

Science 9–10

Chapter 7 — Biological sciences A: reproduction and heredity

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Contents

Section	Page
Reproductive cells and organs in plants and animals: structure related to function	2
Sexual and asexual reproduction, variation and survival of the species	19
DNA, chromosomes, genes and alleles; mitosis and meiosis in passing on genetic information	37
Mendelian inheritance: monohybrid crosses, genotype and phenotype ratios, pedigrees	54

Reproductive cells and organs in plants and animals: structure related to function

Chapter 7 — Biological sciences A: reproduction and heredity (Science, Levels 9 and 10)

Subtopic 7A · VC2 Science Understanding — Biological sciences

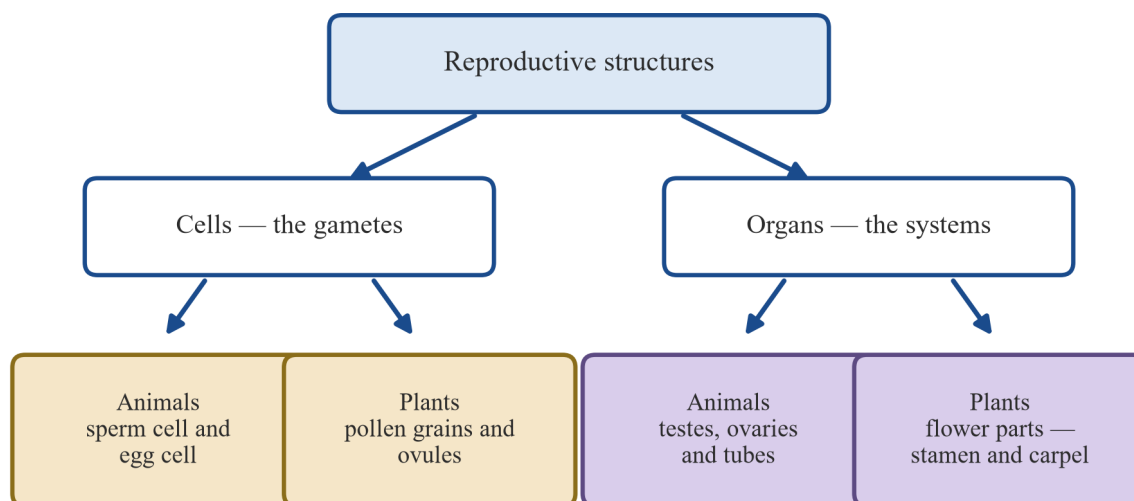
CD code: VC2S10U01 (split delivery †; this subtopic is the accountable owner) **Content description (verbatim):** “the structures of reproductive cells and organs in plants and animals are related to their functions; processes of sexual and asexual reproduction enable survival of a species” **This subtopic’s limb (TOC §4 clause split):** reproductive cells and organs, structure → function. The partner subtopic 7B delivers the other limb: sexual and asexual reproduction, variation and survival of the species. **Elaboration ids drawn on:** VC2S10U01.E01 · VC2S10U01.E02 (ids VC2S10U01.E03–VC2S10U01.E06 are drawn on by Subtopic 7B; no elaboration of this CD is withheld under the TOC’s D10 ICIP decision) **Achievement standard (extract served):** “Students describe how the processes of sexual and asexual reproduction enable survival of the species.” (This is the full standard for the CD; it is assessed across Subtopics 7A and 7B together, with 7A supplying the structure-and-function content it rests on.)

Theory

Life continues because living things reproduce. Every organism you have ever seen exists because a previous generation produced offspring. To do that, organisms carry specialised **reproductive structures**. These structures come in two kinds:

- **reproductive cells** — the sex cells, called **gametes**, that join at fertilisation;
- **reproductive organs** — the larger structures that make the gametes, carry them, and bring them together.

This subtopic is about one idea, applied again and again: **the structure of each of these parts is related to its function**. “Structure” means what a part is made of and what shape it has; “function” means the job it does. A sperm cell is shaped the way it is because its job is to travel. An egg cell is built the way it is because its job is to supply. The more you look, the more often the shape of a part turns out to be a good match for its job.



Every one of these structures has a shape that suits its job — structure related to function.

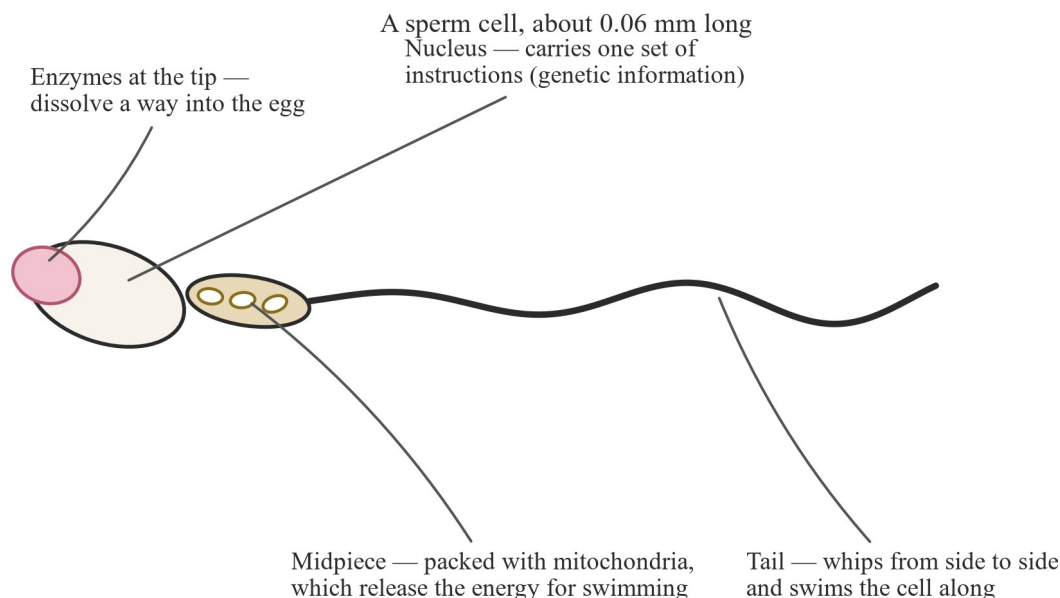
A concept map splitting reproductive structures into two groups: cells (the gametes) and organs (the systems), with an animal example and a plant example of each group.

The words of this subtopic. Two terms do most of the work here, so here they are up front. A **gamete** is a reproductive cell: in animals, a sperm cell or an egg cell. In this subtopic, *fertilisation* means the joining of a sperm

cell and an egg cell to form one new cell. (The Victorian Curriculum uses these terms without giving one fixed wording, so this subtopic works to those definitions, and every question here can be answered from them.) The details of how fertilisation fits into sexual reproduction — and why sexual and asexual reproduction matter for the survival of a species — belong to Subtopic 7B. Here, the focus stays on the structures themselves.

The gametes: sperm and egg (elaboration VC2S10U01.E02)

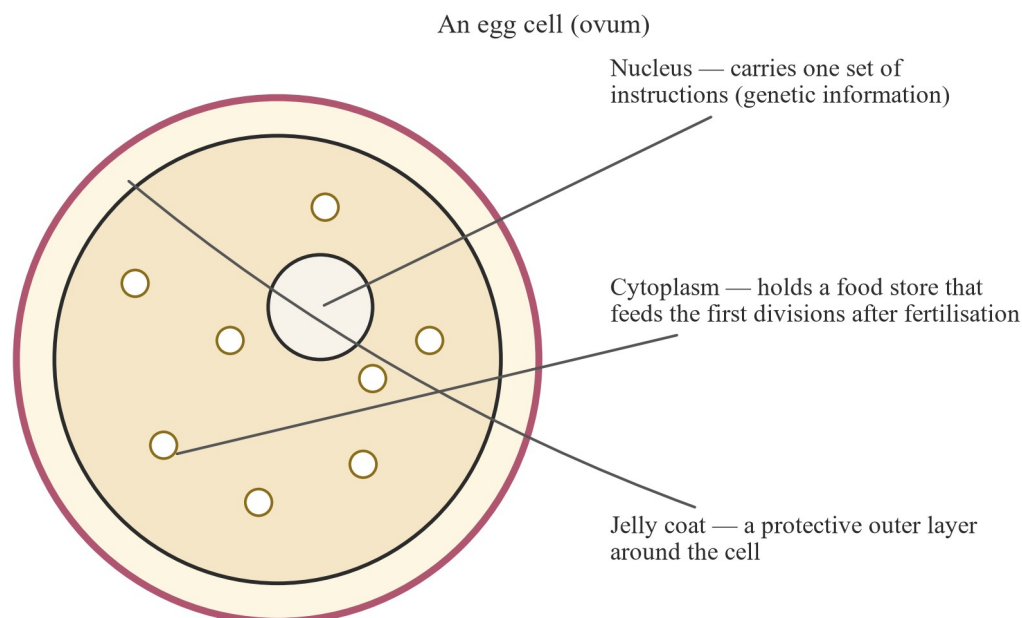
The sperm cell — built to travel. The sperm cell is the male gamete. Its whole job is to reach an egg cell and deliver its set of instructions into it. Every part of it suits that one job.



A labelled sperm cell with a nucleus in its head, enzymes at the tip, a midpiece packed with mitochondria, and a long tail; about 0.06 mm long.

Structure of the sperm cell	What it is like	How that suits its function
Head, with a nucleus inside	the nucleus carries one set of instructions (genetic information)	the instructions join with the egg’s set at fertilisation, so the offspring gets information from both parents
Enzymes at the tip of the head	a packet of enzymes — substances made by living things that speed up chemical changes	the enzymes dissolve a way through the outer layer of the egg so the sperm can get in
Midpiece	packed with mitochondria , the small structures inside cells that release energy	swimming a long way (for a cell) needs a lot of energy, released right where the tail works
Tail	long and thin, whips from side to side	propels the cell along so it can swim toward the egg
Whole shape	very small (about 0.06 mm long) and streamlined	a small, smooth shape moves easily through fluid

The egg cell — built to supply. The egg cell (also called the **ovum**) is the female gamete. Its job is different: it must receive the sperm’s set of instructions and then supply everything the first stages of a new organism need.



About 0.1 mm wide — one of the largest cells in the human body

A labelled egg cell with a nucleus, cytoplasm holding a food store, and a protective jelly coat; about 0.1 mm wide.

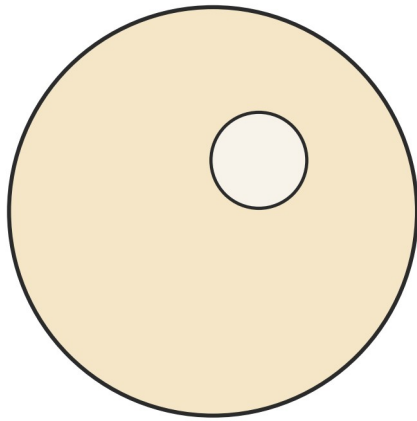
Structure of the egg cell	What it is like	How that suits its function
Nucleus	carries one set of instructions (genetic information)	its set joins the sperm's set at fertilisation
Cytoplasm with a food store	the material filling the cell holds a store of food	the food feeds the first cell divisions after fertilisation, before the new organism can feed itself
Jelly coat	a protective outer layer around the whole cell	protects the cell; after one sperm gets in, the layer changes so no other sperm can enter
Whole shape	large for a cell (about 0.1 mm wide) and round; does not move itself	the size holds the food store; it does not need to travel, so it does not need a tail or an energy supply for swimming

Notice the pattern in the two tables. The sperm's structures are all about **movement and delivery**; the egg's structures are all about **protection and supply**. Same kind of cell (a gamete), opposite jobs — and the shapes match.

How to answer a structure–function question. A full answer does three things in order: **name** the structure, **describe** the feature (its shape, its position, or what it is made of), then **link** that feature to the job it does. “The tail of a sperm cell is long and thin and whips from side to side, which propels the cell along so it can reach the egg.” Naming the part alone is not enough; the link is where the marks are.

Two gametes, two very different scales. The two gametes differ in size as much as in anything else. The egg cell, at about 0.1 mm wide, is one of the largest cells in the human body — just visible as a tiny speck to the naked eye. The sperm cell is about 0.06 mm long in total, and its head is only about 0.005 mm wide: the egg is about **20 times wider** than the sperm's head.

Both drawn at the same scale: the egg is about 20 times wider than the sperm's head.



Egg cell — about 0.1 mm wide



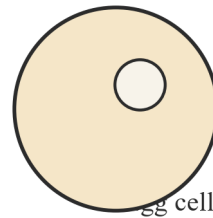
Sperm cell — about 0.06 mm long

An egg cell and a sperm cell drawn at the same scale, showing that the egg is about 20 times wider than the sperm's head.

They differ in numbers too, in a way that also matches their jobs:



Sperm cell



egg cell

Size	Very small — about 0.06 mm long	Large — about 0.1 mm wide
Number made	Made in their millions	Usually one released at a time
Movement	Swims with its tail	Does not move itself

Both carry one set of genetic instructions.

A comparison of the sperm cell and the egg cell by size, number made, and movement; both carry one set of genetic instructions.

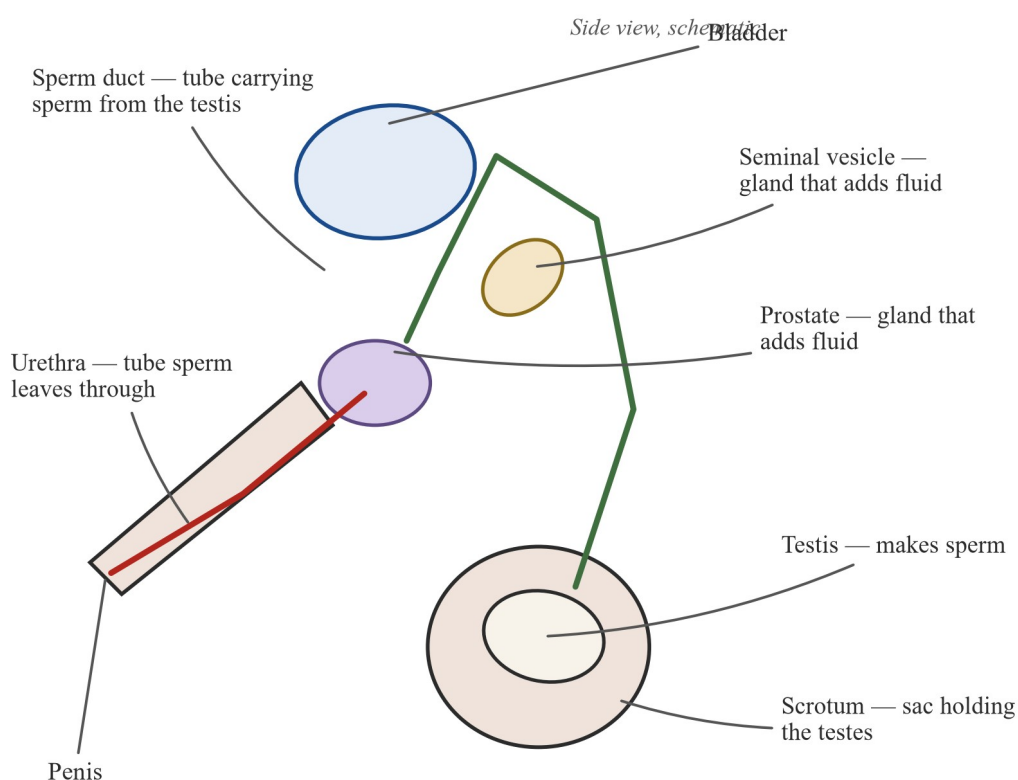
Millions of sperm are made, because the journey to the egg is long and hazardous and only a few ever arrive. Usually only one egg is released at a time, because each egg carries a large food store that is costly for the body to make. Once more: the numbers suit the jobs.

Both gametes carry **one set** of instructions. At fertilisation the two sets join, so the new cell formed carries information from both parents. What those instructions actually are — DNA, genes and chromosomes — is the content of Subtopic 7C.

The organs: systems that work together (elaboration VC2S10U01.E01)

Gametes are made, carried and brought together by **organs** — larger structures of the body, each built from tissues and each with a particular job. An **organ system** is a group of organs that work together at one task. Reproduction is a clear example of the point of VCAA’s elaboration VC2S10U01.E01: the reproductive organs work **collectively**, as systems. No single organ does the job alone — the organ that makes a gamete is not the organ that carries it, and neither is the organ where the gamete meets its partner. The human examples below show the same plan found in many other animals: organs that make gametes, tubes that carry them, and supporting structures around them.

The male reproductive system. The male system’s task is to make sperm cells and deliver them.



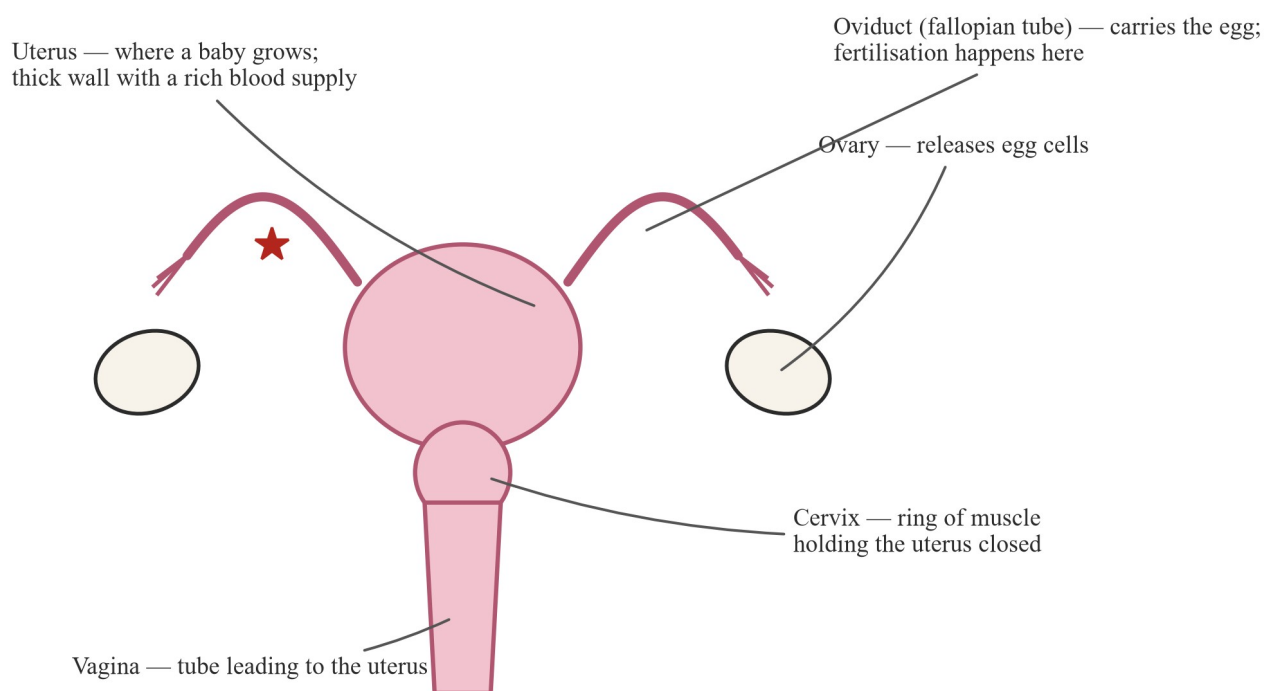
A labelled side view of the male reproductive system: testes in the scrotum, sperm duct, seminal vesicle, prostate, urethra and penis, with the bladder shown nearby.

Organ	Function	How its structure suits the function
Testes (singular: testis)	make sperm cells	two glands, each packed with many fine tubes where sperm develop
Scrotum	holds the testes outside the body	a sac of skin that keeps the testes a little cooler than the inside of the body, the condition in which sperm develop best
Sperm duct	carries sperm away from a testis	a long tube that joins each testis to the tubes leading out of the body
Seminal vesicle and prostate	glands that add fluid	the fluid carries the sperm, gives them food, and helps them travel
Urethra	the tube sperm leave through	runs through the penis to the outside of the body

Organ	Function	How its structure suits the function
Penis	the organ that places sperm near the female system	carries the urethra to its end

Follow the chain: no one organ in that list does the whole job. The testes make sperm, but the sperm cannot leave the body without the ducts, the glands and the urethra. The glands' fluid is not just a taxi — a sperm cell without fluid to swim in would dry out and not travel. That is the meaning of “a system”: each part depends on the others.

The female reproductive system. The female system's task is to release egg cells, and — when fertilisation happens — to support the new organism as it grows.



Front view, schematic

A labelled front view of the female reproductive system: two ovaries, two oviducts, the uterus, cervix and vagina, with a star marking the place in an oviduct where fertilisation happens.

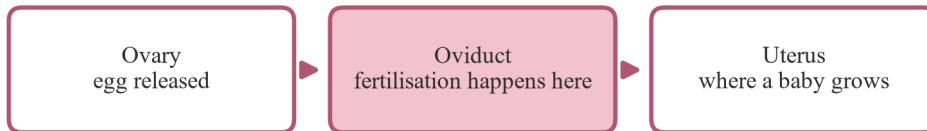
Organ	Function	How its structure suits the function
Ovaries	make egg cells and release them	two glands, each holding many developing egg cells; usually one egg is released at a time
Oviducts (also called fallopian tubes)	carry the egg from an ovary toward the uterus; fertilisation happens here	wide, funnel-shaped openings near each ovary collect the released egg; the tube's inner surface moves the egg along
Uterus	where the fertilised egg settles and a baby grows	a thick, strong wall with a rich blood supply, so the growing baby is protected and fed
Cervix	a ring of muscle at the opening of the uterus	holds the uterus closed while a baby grows, keeping the inside protected
Vagina	the tube leading to the uterus	receives sperm and forms the birth canal

The two systems' routes are worth learning as routes, because several questions in this subtopic ask you to trace a gamete through its system.

The route of a sperm cell



The route of an egg cell

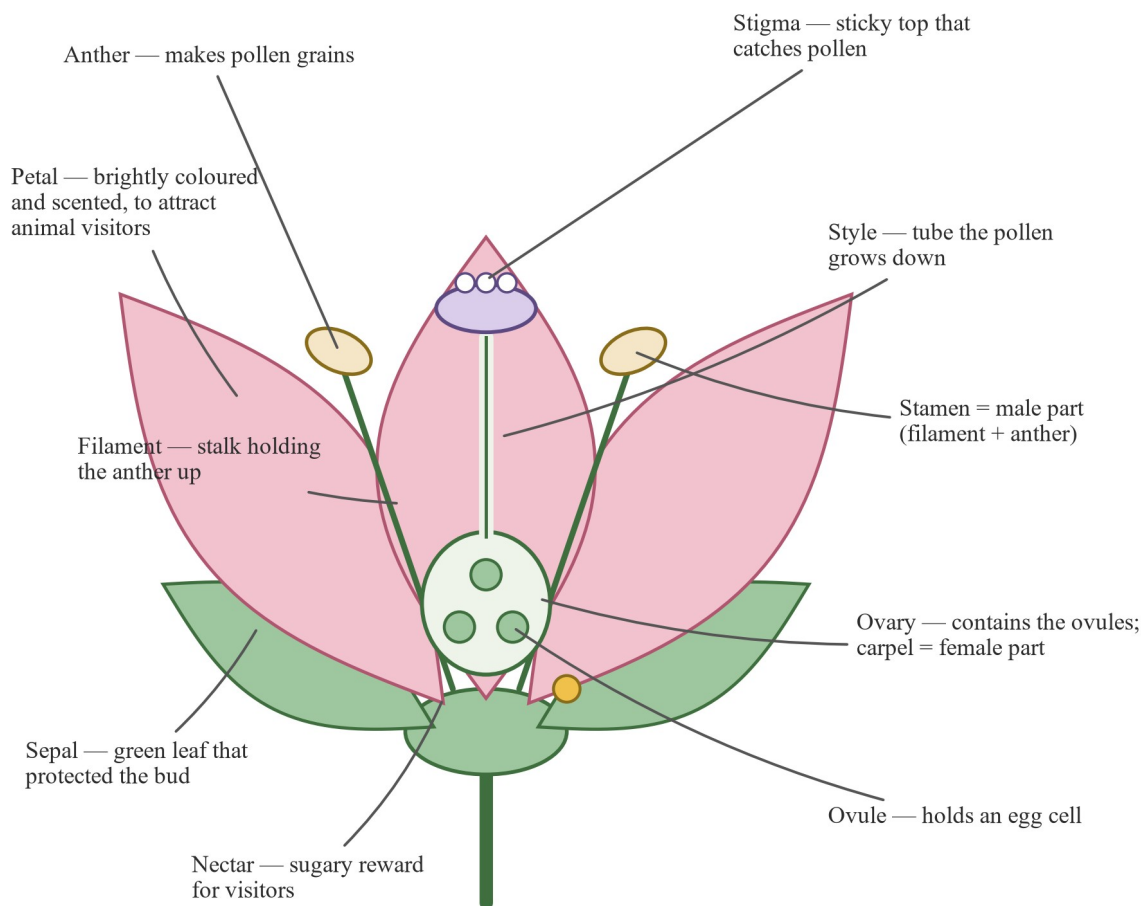


Two routes side by side: a sperm cell's route from testis to outside the body, and an egg cell's route from ovary to uterus, with fertilisation marked on the egg's route.

Check your reading of the pathway. Fertilisation happens in the **oviduct**, not the uterus. The egg is fertilised soon after it is released, while it is still in the tube; the fertilised egg then travels on to the uterus, where it settles in the lining and grows. Answers that place fertilisation in the uterus are a common slip — trace the pathway in the figure before you answer.

The flower: reproductive structures in plants

Plants reproduce too, and flowering plants do it with structures you can see. The reproductive organs of a flowering plant sit in its **flower**. The plan is the same as in animals — male parts that make the male gametes, female parts that hold the female gametes — arranged around one central idea: pollen must get from the male part of one flower to the female part of a flower.



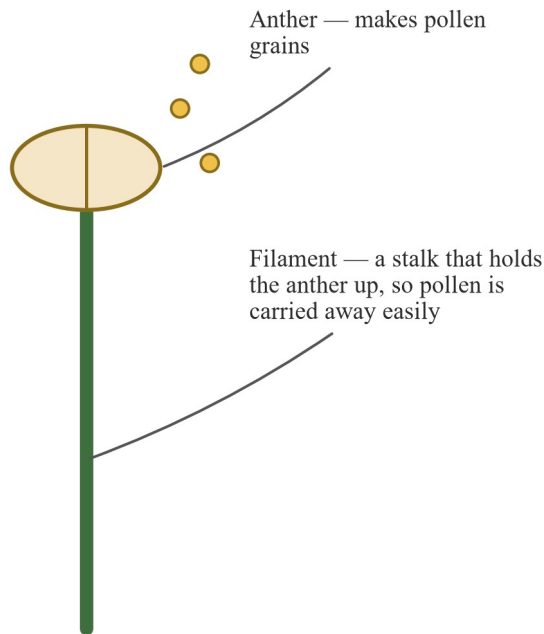
A labelled flower showing sepals, petals, stamens with anthers and filaments, and a carpel with stigma, style and ovary containing ovules, with a drop of nectar at the base.

The flower's parts, with their jobs:

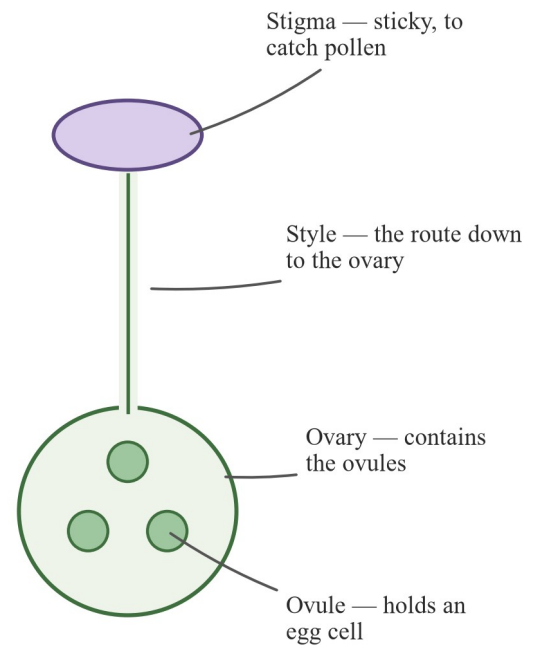
Part of the flower	Function	How its structure suits the function
Sepals	protect the flower bud before it opens	green, leaf-like, wrapped around the bud
Petals	attract animal visitors such as insects and birds	brightly coloured and scented, so visitors notice the flower
Nectar	a sugary reward for visitors	made at the base of the flower, so a visitor must brush past the reproductive parts to reach it
Stamen (the male part)	makes pollen grains	a filament — a stalk — holds the anther up where pollen can be picked up easily; the anther makes the pollen grains
Carpel (the female part)	holds the ovules and receives pollen	a sticky stigma at the top catches pollen; the style is the route down to the ovary , which contains the ovules

Two of those parts deserve a closer look, because they carry the plant's gametes.

Stamen — the male part



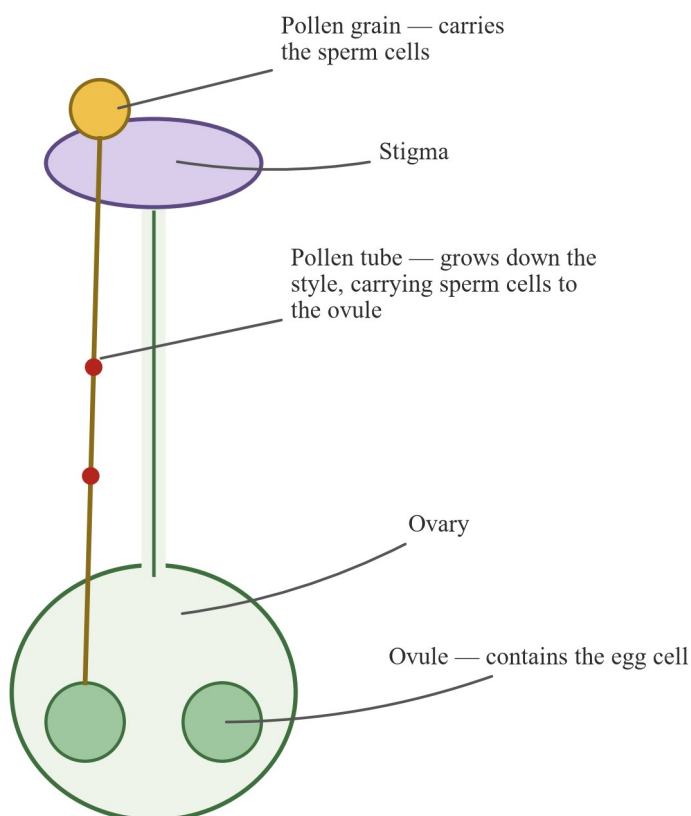
Carpel — the female part



Close-up of a stamen, with its anther making pollen grains on top of a filament, beside a carpel with a sticky stigma, a style, and an ovary containing ovules that hold egg cells.

A **pollen grain** is the structure that carries the plant's male gametes — the sperm cells. Each **ovule** holds an egg cell, the plant's female gamete. So the flower follows the same two-part plan you have already met: a male structure that makes small, mobile carriers of sperm cells, and a female structure that protects and supplies egg cells.

The pollen tube — a route to the egg. A plant cannot move, so its gametes cannot swim to meet each other the way animal gametes can. The flower solves the problem by growing a tube.



A pollen grain resting on a sticky stigma and growing a pollen tube down through the style to an ovule inside the ovary.

When a pollen grain lands on the sticky stigma, it grows a thin **pollen tube** down through the style toward the ovary. The tube carries the sperm cells from the pollen grain to an ovule, where one of them can join with the egg cell inside — the plant version of fertilisation. The sticky stigma, the style as a protected route, and the tube itself are all structures shaped for one function: bringing the plant's gametes together without either of them having to move through the open air.

Pulling the idea together

Look back over the four systems you have met — the sperm cell, the egg cell, the animal reproductive systems and the flower — and one sentence covers all of them: **each reproductive structure has features that suit the job it does**. A sample of the pattern:

Structure	Feature	The job the feature suits
Tail of a sperm cell	long, thin, whips from side to side	moving the cell along
Food store in an egg cell	held in the cytoplasm	feeding the first divisions after fertilisation
Testes in the scrotum	held outside the body	keeping sperm at the right temperature to develop
Lining of the uterus	thick, with a rich blood supply	feeding and protecting a growing baby
Sticky stigma	sticky surface at the top of the carpel	catching pollen grains
Filament	a stalk holding the anther up	placing pollen where visitors pick it up

Sorting structures and functions like this is exactly the skill the next activity practises — and it is the shape of many exam questions on this topic.

Structure	Function
Tail of a sperm cell	Catches pollen grains
Sticky stigma	Moves the cell along
Anther	Attracts animal visitors
Lining of the uterus with a rich blood supply	Feeds a growing baby
Bright, scented petals	Makes pollen grains

structure with

Two columns of cards for a sorting activity: five structure cards on the left and five function cards on the right, to be matched by the reader.

Activities

Activity 1 — Structure–function sort (elaboration VC2S10U01 . E02). The figure above shows five structures and five functions, not matched up. On paper, copy the ten cards and draw a line joining each structure to the function it suits. For every match, write one sentence linking the two, using the three-step pattern from this subtopic: *name the structure, describe the feature, link it to the job*. Then add **three cards of your own** — a structure and a function from this subtopic that the figure did not use — and swap sorts with a partner to check each other’s matches.

Activity 2 — Modelling the scale of the gametes (ratio and scale skills from Subtopic 4B). The egg cell is about **0.1 mm** wide and the sperm cell about **0.06 mm** long, with a head about **0.005 mm** wide. These sizes are hard to picture, so build a scale model. Suppose the egg cell were blown up to the size of a basketball — about **24 cm** across.

- Find the scale factor: 24 cm is 240 mm, and $240 \text{ mm} \div 0.1 \text{ mm} = \mathbf{2400}$, so every real size must be multiplied by 2400.
- Calculate the model sperm: $0.06 \text{ mm} \times 2400 = \mathbf{144 \text{ mm}}$, so the model sperm would be about **14 cm** long. Its head would be $0.005 \text{ mm} \times 2400 = \mathbf{12 \text{ mm}}$ wide.
- Draw the model: on a sheet of paper, draw a circle 24 cm wide, then draw a sperm cell 14 cm long with a head 1.2 cm wide, to the same scale. Stick both drawings on the wall side by side.

Then discuss: the drawing shows that the egg is about 20 times wider than the sperm’s head, but it also shows something the numbers alone do not — how much of the sperm is tail. Write one sentence connecting that observation to the sperm’s function.

Activity 3 — Taking a flower apart. Collect a large flower (lilies and daffodils work well because their parts are big and easy to see). Without using any sharp blades — pull parts apart gently with your fingers, or use scissors if your teacher directs — remove the parts one whorl at a time and lay them out in order: sepals, petals, stamens, then the carpel in the centre. For each part, record in a table (skills from Subtopic 4A): the part’s name, what it looks like, and the function given in this subtopic. Use a hand lens if one is available to look at the anthers (you may see pollen grains on them) and the top of the stigma (often sticky). Two safety notes: wash your hands after handling pollen, and tell

your teacher before the activity if anyone in the group has a pollen or plant allergy. Finish by answering: which parts of your flower are male, which are female, and which protect or attract rather than carry gametes?

Worked examples

Example 1 — scaffolded

Match each structure on the left to the function on the right.

Structure	Function
1. Tail of a sperm cell	A. Feeds the first cell divisions after fertilisation
2. Enzymes at the tip of a sperm cell	B. Carries one set of instructions
3. Food store in an egg cell	C. Moves the sperm cell along
4. Nucleus of an egg cell	D. Dissolves a way through the egg's outer layer

Working	Comment
1 → C. The tail whips from side to side, propelling the sperm cell along.	Ask what each part <i>does</i> : the tail is the only moving part.
2 → D. The enzymes at the tip dissolve a way through the egg's outer layer so the sperm can enter.	Enzymes speed up chemical changes; here the change is dissolving the egg's protective layer.
3 → A. The food store in the egg's cytoplasm feeds the first divisions after fertilisation.	The egg's job is supply — match any egg feature to protection or feeding.
4 → B. The nucleus carries one set of instructions (genetic information).	Both gamete nuclei carry one set; the two sets join at fertilisation.

Example 2 — scaffolded

List the organs a sperm cell passes through, in order, from where it is made to where it leaves the body, and state what happens in each.

Working	Comment
1. Testis — the sperm cell is made here.	Start where the gamete is made.
2. Sperm duct — the sperm cell is carried away from the testis.	Ducts and tubes are for carrying.
3. Glands (seminal vesicle and prostate) — fluid is added, carrying and feeding the sperm.	The fluid is added on the way, before exit.
4. Urethra — the tube the sperm leaves through.	The final tube runs through the penis.
5. Out of the body , at the end of the penis.	End at the exit.

Example 3 — unscaffolded

Explain how the structure of a sperm cell suits its function. (4 marks)

The sperm cell's function is to reach an egg cell and deliver its set of instructions into it. Its structure suits that job in several ways. It has a **long, thin tail that whips from side to side**, propelling the cell along toward the egg. Its **midpiece is packed with mitochondria**, which release the energy the tail needs for the swim. The **head is small and streamlined**, so the cell moves easily through fluid, and it carries a **nucleus with one set of instructions** to join with the egg's set at fertilisation. Finally, **enzymes at the tip of the head** dissolve a way through the egg's outer layer so the sperm can get in. ∴ every part of the sperm cell — tail, midpiece, head and enzyme tip — is shaped for travelling to the egg and entering it.

Example 4 — unscaffolded

A student removes all of the anthers from a flower before any pollen is released. Predict whether that flower can still pass on its male gametes, and explain your reasoning. (3 marks)

No — that flower cannot pass on its male gametes. The **anthers are the structures that make pollen grains**, and pollen grains are what carry the plant's male gametes (the sperm cells). With the anthers removed, the flower makes no pollen at all, so there is nothing to carry its male gametes to another flower's ovules. The flower's **female part, the carpel, is unaffected**: it could still receive pollen grains brought from another flower and be fertilised — but the flower would act only as a female parent, not a male one. $\therefore$ removing the anthers removes the flower's male function while leaving its female function in place.

Practice questions

Scaffolded questions

Question 1 The vocabulary of this subtopic. Define each of the following: (a) gamete; (b) fertilisation; (c) organ; (d) stamen; (e) carpel; (f) pollen tube.

Question 2 Comparing the two animal gametes. Copy and complete the table.

Feature	Sperm cell	Egg cell
Size (about)		
Food store		
Movement		
Number usually released at a time		

Question 3 The sperm cell. (a) Name the part that carries one set of instructions. (b) Name the part that releases the energy for swimming, and state what it is packed with. (c) State how the tail helps the sperm cell. (d) State what the enzymes at the tip of the head do.

Question 4 The male reproductive system. (a) Name the organs that make sperm cells. (b) State where those organs are held, and why that position suits the development of sperm. (c) Name the tube through which sperm leave the body. (d) State what the seminal vesicle and prostate add, and give one reason the sperm need it.

Question 5 The female reproductive system. (a) Name the organs that release egg cells. (b) State where fertilisation happens. (c) Name the organ where a baby grows, and give one feature of its wall that suits that job. (d) State what the cervix is and what it does.

Question 6 The flower. Match each part to its function: anther; stigma; petal; ovary; filament. Functions: makes pollen grains; catches pollen; attracts animal visitors; contains the ovules; holds the anther up.

Unscaffolded questions

Question 7 The egg cell carries a food store in its cytoplasm, but the sperm cell carries none. Explain why each cell is built this way, referring to the job of each gamete. (3 marks)

Question 8 A drawing shows an egg cell that is really 0.1 mm wide drawn at 40 mm wide. (a) Calculate the scale factor of the drawing. (b) A sperm cell is about 0.06 mm long. Calculate its length in the drawing at the same scale. (c) The sperm's head is about 0.005 mm wide. Calculate its width in the drawing. (3 marks)

Question 9 The testes are held in the scrotum outside the body rather than inside it. Explain how this arrangement suits the development of sperm. (2 marks)

Question 10 The uterus has a thick wall with a rich blood supply. Explain how these two features suit the uterus's function. (2 marks)

Question 11 Two flower structures. (a) Explain how the sticky surface of the stigma suits its function. (b) Explain how the filament holding the anther up helps the flower's pollen to be carried away. (2 marks)

Question 12 A pollen grain lands on the stigma of a flower. Explain why the pollen grain then grows a tube down the style, and what the tube carries. (2 marks)

Question 13 A flower has a fault that stops it from making nectar. Predict what would happen to the number of animal visitors to that flower, and explain what that would mean for the movement of its pollen. (2 marks)

Question 14 Copy and complete the table: give the function of each structure and state whether it belongs to a plant or an animal.

Structure	Function	Plant or animal
Tail of a sperm cell		
Ovule		
Lining of the uterus		
Anther		

(4 marks)

Question 15 "The egg cell is large and does not move itself; the sperm cell is small and moves." Explain how each of these features suits the job of the cell it describes. (4 marks)

Question 16 Choose **one** reproductive cell and **one** reproductive organ from this subtopic. For each, name one feature of its structure and explain how that feature suits its function. (4 marks)

Answers

Question 1 (a) a reproductive cell — a sperm or an egg; (b) the joining of a sperm cell and an egg cell to form one new cell; (c) a larger structure of the body with a particular job; (d) the male part of a flower (filament + anther); (e) the female part of a flower (stigma, style and ovary); (f) the tube a pollen grain grows down the style to reach an ovule. **Question 2** Sperm: very small (about 0.06 mm long); no food store; swims with its tail; made in their millions. Egg: large (about 0.1 mm wide); has a food store; does not move itself; usually one at a time. **Question 3** (a) the nucleus; (b) the midpiece, packed with mitochondria; (c) it whips from side to side and propels the cell along; (d) they dissolve a way through the egg's outer layer. **Question 4** (a) the testes; (b) in the scrotum, outside the body — sperm develop best a little cooler than body temperature; (c) the urethra; (d) fluid — it carries and feeds the sperm and helps them travel. **Question 5** (a) the ovaries; (b) in an oviduct (fallopian tube); (c) the uterus — its wall is thick with a rich blood supply; (d) a ring of muscle at the opening of the uterus that holds it closed. **Question 6** Anther → makes pollen grains; stigma → catches pollen; petal → attracts animal visitors; ovary → contains the ovules; filament → holds the anther up. **Question 7** see solution. **Question 8** (a) 400; (b) 24 mm; (c) 2 mm. **Question 9** see solution — sperm develop best a little cooler than body temperature. **Question 10** see solution. **Question 11** see solution. **Question 12** see solution. **Question 13** see solution. **Question 14** see solution. **Question 15** see solution. **Question 16** see solution.

Fully-worked solutions

Question 1 (a) A **gamete** is a reproductive cell — in animals, a sperm cell or an egg cell. (b) **Fertilisation** is the joining of a sperm cell and an egg cell to form one new cell. (c) An **organ** is a larger structure of the body, built from tissues, with a particular job to do. (d) The **stamen** is the male part of a flower: a filament holding an anther, and the anther makes pollen grains. (e) The **carpel** is the female part of a flower: a sticky stigma on top of a style, with an ovary at the base that contains the ovules. (f) The **pollen tube** is the tube a pollen grain grows down through the style toward the ovary, carrying the sperm cells to an ovule.

Question 2 Sperm cell: very small — about 0.06 mm long; **no food store**; moves by swimming with its tail; made **in their millions**. Egg cell: large — about 0.1 mm wide; **has a food store** in its cytoplasm; **does not move itself**; usually **one released at a time**.

Question 3 (a) The **nucleus** carries one set of instructions (genetic information). (b) The **midpiece** releases the energy for swimming; it is packed with **mitochondria**, the structures that release energy in cells. (c) The tail **whips from side to side and propels the cell along**, so the sperm can swim toward the egg. (d) The enzymes at the tip **dissolve a way through the egg's outer layer**, so the sperm can get into the egg.

Question 4 (a) The **testes** make sperm cells. (b) They are held in the **scrotum, outside the body**. Sperm develop best a little cooler than the temperature inside the body, and the scrotum keeps them at that lower temperature. (c) The **urethra**. (d) The glands add **fluid**. The fluid carries the sperm, gives them food, and helps them travel — sperm without fluid would dry out and could not swim to where they need to go.

Question 5 (a) The **ovaries** release egg cells. (b) Fertilisation happens in an **oviduct** (fallopian tube), where the egg is travelling after being released. (c) The **uterus**. Its wall is **thick and has a rich blood supply**, which protects the growing baby and brings it food and oxygen. (d) The **cervix** is a **ring of muscle** at the opening of the uterus; it holds the uterus closed while a baby grows, keeping the inside protected.

Question 6 **Anther** → makes pollen grains. **Stigma** → catches pollen (its sticky surface holds the grains). **Petal** → attracts animal visitors (bright colour and scent). **Ovary** → contains the ovules. **Filament** → holds the anther up.

Question 7 The two gametes have different jobs. The **egg cell's job includes supplying** the new organism after fertilisation: its food store feeds the first cell divisions, before the new organism can feed itself, so a store is essential. The **sperm cell's job is only to travel to the egg and deliver its instructions**: a food store would make it larger and heavier and harder to swim with, and it does not need the store because it does not feed the new organism. Each cell is therefore built around its own job — supply in one case, movement in the other. (1 mark: the egg's store feeds the first divisions; 1 mark: the sperm's job is travel/delivery; 1 mark: a store would work against swimming / is not needed by the sperm.)

Question 8 (a) Scale factor = drawn size ÷ real size = 40 mm ÷ 0.1 mm = **400**. (b) Sperm length in the drawing = 0.06 mm × 400 = **24 mm**. (c) Head width in the drawing = 0.005 mm × 400 = **2 mm**. (1 mark each; working shown as real size × scale factor.)

Question 9 Sperm develop best at a temperature **a little cooler than the temperature inside the body**. The scrotum holds the testes outside the body, where they are kept at that lower temperature, so the sperm they make can develop properly. (1 mark: sperm need a temperature a little below body temperature; 1 mark: the scrotum's outside position provides it.)

Question 10 The uterus's function is to be the place where the fertilised egg settles and a baby grows. The **thick, strong wall** protects the growing baby and supports it as it gets heavier. The **rich blood supply** brings food and oxygen to the growing baby and carries its waste away. Each feature — strength and supply — matches a different part of the organ's job. (1 mark: thick wall protects/supports; 1 mark: blood supply feeds the growing baby.)

Question 11 (a) The stigma's function is to **catch pollen grains**. A **sticky surface holds the grains in place** when they land — carried in by an animal visitor or by the wind — so they are not blown or washed away and can grow their tubes down the style. (b) The **filament holds the anther up** away from the centre of the flower, placing the pollen where visiting insects and birds **brush against it easily** as they move to reach the nectar, so the pollen is picked up and carried to the next flower. (1 mark each.)

Question 12 The pollen grain carries the plant's **sperm cells**, and the egg cell it must reach sits inside an ovule, deep in the ovary at the base of the carpel. Because the plant cannot move, and the gametes cannot swim through air, the pollen grain **grows a tube down through the style** as a protected route to the ovary. The tube **carries the sperm cells** from the pollen grain to an ovule, where one of them can join with the egg cell. (1 mark: the tube carries the sperm cells; 1 mark: it provides the route from stigma to ovule because the gametes cannot travel on their own.)

Question 13 Nectar is the flower's **reward** for animal visitors such as insects and birds. With no nectar, visitors would have no reason to call, so **fewer animals would visit** the flower. Those visitors are what move pollen from flower to flower: while reaching for nectar they brush pollen onto their bodies and carry it to the next flower's stigma. With fewer visitors, **less of the flower's pollen would be carried away**, and less pollen would arrive from other flowers. (1 mark: fewer visitors without the reward; 1 mark: less pollen moved, because visitors are the carriers.)

Question 14 Tail of a sperm cell — moves the sperm cell along — **animal**. Ovule — holds an egg cell; where fertilisation happens in the plant — **plant**. Lining of the uterus — thick wall with a rich blood supply that feeds and protects a growing baby — **animal**. Anther — makes pollen grains — **plant**. (1 mark per correct row.)

Question 15 The egg cell is large because its cytoplasm holds a **food store that feeds the first cell divisions** after fertilisation — the new organism cannot feed itself at once, so the supplies must come with the egg. It **does not move itself** because it does not need to travel: it is released near the place where fertilisation happens and is carried along by the oviduct, so no tail or swimming equipment is needed. The sperm cell is small because its only cargo is one set of instructions and the energy supply for the journey; staying small and streamlined lets it **move easily through fluid**. It **moves** — its tail whips from side to side, powered by the mitochondria in the midpiece — because its job is to **travel the long way to the egg**. In both cells, size and movement match the job. (1 mark each: egg large = food store; egg still = it is carried, no travel needed; sperm small = moves easily; sperm moves = must reach the egg.)

Question 16 One full-mark answer, as an example. **Cell: the sperm cell**. One feature is its **tail, which whips from side to side**; this suits its function because the sperm cell must swim the long way to reach the egg, and the tail propels it along. **Organ: the uterus**. One feature is its **thick wall with a rich blood supply**; this suits its function because the uterus is where the baby grows, and the wall protects the baby while the blood brings it food and oxygen. Any correct cell or organ from this subtopic earns the marks, provided the answer names a real feature and links it to the job it does. (2 marks per structure: 1 mark for a named feature, 1 mark for the link to function.)

Where this leads: the gamete-and-organ picture built here is assumed by VCE Biology Unit 2, Area of Study 1 (“How is inheritance explained?”), which adds the chromosome behaviour in meiosis that gives each gamete one set of instructions and the detail of how fertilisation restores the full set — reference-only for this book, and within this band the DNA, chromosome and cell-division content is taught by Subtopic 7C, not here. VCE also adds hormone control of reproductive cycles and assisted reproduction; those extensions sit above the VC2 9–10 content descriptions and are

not taught in this book (TOC D9). Subtopic 7B delivers the other limb of VC2S10U01 — the processes of sexual and asexual reproduction, the variation they produce, and what that means for the survival of a species — and Subtopics 7C and 7D take up DNA, chromosomes and how traits are inherited.

Sexual and asexual reproduction, variation and survival of the species

Chapter 7 — Biological sciences A: reproduction and heredity (Science, Levels 9 and 10)

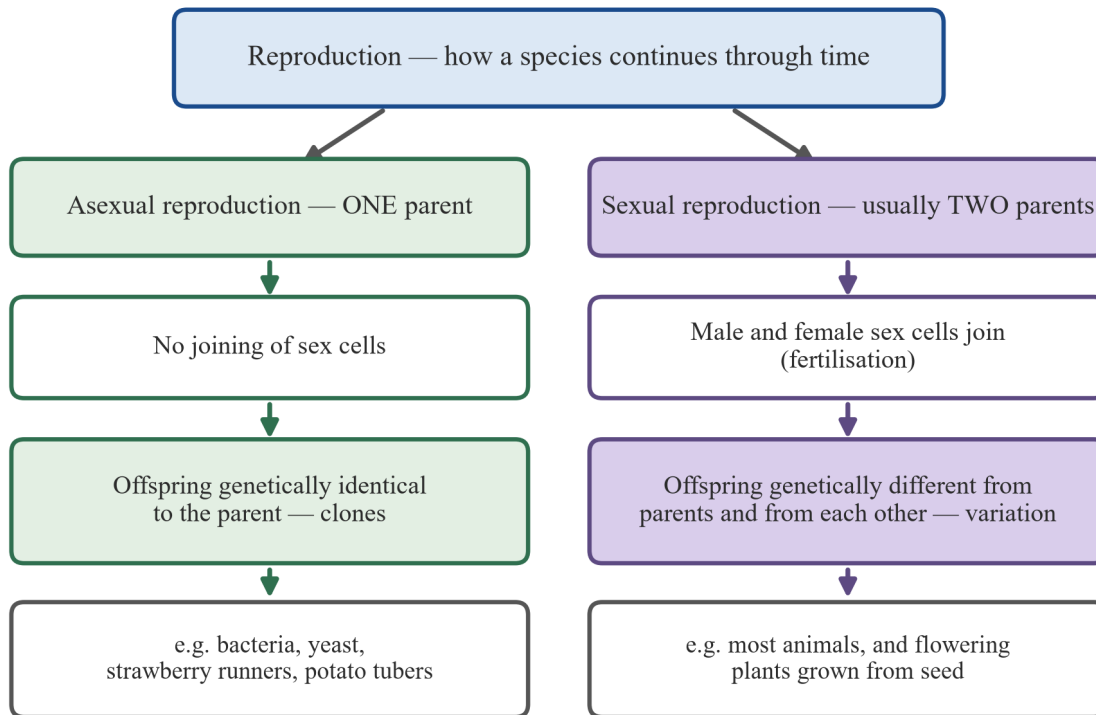
Subtopic 7B · VC2 Science Understanding — Biological sciences

CD code: VC2S10U01 (split delivery †; this subtopic is the partner — the accountable owner is Subtopic 7A) **Content description (verbatim):** “the structures of reproductive cells and organs in plants and animals are related to their functions; processes of sexual and asexual reproduction enable survival of a species” **This subtopic’s limb (TOC §4 clause split):** sexual and asexual reproduction, variation and survival of the species. The owner subtopic 7A delivers the other limb: reproductive cells and organs, structure related to function. **Elaboration ids drawn on:** VC2S10U01.E03 · VC2S10U01.E04 · VC2S10U01.E05 · VC2S10U01.E06 (ids VC2S10U01.E01–VC2S10U01.E02 are drawn on by Subtopic 7A; no elaboration of this CD is withheld under the TOC’s D10 ICIP decision) **Achievement standard (extract served):** “Students describe how the processes of sexual and asexual reproduction enable survival of the species.” (This is the full standard for the CD; Subtopic 7A supplies the structure-and-function content it rests on, and this subtopic is assessed against the processes, the variation they produce, and what that means for survival.)

Theory

Individuals do not last for ever, but species can. Every organism you have ever seen will one day die. A species keeps going only because its members produce new individuals — **offspring** — faster than old ones die. That continuing of a species through time is what this subtopic means by **survival of the species**. It is not about any one organism staying alive; it is about the group still being here, generation after generation. The process that makes this possible is **reproduction**, and it comes in two modes: **asexual reproduction** and **sexual reproduction**. Each mode enables survival in a different way.

The words of this subtopic. Several terms do most of the work here, so here they are up front. **Offspring** are the new individuals produced by reproduction. **Asexual reproduction** is reproduction with **one parent** and **no joining of sex cells**; the offspring are **genetically identical** to the parent and to each other. **Sexual reproduction** usually involves **two parents**, whose sex cells (the **gametes** you met in Subtopic 7A) join at **fertilisation**; the offspring are **genetically different** from the parents and from each other. The differences between individuals of the same species are called **variation**. An organism that is genetically identical to its parent is called a **clone**. (The Victorian Curriculum uses these terms without giving one fixed wording, so this subtopic works to those definitions, and every question here can be answered from them.) The structures that carry out reproduction — the gametes and the organs — belong to Subtopic 7A. Here, the focus is on the **processes** and on what they mean for variation and survival.



Both modes enable a species to survive — but in different ways.

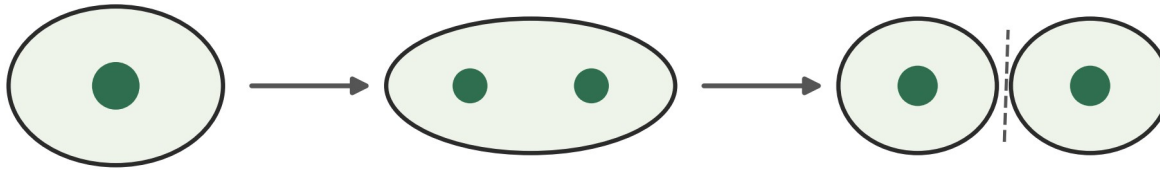
A concept map splitting reproduction into two modes — asexual reproduction with one parent and sexual reproduction with two — and showing that asexual reproduction produces identical offspring (clones) while sexual reproduction produces varied offspring.

Asexual reproduction: one parent, copies (elaboration VC2S10U01 . E03)

In asexual reproduction a single parent makes new individuals on its own. No gametes join, and no mate is needed. The parent's full set of instructions is copied and passed on whole, so the offspring are **genetically identical** to the parent — they are **clones**. Several different methods achieve the same result. Three common ones are **binary fission**, **budding** and **vegetative propagation**.

Binary fission — **one cell splits into two**. Bacteria reproduce asexually by binary fission. The single cell copies its instructions, grows, and then splits down the middle to form two identical cells.

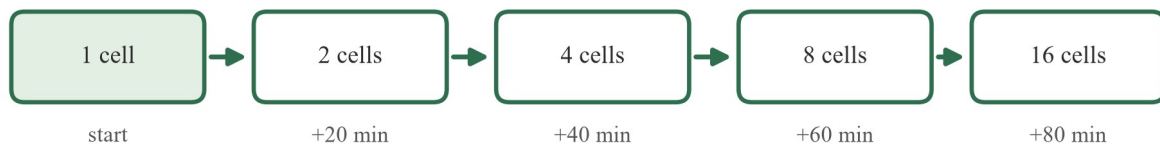
Binary fission — one cell becomes two identical cells



1 A bacterial cell grows, and its instructions are copied

2 The cell gets longer; the copies move apart

3 The cell splits in two — two identical cells

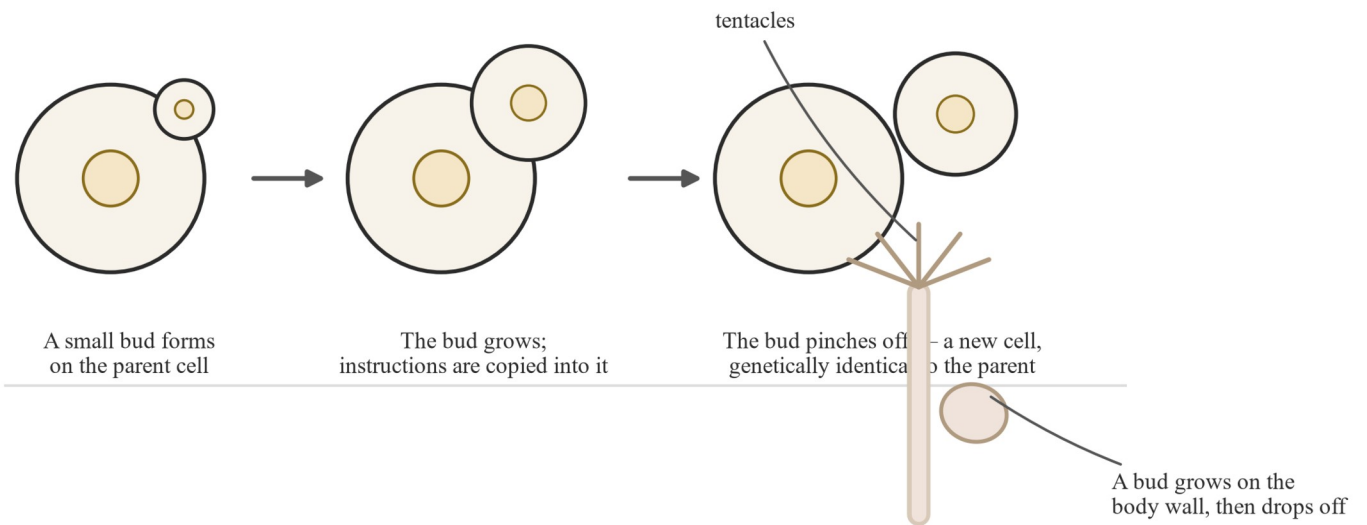


Model: if one cell divides every 20 minutes, the numbers double every 20 minutes.

The three stages of binary fission in a bacterium — the instructions are copied, the cell gets longer and the copies move apart, then the cell splits into two identical cells — with a doubling chain below showing 1, 2, 4, 8, 16 cells at 20-minute intervals.

Under ideal conditions some bacteria divide about every 20 minutes, so the numbers **double** at each step: one becomes two, two become four, four become eight. This fast doubling is one reason bacteria can increase their numbers so quickly when food and warmth are plentiful.

Budding — a new individual grows out of the parent. In budding, a small outgrowth called a **bud** forms on the parent, grows, and eventually separates to live on its own. The bud is a clone of the parent. Yeast (a fungus) buds this way, and so does the hydra, a small freshwater animal.



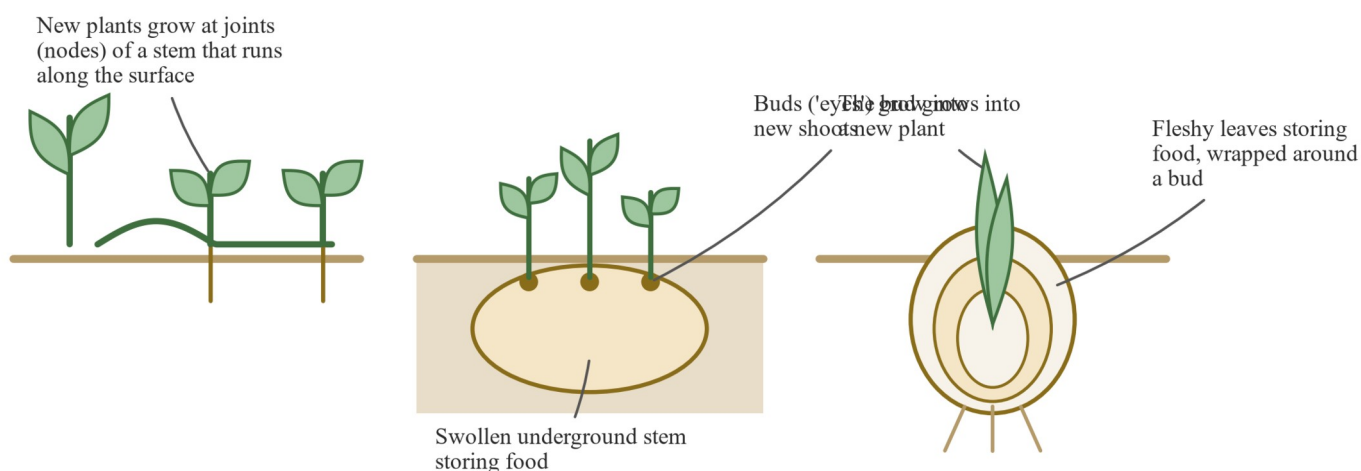
Budding in yeast, showing a bud forming, growing and pinching off the parent cell, drawn beside budding in a hydra, where a bud grows on the body wall and drops off.

Vegetative propagation — plants cloning themselves. Many plants reproduce asexually using parts of the parent plant other than seed. This is called **vegetative propagation**. The new plants grow from a stem, a bud or a storage organ of the parent, so they are clones. Three common structures are **runners**, **tubers** and **bulbs**.

Runner — e.g. strawberry

Tuber — e.g. potato

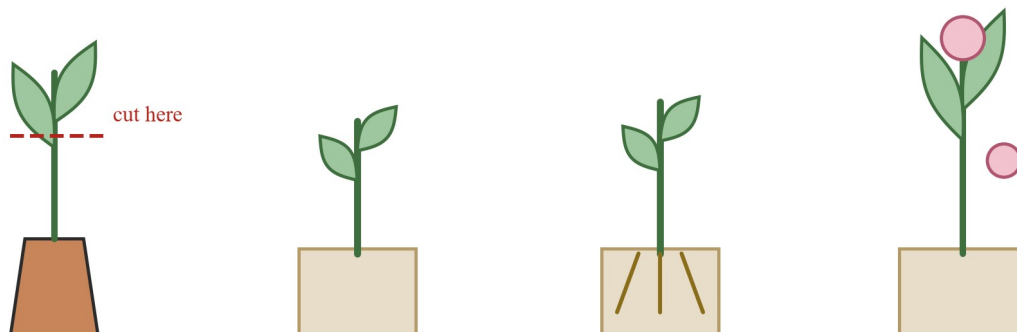
Bulb — e.g. onion



Vegetative propagation in three plants: a strawberry runner sending out a stem along the surface with new plants at its joints, a potato tuber with buds (eyes) growing into new shoots, and an onion bulb with fleshy leaves wrapped around a bud that grows into a new plant.

Structure	Example plant	How it makes a new plant
Runner	strawberry	a stem runs along the surface and new plants grow at its joints (nodes)
Tuber	potato	a swollen underground stem stores food; its buds (the “eyes”) grow into new shoots
Bulb	onion	fleshy leaves store food wrapped around a bud, and the bud grows into a new plant

People put asexual reproduction to work. Gardeners and growers often want to keep a plant they like exactly as it is, so they clone it on purpose. One simple method is taking a **cutting**: a piece of stem is cut from the parent plant and placed in moist soil, where it grows roots and becomes a new plant — a clone of the parent.



Gardeners and growers use cuttings to keep exactly the traits they want — every new plant is identical to the parent.

The four steps of taking a cutting: cutting a stem from the parent plant, placing the cut end in moist soil, roots growing from the cut end, and the new plant growing as a clone of the parent.

Growers use cuttings because every new plant keeps **exactly** the traits they want — the same fruit, the same flower colour, the same taste. If a plant has a desirable feature, cloning it preserves that feature perfectly, generation after generation.

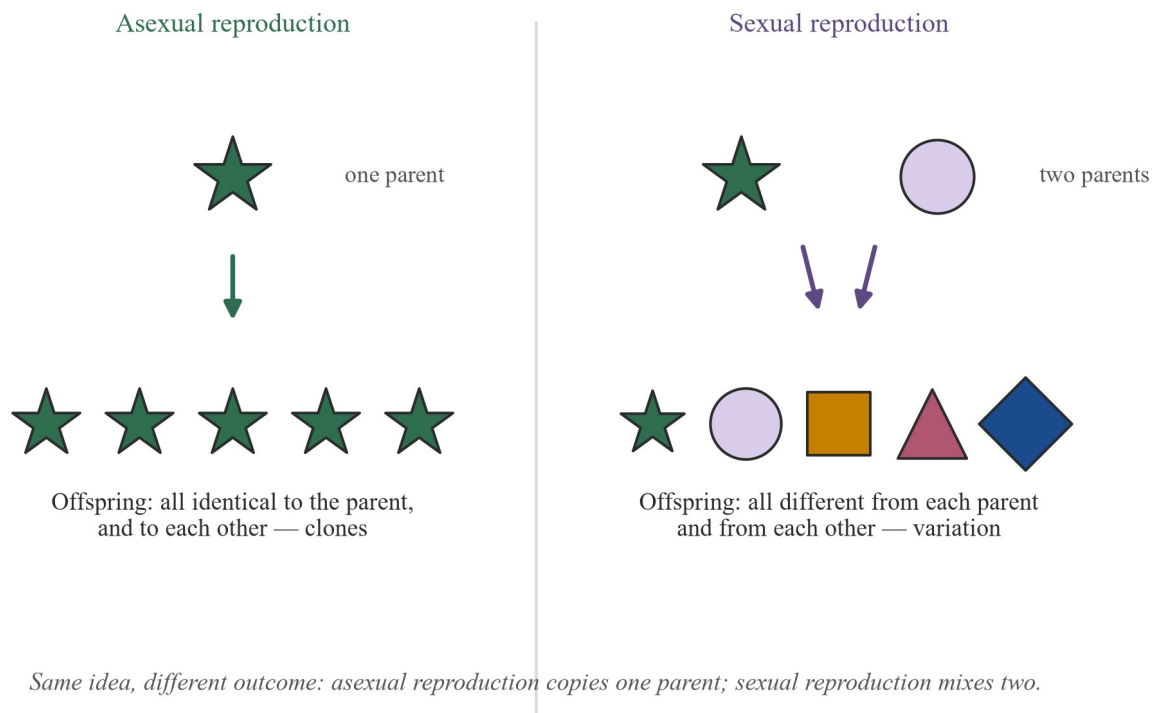
Why asexual reproduction suits some situations. Asexual reproduction has clear advantages when conditions are stable and favourable:

- it is **fast** — no time is spent finding a mate, so numbers can grow quickly;
- a **well-suited parent produces well-suited offspring** — if the parent is well matched to its environment, every clone is too;
- it works even when there is **only one individual** present, because no mate is needed.

But it has one serious weakness, and it comes straight from the fact that the offspring are identical: **there is no variation**. Every individual is the same. If the environment changes — a new disease arrives, the climate shifts, a food source disappears — and the clones are not suited to the new condition, **all of them** are equally at risk. The whole population can be wiped out at once. You will meet this idea again as a model below.

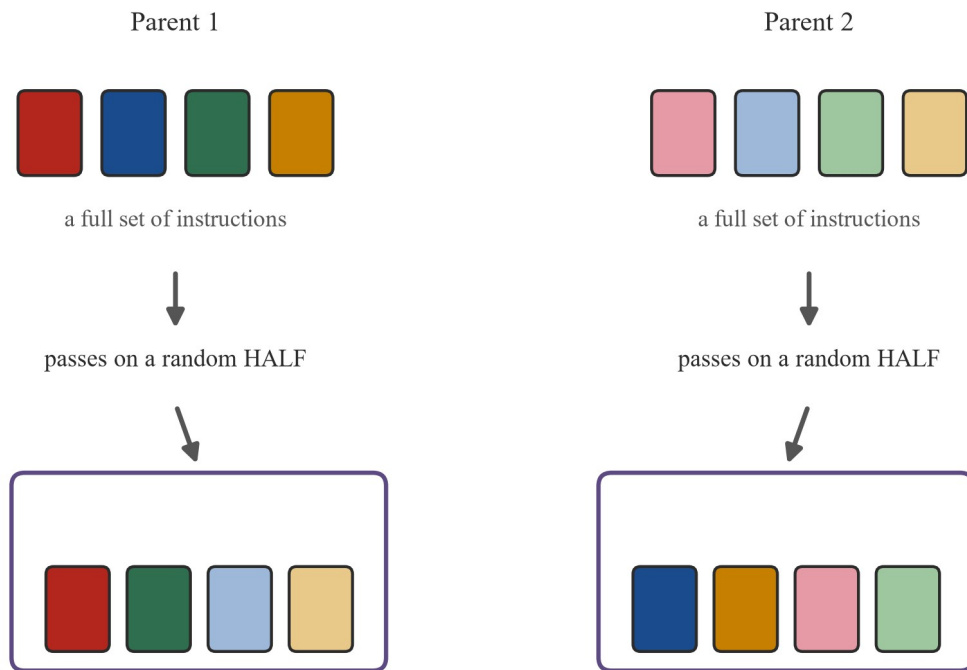
Sexual reproduction: two parents, variation (elaboration VC2S10U01 . E04)

In sexual reproduction, two parents each contribute a sex cell — a **gamete**. The male gamete and the female gamete join at **fertilisation**, and the new individual that develops carries a **mix of instructions from both parents**. Because the mix is different every time, the offspring are **genetically different** from each parent and from each other. This is the source of the **variation** sexual reproduction produces.



Two panels comparing the outcome of each mode: asexual reproduction from one parent produces identical offspring (clones), while sexual reproduction from two parents produces offspring that are all different from each other (variation).

Why sexual reproduction produces variation. Think of each parent's instructions as a full pack of cards. Each parent passes on only a **random half** of their pack, and which half they pass on is different every time. The two halves then join at fertilisation. The result is that each offspring gets a **different combination** of the two parents' instructions.



Each child gets a different mix of the two parents' instructions — that is why brothers and sisters are alike but never identical. (How the instructions are split and joined is covered in Subtopic 7C.)

A card model of sexual reproduction: each of two parents holds a full set of instruction cards, each passes on a random half, and two children end up with different mixes of the two parents' cards.

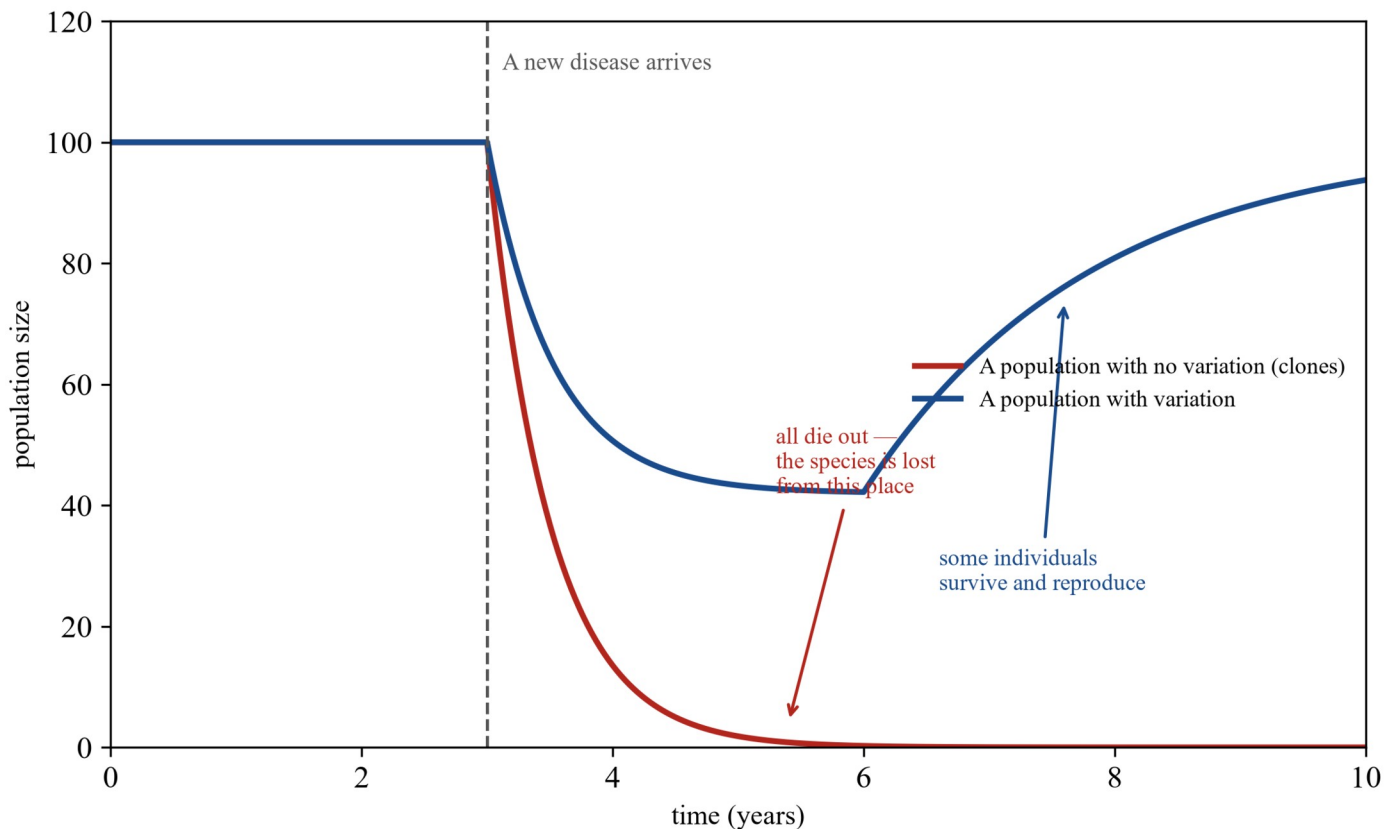
That different mix is why brothers and sisters are alike but never identical: they share the same two parents but each received a different combination. (The exact way the instructions are split into gametes and then rejoined — involving structures called chromosomes and a cell division called meiosis — is covered in Subtopic 7C.)

Compared with asexual reproduction, sexual reproduction produces a **greater rate of variation** among offspring. Asexual reproduction copies one set of instructions exactly; sexual reproduction shuffles two sets together into a new combination every time. That variation is the key to one of sexual reproduction's biggest advantages, which we look at next.

The cost of sexual reproduction. Sexual reproduction is not free. It usually needs **two parents**, so time and energy go into finding and attracting a mate. It is **slower** than asexual reproduction, and each offspring carries a **new, untested combination** of instructions — there is no guarantee the mix suits the environment as well as the parents did.

Variation is what lets a species survive change

Here is the payoff of all that variation. Imagine two populations of the same species. One has **no variation** — every individual is a clone. The other **has variation** — the individuals differ from one another. Now suppose a **new disease** arrives.



Simulated data for practice — a model to show the effect of variation.

Two labelled model curves of population size over time after a new disease arrives: a population with no variation (clones) falls to zero as all individuals die, while a population with variation dips but then recovers as the surviving individuals reproduce. Simulated data for practice.

In the population with **no variation**, every individual is equally unable to resist the disease, so **all of them die** and the species is lost from that place. In the population **with variation**, the individuals differ, so **some** are more likely to be able to resist the disease. Those survivors live and reproduce, passing on the features that helped them survive, and the population **recovers**.

This is the core reason sexual reproduction helps a species survive: the variation it produces means that when the environment changes, **at least some individuals are more likely to survive the change**. A species with variation has a better chance of continuing through drought, disease, new predators or a shifting climate. A species of identical clones puts all its eggs in one basket — one new threat can end it.

The two modes compared

Neither mode is “better”. Each suits different conditions, and many species use both at different times. Here is the comparison feature by feature.

Feature	Asexual reproduction	Sexual reproduction
Number of parents	One	Usually two
Joining of sex cells?	No	Yes — fertilisation
Offspring	Genetically identical to the parent — clones	Genetically different from the parents and from each other
Speed	Fast — no mate needed; numbers can grow quickly	Slower — a mate is usually needed
When it suits	Stable, favourable conditions — a well-suited parent produces well-suited offspring	Changing conditions — variation means some individuals are more likely to survive change
Main risk	No variation: one new disease or change could wipe out the whole population	Takes more time and energy; each offspring carries a new, untested mix

Neither mode is 'better' — each suits different conditions, and many species use both.

A comparison table of asexual and sexual reproduction by number of parents, whether sex cells join, the offspring, speed, when each mode suits, and the main risk of each.

Feature	Asexual reproduction	Sexual reproduction
Number of parents	one	usually two
Joining of sex cells?	no	yes — fertilisation
Offspring	genetically identical to the parent — clones	genetically different from the parents and from each other
Speed	fast — no mate needed, numbers grow quickly	slower — a mate is usually needed
When it suits	stable, favourable conditions — a well-suited parent produces well-suited offspring	changing conditions — variation means some individuals are more likely to survive change
Main risk	no variation: one new disease or change could wipe out the whole population	takes more time and energy; each offspring carries a new, untested mix

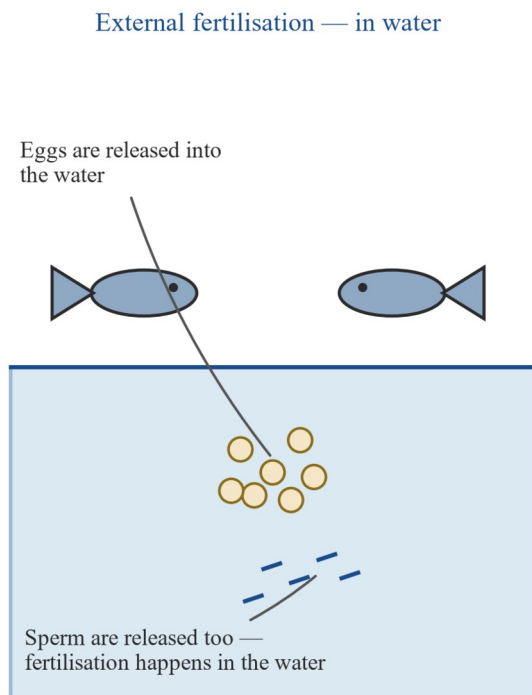
Strategies, the environment and complexity (elaboration VC2S10U01.E05)

The reproductive strategy an animal uses is closely matched to **where it lives** and to **how complex its body is**. A clear example is where fertilisation happens.

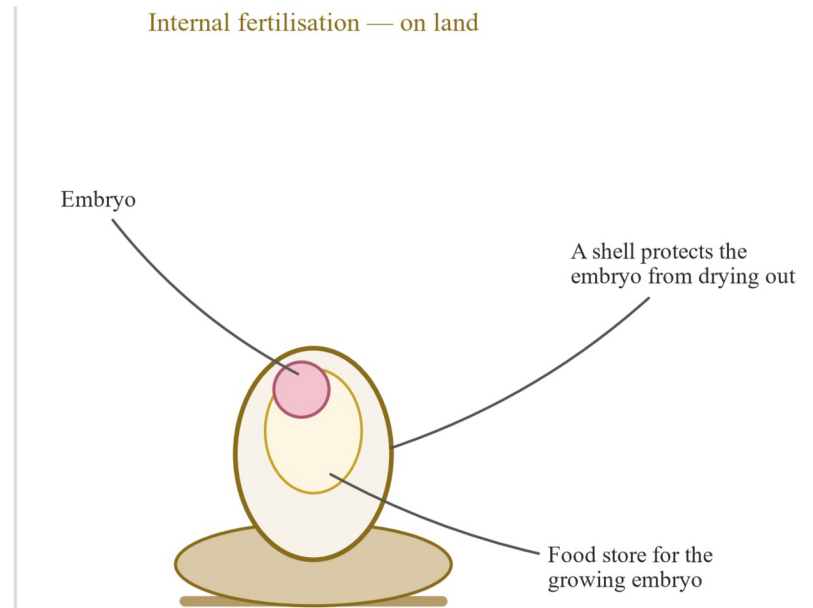
External fertilisation — in water. Many water animals, such as most fish and frogs, release their eggs and sperm into the water, and fertilisation happens outside the body. The water keeps the gametes moist and carries the sperm to the eggs. Because so many of the released gametes and young are lost, these animals usually release **very large numbers**.

Internal fertilisation — on land. On land, gametes would dry out in the air. So land animals — mammals, birds, reptiles and insects — carry out fertilisation **inside** the female's body, where the gametes stay moist. The developing

embryo — the early stage of the new organism, formed after fertilisation — is then protected from drying out, either inside a **shelled egg** (birds and reptiles) or inside the mother's body (most mammals).



Water keeps the sex cells moist and carries them.



The sex cells join inside the mother's body, so they never dry out.

Two panels: external fertilisation in water, where eggs and sperm are released and meet in the water, and internal fertilisation on land, showing a shelled egg with a protective shell, a food store and an embryo inside.

The pattern is that the **environment shapes the strategy**: water allows external fertilisation, while life on land needs internal fertilisation and extra protection for the developing young. In general, more complex animals invest more in protecting and feeding each offspring, which leads to the next idea — how many offspring an animal has, and how much care it gives them.

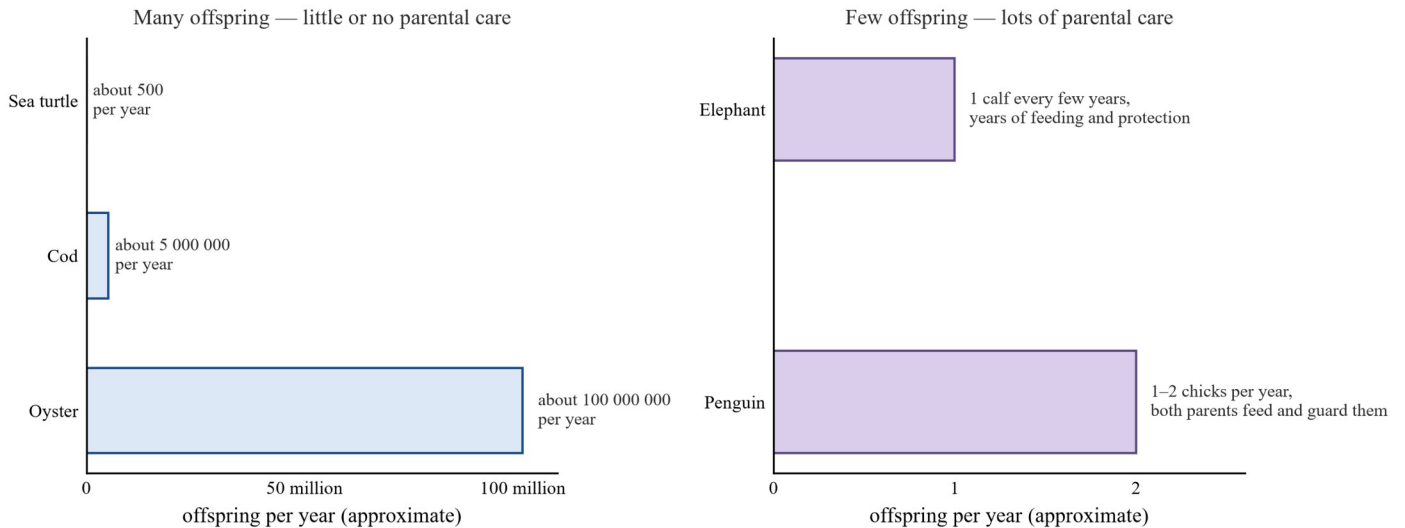
How many offspring, and how much care? (elaboration VC2S10U01.E06)

There is a trade-off built into reproduction: an animal can produce **many offspring and give each one little or no care**, or it can produce **few offspring and give each one a lot of care**. Both strategies can enable survival — they just spread the odds differently.

Many offspring, little or no care. Animals such as oysters, cod and sea turtles release enormous numbers of eggs and leave them to develop on their own. The eggs and the young get no feeding or protection, so **most die** before they grow up. The strategy works because the numbers are so huge that **a few** still survive to adulthood — enough to keep the species going.

Few offspring, lots of care. Animals such as penguins and elephants have only one or two young at a time, but the parents feed, guard and protect them for a long period. Because of that care, **most of the young survive** to adulthood.

How many offspring, and how much care? (illustrative values)

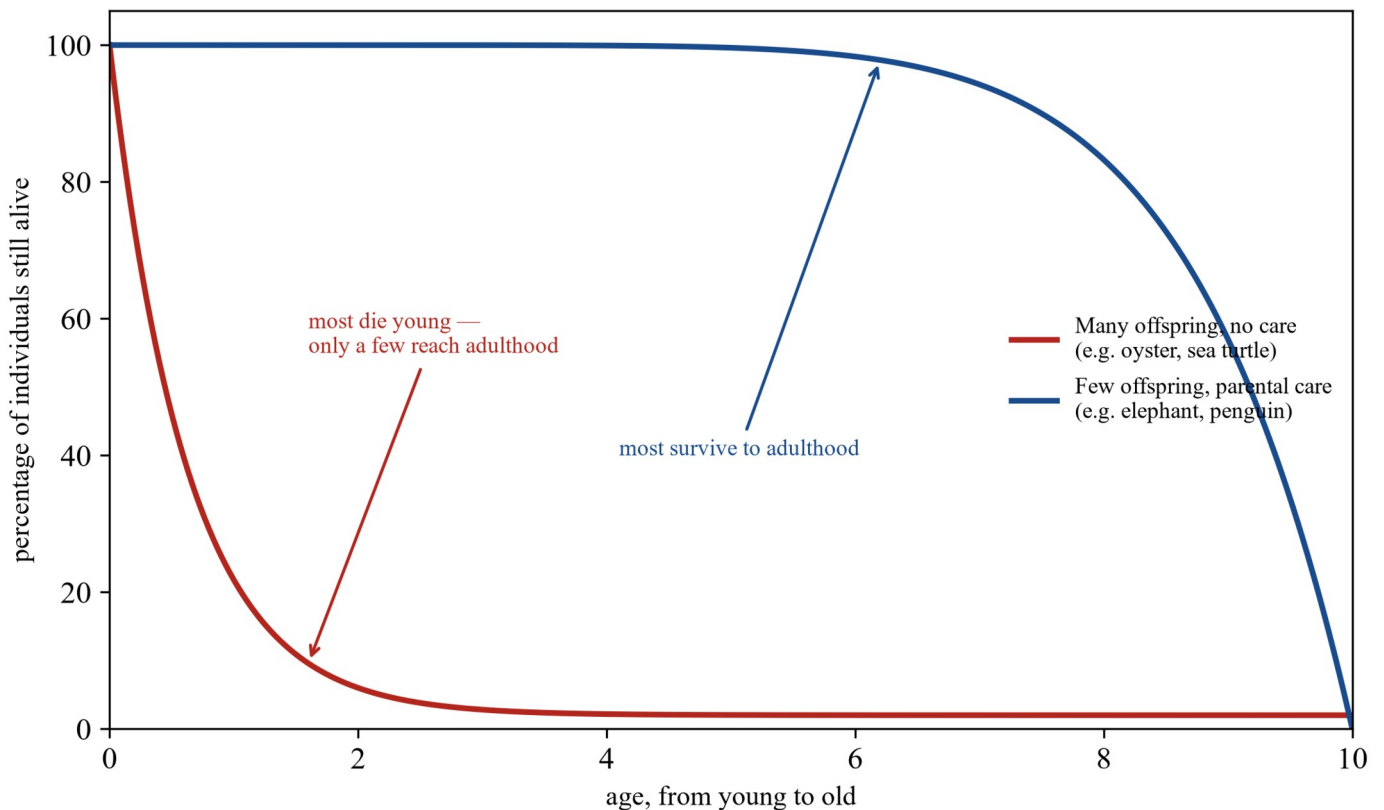


Eggs are left to develop on their own.

Care raises each offspring's chance of reaching adulthood.

Two bar charts: one showing animals that produce many offspring per year with little or no parental care (oyster, cod, sea turtle), and one showing animals that produce few offspring per year with lots of parental care (penguin, elephant). Approximate illustrative values.

The two survival curves below show the result. With **many offspring and no care**, most individuals die young and only a few reach adulthood. With **few offspring and parental care**, most individuals survive to adulthood.



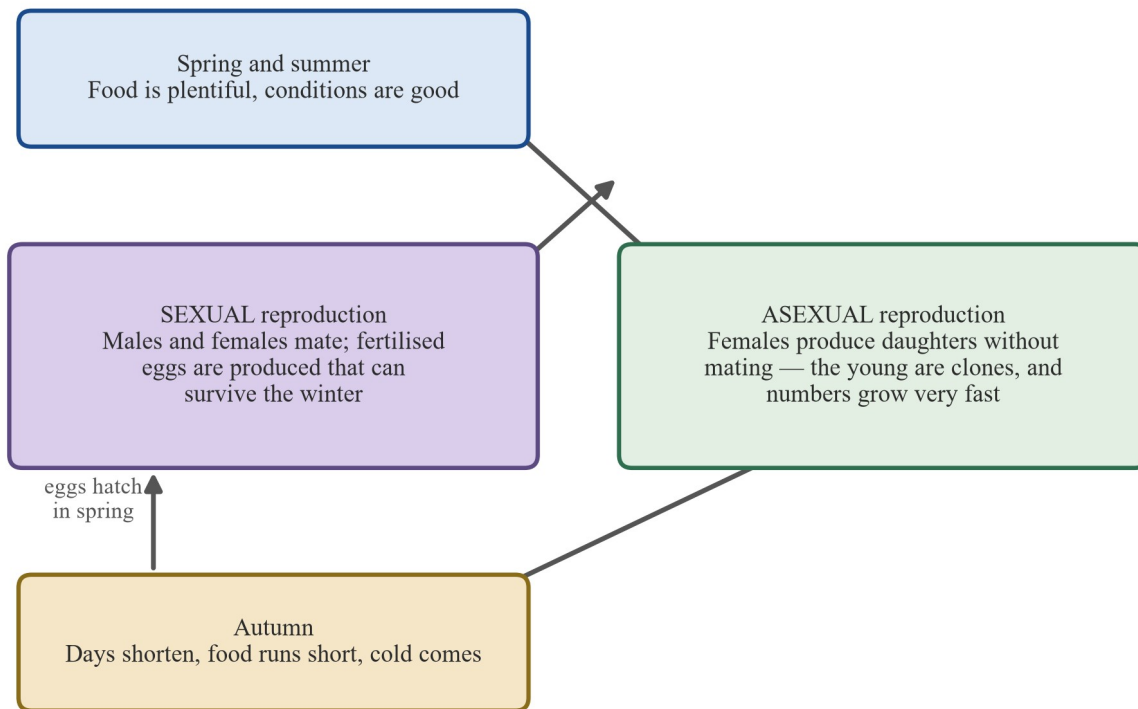
Illustrative model curves — drawn to show the idea, not measurements.

Two labelled model survival curves: one for many offspring with no care, falling steeply so that most die young, and one for few offspring with parental care, staying high so that most survive to adulthood. Illustrative model curves.

Neither strategy is better in every situation. Producing huge numbers suits an animal whose young are exposed to many dangers and get no help; producing few well-cared-for young suits an animal that can defend and feed its offspring. In both cases the outcome is the same: **enough individuals reach adulthood to continue the species.**

Using both: switching strategy with the seasons

Some species do not choose one mode — they use **both**, switching between them as conditions change. The aphid, a small insect, is a clear example.



Aphids — small insects — use BOTH strategies: cloning when times are good, sex when hard times come.

A cycle diagram of the aphid's year: in spring and summer, when food is plentiful, aphids reproduce asexually and females produce cloned daughters so numbers grow fast; in autumn, when days shorten and cold comes, they reproduce sexually and produce fertilised eggs that can survive the winter, hatching again in spring.

In **spring and summer**, when food is plentiful and conditions are good, aphids reproduce **asexually**: females produce daughters without mating, the young are clones, and the numbers grow very fast. This makes the most of the good conditions. In **autumn**, when days shorten and cold comes, aphids switch to **sexual reproduction**: males and females mate and produce fertilised eggs that can **survive the winter**. The variation from sexual reproduction helps the next generation face the changed conditions. The aphid gets the benefits of both modes — speed when times are good, and variation when hard times come.

Pulling the idea together

Both modes of reproduction enable a species to survive, but in different ways. **Asexual reproduction** is fast and efficient: one well-suited parent can quickly produce many well-suited offspring, which suits **stable, favourable conditions**. Its weakness is that it produces **no variation**, so one new threat can wipe out the whole population. **Sexual reproduction** is slower and needs a mate, but it produces **variation**, and that variation means **some individuals are more likely to survive** when the environment changes. A species continues through time because reproduction replaces the individuals that die — and the variation that sexual reproduction adds gives the species a better chance of surviving the changes it meets along the way.

Activities

Activity 1 — Sort the strategies (elaboration VC2S10U01 . E03). On paper, make two columns headed *Asexual reproduction* and *Sexual reproduction*. Sort the following into the correct column, and for each one write one sentence saying why it belongs there: a bacterium splitting in two; a strawberry plant sending out a runner; a fish releasing eggs into the water; a gardener growing a new plant from a cutting; a hydra growing a bud; two birds mating and laying fertilised eggs; a potato tuber sprouting new shoots; an aphid producing daughters without mating. Then add **two examples of your own** — one for each column — and swap lists with a partner to check each other's sorting.

Activity 2 — Modelling the doubling of bacteria (ratio and scale skills from Subtopic 4B). One bacterium divides every 20 minutes under ideal conditions, so the numbers double every 20 minutes. Starting with **one** cell, copy and complete a table like this one for the first 2 hours.

Time (minutes)	Number of divisions	Number of cells
0	0	1
20	1	2
40	2	4
...	...	...
120	...	...

- (i) How many divisions happen in 2 hours (120 minutes)?
- (ii) How many cells are there after 2 hours?
- (iii) How many cells would there be after 3 hours (180 minutes)?
- (iv) Discuss: this model assumes every cell keeps dividing and none die. Give one reason the number in a real population would be lower than the model predicts.

Activity 3 — Watching a potato sprout. A potato is a tuber, and its “eyes” are buds that can grow into new plants. Take a potato that has started to sprout (your teacher can supply one) and draw it, labelling the eyes and any shoots growing from them. Without using any sharp blades, observe where the shoots come from. Record in a table (skills from Subtopic 4A): the number of eyes you can see, how many have shoots, and the length of the longest shoot. Then answer: is a shoot growing from a potato eye an example of sexual or asexual reproduction? Give one reason for your answer, referring to what makes the offspring genetically identical to the parent. Wash your hands after handling the potato.

Worked examples

Example 1 — scaffolded

Sort each description into *asexual reproduction* or *sexual reproduction*.

Description

1. One parent; offspring are clones
2. Gametes join at fertilisation
3. A bud grows on the parent and drops off
4. Offspring are genetically different from the parents

Working

- 1 → Asexual. One parent, no joining of sex cells, offspring identical.
- 2 → Sexual. The joining of gametes at fertilisation needs two parents' sex cells.

Comment

- One parent and clones are the hallmarks of asexual reproduction.
- Fertilisation is the key event of sexual reproduction.

Working	Comment
3 → Asexual. Budding uses one parent, and the bud is a clone.	Budding is a method of asexual reproduction.
4 → Sexual. Offspring different from the parents means the instructions were mixed from two sources.	Variation among offspring is the result of sexual reproduction.

Example 2 — scaffolded

One bacterium divides by binary fission every 20 minutes. How many bacteria are there after 1 hour, assuming none die?

Working	Comment
1 hour = 60 minutes.	Convert the time into minutes first.
Number of divisions = $60 \div 20 = 3$.	The cells divide every 20 minutes, so divide the total time by 20.
The numbers double at each division: $1 \rightarrow 2 \rightarrow 4 \rightarrow 8$.	Start at 1 and double once per division (3 doublings).
After 1 hour there are 8 bacteria.	Three doublings give $2 \times 2 \times 2 = 8$ cells.

Example 3 — unscaffolded

A farmer grows a whole crop of potato plants from tubers taken from a single parent plant. Explain why this crop is at greater risk from a new disease than a crop grown from seed produced by sexual reproduction. (3 marks)

The tubers reproduce **asexually**, so every plant in the crop is a **clone**, genetically identical to the parent and to each other. That means there is **no variation** in the crop. If a new disease arrives and the plants are not able to resist it, **all of them** are equally at risk and the **whole crop can be wiped out** at once. A crop grown from seed produced by **sexual reproduction** has **variation** — the plants are genetically different from each other — so **some are more likely to resist** the disease, survive and keep the crop going. ∴ the clone crop's lack of variation is what makes it more at risk.

Example 4 — unscaffolded

A sea turtle lays hundreds of eggs and leaves them, while an elephant has one calf and cares for it for years. Explain how **each** strategy enables the survival of the species. (4 marks)

The sea turtle uses a **many-offspring, no-care** strategy. It lays a very large number of eggs and gives them no protection, so **most of the young die** before adulthood. The strategy still enables survival because the numbers are so large that **a few** individuals reach adulthood — enough to continue the species. The elephant uses a **few-offspring, high-care** strategy. It has only one calf at a time but feeds, guards and protects it for years, so the calf is **very likely to survive** to adulthood. This strategy enables survival because the care means **most of the (few) young reach adulthood**. In both cases the outcome is the same: enough individuals survive to reproduce and keep the species going. ∴ the turtle spreads the odds across huge numbers, while the elephant invests heavily in each of a few young.

Practice questions

Scaffolded questions

Question 1 The vocabulary of this subtopic. Define each of the following: (a) offspring; (b) asexual reproduction; (c) sexual reproduction; (d) variation; (e) clone; (f) fertilisation.

Question 2 Comparing the two modes. Copy and complete the table.

Feature	Asexual reproduction	Sexual reproduction
Number of parents		
Joining of sex cells?		
Offspring are ...		

Feature	Asexual reproduction	Sexual reproduction
Speed		

Question 3 Binary fission. (a) Name the kind of organism that reproduces by binary fission. (b) State how many parents are involved. (c) State how many offspring result from one division. (d) State whether the offspring are genetically identical to the parent or different from it.

Question 4 Vegetative propagation in plants. (a) Name the three structures shown in this subtopic that plants use for vegetative propagation. (b) Give one example plant for each structure. (c) Explain why vegetative propagation is a form of asexual reproduction.

Question 5 The doubling model. One bacterium divides every 20 minutes. (a) How many divisions happen in 1 hour? (b) Starting with one cell, how many cells are there after 1 hour? (c) Starting with one cell, how many cells are there after 2 hours?

Question 6 Match each animal to its reproductive strategy. Animals: oyster; penguin. Strategies: many offspring with little or no care; few offspring with lots of care. For each animal, name the strategy and state what happens to most of the young.

Unscaffolded questions

Question 7 Explain why asexual reproduction is an advantage when conditions are stable and favourable. (2 marks)

Question 8 Explain why the variation produced by sexual reproduction helps a species to survive when its environment changes. (2 marks)

Question 9 A gardener wants to keep exactly the same flower colour in a new plant. State whether they should grow the new plant from a cutting or from seed, and explain your choice. (2 marks)

Question 10 Aphids reproduce asexually in summer but switch to sexual reproduction in autumn. Explain why switching to sexual reproduction before winter helps the aphids to survive. (2 marks)

Question 11 Most fish carry out external fertilisation in water, while mammals carry out internal fertilisation on land. Explain why each mode suits the animal's environment. (2 marks)

Question 12 An oyster releases millions of eggs but gives them no care. Explain how this strategy can still enable the survival of the species. (2 marks)

Question 13 Look at the two survival curves in this subtopic. State which strategy — many offspring with no care, or few offspring with parental care — results in a greater proportion of individuals reaching adulthood, and explain how you can tell from the curves. (2 marks)

Question 14 A population of a species has no variation — every individual is a clone. Predict what would happen if a new disease that the clones cannot resist arrived, and explain your reasoning. (2 marks)

Question 15 Brothers and sisters have the same two parents but are not identical to each other. Explain why, using the idea that each parent passes on a half of their instructions. (2 marks)

Question 16 “Neither asexual nor sexual reproduction is better — each suits different conditions.” Explain this statement, giving one condition that suits each mode and the reason that mode suits it. (4 marks)

Answers

Question 1 (a) the new individuals produced by reproduction; (b) reproduction with one parent and no joining of sex cells; offspring are clones; (c) reproduction usually involving two parents, whose gametes join at fertilisation; offspring are genetically different; (d) the differences between individuals of the same species; (e) an organism genetically identical to its parent; (f) the joining of a male and a female gamete. **Question 2** Asexual: one; no; genetically identical to the parent (clones); fast. Sexual: usually two; yes; genetically different from the parents and each other; slower. **Question 3** (a) bacteria; (b) one; (c) two; (d) genetically identical. **Question 4** (a) runner, tuber, bulb; (b) strawberry, potato, onion; (c) see solution. **Question 5** (a) 3; (b) 8; (c) 64. **Question 6** Oyster: many offspring, little or no care — most die young. Penguin: few offspring, lots of care — most survive to adulthood. **Question 7** see solution. **Question 8** see solution. **Question 9** see solution. **Question 10** see solution. **Question 11** see solution. **Question 12** see solution. **Question 13** see solution. **Question 14** see solution. **Question 15** see solution. **Question 16** see solution.

Fully-worked solutions

Question 1 (a) **Offspring** are the new individuals produced by reproduction. (b) **Asexual reproduction** is reproduction with **one parent** and **no joining of sex cells**; the offspring are genetically identical to the parent — clones. (c) **Sexual reproduction** is reproduction usually involving **two parents**, whose sex cells (gametes) join at fertilisation; the offspring are genetically different from the parents and from each other. (d) **Variation** is the differences between individuals of the same species. (e) A **clone** is an organism that is genetically identical to its parent. (f) **Fertilisation** is the joining of a male gamete and a female gamete.

Question 2 Asexual reproduction: **one parent**; **no joining of sex cells**; offspring are **genetically identical to the parent (clones)**; it is **fast**. Sexual reproduction: **usually two parents**; **yes**, the sex cells join at fertilisation; offspring are **genetically different from the parents and from each other**; it is **slower**.

Question 3 (a) **Bacteria** reproduce by binary fission. (b) **One** parent is involved. (c) **Two** offspring result from one division. (d) The offspring are **genetically identical** to the parent — they are clones.

Question 4 (a) The three structures are the **runner**, the **tuber** and the **bulb**. (b) Runner: **strawberry**; tuber: **potato**; bulb: **onion**. (c) Vegetative propagation is asexual reproduction because the new plant grows from a part of **one parent** plant (a stem, a bud or a storage organ) with **no joining of sex cells**, so the new plant is **genetically identical** to the parent — a clone.

Question 5 (a) In 1 hour (60 minutes) there are $60 \div 20 = 3$ divisions. (b) Starting with 1 cell, three doublings give $1 \rightarrow 2 \rightarrow 4 \rightarrow 8$ cells. (c) In 2 hours (120 minutes) there are $120 \div 20 = 6$ divisions, so six doublings give $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow 64$ cells.

Question 6 The **oyster** uses the **many-offspring, little-or-no-care** strategy: it releases huge numbers of eggs and leaves them, so **most of the young die** before adulthood. The **penguin** uses the **few-offspring, lots-of-care** strategy: it has one or two chicks and both parents feed and guard them, so **most of the young survive** to adulthood.

Question 7 When conditions are **stable and favourable**, asexual reproduction is an advantage because it is **fast** — no time is spent finding a mate, so numbers grow quickly — and because a **well-suited parent produces well-suited offspring**: since the environment is not changing, the clones are just as well matched to it as the parent was. (1 mark: fast / no mate needed; 1 mark: well-suited parent produces well-suited offspring in unchanged conditions.)

Question 8 Sexual reproduction produces **variation** — the offspring are genetically different from each other and from the parents. When the environment changes, that variation means **some individuals are more likely to be suited to the new conditions** and to survive. Those survivors reproduce and pass on their helpful features, so the species **continues** instead of being wiped out. (1 mark: variation means individuals differ; 1 mark: some are more likely to survive the change and keep the species going.)

Question 9 The gardener should grow the new plant from a **cutting**. A cutting is a form of **asexual reproduction**, so the new plant is a **clone**, genetically identical to the parent, and it keeps **exactly** the same flower colour. A plant grown from **seed** is the result of **sexual reproduction** and would have **variation** — a mix of the two parents' instructions —

so its flower colour could be different. (1 mark: choose the cutting / asexual; 1 mark: the clone keeps the trait exactly, while seed gives variation.)

Question 10 Switching to **sexual reproduction** before winter produces **variation** among the offspring, because the young get a **mix of instructions from two parents** instead of being clones. Winter brings changed, harsh conditions, and the variation means **some individuals are more likely to survive** the cold and the shortage of food. The fertilised eggs produced by sexual reproduction can also **survive the winter** and hatch in spring. (1 mark: sexual reproduction produces variation; 1 mark: variation means some are more likely to survive the changed winter conditions.)

Question 11 Fish live in **water**, which keeps the gametes **moist** and carries the sperm to the eggs, so **external fertilisation** works there — the gametes do not dry out. Mammals live on **land**, where gametes released into the air would **dry out**, so they use **internal fertilisation**, with the gametes joining **inside the female's body** where they stay moist, and the developing young protected from drying out. (1 mark: water keeps gametes moist so external works; 1 mark: on land internal fertilisation stops the gametes drying out.)

Question 12 The oyster releases **millions** of eggs and gives them no care, so **most die** before they grow up. The strategy still enables survival because the numbers are so **huge** that **a few individuals** survive to adulthood — enough to reproduce and keep the species going. (1 mark: most of the many young die; 1 mark: the huge numbers mean a few survive to continue the species.)

Question 13 The **few-offspring, parental-care** strategy results in a greater proportion of individuals reaching adulthood. You can tell because its curve **stays high** across the whole age range, meaning most individuals are still alive by adulthood, while the **many-offspring, no-care** curve **falls steeply** at the start, meaning most individuals die young. (1 mark: the few-offspring, care strategy; 1 mark: its curve stays high while the other falls steeply.)

Question 14 Because the population has **no variation** — every individual is a **clone**, genetically identical — none of the individuals would be able to resist the new disease. So **all of them would be affected**, and the **whole population could be wiped out**, with the species lost from that place. (1 mark: no variation means none can resist; 1 mark: the whole population is wiped out.)

Question 15 Each parent passes on only a **half** of their instructions, and **which half** they pass on is **different every time**. So each child gets a **different combination** of the two parents' instructions. Brothers and sisters share the same two parents but each received a different mix, which is why they are **alike but not identical**. (1 mark: each parent passes on a random half; 1 mark: each child gets a different combination.)

Question 16 Neither mode is better because each suits **different conditions**. **Asexual reproduction** suits **stable, favourable conditions**: it is fast, needs no mate, and a well-suited parent produces well-suited offspring, which is ideal when the environment is not changing. Its weakness is that it produces **no variation**, so one new threat could wipe out the whole population. **Sexual reproduction** suits **changing conditions**: it produces **variation**, so when the environment changes some individuals are more likely to survive and keep the species going. Its cost is that it is slower and needs a mate. So the “better” mode depends on the situation — asexual wins on speed in steady times, and sexual wins on variation when times change. (1 mark each: asexual suits stable/favourable conditions with a reason; sexual suits changing conditions with a reason; the two named weaknesses/costs; and the concluding statement that the better mode depends on conditions.)

Where this leads: the variation produced by sexual reproduction, and how it helps a species survive change, is assumed by VCE Biology Unit 2, Area of Study 2 (“How do inherited adaptations impact on diversity?”), which takes the idea further into how variation and selection shape populations over time — reference-only for this book. The mechanism behind the variation — DNA, chromosomes, genes, alleles, and the cell divisions mitosis and meiosis — is taught within this band by Subtopic 7C, and the inheritance of single traits by Subtopic 7D. VCE adds gene linkage, sex-linkage and population genetics, which sit above the VC2 9–10 content descriptions and are not taught here (TOC D9). Subtopic 7A supplies the reproductive cells and organs whose structures carry out the processes taught here.

DNA, chromosomes, genes and alleles; mitosis and meiosis in passing on genetic information

Chapter 7 — Biological sciences A: reproduction and heredity (Science, Levels 9 and 10)

Subtopic 7C · VC2 Science Understanding — Biological sciences

CD code: VC2S10U04 (split delivery †; this subtopic is the accountable owner) **Content description**

(verbatim): “genetic inheritance involves the function of DNA, chromosomes, genes and alleles, and the roles of mitosis and meiosis in passing on genetic information to the next generation; the principles of Mendelian inheritance can be used to predict ratios of genotypes and phenotypes in monohybrid crosses involving dominant and recessive traits” **This subtopic’s limb (TOC §4 clause split):** DNA, chromosomes, genes and alleles, and the roles of mitosis and meiosis in passing on genetic information.

The partner subtopic 7D delivers the other limb: Mendelian monohybrid prediction of genotype and phenotype ratios. **Elaboration ids drawn on:** VC2S10U04.E01 · VC2S10U04.E02 ·

VC2S10U04.E05 (ids VC2S10U04.E03–VC2S10U04.E04 are drawn on by Subtopic 7D; no

elaboration of this CD is withheld under the TOC’s D10 ICIP decision) **Achievement standard (extract**

served): “They explain the processes that underpin heredity and genetic diversity, and predict the outcomes of monohybrid crosses.” (This is the full standard for the CD; it is assessed across Subtopics 7C and 7D together, with 7C supplying the explanation of the processes — DNA, chromosomes, genes, alleles, mitosis and meiosis — that underpin heredity and genetic diversity, and 7D carrying the prediction of monohybrid-cross outcomes.)

Theory

You are not a copy of either of your parents — but you are clearly related to both of them. Subtopic 7A met the structures that make that possible: the gametes (the sperm cell and the egg cell) and the organs that make and carry them. Each gamete carries **one set of instructions**. This subtopic opens up what those instructions actually are — a molecule called **DNA** — and follows them from one cell to the next. It answers three questions:

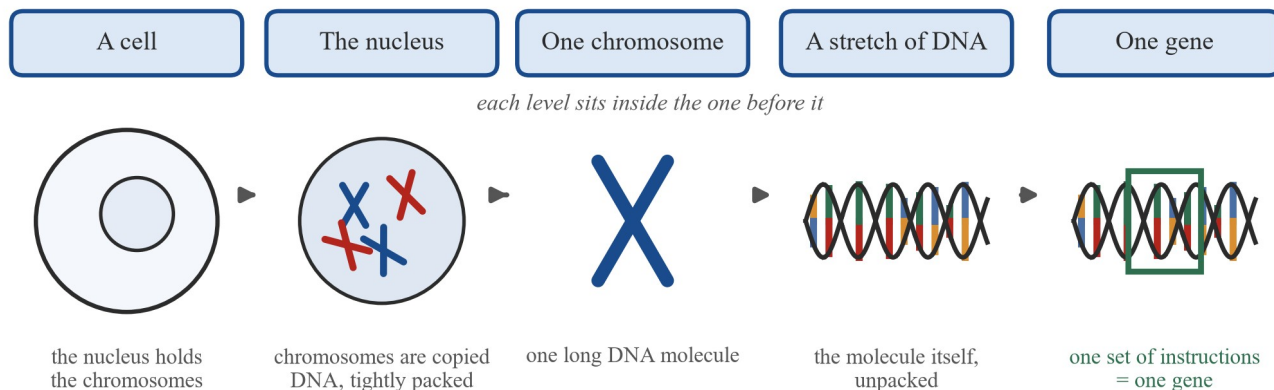
1. **What carries the instructions?** DNA, organised into genes and packed into chromosomes.
2. **How does one cell pass the instructions to the cells that come from it?** By **mitosis**, which copies a cell exactly.
3. **How do parents pass the instructions to their offspring?** By **meiosis**, which makes gametes with half a set, and **fertilisation**, which joins two halves back into a full set.

The passing on of instructions from parents to offspring is called **heredity**, and the study of heredity is **genetics**.

The words of this subtopic. The Victorian Curriculum uses the term *genetic information* without giving one fixed wording. In this subtopic, **genetic information** means *the instructions carried in the DNA of an organism, passed from a cell to the cells that come from it when the cell divides, and from parents to offspring at reproduction*. Every question in this subtopic can be answered on that definition alone. The other key terms — DNA, gene, chromosome, allele, genome and mutation — are each defined where they first appear below.

From a cell to a gene: each level sits inside the last (elaboration VC2S10U04.E01)

Start with one cell from your body and zoom in, step by step. Each level sits inside the one before it:



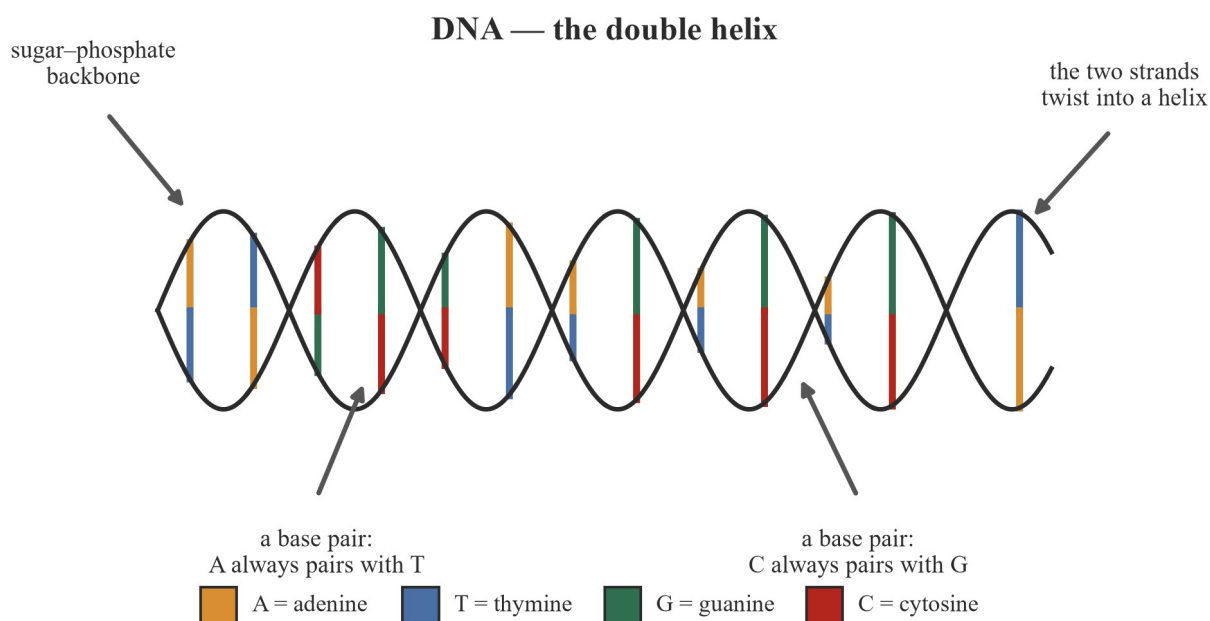
A five-panel diagram zooming from a whole cell to its nucleus, to one chromosome, to a stretch of the DNA molecule, to one marked segment of DNA called a gene, with each level sitting inside the one before it.

Level	What it is
The cell	the unit of life; your body is made of billions of cells
The nucleus	the structure inside the cell that holds the chromosomes
A chromosome	one long DNA molecule, tightly packed
The DNA	the molecule itself — the chemical that carries the instructions
A gene	one stretch of DNA that carries one set of instructions

The **complete set of genetic information** in an organism is called its **genome**. The human genome is carried on the chromosomes in the nucleus of (almost) every cell of the body, and it is written in the DNA. The rest of this subtopic works from the bottom of that list upward: first the DNA, then genes, then chromosomes — and then what cells do with them when they divide.

DNA — the molecule that carries the instructions

DNA (short for deoxyribonucleic acid) is the chemical that stores genetic information in humans and in almost all other living things. Its shape is a **double helix**: two long strands, twisted around each other like a twisted ladder.



A labelled diagram of the DNA double helix: two strands forming a sugar-phosphate backbone, with base pairs joining them as rungs, A pairing with T and C pairing with G, and a key to the four bases.

Each strand has a **backbone** made of sugar and phosphate, and the two strands are joined across the middle by **bases**. There are four bases, known by their first letters: **A** (adenine), **T** (thymine), **G** (guanine) and **C** (cytosine). The bases pair in one fixed rule:

- **A always pairs with T**, and
- **C always pairs with G**.

Each matching pair is called a **base pair**. Because of the pairing rule, the two strands of the helix match each other: read one strand, and you can work out the other. That matching turns out to be the key to how cells copy their DNA exactly — you will see how, in the mitosis section below.

The order of the bases is the information. The four bases are the same in every organism — what differs is the **order** they appear in, and that order is what carries the message. It works like letters of the alphabet: the same letters, in a different order, make a different word.

The order of the bases is the information

one order of bases — one message



a different order — a different message



one base changed

like letters of the alphabet: the same letters, in a different order, make a different word

Two strips of DNA bases: the order A-T-G-C-C-C-T-A-G, and the same letters with one base changed so the order reads A-T-G-C-C-A-T-A-G, highlighting that a different order gives a different message.

The human genome is enormous. It holds about **3 billion bases** — and more than 99 per cent of those bases are the same in all people; it is the small remainder that makes each person different from everyone else.

Source: MedlinePlus Genetics (US National Library of Medicine), “What is DNA?”, medlineplus.gov/genetics/understanding/basics/dna — retrieved 2026-08-21.

Genes — one set of instructions within the DNA

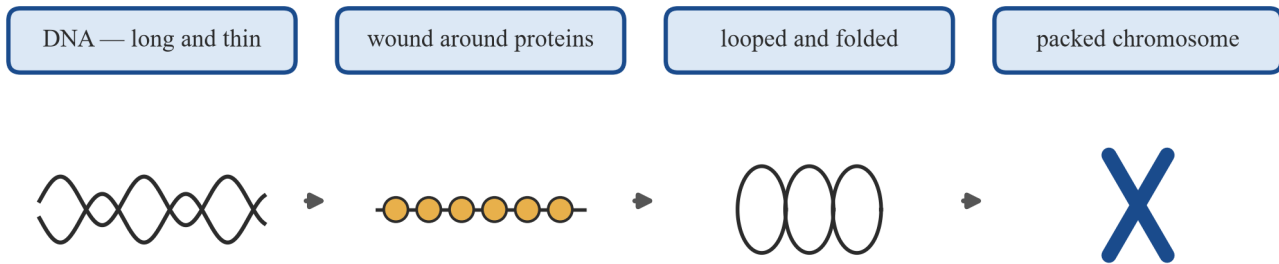
A **gene** is one stretch of DNA that carries one set of instructions — for example, instructions that help to set a feature of the organism, such as the colour of a pea plant’s flowers. Genes are the reason children tend to look like their parents: the instructions for building and running the body are stored in genes, and those genes are passed on.

The human genome holds about **20 000 genes** (estimates range from about 19 900 to 25 000), spread along the DNA of the chromosomes. Most of the DNA between genes does not carry instructions for features in this simple sense.

Source: MedlinePlus Genetics (US National Library of Medicine), “What is a gene?”, medlineplus.gov/genetics/understanding/basics/gene — retrieved 2026-08-21.

Chromosomes — DNA packed so it can be moved

One DNA molecule is extremely long and thin — far too long to float loose inside a cell. Before a cell divides, the DNA is packed up tightly: it is first wound around proteins called histones, then looped and folded again and again, until each DNA molecule forms a short, thick, X-shaped package — a **chromosome**. Packing is what lets the cell move its DNA about safely without tangling or breaking it.



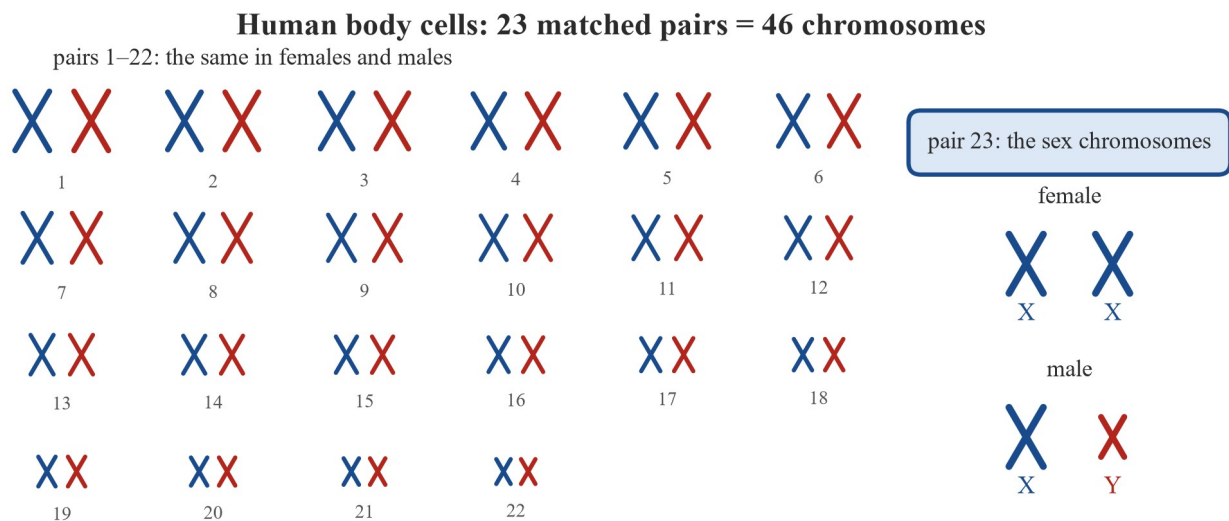
packing is how each cell's very long DNA molecules fit inside a nucleus too small to see

A four-stage diagram of DNA packaging: a long thin molecule, the same molecule wound around proteins, looped and folded, and finally packed into a short thick chromosome.

Source: MedlinePlus Genetics (US National Library of Medicine), “What is a chromosome?”, medlineplus.gov/genetics/understanding/basics/chromosome — retrieved 2026-08-21.

Human body cells carry 23 matched pairs of chromosomes. In a human body cell there are **46 chromosomes altogether, arranged in 23 matched pairs**. The two chromosomes of a pair are the same size and carry the same genes in the same positions — but not always the same versions of those genes (the next section). Of the 23 pairs:

- **pairs 1 to 22** are the same in females and in males;
- **pair 23 is the sex pair**, which decides the sex of the person: females have two X chromosomes (**XX**), males have one X and one much smaller Y chromosome (**XY**).



one chromosome of each pair came from the mother; one from the father

A diagram of the 46 chromosomes of a human body cell arranged as 23 matched pairs, pairs 1 to 22 the same in females and males, with pair 23 shown as XX for a female and XY for a male, and a note that one chromosome of each pair came from the mother and one from the father.

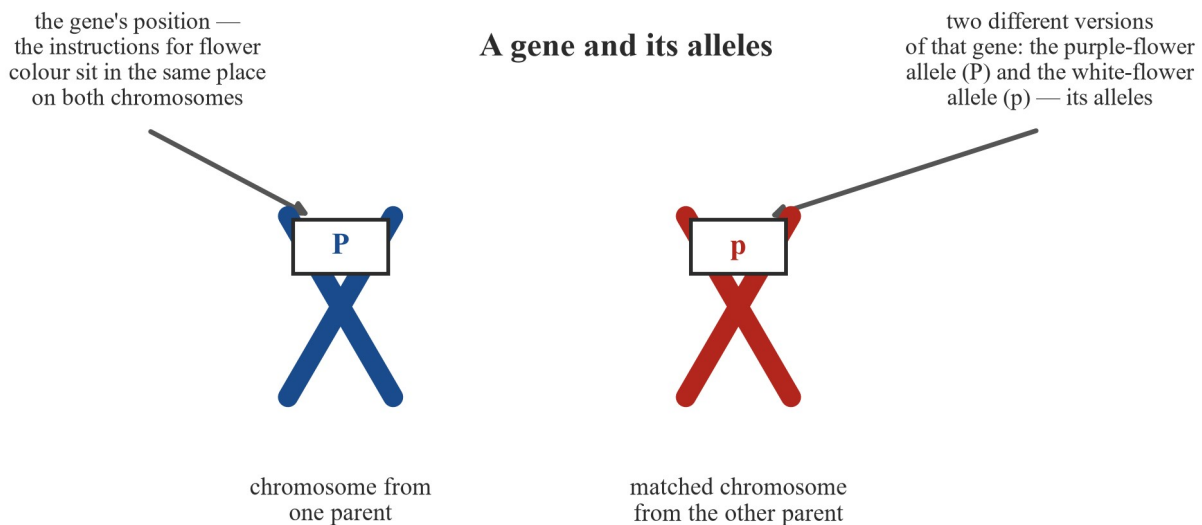
One chromosome of each pair came from your mother; the other came from your father. That is why you are related to both of your parents, but identical to neither.

Notice the difference between body cells and gametes: a **body cell** carries the full set — 46 chromosomes, 23 pairs — while a **gamete** (a sperm cell or an egg cell) carries only **23 single chromosomes**, one from each pair. The meiosis section below explains how gametes get their half-set.

Source: MedlinePlus Genetics (US National Library of Medicine), “How many chromosomes do people have?”, medlineplus.gov/genetics/understanding/basics/howmanychromosomes — retrieved 2026-08-21.

Alleles — different versions of the same gene

The two chromosomes of a matched pair carry the same genes in the same positions. But the **version** of a gene on one chromosome can differ from the version on its partner. A **allele** is one version of a gene. (The word is said as *uh-LEEL*.)



Pea plants: P is dominant over p — one copy of P is enough for purple flowers (Subtopic 7D takes this further).

A diagram of a matched pair of chromosomes, one inherited from each parent, with the same gene position marked on both: the purple-flower allele P on one chromosome and the white-flower allele p on the other, with callouts explaining that the position is the same but the versions differ.

In the figure, the gene is the instructions for flower colour in a pea plant, sitting in the same position on both chromosomes of the pair. The two versions are the **purple-flower allele (P)** and the **white-flower allele (p)** — two alleles of the one gene. Because a body cell has two chromosomes of each pair, it carries **two alleles of every gene** — one on each chromosome of the pair.

Some alleles are **dominant**: one copy is enough for their effect to show. Others are **recessive**: their effect shows only when both copies are that allele. The figure's pea plant shows this — one copy of P is enough for purple flowers. How dominant and recessive alleles are used to **predict** what offspring will be like is the work of Subtopic 7D. Here, the point is only what alleles *are*: different versions of the same gene, sitting in the same position on matched chromosomes.

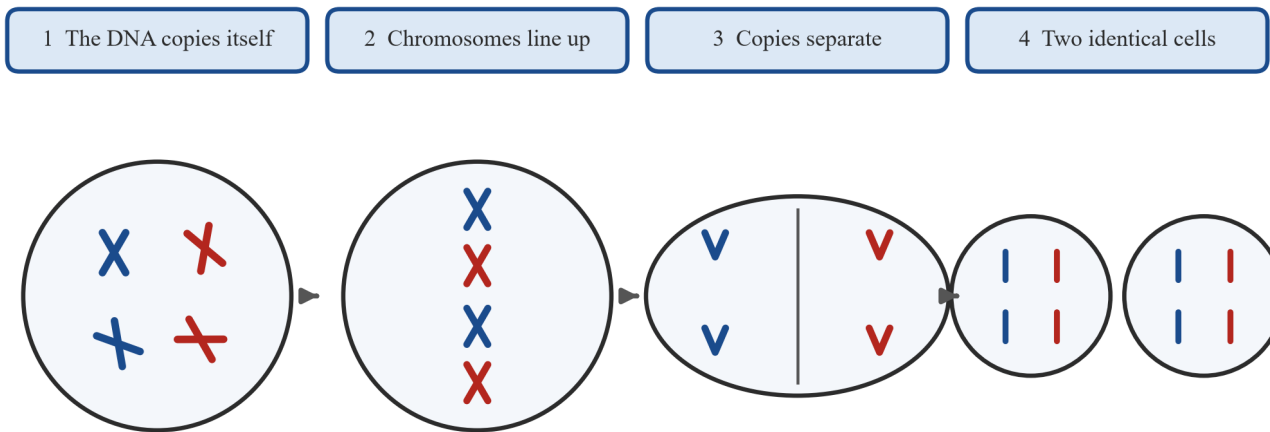
Check your understanding. Three terms are easy to mix up, so fix them now: a **gene** is a set of instructions (a stretch of DNA); an **allele** is one *version* of that gene; and a **chromosome** is one packed DNA molecule carrying *many* genes. A chromosome is not a version of a gene, and a gene is not a version of a chromosome.

Mitosis — copying a cell exactly

Your body began as one single cell — the fertilised egg. Every one of the billions of cells in your body now came from that first cell by repeated cell division. The kind of division that copies a body cell exactly is called **mitosis**.

In mitosis, one cell divides once to make **two daughter cells, each genetically identical to the original cell and to each other**, with the same full set of chromosomes. It works in four steps. The figure shows a cell with just 4 chromosomes so you can follow every one of them; a real human body cell does the same thing with 46.

Mitosis — copying a cell exactly (a cell with 4 chromosomes shown)



each daughter cell has the same 4 chromosomes — the same full set — as the cell that divided

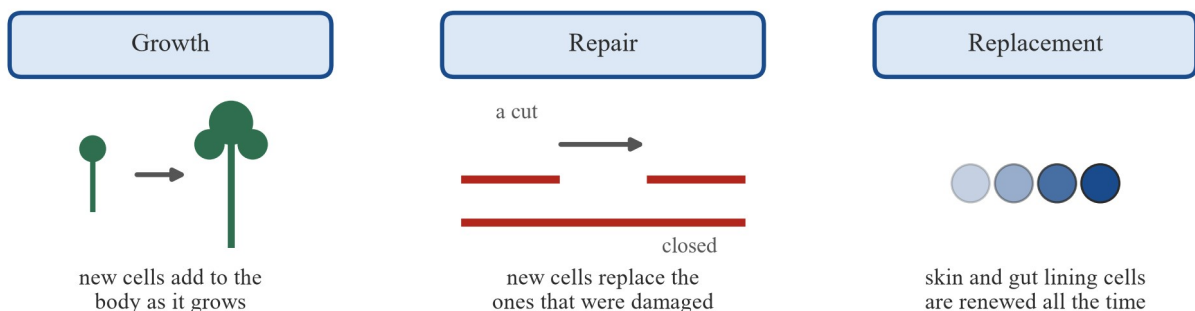
A four-stage diagram of mitosis in a cell with 4 chromosomes: the DNA copies itself, the copied chromosomes line up in the middle, the copies separate to opposite ends, and two identical daughter cells form, each with the same 4 chromosomes.

Stage	What happens
1. The DNA copies itself	each chromosome is copied, so there are two matching copies of every chromosome
2. The chromosomes line up	the copied chromosomes line up across the middle of the cell
3. The copies separate	one copy of each chromosome is pulled to each end of the cell
4. Two identical cells form	the cell divides in two; each daughter cell has one full set of chromosomes

Because every daughter cell gets **one copy of every chromosome**, mitosis passes the genetic information on **complete and unchanged**. That is what makes the daughter cells identical.

What mitosis is for. In your body, mitosis does three jobs:

What mitosis is for



A three-panel diagram of the roles of mitosis: growth, as new cells are added to the body; repair, as new cells close a cut; and replacement, as worn-out cells are renewed.

- **Growth** — new cells add to the body as it grows, from one fertilised egg to an adult of billions of cells.

- **Repair** — when you cut your skin, mitosis makes new cells to close the gap.
- **Replacement** — some cells wear out and are renewed all the time; the cells of your skin and of your gut lining are replaced by mitosis throughout your life.

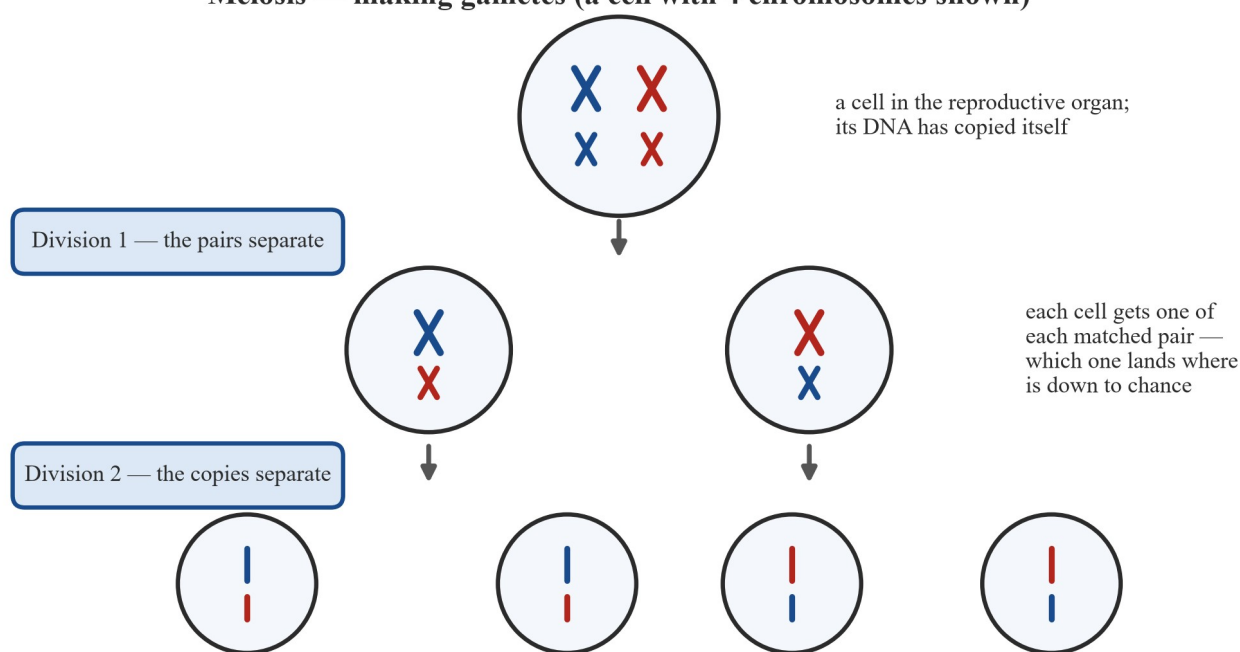
Mitosis is also the basis of **asexual reproduction** — reproduction with one parent, where the offspring are genetically identical to that parent. Subtopic 7B takes that story further.

Meiosis — making gametes with half the set

Gametes cannot carry the full set of 46 chromosomes. If a sperm cell and an egg cell each carried 46, the fertilised egg would have 92 — and the number would double again in every generation. Instead, gametes are made by a different kind of division called **meiosis**, which **halves** the chromosome number.

Meiosis happens in cells of the reproductive organs — the testes and the ovaries. One cell divides **twice** to make **four gametes**, each with **half the starting number**: one chromosome from each matched pair. Again, the figure uses a cell with 4 chromosomes; in humans the starting cell has 46, and each gamete ends with 23.

Meiosis — making gametes (a cell with 4 chromosomes shown)



four gametes — each with HALF the starting number; the shuffle makes millions of possible mixes

In humans the starting cell has 46 chromosomes and each gamete ends with 23.

A diagram of meiosis in a cell with 4 chromosomes arranged as two matched pairs: the DNA copies itself, division 1 separates the matched pairs, division 2 separates the copies, and four gametes form, each with 2 chromosomes — half the starting number.

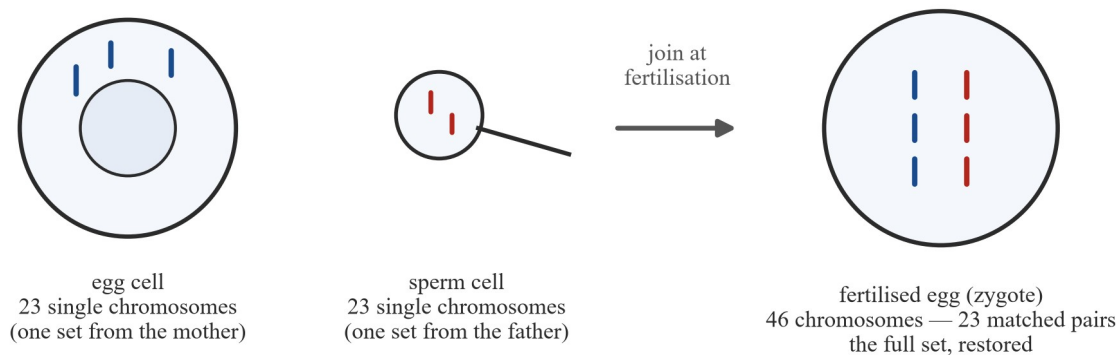
Two things about meiosis matter for what follows:

- **The number is halved.** Each gamete gets one chromosome from each matched pair — 23 single chromosomes in humans, not 23 pairs.
- **The mix is random.** When the pairs separate in division 1, which chromosome of a pair lands in which gamete is down to chance. With 23 pairs, that gives more than **8 million** possible mixes of chromosomes in one person's gametes — before any other source of variation is added.

Fertilisation — two halves restore the pairs

Subtopic 7A defined **fertilisation** as the joining of a sperm cell and an egg cell to form one new cell. Now you can see what that joining does to the chromosome number:

Fertilisation — two halves restore the pairs



A diagram of fertilisation: an egg cell with 23 single chromosomes and a sperm cell with 23 single chromosomes join to form a fertilised egg with 46 chromosomes arranged as 23 matched pairs, the full set, restored.

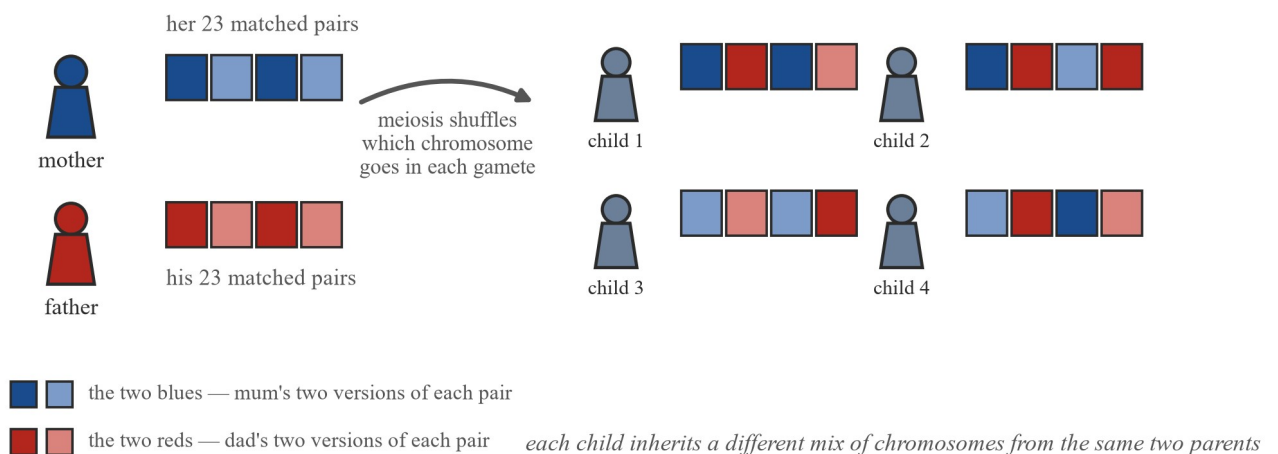
- The **egg cell** brings 23 single chromosomes — one set from the mother.
- The **sperm cell** brings 23 single chromosomes — one set from the father.
- At fertilisation they form one cell, the **fertilised egg (zygote)**, with **46 chromosomes — 23 matched pairs**.

Meiosis halves the number; fertilisation restores it. Every person's body cells carry exactly the arrangement their species needs — 46 chromosomes in humans — and they carry it because the two half-sets joined at fertilisation. **Half from the mother, half from the father.**

Why families vary (elaboration VC2S10U04 . E02)

Here is a fact you can check at any family table: **brothers and sisters are alike, but they are not identical.** Each child of the same two parents is a different mix. Meiosis and fertilisation explain why.

Why brothers and sisters are alike but not identical



A diagram of one mother and one father, each with matched pairs of chromosomes in two shades, whose gametes are dealt out at random by meiosis, producing four children who each inherit a different mix of chromosomes from the same two parents.

- **Meiosis shuffles the chromosomes.** When the matched pairs separate, which chromosome goes into which gamete is down to chance — so every gamete a parent makes carries a different mix.

- **Fertilisation combines one set from each parent.** The offspring gets one chromosome of each pair from the mother and one from the father — so it carries instructions from **both** parents, but a different combination from any of its brothers or sisters.

Together, these two steps mean that sexual reproduction produces offspring that are **similar to their parents but not identical to them or to each other**. The differences between individuals of a species are called **variation**, and meiosis and fertilisation are two of the main processes that create it. Variation matters for the survival of a species — that story belongs to Subtopic 7B and, at a larger scale, to Subtopic 9A (natural selection).

Source: MedlinePlus Genetics (US National Library of Medicine), “What is DNA?” (more than 99 per cent of human DNA bases are the same in all people), medlineplus.gov/genetics/understanding/basics/dna — retrieved 2026-08-21.

Mitosis and meiosis side by side

The two divisions are easy to confuse, so put them next to each other. Read the table until you can say each row from memory:

	MITOSIS	MEIOSIS
Where it happens	body cells, all over the body	cells in the reproductive organs
Role	growth, repair, replacement	making gametes (sex cells)
Divisions	one	two
Daughter cells made	two	four
Chromosomes in each daughter cell	the full set, same as the parent cell	half the set — one of each matched pair
Daughter cells	genetically identical	all genetically different

mitosis keeps the chromosome number the same; meiosis halves it so fertilisation can restore it

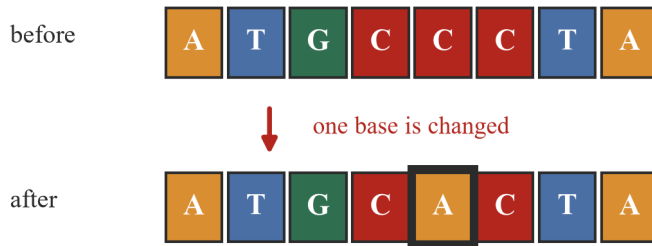
A comparison table of mitosis and meiosis: where each happens, its role, the number of divisions, the number of daughter cells made, the chromosomes in each daughter cell, and whether the daughter cells are genetically identical or all different.

The one-sentence summary: **mitosis keeps the chromosome number the same; meiosis halves it so that fertilisation can restore it.**

When the information changes (elaboration VC2S10U04.E05)

The base sequence of a gene is copied with great care every time a cell divides — but the copying is not perfect. A **mutation** is a change in the base sequence of the DNA. Because the order of the bases *is* the information, a changed base can change the instructions a gene carries — like changing one letter of a word.

A change in a base changes the instructions



the gene now carries different instructions — this kind of change is called a **mutation**

cystic fibrosis
a mutation in the CFTR gene;
thick mucus builds up in the lungs and gut

sickle cell disease
a mutation in the HBB gene;
red blood cells bend into a sickle shape

for both conditions, a person is affected only when **BOTH** copies of the gene carry the mutation — the recessive pattern (Subtopic 7D)

A before-and-after diagram of a base sequence in which one base is changed from C to A, with the caption that the gene now carries different instructions — a mutation — and two example boxes: cystic fibrosis, caused by a mutation in the CFTR gene, and sickle cell disease, caused by a mutation in the HBB gene.

Most mutations have no visible effect, and some are harmful. A harmful mutation in a gene can cause a **genetic disorder** — a condition a person is born with because their DNA carries the changed instructions. Two examples:

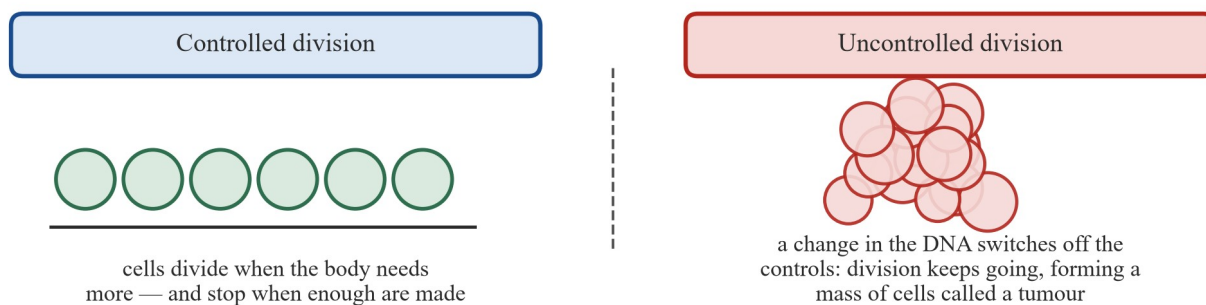
Disorder	The changed gene	What happens
Cystic fibrosis	the CFTR gene	thick, sticky mucus builds up and damages organs, especially the lungs and the parts used in digestion
Sickle cell disease (also called sickle cell anaemia)	the HBB gene	red blood cells bend out of their usual shape into a sickle shape and break down too early

For both conditions, a person is affected only when **both copies** of the gene carry the mutation — the recessive pattern you will learn to predict in Subtopic 7D.

Sources: MedlinePlus Genetics (US National Library of Medicine), “Cystic fibrosis”, medlineplus.gov/genetics/condition/cystic-fibrosis — retrieved 2026-08-21; MedlinePlus Genetics, “Sickle cell disease”, medlineplus.gov/genetics/condition/sickle-cell-disease — retrieved 2026-08-21.

Cancer — when the controls on division fail. Mitosis does not run free: a healthy body controls when cells divide, so new cells are made when the body needs them and no more. A mutation can switch those controls off. When that happens, cells divide out of control and form a mass of cells called a **tumour**; a cancerous tumour is one that grows into and damages the body around it. Cancer is therefore a disease of the DNA’s instructions — changes in genes cause it.

Cell division has controls — cancer is what happens when they fail



A two-panel diagram of cell division with and without control: on the left an orderly row of cells dividing when the body needs more, on the right a disordered mass of cells formed when a change in the DNA switches off the controls.

Source: MedlinePlus (US National Library of Medicine), “Cancer”, medlineplus.gov/cancer.html — retrieved 2026-08-21.

Pulling the idea together

One chain runs through the whole subtopic:

DNA (the molecule) → organised into **genes** (the instructions) → packed into **chromosomes** → copied and shared out by **mitosis** (to cells of the body) and by **meiosis** (to gametes) → joined again at **fertilisation** → passed on, with variation, to the next generation.

The numbers worth remembering:

What	The number
Chromosomes in a human body cell	46 (23 matched pairs)
Chromosomes in a human gamete	23 (one of each pair)
Base pairs in the human genome	about 3 billion
Genes in the human genome	about 20 000

Activities

Activity 1 — Build a paper DNA model and decode a message. You will need: paper, scissors, four coloured pens or pencils, and sticky tape.

- Cut about 12 short strips of paper (the rungs) and two long strips (the backbones). On the short strips, write one letter each using the four base letters A, T, G and C, one colour per base.
- Pair the rungs by the base-pairing rule — A with T, C with G — and tape each pair between the two long backbone strips to make a ladder. Twist the ladder gently to see the helix shape.
- Write a 12-letter message along one strand using only A, T, G and C. Swap your model with a partner, and have them write the matching strand using the pairing rule. Check that every A faces a T and every C faces a G.
- Now change two letters on your strand. Swap back with your partner and ask: is the message on the matching strand the same as before? Write one sentence connecting your answer to the idea that *the order of the bases is the information*.

Activity 2 — Looking at cell division under the microscope. Your teacher will supply prepared microscope slides of a root tip (onion root tips are the usual choice, because roots grow by mitosis and their chromosomes stain darkly).

- (i) Set up a light microscope and focus on the root tip at low power, then move to high power. Handle glass slides with care and report any breakage to your teacher.
- (ii) Find cells in different stages of division: cells where the chromosomes are lined up in the middle, and cells where copies are moving to opposite ends.
- (iii) Draw two cells you can see clearly, and label the stage each one is in, using the four-stage summary from the mitosis section of this subtopic.
- (iv) Most of the cells on the slide will *not* be dividing. Suggest why, thinking about how long each stage of mitosis takes compared with the time a cell spends between divisions.

Activity 3 — The chromosome shuffle. You will need: three pairs of coloured cards or paper squares — for example, 2 blue, 2 red and 2 green (each pair stands for one matched pair of chromosomes).

- (i) Shuffle your six cards. Without looking, deal three into your first “gamete” — but take **only one card from each pair** (one blue-or-light-blue, one red-or-light-red, one green-or-light-green; use two shades of each colour if you have them). Record which three you dealt.
- (ii) Make as many gametes as you can from fresh shuffles and list each mix.
- (iii) Combine one of your gametes with one made by a partner (this stands for fertilisation) and record the result. Repeat with different gametes.
- (iv) Pool the whole class’s results in a table (table skills from Subtopic 4A). How many different mixes appeared? Then think about the real case: with 23 pairs, one person can make more than 8 million different gamete mixes. Write two sentences explaining what this means for brothers and sisters from the same two parents.

Worked examples

Example 1 — scaffolded

One strand of a DNA molecule carries the base sequence **A T G C C A T G**. Write the sequence on the matching strand.

Working	Comment
Write the pairing rule first: A pairs with T; C pairs with G (and T pairs with A; G pairs with C).	The rule works both ways.
Read the given strand one base at a time: A → T ; T → A ; G → C ; C → G ; C → G ; A → T ; T → A ; G → C .	Replace each base with its partner.
Matching strand: T A C G G T A C .	Check every pair: A–T, T–A, G–C, C–G, C–G, A–T, T–A, G–C.

Example 2 — scaffolded

A body cell of a dog contains **78 chromosomes** — the dog’s full set. (a) How many chromosomes does each daughter cell have after the cell divides by mitosis? (b) How many chromosomes does a dog gamete have after meiosis? (c) How many chromosomes does a fertilised dog egg (zygote) have?

Working	Comment
(a) Mitosis copies a cell exactly: each daughter cell gets the same full set — 78 chromosomes .	Mitosis keeps the number the same.
(b) Meiosis halves the number: $78 \div 2 = 39$ chromosomes in each gamete.	Gametes carry one chromosome of each matched pair.
(c) Fertilisation joins two gametes: 39 (egg) + 39 (sperm) = 78 chromosomes in the zygote.	Halving and restoring keep the species number steady from one generation to the next.

Example 3 — unscaffolded

Explain why gametes must carry half the number of chromosomes found in body cells. (3 marks)

Gametes carry half the set because two of them join at **fertilisation**. The egg cell contributes one half-set and the sperm cell contributes the other, so the fertilised egg receives **half from the mother and half from the father**,

restoring the full number — 46 in humans. If gametes carried the full set instead, the fertilised egg would have **twice** the right number, and the number would **double again at every generation**, which would not preserve the species' set. Halving in meiosis is what makes the restoring at fertilisation possible. $\therefore$ gametes carry half the set so that fertilisation restores the full set.

Example 4 — unscaffolded

A gene normally carries the base sequence **T A C G G A T C**. In one person, the sequence is **T A C G C A T C** instead. (a) What is the name for this kind of change? (b) Explain how this change could alter what the gene does. (c) Name one genetic disorder caused by this kind of change in a gene. (4 marks)

- (a) A **mutation** — a change in the base sequence of the DNA.
- (b) The order of the bases *is* the information a gene carries, like the letters of a word. Changing one base — here, the fifth base, from G to C — changes the sequence, so the gene now carries **different instructions**. The feature the gene helps to set may then work differently, or not at all. $\therefore$ one changed base can change the message of the whole gene.
- (c) Any one correct example, for instance **cystic fibrosis** (a mutation in the CFTR gene) or **sickle cell disease** (a mutation in the HBB gene).

Practice questions

Scaffolded questions

Question 1 The vocabulary of this subtopic. Define each of the following: (a) DNA; (b) gene; (c) allele; (d) chromosome; (e) genome; (f) mutation.

Question 2 The base-pairing rule. (a) Copy and complete: A always pairs with ...; C always pairs with (b) One strand of a DNA molecule reads **G A T C C A T G**. Write the sequence on the matching strand.

Question 3 Human chromosome numbers. Copy and complete the table.

Feature	Value
Chromosomes in a body cell	
Matched pairs in a body cell	
Chromosomes in a gamete	
Sex chromosomes of a female	
Sex chromosomes of a male	

Question 4 The stages of mitosis. Put these four stages in the correct order, and state what each daughter cell ends up with: the copies separate and move to opposite ends; the DNA copies itself; two identical daughter cells form; the copied chromosomes line up across the middle.

Question 5 Mitosis or meiosis? Copy and complete the table with the correct entry for each division.

Feature	Mitosis	Meiosis
Where it happens	body cells, all over the body	
Role		making gametes
Number of divisions	one	
Daughter cells made		four
Chromosomes in each daughter cell	the full set	
Daughter cells genetically	identical	
...		

Question 6 The levels of organisation. Put these in order from smallest to largest: nucleus; gene; cell; chromosome. Then write one sentence stating where each one is found.

Unscaffolded questions

Question 7 Explain why DNA is described as carrying a set of instructions. (2 marks)

Question 8 A stretch of DNA contains 200 bases. Sixty of them are adenine (A). (a) How many are thymine (T)? Explain your answer. (b) How many are guanine (G) and cytosine (C) together? (c) How many are guanine (G) alone? (3 marks)

Question 9 Explain why the two daughter cells produced by mitosis are genetically identical to the original cell. (2 marks)

Question 10 Explain why gametes are made by meiosis rather than by mitosis. (3 marks)

Question 11 A body cell of a fruit fly has **8 chromosomes**. (a) How many chromosomes does a fruit fly gamete have? (b) How many chromosomes does a fertilised fruit fly egg have? (c) Name the process that restores the full number of chromosomes. (3 marks)

Question 12 Explain how meiosis and fertilisation together increase the variation within a species. (3 marks)

Question 13 A gene has two alleles, B and b. Explain what an allele is, and state where the two alleles of this gene are found in a body cell. (2 marks)

Question 14 Explain how a change to a single base in a gene could lead to a genetic disorder such as cystic fibrosis. (3 marks)

Question 15 Explain how cancer is related to mitosis. (2 marks)

Question 16 A student says: “Meiosis is just mitosis done twice.” Give **two** reasons why this statement is wrong. (2 marks)

Question 17 Before a cell divides, its very long, thin DNA molecules are packed into short, thick chromosomes. Explain why this packing matters for cell division. (2 marks)

Answers

Question 1 (a) the chemical that stores genetic information; (b) a stretch of DNA carrying one set of instructions; (c) one version of a gene; (d) one packed DNA molecule, carrying many genes; (e) the complete set of genetic information of an organism; (f) a change in the base sequence of the DNA. **Question 2** (a) A pairs with T; C pairs with G; (b) C T A G G T A C. **Question 3** 46; 23; 23; XX; XY. **Question 4** Order: the DNA copies itself → the copied chromosomes line up across the middle → the copies separate and move to opposite ends → two identical daughter cells form. Each daughter cell ends up with the same full set of chromosomes as the original cell. **Question 5** Meiosis occurs in the reproductive organs; two; half the set — one of each matched pair; all different. Mitosis role: growth, repair, replacement. **Question 6** gene → chromosome → nucleus → cell. **Question 7** see solution. **Question 8** see solution. **Question 9** see solution. **Question 10** see solution. **Question 11** see solution. **Question 12** see solution. **Question 13** see solution. **Question 14** see solution. **Question 15** see solution. **Question 16** see solution. **Question 17** see solution.

Fully-worked solutions

Question 1 (a) **DNA** is the chemical (deoxyribonucleic acid) that stores genetic information in humans and almost all other living things. (b) A **gene** is a stretch of DNA that carries one set of instructions — for example, instructions that help to set a feature of the organism. (c) An **allele** is one version of a gene; the same gene can have different versions, sitting in the same position on matched chromosomes. (d) A **chromosome** is one long DNA molecule, tightly packed; it carries many genes. (e) A **genome** is the complete set of genetic information in an organism. (f) A **mutation** is a change in the base sequence of the DNA.

Question 2 (a) **A always pairs with T; C always pairs with G.** (b) Reading the rule one base at a time: G→C, A→T, T→A, C→G, C→G, A→T, T→A, G→C, so the matching strand is **C T A G G T A C**.

Question 3 Chromosomes in a body cell: **46**. Matched pairs in a body cell: **23**. Chromosomes in a gamete: **23**. Sex chromosomes of a female: **XX**. Sex chromosomes of a male: **XY**.

Question 4 The correct order is: (1) the **DNA copies itself**; (2) the **copied chromosomes line up across the middle** of the cell; (3) the **copies separate and move to opposite ends**; (4) **two identical daughter cells form**. Each daughter cell ends up with the **same full set of chromosomes** as the original cell — one copy of every chromosome.

Question 5 **Mitosis**: happens in body cells, all over the body; its role is **growth, repair and replacement**; one division; **two** daughter cells; each with **the full set** of chromosomes; daughter cells genetically **identical**. **Meiosis**: happens in **cells in the reproductive organs** (testes and ovaries); its role is making gametes; **two** divisions; **four** daughter cells; each with **half the set** — **one chromosome of each matched pair**; daughter cells **all genetically different**.

Question 6 From smallest to largest: **gene** → **chromosome** → **nucleus** → **cell**. A gene is a stretch of DNA found on a chromosome; chromosomes sit inside the nucleus; the nucleus sits inside the cell.

Question 7 DNA carries a **set of instructions** because the order of its four bases (A, T, G, C) works like the letters of an alphabet: the same letters in a different order make a different message (*1 mark*). The instructions stored in the order of the bases are used to build and run the organism, and they are passed on when cells divide and from parents to offspring (*1 mark*).

Question 8 (a) Adenine always pairs with thymine, so the number of T equals the number of A: **60 thymine bases** (*1 mark*). (b) The remaining bases are G and C together: $200 - 60 - 60 = 80$ (*1 mark*). (c) Guanine pairs with cytosine, so G and C are present in equal numbers: $80 \div 2 = 40$ **guanine bases** (*1 mark*).

Question 9 Before mitosis, **the DNA copies itself**, so there are two matching copies of every chromosome (*1 mark*). The copies then separate so that **each daughter cell receives one copy of every chromosome** — the same full set the original cell had — which is why the daughter cells are genetically identical (*1 mark*).

Question 10 Gametes must carry **half** the chromosome number because two gametes join at fertilisation (*1 mark*). If gametes were made by mitosis, they would carry the full set, and the fertilised egg would have twice the right number

— doubling again every generation (*1 mark*). Meiosis halves the number, so fertilisation restores the full set and the species number stays the same from one generation to the next (*1 mark*).

Question 11 (a) A gamete carries half the body-cell number: $8 \div 2 = 4$ **chromosomes**. (b) Fertilisation joins two gametes: $4 + 4 = 8$ **chromosomes** in the fertilised egg. (c) **Fertilisation** restores the full number.

Question 12 In meiosis, the matched pairs of chromosomes separate and **which chromosome of each pair goes into which gamete is down to chance**, so every gamete carries a different mix of chromosomes (*1 mark*). At fertilisation, **one gamete from each parent joins**, so the offspring gets one set from the mother and one from the father (*1 mark*). Together, the shuffling in meiosis and the combining at fertilisation give every offspring a new combination of genetic information — increasing the variation within the species (*1 mark*).

Question 13 An **allele is one version of a gene**; the same gene can come in different versions (*1 mark*). In a body cell, the two alleles of the gene are found **in the same position on the two chromosomes of one matched pair** — one allele on each chromosome of the pair (*1 mark*).

Question 14 The order of the bases is the information a gene carries, so **a change to one base — a mutation — changes the instructions the gene carries** (*1 mark*). The gene may then not work properly; in cystic fibrosis a mutation in the **CFTR gene** leads to thick, sticky mucus building up and damaging organs, especially the lungs (*1 mark*). The disorder appears when a person's copies of the gene carry the changed instructions — for cystic fibrosis, when **both copies** do (*1 mark*).

Question 15 In a healthy body, **mitosis is controlled** — cells divide when the body needs more and stop when enough are made (*1 mark*). **Cancer begins when a change in the DNA (a mutation) switches off those controls**, so cells divide out of control and form a mass of cells called a tumour (*1 mark*).

Question 16 Any two correct reasons. For example: (1) meiosis **halves** the chromosome number — each of the four cells ends with one chromosome of each pair, while mitosis keeps the number the same; and (2) the daughter cells of meiosis are **all genetically different**, while mitosis makes genetically identical cells. (A third acceptable reason: mitosis makes two daughter cells per division, meiosis makes four gametes from one starting cell; a fourth: meiosis happens in the reproductive organs to make gametes, mitosis happens in body cells for growth, repair and replacement.)

Question 17 The DNA molecules are extremely long and thin, so without packing they would tangle and could break when the cell tries to move them (*1 mark*). Packed chromosomes are short and firm, so the copies of each chromosome can be **sorted and moved to opposite ends of the cell without losing or damaging any of the genetic information** (*1 mark*).

Sources

- MedlinePlus Genetics (US National Library of Medicine), “What is DNA?” (human DNA: about 3 billion bases; A–T and C–G base pairing; more than 99 per cent of bases the same in all people), medlineplus.gov/genetics/understanding/basics/dna — retrieved 2026-08-21.
- MedlinePlus Genetics (US National Library of Medicine), “What is a gene?” (a gene is the basic physical and functional unit of heredity; about 20 000–25 000 human genes), medlineplus.gov/genetics/understanding/basics/gene — retrieved 2026-08-21.
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- MedlinePlus Genetics (US National Library of Medicine), “How many chromosomes do people have?” (23 pairs, 46 chromosomes; XX female, XY male), medlineplus.gov/genetics/understanding/basics/howmanychromosomes — retrieved 2026-08-21.
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- MedlinePlus Genetics (US National Library of Medicine), “Sickle cell disease” (mutations in the HBB gene; red blood cells sickle and break down early; inherited in a recessive pattern), medlineplus.gov/genetics/condition/sickle-cell-disease — retrieved 2026-08-21.
 - MedlinePlus (US National Library of Medicine), “Cancer” (new cells growing when not needed; cancer as a genetic disease caused by changes in genes; a tumour as a mass of extra cells), medlineplus.gov/cancer.html — retrieved 2026-08-21.
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Where this leads: the DNA–chromosome–cell-division picture built here is the floor that VCE Biology builds on: Unit 2, Area of Study 1 (“How is inheritance explained?”) assumes this subtopic’s chromosome behaviour in meiosis and extends it to sex-linkage, codominance and pedigrees. Unit 3 builds the chemistry of DNA and proteins on this picture, adding how the instructions in genes are read and used — all reference-only for this book, and all above the VC2 9–10 scope ceiling (TOC D9). Within this band, the partner subtopic **7D** takes the next step from exactly this content: using dominant and recessive alleles to predict the outcomes of monohybrid crosses. The variation this subtopic explains — produced by meiosis and fertilisation — is the raw material Subtopic **7B** connects to the survival of a species and Subtopic **9A** connects to evolution by natural selection.

Mendelian inheritance: monohybrid crosses, genotype and phenotype ratios, pedigrees

Chapter 7 — Biological sciences A: reproduction and heredity (Science, Levels 9 and 10)

Subtopic 7D · VC2 Science Understanding — Biological sciences

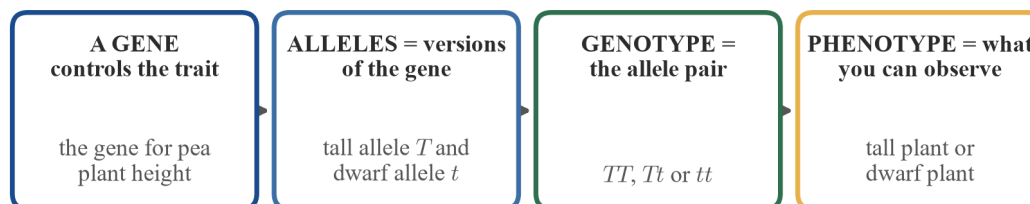
CD code: VC2S10U04 (split delivery †; Subtopic 7C is the accountable owner and this subtopic is the partner) **Content description (verbatim):** “genetic inheritance involves the function of DNA, chromosomes, genes and alleles, and the roles of mitosis and meiosis in passing on genetic information to the next generation; the principles of Mendelian inheritance can be used to predict ratios of genotypes and phenotypes in monohybrid crosses involving dominant and recessive traits” **This subtopic’s limb (TOC §4 clause split):** the principles of Mendelian inheritance, used to predict ratios of genotypes and phenotypes in monohybrid crosses involving dominant and recessive traits; pedigrees. The partner subtopic 7C delivers the other limb: the function of DNA, chromosomes, genes and alleles, and the roles of mitosis and meiosis in passing on genetic information to the next generation. **Elaboration ids drawn on:** VC2S10U04.E03 · VC2S10U04.E04 (ids VC2S10U04.E01, VC2S10U04.E02 and VC2S10U04.E05 are drawn on by Subtopic 7C) **Achievement standard (extract served):** “They explain the processes that underpin heredity and genetic diversity, and predict the outcomes of monohybrid crosses.” (The standard is assessed across Subtopics 7C and 7D together; 7D supplies the prediction of monohybrid-cross outcomes it rests on.) **Maths interlock (TOC §5):** ratio and proportion, VC2M9M05 — every genetic ratio in this subtopic is also read as a probability.

Theory

Heredity is the passing on of traits from one generation to the next. A trait is a feature of an organism — the colour of a flower, the height of a pea plant, the way a person’s blood clots. Subtopic 7C sets up the machinery behind heredity: a **gene** is a section of DNA that controls a trait; an **allele** is one version of that gene; and meiosis gives each gamete (sex cell) just one allele of each gene, so fertilisation puts a pair back together — one allele from each parent. This subtopic takes that machinery and asks a new question: **given the pair of alleles each parent carries, what can we predict about their offspring?**

The answer turns out to be reliable in a very simple way, and it was first worked out in the 1860s by an Augustinian monk and teacher named **Gregor Mendel**, working with pea plants in the garden of his monastery in what is now the Czech Republic. His paper of 1866 is the starting point of modern genetics, and every cross in this subtopic follows his method.

The words of this subtopic, in order



dominant allele: its trait shows when paired with the recessive allele

recessive allele: its trait shows only when no dominant allele is present

homozygous: two of the same allele (*TT* or *tt*) · heterozygous: one of each (*Tt*)

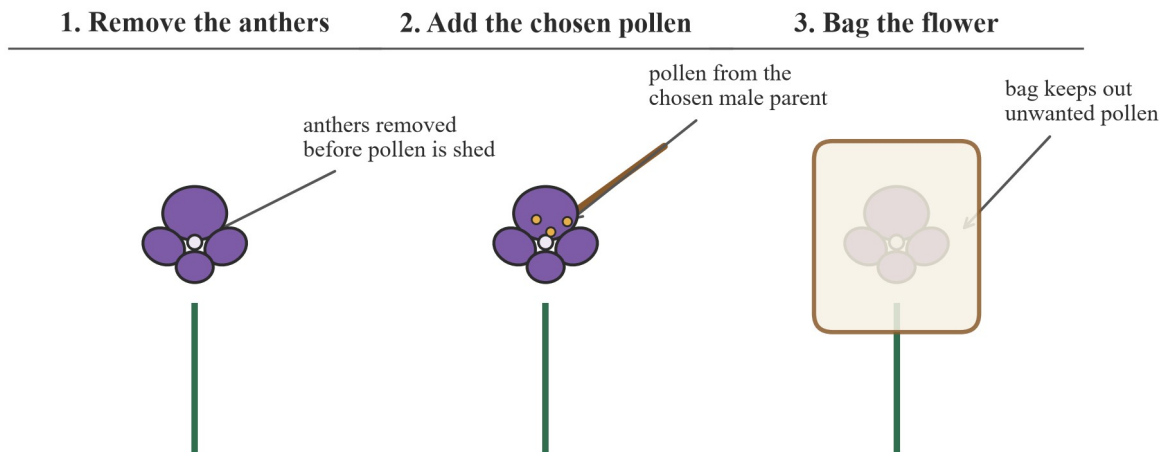
carrier: heterozygous for a recessive allele — does not show the trait but can pass the allele on

A chain of four boxes in order: a gene controls the trait; alleles are versions of the gene; the genotype is the allele pair; the phenotype is what you can observe. Below, the definitions of dominant allele, recessive allele, homozygous, heterozygous and carrier.

The words of this subtopic. A **genotype** is the pair of alleles an organism carries for a gene, written as two letters (for example Tt). A **phenotype** is the trait you can actually observe — what the genotype, plus the organism's development, produces. An organism is **homozygous** for a gene when its two alleles are the same (TT or tt), and **heterozygous** when they are different (Tt). A **carrier** is an organism that is heterozygous for a recessive allele: it does not show the recessive trait, but it can pass the allele on to its offspring. These five words — gene, allele, genotype, phenotype, carrier — do most of the work in what follows.

Mendel's method (elaboration VC2S10U04.E03)

Mendel's genius was control. Pea flowers normally fertilise themselves: the pollen from a flower's own anthers lands on its own stigma. That is fine for growing peas, but it is useless for science, because you cannot tell which parent contributed what. So Mendel took control of every cross, in three steps.



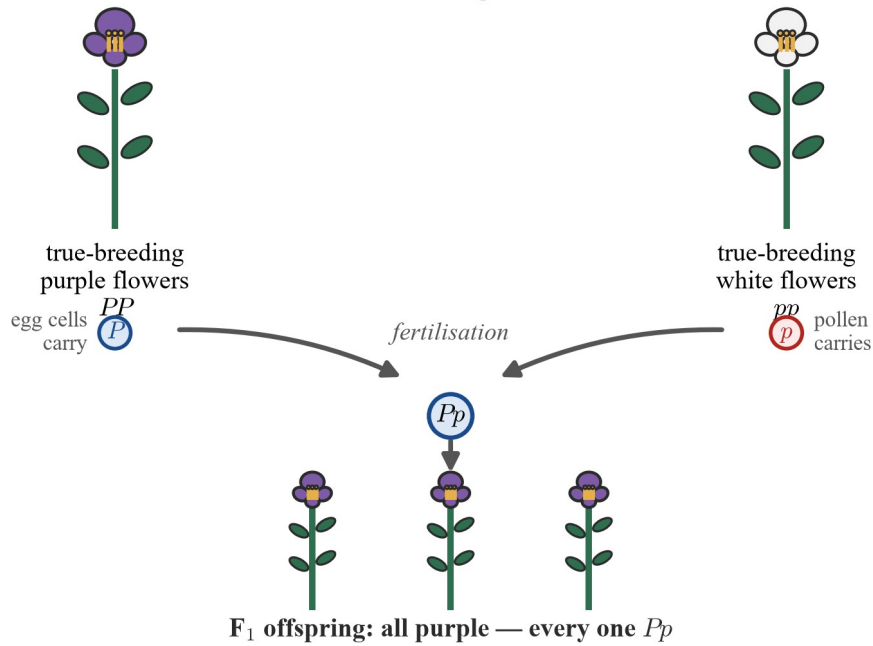
Mendel controlled every cross: the female parent kept its own egg cells, and only the pollen he chose could reach them.

Mendel's three-step crossing method: 1, remove the anthers before pollen is shed; 2, add pollen from the chosen male parent; 3, bag the flower to keep out unwanted pollen.

First he opened a young flower and **removed its anthers before they shed pollen**, so the flower could only act as a female parent. Then he **brushed pollen from a chosen male parent** onto that flower's stigma. Finally he **bagged the flower** so no unwanted pollen could reach it. Every seed that formed therefore had two known parents. Mendel also began with **true-breeding** lines: plants that, when self-fertilised, produced offspring identical to themselves for the trait in question, generation after generation. A true-breeding line carries two copies of the same allele — it is homozygous — although Mendel did not know that yet; he could only see that the line bred true.

Cross 1: the P generation. Mendel crossed true-breeding plants that differed in one trait. For flower colour: true-breeding purple $\times$ true-breeding white. We write the purple parent's genotype PP and the white parent's pp , using a capital letter for one allele and the lower-case of the same letter for the other. Each parent's gametes carry one allele (this is what meiosis does — Subtopic 7C), so the purple parent's egg cells all carry P and the white parent's pollen grains all carry p .

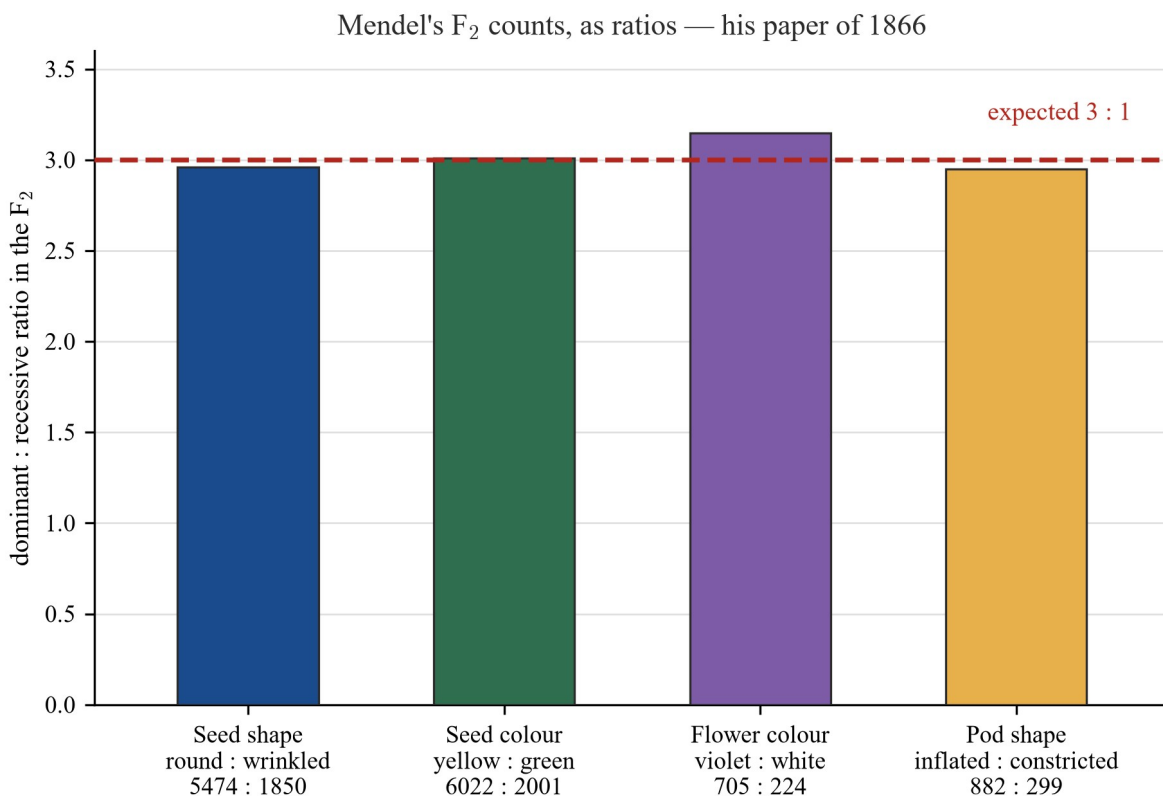
Cross 1: the P generation



Cross 1, the P generation: a true-breeding purple-flowered pea plant (PP) crossed with a true-breeding white-flowered plant (pp); the egg cells carry P and the pollen carries p, and every F1 offspring is purple and Pp.

Every offspring of this cross receives one P and one p, so every one is Pp — and every one has **purple** flowers. The white trait has disappeared in this first offspring generation, called the F₁.

Cross 2: the F₂. Mendel then crossed two F₁ plants with each other (Pp × Pp) and grew the offspring, the F₂. The white trait came back: about one in four F₂ plants had white flowers. Mendel saw the same pattern for every trait he tracked. His actual F₂ counts, shown as ratios, sit close to 3 : 1 in every case.



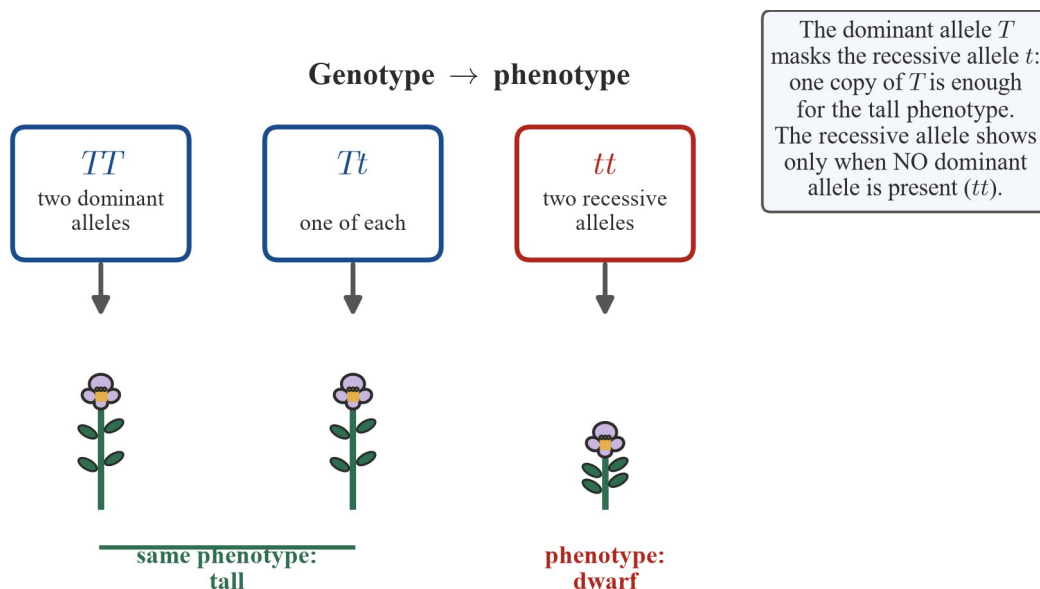
A bar chart of Mendel's real F₂ counts as ratios, from his paper of 1866: seed shape 5474 to 1850, seed colour 6022 to 2001, flower colour 705 to 224, pod shape 882 to 299 — each bar close to the dashed line at the expected 3 to 1.

Source for the counts: Gregor Mendel, 'Versuche über Pflanzen-Hybriden' ('Experiments in Plant Hybridisation'), published 1866 — a peer-reviewed paper; the four ratios are Mendel's own F₂ counts.

Dominant and recessive — what the words mean here

Definitions used in this subtopic. Genetics gives these two words a fixed, stipulated sense, and it is the sense Mendel's results forced on him. A **dominant** allele is one whose trait shows when it is paired with a recessive allele; a **recessive** allele is one whose trait shows **only when no dominant allele is present**. In the pair Pp , P is dominant and p is recessive, so the plant is purple.

What the words do NOT mean. Dominant does not mean stronger, healthier, better, or more common in a population. A dominant allele is not fighting the recessive one and winning; it simply codes for a product that does its job even when a recessive allele is present. Some dominant human traits are rare, and some recessive ones are common. The words describe a **pattern of inheritance in a pair**, nothing more.



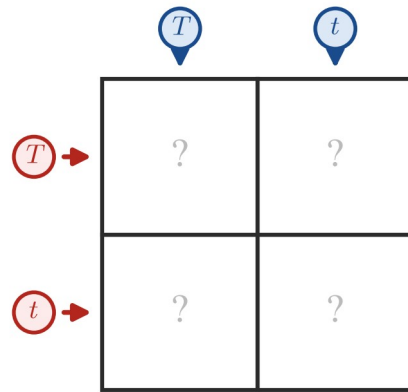
Genotype to phenotype for plant height: TT (two dominant alleles) and Tt (one of each) both give the tall phenotype; only tt gives the dwarf phenotype. Callout: one copy of the dominant allele T is enough for tall; the recessive allele t shows only when no dominant allele is present.

The picture explains why the F_1 was all purple and the F_2 brought white back. Every F_1 plant carried one P (enough for purple) **and** one hidden p . When two F_1 plants cross, some F_2 offspring receive p from both parents — pp — and with no dominant allele present, the recessive trait finally shows.

The Punnett square (elaboration VC2S10U04.E03)

A Punnett square is a tidy way of listing every possible fertilisation. Take the cross $Tt \times Tt$ for plant height, where T (tall) is dominant to t (dwarf). Meiosis gives each parent's gametes one allele each — half the gametes carry T , half carry t — so write one parent's two gamete alleles along the top and the other's down the side, then fill each of the four cells by combining the allele above it with the allele beside it.

male parent Tt — pollen grains, one allele each



female parent Tt —
egg cells, one allele each

each of the 4 cells = one possible fertilisation:
the offspring's genotype is written inside

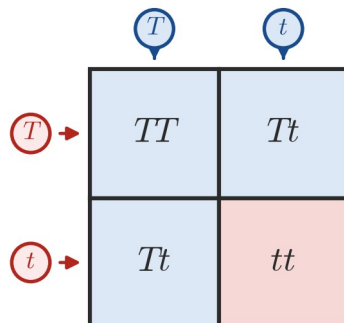
Reading the square

- 1 Write each parent's two alleles.
- 2 Split them: each gamete (egg or pollen grain) gets ONE allele — this is what meiosis does (7C).
- 3 Male gametes along the top, female gametes down the side.
- 4 Fill each cell by combining the allele above it with the allele beside it.
- 5 The four cells are four equally likely outcomes of fertilisation.

How to build a Punnett square for Tt times Tt : the male parent's pollen alleles T and t along the top, the female parent's egg alleles T and t down the side, and each of the four cells is one possible fertilisation whose offspring genotype is written inside.

The four cells are the four equally likely outcomes of fertilisation. Reading them off: one TT , two Tt , one tt .

Cross 2: two F_1 tall plants, both Tt



Reading the result

Genotypes in the four cells:

1 $\times TT$

2 $\times Tt$

1 $\times tt$

genotype ratio 1 : 2 : 1

Phenotypes:

3 tall (TT and Tt look the same)

1 dwarf (only tt)

phenotype ratio 3 : 1



The completed square for two F_1 tall plants, both Tt : cells TT , Tt , Tt and tt , giving a genotype ratio of 1 to 2 to 1 and, because TT and Tt look the same, a phenotype ratio of 3 tall to 1 dwarf.

Two ratios fall out of the one square:

- the **genotype ratio** — 1 TT : 2 Tt : 1 tt , written **1 : 2 : 1**;
- the **phenotype ratio** — TT and Tt are both tall, so **3 tall : 1 dwarf**, written **3 : 1**.

That 3 : 1 is exactly the ratio Mendel counted in his thousands of F_2 plants. The square explains *why* it appears: it is the pattern you get whenever one gene, two alleles, and a dominant–recessive relationship meet in a cross of two

heterozygotes. A cross that follows just **one** gene like this is called a **monohybrid cross** (mono = one, hybrid = the parents carry different alleles).

From ratio to probability (maths interlock VC2M9M05)

A ratio and a probability are two ways of saying the same thing. The square says the four outcomes are equally likely, so the share of outcomes of each kind *is* the probability of that kind. This is precisely the ratio-and-proportion reasoning of VC2M9M05 (Subtopic 4B): 3 of the 4 equally likely outcomes are tall, so the probability of tall is

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

From ratio to probability

the four equally likely outcomes of a $Tt \times Tt$ cross



3 of the 4 are tall

$$\text{probability of tall} = \frac{3}{4} = 0.75 = 75\%$$

1 of the 4 is dwarf

$$\text{probability of dwarf} = \frac{1}{4} = 0.25 = 25\%$$

*The same works for the genotypes: TT is 1 of 4 (0.25), Tt is 2 of 4 (0.50), tt is 1 of 4 (0.25).
A ratio and a probability are two ways of saying the same thing — the maths of Subtopic 4B, VC2M9M05.*

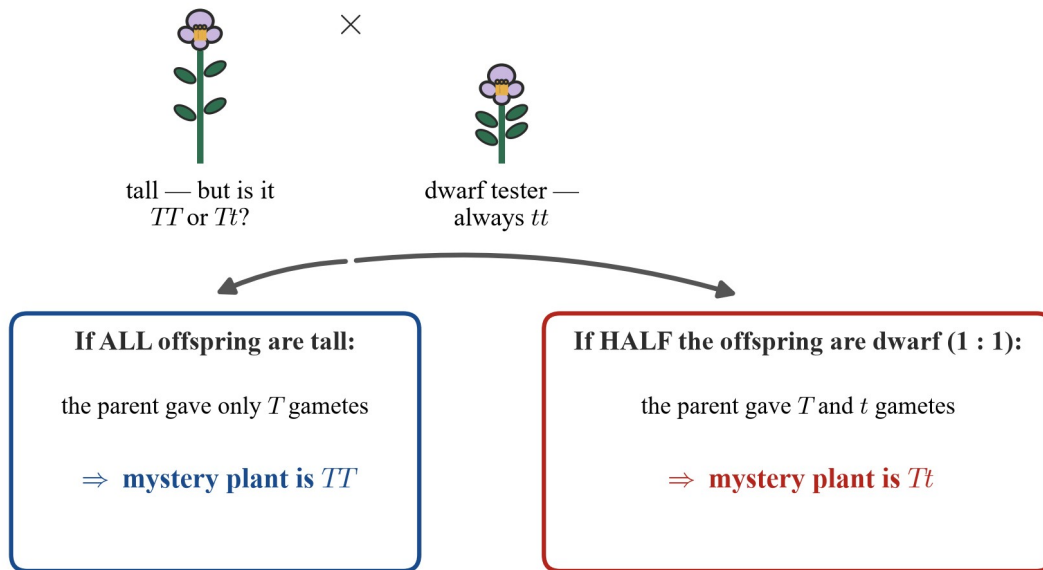
From ratio to probability: the four equally likely outcomes of a Tt times Tt cross shown as four blocks, three tall and one dwarf; probability of tall is 3 over 4, 0.75, 75 per cent; probability of dwarf is 1 over 4, 0.25, 25 per cent.

How to read every prediction in this subtopic. A 3 : 1 ratio means each single offspring has a 75% chance of showing the dominant trait — like one coin toss coming up heads. It does **not** mean “three tall then one dwarf”, any more than a coin owes you a tails after three heads. Each fertilisation is a fresh, independent event. That is also why Mendel’s real counts are *close* to 3 : 1 but never exact: chance wobbles the result, and the wobble shrinks as the numbers grow. With 20 offspring the wobble is large; with Mendel’s thousands, it is small.

The test cross: finding a hidden allele

A dominant phenotype hides its genotype. A tall plant is TT or Tt — the two look identical. Mendel’s trick for telling them apart is the **test cross**: cross the mystery plant with the **recessive form** (here, dwarf, tt), which can only give t gametes, and read the offspring.

The test cross — what is that tall plant's genotype?



Crossing with the recessive form is the test: the offspring's phenotypes reveal the hidden allele.

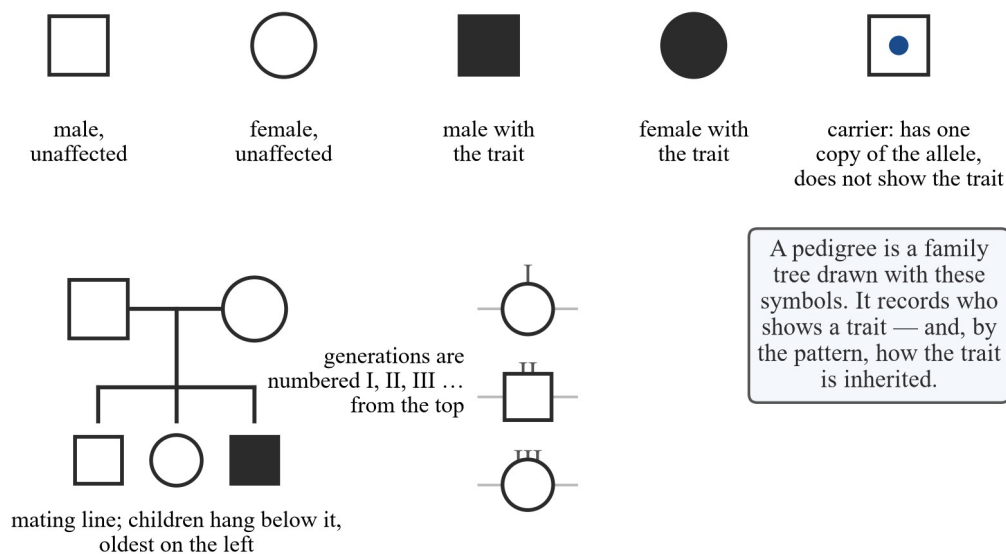
*The test cross: a tall mystery plant (TT or Tt) crossed with a dwarf tester (always tt). Two outcomes: if **ALL** offspring are tall, the parent gave only T gametes, so the mystery plant is TT ; if **HALF** the offspring are dwarf (1 to 1), the parent gave T and t gametes, so the mystery plant is Tt .*

The logic is airtight: a tt tester contributes t to every offspring, so any dwarf offspring must have received a t from the mystery plant too — proof the mystery plant carries a hidden t .

Pedigrees (elaboration VC2S10U04 . E04)

A **pedigree** is a family tree drawn with symbols. It records who in a family shows a trait — and, by the pattern, how the trait is inherited. Pedigrees are how geneticists track traits in humans and other animals, where planned crosses like Mendel's are impossible and families are small, so the patterns have to be read across generations.

Reading a pedigree — the symbols



A pedigree is a family tree drawn with these symbols. It records who shows a trait — and, by the pattern, how the trait is inherited.

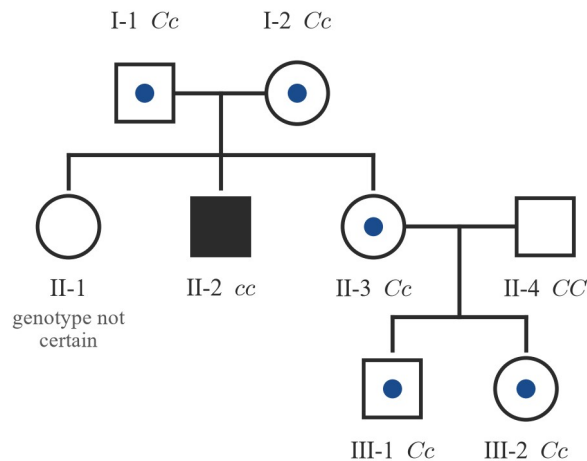
The pedigree symbol key: square for male, circle for female, filled shape for a person with the trait, centre dot for a carrier who has one copy of the allele but does not show the trait; a mating line joins parents and children hang below it, oldest on the left; generations are numbered I, II, III from the top.

A recessive pattern. The pedigree below shows a made-up practice family for cystic fibrosis, a human condition inherited through a recessive allele, written c (the unaffected allele is C).

Clues that a pattern is RECESSIVE:

- unaffected parents can have an affected child;
- the trait can skip generations;
- affected people are often rare in the family.

A recessive pattern (practice family — cystic fibrosis, allele c)



No-one in generations I or III shows the condition, yet it appears in generation II: the recessive allele was carried silently, then two carriers had a child together.

A recessive pattern, practice family for cystic fibrosis (allele c): two unaffected carriers Cc in generation I have an affected child cc in generation II; the trait skips a generation. Callout lists the clues: unaffected parents can have an affected child; the trait can skip generations; affected people are often rare in the family.

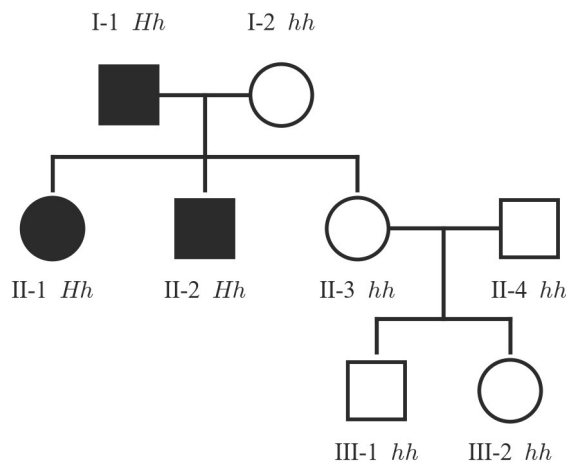
Read the clues. I-1 and I-2 do **not** have the condition, yet their child II-2 does. That single fact proves the allele is recessive: both parents must carry one hidden c (they are **carriers**, Cc), and II-2 received c from each, giving cc . Notice too that the trait can **skip a generation** — it is carried silently in I-1, I-2 and II-3 before showing again.

A dominant pattern. A dominant allele shows in every individual who carries it, so the pattern looks completely different. The practice family below uses Huntington's disease, an inherited human condition caused by a dominant allele, written H (the unaffected allele is h).

Clues that a pattern is DOMINANT:

- every affected person has an affected parent;
- the trait appears in every generation;
- children of an unaffected person are unaffected.

A dominant pattern (practice family — Huntington's disease, allele H)



The condition appears in every generation. II-3 shows that someone without the allele cannot pass it on: her children are all unaffected.

A dominant pattern, practice family for Huntington's disease (allele H): an affected father Hh and unaffected mother hh in generation I; the condition appears in every generation, and unaffected II-3 (hh) has no affected children. Callout lists the clues: every affected person has an affected parent; the trait appears in every generation; children of an unaffected person are unaffected.

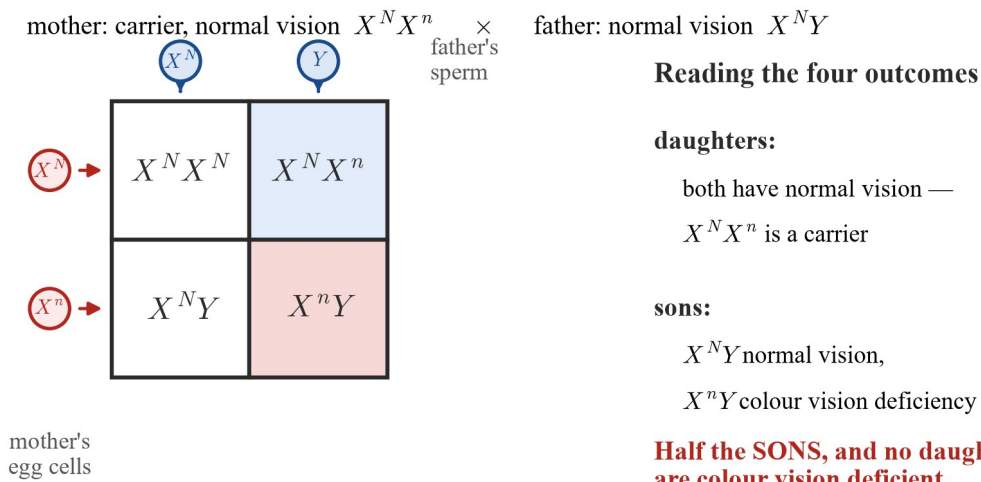
Every affected person here has an affected parent, because an affected child must receive H from someone — and anyone with an H shows the condition. Equally telling is II-3: she is hh , carries no dominant allele, and **none** of her children have the condition. A trait that appears in every generation, with every affected child having an affected parent, is the signature of dominant inheritance.

Sex-linked genes (elaboration VC2S10U04.E03)

Some genes sit on the sex chromosomes. Subtopic 7C covers the X and Y chromosomes: females are XX , males are XY . A gene carried on the X chromosome is called **X-linked** (or **sex-linked**). A male has only **one** copy of any X-linked gene — whatever is on his single X — so a recessive X-linked allele shows in a male with no partner allele at all. That one fact changes the ratios.

The classic example is red–green colour vision deficiency, caused by a recessive X-linked allele written X^n , with the usual allele X^N . Cross a carrier mother ($X^N X^n$, normal vision) with a father with normal vision ($X^N Y$):

A sex-linked cross: colour vision on the X chromosome



A son gets his only X from his mother and his Y from his father — so a father never passes an X-linked allele to his sons, and one copy of the recessive allele is enough to affect a male.

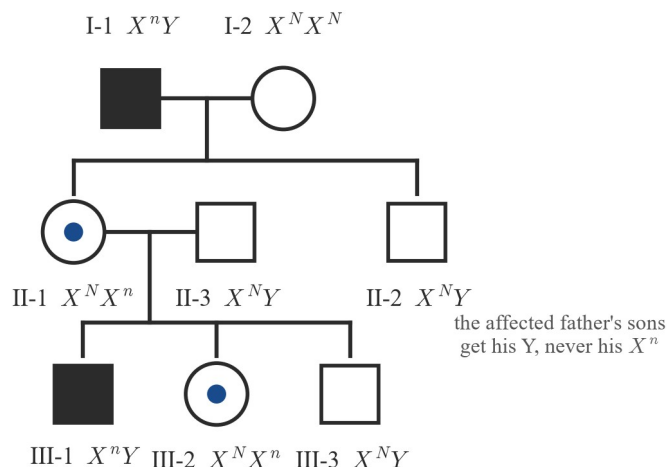
A sex-linked cross as a Punnett square: carrier mother $X^N X^n$ times father with normal vision $X^N Y$. Daughters: $X^N X^N$ and $X^N X^n$, both with normal vision, one a carrier. Sons: $X^N Y$ normal vision and $X^n Y$ colour vision deficiency. Half the sons and no daughters are colour vision deficient.

The ratios now differ **between the sexes**: half the sons are colour vision deficient, while no daughter is (though half of daughters are carriers). The same skipping pattern shows in pedigrees — affected grandfather, carrier daughter, affected grandsons:

Clues that a pattern is X-LINKED:

- many more males than females are affected;
- affected fathers never pass it to their sons;
- it often passes through carrier mothers.

An X-linked pattern (practice family — red-green colour vision deficiency)



The condition skips from an affected grandfather to affected grandsons through a carrier daughter — and it is the males who show it.

An X-linked pattern, practice family for red-green colour vision deficiency: affected grandfather in generation I; his carrier daughter in generation II; affected grandsons in generation III. The affected father's sons get his Y, never his

X-n. Callout lists the clues: many more males than females are affected; affected fathers never pass it to their sons; it often passes through carrier mothers.

The clue to watch for is the middle one: **an affected father never passes an X-linked trait to his sons**, because a son receives his father's Y, not his X. The trait instead travels through carrier mothers to sons. Even so, this is still a **monohybrid** cross — one gene, tracked one pair of alleles at a time — which is exactly the scope this subtopic works to.

The scope of this subtopic

What we do not do here. Every cross above follows one gene with a dominant and a recessive allele, or one X-linked gene. Real inheritance also includes codominance, incomplete dominance, multiple alleles, and genes that sit close together on the same chromosome (linkage); none of these appear in this subtopic, because the content description stops at monohybrid crosses involving dominant and recessive traits (and the sex-linked case shown). Those extensions are VCE Biology territory (TOC D9) — see *Where this leads* below. Likewise, the machinery that makes the ratios possible — DNA, chromosomes, and the behaviour of meiosis and mitosis — is taught in Subtopic 7C, the owner of this CD.

Activities

Activity 1 — Modelling a monohybrid cross with two coins (elaboration VC2S10U04 .E03; ratio and proportion from VC2M9M05). Two coins model the cross $Tt \times Tt$: one coin is the egg cell's allele, the other is the pollen grain's allele; heads = T , tails = t . Toss both coins together and read the pair as a genotype — for example heads + tails is Tt , tall. Each toss is one fertilisation.

- Toss the pair 20 times and record each outcome as tall or dwarf in a tally table.
- Work out your own ratio of tall : dwarf (a ratio is a division: divide your tall count by your dwarf count, or compare both to the prediction).
- Now add your 20 results to the whole class's tally on the board, and work out the class ratio.

Compare: which ratio sits closer to 3 : 1 — yours, or the class's? Write two or three sentences explaining why, using the words *probability*, *chance* and *sample*. (The class total is the bigger sample; chance wobbles a small sample more — exactly why Mendel grew thousands of plants.)

Activity 2 — Draw a pedigree from a description (elaboration VC2S10U04 .E04). Below is a made-up family of guinea pigs and a made-up single-gene trait: a white patch of fur. The allele for a white patch, w , is recessive to the allele for a plain coat, W . Read the description and draw the pedigree using the symbols in the key figure: squares for males, circles for females, filled for animals **with** a white patch, a centre dot for known carriers.

- Generation I: a plain-coated male and a plain-coated female.
- Generation II: their three offspring, oldest first — a male with a white patch, a plain-coated female, and a plain-coated male. The plain-coated female (II-2) is mated with a plain-coated male from outside the family.
- Generation III: II-2 and her partner have two offspring — a plain-coated female and a male with a white patch.

Then, on your drawing: (a) write the genotype of every animal you can be **certain** of (the two with white patches, and any animal whose alleles the pattern forces); (b) for each animal you cannot be certain of, write both possible genotypes; (c) in one sentence, state the single piece of evidence that proves the white-patch allele is recessive in this family.

Activity 3 — Whose genotype? Test-cross reasoning (elaboration VC2S10U04 .E03). A breeder has four mystery tall pea plants and test-crosses each with a dwarf (tt) plant. The offspring are:

Mystery plant	Offspring from the test cross
A	48 tall, 0 dwarf
B	26 tall, 24 dwarf
C	12 tall, 0 dwarf

D

7 tall, 9 dwarf

For each plant, decide TT or Tt and give the one-line reason. Then answer: which decision are you least sure of, and why does that cross deserve more offspring before you call it? (Hint: think about sample size from Activity 1.)

Worked examples

Example 1 — scaffolded

In pea plants, purple flowers (P) are dominant to white flowers (p). Two purple plants, both Pp , are crossed. Predict the genotype and phenotype ratios of the offspring.

Working	Comment
1. Write the parents: $Pp \times Pp$.	One gene, two alleles — a monohybrid cross.
2. Split into gametes: each parent gives P or p , one allele each.	Meiosis gives each gamete one allele (7C).
3. Fill the square: PP , Pp , Pp , pp .	Combine the allele above each cell with the allele beside it.
4. Genotype ratio: $1PP : 2Pp : 1pp = 1 : 2 : 1$.	Count the four equally likely cells.
5. Phenotype ratio: PP and Pp purple, pp white = 3 purple : 1 white .	One copy of P is enough for purple.

Example 2 — scaffolded

A pedigree shows two parents **without** a trait having a child **with** the trait. Decide whether the trait is dominant or recessive, and give the parents' genotypes using A and a .

Working	Comment
1. The child shows the trait, so the child's genotype must produce it.	Start from the certain person.
2. Suppose the trait were dominant: the child would carry A — and A would have to come from a parent, who would then show the trait. But neither parent shows it.	Test the dominant idea against the evidence.
3. $\therefore$ the trait is recessive : the child is aa .	The only reading that fits the facts.
4. Each parent gave one a yet shows no trait, so both are Aa — carriers .	Unaffected + affected child = carrier parents.

Example 3 — unscaffolded

A tall pea plant of unknown genotype is test-crossed with a dwarf plant. Of the 40 offspring, 21 are tall and 19 are dwarf. Identify the mystery plant's genotype and explain the evidence. (3 marks)

The mystery plant is Tt . The dwarf tester is tt , so it gives a t allele to every offspring; the 19 dwarf offspring are tt , and the second t in each must have come from the mystery plant — so the mystery plant carries a hidden t . Yet the plant is tall, so it also carries T : its genotype is Tt . The near 1 : 1 split (21 : 19) is exactly the ratio a $Tt \times tt$ cross predicts — half Tt tall, half tt dwarf — with the usual chance wobble in a sample of 40. $\therefore$ the evidence (dwarf offspring at all, in about half the sample) fixes the genotype as Tt .

Example 4 — unscaffolded

A woman is a carrier for red–green colour vision deficiency ($X^N X^n$) and her partner has normal vision ($X^N Y$). They are expecting a child. Find the probability that the child is colour vision deficient **if it is a son**, and if it is a daughter. (4 marks)

The square $X^N X^n \times X^N Y$ gives four equally likely outcomes: $X^N X^N$ and $X^N X^n$ (daughters), $X^N Y$ and $X^n Y$ (sons).

Sons: a son receives his single X from his mother; half the mother's X alleles are X^n , so the probability a son is colour vision deficient is $\frac{1}{2}$ (0.5, 50%). **Daughters:** every daughter receives X^N from her father, and one X^N is enough for normal vision, so the probability a daughter is colour vision deficient is 0 — though with probability $\frac{1}{2}$ a daughter is a carrier. $\therefore$ the risk sits entirely with sons: 50% for a son, 0% for a daughter.

Practice questions

Scaffolded questions

Question 1 The vocabulary of this subtopic. Define each of the following: (a) genotype; (b) phenotype; (c) homozygous; (d) heterozygous; (e) carrier; (f) monohybrid cross.

Question 2 Genotype to phenotype. Copy and complete the table for plant height, where T (tall) is dominant to t (dwarf).

Genotype	Homozygous or heterozygous?	Phenotype
TT		
Tt		
tt		

Question 3 Completing a Punnett square. Cross $Tt \times tt$. Copy and complete the square, then write the genotype and phenotype ratios of the offspring.

	t	t
T		
t		

Question 4 Ratio to probability. Write each ratio as a fraction, a decimal and a percentage: (a) 3 tall : 1 dwarf, probability of tall; (b) 1 : 1 tall : dwarf, probability of tall; (c) genotype ratio 1 : 2 : 1, probability of Tt .

Question 5 Reading pedigree symbols. Name what each symbol shows: (a) an unfilled circle; (b) a filled square; (c) a circle with a centre dot; (d) the horizontal line joining two symbols; (e) the line from which children hang.

Question 6 True or false — correct the false statements. (a) A dominant allele's trait shows only when two dominant alleles are present. (b) A recessive trait can skip a generation. (c) Dominant traits are always the most common traits in a population. (d) A carrier shows the trait it carries.

Unscaffolded questions

Question 7 (3 marks) In pea plants, purple flowers (P) are dominant to white flowers (p). A true-breeding purple plant is crossed with a white plant. Give the genotype and phenotype of every F_1 offspring, with a square or gamete argument.

Question 8 (3 marks) Two Tt pea plants are crossed and produce 16 offspring: 13 tall and 3 dwarf. A student says the square must be wrong because 13 : 3 is not exactly 3 : 1. Is the student right? Explain.

Question 9 (3 marks) A tall pea plant is test-crossed with a dwarf plant. All 35 offspring are tall. State the mystery plant's genotype and explain why the evidence forces that answer.

Question 10 (4 marks) In a family, two parents without a recessive condition have four children: two with the condition and two without. Using C and c , give the parents' genotypes, the affected children's genotype, and the probability that a fifth child has the condition.

Question 11 (3 marks) A pedigree for a condition shows an affected child whose parents are both unaffected. Explain, in terms of alleles, why the condition cannot be dominant.

Question 12 (4 marks) A pedigree for Huntington's disease (dominant allele H) shows an unaffected woman, $h h$, planning a family. Her partner is also unaffected. Explain, using alleles, whether any of their children could have the condition.

Question 13 (4 marks) A father with red–green colour vision deficiency ($X^n Y$) and a mother who is not a carrier ($X^N X^N$) have children. Give the genotypes and phenotypes of their sons and daughters, and state what this cross shows about father-to-son transmission of X-linked traits.

Question 14 (3 marks) Explain why an affected father never passes an X-linked recessive trait to his sons, but can pass it (as a hidden allele) to his daughters.

Question 15 (4 marks) Two tall pea plants produce a dwarf offspring. Explain how this is possible, give the parents' genotypes, and find the probability that their **next** offspring is dwarf.

Question 16 (3 marks) A student argues: "A dominant allele masks the recessive one in every pair, so dominant traits must become more common in a population over time, and recessive traits must die out." Evaluate the argument.

Answers

Question 1 (a) the pair of alleles an organism carries for a gene; (b) the trait you can observe; (c) having two identical alleles for a gene (TT or tt); (d) having two different alleles for a gene (Tt); (e) heterozygous for a recessive allele — does not show the trait but can pass it on; (f) a cross that follows one gene. **Question 2** TT : homozygous, tall. Tt : heterozygous, tall. tt : homozygous, dwarf. **Question 3** Cells: Tt , Tt , tt , tt . Genotype ratio $1Tt:1tt$ ($2:2$); phenotype ratio 1 tall : 1 dwarf. **Question 4** (a) $\frac{3}{4}$, 0.75, 75%; (b) $\frac{1}{2}$, 0.5, 50%; (c) $\frac{2}{4} = \frac{1}{2}$, 0.5, 50%. **Question 5** (a) a female without the trait; (b) a male with the trait; (c) a female carrier; (d) a mating line (the two are partners); (e) the mating line's drop — children hang below it. **Question 6** (a) False — it shows when paired with a recessive allele too. (b) True. (c) False — dominance is about the pair, not about how common an allele is. (d) False — a carrier does not show the trait. **Question 7** see solution. **Question 8** see solution. **Question 9** see solution. **Question 10** see solution. **Question 11** see solution. **Question 12** see solution. **Question 13** see solution. **Question 14** see solution. **Question 15** see solution. **Question 16** see solution.

Fully-worked solutions

Question 7 The purple parent is PP and the white parent pp . Every egg cell carries P and every pollen grain carries p , so every offspring is Pp — heterozygous — and, because one P is enough for purple, every F_1 plant has **purple flowers**. (1 mark: parents' gametes P and p ; 1 mark: F_1 genotype all Pp ; 1 mark: F_1 phenotype all purple.)

Question 8 No — the student is wrong. The $3:1$ ratio is a **probability statement**: each offspring independently has a $\frac{3}{4}$ chance of being tall, like a coin toss has a half chance of heads. In a small sample of 16, chance wobbles the counts away from the exact $12:4$ prediction; $13:3$ is a normal wobble. The square predicts what happens **on average over large numbers**, which is why Mendel's thousands of plants sat so close to $3:1$ while small families wander. (1 mark: $3:1$ is a probability, each fertilisation independent; 1 mark: small samples wobble, 16 is small; 1 mark: large numbers approach the ratio, as in Mendel's data.)

Question 9 The mystery plant is TT . The dwarf tester (tt) gives a t to every offspring; if the mystery plant carried even one t (Tt), about half the offspring would receive t from both parents and be dwarf. **None of the 35 is dwarf**, so the mystery plant gave only T gametes — it is TT . (1 mark: genotype TT ; 1 mark: tester contributes t to all offspring; 1 mark: a Tt parent would give dwarf offspring, and none appeared.)

Question 10 Both parents are Cc . The affected children are cc , and each c came from one parent; since neither parent shows the condition, each carries a C as well — both are carriers, Cc . The cross $Cc \times Cc$ gives $1CC:2Cc:1cc$, so the probability a fifth child is cc (has the condition) is $\frac{1}{4} = 0.25 = 25\%$ — unchanged by the first four children, because each fertilisation is independent. (1 mark: parents both Cc ; 1 mark: affected children cc ; 1 mark: probability $\frac{1}{4}$; 1 mark: each child independent of the previous four.)

Question 11 If the condition were dominant, every person with it would carry the dominant allele, and that allele would have come from one of their parents — who would then carry it and **show** the condition. Here the affected child's parents are both unaffected, so neither could have passed on a dominant allele; the child's two alleles must both be recessive, one hidden in each unaffected parent. $\therefore$ unaffected parents with an affected child is only possible for a recessive trait. (1 mark: a dominant allele shows in its carrier; 1 mark: an affected child's dominant allele would force an affected parent; 1 mark: so the child is homozygous recessive and the parents are carriers.)

Question 12 No child of this couple could have the condition. Huntington's disease is caused by the **dominant** allele H , and anyone carrying H shows the condition. Both parents are unaffected, so neither carries H — both are hh — and two hh parents can give only h alleles, so every child is hh and unaffected. This is the pedigree clue “children of an unaffected person are unaffected”, and it holds precisely because the allele is dominant: there is no hidden carrier state. (1 mark: dominant allele shows in every carrier; 1 mark: unaffected parents are both hh ; 1 mark: $hh \times hh$ gives only hh ; 1 mark: conclusion — no affected children, no hidden allele to pass on.)

Question 13 Every daughter receives X^n from her father and X^N from her mother, so all daughters are $X^N X^n$: normal vision, **all carriers**. Every son receives Y from his father and X^N from his mother, so all sons are $X^N Y$: normal vision, none carriers (a son has no second X to carry a hidden allele). $\therefore$ an affected father passes the allele to **all** daughters and to **no** sons — direct evidence that the gene sits on the X , because father-to-son transmission is impossible. (1 mark: daughters all $X^N X^n$, normal-vision carriers; 1 mark: sons all $X^N Y$, normal vision; 1 mark: sons get the father's Y , not his X ; 1 mark: conclusion — no father-to-son transmission of an X -linked trait.)

Question 14 A son receives his **Y** chromosome from his father (that is what makes him a son) and his single **X** from his mother. An X -linked allele sits on the father's X , and that X never goes to his sons — so no son can inherit the trait from his father. A daughter, however, receives her father's **only X**, so she always receives his X -linked allele; if the allele is recessive and her mother contributes a usual allele, she carries it without showing it. $\therefore$ the trait skips from father to grandson through carrier daughters. (1 mark: sons receive the father's Y ; 1 mark: the X -linked allele is on the father's X , so it cannot reach sons; 1 mark: daughters receive the father's X and can carry the allele hidden.)

Question 15 A dwarf offspring is tt , so it received one t from **each** parent; both parents are tall yet each carries a hidden t , so both are Tt . The cross $Tt \times Tt$ gives $1TT:2Tt:1tt$, so the probability the next offspring is dwarf (tt) is $\frac{1}{4} = 25\%$. The first dwarf child does not change that probability: each fertilisation is an independent event, and the square is the same for every child. (1 mark: dwarf child tt proves a hidden t in each parent; 1 mark: parents both Tt ; 1 mark: probability $\frac{1}{4}$; 1 mark: independence — the previous child changes nothing.)

Question 16 The argument fails. Dominance describes what happens **inside one individual** — which trait shows when two alleles are paired — not what happens to an allele's frequency in a population. A recessive allele hidden in a carrier is passed on exactly as often as the dominant one: in Tt , half the gametes carry t , so t does not vanish. Real examples disprove the claim both ways: Huntington's disease and polydactyly (extra fingers or toes) are caused by **dominant** alleles yet are rare, and some recessive traits are common. Whether an allele becomes more or less common depends on factors such as whether it affects survival and reproduction — not on dominance. $\therefore$ the student has confused a pattern of inheritance in a pair with a population trend. (1 mark: dominance is about the pair in an individual, not population frequency; 1 mark: recessive alleles persist hidden in carriers and are passed on normally; 1 mark: counter-example — rare dominant traits such as Huntington's disease or polydactyly.)

Where this leads: the prediction machinery built here — monohybrid crosses, genotype and phenotype ratios read as probabilities, and pedigree patterns for dominant, recessive and X -linked traits — is assumed by VCE Biology Units 1–2, Area of Study 1 (“How is inheritance explained?”), which adds codominance, incomplete dominance, multiple alleles and linkage, and the chromosome behaviour in meiosis that makes the ratios possible; all of that is reference-only for this book (TOC D9). Within this band, the other limb of VC2S10U04 — DNA, chromosomes, genes and alleles, and the roles of mitosis and meiosis in passing on genetic information — is taught by Subtopic 7C, the owner of this CD, and the ratio-to-probability moves used throughout this subtopic are the maths of VC2M9M05, taught in Subtopic 4B.