**Strand 4: Processes & Patterns of Evolution**

***Sub-strand 4.3 GENE POOL & ALLELE FREQUENCY***

**LESSON 1: Allele frequency**

**Key Learning Outcome**:

Students are able to demonstrate understanding of gene pools and allele frequencies within gene pools of a population and factors that affect allele frequency.

* gene pool as the sum total of genes within a population
* allele frequency as how often an allele occurs in a gene pool; factors affecting allele frequency - size of population; natural selection, sexual selection, migration (gene flow)

The **specific learning outcomes** targeted in this lesson are provided below: Tick the last column when you have achieved the learning outcome.

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| --- | --- | --- | --- | --- |
| **SLO #** | **Specific Learning Outcomes:**  *Students are able to* | **Skill level** | **SLO code** | **√** |
| 1 | Define gene pool / allele frequency | 1 | Bio4.3.1.1 |  |
| 3 | List the factors that affect allele frequency within a population | 2 | Bio4.3.2.1 |  |
| 4 | Describe how certain factors such as population size, natural selection and gene flow affects the allele frequency | 2 | Bio4.3.2.2 |  |
| 5 | Explain how the size of a population affects allele frequency | 3 | Bio4.3.3.1 |  |
| 6 | Explain how natural selection affects allele frequency | 3 | Bio4.3.3.2 |  |
| 7 | Explain how migration (gene flow) affects allele frequency | 3 | Bio4.3.3.3 |  |

**Recommended Readings:**

|  |  |  |
| --- | --- | --- |
| **Reading Text** | **Page(s)** | **Achieved** |
| Hanson, M., & Sinclair, M. (2006). *Year 13 Biology Study Guide, NCEA Level 3*. Auckland: ESA Pubilcations Ltd. |  |  |
| Bradfield, P., Dodds, J., Dodds, J., and Taylor, N. (2001). *AS Level Biology*. Essex: Pearson Education Limited. |  |  |

**GENE POOLS**

Every member of a population carries genes that determine their overall features and adaptations: physiological, behavioural, structural and also life history.

A gene pool, therefore, is ***the total number of genes*** that are represented by the varying characteristics of members ***within a population***.

Simply put, it is the total number of genes within a population. The varying characteristics of members of a population are specified through the alleles representing a particular gene. For every genotype there exists two alleles or more (as in multiple alleles). The allele can either be dominant, recessive, co-dominant or even show incomplete dominance. The total number of specific alleles within a population is called the ***allele frequency***.

For example:

In a population of 50 beetles, 24 beetles have a mottled coat color (black with grey spots), 10 have white coats and 16 have black coats.

Given that black and white coat are represented by co-dominant alleles (black – B; white – W). The allele frequencies of each phenotype would be as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Phenotype** | **Genotype** | **Number of beetles with phenotype** | **Frequency of alleles** | | |
| B | W | Total (%) |
| Black coat | BB | 24 | 24 x 2 | - | 48 |
| White coat | WW | 10 |  | 10 x 2 | 20 |
| Mottled coat | BW | 16 | 16 x 1 | 16 x 1 | 32 |
| Total | | 50 |  |  | 100 |

**FACTORS AFFECTING GENE POOLS**

The gene pool of a population is largely determined by its allele frequencies therefore any changes in the allele frequencies will change the gene pool. Allele frequency is determined by the presence or absence of individual members of a population. When a member dies, the alleles they have are removed from the gene pool. Unless these alleles can be passed on through their offspring through successful reproduction, then the alleles are maintained within the gene pool.

***Agents that change allele frequencies within a species gene pool***

1. Natural Selection
2. Gene flow
3. Mutation
4. Genetic drift
5. Founder effect

*1. Natural Selection (for detail, see notes from Substrand 4.2 on ‘Natural Selection)*

There are variations in phenotypic traits within any population of organisms. Biotic (such as number of prey, parasites, pests, food availability) and abiotic factors (such as changes in soil temperature and pH) may play a role in selecting for or against particular phenotypes which promote or reduce the ‘fitness’ of an organism. ‘Fitness’ of an organism within its population refers to its ability to adapt, survive and reproduce successfully. As a result, allele frequencies of particular phenotypes may change over time. The population may therefore evolve to show common phenotypic traits that are different from the original population before natural selection took place.

*2. Gene Flow*

The movement and exchange of genes or alleles between and within interbreeding populations is called gene flow. When members of a gene pool mate with members of another gene pool it can add new alleles to the existing gene pool or increase the frequencies of existing alleles. Therefore, emigration (movement of new organisms into the population) (Figure 1) and birth adds new alleles or new allele combinations into the gene pool of a population. Immigration (movement of organisms out of a population) and death removes alleles from a population gene pool.

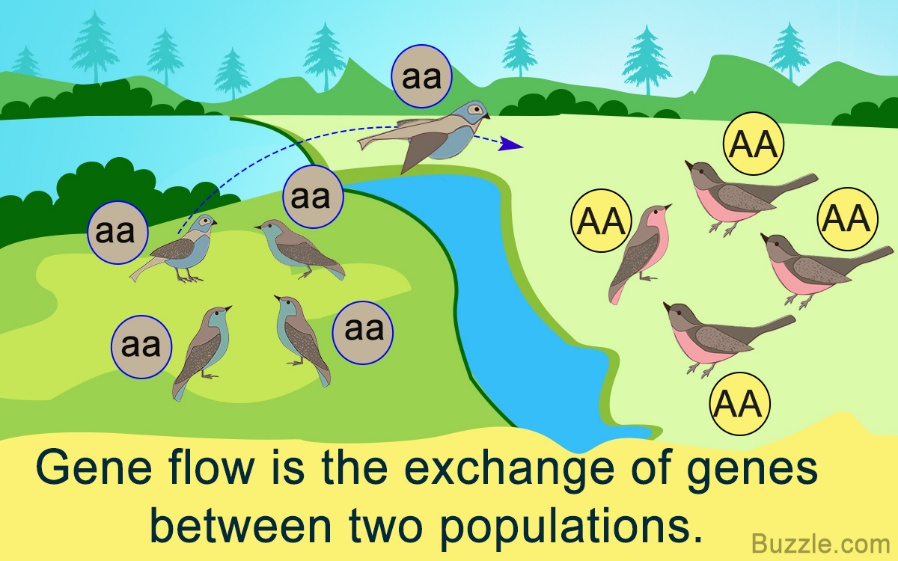


Fig.1. A bird with alleles ‘aa’ from a separate population migrates

into another population and integrates its ‘aa’ alleles into their gene pool. New alleles have been added to increase genetic diversity. Adapted from: <https://media.buzzle.com>

*3. Mutation*

Mutation adds new alleles to a gene pool. If the individual with the mutation is able to survive and reproduce successfully, then this mutation gets passed on to the next generation and becomes part of the gene pool of that population. However, in most cases, mutations can be more harmful than useful and organisms with mutations are rarely able to survive.

An example of a mutation that has maintained itself within a population is that which causes sickle cell anaemia. In Africa, there is a high population of people who suffer from a medical condition called sickle-cell anaemia. Sufferers of sickle cell anaemia have a both recessive alleles for a mutated gene that causes red blood cells to become sickle-celled in shape. This condition causes pleiotropic complications upon the body and health. However, when people with sickle-cell anaemia are bitten by *Anopheles* mosquitoes that carry the malaria-causing protozoan, *Anopheles*, they do not suffer from malaria. They therefore survive and are able to reproduce and pass on the mutated trait to further generations. This therefore increases the allele frequency of sickle-cell anaemia in the gene pool.

*4. Size of a population*

The size of a population also affects allele frequencies.

1. *The effect of large population size*

A large population has many members therefore many alleles within the population gene pool. Any factors which remove ‘weak’ members of a population will also remove the alleles from the population. In large populations, the death of a few individuals in the population may not cause major changes in the gene pool in one generation because of the presence of many others carrying the same alleles.

1. *The effect of small population size*

In small populations, there may already be a very low allele frequency for a specific phenotypic trait. Removal of an individual from the population either through death or emigration can result in the drastic reduction or wiping out of an existing allele (phenotype). Over time as the population attempts to revive its numbers through interbreeding, the allele frequencies may be very different from that of the original population. The effect of small populations is largely evident in three major populations: genetic drift, the founder effect and the bottleneck effect (see Lessons 2 – 4 for more detail on these three topics).

Genetic drift is the change in allele frequency of an originally ***small*** population due to random effects of chance. The founder effect is the establishment of small populations with **non-representative sample of alleles** away from an original population. The bottleneck effect is the drastic reduction of a large population of organisms due to catastrophic events (such as natural disaster or overhunting) resulting in a small population with very low genetic diversity. Allele frequencies of the surviving population may not be representative of the original population therefore the gene pool lacks genetic diversity and may be further affected by natural disaster and genetic drift to cause extinction.

**LESSON ACTIVITY**

**Question One**

Define the following terms: **(L1) (Bio4.3.1.1)**

**(i)Gene pool:**

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**(ii)Allele Frequency:**

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**Question Two**

List down the factors that affect allele frequency within a population. **(L2)(Bio4.3.2.1)**

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**Question Three**

Describe how the following factors affect the allele frequency of a population. **(L2) (Bio4.3.2.2)**

**(i) Population size:**

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(**ii) Natural selection:**

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**(iii) Gene flow:**

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**Question Four**

Explain how the size of a population affects allele frequency. **(L3)(Bio4.3.3.1)**

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**Question Five**

Explain how natural selection affects allele frequency. **(L3) (Bio4.3.3.2)**

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**Question Four**

Explain how migration affects allele frequency. **(L3)(Bio4.3.3.3)**

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**Lesson 2: Genetic Drift**

**Key Learning Outcome:** Students are able to demonstrate understanding of gene pools and allele frequencies within gene pools of a population and factors that affect allele frequency:

* genetic drift – the changes in allele frequency in a population by chance, related to population size.
* founder effect and bottleneck effect as special cases of genetic drift.

**The specific learning outcomes (SLO) targeted in this activity are provided below:** Tick the last column when you have achieved the learning outcome.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SLO#** | **Specific Learning Outcomes:** Students are able to | **Skill level** | **SLO code** | **Achieved** |
| 8 | Define genetic drift | 1 | Bio4.3.1.3 |  |
| 9 | Identify/State a feature or example of genetic drift, in a given context | 1 | Bio4.3.1.4 |  |
| 10 | Explain how genetic drift affect changes in allele frequency in a population by chance | 3 | Bio4.3.3.4 |  |
| 11 | Explain how genetic drift is related to or affected by population size | 3 | Bio4.3.3.5 |  |
| 12 | Discuss the impact of genetic drift on populations and population size | 4 | Bio4.3.4.1 |  |

**Notes:**

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| **Genetic drift** is the random change in allele frequencies in a population; it is determined by chance (not by natural selection). It becomes significant in small populations as there is a higher probability of alleles being lost (or fixed) by chance than in large populations.  **Examples:**   * Amongst humans, genetic drift may have occurred in certain small, exclusive religious sects such as the Dunkers, a group who emigrated to the United States from Germany early in the 18th century. Since then they have only married amongst themselves – they have been just as reproductively isolated from other Americans as if they had been living on an island. One particular Dunker community in Pennsylvania has remained about 300-strong for over a century, and the frequencies of certain alleles such as the ABO blood group alleles are significantly different from those in the United States population as a whole and in Germany from where they came. * In a small population of kakapo, the only two birds carrying a rare allele could be killed by predators, and that allele would disappear. In a large population it is unlikely that all the birds possessing a particular allele would die at the same time.   A **bottleneck effect** occurs when a large population is suddenly reduced in size, the result of either a catastrophic environmental event (e.g. fire, flood, landslip, severe weather) or human impact (e.g. habitat destruction, introduction of predator or competitor). The bottleneck may randomly alter allele frequencies and/or remove alleles so that when the population recovers, allele frequencies may not be representative of the original population and genetic diversity is likely to be reduced. When small (in its ‘bottleneck’ phase), the population is subject to genetic drift (as well as inbreeding) which may further reduce genetic diversity.  *Lack of diversity in small populations increases the likelihood of their extinction should there be a change in the environment.*  Genetic drift is likely to occur in the small number of survivors. When the population increases again, alleles may be present in quite different frequencies from before. The population is also much more likely to be genetically very similar. It is possible that modern humans experienced a bottleneck event early in their evolutionary history as we are genetically much more similar to each other than are our closest relatives, the chimpanzees. When a small number of individual animals or plants are dispersed to say, a distant island, the new arrivals carry only a small proportion of the gene pool of the ‘parent’ population. This is known as the **founder effect**. The alleles of the colonists are therefore only a sample (i.e. not representative) of the parent gene pool. It is largely a matter of chance which alleles are present in the gene pool of the founders.  **Example:** New Zealand hares are descendants of six animals that were originally introduced into Australia. Even though the introduced animals multiplied greatly, their gene pool reflects that of the founders, which would have contained a reduced range of alleles in comparison with that of the parent European population. Over long periods of time however, mutation will gradually increase the diversity of the new gene pool. |

**Lesson Activity.**

**Question One**

In your own words, define genetic drift. **(L1) (Bio4.3.1.3)**

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**Question Two**

In the following examples, state the feature of genetic drift. **(L1) (Bio4.3.1.4)**

a. A small number of Darwin’s finches colonise the Galapagos Islands.

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b. For some reason, the population of the robin in Chatham Island was reduced to only a few.

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**Question Three**

Explain how genetic drift affect changes in allele frequency in a population by chance.

**(L3) (Bio4.3.3.4)**

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**Question Four**

Explain how genetic drift is related to or affected by population size**. (L3)(Bio4.3.3.5)**

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**Question Five**

Discuss the impact of genetic drift on populations and population size. **(L4)(Bio4.3.4.1)**

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Roberts, A. & Sinclair, M. (2013). *ESA study guide level 3 Biology*. ESA Publications: Auckland, New Zealand. pp. 208.

**Lesson 3: Founder Effects and Bottleneck**

**Key Learning Outcome:** Students are able to demonstrate understanding of gene pools and allele frequencies within gene pools of a population and factors that affect allele frequency:

* Founder effect and bottleneck effect as special cases of genetic drift.

**The specific learning outcomes (SLO) targeted in this activity are provided below:** Tick the last column when you have achieved the learning outcome.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SLO#** | **Specific Learning Outcomes:** Students are able to | **Skill level** | **SLO code** | **Achieved** |
| 2 | Define founder effect/bottleneck effect | 1 | Bio4.3.1.2 |  |
| 13 | Describe the features of the founder effect as special cases of genetic drift | 2 | Bio4.3.2.3 |  |
| 14 | Describe the features of bottleneck effect as special cases of genetic drift | 2 | Bio4.3.2.4 |  |
| 15 | Explain the relation between the founder effect and bottleneck effect as special cases of genetic drift | 3 | Bio4.3.3.6 |  |
| 16 | Discuss the impacts of the founder effect and bottleneck effect as special cases of genetic drift | 4 | Bio4.3.4.2 |  |

**Lesson Activity**

**Question One**

Define the following terms: **(L1) (Bio4.3.1.2)**

(i)Founder effect:

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(ii)Bottleneck effect:

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**Question Two**

Describe the features of the founder effect as special cases of genetic drift. **(L2)(Bio4.3.2.3)**

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**Question Three**

Describe the features of bottleneck effect as special cases of genetic drift. **(L2)(Bio4.3.2.4)**

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**Question Four**

Explain the relation between the founder effect and bottleneck effect as special cases of genetic drift. **(L3)(Bio4.3.3.6)**

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**Question Five**

Discuss the impacts of the founder effect and bottleneck effect as special cases of genetic drift. **(L4)(Bio4.3.4.2)**

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