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TOP SCHOLAR



Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2025 Biology

Time allowed: Three hours
Total score: 24

ANSWER BOOKLET

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Write your answers to all THREE questions in this booklet.

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

Check that this booklet has pages 2–27 in the correct order and that none of these pages is blank.

Do not write in the margins (// // //). This area will be cut off when the booklet is marked.

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

PLANNING

ecological extinction:

- comp with toxic debris → flourish → disease spread (cancer)
- overhunting / introduced predators
- prey, so predators decline (eagle, snake)
- prey switching for predators?
- all prey species flourish

Q2.

adaptations / ecological req.

- migration from Alaska → migrate
- photoperiod / temperature
- light / streamline
- moult prepare
- muscle / exercise
- fat stores / metabolism
- abundant food / safe pred. / temp (summer)
- staging → energy for breeding
- only migrate to breed.

benefits > cost!

climate change ...

migratory route	resting	success?
• wind patterns • prevailing from west, causes diff. routes • change → die • storms • other effects on breeding sites / overwintering	• urbanization • loss, loss • resources → low energy → unsuccessful	• temp - mess, wrong time • protected MNZ → other places do!

PLANNING

genetic manipulation:

- transgenesis of genes → from genome?
- cloning from preserved
- then selective breeding
- transgenesis, outbreeding

failure:

- cloning success low
- not viable surrogate

K!

success?

- similar enough genome of donor?
- low rate
- low gen. div. (small).
- changed ecosystem → unsuccessful

PLANNING

Q3

adaptations (chimp)	advantages
link to biped! • rotation torso (upright) • low broad shoulder	
design / manu. trends	which hominids?
• more materials - compound stone → wood → paron → carved → animal function • complex - imagination. • stone → core flake • increase projectile / torque / length with attach.	• neanderthals - wood + stone, achulean 400-200000 (2) • H. sapiens , upper paleo. → ergaster - africa? 3. → or H. sapiens (archaic) • H. sapiens → upper paleolithic / late glacial → tools make tools → neolithic? animal sew. (domestication)

Question 1: Thylacines.

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The Thylacine ~~was~~ is an extinct marsupial endemic to Australia, likely going extinct due to effects of humans on the environment. This has widespread effects on the ecosystem in Australia as they were a keystone species. It is likely that overhunting and habitat destruction from humans led this species to extinction.

Firstly, the Tasmanian devils are a species with an overlapping niche with thylacines, as they share food resources such as carcasses to ~~eat~~ scavenge and ~~prey~~ predation on small mammals and birds. They therefore would have had interspecific competition with ~~Tasmanian~~ thylacines, which would have decreased evolutionary fitness of both species, especially in times where food resources were scarce or their habitats significantly overlapped. However, once thylacines went extinct or endangered then extinct between 1800 and 1936, this competition decreased, causing Tasmanian devil population numbers to increase as food resources were suddenly far less scarce. (more small mammals, birds and carcasses). This would have increased population density of Tasmanian devils until another limiting factor put pressure on their population; in this case, disease spread. With increased density of Tasmanian devils, a mutation causing the devil facial tumour disease had also arisen in their population and spread rapidly due to fast transmission in high density. This has ~~led~~ led to quick deaths within a few months for individuals contracting it, and may lead to a population bottleneck of Tasmanian devils if continues to spread. This decreases genetic diversity as alleles lost from gene pool, which could further lead to extinction of Tasmanian devils if they do not possess adaptations for natural selection to work on in times of environmental change / new disease arises.

For predators of thylacines such as wedge-tailed eagles and tiger snakes, which preyed on their joeys, the extinction of thylacines may have removed a food source they depend on for survival, therefore causing food to become scarce. Since thylacines are endemic and have evolved in Australia alongside other Australian predator, prey and competitor species, these relationships may be obligatory and thylacine extinction may have drastic consequences. Without key food source of joeys, wedge-tailed eagles and tiger snakes may face increased mortality rate due to starvation, which could lead to extinction if there are specialised species with joeys as a dependant food source and no other adaptations present. Or, if they have the ability to be able to hunt and eat other species, such as Dunnarts or Tasmanian devil joeys, they may prey switch, therefore having negative flow-on effects to these new prey populations and causing further endangerment across food web.

As the Tasmanian Devil population flourished - and, potentially, also if prey switching of eagle and snake occurred - the prey species of these animals (including small mammals and birds) may have increased mortality rate due to predation. This would lower genetic diversity and size of gene pool, potentially putting these prey species lower down food chain at risk of extinction if they have reduced genetic div. and do not possess adaptations to cope with introduced disease/environmental change. Furthermore, if these species are greatly reduced in numbers, effects of genetic drift may become more prominent to further reduce genetic diversity as alleles become lost/fixed.

Without predation due to thylacine extinction, other prey

species such as rodents and lizards may have decreased predation, causing these populations to increase similar to Tasmanian devils, as mortality rate decreases. If these species flourish, this may have further effects across species linked in Australian food web as their prey (such as native Australian birds, whose eggs possums and rodents may eat) or competing species may have decreased population numbers due to increased mortality from predation or increased competition. Other species across Australia which rely on scavenged carcasses as food may face increased competition as Tasmanian devil numbers rise.

Introduced predators such as cats and foxes by Europeans may have also contributed to decline of thylacines, and may provide competition to Tasmanian devils or may further disrupt ecosystem by prey switching to endemic species, putting more pressure on these.

Genetic manipulation can be used to deextinct the thylacine and reestablish a population. Cloning could be used, where a frozen somatic cell containing 2n thylacine genome (from museum specimens) would have its DNA removed. This could be placed on a sterile medium with an enucleated ovum of a surrogate mother; the Australian Museum project used quolls and Tasmanian devils, as these are close relative marsupials with a common ancestor, as shown by Fig 2. An electrical pulse causes DNA/genome to fuse within ovum, then another begins mitotic cell division. Once this ovum has divided to form a cluster of cells, it is implanted back into the ~~embryo~~ uterus of the surrogate mother from which came the ovum, which ~~is then~~ then develops as an embryo and is birthed as normal.

For this to be successful, at least 1 (but ideally multiple) ~~sex~~ of each of a female and male thylacine ~~sex~~ would have to be cloned from preserved DNA. Selective breeding could then be used to ~~be~~ increase size of this population. However, genetic diversity would be very low, especially if only a few ~~sex~~ thylacines were initially cloned.

Transgenesis could be used along with cloning and selective breeding to increase genetic diversity. Other alleles from preserved (unc cloned) DNA could be cut out using restriction enzymes and grown on a sterile medium with nutrients and growth hormones. Then, it could be removed using same restriction enzymes and pronuclear injection could be used to insert these genes into ~~same~~ fertilised ovum (or an unfertilised egg, just prior to fertilisation) of a cloned thylacine. This could increase genetic diversity ~~to~~ decrease effects of genetic drift and inbreeding depression and hopefully establish a self-sustaining thylacine population. Would mitigate effects of outbreeding.

The Australian Museum project attempted to use cloning to produce a thylacine organism but failed to produce a viable embryo. Cloning success is currently low, and also cost and m. time demanding. A reason for failure may have been that the egg of enucleated ovum of the Tasmanian devil / quoll was too genetically different to successfully implant the thylacine genome and form an embryo. After all, they are a different genus $\rightarrow$ *Dasyurus*, as opposed to *Thylacinidae*. Maybe cloning could be done with Dunnarts, as these diverged slightly earlier from dade than Quolls and Tasmanian Devils. Furthermore, the DNA from museum of thylacine may have been damaged, without being properly preserved, or may have had telomeres that were already too short due to natural mitotic division, to prevent the cell from

~~are~~ successfully being able to divide to form ~~a~~ an embryo. More recent attempts with better technology may be more successful.

The Colossal Biosciences project uses a genome, sequenced using ~~various~~ various thylacine specimens which were preserved in ethanol. Any gaps in this genome could be filled with dunnart DNA which has been sequenced. This genome would then be transcribed/artificially created into a physical DNA molecule, and inserted into enucleated ovum of a surrogate (eg, Quoll). This may have the advantage of having more ~~into~~ reliable DNA to hopefully form a viable embryo, thus successfully cloning thylacine. Or, they could insert ~~this genome into~~ specific genes from this genome into a fertilised ovum using pronuclear injection (transgenesis), then use this offspring to be a surrogate for clone of thylacine as it would be more genetically similar.

It is, however, unlikely this project will work. Even if the embryo successfully developed, the surrogate may not be able to give birth to it; eg, the dunnart is much smaller so may have issues in fetus and birthing stage. Also, the thylacine relies heavily on K-strategy with mothers giving birth to helpless, rice sized infants, then nurturing them to full development in a pouch. Raising a surrogate mother for cloning, this nurturing process may be different (diff. species = diff. behaviours) and infant may die due to malnutrition, care, food/resources provided, or simply a pouch it could not fit into. Even if successful clones developed, genetic diversity would be low and ~~success~~ many clones of each sex would have to be produced and combined with different genetic manipulation techniques to increase genetic diversity and establish a ~~proper~~ self-sufficient population.

Question 2: The bar-tailed godwit / ¹⁰kuaka.

The bar-tailed godwit / kuaka makes the longest known non-stop flight of any bird, from its breeding grounds in Alaska to overwintering grounds in NZ. This is a return migration, and ~~reproduces~~ reproductively mature ^g kuaka ~~may~~ make the journey back from NZ through South-East Asian staging grounds to Alaska to breed in May.

There are several adaptations allowing godwits to successfully migrate. This response likely began as a mutation ~~at~~ randomly occurring in gene pool from *L. hypoleuca baueri* in Western ~~g~~ Alaska, and ultimately became established in gene pool as provided increased evolutionary fitness.

One adaptation in godwits is the ability to ^{navigate} ~~migrate~~ using a range of techniques, to travel from a starting location to destination over unfamiliar terrain and stay on course. This uses solar navigation during day (position relative to the sun) and stellar navigation at night (star patterns), as well as magnetic field navigation, especially when sky obscured by cloud cover etc. This uses magnetite or lodestone deposits in godwits' heads, allowing them to detect Earth's magnetic field lines and stay on course. Though these navigation techniques can be improved by experience, they are innate, and part of the genome. This navigation requires an endogenously controlled biological clock, to account for seasonal and daily star / sun changes; and biological compass, to have a sense of starting location and destination. When migrating over monotonous landscapes such as ocean, this range of techniques is essential to be able to stay on course.

The godwit also has many physical adaptations selected for to enable more efficient, successful migration. Wings are strong, large and streamlined, allowing efficient flying. The feathers are also streamlined, and moulting is endogenously activated prior to migration (early March, then again ~~at~~ before early September), to ensure feathers are efficient for flying. This ~~is an endo~~ moulting is due to a photoperiodic seasonal response due to day length indicating season, which is innately activated. Dense muscle fibres for wings / flying muscles are also required, and godwits innately exercise to prepare for migration.

Furthermore, the honeycomb lattice of bone is strong yet has low density to minimise weight and improve efficiency by saving energy. Fat deposits are laid down in lower stomach prior to migration, as the godwit innately eats more to pre-fuel their journey - especially in late August prior to 1000km ocean voyage. This, along with efficient metabolism, maximises their energy available to fuel the long journey and allows them to be successful.

Furthermore, there are ecological advantages of migration. By travelling to Alaska at beginning of Northern hemisphere's summer, then ~~again~~ back to NZ for southern hemisphere's summer, godwits maximise the long day length to find food and eat, such as ~~seaweed~~ preyings on aquatic invertebrates and shellfish. Following warmer temperatures decreases energy expenditure staying warm and increases energy for reproduction, finding food and migrating. Breeding grounds in Alaska ensure abundant food supplies to be able to raise young in the largely

uninhabited tundra and coastline of Alaska Arctic, which they ~~require~~ require as part of their niche. Also, all migrating to breeding grounds in Alaska in March to breed in May ensures that individuals sync breeding time and location, to decrease energy expenditure finding a mate and increase/maintain genetic diversity by outbreeding (as all breeding individuals of same species in same location - ground 75000).

Back in NZ for overwintering grounds decreases predation as it is a safe area (so does Alaska as breeding grounds), while also providing warmer temperatures. More food is available in NZ, especially during Northern Hemisphere winter when food supplies there are low. Its migration pattern also aims to avoid treacherous weather conditions, cold, predation and low food supplies, therefore overall increasing energy for reproduction and raising chicks. For this evolutionary response of migration to persist, the advantages have outweighed disadvantages, and staying overall increases reproductive success and migration allele (as well as alleles from ^{random} mutations providing advantageous adaptations enhancing migratory success) have been selected for and increased in frequency in gene pool.

Staging grounds also aid the godwit on its long, energy-intensive journey on the way to breeding grounds from early March-May. This allows godwits to refuel, rest along the way, moult feathers, lay down fat deposits etc., increasing chances of successful migration and ensuring they are reproductively ready and healthy to increase chances of reproductive success. If godwits did not have staging grounds, they may lack energy to grow eggs, feed young or etc. which

would decrease reproductive success. Reproductively immature godwits of <3-4 yo do not migrate at all to prevent energy wastage and minimise risks of predation, bad weather and death. Adults return directly South to NZ due to the westerly prevailing weather conditions, ~~and~~ which would make it difficult and risky to migrate back through staging grounds.

There are many adverse effects of climate change to the godwits' migratory patterns. Urbanisation in Southeast Asia causes significant habitat loss in staging grounds near the Yellow Sea, ~~for~~ bordering coastlines of China and North and South Korea. As these areas become more densely populated, godwits may not be able to access space ~~of~~ or resources for resting, especially as their lundra coastline habitat is replaced by urban sprawl. Overfishing ~~and~~ and collection of marine life by people in these regions may also decrease shellfish and aquatic invertebrates available as food for godwits, meaning they have less energy available to fuel next stages of migration. This is further decreased by pollution of water potentially bottlenecking marine shellfish etc. If godwits are not able to rest in these staging grounds, there is increased risk of them failing to ~~make~~ make migration due to exhaustion, are more susceptible to being blown off course and may die, preventing reproduction in May. Also, introduced pests such as cats in these urban staging grounds may lead to further death/risk of predation.

Climate change also impacts weather patterns. The godwits' migration has evolved using patterns of prevailing winds and weather ~~for~~ trends. However, climate change may increase storms and adverse

weather conditions on route of migration. This could blow godwits off course or prevent them from successfully migrating, or cause them to become lost. If they prevailing winds change due to climate change and they possess the alleles in gene pool to migrate via a different route, this may be selected for and route could change over time. However, if this adaptation is not present - more likely in a smaller gene pool, as population declines 2% / year - then this could simply lead to increased mortality rate and decreased natality rate of godwits, potentially facing them with extinction.

If temperatures change due to global warming, this may incorrectly indicate migration of godwits at a time of the year which is too early due to change in environmental stimulus. This could prevent syncing of godwit breeding, or cause them to face more adverse weather conditions, decreasing success rate of migration and reproduction. Furthermore, climate change may have low on effects to population levels of prey (invertebrates and shellfish), decreasing their numbers and making food resource scarce. This may lead to exhaustion or starvation of godwits.

Also, if sea levels rise with rising temperatures and melting glaciers, then godwits may lose the habitat they require to survive and breed - namely coastal tundra. ~~For~~ If losing nest sites and space to breed, natality rate may drop or they may have to make nests in more inland regions, preventing access to food resources in the water and potentially increasing exposure to predators.

Overall, if the effects of climate change continue and urbanisation on nesting grounds, the likelihood of successful migration of godwits

may likely decrease, so they should be protected with reserved environments and conserved shellfish/marine invertebrates at all locations in ~~major~~ ^{major} ~~admiral~~ migration, to prevent further population decline.

Question 3: Projections

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H. sapiens have evolved divergently from chimpanzees, across a range of transitional forms making up the hominid lineage. Throughout this, many adaptations - both biological and cultural - have evolved in a positive feedback loop to form modern day sapiens.

Some of the initial biological adaptations of hominids to throw projectiles may have evolved as a result of selection towards bipedalism. A cooler, drier Africa, with more open grassland, selected for physical changes increasing bipedal efficiency such as a tall torso. Flattened front to back to a centre gravity down spinal line, this decoupled waist allows the ~~torso~~ *H. sapiens* to rotate their torso to gain momentum and thrust from a larger muscle set. This compares to chimp chimps, with a C-shaped (rather than S-shaped) spine and side-to-side flattened chest. This funnel-shaped torso restricts rotation, preventing effective projectile launching.

Humans also have shoulders which are lowered down from ears, and arms which can extend straight out to the sides. This is enabled by a lowered and straighter ^{from mutation forming GDF5 gene,} scapula, attached by a perpendicular pectoral muscle. This allows a greater external rotation ~~but~~ with the arm cocked back, as shown in (a), as the smaller angle of the scapula attachment allows greater rotation of the humerus in the ball and socket joint. The muscle acts perpendicular to the arm movement, effectively transferring energy and power into the ~~rotational~~ rotation and the release of the spear for a more powerful throw. However, in chimpanzees, the angle of the scapula out from the ~~the~~ chest causes a downward-facing, ~~hunched~~ hunched and swaying motion of the arm. This prevents backwards rotation and means the chimp can ~~a~~ throw at a downwards angle, but throwing a projectile

parallel to the ground is compromised. The angled line of action of the pec conveys less power into the throw, designed for a forwards, quadrupedal walking motion rather than throwing.

The independent rotation of the torso from the pelvis and head allows humans to gather momentum through an initial reverse twist, torso rotation then acceleration and rotation of arm before final release; all while looking towards where the projectile is aimed. This allows humans greater accuracy when using projectiles, allowing early humans such as *Australopithecus* and more recent to be able to increase success rate of hunting using projectiles, as they can follow prey and more likely hit them. This would have been selected for as it allowed greater energy from better hunting, so more energy for reproduction and success. *H. erectus*

H. erectus also shows long legs which help with a stride to stabilise and provide forward thrust in release of projectile. This would have likely also provided advantages for running from predators to catch prey, and to increase bipedal efficiency, saving energy and increasing successful hunting with little avoiding risk of predation and injury. Overall, long legs increased energy for reproduction so naturally selected for due to differential reproductive success.

Flexible wrists wrists of *H. erectus* allow for a powerful release of projectile, increasing its speed, precision in direction, and power, to have better aim and power for hunting more effectively. This may not have been the only advantage, however. *H. erectus*

It also associated with use of controlled fire and the increasingly complex adze/lean bone tool technology. Therefore, flexible wrists may have been selected for as they are more effective craftsmanship for tools & tools, especially aiding the precision grips to direct accurate blows for a more precise stone tool. Flexible wrists also advantageous when using tools, as *H. erectus* ~~to~~ could cut meat, knock out rocks, and hit prey more effectively. Therefore flexible wrists provided a range of advantages to increase energy by efficient hunting/food gathering and increase energy to survive and reproduce, also allows better projectiles with same overall effect.

(ACTN3) *

Projectiles made from over 400,000ya to present have trends in design and manufacture, becoming increasingly complex in design & craftsmanship, planning and resources used. First projectiles were likely used by Australopithecus genus as early as 3mya, unaltered stone rocks as this was before tool technology developed. *H. habilis* may have used a similar rock projectile around 1mya, providing a selective advantage causing the ADFs gene and ACTN3 gene which arose and were established over 1mya. This increased throwing ability - rather than tool-making ability - would have initially been selected for as it provided greater success in hunting → energy → differential reproductive success.

It is likely that untipped throwing spears were created by Neanderthals around 200,000 ya - 300,000 ya, as shown ~~at~~ ^{mentioned} in Figure 6.

Neanderthals, with controlled use of fire and ~~adze/lean~~ ^{moisture} tool technology, had ~~started~~ begun to evolve in ~~area~~ ^{Europe} by this time, after diverging from *H. erectus* or *H. heidelbergensis*. Neanderthals already had begun to use the lever arm technique, with many blows to a

stone to create a tool from a core flake, so may well have used a similar many-blow strategy to create these wooden spears. Neandertals also had integrated wood into their tool technology by this time, so it is believable that they produced these.

Archaic Homo. sapiens in East Africa likely developed the stone-tipped throwing spears, combining wood and stone to make a composite tool. This required further planning and imagination, and is explained by the developing brains of H. sapiens of the time with improved hunting, nutrients from cooked food, tools and $\therefore$ larger, more complex brains. Fig 7 shows more precise and complex edges as production/manufacturing evolved over time.

Poison on stone tipped throwing spears may have been added by ~~the~~ anatomically modern H. sapiens as they dispersed throughout Europe around 54,000 ya. This was forced by interspecific competition and cold conditions causing H. sapiens to migrate out of Africa in waves. The poison on throwing spears would have increased hunting success, especially as H. sapiens had to outcompete Neandertals and when prey/food resources were scarce. This shows improved imagination and the synthesis of information as they integrate poison from other species, as well as a more complex design, and energy efficiency for a ~~less~~ throw which requires less power and penetration.

Atlatls and bow and arrows came about with modern H. sapiens in Europe. Atlatls are upper paleolithic tools reflecting more developed planning and creativity with tools used to make other tools, indicating more complex and larger cerebral cortex/frontal lobe. This is advantageous as increases reach and torque/projectile force when throwing spears beyond physical

imitations, as per Fig 8. Bow and arrows make an even more composite tool integrating animal skins as fangs of bow, as well as wood or bone bow with stone-tipped wood arrow. This tool coincides with beginning of Neolithic era at the very start of animal domestication and permanent settlements, around 10000 ya. This shows creative ability to be able to use different resources such as animal parts, and attach different sections, to with an overall end product imagined. This may have added a selection pressure towards permanent settlements. Advantageous, as provided further precision, power, energy efficiency and dexterity to the tool, increasing hunting ability and energy from more reliable, nutrient-dense food source to improve reproductive rate.

★ ACTN3 gene due to random mutation selected for as it allowed quick movements and dexterity in explosive release, improving a powerful and energy efficient hunting projectile strategy for humans.