

# Variation and selection

## Variation

### Types of variation

- All humans have many features in common as we are all members of the same species
- We have many features in common but there are significant differences which we use to categorize animals into different species
- In biology, the term variation means:
  - Differences between species- we use them when constructing keys
  - Differences within species
- There is considerable variation between individuals of the same species
- Variation occurs in the feature we can see
- Variation also occurs in features we cannot see which need specialist equipment to detect
- For example, the different types of hemoglobin called phenotypic variation
- Genetic variation is the differences between the genotypes of individuals.
- There are two types of phenotypic variation within a species:
  - Continuous variation
  - Discontinuous variation

### Continuous variation

- If a frequency histogram is plotted, it is likely that the mean height will be in the middle of the range and correspond to the group with the largest number of people
- This type of distribution is called a normal distribution
- This type of variation is called continuous variation
- For example, there are many genes that contribute to your overall height
- However, other factors such as quantity and quality of food you eat and the amount of exercise you take also influence your height
- People also go through growth spurts at different ages that influence the results
- Continuous variation also occurs in plants

### Discontinuous variation

- Some people have attached earlobes, other people do not
- This is called discontinuous variation
- In this type of variation there is usually a small number of phenotypes and no intermediates
- Discontinuous variation is caused by genes alone and the environment has no effect
- The ABO blood group is another example
- It is either A, B, AB or O
- There are no intermediates
- Some flowering plant species have flowers of distinctly different colors

### Inheritance versus the environment

- Identical twins develop from the same embryo and are genetically identical
- However, they are different in many ways

- These differences will have come about because they developed slightly differently in the womb and have been exposed to different environmental influences
- Identical twins separated at birth, or shortly afterwards, and brought up apart often show striking similarities
- These are often to do with personality, which shows the influence that genes have on us
- The effect of environmental factors can be investigated with plants
- For example, the Mexican hat plant
- You can detach these plants and grow them in pots and keep them under different conditions
- Any variation shown will be because of environmental factors

### Mutations

- A mutation is a change in a gene or chromosome that may cause a change in a phenotypic characteristic
- A gene mutation is a change in the base sequence of DNA
- Often the change can be harmful, but some mutations can be beneficial or have no effect at all

### Causes of mutation

- Gene mutations are the only way in which new alleles are formed
- They are caused by damage to DNA or by a failure in copying process that occurs before nuclear division
- They occur naturally at random, but the rate at which they occur is increased by exposure to ionizing radiation and some chemicals
- UV radiation, X-rays and Gamma rays are the most damaging
- The greater the dose of radiation, the greater the chance of mutation
- If mutation occur in body cells, they may affect the individual
- Gene mutations are the cause of many human genetic diseases
- Sickle cell anemia is an example
- It is only mutation that occur in gamete-forming cells, or gametes themselves, are important in the long term
- This is because these mutations can be inherited and provide new forms of variation

### Sickle cell anemia

- These red blood cells are in the shape of a sickle
- These cells have abnormal hemoglobin which makes it difficult for the red blood cells to carry oxygen
- SCF can prove fatal if the distorted blood cells block blood vessels
- Or if the spleen destroys the abnormal cells at a greater rate than red blood cells can be produced, causing anemia
- SCF is a genetic disease resulting from a gene mutation
- The normal allele,  $Hb^A$  or  $H^A$ , codes for normal hemoglobin
- The mutant allele,  $Hb^S$  or  $H^S$ , codes for the abnormal form of hemoglobin
- The two alleles are codominant
- People who are heterozygous have both forms of hemoglobin in their red blood cells
- Heterozygous who carry one SCF allele have a much milder form of the disease called a sickle cell trait

- The possession of two SCA alleles puts a great selective disadvantage since the abnormal form of hemoglobin is not very good at transporting oxygen which causes several problems
- The SCA allele is common among people from areas where malaria is common
- This is because people who are heterozygous have both abnormal and normal forms of hemoglobin and do not usually have a problem with transport of oxygen
- But they do have a resistance to malaria as the parasite that causes this disease cannot enter red blood cells
- The link between SCA heterozygotes and resistance to malaria is an example of natural selection
  - There is a strong selection pressure against people who are homozygous for sickle cell anemia,  $H^S H^S$ , because they could die of anemia
  - There is a strong selection pressure against people homozygous for the normal allele,  $H^A H^A$ , because they could die from malaria
- In areas where malaria is common, there is a strong selective advantage for heterozygous individuals,  $H^A H^S$ , since they do not suffer badly from anemia and they are protected from anemia
- So the sickle cell allele remains in the population in areas where malaria is an important selective agent

### Adaptive features

- An adaptive feature is an inherited feature that helps an organism to survive and reproduce in its environment
- Adaptive features are behavioral as well as structural
- Adaptive features are likely to increase an individual's fitness which refers to its chances of surviving in its environment, reproducing and having offspring

### Pond plants

- Hydrophytes are plants that grow submerged or partially submerged in water
- Buoyed up by water, with no need for water transport, floating plants save energy since they produce little or no xylem tissue
- Roots, if present are for anchorage as there is no need to absorb water and mineral// no root hair cells
- The leaves and stems of hydrophytes have little or no cuticle since there is no need to conserve water
- The problem with hydrophytes is that carbon dioxide needed for photosynthesis diffuses slower through water than air
- The same applies for oxygen since it is not soluble in water
- Many hydrophytes have an extensive system of air spaces in their stems and leaves which allow gases to diffuse through quickly
- These air spaces provide buoyancy to keep the plants close to the light
- They are reservoirs of oxygen and carbon dioxide

### Desert adaptations

- All plants have to balance water uptake and loss
- It is important that they maintain the turgor in their cells, or they will wilt
- Very high rates of transpiration can kill a plant if it cannot absorb enough water to prevent long-term wilting

- Xerophytes are plants that exist in conditions where water is scarce
- Cacti are xerophytes that survive in hot, dry, arid and desert regions
- Cacti reduce water loss and conserve water in the following ways:
  - Their leaves are reduced to spines, reducing the surface area over which water can be lost
  - A thick, waxy cuticle covers the plant's surface and reduces transpiration
  - They have swollen stems containing water-storage tissue
  - They have a shallow, spreading root system to quickly absorb any water from rain and overnight condensation
  - Many cacti have a round, compact shape which reduces surface area over which water can be lost
  - They have shiny surfaces which reflect heat and light
  - Their stomata are closed during the day to reduce water loss

### Natural Selection

- Natural selection is the process by which organisms are well adapted to their environment have a greater chance to breed and pass on their alleles to the next generation than those that are less well adapted

### Variation within populations

- Variation is the term used to describe all the differences that exist within populations of organisms
- Gene mutation is the only way in which completely new genetic material is produced
- Some mutation may give an advantage to the individual that expresses them
- Variation is also produced by sexual reproduction between two individuals
- During meiosis, the alleles of different genes are shuffled to give new combinations in the gametes
- At fertilization, when the gametes fuse, alleles from two different individuals are combined within the same nucleus
- Gene mutation, meiosis and fertilization give rise to variation between individuals in every generation

### Competition for resources

- Among the organisms that survive the early stages of life there is competition for resources
- Plants compete for space, light, water and nutrients
- Animals compete for food, water, territories and mates
- This is known as the struggle for existence or struggle for survival
- Competition is fiercer between individuals of the same species
- This is due to the fact that they have the same adaptive features to obtain their resources from the environment
- Individuals in different species also compete but the competition is not as fierce

### Reproduction

- The individuals with features that adapt them to the conditions in the environment are those most likely to survive and reproduce
- Individuals that are not so well adapted are likely to lose out in the competition for resources

- They may die before they have a chance to reproduce, or if they do reproduce, they have few offspring
- The better adapted individuals have a greater chance to pass on their alleles to the next generation

### Natural selection

- If the environment does not change, then natural selection maintains populations of organisms so they do not change much, as many are already well adapted to their environment
- Natural selection will bring about a change in species over time
- Thus selection is the mechanism by which evolution occurs
- Evolution is a process of adaptation whereby population become more suited to their environment over generations

### Antibiotic resistance

- Antibiotics are chemicals that kill bacteria or inhibit their growth
- When bacteria are exposed to an antibiotic they are killed
- However some individual bacteria that have a mutation may have resistance to an antibiotic
- The bacteria may be able to produce an enzyme that breaks down the antibiotic
- These individual bacteria survive and now have more resources available as all their competitors- the non-resistant bacteria, have died
- The resistance bacteria survive to reproduce and pass on this gene to their offspring
- This is an example of natural selection
- Humans have been responsible for the change in environment by introducing antibiotics
- But we have not consciously chosen the bacteria which are resistant to antibiotics

### Selective breeding

- Domesticated plants and animals have changed considerably over time due to artificial selection
- These changes have happened in this way:
  - Humans choose a desirable feature or features of an animal or plant to improve
  - Animals or plants showing these features are bred to produce the next generation
  - The offspring are checked to find those that show an improvement in the desired feature or features. These are kept for breeding the next generation
  - This process of selective breeding continues for many generations
- Selective breeding (artificial selection) involves humans finding organisms with desirable features, crossing them and selecting the best from the next generation
- Commercial farmers want to increase the yields of their crops and animals
- They want to improve features of economic importance to maximize their profits
- This is called artificial selection as it is humans who are the selective agent not the environment
- The danger of selective breeding is that there may be too much inbreeding between closely related individuals
- This may result in harmful recessive alleles being passed on to the descendants and a reduction in vegetation

## Differences between artificial selection and natural selection

<u>Artificial selection</u>	<u>Natural selection</u>
Selection due to human influences	Selection due to environmental factors
Produces varieties of organisms very different from native generations	Produces greater biodiversity
Does not result in new species	May result in new species
Inbreeding is common, leading to loss of vigor in the offspring	Outbreeding is common, leading to hybrid vigor
A relatively fast process	A slow process, taking many years
Proportion of heterozygous individuals in the population is reduced	Proportion of heterozygous individuals in the population remains high

There are two main methods of carrying out selective breeding:

### Outbreeding

- Involves breeding of unrelated animals or plants
- This may be used to combine the good characteristics of separate individuals
- Outbreeding often results in tougher individuals with a better chance of survival
- This is called hybrid vigor

### Inbreeding

- Involves breeding close relative in an attempt to retain desirable characteristics
- There can be harmful effects as a result of inbreeding
- This can include loss of vigor, with the population weakened by a lack of gene diversity and reduced fertility
- There is also a greater susceptibility to disease