

Inheritance

Revision notes · Mendel's work, alleles and key terms, monohybrid crosses, pedigrees, sex determination, ABO blood groups and sex-linked disorders.

For Edexcel GCSE Biology 1BI0 and Combined Science 1SC0. **Triple only** is not in Combined Science. **Higher tier** is only on the Higher paper.

Inheritance **Spec 3.11B-3.18B**

Gregor Mendel **Spec 3.11B Triple only**

Gregor Mendel was a monk who worked out the basis of genetics by breeding pea plants in the mid-1800s. He chose characteristics with clear alternatives, such as tall or short plants, and purple or white flowers.

- He crossed plants with different characteristics and counted the characteristics of the offspring over several generations.
- He found that characteristics are passed on as separate **inherited factors**, one from each parent. We now call these factors **genes**.
- He showed that some factors are **dominant** and others are **recessive**. For example, crossing pure-breeding tall plants with pure-breeding short plants gave all tall plants. Crossing those offspring with each other gave about three tall plants for every one short plant.

Difficulties before the mechanism was discovered

- Nobody knew about **genes, DNA or chromosomes**, so there was no mechanism to explain how characteristics are passed on.
- The behaviour of chromosomes during cell division and fertilisation had not been seen, so his ideas could not be linked to anything observable.
- His work was not recognised or understood at the time. It was only appreciated after the structures and processes involved in inheritance were discovered.

Exam tip: Link both halves: Mendel found patterns in how characteristics are inherited, but could not explain them because genes and chromosomes had not yet been discovered.

Alleles and inherited differences **Spec 3.12**

Different forms of the same gene are called **alleles**. A gene for flower colour may have an allele for purple and an allele for white.

In body cells chromosomes are in pairs, so an organism usually has two alleles of each gene: one inherited from each parent. Individuals can have different combinations of alleles, so they have **different inherited characteristics**.

The alleles of a gene have slightly different base sequences, so they can code for slightly different versions of the same protein. This is why a difference in alleles can cause a difference in a characteristic.

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.

Key genetic terms Spec 3.13

Chromosome	A long molecule of DNA in the nucleus that carries many genes.
Gene	A section of DNA that codes for a specific protein.
Allele	A different version 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 (no dominant allele).
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 (or genes).
Phenotype	The characteristics that are expressed and can be observed.
Gamete	A sex cell (such as a sperm or egg) with half the number of chromosomes.
Zygote	The cell formed when two gametes fuse at fertilisation.

Dominant alleles are written as capital letters (T) and recessive alleles as lower case (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.

Monohybrid inheritance Spec 3.14

Monohybrid inheritance is the inheritance of a characteristic controlled by a single gene. You can show it using a genetic diagram, a Punnett square or a family pedigree.

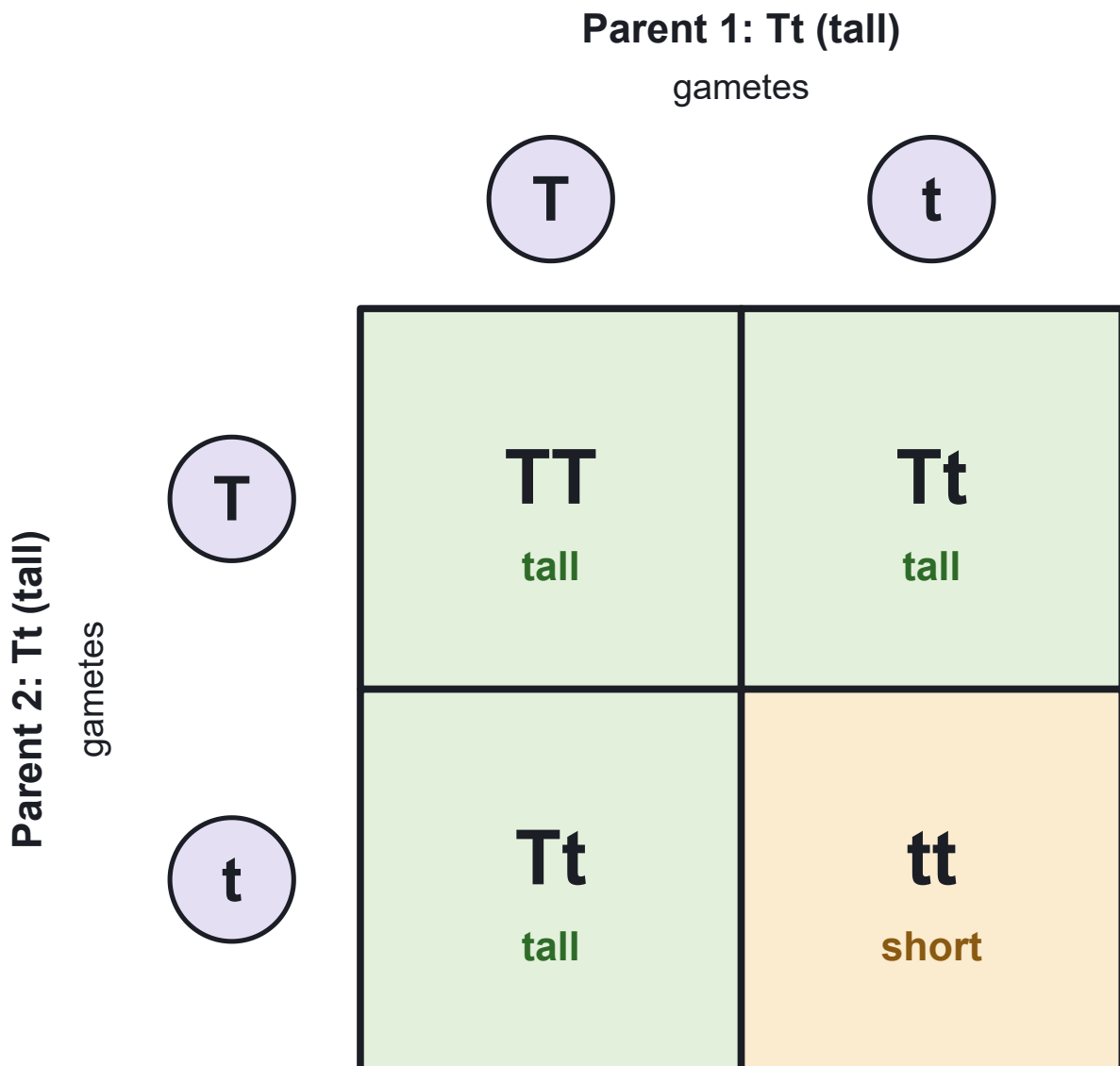
1. Choose letters for the alleles: a capital for dominant, lower case for recessive.
2. Write the genotypes of the parents.
3. Write the possible gametes from each parent. Each gamete has one allele.
4. Combine the gametes in a Punnett square to show the possible genotypes of the offspring.
5. Write 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: top row (gametes from parent 1) T and t; side column (gametes from parent 2) T and t. 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.

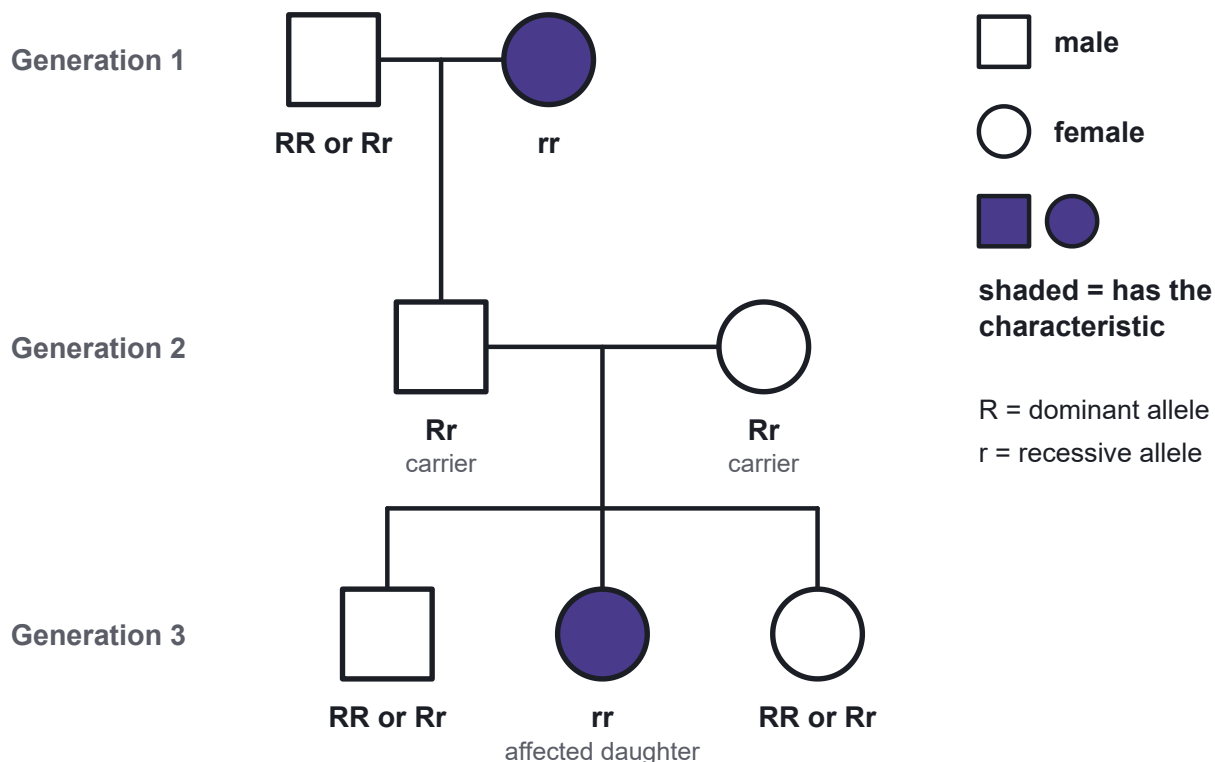


Tt × Tt gives 3 tall : 1 short (1 TT : 2 Tt : 1 tt).

Family pedigrees

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).

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

Sex determination Spec 3.15

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.

Punnett square 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.

Calculating and analysing outcomes Spec 3.16

You need to calculate and analyse the outcomes of monohybrid crosses and pedigrees for dominant and recessive traits. Outcomes can be given as a ratio, a **probability** or a **percentage**.

Ways of giving the same outcome ($Tt \times Tt$)

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%

As a **ratio**, this is 3 tall : 1 short. A 3 : 1 ratio means 1 in 4 offspring are short, not 1 in 3.

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: Show the Punnett square, count the favourable boxes out of the total, then convert to a ratio, fraction or percentage as the question asks.

ABO blood groups Spec 3.17B Triple only

The ABO blood group is controlled by a single gene with **multiple alleles**: more than two alleles of the same gene. There are three alleles, written here as I^A , I^B and I^O . A person inherits two, one from each parent.

Exam tip: In exam papers the second letter is printed small and raised above the I, but it means the same as I^A , I^B and I^O here. Some books write I^O as i .

I^A and I^B are **codominant**: if both are present, both are expressed in the phenotype. I^O is recessive to both.

ABO blood groups

Phenotype (blood group)	Possible genotypes
A	$I^A I^A$ or $I^A I^O$
B	$I^B I^B$ or $I^B I^O$
AB	$I^A I^B$
O	$I^O I^O$

Parents with group A and group B

A mother is $I^A I^O$ and a father is $I^B I^O$. What blood groups could their children have?

1. Mother's gametes: I^A or I^O . Father's gametes: I^B or I^O .
2. Possible children: $I^A I^B$, $I^A I^O$, $I^B I^O$ and $I^O I^O$.

Answer: Group AB, A, B and O, each with a 1 in 4 (25%) probability.

Exam tip: Define codominance as both alleles being expressed in the phenotype of a heterozygous person. Do not call it blending.

Sex-linked genetic disorders

Spec 3.18B

Triple only

Higher tier

A **sex-linked** genetic disorder is caused by an allele on a sex chromosome. Most are caused by a recessive allele on the X chromosome. Haemophilia is an example.

- Males (XY) have only **one X chromosome**, so one copy of the recessive allele is enough to cause the disorder. The Y chromosome does not carry a matching allele.
- Females (XX) have two X chromosomes. They need **two copies** of the recessive allele to have the disorder. With one copy they are **carriers**.
- This is why sex-linked disorders are more common in males.

Carrier mother (XHXh) and unaffected father (XHY)

	XH (egg)	Xh (egg)
XH (sperm)	XHXH unaffected female	XHXh carrier female
Y (sperm)	XHY unaffected male	XhY affected male

Here XH is an X chromosome carrying the dominant normal allele (H) and Xh is an X chromosome carrying the recessive allele for haemophilia (h). The probability that a son has haemophilia is 50%. No daughters are affected, but half are carriers. An affected father passes his X to every daughter and his Y to every son, so his sons do not inherit the disorder from him.

Exam tip: Write the allele next to the X chromosome, for example XhY (exam papers print the h small and raised). Show the Y with no allele.

Quick check

1. What is an allele?
2. What is the difference between genotype and phenotype?
3. Which sex chromosomes do human females and males have?
4. Two parents without a disorder have an affected child. Is the allele dominant or recessive?
5. What is codominance?

Quick check answers

Inheritance

1. A different version of the same gene.
2. Genotype is the alleles an organism has. Phenotype is the observable characteristic that is expressed.
3. Females XX, males XY.
4. Recessive, and both parents are carriers.
5. Both alleles are expressed in the phenotype when both are present, as with I^A and I^B giving blood group AB.