

No part of the candidate's evidence in this exemplar material may be presented in an external assessment for the purpose of gaining an NZQA qualification or award.

SUPERVISOR'S USE ONLY

S

93101A



Draw a cross through the box (X) if you have NOT written in this booklet

☐

+

OUTSTANDING SCHOLARSHIP EXEMPLAR



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.

1/24

Question 1

The Thylacine's extinction in 1936 had multiple consequences on the Australian ecosystem, particularly in the way the food net was disrupted.

The thylacine inhabited an ecological role as a keystone species, essential to the functioning of the ecosystem and interspecific relationships within such. The thylacine had a predator-prey relationship with prey such as possums, rodents, lizards, birds, and scavenged carcasses. This behaviour controlled the population of these prey species, ensuring the ecosystem was not overwhelmed by an increased population in these species which could have a flow-on effect to the rest of the ecosystem. For example, an increase in the possum population due to the removal of the thylacines as a predator would have resulted in increased chances of survival and reproduction for the possum due to the removal of the thylacine as a selection pressure. As a result, an increase in the number of possums and other related predators might result in a decrease in the populations of native birds which are prey to these predator species. As such, the removal of the thylacine from the ecosystem due to its extinction had these ecological consequences.

In terms of the interspecific relationship between thylacines and Tasmanian devil, the removal of competition between thylacines and Tasmanian devil resulted in an increase in the population of the Tasmanian devil. In particular, as they inhabited a similar niche wherein their diets overlapped (scavenged carcasses and eating small mammals and birds), the removal of such competition due to the extinction of the thylacine results in greater fitness and reproductive success for the Tasmanian devil. This is due to a decreased energy cost of competition for food with thylacines, increasing energy available to the Tasmanian devil and allowing it to be allocated towards survival, finding mates, and rearing young for successful reproduction. As a result, the Tasmanian devil population increased which thereby has a flow-on effect to the ecosystem as there is an increased selection pressure on birds and small mammals due to the increase in the fitness of the Tasmanian devil population. Moreover, due to the removal of the thylacine as a selection pressure on the Tasmanian devil, devil facial tumour disease (DFTD) increased in the Tasmanian devil population within Australia as despite the decreased fitness of individuals with the cancer, there is a lack of a strong selection pressure/predator which in the past would have been the thylacine but due to its removal and extinction, no longer exists. As a result, these Tasmanian devil individuals who are less fit and have the facial cancer are not removed from the population and thereby have a greater chance of passing on this facial cancer due to the decrease in predation by thylacines. Thereby, there is an ecological consequence on the ecosystem wherein the lack of a strong selection pressure against Tasmanian devils with DFTD

results in the population of tasmanian devils becoming more susceptible to the facial cancer, decreasing the fitness of the overall population. Thus, due to the lack of a strong directional selection against Tasmanian devils with the harmful phenotype of facial cancer, there are more likely to transmit their disease due to the removal of the thylacine as a selection pressure.

3/24

Furthermore, there is a further decrease in competition within the Australian ecosystem with the removal of the thylacine. As cats and foxes were later introduced to Australia due to European settlement, there should have been increased competition between these species and the thylacine. However, due to the removal of the thylacine, there is a lack of competition and thereby increases the chances of survival and reproduction for the cats and foxes as now they have greater access to food resources such as birds and small mammals (i.e. rodents). Thus, due to the decreased competition between the thylacine, cats, and foxes, the population of cats and foxes is able to increase rapidly, having a flow on effect on the rest of the ecosystem as rodents and native birds decrease in population due to not having any adaptive behaviours to avoid such predators. This can be attributed to the sudden introduction of these species with a different relationship with the prey species compared to the potential co-evolutionary relationship these prey species had with the thylacines. As a result of this decreased population size of the prey species, there is a potential flow on effect wherein the reduction of the number of birds reduces the number of pollinators and predators for invertebrates. These invertebrates increase in population and are potentially harmful to the native fauna. Moreover, a reduction in the number of pollinators decreases the chances of successful cross-pollination for flowering plants in Australia which has a further flow on effect on the ecosystem wherein a decrease in the number of fauna or decreased genetic diversity and therefore fitness of native fauna, because it is a producer species, will result in the decreased fitness of potential consumer species such as herbivores or browsing species. As such, the removal of competition between the thylacine with cats and foxes has ramifications for the ecosystem.

Moreover, the extinction of the thylacine species has a further flow on effect to its predators. As the thylacine joey was also a prey in the predator prey relationship between the thylacine and wedge-tailed eagles, as well as tiger snakes, there is a decreased fitness and chance of survival for these species. While the effect might not be as substantial due to the potential exploitation of other species by these predator species, it removes a potential food source for the predator species, decreasing the amount of food energy they could potentially get and thereby decreasing chances of survival and successful reproduction as there is a reduction in energy or potentially an increased energy cost of finding different prey. This also has the adverse effect of the predator species looking for other prey species to hunt, thereby decreasing the population of a substitute prey species even further. Thus, due to the thylacine's

interspecific relationships with other species within Australia, the extinction and removal of the thylacine species has resulted in a myriad of ecological ramifications. 5/24

However, genetic engineering and manipulation could be used to de-extinct the thylacine species, using SCNT, cloning, CRISPR-CAS9 among other genetic manipulation techniques.

CRISPR could be used to genetically edit fragments of the thylacine DNA to produce a viable embryo. In particular, due to the existing specimens of thylacine, the fragments of such DNA could be pieced together to establish a complete genome of a thylacine. While these fragments might need the genome of other species such as the Dunnart to complete due to the lack of any living thylacine specimens to provide a complete genome, CRISPR could be used to construct a complete genome for the thylacines. Following this, the genome would have to be inserted into an oocyte, likely sourced from a close relative such as the dunnart, quoll, or Tasmanian devil and placed into an appropriate surrogate. It will depend on whether the surrogate is appropriate and will accept the embryo. All surrogates are viable in terms of physical demands because all marsupials give birth to an underdeveloped joey around the size of a grain of rice and therefore there is a reduced risk of the death of a surrogate during embryo development. Therefore, once the embryo has developed within the surrogate mother, perhaps a successful thylacine offspring will be produced and nurtured until full development, perhaps not in the pouch of the surrogate but through human aid. In terms of genetic diversity of this population however, there will be almost no genetic diversity as it will all come from the single cloned thylacine.

The Australian Museum project in 1999 likely failed as it was using DNA extracted from museum specimens, which were likely highly fragmented and not representative of the full thylacine genome present before the 1800s. As the DNA was collected from museum specimens, they likely already had much reduced genetic diversity humans exerted a massive selection pressure on the thylacines following European settlement, resulting in a massive bottleneck event which reduced the species to zero individuals in 1936. This would have resulted in the alleles likely not being representative of the original population and could have potentially resulted in a lethal allele in the museum specimens being expressed in the embryo (and dying as an embryo) and thus there were no viable embryos for this project. Therefore, the DNA from the museum specimens was likely not only non-representative of the original population of thylacines, but also highly fragmented due to the age of the specimens.

Another possible explanation could be that Tasmanian devils and quolls are not genetically similar enough to thylacines. The closest genetic relative to the thylacine is the dunnart whereas the Quoll and Tasmanian devil are further away from the thylacine in a phylogenetic tree. Therefore, perhaps the consideration of the Tasmanian devil and

quoll would not have been viable as the surrogate might reject the embryo and therefore the embryo would not survive, therefore producing no viable offspring.

7/24

The Australian Museum project however, continued from 1999 to 2005, perhaps failing due to insufficient understanding or genetic manipulation technology.

I believe Colossal Biosciences will be successful in cloning a thylacine, although I have some reservations. Colossal Biosciences uses more recent genetic manipulation techniques, having a near-complete genome of the thylacines. While the genome will be fragmented despite being preserved in ethanol, the company aims to fill in these gaps using the fat-tailed dunnart, the closest living relative to the thylacines. Therefore, a more complete genome with fragments of dunnart DNA might actually be more successful than the Australian Museum project. In particular, due to the presence of dunnart DNA, perhaps a surrogate dunnart mother would not reject the embryo and therefore it will successfully develop within the surrogate into a fetus and into a live joey. While there might be issues with using a dunnart as a surrogate considering the more vulnerable/critically endangered nature of these species which might hinder the success of the Colossal Biosciences project, it is in theory possible and therefore I believe it will be more successful. While the resulting individual would be a hybrid between a thylacine and dunnart, it is likely that the thylacine DNA will make up a majority of the thylacine and therefore result in a successful attempt to de-extinct the thylacine.

However, as there are no confirmed successful attempts at cloning marsupials so far, we cannot say whether the hybrid thylacine will survive until adulthood or reach sexual maturity. In particular, while Colossal Biosciences might be able to establish a cloned thylacine, there is no telling whether that clone will be reproductively viable as it might experience a degree of hybrid inviability wherein it cannot produce functional gametes and therefore cannot successfully reproduce. Furthermore, there will be almost no genetic diversity within the new population of thylacines. Even if Colossal Biosciences is able to de-extinct the thylacine through genetic manipulation, the population will likely express harmful phenotypes which would have to be selectively bred out and individuals would have to be kept in captivity until there is an appropriate population with a degree of genetic diversity to survive and reproduce in the wild.

Furthermore, as the dunnart and thylacines, while they are the closest genetic relatives, they are still in different families with the thylacines being in Thylacinidae and dunnarts being in Dasyuridae. As such, perhaps there are already too many genetic differences between the two species which would prevent successful hybridisation. There might be genes missing from the fragmented thylacine DNA which are not available in the dunnart genome. Therefore, while I believe the Colossal Biosciences project will be successful, it will likely take a long while until they produce a reproductively viable cloned thylacine.

9/25

Question 2

In order to undertake such an arduous annual journey, the godwit must have adaptations and be able to exploit its ecology to successfully undertake a migration of 29000km.

In particular, to direct itself towards the breeding and feeding grounds every year, the godwit has to have a way to navigate towards resting staging sites, breeding grounds, and the New Zealand feeding grounds. In particular, as the godwit does not stop flying from Alaska to New Zealand, it must have both stellar and solar navigation to navigate during the night and during the day. As such, this increases the chances of successful navigation on such a long journey as having both stellar and solar navigation allows the godwit to always direct itself on the right path (Alaska to New Zealand) and therefore increase the chances of successful migration as energy is not expended on flying on the wrong path and having to redirect themselves. Moreover, the godwit likely also uses the Earth's magnetic field to align itself and direct the navigation towards its destination. Moreover, in the migration from New Zealand to Alaska, it follows a coastal route, indicating the use of landmarks not just for resting, but for directing itself from New Zealand towards Alaskan breeding grounds. As a result of these navigation methods, they are adaptations which enable the bar-tailed godwit to successfully undertake such a long and energy intensive journey as they are able to direct themselves on the most efficient course and are able to recognise and rest at potential landmarks to rest up. This behaviour is especially important as resting at particular landmarks, one north of Australia, one in at the Yellow Sea, and another in South-Eastern Russia ensures that the godwit is fit for the rest of the journey, enabling it to successfully undertake such an energy intensive journey.

Moreover, its physiological adaptations also allow the godwit to successfully undertake such a journey. In particular, it exhibits a strong honeycomb bone structure which makes the bird not only lightweight, but structurally stable to handle such a long journey. The honeycomb structure decreases the energy cost of flying as it becomes more efficient due to the decreased weight and the stable structure of the honeycomb enables such a long journey due to the decreased chance of bones fracturing and the godwit having a decreased chance of making the migration due to injury. Furthermore, the dense muscle fibres of the godwit means a decreased size but increased muscular power enables the godwit to fly for long periods of time without stopping. In corroboration with the godwit's fat stores and efficient metabolism, it can fly for a long time, with the fat stores and fast metabolism contributing to more efficient energy usage for such an energy intensive journey. In particular, the wing shape of the godwit

provides greater aerodynamic movement which thereby makes the journey more energy efficient as less energy is spent flapping the wings and thus the godwit can fly for longer periods of time. Thus, the physiological adaptations of the godwit enable such a long and energy-intensive journey by making the journey more energy efficient and providing enough energy for the journey as evident in the highly efficient metabolism and fat stores under its dense muscle fibres. 10/25

Furthermore, the godwit exhibits multiple behavioural adaptations which allow it to successfully undertake the long and energy-intensive journey. The behavioural adaptation of not sleeping and undergoing a non-stop flight of 9 days from Alaska to Australia and New Zealand results in successful migration as it decreases the time spent at resting sites, especially during August and September when it is summer/autumn and the temperature gets colder, with a reduction in the populations of aquatic invertebrates and shellfish to feed on. As a result of this non-stop flight behaviour, the godwit is able to successfully undertake such a long journey as it does not expend extra energy on stopping to find food which is a massive energy cost considering the potential lack of food resources in the northern hemisphere during the transition between summer and autumn (temperature decreasing). Moreover, another behavioural adaptation of the godwit which is especially important in its successful migration is the resting in 3 different areas. As mentioned before, navigation directs the godwits towards these resting areas. The behaviour of resting in these particular sites such as the yellow sea and Russia during the North Hemisphere summer means that there are readily available food sources, especially due to the behaviour wherein they rest in/near coastal areas. As such, there is an increase in the chances of survival as they are able to exploit the natural resources of the region to fuel up for the rest of the journey. This increases the chances of successful migration as they refill their fat stores and allow their bodies to process the build-up of lactic acid and thereby increase their chances of making it to Alaska.

Furthermore, in terms of behaviour, the migration is likely triggered by photoperiodism. Because temperature can change quite spontaneously due to climate change (i.e. high temperatures in winter) it can trigger early migration which would result in decreased fitness for the godwit as there might not be resources available in its resting sites. As a result, there is likely an internal clock which triggers migration through day lengths. As day lengths in New Zealand get shorter in winter, migration is triggered which is not only an advantage as there is increased food resources in the northern hemisphere, but also the synchronised nature of the migration increases the success of the journey as an individual being predated upon becomes less likely due to sheer numbers. As such, photoperiodism enables the success of such a long and energy-intensive migration.

Climate change will inevitably have a negative effect on the migration patterns of the bar-tailed godwit.

13/25

In terms of the effect of climate change on the godwits migratory route, there would likely be a change in the route the godwits take. In particular, due to global warming, the prey species of the godwits (aquatic invertebrates and shellfish) might delay their period of activity to earlier in the summer when the temperature is not as extreme or might decrease rapidly in population due to the denaturation of enzymes due to the higher temperatures. As a result of such, there is likely a decrease in the number of prey species for the godwits which thereby not only decreases the chances of successful migration as there is a reduced number of prey species and therefore less energy for the rest of the journey, but may chance the migratory route to stop by another resting site. For example, perhaps instead of the yellow sea, the godwit stops in in the southern hemisphere, perhaps in Malaysia or Taiwan where the temperatures are lower and therefore there are more prey species available compared to the yellow sea. Thus, climate change might alter the route of the godwits, changing the location of resting sites and their migratory route to accommodate for such changes.

Furthermore, the migration route may change in terms of their destination. Alaska might not become a viable breeding ground due to increasing temperatures resulting in predators such as possums or feral cats becoming more active, therefore increasing stress on the godwit, selecting against individuals who migrate to Alaska. As a result of a new potential selection pressure in their breeding grounds, there might be a change of their migratory route towards the West in Russia or further east to Canada resulting from warmer temperatures in their breeding grounds. This could potentially alter the likelihood of successful migration from New Zealand to the far north as there could be an increased energy cost to migrating further west or decrease in survival as the conditions of Eastern Russia are unfavourable for successful migration such much colder temperatures resulting in injuries related to the cold such as the wings becoming injured due to the cold reducing blood flow thereby decreasing the chances of successful migration.

Additionally, there has been the observation that global climate change has resulted in changes in wind patterns, affecting the godwit at all stages of their annual cycle. In particular, more violent and frequent storms due to climate change will impact on the likelihood of successful migration as the godwit becomes more likely to be blown off course and expend energy and time navigating itself back on the right migratory route, decreasing its chances of survival and because time is expended getting back on the route, there is a potential decrease in the chances of reproduction as the godwit individuals becomes desynchronised from the time that reproductively viable godwits arrive at the breeding grounds to court and mate. Moreover, these individuals will likely have a reduced fitness as the risk of injury (due to storms or strong

winds) and increased energy cost to get back on course to their destination means they will have less energy for courtship behaviour and thus be sexually selected against by potential mates. Furthermore, the godwit might use wind patterns to determine their migratory route and therefore changing wind patterns due to climate change might result in different resting areas, a potentially different route and in an extreme case, perhaps a different breeding ground. As a result of climate change's impact on changing wind patterns, it results in much reduced likelihood of successful migration and potential changes in the godwit's migratory route and potential resting sites. 15/24

Furthermore, as the godwits do not breed until their third or fourth year, when the behaviour of migration becomes entrained, it may exacerbate the potential changes to migratory routes, resting sites, and successful migration. Because the godwits only breed after 3-4 years, a change in the behaviour of the godwits in one year associated with migration might become the new norm for the population of godwits in the next year/generation. In this case, there becomes a potential for speciation as the population of godwits which reproduce in different areas and are entrained to do so have a behavioural reproductive isolating mechanism (RIM) which results in a geographic RIM. As a result of such, speciation might occur in the godwit which would further exacerbate differences in the likelihood of successful migration, where their resting sites are, and potential migratory routes between the northern hemisphere and southern hemisphere.

Question 3

H. sapiens are able to utilise projects successfully for hunting, warding off predators, and potentially compete with other hominin species for space and resources much more effectively than chimpanzees are able to due to adaptations in *H. sapiens*.

In particular, a major contributing factor to why *H. sapiens* are able to utilise projectiles can be found in bipedalism. Bipedalism in *H. sapiens* frees up the hands as it is no longer used for locomotion whereas for quadrupeds such as chimpanzees, it is still used for locomotion such as brachiation. The freeing up of hands and straight phalanges in humans opposed to the curve phalanges in chimpanzees means that humans can carry projectiles while standing upright, allowing their feet to be planted on the ground and undergo the necessary motions for successfully throwing projectiles. While chimpanzee's might have had a degree of being able to throw rocks or branches, they would not have been as powerful as a *H. sapien* throwing a projectile, particular due to bipedalism and *H. sapien*'s straight phalanges which make gripping projectiles such as spears easier. As seen in table 1, the first image illustrates the overhand throw

17/24

of a projectile, involving 2 stages; arm-cocking phase, and acceleration phase. Bipedalism would have enabled this because the bony stability gained from bipedalism allows for the H. sapien to stay on the ground while throwing, increasing the force of the throw. In particular, H.sapiens have a decoupled waist which allows the torso to rotate independently of the pelvis and head. This provides an adaptive advantage as H.sapiens are able to generate force using the arm-cocking phase, rotating their torso to the side to generate force while the pelvis keeps the lower body locked into a favourable position to throw and the head remains in the same position to aim the projectile towards a target. Because the torso is able to rotate independently from the pelvis and head, during the acceleration phase, there is maximised external rotation, accelerating the projectile through the energy transfer of the rotating waist into the projectile to be thrown. This would have allowed H. sapiens to more successfully throw projectiles at a faster speed and with more power in the throw. As a result of such, there is an adaptive advantage to this physiological difference between H. sapiens and chimpanzees as it means H. sapiens can effectively throw projectiles from a distance and thus hunt potential prey from a long distance to avoid being seen and allow H. sapiens to increase their chances of defending against potential predators as H. sapiens can throw their projectiles from longer distances, reducing the chances of potential predation or death as they are more likely to be able to run away after throwing a projectile at a predator.

Moreover, H.sapiens, during the throwing of a projectile have the arm positioned parallel to the ground whereas the chimpanzee has their arm around 45 degrees up due to differences in shoulder orientation. Because H.sapiens have a parallel arm position when throwing, it allows them to generate greater force during the acceleration phase as it becomes more efficient to throw compared to chimpanzees where because the arm position is much higher and not parallel, has a higher energy cost and structural inhibitors which inhibit the use of projectiles. Moreover, the major line of action of the pectoralis major, a muscle used in the throwing of projectiles is more parallel to the ground and better articulated in H.sapiens opposed to chimpanzee's providing H.sapiens with greater muscular stability than chimpanzees for throwing projectiles. This line of action being more parallel further contributes to the H.sapiens ability to throw projectiles opposed to the chimpanzee which one oriented at around 45 degrees, making it less efficient to throw projectiles overhead. Moreover, the orientation of the scapula for H.sapiens is more parallel whereas it around 45 degrees for the chimpanzee. While this orientation for the chimpanzee might be advantageous in behaviour such as brachiation, a more parallel scapula enables the throwing of projectiles, enabling the parallel arm position during throwing due to the parallel orientation of the scapula. As a result of these adaptations in H.sapiens, it enables not just throwing, but the ability to throw powerful and accurate overhead projectiles to hunt predators and prey, increasing the chances of survival and successful

reproduction as *H. sapiens* avoid predators through potentially scaring them off with projectiles that can be thrown from far away. Furthermore, there is an increased chance of successful reproduction as they can more easily kill prey species and thus increase the amount of food resources they are able to obtain, thereby increasing the chances of successful reproduction as energy can be allocated towards growth and nurturing social bonds. 19/24

Furthermore, *H. sapiens* have low wide shoulders, with long legs and flexible wrists. Having long wide shoulders meant that the individual could more effectively utilise the energy from the torso rotating independently from the pelvis and head to throw further. Moreover, the increased muscular power within the shoulders from the increased width meant that more power could be generated in a throw which chimpanzees are not able to do given the relatively higher shoulders which are better suited for an arboreal lifestyle. Low wide shoulders would have also been an adaptive advantage for *H. sapiens* as it meant they could carry more back to their shelter and potentially scare off predators by making themselves look bigger. Furthermore, longer legs would not only be an adaptation for throwing as it allowed for greater power generated during the arm-cocking phase and acceleration phase of throwing, but also allowed *H. sapiens* to take longer strides, increasing energy efficiency of bipedalism as it takes less energy to travel to destinations. As a result, it becomes an adaptive advantage especially for migration wherein because it is more efficient to walk due to the longer strides *H. sapiens* can take, they can more effectively disperse across the world. Furthermore, flexible wrists not only provide the necessary motion for rotating the wrist during throwing to ensure the projectile lands in the desired target/area when throwing, but also provides an adaptive advantage in terms of holding tools compared to chimpanzees which do not have this flexible wrist phenotype as it is more advantageous to have a rigid wrist for brachiation and thus chimpanzees are unable to effectively utilise projectiles.

These adaptations were all directionally selected for as there was a selection pressure which selected for phenotypes which were able to effectively use projectiles.

Furthermore, *H. sapiens* have adaptations in their genes which chimpanzees do not, such as the *GDF5* gene associated with enhanced rotational range of motion in the shoulder compared to the chimpanzee which allows for more powerful throwing of projectiles where chimpanzees do not have this gene and therefore are less efficient at throwing projectiles. Moreover, *H. sapiens* have the *ACTN3* gene which produces fast twitch muscle fibres which are needed for performing powerful and explosive movements such as planting the foot in the ground during the arm-cocking phase to generate energy and then fast rotation of the torso and movement of the shoulder and arm to generate large amounts of force when throwing the projectile. Thus, these genetic factors have contributed to the more efficient adaptations which allow

H.sapiens to use projectiles opposed to chimpanzees. The ACTN3 gene would also be advantageous in fast twitch movement such as sprinting towards prey or predators, increasing growth due to increased food resources and increased chance of survival due to more effective evasion of predators. 21/24

There has been a clear trend in the design and manufacture of projectiles throughout human history, becoming more and more complex overtime.

Unaltered rocks were likely used by more archaic hominins or perhaps even chimpanzees as they lacked the cranial capacity to shape the rocks and could only throw them to perhaps kill prey or lure predators away. Thus, due to the simplistic nature of this project, it is likely archaic homonins such as australopithecines or perhaps even archaic H.hablis which used this tool culture. Thus, while it can be argued that H.hablis and australopithecines did use projectiles, it was likely not to the degree of H.erectus, H.neanderthalensis, and H.sapiens which had specific tools and curated projectiles for hunting, avoiding predators, and competition with other hominin species.

Untipped throwing spears which are dated 400-300kya are pieces of wood likely from branches with at least one sharpened end found in the united Kingdom and Germany. As such, due to the area that it was found, we could potentially attribute this projectile to H.erectus or H.neanderthalensis which potentially dispersed/evolved in Europe 400-300kya. While it is relatively simplistic, it is likely not H.hablis or austrlopithecines as there is no current evidence which suggests that these two species ever left Africa to Europe whereas evidence of H.erectus and H.neanderthalensis suggest they dispersed to Europe. The trend shown here is that there is a manipulation of abiotic factors which is a shift from the unaltered rocks.

Stone tipped throwing spears attached to wooden javelins are evidence of early composite tools. The shape of such is in a teardrop shape which resemble the Archeulean tool culture of H.erectus. Moreover, it was found in Ethiopia and can be dated to 280kya which suggests that the most likely homonin associated with such is H.erectus. The evidence provided from figure 7 which illustrate the tear drop shape suggest that the hominin species likely associated with this projectile is H.erectus, suggesting that H.erectus used projectiles.

54kya, tool cultures become much more complex, with evidence of poison on stone-tipped throwing spears, indicating increased capacity of the frontal lobe of abstract thought and critical thinking. It is likely that the hominin species which can be associated with this tool culture could be H.neanderthalensis or perhaps even H.sapiens. This is because both sufficient cranial capacities for abstract thought and critical thinking to understand that poison is more effective at killing potential prey and predators as only one projectile with poison had to hit the target to be effective. Thus,

applying poison to the projectile would make it more efficient to hunt. As a result, because this requires a degree of abstract thought and critical thinking it is most likely not *H. erectus* or its predecessors but rather associated with *H. sapiens* or *H. neanderthalensis* due to their increased cranial capacity. In particular, the Wernicke's and Broca's areas would have to be developed as there would have to be a degree of communication within the populations to understand which plants or animals are poisonous and can be applied to projectiles safely. 23/24

Atlatls (21-17kya) and bow and arrows (11-12kya) are both composite tools, with Atlatls being carved from wood or bone and used to throw a spear whereas bow and arrows are made of wood/bone, with the string made out of animal tendons and the arrow made out of wood. Both these tools can be found in Europe which indicates perhaps late Neanderthals used these projectiles (Mousterian tool culture) or more likely *H. sapiens* used these tools (Upper Palaeolithic tool culture). In particular, we see a shift in projectiles from being more simple throwing projectiles into tools which aid in the throwing of projectiles or becoming the medium of which to use the projectile. The design becomes much more complex in that the manufacturing of the tool requires an idea of what the tool should look like and the necessary parts to make them. For example, the atlatl requires a vision and understanding as to what it will look like in the end from the wood/bone it is carved from, as well as how to carve the wood/bone into the tool. Thus, it becomes much more complex than throwing spears. Moreover, bow and arrows require not only an understanding of more complex composite tools, using animal sinew as strings, but also more complex abstract thought to understand how the bow will work, as well as precision grip to fire the arrows and create the tool itself. Therefore, the trend in projectile development has been that designs have gotten more complex, from unaltered rocks, throwing spears, and to designs which are mechanisms in which to throw the projectile. Moreover, the manufacturing of the projectiles became much more complex, from around ~50 blows to a central stone (Acheulean with stone tipped throwing spears) to more complex methods such as the Levallois method and using other tools to create the projectiles.

As such, *H. erectus*, *H. neanderthalensis*, and *H. sapiens* all likely used more complex projectiles whereas *H. habilis* and australopithecines likely used much simpler projectiles to increase their chances of survival.

Outstanding Scholarship

Subject: Biology

Standard: 93101

Total score: 21

Q	Score	Marker commentary
1	8	A full understanding of the ecological consequences of the thylacine extinction on the Australian ecosystem was convincingly communicated in terms of its role as a predator, prey, and competitor for food. In addition, the importance of this keystone species to the balance of the ecosystem and the indirect effect its extinction has had across many other species was also discussed. The response demonstrated highly developed knowledge of genetic manipulation and the likelihood of thylacine being brought back from extinction. The need for multiple DNA samples to achieve a complete genome using CRISPR and Dunnart DNA, which can be inserted into an oocyte from a closely related species and implanted into a surrogate to develop, was discussed. Challenges faced by scientists were analysed, including the phylogenetic separation of the possible surrogates, the genetic differences between species that might prevent successful surrogacy and the acknowledgement that the synthesised DNA would be a hybrid of thylacine and Dunnart, putting the de-extinction goal in question.
2	6	This response demonstrated a clear understanding of the adaptations that the bar-tailed godwit / kuaka possesses in terms of physiological features, such as fat stores, efficient metabolism, and their importance to successful migration. In addition, photoperiod was identified as a trigger for timing migratory behaviour and navigation methods were clearly discussed. The importance of food and resources at stopover sites to build up fat stores for the long migration journey was considered, along with the impacts of climate change in terms of wind and weather changes, and food abundance. These were discussed in the context of challenges to successful migration.
3	7	This response demonstrated in-depth and comprehensive understanding of the adaptations of the wrist, legs, scapula, shoulder, and waist of <i>Homo sapiens</i> that have been selected for to enhance projectile use for hunting compared to chimpanzees. The adaptive advantage of throwing projectiles from greater

		distances to reduce the chance of injury was also discussed. The increasing complexity of projectile design over time was described, along with analysis of data from the resource and with integration of prior knowledge to match the type of projectile, the approximate age, the location, and the sophistication of the projectile to named hominins.
--	--	---