S

93101Q

931012

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Scholarship 2020
Biology

9.30 a.m. Thursday 19 November 2020
Time allowed: Three hours
Total score: 24

QUESTION BOOKLET

There are THREE questions in this booklet. Answer ALL questions.

Write your answers in Answer Booklet 93101A.

Start your answer to each question on a new page. Carefully number each question.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

QUESTION ONE: HOCHSTETTER'S FROG

The Hochstetter's frog (*Leiopelma hochstetteri*) is native to New Zealand. It possesses the most ancient features of any of the living frogs in the world. Although Hochstetter's frogs live on land in shady, moist forested areas, they are also semi-aquatic and must live close to water. They are more dependent on water than are the other two living species of native New Zealand frogs, and are probably the most water-dependent of all known living and extinct members of *Leiopelma*. They are also the only native frog to have a metamorphling (tadpole-like stage), and the young move into water once hatched. Adults do not travel far, and are found in or near the streams where they hatched.

Hochstetter's frog.

Source: https://rarespecies.nzfoa.org.nz/species/hochstetters-frog/

Hochstetter's frogs are nocturnal and shelter by day in wet crevices or under stones or logs close to the water's edge in shaded streams. Their predators include rats and stoats, and the green and golden bell frog (*Ranoidea aurea*), which is diurnal. Hochstetter's frogs are hard to see, as they are small, well camouflaged, and also sit very still. If threatened, they either remain motionless for long periods, or swim quickly away. Beginning with a "frog-kick" that involves both legs for a few strokes, they swim with single leg kicks, turning their heads from side to side. Unlike others in their genus, they do not assume an elevated head-butting stance to deter predators.

Male Hochstetter's frogs are about 3.8 cm long, are smaller than females (4.7 cm), but have broader and more muscular limbs, making them the only New Zealand native frog that is sexually dimorphic. Hochstetter's frogs do not make loud mating calls like other frogs, as they lack eardrums and vocal sacs, but may find each other by using visual cues or pheromones. The breeding season for the Hochstetter's frog is considered to be from August to February.

Hochstetter's frog eggs.

Source: https://faunarecovery.org.nz/hochstetters-frog/

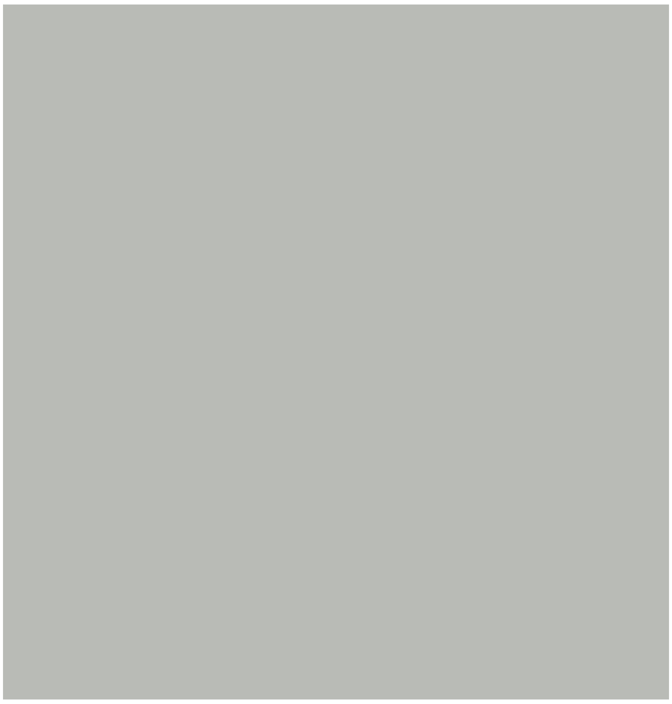
Hochstetter's frog larvae showing negative photoresponse on the day of hatching.

Source: https://doi.org/10.1080/0028825X.2010.482975

After mating, the female lays between 4 and 24 eggs at one time. Hochstetter’s frogs do not brood or protect the eggs. The jelly capsules surrounding each egg swell as the larvae develop, and break open at about 20 mm diameter, when the larvae resemble tadpoles. Larvae move into the water near the laying site. They do not feed during development, and therefore are not considered the same as a tadpole, and so are referred to as metamorphlings. Metamorphlings develop into froglets around 9–10 mm long.

Froglets reach maturity in three to four years, and the lifespan of the frog is approximately 30 years.

Hochstetter’s frogs are dispersed across 19 populations in the North Island of New Zealand. Each population shows varying degrees of karyotype differentiation, but are currently managed as populations of one species.



Some Hochstetter’s frog population locations.

Source: https://bmcevolbiol.biomedcentral.com/articles /10.1186/s12862-015-0342-

A study of alleles from the major histocompatibility complex (MHC) of the Hochstetter’s frog populations found in five different locations, shows that there is a difference in allele frequencies between the populations. MHC are a group of genes that code for proteins found on the surfaces of cells that help the immune system.

Allele frequency of the MHC alleles of Hochstetter’s frogs at 5 different sites

Source: https://bmcevolbiol.biomedcentral.com/articles/10.1186/s12862-015-0342-0

Analyse the information provided in the resource material and integrate it with your biological knowledge to discuss how the biology of the Hochstetter’s frog:

- affects the survival of the individual and the survival of the species
- might impact the future evolution of the populations in the different locations.

QUESTION TWO: MONKEYFLOWERS

Source: www.britannica.com/place/Yellowstone-National-Park

Yellow monkeyflower, *Eurythanthe guttata.*

Source: https://www.flickr.com/photos/93452909@N00/372865089/

The yellow monkeyflower (*Eurythanthe guttata*) is a small, predominantly perennial (a plant that lives more than two years) wildflower. It naturally occurs throughout much of western North America with a range that extends across a wide latitude from Alaska in the north to Mexico in the south. It occupies a wide range of habitats, from sea level to an altitude of 3700 m. It can be found growing in grasslands, forests, peat bogs, on the edges of geysers, and even in mine tailings containing high levels of toxic metals as long as the soil is wet. It is a highly successful species that can out-compete other species, and has become an invasive weed in countries where it has been introduced.

The yellow monkeyflower produces large, yellow, bee-pollinated flowers in summer, generally requiring a minimum of 13 hours of daylight to trigger flowering. Fertilisation is the result of cross pollination, where bees transfer pollen from one individual plant to another. *Eurythanthe* seeds are small and easily dispersed by wind and water.

A study of *E. guttata* was undertaken in Yellowstone National Park. Air temperatures in Yellowstone National Park frequently drop below freezing from mid autumn through to mid spring, and the area gets around two metres of snowfall annually. Yellowstone National Park is a geothermically active region, famous for its hotpools and geysers. This geothermal activity leads to considerable environmental differences between thermal and non-thermal sites. Soils in thermal sites are hotter, and therefore do not freeze during winter and are kept moist with melted snow, but they will dry out completely by early summer. The soils in non-thermal sites are covered by snow for half the year. Researchers sampled *E. guttata* populations from thermal and nearby (less than 500 m away) non-thermal sites in two areas of the park.

A number of differences were observed between plants from the different populations.

Thermal populations of *E. guttata*	**Non-thermal populations of *E. guttata***
show an annual life history	show a perennial life history
flowering initiated in late winter	flowering initiated in mid summer
short internodes (stem length between leaves)	longer internodes (stem length between leaves)
flowers produced close to the ground	flowers produced on tall stems
low total biomass	high total biomass
large number of flowers	fewer flowers than thermal plants
self pollinated	cross pollinated by insect pollinators
stigma (female) and anthers (male) close together inside flower	stigma and anthers separated inside flower

There are a large number of closely related species of *Eurythanthe* that overlap in range with *E. guttata*. One of these species, *E. nastua*, is thought to have evolved from *E. guttata* in central California between 200 000 and 500 000 years ago. *E. nastua* has smaller, mostly closed flowers that are produced in early spring with day lengths of as little as 9 hours, and is almost entirely self pollinated. It is often found in locations with shallow soils that are prone to drying out over summer. Genetic studies of the two species show that *E. nastua* has only one quarter of the genetic diversity of *E. guttata*, and has accumulated a number of harmful mutations. It also shows unique alleles in regions of the genome linked to the timing of flowering.

Eurythanthe nastua.

Source: http://biology.burke.washington.edu/herbarium/imagecollection/taxon.php?Taxon=Erythranthe%20nasuta

Analyse the information provided in the resource material, and integrate it with your biological knowledge to:

- discuss the ecological and evolutionary processes that may have resulted in the differences between the thermal and non-thermal populations of *E. guttata* in Yellowstone National Park
- discuss the ecological and evolutionary processes that may have resulted in the differences between *E. guttata* and *E. nastua.*

QUESTION THREE: DENISOVANS, NEANDERTHALS, AND MODERN HUMANS

When modern humans (*Homo sapiens*) first migrated out of Africa around 60 000 years ago, they found two other hominin species already living in Europe and parts of western Asia – Neanderthals and Denisovans. It is thought both evolved from a common ancestor that migrated out of Africa between 300 000 and 400 000 years ago. Both of these Eurasian populations had endured large shifts in climate due to many glacial and interglacial periods in the time that had elapsed since they left Africa.

While much is known about the Neanderthals, scientists relied on what genetic information they could glean from a single Denisovan tooth (Fossil 1) and finger bone (Fossil 2) discovered in 2008 in a cave in Siberia. The Denisovan layers contain evidence of the earliest use of an eyed-bone needle known in Siberia. The stone tools in the layers in which the Denisovan human remains were located are a variant of the Mousterian tool culture.

In 1980, a fossil hominin jawbone (known as the Xiahe mandible) (Fossil 3) was found on the Tibetan Plateau. Recent scientific analysis found no traces of DNA in the fossil; however, scientists were able to extract proteins from one of the jawbone's teeth. Analysis of these proteins suggests that the Xiahe specimen was closely related to Denisovans, although the plateau where it was found is 2294 km away from the Denisovian cave. It is also interesting to note that the location where the Xiahe fossil was found is about 2500 m higher in altitude. Fossils for each hominin species are usually found in different layers.

Location of Denisovan fossils, showing the direction of migration of modern humans.

Adapted from:

www.sciencenews.org/article/ancient-stone-age-denisovan-finger-bone-surprisingly-humanlike https://www.nationalgeographic.com/science/2018/08/news-denisovan-neanderthal-hominin-hybrid-ancient-human/

www.illustratedcuriosity.com/life/genetics/video-neanderthal-dna-has-subtle-but-significant-impact-on-human-traits/

www.nytimes.com/2020/01/31/science/neanderthal-dna-africa.html

www.nhm.ac.uk/discover/first-adult-neanderthal-skull.html

Interbreeding between *H. sapiens* arriving from their African homeland and other ancient humans inserted sections of DNA from those archaic relatives that have been passed from generation to generation to the present. Today, non-African populations have up to two percent Neanderthal DNA, some of which is, or has been, beneficial to modern humans.

Skeletal differences between modern humans, Denisovans, and Neanderthals.

Adapted from: www.nationalgeographic.com/science/2019/09/dna-reveals-first-look-enigmatic-human-relative/

Genes found in the modern human	
EPAS1 gene – Denisovan gene found in modern humans in Eurasia (Tibet)	A gene that regulates the body’s production of haemoglobin and results in having less haemoglobin in the blood, helping avoid serious problems, such as clots and strokes caused when the blood thickens with more haemoglobin-laden red blood cells.
FOXP2 gene – found in Neanderthal, Denisovan, and modern humans	A gene that is highly expressed during brain development, and regulates some muscle movements, aiding in language production.
TBX15 and WARS2 gene – found in Denisovan and modern humans	This region is thought to be central to cold adaptation by generating heat from a specific type of body fat, called brown fat.
HLA genes – found in Neanderthal, Denisovan, and modern humans	HLA genes carry instructions for making proteins, which help the immune system spot evidence of problems in cells, e.g. infection or cancer, so that it can fight disease by detecting foreign proteins made by bacteria and viruses.

Question Three continues on the following page.

Source: https://twitter.com/ProfMarkMaslin/status/1088720658303983616/photo/1

Analyse the information provided in the resource material, and integrate it with your biological knowledge to:

- compare and contrast how the biological features of Denisovans, Neanderthals and modern humans may have supported their survival
- discuss how the evidence presented here has contributed to our understanding of the evolution of Denisovans, Neanderthals, and modern humans.