

Reproduction and inheritance revision notes

This topic is about how organisms reproduce and how characteristics are passed from parents to offspring. It covers sexual and asexual reproduction in flowering plants and humans, then DNA, genes and protein synthesis, patterns of inheritance, and how mitosis, meiosis and random fertilisation lead to genetic variation.

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** is not in the Double Award and is only examined on Paper 2.

1 Sexual and asexual reproduction, and reproduction in plants

Spec 3.1-3.7

Sexual and asexual reproduction Spec 3.1, 3.2

Sexual reproduction involves two parents. Each parent makes **gametes** (sex cells). A male gamete and a female gamete join in **fertilisation**. The offspring inherit genes from both parents, so they show variation and are genetically different from each other and from the parents.

Asexual reproduction involves only one parent and no gametes. The new cells are made by mitosis, so the offspring are **genetically identical** to the parent. Genetically identical offspring are called clones.

Sexual and asexual reproduction compared

	Sexual reproduction	Asexual reproduction
Number of parents	Two	One
Gametes	Male and female gametes fuse	No gametes involved
Offspring	Genetically different from each other and from the parents	Genetically identical to the parent (clones)
Variation in the population	Lots of variation	Very little variation

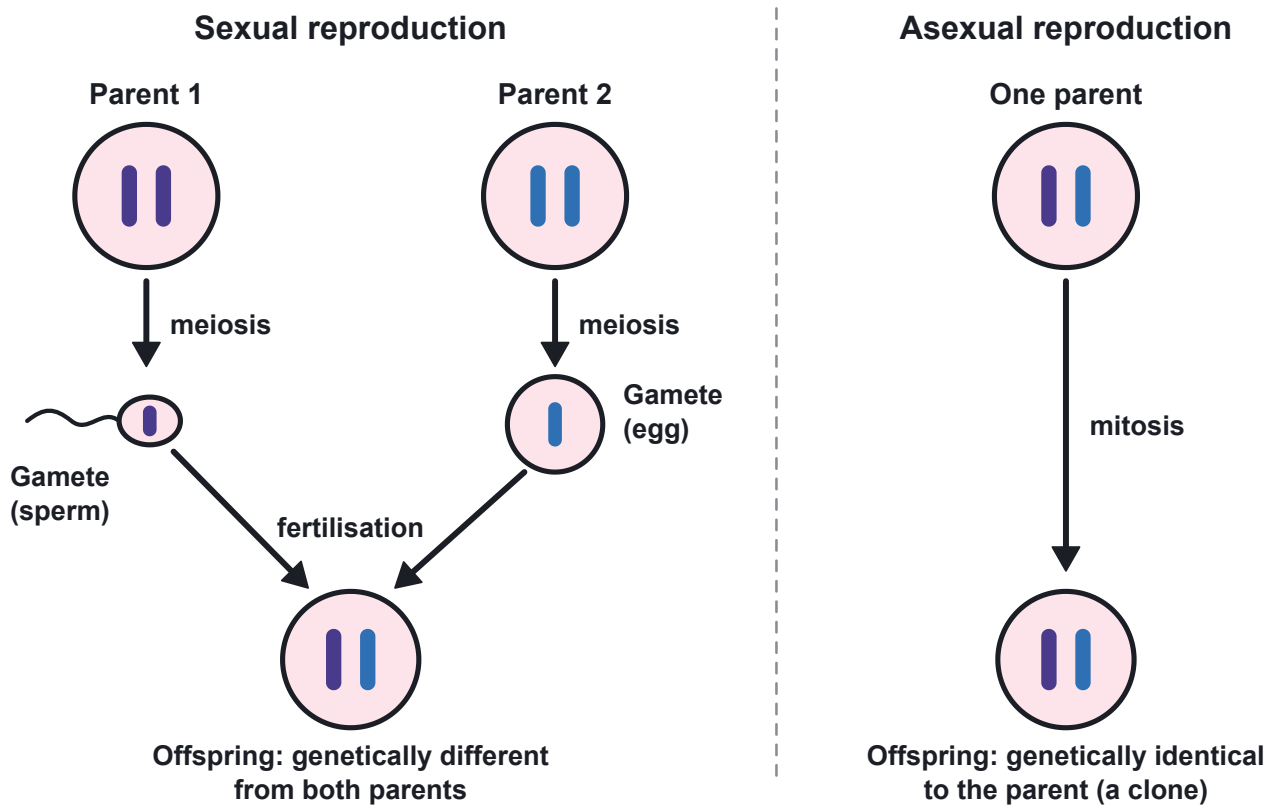
Common mistake: Do not write that asexual offspring are 'similar' to the parent. The mark is for 'genetically identical'.

Fertilisation

In fertilisation, the nucleus of a male gamete fuses with the nucleus of a female gamete. This produces a single cell called a **zygote**.

The zygote then divides again and again by cell division (mitosis). The ball of cells that forms develops into an **embryo**.

1. A male gamete fuses with a female gamete (fertilisation).
2. This produces a zygote.
3. The zygote undergoes cell division (mitosis).
4. The cells develop into an embryo.

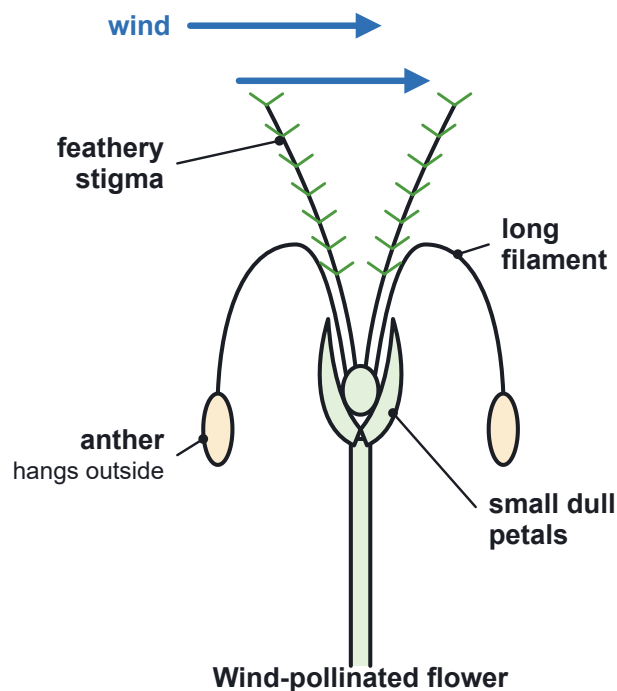
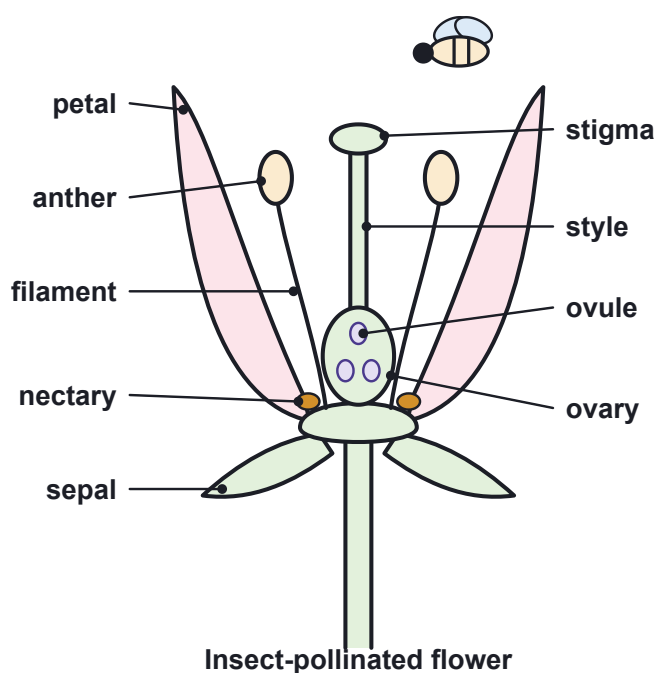


Sexual reproduction mixes genetic information from **two parents**; asexual reproduction makes **genetically identical** clones from one parent.

Insect- and wind-pollinated flowers Spec 3.3

The flower is the organ of sexual reproduction in a flowering plant. **Pollination** is the transfer of pollen grains from an anther to a stigma. Pollen contains the male gametes. The male part of the flower is the **stamen** (anther and filament). The female part is the **carpel** (stigma, style and ovary). Flowers are adapted to be pollinated either by insects or by the wind.

Parts of a flower	
Part	Function
Petals	Large and brightly coloured in insect-pollinated flowers to attract insects
Sepals	Protect the flower while it is a bud
Anther	Makes and releases pollen. Part of the stamen (male part), held on a filament
Filament	Holds up the anther
Stigma	Where pollen lands. The top of the carpel (female part)
Style	Joins the stigma to the ovary
Ovary	Contains the ovules
Ovule	Contains the female gamete (egg cell)
Nectary	Makes sugary nectar to attract insects



An **insect-pollinated** flower has large petals and nectaries inside; a **wind-pollinated** flower has **anthers and feathery stigmas hanging outside**.

Insect-pollinated and wind-pollinated flowers compared

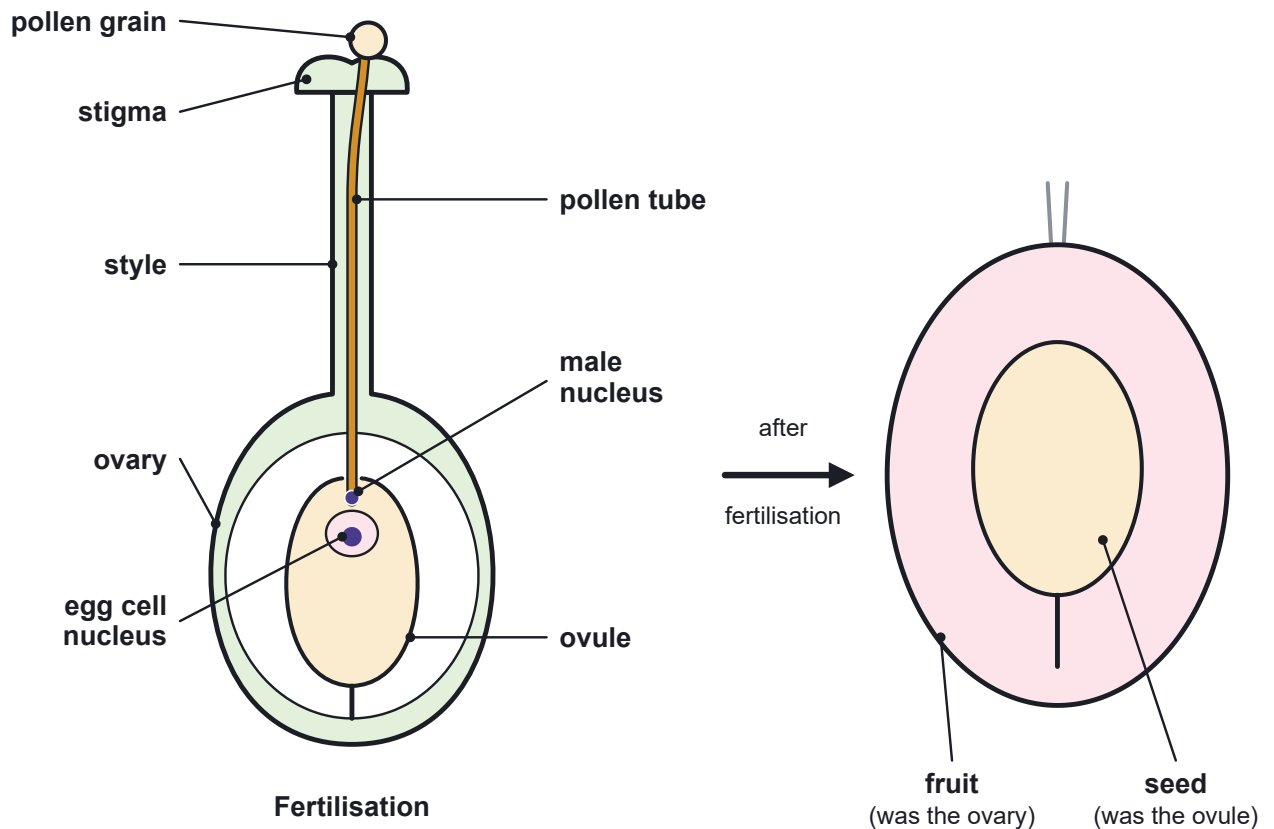
Feature	Insect-pollinated flower	Wind-pollinated flower
Petals	Large, brightly coloured and often scented to attract insects	Small, green or dull, or absent. No need to attract insects
Nectar	Nectaries make nectar as food for insects	No nectar
Anthers	Inside the flower, so insects brush against them	Hang outside the flower on long filaments, so the wind can blow the pollen away
Pollen	Sticky or spiky so it sticks to insects. Smaller amounts	Light and smooth so it is carried by the wind. Made in very large amounts
Stigma	Sticky and inside the flower, so pollen from the insect sticks to it	Large and feathery, hanging outside the flower, to catch pollen from the air

Exam tip: For an 'explain' question, give the feature and the reason. For example: 'feathery stigma (1) gives a large surface area to catch pollen from the air (1)'.

Fertilisation, seeds and fruits Spec 3.4

After pollination, a pollen grain on the stigma grows a **pollen tube**. The tube grows down through the style towards the ovary and into an ovule. The nucleus of the male gamete travels down the tube.

1. A pollen grain lands on the stigma (pollination).
2. A pollen tube grows out of the pollen grain and down through the style to the ovary.
3. The pollen tube enters an ovule.
4. The nucleus of the male gamete fuses with the nucleus of the female gamete (egg cell) in the ovule. This is **fertilisation**.
5. The fertilised ovule develops into a **seed**. The ovary develops into a **fruit** which surrounds the seed.



The **pollen tube** carries the male nucleus to the egg cell. After fertilisation the **ovule becomes the seed** and the **ovary becomes the fruit**.

Common mistake: Pollination is not the same as fertilisation. Pollination is the transfer of pollen to the stigma. Fertilisation is the fusion of the male and female gametes.

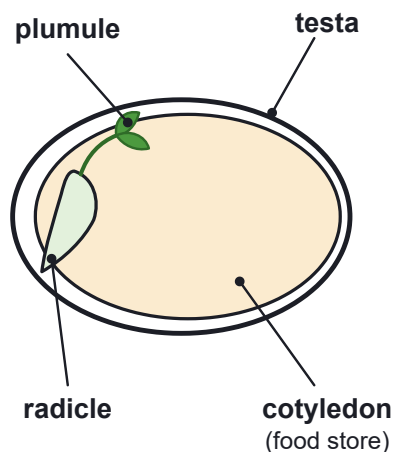
Germination and food reserves Spec 3.6

Germination is when a seed begins to grow into a seedling. A seed contains an embryo plant and a store of food. The **food reserves** are mainly starch and oils (fats), with some protein, stored in the cotyledons or in a separate food store.

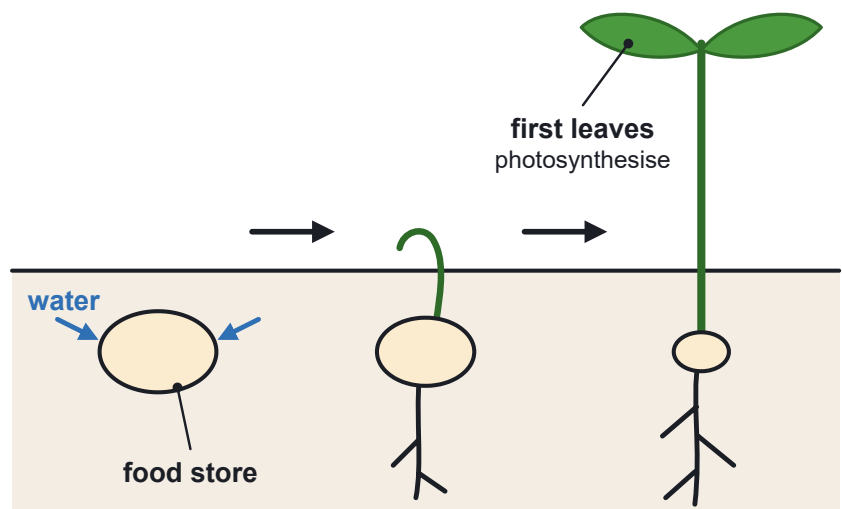
When a seed germinates, **enzymes** break down the stored food into smaller soluble molecules: starch to sugars, oils to fatty acids and glycerol, and proteins to amino acids. Sugars are used in **respiration** to release energy. The products are also used to make new cells for growth.

A young seedling cannot make its own food at first. It uses the food reserves until its first leaves have grown above the soil and can carry out photosynthesis.

1. The seed takes in water and swells.
2. Enzymes break down the stored starch and oil into soluble substances.
3. The root grows downwards and the shoot grows upwards, using energy from respiration.
4. The first leaves reach the light and start to photosynthesise.
5. The seedling no longer relies on the food reserves.



Inside a bean seed



1 Seed takes in water and swells

2 Root grows down, shoot grows up

3 Seedling with green leaves

Food reserves are used until photosynthesis begins

The seed's **food reserves** are used up as it germinates, until the first leaves can **photosynthesise**.

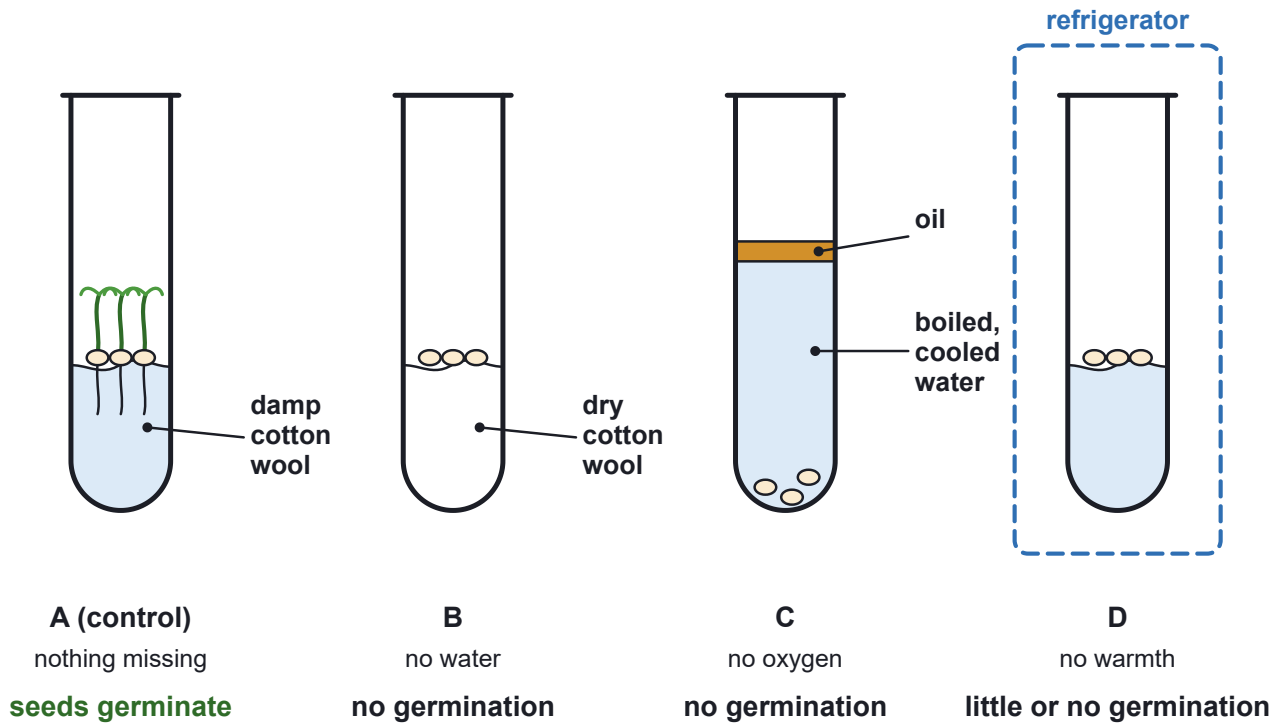
Exam tip: The dry mass of a germinating seed falls at first, because food reserves are used up in respiration and it cannot yet photosynthesise. Dry mass only increases once the leaves start photosynthesising.

Practical: conditions for germination Spec 3.5

Seeds need three things to germinate: **water**, **oxygen** (for respiration) and a **suitable temperature** (warmth, so that enzymes work). They do not need light or soil to start germinating.

Practical: Investigate the conditions needed for seed germination. Use identical seeds (such as cress or mustard) in four labelled test tubes or Petri dishes.

1. Tube A (control): damp cotton wool, seeds on top, left at room temperature. This has water, oxygen and warmth.
2. Tube B (no water): dry cotton wool, seeds on top, left at room temperature.
3. Tube C (no oxygen): seeds covered with boiled, cooled water with a thin layer of oil on top, left at room temperature. Boiling removes dissolved oxygen and the oil stops more entering.
4. Tube D (cold): damp cotton wool, seeds on top, placed in a refrigerator.
5. Keep tubes A, B and C in a dark cupboard at room temperature, because the inside of a refrigerator is dark. This way light is the same for all four tubes.
6. Leave all tubes for several days and count how many seeds have germinated in each (a root or shoot is visible).



Each tube lacks one condition. Only tube **A**, with water, oxygen and warmth, **germinates**.

Expected results		
Tube	Condition missing	Result
A	None (control)	Seeds germinate
B	Water	No germination
C	Oxygen	No germination
D	Warmth	No germination or very little

- **Independent variable:** the condition being changed (water, oxygen or temperature), one at a time.
- **Dependent variable:** the number (or percentage) of seeds that germinate.
- **Control variables:** same type and number of seeds, same age of seeds, same amount of cotton wool, same time, and the same light (all in the dark).
- **Safety:** take care when boiling water and let it cool before adding the seeds, wash your hands after handling seeds (some are treated with chemicals), do not eat the seeds, and mop up any spills.

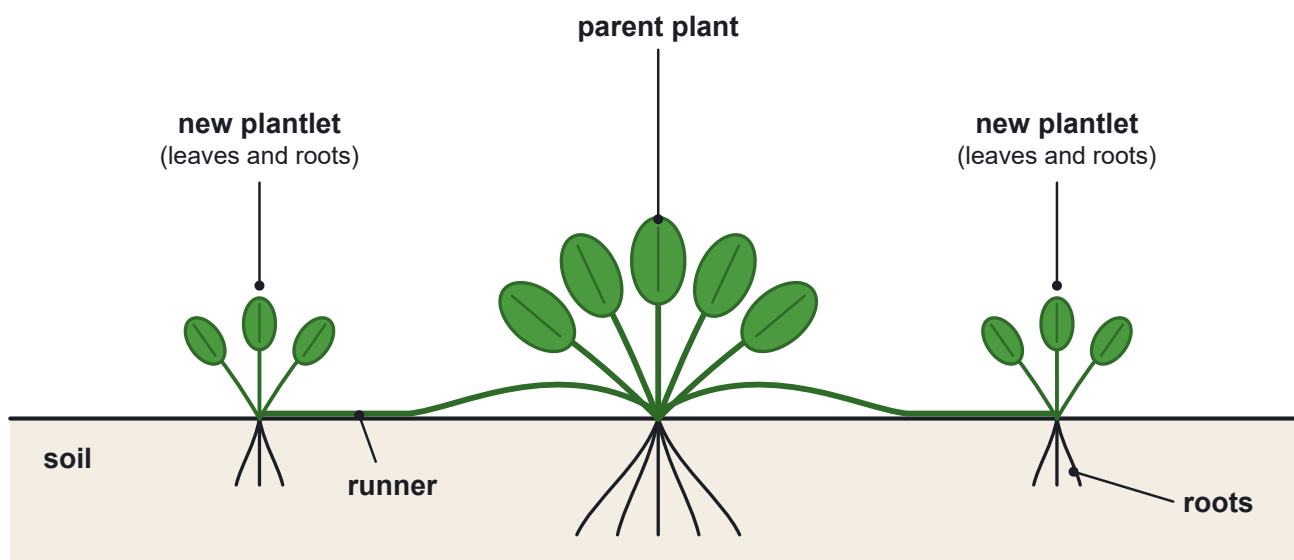
Exam tip: Change only one variable at a time. Tube A is the control, so you can say that the lack of one condition is the reason the seeds fail to germinate.

Asexual reproduction in plants Spec 3.7

Many plants can reproduce asexually. The new plants are **clones** of the parent. There are natural methods and artificial methods.

Natural method: runners

A strawberry plant grows **runners**. These are long stems that grow sideways along the ground. At intervals, roots and a new shoot grow from the runner, forming a new plantlet. When the runner dies, the plantlet becomes an independent plant that is genetically identical to the parent.



The new plantlets are genetically identical to the parent plant

Strawberry **runners** grow new plantlets that are **genetically identical** to the parent plant.

Artificial method: cuttings

1. Cut a short piece of stem from the parent plant, just below a node.
2. Remove the lower leaves.
3. Plant the cutting in moist compost.
4. Keep it moist and covered so it does not lose too much water.
5. Roots grow from the cut stem and a new plant develops, genetically identical to the parent.

Natural and artificial asexual reproduction

Method	Natural or artificial	Example
Runners	Natural: the plant does it without human help	Strawberry
Cuttings	Artificial: people do it to get new plants	Geranium, rose

Exam tip: Gardeners use cuttings to produce lots of plants with the same useful features as the parent, because the offspring are genetically identical.

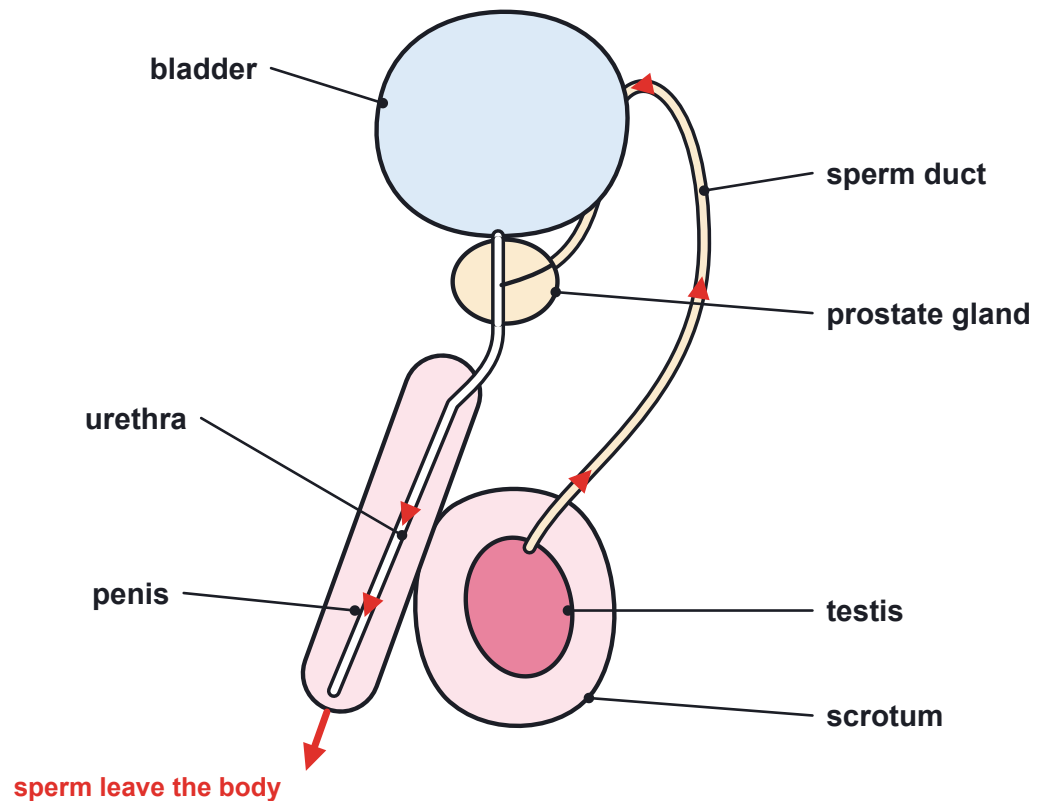
Quick check

1. How many parents are needed for asexual reproduction?
2. What is pollination?
3. What does the ovule become after fertilisation?
4. Name three conditions needed for germination.
5. Give one natural and one artificial method of asexual reproduction in plants.

2 Human reproduction Spec 3.8-3.13

Male and female reproductive systems Spec 3.8

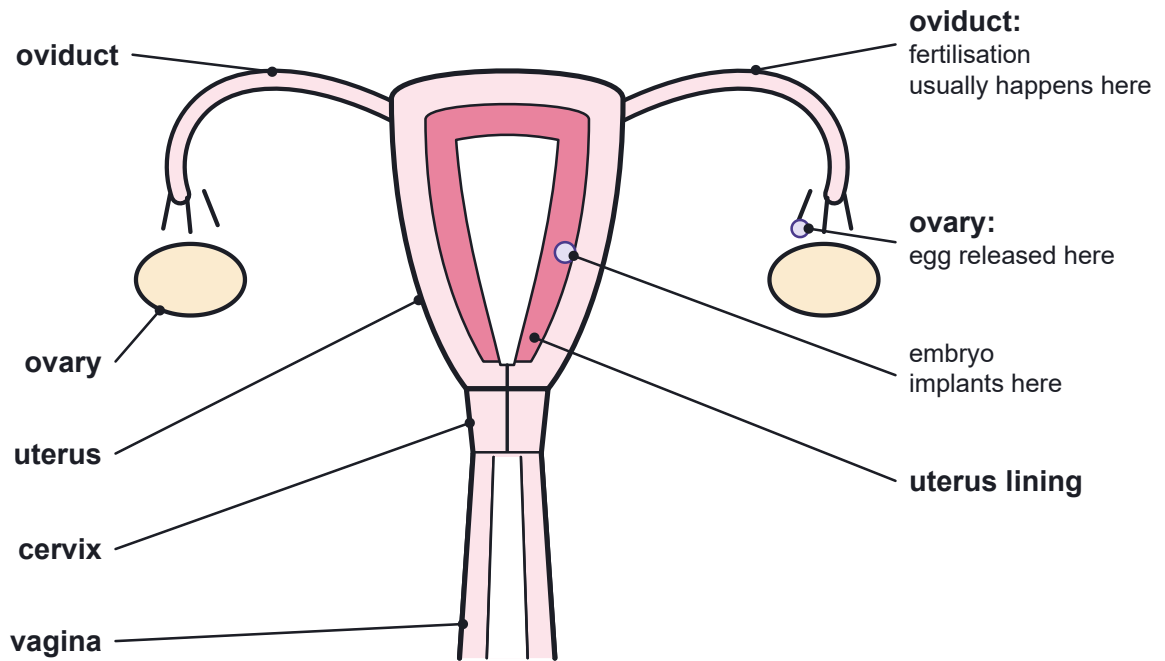
The reproductive systems are adapted for making **gametes**, bringing the gametes together for **fertilisation**, and (in females) protecting and nourishing the developing embryo. Sperm are made in the **testes** and eggs in the **ovaries**.



The male reproductive system. Sperm travel from the **testis** along the **sperm duct** to the **urethra** and out through the penis.

The male reproductive system

Part	Function
Testes	Make sperm (the male gametes) and the hormone testosterone
Scrotum	A bag of skin that holds the testes outside the body, where it is slightly cooler, which is better for sperm production
Sperm duct	A tube that carries sperm from each testis towards the urethra
Prostate gland	Adds fluid to the sperm to make semen. The fluid gives the sperm a liquid to swim in and contains nutrients
Urethra	A tube that carries semen (and urine) through the penis to the outside
Penis	Passes sperm into the vagina during sexual intercourse



The female reproductive system. Fertilisation usually happens in the oviduct and the embryo implants in the uterus lining.

The female reproductive system

Part	Function
Ovaries	Make eggs (the female gametes) and the hormones oestrogen and progesterone
Oviducts	Tubes that carry the egg from the ovary to the uterus. Fertilisation usually happens here. The lining of the oviduct has cilia that move the egg along
Uterus	A muscular organ with a soft lining. The embryo implants in the lining and the fetus develops here
Cervix	A ring of muscle at the opening of the uterus. It keeps the uterus closed during pregnancy
Vagina	Receives the penis and sperm during intercourse. It is also the birth canal

Exam tip: Learn each part as 'name, then job'. Examiners often ask where gametes are made (testes and ovaries) and where fertilisation happens (oviduct).

Oestrogen, progesterone and the menstrual cycle Spec 3.9

The menstrual cycle is a series of changes in a woman that repeats about every 28 days. Each cycle, an egg is released from an ovary and the lining of the uterus is prepared in case the egg is fertilised.

Stages of the menstrual cycle (days are approximate)

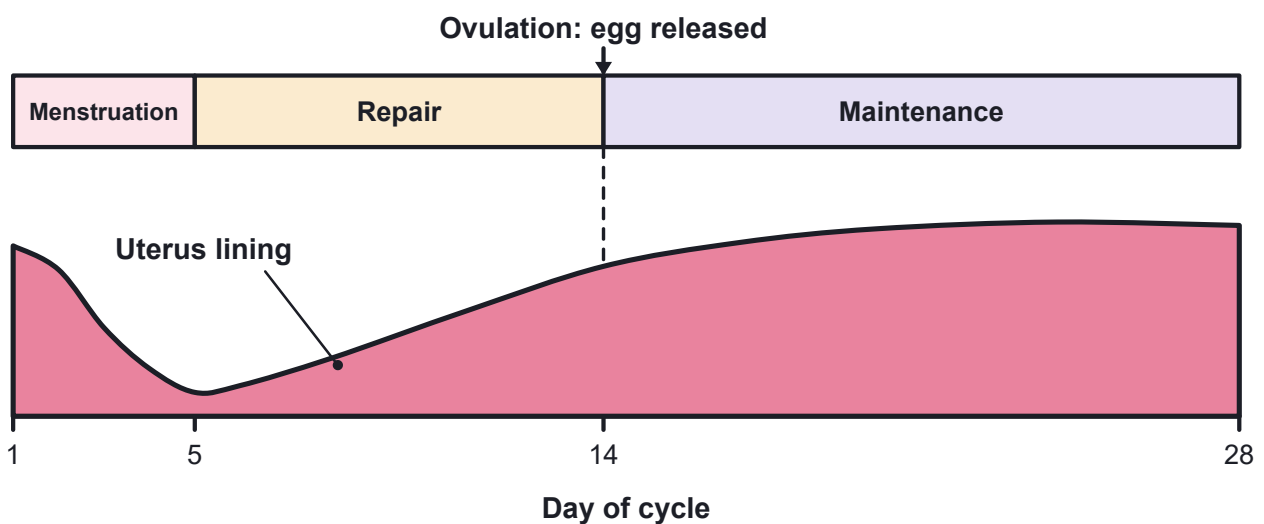
Stage	Days	What happens
Menstruation	1 to 5	The lining of the uterus breaks down and is lost through the vagina with blood
Repair	5 to 14	The uterus lining is repaired and thickens again
Ovulation	Around 14	An egg is released from an ovary
Maintenance	14 to 28	The lining stays thick, ready for a fertilised egg. If there is no pregnancy it breaks down and the cycle starts again

The roles of two hormones

- **Oestrogen** is made in the ovaries. It causes the **repair and growth** of the uterus lining.
- **Progesterone** is made in the ovaries. It **maintains** the uterus lining.

If the egg is not fertilised, the level of progesterone falls. The lining is then no longer maintained, so it breaks down and menstruation begins.

Maths skill: When you read a hormone graph, say which day the change happens on and whether the level rises, falls or peaks. Use figures from the axes.



The stages of the menstrual cycle and how the thickness of the **uterus lining** changes.

FSH and LH in the menstrual cycle Spec 3.10B Biology only

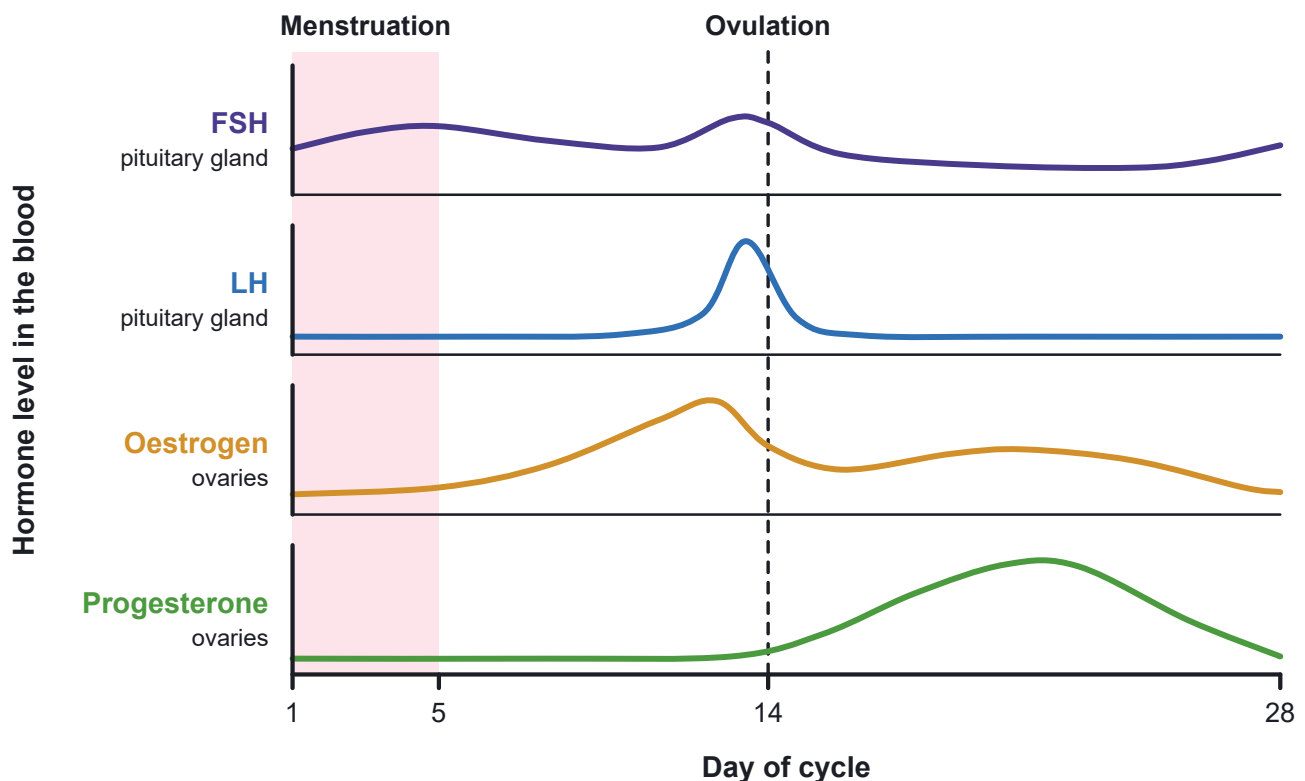
Four hormones interact to control the cycle. **FSH** and **LH** are released by the pituitary gland. **Oestrogen** and **progesterone** are made by the ovaries.

Hormones of the menstrual cycle

Hormone	Made in	What it does
FSH	Pituitary gland	Causes an egg to mature in an ovary. Stimulates the ovaries to produce oestrogen
Oestrogen	Ovaries	Repairs and builds up the uterus lining. Inhibits FSH. Stimulates the release of LH
LH	Pituitary gland	Causes ovulation
Progesterone	Ovaries	Maintains the uterus lining. Inhibits FSH and LH

1. FSH makes an egg mature and stimulates the ovaries to make oestrogen.
2. Oestrogen repairs the uterus lining. When oestrogen is high it inhibits FSH and stimulates the release of LH.
3. LH causes ovulation, around day 14.
4. After ovulation the ovary produces progesterone, which maintains the lining and inhibits FSH and LH, so no more eggs mature.
5. If there is no pregnancy, progesterone falls. The lining is no longer maintained and breaks down. This is menstruation.

Exam tip: Always say what each hormone does to the next one: stimulates or inhibits. Just writing 'oestrogen affects LH' will not score.



Levels of FSH, LH, oestrogen and progesterone. The **LH surge** triggers ovulation around day 14.

The placenta and amniotic fluid Spec 3.11, 3.12

After the embryo implants in the uterus lining, the **placenta** grows. It is a disc-shaped organ that attaches the embryo to the uterus wall. The embryo is joined to the placenta by the umbilical cord,

which contains blood vessels.

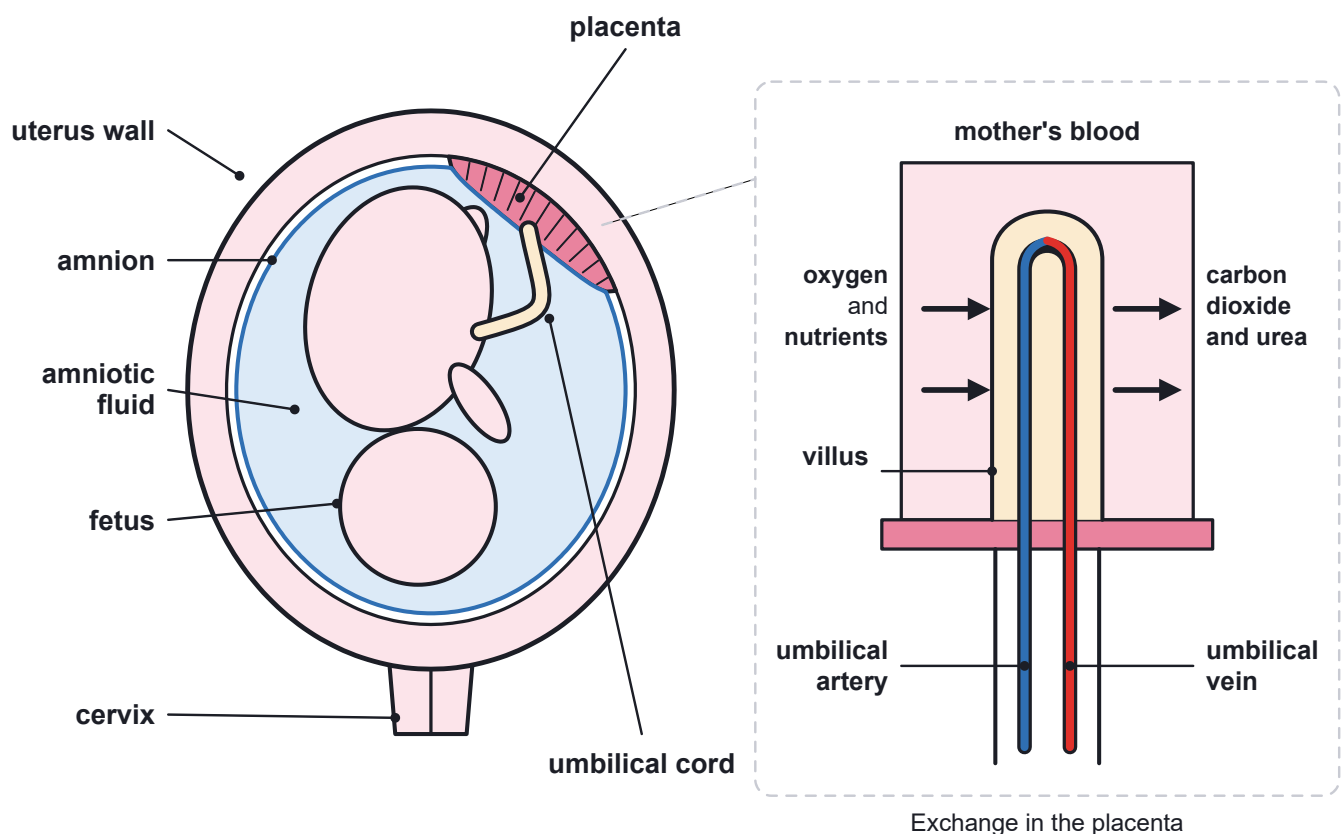
The role of the placenta

The mother's blood and the embryo's blood flow close together in the placenta, but they do not mix. Substances pass between them by **diffusion**.

- Oxygen and **nutrients** (such as glucose and amino acids) diffuse from the mother's blood into the embryo's blood. This provides the embryo with its nutrition.
- Carbon dioxide and urea diffuse from the embryo's blood into the mother's blood, to be removed.
- The placenta has many villi. These give a large surface area for exchange, so more substances can diffuse. A good blood supply and thin walls also make diffusion faster.

Amniotic fluid

The embryo develops inside a bag called the amnion. The amnion is filled with **amniotic fluid**. The fluid **protects** the developing embryo by absorbing shocks and cushioning it against knocks and bumps to the mother's abdomen.



Oxygen and nutrients **diffuse from the mother's blood** into the fetus's blood across the **placenta**; carbon dioxide and urea diffuse the other way.

Common mistake: The mother's blood and the embryo's blood do not mix. Substances move between them by diffusion across the placenta.

Puberty and secondary sexual characteristics Spec 3.13

At **puberty**, the sex hormones cause the body to develop **secondary sexual characteristics**. These are the features that develop at puberty, which are not directly part of the reproductive organs. In girls, the hormone is **oestrogen**, made by the ovaries. In boys, it is **testosterone**, made by the testes.

Secondary sexual characteristics

Hormone	Made by	Effects at puberty
Oestrogen	Ovaries	Breasts develop. Hips widen. Pubic and underarm hair grow. The menstrual cycle begins
Testosterone	Testes	Facial hair grows. The voice deepens. Muscles develop and shoulders broaden. Pubic and underarm hair grow. Sperm production begins

Exam tip: Name the hormone and the gland that makes it, then give the effect. For example: 'testosterone from the testes makes the voice deepen'.

Quick check

1. Where are sperm made?
2. What does oestrogen do in the menstrual cycle?
3. What does progesterone do in the menstrual cycle?
4. **Biology only** Which hormone causes ovulation?
5. How does amniotic fluid protect the embryo?

3 DNA, genes and protein synthesis Spec 3.14–3.18B

The genome, genes and chromosomes Spec 3.14, 3.15

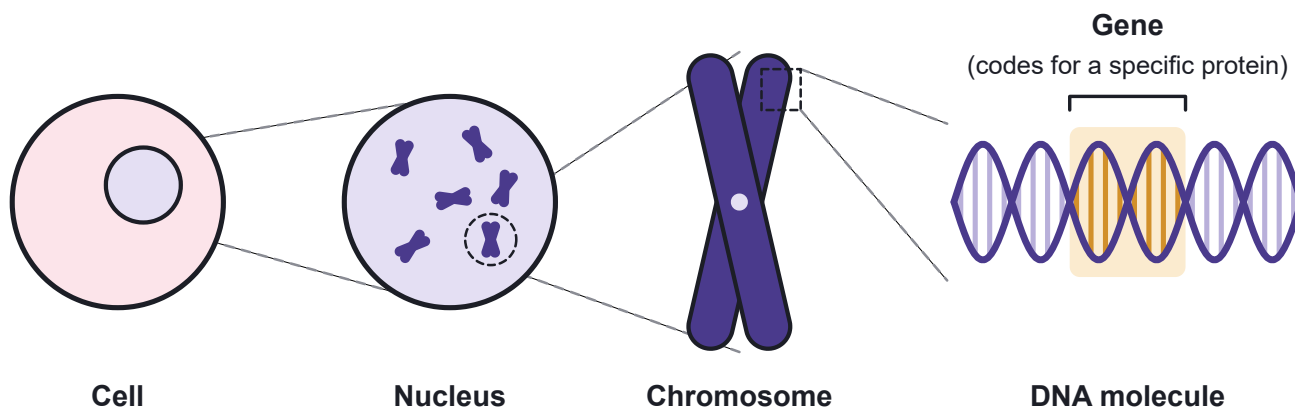
Genome	The entire DNA of an organism.
Gene	A section of a molecule of DNA that codes for a specific protein.
Chromosome	A long molecule of DNA, found in the nucleus, on which genes are located.

The **nucleus** of a cell contains **chromosomes**. Each chromosome is one very long DNA molecule, and many genes are located along it.

The genome includes all of the genes of an organism, as well as the rest of its DNA. A gene is a short section of the DNA. Each gene has a different sequence of bases, so each gene codes for a different protein.

Proteins do most of the work in a cell. Enzymes are proteins, for example. So the genes in a cell decide which proteins it can make, and that helps to decide the characteristics of the organism.

From nucleus to gene	
Structure	What it is
Nucleus	The part of the cell that contains the chromosomes
Chromosome	A long DNA molecule with many genes along it
Gene	A section of DNA that codes for one specific protein
Genome	All of the DNA of the organism



The **nucleus** contains **chromosomes**; each chromosome is a long DNA molecule, and a **gene** is a short section of it.

Exam tip: Use the exact wording. A gene codes for a specific protein, and the genome is the entire DNA, not just the genes.

Common mistake: Genes are located on chromosomes, which are in the nucleus. Do not say that chromosomes are found inside genes.

The structure of DNA Spec 3.16B Biology only

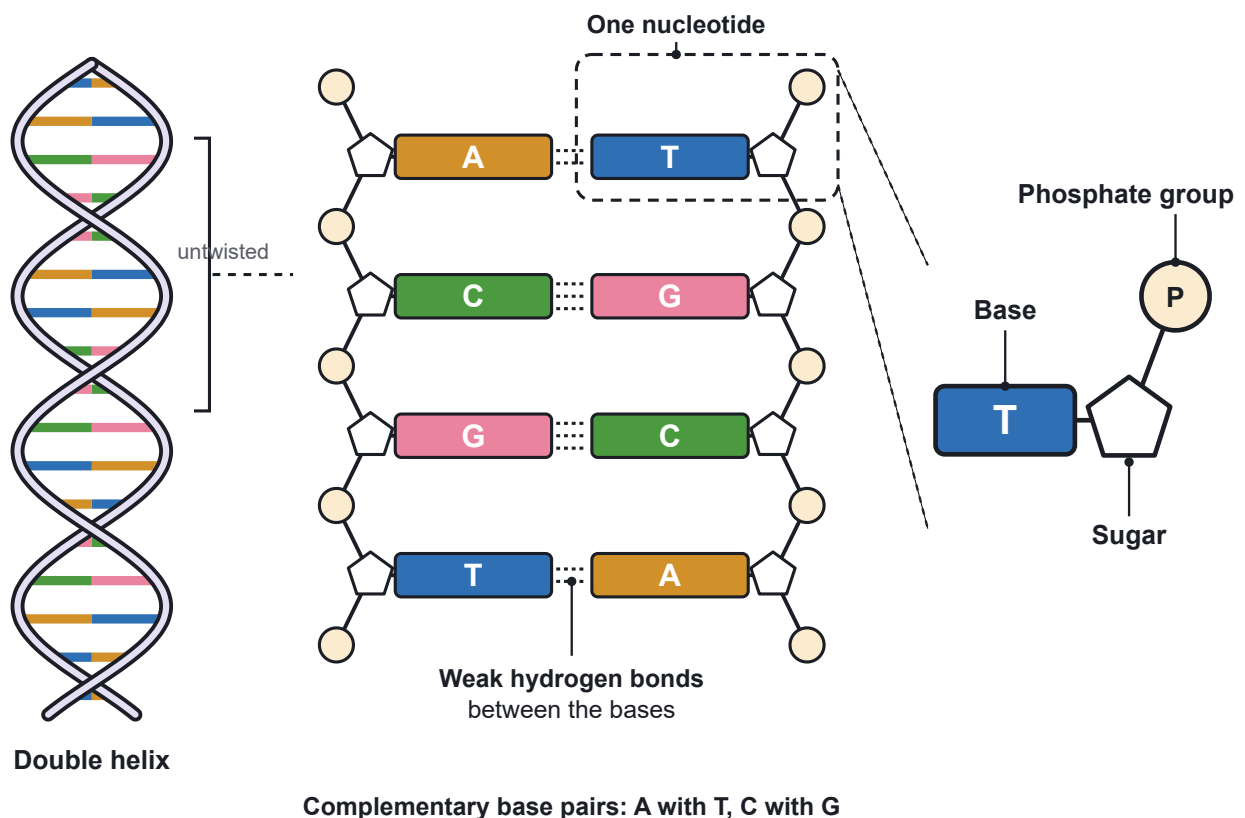
A DNA molecule is made of **two strands** coiled to form a **double helix**. Each strand is a chain of small units called nucleotides.

The two strands are linked by a series of **paired bases**. There are four bases, and each one only pairs with one other.

The four bases and how they pair

Base	Pairs with
Adenine (A)	Thymine (T)
Thymine (T)	Adenine (A)
Cytosine (C)	Guanine (G)
Guanine (G)	Cytosine (C)

Because A always pairs with T and C always pairs with G, the base sequence on one strand tells you the sequence on the other. If one strand reads A T G C, the other strand reads T A C G.



DNA is a double helix of two strands; the bases pair **A with T** and **C with G**.

Exam tip: Write the pairs as A with T and C with G. If you are asked for the complementary strand, swap each base for its partner.

Common mistake: A does not pair with C or G. In DNA there is no uracil; that base is only in RNA.

RNA and protein synthesis Spec 3.17B, 3.18B Biology only

DNA stays in the nucleus, but proteins are made at ribosomes in the cytoplasm. A different molecule, RNA, carries the instructions from the gene to the ribosome.

DNA and RNA		
	DNA	RNA
Number of strands	Two (double helix)	One (single stranded)
Base that pairs with adenine	Thymine (T)	Uracil (U)
Bases present	A, T, C, G	A, U, C, G

A **codon** is a sequence of three bases on mRNA. Each codon codes for one amino acid. An **anticodon** is a sequence of three bases on a tRNA molecule that is complementary to a codon.

Stage 1: transcription (in the nucleus)

1. The two DNA strands separate along the gene.
2. A single strand of **mRNA** (messenger RNA) is made as a copy of the gene, by pairing complementary bases. A pairs with U, T pairs with A, C pairs with G and G pairs with C.
3. The mRNA leaves the nucleus through a pore and goes to a ribosome in the cytoplasm.

Stage 2: translation (at a ribosome)

1. The mRNA attaches to a **ribosome**.
2. **tRNA** (transfer RNA) molecules bring amino acids to the ribosome. Each tRNA carries one specific amino acid.
3. The anticodon of each tRNA pairs with the matching codon on the mRNA.
4. The amino acids are joined together in the order set by the codons, making a chain called a polypeptide. The polypeptide folds up to form a protein.

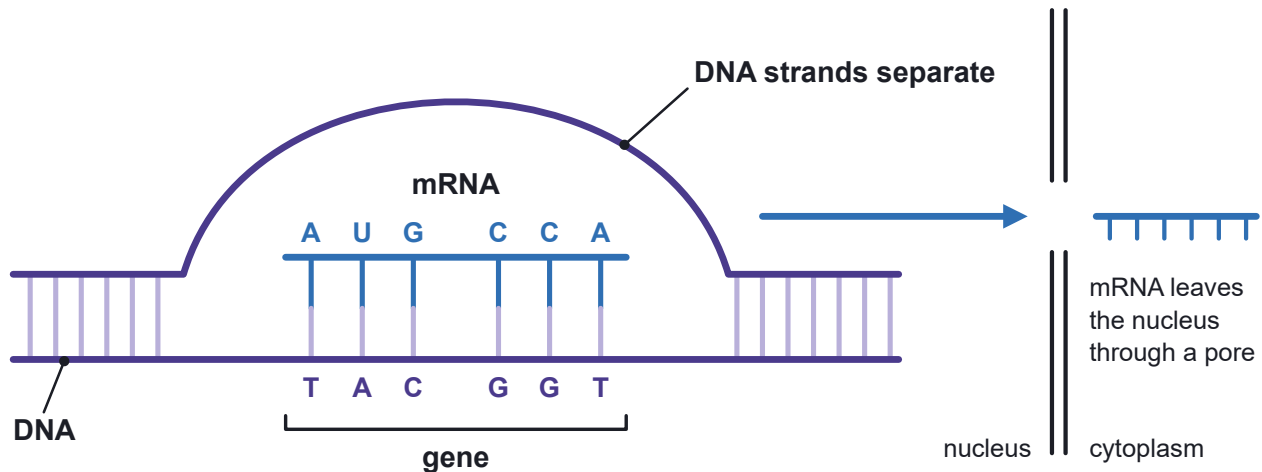
Transcription and translation of a short gene

The DNA template strand reads T A C G G T. Give the mRNA codons and the tRNA anticodons.

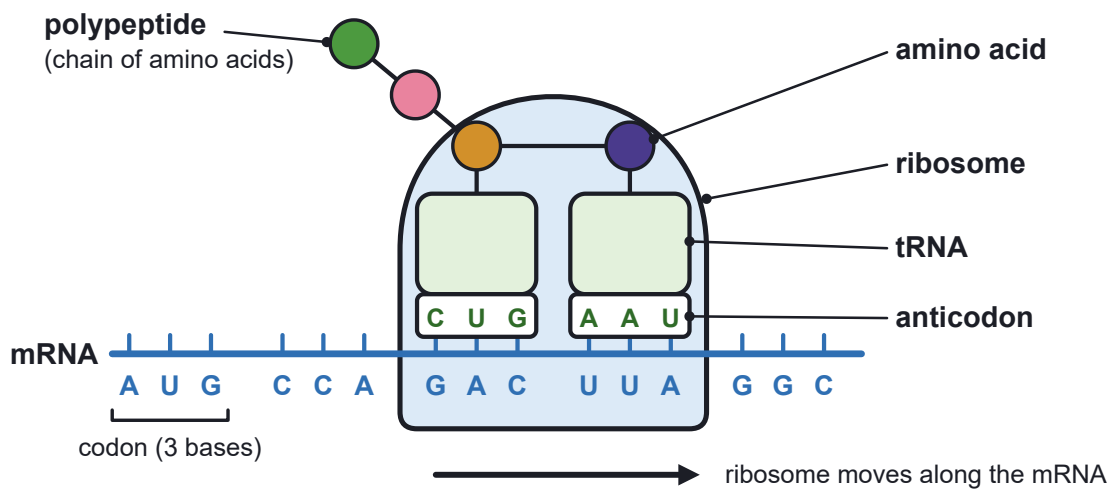
1. Transcription: pair each DNA base with its RNA partner. T gives A, A gives U, C gives G, and so on.
mRNA = A U G C C A.
2. Codons: AUG and CCA.
3. Translation: each anticodon is complementary to its codon. AUG pairs with UAC and CCA pairs with GGU.

Answer: mRNA codons AUG CCA; tRNA anticodons UAC and GGU.

1 Transcription (in the nucleus)



2 Translation (at a ribosome in the cytoplasm)



Transcription makes mRNA from a gene in the nucleus; **translation** at a ribosome joins amino acids in the order set by the codons.

Common mistake: Do not mix up the two stages. Transcription makes mRNA from DNA in the nucleus. Translation makes a polypeptide from mRNA at a ribosome.

Exam tip: Codons are on mRNA. Anticodons are on tRNA. Name the molecule when you use either word.

Quick check

1. What is a gene?
2. What is the genome?
3. **Biology only** Which base pairs with adenine in DNA?
4. **Biology only** Which base is in RNA instead of thymine?
5. **Biology only** Where are amino acids joined together to make a polypeptide?

4 Inheritance Spec 3.19-3.27

Alleles and genetic terms Spec 3.19, 3.20

Genes exist in alternative forms called **alleles**. A gene for flower colour may have an allele for purple flowers and an allele for white flowers.

In body cells, chromosomes are in pairs, so an organism has two alleles of each gene: one from each parent. Different combinations of alleles give rise to **differences in inherited characteristics**.

Allele	A different version (alternative form) of the same gene.
Dominant	An allele that is expressed in the phenotype even when only one copy is present.
Recessive	An allele that is only expressed in the phenotype when two copies are present, so no dominant allele is there.
Homozygous	Having two identical alleles of a gene, for example TT or tt.
Heterozygous	Having two different alleles of a gene, for example Tt.
Genotype	The alleles an organism has for a gene, for example Tt.
Phenotype	The characteristic that is expressed and can be observed, for example tall.

Dominant alleles are written as capital letters (T) and recessive alleles as lower case letters (t). A heterozygous plant, Tt, shows the dominant characteristic.

Exam tip: Genotype is the alleles, such as Tt. Phenotype is what you can see, such as tall. Do not swap them.

Common mistake: An allele is not a different gene. It is a different version of the same gene, found at the same position on a chromosome.

Codominance Spec 3.21B Biology only

Sometimes neither allele is dominant. **Codominance** is when both alleles are expressed in the phenotype of a heterozygous organism.

An example is coat colour in some cattle. The allele for red hair (R) and the allele for white hair (W) are codominant. Both are written as capital letters because neither is dominant. An animal with one of each, RW, has both red hairs and white hairs. It is called **roan**.

Coat colour in cattle (codominance)	
Genotype	Phenotype
RR	Red
WW	White
RW	Roan (red hairs and white hairs)

A cross with codominant alleles

A red bull (RR) is crossed with a white cow (WW). What are the genotype and phenotype of the calves?

1. Gametes from the bull: all R. Gametes from the cow: all W.
2. Every calf receives one of each allele, so every calf is RW.
3. Both alleles are expressed, so every calf has red hairs and white hairs.

Answer: All calves are RW and roan.

If two roan cattle (RW × RW) are crossed, the offspring genotypes are 1 RR : 2 RW : 1 WW. Because the heterozygote has its own phenotype, the phenotype ratio is also **1 red : 2 roan : 1 white**, not 3 : 1.

The ABO blood groups are another example. The allele for blood group A and the allele for blood group B are codominant, so a person who inherits one of each has blood group AB.

Common mistake: Codominance is not blending. In a roan animal, red hairs and white hairs are both there, not pink hairs.

Exam tip: Define codominance as both alleles being expressed in the phenotype of a heterozygous organism.

Polygenic inheritance Spec 3.22

Some characteristics, like flower colour in Mendel's pea plants, are controlled by a single gene. These are the ones used in simple monohybrid crosses.

Most phenotypic features are the result of **polygenic inheritance** rather than single genes. This means that several genes work together to produce the feature.

Features controlled by many genes, such as height, show a **wide range of values** rather than a few clear categories.

Exam tip: If a question asks why a feature does not follow a simple 3 : 1 ratio, one answer is that it is controlled by more than one gene.

Monohybrid inheritance and genetic diagrams Spec 3.23

Monohybrid inheritance is the inheritance of a characteristic controlled by a single gene. You show it using a genetic diagram, such as a Punnett square.

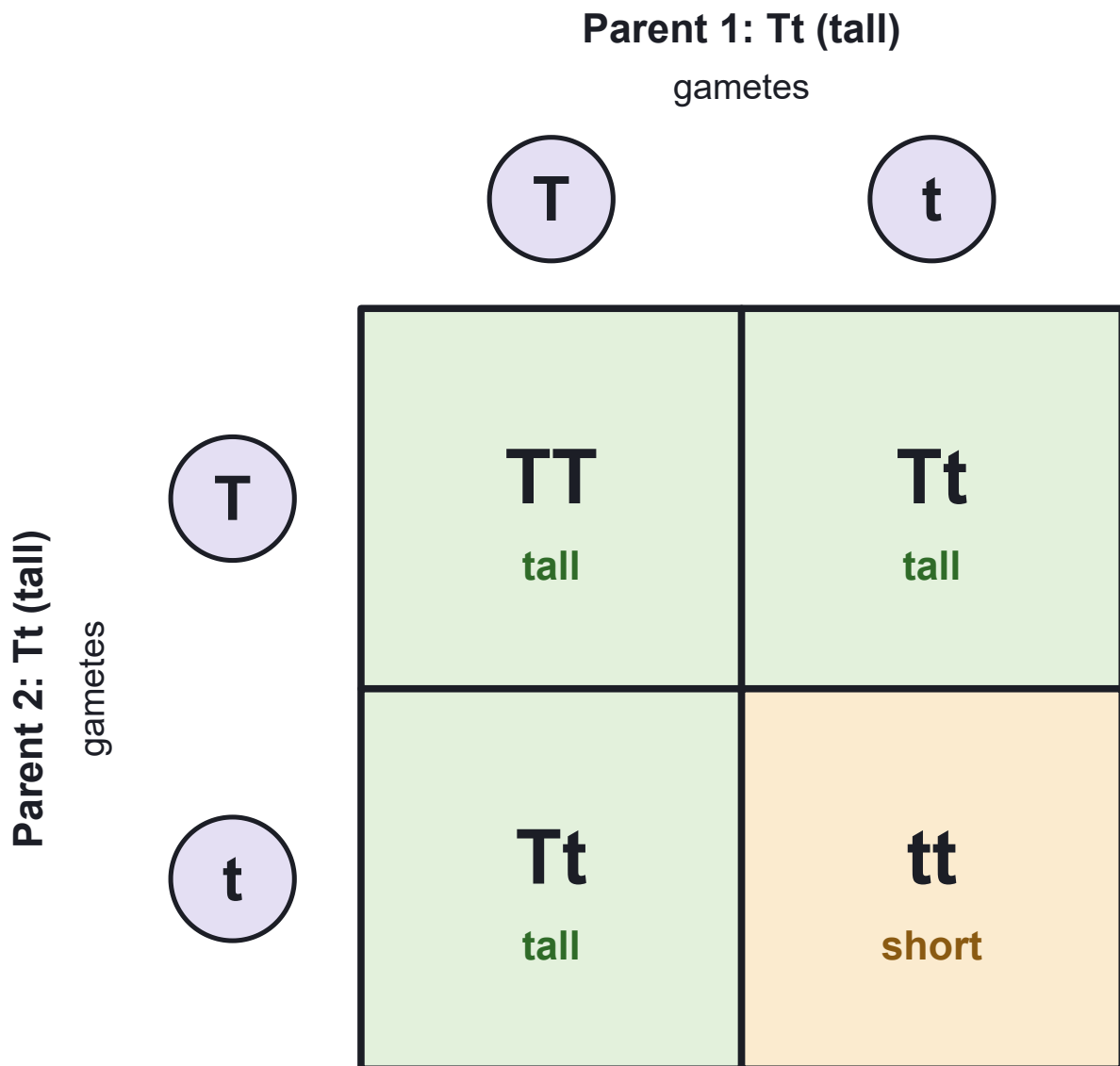
1. Choose letters for the alleles: a capital letter for dominant, lower case for recessive.
2. Write the genotypes of the parents.
3. Write the possible gametes from each parent. Each gamete has one allele.
4. Combine the gametes in a Punnett square to show the possible genotypes of the offspring.
5. Write the phenotype for each genotype.

Crossing two heterozygous pea plants

Tall (T) is dominant to short (t). Two heterozygous tall plants (Tt) are crossed. Show the possible offspring.

1. Parent genotypes: Tt and Tt.
2. Gametes: T or t from each parent.
3. Punnett square: the four boxes are TT, Tt, Tt and tt.
4. Phenotypes: TT, Tt and Tt are tall; tt is short.

Answer: Offspring genotypes: 1 TT : 2 Tt : 1 tt. Phenotypes: 3 tall : 1 short.



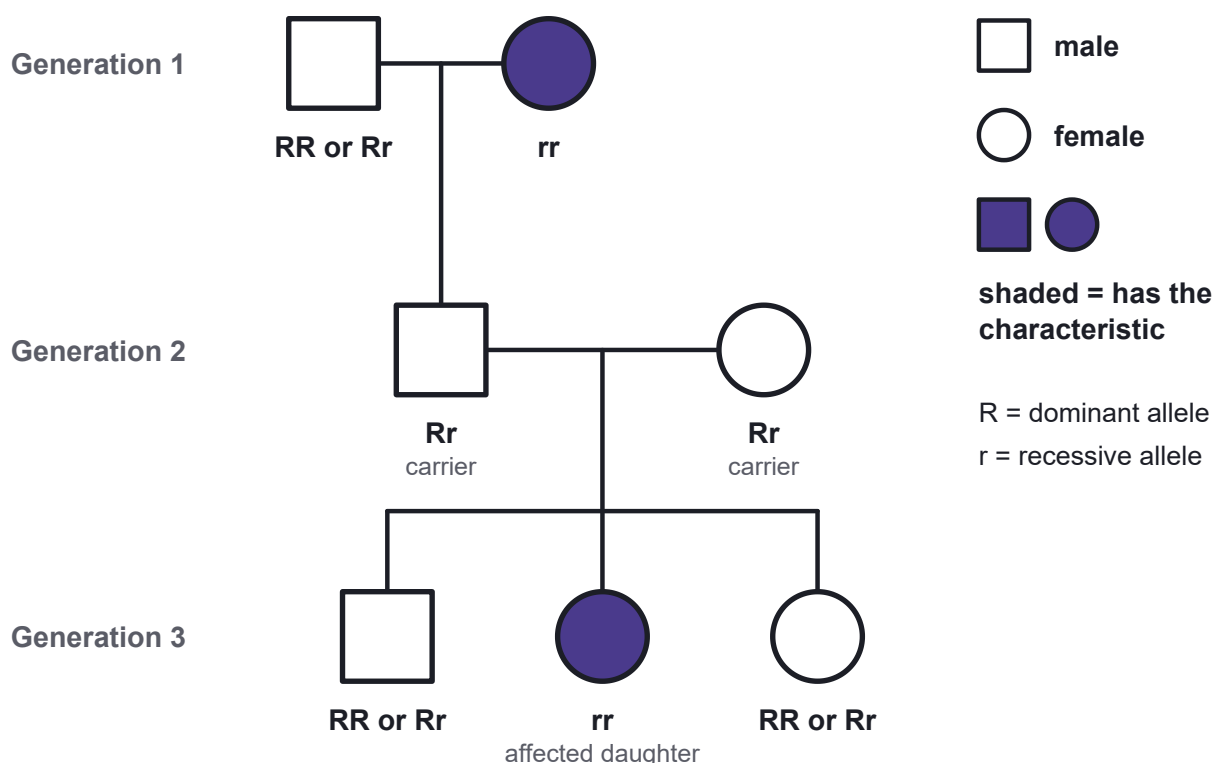
Tt × Tt gives 3 tall : 1 short (1 TT : 2 Tt : 1 tt).

Exam tip: Always write the gametes in circles or in a labelled row and column, and say which letter is dominant. Marks are given for gametes, offspring genotypes and phenotypes.

Family pedigrees and probabilities Spec 3.24, 3.25

A family pedigree (family tree) shows who in a family has a characteristic. Squares are usually males and circles are females. Shaded shapes show people with the characteristic. A horizontal line joins the parents and a vertical line leads down to their children.

- If two parents who do not have a characteristic have a child who does, the characteristic is **recessive**. Both parents must be carriers: heterozygous, with one copy of the recessive allele.
- If two parents who both have a characteristic have a child who does not, the characteristic is **dominant**. Both parents must be heterozygous.



Two unaffected parents with an affected daughter: the characteristic is **recessive** and both parents are carriers (Rr).

Predicting probabilities

You can predict the outcome of a monohybrid cross as a ratio, a **probability** or a percentage.

Ways of giving the same outcome (Tt × Tt)

Outcome	Boxes out of 4	Probability	Percentage
Short plant (tt)	1	1/4 or 0.25	25%
Tall plant (TT or Tt)	3	3/4 or 0.75	75%

Probability for a recessive disorder

A disorder is caused by a recessive allele (f). Two parents do not have the disorder but both are carriers (Ff). What is the probability that their child has the disorder?

1. Gametes from each parent: F or f.
2. Possible offspring: FF, Ff, Ff and ff.
3. Only ff has the disorder. That is 1 out of 4 equally likely outcomes.

Answer: Probability = $1/4 = 0.25 = 25\%$.

Each child is an independent event. If the first child has the disorder, the probability for the next child is still 1 in 4. Probabilities describe chance. They do not guarantee the actual numbers in a family.

Maths skill: A 3 : 1 ratio means 1 in 4 offspring show the recessive feature, not 1 in 3. Count the favourable boxes out of the total.

Exam tip: In a pedigree question, find two parents with the same phenotype and a child with the other phenotype. That tells you which allele is dominant.

Sex determination Spec 3.26, 3.27

Humans have 23 pairs of chromosomes. One pair is the **sex chromosomes**. Females have two X chromosomes (XX). Males have one X and one Y chromosome (XY).

All eggs carry an X chromosome. Half of the sperm carry an X and half carry a Y. The sex of the offspring is decided at **fertilisation** by which sperm fertilises the egg.

Genetic diagram for sex determination		
	X (egg)	X (egg)
X (sperm)	XX female	XX female
Y (sperm)	XY male	XY male

Two outcomes are female and two are male, so the ratio is **1:1** and there is a **50% probability** that a baby will be a boy or a girl.

Common mistake: The father's sperm decides the sex of the baby, because it carries either an X or a Y. Every egg carries an X.

Quick check

1. What is an allele?
2. What is the difference between genotype and phenotype?
3. What does homozygous mean?
4. Two parents without a disorder have an affected child. Is the disorder dominant or recessive?
5. **Biology only** What is codominance?

5 Cell division, variation and evolution Spec 3.28–3.39

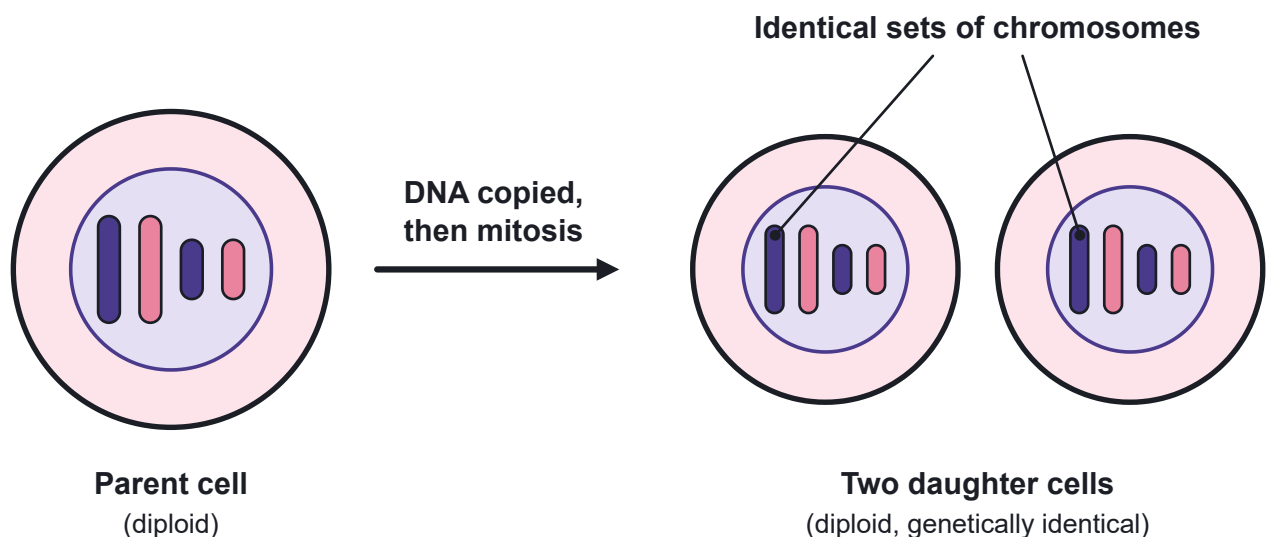
Mitosis Spec 3.28

Body cells are **diploid**. This means the nucleus contains two sets of chromosomes, which form pairs.

In **mitosis**, a diploid cell divides to produce **two cells** (daughter cells). Each daughter cell has an **identical set of chromosomes** to the parent cell, so the two cells are **genetically identical** to the parent and to each other.

The DNA is copied before the cell divides, and the copies are shared equally between the two daughter cells. So each daughter cell is also diploid. In humans each daughter cell has 46 chromosomes.

Mitosis	Division of a diploid cell to produce two cells that contain identical sets of chromosomes.
Diploid	A cell with two sets of chromosomes in its nucleus.
Genetically identical	Having exactly the same genetic information (the same DNA).



Mitosis gives **two genetically identical cells**, each with the same set of chromosomes as the parent.

Exam tip: To describe the result of mitosis, give the key points: **two cells, identical sets of chromosomes to the parent cell, genetically identical. The stages of mitosis are not required.**

Growth, repair, cloning and asexual reproduction Spec 3.29

Mitosis occurs during growth, repair, cloning and asexual reproduction.

- **Growth:** a multicellular organism grows by making more cells by mitosis. All the new cells are genetically identical, so they have the same instructions.
- **Repair:** damaged or worn-out cells are replaced with new cells made by mitosis, for example when skin is cut.
- **Cloning:** a clone is a group of genetically identical organisms or cells. Clones are made using mitosis, for example plants grown from cuttings.
- **Asexual reproduction:** one parent produces offspring that are genetically identical to it. The offspring are made by mitosis, so there is no mixing of genetic information.

Exam tip: **Asexual reproduction needs only one parent and gives genetically identical offspring. Say both if the question asks you to describe it.**

Meiosis, fertilisation and chromosome number Spec 3.30, 3.31, 3.32

Meiosis is the type of cell division that makes gametes (sex cells). In humans it happens in the reproductive organs: the ovaries and the testes.

- One diploid cell divides to produce four cells.
- Each cell has half the number of chromosomes of the parent cell.
- The cells are genetically different from each other and from the parent cell.
- The four cells are **haploid gametes**, with one set of chromosomes.

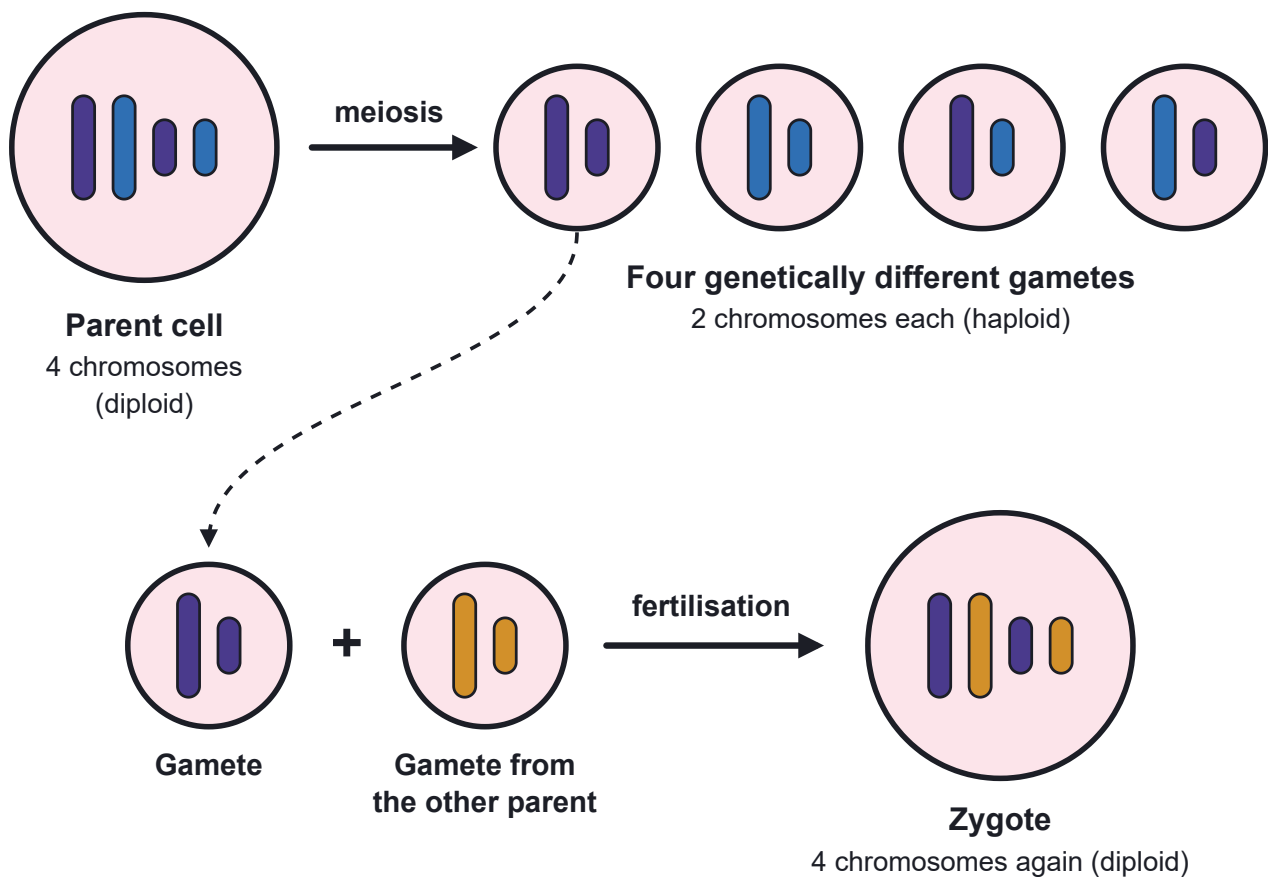
In human cells the **diploid number is 46** and the haploid number is 23. Meiosis makes sperm and egg cells with 23 chromosomes each.

Body cells and gametes		
	Body cell (diploid)	Gamete (haploid)
Chromosomes in a human cell	46	23
Genetically identical to the others?	Yes, if made by mitosis	No, each gamete is different
Made by	Mitosis	Meiosis

Fertilisation and variation

At fertilisation, a sperm and an egg fuse to make a zygote with 46 chromosomes again, half from each parent. Fertilisation is random: any sperm can fuse with any egg.

Each gamete is genetically different, and any gamete can fuse with any other. So random fertilisation produces **genetic variation** in the offspring. Brothers and sisters are not identical to each other, or to either parent.



Meiosis halves the chromosome number; **fertilisation** restores it in the zygote.

Exam tip: The stages of meiosis are not required. Learn the outcome: four genetically different haploid gametes, each with half the number of chromosomes.

Genetic and environmental variation Spec 3.33

Differences between individuals of the same species are called **variation**. Variation within a species can be **genetic**, **environmental**, or a combination of both.

Genetic and environmental variation		
	Genetic variation	Environmental variation
What it is	Differences caused by the alleles an organism inherits	Differences caused by an organism's surroundings and way of life
Examples	Blood group, eye colour, sex	A scar, body mass affected by diet, plant height affected by light

Many features are affected by both. For example, a person's height depends on the alleles they inherit and also on their diet when growing up. A plant's height depends on its alleles, and also on the light and minerals it receives.

Exam tip: Identical twins have the same alleles. Differences between them must be caused by the environment, which is a favourite way of testing this point.

Mutations and the phenotype Spec 3.34, 3.35B, 3.36B

A **mutation** is a rare, random change in genetic material that can be inherited. Usually it is a change in the base sequence of DNA.

Mutations are one source of genetic variation. A mutation in a gamete, or in a cell that makes gametes, can be passed on to offspring.

Biology only

How a mutation can change the phenotype

Biology only

1. A change in the DNA changes the **base sequence** of a gene.
2. This can change the **sequence of amino acids** in the protein that the gene codes for.
3. The protein may then fold into a different shape and no longer work in the same way. For example, an enzyme's active site may no longer fit its substrate.
4. The change in the protein can change the phenotype.

Biology only

- Most genetic mutations have **no effect** on the phenotype.
- Some mutations have a small effect on the phenotype.
- Rarely, a mutation has a **significant effect** on the phenotype.

Biology only

Common mistake: Do not write that all mutations are harmful. Most have no effect on the phenotype.

Causes of mutation Spec 3.37B Biology only

Mutations happen naturally and at random, but the **incidence** (how often they happen) can be increased by exposure to certain things called **mutagens**.

- **Ionising radiation**, for example gamma rays, X-rays and ultraviolet (UV) rays.
- Some **chemical mutagens**, for example chemicals in tobacco.

Exposure to a mutagen makes a mutation more likely. It does not mean that a mutation will definitely happen. This is one reason why people are protected from unnecessary exposure to radiation, and why tobacco smoke is harmful.

Exam tip: Learn one radiation example and one chemical example: for instance X-rays and chemicals in tobacco. Say they increase the rate of mutation.

Darwin's theory of evolution by natural selection Spec 3.38

Evolution is a change in the inherited characteristics of a population over many generations. Darwin's theory explains how it happens by **natural selection**.

1. Individuals in a population show **variation**. Some of this variation is genetic, and arises from mutation and sexual reproduction.
2. More offspring are born than can survive, so individuals compete for resources such as food, space and mates. Some are eaten or die of disease.
3. Individuals with characteristics that suit their environment are more likely to **survive and reproduce**.
4. They **pass on the alleles** for those characteristics to their offspring.
5. Over many generations, the proportion of the population with the advantageous alleles increases.

This is sometimes summed up as 'survival of the fittest'. 'Fittest' means best suited to the environment, not strongest.

Common mistake: Individuals do not change during their lives to cope with their environment. The advantageous allele has to be there already, and the proportion of individuals with it increases over generations.

Exam tip: Write the full chain in your answer: variation, competition, survival and reproduction of the better adapted, alleles passed on, proportion increases.

Antibiotic resistance Spec 3.39

The increase in antibiotic-resistant bacteria is an example of natural selection that can be seen happening within a human lifetime. Bacteria reproduce very quickly, so changes in a population happen fast.

1. In a population of bacteria, a **mutation** produces an allele that makes one bacterium **resistant** to an antibiotic. This is variation.
2. The antibiotic is used. It kills the non-resistant bacteria, but the resistant bacterium survives. The antibiotic is the **selection pressure**.
3. The resistant bacterium reproduces with less competition and passes the resistance allele on to its offspring.
4. Over time the population becomes mostly resistant bacteria, so the antibiotic no longer works against the infection.

As a result, infections caused by resistant bacteria are **difficult to control**. The antibiotic does not work, so the infection can spread to other people. Using antibiotics only when they are needed, and finishing

the course, helps to slow the increase of resistance.

Percentage of resistant bacteria (practice data)

A sample of 300 bacteria had 12 resistant to an antibiotic. After several rounds of treatment, a sample of 300 bacteria had 192 resistant. Calculate the percentage resistant each time.

1. Before: $12 \div 300 \times 100 = 4\%$

2. After: $192 \div 300 \times 100 = 64\%$

Answer: 4% before and 64% after.

Common mistake: Antibiotics do not cause the mutation, and bacteria do not 'get used to' antibiotics. The resistant bacteria were there by chance and are selected by the antibiotic.

Quick check

1. How many cells does mitosis produce, and how do they compare with the parent cell?
2. What is the diploid number and the haploid number of chromosomes in human cells?
3. Name the type of cell division that produces gametes.
4. Give two causes of variation within a species.
5. **Biology only** Name one mutagen.

Quick check answers

Sexual and asexual reproduction, and reproduction in plants

1. One.
2. The transfer of pollen grains from an anther to a stigma.
3. A seed.
4. Water, oxygen and a suitable temperature.
5. Natural: runners. Artificial: cuttings.

Human reproduction

1. In the testes.
2. It repairs and builds up the lining of the uterus.
3. It maintains the lining of the uterus.
4. LH.
5. It absorbs shocks and cushions the embryo against knocks.

DNA, genes and protein synthesis

1. A section of a molecule of DNA that codes for a specific protein.
2. The entire DNA of an organism.
3. Thymine.
4. Uracil (U).
5. At a ribosome (translation).

Inheritance

1. A different version (alternative form) of the same gene.
2. Genotype is the alleles an organism has; phenotype is the characteristic that is expressed.
3. Having two identical alleles of a gene.
4. Recessive.
5. Both alleles are expressed in the phenotype of a heterozygous organism.

Cell division, variation and evolution

1. Two cells, genetically identical to the parent cell.
2. Diploid 46 and haploid 23.
3. Meiosis.
4. Genetic (alleles inherited) and environmental.
5. Ionising radiation (such as X-rays) or chemicals in tobacco.