3

91605

916050

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NZQA
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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.

Merit

TOTAL 16

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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.

Single trunk - southern rātā

Spreading, multiple trunk tree - pōhutukawa

Free-standing tree - northern rātā

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*.

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multiple random selection when speciation

Convergent evolution is the acquisition of the same biological traits despite unrelated lineages whereas divergent evolution occurs when one ancestral species evolves into two or more species which become specialised to occupy different ecological niches. Convergent evolution often arises as having the biological trait is often the most advantageous for the the different species, across the different species in this case females having an elongated ovipositor which is used to deposit eggs in the soils, by having this elongated the female is mostly likely able to deposit a greater number of eggs and means and increased likelihood of the survival of a greater number of offspring, as this trait is more advantageous, different species all have it as it is more efficient and the best method. The Pohutukawa, norther rata and southern rata all share a common ancestor, they most likely underwent divergent evolution due to a mutations arising in the common ancestor, such as a gene where multiples trunks are grown instead of one when this gene is inherited, selection pressures may have changed as the seed is dispersed to a more costal climate on the cliffs for example as oceans resided after ice age as the selection pressure is for a gene which enables the tree to stablise itself, the

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the offspring with the mutation for multiple trunks, what would eventually become the

thus pohutukawa, is able to grow multiple trunks and survive in a costal cliff edge. It now becomes specialised ~~species~~ in a certain niche where the common ancestor couldn't and thus speciation occurs as certain genes for that climate, such as multiple trunks, salt tolerance are continually selected for resulting in speciation, thus divergent speciation occurs. Divergent evolution is associated with homologous structures as these have the same evolutionary traits, despite forming different functions, thus homologous structures are associated with the pohutukawa, and northern and southern rata as comparison of these various structures of the tree show the same basic structure, suggesting a common ancestor. As all trees diverged from a common ancestor the divergent evolution is associated with this structure. Analgous structures carry out the same function despite no relation, thus these are associated with covergent evolution as all land lobsters have very similar analgous structures such as strong powerful armed hind legs and females having elongated oviposter which all carry out the same function as it is more advantageous to do so. Lobsters have a different evolutionary pattern as they do not share a common ancestor and they have evolved due to certain structures being the most advantageous due to similar environments across islands. Metrosideros has a different evolutionary pattern as it has evolved from a

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M6

common ancestor to all different available ecological niches. ~~They are hence different evolutionary patterns as one has to survive in the~~

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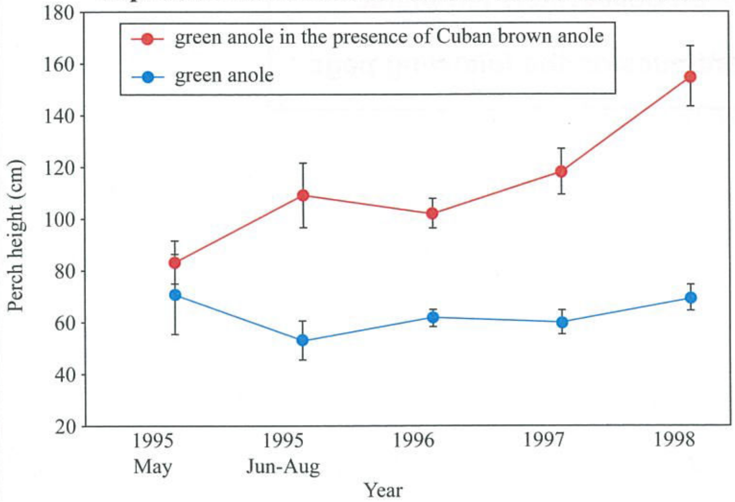
QUESTION TWO

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

Higher perch height!

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

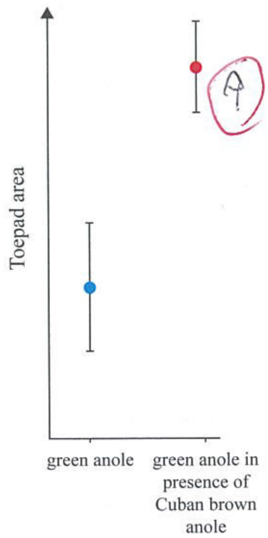
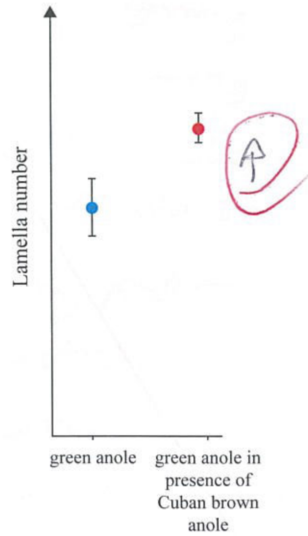


Figure 2b: Lamella number in green anole lizard in absence and presence of Cuban brown anole lizard



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.

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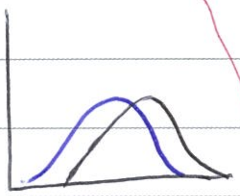
Natural selection is when individuals with the genes best suited to the environment under the current selection pressures are more likely to survive over other species and thus go on to reproduce and contine the survival of the species. ✳ The type of natural selection occuring to the green anole is directional, the current environment favours larger toe pad area and larger lamella number which are useful for inhibiting higher branches as they have to hold on tighter. Thus green anole is undergoing directional selection as drawn.



Competetion negativly affects both the green anole and the cuban anole as they are compeating for the exact same niche, As gauses principale states no two species can both surive if they are competing for the same niche, thus competetion is forcing the green anole to adapt to a different niche, where it is higher up the branches, and thus can access a different pool of resources. The competetion is forcing the green anole to evolve with larger toe pad and larger lamella number so it can stay on higher

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more finer and skinner branches easily, and occupy a different niche so it is not out competed for resources.

* The trends shown by the resource material indicate that in the presence of the cuban anole the green anole occupies higher branches than it does when by itself. ~~It~~ The ~~8L~~ resources also show that in the presence of the cuban anole the green anole has larger toe pads and a greater number of lamella than green anoles have if not in the presence of cuban anoles.

M5

QUESTION THREE

n=9

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 when the genome is represented two or more times, in this case the four wing salt brush has undergone Autopolyploidy which results from the multiplication of the entire genome within a species due to non disjunction. These four wing saltbrush polyploids are ferile as they have even numbers of chromsomes, thus when they undergo meiosis there is a matching homologous pairs for viable gametes to be produced. Polyploid formation could occur for the four wing saltbrush due to non disjunction in meiosis, when the chromsomes

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Seperate they can all go to ~~a~~ one side and thus all into one gamete, thus the gamete now has a ~~greater~~ double the number of chromsomes. ~~A~~ Polyploidy can also occur during cell divison in plants where the chromsomes again do not divide properly. For these polyploids to become seperate species Allopolyploidy would need to take place, this is the hybridisation of two species of the salt brush ~~thus one~~ The resulting hybrid however can be sterile due to no matching homologous pairs, however if chromsome doubling occurs, a fertile hybrid may be produced. This results in instantaneous speciation as the offspring produced is neither one species nor the other, but a combination, which is more advantageous as it combines genes from both ~~species~~ parents and thus both species, so it is more likely to survive if the environment changes or if diseases spread. The species is also more likely to find a better ecological niche as it has genes from both parents.

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m5

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

QUESTION NUMBER

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91605

Annotated Exemplar Template – Merit

exemplar for 91605 - 2015		Total score	16
Q	**Grade score**	**Annotation**	
1	M6	This candidate has explained, using examples, the patterns associated with homologous and analogous structures to gain their Merit points. Although they have described convergent and divergent evolution, if they had discussed the selection pressures involved they may have reached an Excellence level.	
2	M5	The candidate has explained that moving to higher perches selected for larger toe pad area to gain M5. If they had linked this to a reduction in competition for food (or other named resource) they may have gained an M6. An explanation of natural selection leading to an increase in frequency of favourable alleles in future generations may also have gained an M6.	
3	M5	There is an understanding of how a non-disjunction process can lead to the formation of diploid gametes in this answer. A discussion how two diploid gametes fuse to form a new polyploid species (hexaploid) at fertilisation would have been evidence towards an Excellence. This candidate also did not explain that polyploidy has resulted in a named feature (M6) or how this may lead to further speciation (E7).	

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High Merit

TOTAL 17

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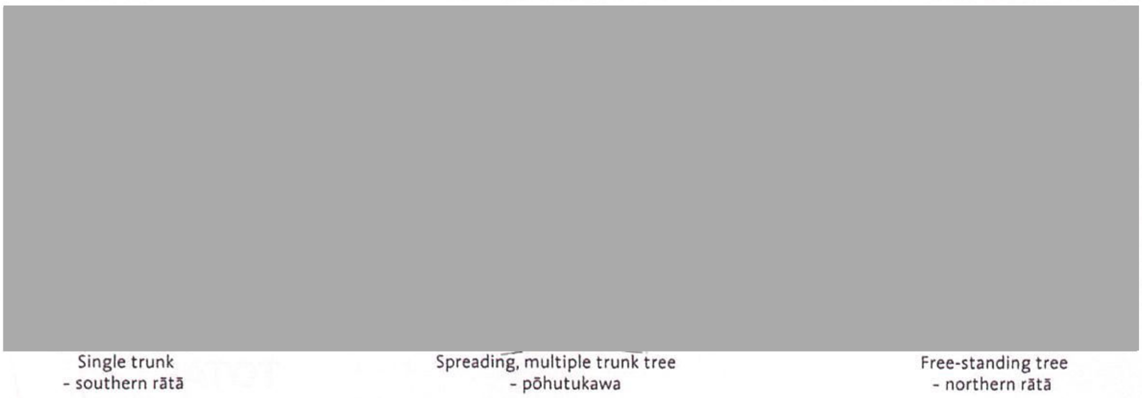

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Convergent evolution is where two (or more) species which (do not) share ~~no~~ a common ancestor evolve to become more similar (ie. in this case the different land lobsters species). Divergent evolution is where two (or more) species ~~which share a common ancestor~~ evolve ~~to become~~ evolve from a single common ancestor. Convergent evolution usually arises when the two (or more) species are subjected to similar selection pressures in their respective ecological niches. In this case, the different land lobsters live in different areas, but males have enlarged and powerfully armed hind legs in many, perhaps as there are predators in the different areas, and so 'land lobsters' which has stronger legs and can run faster are selected for. For the females, perhaps in the different areas each have a predator which digs underground for the eggs of the female, and thus for each species the females with the longer ovipositor which can deposit the eggs deeper into the soil are chosen for — the species convergently evolve. Divergent evolution usually arises when groups of the original species face different selection pressures: Pōhutukawa is a coloniser of coastal cliffs, and thus multiple trunks may be selected for to maximise the amount of support it has in order to stay on the cliff. Southern rātā does not have this pressure, and thus has a single trunk, as arguably with the northern rātā. Thus they have divergently evolved. Homologous structures are phenotypes while evolve from the same ancestor for different purposes — associated with divergent evolution, where eg. the roots of the northern rata has evolved differently from the other two, where the roots are sent down the trunk of another tree to form a trunk.

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Analagous structures are structures which evolve from different ancestors to achieve a similar purpose — associated with convergent evolution, the ovipositor of different species of land lobster have evolved to become longer and achieve the same purpose of being able to deposit eggs safely deep into the ground. Land lobsters have a different evolutionary pattern to Metrosideros as while Metrosideros have undergone a huge environmental change (the ice age), which opens up a large range of new niches and may have geographically isolated the plants as a result (thus resulting in allopatric speciation) there has not been much environmental change for the land lobsters, and thus not as much need to become specialised in any way. The land lobsters live in a similar environment, and thus has evolved in similar ways, while the Metrosideros were geographically isolated to different ecological niches, subjected to different selection pressures, faced with mutations (eg. resulting in multiple trunks for the pōhutukawa) and genetic drift, developed reproductive isolating mechanisms (such as different coloured flowers, thus attracting different pollinators and never pollinating each other) and thus became three separate species (allopatric speciation, the formation of two groups of individuals which ~~do not~~ do not reproduce in nature to form fertile offspring?, with a geographical barrier involved).

due to no gene flow

E7

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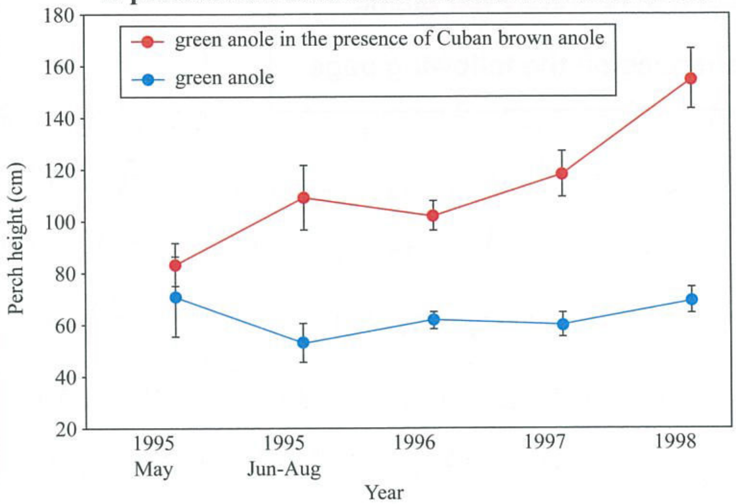
QUESTION TWO

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



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Green anole and Cuban brown anole lizards.

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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

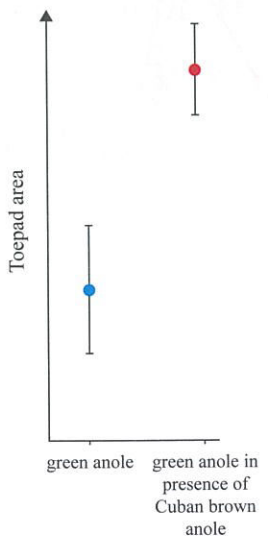
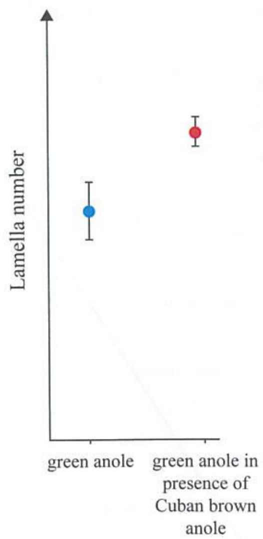


Figure 2b: Lamella number in green anole lizard in absence and presence of Cuban brown anole lizard



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

ASSESSOR'S USE ONLY

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.

Natural selection is where ~~an~~ individuals who ~~carrys~~ an advantageous trait ~~which is 'selected for'~~ are more likely to survive, reach sexual maturation, reproduce and pass on their alleles to the next generation, while less fit individuals are far less likely. The resource material shows that for the anole lizards, ~~the toepad~~ larger toepad areas and a larger Lamella number are selected for. The type of natural selection occuring is (directional selection) where the traits at the extreme end of the spectrum are selected for, ie. lizards with the largest toe pad areas and largest number of Lamella are selected for. This is perhaps due to both increasing the anole lizards' ability to cling to tree branches, minimising the chances of the lizards being knocked off / falling off. Upon the introduction of the brown anole, the graphs show that the perch height, toepad area and Lamella number have increased, indicating that the brown anole is a selection pressure on the green anole (ie. they are competing against one another). Thus, as there is now another species occupying the same area (overpopulation), both species must compete over the limited amount of resources such as food, space etc.* As a result, green anole lizards which are unable to cling to tree ~~tr~~ trunks and survive eg. during storms, or catch as much food die out — they are selected against, and do not pass their alleles down to the next generation. The perch height of the green anole lizard may increase as a result of larger lizards intimidating the brown lizards — thus gaining access to more food and resources, having the ability to survive, reproduce and pass down their high perch height alleles to the next generation. Thus, compared to before the presence of the Cubanbrown anole, the overall perch height of the green anole population increases.

* This competition is especially fierce as the two species are very similar in habitat use, ecology and dietary preferences — they will compete over almost the same resources.

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hence the number of lamelle and toepad area being greater in the population with the presence of the brown anole than the population without the brown anole.

The same applies to the toepad area and lamella number for the green lizard, and thus overall due to the competition, the green anole lizard population becomes 'fitter', in order to outcompete the brown anole //

ASSESSOR'S USE ONLY

A4

QUESTION THREE

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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.

Polyploids usually display hybrid vigour, and are bigger/have more advantageous traits (hence eg. higher resistance to air bubble blockage for the hexaploid). It is also known as instantaneous speciation

Polyploidy occurs as a result of non disjunction during meiosis for a plant, with results in a diploid gamete (instead of a haploid gamete). If this diploid gamete fuses with another diploid gamete, a polyploid is formed, hence the tetraploid (4n=36) is formed from the diploid plant (two 2n, diploid gametes, fusing together to give 4n). The fourwing saltbush polyploids are fertile as they have an even number of chromosomes — they can still produce ~~haploid~~ gametes (eg. tetraploid can produce two 2n gametes), with half of the chromosome number of a diploid 4n cell. Thus, the gametes can still fuse to form a fertile offspring.

For the four-wing saltbush, the diploid saltbush may somehow produce two 2n gametes as a result of non-disjunction at meiosis. These two 2n gametes may somehow fuse eg. during asexual reproduction, forming a 4n cell — ie. the tetraploid saltbush. Non disjunction is where all the ~~chromos~~ chromsomes of a ~~g~~ cell are transferred to a gamete during meiosis.

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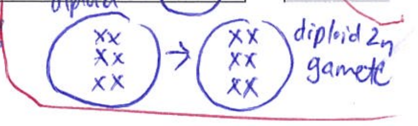
gametes



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In order for the polyploids to become separate species they must have reproductive isolating mechanisms (RIM)! One prezygotic RIM may be the different chromosomial numbers (some gametes, assuming nondisjunction does not occur, cannot fuse to form an offspring). Another may be that the, eg. tetraploid plant produces larger flowers than the diploid plant. The pollinators of the diploid plant may not recognise/pollinate the tetraploid plant, and thus the two plants never reproduce/have pollen transfered between them. The diploid saltbush and hexaploid salt bush inhabit different habitats, the diploid plant inhabiting one with high water availability, while the hexaploid inhabiting soil with low water availability. This is emphasised through their differing xylem widths and resistance to air bubble blockages! Thus, the two plants may be suitable for different types of soil, and may be ~~geographically~~ isolated as a result, due to differing ecological niches. Thus, the pollinators which visit each niche may differ, and the pollen of each plant never reaches the other.

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m6

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

QUESTION NUMBER

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91605

Annotated Exemplar Template – Merit (High)

<table>
<tr><td colspan="3">exemplar for 91605 - 2015</td><td>Total score</td><td>17</td></tr>
<tr><td>Q</td><td>Grade score</td><td colspan="3">Annotation</td></tr>
<tr><td>1</td><td>7</td><td colspan="3">The candidate has explained named analogous and homologous structures, linking them to convergent and divergent evolution respectively. (M6). They have shown a clear understanding of divergent evolution by discussing this process for Metrosideros (E7). The selection pressure of an island (or ground dwelling) environment was not explained which meant the answer provided for convergent evolution did not gain any higher grades.</td></tr>
<tr><td>2</td><td>4</td><td colspan="3">The candidate has clearly described directional (natural) selection as well as interpreting correctly the data contained in the graphs. Although a link was made between increased toe pads and hanging onto branches, this was not linked clearly to an increased perch height. To achieve Merit grades the candidate would need to explain natural selection leading to an increase in frequency of alleles in future generations.</td></tr>
<tr><td>3</td><td>6</td><td colspan="3">The candidate displays a good understanding of the process of polyploidy, explaining how diploid gametes may be formed and the consequence of two diploid gametes fusing. They have not linked polyploidy to a new named feature and how this may lead to increased survival and reproductive success, and possible additional speciation if they inhabit different areas because of the named feature.</td></tr>
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