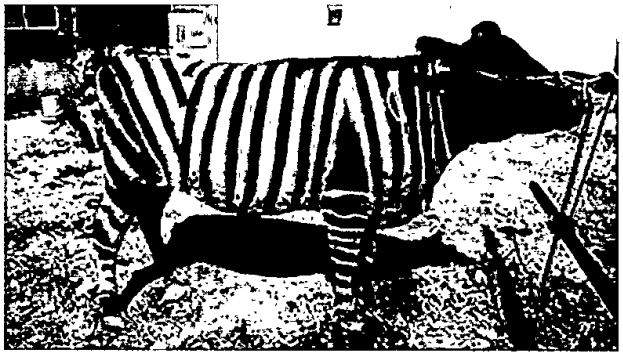
11. Several hypotheses regarding the adaptive significance of zebra stripes have been proposed. One study investigated the effect that stripes might have on biting insects. Biting flies are serious pests of many animals, affecting behaviour and productivity.

In this study, an experiment was carried out that involved painting striped patterns on Japanese Black cows. Changes in fly-repelling behaviours and the number of biting flies landing on the cows were observed.

Three cows were each subjected to three different treatments:

- Treatment 1 (BW) — painted stripes using white lacquer (4–5 cm wide)
- Treatment 2 (BB) — painted stripes using black lacquer (4–5 cm wide)
- Treatment 3 (CONT) — no painted stripes (control)

The figure shows a Japanese Black cow with white painted stripes (BW).



The researchers used a grid called a Latin Square to organise the treatments given to each cow. Each experiment lasted for 9 days and was made up of three periods, each lasting for 3 days.

Each cow experienced all three treatments over the course of the three periods. Only one cow was assigned to each treatment in one period.

(a) Use the codes **BW/BB/CONT** to complete the grid to show one way in which the treatments could have been organised as a Latin Square. **1**

	Period 1	Period 2	Period 3
Cow 1	BW	BB	CONT
Cow 2	CONT	BW	BB
Cow 3	BB	CONT	BW

MARKS

11. (continued)

(b) Explain how the experimental design contributed to minimising any ethical concerns about the study. 1

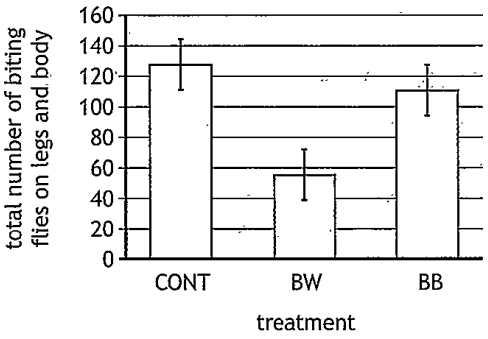
As only 3 cows were used which reduced and minimised the number of animals that were used

(c) Each cow was observed twice a day (am/pm) for 30 minutes. Photo images were used to count the number of biting flies on the body and legs.

(i) Suggest one confounding variable, other than those mentioned, that would need to be controlled in this experiment. 1

They would need to ensure that each cow was placed in the same location for all days so same light intensity + temperature

Results from the experiment are shown in the graph.



(ii) Give one conclusion about the effects of the treatments. 1

painting stripes with white lacquer

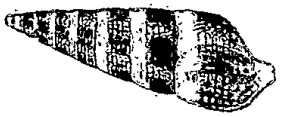
Having treatment 1 (BW) has the least number of biting flies on legs and body.

(d) Assuming that colonies of biting flies can be safely maintained in a laboratory, briefly describe a simple experiment (not using live cows) that could be carried out to check the findings of this research. 2

A box could be used instead of a cow. This boxes would undergo the same 3 treatments that are outlined above and the number of biting flies can be counted at certain intervals.

MARKS

12. *Batillaria cumingi* is a mudsnail species abundant in saltmarshes and mudflats in north-east Asia. This snail is frequently infected with trematode (flatworm) parasites such as *Cercaria batillariae*. A study was carried out to see the effect of these parasites on the growth and behaviour of the snail hosts.



Batillaria cumingi

At the principal study sites infected snails were 20–30% longer than uninfected snails, and their reproductive ability was either blocked or ended.

(a) Suggest one benefit to the parasites of the changes induced in the snails. 1

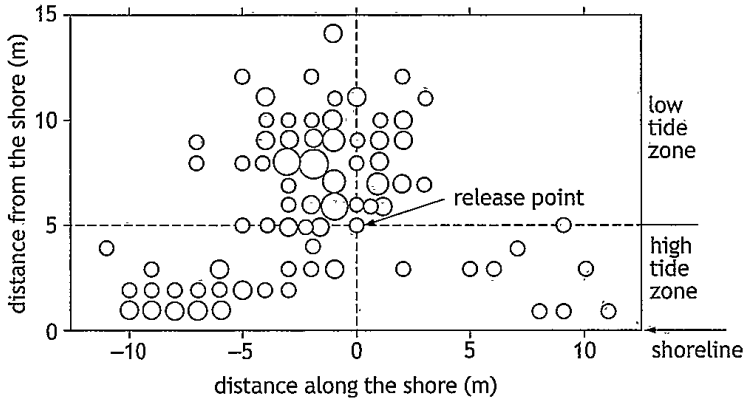
If the reproductive ability was blocked or ended, then the snails would not be able to reproduce and produce offspring with genetic variability. This means that the snails would not be able to overcome the parasitic infection.

MARKS

12. (continued)

A transplant experiment was carried out in which 200 snails, collected from both the upper and lower shores, were moved to the boundary between the upper and lower tidal zones and released. After two weeks the vertical and horizontal distances from the release point were recorded for the snails that were recaptured. All snails were examined for parasites.

Results are shown in the figure.



Key

○ uninfected snails

○ snails infected by *C. batillariae*

The area of each circle is proportional to the number of snails found at each location

(b) Use the figure to describe the effect of parasite infection on the snails' behaviour. 1

Parasite infection causes the snails to move towards to low tide zone, have a greater distance from the shore and move left along the shore line

(c) Suggest how a new ecological niche for these snails may be created by the changes in their growth and behaviour caused by this parasite. 1

As they now have a new niche which they occupy so their food and reproductive output changes. As they move to a new location, their tolerances and requirements as a species changes.

MARKS

12. (continued)

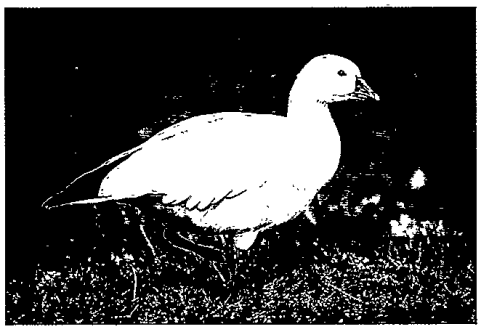
(d) The mark and recapture technique was involved in some stages of this research.

Describe how the mark and recapture technique could be used to estimate the size of a population. 3

A sample of the snails were capatured, marked (M) and released. A second sample would be captured (C) after an interval of time and if there were any individuals who were recaptured (R), then the population size would be calculated using the formula: $N = \frac{MC}{R}$.

MARKS

13. Cooke and Ryder (1971) studied the genetics of Ross's goose (*Anser rossii*). As goslings (baby geese), they have either yellow or grey feathers. Once the geese mature to adulthood, they all become white.



adult Ross's goose

g G.

In a population of geese, observers counted 274 yellow goslings and 423 grey goslings.

(a) (i) Grey is dominant (G) and yellow is recessive (g).

Use the Hardy-Weinberg principle to calculate the frequency of the homozygous dominant genotype to 2 decimal places. **1**

Space for calculation

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

$p + q = 1$

$g = \frac{274}{423}$

$= 0.65$

$p + 0.65 = 1$

$p = 0.35$

0.35

(ii) Not all goslings survive to adulthood. The Arctic skua preys upon yellow goslings more than grey goslings. It was observed that 312 grey goslings survived to adulthood, but only 121 yellow goslings survived.

An absolute fitness value of 0.8 was calculated for yellow goslings.

What does this value indicate about the frequency of this genotype? **1**

This value is less than one and indicates that the frequency of this genotype has decreased.

MARKS

13. (continued)

(b) Ross's geese form a symbiotic relationship with a nematode parasite, *Amidostomum spatulatum*.

What is meant by a symbiotic relationship? 1

A symbiotic relationship is a co-evolved intimate relationship between members of two different species.

(c) For many nemotode parasites, definitive hosts are infected through direct uptake of eggs or larvae passed from faeces of infected definitive hosts.

What is meant by a definitive host? 1

A definitive host is the organism on or in which the parasite reaches sexual maturity, i.e sexual reproduction occurs.

MARKS

14. Attempt **either A or B.** Write your answer in the space below and on *page 34.*

A Discuss animal reproduction strategies under the following headings:

(i) mating systems in animals 3

(ii) courtship and female choice. 6

OR

B Discuss changes in allele frequency under the following headings:

(i) natural selection 4

(ii) genetic drift. 5

B.(i) Natural selection acts on genetic variation in a population. Variation in traits arise as a result of mutation. Mutation is the original source of new sequences of DNA. These new sequences may be novel alleles. Most mutations are harmful or neutral but in some rare cases they may be beneficial to the fitness of an individual. Populations produce more offspring than the environment can support. Individuals with traits that are better suited to their environment tend to survive longer and produce more offspring breeding to pass on those alleles that conferred an advantage to the next generation. Selection results in the non-random increase in advantageous alleles and the non-random decrease in disadvantageous alleles.

(ii) Genetic drift occurs when chance events cause unpredictable fluctuations in allele frequencies from one generation to the next. Genetic drift is more important in small populations where alleles are more likely to be lost from the gene pool. The importance of bottleneck and founder effects to genetic drift. Population bottlenecks occur when the population size is reduced for at least one generation. The founder effects occur through the isolation of a few members of a population

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ADDITIONAL SPACE FOR ANSWER to question 14

from a larger population. The gene pool of the new population is not representative of the original population. A gene pool is altered by genetic drift because certain alleles may be over-represented and under-represented and allele frequencies change.