AQA B6b: Inheritance: Variation and Evolution
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keyword	definition
genome	the entire genetic material of that organism. The whole human genome has now been studied and this will have great importance for medicine in the future.
phenotype	Physical expression of an allele combination for example black fur, blonde hair, blue eyes.
variation	Differences in the characteristics of individuals in a population. This can be due to the genes they have inherited (genetic causes) or the conditions in which they developed (environmental causes), or a combination of the two.
mutation	A change in a chromosome or gene.
evolution	a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species.
natural selection	the process whereby organisms better adapted to their environment tend to survive and produce more offspring.
theory of evolution	The theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago.
species	Organisms that are able to breed together to form fertile offspring (offspring can have young)
selective breeding	(also called artificial selection) is the process by which humans breed plants and animals for particular genetic characteristics.
genetic engineering	A process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.
cloning	Producing identical offspring from a parent organism
fossil	the 'remains' of organisms from millions of years ago, which are found in rocks.
extinction	when there are no remaining individuals of a species still alive. This could be due to extreme geological events, disease, climate change, habitat destruction, hunting by humans.

Variation

The genome and how it interacts with the environment influence the development of the phenotype of an organism.

there is usually extensive genetic variation within a population of a species. In other words, organisms of the same species have differences.

All variants arise from mutations - most of these mutations have no effect on the phenotype; some influence phenotype; very few determine phenotype.

Mutations occur continuously. Very rarely a mutation will lead to a new phenotype. If the new phenotype is suited to an environmental change it can lead to a relatively rapid change in the species.

Evolution

Evolution occurs through the natural selection of variants that give rise to phenotypes best suited to their environment.

If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species.

Natural selection

Charles Darwin, as a result of observations on a round the world expedition, backed by years of experimentation and discussion and linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection:

Individual organisms within a particular species show a wide range of variation for a characteristic and this variation is because of differences in their **genes**

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Animals will compete creating a struggle for existence.

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Individuals with characteristics most suited to the environment are more likely to survive to breed successfully.

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The characteristics that have enabled these individuals to survive are then passed on to the next generation.

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3 key scientists

Alfred Wallace independently proposed the theory of evolution by natural selection and published joint writings with Darwin in 1858 1858 which prompted Darwin to publish On the Origin of Species (1859) the following year.

Charles Darwin's ideas on natural selection were documented in the book *On the Origin of Species*, which was published in 1859. There was much controversy surrounding these revolutionary new ideas.

Other theories, including that of **Jean-Baptiste Lamarck**, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

Speciation

Alfred Wallace worked worldwide gathering evidence for evolutionary theory. He is best known for his work on warning colouration in animals and his theory of speciation. Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation.

The speciation process: Due to isolation of a population of a species e.g. species have a geographical barrier e.g. sea.

Environmental conditions differ for populations e.g. types of food available, habitat.

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Individuals in each population most suited to their environments are more likely to breed successfully.

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Over long periods of time each population will have greater differences in their genotype.

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If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species

The theory of evolution by natural selection was only gradually accepted because:

- the theory challenged the idea that God made all the animals and plants that live on Earth
- there was insufficient evidence at the time the theory was published to convince many scientists
- the mechanism of inheritance and variation was not known until 50 years after the theory was published.

Evidence for evolution

The theory of evolution by natural selection is now widely accepted. Evidence for Darwin's theory is now available as it has been shown that characteristics are passed on to offspring in genes. There is further evidence in the fossil record and the knowledge of how resistance to antibiotics evolves in bacteria.

Fossil evidence

Fossils may be formed:
from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent
when parts of the organism are replaced by minerals as they decay
as preserved traces of organisms, such as footprints, burrows and rootlet traces.

Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain about how life began on Earth.

We can learn from fossils how much or how little different organisms have changed as life developed on Earth.

Antibiotic resistance

Bacteria can evolve rapidly because they reproduce at a fast rate.
Mutations of bacterial pathogens produce new strains. Some strains might be resistant to antibiotics, and so are not killed. They survive and reproduce, so the population of the resistant strain rises. The resistant strain will then spread because people are not immune to it and there is no effective treatment.

MRSA is resistant to antibiotics.
To reduce the rate of development of antibiotic resistant strains:
doctors should not prescribe antibiotics inappropriately, such as treating non-serious or viral infections
patients should complete their course of antibiotics so all bacteria are killed and none survive to mutate and form resistant strains
the agricultural use of antibiotics should be restricted.
The development of new antibiotics is costly and slow. It is unlikely to keep up with the emergence of new resistant strains.

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Selective breeding

Selective breeding (artificial selection) is the process by which humans breed plants and animals for particular genetic characteristics.

Humans have been doing this for thousands of years since they first bred food crops from wild plants and domesticated animals.

Choose parents with the desired characteristic from a mixed population

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Breed together

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From the offspring choose organisms with the desired characteristic

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Breed together

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Continue over many generations until all the offspring show the desired characteristic

The characteristic can be chosen for usefulness or appearance:

- Disease resistance in food crops.
- Animals which produce more meat or milk.
- Domestic dogs with a gentle nature.
- Large or unusual flowers.

Selective breeding can lead to 'inbreeding' where some breeds are particularly prone to disease or inherited defects.

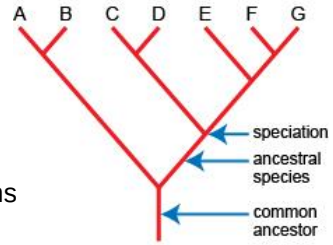
Classification

Carl Linnaeus classified living things into groups depending on their structure and characteristics. He classified living things into:

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	Homo
Species	sapiens

Organisms are named by the binomial system of genus and species. Humans are *Homo sapiens.*

Evolutionary trees are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms.



As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed.

Due to evidence available from chemical analysis there is now a 'three domain system' developed by **Carl Woese**. In this system organisms are divided into:

- **archaea** (primitive bacteria usually living in extreme environments)
- **bacteria** (true bacteria)
- **eukaryota** (which includes protists, fungi, plants and animals).

Gregor Mendel – it took a long time for scientists to recognise the work of Mendel

In the mid-19th century Gregor Mendel carried out breeding experiments on plants. One of his observations was that the inheritance of each characteristic is determined by 'units' that are passed on to descendants unchanged.

In the late 19th century behaviour of chromosomes during cell division was observed using a microscope.

In the early 20th century it was observed that chromosomes and Mendel's 'units' behaved in similar ways. This led to the idea that the 'units', now called genes, were located on chromosomes.
In the mid-20th century the structure of DNA was determined and the mechanism of gene function worked out.

This scientific work by many scientists led to the gene theory being developed.

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Genetic engineering

Plant crops have been genetically engineered to be resistant to diseases or to produce bigger better fruits.
Crops that have had their genes modified in this way are called genetically modified (GM) crops.
Bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes.
In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' and transferred to cells of other organisms.

The main steps in the genetic engineering process

Enzymes are used to isolate the required gene

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Gene is inserted into a vector – a bacterial plasmid or virus

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Vector inserts genes into the required cells

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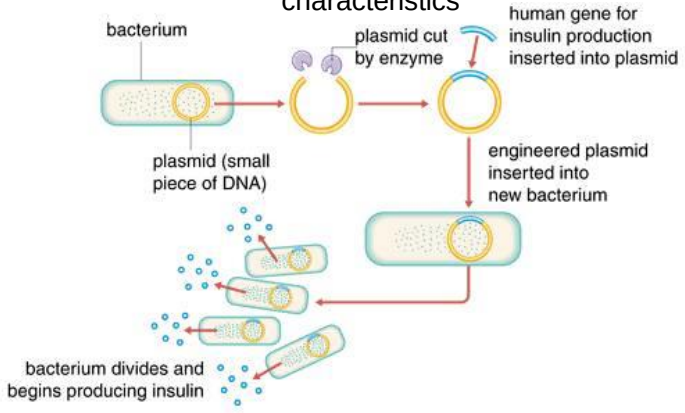
Genes are transferred to plants/animals/microbes at an early stage of development so they develop the required characteristics



Genetic engineering advantages	Genetic engineering disadvantages
GM crops generally show increased yields. GM crops will be resistant to insect attack or to herbicides. Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders.	Concerns about GM crops include the effect on populations of wild flowers and insects. Some people feel the effects of eating GM crops on human health have not been fully explored. Not everyone is convinced genetic engineering is safe or that the effects on health are understood.

Cloning techniques in plants/animals

Tissue culture: using small groups of cells from part of a plant to grow identical new plants. This is important for preserving rare plant species or commercially in nurseries.

Cuttings:an older, but simple, method used by gardeners to produce many identical new plants from a parent plant.

Embryo transplants: Splitting apart cells from animals embryo before they become specialised. New clone embryos are inserted into womb of 'host' adult mothers.

Adult cell cloning:

Nucleus is removed from an unfertilised egg

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Nucleus from body cell is inserted into egg cell.

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An electric shock stimulates the egg to divide into an embryo

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Embryo cells are genetically identical to adult cells.

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When embryo has developed into ball of cells it is inserted into host womb