# 17. Selection and Evolution

## 17.1 Variation

## Paper 4

Question Paper

**1** Variation exists in populations of a species and this may provide the opportunity for evolution to occur.

**(a)** Phenotypic variation exists in many forms and has a number of possible causes.

Describe the main factors that are the cause of phenotypic variation.

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..... [3]

**2** It has been hypothesised that the mutation rate of an animal species may affect how fast animals of that species age and how long they live (lifespan).

Table 7.1 compares the mutation rate and lifespan of five species of mammal.

**Table 7.1**

| species | mutation rate per million base pairs per year | mean lifespan /years |
|---|---|---|
| cattle | 0.08 | 20 |
| ferret | 0.20 | 8 |
| horse | 0.05 | 30 |
| human | 0.02 | 75 |
| house mouse | 0.28 | 3.6 |

**(a) (i)** Describe the relationship shown in Table 7.1.

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..... [1]

**3** The harlequin ladybird, *Harmonia axyridis*, is an insect that shows discontinuous variation in colour pattern and continuous variation in body size.

**(a)** Within a species, the variation that is observed for a particular characteristic can be described as discontinuous or continuous.
Discontinuous variation has a different genetic basis from continuous variation.

State **two** differences between discontinuous variation and continuous variation, **other than** having a different genetic basis.

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..... [2]

**(b)** Fig. 9.1 shows three of the colour patterns seen in *H. axyridis* and the percentage of each in a population.

| **colour pattern** |  *conspicua* |  *spectabilis* |  *succinea* |
|---|---|---|---|
| **percentage** | 5 | 13 | 82 |

**Fig. 9.1**

Suggest the genetic basis of the variation in colour pattern in *H. axyridis*.

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**(c)** The body size of adult *H. axyridis* varies from 5 mm to 8 mm. Adult ladybirds do **not** grow or change size. Adults develop from larvae that hatch from eggs.

State **two** environmental factors that may affect adult body size in *H. axyridis*.

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..... [2]

**4** Phenotypic variation exists in natural populations. There are many causes of variation. Natural selection determines which phenotypes are advantageous.

**(a)** Variation in a particular characteristic can be described as either discontinuous or continuous.

Table 5.1 contains a list of statements that apply to discontinuous variation, continuous variation or both.

Complete both columns of Table 5.1. Put a tick (✓) in the box if the statement applies and leave the box empty if the statement does not apply.

**Table 5.1**

| statement | discontinuous variation | continuous variation |
|---|---|---|
| often involves one gene only | | |
| environmental factors may affect gene expression | | |
| there is an additive effect of genes that contributes to the phenotype | | |
| there are distinct differences between the various forms of a characteristic | | |

[4]

**(b)** There is variation in the quantity of vitamin D stored in the body.

Vitamin D has an important role in keeping bones healthy. The main storage form of vitamin D in the body is serum 25-hydroxyvitamin D (serum 25-OHD).

A study was carried out on 262 healthy women to investigate if the concentration of serum 25-OHD varied between summer and winter. The women had taken no vitamin D supplements. The age range of the women in the sample was 40 to 72 years old.

Table 5.2 shows the results of the study.

**Table 5.2**

| group | mean concentration of serum 25-OHD / ng cm$^{-3}$ | standard deviation |
|---|---|---|
| sampled during summer $n$ = 138 | 32.7 | 7.6 |
| sampled during winter $n$ = 124 | 28.5 | 8.3 |
| whole sample $n$ = 262 | 30.7 | 8.2 |

Additional analysis showed that there was no significant correlation between age and serum 25-OHD concentration.

**(i)** Explain what is meant by standard deviation.

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..... [1]

**(ii)** The *t*-test was used to compare the mean concentration of serum 25-OHD when sampled during the summer with the mean concentration of serum 25-OHD when sampled during the winter, as shown in Table 5.2.

Calculate the value of *t* using the formula provided.

$$t = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

**key to symbols:**
$\bar{x}$ = mean
$s$ = sample standard deviation
$n$ = sample size (number of observations)

Give your answer to **four** significant figures.

There is space for your working.

*t*-test value ..... [3]

**(iii)** The critical value at the 0.0001 probability level is 3.773.

State the conclusion that can be made about the results of the study shown in Table 5.2 **and** explain how the result of your calculation in **(b)(ii)** can be used to support this conclusion.

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**(iv)** Suggest the likely **causes** of variation in quantity of vitamin D stored in the body in this sample of women.

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**5** **(a)** The sea blush, *Plectritis congesta*, is a flowering plant that grows on the west coast of North America.

Individual sea blush plants produce fruit that is either winged or wingless. Investigations have shown that this characteristic is controlled by a single gene with two alleles:

- a dominant winged fruit allele
- a recessive wingless fruit allele.

Fig. 3.1 shows the difference in structure between winged fruit and wingless fruit phenotypes.




**Fig. 3.1**

**(i)** A large sample of sea blush fruits was collected and their fruit-wing characteristic was recorded.

Name the type of variation that is shown for the fruit-wing characteristic of the sea blush.

..... [1]

**(ii)** Different sea blush plants can have fruit with different colours.

Suggest **two** ways in which a new fruit colour could naturally occur in a sea blush population.

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..... [2]

**6** Many factors affect the rate of cellular respiration.

**(a)** Pyruvate carboxylase (PC) deficiency is a rare disease. The rate of respiration in the cells of a person with PC deficiency is much lower than normal.

The passage describes the occurrence of PC deficiency in human populations.

Complete the passage by using the most appropriate scientific terms.

PC deficiency affects one in 250 000 people. A person either has the disease or does not, so there are no intermediate forms of the disease. PC deficiency is caused by a genetic mutation in one gene. Whether a person develops the disease is not influenced by ..... factors. The distribution of PC deficiency in human populations shows ..... variation. [2]

**7** There are more than 600 plant species in the genus *Ipomoea*. Many species are grown for their attractive flowers, and some species are used as crop plants.

**(b)** The Japanese morning glory, *I. nil*, has over 20 different flower colour phenotypes, including shades of blue, purple, red and pink.

The flower colour of *I. nil* is controlled by at least four genes. The flower colour can change gradually after the flowers open each morning and can change with fluctuations in the carbon dioxide concentration of the surrounding air.

A student concluded that the flower colour phenotype in *I. nil* shows continuous variation.

Suggest **two** reasons why the student made this conclusion.

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2 .....

..... [2]

**8** **(a)** In continuous variation, a population shows a range of phenotypes between two extremes with no distinct groups. Height and mass are examples of phenotypic traits that show continuous variation.

Describe the genetic basis for continuous variation.

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..... [3]

**(b)** Environmental factors can contribute to continuous variation.

Suggest **two** environmental factors that may affect the body mass of an animal.

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..... [2]

**9** Domestic goats are small, herbivorous animals that provide milk for human use. This is an important source of food for people in rural South Africa.

Three Northern European goat varieties (breeds) have been imported to South Africa because they have higher milk yields than the native South African goats.

Table 2.1 compares the mean daily milk yields of these three breeds of Northern European goat in three locations, Northern Europe, Barbados and South Africa.

**Table 2.1**

| goat breed | mean daily milk yield / kg in different locations | | |
|---|---|---|---|
| | **Northern Europe** | **Barbados** | **South Africa** |
| British Alpine | 4.09 | 2.55 | 0.75 |
| Saanen | 5.17 | 1.73 | 1.45 |
| Toggenburg | 4.54 | 3.46 | 0.56 |

**(a)** Native South African goats have a mean daily milk yield of 0.25 kg.

Calculate how many times greater the mean daily milk yield will be if a native South African goat is replaced by the Northern European goat breed that gives maximum yield.

Show your working and write your answer to **two** significant figures.

answer ..... [2]

**(b)** **(i)** Explain how the data in Table 2.1 support the claim that some of the variation in mean daily milk yield in goats is due to **genetic** causes.

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**10** Domestic goats are small, herbivorous animals that provide milk for human use. Goats' milk is an important source of food for people living in rural China. Xinong Saanen and Guanzhong are the names of two varieties (breeds) of goat common in China.

In these breeds, there is genetic variation at nucleotide position 5752 of a gene coding for a growth factor. At this position there is either a cytosine (C) or a guanine (G) nucleotide. Some individuals are homozygous for the allele containing C at this position (**CC**), some are homozygous for the allele containing G at this position (**GG**) and some are heterozygous (**CG**).

Table 2.1 compares the mean milk yield of the first milk-producing period (first lactation) and the next milk-producing period (second lactation) for Xinong Saanen goats of each genotype.

**Table 2.1**

| genotype at position 5752 | mean milk yield / kg | |
|---|---|---|
| | first lactation | second lactation |
| **CC** | 679 | 940 |
| **CG** | 622 | 858 |
| **GG** | 616 | 834 |

**(a) (i)** Variation in a phenotypic characteristic such as milk yield is caused by a combination of genetic and environmental factors.

Goats also show variation in milk yield between the first lactation and second lactation.

Suggest, with reasons, whether the variation in milk yield between the first lactation and second lactation, as shown in Table 2.1, is genetic or environmental.

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**11** The stickleback fish, *Gasterosteus aculeatus*, has two distinct forms, the saltwater form and the freshwater form. The larger, freshwater form is thought to have evolved from the smaller, saltwater form. Both forms have armour plating on each side of the body. The plates are made of bone and contain a high proportion of calcium.

The ectodysplasin gene, *EDA*, codes for a protein involved in the development of armour plates. The *EDA* gene has two alleles, low armour and high armour.

Three main morphs of armour plating have been described.

**Complete morph** armour plating:

- is found mainly in the saltwater form
- has many plates from head to tail to cover most of the body
- provides defence against large, predatory fish
- limits the growth of the fish.

**Partial morph** armour plating:

- is found mainly in the freshwater form
- has a reduced number of plates to cover only part of the body.

**Low morph** armour plating:

- is found mainly in the freshwater form
- has very few, undeveloped plates and no body cover.

**(a)** Explain why the variation in armour plating in stickleback fish can be described as discontinuous.

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..... [2]

**12** Steelhead trout, *Oncorhynchus mykiss*, are fish that live in streams in North America.

To increase the number of steelhead trout, captive breeding has occurred since 1992. Fish eggs and sperm are mixed and the young fish grow in large tanks of aerated water for the first year of their lives. Most are then released into the wild, however a few male and female fish are kept to become the parents of the next generation of captive-bred fish.

Each tank may hold up to 50 000 fish. The young captive fish are fed processed food. Some young fish are unable to survive these conditions and a proportion die. Death is usually the result of poor wound-healing after accidents due to overcrowding and due to the spread of diseases.

**(a) (i)** Name the expected pattern of variation in wound-healing ability in a population of fish.

..... [1]

**(ii)** Name the process that results in improved survival of captive fish in second, third and subsequent generations of captive-bred fish.

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**(b)** Suggest **and** explain **three** ways in which the tank environment may make the phenotype of a captive fish different from a wild fish.

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..... [3]

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Each tank may hold up to 50 000 fish. The young captive fish are fed processed food. Some young fish are unable to survive these conditions and a proportion die. Death is usually the result of poor wound-healing after accidents due to overcrowding and due to the spread of diseases.

**(d)** Many of the differences in gene expression between the offspring of the wild and captive-bred fish were in genes coding for proteins involved in the immune response and in genes coding for proteins involved in wound healing. The fish from captive-bred parents expressed these genes to a greater degree.

The researchers concluded that the differences were inherited and adaptive.

Explain why the researchers concluded that the differences in gene expression between the two groups of fish were:

**(i)** inherited

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..... [1]

**(ii)** adaptive.

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..... [1]

**14** The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes. Fig. 2.1 shows how IPD is measured.

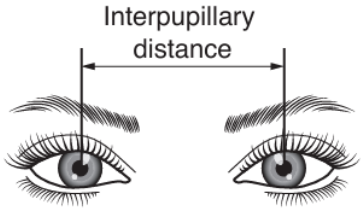



**Fig. 2.1**

IPD is one example of a characteristic of human facial structure that shows variation.

Fig. 2.2 shows the pattern of variation in IPD in a large sample of adults.

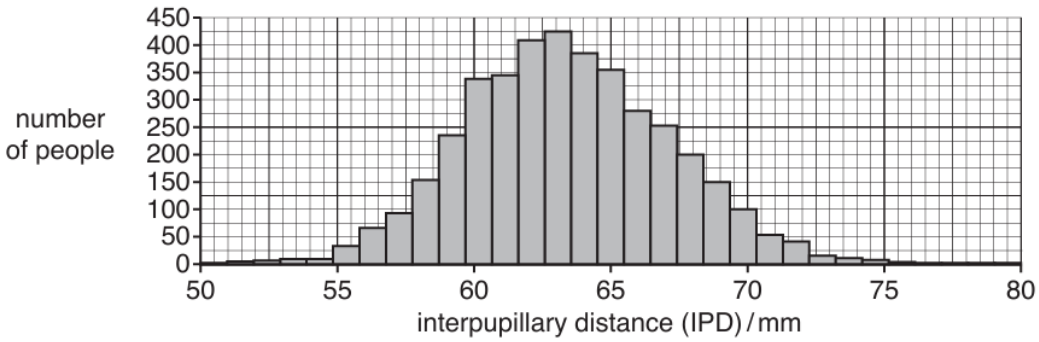



**Fig. 2.2**

**(a) (i)** Name the type of variation shown in Fig. 2.2.

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**(ii)** Suggest **and** explain how genes and the environment contribute to variation in IPD in humans.

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..... [3]

**15** Within a population, the variation for one characteristic is usually the result of genetic and environmental causes.

**(b)** Both genetic and environmental factors contribute to variation in body mass in a bird population.

One cause of variation in body mass in chickens is infection with the gut protoctist *Eimeria*. When fed with the same diet, infected chickens have a lower gain in body mass than healthy chickens in the same population.

**(i)** Suggest reasons why infected chickens have a lower gain in body mass than healthy chickens.

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.....[2]

**(ii)** Suggest **one** environmental factor that affects the growth and reproduction of *Eimeria*.

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.....[1]

**(c)** A study was carried out to investigate the effect of treating infected chickens with extracts from a plant, *Bidens pilosa*.
*B. pilosa* is used in traditional medicine for the treatment of some infectious diseases.

- Three populations, each containing 25 chickens infected with *Eimeria* were observed.
- The body mass of each chicken was measured at the start of the study.
- Each population was given a different treatment for 56 days:
  - standard diet with no *B. pilosa* extract
  - standard diet with low dose of *B. pilosa* extract
  - standard diet with high dose of *B. pilosa* extract.

- The body mass of each chicken was measured at the end of the study and the gain in body mass over the 56 days was calculated.
- The mean gain in body mass was calculated for each population.

The results are shown in Table 3.1.

**Table 3.1**

| treatment | mean gain in body mass / g |
|---|---|
| no *B. pilosa* | 1773.0 ±23.9 |
| low dose of *B. pilosa* | 2093.1 ±34.2 |
| high dose of *B. pilosa* | 2033.3 ±29.9 |

A statistical analysis of the results of the study of these three populations confirmed that there was a significant difference in mean gain in body mass between low dose *B. pilosa* and high dose *B. Pilosa* extract treatments.

**(i)** Name a statistical test that could be used to analyse the results of this study.

.....[1]

**(ii)** Sketch on Fig. 3.1 curves to show the pattern of variation for gain in body mass in chickens treated with low dose *B. pilosa* extract and in chickens treated with high dose *B. pilosa* extract.

Label one curve '**low dose**' and the other curve '**high dose**'.

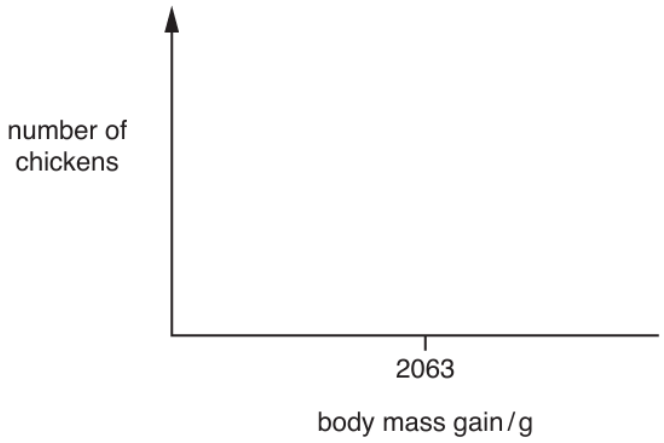



**Fig. 3.1**

[3]

**16** **(c)** The null hypothesis states there is no significant difference between the mean times for 50% of absorbed mesotrione to degrade in the two populations.

A $t$-test can be carried out to compare these two means. The critical value for $t$ at the $p = 0.05$ significance level is 2.23.

**(i)** Use the formula in Fig. 3.1 to calculate the value of $t$.

Show your working.

$$t = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

Key
$\bar{x}$ = mean
$s$ = standard deviation
$n_1$ = 6 (number of readings for test population)
$n_2$ = 6 (number of readings for control population)

**Fig. 3.1**

$t$ = ..... [2]

**(ii)** Use your calculated value of $t$ to explain whether the null hypothesis should be accepted or rejected.

*accept or reject* .....

*explanation* .....

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.....[2]