1. Nov/2019/Paper_41/No.2

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]

(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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[Total: 8]

2. Nov/2019/Paper_41/No.6

The genus *Heliconius* contains more than 40 species of brightly patterned butterflies.

Researchers have investigated in the laboratory how one species, *Heliconius heurippa*, could have developed as a separate species. The phenotype of *H. heurippa* is intermediate between that of two other species, *H. cydno* and *H. melpomene*.

Laboratory breeding experiments showed that:

- matings between *H. cydno* and *H. melpomene* (parent species) produce fertile hybrid offspring
- controlled matings of the hybrids produces individuals identical in appearance to *H. heurippa* within three generations
- hybrid butterflies prefer to mate with each other, rather than with individuals of either of the parent species.

The researchers concluded that the *H. heurippa* species could contain DNA from the two parent species as a result of hybridisation.

(a) **(i)** Suggest, with reasons, **one** prediction that can be made about the chromosome numbers of *H. cydno* and *H. melpomene*.

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(ii) The researchers thought that, because the hybrid butterflies preferred to mate with each other, this could make speciation more likely to occur.

Give reasons why the researchers thought that this made speciation more likely.

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(b) *Heliconius* butterflies taste unpleasant to predators such as birds. The bright colours on the wings of the butterflies act as warnings so that birds avoid eating them.

Individual birds have to learn which patterns to avoid. If one *Heliconius* species is abundant, or if it has a pattern shared with another similar species, predators learn to avoid this pattern faster. Therefore this pattern provides a selective advantage.

In the wild, *Heliconius* hybrids occur in small numbers and have patterns that do not resemble the established warning pattern of either parent species. These hybrids have a selective disadvantage.

This is an example of a post-zygotic isolating mechanism.

Explain how selection against hybrids can act as a post-zygotic isolating mechanism.

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[Total: 8]

3. Nov/2019/Paper_42/No.2

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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(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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[Total: 8]

4. Nov/2019/Paper_42/No.6

The genus *Heliconius* contains more than 40 species of brightly patterned butterflies.

Researchers have investigated in the laboratory how one species, *Heliconius heurippa*, could have developed as a separate species. The phenotype of *H. heurippa* is intermediate between that of two other species, *H. cydno* and *H. melpomene*.

Laboratory breeding experiments showed that:

- matings between *H. cydno* and *H. melpomene* (parent species) produce fertile hybrid offspring
- controlled matings of the hybrids produces individuals identical in appearance to *H. heurippa* within three generations
- hybrid butterflies prefer to mate with each other, rather than with individuals of either of the parent species.

The researchers concluded that the *H. heurippa* species could contain DNA from the two parent species as a result of hybridisation.

(a) **(i)** Suggest, with reasons, **one** prediction that can be made about the chromosome numbers of *H. cydno* and *H. melpomene*.

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.... [2]

(ii) The researchers thought that, because the hybrid butterflies preferred to mate with each other, this could make speciation more likely to occur.

Give reasons why the researchers thought that this made speciation more likely.

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(b) *Heliconius* butterflies taste unpleasant to predators such as birds. The bright colours on the wings of the butterflies act as warnings so that birds avoid eating them.

Individual birds have to learn which patterns to avoid. If one *Heliconius* species is abundant, or if it has a pattern shared with another similar species, predators learn to avoid this pattern faster. Therefore this pattern provides a selective advantage.

In the wild, *Heliconius* hybrids occur in small numbers and have patterns that do not resemble the established warning pattern of either parent species. These hybrids have a selective disadvantage.

This is an example of a post-zygotic isolating mechanism.

Explain how selection against hybrids can act as a post-zygotic isolating mechanism.

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[Total: 8]

5. Nov/2019/Paper_43/No.4

A 28-year study of Magellanic penguins, *Spheniscus magellanicus*, found in Argentina, provides evidence of natural selection.
Magellanic penguins lay their eggs in nests. They use their bills (beaks) to catch prey and feed their chicks (offspring) in the nest. Each breeding pair of penguins uses the same nest each year.

A Magellanic penguin is shown in Fig. 4.1.

Fig. 4.1

- Data were collected for bill size every year from 1983 to 2010.
- Bill size was calculated using the length and depth of the bill.
- Bill size showed variation between the individuals.
- In 1983 all the penguins in one area were tagged.
- All tagged penguins were measured each year and their new chicks were tagged and measured.
- For each year of the study, an estimate of food availability was made.
- A statistical analysis was conducted to quantify whether selection had taken place.

(a) Explain why bill size is an example of continuous variation.

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.... [2]

(b) Statistical analysis of the data showed that selection was **not** significant in most years of the study. However, a significant increase in bill size occurred in four years of the study.

(i) Name the type of selection that occurred in these four years.

.... [1]

(ii) In these same four years, food availability was low.

Explain how the data for bill size and food availability supports the idea of the 'struggle for existence' seen in natural selection.

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(c) Further investigation showed that, in some years, larger bill sizes of adult males correlated with higher reproductive success.

Reproductive success was measured by the number of chicks that survived per adult each year.

Suggest why larger bill size of adult males correlated with higher reproductive success.

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[Total: 6]

6. Nov/2019/Paper_43/No.5

Mimulus is a plant genus containing a diverse range of species that have colourful flowers to attract pollinators, such as bees and hummingbirds. Pollinators transfer pollen between flowers for plant sexual reproduction.

Table 5.1 compares some features of two closely-related species of *Mimulus* that both grow in the same region of North America.

The features in which they differ are:

- the altitude at which the two species grow
- their flower characteristics, including petal colour and the distance from the opening of the flower to the nectar on which the pollinators feed
- the percentages of pollinator visits that they receive from bees or from hummingbirds.

Table 5.1

species of *Mimulus*	altitude / m	petal colour	distance to nectar / mm	percentage of visits from pollinator type	
				bee	hummingbird
M. lewisii	1600 – 3000	pink	14	100	0
M. cardinalis	0 – 2000	red	27	3	97

(a) With reference to the data in Table 5.1, explain the isolating mechanisms that prevent gene flow between *M. lewisii* and *M. cardinalis* populations.

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(b) Breeding experiments in the laboratory show that *M. lewisii* and *M. cardinalis* can breed together and produce offspring. The F1 hybrid offspring are fertile.

(i) Suggest, with reasons, what prediction can be made about the chromosome numbers of *M. lewisii* and *M. cardinalis*.

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.... [2]

(ii) The F1 hybrids produce 50% fewer seeds than either of the two parent species.

Explain how the reduced production of seeds by the inter-species (F1) hybrids can act as a post-zygotic isolating mechanism.

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.... [2]

[Total: 9]

7. June/2019/Paper_41/No.3(b, c)

(b) *PINK1* codes for a protein kinase enzyme that is important in the functioning of mitochondria in neurones.

Most recessive *PINK1* mutations are base substitutions which lead to the production of a non-functioning protein kinase enzyme.

Explain how a base substitution mutation can lead to the production of a non-functioning protein kinase.

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(c) One rare, dominant mutation of the *PINK1* gene codes for a product that inhibits the normal protein kinase.

Explain how this mutation causes EOPD in a heterozygote.

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8. June/2019/Paper_41/No.5

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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.... [1]

(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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.... [1]

(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.

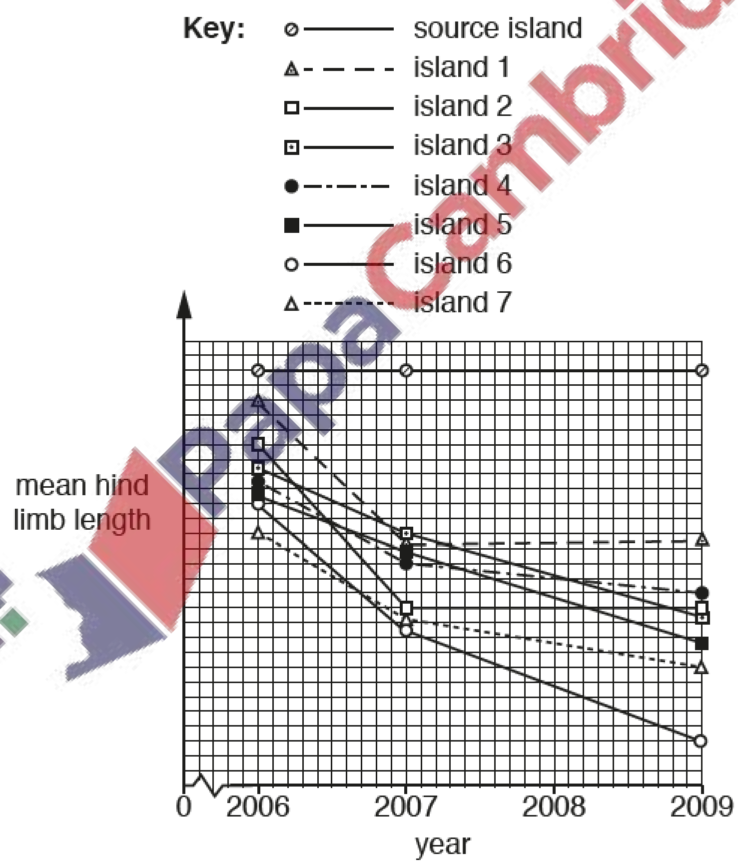

Fig. 5.3

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

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(c) In the investigation, one population of *A. sagrei* was established on each experimental founder island.

Outline how speciation may occur on the seven experimental founder 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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[Total: 13]

9. June/2019/Paper_42/No.6

(a) State the general theory of evolution.

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(b) Different types of organism have evolved different structures containing light receptors. Eyes are organs containing light receptors.

Fig. 6.1 describes the light receptors of several types of organism.

Euglena (a single-celled eukaryote) has a simple eyespot that can only detect the intensity and direction of light.
Turbellarian flatworms have cup-shaped eyes, each with a layer of light receptor cells. They can detect the intensity and direction of light better than *Euglena*. They also detect movement.
The mollusc *Nautilus* has eyes with deeper cups and narrower openings for light to enter. They can form a rough image, see shapes and detect the direction of light better than turbellarian flatworms.
The mollusc *Nucella* has eyes with lenses made of jelly. They can form a more detailed image than the eyes of *Nautilus* and can focus light to a small degree.
Mammals have eyes that are more complex than *Nucella*. They have a fixed lens (the cornea) that bends light and a lens that can change shape to focus on objects at different distances. The lenses focus light onto a deeply cup-shaped layer of light receptor cells. The eyes form a very detailed image.

Fig. 6.1

Using the information in Fig. 6.1, suggest how a complex eye such as that of mammals could have evolved in successive stages.

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(c) Octopuses are molluscs that have eyes very similar to those of mammals.

Octopuses and mammals are not closely related.

Octopuses and mammals have lenses that can change shape to focus on objects at different distances.

Suggest reasons why octopuses and mammals have evolved similar eye structures.

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(d) Molecular evidence is used to investigate evolution. One study involved a marine worm, *Platynereis dumerilii*, that still has characteristics similar to its ancestors from 600 million years ago.

Researchers sequenced all the proteins in light receptor cells of *P. dumerilii* and humans. The results showed that there are many similarities between the protein sequences of *P. dumerilii* and humans, particularly in the light-detecting protein opsin.

(i) State what this molecular evidence indicates about the evolutionary origins of *P. dumerilii* and humans.

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.... [1]

(ii) Explain how amino acid sequences indicate how close the relationship is between two species.

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.... [2]

[Total: 10]

10. June/2019/Paper_42/No.10(b)

(b) Explain how speciation may occur as a result of geographical separation. [7]

11. June/2019/Paper_43/No.3

The cilia of ciliated epithelial cells show variation in length, within an individual and between different individuals.

Samples of ciliated epithelial tissue were removed from the airways of healthy people and the mean cilia length for each individual was calculated.

The people in the study formed two groups:

- people who were exposed to a harmful environmental factor
- people who were **not** exposed to a harmful environmental factor.

The results are shown in Fig. 3.1.

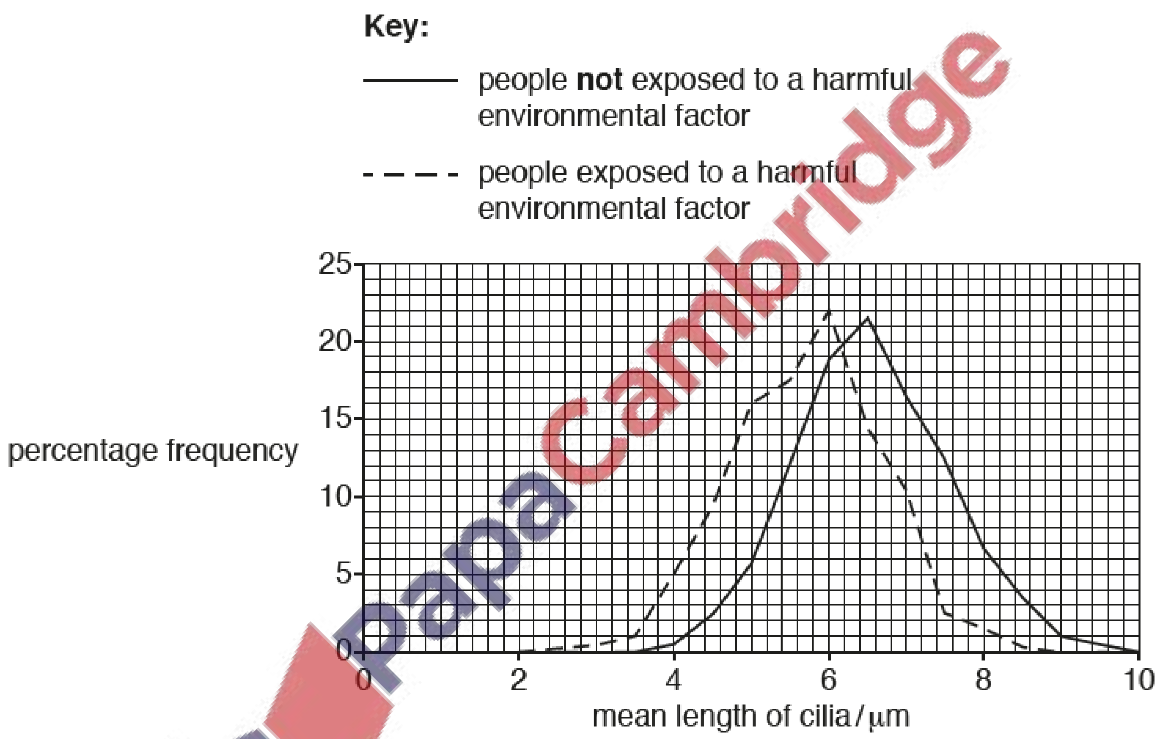

Fig. 3.1

(a) **(i)** Name the type of variation shown for mean cilia length in each group of people in Fig. 3.1.

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(ii) Suggest **two** harmful environmental factors that people might have been exposed to that could explain the difference between the two curves in Fig. 3.1.

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(b) The development and final length of cilia of epithelial cells is controlled by many genes.

Fig. 3.2 summarises the interactions of some of these genes. The arrows represent the genes being switched on.

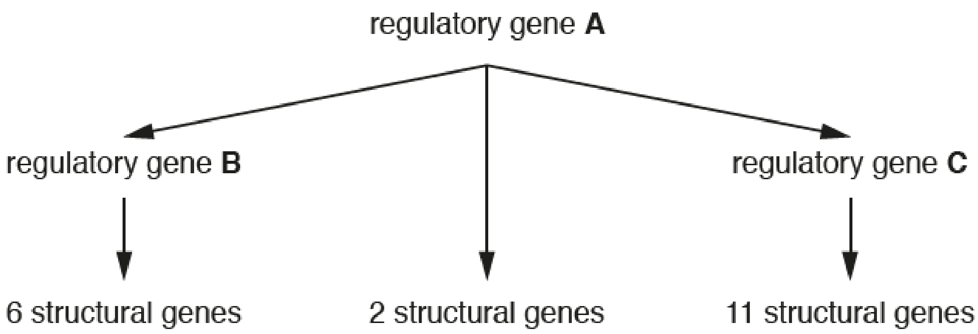

Fig. 3.2

(i) With reference to Fig. 3.2, explain how genes such as **A**, **B** and **C** are able to switch on other genes.

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(ii) Describe how microarray analysis can be used to identify the genes switched on by the product of gene **C**.

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.... [5]

(c) Microarray analysis has shown that ciliated epithelial cells and other epithelial cells in the airways express genes that code for receptor proteins on cell surface membranes. These receptor proteins detect specific chemicals.

When the receptor proteins bind to specific chemicals, this causes coughing, constriction of the airways and an increase in cilia activity. In people who have asthma, the response can be severe and life-threatening.

Suggest how knowledge of the genes for these receptor proteins could help in the treatment of asthma.

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[Total: 15]

12. June/2019/Paper_43/No.6

(a) Regressive evolution is a change in a population over time that involves the **loss** of certain phenotypic characteristics. It is thought to be caused by either genetic drift or natural selection.

An example of regressive evolution is the loss of eyes in one form of the Mexican cavefish, *Astyanax mexicanus*. These eyeless cavefish live in caves that are in total darkness.

There are three theories to explain how the loss of eyes in the cavefish has occurred.

Theory A
There is no advantage to having eyes in a cave that is in total darkness, where energy sources are scarce. Having eyes is a disadvantage as there may be an energy cost.

Theory B
A mutation has occurred in a single gene. This mutation has two effects:

- a lack of eye development
- an increase in the number of chemoreceptors on the skin.

Theory C
Various mutations occurred in the genes responsible for eye development over a period of time. By chance, these mutations increased in frequency in small isolated populations. Eventually this produced a population of eyeless cavefish.

(i) State **one** theory, **A**, **B** or **C**, which describes genetic drift as the cause of loss of eyes.

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(ii) State **and** explain which theory or theories are based on natural selection as the cause of loss of eyes.

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.... [4]

(b) There are several separate populations of eyeless *A. mexicanus* in different caves.

There are populations of *A. mexicanus* that spend time in areas with light and the fish in these populations have eyes.

The mitochondrial DNA (mtDNA) of eyeless *A. mexicanus* was compared to the mtDNA of *A. mexicanus* with eyes.

(i) Suggest how DNA evidence can help find out whether the eyeless *A. mexicanus* and the *A. mexicanus* with eyes are the same species or different species.

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.... [2]

(ii) Suggest why mtDNA is used instead of nuclear DNA when studying the closeness of the relationship between populations.

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.... [3]

[Total: 10]

13. Feb/2019/Paper_42/No.3(b, c)

(b) Transcription factors are proteins. Genes that code for proteins can become mutated.

Describe how different types of gene mutation can cause changes in the protein that is synthesised.

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(c) BLIMP-1 is a transcription factor that is essential for the development of plasma cells and memory B-cells in the process shown in Fig. 3.1. BLIMP-1 reduces the synthesis of c-Myc in B-lymphocytes. c-Myc is a protein that is required for the mitotic cell cycle to continue.

Suggest **and** explain how a mutation in the gene coding for BLIMP-1 can prevent the development of plasma cells and memory B-cells.

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14. Feb/2019/Paper_42/No.4

Mexican spadefoot toads, *Spea multiplicata*, live on land but return to ponds to breed. Eggs are laid in water and hatch into tadpoles, which feed in ponds before developing into adults.

The tadpoles can be classified into two main types: omnivore-type tadpoles and carnivore-type tadpoles. Differences between the phenotypes of these two types of tadpole are related to their different feeding behaviours.

- Omnivore-type tadpoles feed on tiny pieces of detritus (dead material from plants and animals) and algae (microscopic photosynthetic organisms) at the bottom of ponds. These tadpoles grow slowly.
- Carnivore-type tadpoles feed on small animals in the water, such as fairy shrimp and small omnivore tadpoles. These tadpoles grow quickly.

Fig. 4.1 shows two tadpoles of the same age, one of each type. A fairy shrimp is also shown. All three organisms are at the same distance from the camera.

Fig. 4.1

Between these two main types of tadpole there is a continuous range of tadpoles with intermediate body phenotypes and feeding behaviours.

For any individual tadpole, regardless of age, it is possible to calculate a phenotype score depending on the features of the tadpole. A tadpole with a phenotype score close to 3 is a typical omnivore type and a tadpole with a phenotype score close to 7 is a typical carnivore type.

The phenotype scores were determined for a large number of tadpoles sampled from two ponds. The availability of detritus and algae was high for one pond and low for the other pond. All other conditions in the two ponds were similar.

For both ponds, phenotype scores were determined shortly after the tadpoles had hatched from eggs and ten days later.

The results are shown in Fig. 4.2.

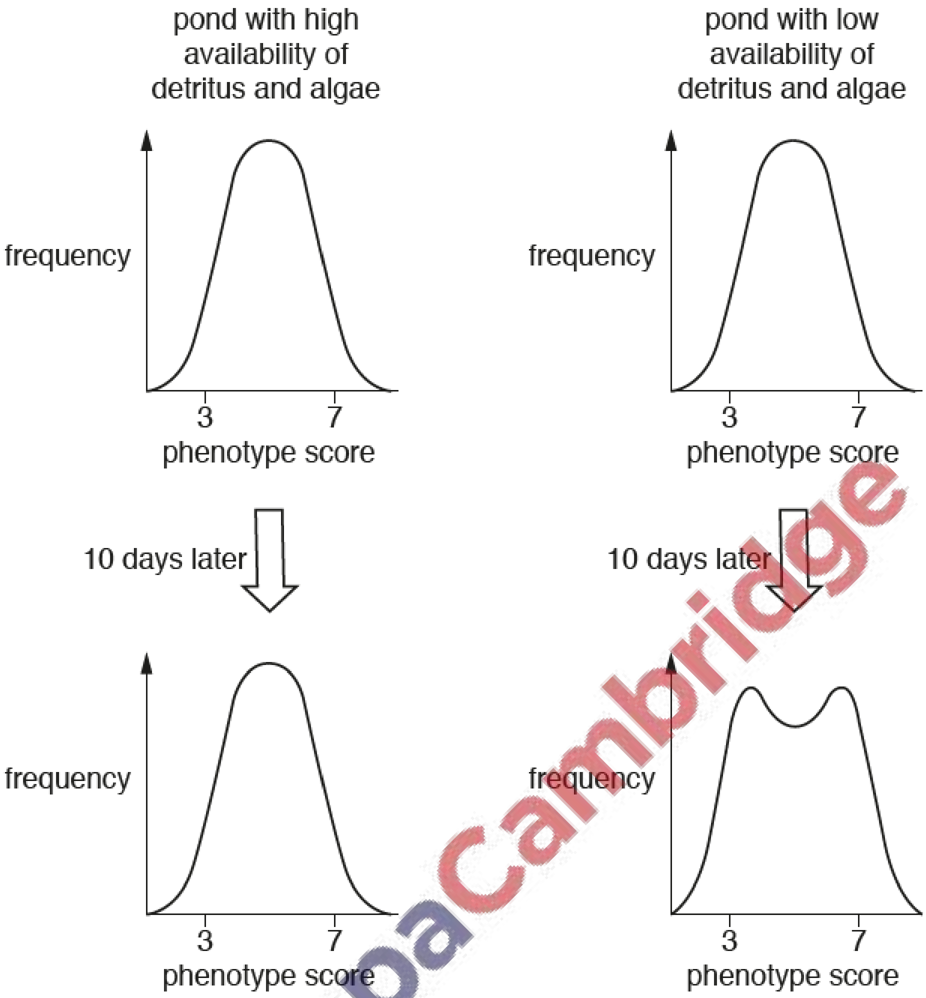

Fig. 4.2

(a) Using the results shown in Fig. 4.2, describe **and** suggest an explanation for the change in frequency of tadpole phenotypes in the pond with **low** availability of detritus and algae.

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.... [4]

(b) Eleven days after eggs had hatched, the mean body masses of omnivore-type tadpoles and carnivore-type tadpoles in the pond with low availability of detritus and algae were measured. The results are shown in Fig. 4.3.

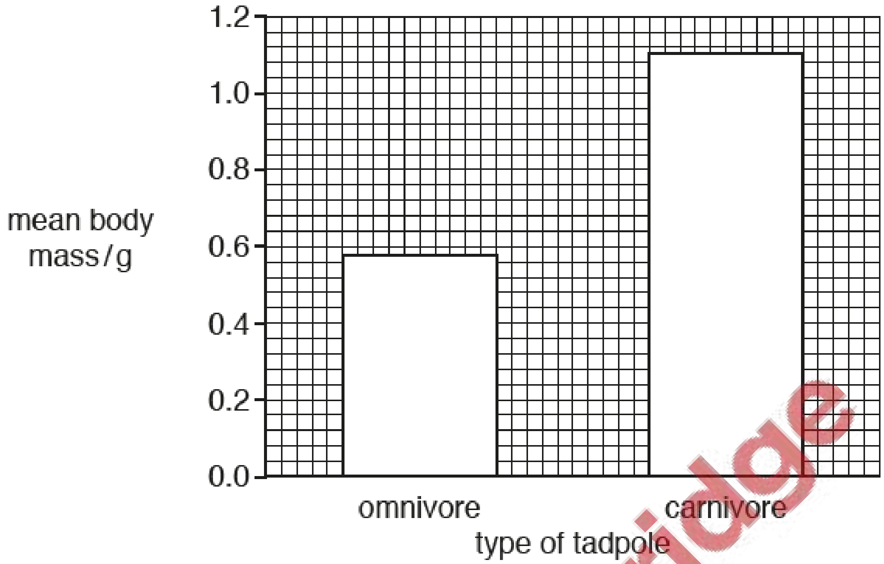

Fig. 4.3

Using the data in Fig. 4.3, calculate the mean body mass of an omnivore-type tadpole as a percentage of the mean body mass of a carnivore-type tadpole.

Show your working.

percentage = ... %
[2]

(c) The phenotype scores of a large number of tadpoles were determined in a different pond with **very low** availability of detritus and algae. All other conditions were the same as the first two ponds. As previously, measurements were taken shortly after the eggs hatched and ten days later. After ten days, nearly all of the Mexican spadefoot toad tadpoles in this pond were carnivore types.

The results are shown in Fig. 4.4.

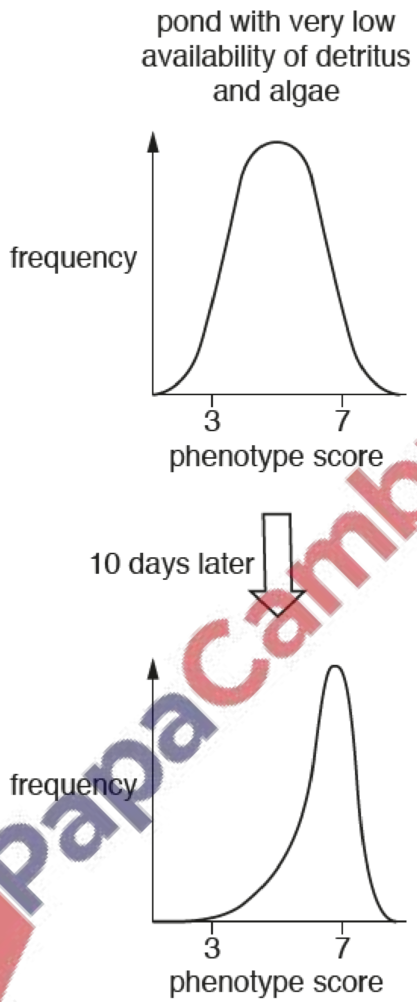

Fig. 4.4

(i) State the type of natural selection that is acting on the tadpoles in the pond with **very low** availability of detritus and algae.

.... [1]

(ii) Suggest explanations for the change in phenotype frequencies of the tadpoles in the pond with **very low** availability of detritus and algae, as shown in Fig. 4.4.

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.... [2]

(d) Mexican spadefoot toad tadpoles develop into adult toads that do not live in water.

In some years, the ponds where Mexican spadefoot toad tadpoles live, dry out quickly.

Suggest why the carnivore-type tadpoles have a selective advantage in the years when ponds dry out quickly.

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.... [1]

[Total: 10]

15. Feb/2019/Paper_42/No.6(b)

(b) Analysis of mtDNA can show how recently species have evolved from each other.

Describe the properties of mtDNA that make it suitable for the study of evolution.

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.... [3]

16. Feb/2019/Paper_42/No.10(a)

(a) State the general theory of evolution and explain the process of natural selection in evolution. [7]