CAIE Biology A-level

Topic 17: Selection and evolution

Notes

This work by PMT Education is licensed under CC BY-NC-ND 4.0

Phenotype – the **characteristics of an organism**, which result from the **interaction of the genes of the organism with the environment** in which it lives.

Types of variation

- **Continuous variation** is variation within a range and it includes mass and height
- **Discontinuous variation** can only take particular values – such as gender or shoe size.

Variation in genotype has an effect on variation in phenotype. Some characteristics are influenced by one gene only and are known as **monogenic**. Such characteristics show **discontinuous variation**. Sometimes times several genes at different loci are involved in determining a characteristic – this is known as **polygenic inheritance and often gives rise to continuous variation.**

Some characteristics are influenced by both genotype and the environment. Examples include:

- **Height** is a polygenic characteristic. However, an organism might not reach its maximum height due to **poor nutrition** which is an environmental factor.
- Some people can be genetically predisposed to **lung cancer** due to the presence of **proto-oncogenes** which regulate the cell cycle. Smoking exposes them to chemicals which convert these genes into active oncogenes in lung cells thus leading to **uncontrolled cell division** in the lungs which can result in lung cancer.
- **Animal hair colour**, for example Siamese cat hair colour, is determined by both genotype and environment. Siamese cats have a gene coding for enzyme **tyrosinase** which darkens the fur which is active only below 31 degrees therefore only **body extremities** of Siamese cats are dark.

The **student's T-test** can be used to compare the mean values of 2 sets of data. This is the formula:

$$t = (\bar{x}1 - \bar{x}2) / \sqrt{(s1^2/n1) + (s2^2/n2)}$$

$\bar{x}1, \bar{x}2$ = *mean of population* 1 *and* 2
$\theta 1, \theta 2$ = *Standard deviation of population* 1 *and* 2
$n1, n2$ = *total number of values in samples* 1 *and* 2

The **null hypothesis** will state that there is **no significant difference** between the 2 means. The **alternative hypothesis** will state that there is a significant difference between the 2 means.

You compare the value you get from the T-test to the **critical value** (which depends on the level of significance). If **t is greater** than the critical value you **reject** the null hypothesis (and accept the alternative hypothesis) and if **t is less** than the critical value you **accept** the null hypothesis.

Natural selection and evolution

CC BY NC ND

The **niche** of a species is **its role within the environment**. Species which share the same niche compete with each other and a better adapted species survive. The idea that better adapted species survive is the basis of **natural selection.**

Organisms are adapted to their environment in various ways

- **Anatomical adaptations** are **physical adaptations**, either external or internal e.g. presence of loops of Henlé which allow desert mammals to produce concentrated urine and minimise water loss
- **Behavioural adaptations** are **changes in behaviour** which improve the organism's chance of survival e.g. mating calls
- **Physiological adaptations** are **processes inside an organism's body** that increase its chance of survival e.g. regulation of blood flow through the skin
-

Natural selection is the process in which **fitter individuals** who are better adapted to the environment **survive and pass on the advantageous genes to future generations.** Evolution is the process by which the **frequency of alleles in a gene pool changes over time as a result of natural selection.** You can find out more about **evolutionary relationships** between species by looking at **DNA sequences.**

Evolution via natural selection

- There are a **variety of phenotypes** within a population
- An **environmental change occurs** and as a result of that the **selection pressure changes**
- Some individuals possess **advantageous alleles which give them a selective advantage and allow them to survive and reproduce**
- The **advantageous alleles are passed on to their offspring**
- Over time, **the frequency of alleles in a population changes** and this leads to evolution

Factors that can affect the evolution of a species

- **Genetic drift** is a phenomenon where there is a small change in allele frequency which occurs as a result of the fact that not all the individuals in a population reproduce. This effect is amplified in very small groups, isolated from the rest of the population.
- **Genetic bottleneck** – rapid reduction in population size which has an effect on the population size and genetic variation in future generations
- **Founder effect** – decrease in genetic diversity which occurs when the population descends from a small number of ancestors

Speciation is the process by which new species arise after a **population becomes separated** and **cannot interbreed**. For instance, **allopatric speciation** is caused by a **physical barrier**. As

CC BY NC ND

the two groups become separated and reproductively isolated as a result, the **gene flow is reduced**. Each group experiences a different selection pressure as the environment they live in is different. Over time, the frequency of alleles changes through **natural selection** and the two parts of the population **can no longer interbreed and become separate species.**
Another type of speciation is **sympatric speciation** where new species evolve from a **single ancestral species** when **inhabiting the same geographic region**, for example as a result of a **chromosomal error during cell division** which leads to **reproductive isolation.**

Antibiotic resistance is an example of natural selection. A **random mutation** occurs in the bacteria which make it resistant to the antibiotic. The bacteria with the mutation are able to **survive and reproduce** passing the mutant allele on over many generations. This means the antibiotic will no longer be efficient in killing the bacteria. This can lead to bacteria like MRSA which is resistant to a wide variety of antibiotics. To prevent antibiotic resistance the whole antibiotic course must be finished and doctors will prescribe antibiotics only when necessary.

The **Hardy-Weinberg Equation** can be used to **estimate the frequency of alleles in a population** and to see whether a **change in allele frequency is occurring in a population over time.**
p = the frequency of the **dominant** allele (represented by A)
q = the frequency of the **recessive** allele (represented by a)
For a population in genetic equilibrium:
p + q = 1.0 (The sum of the frequencies of both alleles is 100%.)
$(p + q)2 = 1$ so $p2+ 2pq + q2 = 1$
The three terms of this binomial expansion indicate the frequencies of the three genotypes:
p2 = frequency of AA (**homozygous dominant**)
2pq = frequency of Aa (**heterozygous**)
q2 = frequency of aa (**homozygous recessive)**

Artificial selection

Artificial selection is the process where selection pressures are artificially created by humans thus allowing the breeding of the desired characteristics.

An example of artificial selection is the **dairy cow**. The milk yield of each cow is measured and recorded to identify the cows with the highest milk yields. This enables the identification of the best quality bulls. The cows with the highest yields are given hormones to increase their egg production. The eggs are fertilised in vitro and subsequently implanted into **surrogate** mothers.

Examples of crop improvement by selective breeding include:

- introduction of **disease resistance** to varieties of wheat and rice
- the **incorporation of mutant alleles for gibberellin synthesis** into dwarf varieties so increasing yield by having a greater proportion of energy put into grain
- **inbreeding and hybridisation** to produce vigorous, uniform varieties of maize

CC BY NC ND

Extinction of organisms

Species can become extinct for a variety of reasons:

- **Killing by humans**- some endangered species are hunted for food, medicine and sport. Species such as the quagga and tasmanian tiger have become extinct as a result of this.
- **Competition**- Organisms compete for food, space, and mates. Competition is one of the main contributors to the evolution of canines, causing the extinction of 40 of their species as the family evolved.
- **Habitat loss and climate change**- climate change can cause habitats to be lost as temperatures rise and natural disasters become more common. Humans can also damage habitats.

CC BY NC ND