bananalearn

GRADE 10 / SCIENCE

Chapter 8

Heredity



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Genes, alleles and traits

A gene is a stretch of DNA that contributes to a biological characteristic. An allele is a version of that gene.



Tall · TT or Tt	Dwarf · tt	Seed encloses an embryo

Tt × tt

Gametes	T	t
t	Tt	tt

Two equally likely outcomes

The tt parent supplies t every time. The Tt parent supplies T or t with equal probability. Expect ½ tall and ½ dwarf.

Chromosomes

In peas, a diploid body cell has two chromosome sets, one from each parent. Each gamete carries one set.

Genotype

The allele combination at a locus. TT and Tt are different genotypes, even when the plants have the same height phenotype.

Phenotype

The observable trait. Under complete dominance in this example, TT and Tt plants are tall and tt plants are dwarf.

Passing on alleles

A Tt plant makes T or t gametes. A tt plant makes only t gametes. Each offspring receives one allele from each gamete.

WORKED EXAMPLE

Why can two tall pea plants produce a dwarf offspring?

If both are Tt, each can contribute t. The chance of tt is ½ × ½ = ¼ for each offspring.

SELF-CHECK

Does a dominant allele have to be common?

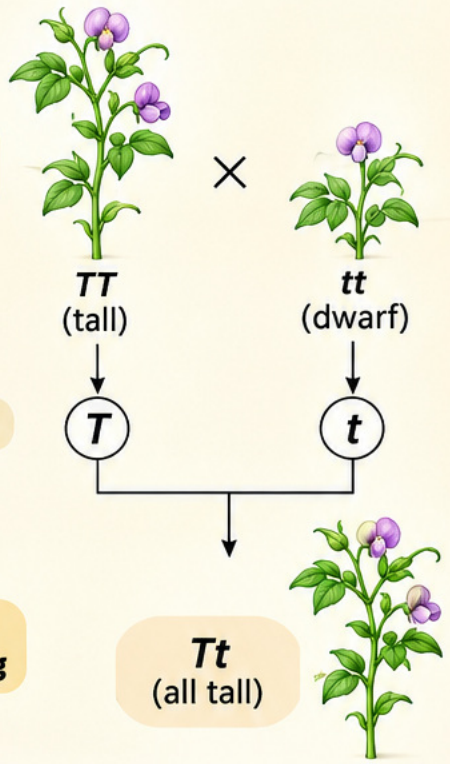
No. Dominance describes the phenotype in a heterozygote. Allele frequency describes how common an allele is.

One-trait crosses

A one-trait (monohybrid) cross studies the inheritance of a single character, e.g. plant height in pea. An **allele** is a variant form of a gene. A dominant allele (T) shows its effect even in a heterozygote, while a recessive allele (*t*) is expressed only in the homozygous state.

Cross 1: *TT* × *tt*

Cross between a homozygous tall plant (*TT*) and a homozygous dwarf plant (*tt*).



Result: **Genotype:** 100% *Tt*; **Phenotype:** 100% tall.

Cross 2: *Tt* × *Tt*

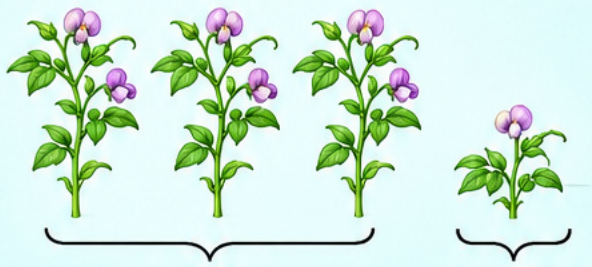
Selfing of F_1 plants (both heterozygous tall): *Tt* × *Tt*.

Gametes: each parent produces *T* and *t*.

♀ \ ♂	*T*	*t*
T	*TT*	*Tt*
t	*Tt*	*tt*

F_2 results:

- **Genotypes:** 1 *TT* : 2 *Tt* : 1 *tt* (1 : 2 : 1)
- **Phenotypes:** 3 tall : 1 dwarf (3 : 1)



Worked example (reasoning)

Q. In the cross *Tt* × *Tt*, what is the chance that an offspring is tall?

Reasoning: From the Punnett square, tall plants are *TT* or *Tt* = 3 out of 4.

Probability of tall = $\frac{3}{4}$ = 0.75 = 75%.

Self-check (answered)

Q. From *Tt* × *Tt*, what are the chances of a dwarf plant?

A. Dwarf plants are *tt* = 1 out of 4.

Probability = $\frac{1}{4}$ = 25%.

Note: These are probabilities, not guaranteed counts. In a small number of offspring, the observed ratio may differ from 3 : 1, but it tends to approach 3 : 1 as the number of offspring increases.

Heredity — Sheet 3 of 5

Two-trait inheritance

With independent assortment and complete dominance at both genes, selfing RrYy gives the expected F_2 phenotype ratio 9:3:3:1. A small sample can differ.

Traits and alleles

- Consider seed shape and seed colour in pea.
- R = round (dominant), r = wrinkled (recessive).
- Y = yellow (dominant), y = green (recessive).



Round, yellow ($R–Y–$)



Wrinkled, yellow ($rrY–$)



Round, green ($R–yy$)



Wrinkled, green ($rryy$)

Gametes from a dihybrid

A round, yellow plant with genotype $RrYy$ produces four types of gametes by independent assortment:

RY **Ry** **rY** **ry**

Key result

- Selfing a dihybrid ($RrYy \times RrYy$) for two independently assorting traits gives the F_2 phenotypic ratio:

9 : 3 : 3 : 1

(Round yellow : Round green : Wrinkled yellow : Wrinkled green)

Dihybrid cross: *RrYy × RrYy*

Each parent produces four gametes: RY, Ry, rY and ry.

	RY	Ry	rY	ry
RY	$RRYY$	$RRYy$	$RrYY$	$RrYy$
Ry	$RRYy$	$RRyy$	$RrYy$	$Rryy$
rY	$RrYY$	$RrYy$	$rrYY$	$rrYy$
ry	$RrYy$	$Rryy$	$rrYy$	$rryy$

→ **F_2 phenotypic ratio = 9 : 3 : 3 : 1**
($R–Y– : R–yy : rrY– : rryy$)

Worked example (probability)

Q A round, yellow plant ($RrYy$) is selfed. What is the probability of getting a wrinkled, yellow ($rrY–$) seed in the F_2 generation?

Solution:

For shape: $Rr \times Rr \rightarrow P(rr) = \frac{1}{4}$

For colour: $Yy \times Yy \rightarrow P(Y–) = \frac{3}{4}$

Since the traits assort independently,

$$P(rrY–) = \frac{1}{4} \times \frac{3}{4} = \frac{3}{16}.$$

Self-check

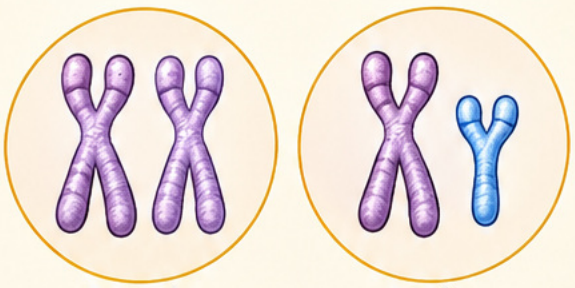
Q In the cross $RrYy \times RrYy$, what is the probability of a round, green ($R–yy$) seed?

Answer: $P(R–yy) = \frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$.

Sex determination

The typical XX/XY model

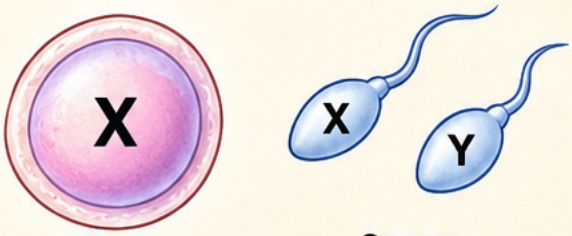
In the school model, eggs carry X and sperm carry X or Y. Fertilisation commonly gives XX or XY. These describe typical chromosomal patterns; human sex development can vary.



Female (XX) Male (XY)

Gametes (sex cells)

- A female produces **eggs**, all carrying one X chromosome (X).
- A male produces two types of **sperm**: one carrying X and the other carrying **Y**, usually in equal numbers.



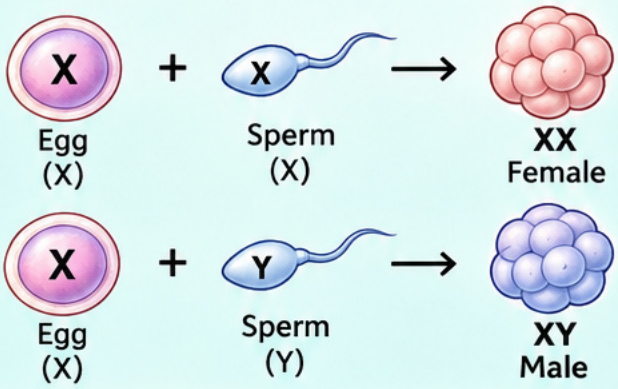
Egg (only X) Sperm (X or Y)

Key idea

The egg always contributes an X, while the sperm contributes either X or Y. Fertilisation is random; hence the chance of a male or a female child is 50% each $\left(\frac{1}{2}\right)$.

How sex is determined

Fertilisation can occur in two equally likely ways:



Expected outcome (Punnett square)

		Sperm (male)	
		X	Y
Egg (female)	X	XX (Female)	XY (Male)

Probability: $P(\text{female}) = \frac{1}{2} = 50\%$

$P(\text{male}) = \frac{1}{2} = 50\%$

- **Note:** These probabilities apply to each fertilisation (each child) independently. A family may have children of the same sex or of both sexes.

Worked example

Q. What is the probability that a couple's next child will be a boy? Also, what is the probability that in two children both are boys?

Solution: $P(\text{boy}) = \frac{1}{2} = 50\%$.

For two children (independent events),

$P(\text{both boys}) = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} = 25\%$.

Self-check (with answer)

Q. A male (XY) and a female (XX) have a child. What are the possible chromosomal combinations in the child and their probabilities?

Ans. XX (female) : 50% and XY (male) : 50%.

Heredity

Reading inheritance evidence

A recessive offspring can reveal an allele hidden in a parent's appearance. The inference depends on the inheritance model.

Test cross: Tt × tt

	t	t
T	Tt	Tt
t	tt	tt

Each box is equally likely. Two boxes give tall Tt. Two give short tt. A new seed is an independent outcome.

What short tells us

In a simple pea-height model, short plants are tt. Every gamete from a tt plant carries t. Tall plants may be TT or Tt.

Reading the cross

If a tall plant crossed with tt has even one short offspring, the tall parent supplied a t allele. Because the parent is tall, its other allele must be T.

WORKED EXAMPLE

A tall × short cross produces eight tall and eight short plants. What are the parents' genotypes?

Tt × tt. The short offspring establishes that the tall parent supplied t. Each offspring has a one-half chance of being tall under this model.

SELF-CHECK

If the next four offspring are all tall, does that disprove Tt × tt?

No. Four tall offspring in a row have probability $(\frac{1}{2})^4 = 1/16$. The ratio describes expected chances, not a fixed order.

ONE LAST CHALLENGE

Can two tall peas have a dwarf offspring?

Both parent plants are tall, and each carries one dwarf allele. Predict the chance for each seed.



THE REVEAL

One chance in four.

Each Tt parent has a one-half chance of passing on t. Only tt gives the dwarf phenotype in this model.

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