CAIE Biology IGCSE

17: Inheritance

Notes

(Content in **bold** is for Extended students only)

Chromosomes, genes and proteins

Key words:

- **Chromosome** - a thread-like structure of DNA that carries genetic information in the form of genes.
- **Gene** - a length of DNA that codes for a particular protein.
- **Allele** - one of a number of different versions of a gene.
- **Diploid nucleus - nuclei which contain a full set of chromosomes (23 pairs).**
- **Haploid nucleus - nuclei which only contain half the number of chromosomes. These cells are egg and sperm cells, which fuse during fertilisation to produce a diploid cell.**

There are 23 pairs of chromosomes in the nucleus of all diploid human cells. One of these pairs **determines gender**. These chromosomes are therefore called the **sex chromosomes.** For females these chromosomes are **XX** and for males the chromosomes are **XY**. All female **egg cells contain only an X** chromosome, whereas male **sperm cells may contain an X or a Y**, thus the gender of the baby depends on which sperm cell fertilises the egg cell.

Protein synthesis:

DNA controls the function of the cell by regulating protein synthesis, including enzymes, membrane carrier proteins and receptors for neurotransmitters. Protein synthesis is important to maintain cell structure, as well as for producing enzymes to catalyse metabolic reactions. The sequence of bases in a gene determines the sequence of amino acids used to make a specific protein.

1. **The gene which codes for the protein is used to make an mRNA copy in the nucleus. mRNA is similar to a single strand of DNA, although it contains base U rather than T.**
2. **The mRNA copy leaves the nucleus and travels through the cytoplasm to a ribosome.**
3. **The ribosome uses the mRNA strand to produce a chain of amino acids which make up the protein. The order of the amino acid chain is determined by the order of bases on the mRNA. This order is specific to each protein made.**
4. **Different sequences of amino acids give different shapes of protein molecules.**

As each type of cell has a different function, not every type of protein is synthesised in every cell. The genes to code for each protein are present in every cell. However, these genes are therefore switched 'on' or 'off'. When the gene is switched on, it is expressed, and the protein associated with the gene is synthesised. When the protein is not required, the gene is switched off.

Mitosis

Mitosis is a form of cell division. During mitosis, nuclear division of a parent cell occurs, producing two genetically identical daughter cells. Mitosis is used to create new cells in the body to repair and replace old and damaged tissues, as well as allowing growth of the organism and playing a role in asexual reproduction. Mitosis involves the splitting of chromosomes into their two halves, each of which are known as a chromatid:

1. Before replication can occur, the chromatids in the parent cell must replicate to produce identical copies of themselves which pair as chromosomes.
2. The chromosomes line-up along the nucleus.
3. The copies of chromosomes separate so that each identical chromatid is pulled to opposite poles of the cell, maintaining the chromosome number in each daughter cell.
4. The cell membrane constricts in the middle and the nucleus is separated as the cell splits into two new daughter cells. Each of these cells will contain a set of chromatids, which then replicate themselves again to produce new chromosomes.

Stem cells:

Stem cells are found in embryos or in the bone marrow. These cells are unspecialised and divide by mitosis to produce daughter cells which can become specialised for specific functions. Cells, once specialised, cannot produce unspecialised cells. For example, a cell which makes up the heart tissue cannot divide to make a cell which can act as skin tissue as the cell produced will already be specialised as a heart cell.

Meiosis

Meiosis is used to make four genetically unique daughter cells and is used in the production of gametes. During meiosis, the chromosome number is halved, and a diploid cell divides to produce four haploid cells. As each gamete produced is genetically unique, each of the offspring will also be unique. This is beneficial for a species as it produces genetic variation.

Monohybrid Inheritance

Key words:

- **Inheritance** - the transmission of genetic information from generation to generation.
- **Genotype** - the genetic makeup of an organism, consisting of all the alleles present.
- **Phenotype** - the observable features of an organism as a result of the expression of particular alleles of the gene.
- **Homozygous** - an organism containing two identical alleles of a particular gene.
- **Heterozygous** - an organism containing two different alleles of a particular gene.

Offspring **inherit characteristics** from both their mother and father and **two sets of genes are inherited**, one from each. If the mother and father pass down the **same allele** for a particular trait, e.g. they both pass down the allele for blue eyes, the offspring will have two identical alleles for this trait, which is referred to as **homozygous**. If two **separate alleles** are passed down, e.g. the mother has blue eyes and the father has brown eyes, the offspring will have two different alleles for the gene, which is called **heterozygous**.

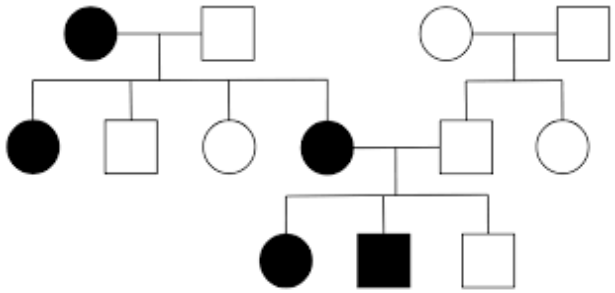
If two **identical homozygous** individuals are bred together, it is referred to as **pure-breeding**, and the offspring will have the **same characteristics as the parents**. Breeding heterozygous parents is not pure-breeding, as there are a number of different alleles that the offspring could display in their phenotype.

Alleles can be **dominant** and **recessive**. A **dominant allele is always expressed if present**, whereas the **recessive allele** is only expressed in the **absence of the dominant allele**. For example, the allele for brown eyes is dominant and the allele for blue eyes is recessive. This means that if two parents with blue and brown eyes were bred, the offspring would have brown eyes as this allele is dominant.

Pedigrees:

A pedigree diagram is used to see the **pattern of inheritance** of a trait in different generations of a family.

- Males are represented by a square shape and females are represented by a circle.
- **Affected** individuals are filled in and **unaffected** individuals are unfilled.
- Horizontal lines link males and females which are mates.
- Vertical lines link couples to their offspring



In the pedigree above, every generation has **affected** individuals. There are four females and one male affected. The rest of the members are unaffected.

If a trait appears in every generation, it is most likely a **dominant** trait. The pedigree above shows a dominant trait.

If a trait skips generations, it tends to be a **recessive** trait. Individuals can carry a recessive **allele** without expressing the trait themselves. These individuals are **carriers**. They can still pass it on to their offspring. If the offspring inherit the recessive **allele** from both parents, the offspring will be affected. This is represented in pedigrees as **unaffected** parents having **affected** offspring.

Monohybrid crosses:

Monohybrid crosses are used to predict the ratios of inherited characteristics in a population. There are always **four outcomes**. The dominant allele is written as a capital letter and the recessive as the lowercase of that letter.

E.g. 1) Crossing two **heterozygous** green and yellow pea plants (both parents contain the alleles for both traits):

G= green (dominant allele)
g= yellow (recessive allele)

Parent one → Parent two ↓	**G**	**g**
G	GG	Gg
g	Gg	gg

The outcomes are GG, Gg, Gg and gg. As G is dominant, there is a 75% chance that the offspring will display this allele in the phenotype and be green. There is a 25% chance that the offspring will be yellow therefore the ratio is **3:1**.

E.g. 2) Crossing a **homozygous recessive** (yellow) pea plant with a **heterozygous** pea plant:

G= green (dominant allele)
g= yellow (recessive allele)

Parent one (homozygous) → Parent two (heterozygous) ↓	**g**	**g**
G	Gg	Gg
g	gg	gg

The outcomes are Gg, Gg, gg and gg. There is a 50% chance of the offspring being green or yellow, therefore the ratio is **1:1**.

Test Crosses:

A test cross is a breeding experiment used to determine whether an organism's genotype is homozygous dominant or heterozygous dominant.

- **The individual with the unknown genotype must breed with an individual with a homozygous recessive genotype.**
- **If all offspring produced show the dominant trait, the organism is homozygous dominant.**
- **If approximately half the offspring produced show the recessive trait, the organism is heterozygous dominant.**

Co-dominance:

Some alleles are co-dominant, meaning that neither is recessive, and they are both displayed in the phenotype. An example of this is blood groups. The three possible alleles for blood groups are A, B and O. The A and B alleles are co-dominant, which leads to the AB blood group. O is recessive, and thus is only displayed in the phenotype if both parents have O blood groups.

When writing codominant alleles, a capital letter is used to show the gene, and a superscript letter is used to denote the allele. For example, an allele for blood group A is written as I^A.

Genetic diagrams can be used to predict blood groups of children if the genotypes of the parents are known.

E.g. When a heterozygous female with blood group A is crossed with a heterozygous male with blood group B:

Female → Male ↓	I^A	I^O
I^B	I^AI^B (AB blood group)	I^BI^O (B blood group)
I^O	I^AI^O (A blood group)	I^OI^O (O blood group)

Therefore the phenotypic ratio is 1:1:1:1.

Sex-linked characteristics:

Some genes are located on the sex chromosomes. A characteristic which comes from one of these genes is referred to as a sex-linked characteristic. A result of this is that some traits are more common to one gender, for example any gene located on the Y chromosome can only be present in males as females do not have this chromosome. An example of a sex-linked characteristic is red-green colour blindness, which is a recessive characteristic found on the X chromosome.

Genetic diagrams can be used to predict sex-linked characteristics in children if the genotypes of the parents are known.

E.g. When a male with normal colour vision is crossed with a carrier female:

Male → Female ↓	X^R	Y
X^R	X^RX^R (female with normal colour vision)	X^RY (male with normal colour vision)
X^r	X^RX^r (female carrier)	X^rY (colour-blind male)

- **There is a 75% chance of producing a child with normal colour vision**
- **There is a 25% chance of producing a colour-blind child.**

Therefore the phenotypic ratio is 3:1.