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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

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

Scholarship 2019
Biology

9.30 a.m. Wednesday 20 November 2019
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 2–7 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: INTRODUCTION OF THE BRUSHTAIL POSSUM INTO NEW ZEALAND

The common brushtail possum, *Trichosurus vulpecula*, is a nocturnal, semi arboreal marsupial, native to Australia, where they are one of five species of brushtail possum in the genus *Trichosurus*. Their main habitat consists of open forest. They are unlikely to be found in wetter forests inhabited by the short-eared possum, *Trichosurus caninus*, and the mountain brushtail possum, *Trichosurus cunninghamii*. Their diet consists largely of *Eucalyptus* leaves. *Eucalyptus* is a genus of plants, whose leaves contain toxic secondary compounds. However, possums will feed on a wide range of other plant species when available.

Being nocturnal, possums retreat to den sites in hollow trees during the day. There is significant overlap in the denning and dietary requirements between the numerous species of possums and gliders (a group of related herbivorous, arboreal marsupials) in Australia.

In Australia, possums are the prey species of feral cats and dogs, foxes, dingoes, eagles, owls, snakes and monitor lizards. They are also host to a wide range of over sixty different species of internal and external parasites.

In an attempt to establish a fur trade in New Zealand, between 1858 and 1921, up to 300 individuals were imported from Australia and successfully released at a number of sites in the North and South Islands. Descendants of these possums were subsequently translocated to new sites around the country, including numerous offshore islands, in order to establish populations in new areas. Further introductions were stopped in 1921 and the possum was declared a pest species in 1946. From the initial introductions the population grew, until at their peak, they numbered an estimated 60 to 70 million individuals in the 1980s. Intensive control has since reduced their numbers to around 30 million.

Introduced possums in New Zealand occupy a wide range of habitat, including rain forest, often in densities much higher than in Australia. They eat a wide range of plants, often targeting highly palatable species such as rātā, kōtukutuku, and kāmahi. Intensive browsing by possums can remove these species from a community. They will also eat invertebrates, birds and bird eggs, and compete with a number of native bird species for food and den sites. Threats to possums in New Zealand include humans and feral cats, and they are known to be hosts to nine species of parasite.

There are five different subspecies of the common brushtail possum in Australia. The Tasmanian subspecies, *T. v. fuliginosus*, made up the bulk of the early introductions into the South Island. The South Island possums were then the source of introductions into Stewart Island and various offshore islands such as Codfish Island and the Chatham Islands. Introductions into the North Island consisted of individuals from mainland Australia (subspecies *T. v. vulpecula*), supplemented by some New Zealand-bred South Island possums.

A genetic analysis of four possum populations in Australia and fourteen populations in New Zealand was carried out to assist understanding of the genetic variation and population structure of this species in New Zealand. Five microsatellite regions of the possum genome were chosen, as these loci are unlikely to be influenced by selection pressures.

Possum scavenging from a kererū, *Hemiphaga novaeseelandiae*, nest.

www.flickr.com/photos/129662450@N02/30342464864/

Geographx

Findings from the study include:

- Populations from the North and South Islands of New Zealand had only slightly reduced diversity when compared to the Australian populations.
- Among the New Zealand populations, diversity was higher in the North Island, while the South Island populations had significantly fewer alleles at the loci studied.
- Populations from Stewart, Codfish, and the Chatham Islands were significantly less diverse than those on the two main islands. At one of the loci studied (Tv58), these three island populations all possess the same allele, which is variable in the other 15 populations studied.

Question

Analyse the information provided in the resource material and integrate it with your biological knowledge to discuss the factors that have contributed to:

- the successful establishment and subsequent classification of the common brushtail possum as a pest in New Zealand, when compared to its status in Australia
- the differences in levels of genetic diversity in the New Zealand populations of possums when compared to those in Australia.

QUESTION TWO: CATFISH AND CICHLIDS

The East African Rift Valley lakes contain a rich fish fauna with approximately 2000 cichlid fish species accounting for about 70% of the diversity. In many African cichlids, females care for their offspring in their buccal cavity (Figure 1), a care system called mouthbrooding. During mating, the eggs are laid on a prepared sand nest and are quickly collected by the female in her mouth. The eggs are fertilised inside the female's mouth when she collects sperm from a male by nipping at egg spots on his anal fin. Eggs hatch inside the female buccal cavity and are retained there for two to three weeks until depletion of the embryonic yolk sac when they become free swimming. The female does not eat while she carries her young.

Figure 1. Cross-section of the buccal cavity.

www.guwsmedical.info/feeding-ecology-3/reproductive-biology-lei.html

Synodontis multipunctatus is a small catfish endemic to Lake Tanganyika, one of the large lakes in the East African Rift Valley. This species of catfish lays its own eggs among the cichlid eggs and in the process consumes some of the cichlid eggs. Even though the catfish eggs are smaller and a different shape and colour, the female cichlid inadvertently picks up the catfish eggs as well. These are subsequently cared for in the cichlid's mouth. The catfish offspring hatch earlier than the cichlids, and three days after hatching they have used up their yolk supply. At this time the cichlids hatch. The catfish young then grab most or all of the cichlid larvae by the head and consume them. The cichlid eventually releases a mixture of her own offspring and catfish, however, commonly no cichlid offspring remain. Catfish are able to lay eggs over a period of two to three days and rely upon mouthbrooding cichlids for successful breeding.

Researchers investigated the frequency of catfish eggs found in a mouthbrooding cichlid that naturally co-occurs with this catfish in Lake Tanganyika and also placed different species of mouthbreeding cichlids from lakes where these catfish are not present, with the catfish. A summary of the prevalence of catfish in broods is given in Table 1.

Table 1. Prevalence of catfish eggs in broods of cichlid species from different lakes

Species of cichlid	Lake of origin	Catfish present in lake?	Prevalence of catfish eggs in broods
Haplochromis sp. 44	Victoria	No	63.0%
Haplochromis aeneocolor	George	No	22.0%
Copadichromis borleyi	Malawi	No	17.0%
Simochromis diagramma	Tanganyika	Yes	5.5%

Adapted from: Blažek, R., *et al.*, *Science Advances*, vol 4 (2018)

Simochromis diagramma from Lake Tanganyika and *Haplochromis aeneocolor* from Lake George were experimentally infected with in vitro fertilised catfish eggs to see what proportion were rejected. Those that had previously been infected (denoted 'experienced' in Figure 2a) were compared to those that had never been infected (denoted 'naïve' in Figure 2a).

Researchers infected *S. diagramma* from Lake Tanganyika and *H. aeneocolor* from Lake George with in vitro fertilised catfish eggs to see what proportion of their own eggs were rejected in the process of rejecting the catfish eggs. The results are shown in Figure 2b.

Researchers infected broods of *S. diagramma* from Lake Tanganyika and *H. aeneocolor* from Lake George with in vitro fertilised catfish eggs and at the end of the natural brooding cycle of each species, measured the proportion of catfish broods that survived. The results are shown in Figure 2c.

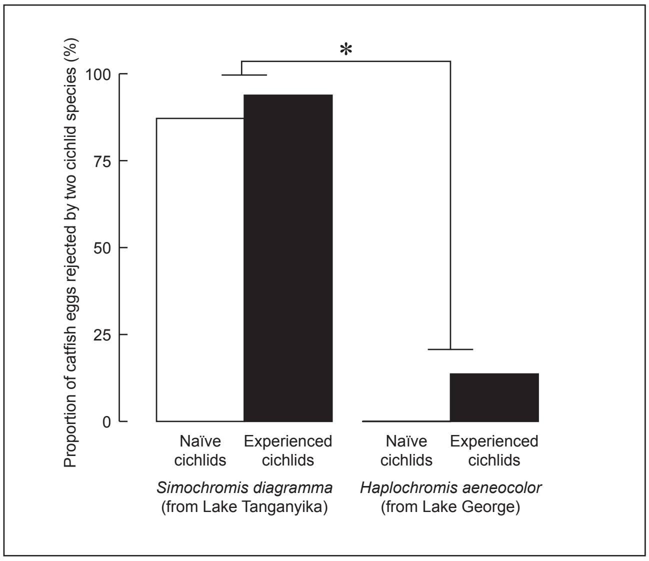

Figure 2a. Proportion of catfish eggs rejected by a cichlid species from Lake Tanganyika and a cichlid species from Lake George.
Asterisk denotes statistically significant difference between rejection of catfish eggs between *S. diagramma* and *H. aeneocolor*.

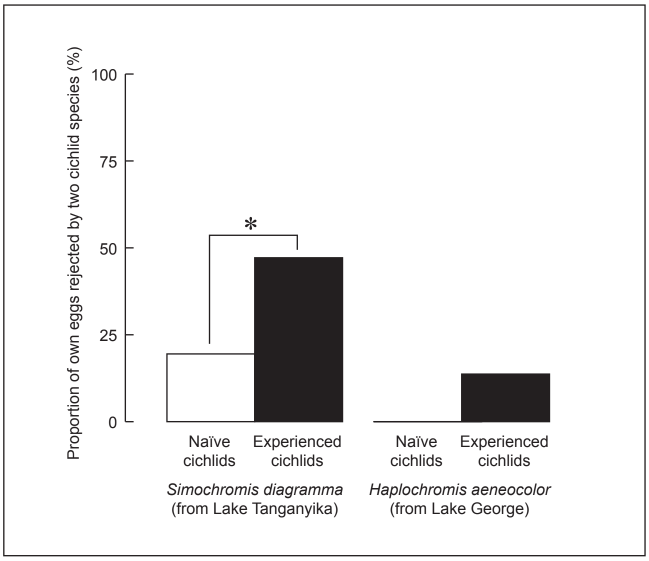

Figure 2b. Proportion of own eggs rejected by a cichlid species from Lake Tanganyika and a cichlid species from Lake George when infected with catfish eggs.
Asterisk denotes statistically significant difference between naïve and experienced females.

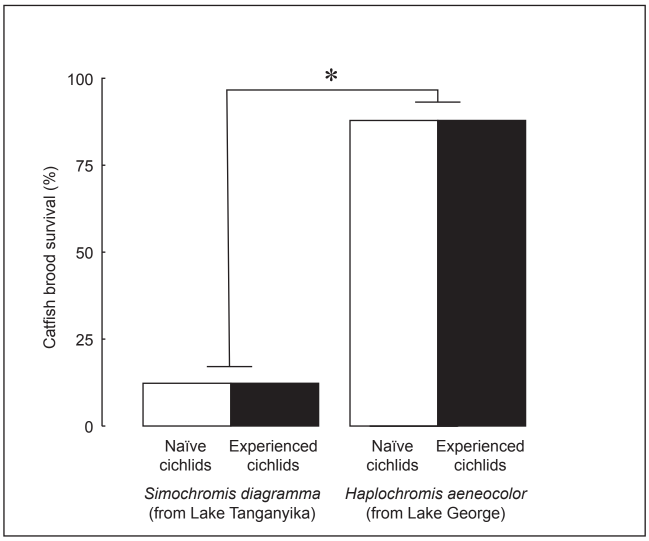

Figure 2c. The survival of catfish over the duration of brood care.
The proportion of broods with at least one juvenile catfish surviving to independence. Asterisk denotes statistically significant difference between *S. diagramma* and *H. aeneocolor*.

Adapted from: Blažek, R., *et al*., *Science Advances*, vol 4 (2018)

Question

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

- discuss the evolutionary and ecological processes that may have resulted in the different reproductive success and fitness outcomes for the two cichlid species, *S. diagramma* and *H. aeneocolor* in the presence of the catfish, *S. multipunctatus*
- evaluate any costs and / or benefits to each species of maintaining these behaviours and relationships.

QUESTION THREE: THE PEOPLING OF AUSTRALIA

The Pleistocene continent of Sahul encompassed the present-day landmasses of Australia, New Guinea, and Tasmania. These were separated by rising sea levels approximately 8000 years ago.

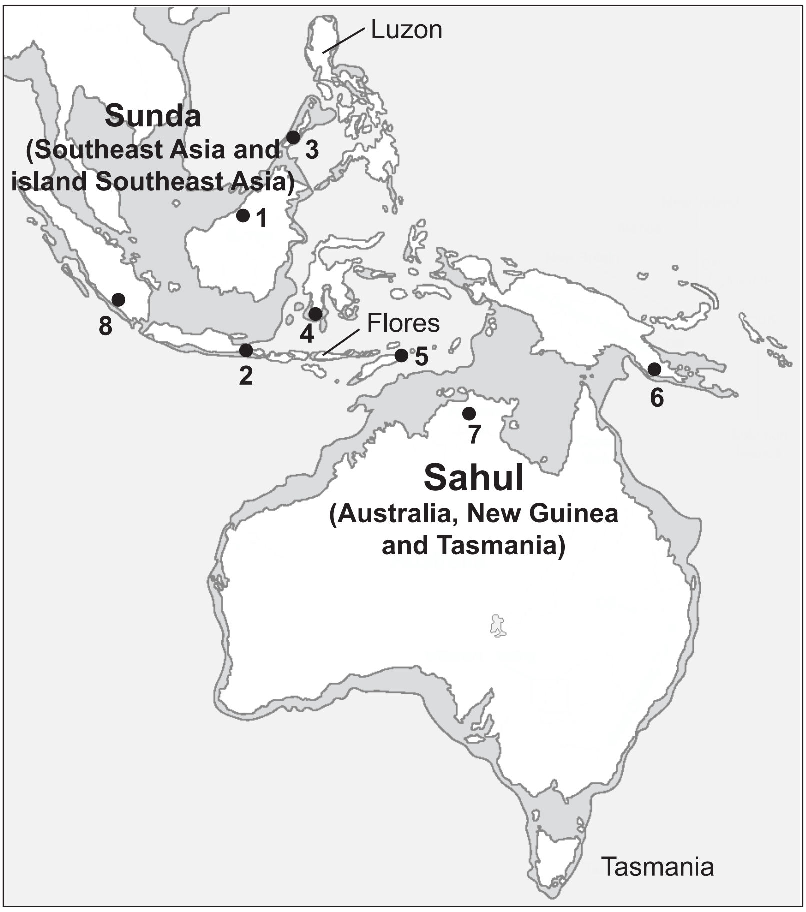

Figure 1. Oldest archaeological sites in island Southeast Asia and Sahul. Numbered black circles represent site locations associated with *H. sapiens*:

1. Niah Cave *c.* 45 kya
2. Wajak *c.* 45 kya
3. Tabon Cave *c.* 47 kya
4. Maros–Pangkep *c.* 40 kya
5. Laili 44.6 kya
6. Kosipe 49 kya
7. Madjedbebe, northern Australia 65 kya
8. Lida Ajer Cave, Sumatra 73–63 kya

Modern coastline indicated. *c* = *circa*, kya = thousand years ago.

Adapted from Norman, K., *et al.*, *Quaternary Science Reviews*, vol 180 (2018) and O'Connell, J. & Allen, J., (2007), 'Pre-LGM Sahul (Pleistocene Australia-New Guinea) and the Archaeology of Early Modern Humans'

Approximately 65 000 years ago, Late Pleistocene ocean levels decreased to depths second only to that of the Last Glacial Maximum.

There is strong evidence of human occupation in Australia and elsewhere in Sahul dating back to approximately 47 000 years. However, recent archaeological evidence is suggesting a much earlier arrival. Establishing when *Homo sapiens* first arrived in Sahul provides valuable information on human evolution and dispersal.

1. Madjedbebe evidence

Archaeological work from Madjedbebe in northern Australia reported evidence of human occupation at approximately 65 000 years ago; far earlier than other evidence has previously indicated. Artefacts include a grindstone, hearths, silcrete flakes, and the oldest known edge-ground hatchets. The occupants used ochre 'crayons' and other pigments, including one of the oldest known examples of reflective micaceous pigment.

Figure 2. Some artifacts from the rock shelter at Madjedbebe. Grinding stone (left) and mortar (right) with possible motif in bottom right corner.

Clarkson, C., *et al.*, *Nature*, vol 547 (2017)

2. Sumatra evidence

Teeth from *H. sapiens* found on Sumatra (part of the Pleistocene continent of Sunda) have been dated to between 73 000 and 63 000 years old.

Figure 3. *H. sapiens* teeth from Lida Ajer Cave, Sumatra, dated to between 73 000 and 63 000 years old. Westaway, K., *et al*., *Nature*, vol 548 (2017)

3. *Sporormiella* evidence

The fungi *Sporormiella* depends on ingestion by herbivores to complete its life cycle as it sporulates in their dung. *Sporormiella* have been shown to be reliable markers of Pleistocene megafaunal biomass. Researchers measured the number of *Sporormiella* from a marine sediment core recovered 100 km offshore from south-western Australia. The results are shown in Figure 4. During this time the climate varied from warm, wet interglacial periods to arid glacial periods.

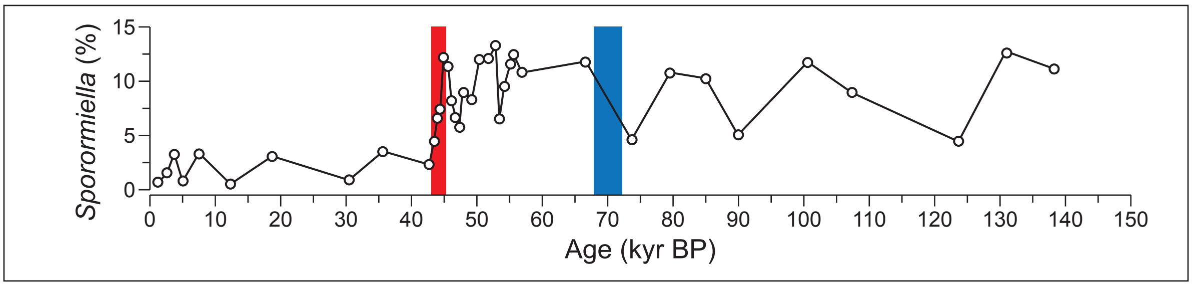

Figure 4. *Sporormiella* percentage over time. The timing of major environmental change in the record approximately 70 000 years ago is indicated by blue shading, and regional extinction of megafauna from 45 000 to 43 000 years ago in south-western Australia by red shading.

Adapted from van der Kaars, S. *et al.*, *Nature Communications*, vol 8 (2017)

4. *Genyornis* evidence

Genyornis newtoni is an extinct Australian megafaunal flightless bird, estimated to have had a mass of up to 200 kg. Analysis of over 200 sites has determined that burnt *Genyornis* eggshell only occurred between approximately 53 900 and 43 400 years ago. The oldest burnt emu (*Dromaius novaehollandiae*) eggshells are dated to the same time period as burnt *Genyornis* eggshell, and persist to modern time.

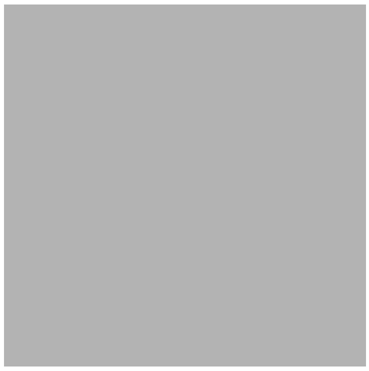

Figure 5. *Genyornis* eggshell. Burnt fragments shown to the right. Miller, G., *et al*., *Nature communication*, vol 7 (2016)

5. Other evidence

Aboriginal Australians, Papua New Guineans, and some related populations in Melanesia and island Southeast Asia carry 3–5% Denisovan admixture. This interbreeding occurred with at least two genetically divergent groups of Denisovans; one about 50 000 years ago, and a second as recently as 15 000 years ago. It is estimated that all non-Africans carry approximately 2% Neanderthal ancestry.

Homo floresiensis seems to have disappeared from its habitat in island Southeast Asia approximately 60 000 – 50 000 years ago. *Homo luzonensis* was present on Luzon Island in the Philippines before 50 000 years ago. A considerable sea crossing has always been necessary to reach Luzon and Flores from the mainland, even during the lowest sea level periods of the Quaternary period.

Question

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

- discuss the evolutionary and ecological implications of the dispersal of *Homo sapiens* to Sahul
- give your justified opinion on the timing of *Homo sapiens* dispersal to Sahul.

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