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Scholarship 2022
Biology

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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 in this booklet.

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

Check that this booklet has pages 2–26 in the correct order. Pages 2–4 are blank and are to be used for planning. Pages 5–26 are lined pages for writing your answers.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

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Question	Score
ONE	
TWO	
THREE	
TOTAL	

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PLANNING

Q2

limited ~~reater~~ niche realisations fundamental.

Breeding — territorial.
/
solitary

· chance success chance ↓.

· Specialized, dependent. → non-changing environment.
90%'

· Black footed ferrets — prairie
↓
· ~~co~~ predation +/-
· ~~expo~~ parasitism +/- · biggie for habitat.
as ~~host~~ ↓ ~~parasite~~ ↓ host ↓, parasite ↓.

Breeding.
· ~~k-selection~~ like K selected. — protection. mother energy demand · small litter size · litter

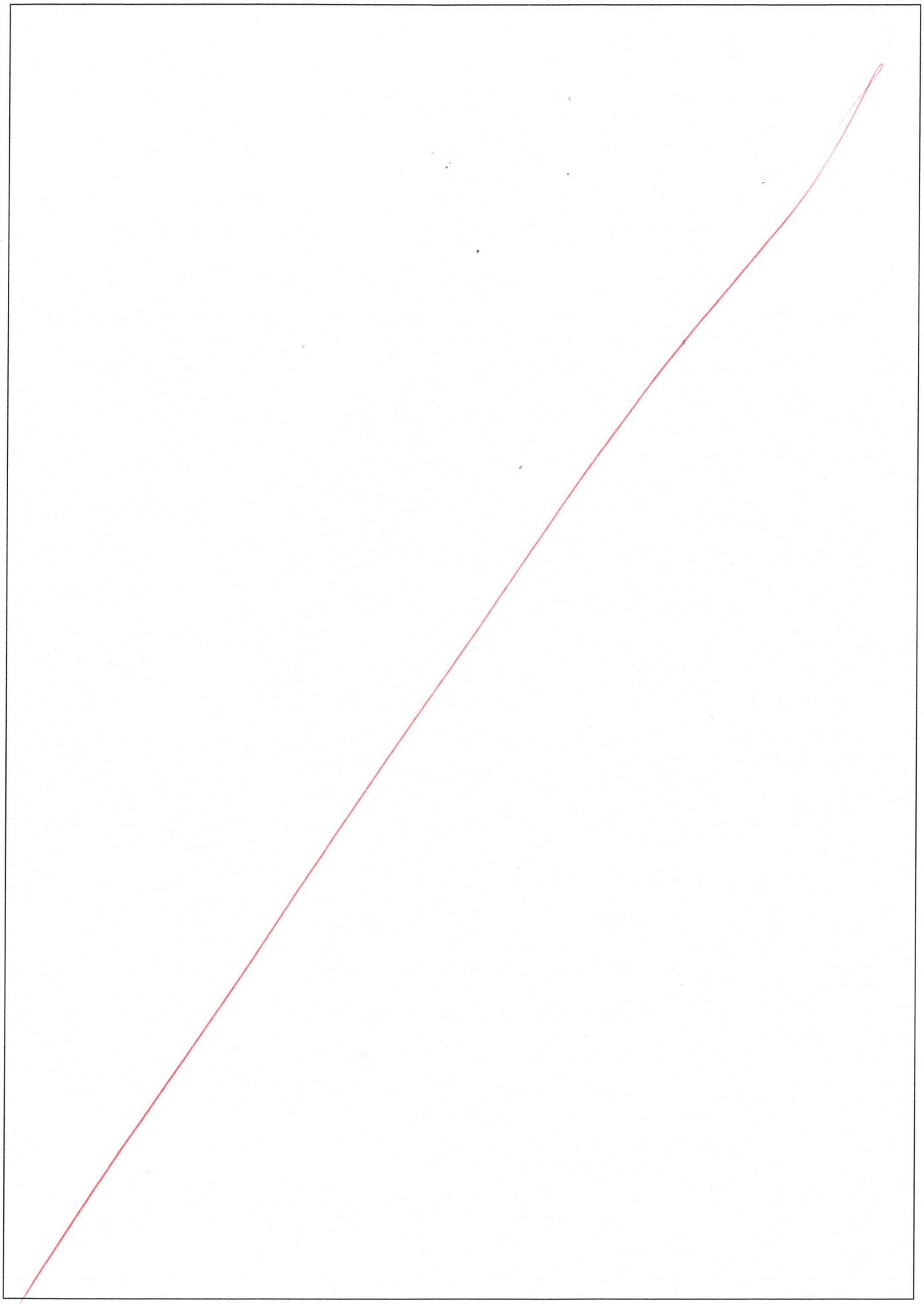
~~Eco~~ Bottleneck 1981 — disease. — small gene pool — AF fixed. — genetic diversity small

Habitat loss, fragmentation
↳ ecological ~~ba~~ barriers, no corridor.

Prairie host — pest — poisoning. Bottleneck epidemics.

01335

PLANNING



PLANNING

Q1.

Galapogas → Antarctic & vice versa.

(1).

Divergent evolution: from Procellariformes.

66mya.

(Cretaceous mass extinction).

Adaptive radiation. (50 species).

↓

unoccupied niche.

(3).

Large

Competition from mammals.

extinction. 25Mya.

(4).

Living

↓

disruptive selection.

↓

selection pressure

divergent

Colder

↓ smaller SA

warmer

larger SA

22mya.

ACC

islands

① gene flow

② allopatric

no flight.

(5).

Great Auk

— convergent evolution — similar selection pressures.

— human intervention.

(2).

Common ancestor — Gondwana land.

— Arrestial features.

- Oceanic carnivore niche elected by reptiles.
- no need for flight — homologous structure wings.
  energy.
- bones
- flexter.

(*) Sympatric speciation may have occurred here via niche & specialization given that so many vacant niches were available.

Q1

The penguins underwent divergent evolution with the Procellariiformes around 66mya. This date coincides with the mass extinction of apex predators during the K-T / Cretaceous Tertiary / Cretaceous-Paleogene extinction leading to a loss of 45% of species present. Divergent evolution is where a common ancestor gives rise to two or more different species, which is what is seen between penguins and the Procellariformes. The mass extinction of apex predators such as sharks and marine reptiles opened new and vacant ecological niches which were unoccupied. This led to adaptive radiation of species to occupy and exploit the resources available (*). Mutations may have occurred in the last common ancestor of Penguins and Procellariformes to allow it to occupy habitats underwater. This would confer an adaptive advantage as it would have less ~~interspecific~~ intraspecific and interspecific competition, leading to a higher survival and reproductive fitness. Therefore, the allele frequency of alleles selecting for the oceanic carnivorous niche would increase, leading to the accumulation of reproductive isolating mechanisms such as ecological & isolation. This would ultimately lead to speciation of penguins from the Procellariformes clade.

Because of the shared ancestry with flying seabirds, the penguins share homologous features ~~as~~ such as modified wings for underwater dives. This further supports the theory of divergent evolution as homologous feature suggest the wings were adapted to a new function in the penguins. The loss of flight would have led to ~~the~~ less energy spent in locomotion which could be allocated to reproduction and survival to increase its fitness. The feathers in penguins are highly specialised, with the streamlined contour features allowing efficient diving and swimming when escaping from predators and in hunting. The insulating plumules allow exploitation of colder habitats as they provide dense insulating functionality. Penguins have dense bones, which would suggest that it is robust ~~and~~ when fighting ~~against~~ for food intraspecies, and ~~can~~ is capable to suffer significant injury. Genes relating to thermoregulation, osmoregulation and diving capacity ~~are~~ were undergoing

Strong selection to increase in allele frequency as they conferred an adaptive advantage for the penguins to increase their survival and reproductive chances.

The common ancestor of extinct and extant penguins were likely to have existed when Gondwana was a land mass connecting the continents of Africa, Antartica, Australasia and New Zealand and South America. Because penguins are not capable of aerial flight, their current distribution globally would ~~suggest that~~ support the biogeographical evidence that Antarctica, Africa, NZ, Australia and South Africa were once connected. This would have made the dispersal across continents more likely to occur. Fossil evidence showed that extinct species had body mass up 145 kg. whereas living penguins were much smaller ranging from 1kg to 30kg. This suggests that adaptive radiation occurred within the penguin species and there was a large range of phenotypes present. The extinction of giant penguins coincided with the time range where toothed whales and seals and other marine mammals increased in abundance. This is likely due to a competitive interspecific relationship where the giant penguins and marine mammals were competing for resources such as food. Because of their similar ecological niches ~~such as~~ of a oceanic carnivore preying on larger fish, Gause's competitive exclusion principle applies. Eventually, the giant penguins were outcompeted by the marine mammals and driven to extinction. There may have been a predatory relationship between penguins and larger ~~marine mammals~~ marine organisms such as orca and seals, although this was not as likely to be the reason of their extinction as the smaller-sized penguins survived.

Living penguins underwent allopatric speciation ~~via niche differentiation~~ where disruptive selection occurred to select for larger body types in colder regions and smaller body types in warmer regions. The larger body type reduced surface area to volume ratio to prevent excessive ~~evaporation of heat & convection~~ loss of heat through convection and be confined

a selective advantage ~~as~~ to survive in colder habitats. Similarly, small body types with higher surface area to volume ratio allowed loss of heat through convective cooling, and thus conferred adaptive advantage in warmer waters. These phenotypes were selected for via natural selection ~~as~~ as there were different selection pressures in the different environments (cold and warm ~~waters~~ waters). The diversification of living penguins from common ancestor around 22mya is an example of ~~a~~ divergent evolution. as ~~Thus~~ multiple species were formed from one ancestor. ~~Thus~~ The evolutionary history of penguins ~~display~~ support the ~~a~~ punctuated equilibrium ~~theory~~ mode of evolution as the diversification of species occured during short periods of time and ~~remained~~ species remained ~~static~~ ~~but~~ different for long periods of time ("stasis"). this is seen again in the living penguins where. their diversification coincided with the separation of Antarctica from Australia and South America. The production of Antarctic circumpolar current led to cooling of Antarctica regions and the current allowed dispersal of penguins to newly formed island groups such as the Galapagos Islands. The Galapagos islands are tropical in nature and fall on the equator, ~~this~~ However because of the Antarctic circumpolar current which brings colder water around, the penguins were able to disperse and occupy the ~~empty~~ vacant niches of the Galapagos Islands.

It is this dispersal which led to the allopatric speciation of penguins. The geographical separation allowed different selection pressures to operate on populations occupying different niches. Over time, the differences accumulated to form reproductive isolating mechanisms (RIMs) such as ecological difference (penguins living in ~~habitats~~ warmer waters unlikely to breed with those in colder waters), temporal difference (breeding seasons may differ), behavioural ~~adaptation~~ isolators (courtship displays / rituals may differ) and mechanical isolation (sexual reproductive parts may not structurally fit together). Because the penguins are on different islands, these RIMs ~~but~~ accumulate and ~~to~~ act as a barrier against gene flow, and thus speciation occured. As penguins

were flightless, the different island groups are less likely to interbreed as they do not overlap in geographical serse. As natural selection acted on the isolated groups with different selection pressures due to different environments, the produced diversity amongst the penguins.

The great auk penguin display convergent evolution with the Southern Hemisphere penguins as both were subjected to similar selection pressures being present in similar environment of cold waters and were hunting similar prey of small fish. Despite being unrelated, the Great auk and the Southern Hemisphere penguins show some phenotypes such as modified flippers to dive. This is an example of an analogous structure since the unrelated species evolved to possess similar morphological traits because of their similar niche. Co evolution with marine mammals such as orca and seals resulted in selection for more efficient escape from predators which led to their streamlined body shape being selected for. Similar selection pressure of predation applied amongst the Northern Hemisphere penguins which therefore parallel evolution to a streamlined body form was also seen in the Southern Hemisphere penguins. As the great auk were habitats in the Northern Hemisphere, they were likely to be separated geographically from the Southern penguins (Laurasia was separated from Gondwana 180 mya). Therefore the only explanation for their similar traits despite their little relatedness is that the derived traits were result of convergent evolution.

Overall, the multiple adaptive radiation due to biogeographic events forming the flightless seabirds led to a huge diverse range of species, both extinct and living.

Q2.

Black-footed ferret is a solitary species. This reduces its chances of successful predatory behaviour associated with cooperative hunting, reducing its survival chances. In addition, black-footed ferrets are territorial, with male and females only coming together during breeding seasons. This reduces the chances of a social bond forming between mates and energy needs to be invested in each year to find a mate and establish a territory. This would have led to decreased reproductive success. The ferrets are a specialist species, which are completely dependant on prairie dogs for food. This means it has a narrow ecological niche, and is subject to higher risk of extinction when environmental conditions change. The ferrets are a ~~parasite of the~~ predator (as is positively impacted in this relationship) to the ~~prairie~~ prairie dogs where ferrets hunt on prairie dogs for food and energy and prairie dogs ~~lose~~ die from hunting (this are negatively impacted). ~~In addition~~ However, because 90% of the ferrets diet is from the prairie dog, it is largely obligate predator of the prairie dog. This means that a decrease in the prairie dog population would lead to decrease in the ferret population. as it is unable to change preys like other mustelids. In addition, the ferrets are parasites on the prairie dog species where the ferrets benefit from prairie dog burrows. They gain protection from predators, use them as shelter from weather (harsh weathers) and den ~~not~~ use them as dens (so the ferrets are positively impacted). The prairie dog species is negatively impacted as they are likely to be killed when they return to the burrow. However, similar to above, the ferrets are likely obligate parasites of the prairie dog species for their burrows. Because ferrets are in ~~a competitive and a~~ are an obligatory parasitic and predatory interspecific relationship with the prairie dog species, which will it is very likely that the prairie dog species can go extinct ~~and~~ lead to the extinction of the ferrets.

In addition, black footed ferrets display a K- reproductive strategy where they have low reproductive rates, only giving birth to 3-4 babies each breeding season. The female invests a lot of energy into nurturing each kit to its own nearby burrow which increases the risk of females death from predation. This decreases

the ~~reproductive~~ survival of the female. ~~In ad~~ Additionally, the kits hunt independently late summer, with a short lifespan of only one year. This means ~~not~~ not all ferrets survive to reproductive maturity and pass on their alleles to the gene pool. the slow reproductive capacity limits increase in ferret population density overall.

Furthermore, the ferret population underwent a population bottleneck in 1986, where a small population of around 130 was hit by a disease and shrunk to only 18 individuals. Because of the small population size, it is likely that genetic drift played a large role. Genetic drift is where alleles are fixed or lost due to chance. In a small population, the death/emigration of ~~a~~ an individual ~~has~~ means changes to a large proportion of the gene pool. Therefore, the genetic diversity of the small ferret population is small. Harmful alleles may have been fixed in the ferret population such as vulnerability to CDV and the sylvatic plague. The captive breeding programme involves only 7 who bred successfully out of 18. this implies large extent of inbreeding, which increases the possibility of harmful ~~allele~~ recessive alleles coming together. The ~~de~~ increase in homozygously of the population decreases genetic variation, thus ~~is~~ without sufficient raw material to work on, natural selection could lead to species extinction. Although numbers are now ~~a~~ higher at 220 captive & 200 wild, genetic diversity would be largely compromised. These factors have led to the critically endangered status of the ferrets.

Moreover, the loss of habitats to agriculture and natural gas extraction decreases habitats of prairie dogs. As ~~previ~~ detailed previously, because ferrets are dependent on prairie dogs for food & habitats, the decrease in prairie dog habitat would lead to possible extinction of ferrets. ~~Because prairie dog~~ ~~is controlled through poisoning, the~~ The fragmentation of habitat would lead to ecological corridors destroyed, limiting the extent of gene flow which

decreases the species overall fitness. Epidemics wiping out entire colonies are of concern as they can impose severe bottleneck effects.

There are multiple options for black-footed ferret management. Firstly, captive breeding programmes with artificial insemination can increase the reproductive success of ferrets. However, this would apply artificial selection pressure as humans are assisting the breeding. for ferrets with better sperm quality. This is seen in genetic studies too. However, artificial insemination can benefit by working with genetic analysis to breed individuals with least relatedness to increase genetic diversity of the population. By analysing genome of the breeding stock, scientists can identify markers for increased immunity against sylvatic plague and CDV. Individuals with alleles coding for increased immunity can be intensively breeded together to increase the allele frequency of beneficial traits.

Secondly, insecticide control of fleas in prairie dog colonies would decrease sylvatic plague through controlling the bacterial disease spread by fleas. This increases the prairie dog colony which would lead to increase numbers of prey available and habitats available for the ferrets. However, an implication of this is the potential of increasing the prairie dog population density since we are removing selection pressure on the prairie dogs. As prairie dogs are considered a pest, increasing their number could lead to flow-on effects on the ecological food chain that may not be desirable for other native species.

Thirdly, vaccination of ferrets against plague and CDV may increase the population immunity against the disease. Increasing ferret survivability and reproductive success However, a high percentage of the population would need to be vaccinated (≥90%) to achieve herd immunity. This would mean considerable efforts into developing vaccine & delivering vaccines to the ferret population. In addition, vaccines against these diseases do not ensure immunity against other diseases. Therefore, outbreak

of other diseases may again lead to reduction of ferret population size. Fourthly, the conservation of prairie and grassland habitats could increase the ~~gene flow~~ ~~of~~ reproductive success of ferrets. The restablishment of habitats can allow dispersal across the range of areas. This would lead to increased genetic diversity as different populations would be subjected to different selection pressure. The higher genetic diversity would allow for a more ~~re~~ ~~fi~~ resistance population against changing environments. Therefore, in my opinion, of the key strategies outlined, the scientists should focus on captive breeding and habitat conservation, as these two provide most significant advantages, and can ensure a self sustaining population without significant negative implications.

Besides the strategies proposed, other options include Cloning and transgenic techniques. Willa is a ferret which existed before the disease outbreak in 1981 population bottleneck caused by the therefore posses ~~three times~~ 3x more genetic diversity than the current population. ~~Her~~ Through including her in the captive breeding programme, ~~the~~ this would increase the ~~of~~ genetic diversity in the current gene pool. ~~Then~~ The second cell line from SB2 died from CDV before breeding. It is likely that his ~~the cell~~ DNA includes harmful alleles which increases susceptibility from CDV. ~~Then~~ Adding him to the gene pool would increase the risk of ~~a future~~ ~~offs~~ offspring dying before reaching sexual maturity. Therefore, the SB2 cell line should not be included into the captive breeding program. Cloning ~~can~~ ~~have~~ can have biological implications which include limited genetic diversity (as offspring is entirely similar). However, since in this scenario, the clone would be added to a pre-existing gene pool, this negative implication is largely negated.

Transgenic techniques can also be used ~~such as~~ t For example, genes coding for increased immunity (such as alleles for MHC proteins) can be spliced into the breeding stock through techniques such as CRISPR. The This would allow innate inheritable immunity to increase ferret health & and survival, ~~etc~~. The is also a heritable if spliced into the gonade producing cells, which means less effort required to sustain the ~~pp~~ population as the R ~~gene edit~~ allele will be inherited naturally in the wild. Transgenesis may be bring on negative implications including ~~the~~ the the hybridisation of ferrets with other species leading to the immunity allele spreading into ~~wild~~ other species this can lead to flow on effects on ecosystem food chains and may lead to other pest species outcompeting the ferrets. Hybrid vigour may also be displayed with transgene hybrids, and this could lead to decline in ferret population and/or the biodiversity of America species

~~Ch~~ In my opinion, Cloning & and transgenic techniques ~~are~~ definately ~~be~~ hve large potential to improve the vulnerable status of black footed ferrets, but they should be tested on smaller scale to minimize any negative implications that may follow.

Planning Q3.

Floresiensis / H. habilis left

Bipedal gait similar.

H. erectus left and then evolved

- large reduction of body size
- significant dwarfing
- of Stegodon supports.

- Lack feature evolved 800kya.
(evidence for this)

- Similar cranial shape
- Receding & small forehead.
(Small brain).

- Hunting small evidence. tools.

- Control fire.

Tool Raft

Q3.

In my opinion, the larger bodied H. erectus left Africa, moved through Indonesia and Flores, then evolved into H. floresiensis. (second model).

One of the evidence to support the theory is that Flores has always been separated from mainland Asia even at the glacial periods. This refers to that Flores, a significant water crossing had to be made over at least 24 kilometers. This implies that the founding population must have had tools and technology such as rafts capable of doing such a significant crossing. At 24 km further away, the Island of Flores would have been visually unable to be seen, thus some forethought and imagination must have been present amongst the founding population. H. habilis is associated with brain size of 614 cm^3, with limited ability of imagination and primitive Oldovan tool technology. Therefore, I find it unlikely that H. habilis would have been able to migrate out of Africa and make significant crossing into Flores. Although it is possible that a storm may have carried the ~~animals~~ ~~here~~ humans over, this is less likely as relatively a large population would have been established in order to maintain reproductive ~~ability~~ capabilities in the population.

Add Another piece of evidence to support this model is that Flores is an

island geographically isolated from other habitats of hominids. The reduced energy environment can lead to dwarfing of species when there is limited food source. Directional selection would have occurred to favour individuals requiring less energy to ~~sustain & and~~ survive; and this could lead to increase in allele frequencies of alleles ~~determining a smaller~~ body size. Dwarfing is an occurance supported by other evidence such as presence of ~~where~~ Stegodon, and other dwarfed species ~~were present~~ on Flores and other small islands ~~evidence~~. On one hand, this supports the dwarfing hypothesis, and on the other hand, this provides evidence that H. floresiensis had food source available to them. Additionally, dwarfing may have been excerbated by the small population size. Significant amounts of inbreeding would have occured, which may lead to ~~homozygous~~ recessive alleles expressed in homozygous individuals. One of these alleles could have been coding for reduced body size, thus ~~the isolation~~ and its allele frequency ~~in~~ high frequencies of inbreeding would have increased its expression. Over time, genetic drift ~~would~~ may have led to this allele being fixed in the Flores population by chance. ~~The founding population~~ (*) However, this can also be seen as evidence for the first model where a ~~hominid~~ species with relatively ~~hominins~~ small body size migrated to Flores and further inbreeding led to an increase in the allele frequency for the small body size. Having said this, I believe dwarfing hypothesis is supported by the evidence of similar occurence of dwarfing amongst other animals and the fact that ~~when~~ Flores with its limited food source would lead to selection for smaller body size.

The wealth of evidence in physical morphology and fossil evidence suggest a mosaic of ~~features between ancient and more~~ primitive and ~~more~~ relatively more modern features. (cont next page).

(*) Similar dwarfing is seen in H. lorentzis population in H. naledi population where the isolated geography and excessive inbreeding along with limited food led to largely reduced body size.

H. floresiensis has a cranial shape similar to H. erectus with a receding and small forehead with a flat face. This is evidence to support my chosen model as comparative anatomy can provide evidence of ancestry. Given ~~that~~ their similarities in cranial shape, it may be likely that H. floresiensis descended from H. erectus rather than H. habilis. ~~The~~ H. floresiensis possessed a relatively large jaw and teeth also resembling H. erectus. However, its bipedal gait is reminiscence of older hominins such as H. habilis and australopithecines. This could be seen as evidence for ancestry from a more primitive hominin such as H. habilis. However, I think a hominin with such an inefficient gait (flat arch lacks spring mechanism for propulsion, shorter thigh bone) would have been unlikely to disperse a long distance from Africa into Flores. Therefore, I propose that there may have been a reverse evolutionary process where once ~~H. bel~~ H. erectus reached Flores, the lack of selection pressure for bipedal gait (Flores is a tropical Island, less need to cover long distances) led to a the transition into a more primitive gait which resemble primitive hominins. Similarly, the wrist bones could have undergo a similar processes. The fact that H. floresiensis lack features that evolved with ancestors of modern humans at least 800 kya implies that H. floresiensis diverged from the modern human lineage at least 800 kya. ~~However, this can be taken as evidence for both models as modern human lineage only developed at 200 kya~~ Given that H. erectus is ~~seen~~ consensually believed to be ancestor of modern humans, this means that H. floresiensis must have diverged from H. erectus 800 kya. This ~~is consistent~~ coincides with the colonisation of Flores and therefore can support the evidence that ~~H. erectus~~ H. floresiensis evolved from H. erectus.

Other evidence to support the chosen model include cultural evidence. Stone tools were found dating 190 kya to 150 kya including tools similar but smaller than those carved by H. erectus. This is reasonable as H. floresiensis has a smaller hand size, and would have made smaller tools //

relatively complex
& fit their grasp. The use of choppers, radial cores, perforaters with cutting
edges indicate Acheulian tool technology. This ~~does~~ does not suppor
that H. floresiensis evolved from a more primitive hominin which used Oldowan tool
technologies. H. floresiensis is proposed to have existed up to ~~130kya~~ 150kya
due to their tools dating to this age. This means they have coexisted with multiple
Homo species including H. sapiens, ~~or~~ H. neanderthalensis etc. Because of its
must have been
geographical isolation, H. Floresiensis ~~was~~ able to survive until replacement by
H. sapiens occured as proposed by the OoA model. The use of fire in Liang
Bua cave provides evidence of controlled fire use in H. floresiensis. Because
H. erectus has been ~~the species~~ believed to first control fire, this again
supports my chosen model ~~(1)~~ H. floresiensis was also believed to be hunting
small elephants. This would suggest social cooperate behaviour, which
requires communication, forethought and planning. The more ~~complex~~ developed
H. erectus is therefore ~~more fit~~ likelier to be the ancestor of H. Floresiensis

~~(1)~~ Fire was also believed to be used for cooking. If the alternative model is
correct, this implies that H. habilis would have been able to control fire,
had a developed tool technology and complex social behaviours.
However, I do not believe this to be correct, and this I believe H. erectus
is the ancestral ~~population~~ species of H. floresiensis. Compiling all
evidence of biological and cultural evolution, I propose that the larger bodied
H. erectus left Africa during the initial migration. ~~So~~ A subset of the initial
The island habitats
were established on Flores ~~and~~ founder effect and ~~etc~~ HIS, genetic drift
and extensive inbreeding led to dwarfism. And finally, the geographical
we ~~at~~ on a temporal scale
isolation on islands meant H. floresiensis could coexist until it was
replaced with H sapiens geographically.