3

91605

916050

SUPERVISOR'S USE ONLY

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Level 3 Biology, 2015

91605 Demonstrate understanding of evolutionary processes leading to speciation

2.00 p.m. Monday 23 November 2015
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of evolutionary processes leading to speciation.	Demonstrate in-depth understanding of evolutionary processes leading to speciation.	Demonstrate comprehensive understanding of evolutionary processes leading to speciation.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 22

ASSESSOR'S USE ONLY

QUESTION ONE

'Land lobsters' are the common name of many species of large, flightless, ground-dwelling insects distributed in New Guinea, New Caledonia, and Lord Howe Island. Land lobsters have a stocky body form. Some males have enlarged and powerfully armed hind legs, and the females have an elongated ovipositor which they use to deposit eggs into the soil. Nuclear and mitochondrial DNA sequence analysis has shown that the different land lobsters species are unrelated to each other, and therefore have undergone convergent evolution.

Different 'land lobster' species, (a) to (f), compared with a winged, canopy-dwelling stick insect, (g).

Adapted from Buckley, T.E. et al. (2009). Extreme convergence in stick insect evolution: phylogenetic placement of the Lord Howe Island tree lobster. Proc. R. Soc. 276, 1055–1062.

Pōhutukawa (*Metrosideros excelsa*), northern rātā (*Metrosideros robusta*), and southern rātā (*Metrosideros umbellata*) are all related species belonging to the same genus. These species have undergone divergent evolution during the ice age that occurred between one and two million years ago.

Pōhutukawa has a coastal distribution and is very salt-tolerant. It has multiple trunks, is a coloniser of coastal cliffs and bare volcanic larva, and is susceptible to light frosts.

Northern rātā usually begins life as an epiphyte perched high on another tree. From here it sends down roots to form a trunk that can grow into a 40 m tree. It has moderate frost tolerance.

Southern rātā usually grows from the ground to a 15 m high, single-trunked tree that can tolerate frost and colder climates.

Different forms of *Metrosideros*.

Adapted from: P. Simpson, *Pohutukawa and Rata*, (Wellington, Te Papa Press, 2005), p. 125.

Discuss the evolutionary patterns AND selection pressures that have contributed to these patterns for land lobsters and *Metrosideros*.

In your answer:

- describe convergent evolution and divergent evolution
- explain, using the evidence given above, how each of these patterns could arise
- explain, by giving examples from the resource material, which pattern is associated with homologous structures AND which pattern is associated with analogous structures
- discuss why land lobsters have a different evolutionary pattern to *Metrosideros*.

ASSESSOR'S USE ONLY

Convergent evolution is a type of evolution in which unrelated species resemble each other due to occupying similar niches and being subject to similar selection pressures. Divergent evolution is a type of evolution in which one species evolves into two as a result of different selection pressures. Convergence arises due to different (unrelated) species being subject to similar selection pressures and occupying similar niches. The 'Land lobsters' have convergd on ~~one~~ a distinctive form as a result of similarity in niche (large, ground-dwelling, flightless) and thus subject to similar pressures. The different species of land lobsters must have been subject to selective pressures that favoured the form they have now (~~the~~ powerful hind legs, body structure similar to stick insect). Natural selection ~~Divergent evolution~~ favoured similar ~~specific~~ attributes (traits) in the lobsters and thus they evolved to resemble each other.

Divergent evolution arises due to one species having populations subject to different selective

There is more space for your answer to this question on the following page.

ASSESSOR'S USE ONLY

pressures. The Metrosideros genus underwent divergence in response to the repeat glacial and inter glacial periods in New Zealand over the past 2 million years. This opened up new, vacant niches to exploid and so populations diverged as they became adapted to different niches, ~~B~~ as shown by the difference in the trees such as frost tolerance, habitat (e.g. pohutakawa lives in coastal regions while rata lives ~~at~~ in forests).

Homolgous structures are similarities in body structure or function that arise due to common ancestry, ~~such as trunck~~ ~~st~~ but have been modified to suit a specific niche such as trunck structure or frost tolerance in Metrosideros.

Analagous structures are structures that evolve in ~~unt~~ unrelated species as a result of similar selective pressures, such as powerful hind less ~~in the land t~~ and enlarged ovipositers in land lobster species.

The type of evolution of the land lobsters differs from the Metrosideros due to the nature of selective pressures acting on them. While natural selection favoured similar characterestics in land lobsters (possibly as a result of similarities in niches), it favoured different traits in each of the Metrosideros species, in order to (initially) minimise competition ~~and make~~ fully exploit

cont. pg 12

E8

E8

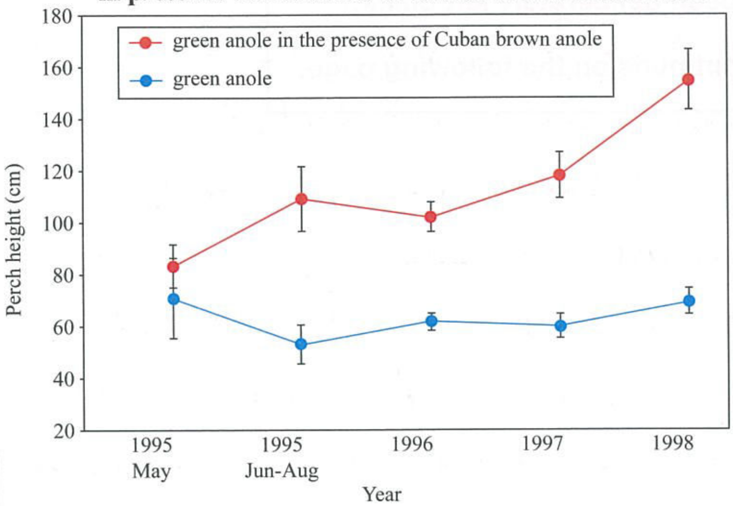
This page has been deliberately left blank.

The examination continues on the following page.

QUESTION TWO

The green anole lizard (*Anolis carolinensis*) is the only native anole in the United States. However, since 1940, the Cuban brown anole lizard (*Anolis sagrei*) has been invading the southeastern United States so that both species exist sympatrically in this area. Both species have adhesive scales on their toe pads called lamellae, and are very similar in habitat use, ecology, and dietary preferences. Biologists studying these anole compared the height at which the green anole perched in trees in the presence AND absence of the Cuban brown anole, and their results are shown in Figure 1. Biologists also measured toe pad area and lamella number in the green anole in the presence AND absence of the Cuban brown anole, and their results are shown in Figure 2a and Figure 2b.

Figure 1: Perch height of green anole lizard in presence and absence of Cuban brown anole lizard



Adapted from: Stuart, Y. E., et al. (2014), 'Rapid evolution of a native species following invasion by a cogener', *Science* 346 (6208): 463–466

Green anole and Cuban brown anole lizards.

http://davewelling.photoshelter.com/image/I0000HVzOE-fE2lmQ

Green anole hind foot showing toe pads.

www.utexas.edu/mews/2014/10/23/anole-lizards-evolution-florida/

Figure 2a: Toe pad area in green anole lizard in absence and presence of Cuban brown anole lizard

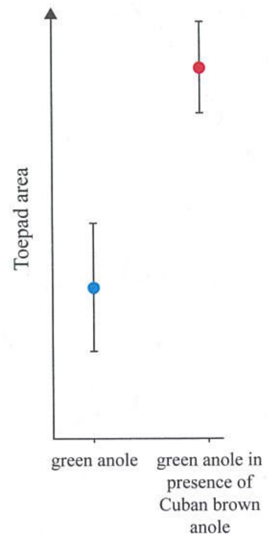
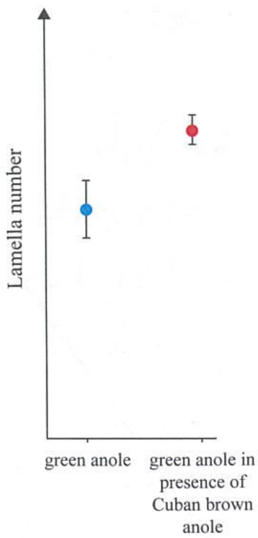


Figure 2b: Lamella number in green anole lizard in absence and presence of Cuban brown anole lizard



Adapted from: Stuart, Y. E., et al. (2014), 'Rapid evolution of a native species following invasion by a cogener', *Science* 346 (6208): 463–466

Discuss the natural selection pressures that have affected evolution in the green anole.

In your answer:

- describe natural selection and the trends shown by the resource material
- explain the type of natural selection occurring in the green anole
- evaluate the impact of competition on the evolution of the green anole.

ASSESSOR'S USE ONLY

Natural selection is the process by which fitter individuals have increased chances of survival and reproduction and will thus contribute their favourable genes in a greater proportion in the ~~ne~~ next generation. The trends shown by the graphs indicate that, over time, natural selection ~~has~~ is favoured those* who perch higher* up, have a higher toe pad area, and more lamellae. This is indicated by the general increase of these statistics in populations of green anole in competition with red anole compared to populations without (competition w/ red anole).

2

The type or mode of natural selection occuring is directional selection, in which one end of the extremes of variation within a population is selected for. In ~~the~~ terms of the green anole (in competition with red anole), directional selection has favoured those who perch higher up, have larger toe pads and more lamellae. This is clearly indicated by the statistics as those phenotypes are increasing in frequncy over time (ie.g. average perch hight ~~has~~ has increased from ~80cm in 1995 to ~150 cm in 1998),

Since the invasion of the red anole in 1940, the

*(green anole)

There is more space for your answer to this question on the following page.

* (e.g. perch height has increased from ~80 cm in 1995 to ~150 cm in 1998)

ASSESSOR'S USE ONLY

green anole has had to adapt in order to survive. Despite being different species, the overlap in niche between the green and red anole is very high (same toe structure, habitat, diet etc.) This ~~has~~ caused ~~a~~ intense interspecific competition with the red anole, and Gauses Principal states that this cannot happen for long before one species outcompetes and displaces the other. In order to avoid such a situation, the green anole has undergone niche differentiation, ~~in wh~~ Individuals who had niches slightly different and thus suffered from less competition with red anoles were favoured. Thus, directional selection favoured those who by perching higher (thus requiring larger toes and more lamallae to hang on), survived better than those who continued to perch in areas with red anole. Thus, these individuals were able to survive and reproduce more effectively than those who were in direct competiton with red anole. Thus, the frequency of genes associated with perching higher (larger toe area, more lamallae) increased in the gene pool and the green anole are able to coexist due to differences in niche with red anole. However, this may also be leading to speciation (divergence) from green anole who do not live in the presence of red anole. This is because selection is favouring

E7

E7

cont page 12

QUESTION THREE

ASSESSOR'S USE ONLY

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 ($2n = 18$)	High	Low	Low
Tetraploid ($4n = 36$)	Moderate	Moderate	Moderate
Hexaploid ($6n = 54$)	Low	High	High

Source: Hao, G et al. 'Polyploidy enhances the occupation of heterogeneous environments through hydraulic related trade-offs in *Atriplex canescens* (Chenopodiaceae)', *New Phytologist* (2013) 197: 970–978.

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.

polyploidy is an instant speciation event that occurs when gametes with more or less than the correct numbers of chromosomes (n = haploid) meet. It occurs due to non-disjunction in meiosis. The four-wing salt bushes are fertile due to them undergoeing amphiploidy, doubling chromosome numbers and restoring fertility in (previously) infertile plants. Polyploid formation could have occured when two diploid gametes from the original species meet, forming the tetraploid plant. This is ~~allop~~ autopolyploidy, as it occured in one species. The

There is more space for your answer to this question on the following page.

hexaploid could have arisen when a haploid gamete from the tetraploid fertillized a haploid gamete from the diploid *2 Initially this would have been infertile * (3n = 27) but doubling of chromosomes (amphiploidy) would have restored fertillility, as each chromosome could match up during meiosis.

Polyploidy itself causes instant speciation. However, to become ~~sp~~ seperate species, there must be the development of reproductive isolating mechanisms (RIMs). These prevent ~~two~~ species from interbreeding / cut gene flow and thus mean that they fit the definition of a species (group of organisms that actually ~~or~~ or potentially interbreed to form fertile offspring but are reproductively isolated from other such groups).

The change in structure of the xylem in the polyploids, as well as the differences in air bubble resistance could ~~let~~ allows then to speciate. This is because these changes in structures may become adaptive ~~a~~ in different niches and allow the polyploids to exploit different niches (for example, the ~~tetraploid~~ ~~has~~ hexaploid lives in low water ~~soil~~ soils but has adaptations in xylem width and resistance to drought-induced air bubbles. This enables it to expand its range into drier conditions, meaning it will become subject

* and would have reproduced through self-pollination or vegitatively

*2 (allopolyploidy)

ASSESSOR'S USE ONLY

to different selection pressures and evolve differently. The increased epidermial layer in leaves and lower guard cell density may also aid in reducing transpiration in such environments. ~~The~~ Therefore, while the hexaploid can adapt and speciate in response to drier habitats and the diploid in wetter habitats, the tetraploid may speciate to exploit some intermediate niche. Being subject to different selection pressures for long enough, they may speciate completly.

E7

E7

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

(1) different niches due to the initial vacancy of niches. Thus, while in the land lobster selection favoured similar traits, in the Metrosideros, selection favoured different traits. This led to convergence in land lobster and divergence in Metrosideros.

(2) different traits in order for them to exist in the presence of red aole (co-evolution). If this keeps happening, RIMs may develop and they may speciate.

ASSESSOR'S USE ONLY

91605

Annotated Exemplar Template – Excellence

Excellence exemplar for 91605 - 2015			**Total score**	**22**
Q	**Grade score**	**Annotation**		
1	8	The candidate has shown a comprehensive understanding of convergent and divergent evolution and the processes that cause them. They have also clearly linked named analogous and homologous structures to the type of evolution. The candidates answer is clear and concise with minimal repetition. All three 'Excellence' points are covered in this answer.		
2	7	The candidate has evaluated the data given in the graphs to explain why selection pressures may cause some green anole to perch higher than others. They have then discussed how this niche differentiation may lead to greater divergence and possibly speciation, and thus they have an E7.		
3	7	This answer has gained an E7 by looking at a new maned feature (wider xylem) that can be a consequence of polyploidy. The candidate has then explained how this feature allows the polyploid to survive in environments that would not otherwise be available to them. They discussed how there would be different selection pressures in the different habitats and how this may lead to speciation. A more detailed discussion of the actual process of non-disjunction, forming diploid gametes and the fusing of these forming a tetraploid which may be a new polyploid species may have earned this candidate an E8.		