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91605

916050

NEW ZEALAND QUALIFICATIONS AUTHORITY
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QUALIFY FOR THE FUTURE WORLD
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Level 3 Biology 2022

91605 Demonstrate understanding of evolutionary processes leading to speciation

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.

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

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

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

Excellence

TOTAL 23

QUESTION ONE: POISON

Pufferfish
Source: www.scienceabc.com/nature/animals/what-are-pufferfish-and-are-they-toxic.htm

Blue-ringed octopus
Source: www.nhm.ac.uk/discover/blue-ringed-octopus-small-vibrant-deadly.html

Rough-skinned newt
Source: www.sciencenewsforstudents.org/article/toxic-germs-on-its-skin-make-this-newt-deadly

The most important poison found in newts, the blue ringed octopus, and pufferfish is tetrodotoxin (TTX). It is one of the most dangerous toxins known. It acts on the nervous system of prey, and can result in muscles not being able to work, leading to death. It is used by the animals as an antipredator defence.

An adaptation of extreme resistance to this chemical has come about in several species of snakes that eat newts.

Snakes living in areas where there are prey who make TTX, have a protein expressed with a different amino acid which prevents nerve and muscle tissue being affected. Some snakes, such as the garter snake (*Thamnophis sirtalis*), are able to eat highly toxic newts because they have developed resistance to TTX, due to changes in a number of protein coding genes.

Researchers studied the success of snakes in eating newts in an area. They gave a percentage performance score based on the survival of the snake population in the survey area, as shown in the graph below. A score of 85% meant that 85% of the snakes in the area survived and reproduced.

Source: www.newscientist.com/article/dn13438-toxic-newts-lose-war-against-super-immune-snakes/

Source: https://evolution4e.sinauer.com/exercise1301.html

Discuss how both coevolution and convergent evolution are demonstrated in this example of animals with TTX- producing genes and those with resistance to TTX.

In your answer

- define the terms coevolution, convergent evolution, and mutation
- explain how the octopus, the pufferfish and the newt each having TTX is an example of convergent evolution
- using data from the graph, discuss how coevolution has led to an increase in TTX production in newts, and evaluate the implications of this for the survival and success of the newt species.

Co-evolution is the simultaneous evolution of two closely interacting species, (interspecific relationship) where any change/advantage to one species over the other acts as a selection pressure on the other species, influencing their evolution. These can be seen in predator-prey relationships, like that of the highly toxic newts (prey) and the toxin-resistant snakes (predators).

Convergent evolution is the development of similar traits/behaviours/forms in unrelated species due to them having similar niches/living in similar environments and experiencing similar selection pressures. → no gene flow between the pops.

New ~~traits~~/alleles arise solely due to mutation, which is the random alteration of base sequences of DNA, causing different proteins to be coded for and thus different phenotypes to occur. Heritable mutations, ones that contribute to the individuals fitness, will persist in the population as those with the advantageous trait, such as the development of the gene in control of TTX producting in pufferfish, newts, and blue ringed octopus, will be more likely to survive/avoid predation and pass on their alleles to future generations, causing the allele frequency of alleles such as the one in control of TTX production to increase in populations. The newt, octopus, and pufferfish are all ~~of~~ unrelated species with their last common ancestor living extremely long ago. As they are all vulnerable, small organisms with lots of predators such as sharks and other fish for the pufferfish and octopus, and predatory birds and fish for the newt, all species experienced a mutation that caused TTX production to occur. All species live ~~mostly~~ in and around water, so experienced similar selection pressures and high levels of predation, so those that developed toxins to deter/kill predators were more likely to survive and pass on their genes, causing the frequency of this trait to increase in all populations.

The ~~genes~~ bases/genes mutated to cause the production of TTX

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would be on completely different loci in possibly different genes, meaning that it is an analogous trait/structure – one that is similar in form on many different species but has different structures and heritage, the traits are just superficially similar due to similar selection pressures. TTX paralyses and kills predators, allowing the prey individual to get away and survive, increasing success and chance of reproduction.

The newt and snake exhibit co-evolution – where the development/mutation causing the toxin TTX in newts to deter the predatory snakes prompted a selection pressure in the snakes to increase their TTX resistance. Snakes with no resistance that ate TTX producing newts would quickly die out as the toxin would act on their nervous system and kill them. Therefore, the snakes with a higher resistance had better access to a low-competition/novel food source that allowed them to be more successful reproductively, passing on their genes to future generations. This increase in TTX resistance ~~was~~ acted as a selection pressure on the newt, which ~~one~~ formed the TTX as an anti-predator defence, causing those newts with lower TTX production, the 85%. that allow the snakes to live, would die out. The 15%. of snakes that die to the newts is because the newt TTX exceeds the snake's resistance.

There is a directional selection pressure on both the snake and the newt that they impose on one another, causing increases in both TTX production and TTX resistance. Both of these traits require a greater energy supply, ~~so~~ which is the cost of the trait, but this is outweighed by ~~the~~ having a large food source (snake) and avoiding predation (newt)

these newts, with greater TTX production will survive and be more successful passing on their genes to create an offspring population with higher TTX production.

QUESTION TWO: TRIPLE-FINNED FISH

Source: www.researchgate.net/figure/Triplefin-species-used-in-this-study-and-their-respective-distributions-Bellapiscis_fig2_351878084

Approximately 130 species of triplefin have been identified worldwide living in many habitats, such as in tropical, subtropical, temperate, subantarctic, and the Antarctic Peninsula polar sea regions. In New Zealand, we see a large diversity of triplefin species. New Zealand has over 20 species of triplefin, all of which are endemic.

Discuss how the New Zealand triplefins are an example of adaptive radiation.

In your answer:

- describe what is meant by the terms endemic and species
- explain how temperature may act as a selection pressure, and leads to different species being found at different zones of the beach, such as the three species of triplefin that are shown in the diagram above
- discuss how the process of natural selection has resulted in such a large number species of triplefin here.

A species is a group / set of organisms that are able to breed among one another, ~~interbreed~~, to produce successful / fertile offspring, but cannot successfully interbreed with other species / groups to create fertile offspring. An endemic species is one that only appears in a single environment / country / area, such as the 20 species of triplefin in NZ.

Temperature may be a selection pressure on the triplefin as they become sympatrically speciated at

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

varying levels of the rock pools. ~~The B. medius at the high rock pools may be more inclined to higher temperatures found there, whereas the~~ The ecological separation of the three species of Tripterygii in the rockpools was likely due to high intraspecific competition for food resources. This caused the fishes, ~~males~~ populations to move to different parts of the tidal zones, creating clines, to exploit the different food resources there - the B. medius in the high tide zone may utilise small fish and crabs and barnacles while the F. varium in the subtidal zone may utilise larger fish or jellyfish. The varying temperatures at the different parts of the tidal zones results in different selection pressures for the separated populations, causing different traits to be selected for as different environments meant that different phenotypes were advantageous. The warmer high tide pools may have selected for darker scaling for more effective camouflage against the rock pools and better heat regulation across the scales / in and out of the body whereas the cool temperatures in the subtidal zone would select for a lighter, reflective scaling with different patterns for better thermoregulation in that environment. The intertidal zone of intermediate temperature would prompt the development of an intermediate form. The different selection pressures, over time, would cause different mutations to amass and eventual reproductive isolation between the species would occur such as behavioural isolation due to different developed courting behaviours, mechanical isolation due to the development of different forms, as well as ecological isolation, because they live in different parts of the tidal zone so have different niches. Those with the best traits, highest fitness, in their realised niche would be most likely to survive and pass on their genes so causing changes in allele frequency leading to the different species being unable to

interbreed to produce fertile offspring, meaning that they have become reproductively isolated and are different species.

Natural selection is the selection of favourable mutations / alleles in a population, causing them to become more frequent in the gene pool, as well as the eradication of unfavourable traits. New Zealand offers a wide range of environments so when the triplegis first migrated here they filled out the vacant niches. They became geographically isolated from the ancestral species, leading first to allopatric speciation due to differing selection pressures, and then to sympatric speciation as each different niche inhabited by the triplegis had different selection pressures and caused different phenotypes to be selected for, causing changes in gene pools with little to no gene flow, causing RIMs to arise like ecological, ~~et~~ mechanical, temporal, geographical, gametic, and behavioural isolation ~~to~~, which caused populations to no longer be able to interbreed and thus creating the 20 species that exist in New Zealand today in a wide array of habitats - sympatric speciation.

QUESTION THREE: POLYPLOIDY AND SPECIATION

When Māori arrived in New Zealand from tropical Polynesia around AD 1250, they brought with them a number of tree and root crops. Polyploidy is inferred in the origins of three of these species – kūmara (sweet potato), tī pore (the Pacific cabbage tree, now only found on Raoul Island, approximately 1000 km from New Zealand), and uwhi (yams). Polyploids are often larger than the species they are formed from, and are reproductively isolated from them.

Kūmara
Source: www.nature.com/articles/nature.2013.12257

Tī pore
Source: www.nzpcn.org.nz/flora/species/cordyline-fruticosa/?web=1&wdLOR=c5453C15F-CE62-0243-961A-E58D334D15C8

Uwhi
Source: https://teara.govt.nz/en/photograph/17506/uwhi

Discuss processes that result in new species.

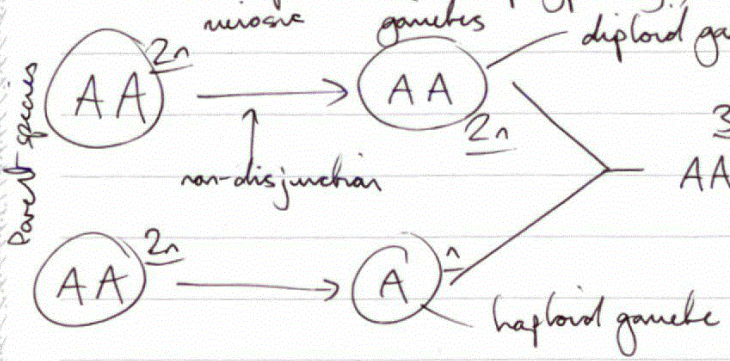
You may use a diagram to support your answer.

In your answer:

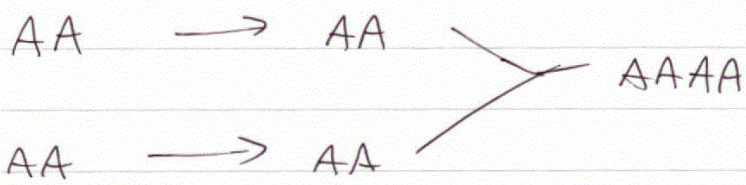
- define the terms polyploid and reproductive isolation
- explain how polyploids are formed
- discuss how the process of polyploidy is an example of sympatric speciation, and explain how two **other** reproductive isolating mechanisms (RIMs) could have contributed to the speciation of the kūmara, tī pore, and uwhi.

A polyploid is an organism with more than two sets of homologous chromosomes, they have chromosome numbers greater than 2n, and are are a result of a malfunction (non disjunction) in the separation of chromosomes in meiosis to create gametes, causing diploid gametes and forming polyploids. This is also termed instant speciation as the offspring cannot reproduce with the parent species to form viable offspring, thus they are reproductively isolated.

Polyploids can be formed from the reproduction of two individuals in the same species (Autopolyploidy)

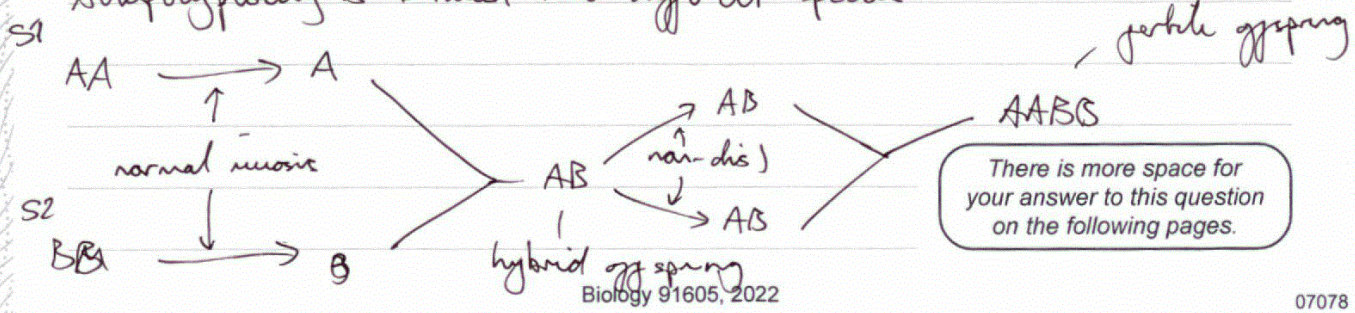


This form of autopolyploidy sees two 2n individuals reproduce, with one forming a diploid gamete (as homologous chromosomes have not separated in meiosis – called non-disjunction), whereas the other gamete is haploid as it is produced as normal. The combining of these gametes forms a triploid offspring which is infertile but has higher heterozygocity and hybrid vigour than the parent species.



This is the same as previously, but both parents have non-disjunction occur and this forms a 4n tetraploid, which can form 2n gametes that are successful, so are fertile and can produce fertile offspring

Allopolyploidy is between two different species:



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The breeding of two species with regular meiosis forms an infertile hybrid, but if this hybrid self-pollinates with diploid gametes (undergoes non-disjunction twice) then it can form a fertile hybrid which will be bigger than the parent, more resistant to disease and change due to increased heterozygocity, and overall more successful in their environment as a result of hybrid vigour.

Polyploidy is sympatric speciation as it occurs with both species in the same habitat becoming reproductively isolated. As well as this, ~~ecological~~ mechanical isolation may have contributed to the speciation of the kumera, ti pore, and wauhi as their reproductive mechanisms - pollen or spores, may not have been able to be fertilised by the other species as the shape would not have allowed successful fertilisation. Hybrid breakdown, a post-zygotic isolating mechanism, may also have contributed as a hybrid may have been made through human input, but over a few generations the 'species' of the hybrid degenerated and could no longer survive. This would have made offspring unsuccessful and likely to die out, meaning that the species could not create fertile, successful offspring and therefore underwent sympatric speciation. Gametic isolation would have also been at play as the gametes of the kumera, ti pore and wauhi could not fuse successfully to create an offspring.

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

QUESTION NUMBER

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

QUESTION NUMBER

Standard	91605	Display ID	61988350	**Total score**	23
		NSN	159388953		
Q	**Grade score**	**Annotation**			
1	E8	Comprehensively discusses the concept of convergence of the three species and co-evolution of the newt and snake – and how it occurs and the future implication to newts, as demonstrated from the data on TTX, **the costs and benefits of the evolutionary strategy**. Links TTX resistance to increased survival and reproductive success in snakes.			
2	E8	Comprehensively discusses how natural selection can give rise to endemic species and adaptive radiation of the triple fin fish, using the data shown, linked to temperature **and** how New Zealand may have 20 species. E.g. links to why New Zealand may have so many niches.			
3	E7	Comprehensively discusses polyploidy as a means of sympatric speciation linked to reproductive isolation, both in terms of chromosome number and chromosome compatibility alongside **and** TWO clear RIMS that can lead to the sympatric speciation of the named plant(s). Includes some explanation of non-disjunction.			