Cambridge (CIE) IGCSE Biology

Your notes

Variation & Natural Selection

Contents

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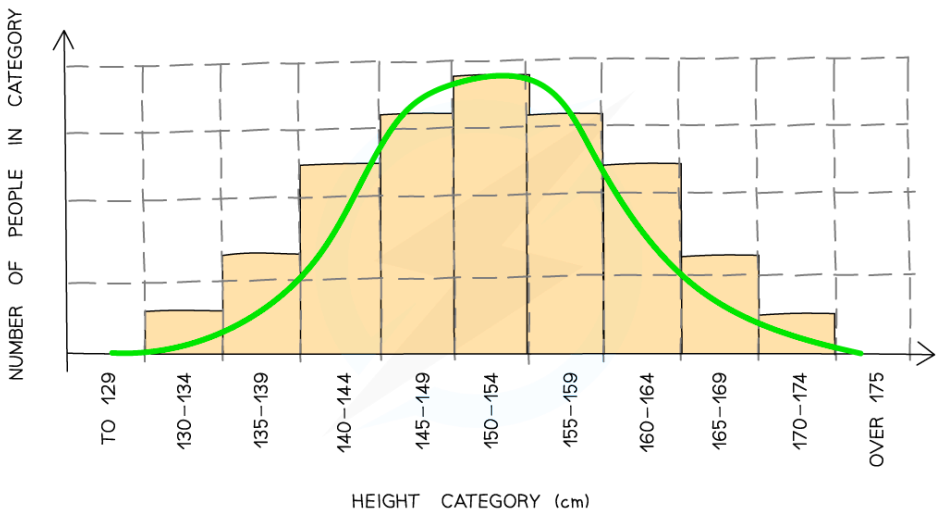
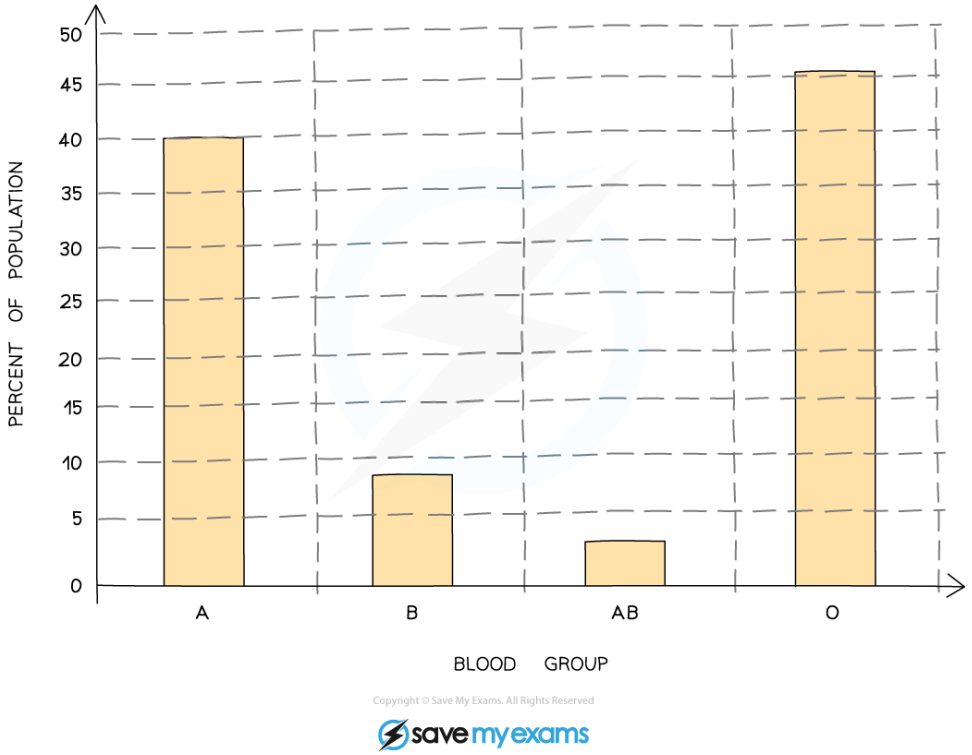
Types of Variation

What is Variation in Biology?

- 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 gives a 'step – like' shape



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

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**

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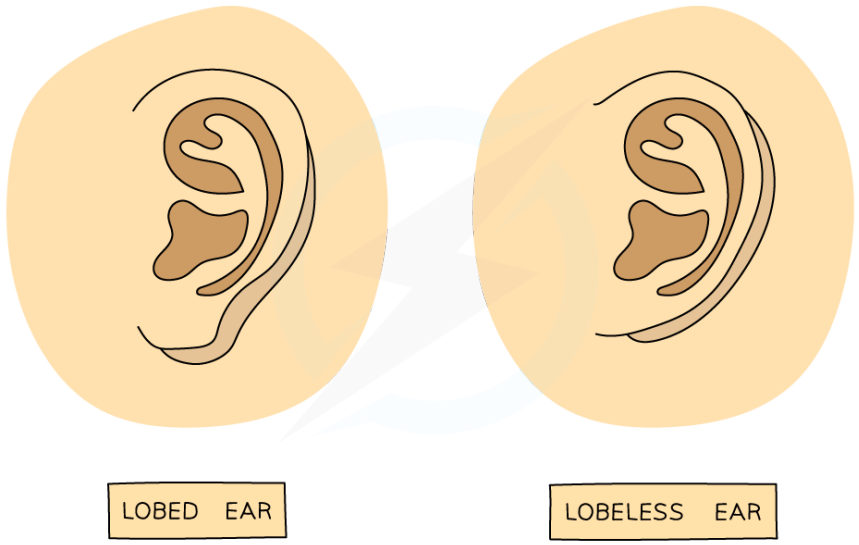

Whether earlobes are attached (lobeless) or free (lobed) is an example of genetic variation

Environmental Variation

- Characteristics of all species can be affected by environmental factors such as climate, diet, accidents, culture and lifestyle
- In this instance 'environmental' simply means 'outside of the organism' and so can include factors like climate, diet, culture, lifestyle and accidents during lifetime
- 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

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- 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

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Mutation

- Mutations are **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 organism - for example, **sickle cell anaemia** in humans
- Mutations happen **spontaneously and continuously** but their frequency can be increased by exposure to the following:
  - **Ionising radiation** (e.g. gamma rays and X - rays) - which can damage bonds and cause changes in base sequences
  - Some **non-ionising radiation (**e.g. ultra-violet) - can also 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

Mutation: Extended

- **Genetic variation** in populations can be caused by a variety of sources:
  - Mutations
    - Mutations are **random genetic changes** to the base sequence of DNA
    - New alleles form through these random changes to DNA
  - Meiosis
    - New allele combinations form through segregation

- Random mating
  - Which partnerships form for sexual reproduction
- Random fertilisation
  - Which sperm and egg combinations occur during sexual reproduction

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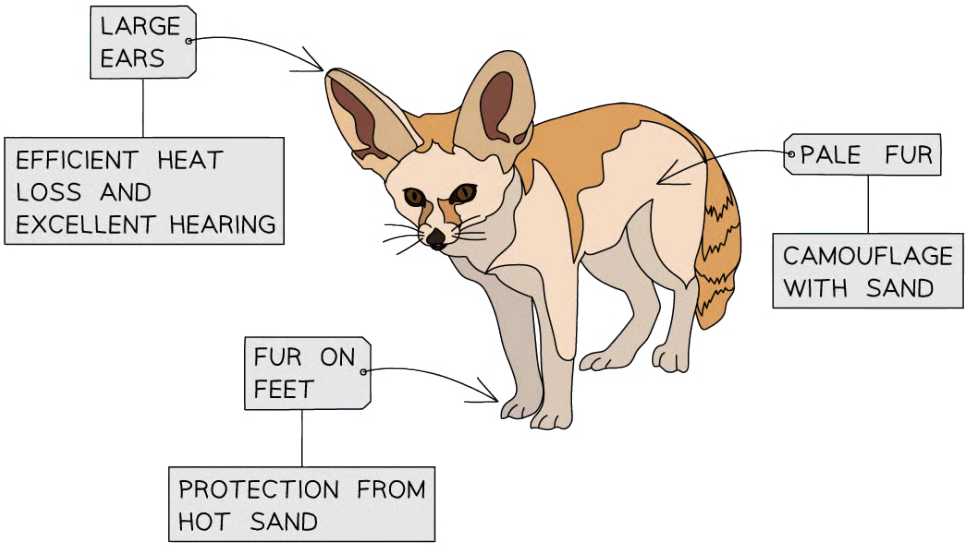
Adaptations & fitness

- Adaptive features can be defined as:

Inherited features that help an organism to survive and reproduce in its environment.

- It is possible to describe adaptive features of an organism using information provided, e.g. from images or data



Adaptive features can be identified in images of unfamiliar organisms, e.g. here a fennec fox can be seen to have large ears, pale fur and furry feet

Worked Example

The table below contains information about the urine concentration of several different mammal species, as well as the environments in which the species live.

Species	Environment	Urine concentration (milliosmoles/L)
Human	Temperate	1450
Beaver	Fresh water	480
Dolphin	Salt water	1500
Gerbil	Desert	5400

Suggest and explain one way in which gerbils are adapted to their environment.

Answer:

- Gerbils are able to produce urine that is much more concentrated than other species
- This allows gerbils to conserve water / excrete less water in their urine

The information provided here tells us that gerbils live in a desert environment, and also allows us to compare urine concentration in several species, so we can see that gerbil urine is around 4× more concentrated than some of the other mammals.

Producing concentrated urine means that gerbils don't lose very much water when they excrete urea in their urine, allowing them to conserve water in an environment where water may be difficult to replace.

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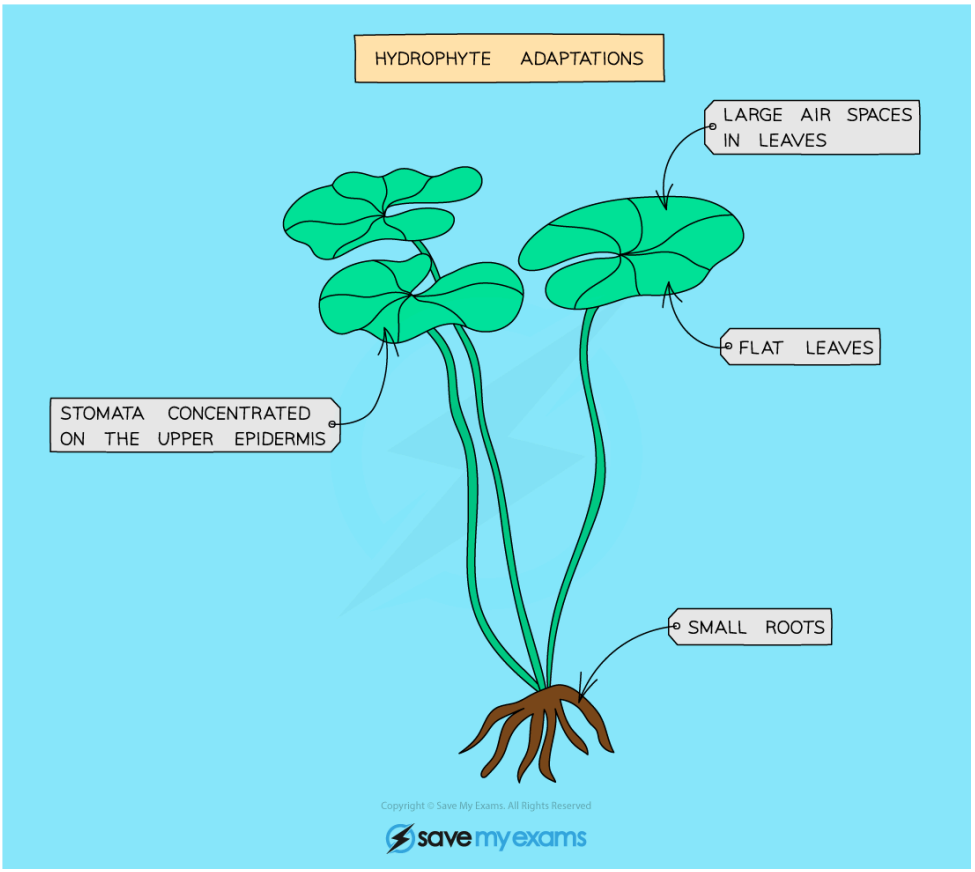
Hydrophytes & Xerophytes: Extended

Extended Tier Only

Hydrophytes

- Plants adapted to live in **extremely wet conditions**
- Common adaptations include:
  - **Large air spaces in their leaves** for flotation, to keep the leaves 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

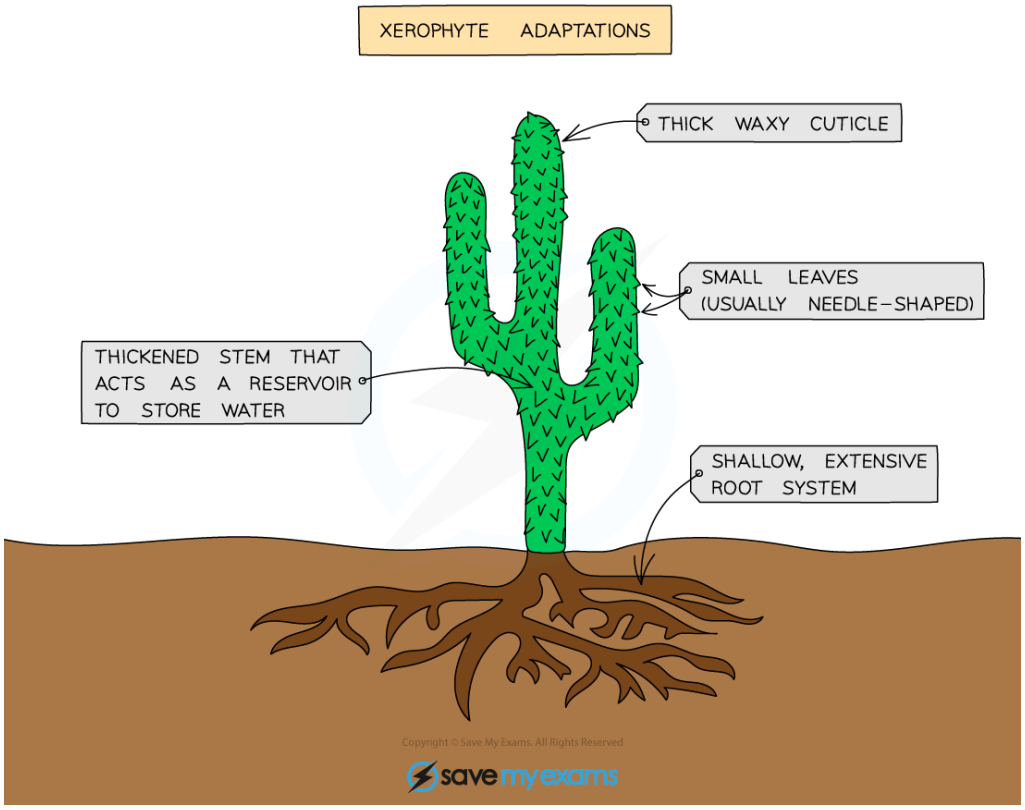


Hydrophytes are adapted to live in wet conditions such as ponds

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 the temperature
  - **Sunken stomata**: stomata may be sunk in pits in the epidermis; moist air trapped here lengthens the diffusion pathway and reduces the 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** allow 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

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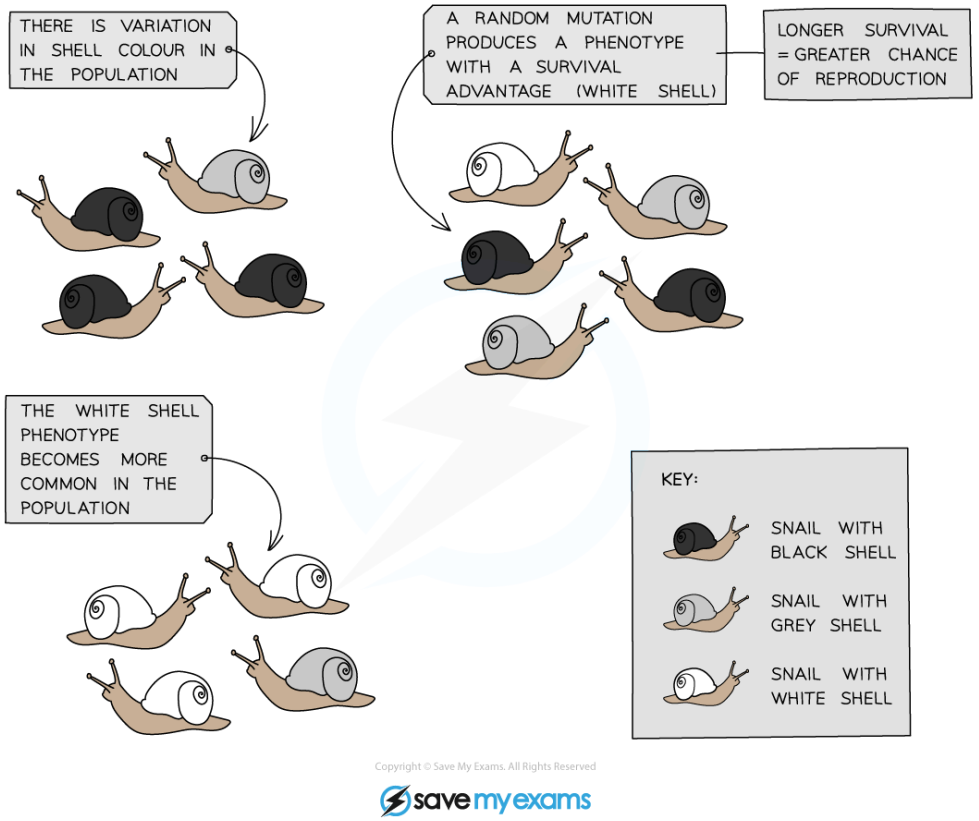
Natural Selection

- 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

- 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

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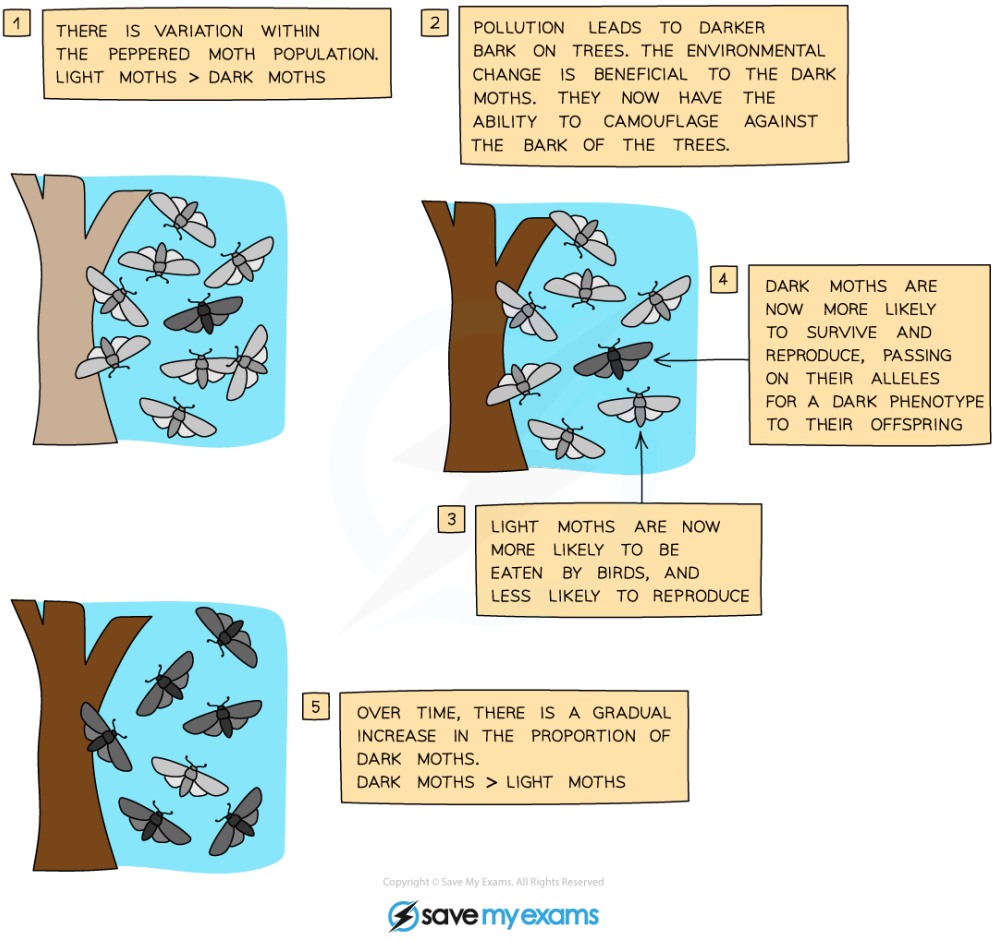

Another good example of natural selection is the evolution of the peppered moths

Examiner Tips and Tricks

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.

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Adaptation by Natural Selection: Extended

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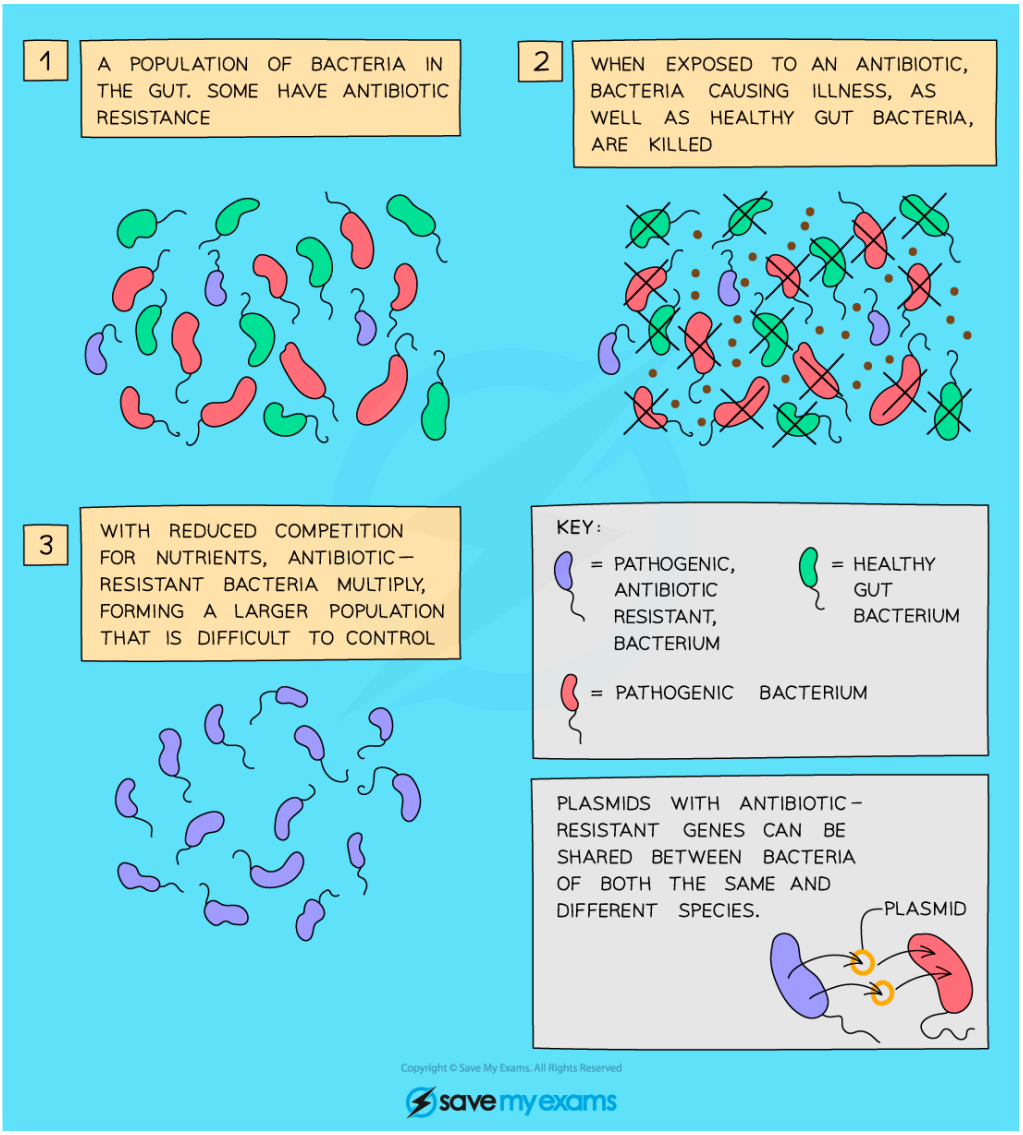
- If the environment **does not change**, selection does not change
- This will favour individuals with the **same characteristics** as their parents
- If the environment **changes**, or a chance mutation produces a **new allele**, selection might now **favour individuals with different characteristics** 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 is how **evolution** occurs
- This means populations of organisms become **better suited to their environment**
- A good example of this is the **development of antibiotic resistance** by bacteria


1
A POPULATION OF BACTERIA IN THE GUT. SOME HAVE ANTIBIOTIC RESISTANCE
2
WHEN EXPOSED TO AN ANTIBIOTIC, BACTERIA CAUSING ILLNESS, AS WELL AS HEALTHY GUT BACTERIA, ARE KILLED
3
WITH REDUCED COMPETITION FOR NUTRIENTS, ANTIBIOTIC-RESISTANT BACTERIA MULTIPLY, FORMING A LARGER POPULATION THAT IS DIFFICULT TO CONTROL
KEY:
= PATHOGENIC, ANTIBIOTIC RESISTANT, BACTERIUM
= HEALTHY GUT BACTERIUM
= PATHOGENIC BACTERIUM
PLASMIDS WITH ANTIBIOTIC-RESISTANT GENES CAN BE SHARED BETWEEN BACTERIA OF BOTH THE SAME AND DIFFERENT SPECIES.
PLASMID
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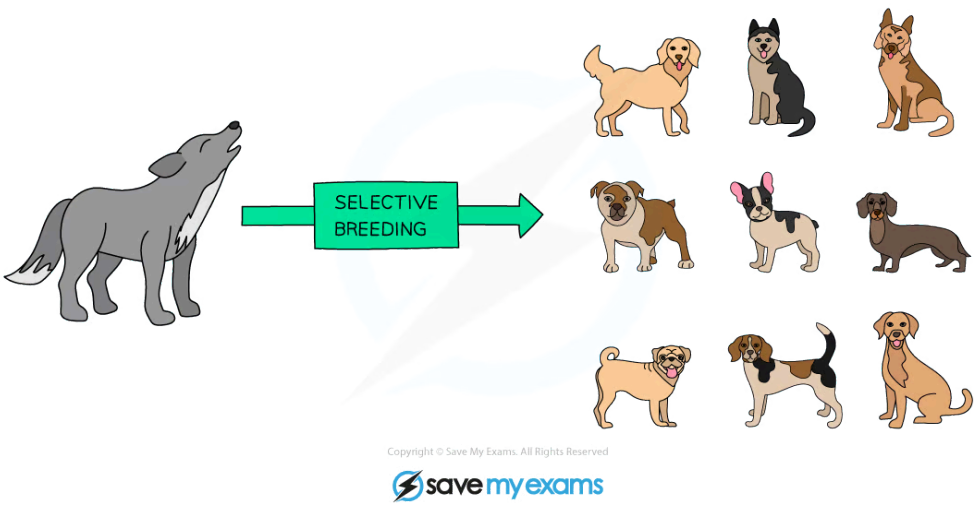
Selective Breeding

- 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

Selective breeding in domesticated animals

- An example of selective breeding is dog breeders who select which dogs can mate together to increase the likelihood of puppies displaying desirable characteristics eg. coat colour

This has given rise to the many recognisable dog breeds of today, all the same species (*Canis familiaris*) and all descended from one breed

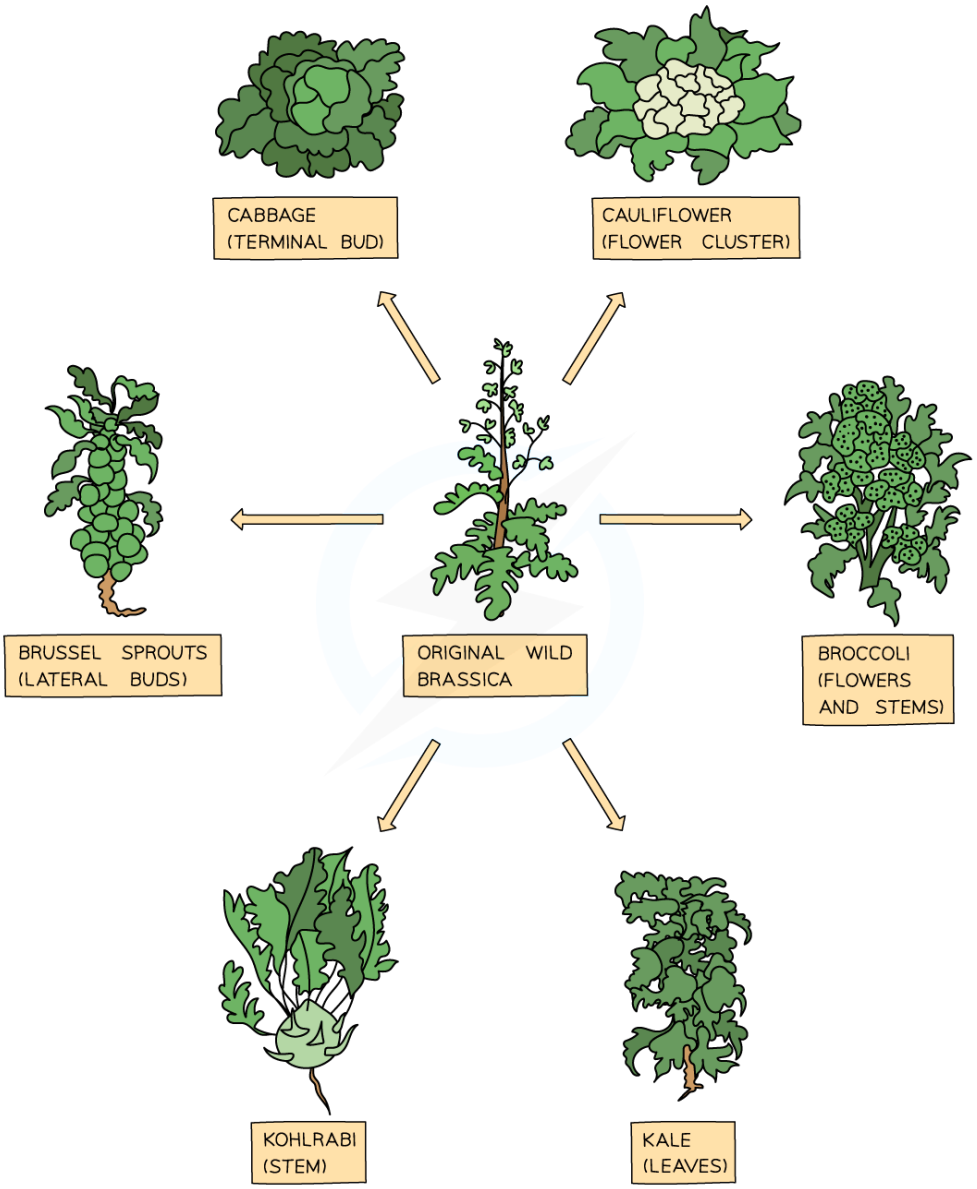


Selective breeding in crop plants

- Plants are selectively bred by humans for the 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, Brussels sprouts, kale and kohlrabi:



Selective breeding in crop plants

Artificial vs natural selection: Extended

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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

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