Department of
Education

GOVERNMENT OF
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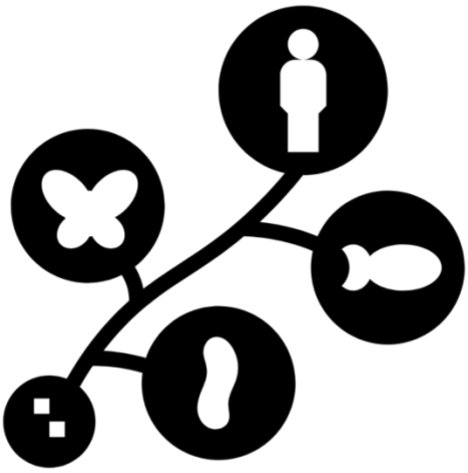
ATAR Year 12 Biology

Unit 3: Mechanisms of Evolution



ATAR YEAR 12 Biology
UNIT 3

Topic: Mechanisms of Evolution

This package focusses on the syllabus point of Continuity of life on Earth. It includes an outline, activities and exam questions based on:

1. Evolution and Natural Selection
2. Speciation: new species from old
3. Change or extinction
4. Selection pressures that lead to extinction

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Syllabus Points covered in this package

Source: School Curriculum and Standards Authority, Biology ATAR Course, Year 12 Syllabus
https://senior-secondary.scsa.wa.edu.au/__data/assets/pdf_file/0006/10410/Biology-Y12-Syllabus-AC-ATAR.pdf

Continuity of life on Earth

- mutation is the ultimate source of genetic variation as it introduces new alleles into a population
- natural selection occurs when selection pressures in the environment confer a selective advantage on a specific phenotype to enhance its survival and reproduction; this results in changes in allele frequency in the gene pool of a population
- in addition to environmental selection pressures, sexual selection, mutation, gene flow and genetic drift can contribute to changes in allele frequency in a population gene pool
- speciation and macro-evolutionary changes result from an accumulation of micro-evolutionary changes over time
- selective breeding (artificial selection) through the intentional reproduction of individuals with desirable characteristics results in changes in allele frequencies in the gene pools over time
- differing selection pressures between geographically isolated populations may lead to allopatric speciation
- populations with reduced genetic diversity face increased risk of extinction

Science as a Human Endeavour

- conservation planning to maintain viable gene pools includes consideration of
  - biogeography
  - reproductive behaviour
  - population dynamics

Workbook: Evolution and Natural selection
This section of the package looks at Evolution and Natural Selection. Read the summary notes carefully. Once you have read the notes, complete the activities. You will find answers to the activities at the end of this package.

Evolution and Natural Selection

Evolution means the slow and gradual change of life over time. The cause or driving force of this change is considered to be a process called natural selection. In 1858, two scientists working independently, put forward similar theories of evolution by natural selection. The two scientists were Charles Darwin and Alfred Russel Wallace.
Evolution through natural selection is based on the idea that the most desirable characteristics of a species are favoured. Individuals with these characteristics tend to survive and pass them on to the next generation. Desirable characteristics are those that are advantageous when competing for a mate, food and shelter and increase the chance of survival.
The theory of evolution by natural selection is based on four observations:

- Variation
- Competition
- Survival of the fittest
- Adaptation

1. Variation
Variation exists within the same species. Individuals may vary in size; colour; camouflage; the ability to escape from predators and resist disease. Darwin did not explain the origin of these variations, but we now know that genes or groups of genes determine which characteristics individuals have.
Variation can be introduced into a population in the following ways.

a) Independent assortment of chromosomes during meiosis
When homologous chromosomes, one from each parent, pair up along the equator of the cell during metaphase 1 of meiosis, the arrangement is determined by chance. New combinations of genes are formed depending on the way the chromosome pairs line up. For example, all the maternal chromosomes may be on one side of the equator and all the paternal chromosomes on the other side, or any combination in between. Independent assortment is also known as random alignment.

b) Crossing over during meiosis
Crossing over involves homologous chromosome exchanging pieces during prophase 1 of meiosis. This allows an exchange of genetic material from the mother and father to take place and results in a new combination of genes in some of the haploid cells (gametes) produced by meiosis.

c) Random mating and random fusion of gametes

Random mating involves individuals pairing by chance, not according to their genotypes or phenotypes. Random mating is a source of variation in a population.

Fertilisation is a random process and ensures a different combination of genes each time, depending on which male gametes combine with the egg. There is a mixing of genetic information as gametes from the male and female parents unite to form the fertilised egg cell known as the zygote.

d) Mutation

A sudden, permanent change in a gene (gene mutation) or chromosome (chromosome mutation) may introduce variation (new alleles) to a population. If a mutation occurs in a gamete, it may be passed on to the offspring. Most mutations are disadvantageous and result in death. However, some mutations result in traits that are advantageous and individuals with these traits are most likely to survive.

2. Competition

Darwin's theory of natural selection is based on the idea that life is an ongoing struggle for survival, and that organisms compete for resources such as food, water, mates, light and space. Within and between species there is a constant struggle for existence where individuals who do not compete successfully have less chance of surviving to maturity and passing on their genes.

3. 'Survival of the fittest'

'Fitness' is taken to represent reproductive success and relates to the survival of individuals within a species. In any species, variation exists and since resources are limited, competition also exists. Individuals who compete successfully for resources are more likely to survive and pass on their favourable characteristics to their offspring.

4. Adaptation

Adaptations are those characteristics which best suit the individual to its environment. Those organisms with adaptations which enable them to survive will reproduce and pass on their favourable characteristics or adaptations to the next generation. Those with unfavourable characteristics usually die before reaching reproductive maturity.

Gradually over a number of generations, the frequency of these favourable characteristics in the population will increase so the population itself becomes better suited or adapted to its environment.

For example, a population of snails may vary in shell colour. If a certain variation, such as a darker shell, offers an advantage in a particular environment, it will be selected for and is likely to increase in frequency over subsequent generations.

Summary

Natural selection is considered to be the mechanism by which evolutionary change has occurred. Evolution through natural selection results in specific adaptations that enable a species to suit its environment.

- Genetic variation exists within a population.
- Certain genotypes improve an individual's chance of survival.
- Individuals with favourable adaptations have more surviving offspring.
- Individuals with favourable adaptations increase in frequency in the population.
- Individuals with unfavourable adaptations decrease in frequency in the population.

Galapagos Island finches

Darwin noted differences in finch populations on the Galapagos Islands and realised that they were an example of natural selection based on beak shape and the ability to obtain food.

Darwin suggested that:

- the original founder population of finches showed variation in beak shape
- separate populations (gene pools) were established
- characteristics offering an advantage were selected.

Finches with long, narrow beaks would be at an advantage in rocky areas as they could reach seeds and insects found in crevices. Finches with short, strong beaks would be able to crack harder seed cases or eat the tough cactus found further inland. Altogether 13 different, but closely related, species of finch were recorded as having probably derived from an original group.

Selection pressures

Selection pressures are environmental factors which may reduce reproductive success in a population and thus contribute to evolutionary change or extinction through the process of natural selection.

Examples of selection pressures include:

- competition
- predation
- disease
- parasitism
- land clearance
- climate change
- pollutants.

A well-known example of a selective pressure is the long legs and long neck of the giraffe. As food sources became depleted, or subject to intense competition in the giraffe's environment, selection pressures favoured those individuals in the population with longer legs and longer necks. These taller varieties could reach the higher foliage, and would be more likely to survive any struggle for existence and pass on their characteristics to the next generation.

The following two activities should help you understand more about selective pressures and the 'struggle for existence' concept.

Activities: Evolution and Natural Selection

ACTIVITY 1: A tea-tree population (struggle for existence)

The data below refers to a study of a population of tea-tree plants (*Leptospermum laevigatum)* on coastal sand hills. The population was destroyed during a bushfire. A month later, and after it had rained, a large number of tea-tree seedlings emerged. A series of one-metre plots were marked out and the tea-tree seedlings counted. The average number of seedlings per square metre was calculated. This process was repeated and the information recorded as follows.

Time after fire	Average number per m^2
1 month	1281.0
1 year	1087.2
5 years	576.8
10 years	240.8
20 years	43.2
30 years	8.6
40 years	2.1

Step 1: Graph the data on graph paper provided.

Step 2: Answer the following questions.

1. What happened to the number of plants in the area over the study period?
2. During the study, no subsequent bushfires occurred in the area and the number of plants removed by consumer organisms was insignificant. There was no evidence of grazing. Propose two hypotheses to account for your answer.
3. Does there appear to be a 'struggle for survival' between members of the species? Explain your answer.
4. Can you suggest any reasons why some individuals survived longer than others?

ACTIVITY 2: The peppered moth (natural selection in action)

The effects of human activity have produced strong selective pressures on some organisms. One well-known example is Kettlewell's study of the peppered moth (*Biston betularia).* The light-coloured variety of the peppered moth was common in England during the early 19th century, just before the Industrial Revolution. The Industrial Revolution produced large amounts of soot which settled on the countryside around industrial towns, killing the light-coloured lichen that grew on the trees. Then, in 1848 the first report on a new variety of the peppered moth was published. This variety was darker and almost invisible when resting on a dark background. Within 50 years, the light variety was almost completely replaced by the dark variety. Following the Clean Air Act (1956–1964), the dark variety declined in frequency and is now extremely rare. Classic experiments by Kettlewell during the 1950s suggested selective pressures were operating on the peppered moth.

Use the information above and other resources to answer the following questions.
1. Suggest the selective pressures that could account for the changes in frequency between the two varieties of the peppered moth.
2. Is it likely that the darker moths existed before the Industrial Revolution? Explain your answer.
3. Define the term 'natural selection'.
4. Briefly explain why Kettlewell's work is considered to be a classical demonstration of natural selection in action.

Workbook: Speciation – new species from old

This section of the package looks at Speciation: new species from old. Read the summary notes carefully. Once you have read the notes, complete the activities. You will find answers to the activities at the end of this package.

Speciation: New species from old

To further understand the evolutionary concept, we need to look at the process of speciation. So far we have considered natural selection as the process by which populations change. We also know that these adaptations are inherited. If the adaptations offer some advantage, the genes responsible will tend to increase in frequency over subsequent generations. While this process may result in a large amount of variation within and between populations, the species itself has not changed.

How do we get new species from old?

Species change over time; however, it is important to realise that change is not at the level of the individual but at the level of the population. An individual cannot evolve but a population can.

Variation in a population can lead to the evolution of a new species through natural selection. To understand this idea fully, you will need a good understanding of the following terms: species, population, gene pool, allele frequency, gene flow.

A population is a group of organisms of the same species living together in a particular place and time. The sum total of all the genes present in a population comprises the gene pool for that population.

How often a particular gene occurs in a particular population is known as the allele frequency. The process of speciation can be considered in the following four stages.

1. **Variation**

Variation exists between individuals within a population. The population shares a common gene pool. However, some variations within the population are better suited to the present environment than others.

2. Isolation

The range of a large population may expand over a wide geographical area. Some part of the population may become isolated from the rest due to the formation of physical barriers, such as mountain ranges or rising sea levels. Mating and migration between the two populations is no longer possible and the transfer of alleles of genes from one population to another (gene flow) is prevented.

Barriers to gene flow include the following:

- geographical
- ecological
- behavioural
- structural.

Geographical barriers to gene flow include mountain ranges, deserts and large bodies of water. For example, the southern cassowary in Queensland is geographically isolated from the cassowary populations found in New Guinea.

Ecological barriers to gene flow occur when populations occupy different habitats. For example, certain types of mosquito mate only in stagnant water while others mate only in running water.

Behavioural barriers to gene flow occur when populations demonstrate behavioural differences toward each other. For example, populations of tree frogs may overlap but the mating call of the male frogs in one population may be distinctly different from the mating call of the male frogs in another population. This behavioural difference keeps the two populations of frogs reproductively isolated.

Structural barriers to gene flow, such as non-complementary female and male genitalia, make breeding physically impossible. For example, insects have a lock-and-key arrangement of their copulatory organs which is species specific.

3. Selection

The isolated population may experience different selection pressures from the original population. Some variations within the isolated population are better suited to the 'new' environment than others. This will result in a change in allele frequency over several generations as the favoured traits are selected for.

4. Speciation

If individuals from one population are unable to breed successfully with individuals from another population due to geographical isolation, and are subjected to different selection pressures, a separate species may evolve over time.
Remember that a species is defined as a group of individuals which is able to interbreed and produce fertile offspring.

The Galapagos Island finches observed by Darwin provide a good example of speciation. The different varieties of finch were isolated for long enough to eventually became so different that they could no longer interbreed to produce viable offspring, ie speciation.
Closely related species that remain geographically isolated and become genetically separated are known as **allopatric species.**

Changes in Allele Frequencies

Changes in allele frequency can be caused by:

1. Natural Selection

Natural Selection is the process which leads the differential survival and reproduction of organisms which are better suited to their environment. It results in those better suited individuals contributing proportionally more offspring to subsequent generations. It is important to realise that variation must already be present in the population. An adaptive characteristic will not suddenly be generated in response to an environmental change. If the environment changes or the population moves into a new environment, the population will need to adapt to the changes in order to survive. An existing variation that offers a survival advantage will be selected for. This will result in changes in allele frequency.

If the allele frequency changes with time, we know that evolution is taking place.
Within a gene pool we can consider how common or how rare some of the genes are. The number of times a certain gene occurs in a particular population is known as the allele frequency. For example, in a study of the frequency of the alleles for the ABO blood group system, a given population may have approximately:

- 42% group A
- 9% group B
- 3% group AB
- 46% group O.

For that population, we can say that the frequency of the A allele and the O allele is high, while the frequency of allele B is low. The ABO frequencies for other populations may be quite different.

The activity below will help you to understand that, over several generations, natural selection may act to bring a change in the allele frequencies of a gene pool. Alleles in the gene pool can be dominant or recessive. Alleles will increase in frequency in the population if they offer a survival and reproductive advantage, so it is possible for recessive alleles to have a high frequency in the population and it is possible for dominant alleles to have a low frequency in the population. Many students confuse these terms, so make sure you understand the difference between a dominant allele and one that has a high frequency in the population.

2. Sexual Selection

Sexual selection is the development of traits in either or both sexes of a species which is due to competition for mates. It is a form of natural selection that affects an individual’s ability to mate. In some species, males compete for mates and the winners tend to do most of the mating. An existing variation that offers a competition advantage will be selected for. This will result in changes in allele frequency. For example, antler size in male deer and antelopes.

3. Genetic Drift

Genetic drift is the random change in the allele frequency in the gene pool which occurs in small populations purely by chance. It has nothing to do with natural selection. We have determined that change in the allele frequencies of a gene pool may occur as a result of natural selection acting on a population. If a population is large enough, the allele frequency will remain constant from one generation to another. For example, predation would not alter the allele frequency of a population of a million snails as much as a small population of snails, as modelled in the changes in gene pool activity. In a small population, such as an isolated population, there is often a change in allele frequency from one generation to another due to chance fluctuations.

Two examples of genetic drift in a small population are the founder effect and bottlenecks:

a. The founder effect

Occasionally a smaller population may branch off from a larger one and become reproductively isolated. The smaller population may or may not be genetically representative of the original population. Some rare alleles may be over-represented or lost completely while previously common alleles may be under-represented in the new population. As a result of the founder effect, even if the new population increases in size, it will have a different gene pool (due to a different allele frequency) from the original population.

For example, macaroni penguins *(Eudyptes chrysolophus)* populate many Antarctic islands. Most of these birds are black-faced; however, a few white-faced varieties are found in some populations. In fact, on one island the population consists of only white-faced varieties. The 'founding' population for this island contains either all or mostly white-faced varieties. It is assumed that the frequency of white and black faces in the founder population for that island was unrepresentative of the original population, which consists mostly of the black-faced variety.

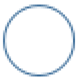
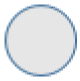
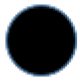
b. Bottlenecks

Population bottlenecks occur when only a small sample of the total gene pool of a species survives. These situations may arise if a population is drastically reduced by non-selective events such as rising sea levels or <u>habitat destruction</u> caused by human activity. <u>Endangered</u> species are often subject to population bottlenecks. For example, the lack of genetic diversity in the small number of Wollemi Pine (*Wollemia nobilis*) left in the wild indicates that this plant went through a population bottleneck.

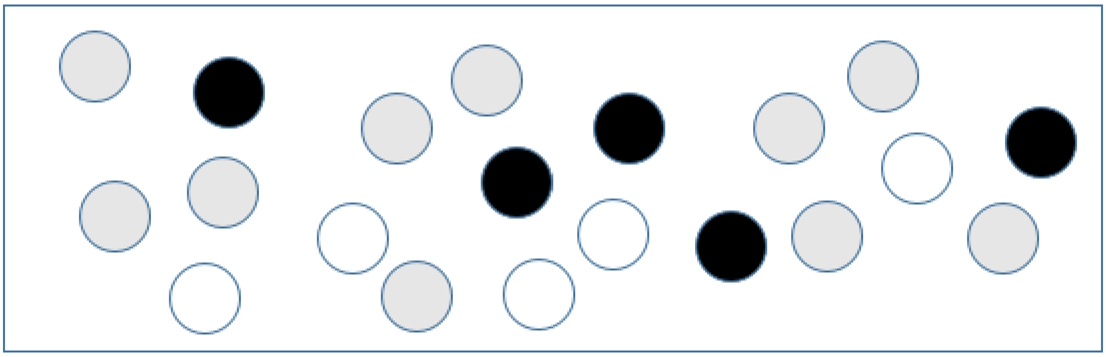
Activities: Speciation – new species from old

Activity 3: Natural Selection – snail population

A population of a snail species has three varieties of shell colour as shown below.

symbol			
Phenotype	Light shell	Pale shell	Dark shell
Genotype	bb	Bb	BB

A. The gene pool for the snail population at a given time is shown below.



For this population, calculate the frequencies of the allele types (B or b) and allele combinations (BB, Bb, bb) by counting the actual numbers, then converting them into a percentage.

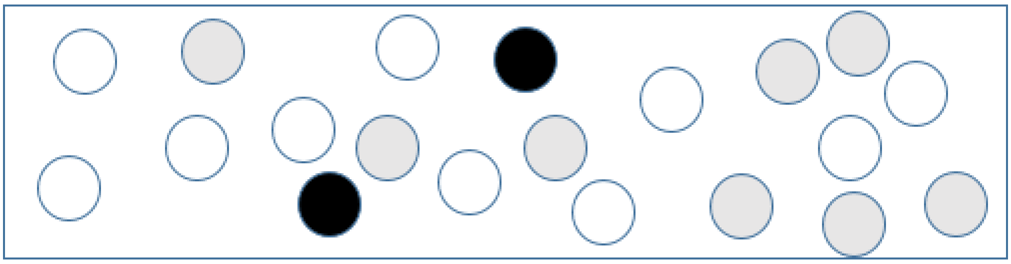
For example, 10 pale (Bb) shelled snails in a population of 20 would have an allele combination percentage frequency of $\frac{10}{20}$ x 100 = 50%.

- Count the numbers of allele types B and b, and the number of allele combinations BB, Bb, bb.
- Calculate the percentage frequency for allele types (B or b) and allele combinations (BB, Bb, bb).

Record your figures in the table below then check your answers.

Gene pool before predation		**count**	**% frequency**
Allele types	B		
	b		
Allele combinations	BB		
	Bb	10	50
	bb		

B. Predatory birds find the dark-shelled snails easy pickings.
Sometime later, in the same gene pool of the snail population, there was a change in allele frequencies due to predation. For the model below, assume that the population numbers are unchanged as births have replaced deaths.



- Count the numbers of allele types B and b and the number of allele combinations BB, Bb, bb.
- Calculate the percentage frequency for allele types (B or b) and allele combinations (BB, Bb, bb).

Record your figures in the table below then check your answers.

Gene pool after predation		**count**	**% frequency**
Allele types	B		
	b		
Allele combinations	BB		
	Bb	10	50
	bb		

Questions:

Answer the following questions, based on your work above:

1. Compare the allele frequency in the gene pool before predation and the gene pool after predation. What do you notice?
2. Compare the frequency of the allele combinations in the gene pool before and after predation. What do you notice?
3. Are the changes to allele types and allele combinations what you expected? Explain.
4. Other than predation, suggest ways the snail population may lose or gain alleles.

ACTIVITY 4: Natural selection – cockatoo example

There are two subspecies of the white-tailed black cockatoo: the short-billed variety or Carnaby's cockatoo (*Calyptorhynchus latirostris*) and the long-billed variety or Baudin's cockatoo (*Calyptorhynchus baudinii*). The short-billed cockatoos, unlike the long-billed variety, usually feed on 'softer' seeds such as those from banksias, grevilleas, hakeas and dryandras. The fine-pointed bill of the long-billed cockatoo enables it to prise seeds from hard, wooden fruits such as marri.

Answer the questions:

1. Explain how the two varieties of cockatoo are able to co-exist throughout the same region.
2. What would be the effect on each variety in the region inhabited by the cockatoos if the marri trees were to be destroyed?
3. What would be the effect on each variety in the region inhabited by the cockatoos if the banksia trees were to be destroyed? Explain.

ACTIVITY 5: Genetic drift

Research has shown that snakes have been preying on cane toads for over 70 years and that the snakes often die from having consumed the cane toads' toxins. However, the snakes with small heads can swallow only small toads. As a result, they consume less toxin than the large snakes and manage to survive.

Crows appear to have 'learned' how to attack and eat cane toads without coming to any harm, and to be 'passing' this information on to other crows. The birds have learned to roll the cane toads onto their backs, thereby avoiding the poisonous glands on the toad's back. Other birds, including kites and ibis, have been observed using similar techniques.

Answer the questions:

1. Are the variations in snakes and the behaviour of the crows examples of natural selection in action? Explain your answer.
2. While cane toads are evolving rapidly and spreading across Australia, they are also suffering for their increased speed with painful arthritis. Using the cane toad (*Bufo marinus*) as an example, briefly discuss the advantages and disadvantages of 'rapid evolution'.

Workbook: Change or Extinction

This section of the package looks at Change or Extinction. Read the summary notes carefully. Once you have read the notes, complete the activities. You will find answers to the activities at the end of this package.

Change or Extinction

Populations with reduced genetic diversity face increased risk of extinction.

Variation

A lack of variation in a population can explain a rapid decline in population size and even lead to extinction. The Tasmanian devil, found only in the wild of Tasmania, could be facing extinction due to a rare, contagious cancer which has killed 70% of the Tasmanian devils. Without resistant individuals in the population the survival of the Tasmanian devil population is unlikely. If a population cannot adapt to a changing environment it faces extinction.

Change

A species that is very diverse will have a better chance of survival. The range of genes within a breeding population of a species must vary enough to allow adaptation to a changing environment. If a species cannot adapt to a changing environment, it is likely to become extinct. Examples of species under threat of extinction include the woylie (*Bettongia penicillata*) and the numbat (*Myrmecobius fasciatus)*.

Extinction

Selection pressures can become so great that species become extinct.
A species is classed as extinct when there is no reasonable doubt that the last individual has died. The best-known animal example in the world is probably the dodo while in Australia, it is the Tasmanian tiger or Tasmanian wolf (thylacine).

Factors within a species can cause extinction

As well as external factors such as habitat destruction, there are also factors within a species that are likely to increase its chances of extinction. These include:

- A specialised life style
- Small population size
- Restricted distribution
- Exist in a rapidly changing habitat
- Limited genetic variability
- Long time to reach reproductive age
- Low numbers of offspring produced.

Activities: Change or Extinction

ACTIVITY 6: Change or extinction

Visit the Western Australian Museum website and answer the questions that follow:
https://australianmuseum.net.au/learn/australia-over-time/extinct-animals/the-thylacine/
(Accessed 30/3/20)

1. When did the thylacine become extinct?
2. Why did it become extinct?

Workbook: Selection pressures that lead to extinction

This section of the package looks at Selection pressures that lead to extinction. Read the summary notes carefully. Once you have read the notes, complete the activities. You will find answers to the activities at the end of this package.

Selection pressures that lead to extinction

The extinction of plants and animals is not a new occurrence. It has been a natural part of evolution and may be caused by natural disasters such as disease or drought. The most spectacular extinction on Earth was the sudden disappearance of dinosaurs where a combination of over-specialisation and natural disasters may have been contributing factors. In recent times, human activity and a rapidly changing environment have contributed to the extinction of many species of plants and animals. This rate of extinction is considered to be well above the rate of natural extinction. For example, at least 50 bird and mammal species and more than 60 plant species have become extinct since European settlement in Australia.

In just 200 years, 18 species of endemic mammals have become extinct (7% of the total in Australia). About 100 species of plants (0.8% of the total) have become extinct. Of the plant species presumed extinct in Western Australia (1.4% of the state's flora), most occurred in the agricultural region of the South-West. This data compares unfavourably with the rest of the world's plant extinction rates with only 27 extinct species in Europe (0.2% of the total), 39 in Africa (0.2% of the total) and 74 in the USA (0.4% of the total).

There are many factors that can influence the status of a plant or animal. Some of these include the gathering of animals for trade, climate change and introduced species. However, the major cause for concern is habitat destruction.

1. Habitat destruction

Since European settlement, Australian ecosystems have changed at an unprecedented rate. In the last 200 years, 90% of temperate woodlands and 50% of rainforests have been cleared. Over 50% of agricultural land needs to be restored because of the damaging effects of salinity and soil erosion. Once a species becomes vulnerable, almost any level of environmental change or disturbance may affect its status.

Examples of environmental changes or disturbance include:

- a reduction in suitable shelter
- a reduction in suitable breeding sites
- a reduction in food supply
- an increase in predators
- competition
- unpredictable events such as fires, floods, disease and droughts which can also pose a serious threat to survival in the wild.

Habitat destruction can lead to the fragmentation of an ecosystem. Without the provision of bush corridors – links between ecosystems – populations of vulnerable species may become small and isolated. Small populations are unable to maintain the genetic diversity that characterises the large populations essential to the long-term survival of a species.

2. Artificial selection

Human activity has contributed to the extinction of many species of plants and animals. However, due to artificial selection, many species of plants and animals have been maintained and their ‘useful’ features or characteristics have been selected for and improved upon. The purpose of artificial selection, also known as selective breeding, is to enhance certain traits of an original ‘wild’ type through a controlled breeding program. However, the artificial selection of many species of plants and animals can also result in the loss of genetic diversity if the original source is not maintained. Breeders of plants and animals strive to produce organisms that will possess desirable characteristics such as high crop yields, resistance to disease, high growth rates and beneficial structural features.

Sexual reproduction generates variation within a species and this knowledge has been used in the selective breeding of crop and garden plants, domesticated animals and in the captive animal breeding programs managed by conservation groups and zoological societies. Captive animal breeding programs came too late for species such as the Tasmanian tiger/wolf. Once a plant with the combination of alleles for a desired phenotype is produced, it can be propagated asexually by taking cuttings, grafting and encouraging runners or through layering.

a. **Artificial selection in animals**

An example of artificial selection in animals is the domestic dog (*Canis familiaris*). All breeds of dog are considered to have originated from a common ancestor, the grey wolf (*Canis lupus)*. Dog breeders artificially select certain traits such as the ridge on the Rhodesian ridgeback or the squashed face of a pug. They then use inbreeding as the mechanism to increase the frequency of these traits in the dog population. While these traits are desirable for the dog breeder, many are detrimental to the dog.

The limited gene pool caused by continued inbreeding means that undesirable genes, already present in the population, increase in frequency and are expressed more often in the phenotype. Undesirable characteristics may include misaligned jaws or other serious conditions. For example, studies of epilepsy in Alsatians have revealed a genetic basis for the condition as a result of inbreeding. Pigeons and cats are also well-known examples of the practical use of artificial selection to produce exotic breeds.

b. Artificial selection in plants

Humans promote the growth and proliferation of the selected variety eg seedless grapes and wild mustard (*Brassica oleracea*). Artificial selection has led to the development of vegetables such as the brussels sprout, cabbage, cauliflower and broccoli. Each of these vegetables has been developed from only one original species: the mustard plant, which is the common ancestor or 'wild' type. The vegetables have been selectively bred to enhance certain traits of the original 'wild' type.

Activities: Selection pressures that lead to extinction

ACTIVITY 7: Artificial selection

Use the internet to help answer these questions:

1. Pedigree dogs suffer from genetic diseases as a result of inbreeding. Some examples include Cavalier King Charles Spaniels with brains too big for their skulls (syringomyelia), and boxers and other breeds with epilepsy. Dog Breeders artificially select certain traits in dogs which may be desirable for the dog breeder but are often detrimental to the dog. Define artificial selection, name the mechanism used by the dog breeders to increase the frequency of these traits in the population and describe one example of artificial selection which is detrimental to the dog.

2. A plant example of artificial selection is the mustard plant (*Brassica oleracea*). Complete the table below by identifying which structure of the wild type mustard plant phenotype would have been selectively enhanced to produce the varieties listed.

Variety	Structure of wild type
brussel sprout	
cauliflower	
cabbage	
broccoli	

3. Dairy cows are continually bred to increase milk yields. Individual milk yields are recorded and selected cows are crossed with bulls produced from a high-milk yield parent. Low-yielding cows are mated with beef bulls and their offspring are usually fattened to produce beef. Would you describe the desire to increase milk yield as a form of culling? Explain your answer.

4. Does natural selection involve culling? Explain.

5. How did Darwin explain the differences between domesticated breeds of plants and animals?

6. From your knowledge of genetics and using a named example you have studied or researched, briefly describe how the process of selective breeding operates.

7. Selective breeding has increased the efficiency of domesticated plants and animals, however, there are some disadvantages.
   a) Discuss the short-term and long-term disadvantages to a species, as caused by selective breeding.
   b) How might these disadvantages be reduced or prevented?

8. The advantage of plant propagation by asexual reproduction is that many plants with the same characteristics can be produced and grown at the same time.

9. Briefly describe the disadvantages of plant propagation by asexual reproduction. Compare asexual and sexual reproduction.

Textbook and Study Guide reference:

1. Read Chapter 7, pages 184-202 of:
   Nelson Biology Units 3 & 4 for the Australian Curriculum (Student Book)
   By Pam Borger, Tony Chiovitti, Jacinta Duncan, Wayne Gerdtz, Patrick-Jean Guay, Genevieve Martin, Katrina Walker, Jim Woolnough, Jane Wright, Sarah Jones | Copyright Year: 2015 | ISBN-13: 9780170243254
   Published:26/03/2015

2. Complete sections 2.2 and 2.3 of:
   Year 12 ATAR Course Study Guide – Biology
   ISBN: 9781876918699 Publisher: Academic Associates

Past WACE exam questions

This section includes a compilation of past WACE exam questions on the Unit 3 topic of Mechanisms of Evolution. Use your notes to work through the questions and/or try to answer them under timed conditions.

Question 31 Source: School Curriculum and Standards Authority, Biology 2019 ATAR Examination
https://senior-secondary.scsa.wa.edu.au/__data/assets/pdf_file/0020/592103/2019_BLY_Written_Examination_Web_Versions.PDF
Date retrieved: 01/04/2020

Question 31

Dung beetles are a type of insect and feed on animal faeces. A recent survey identified over 500 species of dung beetle that are native to Australia.

(a) Define a species. (2 marks)

(b) Explain how new species of dung beetle could evolve by allopatric speciation. (5 marks)

Most dung beetle populations are small and experience genetic drift.

(c) Describe how genetic drift affects the genetic composition of populations. (3 marks)

One species of dung beetle has males with larger horns than the females. The larger horns make movement and eating more difficult.

(d) Explain how the larger horns in the males of this species could have evolved. (5 marks)

Questions 33, 34, 37 Source: School Curriculum and Standards Authority, Biology 2017 ATAR Examination
https://senior-secondary.scsa.wa.edu.au/__data/assets/pdf_file/0004/460480/WEB-ONLY-VERSION-Biology_Exam_2017.PDF
Date retrieved: 01/04/2020

Question 33 (20 marks)

Biologists suspected that a species of fruit fly was developing resistance to a commonly-used insecticide. They collected 1000 fruit flies from an orchard sprayed regularly with this insecticide. In the laboratory they sprayed the fruit flies from the orchard with the recommended dose of insecticide and measured the percentage survival of the flies over the next 100 hours. At the same time, they also sprayed a group of 1000 laboratory-reared fruit flies of the same species that had never been exposed to insecticide and recorded their percentage survival over the next 100 hours. Fruit flies in both groups were kept under identical culture conditions. The data are shown below.

Time in hours since spraying	% fruit flies from the orchard surviving	% fruit flies from the laboratory surviving
0	100	100
20	97	8
40	51	4
60	50	2
80	49	2
100	49	0

(a) On the grid below, graph the percentage of fruit flies surviving over time for both the fruit flies from the orchard and those from the laboratory. (6 marks)

(b) (i) State a hypothesis for the fruit fly experiment. (2 marks)

(ii) Does the fruit fly experiment have a control? Explain your answer. (3 marks)

(c) (i) Calculate the number of flies from the orchard that died between 20 and 40 hours after being sprayed. Show your workings. (2 marks)

(ii) Using your graph, estimate the time by which 50% of the fruit flies from the laboratory had died. (1 mark)

(iii) Explain how you could modify the experiment to improve the accuracy of the estimate of the time by which 50% of the fruit flies from the laboratory had died. (2 marks)

(d) Biologists determined that resistance to the insecticide in the fruit flies was controlled by a single gene but were unsure whether the allele that gave resistance was dominant or recessive to the allele that caused susceptibility.

Describe how the biologists could determine whether the allele that gave resistance was dominant or recessive to the allele that caused susceptibility. (4 marks)

Question 34

Indicate the order in which the following life forms first evolved: eukaryotic cells, prokaryotic cells, land plants and marine animals.

(4 marks)

First (Oldest):
Second:
Third:
Fourth:

(a) Distinguish between microevolution and macroevolution. Include a specific example of each in your answer. (4 marks)

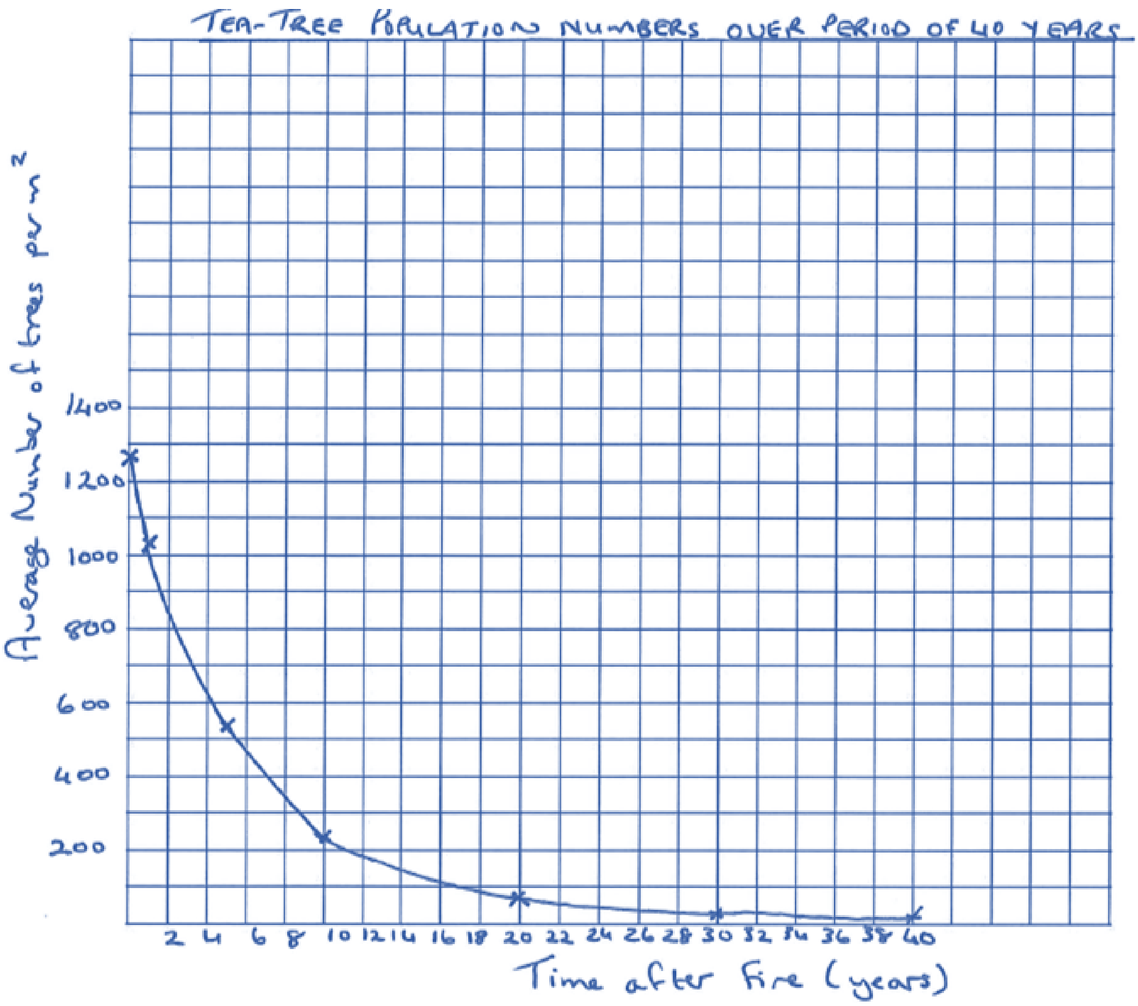
Question 37

(a) Describe the process of allopatric speciation. (10 marks)

UNIT 3 ATAR Biology | Topic: Mechanisms of Evolution

Solutions to Activities

ACTIVITY 1: A tea-tree population (struggle for existence):



1. There was a dramatic decrease in the first few years then a more gradual decrease until relative stability after 30 years.
2. The change in numbers of tea-tree seedlings is due to the lack of nutrients.
    - The change in numbers of tea-tree seedlings is due to disease.
    - The change in numbers of tea-tree seedlings is due to competition with plants of the same species.
    - The change in numbers of tea-tree seedlings is due to competition with plants of other species.
3. Yes. Some survived and some perished under the same environmental conditions, which suggests some seedlings were better adapted.
4. inheritance of favourable characteristics and/or luck

ACTIVITY 2: The peppered moth (natural selection in action):

1. Predation (birds) and pollution (soot)
2. Yes. The variation or trait must exist in a population before it can be selected.
3. It is the evolutionary process where organisms are considered as competing in the struggle for survival. Individuals with desirable characteristics are favoured, and tend to survive and pass the characteristics on to the next generation
4. There is strong supportive evidence. The experiment is simple and easy to understand.

ACTIVITY 3: Natural Selection activity – snail population

a) Natural selection activity: snail population.

Gene pool before predation		**count**	**% frequency**
Allele types	B	20	50
	b	20	50
Allele combinations	BB	5	25
	Bb	10	50
	bb	5	25

b) Natural selection – snail example activity

Gene pool after predation		**count**	**% frequency**
Allele types	B	12	30
	b	28	70
Allele combinations	BB	2	10
	Bb	8	40
	bb	10	50

Answers to Questions

1. Allele B has decreased in frequency (from 50% to 30% of population).Allele b has increased in frequency (from 50% to 70% of population).
2. Allele combination BB has decreased in frequency (from 25% to 10% of population). Allele combination Bb has decreased in frequency (from 50% to 40% of population). Allele combination bb has increased in frequency (from 25% to 50% of population).
3. Yes. Dark-shelled snails are disadvantaged due to predation. Individuals with favourable variations (lighter shells) have more chance of survival and would increase in frequency over several generations.
4. Emigration and migration (gene flow), death, birth, mutation, environmental change

ACTIVITY 4: Natural selection – cockatoo example

1. They eat different diets. The cockatoos are not in competition for the same food source.
2. The long-billed variety would be affected and may compete with the short-billed variety for other seeds.
3. Neither variety would be affected. The long-billed variety does not eat banksia seeds. The short-billed variety can eat other seeds.

ACTIVITY 5: Genetic drift

1. Yes, as far as snakes are concerned. Natural selection will most likely favour those individuals with smaller heads and larger bodies.
   No, as far as crows are concerned. It is learned behaviour and not passed on to offspring.
2. **Advantage**: Larger size toads win out against smaller toads as they move faster and are first to colonise new areas.
   Disadvantage: skeletal deformity (arthritis in the spinal column) caused by its rapid evolution

ACTIVITY 6: Change or extinction activity

1. The last known thylacine died at Hobart zoo in the 1930s.
2. The thylacine became extinct due to a range of rapidly introduced selection pressures such as habitat destruction and disease. They were also deliberately killed for payment as it was believed they attacked sheep and chickens.

ACTIVITY 7: Artificial selection activity

1. Artificial selection is the selection, by humans, of animals [and plants] which have useful features for breeding programs.
   The mechanism used by dog breeders is inbreeding.
   Examples: spaniels with brains too big for their skulls / short faces cause breathing difficulties / ridgeback on Rhodesian Ridgeback / bulldogs unable to mate or give birth unassisted
2.

Variety	Structure of wild type
Brussel sprout	enlarged side buds
Cauliflower	broader leaves
Cabbage	larger flowers or florets
broccoli	larger flowers or florets

   All these structures have been selectively enlarged for the food market.
3. Yes. Undesirable characteristics, such as low milk yield, are culled or removed from a breeding program.
4. Yes. Disadvantageous or 'no-advantage' characteristics may reduce survival and reproduction chances in the population. The frequency in population will be reduced over time.

5. In domesticated breeds varieties are purposefully selected for specific characteristics in offspring that may not be selected for in nature.
6. Undesirable characters are culled or removed from a breeding program, eg bulls (male calves) and low-yield milking cows.
7. a) Disadvantages:
   - Loss of variety (genetic diversity) means that plants and animals are more susceptible to disease.
   - The same nutrients are removed from the crop soil each season and more fertiliser needs to be applied.
   - Pest and weed build up each successive year.

   b) By maintaining the original 'wild' stock
8. Asexual reproduction involves one parent so there is no genetic variation as in sexual reproduction which involves the production and fusion of gametes.
   Disadvantages include the loss of diversity (no genetic variation). The entire crop/population is vulnerable to the same disease or susceptible to the same environmental conditions such as frost or drought.

UNIT 3 ATAR Biology | Topic: Mechanisms of Evolution

Solutions to Exam Questions

Answers to question 31 Source: School Curriculum and Standards Authority, Biology 2019 ATAR Examination, Ratified Marking Key

https://senior-secondary.scsa.wa.edu.au/__data/assets/pdf_file/0003/592104/2019_BLY_Ratified_Marking_Key.PDF

Date retrieved: 30/3/20

Question 31

(a) Define a species. (2 marks)

Description	Marks
Any **two** of:	
Mark one species definition only **Either** Defines the biological species concept • a group of organisms that interbreed • to produce fertile offspring • cannot breed with the individuals of another species **or** Defines the phenetic species concept • a group of organisms that are similar to each other • and are distinct from those in other sets • based on overall similarity (genetic morphological, ecological) **or** Defines the evolutionary species concept • a lineage of organisms that maintains its identity from other lineages • and has its own evolutionary tendencies and fate **or** Provides a taxonomic definition • taxonomic unit/category • that is below genus **or** that comprises populations • main taxonomic/working unit (in biology)	1–2
Total	**2**
Accept other valid species definition	

(b) Explain how new species of dung beetle could evolve by allopatric speciation. (5 marks)

Description	Marks
Explains the process of allopatric speciation (any **five** of):	
• a physical barrier divides population/geographical isolation • prevents gene flow (between the different populations) **or** individuals (from the different populations) from interbreeding • environment/conditions/selection pressures on either side of barrier are different • population on either side of barrier become different due to natural selection • may also become different due to mutation **or** genetic drift • differences will increase/accumulate over time • if individuals are no longer able to interbreed, new species **or** speciation	1–5
Total	**5**

(c) Describe how genetic drift affects the genetic composition of populations. (3 marks)

Description	Marks
Describes the process of genetic drift (any **three** of):	
• changes allele frequencies • changes are random or occur by chance • (causes) loss of diversity/alleles from a population • (causes) differences between populations	1–3
Total	**3**

(d) Explain how the larger horns in the males of this species could have evolved. (5marks)

Description	Marks
states that larger horns have evolved by sexual selection **or** due to their disadvantageous effects	1
Subtotal	**1**
Explains how larger horns evolved by sexual selection:	
• larger horns are not favoured by natural selection • females preferred the males with larger horns/males out-compete other males to mate with females • males with larger horns were more likely to mate **or** breed • therefore males with larger horns left more offspring than males with smaller horns **or** passed on allele/s for larger horns to offspring • therefore the frequency of allele/s for large horns increased over time	1–4
Total	**5**

Answers to question 33, 34, 37 Source: School Curriculum and Standards Authority, Biology 2017 ATAR Examination, Ratified Marking Key

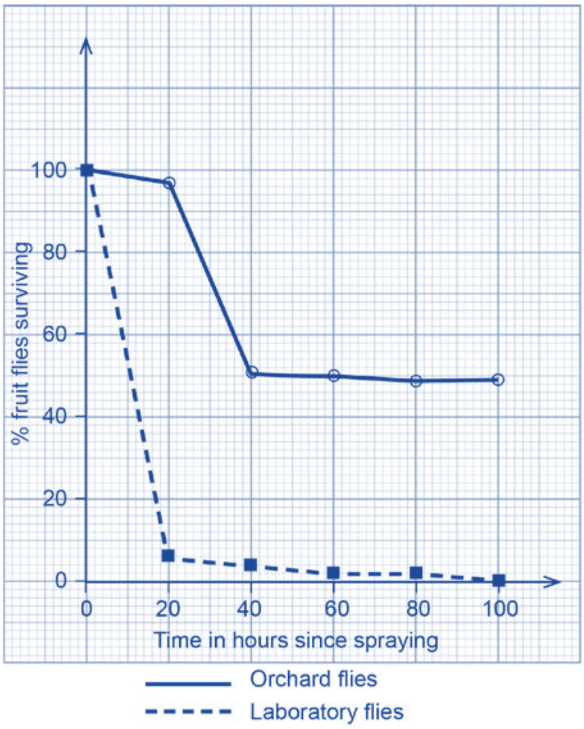
https://senior-secondary.scsa.wa.edu.au/__data/assets/pdf_file/0005/460481/Ratified_Biology_Marking_Key_2017.PDF

Date retrieved: 30/3/20

Question 33

(a) On the grid below, graph the percentage of fruit flies surviving over time for both the fruit flies from the orchard and those from the laboratory. (6 marks)

Survival rates of fruit flies from an orchard and a laboratory when sprayed with an insecticide



Description	Marks
Title, must include both variables	1
Line graph, data plotted separately for each group of flies with key	1
Correct axes (X and Y)	1
Correct scale	1
Labelling – accurate labelling on both axes including units	1
Plotting – data points accurate and accurately joined	1
Total	6

(b) (i) State a hypothesis for the fruit fly experiment. (2 marks)

Description	Marks
Any of the following:	
The survivorship of fruit flies from the orchard will be higher than the survivorship of the fruit flies from the laboratory when sprayed with/exposed to the insecticide **or** The survivorship of fruit flies from the laboratory will be lower than the survivorship of the fruit flies from the orchard when sprayed with/exposed to the insecticide **or** The survivorship of fruit flies from the laboratory and from the orchard will be the same when sprayed with/exposed to the insecticide **or** Fruit flies from the orchard will be more resistance to the insecticide than fruit flies from the laboratory **or** Fruit flies from the laboratory will be more susceptible to the insecticide than fruit flies from the orchard	1
Stated as a proposition, not a question or aim or prediction.	1
Total	**2**

(ii) Does the fruit fly experiment have a control? Explain your answer. (3 marks)

Description	Marks
EITHER	
Yes	1
Any **two** of:	
• the laboratory flies are the control • they had not previously been exposed to the insecticide • all (other) conditions were identical	1–2
or any **two** of:	
• the two groups of flies only differ by one factor • (this factor is) exposure to insecticide • all (other) conditions were identical	1–2
OR	
No	**1**
Need measure survivorship in flies that have not been sprayed (with insecticide)	1
Because the orchard and laboratory flies have come from different environments (which could influence the results)	1
Total	**3**

(c) (i) Calculate the number of flies from the orchard that died between 20 and 40 hours after being sprayed. Show your workings. (2 marks)

Description	Marks
460 (no units required as they are given in question)	1
Any **one** of:	
• number of flies at 20 hours was 970 • number of flies at 40 hours was 510 • 970 – 510	1
Total	**2**

(ii) Using your graph, estimate the time by which 50% of the fruit flies from the laboratory had died. (1 mark)

Description	Marks
11 hours (accept 10 – 12, **must have units**)	1
Total	**1**

(iii) Explain how you could modify the experiment to improve the accuracy of the estimate of the time by which 50% of the fruit flies from the laboratory had died. (2 marks)

Description	Marks
Measure survivorship more often	1
(Especially) between 0 and 20 hours **or** around the time when 50% (of flies) were dead.	1
Total	**2**

(d) Describe how the biologists could determine whether the allele that gave resistance was dominant or recessive to the allele that caused susceptibility. (4 marks)

Description	Marks
EITHER • Use a breeding experiment • Cross resistant flies with susceptible flies • Determine if offspring are resistant or susceptible • If resistance allele is dominant expect all offspring to be resistant • Providing that the resistant parent was a homozygote • Need to obtain parents homozygous/true breeding for resistance **or** need to use a test cross • Could get homozygous parents by inbreeding resistant flies • Can test resistance/susceptibility by spraying with insecticide	1-4
OR • Use a breeding experiment • Cross resistant flies with each other • Determine if offspring are resistant or susceptible • If some of the offspring are susceptible • The susceptible allele must have been present in (some) parents OR (some) parents were heterozygotes • Indicates that the susceptible allele is recessive OR resistance allele is dominant • Can test resistance/susceptibility by spraying with insecticide	1-4
OR • Use a breeding experiment • Cross susceptible flies with each other • Determine if offspring are resistant or susceptible • If some of the offspring are resistant • The resistance allele must have been present in (some) parents OR (some) parents were heterozygotes • Indicates that the resistance allele is recessive OR susceptible allele is dominant • Can test resistance/susceptibility by spraying with insecticide	1-4
Total	**4**

Question 34

(a) Indicate the order in which the following life forms first evolved: eukaryotic cells, prokaryotic cells, land plants and marine animals. (4 marks)

Description	Marks
First (Oldest): Prokaryotic cells	1
Second: Eukaryotic cells	1
Third: Marine animals	1
Fourth: Land plants	1
Total	**4**

(b) Distinguish between microevolution and macroevolution. Include a specific example of each in your answer. (4 marks)

Description	Marks
Microevolution is evolution within a population **or** small scale evolution or changes in the genetic composition of a population (through time)	1
Macroevolution is evolution (at or) above the level of species OR large scale evolution	1
Specific example of microevolution, e.g. evolution of antibiotic/herbicide/insecticide resistance in a species **or** evolution of small/large/different forms of a species on an island **or** evolution of breeds of a species **or** loss of genetic diversity from populations of an endangered species (answer should state type of organism and trait/process & be a clear example of microeveolution).	1
Specific example of macroevolution, e.g. radiation/speciation of Galapagos finches or other lineage **or** extinction of dinosaurs or other lineage **or** change in vertebrate limb or other character through time (answer should state type of organism and trait/process & be a clear example of macroeveolution).	1
Total	**4**

Question 37

(a) Describe the process of allopatric speciation. (10 marks)

Description	Marks
Any **ten** of:	
• (Large ancestral) population is subdivided (into subpopulations) • (Subdivided by) a physical barrier **or** a mountain range or desert or river • Physical barrier prevents individuals moving (between subpopulations) • (Therefore) there is no gene flow between (sub)populations • (Sub)populations evolve independently **or** gene flow can no longer smooth out differences **or** (sub)populations are isolated • (Sub)populations are in different environments **or** face different selection pressure • Therefore (natural) selection will favour different traits in the different (sub)population/environments • Will result in differences in the genetic composition **or** in allele frequencies (of two (sub)populations) • (Sub)populations will be adapted to different environments • Genetic drift may cause (random) differences (in genetic) composition **or** allele frequencies • Mutation may cause (random) differences (in genetic) composition **or** allele frequencies • Genetic differences (between (sub)populations) increase through time/over many generations • Eventually (sub)populations are unable to interbreeding/exchange genes **or** are reproductively isolated • Because individuals are no longer genetically compatible • (Once unable to interbreeding/exchange genes **or** reproductively isolated) (sub)populations are regarded as separate species • (Daughter) species evolved in different locations	1–10
Total	**10**

- End of package -