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Level 3 Biology, 2017

91605 Demonstrate understanding of evolutionary processes leading to speciation

9.30 a.m. Thursday 16 November 2017
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 23

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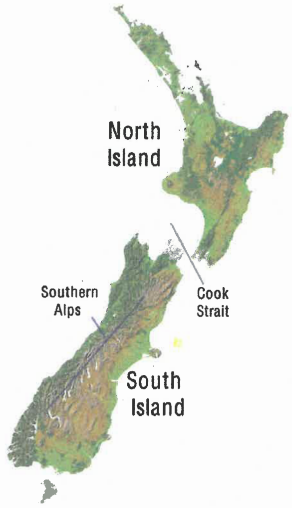
QUESTION ONE

Distribution, dimensions, habitat preference, and bill morphology of moa



Adapted from: Bunce M, et al. 2009. 'The evolutionary history of the extinct ratite moa and New Zealand Neogene paleogeography'. *Proc. Natl. Acad Sci. USA.* 106: 20646–20651; and Attard M, et al. 2016. 'Moa diet fits the bill: virtual reconstruction incorporating mummified remains and prediction of biomechanical performance in avian giants'. *Proc. R. Soc.* 283: 2015–2043

Moa were the dominant group of herbivores in ecosystems in New Zealand/Aotearoa until their extinction about 550 years ago. Moa species had a wide diversity of sizes and significant differences in the structure, strength, shape, and biomechanical performance of the skull and bill. Evidence suggests a single lineage of moa existed 25 million years ago (mya) in the South Island. Recent genetic analysis indicates new species started emerging about 5.8 mya, and by 1.4 mya, all nine known species existed. Fossil evidence indicates many of these species overlapped in geographical range.

Analyse the events that may have led to evolution of the moa.

In your answer you should:

- describe the terms allopatric speciation and sympatric speciation
- describe the pattern of evolution shown by moa, AND explain how this type of pattern can arise
- discuss the evolutionary significance of the diversity in moa bill shape
- analyse the evolutionary processes that contributed to moa speciation.

This canidate used a named species eg "Dinornis species" to discuss allopatric speciation and the geological processes that were involved eg glacial periods causing the linking of North Island with the South Island. This also links to different niches becoming available and is explained to how this could lead to sympatric species as the moa had become genetically isolated. Adaptive radiation is explained and linked to the development of new niches due to the named geological and biological processes such as competition.

Allopatric speciation is speciation occuring in two different places. This occurs when an ancestral population spreads out to occupy new niches in different regions. Populations of the ancestral species become geographically isolated by a land mass / water (reproductive isolating mechanism), preventing gene flow between the populations. This lack of interbreeding allowed genetic differences to accumulate between the populations until the populations lost the potential to reproduce to produce fertile offspring, so allopatric speciation occurred. An example of this is the allopatric speciation of the Dinornis moa. During a glaciation period, sea levels fell and NZ became one large land mass. Moa would have spread out around NZ, to reduce competition and exploit new niches made available. As the sea level rose during an interglacial period, the moa species was separated into a North and South Island population, with the geographic RIM of the Cook strait separating the populations (so no gene flow / interbreeding). Therefore, as the North and South Island had different selection pressures (e.g. different climates), genetic differences accumulated (as natural selection favoured different alleles for each environment) until the populations lost the potential to reproduce to produce fertile offspring, and the populations became two different species (North and South Island Giant Moa). Sympatric speciation is when an ancestral population occupies a variety of niches in the same geographical area. Due to this niche differentiation, there is no / limited gene flow between populations and so genetic differences accumulate (natural selection favours different alleles) until the populations lose the ability to reproduce to produce fertile offspring, and hence become different sympatric species. The pattern of evolution shown by moa is adaptive radiation. Adaptive radiation is

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when an ancestral population diverges into many species as different populations occupy a large number of different unoccupied niches. This type of pattern can arise when, for example in varying glacial and interglacial periods, a number of unoccupied niches are available due to the changing environment. Different environment with different selection pressures lead to sufficient genetic differences accumulating (no gene flow) for the loss reproa offsp The diversity of moa bill shape tells us that adaptive radiation has occurred since many phenotypes have been established, indicating that an ancestral moa population occupied a variety of different niches. These niche differences could be due to diet, as different bill shapes would allow moa to exploit different resources, reducing competition. From around 5.8 - 1.4 million years ago, the climate was changing as a result of glacial/interglacial periods affecting the availability of food sources. The availability of food sources that the ancestral moa population ate would have decreased increasing the competition on moa to obtain sufficient food to survive and reproduce to pass on alleles. To reduce competition, the ancestral moa occupied a variety of different available niches by exploiting different foods. Individuals who were most suited to their new niche (e.g. bill shape most suited obtaining food being eaten) were most likely to obtain the most resources so most likely to survive to reproduce and pass on favourable alleles. The lack of gene flow between populations (niche differentiation) meant genetic and phenotypic differences could accumulate, and bills became more diverse among different populations, until eventually sufficient genetic differences had accumulated that the moa populations became different species. Speciation of moa was

(please see pg 11 :)).

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QUESTION TWO

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the ability to
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https://vtnews.vt.edu/articles/2016/06/fralin-garter.html

The rough-skinned newt (*Taricha granulosa*) is distributed throughout North America. Many populations contain the poison tetrodotoxin (TTX) in the skin, which acts as a defence against predation. Despite TTX being one of the most powerful neurotoxins known, the garter snake (*Thamnophis sirtalis*) is able to prey on the rough-skinned newt. The levels of toxicity of newts and the resistance of the garter snakes vary geographically.

TTX Resistance vs Speed at which the garter snake can move

TTX resistance	Number of amino acid mutations	Speed at which the snake can move
Least resistant	1	fast
Intermediate resistant	2	intermediate
Most resistant	3	slow

Analyse the evolutionary relationship between the rough-skinned newt and the garter snake.

In your answer you should:

- describe the **pattern of evolution** shown by the relationship
- explain how this kind of relationship develops
- discuss the role of **natural selection and mutation** in the evolution of the features shown
- analyse the selection pressures that work both for AND against the relationship.

The evolutionary relationship between the rough-skinned newt and the garter snake is co-evolution. Co-evolution is when two interacting species act as selection pressures

There is more space for your

This candidate has demonstrated comprehensive understanding by linking biological ideas using scientific evidence about natural selection, mutation and co-evolution leading reproductive success and speciation. For example this candidate is able to analyse the information about TTX resistance of the Garter snake and the speed they move linked to number of mutations and the effect this has on the survival of each species. The linking of ideas involved analysing the evolutionary processes that lead to speciation by explaining how this relationship develops by natural selection.

selective pressures the snake and the newt are explained and linked to natural selection. One negative selection pressure for the the newt is explained and linked to natuaral selection.

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evolutionary effect on each other as both species evolve in response to the other. This kind of relationship develops when both species influence the chance of survival of the other, so the species must evolve genetic differences to influence (help or harm) the other species. The ~~go~~ rough-skinned newt has evolved the physiological defense of having the TTX neurotoxin in its skin. Newts who have this neurotoxin are more likely to survive to reproduce and pass on their alleles since this toxin will ~~kill o~~ harm the predator, (garter snake) who will likely drop the newt (allowing it to escape and survive) and then kill the predator, further increasing chance of survival of the newt and newt population. Therefore, the TTX poison in the newt's skin provides a selective advantage to the newts and consequently ~~this~~ the presence of this poison will be selected for by natural selection ~~(individuals in~~ (newts with the poison are more likely to survive to reproduce and pass on favourable alleles, ie. have offspring who will also have the TTX poison in their skin). Newts who don't have the selective advantage of the TTX poison are more vulnerable to predation by the garter snake and are therefore less likely to survive to reproduce and pass on their unfavourable alleles. Therefore these newts are selected against. However, a mutation occurring in garter snakes has given garter snakes an adaptive advantage - this mutation gives partial resistance to the ~~garter snake~~ TTX toxin so although ~~they~~ the garter snakes are unlikely to be able to eat the newt, they will likely survive the attempt at eating the newt. Garter snakes with this mutation are therefore more likely to survive to reproduce and pass on their favourable alleles (including

* and the reciprocal effects of these selection pressures will re-inforce the co-evolutionary relationship.

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the mutation, assuming it was a gametic mutation). Over time, more mutations which have given garter snakes resistance to the TTX toxins have become established in the gene pool as they are beneficial mutations, so have been selected for by natural selection (individuals with the mutation more likely to survive an attempt at eating the newt and potentially being able to successfully consume the newt ("prey on it") if the individual has a large number of the mutations (e.g. 3). These individuals (many mutations) are the most likely to survive to reproduce and pass on their large number of TTX-resistant mutations to offspring so overall the resistance of the garter snake population to the TTX poison increases. (mutated alleles become more common in the gene pool). Garter snakes with the greatest resistance to the TTX poison (3 amino acid mutations) move the slowest. This is because these individuals tend to be more successful in predating the newts and hence have greater access to a food resource that those garter snakes with very little resistance to the TTX poison (e.g. only 1 amino acid mutation) do not have access to. Therefore, the most resistant garter snakes do not need to expend as much energy ~~the~~ to catch prey while individuals with very little ~~an~~ resistance must travel very fast to be a successful predator on other food sources. Selection pressures working for the relationship are that garter snakes that are resistant to the newts have a greater energy intake and is a more effective predator ... and in response newts may become more toxic* so are more likely to survive to reproduce, however selection pressures working against the relationship are that newts may have to evolve new defenses against the garter snake, so garter snakes may have to find ~~a~~ new food sources to predate, ie. the co-evolutionary relationship will no longer exist.

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QUESTION THREE

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Shireplitis is a newly discovered genus of wasp endemic to New Zealand/Aotearoa. These species are mostly found in moss, litter, or tussock grasslands, at moderate altitude on mountain ranges.

Paroplitis is an unrelated genus of wasp, mostly distributed in Europe and North America, with some species living at moderate altitudes.

Shireplitis and *Paroplitis* look similar, with shared features being their relatively small size with a body length of about 2 mm, short and smooth abdomen, dark colour, short and robust legs, and short antenna. *Shireplitis* and *Paroplitis* both parasitise caterpillars. Host caterpillars are only known for the European species *Paroplitis wesmaeli*. One of these host species feeds on moss while another feeds on moss and grasses. Biologists hypothesise that *Shireplitis* may parasitise caterpillars that feed on moss, leaf-litter, dead wood, or fungi.

Shireplitis bilboi **Shireplitis frodoi** **Shireplitis meriadoci**

Shireplitis peregrini **Shireplitis samwisei** **Shireplitis tolkieni**

The six species of *Shireplitis.*

http://microgastrinae.myspecies.info/microgastrinae/shireplitis

Paroplitis wesmaeli

http://microgastrinae.myspecies.info/gallery?f[0]=im_field_taxonomic_name%3A28649&f[1]=im_field_taxonomic_name%3A28644

Discuss the evolutionary pattern AND selection pressures that have contributed to this pattern for *Shireplitis* and *Paroplitis*.

In your answer:

- describe selection pressure AND the pattern of evolution shown by *Shireplitis* and *Paroplitis*
- describe homologous structures and analogous structures
- using the information above, explain how analogous structures are related to the pattern of evolution shown by *Shireplitis* and *Paroplitis*
- discuss, using the evidence from the resource material, how this evolutionary pattern could arise.

Selection pressure is any factor that causes a species to evolve / its gene pool to change, as selection pressures cause different alleles to be favourable and be selected for, by natural selection. The pattern of evolution shown by Shireplitis and Paroplitis is convergence. Convergence is when two unrelated species become more genetically

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similar in response to selection pressures, due to occupying similar niches with similar selection pressures (ie. similar alleles are selected for in each species by natural selection). Homologous structures are structures that are similar in structure (indicating common ancestry) but different in function (indicating adaptation to different ~~environments~~ niches/environments with different selection pressures. Homologous structures indicate divergence. However, analogous structures are structures that are similar in function (indicating adaptation to a similar niche with similar selection pressures) but different in structure (indicating unrelated ancestry). Analogous structures of Paroplitis and Shireplitis have been evolved as Paroplitis and Shireplitis exploit similar niches with similar selection pressures. For example, both species live at moderate altitudes in an alpine environment. Both species also parasitise caterpillars, and some of their host caterpillars both feed on moss. Therefore, similar selection pressures act on the Paroplitis and Shireplitis species ~~as~~ as they occupy similar niches, so the species have evolved similar structures in response to these similar selection pressures. These similar structures are analogous structures and include a relatively small size, short abdomen, antenna and legs, as well as dark colour. These traits would have been selected for in both similar environments since the small size would have ~~be~~ provided a selective advantage for 2 reasons. Firstly, a small size would allow the ~~w~~ Paroplitis and Shireplitis individuals more effectively parasitise their host caterpillars. A small size is less noticeable to host caterpillars and so the wasps will be able to better parasise the caterpillars without the caterpillars

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being aware of their presence. This improves the chance of survival of the wasps as ~~they~~ the host caterpillars are less likely to evolve defenses that would aid their (the caterpillars') survival (for example, becoming toxic to the wasps). Therefore with alleles for small size, the wasps from both species are more likely to survive to reproduce and pass on their favourable alleles to offspring so in both Paroplitis and Shireplitis, alleles for a small size have become more common in both gene pools and hence ~~small size of~~ abdomen, antennae, and legs have become analogous structures, as both are relatively small. (function) while the structures have different evolutionary origin. (indicating a lack of common ancestry). Both species have evolved the analogous structure of dark colour suggesting that both exploit similar host caterpillars which are dark in colour. The individuals of both species that have the alleles for dark colour are most likely to camouflage into the host caterpillar and are unlikely to be seen. Not only does this reduce the chance of the host caterpillar species evolving defences against the wasps but also protects the wasps from other predation. Therefore dark colour is selected for in both species as in both species, individuals who are dark in colour are most likely to survive to reproduce and pass on their dark colour ~~ge~~ allele so in both species, dark colour becomes more common (analogous 'structure') as similar selection pressures are acting on the species in their similar niches. If genetic similarities continue to accumulate between the two species due to similar niches resulting in similar selection pressures

(please see pg 11 :))

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

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(1) a combination of sympatric speciation and allopatric speciation as both the changing sea level (allopatric speciation) and niche differentiation (to reduce competition as a result of the changing environment depleting resources → sympatric speciation) influenced the divergence of moa from its common ancestor.

(3) acting on the two species, sufficient genetic similarities may exist that the two wasp ~~pa~~ species, Paroplitis and Shireplitis (genus) ~~may~~ can interbreed to produce fertile offspring, and hence may fully converge into one species. ~~Howev~~ The chance of this occurring would depend on the viability of hybrids and their success in the environment, as well as whether a potential 'migration' could occur to facilitate this inter-breeding, since Shireplitus genus lives in NZ while Paroplitis lives in America. This would be a very large journey for either species to make so ~~convergence~~ it would be difficult to confirm whether the ~~po~~ two 'populations' have become one species, ie. if they can reproduce to produce fertile offspring.

The candidate discusses convergent evolution by linking the evidence of analogus structures provided in the information and links this to named selective pressures. eg "small size, short abdomen, antena and legs as well as dark colour. These traits would have been selected for 2 reasons. Firstly a small size is less noticeable to host caterpillars and so the wasps will be able to better parasitise the caterpillars"..... links selective pressures to analogus structres.

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

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