Biology Knowledge Organiser
B14 - Variation and evolution

Variation

Organisms vary, both organisms of different species (obviously) and organisms of the same species (also obviously!). Variation (differences) are caused by both genetic causes and environmental causes.

- Some differences are only due to **inherited** genes – they are entirely **genetic**;
- Some differences are only due to the conditions in which an organism developed and lives – they are entirely **environmental**;
- Some differences are due to a **combination** of genetic and environmental influences. In this case, we say the genome of an organism and its environment **interact** to affect the phenotype of the organism.

In most populations of most species of organism, there is a lot of genetic variation. The general term for versions of the same organism (i.e. different individuals of a species) is with different genetic information is **variants**. All variants arise from **mutations**. Mutations can be dangerous (remember your work on cancer, for instance), but usually have no effect. Sometimes, they have a beneficial effect. Overall:

- Mutations happen continuously;
- most mutations will not affect the phenotype at all;
- some will influence the phenotype (maybe change it a bit);
- very few mutations cause a total change in phenotype.

The last case is rare, but very important. If a mutation occurs that leads to a new phenotype, and the new phenotype makes the organism better suited to the environment, it will lead to a rather rapid change in the species, by **natural selection**.

Evolution

Evolution is the change in inherited (genetic) characteristics of organisms over time. Many theories of evolution have been suggested, but Darwin's theory of natural selection is the one with by far the most evidence. Darwin noticed that all organisms produce more offspring than they need to replace themselves, and yet population sizes stay pretty steady from generation to generation. He also observed that all species show variation, and that life is tough for organisms – only the best adapted survive. So, based on these observations, we can explain evolution by natural selection like this:

1. A population of organisms shows variation – there are **variants** in the population
2. The organisms are in **competition** to survive
3. **Survival of the fittest** – only the variants with the phenotypes best suited to the environment get to survive
4. **Reproduction** – those who survive get to reproduce
5. **Genetic inheritance** – their offspring inherit the genes from their parents, so the successful phenotype becomes more common in the next generation. This continues from generation to generation.

Key Terms	Definitions
Variation	Differences in the characteristics of individuals in a population.
Genetic variation	Differences in the genome between individuals. This often causes differences in physical characteristics.
Variants	Different versions of the same thing. Often this term is used to describe individuals who are different from others in a specific genetic way – for instance the 'long haired cat variant' from earlier.
Mutation	A change to DNA. Mutations can cause a change in the sequence of amino acids being produced, affecting the protein being produced from the DNA code.
Evolution	Change in the inherited characteristics of organisms over time. Evolution happens through **natural selection**.
Natural selection	The process that changes the inherited characteristics of organisms over time. This explains the adaptations of organisms to their environment AND the formation of new species of organism.
Common ancestor	An ancestor in common. For instance, if you have a sister, your granddad is a common ancestor to you both.

New species

The theory of evolution by natural selection tells us that all species of living things have evolved from a single, simple type of life form. We know this **common ancestor** was alive on Earth over three billion years ago. How we ended up with millions of different species from this single species is also explained by evolution by natural selection.

Essentially, two populations of one species (e.g. a population of fish is divided into two populations by geographical changes such as the joining of North and South America) can become two different species. This happens when the two populations become so different in their phenotypes that they can no longer **interbreed** to produce **fertile offspring**. This is the point when we define them as different species. For example, tigers and lions are different species (the population of their common ancestor has been separated for a long time) – they can interbreed (producing a liger), but ligers are infertile. So their parents are different species.

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Selective breeding

In selective breeding, domesticated animals or plants are bred for particular **genetic** characteristics. This is not a new thing: humans have been choosing which animals/plants to breed together ever since agriculture was invented many thousands of years ago. The organisms with desired characteristics are chosen and deliberately bred together – if all goes well, the offspring have inherited the desired characteristics. The offspring with those characteristics are then bred together, and so on for many generations until all the offspring have the desired characteristic. Some examples of characteristics that selective breeding is used to obtain:

- Disease resistance in food crops
- Animals which produce more e.g. milk or meat
- Domestic (pet) dogs with gentle natures, high intelligence and so on
- Large or unusual flowers.

So, selective breeding is very useful. However, because of the deliberate selection of organisms with certain genetic characteristics for breeding, **inbreeding** can result from its use.

Genetic engineering

Genetic engineering is common and extremely useful. Recall that one gene codes for one protein, which in turn leads to specific characteristic. If an organism has the gene for a characteristic you want, you can transfer that gene into the genome of a different organism altogether. This has allowed, for example, the genetic engineering of plant crops to make them resistant to disease or to produce bigger, better fruit. Another key example is the genetic engineering of bacteria so they produce human insulin for treatment of type 1 diabetes.

How genetic engineering works:
Genes from an organism with a desired characteristic are 'cut out' of their genome and transferred to the cells of other organisms, in such as way that the second organism uses the gene from the first one. The resulting organism is called a **genetically modified** organism.

Good examples of GM crops include those that are now resistant to attack by insects, or are not affected by the herbicides that farmers use to kill weeds (obviously, it would be bad news to use a herbicide that kills your weeds but also your crops). GM crops are also often produced to have higher **yields**.

Key Terms	Definitions
Selective breeding	Also known as **artificial selection**. A technique of improving domesticated animals and plants for humans benefit, by breeding for particular genetic characteristics.
Domesticated	Animals/plants used in agriculture (or for pets!) are called domesticated species.
Inbreeding	The result of selective breeding can be inbreeding, where limited genetic variation can make organisms more prone to disease or inherited defects.
Genetic engineering	Modifying the genome of an organism by introducing a gene from another organism, giving a desired characteristic.
Genetically modified	GM for short. Describes organisms (especially crops) that have had their genome modified by genetic engineering.
Yield	The amount of useful product you get from a plant or animal used in agriculture (e.g. mass of fruit).
Vector (HT)	In the context of genetic engineering, a vector is a piece of genetic material used to transfer a gene. It is usually a bacterial plasmid or virus.

Genetic engineering – the controversy

There are some concerns about GM crops. The most important include concerns about how the GM crops may effect wild flowers and insects. There is not thought to be any risk to human health eating them, but some people call for more research on this.
Research is going on into how genetic modification might be used to overcome inherited disorders in humans.

HT: Genetic engineering – the steps

The summary is given left. The steps in more detail:

1. **Enzymes** are used to cut out, or *isolate*, the required gene.
2. This gene is placed in a **vector**, so it can be *transferred* to the organism you intend to genetically modify.
3. The vector is used to insert the gene into cells of the second organism (e.g. the food crop). This has to be done at an early stage of development (i.e. as a tiny *embryo*) so the organism develops with the desired characteristic.

[It wouldn't be much help to add the gene to an adult, since you'd have to add it to every cell to give them the desired characteristic.]