Index

The big picture

? Guiding question(s)

- How does asexual or sexual reproduction exemplify themes of change or continuity?
- What changes within organisms are required for reproduction?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

The process of reproduction seems pretty straightforward; however, it can take different forms in different species. For example, the species of the Amazon molly (*Poecilia formosa*) (**Figure 1**), a fish that lives in fresh waters along the Mexico–Texas border, is made up entirely of females. If you think that this species reproduces asexually, you are right but only partially.

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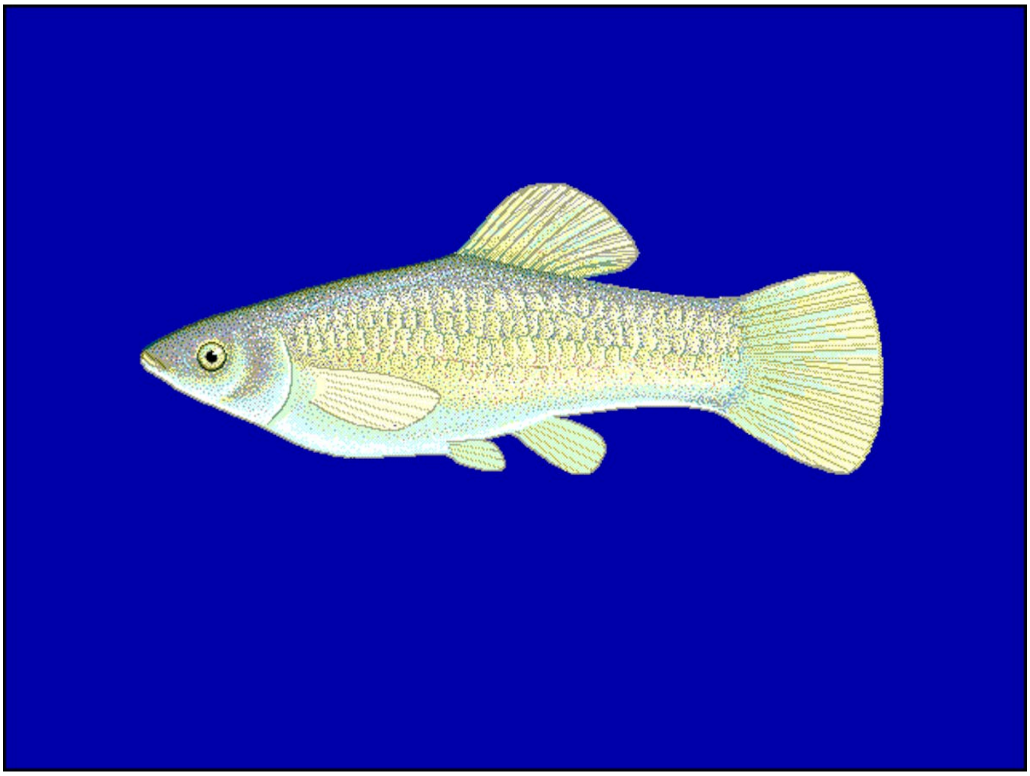

Figure 1. The Amazon molly fish has thrived for thousands of generations.

Source: "Pofor u0 (https://commons.wikimedia.org/wiki/File:Pofor_u0.gif)" by Robbie Cada is in the public domain

Unlike most other fish species, Amazon molly fish do not lay eggs. Instead they give birth to large broods of live offspring, thereby creating clones of themselves. However, they still need sperm to kickstart the process of embryonic development. The Amazon molly mates with males of a closely related Molly fish species. The sperm released by the males activates embryonic development but in a unique twist, this is not incorporated into the offspring.

The Amazon molly has thrived for thousands of years, appearing to be an exception to the idea that genetic diversity (see subtopic A4.1 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43246/)) is needed for evolutionary longevity. As more different examples of forms of reproduction are discovered in animal species, one thing is certain: although reproduction is essential for the continuity of life, there are many questions still to be answered. For example, does sexual reproduction actually confer evolutionary advantages? How do asexual or sexual reproduction exemplify themes of change or continuity? What changes within organisms are required for reproduction?

You can read more about asexual reproduction in the Amazon molly in this article (https://phys.org/news/2018-02-odds-fish-species-bypasses-sexual.html).

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Prior learning

Before you study this subtopic make sure that you understand the following:

- Cell and nuclear division (see subtopic D2.1 (/study/app/bio/sid-422-cid-755105/book/cytokinesis-id-44288/)).
- Control of the endocrine system by the hypothalamus and pituitary gland (see section C3.1.11—13 (/study/app/bio/sid-422-cid-755105/book/more-about-the-endocrine-system-id-46101/)).

Asexual and sexual reproduction

D3.1.1: Differences between sexual and asexual reproduction D3.1.2: Role of meiosis and fusion of gametes in the sexual life cycle

Learning outcomes

By the end of this section you should be able to:

- Differentiate between sexual and asexual reproduction.
- Describe the role of meiosis in creating variation in sexually reproducing organisms.

Cloning is a popular theme in movies. In ‘Star Wars’, human clones were used to build an army while in ‘Jurassic Park’, dinosaurs were cloned. However, cloning is not restricted to movies; on 23 February 1997, the first mammal – a sheep named Dolly – was cloned. This was just the beginning: Cululina the mouse, Noto and Kaga the cows and Mira the goat being some other examples (**Figure 1**). Cloning is a natural process in the living world, a form of asexual reproduction. What are the advantages of mechanisms like cloning in the living world? Why are clones genetically identical to their parents? Why does sexual reproduction result in variation?

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Figure 1. The long-tailed macaque is the first successfully cloned monkey.

Reproduction

Reproduction is a fundamental aspect of life – it is the way by which organisms pass on their genes to future generations and ensure the continuity of their species. There are two types of reproduction: asexual reproduction and sexual reproduction.

Asexual reproduction

Asexual reproduction involves one parent. It is seen in bacteria, fungi, many plants and some animals. For example, buds are common in potatoes and when conditions are right, these buds grow into new plants (**Figure 2**). A single parent plant gives rise to multiple offspring.

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Figure 2. Budding is a common form of asexual reproduction.

Credit: Hi, Getty Images

Asexual reproduction takes place in different ways, including fission, budding, fragmentation and parthenogenesis. As asexual reproduction normally involves mitosis (see section D2.1.7–8 (/study/app/bio/sid-422-cid-755105/book/mitosis-id-43811/)) followed by cell division, the offspring are clones of the parents and are genetically identical to the parent, and to each other.

As only one participant is needed, asexual reproduction ensures that a large number of offspring can be produced within a relatively short period of time (time and energy need not be spent on finding a mate!). This acts as an advantage in a relatively stable environment, as all the organisms are well-adapted to the environment and can colonise a habitat faster.

Asexual reproduction is less costly in terms of energy and time, and definitely a less complex process. Yet, there are some disadvantages. As the same genetic material is duplicated and passed on to the offspring, chances of genetic variation are low. This, in turn, decreases genetic diversity (see section A4.2.1–2 (/study/app/bio/sid-422-cid-755105/book/title-to-come-id-43810/)), the raw material for evolution, which may have disastrous consequences when the environment changes. Similarly, harmful mutations in genes could be catastrophic to the existence of asexually reproducing organisms.

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Sexual reproduction

Sexual reproduction requires two parents. It involves the union of specialised sex cells or gametes, one from each parent. The gametes are produced by meiosis (see section D2.1.9–11 (/study/app/bio/sid-422-cid-755105/book/meiosis-id-43812/)). The offspring are similar but not genetically identical to their parents or to each other.

Sexual reproduction is more expensive in terms of time and energy, and is complex process, yet it confers many advantages. Sexual reproduction results in genetic variation. As a result, the species are better adapted to a changing environment, increasing their survival rate.

Many organisms can reproduce both asexually (mitosis and cell division) and sexually.

Study skills

In cells, nuclear division is followed by cell division (cytokinesis). There are two types of nuclear division: mitosis and meiosis. Mitosis is an equational division where the chromosome number is maintained. Meiosis, on the other hand, is reductional division as the chromosome number is halved. It would be helpful to brush up on your knowledge of these two types of nuclear division (see subtopic D2.1 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43548/)) before reading further.

Causes of genetic variation in sexual reproduction

Sexual reproduction involves the fusion of two haploid gametes to form a diploid zygote, which then grows into a new individual. The offspring produced by sexual reproduction are genetically similar, but not identical to the parents (unlike in asexual reproduction).

The possibility for genetic variation in sexual reproduction is enormous and can happen during the formation of gametes as well as during fertilisation, as outlined below.

- During meiosis I, genetic material is exchanged between non-sister chromatids of homologous chromosomes, a process known as crossing over. Homologous chromosomes are pairs of chromosomes: one set inherited from the mother, and one from the father. The swapping of genetic material between the two homologous chromosomes of a pair leads to new combinations of genes in each chromosome and thereby genetic variation. **Interactive 1** illustrates the mechanism of crossing over.

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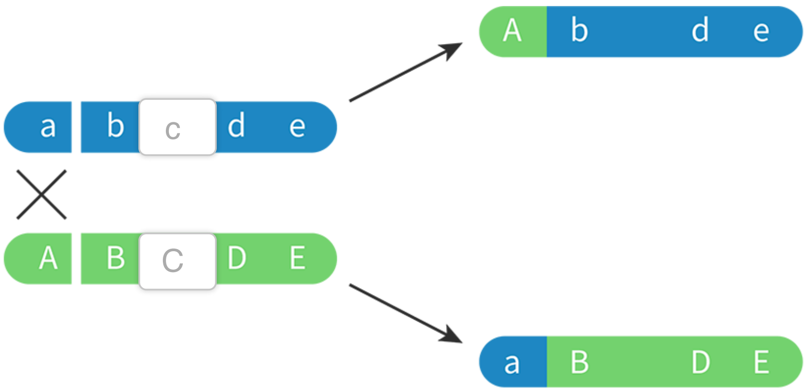

Check

- **Interactive 1.** Crossing Over.

More information for interactive 1

This drag and drop interactive depicts a visual representation of genetic recombination. On the left, there are two horizontal bars, one above the other, representing chromosomes. The top bar is blue with lowercase letters "a", "b", "c", "d", and "e" arranged linearly along its length. The letter "c" is highlighted with a light grey box around it as it is the draggable option.

Below the first bar is a second horizontal bar, green in color, with uppercase letters "A", "B", "C", "D", and "E" arranged linearly along its length, directly aligned with the letters on the blue bar above. The letter "C" on this green bar is also highlighted with a light grey box, directly beneath the highlighted lowercase "c" on the blue bar as it is the draggable option.

Between these two horizontal bars, towards the left side, is a large black "X" symbol, indicating a crossing-over event.

Two arrows originate from the region of the "X" and point towards the right side of the image. The top arrow points to a third horizontal bar. This bar is segmented, with the left portion being green and containing the uppercase "A". This is followed by a blue segment containing the lowercase "b", then a green segment with the uppercase "D", and finally a blue segment with the lowercase "e".

The bottom arrow points to a fourth horizontal bar, also segmented. The left portion is blue and contains the lowercase "a". This is followed by a green segment containing the uppercase "B", then a blue segment with the

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lowercase "d", and finally a green segment with the uppercase "E".

The image visually shows an exchange of segments between the two initial horizontal bars at the point indicated by the "X", resulting in two new recombinant bars on the right with a mix of colors and letter cases as a result of crossing over.

Read below for the solution:

Drag the lowercase letter c to the right side top gap on the blue bar and drag the uppercase letter C to the right side bottom gap on the green bar.

- Variation also comes in when the members of homologous pairs separate during meiosis I. The maternal and paternal chromosome of each pair segregate independently of the other pairs, a process called independent assortment. As a result, gametes with many different variations in the homologous chromosomes are formed. Here is an example to help you to understand this.

Picture a diploid cell with $2n = 6$. This cell has three pairs of homologous chromosomes: **A** a, **B** b and **C** c (chromosomes in bold are the paternal chromosomes and those in standard text are the maternal ones).

At the end of meiosis I, due to independent assortment of the homologues, eight possible combinations of chromosomes may occur (**Table 1**).

Table 1. Possible combinations of chromosomes.

Gamete 1	A B C	A B c	A b C	A b c
Gamete 2	a b c	a b C	a B c	a B C

- Genetic variation also occurs at the time of fertilisation. The fusion of the male gamete with the female gamete results in a new combination of chromosomes in the resulting zygote. Fertilisation is a random event as there is no way of determining which of the gametes will unite to produce an offspring.

Making connections

Meiosis results in the formation of haploid gametes while fertilisation ensures the restoration of the diploid status. Both these events ensure that the chromosome number of a species is maintained (see section D2.1.9—11 (/study/app/bio/sid-422-

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cid-755105/book/meiosis-id-43812/)). They also ensure genetic diversity (see section D2.1.4—6 (/study/app/bio/sid-422-cid-755105/book/shared-features-of-mitosis-and-meiosis-id-45676/)).

Try the activity to compare asexual with sexual reproduction.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Asking questions and framing hypotheses based upon sensible scientific rationale
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

Consolidate your knowledge about sexual and asexual reproduction by completing **Interactive 2.** Drag and drop the phrases into the appropriate column.

Once you have done this, form pairs and classify which of these points would be advantages and which of these would be disadvantages for either type of reproduction. Justify your answers.

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Asexual reproduction	Sexual reproduction

One parent	Is faster	Energy saving
Energy expensive	Involves gametes	Is slower
Lower adaptability to environmental changes	Two parents	Does not involve gametes
Genetically different from the parents	Higher adaptability to environmental changes	Genetically identical to the parents

Check

Interactive 2. Exploring Each Reproductive Method.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Male and female reproductive systems

D3.1.3: Differences between male and female sexes in sexual reproduction

D3.1.4: Anatomy of human male and female reproductive systems

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Learning outcomes

By the end of this section you should be able to:

- Compare the differences between the male and female sexes.
- Draw diagrams of the male (typical) and female (typical) reproductive systems.
- Annotate the names of the parts and their functions on the diagrams.

Figure 1 shows a small yet spiny inhabitant - the sea-urchin. Looking at the image, can you tell whether it is a male or a female?

Figure 1. Purple sea-urchins, *Strongylocentrotus purpuratus*.

Credit: Tammy616, Getty Images

It is easy to identify a human male or a female as there are obvious anatomical differences; however, in many animals such differences are not evident. For example, it is difficult to tell a male sea-urchin from a female sea-urchin due to the absence of any external distinguishing features. Some animals live as hermaphrodites, that is, they have both male and female reproductive organs or produce both male and female gametes. This phenomenon is common in many invertebrates, such as earthworms, snails, and certain fish species. In plants, hermaphroditism is widespread, with most flowering plants having both male and female reproductive structures.

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In humans, the term "hermaphrodite" is outdated and has been replaced by "intersex" to describe conditions where an individual has biological characteristics of both sexes. These conditions are rare in humans and can involve complex genetic and developmental factors.

Examples of hermaphroditic animals include:

1. **Earthworms**: These simultaneous hermaphrodites can exchange sperm with other earthworms during mating.
2. **Snails**: Many snail species are hermaphroditic, allowing them to reproduce even in isolation.
3. **Clownfish**: These are sequential hermaphrodites, starting life as males and later becoming females.
4. **Banana Slugs**: These mollusks are simultaneous hermaphrodites, capable of mating with any other banana slug they encounter.
5. **Groupers**: These fish are protogynous hermaphrodites, meaning they start as females and can become males later in life.

Difference between sexes

One feature that can adequately define the sexes is the gametes produced by meiosis. During the process of fertilisation, two gametes fuse together to produce the zygote. In humans and most multicellular animals, the gametes differ in size and form. The smaller of the two is the male gamete or the sperm, while the larger is the female gamete or the egg. This difference in sizes acts as a fundamental difference between males and females. In humans, the sperm are produced by the testes (an organ in the male reproductive system), whereas the eggs or ova are produced by the ovaries (an organ in the female reproductive system).

If you look at **Figures 2** and **3**, you will notice striking dissimilarities between the sperm and eggs – these are adaptations to increase the chances of fertilisation. The sperm (see section D3.1.5–7 (/study/app/bio/sid-422-cid-755105/book/menstrual-cycle-and-fertilisation-id-45415/)) must travel up the female reproductive tract to fuse with the egg (or ovum), hence they are smaller and motile. Their tails (flagella) help them to swim to the egg, while the mitochondria generate energy for flagellar movement. Moreover, millions of sperm are produced every day to increase the chances of some of them reaching the mature egg.

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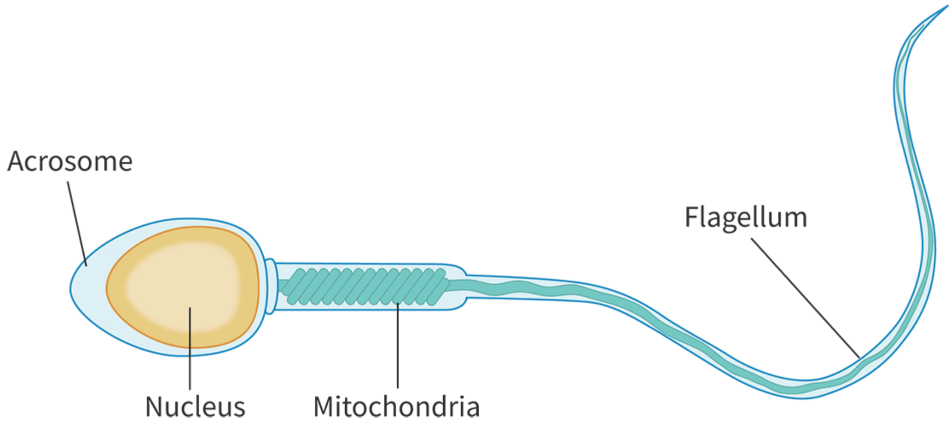

Figure 2. Sperm.

More information for figure 2

The image is a diagram illustrating a sperm cell. The diagram includes labeled parts of the sperm: the head, which contains the nucleus; the midpiece, which is packed with mitochondria that provide energy; and the long, whip-like tail called the flagellum that enables movement. The head is depicted as an oval shape, while the tail is a long, coiled structure extending from the midpiece. The labels point to each part, clarifying their structure and function. This diagram visually explains how each segment of the sperm contributes to its overall role in fertilization.

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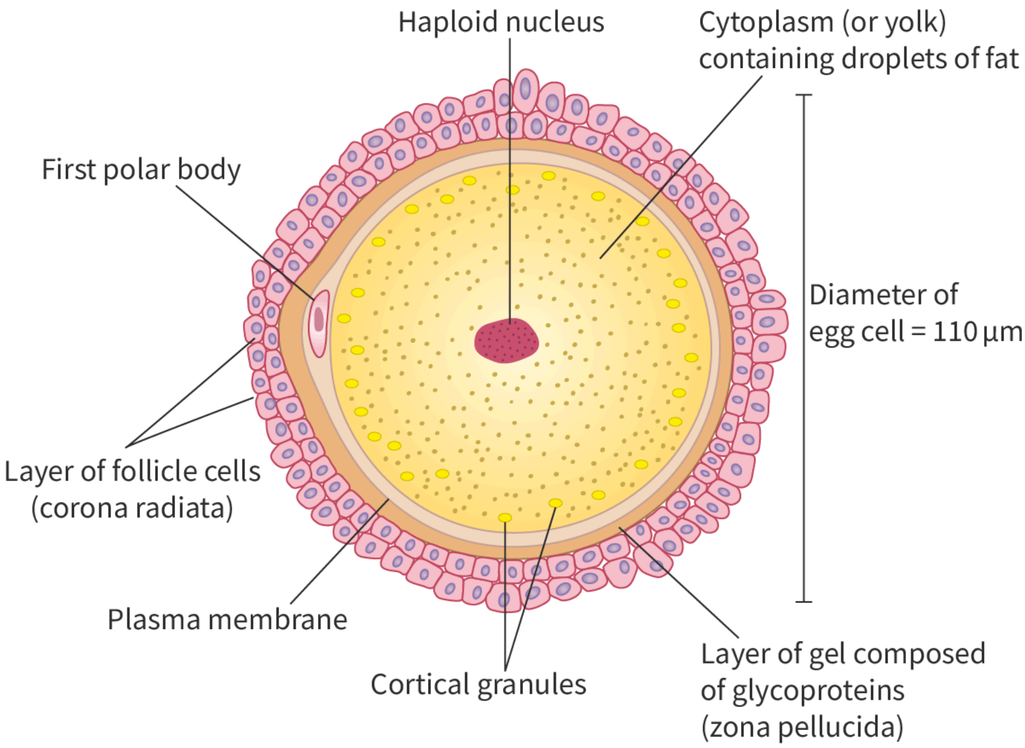

Figure 3. Ovum.

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More information for figure 3

This is a cross-sectional diagram of an ovum. The outer layer comprises numerous small circular cells forming a boundary around the ovum. Inside, there is a larger space with a dotted texture representing the cytoplasm. At the center, a nucleus is illustrated, shown as a distinct, darker, circular shape. Radial lines with labels pointing to various parts of the ovum indicate components like the follicular cells and other structures. The diagram highlights the structure and components of an ovum, showing how it is larger and immotile, with food reserves to provide energy for the developing zygote.

[Generated by AI]

On the other hand, the eggs or ova (see section D3.1.5–7 (/study/app/bio/sid-422-cid-755105/book/menstrual-cycle-and-fertilisation-id-45415/)) are larger and immotile. They carry food reserves that act as energy sources for the dividing zygote.

Higher level (HL)

Normally in humans, only one egg is released by the ovary every month (see section D3.1.13–14 (/study/app/bio/sid-422-cid-755105/book/puberty-and-gametogenesis-hl-id-45735/) for details).

Male and female reproductive systems

The male reproductive system produces the sperm and facilitates their transfer to the female reproductive tract. It consists of two testes enclosed in a sac-like scrotum, the penis, the epididymis, the tubes through which the sperm pass, and the sperm ducts. It also includes associated glands, mainly the seminal vesicles and the prostate gland.

The female reproductive system produces the ova and nourishes the developing foetus until birth. It consists of the ovaries, the fallopian tubes or oviducts, the uterus and the vagina.

The testes and the ovaries produce the sperm and the eggs. In addition, they also produce the male and female sex hormones. Use the hotspots in **Interactive 1** to view the different parts of the male reproductive system.

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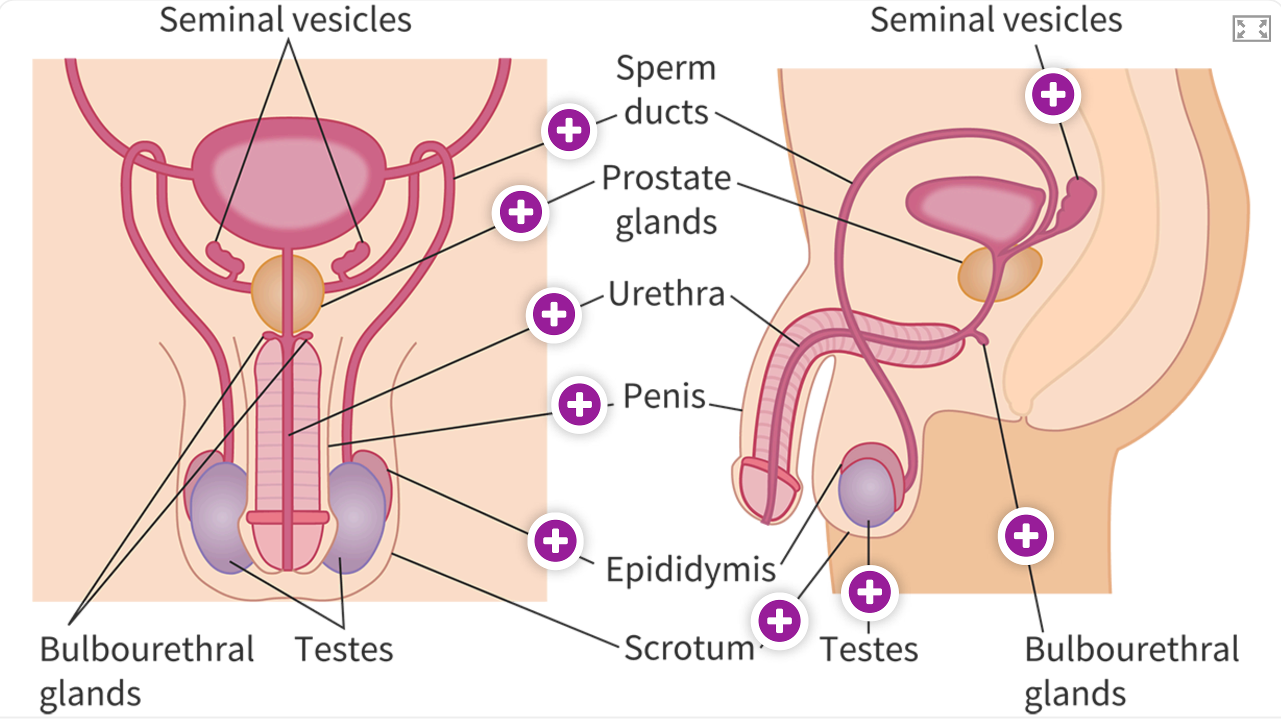

Interactive 1. Male Reproductive System.

More information for interactive 1

An interactive illustration features the front and side views of the male reproductive system, highlighting key anatomical structures and their spatial relationships. It also contains a series of hotspots over each structure and provides information about them.

The parts marked are as follows: Seminal vesicles, sperm ducts, prostate glands, urethra, penis, epididymis, scrotum, testes, and bulbourethral glands.

The hotspots reveal the following:

A pair of seminal vesicles: Produces fluids that help in the transport and nourishment of the sperm. The sperm together with these fluids are referred to as semen. Semen is a slightly alkaline fluid that keeps the sperm viable.

Sperm ducts: Tubes through which the sperm travel from the testes to the urethra during ejaculation.

Prostate gland: Produces fluids that help in the transport and nourishment of the sperm. The sperm together with these fluids are referred to as semen. Semen is a slightly alkaline fluid that keeps the sperm viable.

Urethra: A common tube through which both the sperm and urine leave the penis.

Penis: A muscular, erectile organ that helps in the transfer of sperm from the male reproductive system to the vagina of the female reproductive system.

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Epididymis: Highly coiled tubes where sperm mature and are stored (till the time of ejaculation).

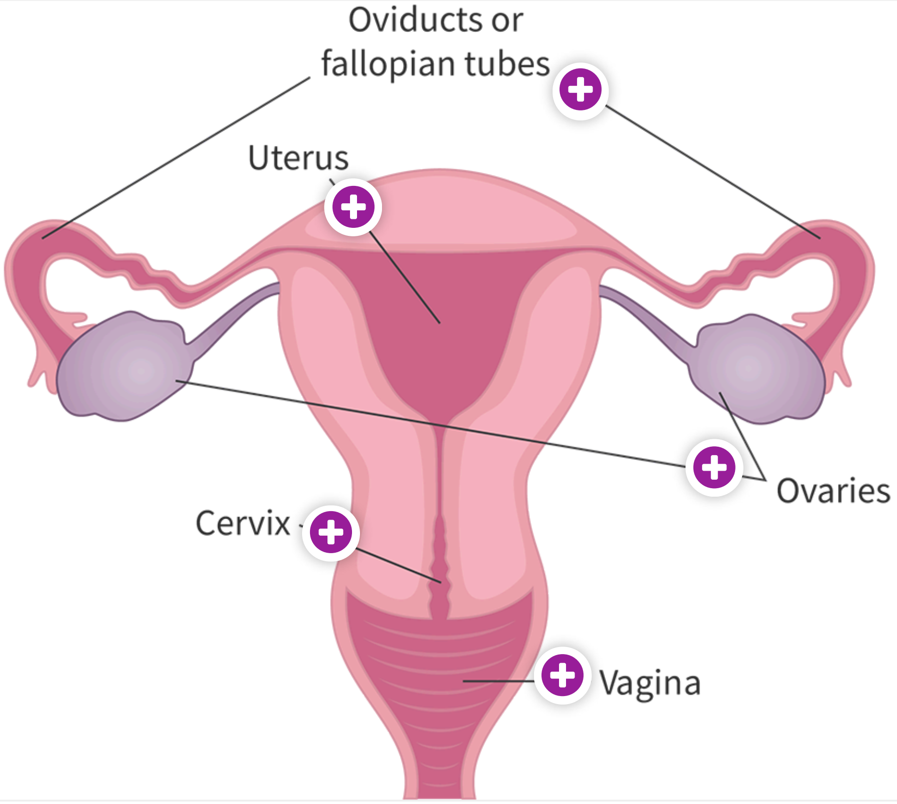
Scrotum: Sacs that hold the testes and maintain them at a temperature 2—3 °C lower than the body temperature facilitating sperm production.

A pair of testes suspended in the scrotum: Produce sperm and testosterone (the male sex hormone).

Bulbourethral glands: Produce fluids that help in the transport and nourishment of the sperm. The sperm together with these fluids are referred to as semen. Semen is a slightly alkaline fluid that keeps the sperm viable.

This interactive illustration helps users to understand the parts of the male reproductive system and their functions.

Explore the parts of the female reproductive system with **Interactive 2**.



Interactive 2. Female Reproductive System.

More information for interactive 2

The interactive diagram provides a schematic representation of the female reproductive system, focusing on key anatomical structures including oviducts or fallopian tubes, uterus, ovaries, cervix, and vagina and their organization. A series of hotspots over each organ provides information about them. The hotspots are indicated as plus signs with

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numbers.

Read below to understand the roles of each organ of the female reproductive system.

The fallopian tubes or oviducts are located on either side of the uterus. Each of the tubes is attached to the ovaries below them. The Hotspot 1 of the oviducts read: Tube through which the eggs (ova) travel from the ovaries. Fertilisation occurs here.

The uterus is located in the middle of the reproductive system. It is a U-shaped organ connected directly with the fallopian tubes. The Hotspot 2 of the uterus reads: Nourishes the developing fetus till birth. It is also called the womb.

A pair of "Ovaries" are located near the lateral pelvic walls and are connected to the pelvic wall and the uterus via ligaments. They are irregularly shaped oval structures. The Hotspot 3 of the ovaries read: Produce eggs and the female hormones oestradiol and progesterone.

The cervix is located in the narrow lower portion of the uterus. The Hotspot 4 of the cervix reads: Lower part of the uterus. Menstrual blood passes from the uterus to the vagina through the cervix. Widens during the birth of the baby.

The vagina is the birth canal and receives sperm during intercourse. The Hotspot 5 of the vagina reads: Muscular canal that extends from the outside to the cervix.

The "Fullscreen" icon at the top right allows the users to view the diagram in a zoomed-in version.

Please note that some of the structures shown or marked in the diagram, such as the urinary bladder, ureter, anus and rectum are not a part of the reproductive system – they are just found in the same area of the body.

Theory of Knowledge

Knowledge management is the process of collecting, structuring and sharing knowledge, often within an organisation. Studies reveal that gender plays an important (although often not verbalised) role in knowledge-sharing.

Preconceived generalisations based on gender lead to the attribution of certain characteristics to individuals of a particular gender. As a result, their ideas, expertise or work are often overlooked and/or undervalued. For instance, studies show that women are underrepresented in STEM fields. Research has shown that negative stereotyping often around the abilities of girls in subjects like Maths and Science, can not only lower test performance but also decrease their interest in STEM careers. The reverse holds true, with subjects like arts and humanities traditionally being associated with women.

Gender stereotyping is often deeply rooted and could have cultural or ethics aspects. How does gender affect knowledge management? Does gender stereotyping lead to arbitrary assumptions about a person's level of knowledge or ability?

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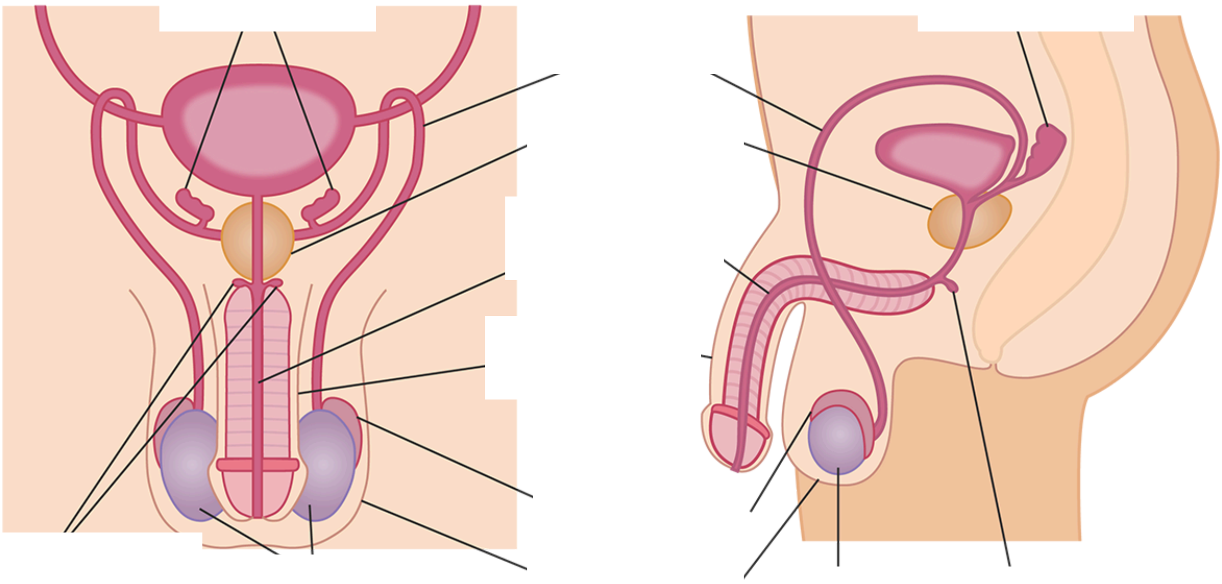
Test your knowledge of the structures of the male and female reproductive systems in **Interactive 3**; drag and drop the labels into the correct places.



Sperm duct | Testis | Seminal vesicles | Penis

Epididymis | Urethra | Prostate glands | Bulbourethral glands | Scrotum

Check

Interactive 3. Male Reproductive System (Front View and Side Views).

More information for interactive 3

This is a screen interactive with drag-and-drop activities.

The first screen has two diagrams side-by-side, illustrating the male reproductive system.

On the left, picture a frontal view. At the top, a smooth, oval shape pink in color represents the bladder. Two slender tubes, the ureters, curve downwards from the sides of the bladder. Below the bladder and slightly behind it, a smaller, rounded gland, the prostate, is nestled. A single tube, the urethra, extends downwards from the bottom of the bladder, passing through the prostate.

Continuing downwards, the urethra is enclosed within a longer, cylindrical structure, the penis. Imagine the penis hanging vertically. Two oval-shaped testes are suspended below the penis within a sac-like structure, the scrotum.

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Two more tubes, the vas deferens, rise from the top of each testis, looping upwards and backward, eventually connecting behind the bladder. Small, pouch-like seminal vesicles are shown attached to the back of the bladder, near where the vas deferens join.

On the right, the same structures are shown in a side view, allowing you to see their relative positions within the body. The bladder sits at the front, with the prostate tucked underneath and behind it. The urethra curves downwards and then forward through the penis. The testis hangs below and behind the penis. It can be seen that the vas deferens ascend from the testis, curve behind the bladder, and join with the duct from the seminal vesicle to form the ejaculatory duct, which then enters the prostate and connects to the urethra. This view emphasizes the pathway of sperm from the testes, through the vas deferens, past the seminal vesicles, through the prostate, and out through the urethra.

There are 12 drop boxes given on the screen. And, there are 9 labels at the bottom of the screen. The options read as follows, Sperm duct, Testis, Seminal vesicles, Penis, Epididymis, Urethra, Prostate glands, Bulbourethral glands and Scrotum.

Read below for the answers.

The top label for both images is seminal vesicles.

The structures in the middle from top to bottom include: Sperm ducts, Prostate glands, Urethra, Penis, Epididymis, and Scrotum. The labels on the bottom for the left and right images are bulbourethral glands and testes.

The right arrow at the bottom right helps to navigate to the next interactive.

The second interactive represents the female reproductive system.

There is a pear-shaped organ in the center, this is the uterus. It is wider at the top and tapers down towards the bottom. From the upper corners of the uterus, two curved tubes, the fallopian tubes, extend outwards and slightly upwards. The ends of these tubes flare out like open hands with finger-like projections. Attached to the end of each fallopian tube, like almonds on either side, are the ovaries. These are oval-shaped structures.

Below the uterus, the narrow lower section, the cervix, leads into another tube-like structure, the vagina, which extends downwards. The walls of the vagina are shown with horizontal lines, suggesting folds or ridges.

There are 6 drop boxes distributed on either side of the structure. At the bottom, there are five draggable options representing the different parts of the female reproductive system. The options are Ovary, Uterus, Cervix, Fallopian tube and Vagina.

Read below for the answers.

At the very top, the structures indicated are Fallopian tube. Below that we have Uterus.

On the left side, we have a cervix.

On the right side, we have Ovary which is purple. Below that, we have Vagina.

The “Check” button at the bottom left allows users to check their answers for both interactives. The total number of correct answers is indicated with a slider. When wrong answers are inputted, a “Retry” button occurs at the bottom left that allows the users to redo the interactive.

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Try out your drawing skills in the activity to summarise your learning about human reproductive systems.

Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Self-management skills — Drafting, revising and improving academic work
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

Your task

1. Draw diagrams of the human male and female (typical) reproductive systems.
2. Annotate with the names of the structures and their function.
3. Shade the organs that produce the gametes in both the systems.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Menstrual cycle and fertilisation

D3.1.5: Ovarian and uterine cycles and their hormonal regulation D3.1.6: Fertilisation in humans

D3.1.7: Use of hormones in IVF treatment

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Learning outcomes

By the end of this section you should be able to:

- Describe the hormonal regulation of the menstrual cycle.
- Elucidate the sequence of events leading to fertilisation.
- Explain the role of hormones in IVF.

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Periods are a normal and natural biological process for most women. Beginning with the onset of puberty, they continue until menopause. This means that an average woman will have approximately 450 periods in her lifetime. This translates to nearly 3500 days! Yet this very common and natural phenomenon is often not discussed and shrouded in mystery. What does it mean to get periods? What are the physiological changes seen in the body during this time in human females?

Menstrual cycle

The menstrual cycle marks the onset of puberty in human females. Every month, the female body prepares itself for a possible pregnancy. This cycle of recurring changes that results due to variation in the levels of ovarian and pituitary hormones is known as the menstrual cycle.

Typically, the menstrual cycle lasts for 28 days and comprises the ovarian cycle and the uterine cycle. It is important to note that the changes in both the organs happen simultaneously.

Ovarian cycle

The ovarian cycle refers to the cyclic changes seen in the ovaries and can be further subdivided into three phases: the follicular phase, ovulation and the luteal phase.

Follicular phase

The follicular phase lasts for approximately 14 days (in a 28-day cycle) and begins with the first day of the menstrual flow (bleeding). At this point, the levels of both ovarian and pituitary hormones are low. The anterior pituitary secretes follicle-stimulating hormone (FSH) and luteinising hormone (LH). Inside each ovary are small sac-like fluid-filled structures or the follicles, with each follicle containing one immature egg. FSH stimulates the growth of these ovarian follicles. The growing follicle secretes oestradiol (the primary form of oestrogen in a human female). It is important to note that although many follicles begin to develop simultaneously, usually only one of these follicles matures while the others regress.

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Ovulation

Around the middle of the cycle (around Day 12), a sharp rise in the level of oestradiol stimulates the anterior pituitary to secrete LH (to a greater extent) and FSH (to a lesser extent). The spurt of LH causes the follicle to rupture, releasing the mature egg. This is known as ovulation and occurs in the middle of the menstrual cycle (around Day 14 of a 28-day cycle). The egg begins its passage to the uterus.

Creativity, activity, service

Strand: Activity
Learning outcome: Demonstrate engagement with issues of global significance

Period poverty is an issue that affects women, especially those from low-income backgrounds who often have no access to either suitable period products or hygienic bathroom facilities during their menstrual cycles. This, in turn, can affect an individual's ability to carry out daily activities like attending school or participating in sports or going to work. It can also result in health complications.

Form groups. Brainstorm and come up with ways that you can alleviate period poverty. The website here (https://www.dosomething.org/us/articles/10-young-people-fighting-period-poverty) highlights the work done by some young people in this field. This could be a starting point for your discussion.

Implement!

Luteal phase

Following ovulation, LH and FSH levels drop. Under the influence of LH, the ruptured follicle is converted into the corpus luteum (yellow body) wherein the ruptured follicle is filled with cells. This period is known as the luteal phase. The corpus luteum secretes progesterone and oestradiol. As the levels of oestradiol and progesterone rise, the secretion of FSH and LH is inhibited by a negative feedback mechanism. This stage lasts for about 14 days.

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Uterine cycle

The uterine cycle refers to the changes that occur in the uterus and can be divided into menstruation, the proliferative phase and the secretory phase. It is important to note that the changes in the ovaries and the uterus happen simultaneously.

Proliferative phase

The proliferative phase coincides with the follicular phase and continues till ovulation. Oestradiol secreted by the growing follicle causes a thickening of the endometrial lining of the uterus preparing it for a possible pregnancy.

Secretory phase

The secretory phase roughly corresponds to the luteal phase of the ovarian cycle. Under the influence of progesterone, the uterine lining thickens further and changes into a secretory layer, in preparation for a potential implantation.

Menstruation

Towards the end of the luteal phase, the decrease in levels of FSH and LH causes the corpus luteum to break down. The subsequent decrease in the levels of progesterone and oestradiol causes the thickened lining of the uterus to break down. The sloughed off layers, the unfertilised egg and blood are shed from the body through the vagina, resulting in menstrual bleeding.

In response to the low levels of ovarian hormones, the anterior pituitary secretes FSH and LH, a new follicle develops and the next cycle begins.

This cycle of events is shown in **Figure 1** and **Video 1**. A typical menstrual cycle lasts for 28 days and begins with the first day of the menstrual flow. The menstrual cycle marks the onset of puberty and continues until menopause.

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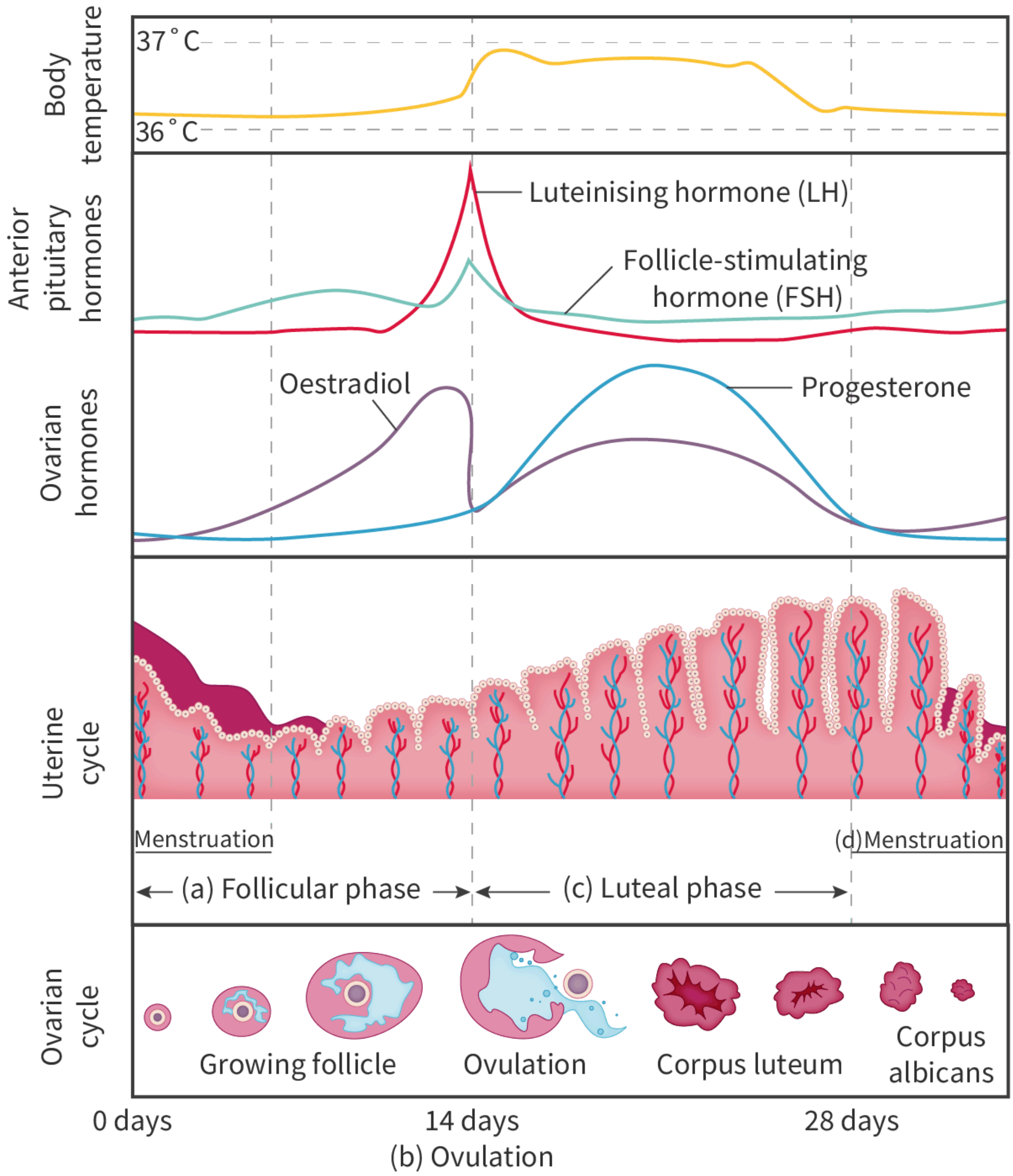

Figure 1. The menstrual cycle.

More information for figure 1

The image is a detailed diagram illustrating the menstrual cycle, spanning 28 days. It consists of several stacked sections:

1. **Body Temperature:** At the top, a yellow line graph showing body temperature ranging from 36°C to 37°C, with slight rise and fall around ovulation.

2. **Hormones:**

3. **Anterior Pituitary Hormones:** A graph showing peaks in Luteinising Hormone (LH) and Follicle-stimulating Hormone (FSH) around ovulation.
4. **Ovarian Hormones:** Curved lines depicting Oestradiol and Progesterone levels with Oestradiol peaking near ovulation and Progesterone rising during the luteal phase.

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5. **Uterine Cycle:** Illustrates changes in the uterine lining, showing thickening and shedding between menstruations.

6. **Ovarian Cycle:** Visuals of the ovary's changes during the cycle, labeled as follows:

7. Day 0: Growing follicle
8. Day 14: Ovulation
9. Luteal phase: Corpus luteum
10. Before menstruation: Corpus albicans

The phases are labeled: (a) Follicular phase, (b) Ovulation, (c) Luteal phase, and (d) Menstruation.

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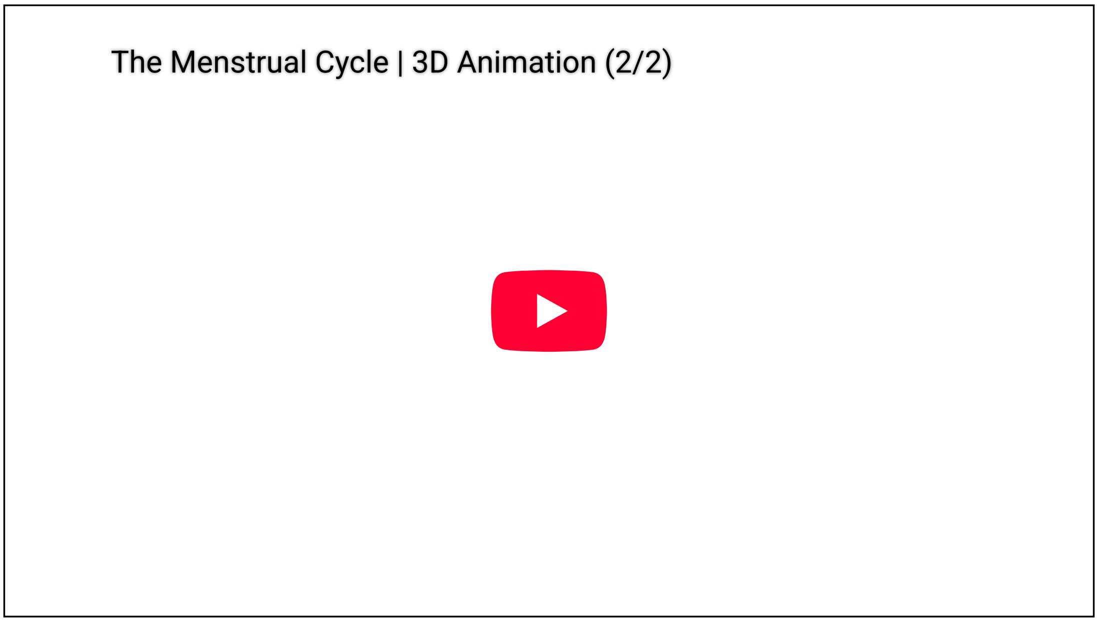

Video 1. Changes during the menstrual cycle.

Positive and negative feedback

The menstrual cycle is controlled by both positive and negative feedback mechanisms (**Figure 2**). Negative feedback occurs when an increase in the level of one hormone inhibits the secretion of other hormones. For example, as the levels of oestradiol increase in the follicular phase, FSH secretion is inhibited, causing the other follicles to regress.

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Eventually, the surge in oestradiol levels in the middle of the cycle causes a rise in the levels of LH and FSH. This is an example of positive feedback, where the rise in the level of one hormone causes an increase in the levels of other hormones.

Soon after ovulation, the follicle is converted to the corpus luteum and secretes both progesterone and oestradiol (to a lesser extent). As the level of progesterone increases, the release of both FSH and LH is inhibited, that is negative feedback sets in.

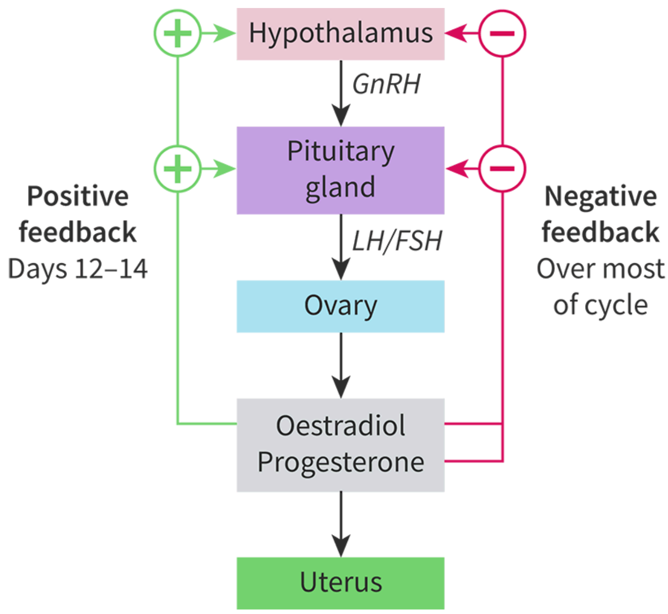

Figure 2. Positive and negative feedback control of the menstrual cycle.

More information for figure 2

The diagram illustrates the feedback control of the menstrual cycle. It begins with the hypothalamus, which sends signals to the pituitary gland. Below the pituitary gland, arrows indicate signals sent to the ovary. The ovary releases oestradiol and progesterone, which affect the uterus. The diagram shows the positive feedback loop on the left side with green plus signs, indicating stimulation from the hypothalamus and pituitary gland to the ovary and further. On the right side, red negative symbols indicate the negative feedback loop, where increased levels of oestradiol and progesterone inhibit the pituitary gland and hypothalamus, reducing FSH and LH release.

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Fertilisation of the egg

Fertilisation is the union of the sperm with the egg resulting in a diploid zygote. The egg released from the follicle travels down the oviduct. At this point, if the egg encounters a sperm, then fertilisation may take place. Thus, fertilisation takes place in the oviduct.

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Gametes prior to fertilisation

Let us have a look at the structure of the egg and the sperm (see section D3.1.3–4 (/study/app/bio/sid-422-cid-755105/book/male-and-female-reproductive-systems-id-45750/)). The egg that is released from the follicle has not yet completed meiosis II (see section D2.1.9–11 (/study/app/bio/sid-422-cid-755105/book/meiosis-id-43812/)) and is referred to as the secondary oocyte. The cytoplasm contains cortical granules filled with enzymes. Outer to the plasma membrane are two layers: the zona pellucida and the corona radiata. The zona pellucida is a jelly-like, non-cellular layer composed of glycoproteins that prevents the entry of sperm. Outer to the zona pellucida is the corona radiata, which consists of follicular cells that provide nourishment to the egg.

The sperm consists of a head, midpiece and tail. The head contains the haploid nucleus, a cap-like acrosome which contains hydrolytic enzymes and paired centrioles. The midpiece carries the mitochondria that power the movement of the sperm. The tail is a flagellum that helps in movement.

Events of fertilisation

The sperm that enter the female reproductive tract move towards the oocyte. The sperm undergo physiological changes in the female reproductive system that lead to their activation. This is called capacitation.

Higher level (HL)

Of the millions of sperm that enter the female reproductive tract, only a few reach the oocyte and still fewer start to traverse through the zona pellucida (see section D3.1.15 (/study/app/bio/sid-422-cid-755105/book/post-fertilisation-events-and-embryonic-development-hl-id-46230/)– (/study/app/bio/sid-422-cid-755105/book/male-and-female-reproductive-systems-id-45750/)17 (/study/app/bio/sid-422-cid-755105/book/post-fertilisation-events-and-embryonic-development-hl-id-46230/)).

The complementary receptors present on the head of the first sperm that reaches the cell membrane bind to the proteins on the oocyte plasma membrane. As a result, both the cell membranes fuse together. The binding of the sperm activates the oocyte in a step called egg activation. This results in a series of changes, like the rise of intracellular calcium levels,

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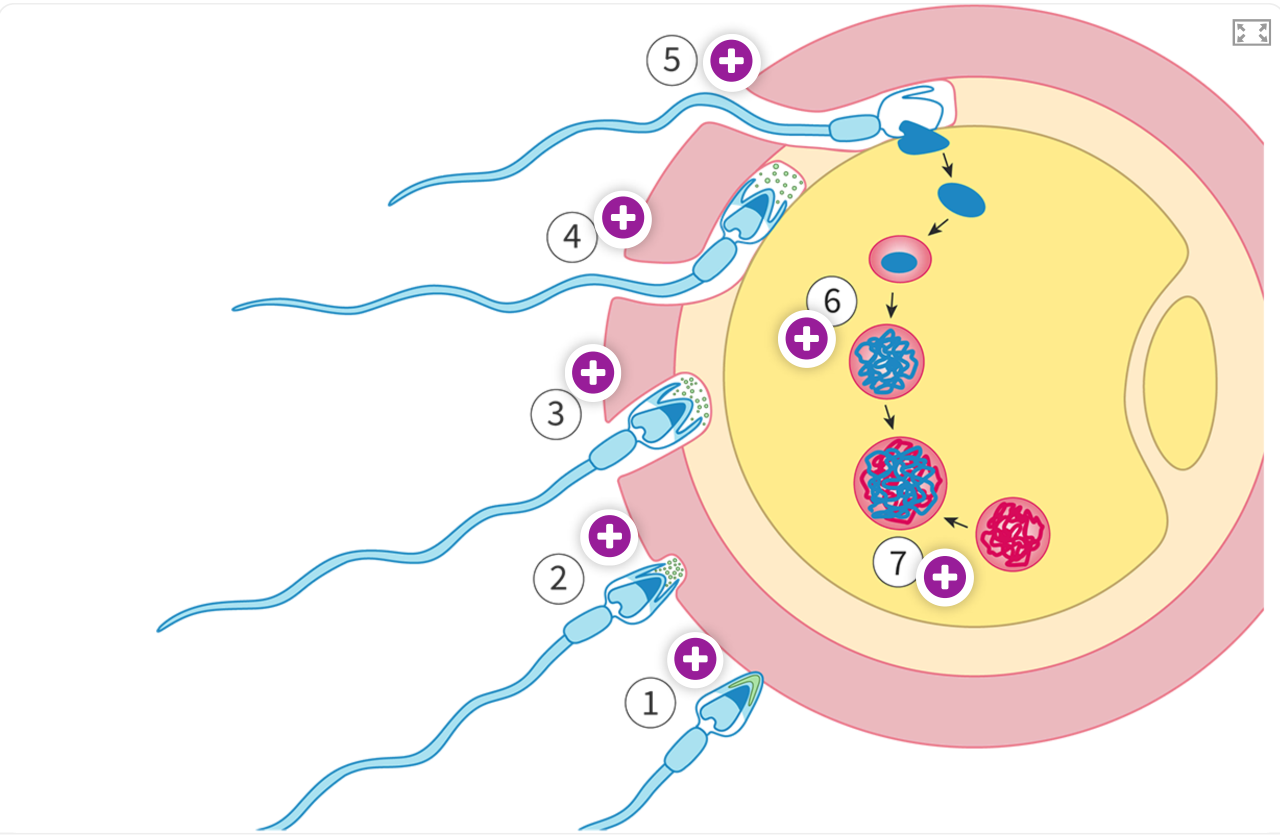
completion of meiosis II and the cortical reaction. The resulting changes in the plasma membrane of the egg and the zona pellucida prevent other sperm from fusing with the fertilised egg.

When the fertilising sperm binds to the oocyte, the head of the sperm enters the cytoplasm of the egg, while the midpiece and tail are destroyed. The sperm nucleus undergoes a series of changes to form the male pronucleus. The male pronucleus and the female pronucleus both have a haploid genome. The nuclear membranes of the male and female pronuclei dissolve, chromatin from both nuclei condense to form chromosomes resulting in a single-celled diploid organism. The diploid zygote now undergoes mitotic division.

These steps are outlined in **Interactive 1**.



Interactive 1. Events of Fertilisation.

More information for interactive 1

The interactive explains the key stages of fertilization, showing sperm-egg fusion and zygote formation.

The interactive diagram shows an oocyte. The oocyte is spherical in shape, with 3 layers, the outer layer is called zona pellucida, the middle layer is the plasma membrane and the innermost space is the cytoplasm. There is also a small polar body beside the cytoplasm. The interactive also shows sperm cell at different stages of fertilization. The sperm cell looks like a tadpole with an oval-shaped head, a slender midpiece, and a long tail. Inside the cytoplasm of the oocyte, other processes of fertilization such as sperm nucleus entering the cytoplasm, formation of pronucleus, fusion

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of male and female pronucleus, and formation of zygote are shown. There are 7 different hotspots labeled 1 to 7, each representing a stage of fertilization. Clicking on these hotspots reveals information about the corresponding stage.

Read below to learn about the text in each hotspot:

Hotspot 1: The sperm comes into contact with the egg.

Hotspot 2: Enzymes released by the acrosome digest the zona pellucida.

Hotspot 3: The sperm binds with the plasma membrane of the oocyte.

Hotspot 4: The plasma membrane of the sperm fuses with the plasma membrane of the egg

Hotspot 5: The sperm nucleus enters the egg.

Hotspot 6: The sperm nucleus undergoes changes to form the male pronucleus.

Hotspot 7: The male pronucleus binds to the female pronucleus to form the diploid nucleus.

This interactive diagram helps viewers understand the different stages of fertilization, an important process in reproduction. It helps viewers to understand how sperm enters the oocyte and how the pronucleus of sperm and oocyte fuse to create a zygote ready for mitosis.

Video 2. Events of fertilisation.

In vitro fertilisation

Louise Brown was the first baby to be conceived by a then revolutionary technique called in vitro fertilisation (IVF). Today, IVF is a common and effective form of assisted reproductive technology, used as a treatment for infertility or to overcome genetic problems. ‘In vitro’ means outside the body. Unlike natural conception, in IVF, the fertilisation of the egg and the sperm take place in a laboratory.

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IVF involves a series of steps, as outlined below.

1. The normal menstrual cycle is suppressed using medicines. This treatment takes about 2 weeks and helps the healthcare worker to control the timing of ovulation.
2. The person undergoing treatment is given fertility drugs. These drugs contain FSH which stimulates follicles, resulting in superovulation or the production of multiple eggs (against the normal of one egg per month). Increasing the number of eggs produced increases the chances of successful fertilisation.
3. The person undergoing treatment is then injected with the hormone human chorionic gonadotropin (hCG), which causes the follicles to mature. Before the follicles rupture, the eggs are collected by a technique called follicular aspiration.
4. The eggs are put into a petri dish and the sperm from the donor is transferred to the dish. After 16–18 hours, the sample is assessed to see whether fertilisation has occurred.
5. If fertilisation has occurred, the fertilised eggs are allowed to grow in a specially formulated culture medium in the laboratory.
6. Healthy embryos are selected and transferred to the uterus. This can happen on Day 3 or Day 5. This is known as implantation. Often, multiple embryos are transferred to improve chances of implantation and this may lead to multiple births.
7. A pregnancy test approximately 2 weeks after implantation determines whether the process was successful or not.

Try the activity in pairs – you will work together to summarise the key events of the ovarian and uterine cycles.

Activity

- **IB learner profile attribute:** Knowledgeable
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 15 minutes
- **Activity type:** Pair activity

Summarise the key events that occur in the ovarian cycle and the uterine cycle.

Mark the different stages of the ovarian/uterine cycle on the 28-day menstrual cycle. Make sure that you colour-code the phases.

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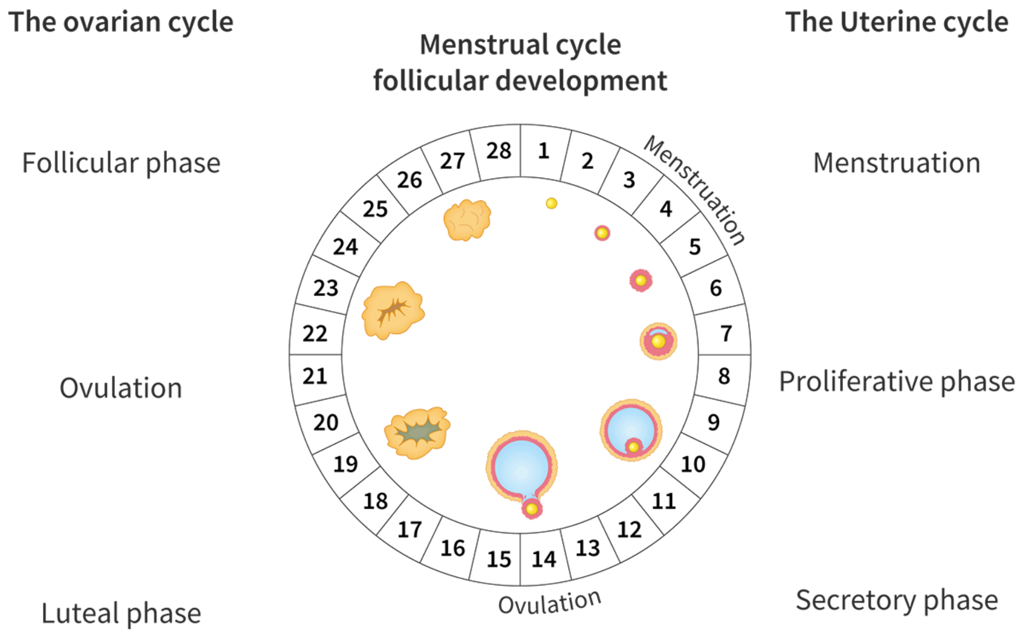
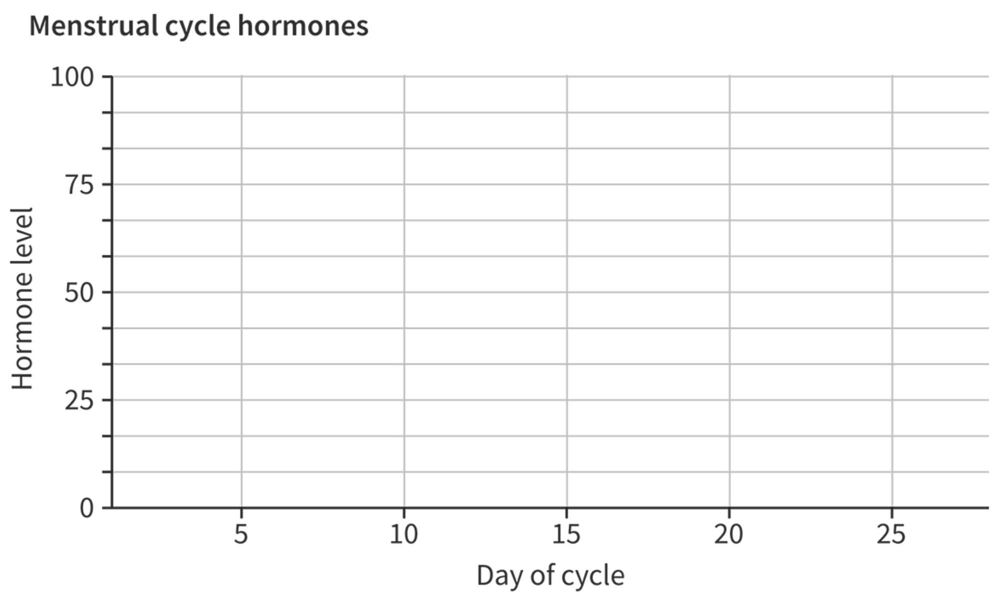
Graph the changes seen in levels of the hormones.





More information

The diagram illustrates the human female menstrual cycle, highlighting the stages of the cycle around a circular display. Key stages like menstruation, follicular phase, ovulation, and luteal phase are visually represented. Numbered or labeled segments detail these stages, illustrating hormone level changes and their impact on the cycle. The diagram is organized in a cyclic manner to show the continuous nature of the menstrual cycle, with specific hormone symbols or icons representing the fluctuations during each stage. This structural layout emphasizes the interrelated processes in the menstrual cycle.

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Figure 3. The human female menstrual cycle.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Sexual reproduction in flowering plants

D3.1.8: Sexual reproduction in flowering plants D3.1.9: Features of an insect-pollinated flower

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Learning outcomes

By the end of this section you should be able to:

- Describe the mechanism of sexual reproduction in plants.
- Explain the features of insect-pollinated flowers.
- Draw labelled diagrams of insect-pollinated flowers.

Mechanism of sexual reproduction

Flowering plants are the most colourful and diverse group of plants. In spring, especially in temperate regions, you can see a wide range of flowers around you that differ in shape, size and colour. The diversity in flowers lies not just in their colour and shape. Look at the pictures in **Figure 1**; the flowers may look similar, but they are actually male and female reproductive structures. The female structures on the left are archigoniphores and have a finger-like structure while the male structures on the right are antheridiophores and are umbrella-like.

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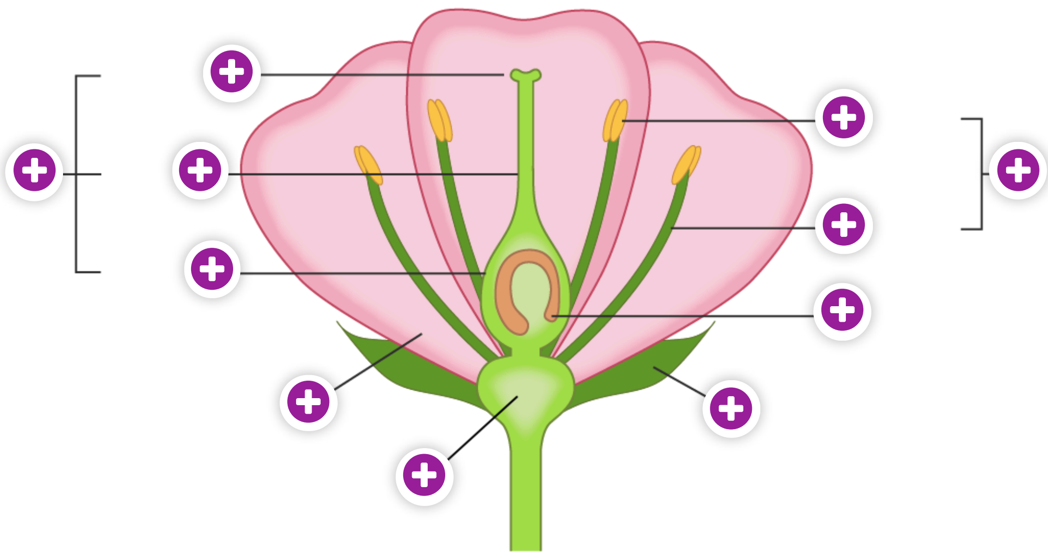
Figure 1. Female (left) and male (right).

More information for figure 1

Flowers play a vital role in reproduction. What are the parts of the flowers that help in reproduction? Do flowers produce male and female gametes?

What are flowers?

Flowers are the reproductive structures in flowering plants or angiosperms. A typical flower is a complex structure composed of four layers. The layer that you are probably most familiar with is the petals. In addition, there are the leaf-like sepals, the stamens or the male reproductive structures, and the pistils (carpels) or the female reproductive structures, arranged as shown in **Interactive 1**.



Interactive 1. A Perfect Flower.

More information for interactive 1

An interactive diagram provides a comprehensive visual breakdown of a flower's anatomical structure, highlighting its four primary layers and reproductive components. Each part includes a selectable hotspot that labels the structure.

The flower is divided into four concentric layers, each serving a distinct purpose. Sepals form the outermost layer and protect the developing bud before blooming. Petals are colored structures. Stamens represent the male reproductive parts and include anther and filament. The pistil/carpel is the female reproductive part and includes the stigma, style, and ovary.

The hotspot reveals the following:

Hotspot on the central long green tube in the center, comprising the stigma, style, and ovary: Pistil
Hotspot on the sticky pollen receptor at the top: Stigma
Hotspot on the long, slender green tube connecting the stigma to the ovary: Style
Hotspot on the swollen chamber at the pistil's base, which contains ovules: Ovary
Hotspot on the three bright pink, leaf-like structures: Petal
Hotspot on the swollen base where all floral parts attach: Receptacle
Hotspot on the four thin thread-like structures, each with a sac-like tip: Stamen
Hotspot on the yellow, sac-like structures at the top of each stamen: Anther

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Hotspot on the thin, thread-like support beneath the anther: Filament

Hotspot on the bead-like structures present inside the ovary: Ovule

Hotspot on the green and leaf-like structure: Sepal

This interactive diagram helps users to identify and describe the main structural and reproductive parts of a flower.

If all the four layers are present, the flower is termed as a complete flower, if not it is an incomplete flower. In addition, some flowers could have both stamens and pistils – these flowers are bisexual (hermaphroditic) flowers. Some may have either the stamens or the pistils, these flowers are unisexual flowers. In other words there could be male flowers or female flowers. A perfect flower is one that has the male and the female parts, while an imperfect flower has either the male or female parts.

Reproductive structures and cells of the flower

Stamen

Each stamen consists of two parts: a tube-like filament and a sac-like anther. Present within the anther are the pollen grains. The pollen grains, when mature, are released from the anther. Each pollen grain consists of a generative cell and a larger tube cell. Two layers, an outer tough exine and an inner intine made of cellulose, surround the tube cell.

Pistil or carpel

The pistil is located in the centre of the flower and consists of three regions: the swollen base or the ovary, the stalk or style and the stigma. The ovary contains the ovules. Inside each ovule is the embryo-sac with seven cells and eight haploid nuclei as shown in **Interactive 3**.

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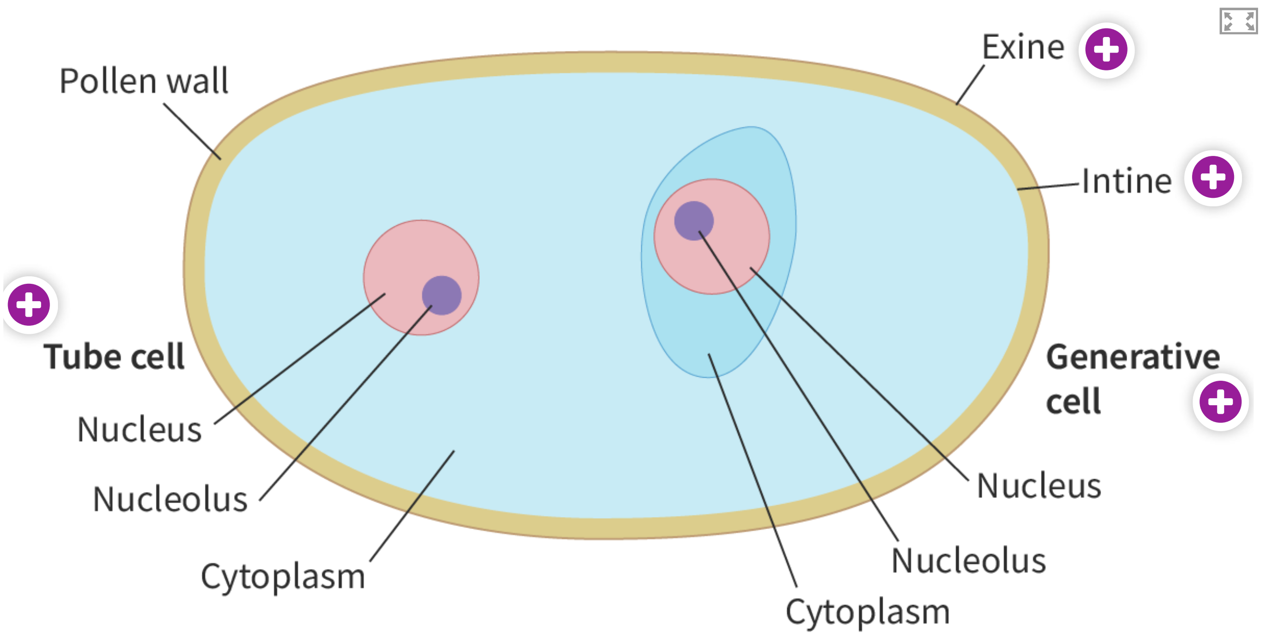

Interactive 2. A Pollen Grain.

More information for interactive 2

The interactive describes the structure of pollen grain, the male gametophyte, focusing on cellular and wall components. There are various hotspots across the illustration indicated as plus signs with specific numbers that explain certain structures.

Read the following to understand the individual structures of a pollen grain.

The wall components of a pollen grain include exine and intine. Exine is the outermost layer of a pollen grain marked by a brown line. The attached hotspot reads: Tough outer layer, provides protection. The intine is the innermost layer and the attached hotspot reads: The inner wall made of cellulose, helps in the maturation of the pollen grain. The space between these two layers marked by light-skin color is the “pollen wall”.

The cellular components of a pollen grain include generative cells and tube cells. The generative cell is the irregularly shaped blue oval containing a round pink, which, in turn, consists of a purple circle. The space between the oval and pink structure is the “cytoplasm.” The round pink is the “nucleus.” The purple circle is the “nucleolus.” The hotspot for the generative cell reads: Gives rise to two haploid sperm cells.

The tube cell, on the other hand, is a perfect round pink cell with a purple round inside. They are the nucleus, and nucleolus, respectively. The hotspot for the tube cell reads: The haploid tube cell grows to form the pollen tube, providing a pathway for the male gamete.

Both the generative and tube cells are present in the cytoplasm of the pollen grain. This region is marked in light blue and is surrounded by the intine.

The zoom-in icon at the top right allows for a larger view of the pollen grain structure.

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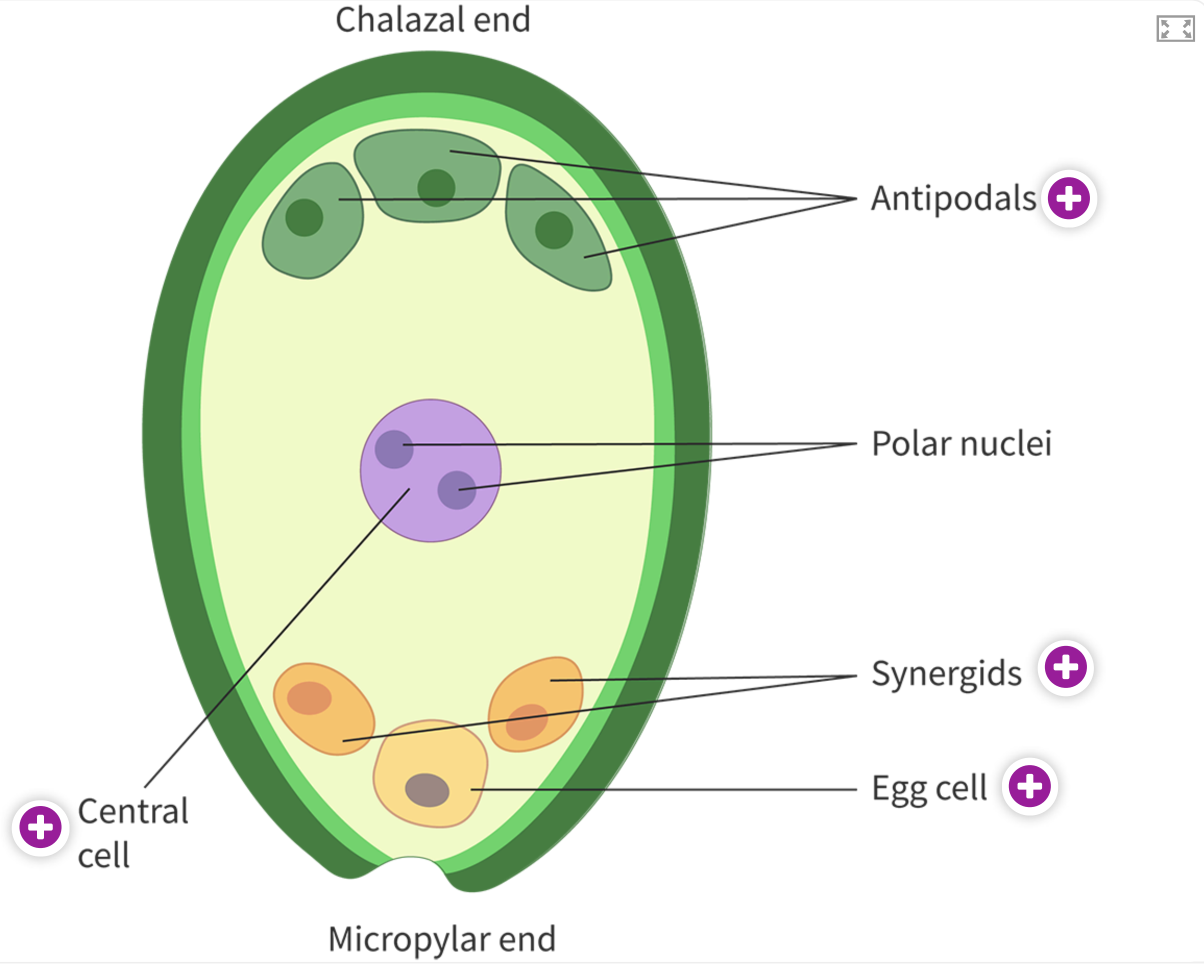

Interactive 3. An Ovule.

More information for interactive 3

The interactive depicts the structure of an embryo sac (female gametophyte) within the ovule of a flowering plant.

The interactive focuses on the key cellular components and their spatial organization within the embryo sac.

There are various hotspots across the illustration, which are indicated as plus signs with numbers. When clicked, they provide additional information about the specific structure.

Read below to understand the positioning of various components of an embryo sac and their role.

The embryo sac is depicted as an oval structure with two layers. The outer layer is highlighted with dark green, and the inner layer is highlighted with light green. The “Chalazal end” is present at the top of the embryo sac. There are three antipodals present at this end. The hotspot of the antipodals reads: Three small cells located at the end opposite to the egg cell. Provides nourishment to the egg cell.

At the center of the sac, below the chalazal end, is the central cell with two polar nuclei. The hotspot of the central cell reads: Large cell with two haploid nuclei. The nuclei are known as polar nuclei. Plays an important role in endosperm development post-fertilization.

The bottom of the sac is marked as the micropylar end. The layers of the sac are absent here, and only a thin line marks the end. Two synergid cells on either side of an egg cell are present at this end of the sac. The hotspot of the synergid reads: Located on either side of the egg cell. Guides the growth of the pollen tube in the ovule for successful fertilization. The hotspot on the egg cell reads: Female gamete.

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The “Fullscreen” icon at the top right allows the users to view the illustration in full-screen mode.

Pollination and fertilisation

Sexual reproduction in plants involves the fusion of the male gametes (sperm cells) within the pollen with the female gametes (the egg) to form a diploid zygote. However, before fertilisation can take place, the pollen grains need to be transferred from the stamen to the carpel. This process is known as pollination and takes place with the help of modulators like insects and other animals, wind and even water.

Pollination

Multiple pollen grains land on the stigma. Once a pollen grain reaches the stigma, it begins to germinate. The tube cell elongates forming the pollen tube (**Figure 2**). The pollen tube grows down the length of the style into the ovary in response to the chemicals secreted by the synergids. The generative cells divide mitotically to form the sperm cells. The sperm cells move through the tiny opening or micropyle into the ovule.

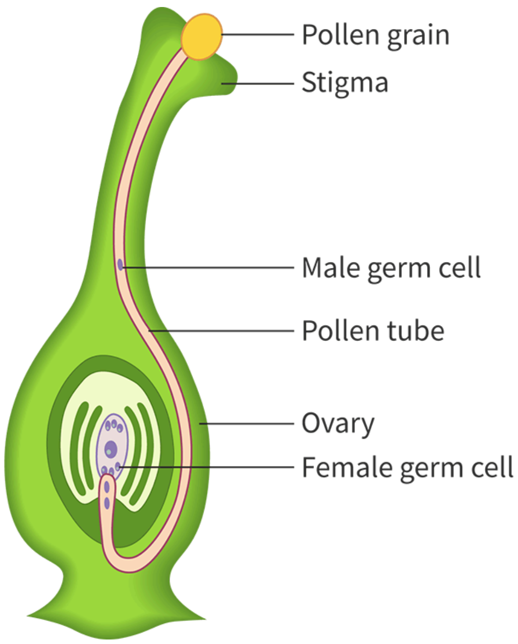

Figure 2. Growing pollen tube.

More information for figure 2

The diagram illustrates the process of pollen tube growth in a flower. At the top, a pollen grain is seen on the tip of the pistil, which extends down as a long tube called the pollen tube. This tube passes through the style and moves toward the ovary. Labels in the diagram mark different parts including the pollen grain, pollen tube, style, and ovule.

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Within the ovule, several structures are visible, indicating the path the sperm cells will take via the micropyle to reach the ovule. The diagram visually explains the interaction between these structures during the germination and fertilization process.

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Fertilisation

One of the sperm nuclei fuses with the egg to form the diploid zygote. This, in turn, develops into the embryo. The second sperm nucleus fuses with the central cell. Remember that the central cell consists of two haploid polar nuclei. Hence, this process is called triple fusion and results in a triploid cell (3n). This triploid cell gives rise to the endosperm, which surrounds and nourishes the developing embryo. The entire process of fertilisation and triple fusion is known as double fertilisation and is seen only in flowering plants. The process of double fertilisation is shown in **Video 1**.

Video 1. Double fertilisation in flowering plants.

Insect-pollinated flowers

For plants to reproduce successfully, enough pollen must land on the stigma of flowers - in other words, the rate of pollination must be high. Flowers show multiple adaptations to ensure that pollination happens (**Interactive 3**).

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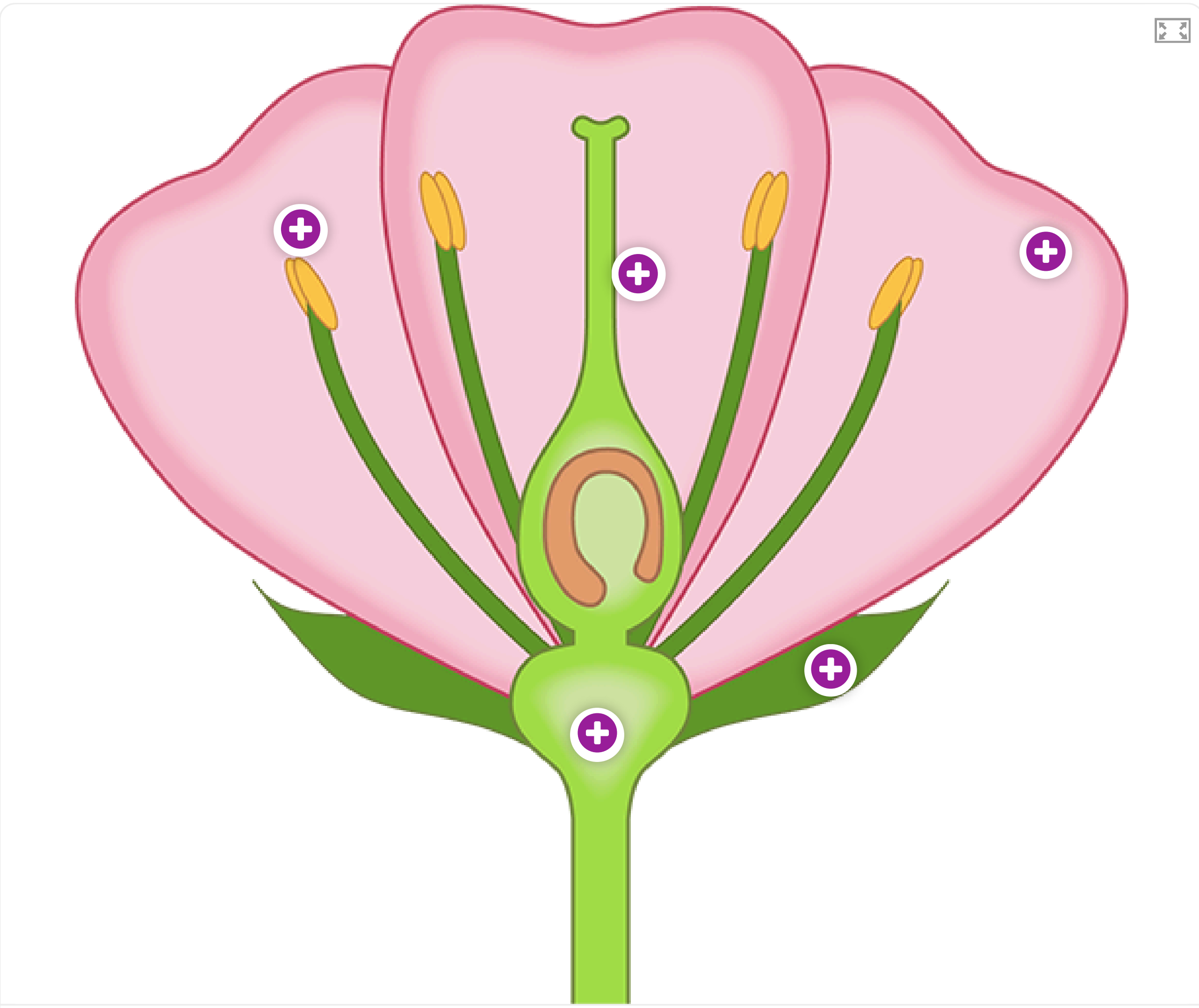

Interactive 4. Parts of an Insect-pollinated Flower.

More information for interactive 4

An interactive illustration of a flower that explains the floral adaptations in an insect-pollinated flower.

The illustration possesses hotspots, indicated by plus signs with numbers, for each organ. These hotspots provide detailed information about each organ in a flower.

The flower contains three petals, one pistil (female reproductive organ), four stamens (male reproductive organ), two sepals, and a receptacle.

The Hotspot 1 of stamen reads: The stamens are the male reproductive parts. They consist of a filament and an anther. a) The filament is a stalk-like structure that attaches the anther to the flower stem. b) The anther is a sac-like structure that encloses pollen grains. Pollen grains vary in shape, size and texture from one plant species to another.

The Hotspot 2 of petals read: The petals are large and brightly coloured. They often have nectar-producing glands at their base or are fragrant. The petals can be fused together to form a tube or can be separate. In some flowers, the petals are modified, forming landing platforms for insects. Petals are collectively known as corolla.

The Hotspot 3 of the pistil, which is located at the centre of the flower reads: The pistils or carpels are the female reproductive structures. a) The stigma is sticky on which the pollen grains land and germinate. b) The style is a slender tube that connects the stigma to the ovary. c) The ovary is the swollen base of the pistil and contains one or

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more ovules.

The Hotspot 4 of the sepals or calyx reads: The calyx is the ring of green leaf-like sepals that forms the outermost layer of the flower. Sepals are protective in nature. Sometimes, sepals are brightly coloured too.

The Hotspot 5 of the receptacle reads: The receptacle is the thickened part of the stem at the base of the flower. It is the swollen tip of the flower stalk where all floral parts attach.

The “Fullscreen” icon at the top right allows the users to view the flower in full-screen mode.

In insect pollination, the pollen grains are carried from one flower to another by the insects. It is evident that insects favour flowers that are more attractive to them (**Figure 3**). Some of the adaptations seen are:

- Some flowers produce nectar, a popular insect food, to lure insects. As the insect drinks the nectar, the anther brushes against its legs, transferring pollen. When the insect visits another flower, some pollen gets transferred to the stigma, resulting in pollination.
- Some flowers like *Magnolia* or lilies (*Lilium*) have developed strong scents to attract insects.
- Yet others are white or brightly coloured to attract insects.
- Pollen produced by insect-pollinated flowers is heavy and sticky to ensure that the pollen gets stuck to the body of the insect.

Credit: Ed Reschke, Getty Images

Student view

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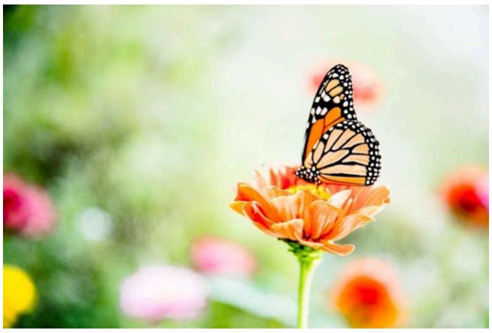
Credit: Hilde / 500px, Getty Images



Credit: 130920, Getty Images

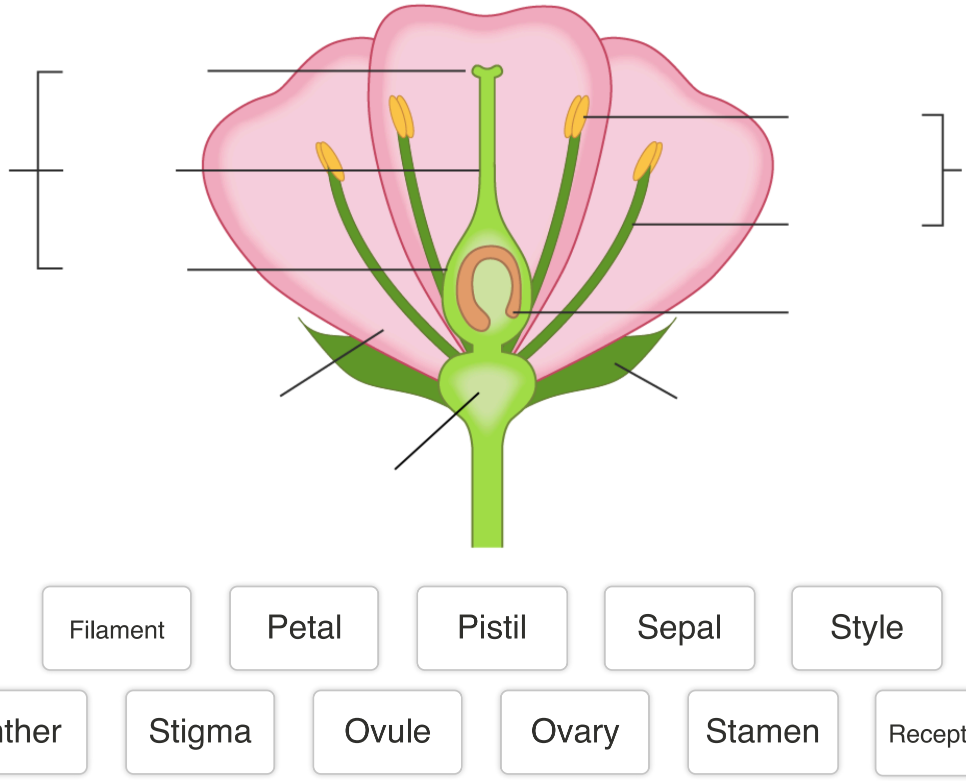
Credit: Image by cuppyuppycake, Getty Images

Figure 3. Insect pollinators.

To ensure that the pollen is not wasted on a plant of another species, flowers have evolved in ways to encourage visits by a few specific pollinators. For example, the colour and scent of the pea flowers attract bees. Thus, flowers and insects have evolved leading to symbiotic relationships.

Drag and drop the words in **Interactive 4** to label the flowers.

Student view



Check

Interactive 4. Parts of a Flower.

More information for interactive 4

This is a drag and drop interactivity which shows an image of a simplified, vertical cutaway view of a flower. The flower is mostly pink and green and is positioned against a white background.

In the given illustration, the outermost pink parts are the petals, which attract pollinators. Inside the petals are multiple long, thin filaments topped with yellow anthers—these make up the stamens, the male reproductive parts, which produce pollen. At the center of the flower is the pistil, the female reproductive organ, consisting of the stigma (the sticky top that receives pollen), the style (a tube connecting the stigma to the ovary), and the ovary at the base, which contains the ovule where fertilization occurs. Beneath the petals are green structures called sepals that protect the flower bud before it opens. All parts are attached to the receptacle at the flower's base, which connects to the stem.

This drag and drop interactive has a total of 11 blanks pointing to different parts of a flower. There are also 11 draggable options given at the bottom of the screen. They are: Filament, Petal, Pistal, Sepal, Style, Anther, Stigma, Ovule, Ovary, Stamen and Receptacle.

Read below for the solution:

In the left side of the flower: From top to bottom- Pistal, which consists of three parts, the first one is stigma, the second is style and the third is ovary. The pink part is petal and the part where all the flower parts are attached is the receptacle.

Moving to the right side of the flower: From top to bottom- yellow part is anther, the thin part below the anther is filament. Filaments with anther is stamen. The center portion is ovule and the green part below the petal is sepal.

International Mindedness

Most of the plants that you see around you, including fruit trees or vegetable plants, are flowering plants, and most depend on insects for pollination. Yet, the populations of most pollinators are on the decline due to habitat loss and the indiscriminate use of pesticides. This has serious implications for us. The Food and Agriculture Association (United Nations) (https://www.fao.org/pollination/background/en/) has developed a global action plan for the conservation and sustainable use of pollinators. In addition, some organisations, both governmental and non-governmental, have come up with strategies to protect pollinators. You can read more about this here (https://www.epa.gov/pollinator-protection/pollinator-protection-strategic-plan) and here (https://extension.missouri.edu/programs/master-pollinator-steward).

Try the modelling activity to help with your understanding of pollination.

Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Social skills — Working collaboratively to achieve a common goal
- **Time required to complete activity:** 15 minutes
- **Activity type:** Pair activity

Materials

Modelling materials such as modelling clay, coloured paper, beads, coloured wool, twine, pipe cleaner, wire, etc.

Your task

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Working in pairs, draw a diagram of a hypothetical, complete, perfect, insect-pollinated, flower. Then, make a model of the insect-pollinated flower using modelling clay or any other material you have on hand. Your model should include the following parts: sepals, petals, stamen (filament, anther, pollen) and pistil (ovary, ovule, style and stigma).

Label these parts.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Self- and cross-pollination, dispersal and germination

D3.1.10: Methods of promoting cross-pollination D3.1.11: Self-incompatibility to increase genetic variation within a species

D3.1.12: Dispersal and germination of seeds

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Learning outcomes

By the end of this section you should be able to:

- Describe strategies that facilitate cross-pollination in plants.
- Determine the role of self-incompatibility mechanisms in increasing genetic variation in a plant species.
- Explain the mechanism of seed dispersal and germination.

Many flowers like the flowers of tomato, mango and lily are hermaphroditic. The transfer of pollen grains is foolproof as the pollen grains need only to be transferred within the flower. Yet, many of these flowers depend on pollinators to carry their pollen grains to flowers on other plants. What could be the advantage of this?

Cross-pollination versus self-pollination

There are two types of pollination.

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- Cross-pollination is the transfer of pollen grains from one flower on one plant to the stigma of another flower on another plant.

The pollen grains are transferred by animals including insects, birds and bats (**Figure 1**), and by wind. These flowers have many features to lure the animals (see section D3.1.8 (/study/app/bio/sid-422-cid-755105/book/sexual-reproduction-in-flowering-plants-id-45746/)– (/study/app/bio/sid-422-cid-755105/book/male-and-female-reproductive-systems-id-45750/)9 (/study/app/bio/sid-422-cid-755105/book/sexual-reproduction-in-flowering-plants-id-45746/))

Many grasses and cereal crops are pollinated by wind. The flowers are small, unscented and do not have nectar, unlike flowers pollinated by animals. Moreover, the pollen grains are lighter so that they can be easily carried by the wind. The feathery stigma helps 'catch' the pollen (**Figure 2**).

Credit: ©Juan Carlos Vindas, Getty Images

Credit: Dan Ripplinger / 500px, Getty Images

Figure 1. Bats and hummingbirds are pollinators.

Student view

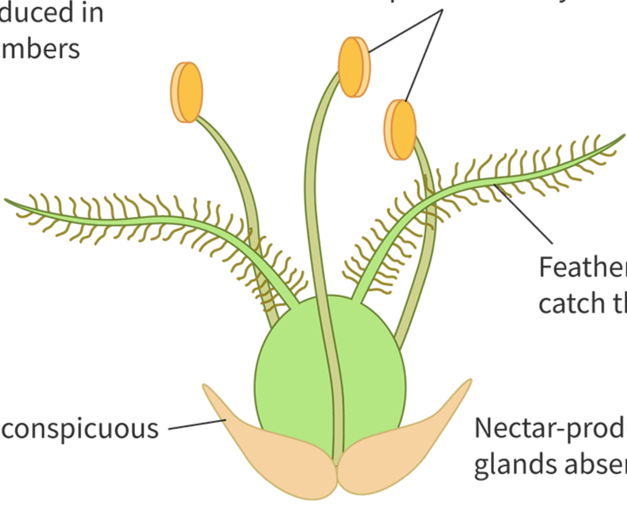

Figure 2. Features of wind-pollinated flowers.

More information for figure 2

The image is a labeled illustration highlighting the features of wind-pollinated flowers. It includes labeled parts such as the long anther, feathery stigma, loosely attached pollen, and small petals. Each part is clearly marked with text, making it an informative diagram focused on the structural elements of the flower related to wind pollination. The illustration conveys how the physical structure aids in the process of pollen being carried by the wind, emphasizing the adaptations these flowers have for successful pollination without animal interaction.

[Generated by AI]

- Self-pollination is transfer of pollen grains to the stigma of the same flower or to the stigma of another flower on the same plant.

It is evident that cross-pollination brings in genetic diversity as the male and female gametes are from two different plants. This has evolutionary (see section A4.1.1 (/study/app/bio/sid-422-cid-755105/book/evolution-as-change-in-heritable-characteristics-id-43790/)) advantages. When the environment changes, plants with favourable variations survive and reproduce, thereby ensuring survival of the species.

Mechanisms that promote cross-pollination

A number of adaptations are seen in flowering plants that facilitate cross-pollination and prevent self-pollination.

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- In some plants like the date palm (*Phoenix dactylifera*) and the papaya (*Carica papaya*), the male and female flowers are located on different plants, mandating cross-pollination.
- In plants where the male and female flowers are located on the same plant, the maturation time of the male and female flowers differs. For example, the male flowers mature before the female flowers and release their pollen. An example of this is seen in avocado.
- In plants with hermaphroditic flowers, the time at which the anthers and pistils mature varies. The pistils may mature faster than the stamens as seen in arum lilies (*Zantedeschia aethiopica*) and vice versa. For example, in plants like ivy (genus *Hedera*), carrot (*Daucus carota*) and *Salvia* the anther mature and release pollen; however, the stigma is still immature and non-receptive to the pollen grains.
- The anatomical structure of bisexual flowers also facilitates cross-pollination. For example, primrose (*Primula vulgaris*) produces two forms of flowers as shown in **Figure 3**.

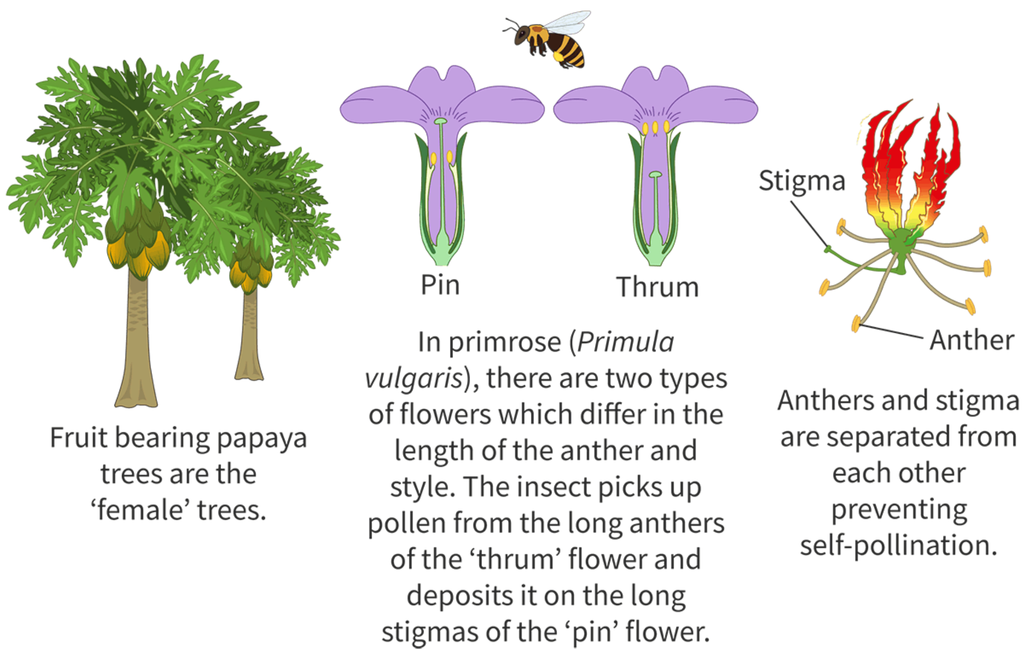

Figure 3. Preventing self-pollination.

More information for figure 3

This illustration depicts various mechanisms plants use to prevent self-pollination. From left to right, the image features: two papaya trees with visible fruits, showing the need for spatial separation of male and female flowers; two identical flowers with a bee hovering between them, illustrating the role of pollinators in transferring pollen between different plants; and a flower displaying structural adaptations such as different heights of stamens and pistils to prevent self-pollination. Text labels describe each mechanism below the respective visuals.

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Self-incompatibility mechanisms

Self-pollination is a form of inbreeding or mating among close relatives. The genetic makeup of the offspring is similar to the parents, reducing the genetic diversity. In a changing environment, the lack of genetic diversity could be disastrous.

Studies have shown that, in species where both self- and cross-pollination work, the seeds produced by cross-pollination are of better quality and greater vigour.

In plants with hermaphroditic flowers, self-incompatibility mechanisms prevent self-fertilisation. Self-incompatibility is often defined as the inability of hermaphroditic plants to produce zygotes after self-pollination. It is characterised by failure of any of these stages: pollen germination, growth of the pollen tube, fertilisation and embryo development.

This could be due to variations in the flower structure such as differences in the length of the stamen and style as described in the previous section. These variations are governed by self-incompatibility genes.

The incompatibility could also be due to the genes for self-sterility present in some plants. Most often these genes have multiple alleles. A plant carrying one allele, say 's^1' is unable to pollinate another plant with the same allele (s^1) as the pollen grain fails to germinate (note that this is a simplified explanation of a complex process). In cases where the pollen tube grows, fertilisation and seed formation does not happen. This ensures that plants do not produce seeds if they are self-pollinated or pollinated by genetically similar plants.

Thus, genetically determined self-incompatibility facilitates cross-pollination and encourages variability in the population. It is seen in white clover (*Trifolium repens*) and cabbage (*Brassica oleracea*).

Dispersal and germination of seeds

Soon after fertilisation, a series of changes occurs. Most of the parts of the flower dry and fall off. Inside the ovule, the zygote divides mitotically to form the embryo while the triploid cell develops into the endosperm. The wall of the ovule becomes the seed coat enclosing the embryo and the endosperm (**Figure 4**). The ovary forms the fruit.

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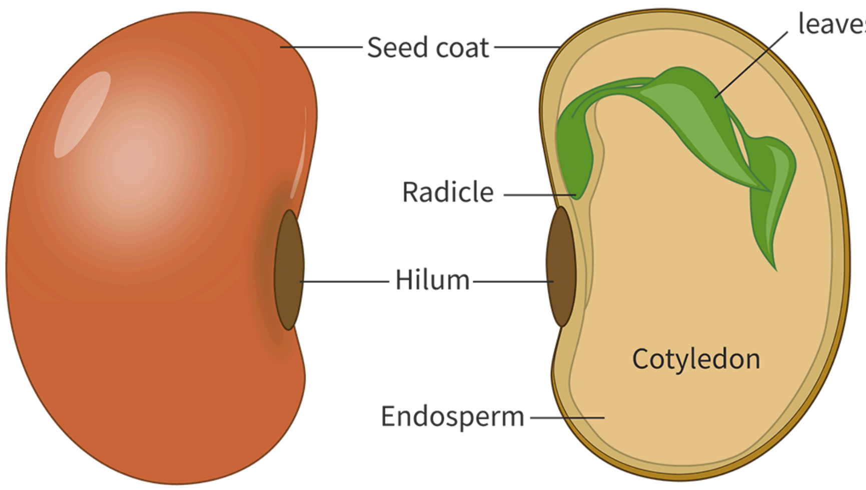

Figure 4. A typical seed.

More information for figure 4

The image is a detailed illustration of a typical seed, depicted in two parts to show both external and internal structures. On the left, there is a view of the whole seed with a reddish-brown outer coat. It appears smooth and slightly elliptical in shape.

To the right, the seed is bisected to reveal internal components. The inside of the seed shows a large beige cotyledon labeled as such. Above this, there is a green structure labeled as the embryonic shoot which is partially unfolding. Within this bisected section, the embryonic parts are depicted as sprouting from the center, illustrating how they are encased by the cotyledon. This diagram is likely educational, helping to explain the anatomy of a seed and its development following fertilization.

[Generated by AI]

Seed dispersal

If all the seeds fall close to the parent plant, there will be intense competition for resources like water, soil and sunlight. To prevent this, seeds must be dispersed to new areas. Seed dispersal can happen via wind, water or animals (**Figure 5**).

Dispersal by wind

Wind-dispersed seeds are light and have a number of adaptations like wings or hair that help them to be carried by the wind. Examples include dandelion (*Taraxacum officinale*), seeds of many grasses, seeds of drumstick (*Moringa oleifera*) and seeds of maple (genus *Acer*).

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Dispersal by water

Seeds dispersed by water like those of water lilies (genus *Nymphaea*) and coconut (*Cocos nucifera*) are buoyant. The fibrous covering of coconuts and specialised structures called aril in water lilies help these seeds to float.

Dispersal by animals

Animals help in the dispersal of seeds in many ways. Animals may feed on fleshy fruits, and toss the seed some distance away. Other animals may eat the fruit along with the seeds. The seeds pass through the digestive system undigested and are thrown out as faeces. Animals like squirrels and chipmunks may collect and hoard seeds in different places. Some seeds have hooks and spines that cause them to attach to the skin and fur of passing animals.

(a)

Credit: BrianAJackson, Getty Images

(b)

Credit: PeskyMonkey, Getty Images

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(c)

Credit: visual7, Getty Images

Figure 5. (a) Wind-dispersed seeds – dandelion, *Taraxacum officinale*, and maple, genus *Acer*, (b) Water-dispersed seeds – coconut, *Cocos nucifera*, (c) Seeds with hooks – burdock, genus *Arctium*.

Making connections

Both the transfer of pollen (see section D3.1.8—9 (/study/app/bio/sid-422-cid-755105/book/sexual-reproduction-in-flowering-plants-id-45746/)) and the dispersal of seeds happen with the help of wind, water and animals. Yet, it is important to remember that they are two distinct processes serving different purposes.

Growth and development of the embryo and mobilisation of resources

Seed germination

Germination is the development of the seed, which begins with the uptake of water of the seed and is completed when the radicle emerges from the seed. Germination occurs only when the conditions are suitable for the growth of the plant. Until then, the seed remains dormant, a condition where all metabolic activities are slowed down. The period of dormancy varies from one plant species to another. Some seeds – like those of the magnolia – can remain dormant for only a few weeks; others – like the seeds of desert wildflowers – can remain dormant for years.

Student view

Conditions for germination

Although the conditions for germination can vary, there are three essential factors.

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- Water, as it hydrates and thereby activates the metabolic reactions of the embryo.
- A favourable temperature. Most seeds germinate best at temperatures between 25 °C and 30 °C. Very low temperatures or very high temperatures prevent germination.
- Oxygen. Shortly before the seed coat ruptures, the embryo begins to respire. Cellular respiration and other metabolic activities of the growing embryo require oxygen.

Germination and the post-germination changes that lead to the growth and development of the embryo are outlined below (**Figure 6**).

- Imbibition of water.
  The dry seeds imbibe water and swell up, causing the seed coat to rupture.

- Respiration.
  The metabolic activities are suspended or reduced during dormancy. Soon after the imbibition of water, the various metabolic processes resume and the rate of respiration of the embryo increases.

- Mobilising food reserves.
  Until it becomes self-supporting, the embryo depends on the food reserves present in the endosperm. These reserves are in the form of carbohydrates, proteins and lipids which need to be mobilised (broken down) and translocated. Studies show that in cereals, following the uptake of water, the embryo produces gibberellins (see section C3.1.17–19 (/study/app/bio/sid-422-cid-755105/book/tropisms-and-role-of-phytohormones-hl-id-46103/)). These hormones cause the release of enzymes that break down the stored food reserves converting them into sugars, amino acids and fatty acids. The food is then absorbed by the cotyledons and transported to the growing embryo.
- Development of the embryo axis into a seedling.
  Rapid growth results in the emergence of the primary root or radicle in most species (marking the end of germination). It is then followed by the emergence of the plumule (or the shoot). At this point the baby plant is known as the seedling. The shoot develops green leaves which, in turn, begin to synthesise food.

- Effect of light on seed germination.
  Once the plumule has emerged, light plays an important role in the orientation of the seedling. When the plumule emerges it is bent over to protect the delicate growing tip. The straightening of the plumule occurs on exposure to light.

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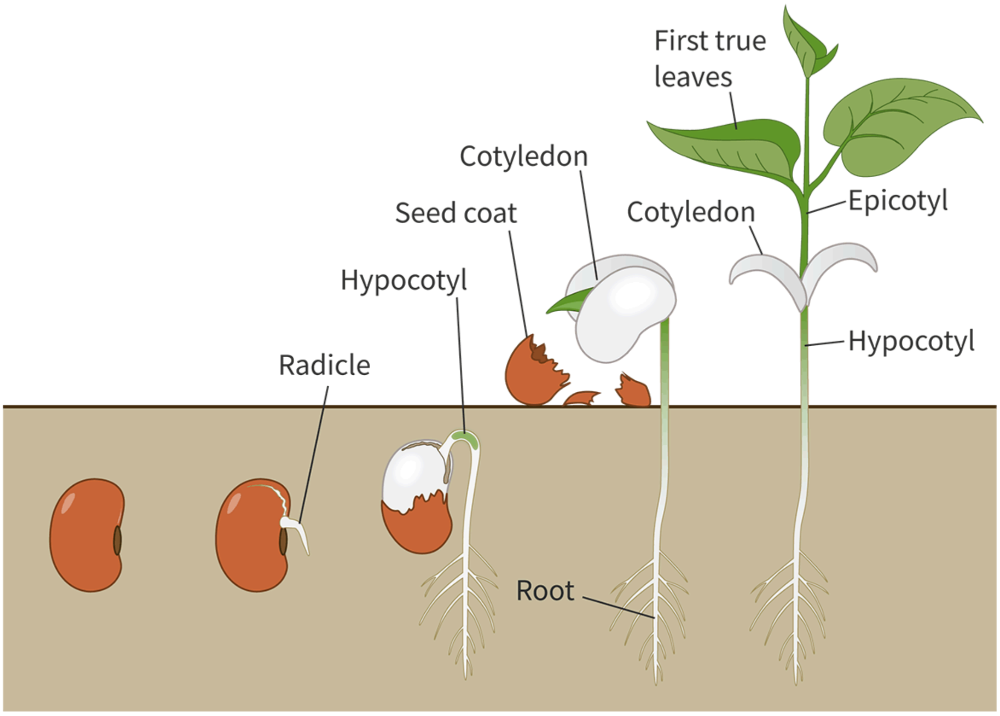

Figure 6. Stages of seed germination and seedling development.

More information for figure 6

The image is an illustration showing the stages of seed germination and seedling development, from a small seed to a mature plant. From left to right:

1. Stage 1: Shows a seed with a red-brown coat.
2. Stage 2: The seed begins to sprout, showing a small root emerging from the coat.
3. Stage 3: The seed continues to sprout, the seed coat breaks and a young root grows downward.
4. Stage 4: The plant starts emerging above the soil, with two seed leaves visible, and roots further developing below the soil.
5. Stage 5: A young seedling stands with its seed leaves and initial true leaves growing larger. The root system is more developed and labeled as "Root."

[Generated by AI]

Try the activity to observe and illustrate the parts of a seed.

Activity

- **IB learner profile attribute:** Knowledgeable

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- **Approaches to learning:** Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 15 minutes
- **Activity type:** Pair activity

Materials

Seeds such as lima seeds/kidney bean/chickpeas soaked in water overnight, needles.

Your task

1. Take a seed.
2. Peel away the seed coat.
3. Gently open the seed (without breaking it into two).
4. Observe the parts — the cotyledons and the embryo.
5. Make a sketch, annotate the names of the parts.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Puberty and gametogenesis (HL)

D3.1.13: Control of the developmental changes of puberty (HL) D3.1.14: Spermatogenesis and oogenesis in humans (HL)

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Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Outline the role of GnRH, LH, FSH and the sex hormones in the changes associated with puberty.
- Describe oogenesis and spermatogenesis in humans.

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Think of a lion and you would probably picture its golden mane. The gold mane distinguishes the male from the female. Similarly, the comb and spurs of the rooster, the enlarged proboscises in male elephant seals and the bright facial colouration of the male mandrill, *Mandrillus sphinx* (**Figure 1**) are secondary sexual characteristics that help to distinguish between the sexes. What causes the development of these features?

Credit: Charlotte Bleijenberg, Getty Images

Credit: Laura M. Vear, Getty Images

Figure 1. The male mandrill has a brightly coloured face with blue and red stripes on the cheek and nose.

The role of hormones

In males

Testosterone is the primary male hormone. It is secreted by the testes. The secretion of testosterone is controlled by a negative feedback mechanism that involves the hypothalamus and the anterior pituitary (**Figure 2**).

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The level of testosterone remains fairly low in early childhood. Puberty is initiated by the release of gonadotropin-releasing hormone (GnRH) by the hypothalamus. GnRH, in turn, acts on the anterior pituitary, stimulating the release of follicle-stimulating hormone (FSH) and luteinising hormone (LH). Both LH and FSH are carried by the blood to the testes. LH stimulates the release of testosterone by the Leydig cells while FSH plays a role in the production of sperm by stimulating the Sertoli cells.

The surge in the level of testosterone leads to the development of secondary sexual characteristics like growth of reproductive organs, an increase in height and musculature, deepening of the voice and development of hair – particularly on the face, underarms and pubic region.

As the levels of testosterone in the bloodstream increase, the release of GnRH from the hypothalamus is inhibited, which, in turn, inhibits release of FSH and LH by the anterior pituitary. Testosterone acts directly on the anterior pituitary too. Inhibin secreted by the Sertoli cells also inhibits the production of FSH.

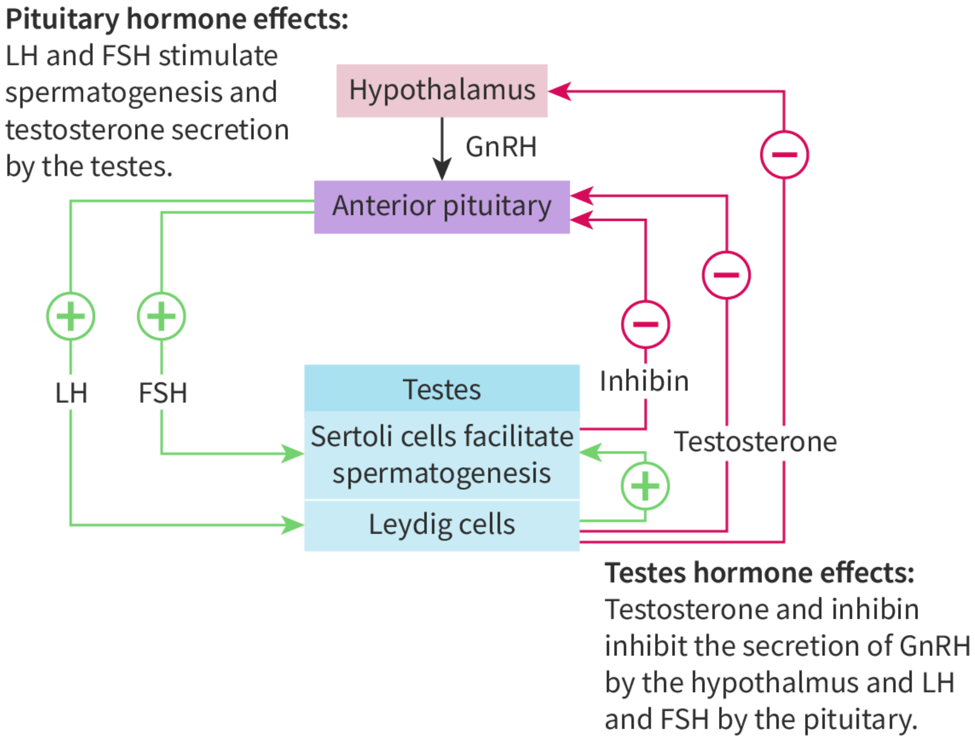

Figure 2. Hormonal feedback mechanisms in males.

More information for figure 2

The diagram shows the hormonal feedback mechanisms in males, focusing on the roles of the hypothalamus, anterior pituitary, and testes. It includes several components connected by arrows indicating regulatory effects.

1. **Hypothalamus:** Releases GnRH, which inhibits the anterior pituitary when bound by testosterone.

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2. **Anterior Pituitary:** Releases LH and FSH in response to GnRH from the hypothalamus. Both LH and FSH stimulate the testes.
3. **Testes:** Contain Sertoli cells that facilitate spermatogenesis and Leydig cells that secrete testosterone.
4. **Inhibin and Testosterone:** Produced by the Sertoli and Leydig cells, respectively, inhibit the production of GnRH by the hypothalamus and the release of LH and FSH by the pituitary.

Arrows illustrate: - Positive feedback (+) from LH and FSH to the testes. - Negative feedback (−) from testosterone and inhibin to the hypothalamus and anterior pituitary.

The diagram provides a visual representation of how testosterone and inhibin regulate the production of other hormones through feedback loops.

[Generated by AI]

In females

In females, steroid hormones – including oestradiol and progesterone – are the primary female hormones secreted by the ovaries. As in males, puberty in females begins with GnRH stimulating the release of FSH and LH from the anterior pituitary. These, in turn, cause release of the female sex hormones (see section D3.1.5–7 (/study/app/bio/sid-422-cid-755105/book/menstrual-cycle-and-fertilisation-id-45415/)). Positive and negative feedback mechanisms regulate the levels of the hormones (**Figure 3**).

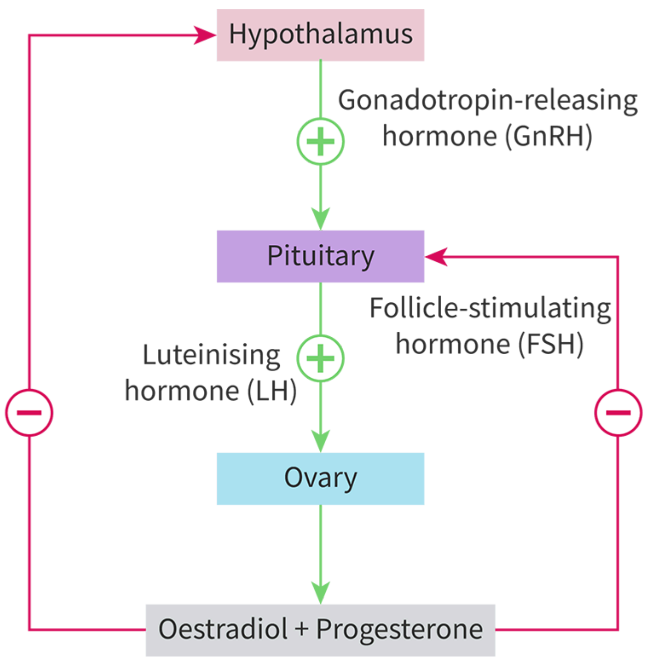

Figure 3. Hormonal feedback mechanisms in females.

More information for figure 3

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The diagram illustrates the hormonal feedback mechanisms in females, focusing on the interactions between the hypothalamus, pituitary gland, and ovaries. At the top, the hypothalamus releases signals that influence the pituitary gland, depicted with a positive sign indicating stimulation. The pituitary then sends signals to the ovaries, also illustrated with a positive sign, promoting the release of oestradiol and progesterone hormones. These hormones provide feedback to the hypothalamus and pituitary, with a negative sign depicted on both sides indicating inhibitory feedback to regulate hormone levels. Text within the diagram labels each component and highlights the positive and negative feedback loops, forming a dynamic regulatory system.

[Generated by AI]

An increase in the level of oestradiol leads to the development of secondary sexual characteristics in females like maturation of the ovaries, development of the breasts and development of body hair, as well as the onset of the menstrual cycle.

Theory of Knowledge

In many cultures, the onset of puberty referred to as 'coming of age' is celebrated with ceremonies that involve the family and community. To what extent does our cultural background affect our perception about puberty? Does the same knowledge take on different perspectives in different cultures as well as different families?

Gametogenesis — spermatogenesis and oogenesis

Gametogenesis – the formation of haploid gametes, occurs through meiosis and is an integral aspect of sexual reproduction. Gametogenesis in males is referred to as spermatogenesis and in females, as oogenesis. While the basic mechanism in both the processes remains the same, there are variations in the numbers of sperm and eggs produced in each cycle.

Making connections

Meiosis (see section D2.1.9—11 (/study/app/bio/sid-422-cid-755105/book/meiosis-id-43812/)) plays a crucial role in gametogenesis, resulting in the formation of four haploid cells from one diploid nucleus. Prior to cell division — in both mitosis and meiosis, the chromosomes duplicate (see section D2.1.4—6 (/study/app/bio/sid-422-cid-

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755105/book/shared-features-of-mitosis-and-meiosis-id-45676/)). Each chromosome consists of two identical chromatids joined by the centromere.

Spermatogenesis

Spermatogenesis (**Figure 4**) in males occurs with the onset of puberty. Within each testis are the highly coiled seminiferous tubules – these are the sites for sperm production. Between the seminiferous tubules are the Leydig (interstitial cells) cells, which produce testosterone. The basement membranes are lined by the spermatogonia.

- Spermatogonia to primary spermatocytes (multiplication phase)

  The spermatogonia are diploid cells (2n) and have 44 autosomes and two sex chromosomes. Spermatogonia divide mitotically to produce more cells. Some of these cells continue dividing, others move away from the basement membrane and differentiate to form the primary spermatocyte. The primary spermatocyte is a diploid cell.

- Primary spermatocyte to secondary spermatocyte (growth phase)

  Primary spermatocytes undergo the first meiotic division to produce the secondary spermatocytes. A single primary spermatocyte (2n) produces two secondary spermatocytes (n), each with 22 autosomes and either an X or a Y sex chromosome. Crossing over and independent assortment of chromosomes brings in genetic variation.

- Secondary spermatocyte to spermatids (maturation phase)

  Each secondary spermatocyte completes the second meiotic division to produce two spermatids. There is no change in the chromosome number, that is, both the secondary spermatocyte and the spermatids are haploid.

- Spermatid to sperm (spermiogenesis)

  The spermatids undergo differentiation to form the sperm or spermatozoa. The process, called spermiogenesis, is supported by the secretions of the Sertoli cells of the seminiferous tubules.

Thus each primary spermatocyte produces four haploid spermatozoa or sperm. **Video 1** outlines the process.

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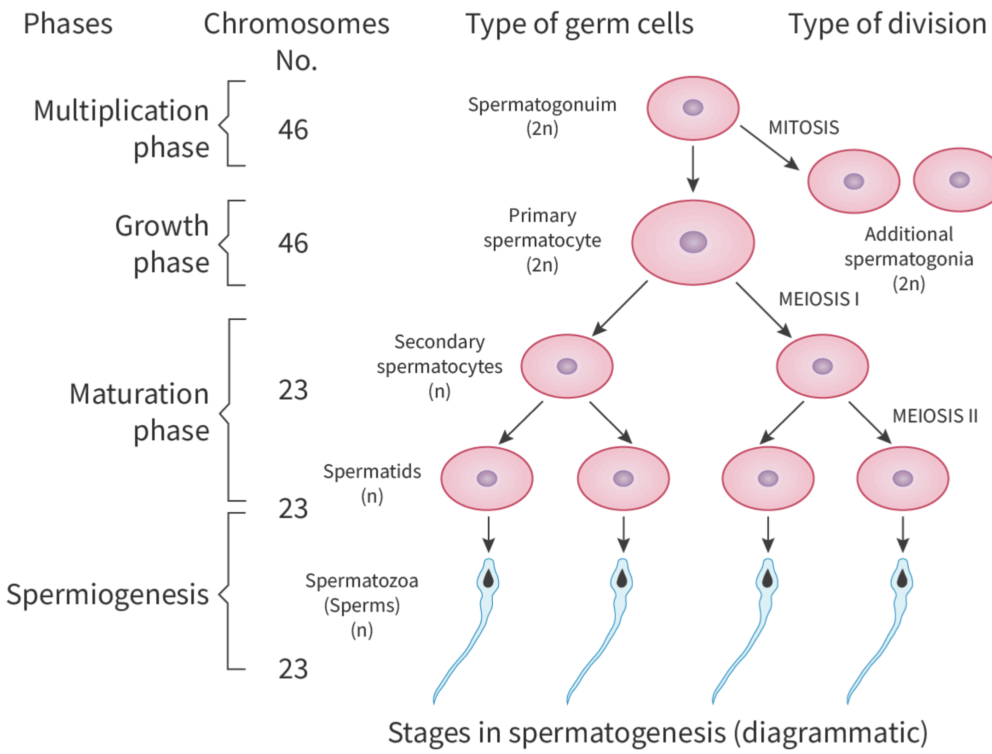
Video 1. Spermatogenesis.



More information

The diagram illustrates the stages in spermatogenesis. It is divided into phases and shows the type of germ cells and type of division. The phases include:

1. **Multiplication phase**:
2. Chromosomes number is 46.
3. Germ cell: Spermatogonium (2n).
4. Division type: Mitosis, producing additional spermatogonia (2n).
5. **Growth phase**:

Student view

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6. Chromosomes number remains 46.
7. Transition to the primary spermatocyte stage (2n).
8. **Maturation phase:**
9. Chromosomes number is reduced to 23.
10.
11. Primary spermatocyte undergoes Meiosis I, producing secondary spermatocytes (n).
12. Secondary spermatocytes undergo Meiosis II, forming spermatids (n).
13. **Spermiogenesis:**
14. Chromosomes number remains 23.
15. Spermatids mature into spermatozoa (sperms) (n).

The diagram shows the flow of division with arrows indicating processes from one cell to the next stage, ultimately leading to mature sperm.

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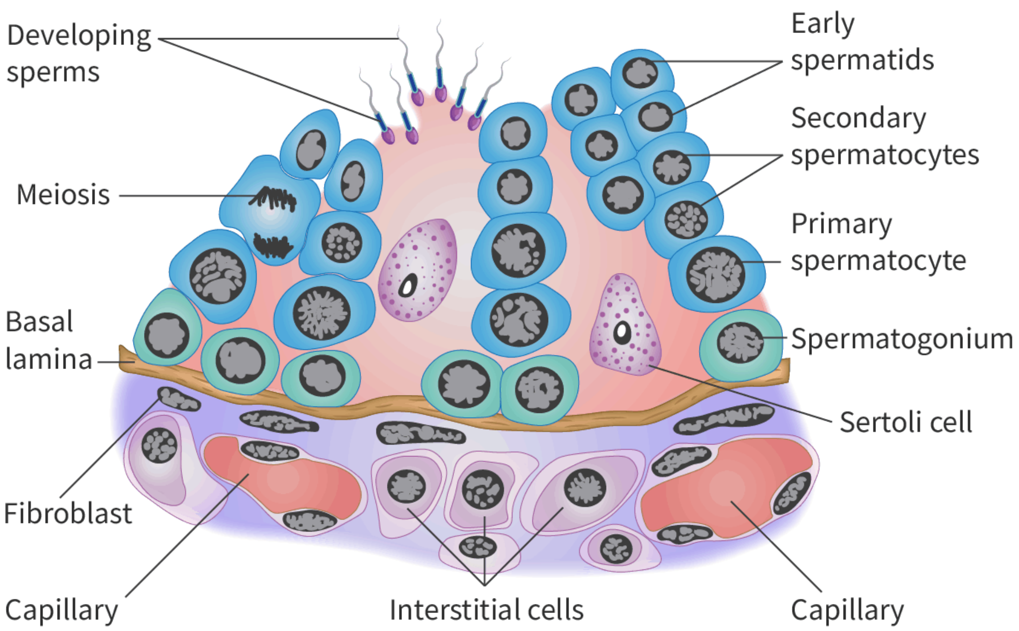

Figure 4. (a) Stages of spermatogenesis, (b) Stages of spermatogenesis in the wall of the seminiferous tubule.

More information for figure 4

This diagram illustrates the stages of spermatogenesis within the wall of the seminiferous tubule. It shows the progression from spermatogonium at the base, through primary and secondary spermatocytes, to early spermatids. Key components are labeled, including: 'Developing sperms', 'Early spermatids', 'Secondary spermatocytes', 'Primary spermatocyte', 'Spermatogonium', 'Sertoli cell', 'Interstitial cells', 'Capillary', 'Fibroblast', and 'Basal lamina'. The progression is indicated by the arrangement from lower to upper levels, depicting the development stages of sperm cells in the tubule. The diagram details the structure and cellular components involved in this biological process, including meiosis stages and supportive cells.

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Oogenesis

Unlike in males, the process of oogenesis begins during foetal development. Oogenesis begins with diploid oogonia (**Figure 5**). The oogonia undergo mitosis. Some of the oogonia develop to form primary oocytes. The diploid primary oocyte begins meiosis I; however, this is arrested at prophase 1. At the time of birth, each ovary has numerous follicles each containing primary oocytes. Many of these follicles degenerate from birth to puberty.

- After the onset of puberty

  The onset of puberty marks the beginning of the menstrual cycle. Under the influence of the hormones, many of the follicles start growing; however, only one matures. The primary oocyte now completes the first meiotic division resulting in formation of two haploid cells. Due to unequal division of the cytoplasm, these cells differ in size and are termed as the secondary oocyte (n) and the first polar body (n). The first polar body disintegrates. The secondary oocyte begins meiosis II but this is arrested at metaphase II. At the time of ovulation, the secondary oocyte is released from the ovary.

- On fertilisation

  If fertilisation occurs, the secondary oocyte (n) completes meiosis II forming the ovum (n) and the second polar body (n). If fertilisation does not occur, the secondary oocyte is discharged from the body during the menstrual flow.

It is to be noted that each primary oocyte gives rise to one ovum. **Video 2** sums up the process.

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Video 2. Oogenesis.

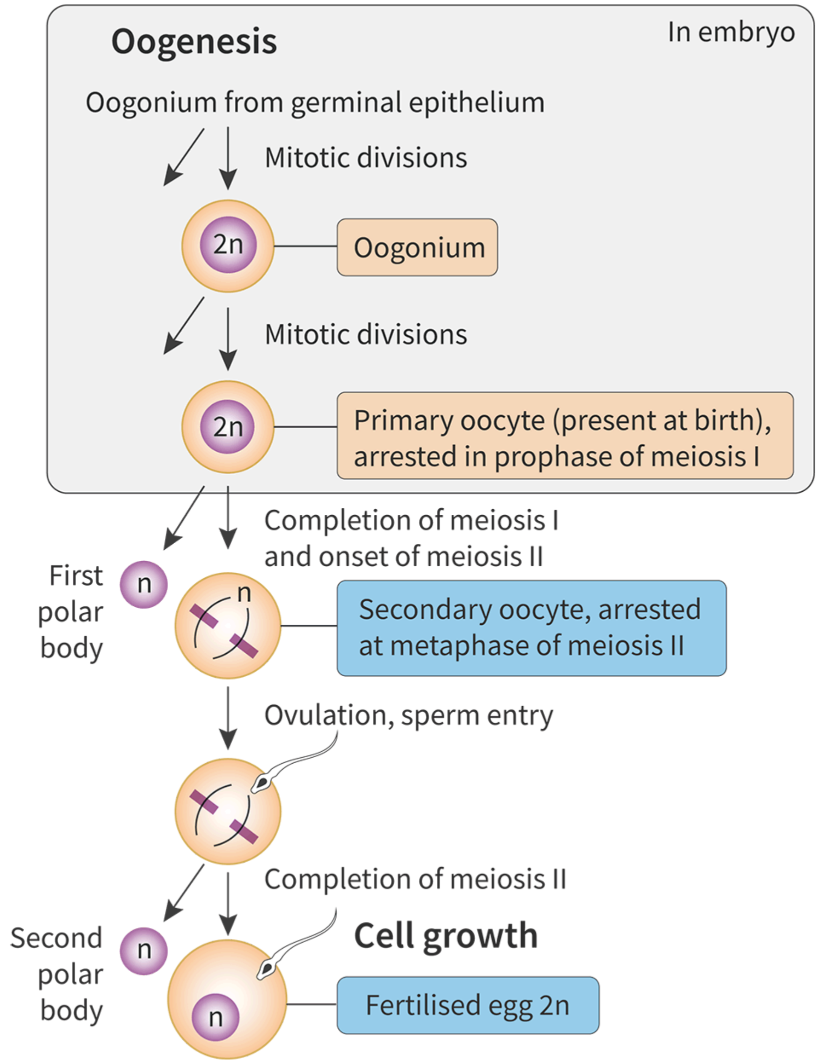

Figure 5. Stages of oogenesis.

More information for figure 5

The diagram illustrates the stages of oogenesis, highlighting the process starting from the oogonium, which undergoes mitotic divisions. It begins with the oogonium from germinal epithelium labeled as "2n Oogonium" in the diagram. Following further mitotic divisions, it progresses to a "Primary oocyte (present at birth), arrested in prophase of meiosis I," also labeled as "2n." The next stage depicted is the development of a secondary oocyte, arrested at metaphase of meiosis II, labeled as "n n Secondary oocyte." The final part of the diagram shows a fertilized egg labeled "Fertilized egg 2n," signifying the outcome post-fertilization. Arrows within the diagram indicate the sequence of progress from one stage to the next, beginning from the embryo.

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Student view

Try the activity to review your learning on spermatogenesis and oogenesis.

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Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 30 minutes
- **Activity type:** Pair activity

Materials

Modelling clay

Instructions

Read about the process of gametogenesis covered in this section.

In pairs, discuss and recall key concepts. You can use the draft table in **Table 1** to note these concepts.

Table 1. Key concepts.

	Spermatogenesis
Onset	
Begins with (describe the cells in terms of size and chromosome number)	
Cells seen at the end of meiosis I (describe the cells in terms of size and chromosome number)	
Cells seen at the end of meiosis II (describe the cells in terms of size and chromosome number)	

Divide the task: using the modelling clay, one of you will make a model of spermatogenesis and one will make a model of oogenesis.

Begin by making the oogonium (2n)/spermatogonium (2n).

Make sure that your models accurately represent the stages as well as the chromosome number in each stage.

Explain your model to your partner and listen to their explanation of their model.

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Use your model to discuss the differences between spermatogenesis and oogenesis.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Post-fertilisation events and embryonic development (HL)

D3.1.15: Mechanisms to prevent polyspermy (HL) D3.1.16: Development of a blastocyst and implantation (HL)

D3.1.17: Pregnancy testing (HL)

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/post-fertilisation-events-and-embryonic-development-hl-id-46230/print/) Assign

Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Identify the mechanisms that prevent polyspermy.
- Outline the development of the blastocyst and subsequent implantation in the endometrium.
- State the role of hCG in pregnancy and pregnancy testing.

Look at the cartoon in **Figure 1**. How does the egg safeguard itself from the many sperm that approach it?

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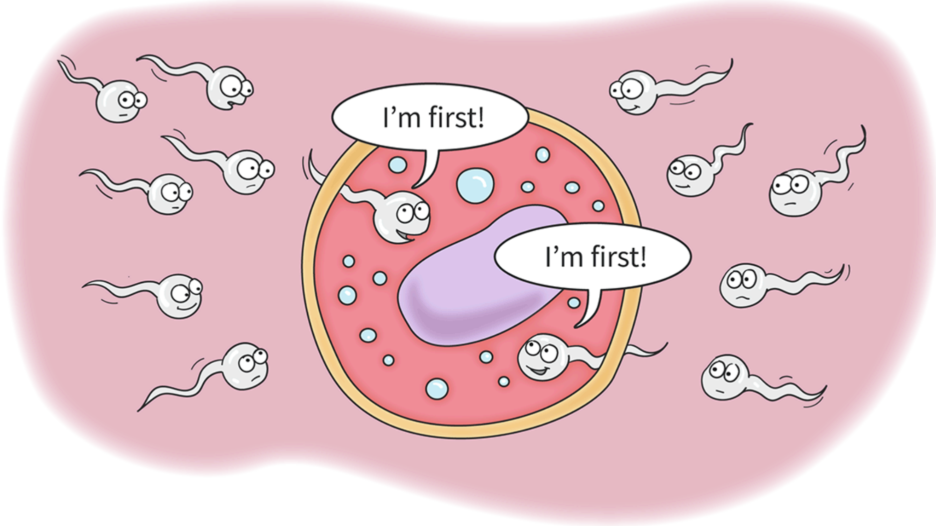

Figure 1. Too many sperm.

Mechanisms to prevent polyspermy

Millions of sperm enter the female reproductive system. The sperm that eventually manage to reach the vicinity of the egg have to traverse through the jelly-like zona pellucida. They begin the journey by binding to specific binding sites on the zona pellucida. Then the hydrolytic enzymes released by the acrosome digest and soften the layer, helping the sperm to push their way through. This is known as the acrosome reaction.

Polyspermy is the fusion of more than one sperm with the egg, resulting in a non-viable zygote. The egg needs to be safeguarded against polyspermy. Soon after fertilisation, the following changes are seen.

- The plasma membrane of the fertilised egg becomes impermeable to the entry of sperm due to changes in the membrane potential (see section B2.1.14—16 (/study/app/bio/sid-422-cid-755105/book/more-about-transport-mechanisms-hl-id-44647/)).
- The cortical granules fuse with the plasma membrane and release their contents into the space between the plasma membrane and the zona pellucida by exocytosis. This is known as the cortical reaction and has a two-fold effect. The enzymes of the cortical granules destroy the sperm receptors on the zona pellucida preventing the binding of other sperm. In addition, the zona pellucida hardens, stopping the sperm from moving towards the egg.

To summarise, the acrosome reaction permits the movement of sperm through the zona pellucida while the cortical reaction opposes the movement of sperm. Watch **Video 1**, which summarises this process.

Student view

Video 1. Post-fertilisation events (part 1).

Implantation of the blastocyst

All of us began life in a similar way – as a single fertilised egg. How did this one cell develop into the trillions of cells that make our body?

Fertilisation results in the formation of a single-celled diploid zygote. Soon after fertilisation, the single-celled diploid zygote starts dividing mitotically. This rapid cell division is known as cleavage. The zygote quickly transitions from a two-cell stage to a four-cell stage to an eight-cell stage and so on. The 16-cell stage is known as the morula and is the same size as the zygote. The zona pellucida still surrounds the morula. It should be noted that rapid cell division prevents growth, hence the size of the zygote and the 16-cell stage remain the same.

Around Day 4, the dividing cells rearrange themselves to form two layers: an outer trophoblast and the inner cell mass. A fluid-filled cavity develops in the centre called the blastocoel. At this point the embryo is known as a blastocyst. It would help you to remember that while the morula is a solid ball of 16 cells, the blastocyst is a hollow ball of 32 cells (**Figure 2**).

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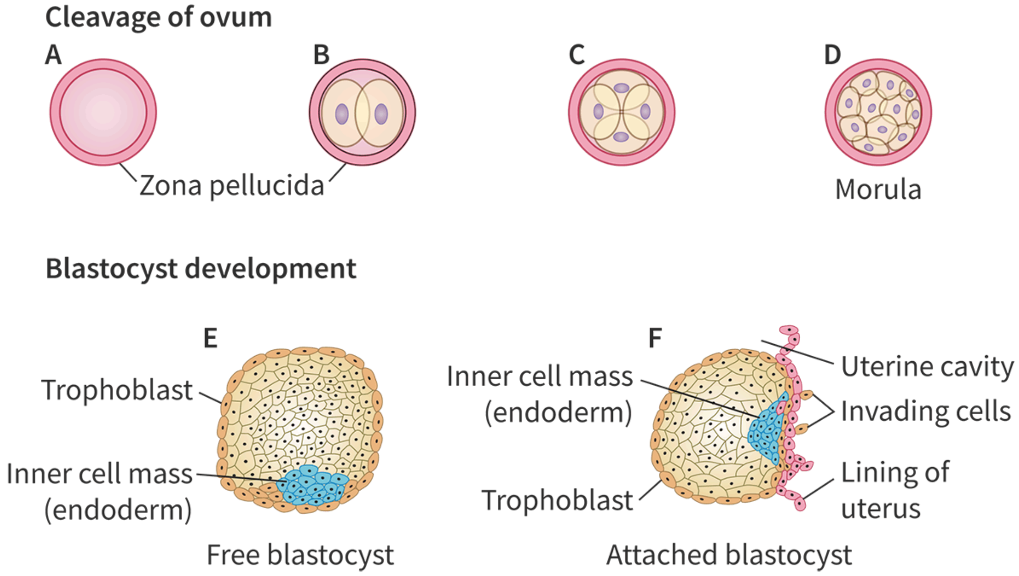

Figure 2. Fertilised egg to blastocyst.

More information for figure 2

The diagram shows the development stages from a fertilized egg to a blastocyst. It starts with a single fertilized egg, then progresses through several stages of cellular division. Initially, there is a 2-cell stage, followed by a 4-cell stage, then an 8-cell stage, and finally a morula stage. The morula is shown as a solid ball of cells. Finally, the blastocyst stage is depicted, characterized by a hollow cavity with an inner cell mass and an outer trophoblast layer. Arrows indicate the progression from one stage to the next, highlighting the transition and development at each step.

[Generated by AI]

The trophoblast will eventually differentiate into structures that would help in the attachment or implantation of the embryo to the endometrium of the uterus. Most of the inner cell mass will eventually differentiate into the structures of the embryo.

The blastocyst now sheds the zona pellucida in a process called hatching. By the seventh or eighth day after fertilisation, the blastocyst adheres itself to the uterine endometrium with the help of the trophoblast cells, resulting in implantation. **Video 2** shows the changes that happen in the zygote.

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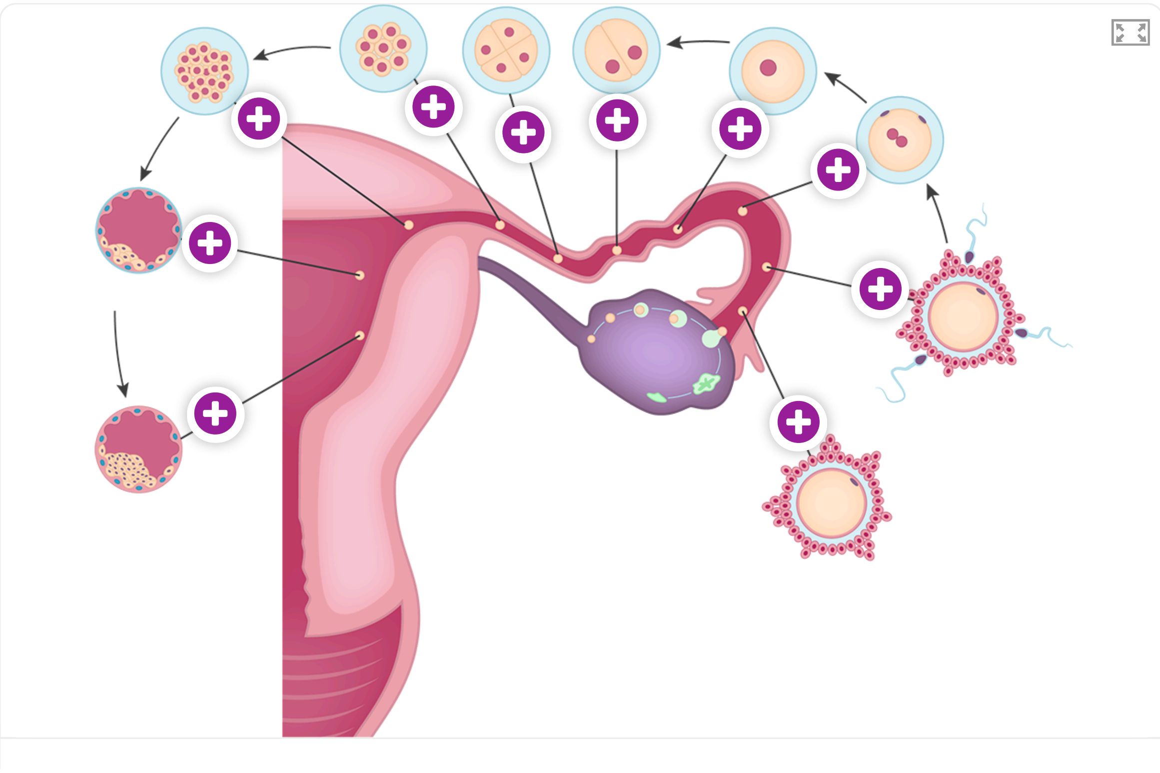
Human Physiology - Fertilization and Implantation

Video 2. Post-fertilisation events (part 2).

If the blastocyst is unable to attach itself to the uterine wall, it is shed along with endometrium during the menstrual flow.

An overview of the stages from fertilisation to implantation is given in **Interactive 1.**



Interactive 1. Fertilisation to Implantation.

More information for interactive 1

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The interactive diagram of fertilisation to implantation illustrates the key stages from fertilisation to embryo implantation in human reproduction. It contains a series of hotspots that label each step.
In the fallopian tube, the hotspot over the first image reads Ovum, which is an unfertilised egg. The hotspot over the second image reads Fertilisation and shows sperm penetrating the egg's zona pellucida. The hotspot over the third image reads Fusion of egg and sperm pronuclei and shows the egg and sperm nuclei merging to form a diploid zygote. The hotspot over the fourth image reads Zygote. The next image reads 2-celled cleavage and shows that the cell divides mitotically into 2-cells, then 4 cells, 8-cells and so forth. The hotspot over the next images read 4-celled cleavage and 8-celled cleavage. The hotspot over the next image reads Morula, which contains $16 - 32$ cells. The hotspot on the next image reads Blastocyst, which is formed when a morula hollows out. The hotspot over the last image reads Implanted blastocyst which attaches to the uterine lining or endometrium.

Role of hCG in pregnancy

As you may recall, in the menstrual cycle, in the absence of fertilisation, the endometrial lining is shed due to the breakdown of the corpus luteum and the sudden decrease in the progesterone levels. For a successful pregnancy, it is imperative that the endometrial lining be maintained. This is done by the continued production of oestradiol and progesterone in the early days of pregnancy.

Soon after implantation, the cells of the trophoblast (that will eventually form the placenta), start secreting a hormone called human chorionic gonadotropin (hCG). This hormone maintains the corpus luteum so that it continues to secrete progesterone. By the third month, the placenta takes over the role of the corpus luteum and starts secreting progesterone and oestradiol needed for maintaining the pregnancy.

Pregnancy testing

Pregnancy test kits are designed to detect the presence of hCG in a woman's urine. The test kit consists of a pregnancy test stick coated with monoclonal antibodies specific to hCG (**Figure 3**). When a woman urinates onto the pregnancy stick, hCG – if present in her urine – binds to the monoclonal antibodies on the stick. This results in a change in the colour indicating a positive pregnancy. A few days after implantation, the embryo secretes enough hCG to give a positive pregnancy test.

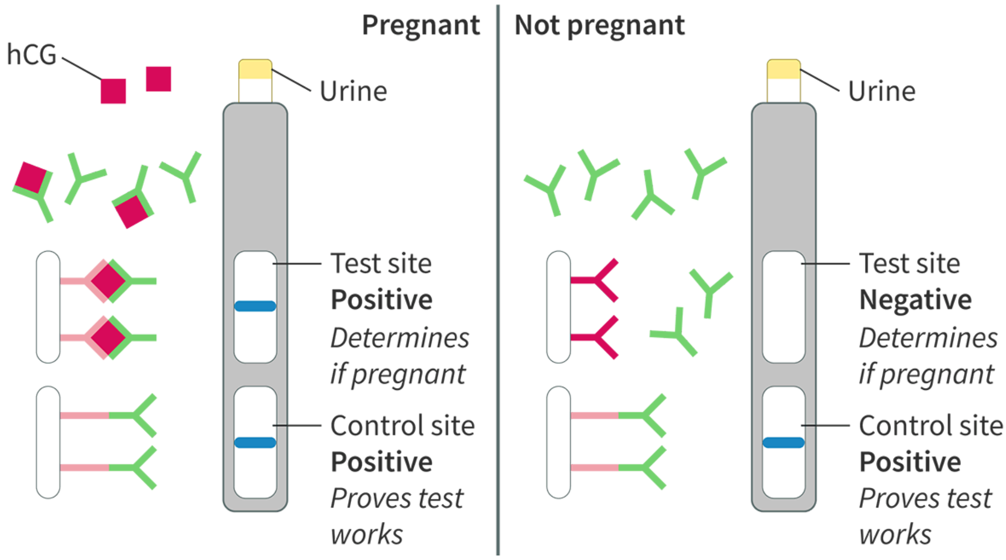

Figure 3. Monoclonal antibodies in determining pregnancy.

More information for figure 3

The diagram illustrates how monoclonal antibodies are used in pregnancy test sticks to detect hCG hormone levels in urine. The image consists of a detailed cross-section view of two pregnancy test sticks, one on the left and one on the right, each having distinct sections and labels.

On the left side, labeled components illustrate the presence of hCG and the consequent activation of the test. The steps are outlined with arrows and various colored sections. Text labels indicate interactions between hCG and antibodies, resulting in a change in color to signify a positive result.

On the right side, the absence of hCG is demonstrated, showing no color change in the test stick. There is a clear distinction between the two sides of the diagram, emphasizing the role of hCG in altering the result of the test.

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Aspect: Experiments

Antibodies are molecules produced by the body to defend themselves. Monoclonal antibodies (mAbs) are laboratory produced antibodies that have multiple uses. The technique involves the production of clones of one type of antibodies in large quantities by genetic engineering. mAbs are used in the treatment of cancer and immunological diseases, to type blood and tissues and as research probes. They are also used to detect pregnancy, ovulation and menopause. They form a major class of

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therapeutic agents and are an area of increasing scientific interest. Key discoveries in the mid-1970s laid the groundwork of this field; however, research is still ongoing and newer, better versions are in the pipeline.

Try the activity to summarise your learning on fertilisation.

Activity

- **IB learner profile attribute:** Reflective
- **Approaches to learning:** Self-management skills — Breaking down major tasks into a sequence of stages
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

Compare the journey of an unfertilised egg and a fertilised egg through the human female reproductive system by drawing diagrams. Annotate as required.

Use one half of your diagram of the female reproductive system to show the journey of the fertilised egg and the other half to show the journey of an unfertilised egg.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Placenta and hormonal control of pregnancy; HRT (HL)

D3.1.18: Role of the placenta in foetal development (HL) D3.1.19: Hormonal control of pregnancy and childbirth (HL)

D3.1.20: Hormone replacement therapy and coronary heart disease risk (HL)

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Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Describe the role of the placenta during foetal development.
- Discuss the role of hormones in maintaining pregnancy and initiating childbirth.
- Correlate between HRT and risk of coronary heart disease.

If you look at the different groups of mammals, you will note that placental mammals have longer pregnancies. For example, a normal human pregnancy lasts for 40 weeks while that of a horse lasts 11–12 months and that of an elephant lasts 22 months. Moreover, apart from humans, within hours of birth the offspring are on their feet and ready to face the world. On the other hand, in the case of marsupials like kangaroos and wombats, the pregnancy lasts for just 21–33 days. The babies born are immature and must make their way into the mother's pouch to survive (**Figure 1**). Why are these such differences between pregnancies in these groups of mammals?

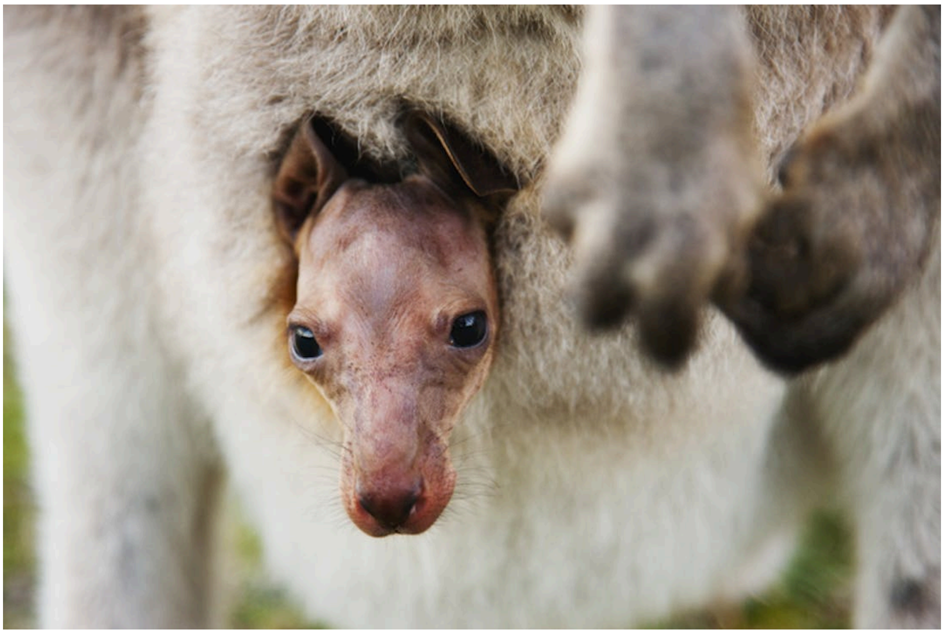

Figure 1. A new-born joey is the size of a jellybean — it grows and develops inside the mother's pouch.

Credit: Jami Tarris, Getty Images

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Role of the placenta

Once the blastocyst is implanted, the extraembryonic membrane starts forming. One of the extraembryonic membranes forms the umbilical cord – a rope-like structure connecting the embryo to the wall of the uterus. Yet another is the chorion. By the 14th day, the chorionic villi (finger-like projections of the chorion) start forming. These represent the beginning of the placenta.

The placenta is a spongy tissue composed of both maternal tissue and embryonic tissue that begins to form by the fourth week of pregnancy. All the exchanges between the mother and embryo take place through the placenta.

It would help you to refer to **Figure 2** while reading this section of the text. The maternal portion of the placenta is the uterine endometrium. The embryonic portion of the placenta is the chorionic villi or the finger-like projections of the chorion. These villi extend into the intervillous space and increase the surface area. Maternal blood from the open endometrial arteries pools in the intervillous spaces (and of course, returns by the endometrial veins). Thus the chorionic villi are bathed in maternal blood. It is important to remember that while the chorionic villi are surrounded by maternal blood, the maternal and foetal circulatory systems are not connected.

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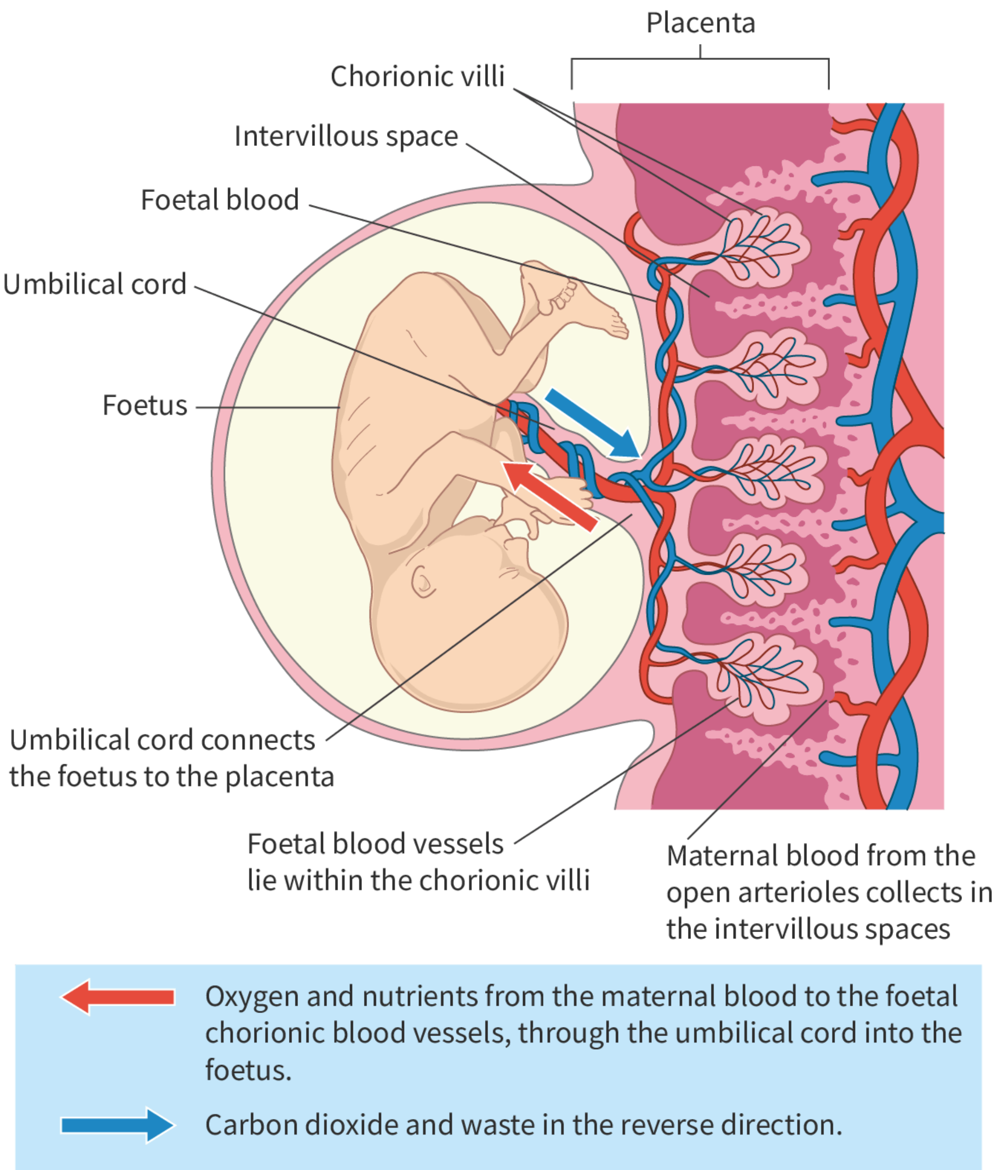

Figure 2. Interaction between the foetus and placenta.

More information for figure 2

The diagram illustrates the interaction between a fetus and placenta. The fetus is shown inside a circular area, connected to the placenta via the umbilical cord. Labels identify the chorionic villi, intervillous space, maternal blood, and fetal blood vessels. The umbilical cord connects the fetus to the placenta, where the fetal blood vessels are situated within the chorionic villi. Maternal blood from open arteries collects in the intervillous space, bathing the chorionic villi. Oxygen and nutrients from the maternal blood diffuse into fetal blood in the chorionic villi and are carried through the umbilical cord to the fetus. Carbon dioxide and waste move in the opposite direction, from the fetal blood vessels back to the maternal blood. Arrows on the diagram indicate the direction of nutrient and waste exchange.

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Student view

The maternal blood is rich in oxygen and nutrients. These diffuse from the maternal blood that collects in the intervillous spaces to the foetal blood vessels in the

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chorionic villi of the placenta. The oxygen and nutrients then travel down the umbilical cord, via the umbilical vein, entering the foetal circulation. Waste and carbon dioxide produced by the developing embryo travel from the umbilical blood vessels (umbilical arteries) to the placenta. Here they diffuse into the maternal blood present in the intervillous space of the placenta. These waste products are then removed by the mother.

Apart from its role in exchange of material between the mother and the foetus, the placenta acts as an endocrine gland secreting progesterone and oestradiol to maintain the pregnancy.

Coming back to the question at the start of this section – in placental mammals, the growing foetus is nourished by the placenta. This, in turn, permits a longer pregnancy ensuring that the offspring completes most of its development within the uterus. On the other hand, marsupials do not have a placenta and hence the offspring is born immature.

Note: The term embryo is used until about 11 weeks of pregnancy; thereafter the term foetus is used.

Hormonal control of pregnancy and childbirth

A typical pregnancy lasts for 40 weeks. Parturition or childbirth is the process by which the foetus is expelled from the body.

You may recall that the pregnancy is maintained by progesterone that is initially secreted by the corpus luteum and later by the placenta. The progesterone prevents uterine contractions. However, by the seventh month of pregnancy, in anticipation of the eventual expulsion of the baby, the levels of progesterone plateau and then start declining (**Figure 3**).

Simultaneously, the growth of the baby causes the walls of the uterus to stretch. The stretch is detected by receptors present on the uterine wall. The stretching of the uterus exerts a physical stress on both the baby and the mother, causing the secretion of stress hormones like cortisol. The rise in the levels of stress hormones stimulates the release of an oestrogen called oestriol. Oestriol inhibits the production of progesterone by the placenta. It also makes the smooth muscles of the uterus more receptive to oxytocin.

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Now that the stage has been set, oxytocin is released by the posterior pituitary. Oxytocin causes uterine contraction initiating parturition. The foetus responds by secreting prostaglandins, which, in turn, intensifies the uterine contraction. This causes the posterior pituitary to release more oxytocin. Thus a positive feedback loop eventually leads to the expulsion of the baby down the birth canal and out of the body and pushing out of the placenta.

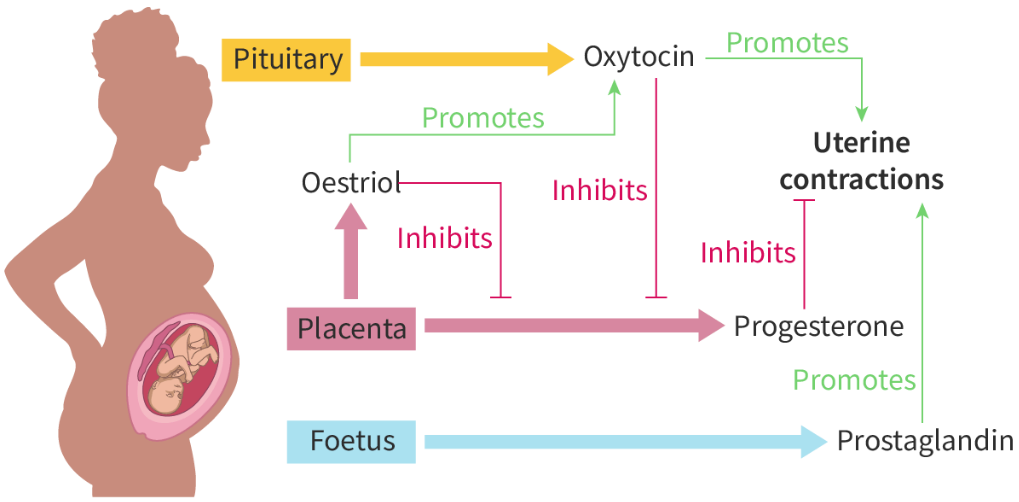

Figure 3. Hormonal control of childbirth.

More information for figure 3

The diagram illustrates the hormonal control of childbirth, depicting the interactions of various hormones and parts of the body. A side view of a pregnant woman is shown, emphasizing the fetus in the womb.

To the right, a series of arrows and labels detail the hormonal interactions:

1. The pituitary gland releases oxytocin, depicted by a yellow arrow.
2. Oxytocin promotes uterine contractions, indicated by a vertical green arrow.
3. Uterine contractions further encourage the secretion of oxytocin, suggesting a positive feedback loop.
4. The placenta impacts hormone levels:
5. It secretes oestriol, which inhibits progesterone.
6. Progesterone inhibits uterine contractions but is counteracted by oestriol.
7. The placenta also influences the secretion of prostaglandin.
8. The fetus produces prostaglandins, directed towards promoting uterine contractions.

Words like "promotes" and "inhibits" are used to denote the effects of each hormonal interaction. The diagram highlights a complex feedback system essential for parturition.

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Video 1. In utero development.

Hormone replacement therapy

The onset of menopause is marked by a decrease in the levels of oestradiol and progesterone. This results in a range of physical symptoms like hot flashes and vaginal dryness. Hormone replacement therapy or HRT is a treatment that relieves the symptoms of menopause. In HRT, the person undergoing treatment is given medication that contains low doses of oestradiol or a combination of oestradiol-progestin (progestin is a synthetic derivative of progesterone). Current research is still ambiguous on the benefits of HRT.

Nature of Science

Aspect: Evidence

Coronary heart disease occurs when the blood supply to the heart is blocked due to a buildup of fatty substances in the coronary arteries. It is believed to be the leading cause of death in postmenopausal women. Early studies suggested that postmenopausal women on HRT had a reduced risk of CHD. The many effects of oestradiol seemed to indicate a cardioprotective role and hence, theoretically, HRT should have decreased the risk of CHD in postmenopausal women (as it maintained premenopausal levels of oestradiol). However, a different picture is emerging from recent clinical trials. Reports from the Women's Health Initiative (WHI) seem to suggest that HRT has no role in the prevention of CHD. This indicates that there is no cause-and-effect relationship

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between HRT and CHD. You can read more about this here (https://onlinelibrary.wiley.com/doi/10.1002/clc.22891) and here (https://www.amjmedsci.org/article/S0002-9629(15)34385-8/fulltext).

Try the activity to summarise your understanding of hormonal control of the female reproductive system.

Activity

- **IB learner profile attribute:** Reflective
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 15—20 minutes
- **Activity type:** Individual/pair activity

Over the course of this subtopic, you have read about the hormonal control of the female reproductive system. Reflect on your learning to create a mind-map on this topic. Make sure that you include the various hormones that come into play at various times like menstruation, pregnancy and childbirth. Link hormones using +/- symbols to indicate positive/negative feedback.

You can use either pen and paper or an online tool like Mindmeister (https://www.mindmeister.com). You can do this individually or in pairs.

5 section questions

D3. Continuity and change: Organisms / D3.1 Reproduction

Summary and key terms

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- Sexual reproduction results in genetic variation needed for adaptation to a new environment. The variation arises during gamete formation by meiosis and fertilisation.

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- The male gamete or sperm is smaller, motile and produced in large numbers unlike the female gamete or egg which is larger, non-motile and produced in smaller numbers.
- The menstrual cycle is the cycle of monthly changes in the ovary and the uterus to prepare for a possible pregnancy. It is governed by ovarian hormones like oestradiol and progesterone and pituitary hormones like LH and FSH.
- Fertilisation occurs in the fallopian tube and restores the diploid status of the organism.
- In flowering plants, the male gametes are enclosed within the pollen grains and the female gamete within the ovule. Fertilisation is preceded by pollination, which could be self-pollination or cross-pollination. Nature favours cross-pollination as it builds genetic diversity. Fertilisation is followed by seed dispersal and germination.

Higher level (HL)

- Developmental changes of puberty are controlled by a feedback mechanism. The GnRH released by the hypothalamus stimulates the anterior pituitary to release FSH and LH. These hormones, in turn, stimulate the release of sex hormones from the gonads, resulting in the changes associated with puberty. Oogenesis and spermatogenesis result in the production of eggs and sperm.
- The acrosome reaction helps the sperm to penetrate the zona pellucida while the cortical reaction prevents polyspermy.
- The fertilised egg undergoes rapid cleavage as it moves down the fallopian tube. The cells reorganise to form the blastocyst that implants on the uterine wall. The placenta is a composite tissue through which the exchange of material between the mother and child occurs.
- The pregnancy is maintained by progesterone. In the initial days of the pregnancy, progesterone is secreted by the corpus luteum and later by the placenta. A decrease in progesterone levels triggers changes associated with childbirth and stimulates release of oxytocin which causes uterine contractions.
- hCG secreted by the embryo can be detected in the mother’s urine using monoclonal antibodies that bind to hCG.

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Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. The follicular phase sees the growth of the ovarian follicles under the influence of ______ secreted by the anterior pituitary. ______ secreted by the follicles leads to thickening of the endometrium.
2. The release of the egg or ______ is associated with a surge of ______. After ovulation the ruptured follicle is converted to the ______, which produces ______ leading to a further thickening of the uterine wall.
3. The plasma membrane of the egg is surrounded by a jelly-like ______ and a layer of follicular cells called ______.
4. During IVF, fertility drugs result in ______. The eggs are then harvested and fertilised in the lab using donor sperm.
5. In flowers, the female reproductive structures consist of the ______ (where pollen grains land and germinate), the ______ (which forms the pistil), and the ______ (which matures into a fruit).
6. The transfer of pollen grains from the anther to the stigma of two flowers on the same plant is ______. When the pollen tube fails to grow despite pollen landing on the stigma of the same species, this could be due to ______ mechanisms. Male and female flowers are borne on different plants in papaya and this is a strategy that promotes ______.

zona pellucida | LH | progesterone | self-incompatibility | corona radiata | style | superovulation | self-pollination | ovulation | ovary | FSH | cross-pollination | corpus luteum | Oestradiol | stigma

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Interactive 1. Human and Plant Reproduction Key Terms.

Higher level (HL)

Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. Increased levels of testosterone in the blood inhibit the secretion of ______ from the hypothalamus. This is an example of a ______ feedback mechanism. On the other hand, the release of oxytocin at the time of childbirth operates on a ______ feedback mechanism.
2. At the end of spermatogenesis four ______ are formed from a single diploid ______. During oogenesis the ______ is released at the time of ovulation. If fertilisation occurs, the cell completes meiosis to form the ______ and the second polar body.
3. The ______ allows the sperm to travel through the zona pellucida while the ______ prevents sperm from passing through.
4. The ______ are finger-like projections that extend into the ______ of the mother and are bathed in maternal blood.

negative | spermatids | positive | ovum | cortical reaction | primary spermatocyte | endometrium | acrosome reaction | chorionic villi | GnRH | secondary oocyte

Check

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Interactive 2. Human Fertility and Development Key Terms.

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D3. Continuity and change: Organisms / D3.1 Reproduction

Checklist

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/checklist-id-46514/print/) Assign

What you should know

After studying this subtopic you should be able to:

- Differentiate between sexual and asexual reproduction.
- Describe the role of meiosis in creating variation in sexually reproducing organisms.
- Compare the differences between the male and female sexes.
- Draw diagrams of the male (typical) and female (typical) reproductive systems.
- Annotate the names of the parts and their functions on the diagrams.
- Describe the hormonal regulation of the menstrual cycle.
- Elucidate the sequence of events leading to fertilisation.
- Explain the role of hormones in IVF.
- Describe the mechanism of sexual reproduction in plants.
- Explain the features of insect-pollinated flowers.
- Draw annotated diagrams of insect pollinated flowers.
- Describe strategies that facilitate cross-pollination in plants.
- Determine the role of self-incompatibility mechanisms in increasing genetic variation in a plant species.
- Explain the mechanism of seed dispersal and germination.

Higher level (HL)

- Outline the role of GnRH, LH, FSH and the sex hormones in the changes associated with puberty.
- Describe oogenesis and spermatogenesis in humans.
- Identify the mechanisms that prevent polyspermy.
- Outline the development of the blastocyst and subsequent implantation in the endometrium.
- State the role of hCG in pregnancy and pregnancy testing.

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- Describe the role of the placenta during foetal development.
- Discuss the role of hormones in maintaining pregnancy and initiating childbirth.
- Correlate between HRT and risk of coronary heart disease.

Investigation

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/investigation-id-46515/print/) Assign

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills – Comparing, contrasting and validating information
- **Tool 1:** Experimental techniques – Applying techniques
- **Inquiry 2:**
    - Collecting data – Identify and record relevant qualitative observations, Collect and record sufficient relevant quantitative data
    - Interpreting results – Identify, describe and explain patterns, trends and relationships
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity

Your task

Your task is to investigate the features seen in insect-pollinated flowers.

Materials

Different types of flowers that are available locally, water, a hand lens (optional) and a needle.

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Instructions

1. Examine your flower. Begin by identifying the sepals and the petals. Note down their numbers, colour and arrangement.
2. Remove the sepals and petals by gently pulling them off the stem. At this point you could trace the outline of the sepal/petal and measure their size.
3. Locate the stamens. These are easily identifiable due to the presence of the pollen-filled anthers. Note the number of stamens.
4. Locate the pistil with the help of its stigma. (Remember that your flower could be unisexual or bisexual.)
5. Cut an anther. Place it on a slide and, with the help of the needle, pry it open. The yellow dots are the pollen grains. Observe the grains using the hand lens.
6. Slit the ovary lengthwise. Examine the ovary, use a hand lens if needed. The ovules are the small dot-like structures that are present inside each half of the ovary.
7. Make a data table noting down your observations.

Analyse and conclude

1. Make a list of the adaptations generally seen in insect-pollinated flowers (see section D3.1.8–9 (/study/app/bio/sid-422-cid-755105/book/sexual-reproduction-in-flowering-plants-id-45746/)). Which of these adaptations are seen in the flowers that you examined? What are the exceptions/variations you see? Is there any recurring pattern?
2. Estimate the number of ovules and the number of pollen grains of each flower. Is there a pattern you notice when you compare the numbers of ovules with the number of pollen grains? Explain your answer.

D3. Continuity and change: Organisms / D3.1 Reproduction

Reflection

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/reflection-id-46896/print/) Assign

Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

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Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Reflection

Now that you've completed this subtopic, let's come back to the guiding question introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43252/).

- How does asexual or sexual reproduction exemplify themes of change or continuity?
- What changes within organisms are required for reproduction?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

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Submit

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