● BIOLOGY

Demonstrate understanding of evolutionary processes leading to speciation

Polyploidy

(2015,3)

The four-wing saltbush (*Atriplex canescens*) is a shrub that has undergone polyploidy. It has a haploid number of nine chromosomes (*n* = 9). Biologists studied four-wing saltbushes with different numbers of chromosomes. Each type of saltbush lives in a slightly different habitat depending on how much water is available. Biologists measured the width of the water transport system (called the xylem) in each type of saltbush, and the results are shown in the table below. The xylem can be blocked by air bubbles in drought conditions.

Type of saltbush	**Habitat (relative soil water availability)**	**Relative Xylem width**	**Resistance to air bubble blockage**
Diploid (2*n* = 18)	High	Low	Low
Tetraploid (4*n* = 36)	Moderate	Moderate	Moderate
Hexaploid (6*n* = 54)	Low	High	High

Polyploid plants also tend to have lower guard cell density and a thicker epidermal layer in their leaves.

Discuss the implications of polyploidy on the evolution of the four-wing saltbush.

In your answer:

- describe polyploidy and describe why the four-wing saltbush polyploids are fertile
- explain how polyploid formation could occur in the four-wing saltbush
- discuss what processes need to occur for the polyploids to become separate species
- discuss how the change in structure of the polyploids may lead to speciation.

Answers:
Polyploidy is where an organism has more than two homologous sets of chromosomes in their somatic cells.
The polyploids are fertile because they have homologous pairs / even number of chromosomes so can form viable gametes.

Polyploidy can be caused by the spindle pulling an incorrect number of chromosomes to one end. This non-disjunction may result in 2n gametes. If two 2n gametes fuse, a tetraploid (4n) may result.

Postzygotic RIMs such as hybrid infertility / hybrid sterility may keep polyploids isolated. E.g. tetraploid with 18 chromosomes in gametes + hexaploid with 27 chromosomes in gametes results in hybrid with 45 chromosomes, which cannot form viable gametes because the chromosomes cannot pair at meiosis because some have no homologues.

Changes in morphology resulting from polyploidy contribute to habitat / niche differentiation. These new physiological tolerances allow them to exploit novel niches. Different habitats / niches have different selection pressures such as water availability which may lead to (sympatric) speciation. For example, polyploids have lower stomata density and thicker epidermis which reduces water loss / transpiration and maintains turgor. The wider xylem reduces the chances of air blockage in drought conditions, which gives an adaptive advantage in these conditions and allows photosynthesis to be maintained.

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(2011, 2)

Hebe odora, Leucogenes leontopodium and *Celmisia haastii* are three low-growing, shrubby plants with small leathery leaves, ideally suited to their exposed mountain habitats. Despite these similarities, they are not related.

		
Hebe odora	*Leucogenes leontopodium*	*Celmisia haastii*

(a) Explain the pattern of evolution shown by these three different plant species.

(b) The *Hebe* is New Zealand's largest genus of shrubs. There are about 100 species of Hebe found in New Zealand.

The main genera of the *Hebe* complex probably evolved five million years ago, after the arrival of a single ancestral founding species. *Hebe* then evolved into about 100 species during the last million years. Four diverse examples are shown below.

Species	Habitat	Structure	Chromosome No (n)
 *Hebe speciosa*	Exposed sea cliffs on the western side of both islands.	Leaves 5–10 cm long; rounded shrub up to 2 m tall.	20
 *Hebe hectorii*	Wet sub-alpine scrub and tussock of the South Island.	Whipcord plant; erect, rigid plant that grows up to 0.75 m tall.	20
 *Hebe gracillima*	Damp swampy places in the South Island.	Leaves 1–2 cm long; shrub up to 2 m tall.	40
 *Hebe venustula*	Sub-alpine, mostly North Island.	Leaves 1–2 cm long; erect bushy shrub up to 1.5 m tall.	60

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Compare and contrast the processes of **polyploidy** and **geographical isolation** and how they are **both** likely to have impacted on the evolution of *Hebe* species in New Zealand.
In your answer:

- describe the process of adaptive radiation
- explain how both polyploidy and geographical isolation could occur
- discuss the impact of both processes on reproduction and gene flow within the *Hebe* genus.

Answers

(a) Explains convergent evolution. Species arising from different evolutionary lines / without a common ancestor (must indicate no relation in the past) similar phenotypes / adaptations / traits / structures / analogous structures have evolved due to occupation of similar niches / having similar selection pressures / similar habitats / similar environmental conditions.

(b) Discusses how both polyploidy and geographical isolation occur and have likely impacted on the evolution of Hebe in New Zealand. Discusses the impact of each process on the adaptive radiation of Hebe.

Polyploidy is due to nondisjunction / failure of chromosomes to separate during meiosis resulting in an extra set of chromosomes in the offspring. This leads to instant speciation / new species. The offspring cannot reproduce with is parent species / can only reproduce vegetatively / asexually and so gene flow does not occur.

Geographical isolation can happen when populations become geographically separated due to environmental events such as mountain uplift / tectonic plate movement / sea level changes / ice ages so gene flow cannot happen between populations so becomes reproductively isolated. Physical barriers may change the environment / habitat / niche, which alters the selection pressures. New phenotypes / adaptations lead to new species.