Model Answers: Hard

1a

a)

i) The effect of natural selection on mean hind limb length of *A. sagrei* on the seven experimental founder islands would be…

- (Mean hind limb length) will decrease / get shorter; [1 mark]

ii) Collecting individuals at random for the seven founding pairs would affect the mean hind limb length of *A. sagrei* on the different islands as follows…

- (Mean hind limb length) will vary (between the different islands); [1 mark]

[Total: 2 marks]

Both of these question parts specifically ask about the **limb length** of the lizards. Answers that describe the process of natural selection or the importance of randomness in scientific investigations will not be credited.

1b

b) The data in Fig. 3 can be described and explained as follows…

Any **five** of the following:

Description

- Limb length decreases on all of the experimental islands; [1 mark]
- Limb length remains the same on the source island; [1 mark]

Explanation in context of experimental islands

- Limb length decreases due to directional selection (on experimental islands; [1 mark]
- The (reduced) branch diameter is a selection pressure; [1 mark]
- Short hind limbs give a selective advantage / are selected for; [1 mark]
- Short hind limbs increase survival; [1 mark]
- Survivors are more likely to reproduce / pass on the alleles for short (hind) limbs; [1 mark]
- The allele for short (hind) limbs increases in frequency; [1 mark]

Explanation in context of source island

- Limb length remains the same due to stabilising selection; [1 mark]

[Total: 5 marks]

Make sure that you spend time both describing **and** explaining the results here; answers that only contain description can gain a maximum of two marks.

When explaining the process of natural selection in any context there are several points that should always be included, so make sure that you learn these and can apply them in any example presented:

- Genetic **variation** exists in a population (e.g. due to mutation)
- **Selection pressures** in the environment mean that individuals with certain alleles are **more likely to survive**
- Surviving individuals are more likely to **reproduce** and **pass on** their advantageous alleles
- The advantageous **alleles increase in frequency** in the population

1c

c) Speciation may occur on the seven experimental founder islands as follows…

Any **three** of the following:

- Allopatric (speciation would occur); [1 mark]
- The lizard populations would be geographically isolated; [1 mark]
- Different selection pressures / environmental conditions would act on the populations; [1 mark]
- Different (random) mutations would occur (in the different populations); [1 mark]
- Genetic drift (would occur); [1 mark]
- There would be no gene flow / exchange of genes between the different populations; [1 mark]
- Genetic differences would accumulate; [1 mark]

Reject *any references to selection pressures causing mutation in marking point 4.*

[Total: 3 marks]

It is essential to note that mutations occur **randomly** in populations, and then any selection pressures that are present will determine whether or not a new mutation is passed on to the next generation. Selection pressures **NEVER** cause mutations to occur.

Genetic drift is also a **random** process; alleles can be lost or passed on in a population purely **by chance** due to fact that only half an individual's genes are passed on to their offspring via their gametes. Be careful not to confuse the random process of genetic drift with the process of natural selection.

1d

d) The experimental founder populations are at high risk of extinction because...

Any **three** of the following:

- (Each island has a) small population; [1 mark]
- (Within small populations) there is low genetic diversity / a small gene pool; [1 mark]
- Inbreeding depression can occur **OR** there is low heterozygosity / high homozygosity; [1 mark]
- Environmental change / a natural disaster could kill/wipe out the entire population; [1 mark]

[Total: 3 marks]

Small populations have **low genetic diversity** due to the low total number of alleles of each gene present in the population. This increases the risk of any offspring inheriting two identical alleles from their parents (this is **homozygosity**), which can then further reduce the genetic diversity in the next generation. Inheriting two identical copies of a gene also increases the risk of inheriting **two harmful recessive alleles**, leading to the problem of **inbreeding depression**.

Populations with low genetic diversity are less likely to be able to adapt (by natural selection) to a changing environment, and are therefore more likely to be wiped out by such change, and small populations are also at greater risk of being entirely wiped out by a natural disaster.

2a

(a)

(i) The volume of a typical horse semen sample is ...

- 50 cm^3; [1 mark]

Calculation as follows:

- Each 0.5 cm^3 straw can hold 7.5×10^7 sperm cells.
- A typical sample of horse semen contains 7.5×10^9 sperm cells.

a)

i) Calculate the volume of a typical horse semen sample.

.....cm^3 [1]

ii) To inseminate one female horse, 5.0×10^8 sperm cells are needed.

Calculate the minimum number of straws needed to carry out this process.

minimum number = ... [1]

(i)

Step 1: divide the number of sperm in a horse's semen sample by the no. of sperm cells held in each straw

$\frac{7.5 \times 10^9}{7.5 \times 10^7}$ = 100 straws

Step 2: multiply the number of straws needed to contain all of a horse's semen sample by the volume of one straw.

100 × 0.5 cm^3 = 50 cm^3 [1 mark]

(ii) The minimum number of straws needed to carry out the process of inseminating one horse is...

- 7; [1 mark]

[Total: 2 marks]

Calculation as follows:

- Each 0.5 cm^3 straw can hold 7.5×10^7 sperm cells.
- A typical sample of horse semen contains 7.5×10^9 sperm cells.

a)

i) Calculate the volume of a typical horse semen sample.

.....cm^3 [1]

ii) To inseminate one female horse, 5.0×10^8 sperm cells are needed.

Calculate the minimum number of straws needed to carry out this process.

minimum number = ... [1]

(ii) Step 1:

Divide the number of sperm cells needed to inseminate a horse by the number of sperm cells held in each straw.

$\frac{5 \times 10^8}{7.5 \times 10^7} = 6.6$

Step 2: Round up to the nearest whole no. of straws

= 7 straws [1 mark]

Always reality-check your numerical answers by applying a common sense test. If your answer to a (i) works out in thousands of litres, then clearly that's a volume that is not credible when the question is asking you how much semen an animal produces, even a large animal! Similarly if you work out that a semen sample is impossibly small (say $1mm^3$) then that should make you question your maths and look for where you have made the calculation error.

2b

(b) This question can be answered as follows.

Any **four** from the following:

How this apparatus could be used to estimate the number of sperm cells per cm^3 of semen is...

- To calculate the volume of the sample; [1 mark]
    - (for mm^3) $0.25 \times 0.25 \times 0.1$ / 0.00625 / 6.25×10^{-3} mm^3

- (for cm^3) 0.025 × 0.025 × 0.01 / 0.00000625 / 6.25 × 10^{-6} cm^3

- Divide the number of sperm by the volume **and** method of converting to cm^3; [1 mark]

A description of how the technician decided which sperm cells to include in the count is…

- Count those sperm where the cells are fully inside the square / 0.0625 (mm^2) / all (small) squares / haemocytometer / quadrant / grid; [1 mark]
- To include those cells touching the (line) top and left / up and right **OR** exclude those touching bottom and right / down and left; [1 mark]

Detail of the method is…

- Dilution of the sample / stirring of the sample / evenly spreading the cells around / immobilising the sperm / use of a coverslip / use a screenshot for counting; [1 mark]

[Total: 4 marks]

2c

(c) It is necessary for the solution to contain these three substances because…

- *Sugar:* provides or gives energy / is an energy source / (is used) in respiration / (is used) to produce ATP / maintains water potential of the sample; [1 mark]
- *Buffer:* (a change in pH may) denature enzymes/proteins; [1 mark]
- *Antibiotics:* killing / stopping reproduction of bacteria (**NOT** viruses); [1 mark]

[Total: 3 marks]

Remember to avoid the frequently-held misconception that energy is made, or just to state that the sugar is for energy or for nutrition, which is not enough to earn the mark.

The fact that the buffer was added to maintain the pH was stated in the question, so repeating that will not earn you a mark. But if you do, you should then go on to explain that the buffer was to prevent the denaturing of the enzymes/proteins in the sperm.

Other misconceptions to avoid are ‘killing the enzymes’ or ‘denaturing the sperm’ and ‘protecting the sperm from acids’ as these are imprecise and factually incorrect. Also, that antibiotics kill viruses. ‘Fighting bacteria’ or ‘protecting against bacteria’ are other vague ways to fall short of the detail required to gain the marks here.

3a

a) i) The type of selection that has caused this increase is…

- Directional; [1 mark]

a) ii) There was selection for lactose persistence in humans several thousand years ago because…

Any **three** of the following:

- Lactose/milk (products) acts as a selection pressure **OR** people have reliance on milk (products); [1 mark]
- (Selective) advantage to digest lactose/milk (products) **OR** individuals with lactose persistence have a (selective) advantage; [1 mark]
- (Those individuals) more likely to survive/reproduce; [1 mark]
- They will pass on the (mutated) allele (to their offspring); [1 mark]
- Over many generations the allele frequency is increased; [1 mark]

[Total: 4 marks]

When answering questions about natural selection your answer should always follow the same template of key words and phrases, with the information from the example given in the

question being different for each question. Make sure you don't confuse key words such as gene and allele, which are not interchangeable.

3b

b) i) The frequency of allele **T** is...

- q^2 = 58÷166 **OR** 0.35; [1 mark]
- q = √0.349 **OR** 0.59; [1 mark]
- p = 0.409 **OR** 0.41; [1 mark]

The mutation which causes lactose persistence is in a regulatory gene (**T/t**).

- People with lactose intolerance have the genotype **tt**.
- People with lactose persistence have the genotypes **TT** and **Tt**.
- 166 people were tested for their genotype.
- 58 people were found to have lactose intolerance.

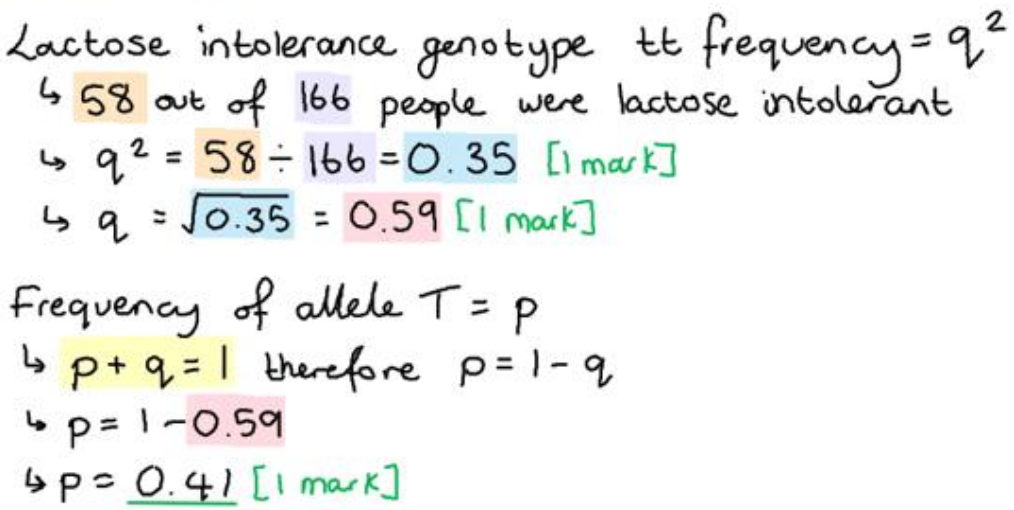
The Hardy–Weinberg principle can be used to calculate allele, genotype and phenotype frequencies in populations.

The Hardy–Weinberg equations are shown in Fig. 2.1:

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

Fig. 2.1

Calculate the frequency of allele **T**.



b) ii) Two reasons why the percentage of people with lactose intolerance was much higher in the test population than in the general population are...

Any **two** of the following:

- Test population is (too) small; [1 mark]
- Test population not representative of general population / not random / is biased; [1 mark]
- Migration / ethnic origin; [1 mark]

[Total: 5 marks]

It is incorrect to say that lactose consumption was low, because you are not taking into

account the fact that the selection would have already happened a very long time ago.

3c

c) i) Transcription factors carry out their role by...

Any **two** of the following:

- Proteins that bind to DNA; [1 mark]
- Binds to the promoter/enhancers; [1 mark]
- Control gene expression / transcription / mRNA synthesis; [1 mark]
- Allow attachment of RNA polymerase to DNA; [1 mark]

c) ii) One type of control sequence found in human DNA is...

- Promoter / enhancer / silencer / insulator; [1 mark]

c) iii) Most changes in human phenotype are due to mutations in regulatory genes because...

- Most genes are regulatory genes (in the genome); [1 mark]
- Mutations in regulatory genes less likely to be harmful/selected against/affect survival; [1 mark]

[Total: 5 marks]

Remember that most genes are regulatory, with structural genes only making up 2%.