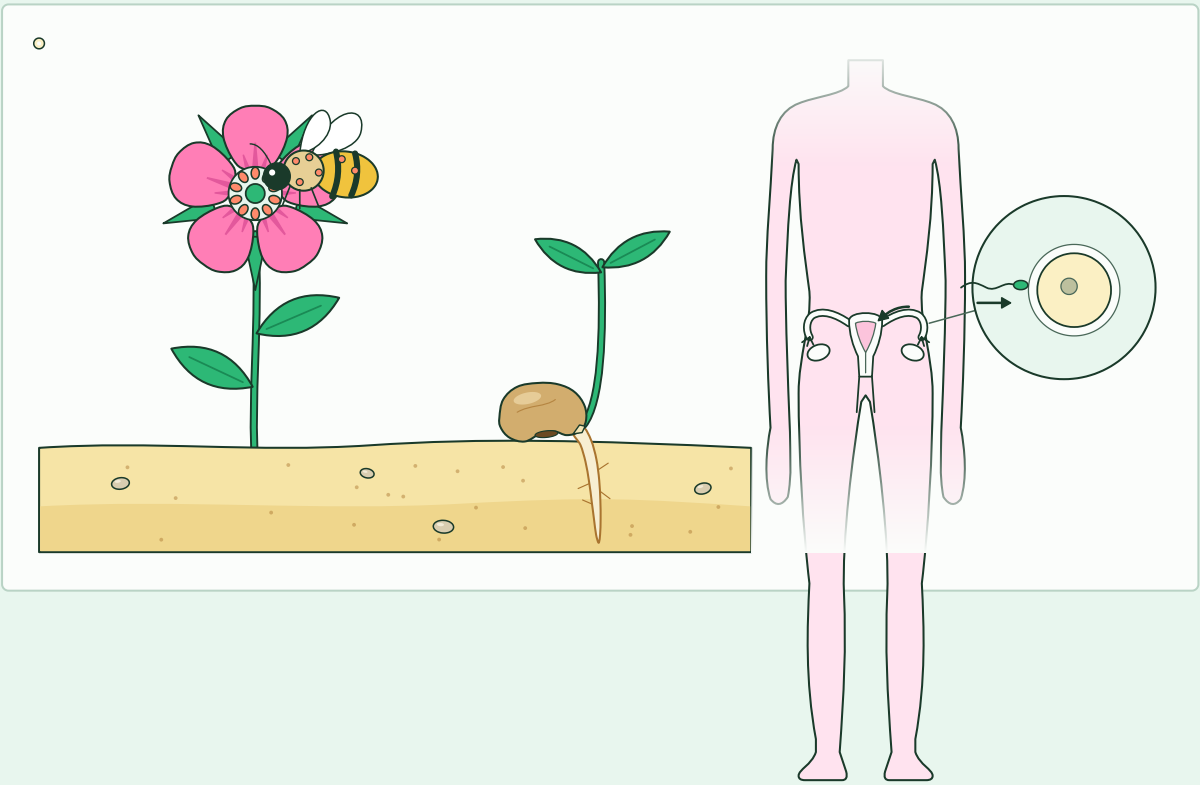
REVISION GUIDE

How new life *begins*

Reproduction

A plant cannot move, and an animal can, but both have to bring two gametes together and give the new individual a start. The plant half follows a flower from pollen to seedling; the human half follows the gametes, the monthly cycle, fertilization and, at higher level, pregnancy and birth.



25 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ib-biology-d3-1-reproduction

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	Answers	98

By the end you can

- [ ] Explain sexual reproduction in flowering plants: gametes in pollen and ovules, pollination, the pollen tube, fertilization and the embryo, and why it is sexual even in a hermaphrodite flower D3.1.8
- [ ] Draw and annotate an insect-pollinated flower, naming each structure and its function D3.1.9
- [ ] Explain how plants promote cross-pollination: different timing, separate male and female flowers or plants, and animals and wind D3.1.10
- [ ] Explain how self-incompatibility keeps gametes from the same plant apart, and why inbreeding lowers diversity and vigour D3.1.11
- [ ] Distinguish seed dispersal from pollination, and explain germination: the embryo's growth and the mobilization of food reserves D3.1.12
- [ ] Compare sexual and asexual reproduction, and say which suits an unchanging environment and which a changing one D3.1.1
- [ ] Explain how meiosis breaks up parental combinations of alleles and fertilization makes new ones, and follow the chromosome number round the life cycle D3.1.2
- [ ] Explain why the male gamete is small and the female gamete large, and how that shapes their numbers and the parents' strategies D3.1.3
- [ ] Draw and annotate the male-typical and female-typical reproductive systems with each structure's job D3.1.4
- [ ] Explain the ovarian and uterine cycles and how FSH, LH, oestradiol and progesterone regulate them through negative and positive feedback D3.1.5
- [ ] Describe fertilization in humans, from the fusion of the two cell membranes to the first mitosis D3.1.6
- [ ] Explain how hormones suspend a woman's own cycle and bring on superovulation in IVF D3.1.7
- [ ] Explain how GnRH, LH, FSH and the sex hormones bring on puberty D3.1.13
- [ ] Compare spermatogenesis and oogenesis: the stages, the numbers made and the cytoplasm D3.1.14
- [ ] Explain how the acrosome reaction lets one sperm through and the cortical reaction keeps the others out D3.1.15
- [ ] Describe the blastocyst and its implantation in the endometrium D3.1.16
- [ ] Explain how a pregnancy test detects hCG with monoclonal antibodies D3.1.17
- [ ] Explain what crosses the placenta, how, and why its villi's large surface area matters D3.1.18
- [ ] Explain how progesterone keeps a pregnancy going, and how its fall lets oxytocin and positive feedback drive birth D3.1.19
- [ ] Judge the evidence on HRT and heart disease, and say why an early observational link was not cause and effect D3.1.20

Tick each one when you can do it without the book.

D3.1.9 01 FEATURES OF AN INSECT-POLLINATED FLOWER

01 A flower, *part by part*

Go deeperthe detail, in the exam, watch out

The detail

A plant cannot walk to a mate, so its pollen travels instead, carried by insects, other animals or the wind.

Sepals: usually small and green. They wrapped and protected the flower as a bud.

Petals: often large and brightly coloured, the ring just inside the sepals.

Nectaries: often at the base of the petals. They make nectar, a sugary drink that rewards visiting insects.

Filament: holds the anther where a visiting insect brushes against it.

Style: holds the stigma up. Pollen tubes grow down through it (chapter 2).

Ovule: holds one egg cell and can become a seed. The ovary around the ovules becomes the fruit.

Most flowering plants have stamens and carpels in the same flower: the flower is **hermaphrodite**. Chapter 4 meets plants that keep the two apart.

In the exam

Draw a **half-flower**: cut lengthways through its centre, so every part shows at once.

Clear outlines, no shading.

Rule each label line so it ends on its part and never crosses another.

Beside each name write what that part does. That is what **annotate** means here.

Watch out

"The stamen is the anther." The stamen is the anther **and** its filament together.

The carpel is the stigma, the style and the ovary together, not any one of them.

KEY TERMS

sepals
The outer ring of a flower's parts, usually small and green. They cover and protect the flower while it is a bud.

petals
The ring of a flower's parts inside the sepals, often large and brightly coloured.

stamens
The male part of a flower: an anther on a filament.

carpel
The female part of a flower: the stigma, style and ovary together.

stamen
The male part of a flower: an anther on a filament.

anther
The top of a stamen, where pollen grains are made.

filament
The stalk of a stamen. It holds the anther where visiting insects brush against it.

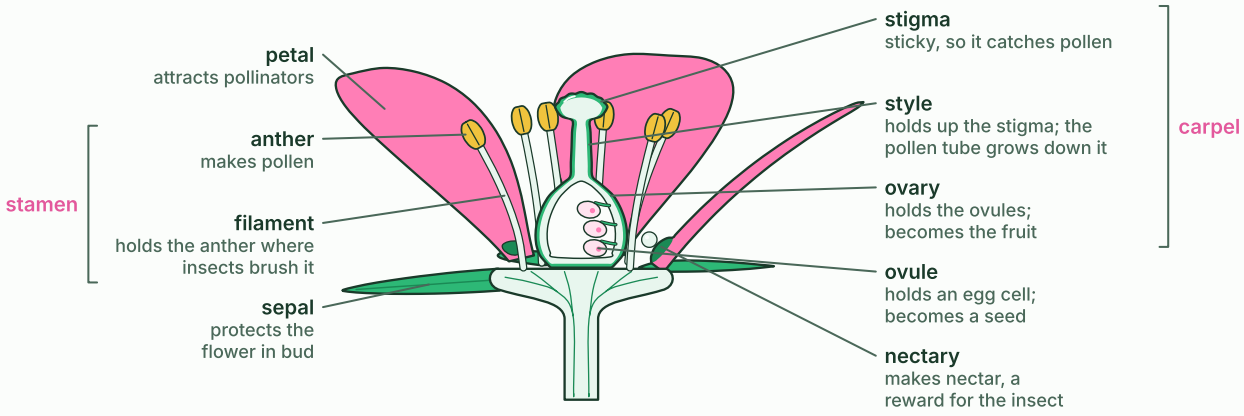
stigma
The sticky top of the carpel, which catches pollen grains.

style
The stalk of the carpel. It holds the stigma up, and pollen tubes grow down through it.

ovary
The swollen base of the carpel, which holds the ovules. It becomes the fruit.

ovules
A small structure inside the ovary that holds an egg cell. After fertilization it becomes a seed.

hermaphrodite
Having both male and female parts: here, a flower with both stamens and carpels.

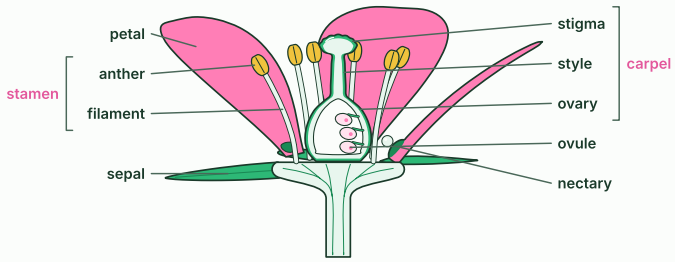


Take the flower apart from the outside in, then name each part of the half-flower and say what it does.

STEP BY STEP

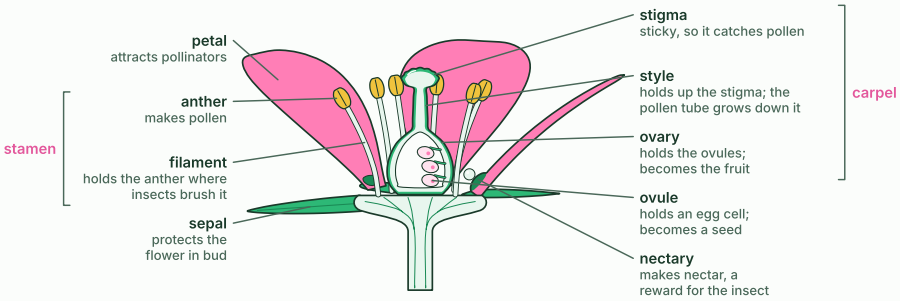
2 STEPS

1



Cut lengthways, a half-flower shows every part at once. A stamen is an anther on a filament; the carpel is the stigma, the style and the ovary, with the ovules inside it.

2



The drawing to learn: each part named on a ruled line, with what it does. Pollen is made in the anthers; the egg cell is in an ovule, inside the ovary.

REMEMBER IT

The parts from the outside in: Sweet Peas Smell Clean

S Sweet	P Peas	S Smell	C Clean
Sepals protect the bud	**Petals** the bright ring	**Stamens** anther and filament: make pollen	**Carpel** stigma, style and ovary: catch pollen, hold the ovules

PREDICT

A flower's petals are removed before it opens. What does the plant lose?

(A) Its pollen, because the petals are the part of the flower that makes it

(B) Its ovules, because they sit hidden inside the base of each petal

(C) The signal that brings insects in, so fewer of them visit with pollen

(D) Nothing much, since insects find every flower by its scent alone

Decide before you look. Answer on page 98.

D3.1.8 02 SEXUAL REPRODUCTION IN FLOWERING PLANTS

02 From pollen to *embryo*

Go deeperthe detail, beyond the course, watch out

The detail

The female gamete, the egg cell, is made inside an ovule, deep in the ovary.

The male gametes are made inside pollen grains, which form in the anthers.

A pollen grain is not a gamete: it is a carrier with a tough wall, and the male gametes are inside it.

Both kinds of gamete come from cells made by meiosis, so each has one set of chromosomes, half the number in the plant's body cells (D3.2's first chapter has the film).

After pollination nothing has fused yet, and it may never: the pollen may be from the wrong plant, or arrive too late.

The pollen tube enters the ovule through the **micropyle**, a tiny gap in the ovule's outer layers.

In many plants the journey takes from a few hours to a day or two.

The embryo is a tiny plant with a root, a shoot and one or two seed leaves.

Beyond the course

A pollen tube carries two male gametes. The second fuses with another cell in the ovule, the central cell, and that starts the seed's food store.

The IB does not ask for this, but it is why the drawing shows two male gametes in the pollen grain.

Watch out

"Pollen is the male gamete." A pollen grain **carries** the male gametes inside its wall.

"Pollination is fertilization." Pollination only delivers the pollen. Fertilization comes later, if at all.

"Fertilization makes the seed." It makes a zygote, which grows into the embryo. The whole ovule becomes the seed.

KEY TERMS

pollination
The transfer of pollen from an anther to a stigma.

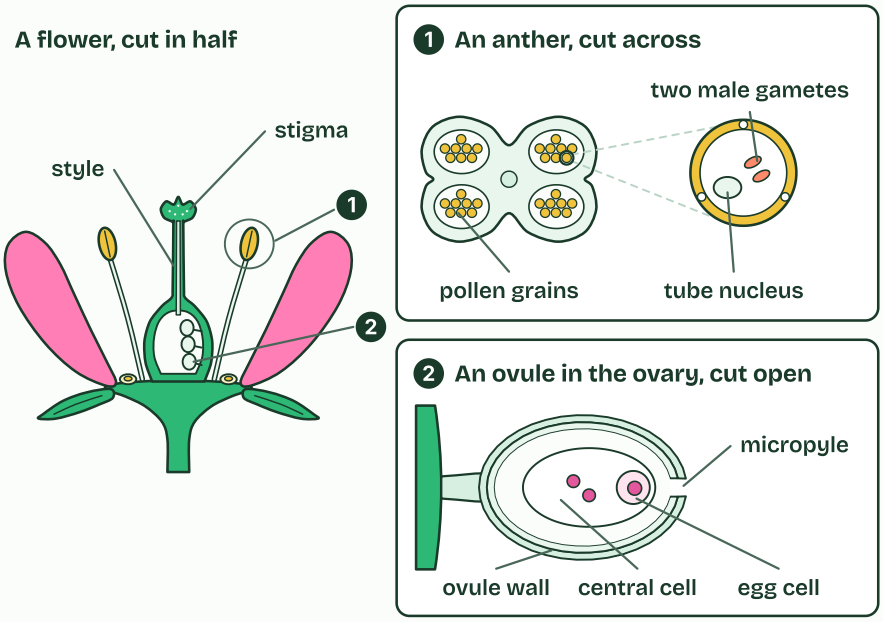
pollen tube
A tube that grows out of a pollen grain on a stigma, down through the style to an ovule, carrying the male gametes.

fertilization
The fusion of a male and a female gamete, making a zygote.

zygote
The single cell made when two gametes fuse. It divides by mitosis to form an embryo.

embryo
The young plant inside a seed, grown from the zygote by mitosis: a radicle, a plumule and one or two cotyledons.

micropyle
A tiny gap in the outer layers of an ovule. The pollen tube grows in through it, and in the seed it stays as a tiny pore.



Anther Pollen grains are made in its four pollen sacs. When they are ripe, the anther splits open and sheds them.

Ovule Inside the ovary. Each ovule holds one egg cell, and after fertilization the whole ovule becomes a seed.

Anther Pollen grains are made in its four pollen sacs. When they are ripe, the anther splits open and sheds them.

Anther Pollen grains are made in its four pollen sacs. When they are ripe, the anther splits open and sheds them.

Pollen grains Every sac is packed with them. Each grain grows from a cell made by meiosis, so it has one set of chromosomes, and so do the gametes it makes.

Two male gametes Made inside the pollen grain (in many plants only once its tube has started to grow). They cannot swim: the pollen tube carries them to the egg cell.

Central cell A large cell beside the egg cell. The second male gamete fuses with it, and that starts a food store for the seed. The IB does not ask for this.

Micropyle A tiny gap in the ovule wall. The pollen tube enters the ovule through it. In the seed it stays as a tiny pore, and water can get in through it.

Style A pollen grain on the stigma grows a tube down through the style to an ovule, carrying its male gametes.

Stigma Pollen lands here. Pollination is pollen carried from an anther to a stigma.

Ovule Inside the ovary. Each ovule holds one egg cell, and after fertilization the whole ovule becomes a seed.

Pollen grains Every sac is packed with them. Each grain grows from a cell made by meiosis, so it has one set of chromosomes, and so do the gametes it makes.

Tube nucleus The nucleus of the pollen grain's tube cell, the cell that grows the pollen tube. It is not a gamete.

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Ovule wall Layers of cells round the ovule. After fertilization they become the seed coat, the testa.

Egg cell The female gamete. It has one set of chromosomes; when a male gamete fuses with it, it becomes a zygote.

Anther Pollen grains are made in its four pollen sacs. When they are ripe, the anther splits open and sheds them.

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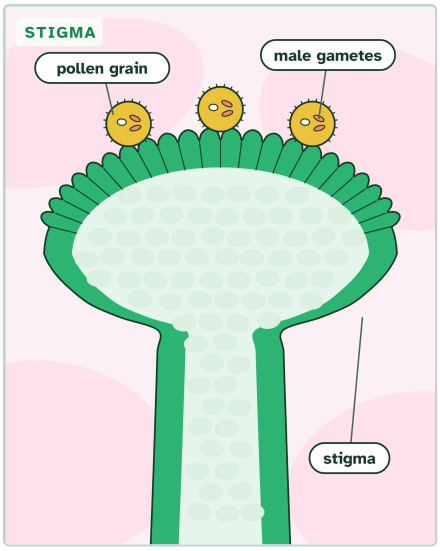
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ANIMATION · FROM POLLEN TO EMBRYO

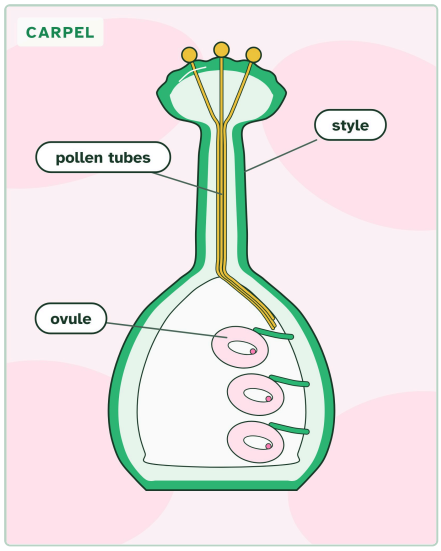
4 MOMENTS

1 MINUTES PASS



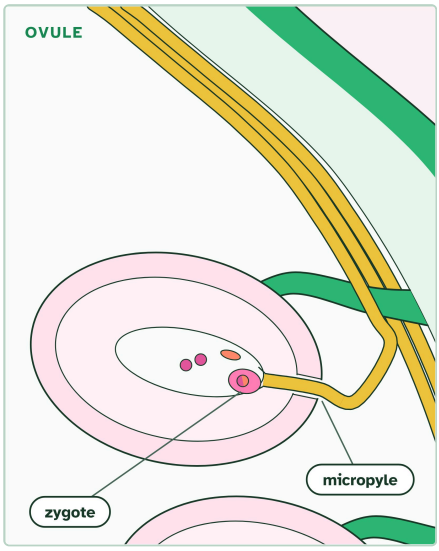
A **pollen grain** is not a gamete. It carries two **male gametes** inside it.

2 HOURS PASS



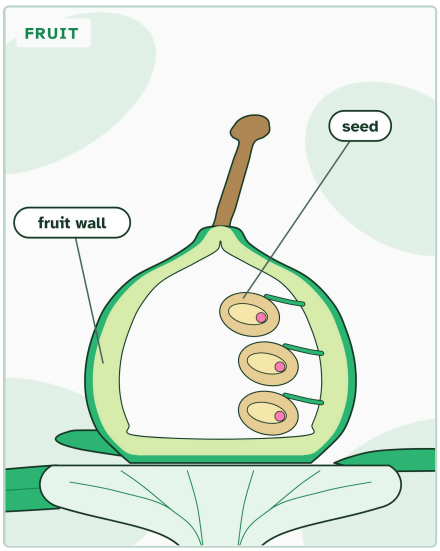
Over hours, each tube grows down through the **style** to an **ovule**.

3 HOURS PASS



One male gamete fuses with the **egg cell**: **fertilization**. The new cell is a **zygote**.

4 WEEKS PASS



Over weeks the ovule grows into a **seed** and the ovary into a **fruit**. The petals wither and fall.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#fertilization

PREDICT

A flower is fertilized by pollen from its own anthers. Is the seed the product of sexual reproduction?

(A) No: with only one parent involved, the seedling is a clone of that plant

(B) Yes: gametes from cells made by meiosis still fuse, as in a cross

(C) No: no insect carried the pollen, so no gametes were ever joined up

(D) Yes, but only because an insect still had to carry the pollen to it

Decide before you look. Answer on page 98.

03 Built for an *insect*

D3.1.9 03 FEATURES OF AN INSECT-POLLINATED FLOWER

Go deeperthe detail, who gains what

The detail

Nearly nine in ten species of flowering plant rely on animals to carry their pollen, most of them on insects.

Nectar guides: lines or spots on the petals that lead to the nectar. Some show only in ultraviolet light, which bees can see and we cannot.

Scent helps insects find the flower.

Sticky or spiky pollen clings to an insect's hairy body. A **sticky stigma** picks it off again.

Less pollen than a wind-pollinated flower makes: an insect carries it from flower to flower, so less is wasted.

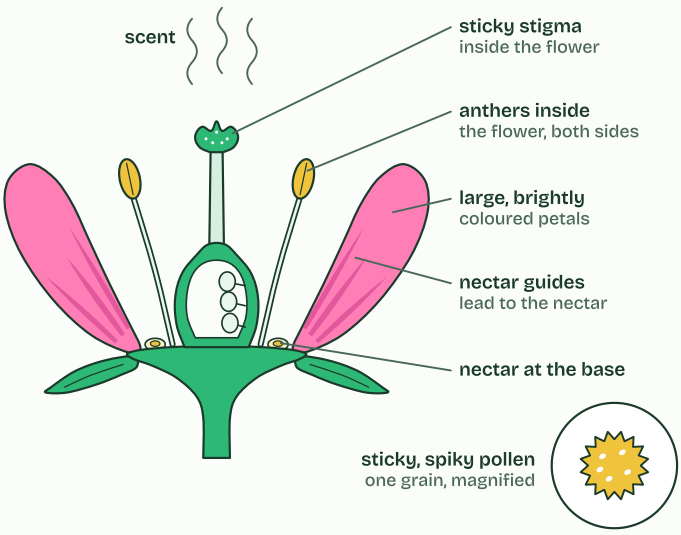
Who gains what

The insect is fed: nectar is a sugary drink, and bees also collect pollen, which is rich in protein, to feed their young.

The plant gets its pollen carried to another plant.

KEY TERMS

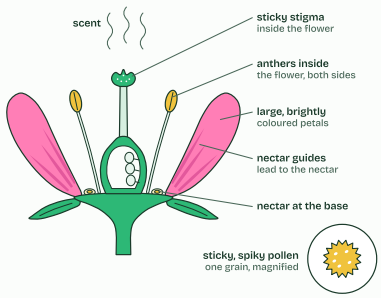
mutualism
A relationship between two species in which both benefit.



One flower built two ways. Answer the question in the text before you switch to the wind-pollinated flower.

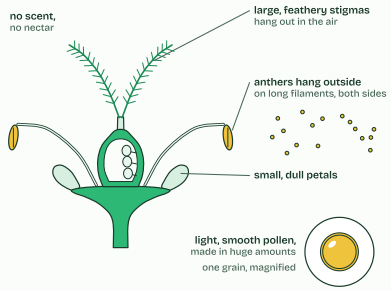
SWITCH IT
2 SETTINGS

1



Insect pollinated

2



Wind pollinated

Which kind of flower is built this way?

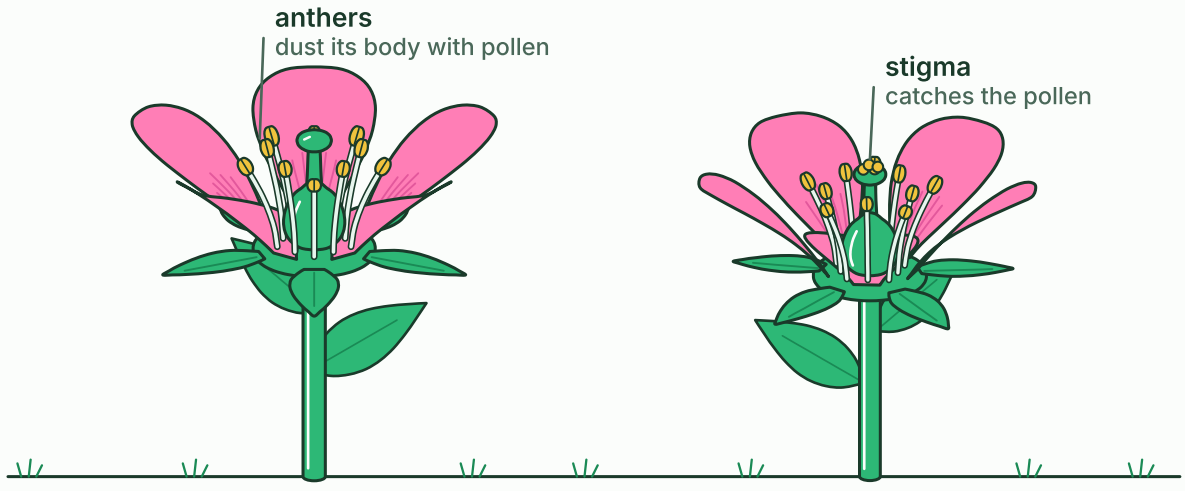
Insect-pollinated
built to attract and dust an insect

- bright petals
- sticky grains
- anthers inside
- scent, nectar
- less pollen
- sticky stigma

Wind-pollinated
built to shed and catch pollen

- feathery stigma
- no scent
- lots of pollen
- smooth grains
- anthers out
- dull petals

Petals, scent and nectar, pollen, anthers and stigma: each feature suits one way of being pollinated. Sort all twelve.

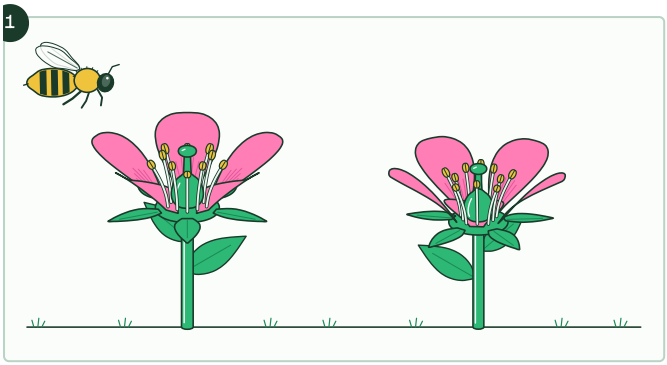


Predict which two parts the bee will brush, then watch its visit: where the pollen comes from, and where it goes.

STEP BY STEP

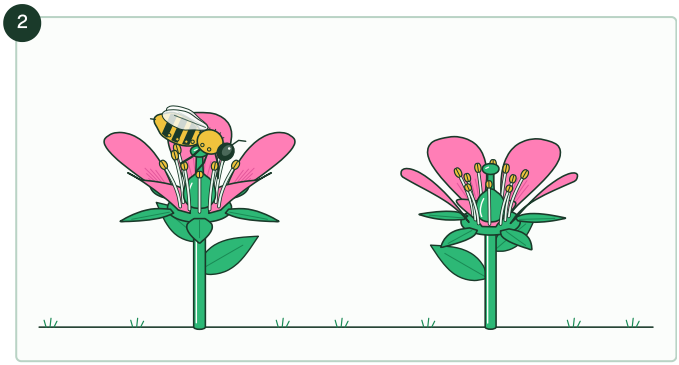
3 STEPS

1



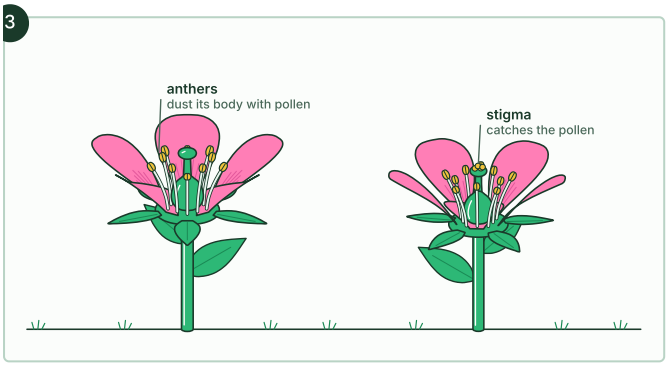
A bee flies in to feed. Which two parts of the flower must its body touch to carry pollen to another plant?

2



Reaching down for the nectar, it pushes between the stamens: the anthers brush its hairy body, and pollen sticks to it.

3



At a flower on another plant, its body presses on the sticky stigma, which catches some of the pollen. That is pollination: pollen carried from an anther to a stigma.

PREDICT

A flower has no scent, tiny green petals and feathery stigmas hanging outside it. How is it pollinated?

(A) By insects that fly at night and find their way to it by touch

(B) By its own pollen, which falls from its anthers onto its stigma

(C) By rain, which washes the pollen down from one flower to the next

(D) By the wind, which needs the stigmas out in the air, not insects

Decide before you look. Answer on page 98.

04 Getting pollen to *another plant*

D3.1.10 04 METHODS OF PROMOTING CROSS-POLLINATION

Go deeperthe detail, watch out

The detail

A hermaphrodite flower has its own pollen right beside its own stigma. Pollen from another plant brings a different set of alleles. Chapter 5 shows what too much selfing costs.

Different times: in many flowers the anthers shed their pollen before the same flower's stigma is ready. In others the stigma is ready first.

Separate flowers: male flowers have stamens and no carpel, female flowers a carpel and no stamens, so pollen has to travel at least from one flower to another.

Separate plants: each plant is male or female.

The first two methods make self-pollination less likely, but do not stop it: pollen can still reach another flower on the same plant, one at a different stage or of the other sex.

The step-through draws the three methods. Then match three real plants to the way each one uses.

The film at the end shows each way at work, with maize, papaya and primrose as its plants.

Watch out

A **flower** with both male and female parts is hermaphrodite.

A **plant** with separate male and female flowers is monoecious ("one house").

A **species** with separate male and female plants is dioecious ("two houses").

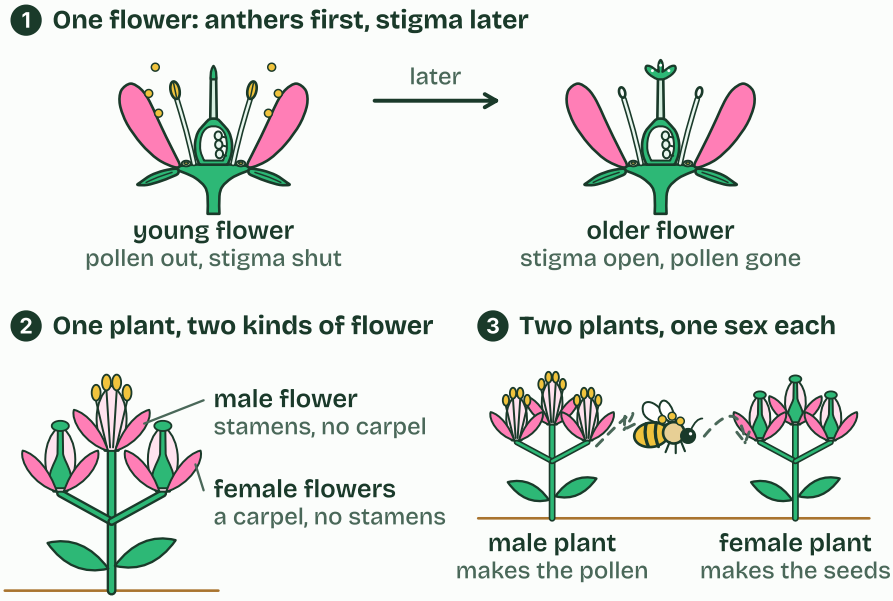
The IB does not ask for the last two words, but you will meet them. They are about whole plants, not single flowers.

KEY TERMS

Self-pollination
Pollen reaching a stigma of the same flower, or of another flower on the same plant.

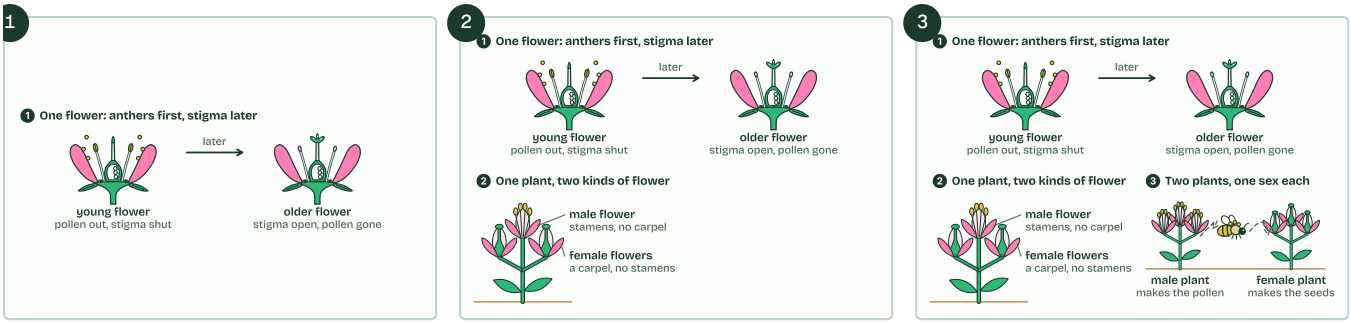
Cross-pollination
Pollen from one plant reaching a stigma on another plant of the same species.

flower
The organ of sexual reproduction in a flowering plant.



STEP BY STEP

3 STEPS

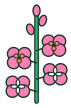


Different times. In this flower the anthers ripen first and shed their pollen while the stigma is still shut. By the time the stigma opens, the flower's own pollen has gone.

Separate male and female flowers on one plant. Pollen has to travel at least from one flower to another, though it can still be on the same plant.

Separate male and female plants. Each plant is one sex.

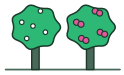
Three plants



Rosebay willowherb
Each young flower sheds its pollen while its own stigma is still shut.



Maize
Wind blows pollen from the tassel at the top to silks on the cobs lower down.



Holly
Only some bushes ever carry berries, and only with another holly nearby.

Three ways to get pollen to another plant

Different times
one flower, two stages
Rosebay willowherb

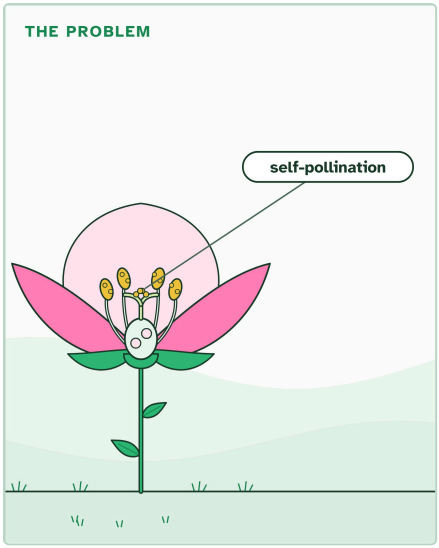
Separate male and female flowers
both on one plant
Maize

Separate male and female plants
each plant one sex
Holly

Three real plants and three ways to get pollen to another plant. Which way does each one use, and what in its clue tells you?

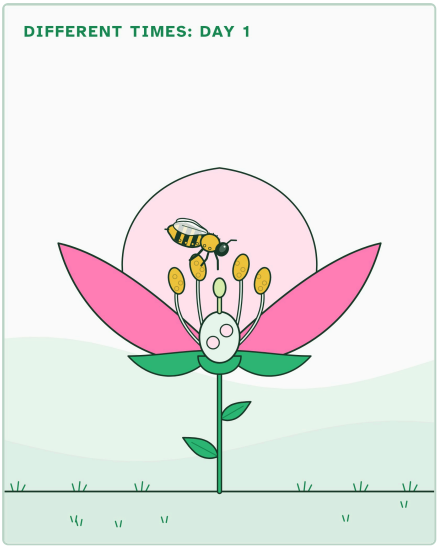
ANIMATION · KEEPING POLLEN FROM ITS OWN STIGMA
6 MOMENTS

1 THE PROBLEM



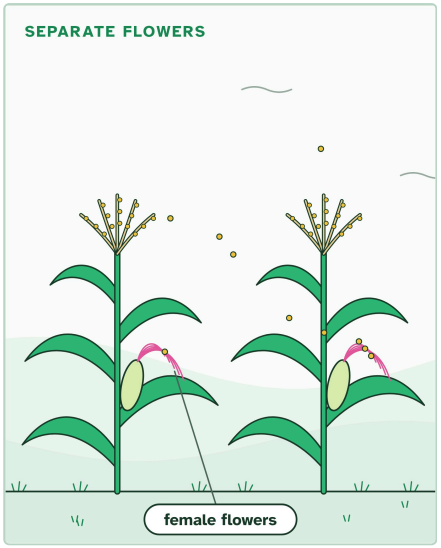
A flower's own pollen can land on its own stigma: **self-pollination**. The seeds then have one parent, so they vary little: **inbreeding**.

2 WAY 1 OF 5



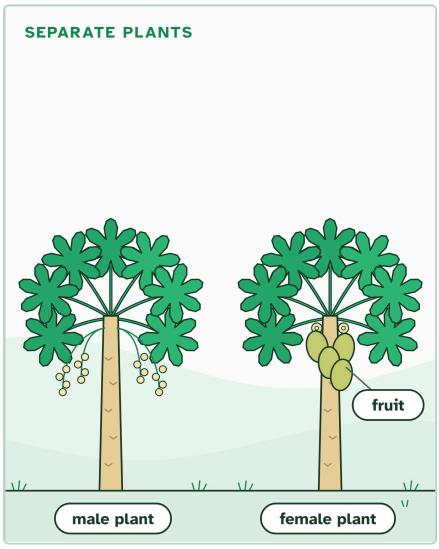
Different times. On day 1 the anthers shed their pollen while the stigma is still shut. An insect carries the pollen away.

3 WAY 2 OF 5



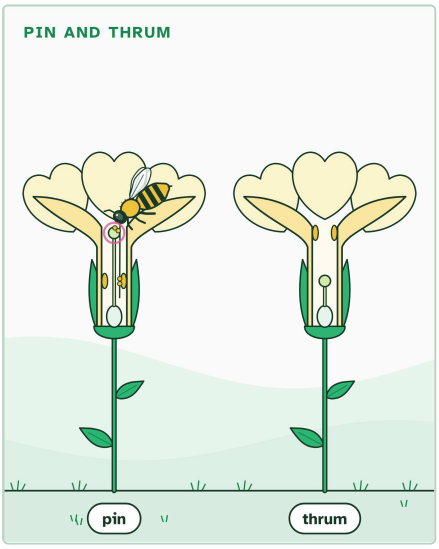
Separate male and female flowers on one plant, as in maize. Wind blows pollen from the male flowers to female flowers, often on another plant.

4 WAY 3 OF 5



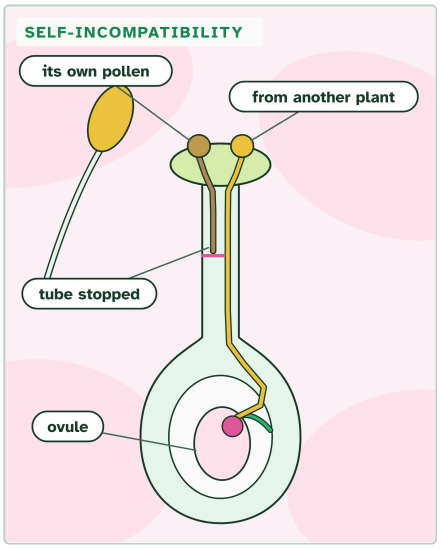
Separate male and female plants, as in papaya. A moth brings pollen from a male plant. A female plant makes none, so every seed in its fruit has two parents.

5 WAY 4 OF 5



Thrum pollen sticks to the insect about where a pin's stigma will touch it, and pin pollen where a thrum's stigma will.

6 WAY 5 OF 5



Self-incompatibility. If a plant's own pollen still lands, its genes stop that pollen tube in the style. Pollen from another plant grows on to an ovule.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#cross

PREDICT

In one species, some plants have only male flowers and the rest only female ones. What does this guarantee?

(A) Every seed is identical to its mother, since only the females make seeds

(B) Every seed has two parents: a female can get pollen only from a male

(C) The plants need no pollinator, since the males grow beside the females

(D) Half of all the seeds come from selfing, because half the plants are female and half male

Decide before you look. Answer on page 98.

D3.1.11 05 SELF-INCOMPATIBILITY MECHANISMS TO INCREASE GENETIC VARIATION WITHIN A SPECIES

05 Refusing your *own* pollen

Go deeperthe detail, how self-incompatibility works, how we know, watch out

The detail

A plant's own pollen and its own ovules draw on the same pairs of alleles, so its seedlings are more often **homozygous** for a gene (D3.2 has the words).

In a simple case, each generation of selfing halves the share of plants with two different alleles. The step-through shows it.

Diversity falls: seeds differ less and less from each other, so there is less variation for natural selection to act on (D4.1).

Vigour falls: a plant that usually crosses carries harmful recessive alleles hidden beside dominant ones. Two copies let them show.

Inbred plants are more often small, weak or slow growing, and they make fewer seeds.

How self-incompatibility works

One well-studied kind is found in apple, cherry and petunia.

A self-incompatibility gene has many alleles in the species, and every plant carries two of them.

Each pollen grain carries just one of its parent's two alleles.

A grain's allele is checked against the two the plant carries.

Other species, cabbages among them, stop their own pollen on the stigma instead. The result is the same: seeds that come from two parents.

How we know

Darwin tested inbreeding with maize. He grew fifteen pairs of plants under the same conditions, one of each pair from a crossed flower and one from a self-pollinated flower.

On average the crossed plants grew taller.

Watch out

"Selfed offspring are identical to their parent." Where the parent has two different alleles of a gene, meiosis still shuffles them, so selfed seedlings differ from one another.

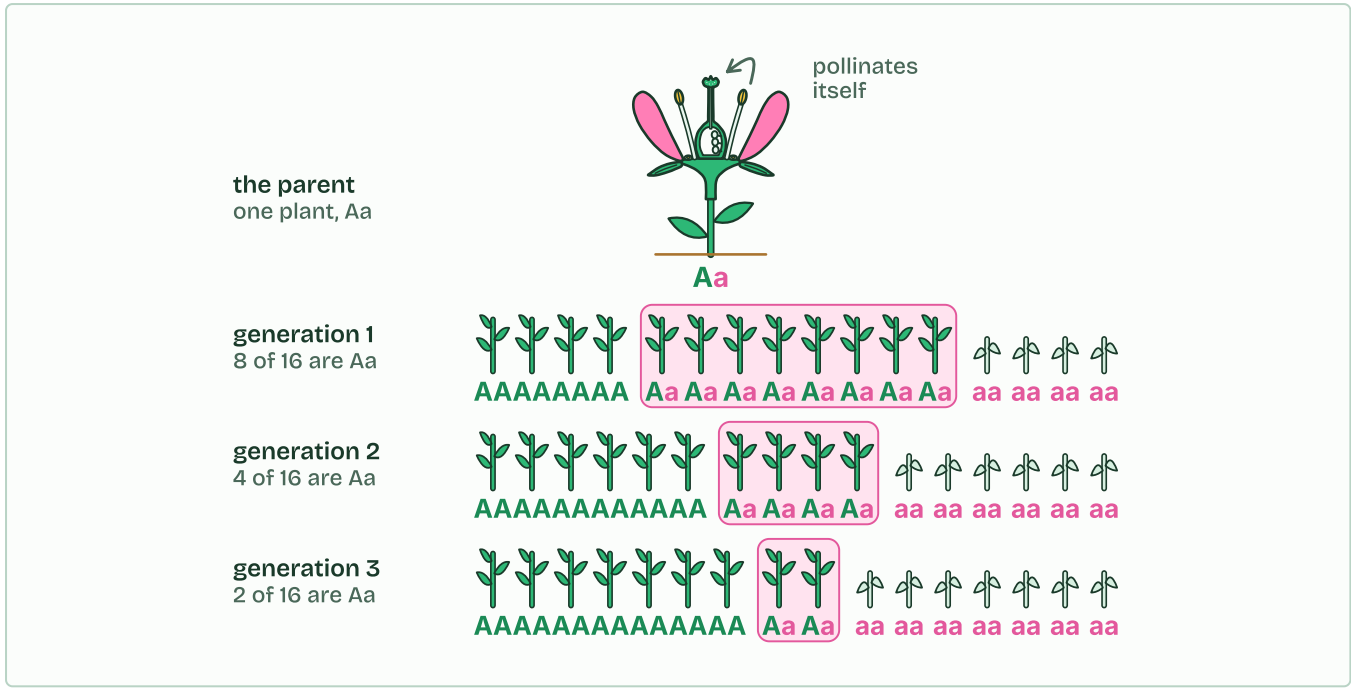
What selfing does is raise the share of offspring with two copies of the same allele.

KEY TERMS

inbreeding
Breeding between close relatives, or of a plant with itself, so that offspring more often get two copies of the same allele.

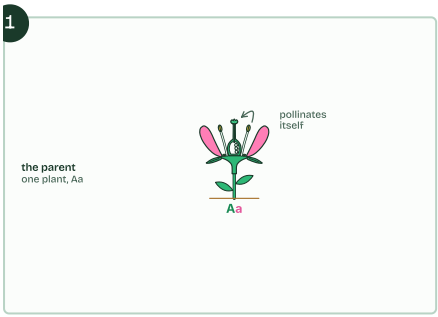
Self-incompatibility
A genetic mechanism that stops a plant's own pollen from fertilizing its ovules, so the gametes that fuse come from different plants.

homozygous
Having two copies of the same allele of a gene.



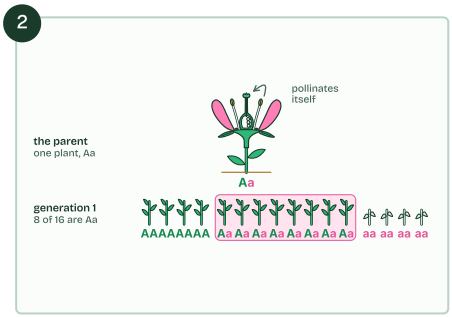
STEP BY STEP 4 STEPS

1



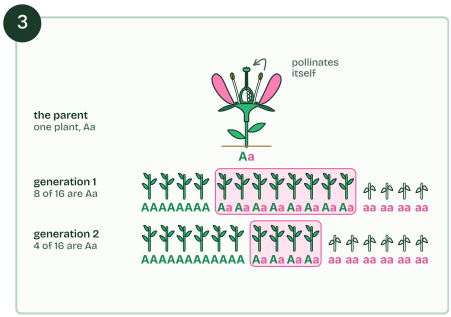
A plant carries two different alleles of a gene, **A** and **a**, where a is a harmful recessive allele. It pollinates itself, and we suppose every seedling grows up to do the same.

2



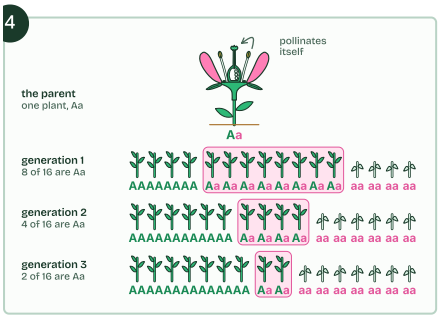
Its offspring: a quarter AA, a half Aa and a quarter aa. Only **8 of 16** still have two different alleles. The aa plants show the harmful allele: they are small and pale.

3

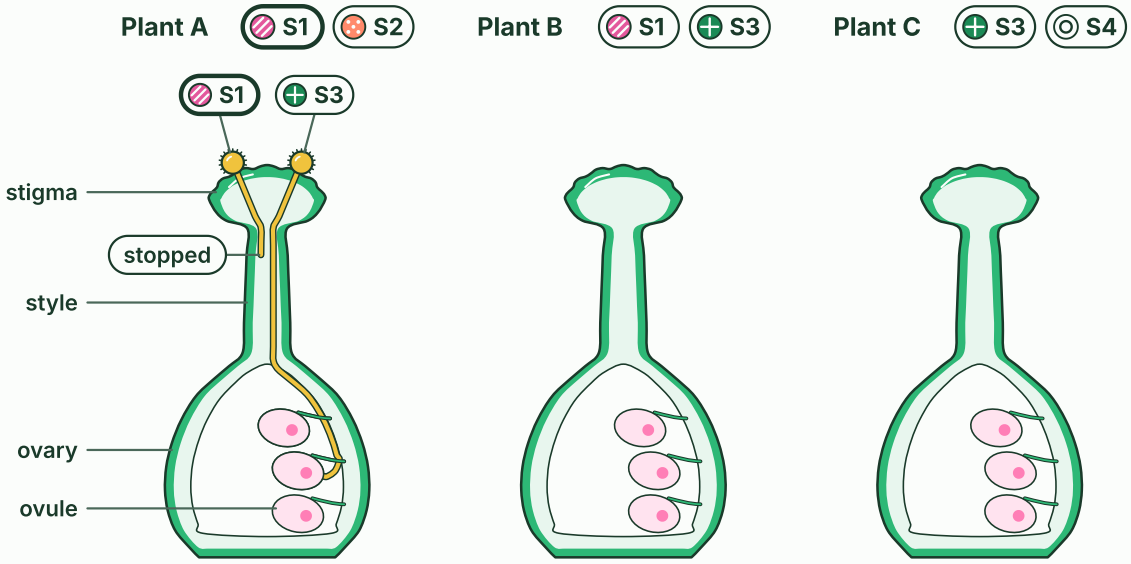


Every plant pollinates itself again. AA and aa plants pass on only one kind of allele, so only the Aa plants can make Aa offspring, and only half of theirs are Aa: **4 of 16**.

4



One more generation: **2 of 16**. The share with two different alleles halves every generation, from a half to a quarter to an eighth, while the weak aa plants rise from 4 to 6 to 7 of 16.

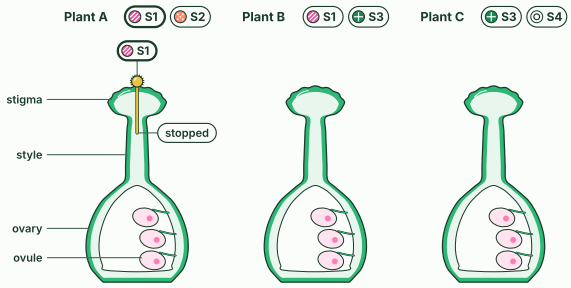


Predict Grow or Stop for each grain, then drop it on a stigma and watch its tube. Last, find the plant whose pollen all grows on plant A.

STEP BY STEP

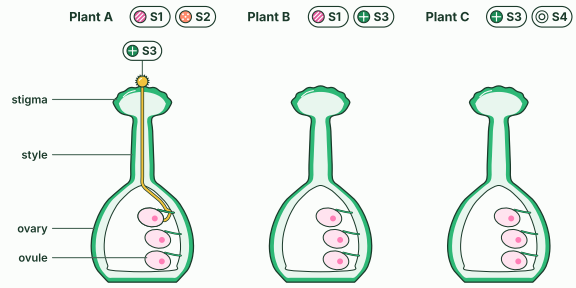
3 STEPS

1



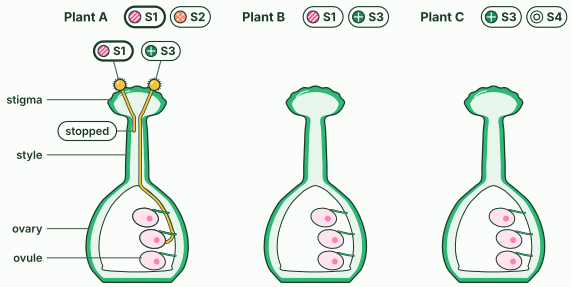
Plant A's own pollen: the grain carries S1, and plant A has S1 too, so plant A's style stops its tube in the top third.

2



Pollen from plant C: this grain carries S3, which plant A does not have, so its tube grows down the style to an ovule.

3



Pollen from plant B: its S1 grains are stopped and its S3 grains grow on, so only half of plant B's pollen can fertilize plant A.

PREDICT

Plant B, with alleles S1 and S3, sheds pollen onto the stigma of plant A, whose alleles are S1 and S2. What share of that pollen can grow a tube to an ovule?

(A) All of it, because B and A are two different plants with different alleles

(B) Half of it: the grains that carry S3 grow, and those that carry S1 stop

(C) None of it, because the two plants have an allele, S1, in common

(D) A quarter of it, because each plant carries only one allele in four

Decide before you look. Answer on page 98.

06 Moving the *seeds*

D3.1.12 06 DISPERSAL AND GERMINATION OF SEEDS

Go deeperthe detail, built for the way they travel

The detail

Both pollination and dispersal move something, and both often use the wind or an animal. Keep them apart by **what** is moved, and **when**.

A seed that drops straight under its parent competes with the parent, and with every other seed that fell there, for light, water and minerals.

Seeds carried away face less competition, and some reach new places where the species can grow.

Built for the way they travel

Wind: wings that spin and parachutes of fine hairs keep a seed in the air for longer, so it is blown further.

Animals: some fruits are juicy and eaten. Hooked fruits catch in fur and are carried off.

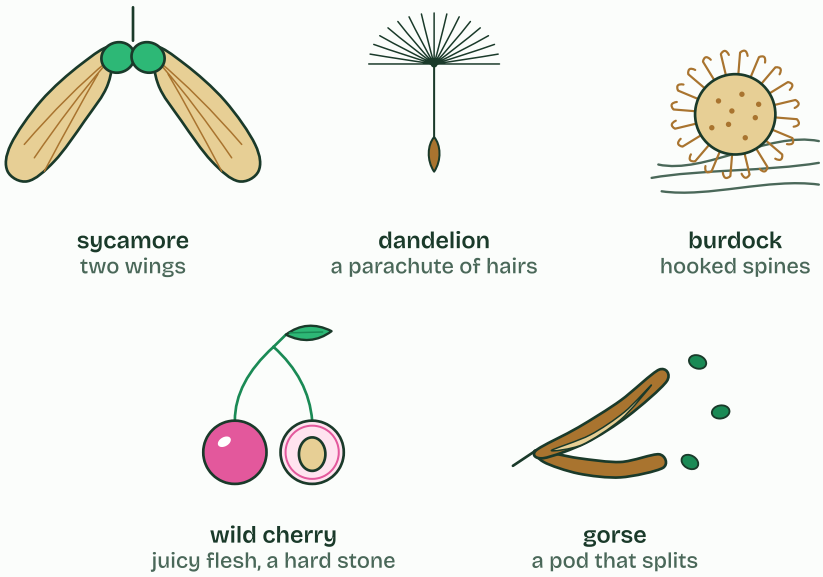
Water: some fruits float. A coconut can drift on the sea.

The plant itself: some pods dry out, split open and fling their seeds.

KEY TERMS

seed dispersal
The carrying of seeds away from the parent plant.

pollination
The transfer of pollen from an anther to a stigma.



sycamore
two wings

dandelion
a parachute of hairs

burdock
hooked spines

wild cherry
juicy flesh, a hard stone

gorse
a pod that splits

Sycamore: wind Each fruit has a long wing. As it falls it spins like a helicopter blade, which slows its fall, so the wind carries it further from the tree.

Burdock: animals, on the outside Its burs, dried heads full of fruits, are covered in hooks that catch in fur. An animal carries them off until they fall or are pulled out, often far from the parent.

Gorse: the plant itself On hot, dry days the ripe pods dry out and split with a crack, flinging the seeds up to a few metres.

Dandelion: wind Each fruit holds one seed under a parachute of fine hairs, which can keep it in the air for a long way.

Wild cherry: animals, on the inside Birds such as thrushes and blackbirds eat the juicy fruit. The hard stone with the seed inside is dropped or passed out later, often far from the tree.

Sycamore: wind Each fruit has a long wing. As it falls it spins like a helicopter blade, which slows its fall, so the wind carries it further from the tree.

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Gorse: the plant itself On hot, dry days the ripe pods dry out and split with a crack, flinging the seeds up to a few metres.

What is being moved: pollen or seeds?

Pollination
pollen moved to a stigma

- bee
- hazel catkins
- moth at night
- hummingbird

Seed dispersal
seeds moved from the parent

- sycamore fruit
- cherry stone
- burdock burs
- gorse pod

Wind and animals carry both pollen and seeds. Sort each card by what is being moved.

PREDICT

Why do many plants spend energy making fruits that animals eat?

(A) The animal carries the seeds off and drops them far from the parent

(B) The fruit feeds the seed as it germinates, so the seedling grows faster

(C) The animal pollinates the flower while it is eating the fruit there

(D) The fruit protects the seed from being eaten by the animal itself

Decide before you look. Answer on page 98.

07 A seed *wakes up*

D3.1.12 07 DISPERSAL AND GERMINATION OF SEEDS

Go deeperinside a broad bean, growing, mobilizing the food reserves, watch out, try it

Inside a broad bean

A dry seed is alive but almost inactive, and many can stay that way for months or years.

Soak a broad bean overnight and you can take one apart, as in the drawing.

Hilum: the scar where its stalk attached it to the pod.

Micropyle (chapter 2): a tiny pore beside the hilum that water can get in through.

Radicle: becomes the root. **Plumule:** becomes the shoot.

Cotyledons: two seed leaves swollen with stored starch and protein.

Growing

The radicle breaks out through the testa and grows down, anchoring the seedling and taking up water.

In a broad bean, as in many seedlings, the shoot is bent over in a hook as it pushes up through the soil, which protects its tip.

In the light it straightens, and its first leaves open and start to photosynthesise.

A broad bean's cotyledons stay below ground, inside the testa, and its first leaves come from the plumule.

In some other plants, such as the French bean, the cotyledons are lifted above the soil and turn green for a while.

Mobilizing the food reserves

Starch and protein molecules are too large to move out of the store.

Once the seed has taken up water, enzymes break them down.

Amylase hydrolyses starch to maltose, and **maltase** splits maltose into glucose.

Proteases break the stored proteins into amino acids.

Sugars and amino acids are small and soluble, so they can be carried to the tips of the radicle and plumule, where cells are dividing and growing.

There, glucose is respired to make ATP, or built into new molecules such as the cellulose of new cell walls. Amino acids are built into new proteins.

Watch out

"The cotyledons always come up as the first green leaves." Only in some seeds, such as the French bean.

"Maltose is built into cellulose." Cellulose is built from glucose.

Try it

Germinating seeds use oxygen fast enough to measure. C1.2's dry lab seals them in a respirometer, where a drop of coloured liquid creeps along a scale as they use it.

This guide's dry lab is a bench of cress seeds. Test what a seed needs with the water, the oxygen, the temperature or the light, and count how many seeds germinate.

KEY TERMS

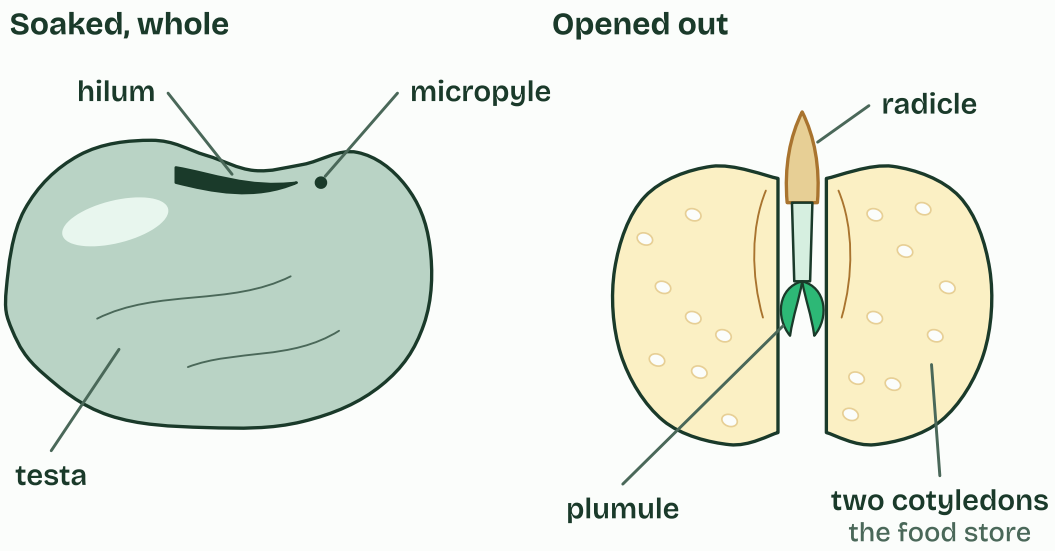
embryo
The young plant inside a seed, grown from the zygote by mitosis: a radicle, a plumule and one or two cotyledons.

testa
The tough seed coat, made from the outer layers of the ovule.

radicle
The embryo's root, the first part of a seed to grow out.

plumule
The embryo's shoot, which grows into the stem and the first leaves.

micropyle
A tiny gap in the outer layers of an ovule. The pollen tube grows in through it, and in the seed it stays as a tiny pore.



Testa The seed coat, made from the ovule wall. It is tough and protects the embryo inside; after a soak it peels off.

Micropyle A tiny pore beside the hilum: the gap in the ovule wall that the pollen tube once entered. Water can get into the seed through it.

Radicle The embryo's root. It is the first part to break out through the testa, and it grows down.

Hilum The scar where the seed's stalk attached it to the inside of the pod.

Cotyledons The two seed leaves, swollen with stored food: starch, and protein too. A broad bean's stay below ground and feed the seedling until its leaves can photosynthesise.

Plumule The embryo's shoot, its first tiny leaves folded at its tip. It grows up into the stem and leaves.

Testa The seed coat, made from the ovule wall. It is tough and protects the embryo inside; after a soak it peels off.

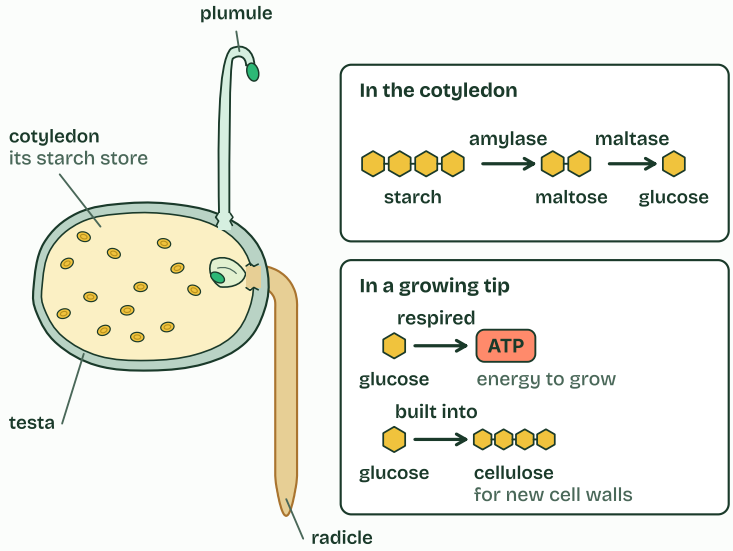
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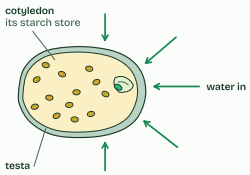
Plumule The embryo's shoot, its first tiny leaves folded at its tip. It grows up into the stem and leaves.



STEP BY STEP

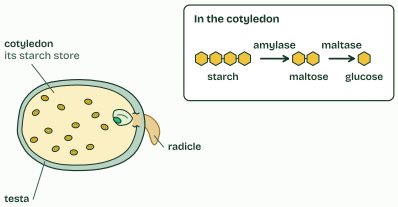
4 STEPS

1



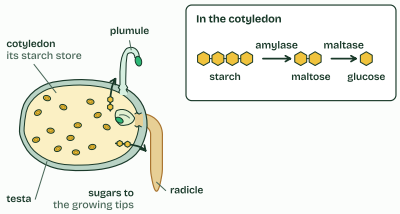
Water soaks in through the testa and the micropyle. The seed swells, and its enzymes start to work.

2



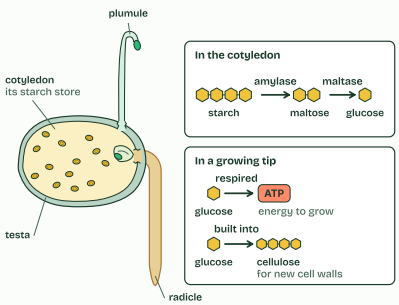
In the cotyledons, **amylase** hydrolyses starch to maltose, and **maltase** splits maltose into glucose. Proteins are broken down to amino acids. The radicle breaks out through the testa.

3



Sugars and amino acids are carried to the growing tips: into the radicle, and up into the plumule.

4



In a growing tip, glucose is **respired** to make ATP, or **built into cellulose** for new cell walls. The radicle grows longer and the plumule pushes up.

REMEMBER IT

What a seed needs: a waking seed says "Wow! Oh, wow!"

W Wow	O Oh	W Wow
Water taken up by the dry seed	**Oxygen** for the seed's respiration	**Warmth** a suitable temperature

PREDICT

Seeds are kept warm and damp in a jar with almost no oxygen. What happens?

(A) Most germinate as usual, since the food store holds the energy they need

(B) They germinate faster than usual, because the jar keeps them so damp

(C) They germinate, but their seedlings soon turn green with no oxygen

(D) Few or none germinate: without oxygen they make too little ATP to grow

Decide before you look. Answer on page 99.

08 Copies or new *combinations*

D3.1.1 08 DIFFERENCES BETWEEN SEXUAL AND ASEXUAL REPRODUCTION

Go deeperthe detail, examples, watch out

The detail

A clone is genetically identical to the parent and to each other, apart from rare mutations.

In sexual reproduction the two gametes usually come from two parents, so a family is varied.

Asexual: a combination of alleles that already works in that place is passed on whole, quickly and cheaply, with no partner to find.

Sexual: variation gives natural selection something to act on (D4.1).

Each has a cost. Sex takes energy for gametes and a partner to meet. A clone shares one genotype, so a disease that can kill one can kill them all.

Examples

A *Hydra* grows a bud that breaks off.

A spider plant sends out plantlets on runners.

A bacterium splits in two.

Aphids do both: they breed asexually all summer, filling a plant fast, and switch to sexual reproduction in autumn, when conditions are about to change.

Watch out

"Sexual reproduction is simply better." It wins where things change and loses where they stay the same.

Asexual reproduction is not only for simple organisms: plants and some animals do it too.

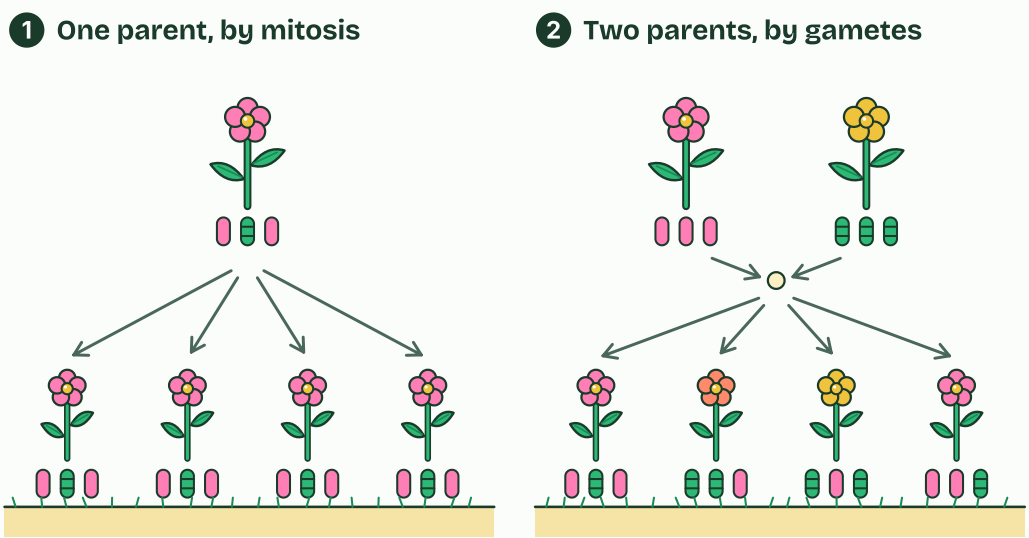
"Sexual" does not always mean two parents: chapter 2's flower pollinated itself, and its seeds were still not copies.

KEY TERMS

asexual reproduction
Reproduction by one parent alone, by mitosis, with no gametes; the offspring are genetically identical to the parent.

clone
A group of genetically identical organisms, all descended from one parent by asexual reproduction.

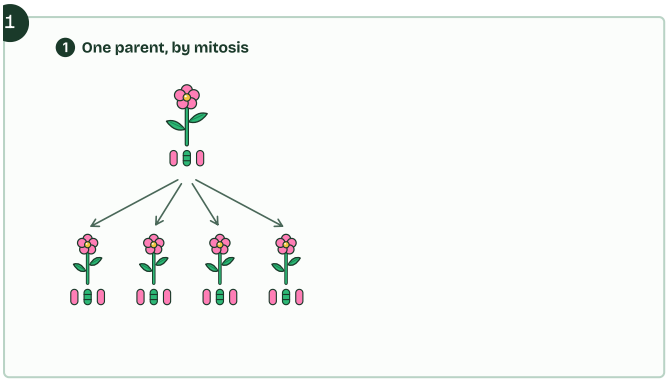
sexual reproduction
Reproduction in which two gametes, made by meiosis, fuse; the offspring carry new combinations of alleles.



the same field, no change: every young plant grows

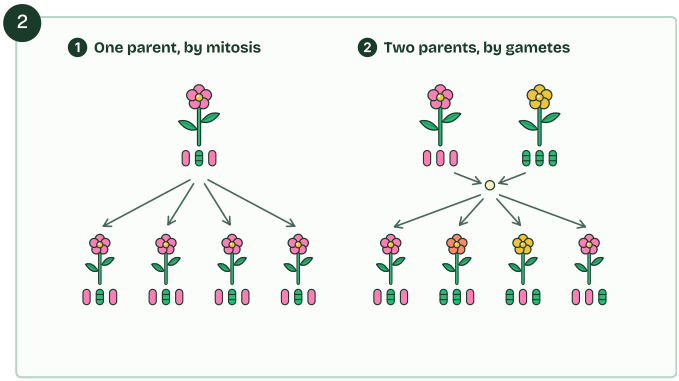
STEP BY STEP
3 STEPS

1



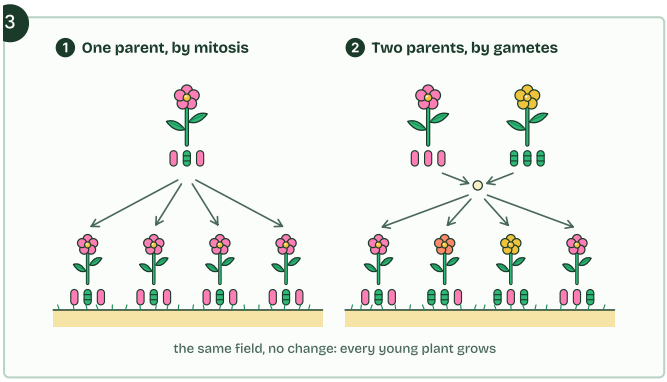
One parent makes four offspring by mitosis. Each carries the parent's own chromosomes: all four are the same as the parent and as each other.

2



Two parents each make gametes by meiosis, and pairs of gametes fuse. Each of the four offspring carries a different mixture of the two parents' chromosomes.

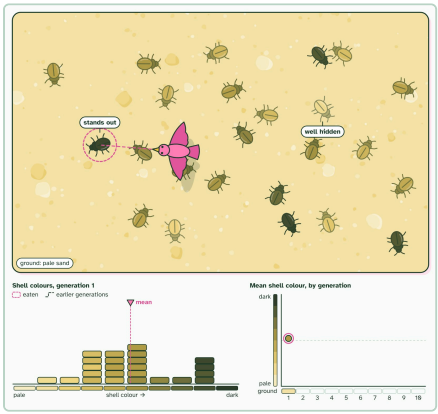
3



Both families grow in the same field, where nothing has changed. The clone suits it as well as its parent did, and so far every plant survives.

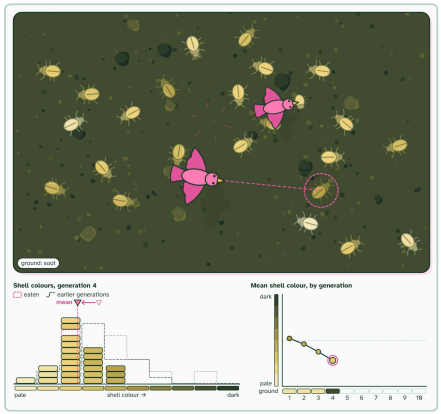
ANIMATION · WHEN THE ENVIRONMENT CHANGES
3 MOMENTS

1 GENERATION 1



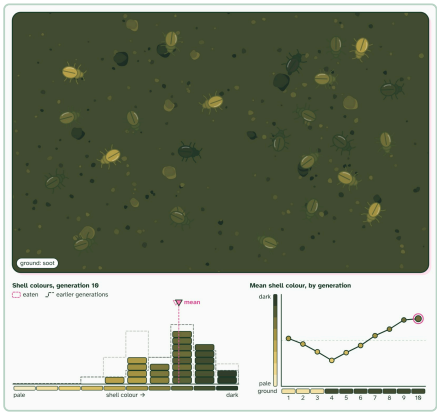
Birds spot the beetles that stand out. The **best hidden** survive and breed.

2 GENERATION 4



Then soot from a fire darkens the ground. Now the **pale** beetles stand out.

3 GENERATION 10



No beetle ever changed its shell. The **population** changed: that is evolution.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#copies

PREDICT

A new disease sweeps through two fields: one of plants all grown from cuttings of a single parent, and one of plants grown from seed. Which field is more likely to lose almost every plant, and why?

(A) The field of cuttings, because every plant has the same alleles, so if one is open to the disease all are

(B) The field grown from seed, because seedlings are always weaker and slower to fight off an infection

(C) Neither field, because a new disease kills plants at random, whatever alleles each of them happens to carry

(D) The field of cuttings, because cuttings cannot take up water or fight disease until they grow new roots

Decide before you look. Answer on page 99.

09 Halve, then fuse, *round and round*

D3.1.2 09 ROLE OF MEIOSIS AND FUSION OF GAMETES IN THE SEXUAL LIFE CYCLE

Go deeperone human life round the loop, the alleles are shuffled twice, watch out

One human life round the loop

A zygote has 46 chromosomes in 23 pairs, one of each pair from each parent: it is diploid.

Mitosis builds the whole body from it, every cell with the same 46.

In the ovaries or testes some cells divide by meiosis and make gametes with one of each pair, 23 in all: haploid.

Two gametes fuse, the number is back to 46, and the loop closes.

D3.2 shows the halving and the fusing step by step (D3.2, chapter 1).

The alleles are shuffled twice

In meiosis: each gamete gets one of each pair, and which one is down to chance, so a parent's gametes differ from each other. Crossing over mixes them further.

At fusion: which egg meets which sperm is also chance.

Watch out

Gametes are made by **meiosis**, not mitosis.

The zygote has 46 chromosomes, not 23.

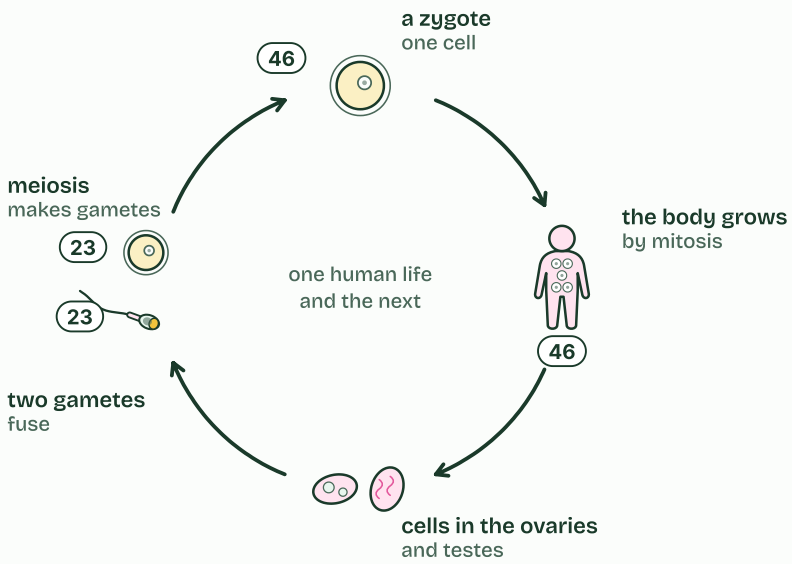
Meiosis makes no new alleles: it shuffles the ones there are. New alleles come only from mutation.

KEY TERMS

meiosis
A division of the nucleus in two stages that halves the chromosome number and makes cells with new combinations of alleles.

haploid
Having one set of chromosomes (in humans 23).

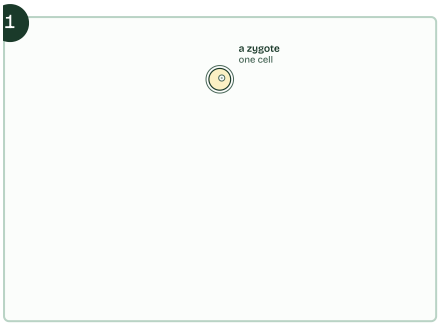
diploid
Having two sets of chromosomes, one from each parent (in humans 46).



STEP BY STEP

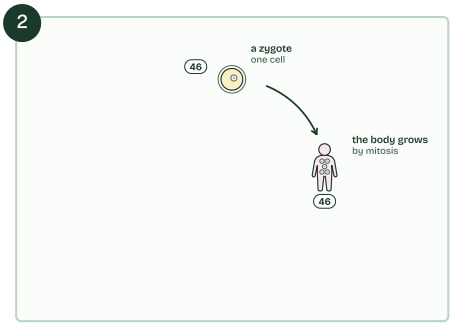
5 STEPS

1



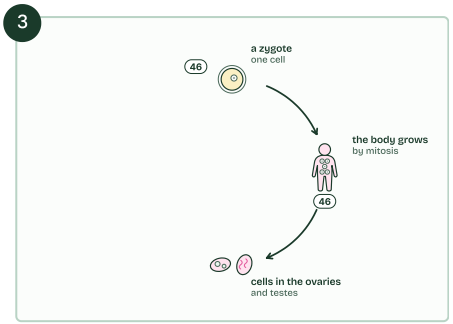
A new life starts as one cell, a zygote.

2



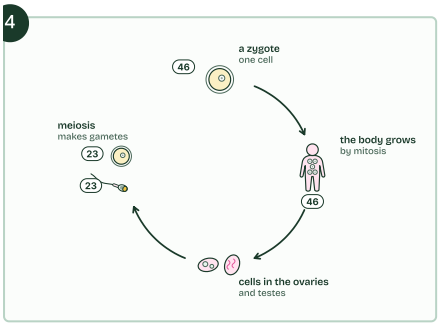
The body grows by mitosis: every cell keeps all **46** chromosomes.

3



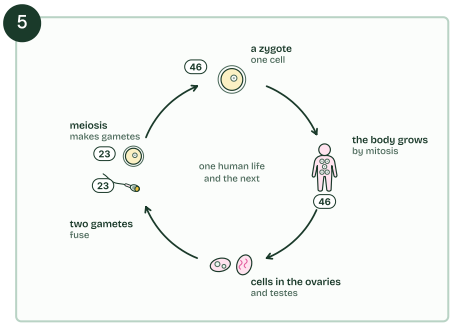
In the ovaries or testes, some cells are set aside to make gametes.

4



They divide by meiosis: each gamete has **23**, one of each pair.

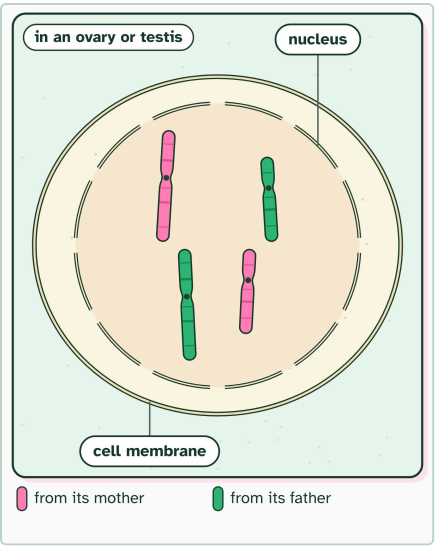
5



An egg and a sperm fuse, 23 and 23 make 46 again, and the loop begins once more.

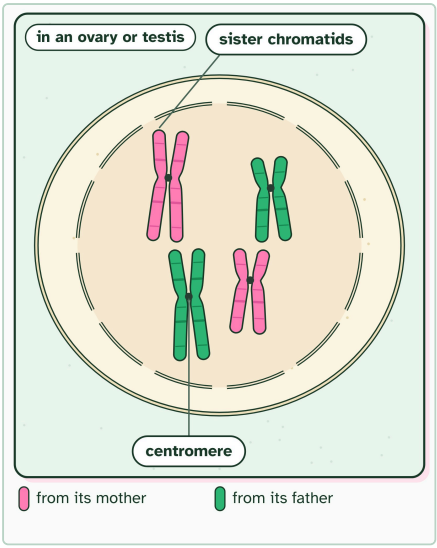
ANIMATION · HALVING, THEN FUSING, AGAIN
9 MOMENTS

1 DIPLOID CELL, 2N = 4



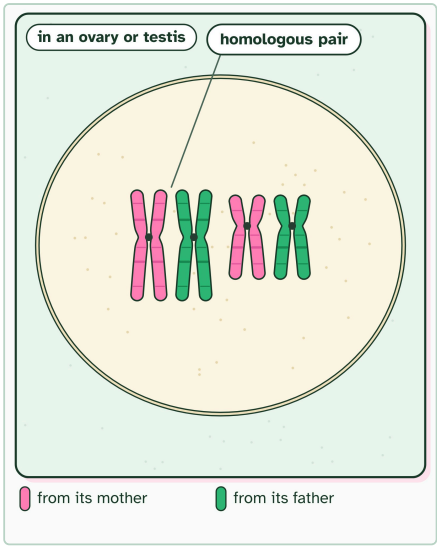
A **diploid** cell of a parent. Its chromosomes are in pairs: one of each pair came from its mother (pink), one from its father (green).

2 2N = 4, DNA COPIED



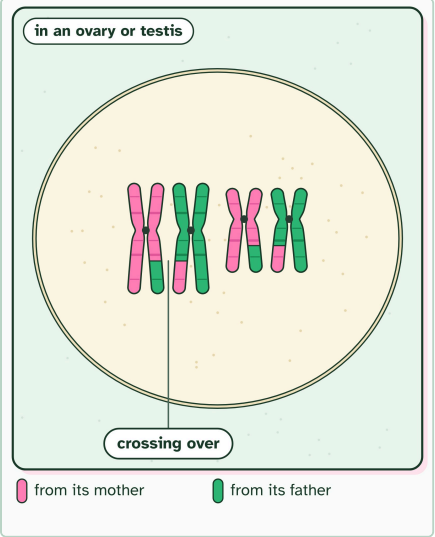
First the DNA is copied: each chromosome becomes two identical **sister chromatids**, joined at a **centromere**.

3 2N = 4, DNA COPIED



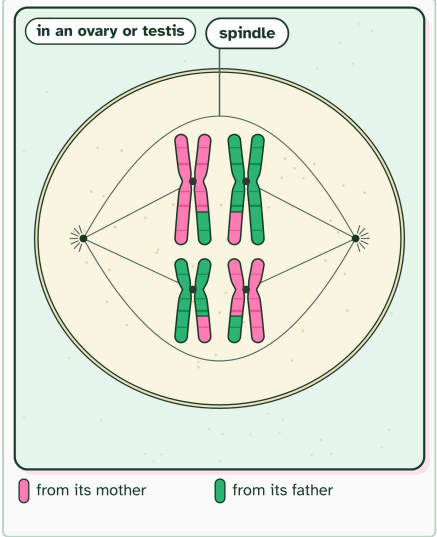
The nucleus breaks down and each chromosome lies beside its partner: a **homologous pair**, with the same genes in the same order.

4 2N = 4, DNA COPIED



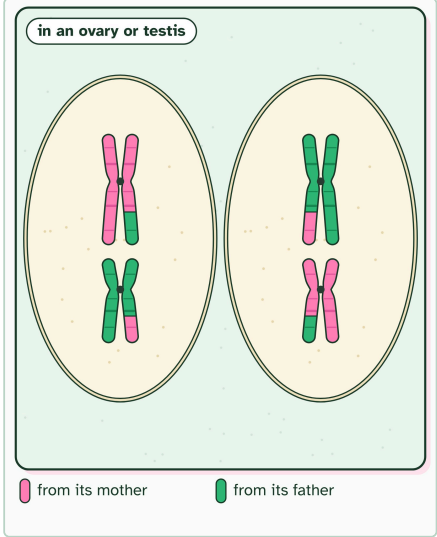
Crossing over: chromatids of a pair swap matching sections, making new mixes of the mother's and the father's alleles.

5 2N = 4, DNA COPIED



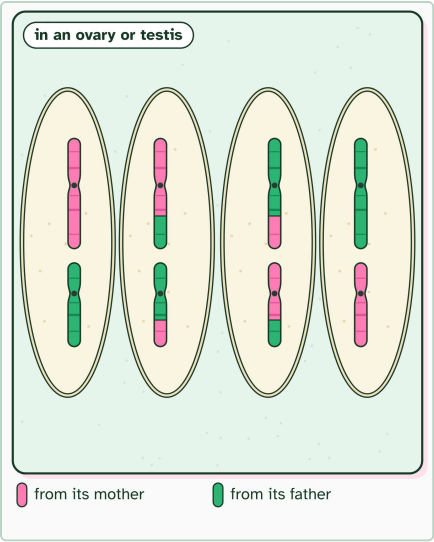
A spindle forms and the pairs line up across the middle. Which way round each pair lies is down to chance: **random orientation**.

6 2 CELLS, N = 2



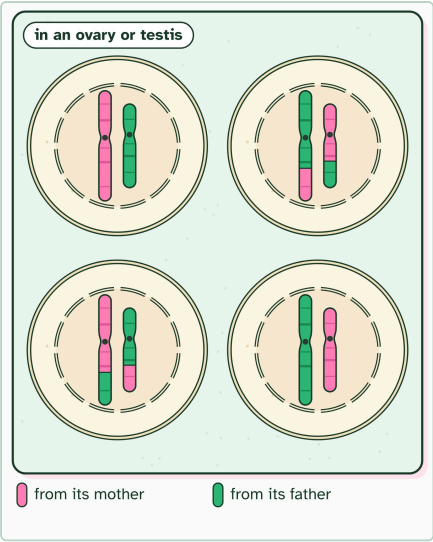
Meiosis I: one chromosome of each pair is pulled to each end, and the cell divides. Each new cell has half the number of chromosomes.

7 4 CELLS, N = 2



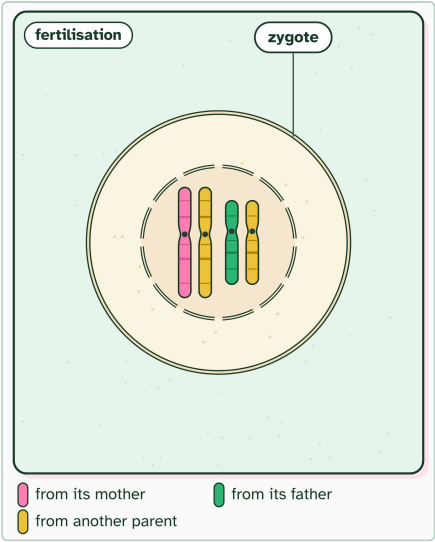
Meiosis II: in each cell the sister chromatids are pulled apart, and both cells divide again.

8 4 GAMETES, N = 2



Four **haploid** gametes, each with one chromosome of every pair, and no two alike.

9 ZYGOTE, 2N = 4



Fertilisation: the gamete fuses with one from another parent (yellow). The **zygote** is diploid again, with one of each pair from each parent.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#lifecycle

PREDICT

Two brothers have the same two parents and are not identical twins. Why are they not copies of each other?

(A) One of them must carry a new mutation, because the same two parents would otherwise always make identical children

(B) Their father's sperm changed as he grew older, so the second son was given different alleles from the first son

(C) Each parent's meiosis shared out different alleles into each egg and sperm, and a different egg met a different sperm

(D) Their mother's body changes the genes in each egg as it matures in the ovary, so no two of her eggs are ever alike

Decide before you look. Answer on page 99.

10 One travels, *one waits*

D3.1.3 10 DIFFERENCES BETWEEN MALE AND FEMALE SEXES IN SEXUAL REPRODUCTION

Go deeperthe detail, examples, links across the course, watch out

The detail

A gamete that travels must be small and light. A gamete that waits can be large, with food reserves for the zygote's first days.

The words describe gametes, not how anyone behaves.

Small gametes are cheap: a man makes on the order of a hundred million sperm a day from puberty on, and one ejaculation holds tens to hundreds of millions.

Large gametes are costly: a woman usually releases one egg a cycle, a few hundred in a lifetime.

One sex makes a great many cheap gametes. The other puts more into each gamete, and in mammals then into the young: the embryo develops inside her and is fed after birth.

Examples

How care is shared varies between species: in birds both parents often feed the young, and a seahorse father carries the eggs.

A flowering plant follows the same rule. Pollen grains are tiny and made in millions. The ovule waits in the ovary with a food store (chapters 2 and 7).

Plants that cannot move rely on other species to carry their pollen and seeds: insects, birds and mammals (chapters 3 and 6).

Links across the course

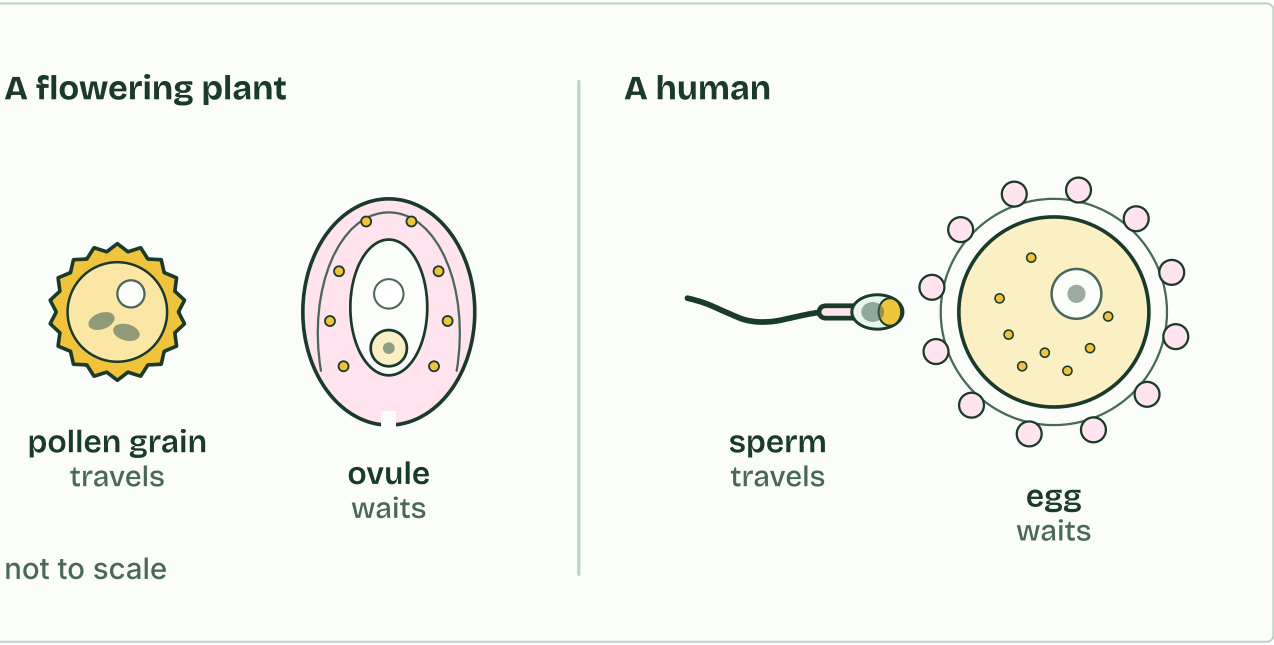
Whether a person has XX or XY chromosomes is another subject: D3.2, chapter 11.

Watch out

The egg is **far bigger** than the sperm, not the same size.

The sperm carries half the chromosomes but almost none of the cytoplasm.

Males are not always the ones that compete or the ones that leave the care to others: it depends on the species.



Pollen grain A flowering plant's male gametes travel inside it, carried to another flower by an insect or the wind. It is tiny and light, with almost no food, and an anther makes thousands.

Ovule It stays in the ovary, and the egg cell inside it waits. After fertilization the ovule becomes the seed, with a store of food for the embryo (chapter 7).

Sperm The male gamete swims to the egg. It is one of the smallest cells in the body: a nucleus, an engine of mitochondria and a tail, and almost no food. Millions are made every day.

Pollen grain A flowering plant's male gametes travel inside it, carried to another flower by an insect or the wind. It is tiny and light, with almost no food, and an anther makes thousands.

Egg The female gamete waits to be reached. It is one of the largest cells in the body, its cytoplasm stocked for the first days of the zygote. Only a few hundred are released in a lifetime.

Ovule It stays in the ovary, and the egg cell inside it waits. After fertilization the ovule becomes the seed, with a store of food for the embryo (chapter 7).

Sperm The male gamete swims to the egg. It is one of the smallest cells in the body: a nucleus, an engine of mitochondria and a tail, and almost no food. Millions are made every day.

Egg The female gamete waits to be reached. It is one of the largest cells in the body, its cytoplasm stocked for the first days of the zygote. Only a few hundred are released in a lifetime.

PREDICT

A gamete has to swim a long way to reach its partner. What does being small let the parent do, and what does it cost the gamete?

(A) It lets the gamete carry more food on the journey, and it costs the gamete its speed

(B) It lets the parent make far more of them for the same energy, and each carries almost no food

(C) It lets the parent make fewer gametes that are each certain to arrive, and costs the gamete nothing

(D) It lets the gamete share its partner's food, and costs it the chance of being chosen by the egg

Decide before you look. Answer on page 99.

D3.1.4 11 ANATOMY OF THE HUMAN MALE AND FEMALE REPRODUCTIVE SYSTEMS

11 The male-typical *system*

Go deeperthe detail, in the exam, watch out

The detail

Follow the structures in the order a sperm meets them.

Testis (two): sperm are made in its coiled seminiferous tubules, testosterone in the cells between the tubules.

Epididymis: a long coiled tube on each testis.

Sperm duct (vas deferens): runs up from the scrotum and over the bladder to the urethra.

Seminal vesicles: their fluid is rich in fructose, a sugar the sperm respire.

Prostate gland: its fluid is thin and milky.

Semen as a whole is slightly alkaline, which helps sperm survive the acid of the vagina.

Urethra: carries semen, or urine, never both at once.

Testosterone (chapter 17) brings on the changes of puberty and keeps sperm production going.

In the exam

Draw the male-typical system from memory first, then check it against the step-through and the tool.

Annotate each structure with its job.

The bladder and the pelvic bones are drawn so you can see where the organs lie.

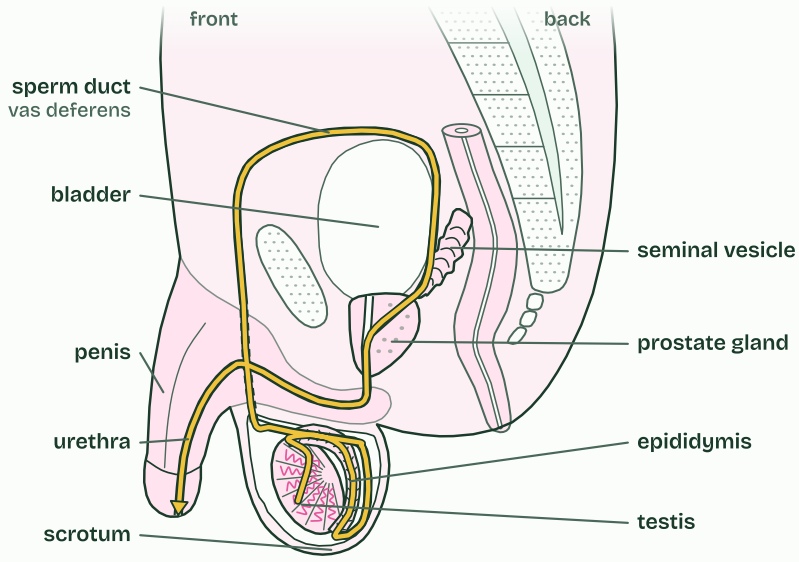
Watch out

The testes make **sperm, not semen**: the glands add most of the fluid.

Sperm are made in the testis and mature in the epididymis.

Testosterone comes from the cells between the tubules, not the tubules.

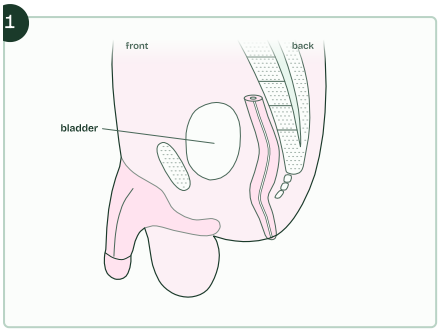
The urethra carries urine as well as semen.



STEP BY STEP

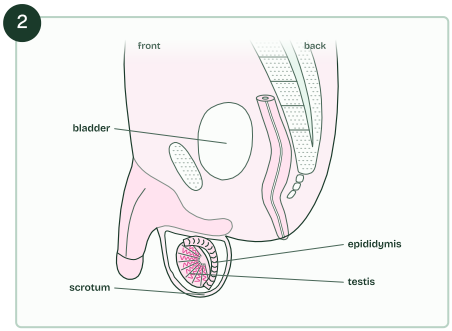
5 STEPS

1



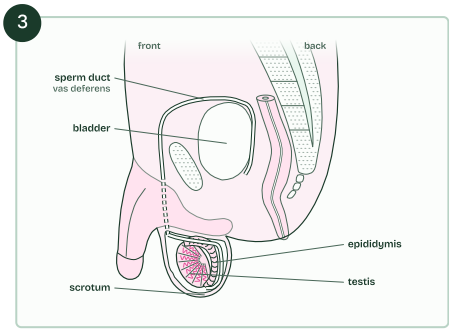
The pelvis cut down the middle and seen from the side: the pubic bone at the front, the bladder behind it.

2



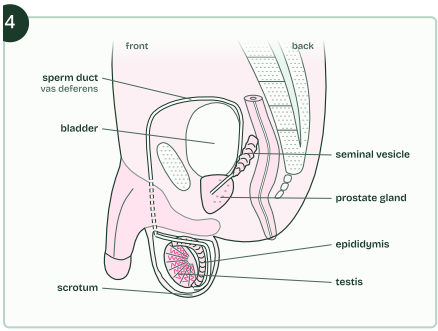
A testis in the scrotum, below the body, with the epididymis on it.

3



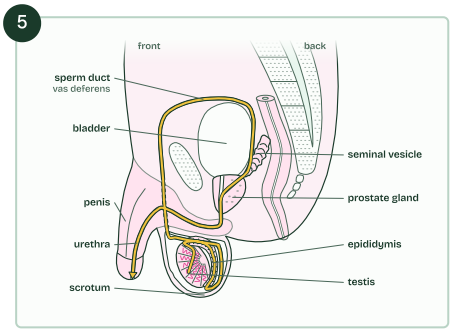
The sperm duct runs up from the epididymis, loops over the bladder and turns down behind it.

4

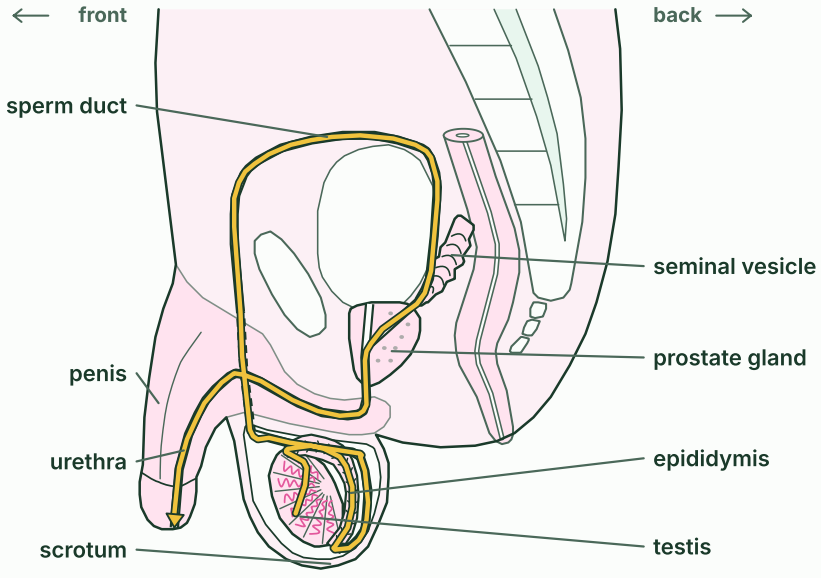


The seminal vesicle behind the bladder and the prostate gland under it add their fluids.

5



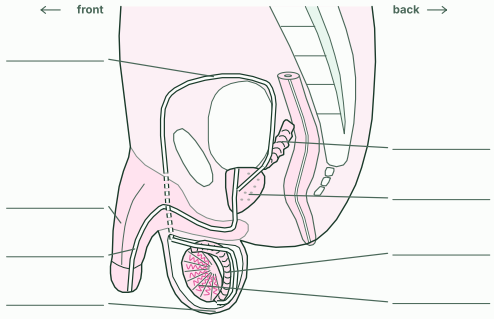
The urethra runs from the bladder through the prostate and along the penis. The gold line is the sperm's route out.



Tap each structure for its job, then label the drawing yourself and follow a sperm's route out of the body.

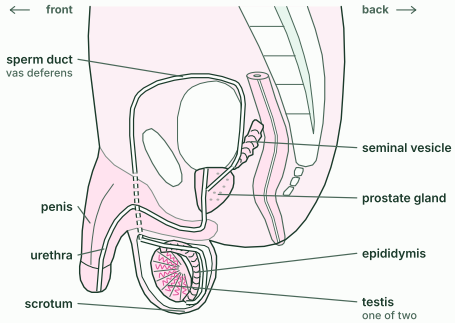
STEP BY STEP
3 STEPS

1



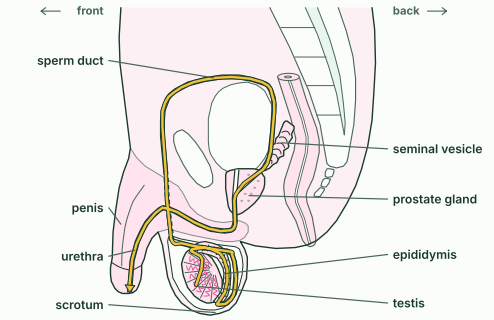
The male reproductive system in a median section, seen from the side: the front is on the left. Label the parts on the lines.

2



The **testes** make sperm; the **epididymis** stores them as they mature. The **sperm duct** carries them to the **urethra**; the **seminal vesicle** and **prostate gland** add the fluids that make semen.

3



The sperm's route out: testis, epididymis, sperm duct (over the bladder), past the seminal vesicle's duct, through the prostate gland, and along the urethra.

PREDICT

The testes hang in a bag outside the body, where it is a little cooler than inside. What does that suggest about making sperm?

(A) That sperm are damaged by contact with the body's blood, so the testes are kept away from it

(B) That the testes need room to grow larger as more and more sperm are stored in them

(C) That sperm production works better a few degrees below the temperature of the body's core

(D) That sperm cannot survive the acidity of the body cavity, so they are made outside it

Decide before you look. Answer on page 99.

12 The female-typical *system*

D3.1.4 12 ANATOMY OF THE HUMAN MALE AND FEMALE REPRODUCTIVE SYSTEMS

Go deeperthe detail, watch out

The detail

The system is drawn from the front, cut open, as if facing you, so the patient's right is on your left.

Ovary (two): holds the follicles, each with an egg cell (hormones in chapter 14).

Oviduct (also uterine tube or Fallopian tube): its open funnel, fringed with finger-like fimbriae, catches the egg. Cilia and muscle move it towards the uterus.

The oviduct is **not joined** to the ovary: its funnel lies over the ovary and catches the egg as it is released.

Uterus: its wall stretches in pregnancy and contracts in birth. The endometrium thickens each cycle ready for an embryo, and is shed if none arrives.

Cervix: a ring of muscle, closed by mucus. It widens at birth.

In the side view, which the tool shows too, the uterus lies between the bladder in front and the rectum behind.

Watch out

The egg is released into the oviduct's funnel, **not into the uterus**.

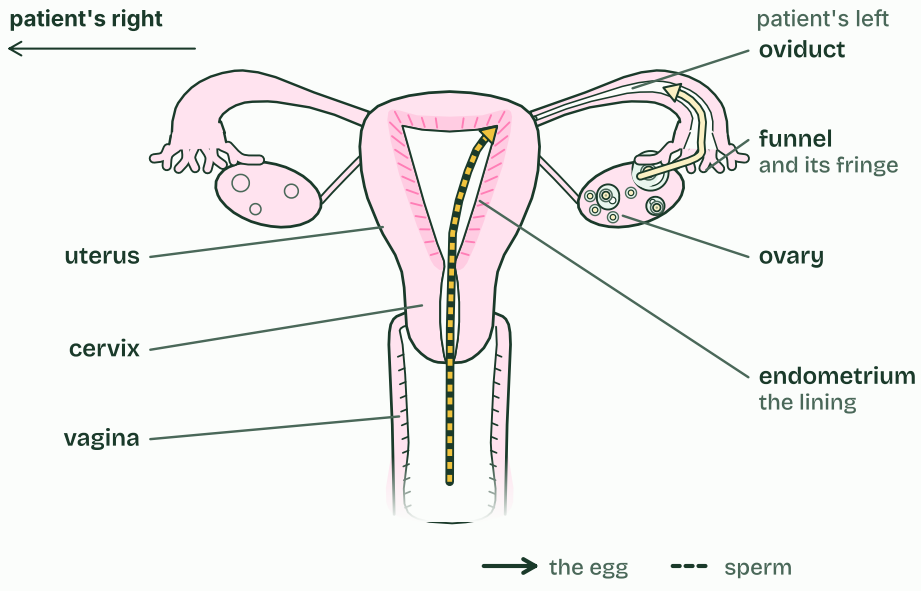
Fertilization happens in the oviduct, not the uterus.

The uterus is not a passive bag: its wall is thick muscle.

KEY TERMS

ovary
The swollen base of the carpel, which holds the ovules. It becomes the fruit.

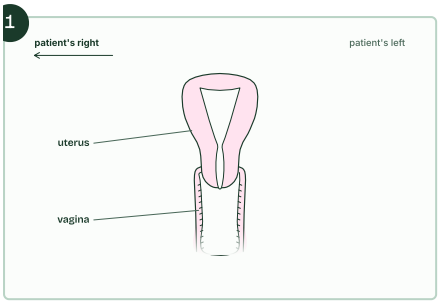
endometrium
The lining of the uterus, which thickens each cycle, rich in blood vessels and glands, and is where an embryo implants.



STEP BY STEP

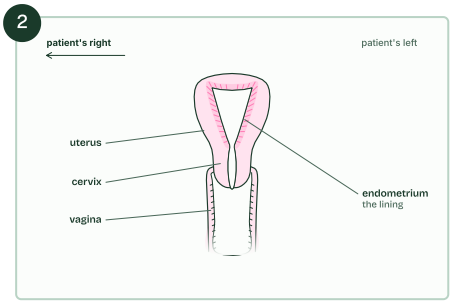
5 STEPS

1



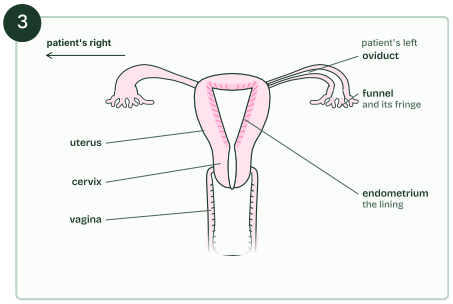
The uterus and the vagina, cut open and seen from the front.

2



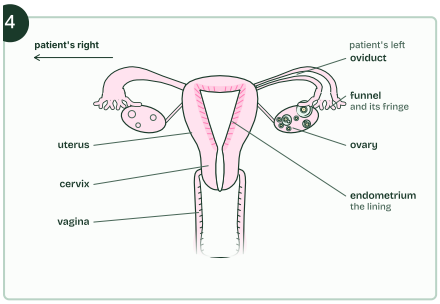
The cervix at the neck of the uterus, and the endometrium lining it.

3



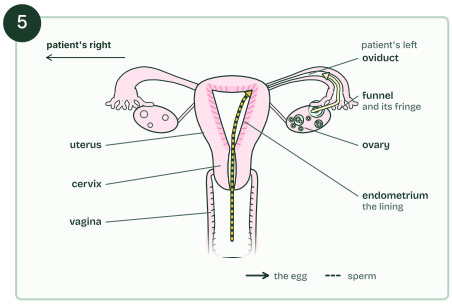
An oviduct from each top corner, ending in an open funnel with fimbriae.

4

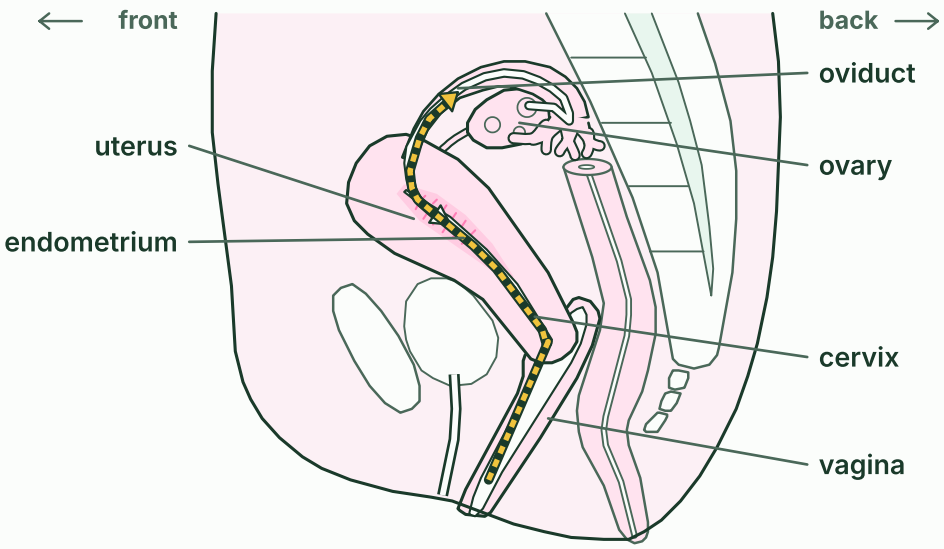


An ovary under each funnel, held in place but not joined to it.

5



The egg's route from the ovary into the oviduct, and the sperm's route in through the cervix and up the uterus.

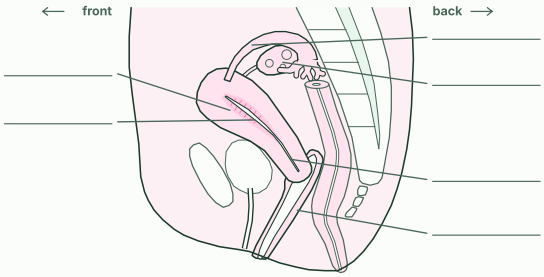


Tap each structure for its job, switch between the front and side views, then label the drawing and follow the egg and the sperm.

STEP BY STEP

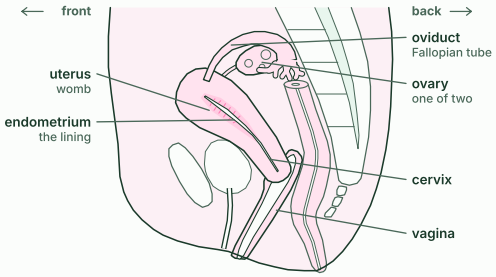
3 STEPS

1



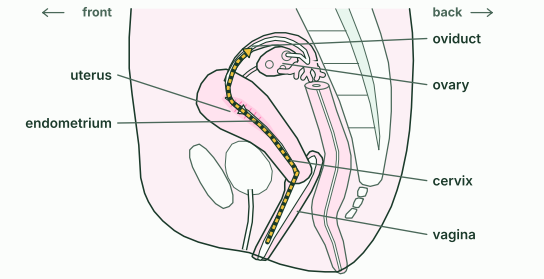
The female reproductive system in a median section, seen from the side: the front is on the left. Label the parts on the lines.

2



The **ovaries** release eggs; the **oviducts** carry them to the **uterus**, lined by the **endometrium**. The **cervix** opens into the **vagina**.

3



Two routes: the egg (solid) from the ovary into the oviduct and on to the uterus; sperm (dashed) up from the vagina through the cervix and uterus into the oviduct.

PREDICT

An egg lives for only about a day after ovulation. In which part of the female system is it most likely to meet a sperm, and why there?

(A) In the uterus, because that is where the embryo will settle and grow once fertilization has happened

(B) In the vagina, because that is where the sperm enter the female system, so they are most numerous there

(C) In the ovary, because the egg is still held inside its follicle until a sperm swims all the way to reach it

(D) In the oviduct, because the egg is carried there straight after release, so it waits there as sperm swim up

Decide before you look. Answer on page 99.

13

D3.1.5 13 CHANGES DURING THE OVARIAN AND UTERINE CYCLES AND THEIR HORMONAL REGULATION

A month in the ovary and the *uterus*

Go deeperthe ovarian cycle, the uterine cycle, timing, watch out

The ovarian cycle

Each cycle several follicles begin to grow, each an egg cell inside a ball of supporting cells.

Usually one goes on to mature while the rest stop.

The mature follicle bulges at the ovary's surface and bursts.

The corpus luteum ("yellow body") is a gland. If no pregnancy follows, it breaks down after about two weeks.

The uterine cycle

The lining is shed over the first few days.

It is then built up again, thick and rich in blood vessels and glands.

If no embryo arrives it is shed again, and a new cycle begins.

Timing

Cycles of 21 to 35 days are normal, and from one cycle to the next the day of ovulation varies.

The second half, from ovulation to the next period, is the steadier one: about two weeks.

Chapter 14 adds the hormones that keep the two cycles in step.

Watch out

The egg is **not released on day 14 in everyone**.

The follicle stays behind: only the egg, with a few cells round it, leaves.

The lining is tissue, glands and blood vessels, not blood alone.

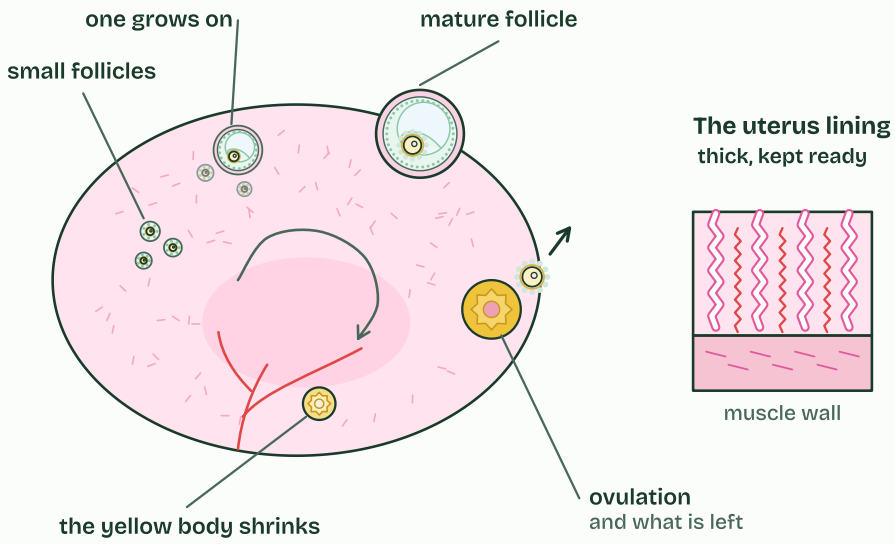
The ovaries do not take reliable turns.

KEY TERMS

ovulation
The release of an egg from a mature follicle at the surface of the ovary.

corpus luteum
The gland the empty follicle becomes after ovulation; it secretes progesterone and oestradiol for about two weeks.

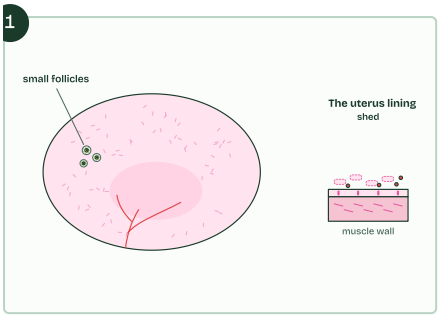
menstruation
The shedding of the uterus lining, with some blood, through the vagina; its first day is day 1 of the cycle.



STEP BY STEP

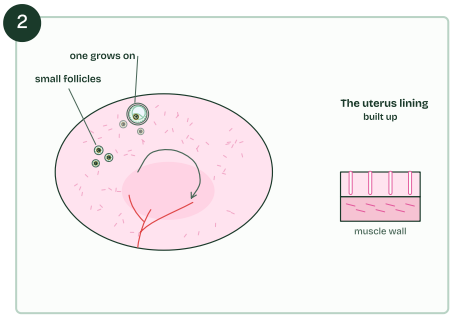
5 STEPS

1



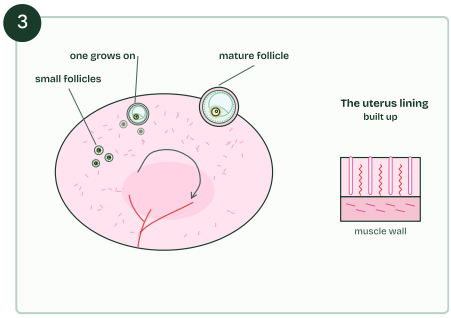
The start of a cycle: a few small follicles begin to grow, and the lining of the uterus is being shed.

2



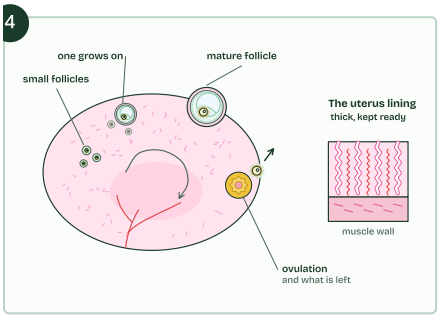
One follicle grows on and fills with fluid; the others shrink. The lining starts to build up again.

3



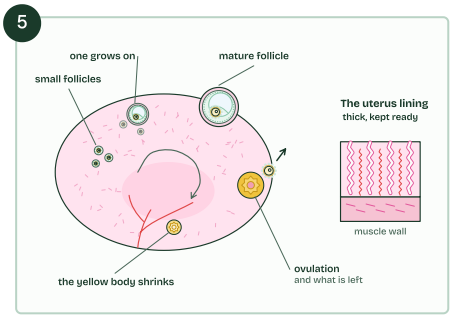
The mature follicle bulges at the surface of the ovary. The lining is thicker.

4



The follicle bursts and releases its egg: ovulation. What is left of it stays in the ovary and turns yellow. The lining is thick, with blood vessels and glands.

5

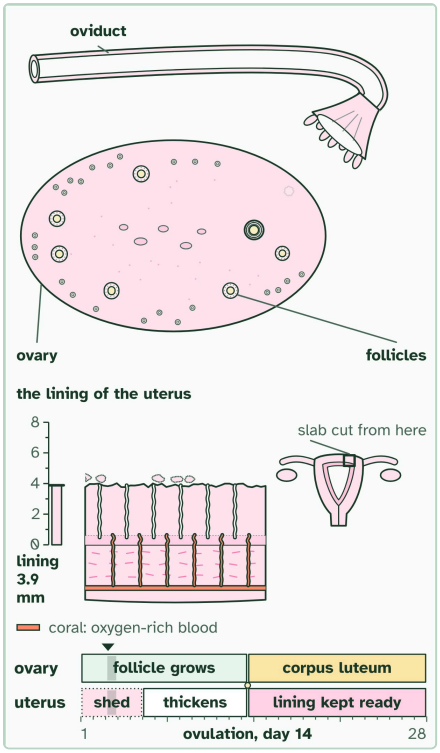


With no pregnancy, the yellow body shrinks after about two weeks, and the next cycle begins.

ANIMATION · A MONTH IN THE OVARY

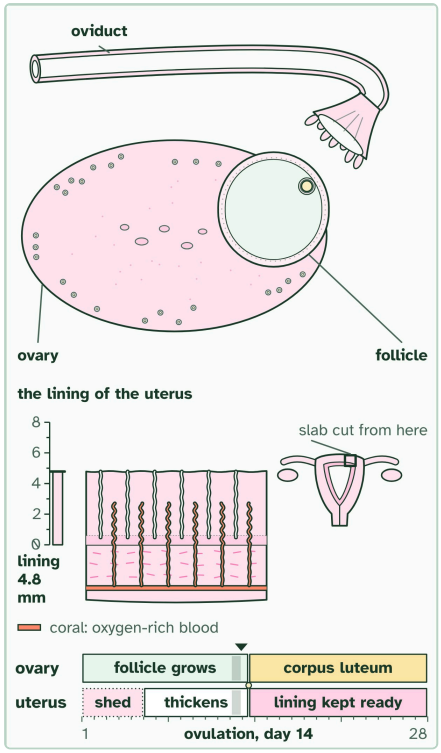
4 MOMENTS

1 DAY 3 OF 28



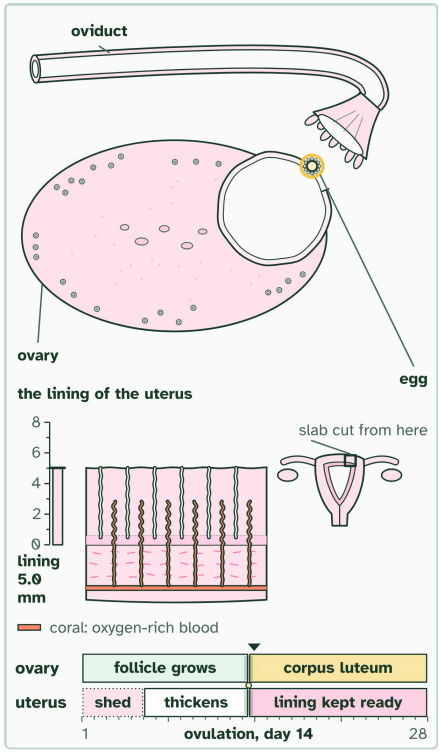
Day 1. In the ovary several **follicles** start to grow: each is an egg cell inside a ball of cells that feed it.

2 DAY 13 OF 28



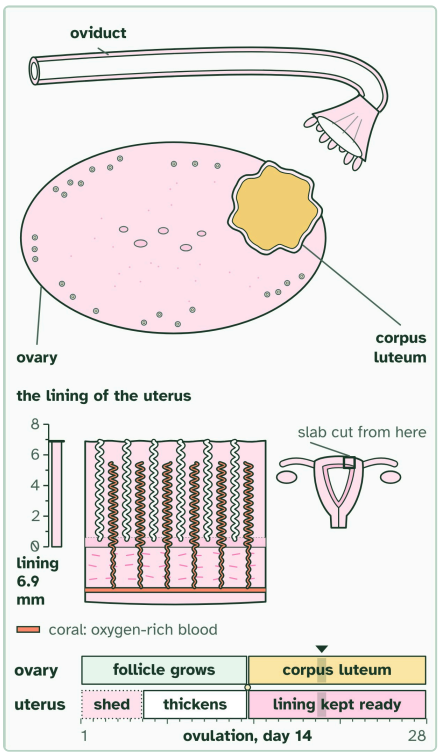
The follicle that is left is **mature**: a large space of fluid, the egg on a mound of cells at one side. It bulges at the ovary's surface.

3 DAY 14 OF 28



Ovulation, about day 14: the follicle bursts and the egg is released, with a coat of cells. The funnel of the oviduct sweeps it in.

4 DAY 20 OF 28



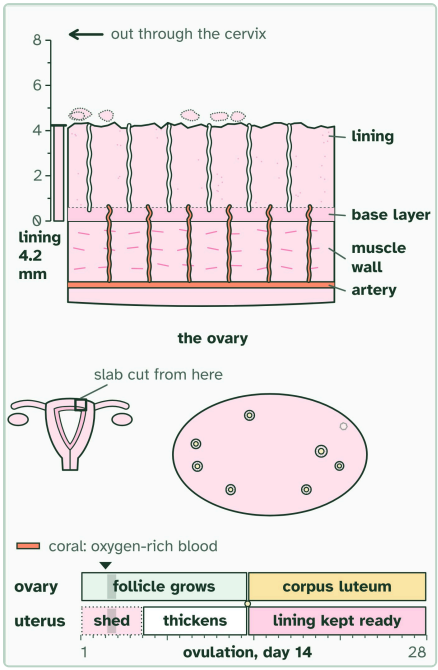
With no pregnancy the corpus luteum lasts about two weeks. Then it shrinks and pales to a small scar.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#cycle

ANIMATION · A MONTH IN THE UTERUS

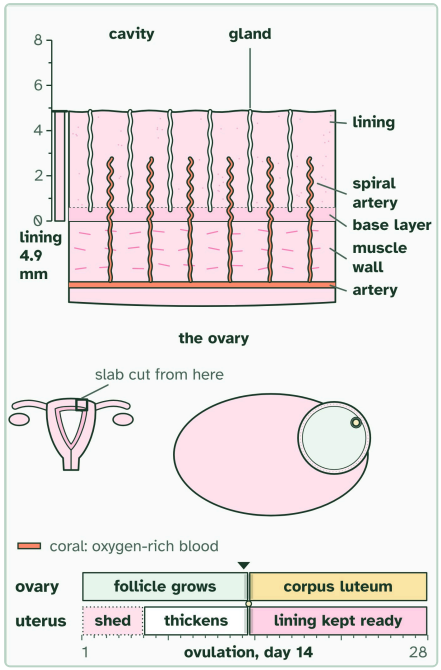
3 MOMENTS

1 DAY 3 OF 28



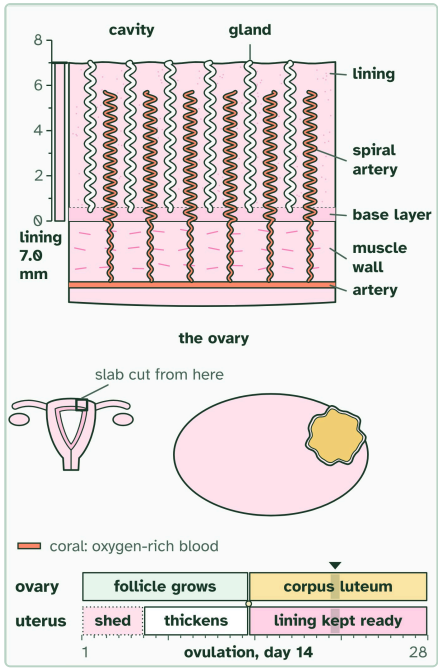
Day 1: **menstruation**. The thick lining of the uterus (the **endometrium**) breaks down and is shed, with some blood, for about five days.

2 DAY 14 OF 28



By ovulation, about day 14, the lining is several millimetres thick, its glands still straight.

3 DAY 21 OF 28



After ovulation the lining is kept thick and ready for an embryo: its glands coil and secrete, and its arteries coil up through it.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#cycle

PREDICT

After ovulation the empty follicle does not just disappear. What does it become, and what would you expect it to do?

(A) Scar tissue, which seals the surface of the ovary where it burst and then does nothing more

(B) The corpus luteum, a gland whose hormones keep the lining of the uterus thick and ready

(C) A second follicle, which releases another egg from the same place about two weeks later

(D) A fluid cushion, which protects the ovary from the muscle of the oviduct as it moves

Decide before you look. Answer on page 99.

D3.1.5 14 CHANGES DURING THE OVARIAN AND UTERINE CYCLES AND THEIR HORMONAL REGULATION

14 Four hormones, two kinds of *feedback*

Go deeperone cycle, step by step, the detail, links across the course, watch out

One cycle, step by step

FSH (follicle-stimulating hormone) rises at the start and stimulates follicles to grow.

The growing follicle secretes **oestradiol**, which builds up the lining.

Rising oestradiol inhibits the pituitary's release of FSH and LH. With less FSH, usually only one follicle matures.

Once oestradiol has stayed high for long enough, its effect reverses: it stimulates a surge of **LH** (luteinizing hormone), and some FSH.

The LH surge triggers ovulation and turns the follicle into the corpus luteum.

The corpus luteum secretes progesterone (and oestradiol). With oestradiol, progesterone inhibits FSH and LH, so no new follicles ripen.

With no pregnancy the corpus luteum breaks down. With the inhibition gone, FSH rises and the next cycle starts.

The detail

The positive loop does not run away for ever: ovulation changes the follicle, and its oestradiol falls, so the surge ends.

Oestradiol and progesterone are steroids, which enter their target cells and change which genes are expressed (D2.2).

The combined contraceptive pill uses the same negative feedback to stop ovulation (beyond the course).

Links across the course

Feedback of both kinds comes back in C3.1 and D3.3.

Watch out

LH does **not** cause menstruation: the fall in progesterone and oestradiol does.

LH, not progesterone, triggers ovulation.

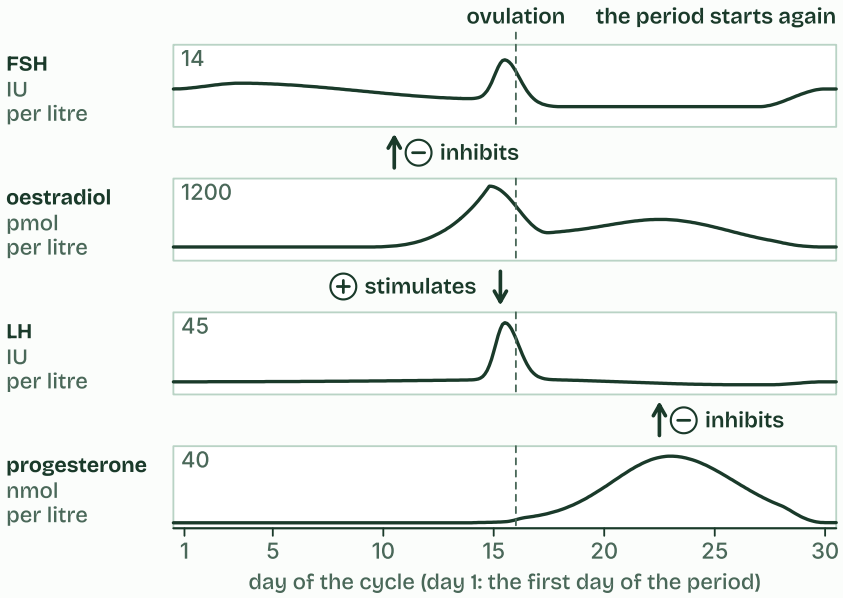
FSH and LH come from the pituitary, oestradiol from the ovary.

Not every cycle is 28 days long.

KEY TERMS

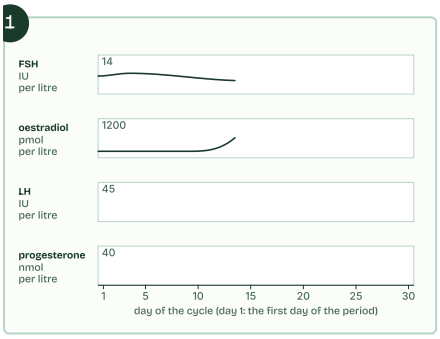
negative feedback
A response that reverses the change that caused it, so a level is held near a set point.

positive feedback
A response that increases the change that caused it, so the change grows until something stops it.

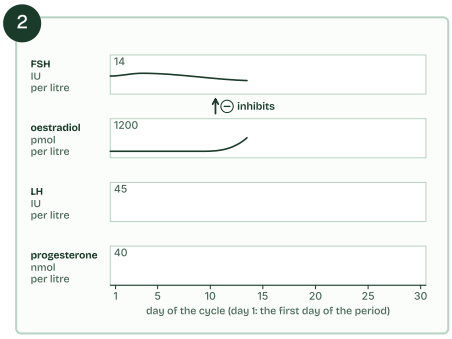


STEP BY STEP

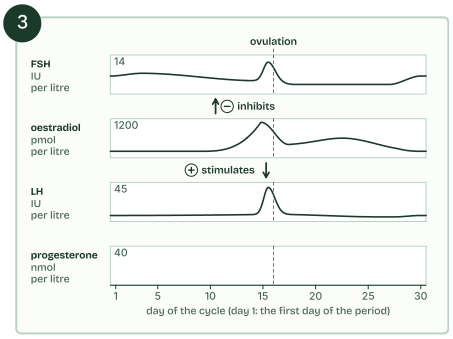
5 STEPS



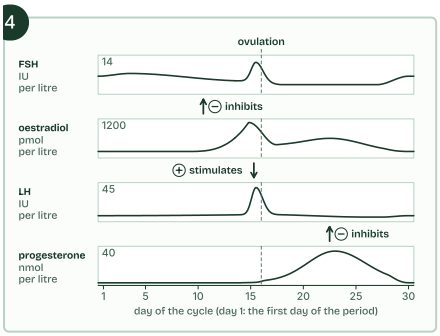
A cycle of 30 days. In the first fortnight FSH rises and then falls, while oestradiol from the growing follicle climbs. Each hormone has its own panel and its own units.



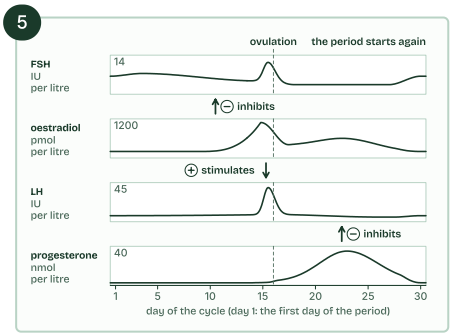
Rising oestradiol **inhibits** FSH release by the pituitary: negative feedback.



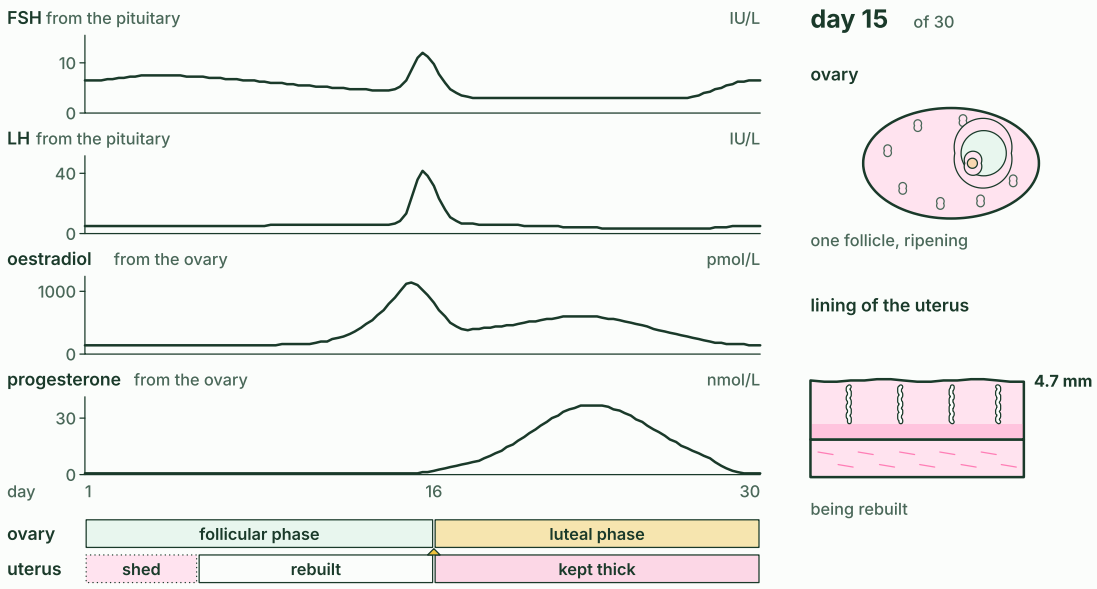
High oestradiol now **stimulates** a surge of LH: positive feedback. The surge triggers ovulation.



The corpus luteum secretes progesterone. With oestradiol, it **inhibits** FSH and LH: negative feedback again.



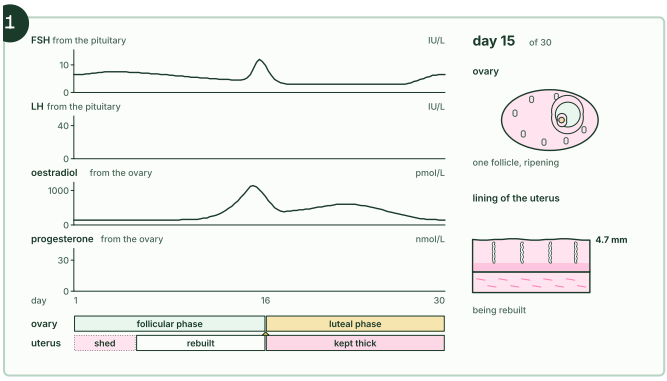
The corpus luteum breaks down, progesterone falls, the lining is shed, and FSH starts to rise for the next cycle.



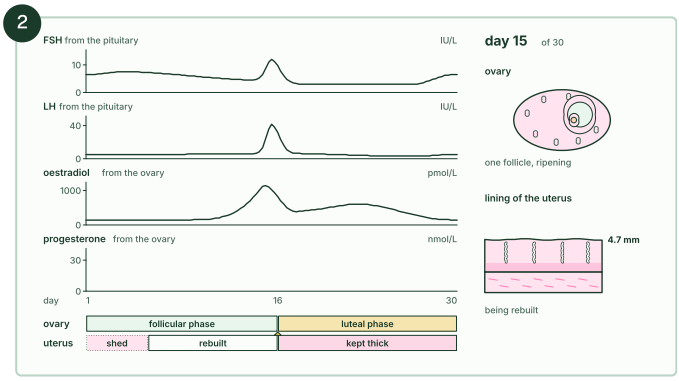
Drag the day along the cycle and read all four hormones, then switch to Feedback to see which links inhibit and which stimulate. Change the cycle's length: which half changes?

STEP BY STEP

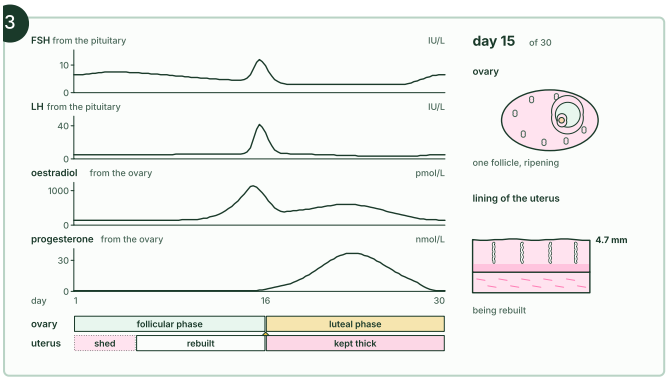
3 STEPS



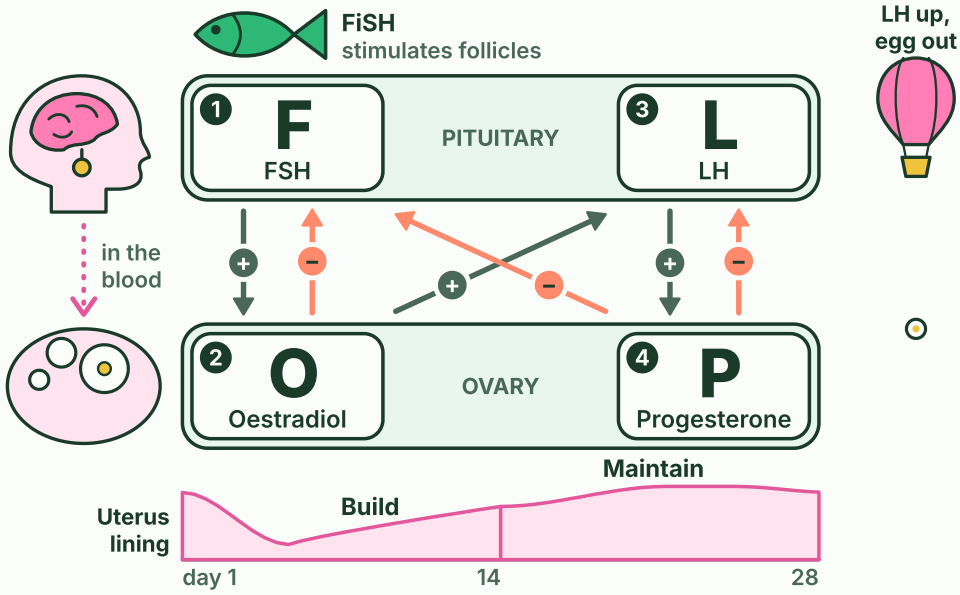
A 30 day cycle. FSH from the pituitary is high at the start and falls as oestradiol from the growing follicle rises.



LH from the pituitary surges just after oestradiol peaks; ovulation follows about a day and a half after the surge begins.



Progesterone from the corpus luteum rises after ovulation; as it and oestradiol fall, FSH rises and the lining is shed.

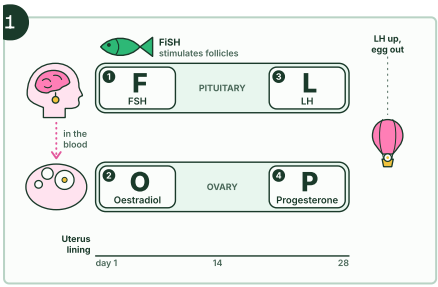


Go round F, O, L and P, watch the cycle run, then write the 8 mark answer.

STEP BY STEP

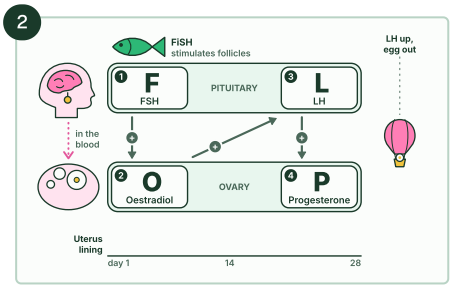
4 STEPS

1



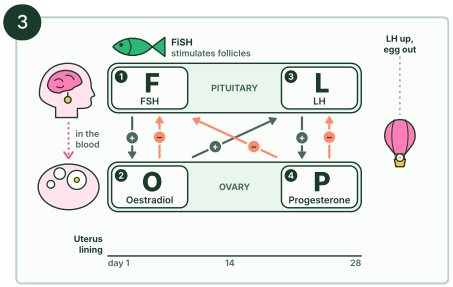
Four hormones in the order you recount them, F, O, L, P. FSH and LH are made in the pituitary gland; oestradiol and progesterone are made in the ovary.

2



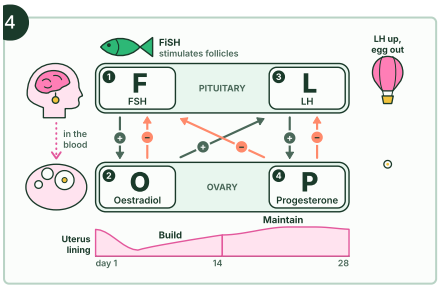
Grey arrows promote. FSH promotes the secretion of oestradiol by the follicles it stimulates, LH promotes the secretion of progesterone, and oestradiol at its peak promotes the release of LH: positive feedback.

3



Coral arrows inhibit. Oestradiol inhibits the release of FSH, and progesterone inhibits the release of FSH and LH: negative feedback.

4



The surge of LH releases the egg: the balloon goes up and drops it. Oestradiol builds up the lining of the uterus and progesterone maintains it.

PREDICT

Oestradiol from the growing follicle rises through the first half of the cycle, while FSH falls over the same days. What does that suggest oestradiol does to the pituitary at these levels?

(A) It inhibits the pituitary's release of FSH, so as one level rises the other falls: negative feedback

(B) It stimulates the pituitary to release more FSH, which then falls only because the follicles use it up

(C) It destroys the cells of the pituitary that make FSH, once they have made enough for the whole cycle

(D) It has no effect on the pituitary at all, since two curves that move together are never related

Decide before you look. Answer on page 99.

D3.1.6 15 FERTILIZATION IN HUMANS

15 The first hours of a *new cell*

Go deeperthe detail, mitochondria come from the egg, watch out

The detail

This is the human version of chapter 2's fertilization: no pollen tube, a sperm that swims instead.

The two nuclei never fuse into one before the first division: their condensed chromosomes meet on the spindle.

The **zygote** is the cell from the fusion of the membranes to that first division.

Mitochondria come from the egg

Because the sperm's mitochondria are destroyed, nearly all of an embryo's mitochondria come from the egg, and with them their own small loop of DNA.

Mitochondrial DNA is passed down from mother to child. A father's has been reported to pass on only in very rare cases.

That is why it is used to trace ancestry through the female line.

Watch out

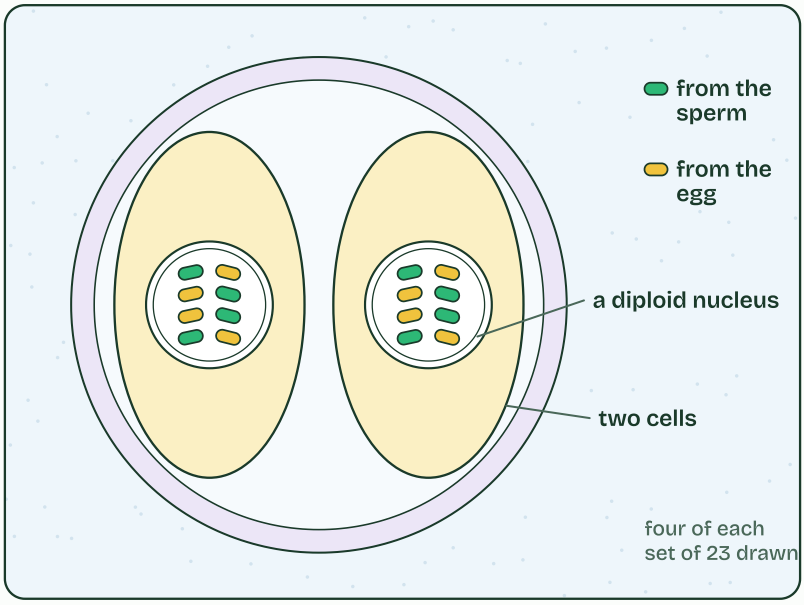
The **whole sperm does not stay** in the egg: its tail and mitochondria are destroyed.

The two nuclei do not merge before the first division.

The egg is not passive: chapter 19 (HL) shows how it keeps other sperm out.

KEY TERMS

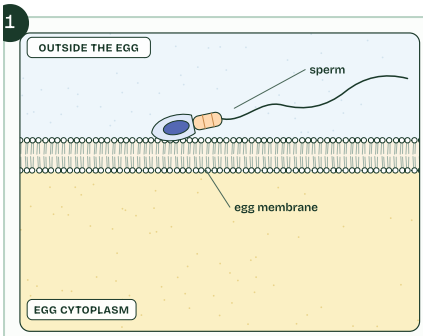
zygote
The single cell made when two gametes fuse. It divides by mitosis to form an embryo.



STEP BY STEP

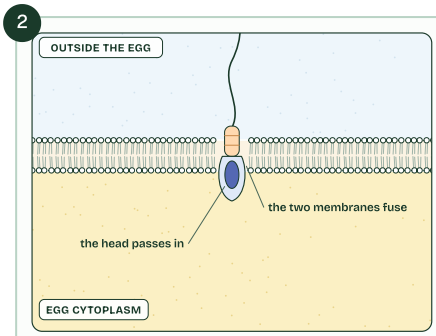
5 STEPS

1



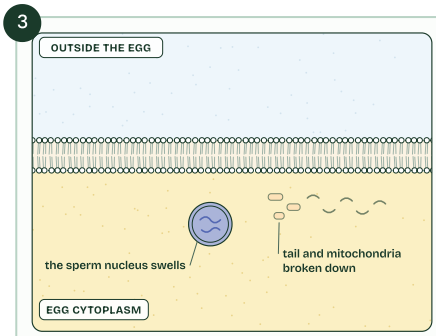
A close view of the egg's surface: a sperm lies against the egg's membrane.

2



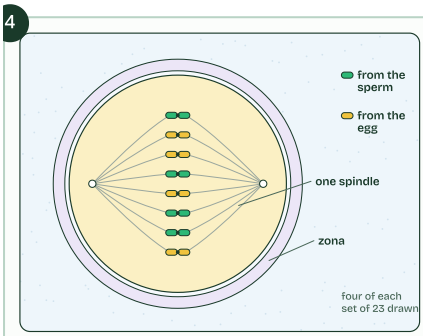
The two cell membranes fuse, and the sperm's head passes into the egg.

3



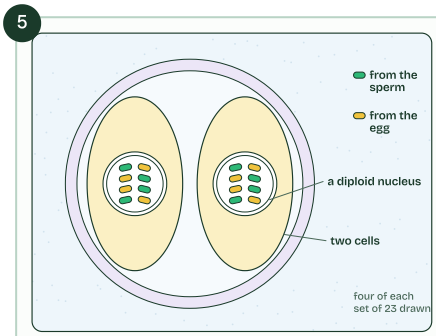
The tail and its mitochondria are broken down. The sperm's nucleus swells.

4



The whole cell: both nuclear membranes have dissolved, and the chromosomes from the sperm and the egg line up on one spindle.

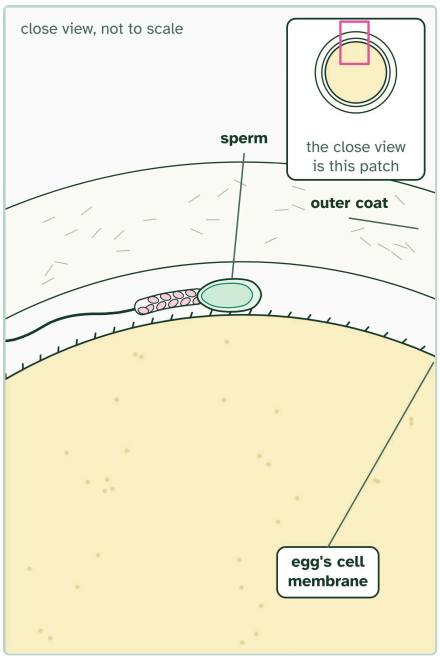
5



A joint mitosis: two cells, each with a diploid nucleus.

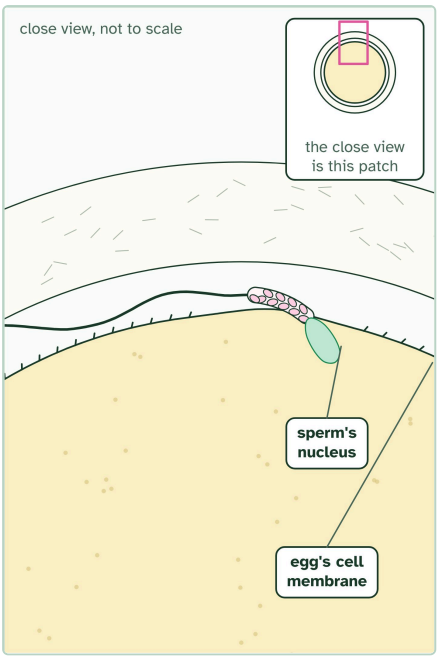
ANIMATION · THE FIRST HOURS OF A NEW CELL
7 MOMENTS

1



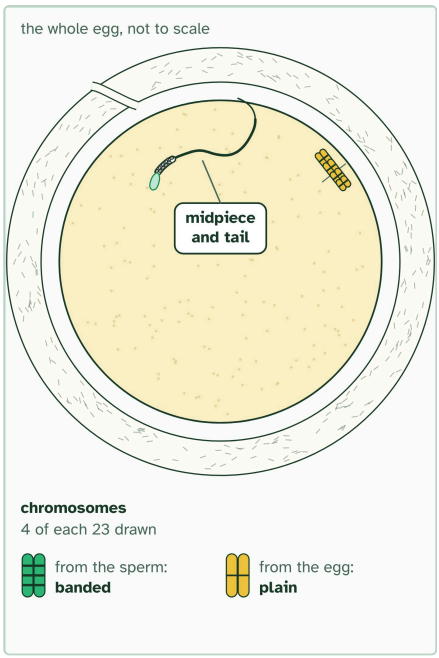
A sperm has made its way through the egg's outer coat. It lies along the egg's **cell membrane**, side on.

2



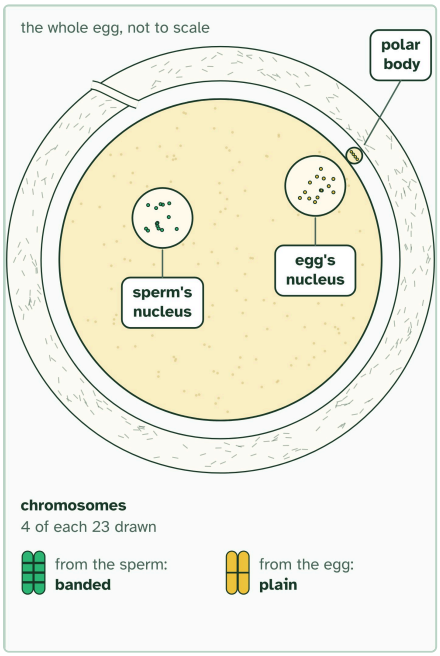
The sperm's cell membrane **fuses** with the egg's cell membrane: the two cells become one, and the sperm's **nucleus** passes into the egg.

3



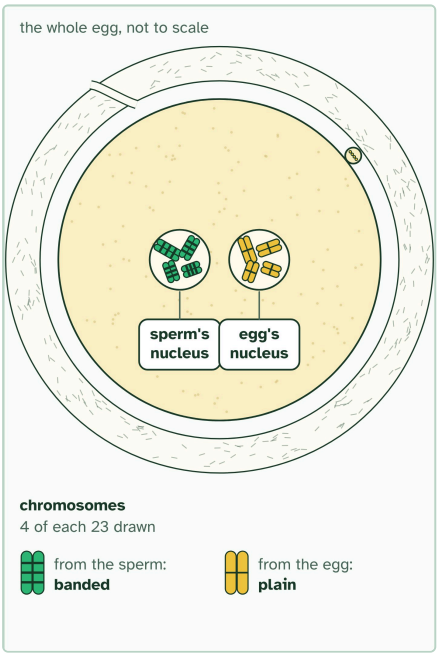
Its midpiece and tail are drawn in after it, but they are **broken down**: the sperm's tail and its **mitochondria**, in the midpiece, are destroyed.

4 23 + 23 CHROMOSOMES



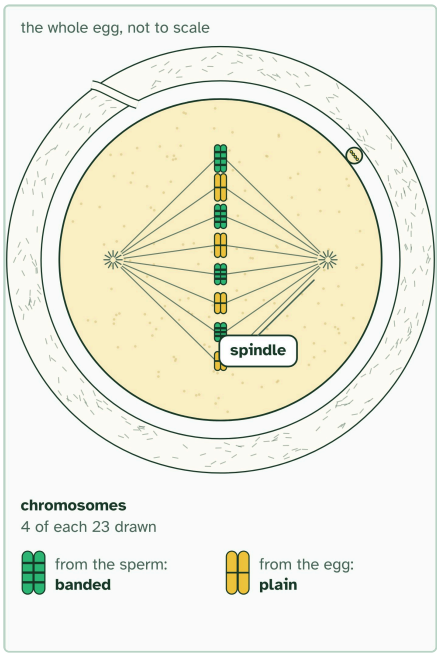
The sperm's nucleus swells. The egg finishes its own division, giving off a tiny **polar body**, and the chromosomes it keeps get a nucleus too. Each nucleus holds one set: **23** chromosomes.

5 23 + 23 CHROMOSOMES



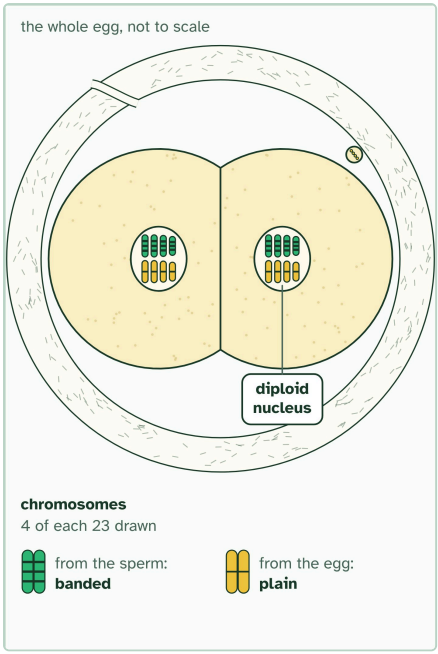
The two nuclei move together. In each, the chromosomes are copied and **condense**, ready for mitosis.

6 46 ON ONE SPINDLE



The **nuclear membranes** of both nuclei break down. All the chromosomes, from the sperm and from the egg, line up on **one spindle**: a joint mitosis.

7 2 CELLS, 46 EACH



Two cells, each with a **diploid** nucleus: 46 chromosomes, 23 from each parent.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#fusion

PREDICT

After the sperm's nucleus has entered the egg, its tail and mitochondria are broken down. What does that mean for the mitochondria in the cells of the new embryo?

(A) Almost all come from the egg, so the embryo's mitochondria, and their DNA, come from its mother

(B) Half come from each parent, because the two gametes contribute equally to the zygote they make

(C) They all come from the father, because a sperm needs far more mitochondria than an egg ever does

(D) None of them is inherited, because new mitochondria are built from scratch by the cell's nucleus

Decide before you look. Answer on page 100.

D3.1.7 16 USE OF HORMONES IN IN VITRO FERTILIZATION (IVF) TREATMENT

16 Switching the cycle off and *on again*

Go deeperone treatment cycle, in outline, why so many eggs, and the risks, watch out

One treatment cycle, in outline

IVF, in vitro fertilization, means fertilization in glass. It helps people who cannot conceive in the usual way.

A drug stops her pituitary releasing FSH and LH: her own cycle is paused.

Daily injections of FSH for about ten days.

When the follicles are ready, the trigger injection does the job of the LH surge: the eggs complete their maturing. hCG is a hormone that acts like LH (HL students meet it in chapter 21).

About a day and a half later the eggs are collected from the follicles with a fine needle.

A few days after fertilization an embryo is placed in the uterus.

Days vary between clinics and drug plans.

Why so many eggs, and the risks

Not every egg is fertilized, and not every embryo grows.

The clinic checks the follicles with ultrasound scans and blood tests.

The ovaries can over-respond.

Transferring more than one embryo can lead to twins or more, so clinics now often transfer one.

Watch out

IVF does not simply replace her hormones: it first **suspends** her own, then adds FSH and a trigger.

The eggs mature in the ovary, not the dish.

IVF does not always use donor eggs.

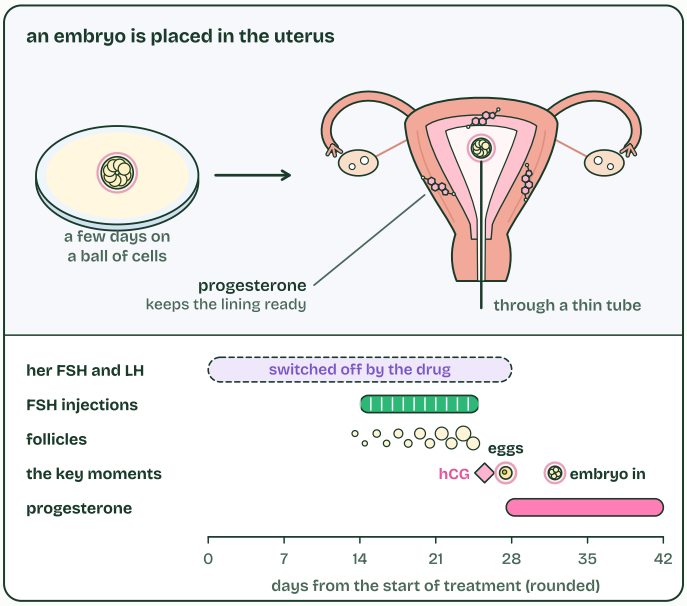
A baby conceived by IVF is not genetically different from any other.

KEY TERMS

IVF
In vitro fertilization: eggs are fertilized with sperm in a dish outside the body, and an embryo is placed in the uterus.

superovulation
Many follicles brought to maturity at once by doses of FSH, where a natural cycle matures one.

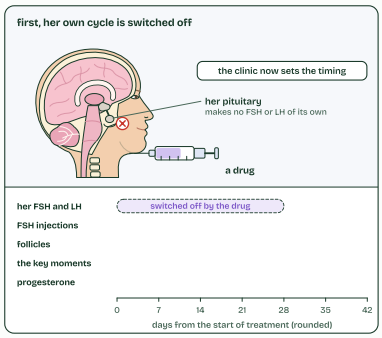
hCG
Human chorionic gonadotropin: a hormone made by the embryo's outer cells and then the placenta, which keeps the corpus luteum going.



STEP BY STEP

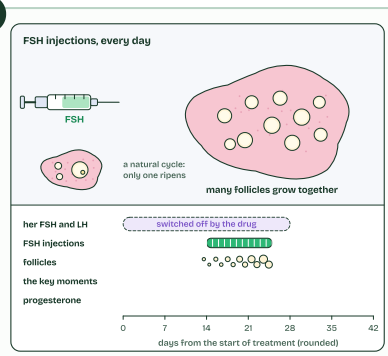
5 STEPS

1



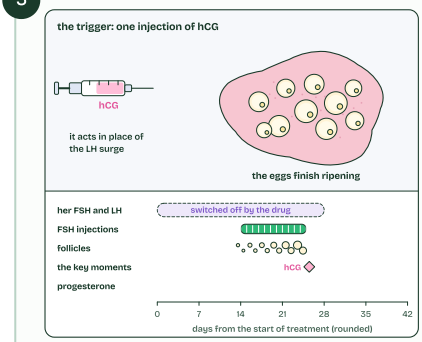
One treatment cycle as a timeline. First a drug switches off her own release of FSH and LH.

2



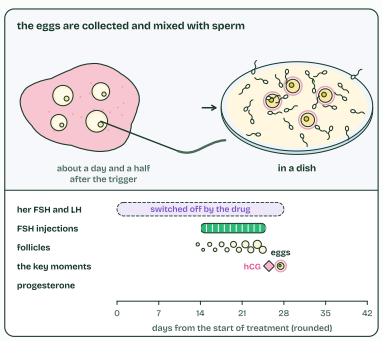
Daily FSH injections, and many follicles growing together in her ovaries.

3



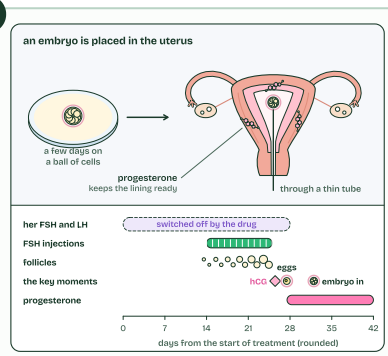
The trigger injection of hCG, in place of the LH surge.

4

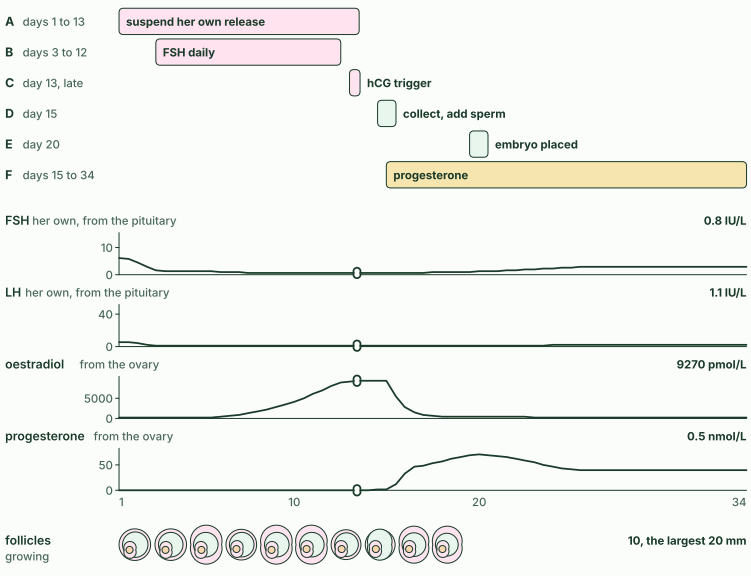


About a day and a half later the eggs are collected and mixed with sperm in a dish.

5



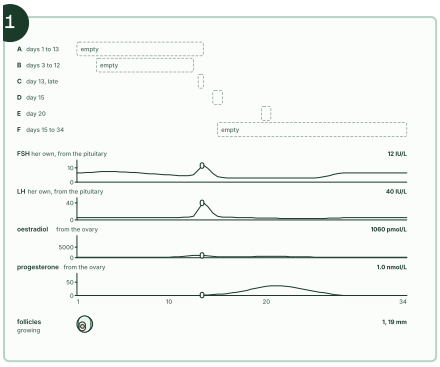
A few days on, an embryo is placed in the uterus, and progesterone keeps the lining ready.



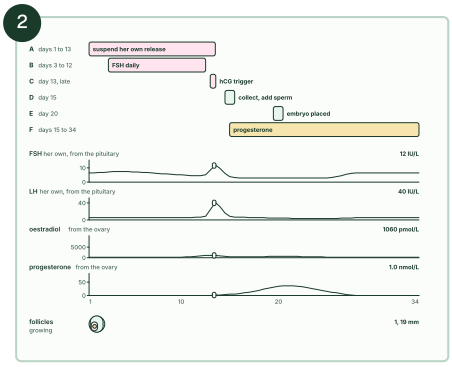
Put the drugs on the timeline and run the cycle: how many follicles mature, and are the eggs collected before they are released?

STEP BY STEP

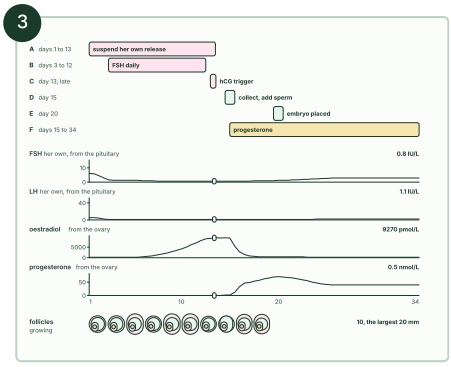
3 STEPS



A treatment cycle as six windows of time, the woman's own hormones under them: with nothing given, her own cycle runs, one follicle grows and her own LH surge releases its egg.



The plan: her own FSH and LH release suspended, FSH injections, a trigger, egg collection and fertilization in a dish, the embryo placed, and progesterone.



By the trigger about ten follicles have grown together (superovulation) and her oestradiol is many times its natural peak, while her own FSH and LH stay low.

PREDICT

Before the FSH injections start, a woman's own FSH and LH release is stopped with a drug. Why do that first?

(A) So that her own hormone levels can be measured accurately, with none of the drugs getting in the way of the tests

(B) So that her follicles stop growing completely for a while, since the FSH injections will then start them growing again

(C) So her own hormones cannot set the timing, and many follicles mature together and are collected before any ovulate

(D) So that the lining of her uterus is shed first, and a fresh lining can be built up to order later in the treatment

Decide before you look. Answer on page 100.

D3.1.13 HL 17 CONTROL OF THE DEVELOPMENTAL CHANGES OF PUBERTY BY GONADOTROPIN-RELEASING HORMONE AND STEROID SEX HORMONES

17 The signal that starts *puberty*

Go deeperthe detail, watch out

The detail

Through childhood the reproductive hormones are low.

GnRH is gonadotropin-releasing hormone.

The testes make mostly testosterone. The ovaries make mostly oestradiol and progesterone.

The changes: the reproductive organs grow, gamete production starts, the menstrual cycle or sperm production begins, and there is a growth spurt.

It is the same chain as chapter 14's, seen across years rather than a month.

What makes the GnRH rise begin is beyond the IB's course. Body size and nutrition play a part.

When it begins varies widely, and anywhere in a wide range is normal.

Both sexes make all of these hormones, in different amounts.

Watch out

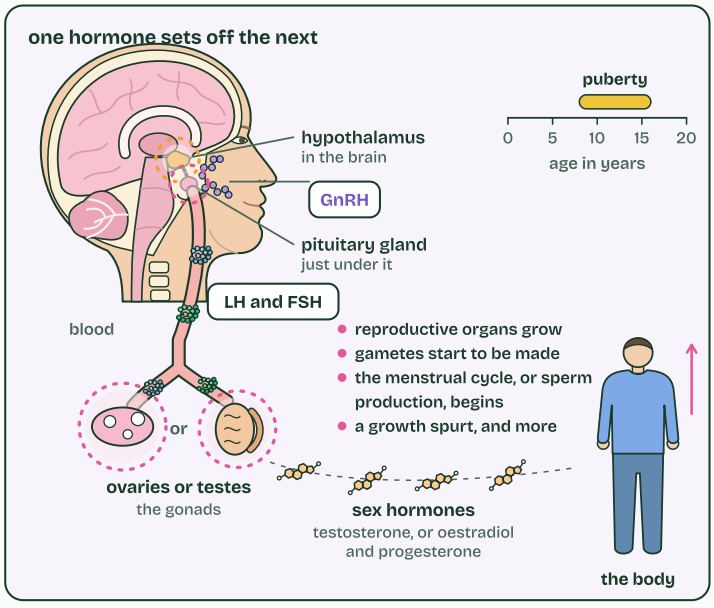
Puberty is **not started by the gonads**: the hypothalamus starts it, and the sex hormones then drive the growth spurt.

The testes do not make all the hormones of puberty.

KEY TERMS

hypothalamus
A part of the brain, just above the pituitary gland, that links the nervous system to the hormone system.

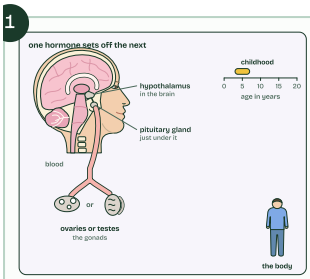
GnRH
Gonadotropin-releasing hormone: made by the hypothalamus; it makes the pituitary release LH and FSH.



STEP BY STEP

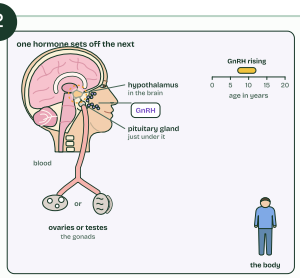
4 STEPS

1



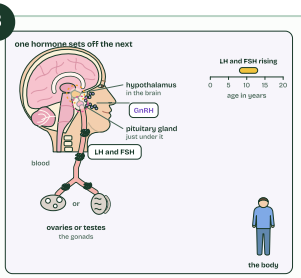
Childhood: the hypothalamus, the pituitary and the gonads are all quiet.

2



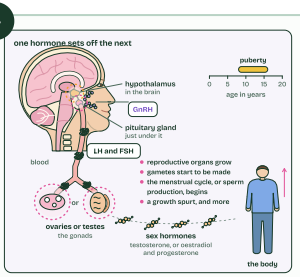
The hypothalamus releases more GnRH.

3



The pituitary responds with more LH and FSH.

4



The gonads make more sex hormones, and the body changes. The age bar is a wide range, and all of it is normal.

PREDICT

In a child, the hypothalamus starts to release more GnRH. What do you expect to happen next to the blood levels of LH and FSH, and then to the gonads?

(A) LH and FSH fall, because the pituitary stores them up until the gonads are ready to respond to them

(B) LH and FSH rise as the pituitary responds to GnRH, and the gonads then make more sex hormones

(C) The gonads release GnRH in response, so the chain loops straight back to the hypothalamus

(D) LH and FSH rise, but the gonads cannot respond to them until the body has finished growing

Decide before you look. Answer on page 100.

D3.1.14 HL 18 SPERMATOGENESIS AND OOGENESIS IN HUMANS

18 One cell in, *four or one* out

Go deeperthe four stages, spermatogenesis, oogenesis, watch out

The four stages

Mitosis makes a supply of germ cells.

The cells grow.

Two divisions of meiosis halve the chromosome number.

The cells differentiate into sperm or eggs.

Spermatogenesis

Goes on in the tubules of the testes.

Takes about ten weeks from start to finish.

On the order of a hundred million sperm a day.

Oogenesis

The mitosis is finished in the foetal ovary.

A girl is born with all the egg cells she will have, around a million or two, waiting part way through meiosis.

Most are lost before puberty, when some 300,000 to 400,000 remain.

From puberty, one of them usually completes the first division in each cycle.

The second is completed only if a sperm fuses with it.

In both divisions one cell keeps almost all the cytoplasm. That is how the egg comes to hold the food reserves of chapter 10.

Polar bodies are too small to develop.

Watch out

Oogenesis does **not make four eggs**, and it does not begin at puberty.

Neither gamete is made by mitosis alone.

Polar bodies are not failed eggs: they are the by-product of dividing unequally.

KEY TERMS

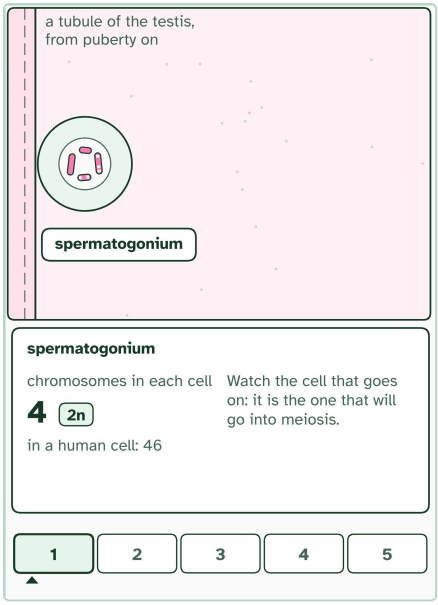
spermatogenesis
The making of sperm in the seminiferous tubules of the testes.

oogenesis
The making of eggs in the ovaries.

polar bodies
A small cell made by an unequal division in oogenesis; it gets very little cytoplasm and breaks down.

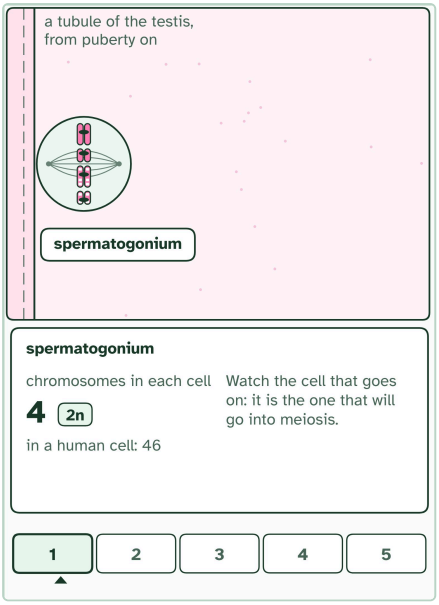
ANIMATION · MAKING SPERM
6 MOMENTS

1 STAGE 1 OF 5: MITOSIS



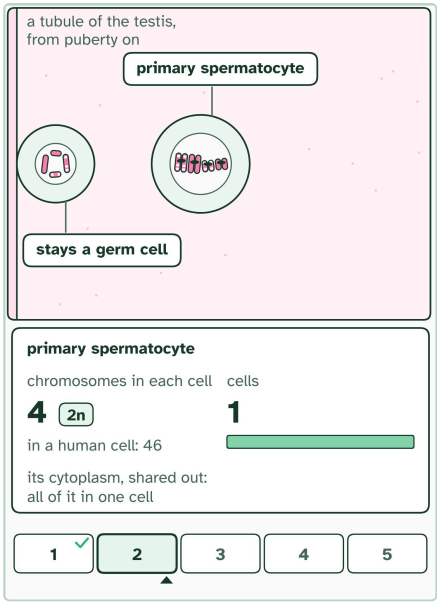
In a tubule of the testis, from puberty on: a **germ cell** on the tubule's wall. It is diploid (2n): two sets of chromosomes, drawn here as 2 pairs (a human cell has 23 pairs).

2 STAGE 1 OF 5: MITOSIS



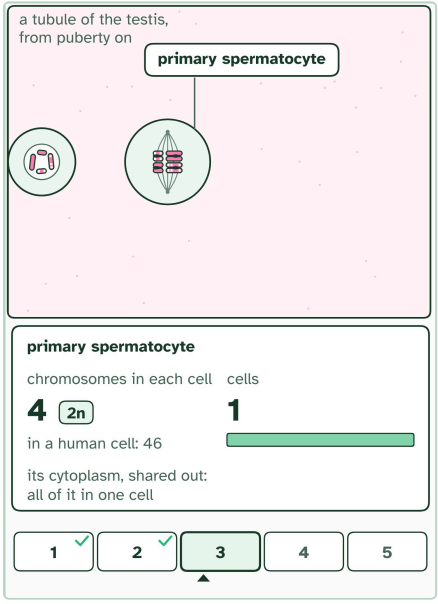
Mitosis: the cell copies its DNA and divides into two cells like itself. One stays on the wall as a germ cell, so the supply never runs out; the other goes on.

3 STAGE 2 OF 5: GROWTH



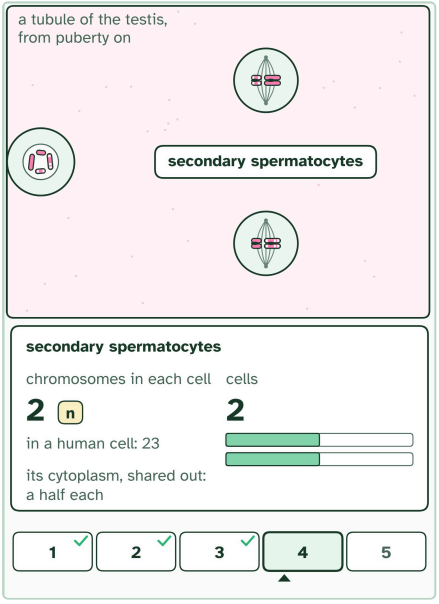
Growth: the cell that goes on grows larger and copies its DNA again, ready for meiosis. The two chromosomes of each pair come together.

4 STAGE 3 OF 5: MEIOSIS I



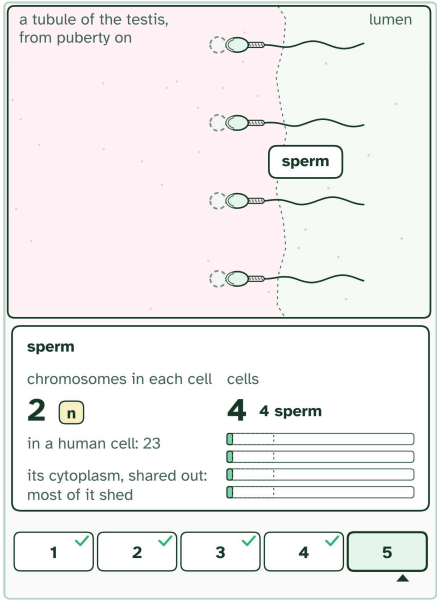
Meiosis I: the two chromosomes of each pair are pulled apart and the cell divides equally. Two haploid cells (n), each with half the cytoplasm.

5 STAGE 4 OF 5: MEIOSIS II



Meiosis II: in each cell the two chromatids of every chromosome separate, and both cells divide equally again. Four small haploid cells.

6 STAGE 5 OF 5

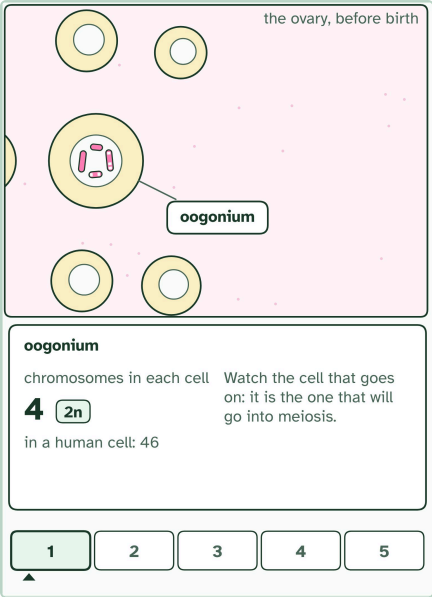


Differentiation: each cell grows a tail, packs its nucleus into a head under an acrosome and sheds most of its cytoplasm. Four sperm from one cell, after about two months.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#gametogenesis

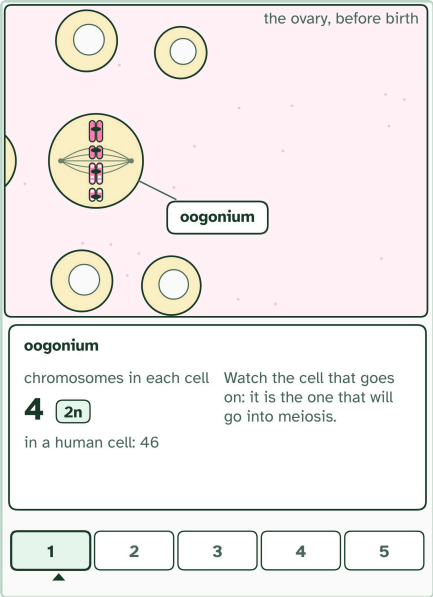
ANIMATION · MAKING AN EGG
7 MOMENTS

1 STAGE 1 OF 5: MITOSIS



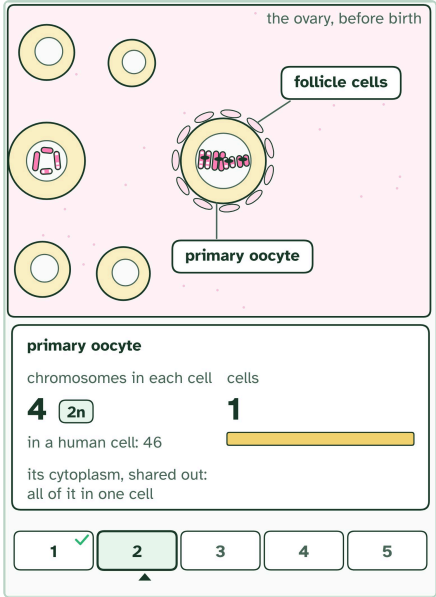
Before birth, in the ovary of a female foetus: a **germ cell** among many others. It is diploid (2n): drawn here as 2 pairs of chromosomes (a human cell has 23 pairs).

2 STAGE 1 OF 5: MITOSIS



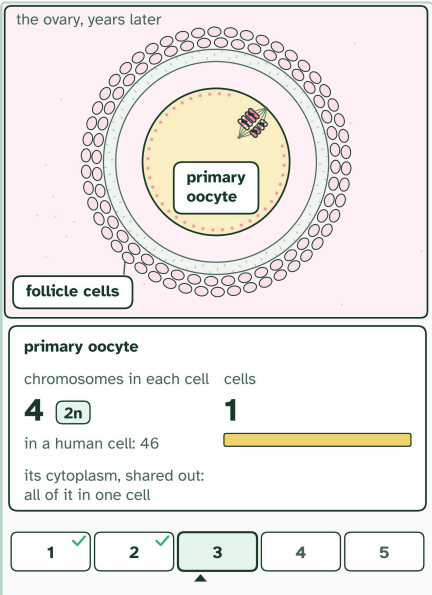
Mitosis: the germ cells copy their DNA and divide again and again, making a supply of millions. This happens only before birth: no more are made later.

3 STAGE 2 OF 5



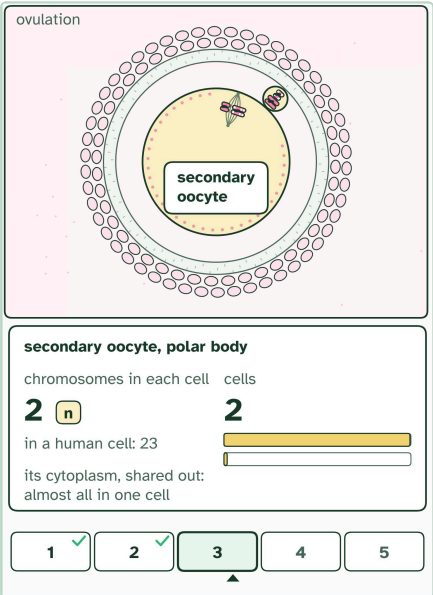
Growth begins: a cell grows a little, gains a layer of follicle cells, copies its DNA and starts meiosis I. Then it stops, its pairs of chromosomes together.

4 STAGE 3 OF 5: MEIOSIS I



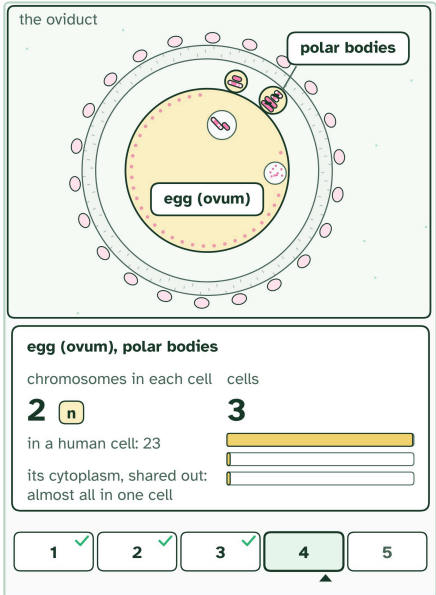
Meiosis I, just before ovulation: the pairs separate, but the cytoplasm divides unequally. One large haploid cell (n) keeps almost all of it; the other set of chromosomes leaves in a tiny **polar body**.

5 STAGE 3 OF 5: MEIOSIS I



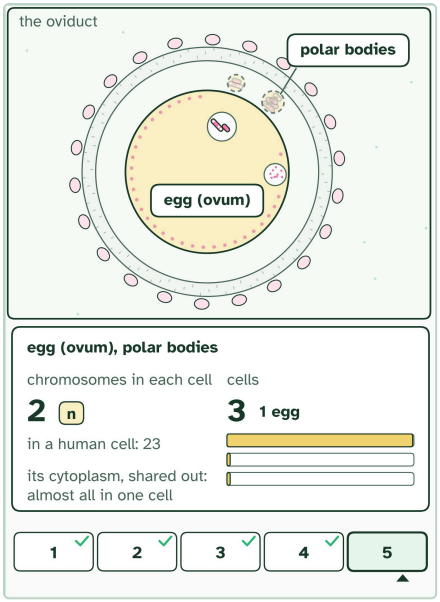
The large cell starts meiosis II and stops again, its chromosomes lined up. This is the cell released at ovulation, with a few follicle cells still round it.

6 STAGE 4 OF 5: MEIOSIS II



Inside the egg now, two haploid nuclei: **its own** and **the sperm's**. They come together at fertilization.

7 STAGE 5 OF 5



The polar bodies break down (the first may divide first). From one cell into meiosis: **one egg**, with almost all the cytoplasm and its store of food.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#gametogenesis

PREDICT

One cell in the testis and one cell in the ovary each go through meiosis. How many cells that can become functional gametes does each make?

(A) One sperm and one egg, because only one of the four products of any meiosis ever survives

(B) Four of each, because meiosis always divides one cell into four equal cells in both sexes

(C) Two sperm and two eggs, because in both sexes only the first division of meiosis is unequal

(D) Four sperm from the cell in the testis, but only one egg from the cell in the ovary

Decide before you look. Answer on page 100.

19 One sperm and *no more*

D3.1.15 HL 19 MECHANISMS TO PREVENT POLYSPERMY

Go deeperthe detail, links across the course, watch out

The detail

Many sperm reach the egg, and only one may get in. Two or more would give extra sets of chromosomes.

The **zona pellucida** is a coat of glycoproteins round the egg's membrane.

The **acrosome** is a vesicle in the cap of the sperm's head. When the sperm binds to the zona, it releases digestive enzymes by exocytosis.

The sperm swims through to the egg's membrane.

When the first sperm's membrane fuses with the egg's, **cortical granules** just under the egg's surface release their enzymes by exocytosis into the space outside the membrane.

Some animals, sea urchins among them, also have a fast electrical block. Whether humans do is not clear.

Links across the course

The zona is a barrier that the first sperm opens and the egg then closes behind it: one answer to this guide's question on the roles of barriers.

Others: the style that stops the wrong pollen (chapter 5) and the placenta that keeps two bloodstreams apart (chapter 22).

Watch out

The acrosome reaction is the **sperm's** and the cortical reaction is the **egg's**: two events, not one.

The acrosome's enzymes digest a path through the zona, not the egg.

The zona is a coat outside the membrane, not the membrane itself.

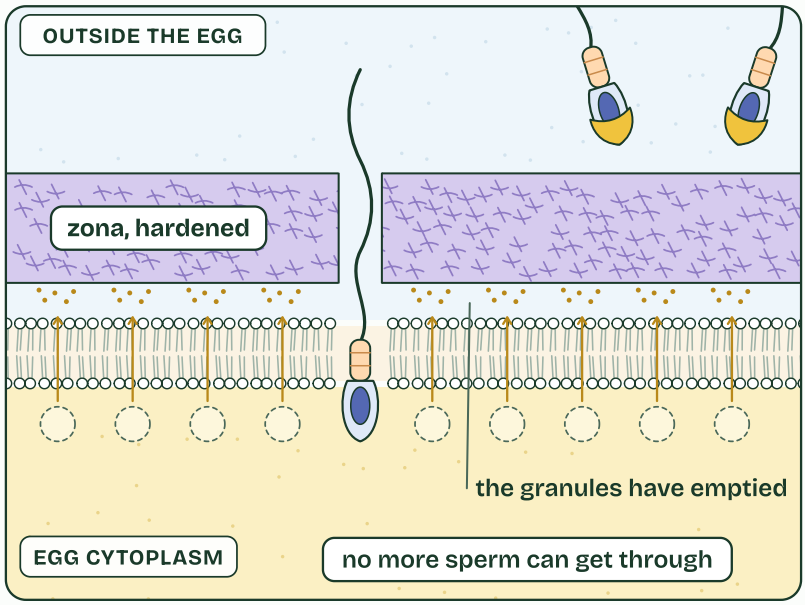
KEY TERMS

polyspermy
Fertilization of one egg by more than one sperm; the zygote has extra sets of chromosomes and cannot develop normally.

acrosome reaction
The release of enzymes from the acrosome of a sperm when it binds the zona pellucida, digesting a path through it.

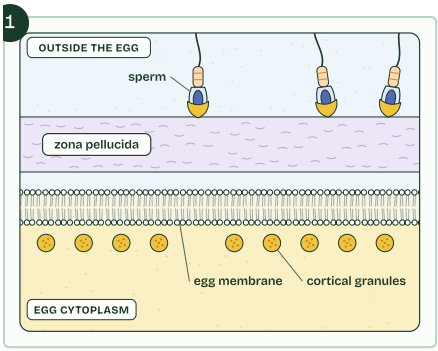
zona pellucida
A thick coat of glycoproteins round the egg, outside its cell membrane.

cortical reaction
The release of enzymes from cortical granules under the egg's membrane after the first sperm fuses, which changes the zona so no other sperm can bind or pass.

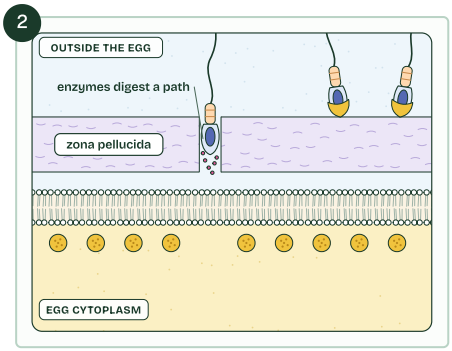


STEP BY STEP

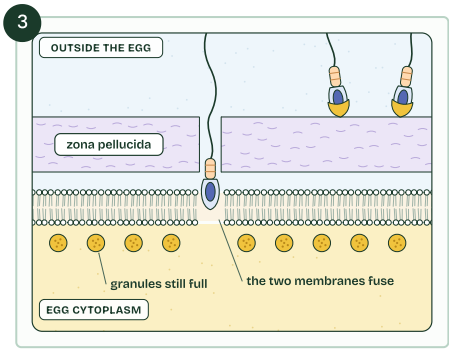
4 STEPS



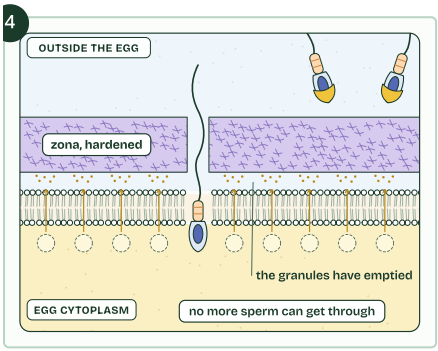
A patch of the egg's surface. Sperm arrive at the zona pellucida; just under the egg's membrane lies a row of granules.



One sperm binds the zona and releases enzymes from its acrosome. They digest a path, and it swims through.



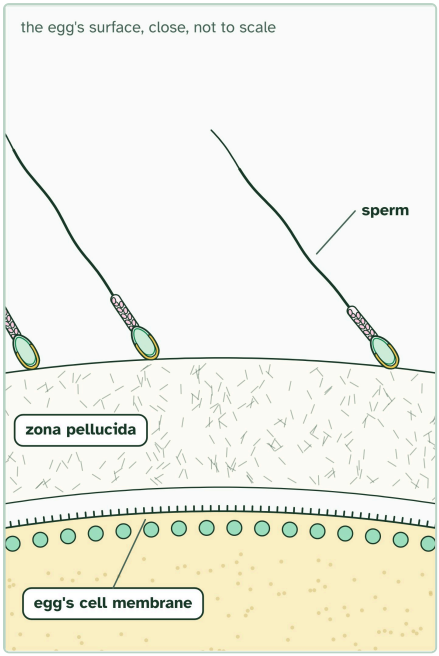
Its membrane fuses with the egg's. The granules are still full.



The granules empty their enzymes into the space outside the membrane, and the zona changes. The other sperm are held off.

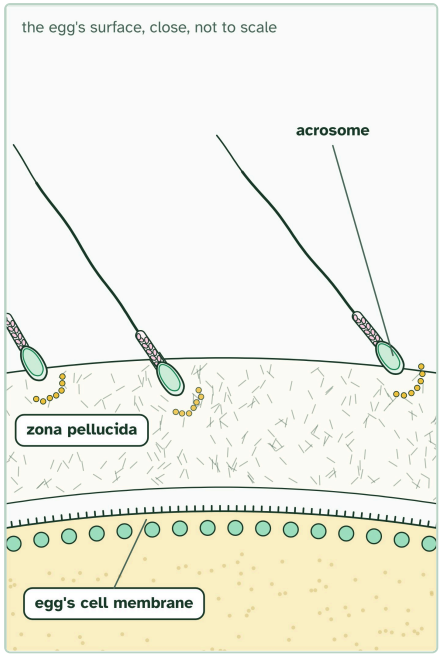
ANIMATION · ONE SPERM AND NO MORE
4 MOMENTS

1 SPERM FUSED: 0



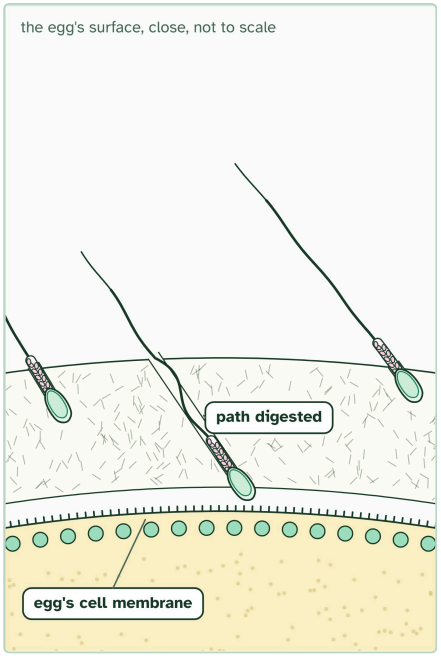
Sperm reach the egg's coat, the **zona pellucida**, a thick layer of glycoprotein outside its cell membrane, and bind to it.

2 SPERM FUSED: 0



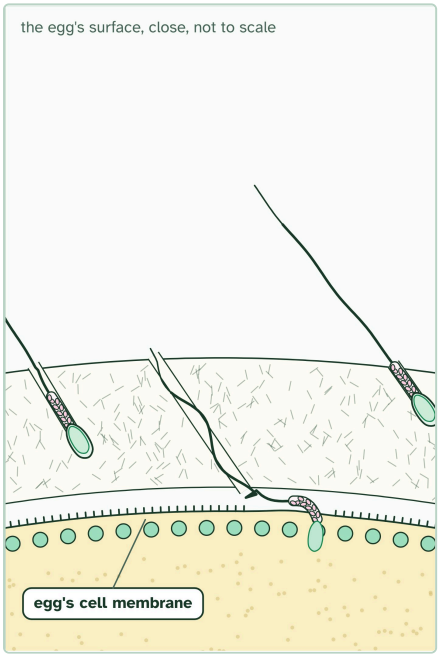
The **acrosome reaction**: the cap on each sperm's head, the **acrosome**, releases enzymes that digest a path into the zona.

3 SPERM FUSED: 0



Each sperm swims in along its path. The first through crosses the narrow space beyond and lies on the egg's cell membrane.

4 SPERM FUSED: 1



The first sperm's membrane fuses with the egg's, and its nucleus passes in.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#block

PREDICT

The first sperm has fused with the egg. What stops a second sperm from getting in?

(A) The first sperm's tail wraps round the egg, blocking the path of any that arrive later

(B) The egg's membrane closes up behind the first sperm and seals itself against all others for good

(C) Granules under the egg's surface release enzymes that change the zona, so no sperm can bind or pass

(D) The sperm that arrive later are too tired to digest the zona, having swum so much further

Decide before you look. Answer on page 100.

20 A ball of cells finds a *home*

D3.1.16 HL 20 DEVELOPMENT OF A BLASTOCYST AND IMPLANTATION IN THE ENDOMETRIUM

Go deeperthe detail, watch out

The detail

Two cells, four, eight and more. By about day 3 to 4 it is a solid ball of cells, and it reaches the uterus.

The blastocyst has about a hundred cells, with a cluster on one side that will become the embryo and an outer layer that will help form the placenta (chapter 22).

It is still inside its zona. It breaks out, and from about day 6 to 7 its outer cells attach to the endometrium.

By now the lining is rich in blood vessels and glands (chapter 14).

The outer cells soon start to make hCG (chapter 21).

The IB asks for no other stage names.

Implantation does not always succeed. Rarely, a blastocyst implants outside the uterus, most often in an oviduct, which is a medical emergency.

Watch out

Implantation is **not fertilization**: it comes about a week later.

The embryo does not grow as it divides in the oviduct: its cells get smaller.

It is not in the uterus from the first day.

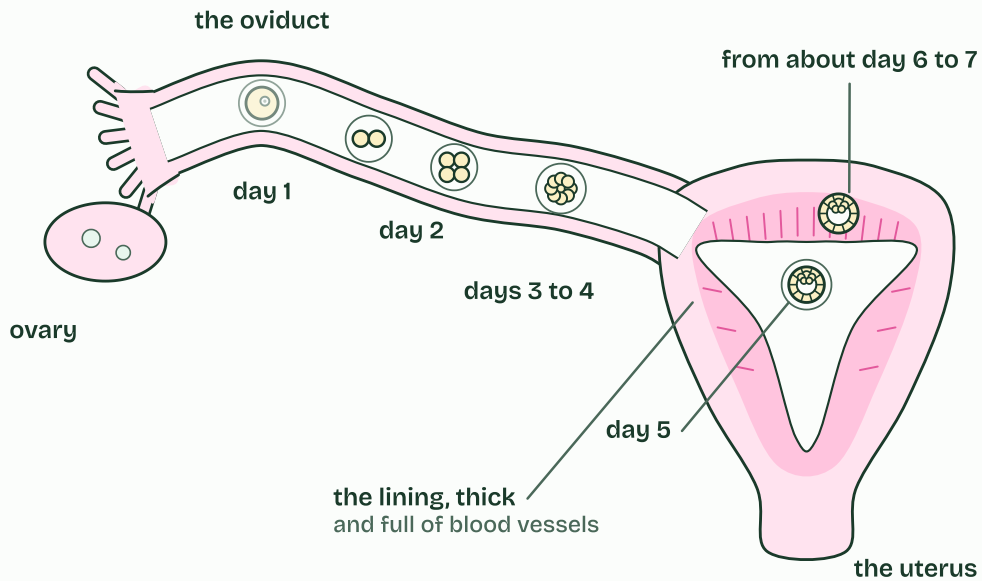
It becomes a blastocyst in the uterus, not in the oviduct.

KEY TERMS

blastocyst
A hollow ball of about a hundred cells, an embryo about five days after fertilization, with a cluster of cells on one side.

endometrium
The lining of the uterus, which thickens each cycle, rich in blood vessels and glands, and is where an embryo implants.

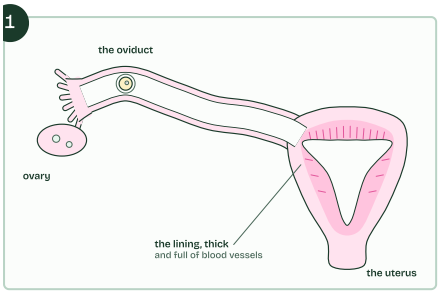
implantation
The burying of the blastocyst in the endometrium, from about a week after fertilization.



STEP BY STEP

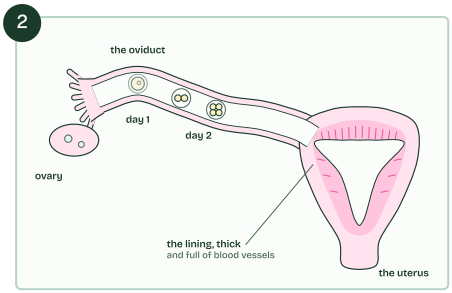
5 STEPS

1



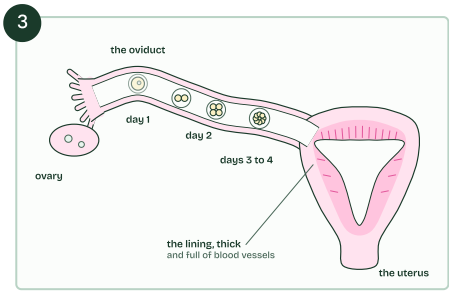
The zygote in the oviduct, near the ovary.

2



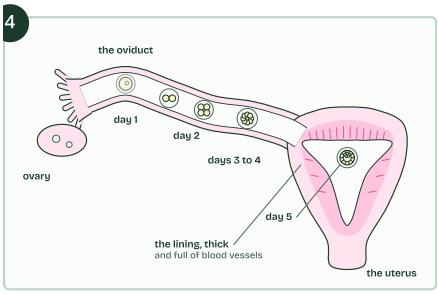
Moved along the oviduct, it divides: two cells, then four, each smaller than the one before.

3



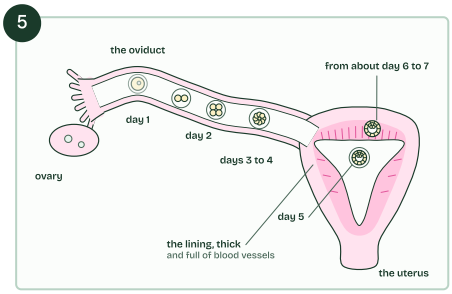
By about day 3 to 4 it is a solid ball of cells, and it reaches the uterus.

4



In the uterus, by about day 5, it becomes a hollow ball of cells, the blastocyst, still inside its zona.

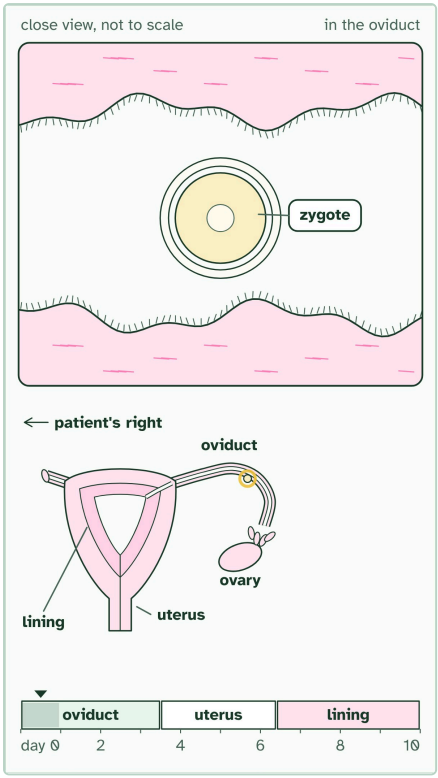
5



From about day 6 to 7 it is out of the zona and sinking into the thick lining: implantation.

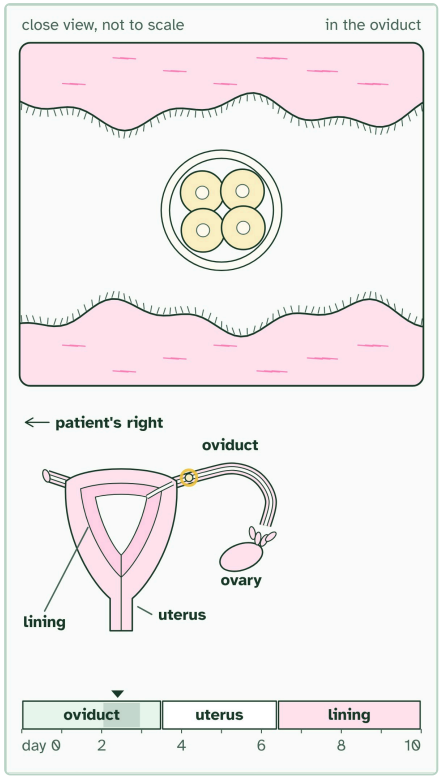
ANIMATION · FROM THE OVIDUCT TO THE LINING
7 MOMENTS

1 DAY 0, 1 CELL



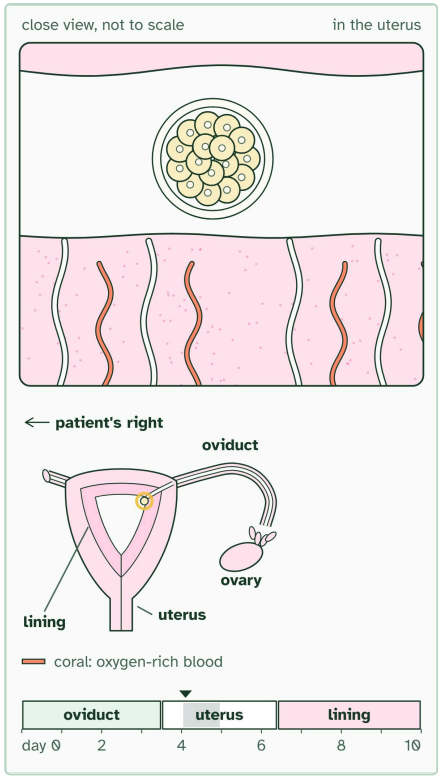
Day 0: the **zygote**, one cell inside the zona, in the oviduct near where it was fertilized. Cilia and muscle in the oviduct's wall move it along.

2 DAY 2, 4 CELLS



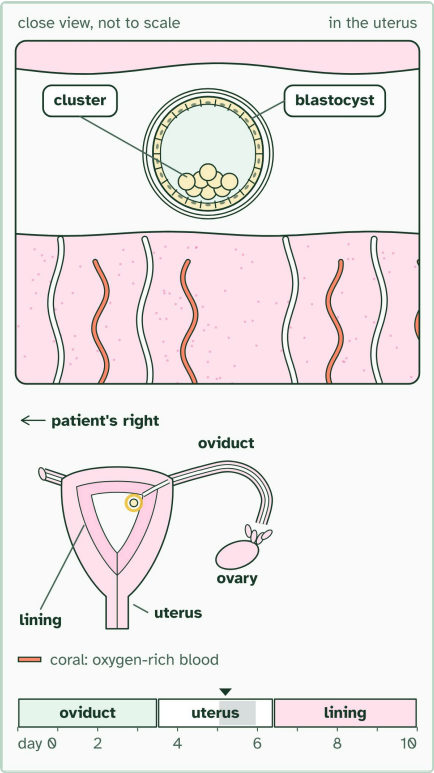
It divides by **mitosis**: two cells by about day 1, four by day 2. It does not grow, so each cell is smaller than the one it came from.

3 DAY 4, 16 CELLS



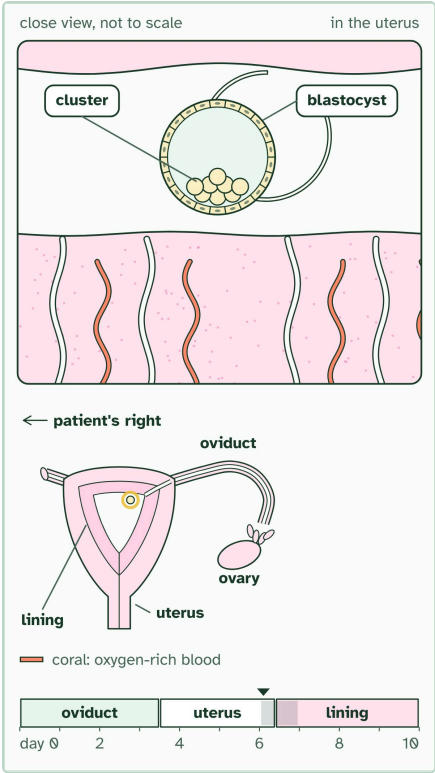
By about day 3 it is a ball of 8 to 16 small cells, still inside the zona, and it reaches the **uterus**.

4 DAY 5, ABOUT 100 CELLS



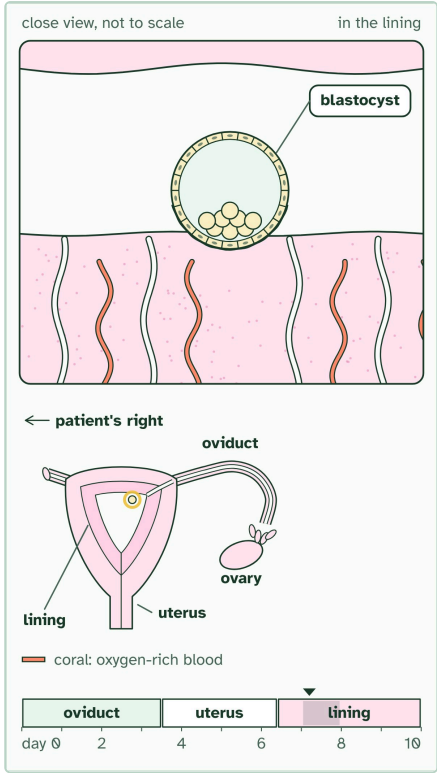
A space filled with fluid opens inside it: by about day 5 it is a **blastocyst**, a hollow ball of about a hundred cells, with a cluster of cells on one side. (The cluster is the *inner cell mass*, which forms the embryo; the outer layer, the *trophoblast*, helps form the placenta.)

5 DAY 6, ABOUT 100 CELLS



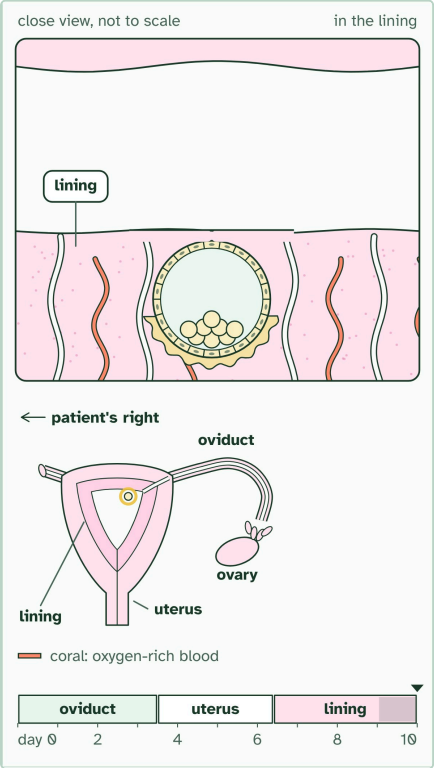
At about day 6 the blastocyst **hatches**: it breaks out of the zona.

6 DAY 7, OVER 100 CELLS



Its outer cells stick to the lining of the uterus, the **endometrium**, which has been kept thick, with glands and blood vessels, since ovulation.

7 DAY 10, OVER 100 CELLS



The outer cells burrow into the lining: **implantation**. By about day 10 the blastocyst is buried in it.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d3-1-reproduction#implant

PREDICT

A blastocyst, about five days after fertilization, is in the uterus. Why must the lining be thick and rich in blood vessels at just that time?

(A) Because the blastocyst embeds in it, and it is the embryo's first source of food and oxygen

(B) So that it can be shed, letting the blastocyst settle directly on the bare muscle of the wall

(C) So the blastocyst can push through it easily and reach the mother's blood on the other side

(D) Because it must feed the next egg, which the ovary is due to release in the coming month

Decide before you look. Answer on page 100.

21 A hormone that *gives it away*

D3.1.17 HL 21 PREGNANCY TESTING BY DETECTION OF HUMAN CHORIONIC GONADOTROPIN SECRETION

Go deeperthe detail, along the strip, watch out

The detail

hCG is human chorionic gonadotropin. It passes into the mother's blood and rises fast over the first weeks. Chapter 23 shows its job.

An **antibody** is a protein that binds one particular shape on another molecule, its antigen (B1.2).

Monoclonal antibodies are all copies of one, made by a single clone of cells, so all bind the same site.

A strip uses two kinds, each binding a different site on hCG.

Along the strip

Urine soaks along the strip by **capillary action**.

On a pad near the start, the first antibody is free to move and carries a coloured particle. Any hCG in the urine binds it, and the urine carries both on.

In the test zone the second antibody is fixed. It catches hCG that already carries a coloured antibody.

In the control zone a third antibody catches the coloured antibody, with hCG or without: the urine has flowed and the antibodies work.

hCG has two parts, and one is shared with LH, so at least one antibody must bind the part only hCG has.

Watch out

The test detects a **hormone**, not the embryo itself.

The hormone comes from the embryo's cells and the placenta, not the pituitary.

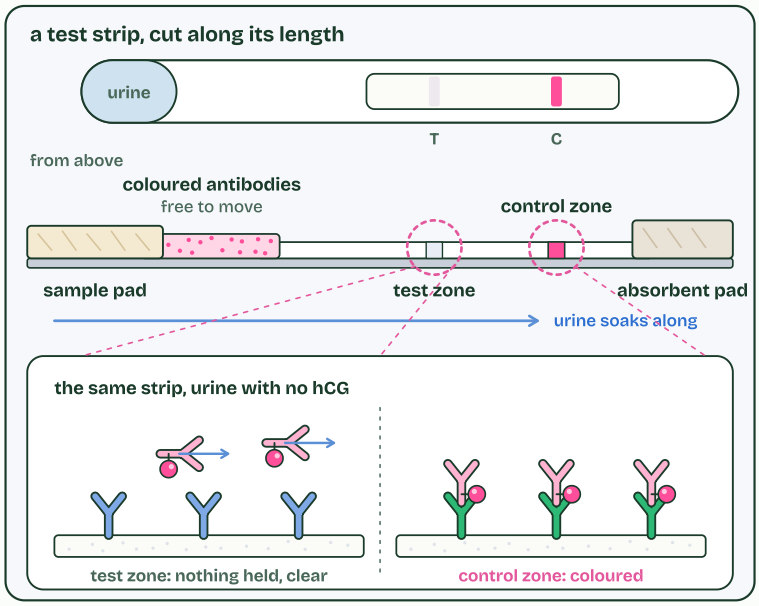
A positive test does not date a pregnancy, and a negative test very early can be wrong.

This chapter is about how the test works, not medical advice.

KEY TERMS

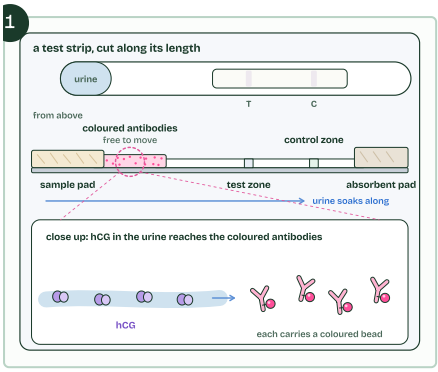
hCG
Human chorionic gonadotropin: a hormone made by the embryo's outer cells and then the placenta, which keeps the corpus luteum going.

monoclonal antibodies
Identical antibodies made by one clone of cells, so all bind the same site on the same molecule.

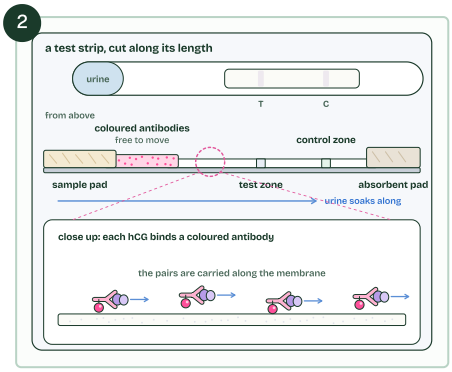


STEP BY STEP

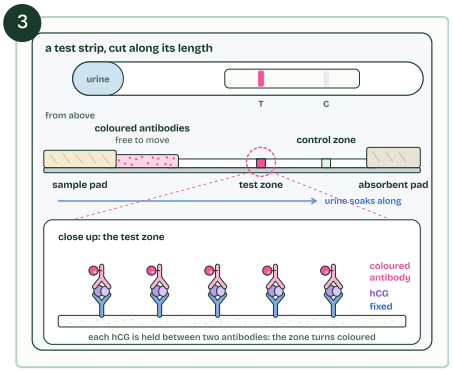
5 STEPS



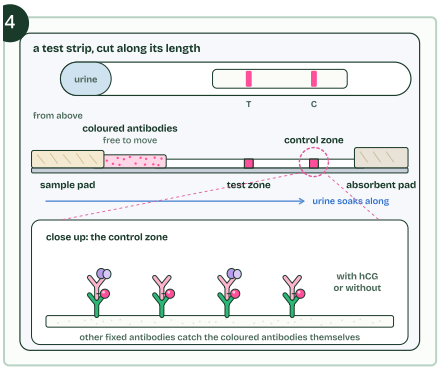
A strip cut along its length and seen from the side. Urine soaks into the sample pad and on to a pad of coloured antibodies that are free to move.



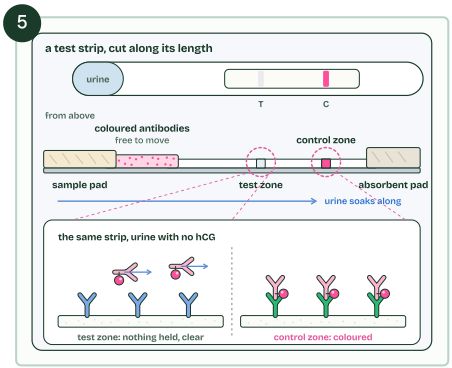
hCG in the urine binds the coloured antibodies, and the pairs are carried along the membrane.



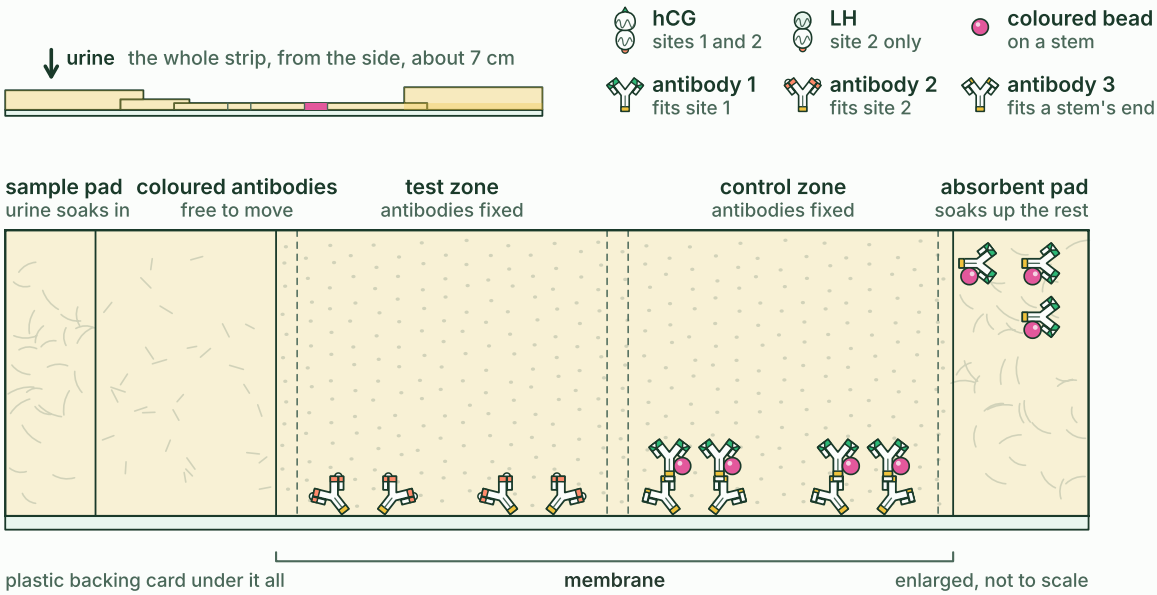
In the test zone, fixed antibodies catch the pairs: each hCG is held between two antibodies, and the zone turns coloured.



In the control zone, other fixed antibodies catch coloured antibodies, with hCG or without.



The same strip run with urine that holds no hCG: only the control zone is coloured.

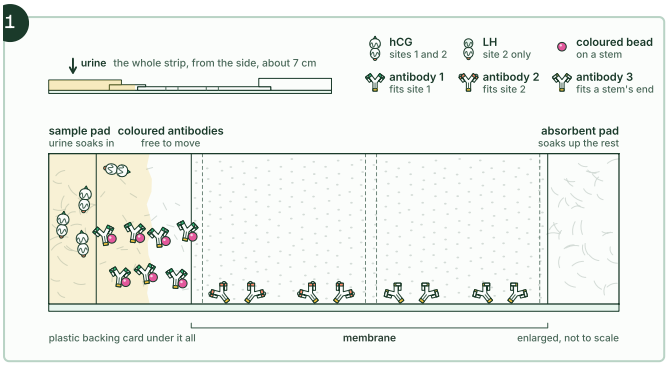


Put the antibodies where they belong, then run urine samples through your strip and say what each result shows.

STEP BY STEP

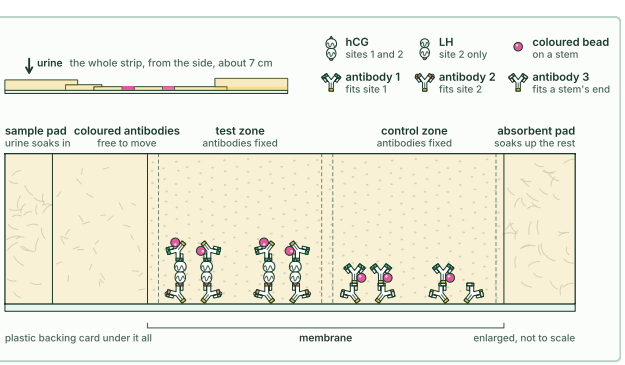
3 STEPS

1



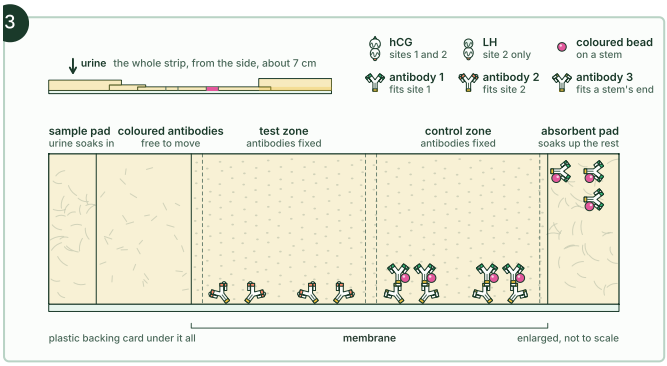
A test strip cut along its length, and the same strip enlarged. Urine soaks into the sample pad and on to a pad of antibodies, each carrying a coloured bead and free to move.

2



With hCG: each hCG is held in the test zone between a fixed antibody, on site 2, and a coloured one, on site 1, so the zone colours. The coloured antibodies left over are held in the control zone.

3



With no hCG: nothing holds coloured antibodies in the test zone, but the control zone still colours, so the strip worked.

PREDICT

A test strip uses two different antibodies to hCG: one coloured and free to move, one fixed in a zone. Why not use just one, fixed in place?

(A) One antibody could not bind hCG at all, since antibodies can only ever bind their antigen in pairs

(B) The fixed antibody would catch every protein in the urine, so the zone would always show a colour

(C) Two are needed to make the urine flow along the strip, since each one pulls the other towards it

(D) One fixed antibody would hold hCG but show nothing; the coloured one stays only if hCG holds it there

Decide before you look. Answer on page 100.

22 The organ between two *bloodstreams*

D3.1.18 HL 22 ROLE OF THE PLACENTA IN FOETAL DEVELOPMENT INSIDE THE UTERUS

Go deeperthe detail, what crosses, and how, beyond the course, examples, watch out

The detail

The placenta grows from the blastocyst's outer cells and the lining of the uterus into a disc on the uterus wall.

It is joined to the foetus by the **umbilical cord**.

Finger-like villi of foetal tissue, each with foetal capillaries, branch into spaces filled with the mother's blood.

The placenta also makes hormones (chapter 23).

What crosses, and how

Oxygen: simple diffusion.

Glucose: facilitated diffusion.

Amino acids and ions: active transport.

Some of the mother's antibodies: endocytosis.

Carbon dioxide and urea: diffusion, for her lungs and kidneys to remove.

Unwanted: alcohol, nicotine, some drugs and some viruses cross too.

Beyond the course

Foetal haemoglobin binds oxygen more strongly than the mother's, which helps it take oxygen across (B3.1).

The cord, the blood spaces and foetal haemoglobin go beyond the course, which asks only that the villi give a large surface area.

Examples

A human foetus can stay in the uterus for about 38 weeks after fertilization.

A mammal without a long-lasting placenta must let its young go earlier: a kangaroo's are born tiny and finish developing in a pouch, and a platypus lays eggs.

Watch out

The mother's blood does **not flow into the foetus**.

The placenta is not a perfect filter.

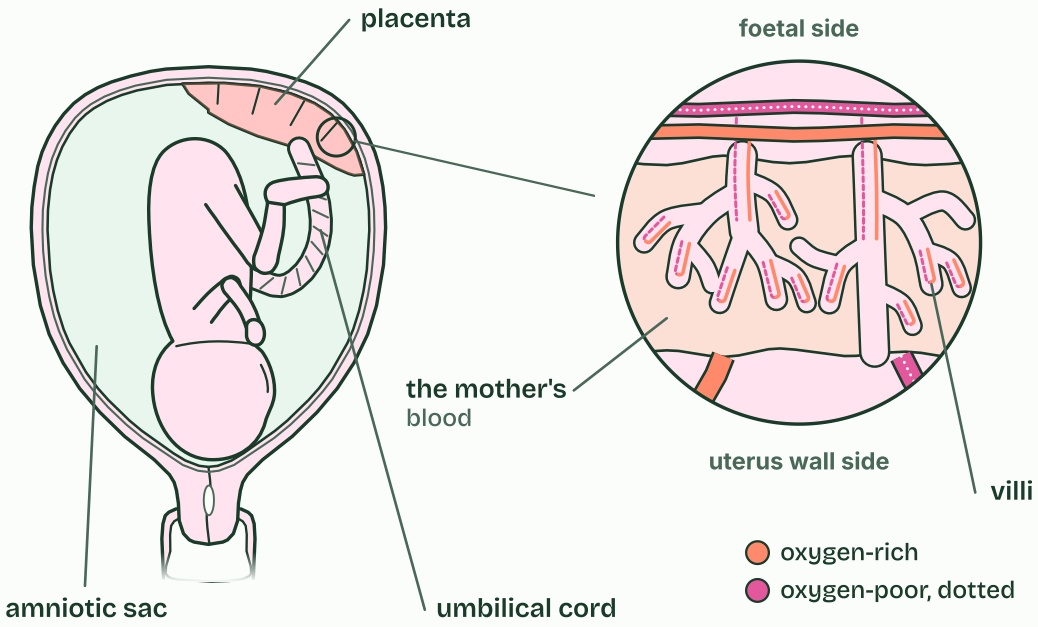
The umbilical vein carries oxygen-rich blood to the foetus.

The foetus does not breathe through the placenta: it exchanges gases there, while its lungs are not yet in use.

KEY TERMS

placenta
The organ, grown from the embryo's outer cells and the uterus lining, where substances pass between the mother's blood and the foetus's.

villi
Branching, finger-like projections of foetal tissue in the placenta, each with foetal capillaries, bathed in the mother's blood.



Uterus wall Muscle, stretched round the growing foetus. The cervix below stays shut until labour.

Umbilical cord Joins the foetus to the placenta. Its two arteries carry the foetus's blood out to the villi, and its vein brings it back.

The mother's blood Her arteries in the uterus wall pour blood into a space round the villi, and her veins drain it. It never enters the foetus's vessels.

The foetus's blood Branches of the umbilical arteries bring it, oxygen-poor, to a capillary loop in each villus; branches of the umbilical vein take it back, oxygen-rich.

Placenta A disc on the uterus wall, grown from the embryo's outer cells and the lining. Here the foetus's blood comes close to the mother's for exchange; it also makes hormones (chapter 23).

Foetus and amniotic sac The foetus floats in fluid in the amniotic sac. Its lungs are not yet in use: all its exchange happens at the placenta.

Villi Finger-like branches of foetal tissue hanging in the mother's blood. Branching gives a large surface area, and each finger's wall is thin: a short path between the two bloods.

Placenta A disc on the uterus wall, grown from the embryo's outer cells and the lining. Here the foetus's blood comes close to the mother's for exchange; it also makes hormones (chapter 23).

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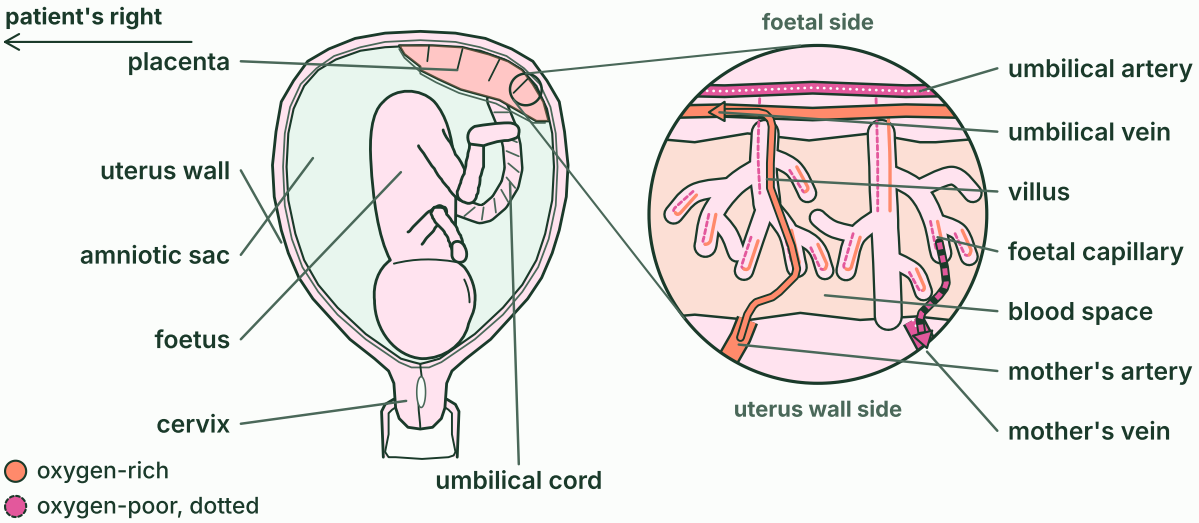
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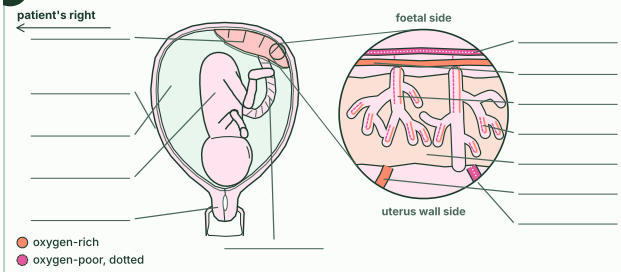


Follow oxygen from the mother's artery across a villus to the foetus, then carbon dioxide back the other way.

STEP BY STEP

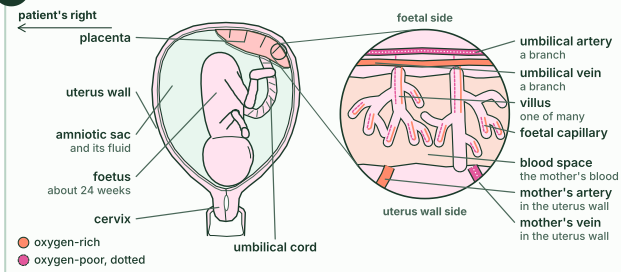
3 STEPS

1



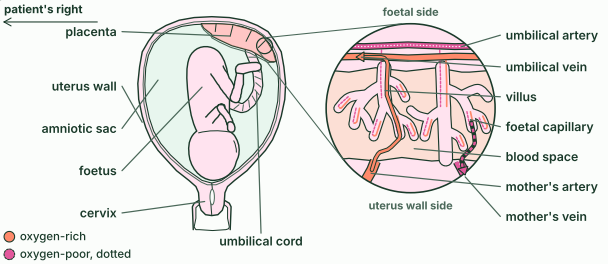
The uterus at about 24 weeks, and a lens on the placenta. Label the parts on the lines.

2



The **placenta**: foetal **villi** in a **blood space** filled by the **mother's artery** and drained by her **vein**. The foetus's blood flows in a **capillary** loop in each villus, to and from the **umbilical cord**.

3



Exchange without mixing: oxygen (solid) from the mother's blood across the villus wall into the foetal capillary and away in the umbilical vein; carbon dioxide (dashed) the other way, into the mother's vein.

PREDICT

The mother's blood and the foetus's blood never mix. How, then, does oxygen get from her to the foetus?

(A) Her blood flows along the umbilical cord into the foetus's lungs, where the oxygen is then taken up by its cells

(B) The villi pump it across by active transport, since it must pass into foetal blood that already holds less of it

(C) It diffuses across the thin villus walls from her blood, where it is high, into foetal blood, where it is low

(D) Her red blood cells carry it across the barrier, and then they stay on in the foetus's own circulation for good

Decide before you look. Answer on page 100.

23 Keeping a pregnancy *going*

D3.1.19 HL 23 HORMONAL CONTROL OF PREGNANCY AND CHILDBIRTH

Go deeperthe detail, watch out

The detail

At the end of a cycle with no embryo, the corpus luteum breaks down, its progesterone falls, and the lining is shed. A pregnancy must stop that.

hCG (chapter 21) keeps the corpus luteum alive past the point where it would shrink, so there is no period.

hCG peaks near the end of the takeover, at about weeks 8 to 11, then falls.

Progesterone also keeps the muscle of the uterus wall from contracting (chapter 24).

With oestradiol it stops the release of FSH and LH, so no new follicles ripen.

A missed period is a sign of pregnancy but not proof of one: a test for hCG is the check.

Watch out

Progesterone is **not made by the foetus**.

The ovary does not make it all through pregnancy: the placenta takes over.

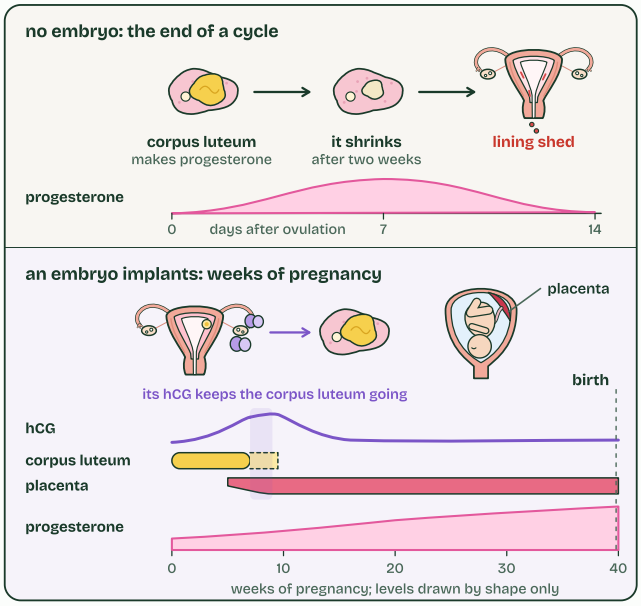
hCG does not stop eggs being released: progesterone and oestradiol do that.

KEY TERMS

hCG
Human chorionic gonadotropin: a hormone made by the embryo's outer cells and then the placenta, which keeps the corpus luteum going.

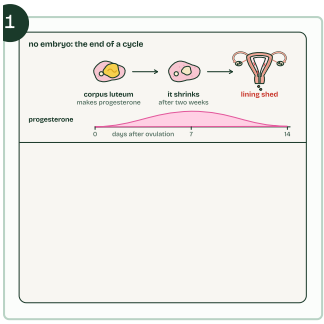
corpus luteum
The gland the empty follicle becomes after ovulation; it secretes progesterone and oestradiol for about two weeks.

placenta
The organ, grown from the embryo's outer cells and the uterus lining, where substances pass between the mother's blood and the foetus's.

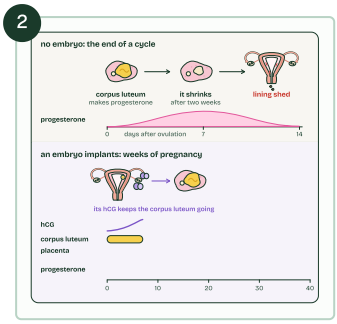


STEP BY STEP

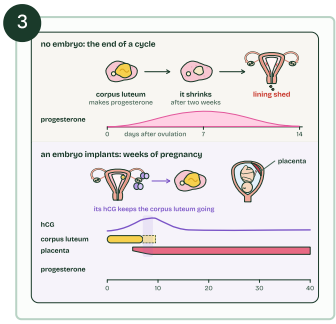
4 STEPS



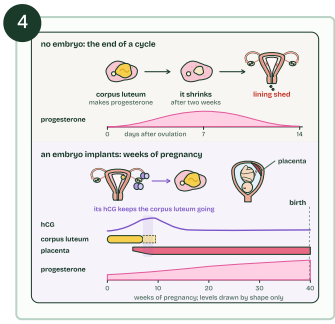
A cycle with no embryo: the corpus luteum makes progesterone for about two weeks, then shrinks, and the lining is shed.



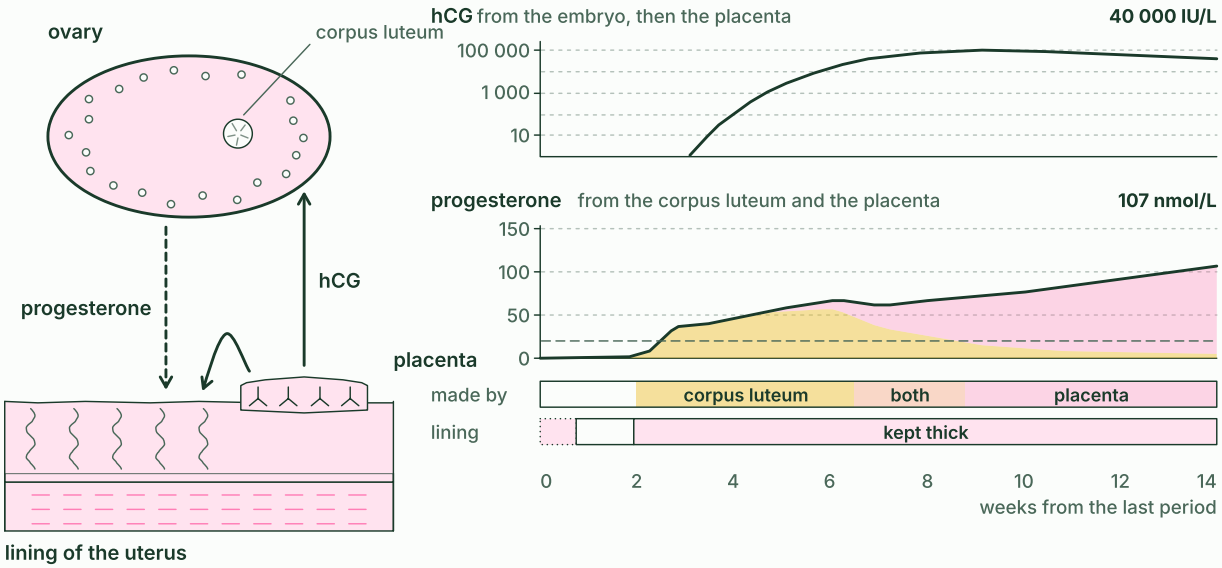
An embryo implants, and the corpus luteum goes on making progesterone past the point where it would shrink.



From about weeks 7 to 9 the placenta takes over making progesterone. The corpus luteum fades; hCG peaks near the end of the takeover, then falls.



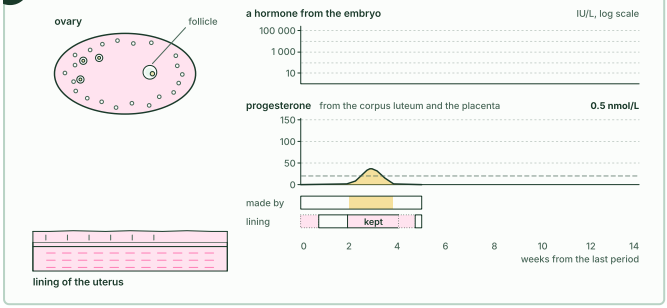
Progesterone stays high to the end of the pregnancy. Levels are drawn by shape only.



Follow the weeks: watch where the progesterone comes from, and what happens to the lining if hCG never rises.

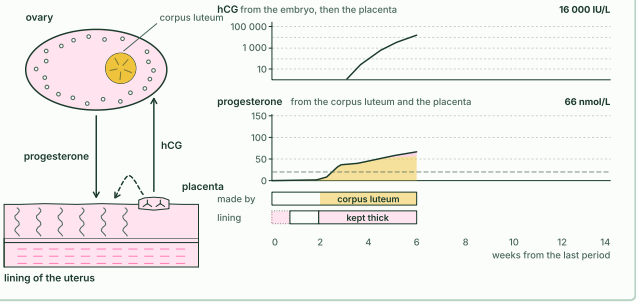
STEP BY STEP
3 STEPS

1



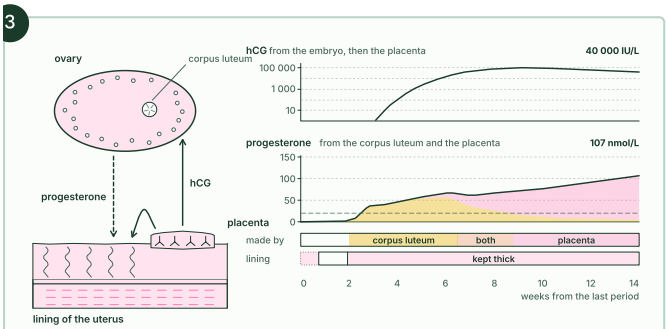
No embryo: the **corpus luteum** makes progesterone for about two weeks after ovulation, then breaks down. Progesterone falls, the lining is shed and a new cycle starts. Predict: what must an embryo do to stop this?

2



An embryo implants and its outer cells make **hCG**. hCG keeps the corpus luteum making **progesterone** past the end of the cycle, so the lining is kept and there is no period.

3



From about week 7 to 9 the **placenta** takes over making progesterone; the corpus luteum fades and hCG falls from its peak. The placenta keeps progesterone rising to the end of pregnancy.

PREDICT

In a normal cycle the corpus luteum shrinks after about two weeks. In early pregnancy it does not. Which hormone from the embryo do you think prevents that?

(A) LH from the embryo's own pituitary gland, since LH is the hormone that makes a corpus luteum

(B) hCG from the blastocyst's outer cells, which signals the corpus luteum to keep making progesterone

(C) FSH, which starts a fresh follicle that takes over the work of the corpus luteum as it shrinks

(D) Progesterone from the embryo, passed into the uterus to tell the lining that it must stay thick

Decide before you look. Answer on page 101.

24 Positive feedback brings *the baby*

D3.1.19 HL 24 HORMONAL CONTROL OF PREGNANCY AND CHILDBIRTH

Go deeperthe detail, links across the course, watch out

The detail

This is the IB's account. In humans the level of progesterone in the blood may not fall much: what falls may be its effect on the muscle.

Oxytocin is made in the hypothalamus and released from the pituitary gland.

Contractions of the uterus wall push the baby's head against the cervix.

Stretch receptors in the cervix send nerve impulses to the hypothalamus, and more oxytocin is released.

Each round is bigger than the last.

Once the baby is out, the cervix is no longer stretched and the loop is broken.

A synthetic oxytocin drip is used in hospitals to start or speed up labour.

Links across the course

Negative feedback holds a level steady (chapter 14, and D3.3). **Positive feedback** drives a change to its end, and needs a stop.

Ripening fruit has a loop of the same kind (C3.1).

Watch out

Progesterone's hold on the muscle **falls** at birth. It does not rise.

Positive feedback is neither good nor bad in itself: it is a loop that drives one way and needs something to stop it.

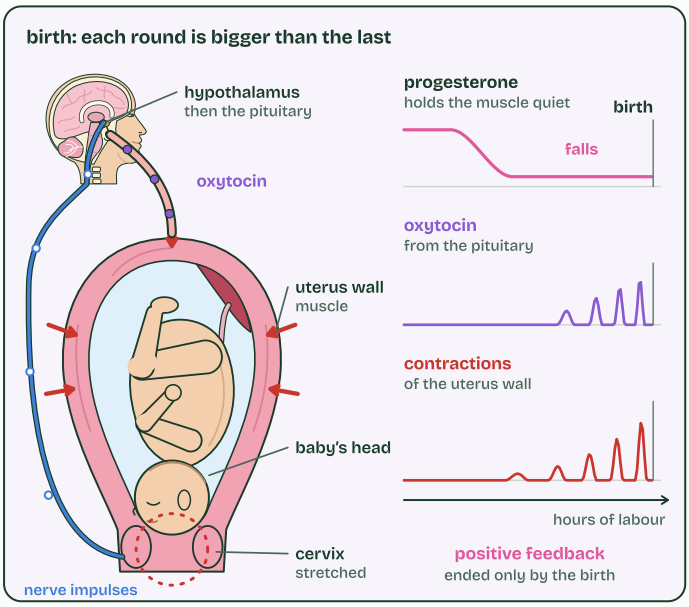
It does stop: the birth ends it.

KEY TERMS

oxytocin
A hormone made in the hypothalamus and released from the pituitary; it makes the muscle of the uterus wall contract.

positive feedback
A response that increases the change that caused it, so the change grows until something stops it.

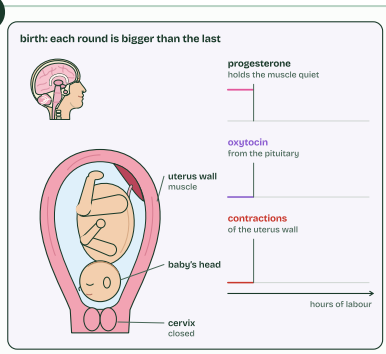
negative feedback
A response that reverses the change that caused it, so a level is held near a set point.



STEP BY STEP

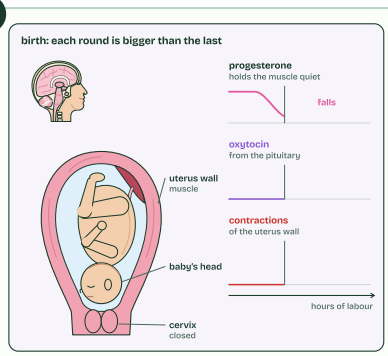
5 STEPS

1



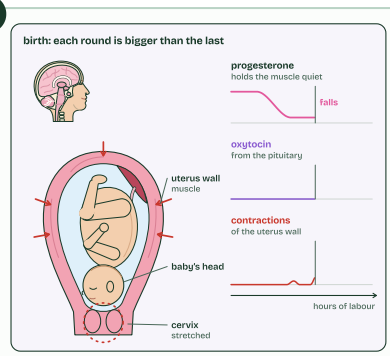
Late in pregnancy: progesterone is high and the muscle of the uterus is quiet. The baby's head rests on the closed cervix.

2



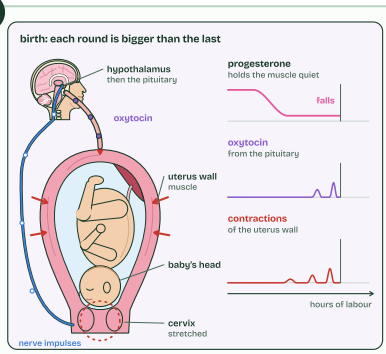
Progesterone falls.

3



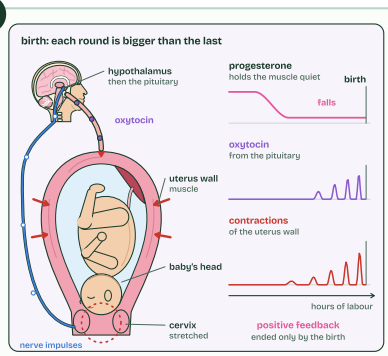
The first contractions press the head on the cervix, which starts to stretch.

4

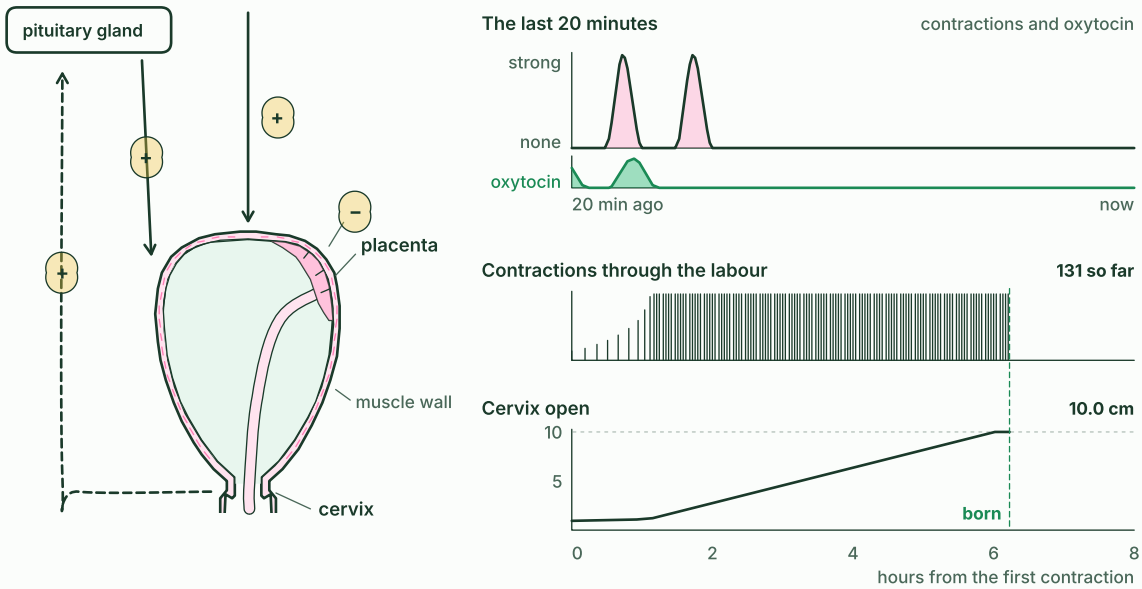


Stretch sends nerve impulses to the hypothalamus, and oxytocin is released in pulses: the contractions grow stronger and closer.

5



Each round is bigger than the last, until the birth ends the stretch and the loop.

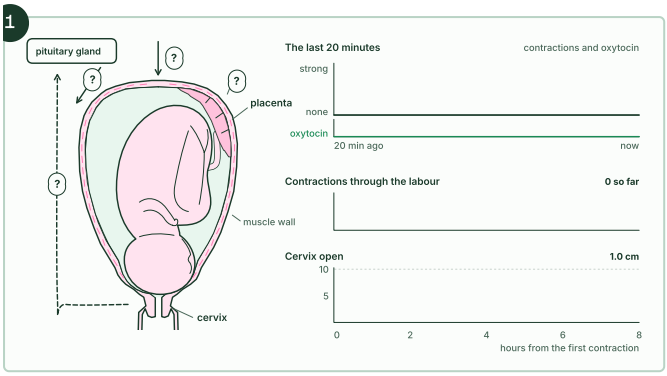


Lower the progesterone and start labour: watch the oxytocin and the contractions build, and what ends the loop.

STEP BY STEP

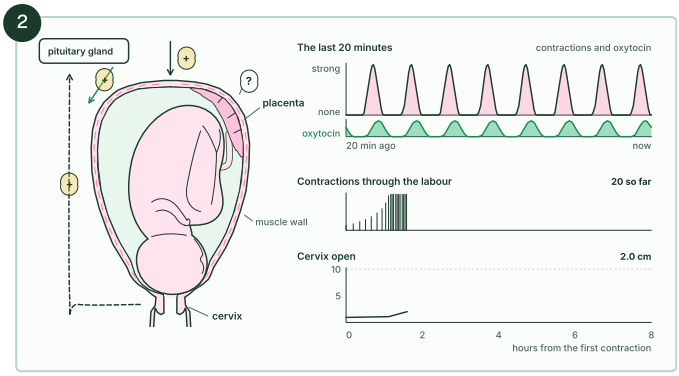
3 STEPS

1



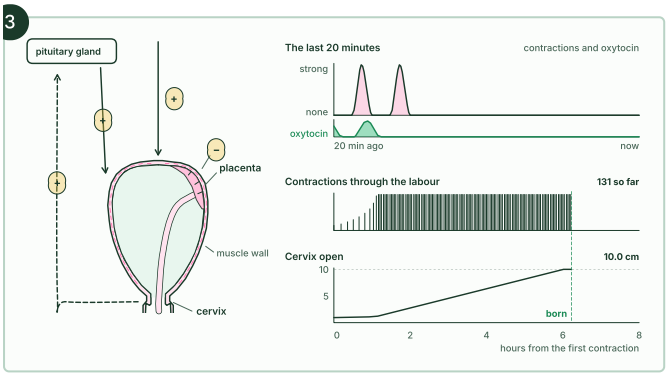
Late in pregnancy **progesterone** holds the uterus's muscle quiet. Predict: what lets the contractions start, and what keeps them growing?

2



Progesterone's hold falls. A contraction pushes the baby's head onto the **cervix**; the stretch sends nerve signals to the brain and the pituitary releases **oxytocin**, which makes the next contraction stronger.

3



Positive feedback: each contraction calls for more oxytocin, which makes a stronger contraction, until the cervix is fully open and the baby is born. Then the stretch ends and the loop stops.

PREDICT

A woman's cervix is stretched a little by the baby's head, and her progesterone has fallen. What happens next?

(A) Oxytocin is released and stops the contractions at once, since the cervix has now been stretched far enough

(B) The contractions pass in waves of equal strength, until the baby's weight alone is enough to open the cervix

(C) The baby's head sends a hormone to the placenta, which makes more progesterone to relax the uterus again

(D) Oxytocin is released; stronger contractions push the head harder on the cervix, releasing more, until birth

Decide before you look. Answer on page 101.

25 Does it prove it? HRT and *the heart*

D3.1.20 HL 25 HORMONE REPLACEMENT THERAPY AND THE RISK OF CORONARY HEART DISEASE

Go deeperthe detail, how we know, links across the course, watch out

The detail

At the **menopause**, often around the age of 50, the ovaries stop releasing eggs and make much less oestradiol and progesterone.

The negative feedback of chapter 14 is lost, so FSH and LH rise, and the change can bring symptoms.

HRT, hormone replacement therapy, gives back oestrogen, usually with a progestogen for a woman who still has a uterus.

How we know

The early studies compared women who took HRT with women who did not.

It was argued, and for a while accepted, that HRT protected the heart: cause and effect.

The trials put women by chance into an HRT group or a placebo group.

The largest trial used oestrogen and a progestogen, in women who had started it, on average, years after the menopause.

Higher socioeconomic status lowers CHD risk through diet, exercise, smoking and health care. That was a **confounding variable**.

Random allocation shares out every difference, known and unknown, by chance, so in a large enough trial only the treatment differs between the groups.

Links across the course

This is B3.2's lesson on correlation and cause, met in a human-health claim.

Watch out

A strong correlation is **not proof of cause**.

The trials found a small increase in CHD among the women they studied. They do not show that HRT harms everyone.

A placebo is not no treatment: it is a dummy one, so expectations are the same in both groups.

The chapter is about evidence, not treatment: decisions about HRT are for a woman and her doctor, and later work looks at the age it is started and the type used.

KEY TERMS

HRT
Hormone replacement therapy: oestrogen, usually with a progestogen, given to relieve the symptoms of the menopause.

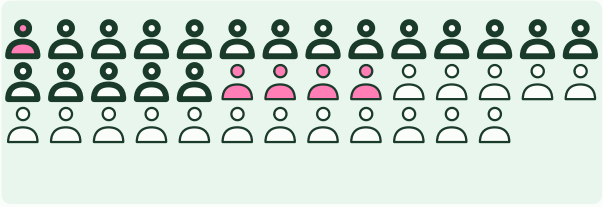
randomized controlled trials
A trial in which participants are put into a treatment group or a control group at random, so the groups differ only in the treatment.

confounding variable
A variable that affects the outcome and differs between the groups compared, so it can make a link look like cause and effect.

At random: a randomized controlled trial

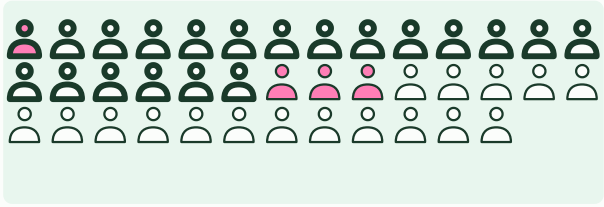
Invented data: each figure is 25 women

HRT
1 000 women



CHD 120 (12.0%)

Placebo (dummy)
1 000 women



CHD 99 (9.9%)

Risk ratio 1.21: 12.0% with HRT against 9.9% without
Higher socioeconomic level: 49% of the HRT group, 49% of the placebo group
thick outline: higher level; thin: lower; filled: CHD in 10 years

Run an observational study, then a randomized trial, and compare what each says about HRT and the heart.

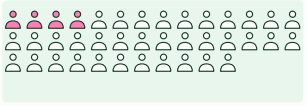
STEP BY STEP

3 STEPS

1

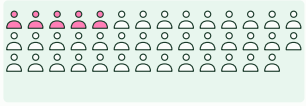
They choose: an observational study — Invented data: each figure is 25 women

HRT
964 women



CHD 87 (9.0%)

No HRT
1 036 women



CHD 122 (11.8%)

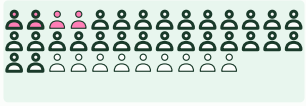
Risk ratio 0.77: 9.0% with HRT against 11.8% without

They choose (invented data): 2000 women past the menopause, each figure 25 of them, followed for 10 years; filled figures had coronary heart disease. The HRT group had less CHD: risk ratio 0.77. Does HRT protect the heart?

2

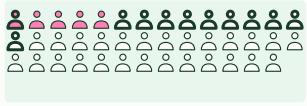
They choose: an observational study — Invented data: each figure is 25 women

HRT
964 women



CHD 87 (9.0%)

No HRT
1 036 women



CHD 122 (11.8%)

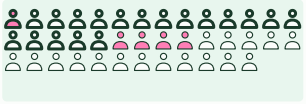
Risk ratio 0.77: 9.0% with HRT against 11.8% without
Higher socioeconomic level: 73% of the HRT group, 26% of the other group
thick outline: higher level; thin: lower; filled: CHD in 10 years

The **hidden factor**: thick outlines are women of a higher socioeconomic level, who were likelier to choose HRT and have a lower risk of CHD anyway. It is a **confounding variable**: the groups differed before anyone took a tablet.

3

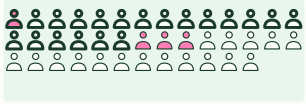
At random: a randomized controlled trial — Invented data: each figure is 25 women

HRT
1 000 women



CHD 120 (12.0%)

Placebo (dummy)
1 000 women



CHD 99 (9.9%)

Risk ratio 1.21: 12.0% with HRT against 9.9% without
Higher socioeconomic level: 49% of the HRT group, 49% of the placebo group
thick outline: higher level; thin: lower; filled: CHD in 10 years

At random: a randomized controlled trial, half on HRT and half on a placebo. Chance shares the levels out evenly, so the tablets are the only planned difference, and HRT shows a small increase: risk ratio 1.21, the small harm this invented model gives it.

PREDICT

In an early study, women who took HRT had fewer heart attacks than women who did not. Which new study would best show whether HRT caused this?

(A) One in which women are given HRT or a dummy tablet at random, so the groups differ only in treatment

(B) A study of the same kind but ten times bigger, in which every woman again chose her own treatment

(C) A study in which each woman keeps a diary of her diet and exercise alongside her own treatment for a year

(D) A study of women of many ages, comparing the heart attacks of the oldest group with the youngest

Decide before you look. Answer on page 101.

Key terms

Every term this guide defines, A to Z, with the chapter it is in. Cover the right-hand side and test yourself.

acrosome reaction 19
The release of enzymes from the acrosome of a sperm when it binds the zona pellucida, digesting a path through it.

anther 01
The top of a stamen, where pollen grains are made.

asexual reproduction 08
Reproduction by one parent alone, by mitosis, with no gametes; the offspring are genetically identical to the parent.

blastocyst 20
A hollow ball of about a hundred cells, an embryo about five days after fertilization, with a cluster of cells on one side.

carpel 01
The female part of a flower: the stigma, style and ovary together.

clone 08
A group of genetically identical organisms, all descended from one parent by asexual reproduction.

confounding variable 25
A variable that affects the outcome and differs between the groups compared, so it can make a link look like cause and effect.

corpus luteum 13
The gland the empty follicle becomes after ovulation; it secretes progesterone and oestradiol for about two weeks.

cortical reaction 19
The release of enzymes from cortical granules under the egg's membrane after the first sperm fuses, which changes the zona so no other sperm can bind or pass.

Cross-pollination 04
Pollen from one plant reaching a stigma on another plant of the same species.

diploid 09
Having two sets of chromosomes, one from each parent (in humans 46).

embryo 02
The young plant inside a seed, grown from the zygote by mitosis: a radicle, a plumule and one or two cotyledons.

endometrium 12
The lining of the uterus, which thickens each cycle, rich in blood vessels and glands, and is where an embryo implants.

fertilization 02
The fusion of a male and a female gamete, making a zygote.

filament 01
The stalk of a stamen. It holds the anther where visiting insects brush against it.

flower 04
The organ of sexual reproduction in a flowering plant.

GnRH 17
Gonadotropin-releasing hormone: made by the hypothalamus; it makes the pituitary release LH and FSH.

haploid 09
Having one set of chromosomes (in humans 23).

hCG 16
Human chorionic gonadotropin: a hormone made by the embryo's outer cells and then the placenta, which keeps the corpus luteum going.

hermaphrodite 01
Having both male and female parts: here, a flower with both stamens and carpels.

homozygous 05
Having two copies of the same allele of a gene.

HRT 25
Hormone replacement therapy: oestrogen, usually with a progestogen, given to relieve the symptoms of the menopause.

hypothalamus 17
A part of the brain, just above the pituitary gland, that links the nervous system to the hormone system.

implantation 20
The burying of the blastocyst in the endometrium, from about a week after fertilization.

inbreeding 05
Breeding between close relatives, or of a plant with itself, so that offspring more often get two copies of the same allele.

IVF 16
In vitro fertilization: eggs are fertilized with sperm in a dish outside the body, and an embryo is placed in the uterus.

meiosis 09
A division of the nucleus in two stages that halves the chromosome number and makes cells with new combinations of alleles.

menstruation 13
The shedding of the uterus lining, with some blood, through the vagina; its first day is day 1 of the cycle.

micropyle 02
A tiny gap in the outer layers of an ovule. The pollen tube grows in through it, and in the seed it stays as a tiny pore.

monoclonal antibodies 21
Identical antibodies made by one clone of cells, so all bind the same site on the same molecule.

mutualism 03
A relationship between two species in which both benefit.

negative feedback 14
A response that reverses the change that caused it, so a level is held near a set point.

oogenesis 18
The making of eggs in the ovaries.

ovary 01
The swollen base of the carpel, which holds the ovules. It becomes the fruit.

ovulation 13
The release of an egg from a mature follicle at the surface of the ovary.

ovules 01
A small structure inside the ovary that holds an egg cell. After fertilization it becomes a seed.

oxytocin 24
A hormone made in the hypothalamus and released from the pituitary; it makes the muscle of the uterus wall contract.

petals 01
The ring of a flower's parts inside the sepals, often large and brightly coloured.

placenta 22
The organ, grown from the embryo's outer cells and the uterus lining, where substances pass between the mother's blood and the foetus's.

plumule 07
The embryo's shoot, which grows into the stem and the first leaves.

polar bodies 18
A small cell made by an unequal division in oogenesis; it gets very little cytoplasm and breaks down.

pollen tube 02
A tube that grows out of a pollen grain on a stigma, down through the style to an ovule, carrying the male gametes.

pollination 02
The transfer of pollen from an anther to a stigma.

polyspermy 19
Fertilization of one egg by more than one sperm; the zygote has extra sets of chromosomes and cannot develop normally.

positive feedback 14
A response that increases the change that caused it, so the change grows until something stops it.

radicle 07
The embryo's root, the first part of a seed to grow out.

randomized controlled trials 25
A trial in which participants are put into a treatment group or a control group at random, so the groups differ only in the treatment.

seed dispersal 06
The carrying of seeds away from the parent plant.

Self-incompatibility 05
A genetic mechanism that stops a plant's own pollen from fertilizing its ovules, so the gametes that fuse come from different plants.

Self-pollination 04
Pollen reaching a stigma of the same flower, or of another flower on the same plant.

sepals 01
The outer ring of a flower's parts, usually small and green. They cover and protect the flower while it is a bud.

sexual reproduction 08
Reproduction in which two gametes, made by meiosis, fuse; the offspring carry new combinations of alleles.

spermatogenesis 18
The making of sperm in the seminiferous tubules of the testes.

stamen 01
The male part of a flower: an anther on a filament.

stamens 01
The male part of a flower: an anther on a filament.

stigma 01
The sticky top of the carpel, which catches pollen grains.

style 01
The stalk of the carpel. It holds the stigma up, and pollen tubes grow down through it.

superovulation 16
Many follicles brought to maturity at once by doses of FSH, where a natural cycle matures one.

testa 07
The tough seed coat, made from the outer layers of the ovule.

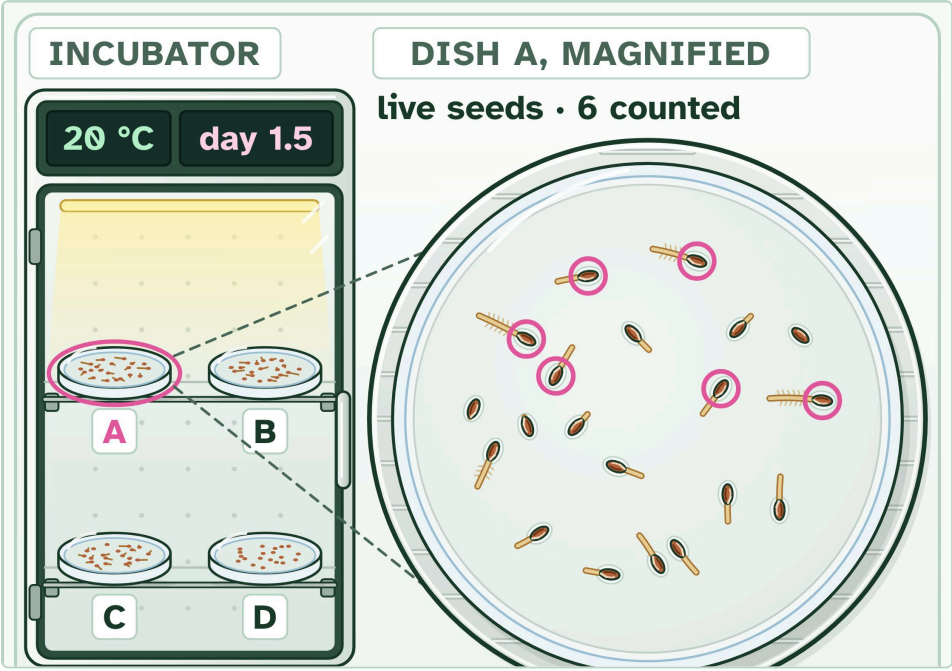
villi 22
Branching, finger-like projections of foetal tissue in the placenta, each with foetal capillaries, bathed in the mother's blood.

zona pellucida 19
A thick coat of glycoproteins round the egg, outside its cell membrane.

zygote 02
The single cell made when two gametes fuse. It divides by mitosis to form an embryo.

Dry lab: *Waking seeds*

Four dishes of cress seeds on filter paper, in an incubator. Change the water, the oxygen, the light or the temperature, then count the seeds that have germinated every half day for a week.



Run it online: change the variables, run the trials, and the table and graph fill in as you go. `biologybybradford.com/guides/ib-biology-d3-1-reproduction#lab`

Your question

What does a seed need before it will germinate? Pick one condition (water, oxygen, light or temperature) and find out how it changes how many seeds germinate and how fast.

What you can change

Choose one thing to change: the water (dry paper, damp paper, or flooded so that the seeds sit under water), the oxygen (an open dish, or a sealed jar with an oxygen absorber), the light (light, or dark under foil) or the temperature of the incubator, which is the same for every dish. Keep everything else the same, with a dish in ordinary conditions to compare, and a dish of boiled seeds as a control, which the bench sets out with every run.

What to record

Count the germinated seeds in each dish every half day. A seed counts once its root is at least 2 mm long: decide this before you start, and keep to it. Work out the time for half the seeds (10 of 20) to germinate, and the rate, 1 ÷ that time. Plan at least three dishes at each setting: dishes scatter, as real ones do. The coach under the bench helps you plan, process and evaluate.

Find out

- **Does a seed need water?** Run dishes kept dry, damp and flooded (the seeds under water), all at the same temperature. Write down what you expect before each run. Which dishes germinate, and how fast?
- **Does a seed need oxygen?** Compare damp dishes in open air with damp dishes sealed in a jar with an oxygen absorber, at the same temperature.
- **How warm is best?** Run the same damp, open dishes at several incubator temperatures, from cold to hot. Where is germination fastest, and what happens at each end of the range?
- **Does light matter?** Compare damp dishes in the light and in the dark. Decide what you expect, and why, before you run them, and look at the seedlings as well as the counts. If the counts match, that is a result too: say so in your evaluation.
- **Keep it fair.** Every dish holds 20 seeds from one packet on the same paper. Change one thing at a time, and keep a dish in ordinary conditions (damp, open to the air, in the light) to compare with the others. Every run also sets out a dish of boiled seeds as a control.

Record

- For every dish: its settings, and how many seeds have germinated at each half-day count.
- The rule for counting: a seed has germinated once its root (the radicle) is at least 2 mm long. Fix the rule before you start and keep to it, or the counts cannot be compared.
- The seeds germinated at each count (as a number, or a percentage of the 20), plotted against time, one line for each dish.
- For each dish, the time for half the seeds sown (10 of the 20) to germinate, read between the two counts either side of 10, and the rate of germination, 1 ÷ that time. A dish that never reaches 10 has no rate: record that it did not reach half.
- At least three dishes at each setting, with the mean. Dishes scatter, as real ones do, and even a good dish seldom reaches 100 percent.

Your question What does a seed need before it will germinate? Pick one condition (water, oxygen, light or temperature) and find out how it changes how many seeds germinate and how fast.**What you can change**Choose one thing to change: the water (dry paper, damp paper, or flooded so that the seeds sit under water), the oxygen (an open dish, or a sealed jar with an oxygen absorber), the light (light, or dark under foil) or the temperature of the incubator, which is the same for every dish. Keep everything else the same, with a dish in ordinary conditions to compare, and a dish of boiled seeds as a control, which the bench sets out with every run.**What to record**Count the germinated seeds in each dish every half day. A seed counts once its root is at least 2 mm long: decide this before you start, and keep to it. Work out the time for half the seeds (10 of 20) to germinate, and the rate, 1 ÷ that time. Plan at least three dishes at each setting: dishes scatter, as real ones do. The coach under the bench helps you plan, process and evaluate.

Back to seeds

Use your results to explain what a seed needs before it will germinate, and what it uses each one for.

QUESTIONS ON THE LAB

QUESTION 1

One dish of seeds is kept dry. The others are on damp paper. What happens in the dry dish?

(A) They germinate more slowly, using the small amount of water stored inside each seed

(B) None germinate: without water a seed cannot swell or set its enzymes working

(C) They germinate as usual, taking all the water they need from the incubator's air

(D) They germinate, but the seedlings die once the food stored in the seed runs out

Answer on page 101.

QUESTION 2

Seeds sit under water in a flooded dish, at a temperature that suits them. What do you expect?

(A) They germinate fastest of all, because they have the most water there to take up

(B) They all germinate, but their radicles grow upwards to reach the air above them

(C) None germinate, because the water washes the food store out of every single seed

(D) Few germinate, or slowly: under water they get too little oxygen to respire

Answer on page 101.

QUESTION 3

Damp seeds are kept in an incubator turned up to the top of its range. Fewer germinate than at a middle temperature. Why?

(A) Heat speeds up every enzyme, so the food store is used up before growth starts

(B) The heat makes the testa so hard that the radicle cannot break out through it

(C) Their enzymes begin to denature, so the reactions that drive growth fail

(D) Oxygen cannot get into a warm seed, so it cannot respire aerobically at all

Answer on page 101.

WRITE IT UP AS AN INVESTIGATION

Your results from this dry lab can be written up the way an IB scientific investigation is: four criteria, each worth 6 marks. Tick each line as your write-up does it. The coach on the page checks these as you go; it never gives a mark.

1 Research design

A focused question set in its biology; your choices of what to measure, how, over what range and how often, explained rather than listed; what you kept the same and how; safety, ethics and the environment; a method someone else could follow and repeat.

- [ ] My question names what I changed.
- [ ] It gives the range I used, with units.
- [ ] It names what I measured and how.
- [ ] It names the organism or system.
- [ ] My background explains, with the biology, why the two should be linked.
- [ ] I cite my sources, and each reference can be traced.
- [ ] If I give a hypothesis, it predicts and explains.
- [ ] Every variable has its How, Why and Units.
- [ ] For each thing kept the same, I say how I kept it so.
- [ ] I list at least three things I kept the same.
- [ ] I name the apparatus that set what I changed, and the instrument that measured.
- [ ] I test enough values.
- [ ] My values spread wide enough.
- [ ] I run at least three trials at every value.
- [ ] I run a control.
- [ ] I explain why these values, this many and this often.
- [ ] Someone else could repeat my method.
- [ ] I deal with safety, ethics and the environment.

2 Data analysis

Raw data recorded clearly, with titles, units, uncertainties and the same decimal places down a column; what you saw as well as what you measured; processing that suits the question, shown with a worked example; the spread shown; a graph a reader can trust.

- [ ] Each table has a numbered title that says what it shows.
- [ ] Every heading has its quantity and its unit.
- [ ] Every raw data heading has its uncertainty.
- [ ] Each uncertainty is realistic for the instrument.
- [ ] Each uncertainty has the same decimal places as its readings.
- [ ] I record what I saw as well as what I measured.
- [ ] I show one worked example of my processing, and it is right.
- [ ] I say why I left out any trial.
- [ ] My error bars show a spread my repeats can support.
- [ ] My graph has a numbered title and labelled axes with units.
- [ ] I say what the error bars show.
- [ ] A straight line, if I draw one, has its R^2.
- [ ] A statistical test, if I run one, has its hypotheses and suits the data.

3 Conclusion

Your question answered from the processed data, with numbers quoted and the spread taken into account; the biology that explains the pattern; a comparison with published work; no claim bigger than the data.

- [ ] I answer my question in a sentence, naming both variables.
- [ ] I quote my processed numbers.
- [ ] I say how sure the spread lets me be.
- [ ] I say whether my hypothesis is supported.
- [ ] I explain the pattern with biology.
- [ ] I compare my result with published work, and cite it.
- [ ] I claim no more than my data show.

4 Evaluation

Weaknesses and limitations of this method (not slips in carrying it out), with evidence from your own data, the effect each had on the results, which mattered most and why, and a realistic improvement for each.

- [ ] I give at least three weaknesses or limitations.
- [ ] Every row is filled in.
- [ ] No slips in carrying it out: weaknesses of the method itself.
- [ ] Each improvement is specific: which instrument, how many, what changes.
- [ ] Each effect says what it did to my data.
- [ ] At least two rows point to evidence in my own data.
- [ ] At least one limitation: what this experiment cannot tell me.
- [ ] I say which mattered most, and why.
- [ ] I deal with what stands out in my data.
- [ ] My improvements improve this investigation, not a new one.

Variables

Variable	How?	Why?	Units
Independent: temperature			
Dependent: rate of germination (1 ÷ time for half the seeds to germinate)			
Kept the same: the same volume of water on every paper (damp, not flooded)			
Kept the same: every dish open to the air			
Kept the same: the same light on every dish			
Kept the same: number of seeds in each dish (20)			
Kept the same: seeds from one packet (one batch, one variety)			
Kept the same: the same filter paper and dish			
Kept the same: what counts as germinated (a root at least 2 mm long)			
Kept the same: counting every half day for 7 days			

Evaluation

Weakness or limitation	Which?	Evidence in my data	Effect on my results	Improvement

Data generated with the germination dry lab, biologybybradford.com (a simulation). These checks catch what is missing. They cannot judge how good it is: that is what your teacher does.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on D3.1 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=D3.1&level=HL&paper=quiz&marks=15&src=ep

Answers

PREDICTIONS IN THE CHAPTERS

01 A flower's petals are removed before it opens. What does the plant lose?

C The signal that brings insects in, so fewer of them visit with pollen

The signal that brings insects. Petals attract insects, and are mostly advertising: their size and colour draw insects in, and lines on many of them show the way to the nectar. Without them fewer insects visit, so less pollen reaches the stigma and fewer seeds are made. Scent helps too, but bees, for example, also find flowers by their colours and patterns, not by smell alone. The pollen and the ovules are made in the anthers and the ovary, not in the petals.

02 A flower is fertilized by pollen from its own anthers. Is the seed the product of sexual reproduction?

B Yes: gametes from cells made by meiosis still fuse, as in a cross

Yes. Many flowers can pollinate themselves, and the IB stresses that this is still sexual reproduction. The male gamete and the egg cell come from cells made by meiosis, and they fuse at fertilization, with or without a pollinator, even when only one plant is involved. Wherever the parent has two different alleles of a gene, its seedlings can differ from it and from each other.

03 A flower has no scent, tiny green petals and feathery stigmas hanging outside it. How is it pollinated?

D By the wind, which needs the stigmas out in the air, not insects

By the wind. A wind-pollinated flower has no insects to attract, so it spends little or nothing on scent, nectar or big petals. Its anthers hang out on long filaments, where the wind shakes the pollen loose, and its large, feathery stigmas comb pollen out of the air. The wind scatters pollen in all directions and much of it never lands on a stigma, so these flowers make far more pollen than insect flowers do, and it is light and smooth. About one species in eight is pollinated this way, among them the grasses, such as maize, and trees such as hazel. Switch the drawing to see one.

04 In one species, some plants have only male flowers and the rest only female ones. What does this guarantee?

B Every seed has two parents: a female can get pollen only from a male

Every seed has two parents. A female plant makes no pollen, so every grain that reaches its stigmas comes from a male plant. The plants still need the wind or an animal to carry the pollen across. Of the three methods, only separate male and female plants make sure that every seed is a cross.

05 Plant B, with alleles S1 and S3, sheds pollen onto the stigma of plant A, whose alleles are S1 and S2. What share of that pollen can grow a tube to an ovule?

B Half of it: the grains that carry S3 grow, and those that carry S1 stop

Half of it. If a grain's allele matches either of the plant's own, the style stops its tube, and its male gametes never reach an egg cell. A grain whose allele matches neither grows on down to an ovule. Each grain carries just one of B's two alleles, so half carry S1 and are stopped, because plant A has an S1 allele of its own, and half carry S3, which plant A lacks, and grow on. The tool in this chapter, Will the tube grow?, lets you try each kind of grain, starting with the plain case of S1 on a plant with S1 and S2.

06 Why do many plants spend energy making fruits that animals eat?

A The animal carries the seeds off and drops them far from the parent

The animal carries the seeds away. It eats the fruit and later drops or passes out the seeds unharmed, often far from the parent, where the seedlings do not compete with it. Many seeds come through an animal's gut unharmed.

07 Seeds are kept warm and damp in a jar with almost no oxygen. What happens?

D **Few or none germinate: without oxygen they make too little ATP to grow**

Few or none germinate. Oxygen is needed for aerobic respiration, which makes the ATP that growth needs. Without it they cannot respire aerobically, so they make too little ATP to grow. The food store holds energy, but only respiration releases it as ATP, the form a cell can use.

08 A new disease sweeps through two fields: one of plants all grown from cuttings of a single parent, and one of plants grown from seed. Which field is more likely to lose almost every plant, and why?

A **The field of cuttings, because every plant has the same alleles, so if one is open to the disease all are**

The field of cuttings. They are a clone, so they share every allele: if the disease can attack one, it can attack them all. The seedlings differ, and some may carry alleles that resist it. That is the price of copying, and the step-through stops in the field before the disease arrives.

09 Two brothers have the same two parents and are not identical twins. Why are they not copies of each other?

C **Each parent's meiosis shared out different alleles into each egg and sperm, and a different egg met a different sperm**

Meiosis and fertilization. Each of the mother's eggs got its own share of one allele from each of her pairs, and so did each of the father's sperm; then a different egg met a different sperm. With 23 pairs there are millions of possible gametes from each parent, before crossing over is counted. Brothers share about half their alleles, not all of them.

10 A gamete has to swim a long way to reach its partner. What does being small let the parent do, and what does it cost the gamete?

B **It lets the parent make far more of them for the same energy, and each carries almost no food**

Far more gametes for the same energy, each with almost no food. Most will never arrive, so numbers matter more than stores. The egg's food has to last the zygote until the embryo can feed from its mother.

11 The testes hang in a bag outside the body, where it is a little cooler than inside. What does that suggest about making sperm?

C **That sperm production works better a few degrees below the temperature of the body's core**

Sperm production works best a few degrees below core body temperature, and the scrotum holds the testes there. Muscle in its wall draws the testes closer to the body in the cold and lets them hang lower in the warm.

12 An egg lives for only about a day after ovulation. In which part of the female system is it most likely to meet a sperm, and why there?

D **In the oviduct, because the egg is carried there straight after release, so it waits there as sperm swim up**

The oviduct. The egg is swept into it at ovulation and moves slowly along it, while sperm swim up through the uterus to meet it. An egg that is not fertilized within about a day breaks down.

13 After ovulation the empty follicle does not just disappear. What does it become, and what would you expect it to do?

B **The corpus luteum, a gland whose hormones keep the lining of the uterus thick and ready**

The corpus luteum. It is a gland: it secretes progesterone, which keeps the lining ready for an embryo. When it breaks down, the lining goes too. Chapter 14 shows how.

14 Oestradiol from the growing follicle rises through the first half of the cycle, while FSH falls over the same days. What does that suggest oestradiol does to the pituitary at these levels?

A **It inhibits the pituitary's release of FSH, so as one level rises the other falls: negative feedback**

It inhibits FSH release: negative feedback. A rise in oestradiol brings a fall in FSH, which slows the growth of other follicles. Then, at mid-cycle, high oestradiol does the opposite: it stimulates the LH surge. Try both in the tool's Feedback mode.

15 After the sperm's nucleus has entered the egg, its tail and mitochondria are broken down. What does that mean for the mitochondria in the cells of the new embryo?

A **Almost all come from the egg, so the embryo's mitochondria, and their DNA, come from its mother**

Almost all from the egg, and so from the mother. The sperm's mitochondria powered its swim and are then broken down (in all but very rare cases none survives); the egg's divide along with the cells of the embryo. Mitochondria are never built from scratch: each comes from one before it.

16 Before the FSH injections start, a woman's own FSH and LH release is stopped with a drug. Why do that first?

C **So her own hormones cannot set the timing, and many follicles mature together and are collected before any ovulate**

So the clinic, not her own cycle, sets the timing. Left to itself, her own negative feedback would let only one follicle win, and her own LH surge could release the eggs before they were collected. With her own release switched off, the FSH doses ripen many follicles together, and the trigger is given exactly when the eggs are ready.

17 In a child, the hypothalamus starts to release more GnRH. What do you expect to happen next to the blood levels of LH and FSH, and then to the gonads?

B **LH and FSH rise as the pituitary responds to GnRH, and the gonads then make more sex hormones**

LH and FSH rise, and the gonads respond with more sex hormones. Each link releases a hormone that makes the next gland release its own. The step-through builds the chain one link at a time.

18 One cell in the testis and one cell in the ovary each go through meiosis. How many cells that can become functional gametes does each make?

D **Four sperm from the cell in the testis, but only one egg from the cell in the ovary**

Four sperm, one egg. The divisions in the testis share the cytoplasm equally; those in the ovary give nearly all of it to one cell, and the small polar bodies break down. The films show both.

19 The first sperm has fused with the egg. What stops a second sperm from getting in?

C **Granules under the egg's surface release enzymes that change the zona, so no sperm can bind or pass**

The cortical reaction. The cortical granules empty their enzymes outside the egg's membrane, and the changed zona no longer binds sperm or lets them through. In the film, block the cortical reaction and watch what happens instead.

20 A blastocyst, about five days after fertilization, is in the uterus. Why must the lining be thick and rich in blood vessels at just that time?

A **Because the blastocyst embeds in it, and it is the embryo's first source of food and oxygen**

The blastocyst buries itself in the lining and lives on it until the placenta forms. That is why progesterone holds the lining ready through the second half of every cycle, and why, if the lining is shed, a blastocyst cannot implant.

21 A test strip uses two different antibodies to hCG: one coloured and free to move, one fixed in a zone. Why not use just one, fixed in place?

D **One fixed antibody would hold hCG but show nothing; the coloured one stays only if hCG holds it there**

hCG has no colour. A fixed antibody alone would catch it invisibly. The coloured antibody is held in the test zone only by hCG, bound between the two antibodies, so colour there means hCG was in the urine. In the tool, build a strip yourself and run samples through it.

22 The mother's blood and the foetus's blood never mix. How, then, does oxygen get from her to the foetus?

C **It diffuses across the thin villus walls from her blood, where it is high, into foetal blood, where it is low**

By diffusion, down its concentration gradient. The mother's blood keeps the oxygen high on her side and the foetal blood carries it away on the other, so the gradient stays steep. In the tool's Follow mode, take one oxygen molecule from her artery across a villus and into the umbilical vein.

23 In a normal cycle the corpus luteum shrinks after about two weeks. In early pregnancy it does not. Which hormone from the embryo do you think prevents that?

B **hCG from the blastocyst's outer cells, which signals the corpus luteum to keep making progesterone**

hCG. It is the embryo's signal: it keeps the corpus luteum making progesterone until the placenta can make enough of its own. If hCG never rose, the corpus luteum would shrink on time and the lining would be shed as usual.

24 A woman's cervix is stretched a little by the baby's head, and her progesterone has fallen. What happens next?

D **Oxytocin is released; stronger contractions push the head harder on the cervix, releasing more, until birth**

The loop builds. Stretch releases oxytocin, oxytocin strengthens the contractions, and stronger contractions stretch the cervix further. The contractions come harder and closer together until the baby is born, which ends the stretch and the loop.

25 In an early study, women who took HRT had fewer heart attacks than women who did not. Which new study would best show whether HRT caused this?

A **One in which women are given HRT or a dummy tablet at random, so the groups differ only in treatment**

The randomized trial. A bigger study of women who choose for themselves only measures the same confounded link more precisely. Chance allocation balances wealth, health and habits between the groups, so a difference in heart attacks can be put down to the treatment.

QUESTIONS ON THE DRY LAB

Q1 One dish of seeds is kept dry. The others are on damp paper. What happens in the dry dish?

B **None germinate: without water a seed cannot swell or set its enzymes working**

None germinate. A seed needs water to swell and split its testa, and to set its enzymes to work on the food store. Without it the seed stays alive but inactive, just as it was in the packet.

Q2 Seeds sit under water in a flooded dish, at a temperature that suits them. What do you expect?

D **Few germinate, or slowly: under water they get too little oxygen to respire**

Few germinate, and those that do are slow. Water holds far less oxygen than air, and oxygen spreads through it only slowly, so seeds under water get too little for aerobic respiration and make too little ATP. More water is not better: a seed needs water and air.

Q3 Damp seeds are kept in an incubator turned up to the top of its range. Fewer germinate than at a middle temperature. Why?

C **Their enzymes begin to denature, so the reactions that drive growth fail**

Their enzymes begin to denature. Up to a point, warmth speeds germination, because enzymes work faster. Too hot, and the enzymes and other proteins lose their shape, so the reactions that mobilise the store and build new cells fail. Germination is fastest at a middle temperature and falls away on both sides of it.

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.

Written and drawn for Biology by Bradford, biologybybradford.com. Free to print and share with a class.