Variation

Matthew Williams • Biology • April 14, 2026

Variation

Variation refers to the differences observed among individuals of the same species. These differences may be physical, physiological, or behavioural. Variation is critical for survival because it allows populations to respond to environmental changes. Without variation, all individuals would be identical, and a single environmental pressure could eliminate the entire population.

Variation arises from two main sources: genetic factors and environmental influences. Genetic variation is inherited and passed from one generation to the next, while environmental variation is acquired during an organism's lifetime and is not inherited.

Continuous and Discontinuous Variation

Variation can be classified into two distinct types based on how traits are distributed within a population.

Discontinuous Variation

Discontinuous variation occurs when individuals fall into clearly defined categories with no intermediate forms. Each individual either possesses a trait or does not. These traits are typically controlled by a single gene or a small number of genes, and environmental influence is minimal or nonexistent.

Examples include blood group, tongue rolling ability, and earlobe attachment. In each case, there are discrete categories, and individuals cannot fall between them.

Because these traits are genetically controlled, they tend to follow simple Mendelian inheritance patterns.

Continuous Variation

Continuous variation occurs when traits show a gradual range of differences between two extremes. Instead of distinct categories, there is a spectrum of possible values. These traits are usually controlled by many genes acting together, a phenomenon known as polygenic inheritance.

Examples include height, body mass, skin colour, and intelligence. These traits are also significantly influenced by environmental factors such as nutrition, climate, and lifestyle.

Unlike discontinuous variation, continuous variation produces a distribution pattern in populations, often forming a normal distribution where most individuals cluster around the average.

[DIAGRAM PLACEHOLDER: Histogram showing continuous variation distribution]

Genetic vs Environmental Influence

An organism's phenotype is the result of the interaction between its genotype and its environment. While genetic variation is heritable, environmental variation is not. This distinction is crucial when analysing traits.

For example, two genetically identical plants grown under different light conditions may show different growth patterns. The difference in phenotype is due to environmental influence, not genetic change.

Natural Selection

Natural selection is the mechanism by which populations become better adapted to their environment over time. It operates on existing variation within a population and favours individuals with advantageous traits.

The process is driven by several key principles:

- Organisms produce more offspring than can survive
- There is competition for limited resources such as food, space, and mates
- Individuals within a population show variation
- Some variations provide a survival or reproductive advantage

Individuals with beneficial traits are more likely to survive and reproduce. As a result, these traits become more common in the population over successive generations.

Origin of Variation

Variation exists in populations due to several biological processes:

- **Independent assortment** during meiosis results in different combinations of chromosomes in gametes
- **Crossing over** exchanges genetic material between homologous chromosomes, increasing diversity
- **Mutations** introduce new alleles into the gene pool

These processes ensure that no two individuals are genetically identical, providing the raw material for natural selection to act upon.

Survival of the Fittest

The phrase “survival of the fittest” refers to the idea that individuals best suited to their environment are more likely to survive and reproduce. Fitness in this context refers to reproductive success, not physical strength.

Over time, natural selection leads to populations that are increasingly well adapted to their environment. This process can eventually result in the formation of new species.

Examples of Natural Selection

Natural selection can be observed in real-world scenarios.

One example is the peppered moth, where darker-coloured moths became more common during industrialisation due to increased pollution, which made them less visible to predators.

Another example is antibiotic-resistant bacteria. When bacteria are exposed to antibiotics, those with mutations that confer resistance survive and reproduce, leading to populations that are increasingly resistant.

Natural Selection and Evolution

Natural selection is the driving force behind evolution. Over long periods, the accumulation of small changes can result in significant differences between populations.

Darwin's observations of finches in the Galápagos Islands demonstrated how different environmental pressures can lead to the development of different traits. Variations in beak shape allowed different species to exploit different food sources, leading to adaptive radiation.

Mutation

A mutation is a random change in genetic material. Mutations are the ultimate source of new genetic variation and can occur at the level of genes or chromosomes.

- **Gene mutations** involve changes in the DNA sequence
- **Chromosomal mutations** involve changes in chromosome structure or number

Mutations that occur in gametes can be inherited by offspring.

Effects of Mutation

Mutations can be:

- Beneficial, providing an advantage in a given environment
- Harmful, reducing survival or reproductive success
- Neutral, having no significant effect

Examples of Genetic Conditions

Albinism

Albinism is caused by a recessive allele that prevents the production of melanin, the pigment responsible for skin, hair, and eye colour. Individuals with albinism are highly sensitive to sunlight due to the lack of protective pigmentation.

Sickle-Cell Anaemia

Sickle-cell anaemia is a recessive genetic disorder caused by a mutation in the haemoglobin gene. Red blood cells become sickle-shaped under low oxygen conditions, reducing their ability to carry oxygen.

[DIAGRAM PLACEHOLDER: Normal vs sickle-shaped red blood cells]

Interestingly, individuals who are heterozygous for the sickle-cell allele have increased resistance to malaria. This demonstrates how a mutation can persist in a population due to selective advantage.

Down's Syndrome

Down's syndrome is caused by a chromosomal mutation in which an individual has an extra copy of chromosome 21, a condition known as trisomy 21. This affects physical development and cognitive ability.

Mutagenic Agents

Mutagens are factors that increase the rate of mutation. These include:

- Radiation such as ultraviolet light and gamma rays
- Chemical substances such as nitrosamines and mustard gas

Exposure to mutagens increases the likelihood of genetic changes, some of which may lead to disease.

Artificial Selection

Artificial selection is the process by which humans deliberately select organisms with desirable traits to reproduce. Unlike natural selection, which is driven by environmental pressures, artificial selection is controlled by humans.

Plant Breeding

In plant breeding, individuals with desirable traits are selected and crossed to produce improved varieties. For example, a plant with high yield may be crossed with one that is resistant to disease to produce offspring that combine both traits.

Animal Breeding

In animal breeding, similar principles apply. For example, cattle may be bred to combine traits such as high milk production and resistance to environmental stress.

Artificial selection can produce rapid changes in populations, but it may also reduce genetic diversity.

Genetic Engineering

Genetic engineering involves the direct manipulation of an organism's genetic material. This is achieved by transferring genes from one organism to another, often across species.

Organisms that receive foreign genes are known as transgenic organisms.

Applications

Genetic engineering has several important applications:

- Production of insulin using bacteria
- Development of crops resistant to pests or herbicides
- Improvement of nutritional content in food

Risks and Concerns

Despite its benefits, genetic engineering raises several concerns:

- Health risks, including potential allergens in genetically modified foods
- Environmental risks, such as disruption of ecosystems
- Economic issues, particularly for small farmers

- Ethical concerns regarding manipulation of genetic material

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Key Principles

Variation is essential for survival and evolution. It arises from genetic and environmental factors and provides the basis for natural selection.

Natural selection ensures that beneficial traits become more common over time, while mutation introduces new variation into populations.

Artificial selection and genetic engineering allow humans to influence these processes, but they must be approached with caution due to their potential consequences.

> **📝 Exam Tip**
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> To perform well in examinations, you must be able to:
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> - Distinguish clearly between continuous and discontinuous variation
> - Explain the role of environmental factors in phenotype expression
> - Describe natural selection and apply it to real-world examples
> - Explain the origin and significance of genetic variation
> - Describe mutation and its effects
> - Compare natural and artificial selection
> - Discuss the advantages and risks of genetic engineering
>
> Precision and clarity are critical. Most errors come from vague explanations rather than lack of knowledge.