18 VARIATION & SELECTION

YOUR NOTES

CONTENTS:

18.1 VARIATION

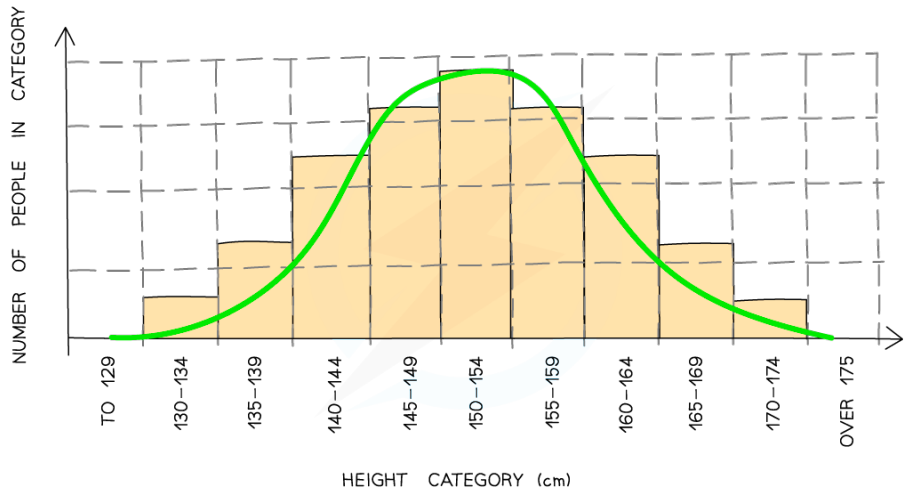
Types of Variation

- Variation is defined as **differences between individuals of the same species**
- **Phenotypic variation** is the difference in features between individuals of the same species
- Some of these differences are caused by differences in genes, which is **genetic variation**
- Phenotypic variation can be divided into two types depending on **how you are able to group the measurements:**
    - **Continuous Variation** is when there are very many small degrees of difference for a particular characteristic between individuals and they are arranged in order and can usually be measured on a scale
    - Examples include height, mass, finger length etc. where there can be many 'inbetween' groups
    - **Discontinuous Variation** is when there are distinct differences for a characteristic
    - For example, people are either blood group A, B, AB or O; are either male or female; can either roll their tongue or not – there are no 'inbetweens'
- When graphs of these data are plotted, continuous variation gives smooth bell curves (a result of all the small degrees of difference), whereas discontinuous variation gives a step-like shape

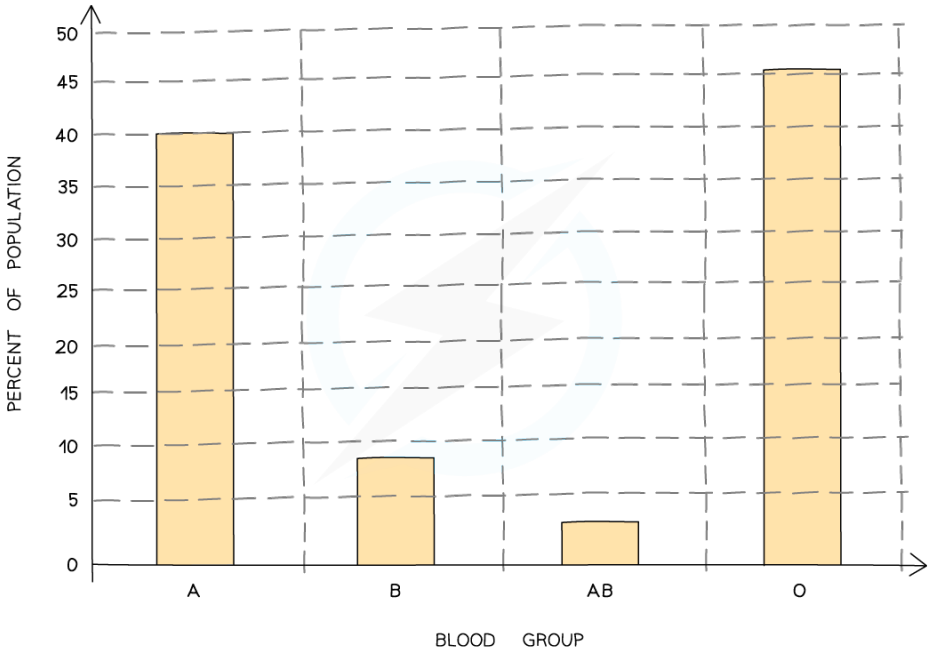
18 VARIATION & SELECTION

18.1 VARIATION cont...

YOUR NOTES



Height is an example of continuous variation which gives rise to a smooth bell-shaped curve when plotted as a graph



Blood group is an example of discontinuous variation which gives rise to a step-shaped graph

18 VARIATION & SELECTION

18.1 VARIATION cont...

YOUR NOTES

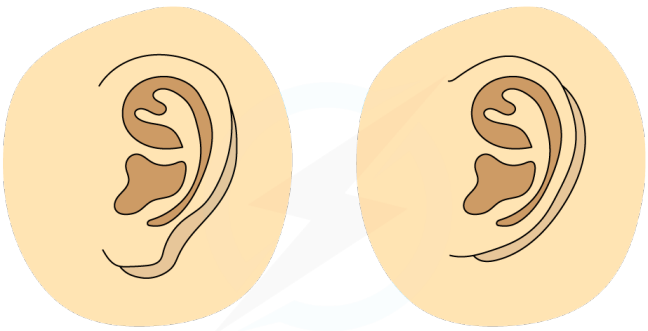
EXTENDED ONLY

Phenotypic Variation

- Phenotypic variation can be caused in two main ways:
  - It can be **genetic** – controlled entirely by genes
  - Or it can be **environmental** – caused entirely by the environment in which the organism lives

Genetic Variation

- Examples of genetic variation in humans include:
  - **blood group**
  - **eye colour**
  - **gender**
  - **ability to roll tongue**
  - **whether ear lobes are free or fixed:**



Whether earlobes are attached (lobeless) or free (lobed) is an example of genetic variation

18 VARIATION & SELECTION

18.1 VARIATION cont...

YOUR NOTES

EXTENDED ONLY cont...

Environmental Variation

- Characteristics of all species can be affected by environmental factors such as climate, diet, accidents, culture, lifestyle and accidents during lifetime
- In this instance 'environmental' simply means 'outside of the organism'
- Examples include:
  - An accident may lead to **scarring** on the body
  - Eating too much and not leading an active lifestyle will cause **weight gain**
  - Being raised in a certain country will cause you to speak a certain **language** with a certain **accent**
  - A plant in the shade of a big tree will grow **taller** to reach more light

Genetic and Environmental Causes

- Discontinuous variation is usually caused by **genetic variation alone**
- Continuous features often vary because of a combination of genetic and environmental causes, for example:
  - tall parents will **pass genes** to their children for height
  - their children have the **genetic potential** to also be tall
  - however if their **diet is poor** then they will not grow very well
  - therefore their **environment** also has an impact on their height
- Another way of looking at this is that although genes decide what characteristics we inherit, the surrounding environment will affect how these inherited characteristics develop

18 VARIATION & SELECTION

18.2 MUTATIONS

YOUR NOTES

Causes & Effects of Mutations

- Mutations are **random genetic changes**
- Most mutations have **no effect** on the phenotype as the protein that a mutated gene produces may work just as well as the protein from the non-mutated gene
- Rarely, mutations lead to the development of new alleles and so new phenotypes and if they do, most have a **small effect** on the organism
- Occasionally, the new allele gives the individual a **survival advantage** over other members of the species
- For example:
  - A bird develops a mutation leading to a change in feather colours
  - This makes it more attractive to birds of the opposite sex
  - Which causes the bird to breed more frequently and have more chances of passing on the mutated phenotype to the next generation
- Mutations can also lead to **harmful changes** that can have dramatic effects on the body – for example, **sickle cell anaemia** in humans
- Mutations happen **spontaneously and continuously** but their frequency can be increased by exposure to the following:
  - **Gamma rays, x – rays and ultraviolet rays** – all types of ionising radiation which can damage bonds and cause changes in base sequences
  - **Certain types of chemicals** – for example chemicals such as tar in tobacco
- Increased rates of mutation can cause cells to become **cancerous**, which is why the above are linked to increased incidence of different types of cancer

EXTENDED ONLY

Sickle Cell Anaemia

Symptoms

- Sickle cell anaemia was the first genetic disease to be described in terms of a **gene mutation**
- A gene mutation is a **change in the base sequence of DNA**
- The mutation **changes the molecule haemoglobin**, causing the red blood cells (RBC's) to become stiff and sometimes **sickle-shaped** when they release oxygen to the body tissues
- The sickled cells tend to get **stuck** in narrow blood vessels, **blocking the flow of blood**

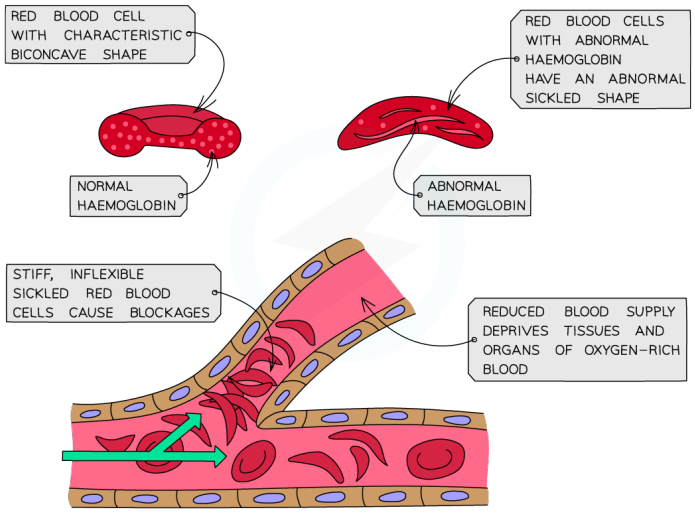
18 VARIATION & SELECTION

18.2 MUTATIONS cont...

YOUR NOTES

EXTENDED ONLY cont...

- As a result, those with sickle cell disease suffer painful "crises" in their joints and bones
- They may suffer **strokes, blindness, or damage to the lungs, kidneys, or heart**. They must often be hospitalized for blood transfusions and are at risk for a life-threatening complication called **acute chest syndrome**
- Although many sufferers of sickle cell disease die before the age of 20, modern medical treatments can sometimes prolong these individuals' lives into their 40s and 50s



Sickle cell anaemia is caused by abnormal haemoglobin which changes the shape of red blood cells

Inheritance

- There are two versions or alleles of the gene important for the inheritance of sickle cell anaemia : **A and S**
- The two alleles are **codominant**, meaning there is no 'dominant' or 'recessive' version of the gene
- Individuals with two A alleles **(Hb^AHb^A)** have **normal haemoglobin**, and therefore normal RBCs
- Those with two S alleles **(Hb^SHb^S)** develop **sickle cell anaemia**
- Those who are **heterozygous** for sickle cell **(Hb^AHb^S) produce both normal and abnormal haemoglobin** (as the alleles are codominant)
- Heterozygous individuals are usually healthy, but they **may suffer some symptoms of sickle cell anaemia under conditions of low blood oxygen**, such as high altitudes or during exercise
- Heterozygous individuals are said to be '**carriers**' of the sickle cell gene and are said to have **'sickle cell trait'**

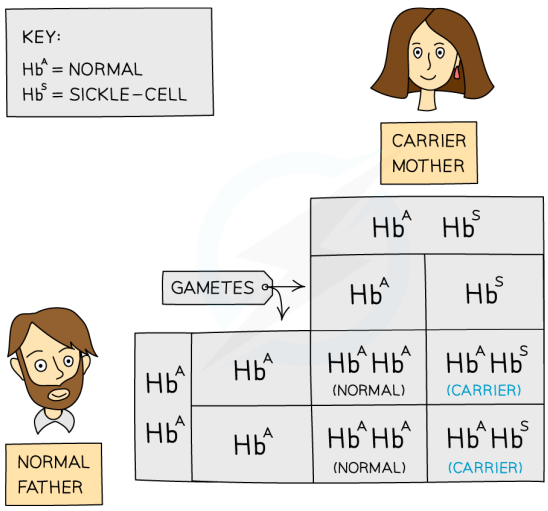
18 VARIATION & SELECTION

18.2 MUTATIONS cont...

YOUR NOTES

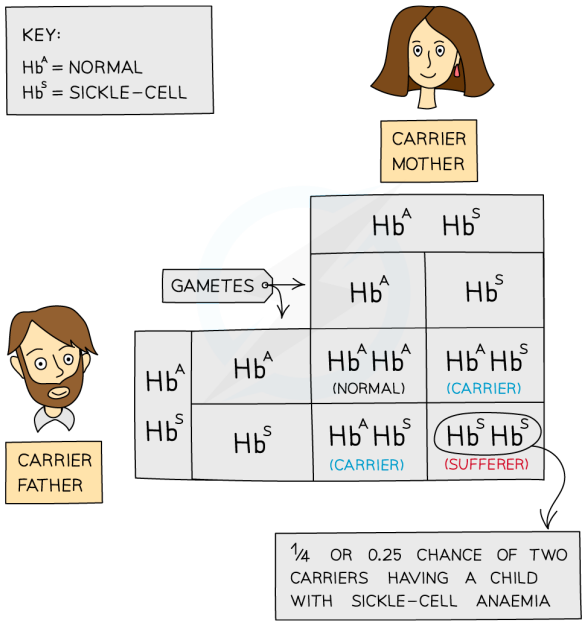
EXTENDED ONLY cont...

- Inheritance of sickle cell trait:



If one parent is a carrier of the sickle cell trait, there is a 1/2 chance their offspring will inherit the trait

- Inheritance of sickle cell disease:



If both parents are carriers of the sickle cell trait, there is a 1/4 chance they will have a child that suffers from sickle cell disease

18 VARIATION & SELECTION

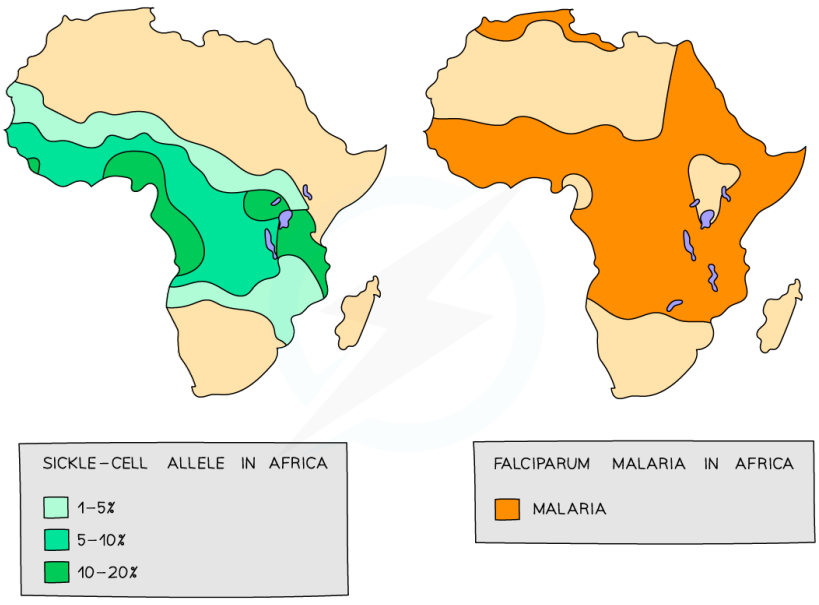
18.2 MUTATIONS cont...

YOUR NOTES

EXTENDED ONLY cont...

Sickle cell anaemia & natural selection

- In the United States, about **1 in 500** African-Americans develops sickle cell anaemia
- In Africa, about **1 in 100** individuals develops the disease
- Why is the frequency of such a serious disease so much higher in Africa? The answer is to do with **malaria**
- Malaria is a disease spread by **mosquitoes that are endemic in many areas of Africa** and causes over 1 million deaths per year
- In the late 1940s, studies of diseases in populations suggested a connection between African populations, malaria and sickle cell disease
- A theory was suggested; if the heterozygous individuals (Hb^AHb^S) are protected from malaria, and the negative effects (of sickle cell) are only present in the small proportion of people who are homozygous for the affected allele (Hb^SHb^S), then the affected allele could become more common
- Later studies supported this theory, showing that **African children who are heterozygous for the sickle cell allele have a ten-fold reduction in their risk of getting malaria**
- This means that there is a strong correlation between the prevalence of sickle cell anaemia in areas of the world where malaria is common



In areas of Africa where malaria is common, there is a corresponding higher rate of sickle cell disease

18 VARIATION & SELECTION

18.2 MUTATIONS cont...

YOUR NOTES

EXAM TIP

You should be able to explain **how these maps support the idea** that having a sickle cell allele gives resistance to malaria.

You should also be able to use **numerical data and graphs** given in exam questions to explain this.

18.3 ADAPTIVE FEATURES

Adaptations

- An adaptive feature is an **inherited feature that helps an organism to survive and reproduce in its environment**
- You should be able to interpret images or other information about a species in order to describe its adaptive features, for example:
    - Plants that live in different types of habitat have leaves that show adaptations for survival. The table shows some features of the leaves of three species of plant from different types of habitat.

SPECIES	HABITAT	ORIENTATION OF THE LEAVES	INDIVIDUAL LEAF AREA / cm^2	MEAN STOMATAL DENSITY / NUMBER OF STOMATA PER mm^2	
				UPPER EPIDERMIS	LOWER EPIDERMIS
ANNUAL MEADOW GRASS, POA ANNUA	GRASSLAND	VERTICAL	1 – 10	125	135
WHITE WATER LILY, NYMPAEA ALBA	THE SURFACE OF PONDS AND LAKES	HORIZONTAL	MORE THAN 1000	460	NONE
COMMON MYRTLE, MYRTUS COMMUNIS	DRY SCRUBLAND	HORIZONTAL	2 – 4	NONE	508

A typical question might be to explain how the leaf area and distribution and density of stomata help different species of plant survive in their different habitats

18 VARIATION & SELECTION

18.3 ADAPTIVE FEATURES cont...

YOUR NOTES

EXTENDED ONLY

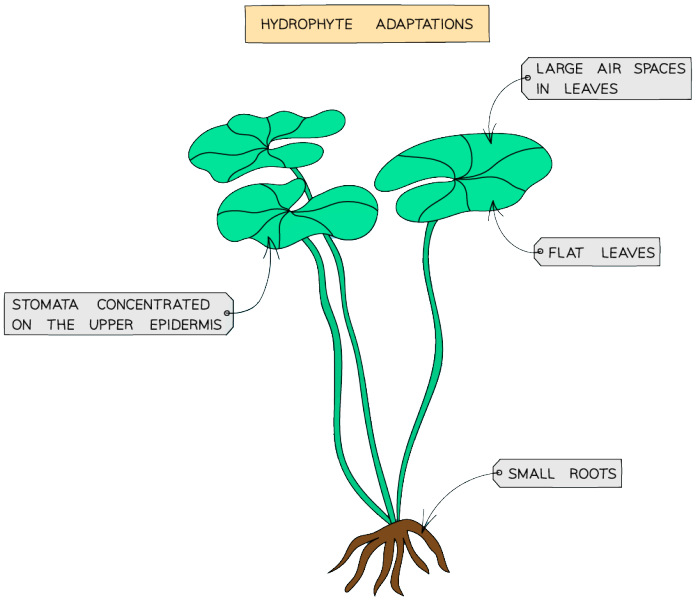
Adaptations & Fitness

- Adaptive features are the **inherited functional features of an organism that increase its fitness**
- Fitness is the **probability of an organism surviving and reproducing in the environment in which it is found**

Hydrophytes & Xerophytes

Hydrophytes

- Plants adapted to live in extremely wet conditions
- Common adaptations include:
  - Large air spaces in their leaves to keep them close to the surface of the water where there is more light for photosynthesis
  - Small roots as they can also extract nutrients from the surrounding water through their tissues
  - Stomata usually open all the time and mainly found on the upper epidermis of the leaf where they can exchange gases much more easily with the air



Hydrophytes are adapted to live in wet conditions such as ponds

18 VARIATION & SELECTION

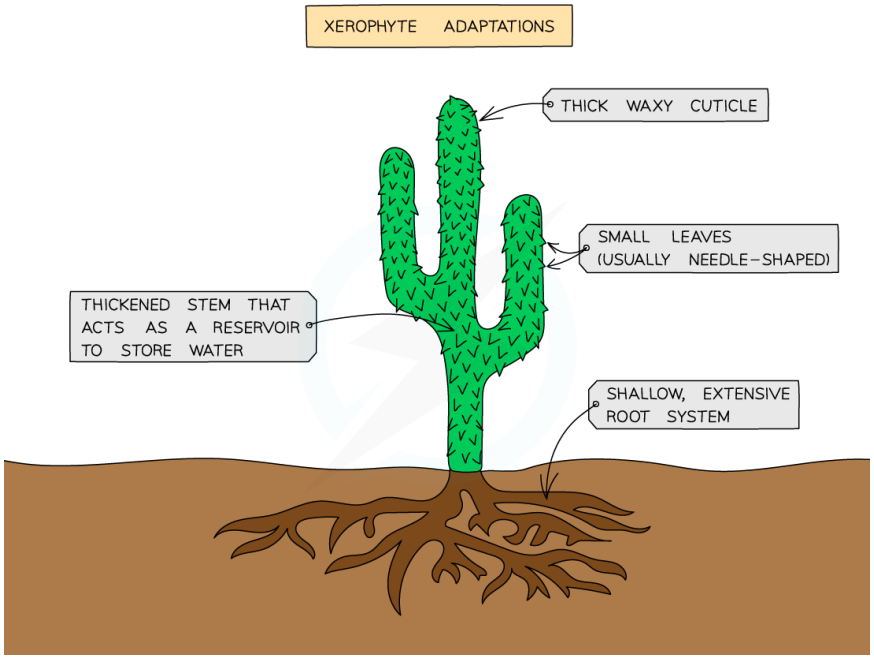
18.3 ADAPTIVE FEATURES cont...

YOUR NOTES

EXTENDED ONLY cont...

Xerophytes

- Plant adapted to live in **extremely dry conditions**
- Common adaptations include:
  - **Thick waxy cuticle** – the cuticle cuts down water loss in two ways: it acts as a barrier to evaporation and also the shiny surface reflects heat and so lowers temperature
  - **Sunken stomata**: stomata may be sunk in pits in the epidermis; moist air trapped here lengthens the diffusion pathway and reduces evaporation rate
  - **Leaf rolled** with stomata inside and an inner surface **covered in hairs** – traps moist air and prevents air movement across stomata which reduces transpiration
  - **Small leaves**: many xerophytic plants have small, needle-shaped leaves which reduce the surface area and therefore the evaporating surface
  - **Extensive shallow roots** allowing for the quick absorption of large quantities of water when it rains
  - **Thickened leaves or stems** which contain cells that store water



Xerophytes are adapted to live in extremely dry conditions such as deserts

18 VARIATION & SELECTION

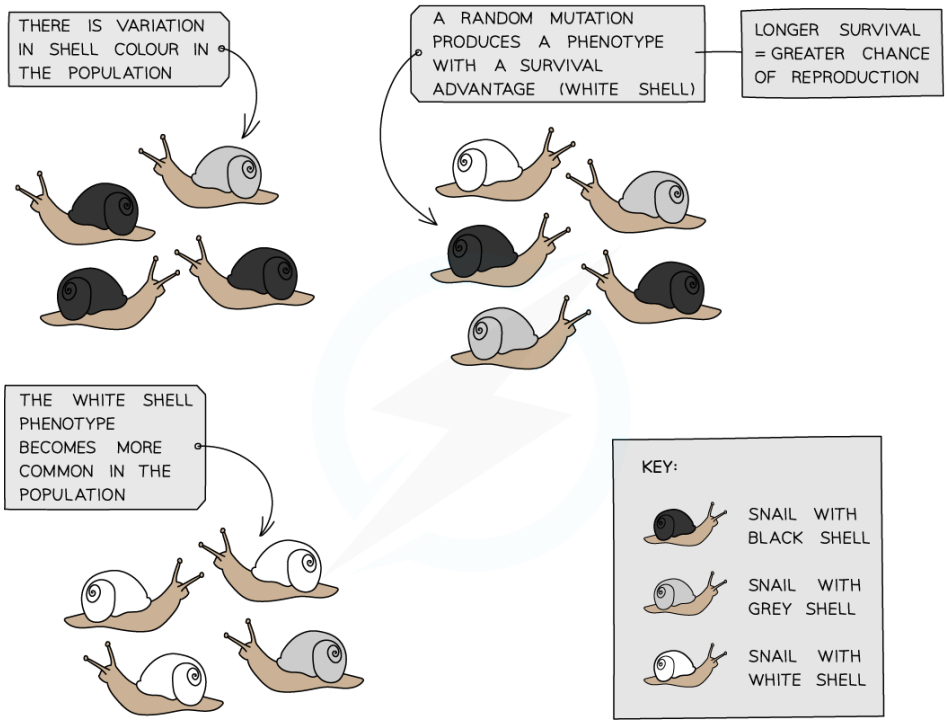
18.4 NATURAL SELECTION & EVOLUTION

YOUR NOTES

Natural Selection

- In any environment, the individuals that have the best adaptive features are the ones most likely to survive and reproduce
- This results in **natural selection**:
  - Individuals in a species show a **range of variation** caused by differences in genes
  - When organisms reproduce, they **produce more offspring** than the environment is able to support
  - This leads to **competition** for food and other resources which results in a **'struggle for survival'**
  - Individuals with characteristics **most suited to the environment** have a higher chance of survival and **more chances to reproduce**
  - Therefore the alleles resulting in these characteristics are **passed to their offspring at a higher rate** than those with characteristics less suited to survival
  - This means that in the next generation, there will be a **greater number of individuals** with the **better-adapted variations** in characteristics
- This theory of natural selection was put forward by **Charles Darwin** and became known as **'survival of the fittest'**

An example of natural selection



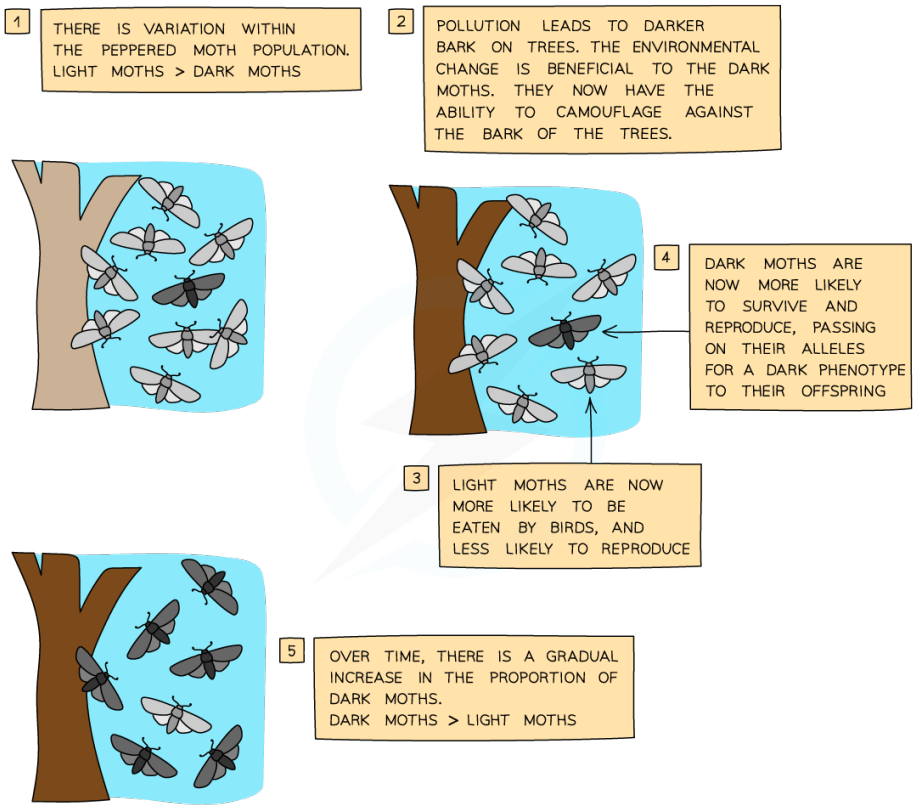
Natural selection illustrated by snail shell colour

18 VARIATION & SELECTION

18.4 NATURAL SELECTION & EVOLUTION cont...

YOUR NOTES

- Within the population of snails there is variation in shell colour
- Normal varieties of shell colours in this snail species is black or grey (as evidenced by the first picture)
- **Chance mutations** lead to a small number of snails / one snail having a white shell
- This 'small number' is shown in the second diagram where there are less white shelled snails than black or grey shelled snails
- The white shelled snail(s) **survive longer**
- This is the 'survival of the fittest', a term used to explain why some organisms succeed in the competitive struggle for survival against other members of their population
- The reason the white shelled snail(s) survive longer is **because they are better camouflaged**
- This means that they are **less likely to be seen by predators** and eaten
- As they survive longer they get **more opportunities to reproduce**
- And so the allele for white shells is passed onto offspring more frequently than the alleles for black or grey shells
- **Over generations, this is repeated** until the majority of snails in the population have white shells



Another good example of natural selection is the evolution of the peppered moths

18 VARIATION & SELECTION

18.4 NATURAL SELECTION & EVOLUTION cont...

YOUR NOTES

EXAM TIP

There are hundreds of thousands of examples of natural selection and you cannot possibly be familiar with all of them, however, they ALL follow the same sequence described above:

Based on the idea that within a species there is always variation and chance mutations, some individuals will develop a phenotype (characteristic) that gives them a survival advantage and therefore will:

- live longer,
- breed more
- and be more likely to pass their genes on.

Repeated over generations, the 'mutated' phenotype will become the norm.
Remember, it is the concept you have to understand, not the specific example.

EXTENDED ONLY

Evolution

- If the environment **does not change**, selection does not change
- This will favour individuals with the **same characteristics** as their parents
- If the environment **changes**, or a chance mutation produces a **new allele**, selection might now **favour individuals with different characteristics** or with the new allele
- So the individuals that survive and reproduce will have a **different set of alleles** that they pass on to their offspring
- Over time, this will bring about a **change in the characteristics of the species** – it will produce **evolution**
- Evolution is defined as the **change in adaptive features of a population over time as a result of natural selection**
- Natural selection results in a **process of adaptation**, which means that, over generations, those features that are better adapted to the environment become more common
- This means populations of organisms become **better suited to their environment**
- A good example of this is the **development of antibiotic** resistance by bacteria

18 VARIATION & SELECTION

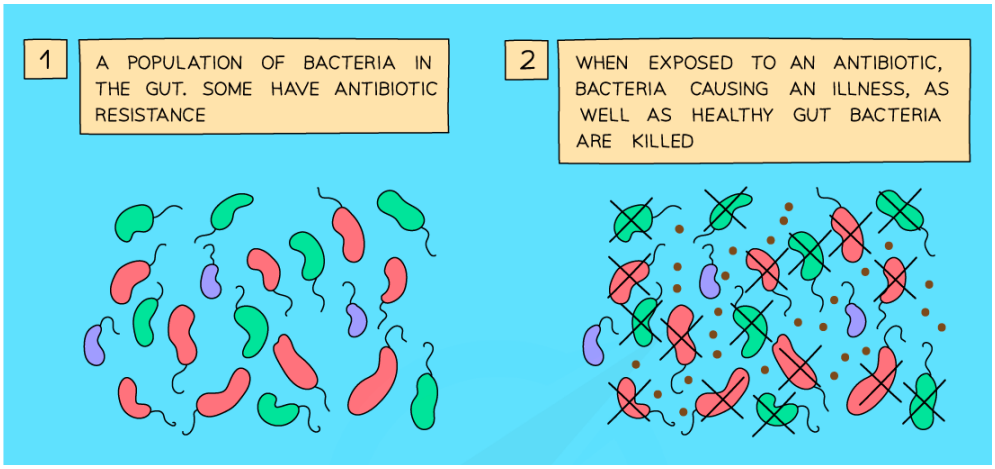
18.4 NATURAL SELECTION & EVOLUTION cont...

YOUR NOTES

EXTENDED ONLY cont...

Antibiotic Resistance in Bacteria

- An **antibiotic** is a chemical that can kill or inhibit the growth and reproduction of bacteria
- They are extremely useful to humans as some bacteria are **pathogenic** and can cause life-threatening disease
- Bacteria reproduce, on average, every 20 minutes and therefore **evolution occurs in a much shorter time span**
- Like all other organisms, **within a population there will be variation** caused by mutation
- A chance mutation might cause **some bacteria to become resistant** to an antibiotic (eg penicillin)
- When the population is treated with this antibiotic, the **resistant bacteria do not die**
- This means they can **continue to reproduce with less competition** from non-resistant bacteria, which are now dead
- Therefore the **genes for antibiotic resistance are passed on** with a much greater frequency to the next generation
- Over time the **whole population of bacteria becomes antibiotic-resistant** because the bacteria are best suited to their environment
- This is an example of natural selection that humans have helped to develop due to **overuse of antibiotics** in situations where they were not really necessary, for example:
    - for treatment of non-serious infections
    - routine treatment to animals in agriculture
    - failure to finish prescribed course of antibiotics

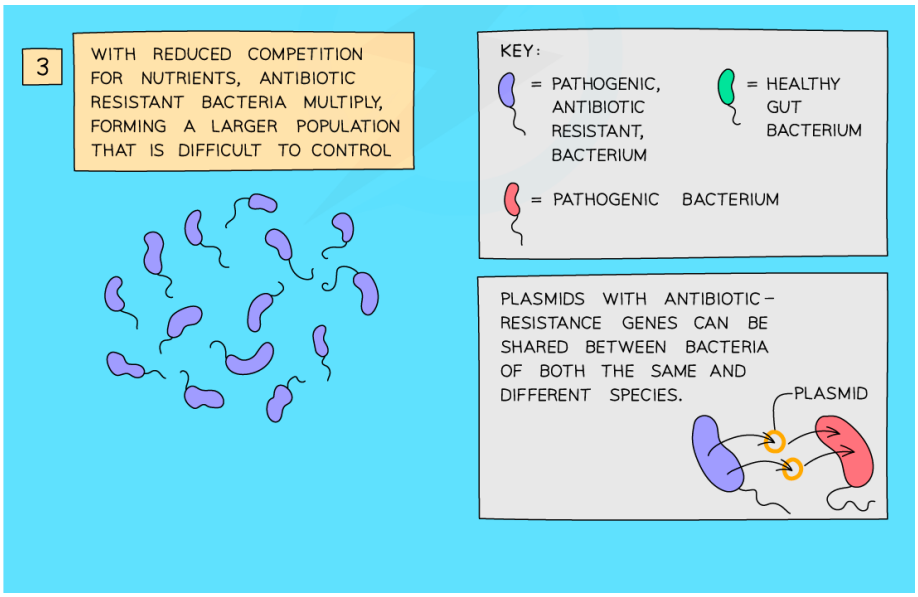


18 VARIATION & SELECTION

18.4 NATURAL SELECTION & EVOLUTION cont...

YOUR NOTES

EXTENDED ONLY cont...



Development of antibiotic resistance in bacteria

- Increases in the population of antibiotic-resistant bacteria cause infections and diseases which are harder to control as it is **difficult to find antibiotics that certain strains of bacteria are not resistant to**
- An example of this is **MRSA**, a very dangerous bacterial strain that is resistant to most antibiotics
- If someone gets infected with MRSA they cannot be treated easily
- Adding to these difficulties, the number of new antibiotics discovered has slowed significantly

18 VARIATION & SELECTION

18.5 SELECTIVE BREEDING

YOUR NOTES

Artificial Selection

- Selective breeding means to **select individuals with desirable characteristics and breed them together**
- The process doesn't stop there though because it's likely that not all of the offspring will show the characteristics you want so **offspring that do show the desired characteristics are selected and bred together**
- This process has to be **repeated for many successive generations** before you can definitely say you have a **'new breed'** which will **reliably** show those selected characteristics in all offspring

EXTENDED ONLY

Natural vs Artificial Selection

NATURAL SELECTION	ARTIFICIAL SELECTION
OCCURS NATURALLY	ONLY OCCURS WHEN HUMANS INTERVENE
RESULTS IN DEVELOPMENT OF POPULATIONS WITH FEATURES THAT ARE BETTER ADAPTED TO THEIR ENVIRONMENT AND SURVIVAL	RESULTS IN DEVELOPMENT OF POPULATIONS WITH FEATURES THAT ARE USEFUL TO HUMANS AND NOT NECESSARILY TO SURVIVAL OF THE INDIVIDUAL
USUALLY TAKES A LONG TIME TO OCCUR	TAKES LESS TIME AS ONLY INDIVIDUALS WITH THE DESIRED FEATURES ARE ALLOWED TO REPRODUCE

Selectively Breeding Plants

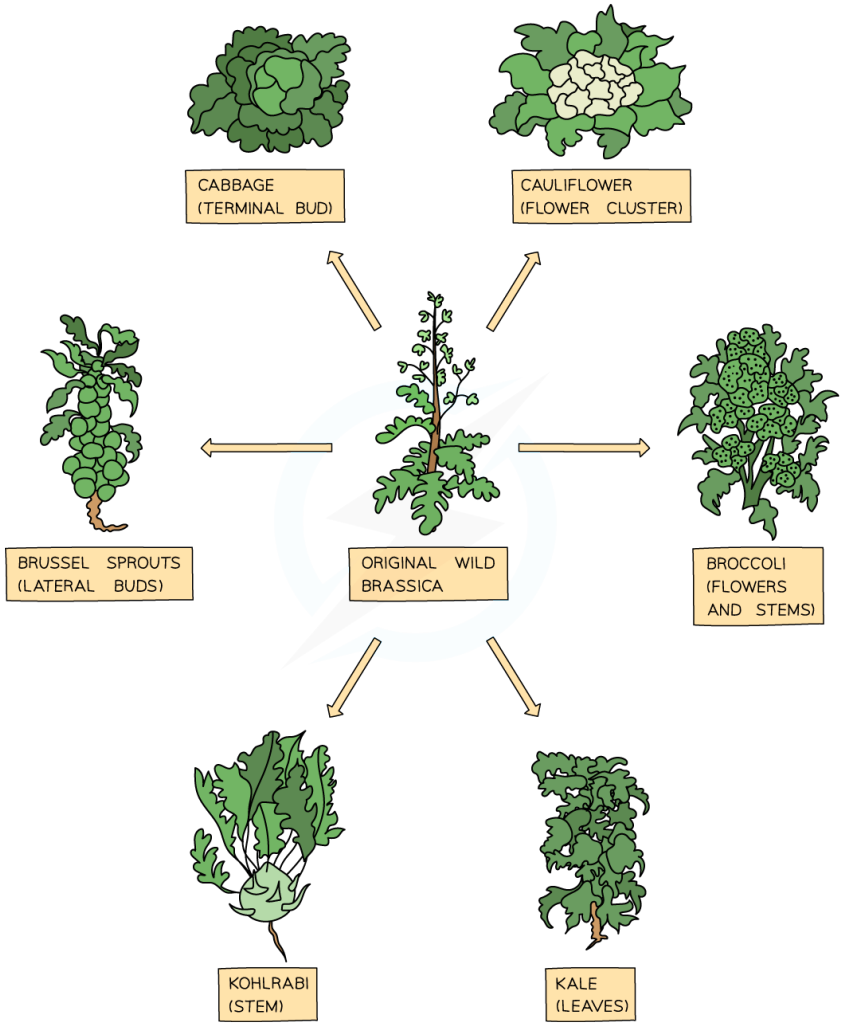
- Plants are selectively bred by humans for development of many characteristics, including:
  - disease resistance in food crops
  - increased crop yield
  - hardiness to weather conditions (e.g. drought tolerance)
  - better tasting fruits
  - large or unusual flowers
- An example of a plant that has been selectively bred in multiple ways is wild brassica, which has given rise to cauliflower, cabbage, broccoli, brussel sprouts, kale and kohlrabi:

18 VARIATION & SELECTION

18.5 SELECTIVE BREEDING cont...

YOUR NOTES

EXTENDED ONLY cont...



An example of selective breeding in plants

Selectively Breeding Animals

- Selective breeding of animals has been carried out by humans for thousands of years
- It takes place in the same way as selective breeding of plants
- Individuals with the **characteristics you want are bred together** (often several different parents all with the desired characteristics are chosen so siblings do not have to be bred together in the next generation)
- Offspring that show the desired characteristics are **selected and bred together**

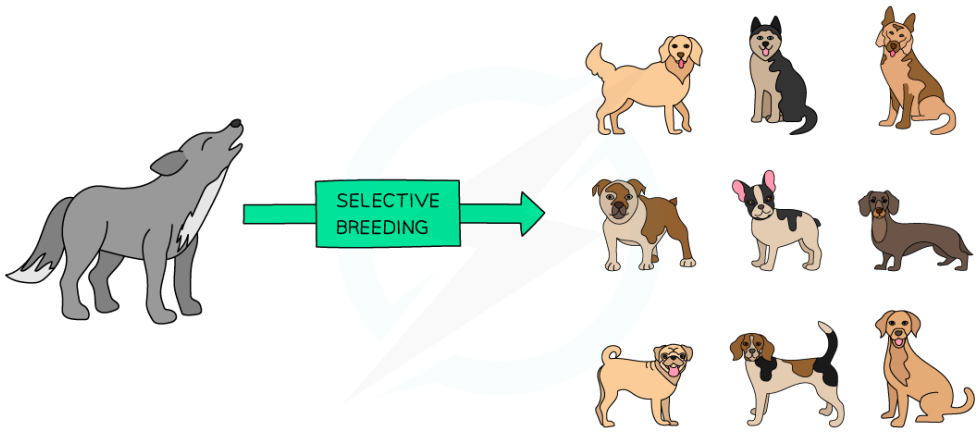
18 VARIATION & SELECTION

18.5 SELECTIVE BREEDING cont...

YOUR NOTES

EXTENDED ONLY cont...

- This process is **repeated for many successive generations** before you can definitely say you have a 'new breed' which will reliably show those selected characteristics in all offspring
- Animals are commonly selectively bred for various characteristics, including:
  - **cows, goats and sheep that produce lots of milk or meat**
  - **chickens that lay large eggs**
  - **domestic dogs that have a gentle nature**
  - **sheep with good quality wool**
  - **horses with fine features and a very fast pace**
- An example of an animal that has been selectively bred by humans in many ways to produce breeds with many different characteristics is the **domestic dog**, all breeds of which are descended from wolves



Selective breeding has produced many different breeds of domestic dog

EXAM TIP

Make sure that you include the need to **repeat the selective breeding for many generations** in any exam answer you give

Selecting two parents with desired characteristics, breeding them and stopping there is not selective breeding and will not give rise to a new breed.

> NOW TRY SOME EXAM QUESTIONS

18 VARIATION & SELECTION

EXAM QUESTIONS

YOUR NOTES

QUESTION 1

An island's entire population of a species of butterfly are descended from just two parents. These were introduced from the mainland.

Which of the following statements about this species of butterfly, compared with that of the mainland, is correct?

A The population shows more genetic variety.

B The population will adapt more slowly to environmental changes.

C The population shows more genetic variety.

D The population is less in danger of collapsing from disease.

QUESTION 2

What is a mutation?

A A process used in genetic engineering.

B A type of continuous variation.

C A condition caused by a dominant allele.

D A change in a gene.

QUESTION 3

Which of the following characteristics show discontinuous variation?

A Length of foot

B Weight

C Tongue rolling

D Height

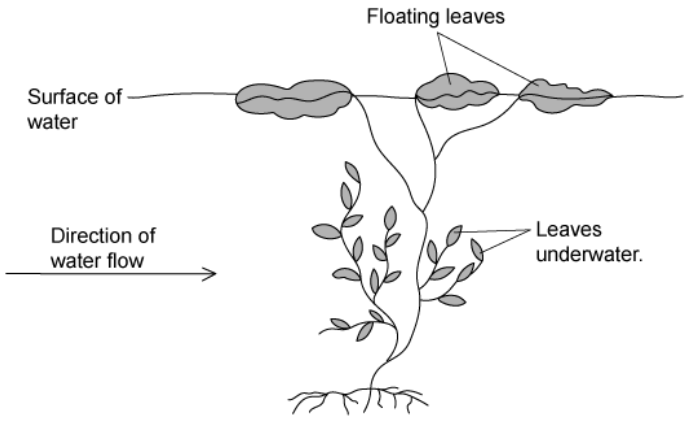
18 VARIATION & SELECTION

EXAM QUESTIONS cont...

YOUR NOTES

QUESTION 4

The diagram shows a hydrophyte in a stream.



What statement is true about the leaves underwater?

A They offer little resistance to water flow.

B They have a thick cuticle.

C They require many xylem vessels for support.

D They cannot photosynthesise.

QUESTION 5

A patient with a bacterial infection is treated with antibiotics, but some of the bacteria survive.

Which statement is correct about the bacteria that have survived?

A The bacteria will now be resistant to all antibiotics.

B The resistant bacteria is a result of selective breeding.

C The bacteria will have undergone a process of natural selection.

D The antibiotic will now work better on the next generation of bacteria.

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