Name: _____

GCSE Inheritance Triple booklet

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1b	Protein synthesis			
2	Reproduction			
3	Meiosis and comparison of Meiosis and mitosis			
4	Sex Determination			
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Biology Knowledge Organiser
Topic 17: How and Why do Organisms Reproduce?

Types of reproduction

Organisms can reproduce sexually or asexually.

- **Sexual reproduction** involves two parents and produces genetically unique offspring. Each parent produces a sex cell (**gamete**), which fuse as part of sexual reproduction. This means that each parent contributes 50% of the genetic information to the offspring, and the offspring is *genetically unique*.
- **Asexual reproduction** involves only one parent and there is **no** fusion of gametes. As a result, there is **no** mixing of genetic information and the offspring are *genetically identical* to the parent (they are **clones** of their parent). No meiosis takes place (since there are no gametes); only mitosis is involved.

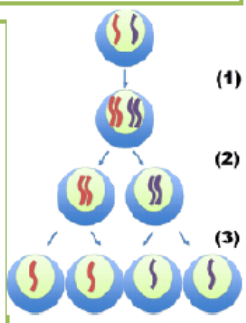
Key Terms	Definitions
Reproduction	Making offspring. All organisms reproduce.
Offspring	Offspring is a generic term for children – it applies to any type of organism.
Gametes	Sex cells, such as pollen, egg cells, sperm cells. Gametes are produced by meiosis.
Meiosis	Type of cell division that produces gametes. Gametes are genetically unique (compare to *mitosis*, where genetically identical daughter cells are produced).
Fusion	The joining/fusing of sex cells in sexual reproduction.
Differentiation	The process of becoming a specialised cell. Specialised cells are the result of differentiation of **stem cells**.

Meiosis

You already know how mitosis is used to replace cells in the body. Meiosis is the other form of cell division, but quite different. Meiosis produces **gametes**, so it happens in **reproductive organs** (e.g. sperm cells are produced by meiosis in the testes; egg cells are produced by meiosis in the ovaries).

DNA in the nucleus of cells is arranged into structures called **chromosomes**. In all body cells, the chromosomes appear in pairs (in humans, there are 23 pairs, so 46 chromosomes altogether). However, in gametes, there are **half** the number of chromosomes of body cells, since they contain one from each chromosome pair (in humans, this means that gametes contain 23 chromosomes).

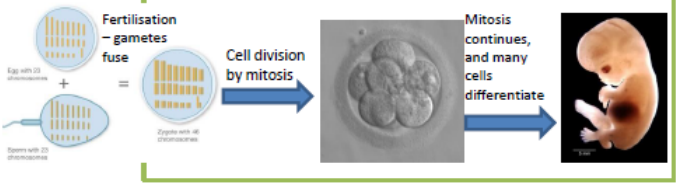
In meiosis, the DNA is replicated to start with (just like mitosis – step 1 in diagram). But then the cell divides **twice** – i.e. divides into *four* cells – so each cell ends up with **half** the genetic information: a single set of chromosomes. At stage 2 – the pairs are split up, then at stage 3 the copies of chromosomes are separated. The four cells produced are **gametes**, and all of them are **different** to each other – they are genetically unique.



Fertilisation

Obviously, fertilisation only happens in sexual reproduction. The male and female gametes **fuse**. Their nuclei join together into one and the genetic information is combined. Consequently, you have 50% of your genetic information from your mother and 50% from your father. The cell that is produced has the full set of chromosomes (in pairs again) – the normal number is restored. Again, this is 46 chromosomes (23 pairs) in humans. The diagram shows this.

The new cell is ready to grow into an embryo. It does this through mitosis, increasing the number of cells. To be precise, each cell divides to make two cells. This means that a young embryo doubles the number of cells each 'round' of mitosis. After a ball of cells is produced, the cells start to **differentiate** – become specialised. So you are no longer just a blob.



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Topic 17: How and Why do Organisms Reproduce?

Genetic inheritance

All the genes you have, you inherited from your parents. They gave you half your genome each. Since they gave you one from each pair of chromosomes you have now, they in fact gave you one copy of each gene each – i.e. genes for the same thing. We call the two different versions of each gene **alleles**. Some characteristics are controlled by one gene – or rather, the two alleles of a single gene. E.g. fur colour in mice, red-green colour blindness in humans. However, most characteristics come about thanks to many genes and their interactions, not just one gene.

The alleles present in an individual organism cause body cells to produce certain proteins, or versions of proteins (as this is what a gene does remember). This is called **expression** of a gene, and leads to physical characteristics we call **phenotypes**.

This is easier with an example. Look at the cats below: the allele for short fur in cats is dominant to the allele for long fur. Let's call the alleles F and f respectively. In the top example, both parents are homozygous dominant (genotype: FF). This means all the gametes they produce will have one F in them, so at fertilisation the only possibility is for the offspring to get FF. So all their offspring have the short fur **phenotype**.

In the second row, both parents have long hair, so they must both have the genotype ff (homozygous recessive). Consequently, all their offspring must have long hair too.

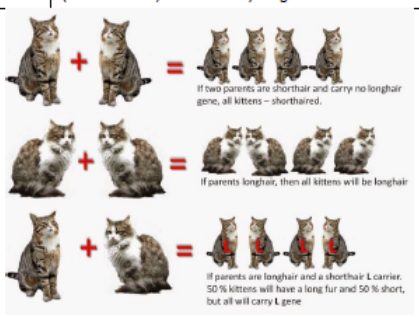
In the third row, the first parent has short hair but is heterozygous (genotype: Ff) – so they still have short hair as the short hair allele is dominant. If they mate with a long hair cat (genotype ff), there are different probabilities for offspring phenotypes, as they will get *either* F or f from the first parent. So, half of them will have short hair (with genotype Ff) and half will have long hair (with genotype ff).

Probability and ratios

Knowing the genotypes of the parents allows you to work out the **probability** of each genotype (and therefore phenotype) in the offspring. It does not guarantee, like in the bottom cat example, that they'll have four kittens, or that half will have long hair. What it tells us is: for each kitten, there is a 50% chance of it having long hair.

The other way of saying this is that the **expected ratio** of offspring genotypes is 1:1 for long:short hair. So if the bottom two cat parents had 50 kittens, we'd expect 25 of each hair length.

Key Terms	Definitions
Allele	A form or version of a gene. Since you inherit a copy of each chromosome from each parent, you have two copies of each gene – we call these two versions alleles.
Express	In genetics, to 'express' a gene means for it to be used by the body to make a protein, causing a characteristic.
Dominant	Describes alleles that are always expressed (so you see the effects in the organism). Indicated with a capital letter to represent the allele e.g. D.
Recessive	Describes alleles that are only expressed if there are two recessive copies (one from each parent). In other words, recessive alleles are only expressed if there is **no** dominant allele present. Indicated with a lower case letter to represent the allele e.g. d.
Genotype	The combination of alleles that an individual has. Often represented with two letters: e.g. DD, Dd or dd.
Phenotype	The physical characteristic that results from a particular genotype.
Homozygous	Describes a genotype where both alleles are the same – e.g. DD is homozygous dominant; dd is homozygous recessive.
Heterozygous	Describes a genotype where the two alleles are different (one dominant, one recessive) – e.g. Dd.



Biology Knowledge Organiser
Topic 17: How and Why do Organisms Reproduce?

Inherited disorders

Some disorders (or diseases – same thing really) are inherited, so we can also call them **genetic disorders**. If someone inherits a certain allele/combination of alleles, they have the inherited disorder. Two examples to know:

- **Polydactyly**: a condition where people have extra fingers or toes. This is caused by a dominant allele, so only one copy is needed to have the condition.
- **Cystic fibrosis**: a condition where protein pumps in cell membranes don't work properly, leading to thick and sticky mucus being produced in the lungs and intestines. This is caused by a recessive allele, so individuals with cystic fibrosis are all homozygous recessive.

Studying family trees can help genetic scientists decide whether a disorder is caused by a recessive or dominant allele. In the family tree shown, C is the allele for healthy cell membranes, and c is the allele for disordered cell membranes. Both parents must have at least one c to have children with cystic fibrosis, as the family tree shows. (Note: anyone without a genotype shown has the genotype CC).

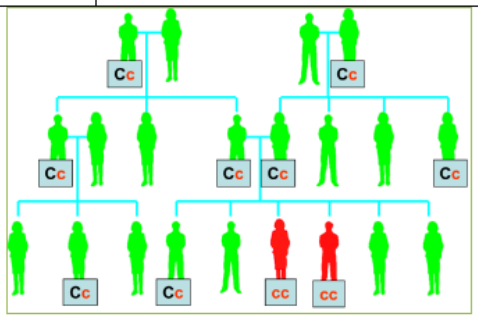
Since we know which alleles cause conditions like these, unborn babies, or embryos produced during IVF, can be checked – or **screened** – to see if they have the inherited disorder. This practice, *embryo screening*, can be used to inform whether an embryo should be implanted in IVF, or, if used during pregnancy, to decide whether an abortion should take place. Obviously, these are huge decisions and the right to life of the embryo must be weighed against the difficulties they'll face with an inherited condition and the personal choice and beliefs of the parents.

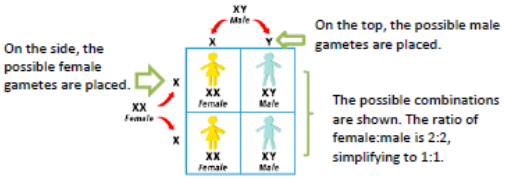
Sex determination

In biology, sex is not short for sexual intercourse. Sex means male or female – so is only relevant to organisms that reproduce sexually. The sex of offspring is determined by the combination of sex chromosomes inherited from the parents. Of the 23 pairs of chromosomes all humans have, 22 control body characteristics and the 23rd pair determines sex. [Note: like all chromosomes, the sex chromosomes carry genes, they just have the extra function of sex determination.] Human females have the combination for pair 23: XX. We say they have two X chromosomes. Human males have the combination XY for pair 23 (they are different).

When having children, then, mothers always pass on one X chromosome to their offspring. Males can pass on an X chromosome OR a Y chromosome – there's a 50:50 chance of each. This is because, when cells divide by meiosis to make gametes, all the female gametes contain an X, but half the sperm cells have an X, half have a Y. How these combine to give a 50% chance of a girl is shown in the **Punnett square** to the right.

Key Terms	Definitions
Screening	The practice of checking for a disease or an inherited disorder.
Carrier	An individual with one copy of the recessive allele that causes an inherited disorder (e.g. Cc for the cystic fibrosis genotype). As a result, they don't have the disorder, but they can pass one allele for it onto their offspring.
Sex chromosomes	Pair 23 in humans. Females have the combination XX, males have the combination XY.
Genetic cross	An unglamorous term given to mating between two individuals, producing offspring.
Punnett square	A tool used to predict the outcome of a genetic cross.





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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.

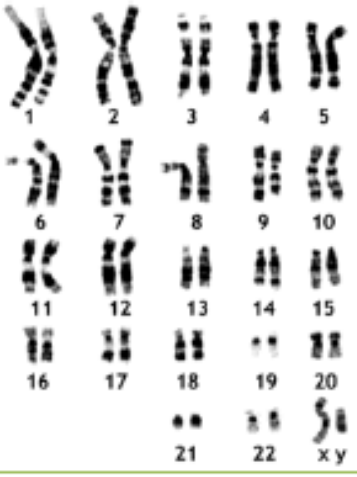
[It wouldn't be much help to add the gene to an adult, since you'd have to add it to every cell to give them the desired characteristic.]

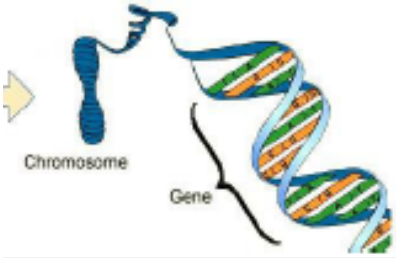
The genome

The genome is the word to describe all the genetic material of an organism. The human genome has been fully sequenced, so we know exactly the order of genes on each chromosome. (Note: in genetic terms, humans are extremely similar so we do have a general human genome. Everyone will vary slightly from it, but by less than 1%.) The micrograph shows the 23 pairs of chromosomes found in human cells, where pair 23 is the sex chromosomes (XY in this person).

Understanding the human genome is very useful for all sorts of reasons, including:

- Helping the search for genes linked to specific diseases
- Understanding inherited disorders (more on these later)
- Using the tiny differences in genetic information between people to track how humans have migrated all over the planet.





DNA

DNA is a chemical, a compound made of elements you know – carbon, hydrogen, nitrogen, oxygen, phosphorus. It is a polymer – meaning a very long molecule with units that repeat over and over. Each molecule of DNA is in fact made of two strands that run opposite one another and join in the middle (see diagram). These two strands form a spiral we call a **double helix** – double because there are two strands, and helix is just another word for spiral.

DNA is contained in **chromosomes**, where each chromosome contains one molecule of DNA – one long double helix each (there are also protein molecules as part of chromosomes). Short (compared to the whole molecule) sections of DNA called **genes** code for *proteins* (see diagram). This is how DNA gives you characteristics – the genes inherited from the parents, on the chromosomes they pass on to you, code for the *sequence of amino acids to make specific proteins.*