

Inheritance

Revision notes · Alleles, dominant and recessive, codominance, genetic diagrams, family pedigrees, probability and how sex is inherited.

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.

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.

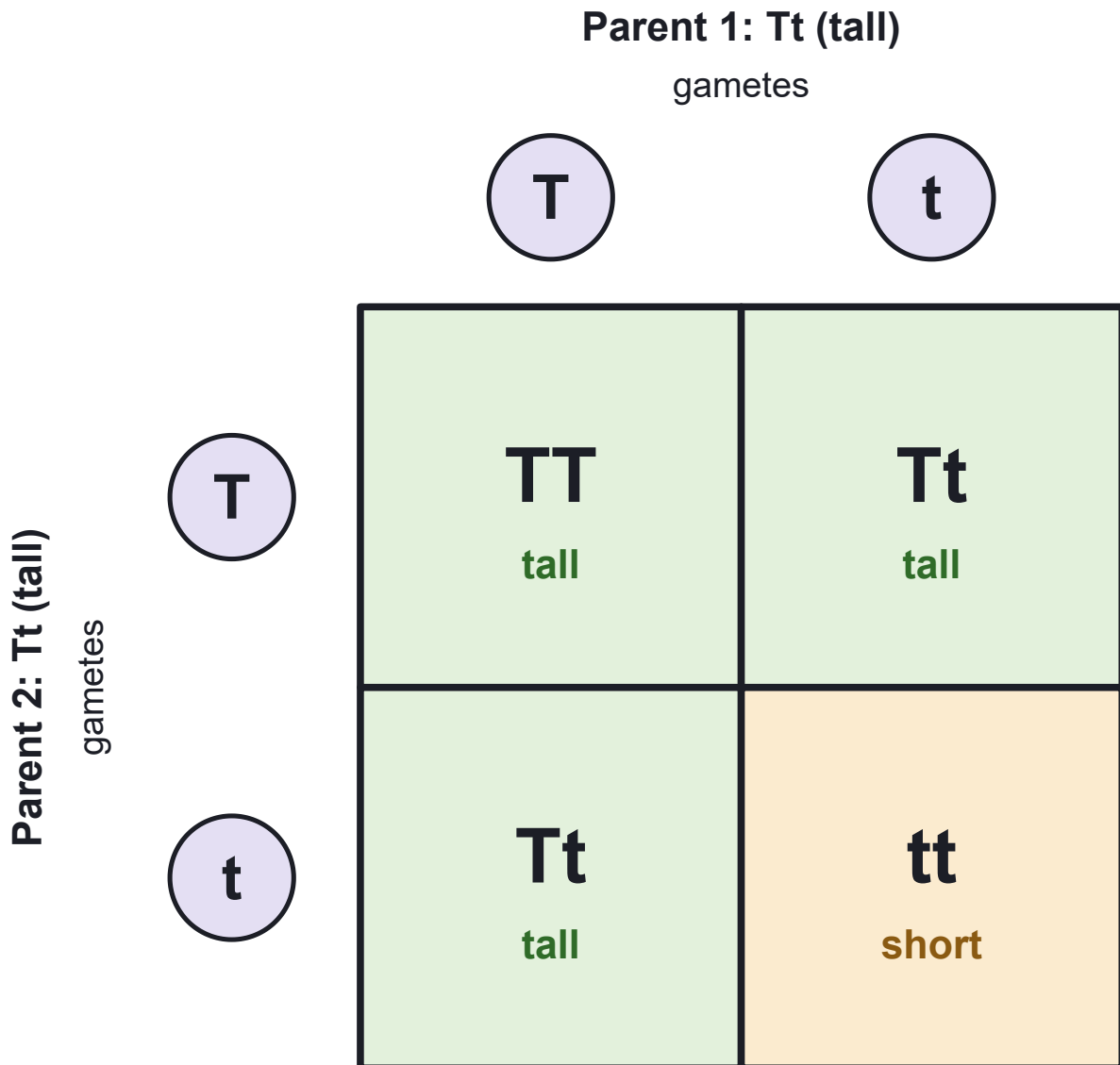
1. Choose letters for the alleles: a capital letter for dominant, lower case for recessive.
2. Write the genotypes of the parents.
3. Write the possible gametes from each parent. Each gamete has one allele.
4. Combine the gametes in a Punnett square to show the possible genotypes of the offspring.
5.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



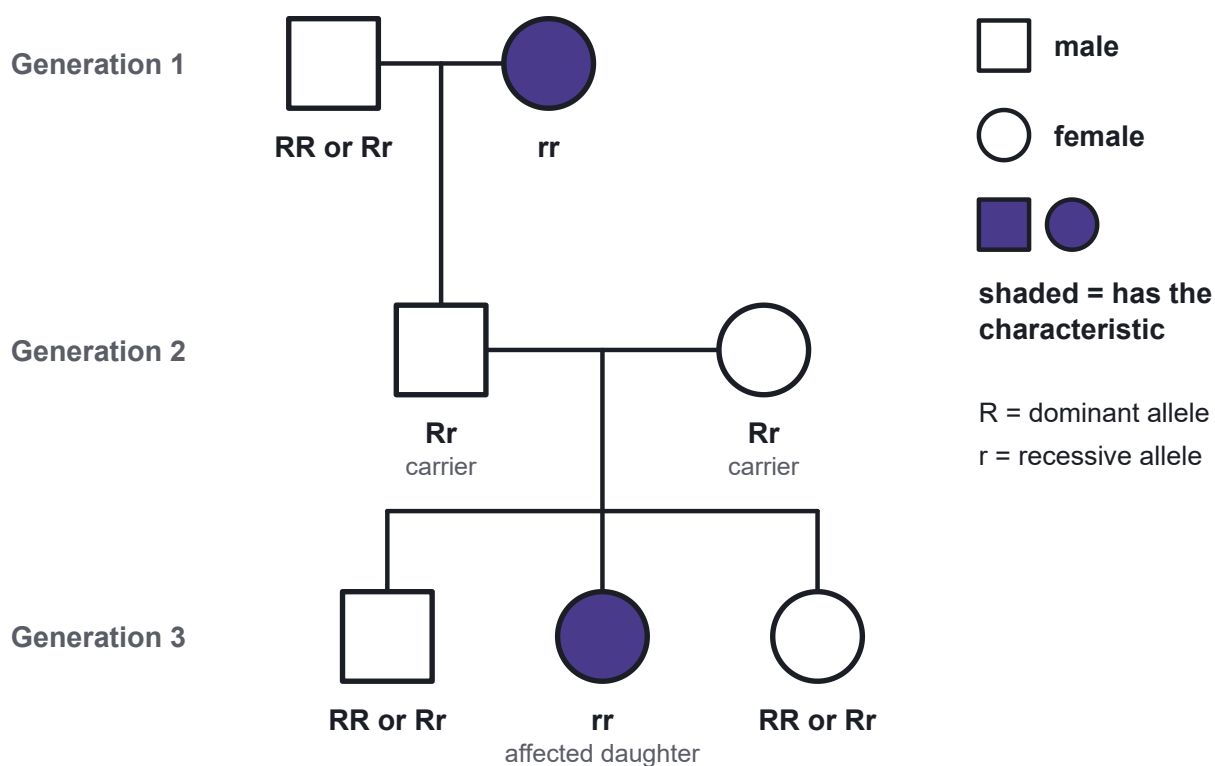
Tt × Tt gives **3 tall : 1 short** (1 TT : 2 Tt : 1 tt).

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?

Quick check answers

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.