### 91. NCEA Style Question: Mutation and Evolution (page 123)

1. (a) The CCR5Δ32 mutation is a deletion mutation. The deletion of the 32 base pairs from the DNA causes a reading frame shift and results in a premature stop codon in the mRNA. When the mRNA code is translated to a protein, translation is prematurely ended when the stop codon is encountered. The resulting protein is shorter than the normal protein, and is probably not functional. The mutated protein is not recognised by HIV-1 and, because it cannot not dock with a host T-cell, no HIV infection occurs.

(b) The highest frequencies of the CCR5Δ32 mutation are centred in Europe. The highest rates are found in white-skinned people of European descent in Northern and Western Europe. Prevalence of the CCR5Δ32 mutation decreases in southern and western Europe, and is virtually absent throughout neighbouring Asia and the Middle East. Note the use of Caucasian in the text has been removed since printing. Historically, it referred to people of the Caucasus region (parts of Europe, Africa, and Asia) regardless of skin colour, but came to be associated with white-skinned people and is no longer widely used because of its ambiguity and racial overtones.

In the past, Europe suffered epidemics of plague and smallpox. The plague and smallpox both present strong selection pressures because both resulted in high mortality. Survivors with the mutation (especially those that were young at the time) are likely to have passed on the mutation when they had children of their own. This would increase the frequency of the mutation in the population and would account for its presence in European populations today. The current HIV epidemic may provide a selection pressure for the CCR5Δ32 mutation, because it appears to provide resistance against HIV-1. However, it may not provide as strong a selection pressure as smallpox or the plague because medical intervention for HIV sufferers allows them to lead longer (including reproductive) lives.

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### 92. KEY TERMS AND IDEAS: Processes In Gene Pools (page 124)

1. adaptation (noun) (B), evolution (I), fitness (G), gene pool (E), genetic drift (F), mutation (H), natural selection (D), phenotype (A),variation (C).
2. Mutations are changes in an organism's **DNA** and they are the source of new **alleles** in a population. Most mutations are **harmful** and so are **eliminated** from the population. Inherited beneficial mutations provide an **adaptive advantage** so are retained in the population. Mutations that do not change the amino acid sequence are called **silent** mutations. They are retained in the population but may not be subjected to selection pressures unless the **environmental conditions** change.
3. Genetic drift and natural selection are both capable of changing the genetic makeup of a population but they operate in completely different ways to different effect. Natural selection is the process by which the phenotypes with the highest fitness in the environment become more common with each generation. Natural selection leads to adaptation and constantly tests all phenotypic variants and adjusts the phenotypic norm so the best suited phenotypes survive and reproduce (differential survival of favourable phenotypes). Genetic drift, in contrast, is a random process. Fluctuations in allele frequency in a population as a result of random loss of alleles (genetic drift) are thus unrelated to phenotypic fitness and can affect the fittest or least fit phenotypes. Genetic drift can cause large changes in allele frequencies, especially in small populations, but these are unrelated to fitness and do not result in adaptation.
4. (a) When stabilising selection is operating, fitness is highest for the most common phenotype and there is selection against phenotypes at the extremes of the phenotypic range, e.g. as occurs in human birth weights. Stabilising selection acts to maintain the status quo.

(b) Selection can shift from stabilising to directional if there is an environmental change so that the most common phenotype no longer has the highest fitness. This shifts the phenotypic norm. Directional selection was observed in the UK during the industrial revolution when heavy soot pollution favoured a melanic morph of the *Biston* moth, which had higher fitness in the polluted environment.

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### 93. The Biological Species Concept (page 125)

1. (a) A biological species is a group of organisms that can successfully interbreed to produce fertile offspring and are reproductively isolated from other such groups.
   (b) Some species of the *Canis* family can interbreed to produce fertile hybrids (thus contradicting the species definition).
2. Behavioural (they show no interest in each other).
3. Physical barrier; sea separating Australia from SE Asia.
4. The red wolf is rare and may have difficulty finding another member of its species to mate with.

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### 94. What Are Ring Species? (page 126)

1. A ring species is a connected series of closely related populations, distributed around a geographical barrier. The adjacent populations in the ring can interbreed but those at the extremes of the ring are reproductively isolated.
2. The phenomenon of ring species is interesting to evolutionary biologists because it may show speciation in action. Although true ring species are rare, the concept is useful as it allows researchers to reconstruct how populations diverged from an ancestral species. (The assumption being that geographical distance equates to evolutionary time) It also demonstrates that speciation can occur without complete geographical isolation.
3. The species in the ring represent a cline in variation. At each extreme of the ring, the populations are too different from one another to interbreed.

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### 95. Ring Species: The Greenish Warbler (page 127)

1. The populations of eastern and western greenish warblers have very different songs, neither species recognises the song of the other. They also have morphological differences. The greenish warbler in the west has one light bar across the top of its wing, while the greenish warbler in the east has two.
2. As the greenish warblers spread east and west from the ancestral population, unique characteristics evolved in each subsequent population as a result of different selection pressures in each environment.
3. The greenish warbler appears to be a true example of a ring species and shows the divergence of to populations from an ancestral one. The eastern and western populations of greenish warblers coexist in the same geographical location, but cannot interbreed. This species isolation has arisen because one ancestral population has diverged with geographical distance in response to prevailing selection pressures.

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### 96. Prezygotic Reproductive Isolating Mechanisms (page 128)

1. (a) A RIM is any aspect of a species biology that prevents interbreeding with another species.
   (b) RIMs prevent individuals of one species from successfully interbreeding with individuals of another species, so the gene pool of each is isolated from the other.
2. A prezygotic RIM is a reproductive isolating mechanism that operates before fertilisation.
3. (a) Geographical isolation isolates a species gene pool but the isolation is not part of the species biology.
   (b) Geographic isolation is often the first step in a population becoming reproductively isolated from another (species formation). Once gene flow is prevented (through


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geographical isolation), isolated populations can evolve in response to (differing) selection pressures so that biological mechanisms isolating them will eventually arise.

4. Geographical isolation refers to isolation of a population by a physical barrier such as a mountain range. Ecological isolation refers to isolation as a result of different habitat preferences within the same general geographic region (common in sub-species).
5. (a) Temporal isolation
   (b) Behavioural isolation
   (c) Temporal isolation and probably also gamete and mechanical isolation
   (d) Ecological isolation
   (e) Mechanical (morphological) isolation

## 97. Postzygotic Isolating Mechanisms (page 178)

1. Postzygotic isolating mechanisms are a secondary backup if the first isolating mechanism fails. The majority of species do not interbreed because of prezygotic mechanisms. Postzygotic mechanisms are generally rarer events.
2. (a) Hybrid inviability: If fertilisation occurs, the zygote does not develop (zygote usually fails to divide).
   (b) Hybrid sterility: The hybrid offspring are viable but sterile, so cannot breed themselves. The gene pool of each of the contributing species remains isolated.
   (c) Hybrid breakdown: Although first generation offspring may be fertile, subsequent generations are not, so the persistence of the hybrid is limited.

## 98. Allopatric Speciation (page 132)

1. Sympatric species are closely related species whose distribution overlaps. Allopatric species are species that are geographically separated.
2. Animals may move into new environments to reduce competition for resources or because a new habitat becomes available (loss of geographical barrier or loss of another species freeing up an existing niche).
3. Plants disperse into new environments through producing seeds, which can be carried by wind, water, or animals.
4. Gene flow between the parent population and dispersing population is regular.
5. Cooler periods (glacials) result in a drop in sea level as more water is stored as ice. As the temperature increases, the ice will begin to melt, and sea level will rise. The variation in sea level will depend on how much water is stored and released in response to the temperature change.
6. (a) Physical barriers that could isolate populations include the formation of mountain ranges, the formation of rivers or their change of course, the expansion or formation of desert, the advance of ice sheets, glacial retreat (isolating alpine adapted populations), and sea level rise. On a longer time scale, the formation of seas as a result of continental drift can isolate populations too.
   (b) Emigration will potentially reduce the genetic diversity of both gene pools as alleles 'leave' the population. The population that has dispersed will diverge from the parent population in response to different selection pressures.
7. (a) The selection pressures on an isolated population may be quite different for that of the parent population. The immediate physical environment (e.g. temperature, wind exposure) as well as climatic region (e.g. temperate to tropical) may differ, as will biotic factors, such as competition, predation, and disease. In a different region, the food type and availability is also likely to be different for the two populations. The shift in selection pressures may result in changes in allele frequencies as those best adapted to the new conditions survive to reproduce.
   (b) Some individuals in the isolated population will have allele combinations (and therefore a phenotype) that better suits the unique set of selection pressures at the new location. Over a period of time (generations) certain alleles for a gene will become more common in the gene pool, at the expense of other less suited alleles.
8. Reproductive isolation could develop in geographically isolated populations through the development of prezygotic and then postzygotic barriers to breeding. Prezygotic isolation would probably begin with ecological isolation, e.g. habitat preferences in the isolated population would diverge from the parent population in the new environment. Prezygotic isolating mechanisms that could develop subsequently to prevent successful mating include temporal isolation (e.g. seasonal shifts in the timing of breeding), incompatible behaviours (e.g. different mating rituals), and structural incompatibilities (e.g. incompatible mating apparatus). Gamete mortality (failure of egg and sperm to unite) can also prevent formation of the zygote in individuals that manage to copulate successfully. Once prezygotic isolation is established, post-zygotic mechanisms such as zygote mortality (in which the fertilised egg dies), reduced fertility in the hybrid, or hybrid breakdown (e.g. sterile F2) increase the isolation of the new species and prevent gene flow between it and the parent species.

## 99. Small Flies and Giant Butterflies (page 181)

1. When the original species of drosophilidae arrived on the Hawaiian islands it found many new unoccupied niches into which it expanded, resulting in a extensive adaptive radiation.
2. The fruit flies are of interest because there are so many closely related species within a small area and speciation has been relatively frequent. The flies also have a relatively simple genome, making genetic studies relatively easy.
3. In general the oldest species of flies are found on the oldest islands. As islands appeared out of the sea the flies spread to new environments and diversified, giving rise to newer species.
4. Buttercups living in alpine areas periodically have their habitats reduced and their range restricted during periods of climatic warming. This restricts gene flow and leads to speciation. Periods of cooling allow for the expansion of their range and movement to new environments as well as hybridisation to form new species. Repeated many times, these cycles lead to a large range of species.

## 100. Divergence in Allopatric Populations (page 135)

1. Some butterflies rested on top of boulders, others rested in the grass.
2. Selection pressure on BSBs is the need to maintain operating body temperature at the high altitude (fitness is higher when they can efficiently absorb heat from boulders). Selection pressure on the GSBs is probably predation as these lowland butterflies survive better where they can avoid detection.

## 101. Polyploidy as a Source of Variation (page 136)

1. Polyploidy changes the number of chromosome sets so that the polyploid has a different ploidy from the parent plant. This instantly isolates it genetically from the parent because the chromosomes cannot pair up equally at meiosis.
2. (a) Polyploids show hybrid vigour, growing larger or more vigorously than the parental types.
   (b) Hybrid vigour is a result of increased heterozygosity and reduced frequency of expressed recessive mutations. Gene redundancy also creates opportunities to diversity gene function offering an evolutionary advantage.
3. Autopolyploidy involves a polyploidy event within a species, whereas allopolyploidy involves a polyploidy event in the hybrid offspring of two species.
4. (a) Non-disjunction (failure of chromosomes to separate during cell division) produces a gamete with an extra set of chromosomes. When this gamete joins within another in fertilisation, the zygote will carry more than the diploid number of chromosomes.
   (b) By deliberately inducing non-disjunction, seeds can be produced with more than the usual diploid number of chromosomes. These can be propagated and the plants crossed (if fertile) to produce a new plant variety. This procedure can sometimes be performed to restore fertility


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to a hybrid that is sterile because of incompatibilities in chromosome number.

## 102. Sympatric Speciation (page 138)

1. Sympatric speciation is the formation of a new species from an ancestral or parent species while they both remain in the same geographic region.
2. Instant speciation involves polyploidy (duplication of an entire set of chromosomes. It is rare in animals because it disturbs the sex determining mechanisms and is usually lethal, but more common in plants, which can reproduce vegetatively or self pollinate. Polyploid fertility can be restored later by crossing of two polyploids.
3. Individuals within a population occupying the same (heterogeneous) environment may become genetically and then reproductively isolated if they have microhabitat preferences that keep them away from most of the population. If these individuals always frequent a different microhabitat, they will never mix genetically with the main population and will become reproductively isolated (new species). This has been documented in plant-feeding insects that show host plant preferences.

## 103. Polyploidy and Speciation in *Melicytus* (page 139)

1. Allopolyploidy.
2. Polyploidy in *Melicytus* has resulted in the evolution of new species by instant speciation. *M. flexuosus* is a normal diploid (2N) but *M. alpinus* is a tetraploid (4N). *M. drucei* is a triploid (3N) and most probably arose as a result of a hybridisation event between these two parent species. It is unusual in being a stable triploid and produces viable offspring.
3. In their current distributions, both the parent species *M. flexuosus* and *M. alpinus* occur in the central North Island but not within Egmont National Park so the hybridisation probably occurred when their distributions were wider. The current restricted range of *M. drucei* suggests a single hybridisation event.

## 104. Polyploidy and Domestication of Wheat (page 140)

1.

| Name | Genome | 2N no. |
|---|---|---|
| Wild einkorn | AA | 14 |
| Einkorn | AA | 14 |
| Wild grass | BB | 14 |
| Emmer wheat | AABB | 28 |
| Goat grass | DD | 14 |
| Common wheat | AABBDD | 42 |

2. $F_1$ hybrid vigour refers to the increased size, growth rate, productivity etc. of offspring resulting from a cross between parents from two inbred lines of a species.
3. Both interspecific hybridisation and polyploidy have been important at different times in the evolution of wheat. Interspecific hybridisation produced (initially infertile) hybrids with new properties. Polyploidy provided a means by which these sterile interspecific hybrids could become fertile.
4. (a) Large grain size, high gluten (protein) content, high yield, less tendency for stalks to break, disease resistance, non-shattering heads.
   (b) Each year, farmers would have chosen seed from plants with the most desirable characters(e.g. disease resistance). Over generations, the qualities of the stock would gradually move towards the desired phenotype.
5. Cultivated American cotton would have originated from the interspecific hybridisation of Old World cotton and wild American cotton.
6. Wild plants and ancient breeds possess alleles that may have been lost from inbred lines. The retention of these ancient cultivars provides a gene bank and a buffer of genetic diversity which can be used to improve the inbred cultivars in the future.

## 105. What You Know So Far: Isolation and Speciation (page 142)

Student's own summary.

## 106. NCEA Style Question: Speciation (page 143)

1. Sympatric speciation refers to the divergence of a new species while it remains in the same geographical range as the parent species (sympatric meaning same place). Sympatric speciation differs from allopatric speciation in which parts of a parent population are geographically separated (through geological events or dispersal) and the two populations follow different evolutionary paths in response to differing selection pressures in different environments.

   There are two main mechanisms by which sympatric speciation can occur, 1) through niche differentiation and 2) through polyploidy (instant speciation). Polyploidy is common in plants but is rare in animals because it upsets the sex determining mechanisms. Separation by niche differentiation has been documented in plant-feeding insects, which may show preference for associating only with specific plant types. Niche preference leads to ecological isolation of sub-populations within the same area and eventually leads to the development of other reproductive isolating mechanisms (such as differences in the timing of breeding), which reinforce increasing genetic isolation and result (eventually) in the formation of a new species.

   Sympatric speciation by niche differentiation appears to be the mechanism operating in the orca populations. Each population occupies a different region of the Antarctic waters and targets a specific prey species in preference to others. This isolation of feeding and habitat preferences results in the populations not mixing and has resulted in different hunting behaviours. Studies show that their genetic divergence began about 250,000 years ago, so the populations are now beginning to show genetic distinctiveness. The evidence suggests that the current Antarctic populations of orca are undergoing sympatric speciation by niche differentiation with a necessary assumption being that the environment in which this is occurring is relatively homogeneous.

## 107. KEY TERMS AND IDEAS: Isolation and Speciation (page 144)

1. allopatric speciation (H), ployploidy (E), postzygotic isolating mechanism (A), prezygotic isolating mechanism (G), reproductive isolation (C), speciation (B), species (F), sympatric speciation (D).
2. (a) Cotton: post-zygotic. Mechanism: hybrid breakdown
   (b) Floral parts: pre-zygotic. Mechanism: mechanical (aka structural or morphological).
   (c) Skunks: prezygotic. Mechanism: temporal
   (d) *Rana*: postzygotic. Mechanism: hybrid inviability
3. (a) Gene flow common. Populations A and B interbreed freely.
   (b) Gene flow very reduced. Subspecies A and B interbreed infrequently and reproductive isolating mechanisms are becoming established, e.g. differences in behaviour or timing of reproductive activity.
   (c) Gene flow stopped. Species A and B do not interbreed and are reproductively isolated through the evolution of several reinforcing reproductive isolating mechanisms (temporal, behavioural, mechanical).

## 108. Divergent Evolution (page 145)

1. (a) Divergent evolution is the accumulation of differences between initially similar lineages so that new species arise from a common ancestor.
   (b) Geographic isolation.
2. The North and South Island saddlebacks are very closely related. They were once widespread throughout New Zealand but mammalian predators introduced during European


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settlement reduced their range and distribution to small isolated remnants in the north and south. Their restriction to small non-overlapping ranges has contributed to their genetic isolation and divergence into separate species.

**Teacher's note**: The saddlebacks are very closely related and have only recently been recognised as having separate species status. Their divergence into South and North Island populations probably began with the formation of Cook Strait in the later tertiary (as with North and South Island kaka) although the evolutionary history of the taxon is poorly known. The decimation of both North and South Island populations to small genetically impoverished remnants on offshore islands in the north (Hen Is.) and south (Big South Cape Is.) and their current non-overlapping ranges have contributed to their continued divergence.

## 109. Convergent Evolution (page 146)

1. (a) Streamlined body shape to reduce drag in the viscous, aquatic environment.
   (b) Forelimbs developed into flippers for efficient propulsion through the water, as well as control and manoeuvrability.
2. (a) Need for speed to catch fish and avoid predators.
   (b) Need for manoeuvrability (quick turns) for the same reasons as above.
3. The similarities are due to convergence rather than common ancestry. The taxa in different regions have evolved from common ancestors locally and have undergone their own evolution in response to local similar selection pressures.
4. (b) **Flying phalanger / flying squirrel**
   Adaptations: Both have similar body size and shape. Skin stretched between forelimbs and hind limbs to enable gliding between trees. Both eat insects and some plants.
   Selection pressures: Predator avoidance on the ground as well as an energy efficient means of travelling between trees in search of food resources.
   (c) **Marsupial mole / mole**
   Adaptations: Reduced vision, streamlined body shape, powerful forelimbs with effective shovel-like claws for digging through soft soil. Both eat insects.
   Selection pressures: Digging into earth and moving through small borrows underground.
   (d) **Marsupial mouse / mouse**
   Adaptations: Small size, agile climbers inhabiting low shrubs in dense ground cover. Active at night.
   Selection pressures: Predator avoidance (nocturnal habit) and ability to exploit food resources on bushes capable of taking only a little weight.
   (e) **Tasmanian wolf (tiger) / wolf**
   Adaptations: Strong skull and associated musculature, with canine and carnassial teeth adapted for shearing and tearing meat. The limb bones are long and slender, suitable for running.
   Selection pressures: Catching, killing, and dismembering prey. Ability to pursue prey over distance with rapid bursts of speed for prey capture.
   (f) **Bandicoot / rabbit**
   Adaptations: While the rabbit is a vegetarian, the long-eared bandicoots are varied in their diet. Some are plant eaters while others eat insects. Both have long ears for hearing potential danger signals, and long hind legs adapted for a hopping form of locomotion.
   Selection pressures: Predator avoidance: detecting the approach of danger and then escaping.

## 110. Coevolution (page 148)

1. (a) Coevolution is a reciprocal evolutionary change in species with a close ecological relationship (genetic change in one population is met with genetic change in the other). Examples include predator-prey and parasite-host relationships and mutualistic relationships such as those between flowering plants and their pollinators.
   (b) Coevolution occurs because each party involved exerts selection pressures on the other. The species involved adapt (through natural selection) in response to those selection pressures so that over time they evolve a relationship that frequently involves mutual dependency.
2. Flowers advertising the presence of nectar and pollen have evolved to attract insect pollinators. This includes colour, scent, shape and arrangement. Even the time of day of flower opening can coincide with the activity of a desirable pollinator. Some flowers reflect UV and act as nectar guides to guide the pollinator to the nectary.
3. A parasite evolves to exploit its host but it also depends on the host for survival so it cannot kill the host (at least not most of the time). Killing the host would jeopardise its own survival as a species and constrains how exploitative it can be.
4. (a) The beech mistletoe and the bellbirds both benefit from the relationship. The bellbird obtains nectar and the mistletoe has its flowers pollinated.
   (b) If tui and bellbird numbers were much reduced (e.g. by predation) the mistletoe would lack efficient pollinators and many of its flowers would not be pollinated. This would markedly reduce its reproductive success and long term survival as a species (i.e. it could become extinct). Unlike the birds, which can feed on other flowers, the mistletoe's mutualism with its bird pollinators is obligate. It cannot survive without them.
5. (a) Exploitation (herbivory)
   (b) The selection pressures on the monarch are associated with avoiding the toxic effects of the milkweed. The selection pressures on the milkweed are associated with limiting browse damage. The relationship is a coevolution because the milkweed and monarch have a close ecological relationship in which each party is responding to selection pressures imposed by the other.

## 111. Adaptive Radiation in Mammals (page 150)

1. Adaptive radiation involves a rapid increase in diversity and morphological change within a lineage. With the extinction of the dinosaurs, many niches were made vacant, providing the opportunity for mammals to diversify rapidly to occupy these niches. **Note**: The mammals share a distant common ancestor 195 mya; long before their main period of adaptive radiation. For a long period of their evolutionary history, there was very little diversification, with the exception of the early divergence of the marsupials.
2. Common ancestors (ancestral forms also acceptable).
3. A divergence occurred (one group of early mammals split into two lines: marsupials and placentals).
4. They were ancestral to many other mammal orders.
5. Rodents and odd-toed ungulates (widest grey shape which indicates the largest number of species).
6. Evolutionary lines that became extinct (dead ends).
7. Palaeocene
8. Rodents have a generalised morphology and are highly adaptable, which contributed to their successful diversification into many niches. They have diversified to occupy a very wide range of niches (habitats and lifestyles) including tree-dwelling (e.g. squirrels), underground colonial groups (e.g prairie dogs), desert-dwelling (mice, kangaroo rats), aquatic and semi-aquatic (e.g. capybaras, beavers, rats), and opportunists in heavily modified human occupied areas (rats, mice).

## 112. Divergent Evolution in Ratites (page 152)

1. (a) Flightlessness (wings very reduced in size), flat breastbone, primitive palate.
   (b) Based on new mtDNA evidence, tinamous are the closest relatives to moa.
2. (a) Anatomical change: Reduction in wing size.
   Selection pressure: Advantages gained by putting energy into developing other parts of the body, rather than into a structure (wing) that is not used.
   (b) Anatomical change: Larger, stronger legs.
   Selection pressure: A need to improve the strength of the legs for locomotion after losing the ability to fly. Legs would have been used both for escape and as weapons to repel predators.


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