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MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
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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.

Achievement

TOTAL 11

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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.

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

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

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 differences in allele combinations in a population - it can be due to different selection pressures acting upon certain parts of the population, different mutations, or due to recombination processes in meiosis. All in all, genetic variation is important as it means populations are diverse, have different genotypes and phenotypes in gene pool, and hence have a greater chance of surviving different selection pressures and are less likely to be effected by genetic drift and Bottleneck effect. The Mexican

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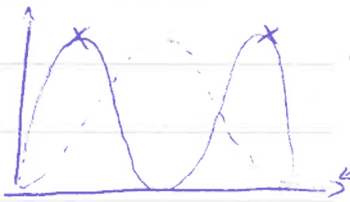
Spade foot ~~toad~~ toad has great variation. In ponds with low abundance of food resources and high density of tadpoles, natural selection has acted upon the Toads in a ~~sta~~ disruptive selection process. Both extremes of toad tadpoles are selected for simultaneously and here there ~~is a~~ are two distinct and varying populations - 1 (omnivore morph) has a round body, long intestine, small jaw muscles and smooth mouth parts and is omnivorous, while the other one (carnivore morph) displays opposite characteristics functions / such as having a ~~round~~ narrow body, short intestine, enlarged jaw muscles, teeth-like mouth parts and has a carnivorous diet. Both 2 extremes of Toads are selected for by the process of natural selection.



The selection pressures which promote disruptive selection is the low abundance of food found in the pond which means that either toads need to eat omnivorous diet or a carnivorous diet to allow to enough food for the population to survive. This selection pressure has meant that the omnivore morph has adapted to be small in stature, and requires smaller teeth for eating algae and small crustaceans, while the carnivore morph has adapted as be a bigger, larger toad with bigger jaw muscles, more fitted for a carnivorous diet, and for surviving off feeding off fairy shrimps.

In a pond with high levels of food abundance, stabilising selection occurs where the average and intermediate phenotype is selected for, as they fit the environment best.

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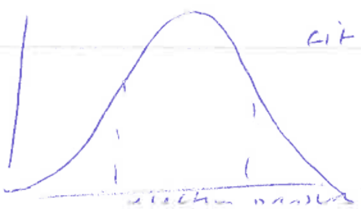

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The selection pressure is having higher food source available in pond for stabilising selection and here the average phenotypes are chosen.

For speciation to occur - the formation of new toad species would occur if they remain reproductively isolated for an extended / long period of time, and there is no gene flow between populations.

The toad ~~species~~ population would need to be split - either by a geographical barrier (allopatric speciation) or with another reproductively isolating mechanism which would prevent gene flow between them and hence create a new species.

Ecological barriers may already be present: they may be living in the same location, but living in different habitats and niches due to the natural selection pressures already placed on them. Hence, sympatric speciation can occur by which they continue to live in the same geographical location, but are reproductively isolated with no gene flow, and perhaps different selection pressures will cause different mutations, creating new species of toads.

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QUESTION TWO: THREE-SPINED STICKLEBACK

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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.

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 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

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.

Mutations are permanent changes to genetic code /DNA sequence which can be silent, neutral or harmful. Natural selection is when those individuals who are most fitted to the environment are chosen and selected for and hence pass on their alleles to their offspring, and enjoy reproductive success and are better able to adapt to change in environment due to their allele combinations.

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

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Selection pressures act differently in each marine and freshwater habitat on bony plate number and spine length. In fresh water, fish have ~~longer~~ low numbers of bony plates and short spines. The selection pressures acting on them are predators including grasping insects. They also live in a freshwater environment with lots of shelter. Due to lots of shelter, ~~a~~ they are at less of a risk of being attacked by their grasping insect predators, and hence need less bony plate numbers ~~and have~~ short spines - these are good adaptations for hiding in the shelter, away from the predators, as well as the fact that they need less bony plates to swim as fast / to protect themselves from the predators. Hence, they are fitted to surviving in the freshwater environment and can reproduce, find food and survive.

On the other hand, selection pressures like larger fish predators, and low amounts of shelter to the sticklebacks means that they have higher amounts of bony plates and large spines for protecting themselves against these big fish, and having little shelter so having to be able to protect themselves by swimming away ~~a~~ or ~~finding places to stay~~ trying to protect themselves against their predators. This would require more bony plates and longer spines to combat the harder living conditions for the marine living sticklebacks.

Mutations play a large role in evolution. The mutation in EDA gene and PITX1 gene

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which created variation in plate number and spine length helped the stickleback survive and was a beneficial mutation. Speciation came over without mutations in the germ line (passed on by zygote) hence, mutation can be very influential in the evolutionary process of stickleback. Mutations allowed them to survive and reproduce in their varying environments and to survive the different selection pressures acted upon them.

Natural selection chose the most fitted sticklebacks for each habitat - marine vs freshwater, and allowed them to carry out life feeding, reproduced and pass on their alleles to their offspring - more fitted offspring, hence greater variation and strong gene pool.

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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

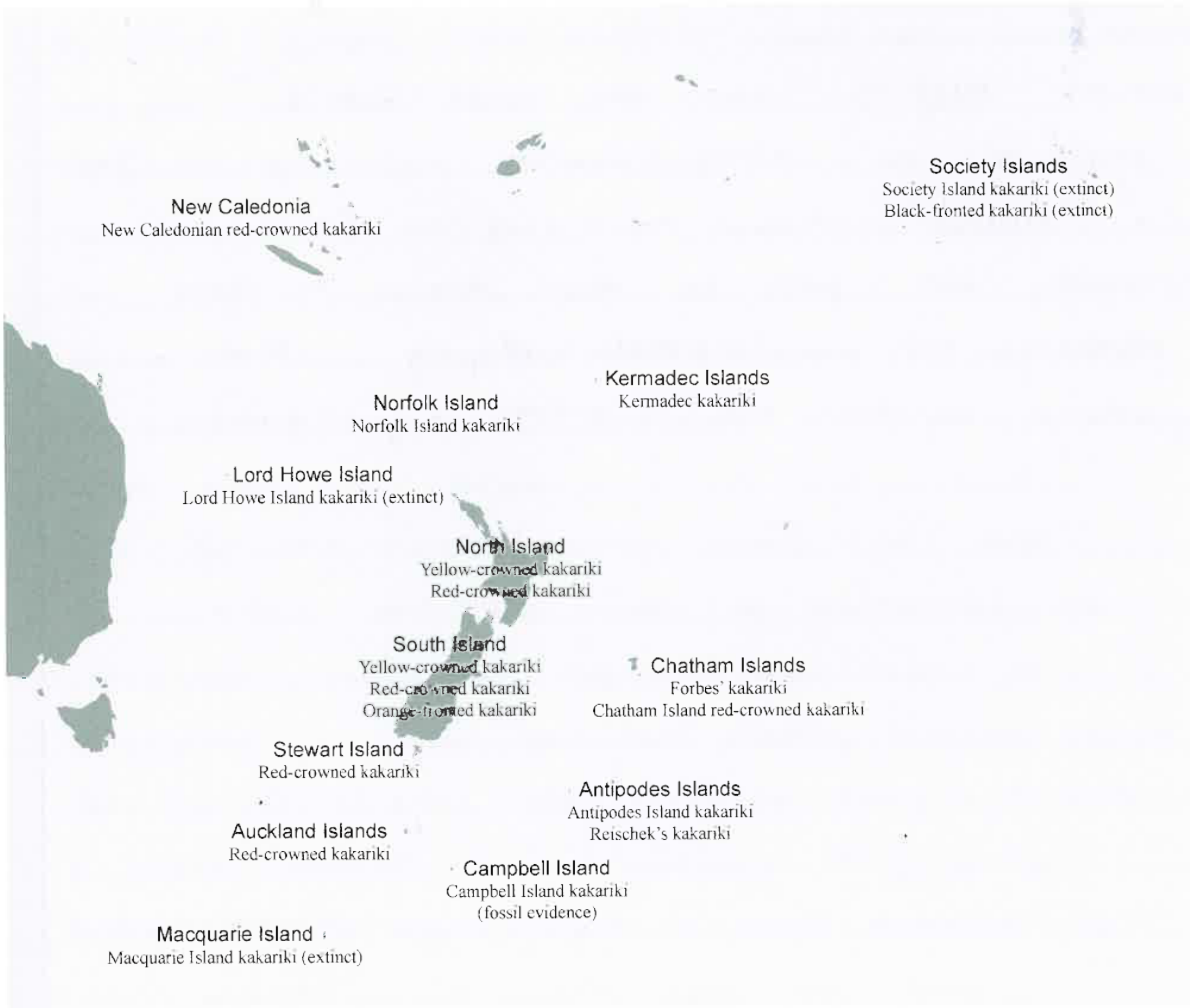

Figure 5: Kakariki distribution in the South Pacific.

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.

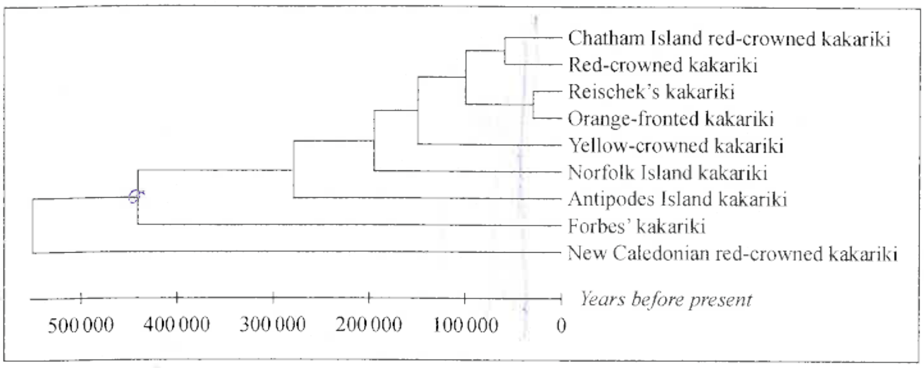

Figure 6. Phylogenetic tree for *Cyanoramphus*.
The time scale for evolutionary divergence is indicated above.

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).

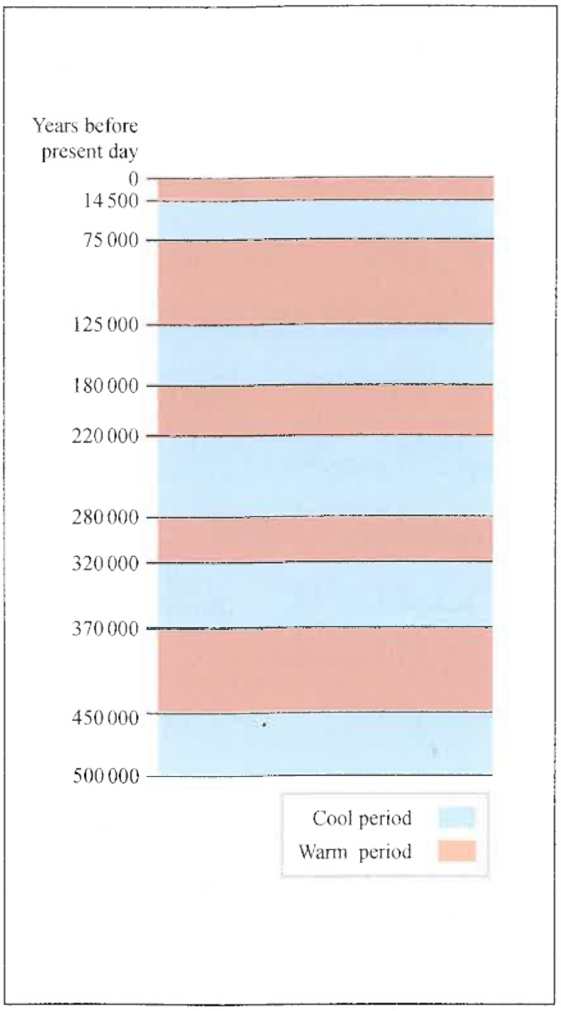

Figure 7. Glacial periods in Aotearoa.

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

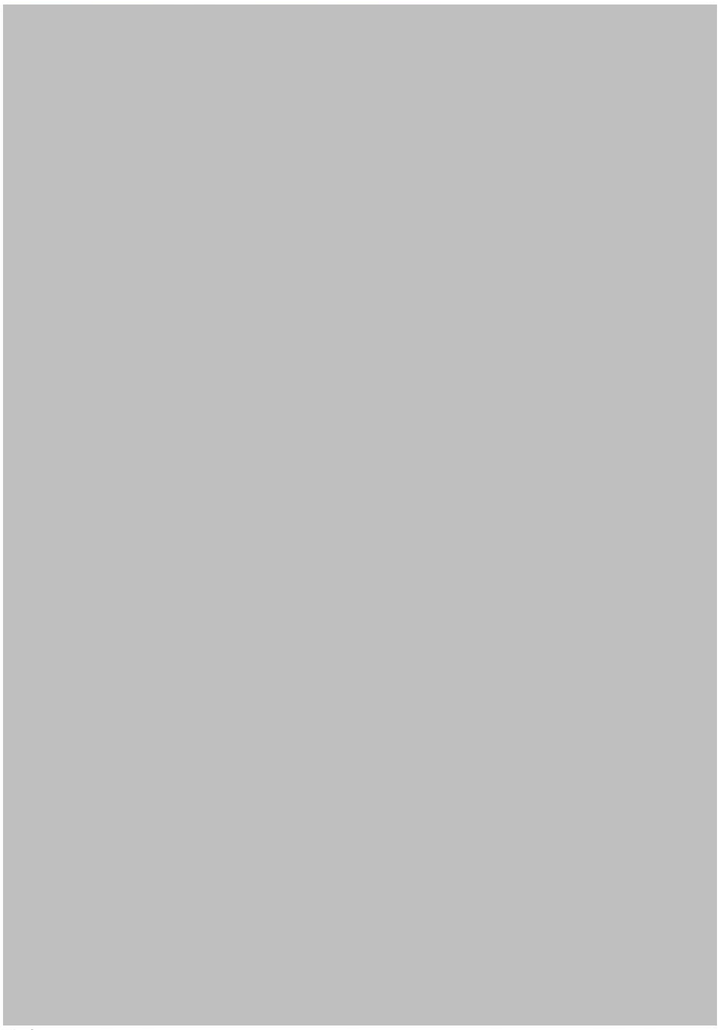

Figure 8. Aotearoa vegetation cover 19 000 – 29 000 years b. p. as reconstructed from pollen, macrofossil, beetle and geographic evidence.

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.

The phylogenetic tree of evolution of kakariki shows divergent evolution in which from a common ancestor, different kakariki species have evolved due to different selection pressures acting upon them, being reproductively isolated, and hence no gene flow occurring between the kakariki. The phylogenetic tree ~~is~~ shows ~~equ~~ punctuated equilibrium in which there are periods of stasis (few change) and then at times more evolution / speciation occurs at a more increased rate. From 200,000 - 100-000 years to now, there has been more recent speciation shown by the shorted period's which represent more recent taxa being formed.

The Phylogenetic tree shows divergency from a common kakariki ancestor which is shown by the connection of the nodes which represent common ancestory.

It is an example of allopatric speciation occurring in which the initial kakariki population was separated by a geographical barrier, then different selection pressures acted upon the different isolated populations such as differences in vegetation where they were inhabiting. In New Zealand, different areas such as the bottom of north island and

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top of south island had shrubland grassland with patches of beech forest which varied from the bottomost south island which had glaciers or permanent snow. These completely different environments would have meant different niches, living conditions and temperatures and would have enabled the kokako to become (more reproductively isolated.)

Geographical barriers formed by living in different parts of NZ and on different neighbouring islands ~~provided~~ meant the population were reproductively isolated, and gene flow stopped. Hence, speciation could occur.

Biological factors contributing to speciation of kokako could be due to differen ecological environments, and different reproductively isolating mechanisms such as behavioural, temporal and genetic differences which mean lack of gene flow and no interbreeding hence speciation.

In the case of allopatric speciation, after the geographic barriers were lifted, some of the kokako ~~at~~ ~~some~~ are living sympatrically - still reproductively isolated but in the same location as speciation has occurred.

The chatham island red-crowned kakariki, red crowned kakariki, malherbes kakariki and orange fronted kakariki all evolved more recently, during warmer temperatures and came from a common ancestor as shown by using comparison of their nuclei

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

QUESTION NUMBER

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1111Annotated Exemplar Template

Achieved exemplar 2016

Subject:	**Biology**	**Standard:**	**91605**	**Total score:**	**11**

Q	**Grade score**	**Annotation**
1	3	Genetic diversity in the Mexican spadefoot toad tadpole is described. Disruptive selection is described for both carnivore and omnivore morphs. Intermediate phenotype associated with stabilising selection.
2	4	Mutation is described and natural selection is described. Plate number and spine length mutations are also described.
3	4	Divergent evolution is described. Punctuated equilibrium is also identified and described Describes stimulus for allopatric speciation. Allopatric speciation described.