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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 2022
Biology

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.

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: FLIGHTLESS SEABIRDS

Penguins are a group of flightless seabirds belonging to the order Sphenisciformes. There are around 20 species of penguin, found almost exclusively in the Southern Hemisphere. Penguins can be found living in a range of diverse and extreme environments, from the tropical Galápagos Islands to the coastlines of the sub-Antarctic islands, and the sea ice around Antarctica.

Figure 1: Distribution of penguins and great auks

Adapted from: https://penguinchum.com/where-do-penguins-live/
and https://elifesciences.org/articles/47509

Penguins are well adapted to the niche of an oceanic carnivore. They have a wide range of adaptations not seen in most other bird species. Penguins have completely lost aerial flight, and instead use their modified, flipper-like wings for their prolonged underwater dives. They have very dense bones, and highly specialised feathers consisting of a layer of streamlined contour feathers sitting on top of a dense mat of insulating softer shorter feathers, called plumules, next to the skin. Penguins also have increased visual sensitivity of the eye lens, enhanced thermoregulation, and the ability to go for long periods without feeding. Genome research has found more than 100 genes under strong selection. These genes are linked to thermoregulation, osmoregulation, and diving capacity.

Genetic studies of penguins show they also share a flying common ancestor with the Procellariiformes (albatrosses, shearwaters, and petrels). This split occurred around 66 million years ago (mya), putting it close to the Cretaceous-Paleogene boundary, which saw the extinction of apex predators, such as large sharks and marine reptiles.

Penguins have an extensive fossil record, with the remains of more than 50 extinct species found. Fossils reveal that many of the extinct penguin species were large with a body mass up to 115 kg. These giant penguins became extinct around 25 mya, when marine mammals, such as toothed whales and seals, were becoming more abundant.

In contrast, living species of penguins range in size from the 1 kg little blue penguin (*Eudyptula minor*) to the 30 kg emperor penguin (*Aptenodytes forsteri*), with larger penguins generally found in colder regions, and smaller penguins inhabiting regions with warmer waters. They diversified from a common ancestor around 22 mya in the seas around New Zealand. Around this time, the final separation of Antarctica from Australia and South America had produced the Antarctic circumpolar current (ACC), leading to cooling in Antarctica, and enabling the dispersal of penguins to newly formed island groups.

Figure 2: Height comparison of extinct and living penguin species

Source: www.newscientist.com/article/dn25990-extinct-mega-penguin-was-tallest-and-heaviest-ever/

The cold waters of the subarctic region in the Northern Hemisphere were also home to a large, flightless diving bird known as the great auk (*Pinguinus impennis*), until they were driven to extinction by humans in the mid 1800s. It occupied a similar niche to Southern Hemisphere penguins and, despite being unrelated to them, shared many of their characteristics. Great auks were a wing-propelled hunter, with a diet that consisted of small fish. They could dive to depths of a kilometer, and stay underwater for around 15 minutes. Their main predators were marine mammals, such as orca and seals.

Analyse the information provided in the resource material, and integrate it with your biological knowledge to discuss the ecological and evolutionary processes that have led to the diversity of extinct and living species of these flightless seabirds.

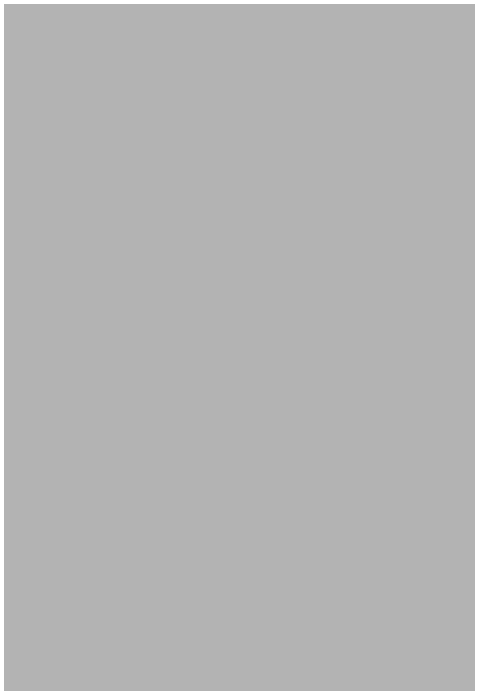

Figure 3: Great auk

Source: https://en.wikipedia.org/wiki/Great_auk#/media/File:Great_Auk_(Pinguinis_impennis)_specimen,_Kelvingrove,_Glasgow_-_geograph.org.uk_-_1108249.jpg

QUESTION TWO: BLACK-FOOTED FERRETS

The black-footed ferret (*Mustela nigripes*) is a medium-sized mustelid, and the only species of ferret native to the Americas. Their main habitat is prairie (a large open area of grassland), and in the past, their geographic range stretched from southern Canada, through the USA to northern Mexico.

Figure 1: Black-footed ferret

Source: https://www.kold.com/2021/07/14/black-footed-ferret-way-back-hurdles-remain-experts-say/

Black-footed ferrets are a solitary and territorial species, only coming together during breeding season. The size of their territory varies and is based on prey availability.

Black-footed ferrets are highly specialised carnivores. Unlike other mustelids, who can be indiscriminate hunters, black-footed ferrets are specialists and are completely dependent on prairie dogs (*Cynomys spp*.) which are a type of herbivorous burrowing rodent, sharing the same habitat. Studies have shown that prairie dogs make up more than 90% of the diet of black-footed ferrets.

As well as relying on prairie dogs as a food source, prairie dog burrows are used by black-footed ferrets. They are slept in during the day, provide shelter from harsh weather, protection from predators, and are used as dens by females to raise their young.

Black-footed ferrets have low reproductive rates. Females usually give birth to an average litter of 3 – 4 babies (kits) in late spring. Once weaned, the mother moves each kit to its own nearby burrow. By late summer the kits are hunting independently and disperse to new territories.

Average lifespan in the wild is most likely only one year, though some individuals may live up to 5 years.

During the 20th century the population of black-footed ferrets declined, and by the late 1970s they were thought to be extinct. However, in 1981 a small population of around 130 was discovered in Wyoming. The population was unfortunately hit by a disease outbreak and by 1986 it had shrunk to only 18 individuals. These were all captured and put into a captive breeding programme. Of the 18 survivors,

Figure 2: Black-footed ferret hunting prairie dog

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/e/ee/Black-footed_Ferret_Learning_to_Hunt.jpg/1024px-Black-footed_Ferret_Learning_to_Hunt.jpg

only seven successfully bred. Today, a number of captive bred animals have been released back into the wild and the current population is estimated at around 320 captive and 300 wild individuals.

Prairie and grassland habitats in North America are under threat. They have highly fertile and productive soils that have been converted for agricultural use. They are also the location of oil and natural gas exploration and extraction. This has put pressure on both the black-footed ferret and prairie dog populations. Around 95% of prairie dog habitat has been lost and the remaining areas are often fragmented. Seismic disturbance from oil and gas extraction can cause prairie dog burrows to collapse.

Prairie dogs are often perceived as pests, and subjected to population control through poisoning. Prairie dogs are also susceptible to the introduced disease sylvatic plague, a bacterial disease spread by fleas. Epidemics can wipe out entire colonies. Studies in 2008 have shown that black-footed ferrets are also susceptible to sylvatic plague. Black-footed ferrets are also impacted by another introduced disease caused by the canine distemper virus (CDV), which is usually fatal.

Since 1981, a recovery programme has been in place to try to increase the numbers of black-footed ferrets and re-establish wild populations. Key strategies to achieve these goals are:

- captive breeding programmes, including the use of assisted reproduction (artificial insemination)
- insecticide control of fleas in prairie dog colonies
- vaccination of black-footed ferrets against sylvatic plague and CDV
- conservation of prairie and grassland habitats.

Genetic studies have shown that there has been a big loss of genetic diversity (more than 55%) in captive bred individuals since the 1980s. There has also been a reduction in sperm quality of males, which has led to reduced fertility, pregnancy rates, and litter sizes.

In 2020, researchers used frozen tissue from one of the original 18 ferrets, a female named Willa which died in 1988 without breeding, and successfully produced a clone of her. An analysis of her DNA shows she has three times more genetic diversity than the current black-footed ferret population, and it is hoped her clone will become part of the captive breeding programme. A second preserved cell line also exists, from a male named SB2, which died from CDV before breeding.

Researchers are also investigating the possibility of using transgenic techniques to boost immune system function in black-footed ferrets in an attempt to establish innate, inheritable immunity to sylvatic plague.

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

- discuss the likely role and interaction of named factors that have contributed to the critically endangered status of the black-footed ferrets
- analyse options for the management of the black-footed ferret to improve their vulnerable status.

QUESTION THREE: THE HOBBIT

Homo floresiensis is commonly referred to as the hobbit, in reference to their small size and large feet. Homo means 'human' or 'man' in Latin, and floresiensis recognises the island Flores in Indonesia where the remains were discovered. All fossils have been discovered from the cave of Liang Bua on the Island of Flores. Flores has always been separated from the mainland Asia – even at low sea level the water-crossing was at least 24 kilometres.

The recent discovery of a jawbone and some teeth that date to 700 000 years ago, indicate that a hominin species was probably living on the island at that time.

Flores is a heavily forested tropical island, with limited food sources. There has been little change in the geological environment since *H. floresiensis*. This reduced-energy environment is typical of such islands. Several dwarf species, including the extinct pygmy elephant, Stegodon, have been recovered on Flores and other small islands.

H. floresiensis is very small, about 1 m tall, and has a wide pelvis and hunched shoulders, giving it a different body shape from *H. sapiens*.

They have a small brain averaging 380 cc, about the size of a chimpanzee, as well as an enlarged Brodmann area 10, an area of the frontal-lobe part of the brain that appears to help with cognitive activities.

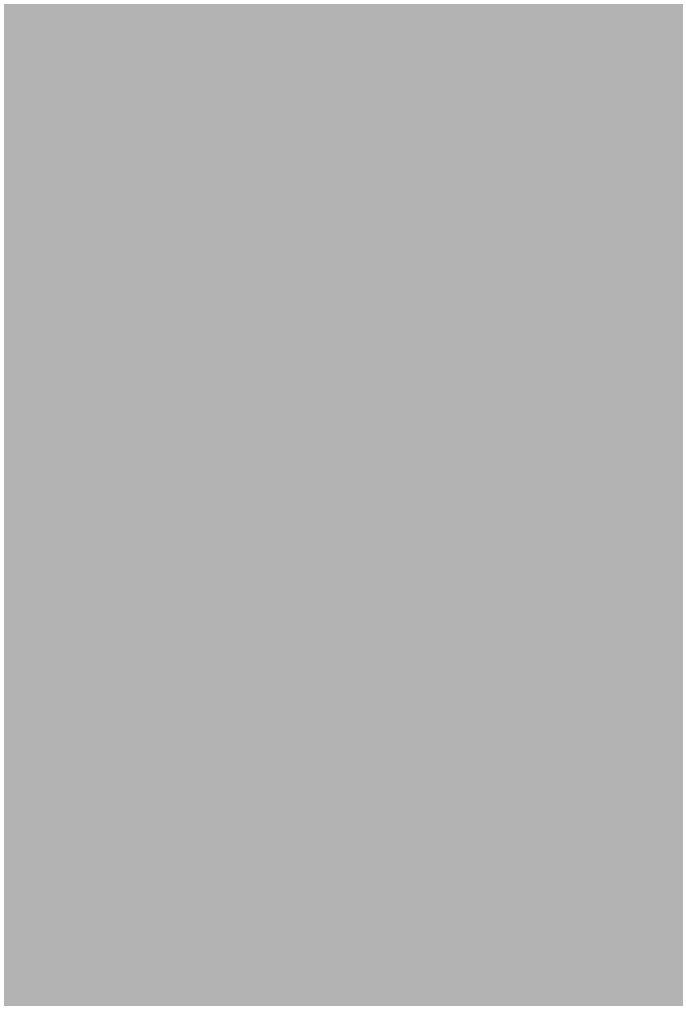

Figure 1

Source: https://australian.museum/learn/science/human-evolution/homo-floresiensis/

The cranial shape is long and closer to that of *H. erectus* than *H. sapiens*, with a receding and small forehead and a flat face.

They have a relatively large jaw and teeth that resemble *H. erectus* but with more primitive features.

Bones and joints of the arm, shoulder and the lower limbs suggest that *H. floresiensis* was more similar to archaic humans than modern humans.

Several primitive features include a relatively long foot for its body size (70% as long as the thigh bone, compared with 55% for modern humans), a flat arch lacking the spring-like mechanism used to store and release energy during running, and a short big toe. These features are similar to ancient hominins such as *H. habilis* and *australopithecines*, and suggest the gait was different from and less efficient than modern humans.

Wrist bones differ significantly from those of modern humans, and are more similar to African apes or australopithecines. They lack features that evolved with the ancestors of modern humans at least about 800 000 years ago.

Stone tools were found in a number of different layers dating from 190 000 to 150 000 years ago. Tools include simple flakes, points, perforators, hammer stones, small choppers, radial cores (Figure 2), and blades and microblades which were possibly used as barbs. These tools are typically smaller than those carried by *H. erectus*. Some were found with the remains of *H. floresiensis*, but most came from the

same location as the remains of Stegodon. This suggests that *H. floresiensis* was hunting these small elephants.

There is evidence of the use of fire in the Liang Bua cave. The remains of numerous juvenile Stegodon have charred bones, possibly indicating that *H. floresiensis* was able to control fire for cooking.

There are two main models for the evolutionary origin of *H. floresiensis*. One possibility suggests that *H. floresiensis*, *H. habilis*, or a similar form that also had a relatively small body and brain, left Africa by 2 million years ago and reduced in size even further. Alternatively, the larger bodied *H. erectus* left Africa, and later moved through Indonesia and Flores, evolving into *H. floresiensis*.

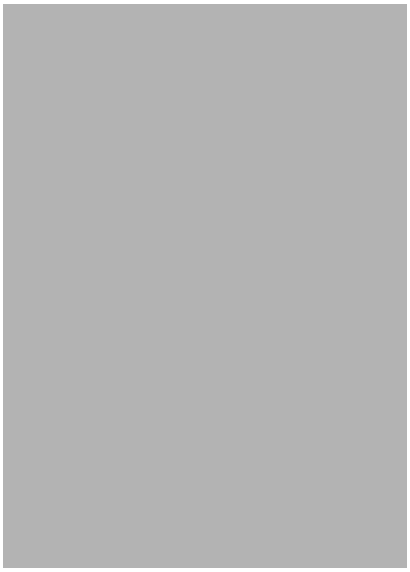

Figure 2: *H. floresiensis* tools

Source: www.peterbrown-palaeoanthropology.net/Stone%20Tools%20on%20Flores%201.htm

Figure 3: Candidates for the ancestry of *Homo floresiensi*s

Source: https://www.natgeomedia.com/environment/article/content-2058.html

Evaluate the two models of the evolutionary origin of *H. floresiensis*, and justify which model is most likely, discussing the possible reasons for the cultural and unusual biological evolution.