Inheritance and Variation

Continuous and discontinuous variation, the structure of DNA and genes, monohybrid crosses and Punnett squares, codominance, sex determination, mutation, and natural and artificial selection.

18.1 Variation

Variation is the differences between individuals of the same species.

	Continuous variation	Discontinuous variation
phenotypes	a **range** between two extremes, with intermediates	a **limited number** of phenotypes, with **no intermediates**
examples	body length, body mass, height	**ABO blood groups**, seed shape and seed colour in peas
causes	**genes and the environment**	usually caused by **genes only**
graph	a smooth curve (a bell shape)	a bar chart with separate bars

Investigating. Measure the height of students or the length of leaves (continuous: plot a histogram, which gives a bell-shaped curve), and compare it with a feature such as blood group or tongue rolling (discontinuous: a bar chart).

17.1 Chromosomes, genes and DNA

A DNA molecule is made of two strands coiled together to form a double helix. Each strand is a chain of nucleotides. Each nucleotide contains a base (A, T, C or G). Bonds between pairs of bases hold the strands together, and the bases always pair in the same way: A with T, and C with G.

A gene is a length of DNA that codes for a protein.

- **DNA controls cell function** by controlling the production of **proteins**, including **enzymes**.
- The **sequence of bases** in a gene determines the **sequence of amino acids** needed to make a specific protein.

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- Different sequences of amino acids give **different shapes** to protein molecules, and the shape determines the protein's function (for example the shape of an enzyme's active site).

> **TRY IT**
>
> One strand of DNA has the base sequence A T T G C A. What is the sequence on the other strand?

A pairs with T and C pairs with G, so the other strand is **T A A C G T**.

17.4 Inheritance

> **Inheritance is the transmission of genetic information from generation to generation. An allele is an alternative form of a gene.**

Terms

Term	Meaning
dominant	an allele that shows its effect even if there is only one copy (written as a capital letter)
recessive	an allele that only shows its effect when there are two copies and no dominant allele (a small letter)
genotype	the alleles that an organism has (for example Tt)
phenotype	the observable features of an organism (for example tall)
homozygous	two **identical** alleles for a gene (TT or tt)
heterozygous	two **different** alleles for a gene (Tt)

Two identical homozygous individuals that are bred together are **pure-breeding**: all their offspring will be the same.

Monohybrid crosses

A **monohybrid cross** looks at the inheritance of one gene. Use a **genetic diagram** or **Punnett square**.

Example. Tall (T) is dominant to dwarf (t) in pea plants. Cross two heterozygous (Tt) plants.

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	T	t
T	TT	Tt
t	Tt	tt

Offspring genotypes: 1 TT : 2 Tt : 1 tt. Phenotypes: **3 tall : 1 dwarf**, a ratio of **3 : 1**.

Cross a heterozygous plant (Tt) with a homozygous recessive plant (tt) (a test cross):

	T	t
t	Tt	tt
t	Tt	tt

Offspring: 2 Tt : 2 tt, so **1 tall : 1 dwarf** (a **1 : 1** ratio).

Why do observed ratios differ from expected ratios? The Punnett square gives only the **probability**. Fertilisation is **random**, so when the number of offspring is **small**, the observed ratio can be quite different. With a large number of offspring, it gets closer to the expected ratio.

> TRY IT
>
> Brown eyes (B) are dominant to blue eyes (b). Two brown-eyed parents have a blue-eyed child. What are the genotypes of the parents?

The child is **bb**, so each parent passed on a b. The parents are brown-eyed (dominant allele B), so both are **Bb** (heterozygous).

Codominance: ABO blood groups

> **In codominance, both alleles in a heterozygote are expressed in the phenotype.**

The ABO blood group gene has three alleles: I^A, I^B and I^O. I^A and I^B are **codominant**, and both are dominant to I^O (recessive).

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Phenotype	Genotype
A	I^AI^A or I^AI^O
B	I^BI^B or I^BI^O
AB	I^AI^B
O	I^OI^O

Sex determination

Humans have 23 pairs of chromosomes, one pair being the **sex chromosomes**. Females are **XX** and males are **XY**.

	X	**X**
X	XX	XX
Y	XY	XY

All eggs carry an X chromosome, and half of the sperm carry an X and half a Y. So there is a **50% chance** of a boy (XY) or a girl (XX) at each birth. The sex of the baby is decided by the **sperm** that fertilises the egg.

Mutation

> **A gene mutation is a random change in the base sequence of DNA.**

Example: sickle cell anaemia. A change in one base in the gene for haemoglobin gives a different haemoglobin, which makes the red blood cells a sickle shape, so they carry less oxygen and block capillaries.

> **A chromosome mutation is a change in the chromosome number or structure.**

Example: Down's syndrome. A person has **47 chromosomes** instead of 46 (an extra chromosome 21).

Sources of genetic variation in populations: mutation, **meiosis** (which shuffles the alleles into gametes), **random mating** and **random fertilisation**.

Ionising radiation (such as X-rays, gamma rays and ultraviolet light) and **some chemicals** (such as chemicals in tobacco smoke) **increase the rate of mutation**.

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18.3 Selection

Natural selection

> **Natural selection is the process by which organisms that are better adapted to the environment are more likely to survive and reproduce, and pass on their alleles to the next generation.**

The steps:

1. There is **variation** within a population (for example due to mutation).
2. Organisms produce **many offspring**.
3. There is a **struggle for survival**, because of competition for resources, predators and disease.
4. Individuals that are **better adapted** to the environment survive and **reproduce**.
5. They **pass on their alleles** to the next generation, so the proportion of those alleles increases.

Over many generations, the **inherited features of a population change** (**evolve**) as a result of natural selection.

Antibiotic-resistant bacteria (such as MRSA). In a population of bacteria, a random **mutation** can make one bacterium resistant to an antibiotic. When the antibiotic is used, the non-resistant bacteria are killed, but the resistant one **survives and reproduces**, and passes on the allele, so the resistant strain increases. This is an example of natural selection.

Artificial selection (selective breeding)

> **Artificial selection is where humans select animals or plants with desirable features and breed them.**

1. **Select** animals or plants with the **desirable features** (for example high milk yield).
2. **Cross** them (breed them together) to produce the next generation.
3. **Select** offspring that show the desirable features.
4. **Repeat** over many generations.

It is used to produce economically important organisms, such as **cows with a high milk yield**, **crops with a high yield or resistance to disease**, and **fast-growing chickens**.

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	Natural selection	Artificial selection
selected by	the environment	humans
features selected	those that help survival	those that humans want
speed	slow	faster

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