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Level 3 Biology, 2016

91605 Demonstrate understanding of evolutionary processes leading to speciation

2.00 p.m. Thursday 10 November 2016
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

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QUESTION ONE: MEXICAN SPADEFOOT TOAD

The Mexican spadefoot toad (*Spea multiplicata*) is found in southwestern United States and Mexico. In ponds with low abundance of food resources and high density levels of tadpoles, two populations predominate. One population (called the omnivore morph) has a round body with a long intestine, small jaw muscles, smooth mouth parts, and has a generalist omnivorous diet of algae and small crustaceans found on the bottom of the pond. The other population (called the carnivore morph) has a narrow body with a short intestine, enlarged jaw muscles, teeth-like mouthparts, and has a specialist carnivorous diet of fairy shrimps found in the water column.

On the other hand, in ponds of high abundance of food resources and low density levels of tadpoles, only one population, of intermediate phenotype, is found.

Figure 1: Mexican spadefoot toad tadpoles from a high density, low food resource pond. *Top:* the omnivore morph. *Bottom:* the carnivore morph.
http://labs.bio.unc.edu/pfennig/LabSite/Photos.html

Compare and contrast the impact of disruptive and stabilising selection on genetic diversity AND discuss how speciation could occur in the Mexican spadefoot toad.

In your answer you should:

- describe genetic variation
- describe the terms disruptive and stabilising selection, and describe which population(s) of Mexican spadefoot toad tadpole is associated with each type of selection
- explain the selection pressures that promote disruptive selection, AND the selection pressures that promote stabilising selection in the Mexican spadefoot toad tadpole.

Well labelled diagrams can be used to support your answer.

• Genetic variation is the variety of different alleles which occur in the gene pool of a population.
• Disruptive selection is when natural selection provides selection pressures which favour two phenotypic extremes, as the extreme phenotypes best match the environmental conditions, whilst not favouring the average phenotype. This is shown by the two contrasting phenotypes of the omnivore morph and carnivore morph. Stabilising selection occurs when natural selection provides selection pressures which favour the average phenotype, as this is deemed the most beneficial to suit environmental conditions. This is promoted

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in the population of Mexican spadefoot toad tadpoles which inhabit the other pond, where an intermediate phenotype is found.

- The low abundance of food resources paired with high density levels of tadpoles in some ponds has provided the selection pressures which led to disruptive selection in order to reduce intraspecific competition by creating niche differentiation. This has led to one group filling the generalist omnivorous algae & small crustacean eating niche, feeding on the bottom of the pond. This has led this group to evolve adaptations such as a round body, long intestine, small jaw muscles & smooth mouth parts to suit their diet. The other population has filled the specialist carnivorous fairy shrimp-eating niche, feeding in the water column. This has led to this group evolving a narrow body, short intestine, enlarged jaw muscles and teeth like mouthparts. This niche differentiate may lead to sympatric speciation, as both species and develop different adaptations which may create reproductive isolating mechanisms. inhabit the same area. The intermediate phenotype found in other ponds has ~~less~~ less selection pressures ~~acting~~ to pressure the population due to a high abundance of food resources and low density level of tadpoles, hence reduced intraspecific competition. This means the average phenotype is favoured and selected for - an intermediate between these two previously mentioned extremes, which can utilise both feeding strategies - as this is the most suited to the pond environment without these harsh selection pressures.

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

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QUESTION TWO: THREE-SPINED STICKLEBACK

The three-spined stickleback (*Gasterosteus aculeatus*) is a small (30 – 90 mm) fish found in the Northern Hemisphere. Some populations live in coastal marine habitats, while other populations live in freshwater.

Three-spined sticklebacks lack the scales typical of most fishes; instead they possess (protective) bony plates and spines. Three-spined stickleback populations living in a marine habitat have high numbers of bony plates and long spines, whereas freshwater populations typically have low numbers of bony plates and short spines. Genetic evidence suggests that a mutation in the Ectodysplasin (EDA) gene causes variation in plate number, and a mutation in the PITX1 gene causes variation in spine length.

Figure 2. *Top:* Typical three-spined stickleback from a marine population. *Bottom:* Typical three-spined stickleback from a freshwater population. Fish have been stained with alizarin red to highlight bony plates and spines.
http://unews.utah.edu/wp-content/uploads/sticklebackfigure1.jpg

The main predators of three-spined stickleback in marine habitats are larger fish. In freshwater habitats, grasping insects (such as dragonfly larvae) are the main predators, especially of juvenile three-spined stickleback. Marine habitats typically have low amounts of shelter suitable for the three-spined stickleback, whereas freshwater habitats have high amounts of shelter. The growth rate and acceleration / burst speed of three-spined sticklebacks is highest when the bony plate number is lowest.

Figure 3. Typical three-spined stickleback predators in ocean and freshwater habitats.
http://learn.genetics.utah.edu/content/selection/stickleback/

Discuss how EDA and PITX1 gene mutations AND natural selection have affected evolution in three-spined stickleback.

In your answer you should:

- describe the terms mutation AND natural selection
- explain how selection pressures in marine AND freshwater habitats act differently on bony plate number and spine length
- discuss the roles of mutation AND natural selection on three-spined stickleback evolution.

· A mutation is a change which occurs in an organism's gene. These can be harmful, beneficial or ineffectual. If mutations occur in a somatic cell they will not be passed on, but if a mutation occurs at meiosis in sexual reproduction, it may be passed to offspring.

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

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Natural selection occurs when the organisms with genes best suited to the environment will make them more likely to survive to reproduce & pass on these beneficial genes, whereas organisms with alleles least suited to the environment will make them less likely to survive to reproduce and pass on these unsuitable genes. Selection pressures are the driving force of natural selection, and work on phenotypes to ensure "the survival of the fittest".

- The main selection pressure in the marine environment for the three-spined stickleback is predation from larger fish. They also have low amounts of available shelter. Hence selection has selected marine populations to have longer spines in order to appear more intimidating to potential predators (to attempt to reduce the chances of predation), and a greater number of bony plates to make them less palatable to predators. The main selection pressure in the freshwater habitat is predation from grasping insects such as dragonfly larvae, especially of juveniles. Hence, in contrast, these selective pressures have selected for a higher growth rate & acceleration speed, associated with the lower number of bony plates, so they may escape predators faster. Shorter spines are selected for as the longer spines aren't employed as an intimidation technique.
- A mutation in the Ectodysplasin (EDA) gene led to variation in plate number, whereas mutation in the PITX1 gene caused difference in spine length. These mutations differed between each species (evident by difference in plate number / spine length) as they were beneficial in different ways for each respective population, hence these mutations became more dominant in the gene pool of one population than of the other, depending whether natural selection selected for

these mutations in deeming whether they provided a selective advantage in the different environments. Hence this has led to a difference in evolution between the two populations; the marine population is benefitted most from mutations causing longer spine length & more bony plates, whereas the freshwater population benefits most from mutations causing shorter spine length & less bony plates, as there are different selection pressures in each respective environment selecting some genes (including mutations) over others depending on the environmental conditions.

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E7

QUESTION THREE: KAKARIKI

Kakariki are the most common species of parakeet in the genus *Cyanoramphus* and are distributed throughout the South Pacific (Figure 5). Aotearoa has the largest number of species. Kakariki live in a wide range of habitats, including subantarctic tussock (Antipodes Island kakariki and Reischek's kakariki), beech forests in mainland Aoteoroa (yellow-crowned kakariki and orange-fronted kakariki), and tropical rainforests (New Caledonian red-crowned kakariki).

Figure 4. Forbes' kakariki, Chatham Island.
www.nzbirdsonline.org.nz/species/forbes-parakeet

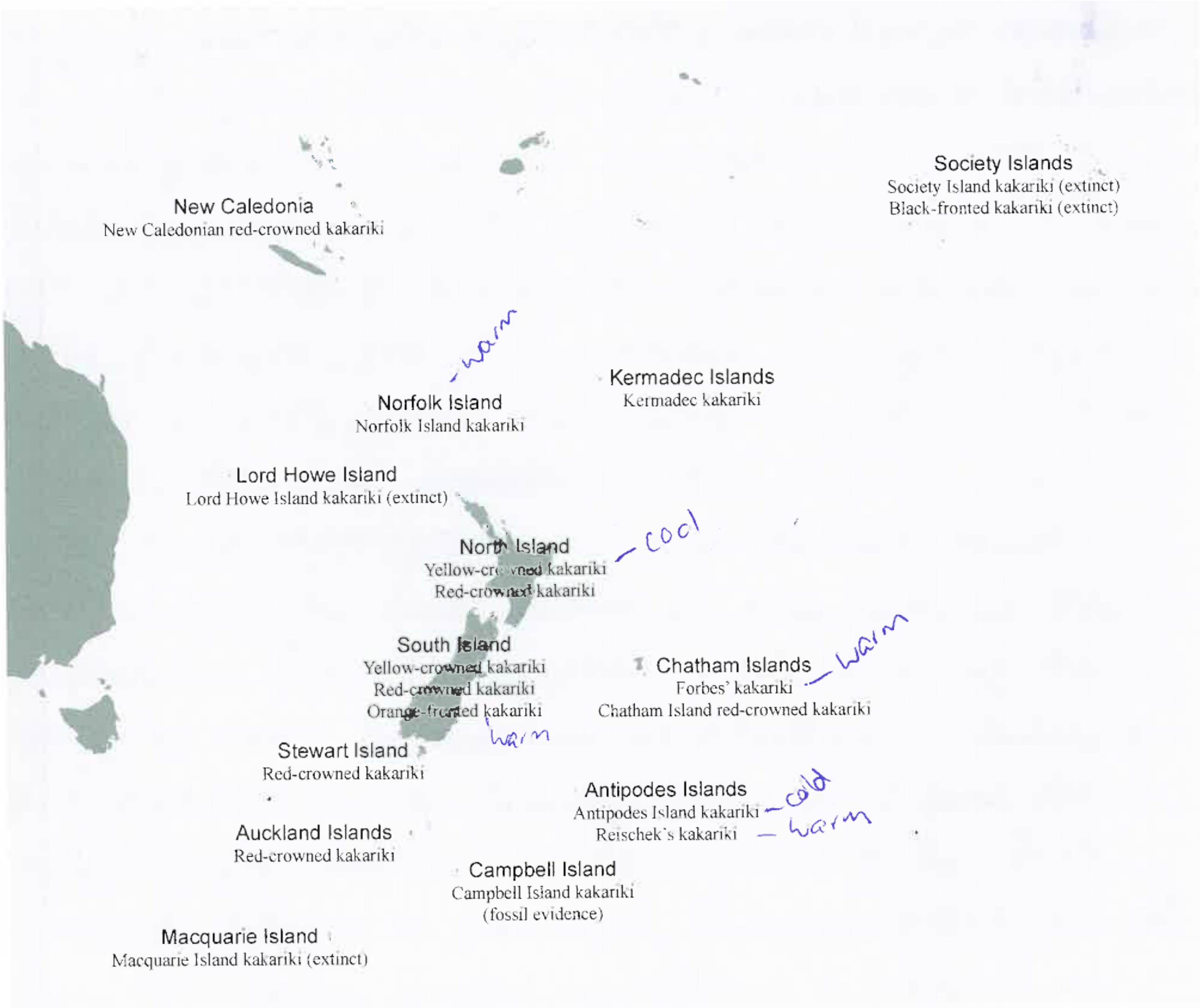

Figure 5: Kakariki distribution in the South Pacific.

The evolutionary relationships of kakariki species have been determined using mitochondrial DNA sequence analysis. The phylogenetic tree based on this analysis is shown in Figure 6. The climate during this period is shown in Figure 7, and the reconstructed vegetation cover at the height of the last glacial period is shown in Figure 8.

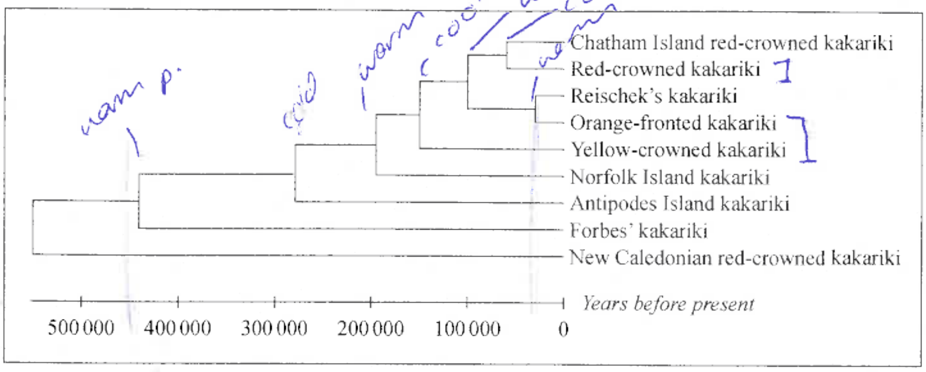

Figure 6. Phylogenetic tree for *Cyanoramphus*.
The time scale for evolutionary divergence is indicated above.

Adapted from Boon, W. M. *et al.* (2001). 'Molecular systematics and conservation of the kakariki (*Cyanoramphus* spp.)', *Science for Conservation*, 176 (Department of Conservation, Wellington).

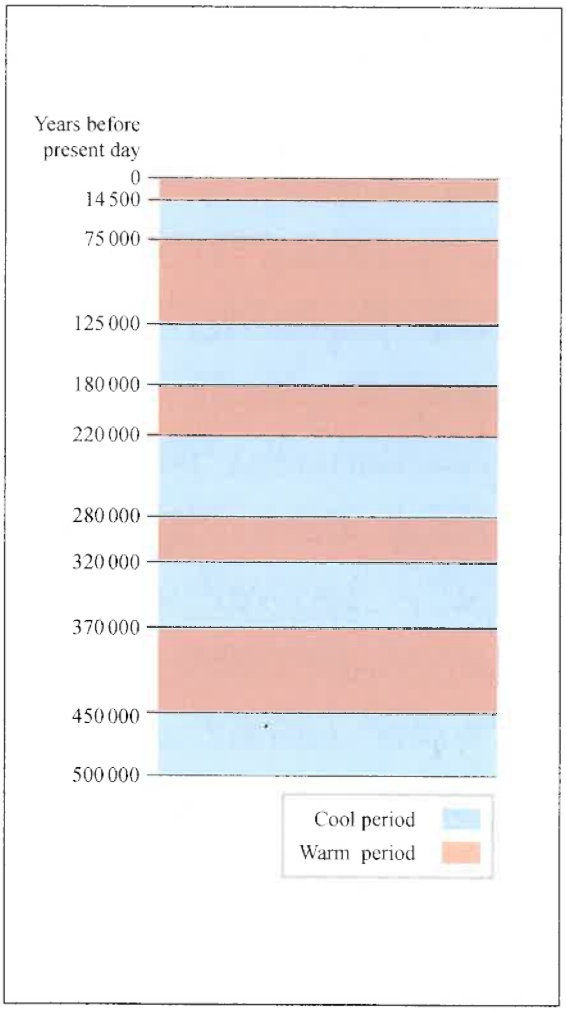

Figure 7. Glacial periods in Aotearoa.

Adapted from www.teara.govt.nz/en/diagram/10741/glacial-periods-in-new-zealand

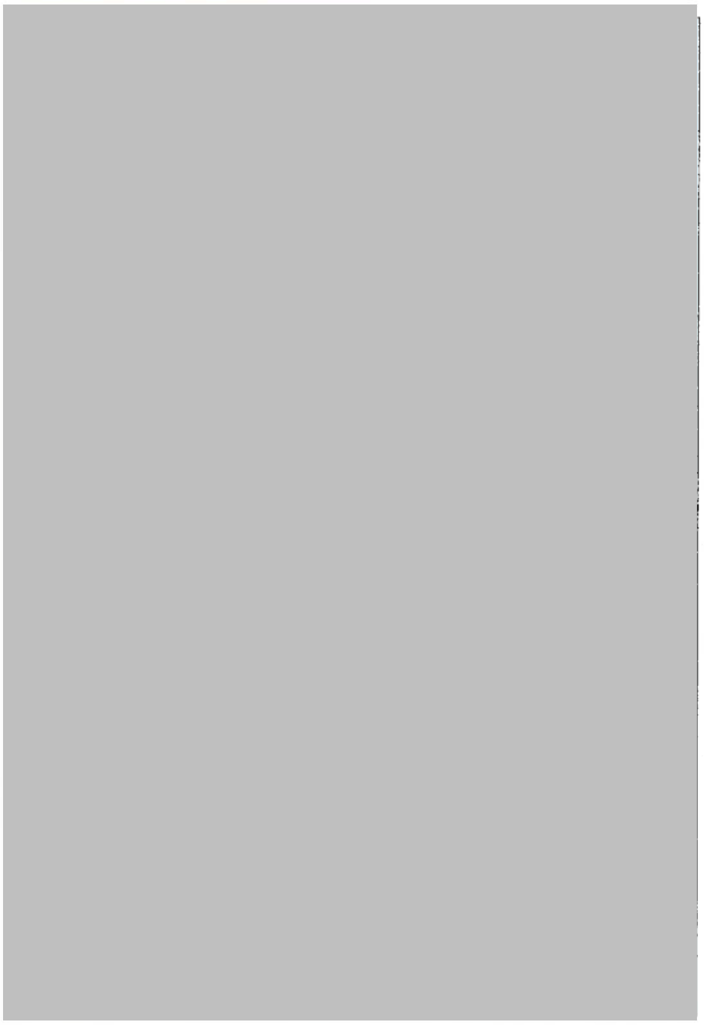

Figure 8. Aotearoa vegetation cover 19 000 – 29 000 years b. p. as reconstructed from pollen, macrofossil, beetle and geographic evidence.

Adapted from: Newnham, R, *et al.* (2010). 'The vegetation cover of New Zealand during the last glacial maximum', *terra australis*, 32, p. 59 (ANU E Press, Canberra). http://press.anu.edu.au/wp-content/uploads/2011/02/ch0417.pdf

Discuss the pattern of evolution in kakariki, and the factors that have affected kakariki evolution.

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In your answer you should:

- describe the evolutionary pattern AND type of speciation indicated by the resource material
- explain the origin and distribution of kakariki in Aotearoa with reference to the phylogenetic tree
- using the information provided, discuss how biological and geographical factors have contributed to kakariki speciation.

Adaptive radiation has occurred as the original kakariki species' ancestor diverged, at many different points through its evolution, to form today's 9 different Aotearoa & south Pacific region species from in order to take advantage of a variety of available niches in the Pacific region. Both allopatric speciation & sympatric speciation appear to have occurred in the kakariki's evolution. In some cases, a population of kakariki migrated to a different environment (i.e approx 280,000 years ago a group migrating to Antipodes Island), creating a geographic barrier to gene flow as different selection pressures in the different environments mean different allele frequencies occur in separate gene pools, eventually leading to genetic differences creating reproductive isolating mechanisms that prevent these groups interbreeding & speciating them. Sympatric speciation occurs when there's no geographic barrier to gene flow (i.e the yellow-crowned & red-crowned kakariki which appear to inhabit the same North Island habitat in Aotearoa), but a variety of available niches leads to niche differentiation (due to a variety of available niches / in effort to reduce competition for habitat & resources) or instant speciation in the form of polyploidy occurs in order to sympatrically speciate these groups from each other. Aotearoa has 3 kakariki species. The yellow-crowned kakariki was established in NZ approx 150,000 years ago, when the climate was cool, and inhabited beech forests. The red-crowned kakariki arrived approx. 75,000 years ago

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when the climate went through another cooling period and inhabited ~~the~~ similar beech forest areas in mainland NZ. Orange fronted kakariki arrived approx. 40,000 years ago ~~as~~ when the climate was cool, and also inhabited this similar beech forest area. Divergence of kakariki species have coincided with ~~[illegible]~~ ~~[illegible]~~ changes in climate as the glacial periods in Aotearoa have changed from warm to cool climates through time. In these changes of climates, different kakariki groups have sought to inhabit different areas, depending on whether the genes possessed in their particular population gene pool have suited or not suited the climate, leading them to seek habitats where their adaptations will be most advantageous in allowing them to survive in those respective environmental conditions. This is similar with geographical factors. Certain groups, over time, have become specialised in residing in a certain type of niche habitat - some species (i.e New Caledonian red-crowned kakariki) had genes better suited to surviving in tropical rainforest areas, whereas others were better suited to subantarctic tussock areas (i.e. Reischek's ~~[illegible]~~ kakariki). Hence, different allele frequencies, ~~[illegible]~~ means some groups have alleles better suited to different areas than others, in combination with niche differentiation, has led to the speciation & varied distribution of members of the kakariki species.

and different selection pressures which act differently upon birds with different gene pools

i.e during a warm period approx. 40,000 years ago, the species diverged as one group preferred to inhabit Reischek's island (subantarctic, tussock habitat) ~~[illegible]~~ Reischek's kakariki — the warm climate, whereas the other group – the orange fronted kakariki – preferred to inhabit the warmer beech forest area in Aotearoa mainland.

E8

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

QUESTION NUMBER

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Annotated Exemplar Template

Excellence exemplar 2016

Subject:	Biology	Standard:	91605	Total score:	22

Q	Grade score	Annotation
1	7	This is an E7 because the selective pressure is identified as high intraspecific competition as being high in low abundance of food and high density levels of tadpoles. The high intraspecific competition is linked to disruptive selection and the low intraspecific competition is linked to stabilising selection. The adaptations linked to the survival and success of each phenotype is explained and is also linked to sympatric speciation in the disruptive selection caused by reproductive isolating mechanisms.
2	7	Explains the process of natural selection in the context of the example provided of the three-spined stickleback fish. The role of mutation is linked to natural selection. Both biotic and abiotic factors are discussed and linked to the correct habitat.
3	8	Adaptive radiation and allopatric speciation are explained with reference to glaciation. Integrated information from the resource material to discuss how biological and geographical events have contributed to Adaptive radiation and allopatric speciation.