17. Selection and Evolution

17.2 Natural and Artificial Selection

Paper 4

Question Paper

1 White-clawed crayfish, *Austropotamobius pallipes*, live in rivers and lakes in Europe.
In the 1850s, the North American signal crayfish, *Pacifastacus leniusculus*, was introduced to Europe. The introduced species carried a pathogen that causes a disease known as crayfish plague. This disease kills *A. pallipes*.
Since 1850, the population size of *A. pallipes* has reduced in many areas of Europe due to the spread of crayfish plague.

(a) North American *P. leniusculus* can carry the crayfish plague pathogen without showing symptoms because they have evolved resistance to it.

Explain how *P. leniusculus* could have evolved resistance to the crayfish plague pathogen.

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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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(ii) Use Table 7.1 to explain how these species may differ in the rate at which they can adapt if environmental selection pressures change.

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(b) (i) Compare the timescales needed for selective breeding and genetic engineering to increase the frequency of a rare allele in cattle. Give a reason for your answer.

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3 Several different processes can affect allele frequencies in populations.

(a) Outline the processes that may affect allele frequencies in wildlife populations.

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(b) The process of selective breeding changes allele frequencies in a population. Plant breeders use selective breeding to improve crop plants such as maize.

Explain how selective breeding can be used to obtain a variety of maize where the plants are vigorous and of uniform height.

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4 *Spea multiplicata* is one of several species of American spadefoot toad.

(a) Young spadefoot toads are called tadpoles and live in water in ponds.

S. multiplicata tadpoles show three different phenotypes due to genetic variation. The three phenotypes are: detritus feeder, intermediate and carnivore.

Detritus feeders are small, and carnivores are large. Intermediates vary in size between the two extremes.

A detritus feeder and a carnivore are shown in Fig. 7.1.



Fig. 7.1

Detritus feeders:

- eat detritus (small pieces of dead organic matter) and algae (photosynthetic protoctists)
- have smooth mouthparts, small jaw muscles and long intestines.

Intermediates:

- can eat all available food (detritus, algae and fairy shrimps)
- have teeth-like mouthparts, medium-sized jaw muscles and medium-sized intestines.

Carnivores:

- eat fairy shrimps and other small animals
- have teeth-like mouthparts, large jaw muscles and short intestines.

Scientists counted the number of each type of tadpole in two different ponds: pond 1 and pond 2.

(i) In pond 1, the scientists observed:

- a high density of tadpoles
- a low abundance of food
- that most of the tadpoles they counted were either detritus feeders or carnivores, with very few intermediates present.

Describe **and** suggest explanations for the type of natural selection that appears to be acting in pond 1.

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(ii) In pond 2, the scientists observed:

- a low density of tadpoles
- sufficient food availability for all tadpoles
- that most of the tadpoles they counted were intermediates, with fewer detritus feeders or carnivores.

Describe **and** suggest explanations for the type of natural selection that appears to be acting in pond 2.

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5 **(b)** Natural selection occurs in populations, such as in populations of sea blush plants.

Explain why natural selection occurs in populations.

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6 **(a)** Warfarin is a poison used to kill rats. Some rats are resistant to warfarin and can survive the effects of the poison. Warfarin resistance is due to a mutant dominant allele at a single gene locus.

Researchers investigated the population of brown rats on a large island where there are no predators of rats. On this island, warfarin is used to try to control the rat population.

The researchers found that 40% of the population of rats was resistant to warfarin.

(i) Use Hardy–Weinberg equation 1 and equation 2 to calculate the percentage of the population of rats on the island that is heterozygous for warfarin resistance.

equation 1 $p + q = 1$

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

Show your working.

answer ..... % [3]

(ii) In natural populations, it is usual to find that only some of the conditions of the Hardy–Weinberg principle are met.

Suggest **and** explain which of the conditions of the Hardy–Weinberg principle are most likely to be met for the island population of brown rats.

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(b) Dominant advantageous alleles and recessive advantageous alleles both naturally occur in populations.

Explain why, when a new **dominant** advantageous allele occurs, its frequency increases more quickly in the population than when a new **recessive** advantageous allele occurs.

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7 *Oryza* is a genus of grass plants that includes the rice, *Oryza sativa*, a food crop.

(a) Farmers flood fields of rice because this encourages faster growth and higher yields.

(iii) Another adaptation in some varieties of rice is the fast growth of stems.

Describe how selective breeding could produce varieties of rice with fast-growing stems.

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8 Research suggests that selective breeding began about 10 000 years ago. Selective breeding has been important in satisfying the global demand for food.

(a) The introduction of disease resistance to varieties of wheat is an example of selective breeding.

Outline the steps involved in the introduction of disease resistance to varieties of wheat.

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(b) Suggest **two** possible disadvantages of selective breeding.

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9 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.

(a) Fig. 3.1 shows *Ipomoea purpurea*, the common morning glory.



Fig. 3.1

The gene that determines flower colour in *I. purpurea* has two alleles:

- a dominant allele that results in purple flowers
- a recessive allele that results in red flowers.

A student recorded the flower colour of all the *I. purpurea* plants in a field.

The student recorded 660 plants with purple flowers and 440 plants with red flowers.

Assuming the Hardy-Weinberg principle applies to this population, calculate the number of plants in the field that are heterozygous.

Use the equations:

$p + q = 1$

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

Show your working and give your answer to the nearest whole number.

number of heterozygous plants ..... [3]

10 Biodiversity can be assessed at three different levels. One of these is the genetic variation within each species.

(d) Genetic variation is considered important in the conservation of species. Low genetic variation is assumed to decrease the chance of the long-term survival of a species.

(i) Give reasons why low genetic variation may decrease the long-term survival of a species.

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11 Green lacewings are a family of insects with more than 1300 species.

The common green lacewing, *Chrysoperla carnea*, is shown in Fig. 9.1.

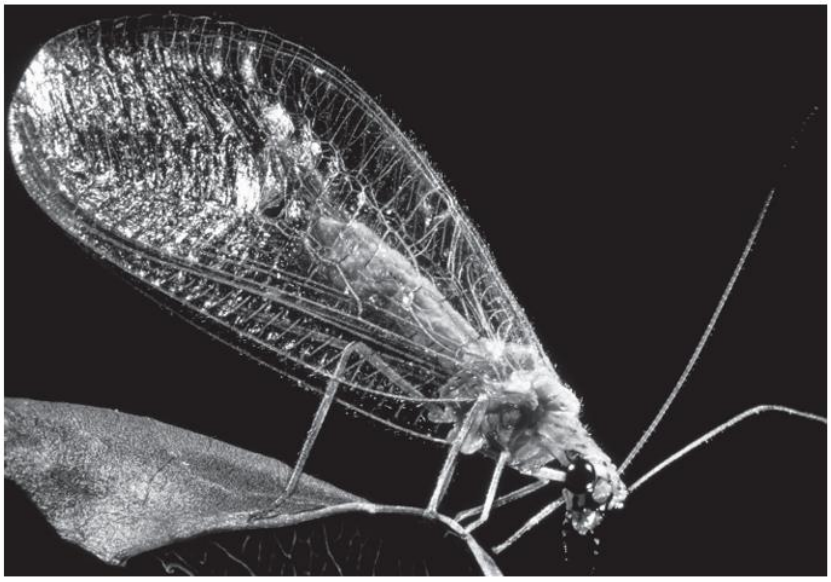


Fig. 9.1

(a) Green lacewings have sense organs, known as tympanal organs, that detect sound.

The tympanal organ of green lacewings has evolved to detect the high frequency sounds that bats make when they are hunting. Bats eat green lacewings.

When a green lacewing senses the presence of a bat, it moves away or closes its wings in flight to escape.

(i) Outline how the tympanal organ of green lacewings could have evolved by natural selection.

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12 Selective breeding has been used to improve the characteristics of crop plants, including maize and rice.

(a) Outline how vigorous, uniform varieties of maize were developed by selective breeding.

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(b) IR8 is a variety of rice plant that was developed in the 1960s.

IR8 was developed by breeding together two different varieties of rice:

- PETA, which produces a high yield
- DGWG, which is a dwarf variety.

Fig. 6.1 is a diagram showing the three varieties of rice.

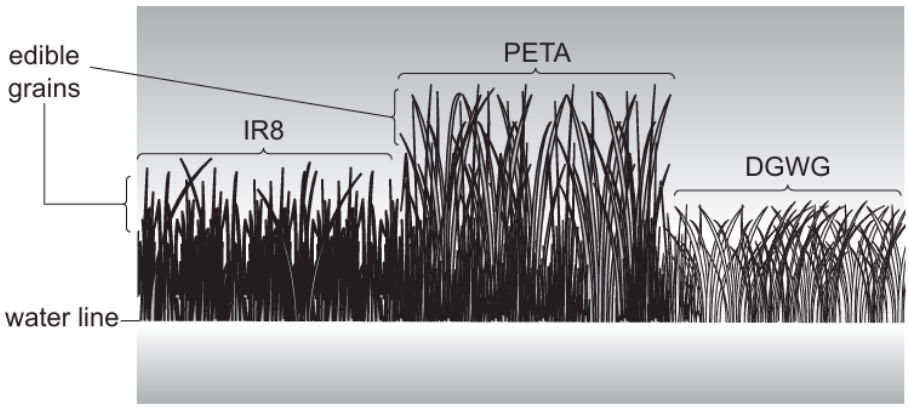


Fig. 6.1

(i) Suggest why IR8 is an improvement on the PETA variety of rice.

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(ii) In 2009, scientists produced a new variety of rice, IR64-Sub1, by breeding together:

- FR13A, a variety which has a low yield but has an allele for flood tolerance
- IR64, a variety which produces a high yield.

The scientists sequenced the DNA of these three rice varieties.

Suggest the benefit of sequencing the DNA of IR64-Sub1.

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(iii) After a few generations of breeding, the scientists crossed IR64-Sub1 with IR64.

Explain why the scientists crossed IR64-Sub1 with IR64.

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13 **(a)** The golden mantella, *Mantella aurantiaca*, is a small terrestrial frog found in Madagascar.

Fig. 1.1 shows a golden mantella.



Fig. 1.1

(ii) The skin of the golden mantella is brightly coloured and contains a toxin.

Suggest a benefit to the frog of being brightly coloured.

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14 Two subspecies of reindeer, *Rangifer tarandus*, live in North America. Members of the different subspecies belong to the same species but have some morphological differences and are found in different geographical locations.

Fig. 5.1 shows a reindeer.



Fig. 5.1

Table 5.1 compares the features of the two North American reindeer subspecies.

Table 5.1

feature	**woodland subspecies, *R. tarandus caribou***	**barren ground subspecies, *R. tarandus groenlandicus***
habitat	southern woodland (warmer)	northern tundra (colder)
type of food	tree leaves, grass	lichens, moss
summer and winter feeding grounds overlap	yes	no
carry out long migrations	no	yes
body size	large	small
colour of fur	dark	light

(b) Assess the relative importance of natural selection and genetic drift in producing:

(i) the different colours of fur of the two subspecies of reindeer

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(ii) the different body sizes of the two subspecies of reindeer.

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(c) Hybridisation has occurred between individuals of the two subspecies which now live in the area previously covered by the ice sheet.

Comment on how the hybrid populations compare to the pure subspecies in terms of genetic variation and potential to adapt to climate change.

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15 Bison are a type of large wild cattle. Ancestors of modern bison appeared in Asia 2.5 million years ago. This ancestral bison species increased its range into Europe and North America.

While the ancestral species is now extinct, its descendants include *Bison bonasus*, the European bison, and *Bison bison*, the American bison.

Fig. 5.1 shows an American bison.



Fig. 5.1

(b) Table 5.1 compares features of European bison and American bison.

Table 5.1

feature	European bison, *B. bonasus*	American bison, *B. bison*
type of food	grass and higher vegetation such as leaves of bushes and trees	grass and low vegetation
height / m	2.1	2.0
maximum mass / kg	1000	1270

Assess the relative importance of natural selection and genetic drift in producing the different heights and masses of the two species of bison.

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16 **(c)** Humans have used selective breeding (artificial selection) for thousands of years to improve the quality of livestock.

Outline the principles of selective breeding in livestock.

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17 **(a)** Humans use selective breeding to improve the features of crop plants and domestic animals.

(i) State another term for selective breeding.

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(ii) Describe how selective breeding can be used to improve the milk yield of dairy cattle.

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(b) Explain what is meant by disruptive selection.

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18 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

(c) Native South African goats are better adapted to the local conditions in South Africa than a Northern European breed, such as the Saanen. However Saanen goats have the potential for very high milk yield.

Outline a programme of selective breeding that could produce a goat with a high milk yield that is adapted to the local conditions in South Africa.

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19 Sickle cell anaemia is a non-infectious chronic disease. If not treated, sickle cell anaemia can be painful and life-threatening.

Sickle cell anaemia is caused by a base substitution mutation in the gene coding for the β-globin polypeptide of haemoglobin. This leads to a change in the primary structure of the polypeptide, as valine is present instead of glutamine. This results in abnormal sickle-shaped red blood cells, which stick together in blood vessels.

Symptoms of sickle cell anaemia include painful attacks when red blood cells block capillaries in tissues and organs.

(c) The number of cases of sickle cell anaemia is highest in sub-Saharan Africa, the Middle East and India. These areas also have a high incidence of malaria.

People with SCT (heterozygotes) are either unaffected or may have mild symptoms of sickle cell anaemia. One advantage of SCT is an increased resistance to malaria.

(i) Explain how natural selection operates to maintain the presence of the sickle cell allele in populations in areas with malaria.

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20 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

(b) In a population of 268 Xinong Saanen goats:
- the frequency of the **C** allele (q) is 0.30
- the frequency of the **G** allele (p) is 0.70.

The Hardy-Weinberg principle can be used to predict the number of goats with **CC**, **CG** and **GG** genotypes in the population, using the equation:

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

For example, the number of goats with genotype **GG** can be predicted to be 131.

(i) Use the Hardy-Weinberg principle to predict the number of goats with genotypes **CC** and **CG** in this population of Xinong Saanen goats.

number of goats with genotype **CC** .....

number of goats with genotype **CG** .....

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Table 2.2 shows the **actual** number of goats with each genotype in a population of Xinong Saanen goats and in a population of Guanzhong goats.

Table 2.2

population	total number of goats	number of goats of each genotype			allele frequency	
		CC	CG	GG	*p*	*q*
Xinong Saanen	268	22	116	130	0.70	0.30
Guanzhong	440	47	69	324	0.81	0.19

(ii) A close match between your predicted figures in **(b)(i)** and the actual numbers in Table 2.2 would mean that the Xinong Saanen population is in Hardy-Weinberg equilibrium.

State the name of a statistical test that could be used to find out whether or not the Xinong Saanen population is in Hardy-Weinberg equilibrium.

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(iii) The **predicted** numbers of goats with each genotype in the Guanzhong population according to the Hardy-Weinberg principle are:

- **CC** = 16
- **CG** = 135
- **GG** = 289.

These figures are significantly different from the actual figures in Table 2.2.

With reference to Table 2.2, describe the evidence that shows that the Guanzhong population is **not** in Hardy-Weinberg equilibrium **and** suggest reasons for this.

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21 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.

(b) In 1982, at Loberg Lake in Southern Alaska, the entire freshwater stickleback fish population was accidentally destroyed by humans.

In 1990, a new population of stickleback fish was found in the lake. Most of these fish had armour plates from head to tail on each side.

Suggest why these new stickleback fish have armour plates from head to tail on each side, despite living in freshwater.

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(c) From 1990, annual sampling took place in the lake.

Each year showed a reduction in the number of individuals with complete morph armour plating (from head to tail on each side). This change took place in a relatively short period of time.

- In 1990, 96% of the stickleback fish population had complete morph armour plating.
- In 1993, 39% of the stickleback fish population had complete morph armour plating.

Explain how natural selection has occurred in this new stickleback fish population.

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22 Oculocutaneous albinism (OCA) is a type of albinism. There are many different forms of OCA.

OCA1A is one form of OCA, caused by a recessive mutation in the autosomal gene, *TYR*, coding for the enzyme tyrosinase. This enzyme is involved in the biosynthetic pathway that results in the production of melanin, the pigment responsible for the colour of hair, skin and eyes.

A person with OCA1A has white hair, very pale skin and pink eye colour.

(c) Worldwide, 1 in 17 000 people are born with OCA. This compares with 1 in 165 people among the Guna people of Panama. The Guna people of Panama have a small population and mostly live on many small islands off the coast of Panama.

Suggest reasons why the Guna population of Panama has a relatively high number of cases of OCA.

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23 Researchers investigated the extent to which the founder effect and natural selection affected evolutionary change.

Fig. 5.1 shows the brown anole lizard, *Anolis sagrei*. These lizards live on a number of Caribbean islands and feed on a variety of invertebrates and other small animals.



Fig. 5.1

A. sagrei spends a lot of time perching (resting) on, or moving along, branches of shrubs and trees. The width of the branch that *A. sagrei* perches on is known as the perch diameter, as labelled in Fig. 5.1.

There is a positive correlation between perch diameter and hind limb length of *A. sagrei*.
- Longer hind limbs allow *A. sagrei* to run faster on vegetation with a larger diameter.
- Shorter hind limbs are needed to provide stability on vegetation of a smaller diameter.

In 2004, a hurricane caused the death of all the *A. sagrei* lizards on seven islands.

In 2005, the researchers randomly collected seven male and seven female lizards from a source population on a nearby island. For each of the seven islands affected by the hurricane, a male and female lizard were mated and placed on each island. These islands formed the experimental founder islands where new populations of *A. sagrei* were successfully established from each founding pair.

Fig. 5.2 shows the difference in vegetation between the source island and the seven experimental founder islands.



Fig. 5.2

(a) **(i)** Predict the effect of natural selection on mean hind limb length of *A. sagrei* on the seven experimental founder islands.

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(ii) Predict how collecting individuals **at random** for the seven founding pairs affects the mean hind limb length of *A. sagrei* on the different islands.

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(b) Many generations of *A. sagrei* were produced over the four years after the introduction of the founding pairs.

Fig. 5.3 shows how the mean hind limb length of *A. sagrei* changed on the seven experimental islands and on the source island.

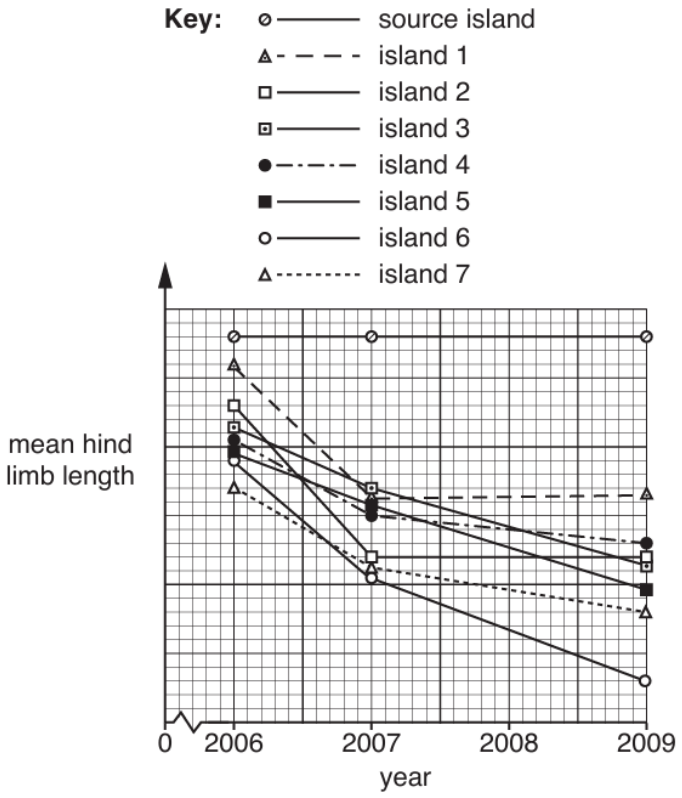


Fig. 5.3

With reference to Fig. 5.2 and Fig. 5.3, describe **and** suggest explanations for the results for the islands.

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(d) Speciation is one possible outcome for the experimental founder populations, but there is also a high risk that they may become extinct.

Explain why the experimental founder populations are at high risk of extinction.

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24 Adult *Drosophila* fruit flies feed on yeasts on the surface of ripe fruits. Female flies lay their eggs inside the fruit and the larvae feed inside the fruit before developing into adults.

The tree *Morinda citrifolia* produces fruits called noni fruits. Noni fruits contain a toxin and are avoided by nearly all *Drosophila* species, including *Drosophila yakuba* in mainland Africa.

One population of *D. yakuba* lives on the island of Mayotte off the coast of Africa. The population of *D. yakuba* on Mayotte has specialised to feed on noni fruit. Flies of this population produce enzymes that give them resistance to the toxin in noni fruits. Adults are able to feed on yeasts on the fruit surface and their eggs and larvae can develop and grow inside the fruit.

Scientists have used bioinformatics to estimate that the unique *D. yakuba* population on Mayotte originated in the last 30 000 years.

(a) Describe how a population of *Drosophila* can develop resistance to noni fruit toxin.

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25 Scientists have found very little evolutionary change in populations of two Australian songbirds, the zebra finch, *Taeniopygia guttata castanotis*, and the budgerigar, *Melopsittacus undulatus*.

(a) Describe the process of evolution by natural selection.

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(b) The number of eggs a bird lays in its nest is called the clutch size.

The variation in clutch size was investigated in the zebra finch over several years.

The data are shown in Fig. 2.1.

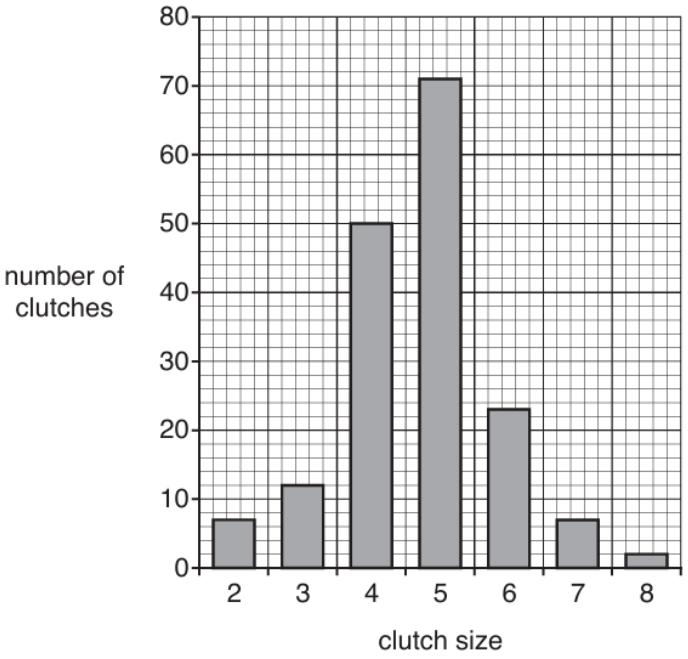


Fig. 2.1

(i) Describe the pattern shown by the data in Fig. 2.1.

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(ii) The data in this investigation were collected over 60 years ago.

The same investigation, carried out today, would produce the same pattern of results.

Explain how the selection factors acting on zebra finches would maintain the same pattern of results.

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(c) The Hardy–Weinberg principle is used to calculate allele, genotype and phenotype frequencies in populations.

- A breeder of birds keeps a population of 86 budgerigars in one enclosed area.
- Two distinct phenotypes are present, blue feathers and green feathers.
- Feather colour is controlled by one gene:
  - **G** is the allele for green feathers
  - **g** is the allele for blue feathers.
- Only 17 of the budgerigars have blue feathers.

(i) The Hardy–Weinberg equations are shown in Fig. 2.2.

$$p + q = 1$$

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

Fig. 2.2

Calculate the number of heterozygous individuals in the population.

Show your working.

number = ...[3]

(ii) The Hardy–Weinberg principle cannot be applied to all populations.

State **two** conditions when the Hardy–Weinberg principle **cannot** be applied.

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26 The Bali starling, *Leucopsar rothschildi*, is found on the island of Bali, Indonesia.

Fig. 1.1 shows a Bali starling.



Fig. 1.1

(b) Explain the consequences on genetic biodiversity of having a wild population of just six birds.

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