Exam Papers Practice

Boost your performance and confidence with these topic-based exam questions

Practice questions created by actual examiners and assessment experts

Detailed mark schemes

Suitable for all boards

Designed to test your ability and thoroughly prepare you

Reproduction

IB Biology - Revision Notes

www.exampaperspractice.co.uk

Sexual & Asexual Reproduction

Comparing Sexual & Asexual Reproduction

- **Sexual reproduction** involves **two parents** and is the fusion of the nuclei of two gameteto form a zygoteand the production of **offspring that are genetically different** from each other
  - A **gamete** is a sex cell (in animals: sperm and ovum; in plants: pollen nucleus and ovum)
    - Gametes differ from normal cells as they contain **half the number of chromosomes** found in other body cells - we say they have a **haploid nucleus**
    - This is because they only contain **one copy of each chromosome**, rather than the two copies found in other body cells
    - In human beings, a normal body cell contains **46 chromosomes** but each gamete contains **23 chromosomes**
  - When the male and female gametes fuse, they become a **zygote** (fertilised egg cell)
    - This contains the full **46 chromosomes**, half of which came from the father and half from the mother - we say the zygote has a **diploid nucleus**
- There are number advantages and disadvantages to an organism carrying out sexual reproduction

Advantages & disadvantages of sexual reproduction table

ADVANTAGES	DISADVANTAGES
INCREASES GENETIC VARIATION	TAKES TIME AND ENERGY TO FIND MATES
THE SPECIES CAN ADAPT TO NEW ENVIRONMENTS DUE TO VARIATION, GIVING THEM A SURVIVAL ADVANTAGE	DIFFICULT FOR ISOLATED MEMBERS OF THE SPECIES TO REPRODUCE
DISEASE IS LESS LIKELY TO AFFECT POPULATION (DUE TO VARIATION)	

- **Asexual reproduction**
  - Asexual reproduction does **not** involve **gametes** or **fertilisation**
    - **Only one parent is required** so there is no fusion of gametes and no mixing of genetic information
    - As a result, the offspring are **genetically identical to the parent and to each other** (they are clones)
  - Many **plants** reproduce via asexual reproduction

- **Bacteria** produce exact genetic copies of themselves in a type of asexual reproduction called **binary fission**
- There are a number of advantages and disadvantages to an organism carrying out asexual reproduction

Advantages & disadvantages of asexual reproduction table

ADVANTAGES	DISADVANTAGES
POPULATION CAN BE INCREASED RAPIDLY WHEN CONDITIONS ARE RIGHT	LIMITED GENETIC VARIATION IN POPULATION – OFFSPRING ARE GENETICALLY IDENTICAL TO THEIR PARENTS
CAN EXPLOIT SUITABLE ENVIRONMENTS QUICKLY	POPULATION IS VULNERABLE TO CHANGES IN CONDITIONS AND MAY ONLY BE SUITED FOR ONE HABITAT
MORE TIME AND ENERGY EFFICIENT	DISEASE IS LIKELY TO AFFECT THE WHOLE POPULATION AS THERE IS NO GENETIC VARIATION
REPRODUCTION IS COMPLETED MUCH FASTER THAN SEXUAL REPRODUCTION	

- The key differences between sexual and asexual reproduction include:
  - The **number of parent organisms**
  - **How** offspring are produced (the **type of cell division** required)
  - The **level of genetic similarity** between offspring
  - The possible **sources of genetic variation** in offspring
  - The **number of offspring** produced
  - The **time taken** to produce offspring

Sexual Reproduction

Meiosis & Fertilisation in Sexual Reproduction

- Meiosis is a form of nuclear division that results in the **production of** haploid **cells from** diploid **cells**
- It produces **gametes** in plants and animals that are used in **sexual reproduction**
- It takes place in two successive divisions: **meiosis I** and **meiosis II**
- More information about meiosis can be found here
- During meiosis, **specific mechanisms occur to lead to genetic variation** within the resulting gametes, this breaks up parental combinations of alleles derived from the mother and father chromosomes
  - **Crossing over** - the process by which non-sister chromatids exchange alleles during meiosis I
  - **Independent assortment** - the production of **different combinations of alleles** in daughter cells due to the **random alignment of** homologous **pairs of chromosomes** during meiosis I
  - **Random fertilisation** - there are millions of combinations of sperm and egg cells and the fusion of these sperm and egg cell
- Within each division there are four stages; prophase, metaphase, anaphase and telophase
- Meiosis occurs:
  - In the **testes** of male animals and the **ovaries** of female animals
  - In the **anthers** and **ovaries** of flowering plants
- Meiosis leads to the production of the following haploid gametes:
  - **Spermatozoa,** or **sperm cells,** in male animals, **ova** (singular ovum) in female animals
  - Male plant gametes are carried in **pollen** grains and female plants gametes are held in the **ovules** within the plant ovary
- The **fusion of gametes during fertilisation** produces **new combinations of alleles** leading to genetic variation

Male & Female Differences in Sexual Reproduction

- The process of meiosis in males and females is identical, however the resulting gametes are very different
- This leads to a number of difference in the reproductive strategies in males and females

Comparison of male & female gametes table

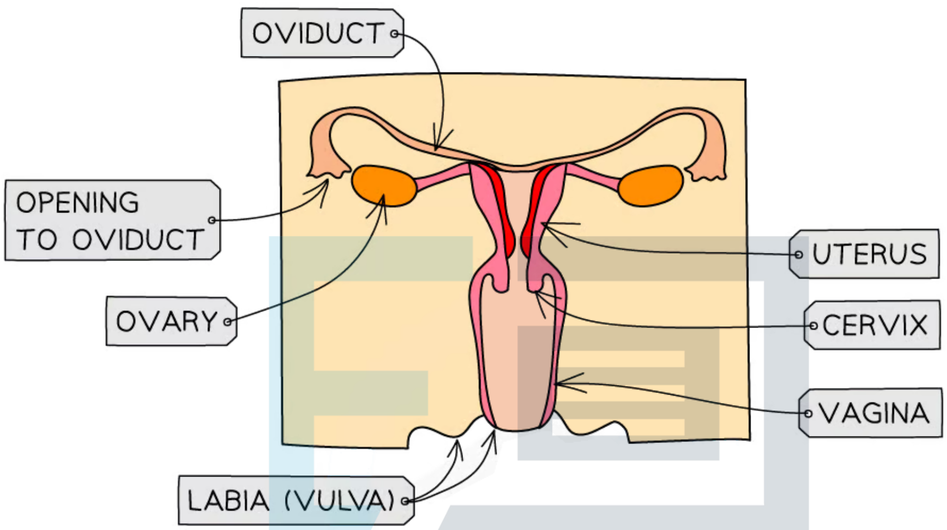
	SPERM	EGG
SIZE	VERY SMALL (45 μm)	LARGE (0.15 mm)
STRUCTURE	HEAD REGION AND FLAGELLUM, MANY STRUCTURAL ADAPTATIONS	ROUND CELL WITH FEW STRUCTURAL ADAPTATIONS, COVERED IN A JELLY COATING
MOTILITY	CAPABLE OF LOCOMOTION	NOT CAPABLE OF LOCOMOTION
NUMBERS	PRODUCED EVERY DAY IN HUGE NUMBERS (AROUND 100 MILLION PER DAY)	THOUSANDS OF IMMATURE EGGS IN EACH OVARY, BUT ONLY ONE RELEASED EACH MONTH

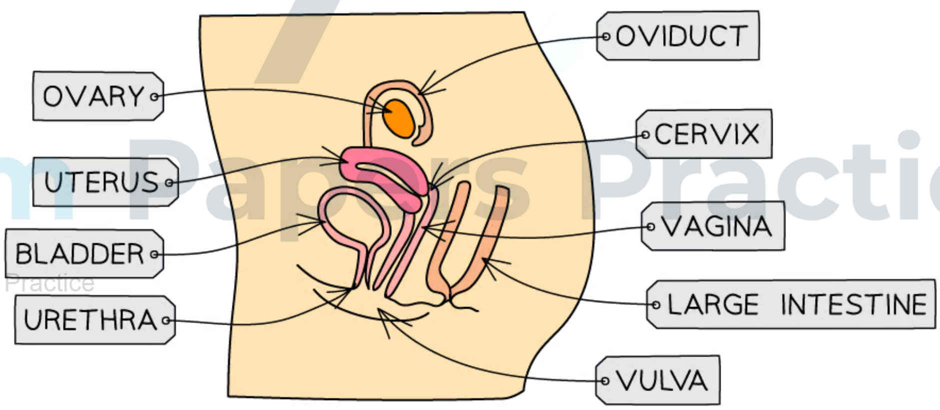
- The differences between male and female gametes, not just in humans, means that there are differences in the strategies developed for reproductive success
  - **Human females release only one egg cell** (per menstrual cycle) whereas a **male will release many thousands of sperm cells** per ejaculation, this is because the majority of which will not reach the egg cell (only one sperm cell can fertilise an egg cell)

Male & Female Reproductive Systems

- You should be able to **draw** and **annotate diagrams** of the female and male **reproductive systems** to identify the different **structures**
- You should also be able to recall the **function** of each of these structures

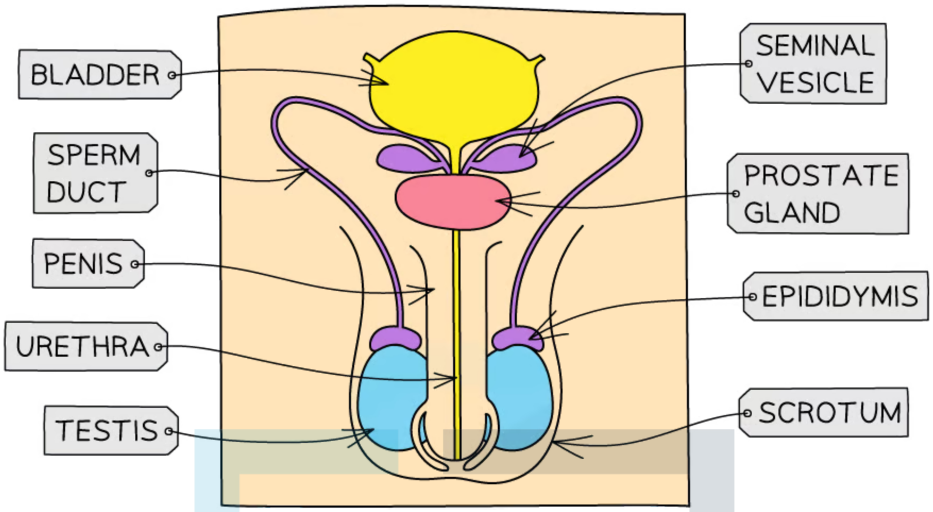
Female reproductive system diagrams

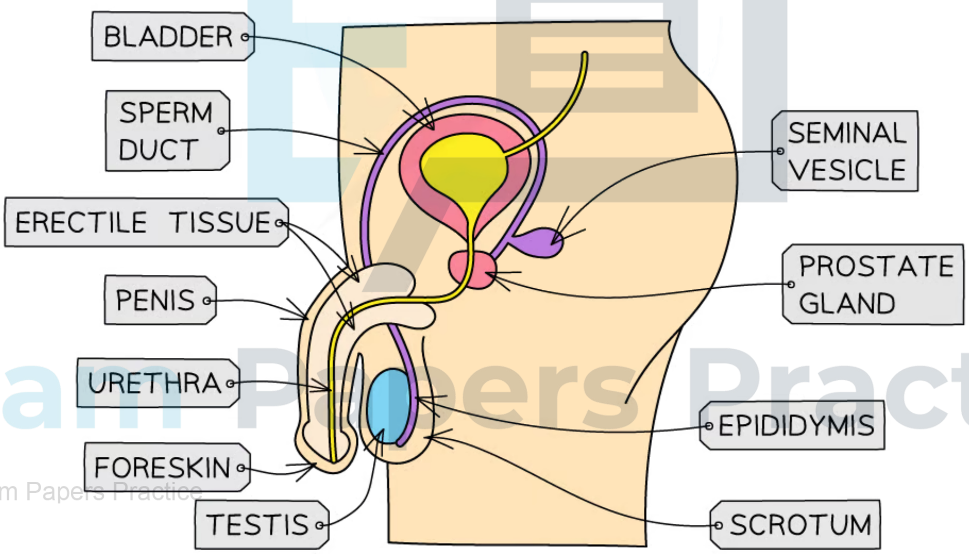




Front and side view of the female reproductive system

Female reproductive system table





Front and side view of the male reproductive system

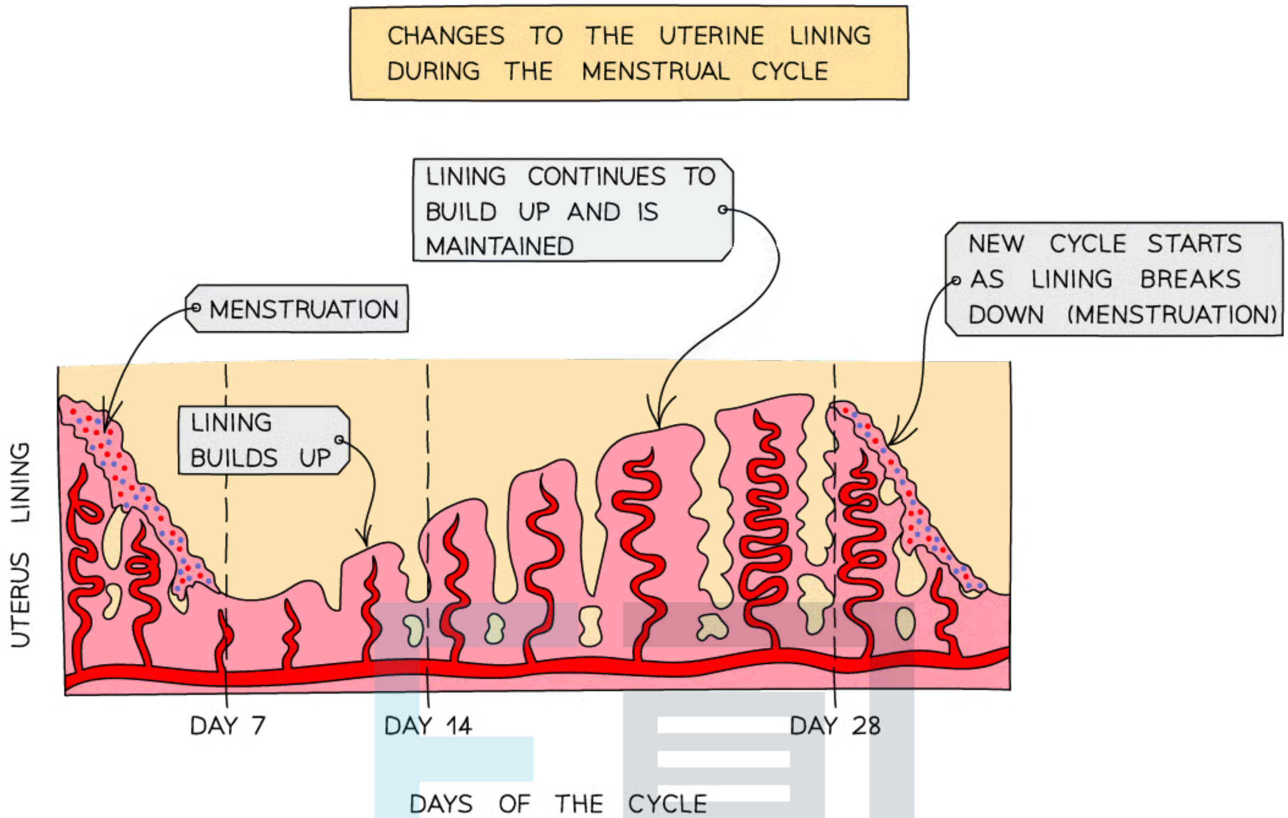
Male reproductive system table

The Menstrual Cycle

The Menstrual Cycle

- The **menstrual cycle** is the series of changes that take place in the female body leading up to and following the release of an egg from the ovaries
  - It starts in early adolescence in girls and is controlled by **hormones**
  - The average menstrual cycle is **28 days** long
- The **uterus lining**, or **endometrium**, thickens from **day 7** through to **day 28** of the cycle in preparation for receiving a fertilised egg
- The release of an egg, or **ovulation**, occurs about **half way** through the cycle on **day 14**, and the egg then travels down the oviduct to the uterus
  - Eggs develop inside fluid-filled sacs known as **egg follicles** inside the ovary
  - The follicle releases the egg at ovulation and becomes an empty follicle known as a **corpus luteum**
- Failure to fertilise the egg leads to **menstruation,** commonly known as a period
  - Menstruation involves the loss of menstrual blood via the vagina
  - This is caused by the **breakdown of the endometrium**
- Menstruation takes place roughly between **days 1–7** of the cycle
  - The number of days during which menstruation occurs can vary
- After menstruation finishes, the endometrium starts to **thicken again** in preparation for the **possible implantation** of a fertilised egg in the next cycle

The menstrual cycle diagram



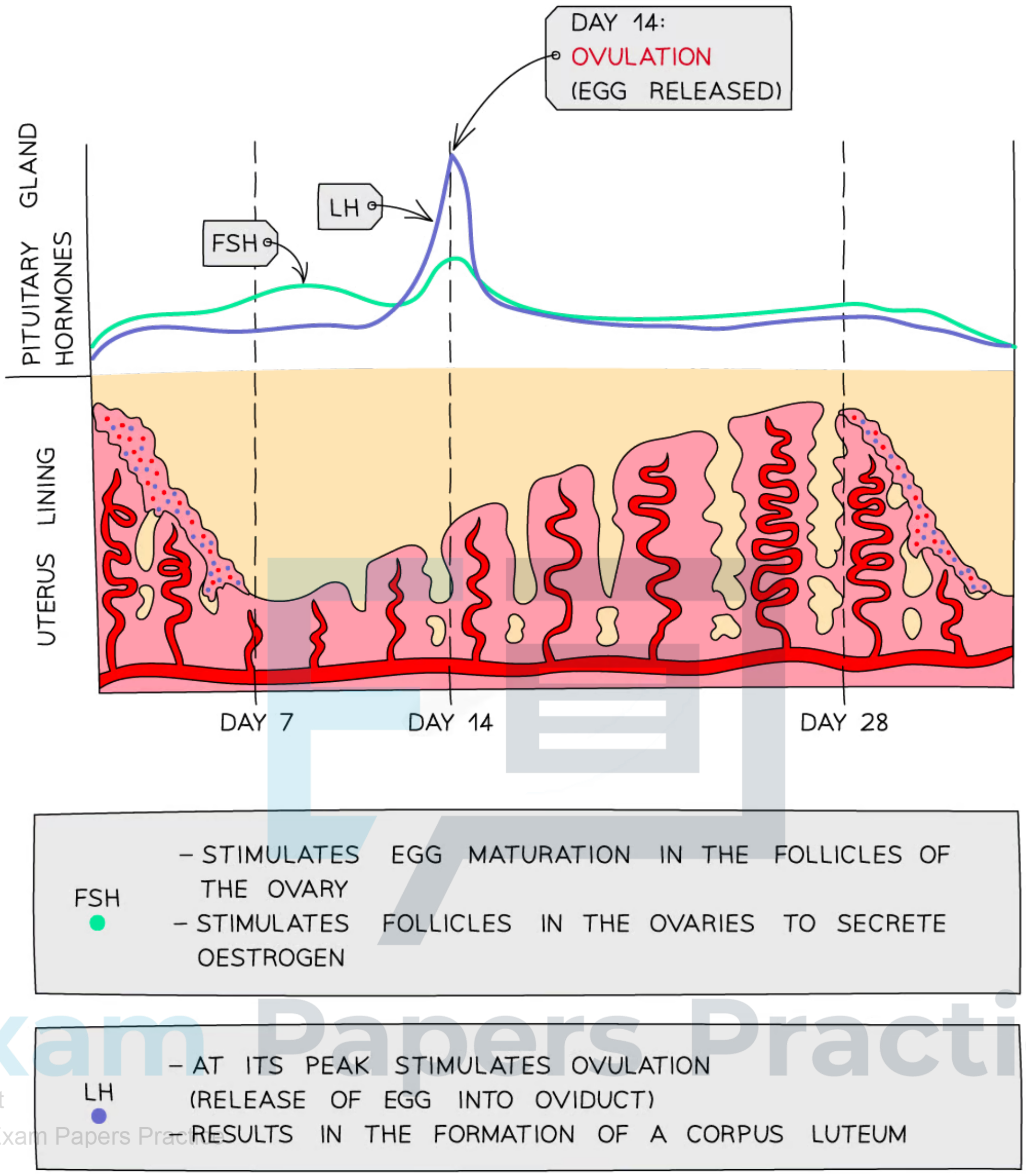
Changes in the endometrium during the menstrual cycle

How ovarian and pituitary hormones control the menstrual cycle

- **Four hormones** control the events that occur during the menstrual cycle:
  - Two of these hormones are produced by the **pituitary gland** in the brain
    - **F**ollicle-**s**timulating **h**ormone (**FSH**)
    - **L**uteinising **h**ormone (**LH**)
  - The other two hormones are produced in the **ovaries**
    - **Oestrogen** (also known as **oestradile**); produced by the **egg follicle**, and by the **corpus luteum** after ovulation
    - **Progesterone;** produced by the corpus luteum
  - The roles of FSH and LH:
    - FSH is secreted by the **pituitary gland** and stimulates the **development** of several immature **egg cells** in **follicles** in the **ovary**
    - FSH also stimulates the **secretion of oestrogen** by the **follicle wall**

- The **pituitary gland** is stimulated to release LH when **oestrogen** levels have reached their **peak**
- LH causes **ovulation to occur;** the shedding of the mature egg cell from the follicle and its release from the ovary
  - The shedding of the mature egg cell leaves behind an empty egg follicle called the corpus luteum
- LH also **stimulates** the production of **progesterone** from the corpus luteum

Diagram to show the impact of LH and FSH on the menstrual cycle

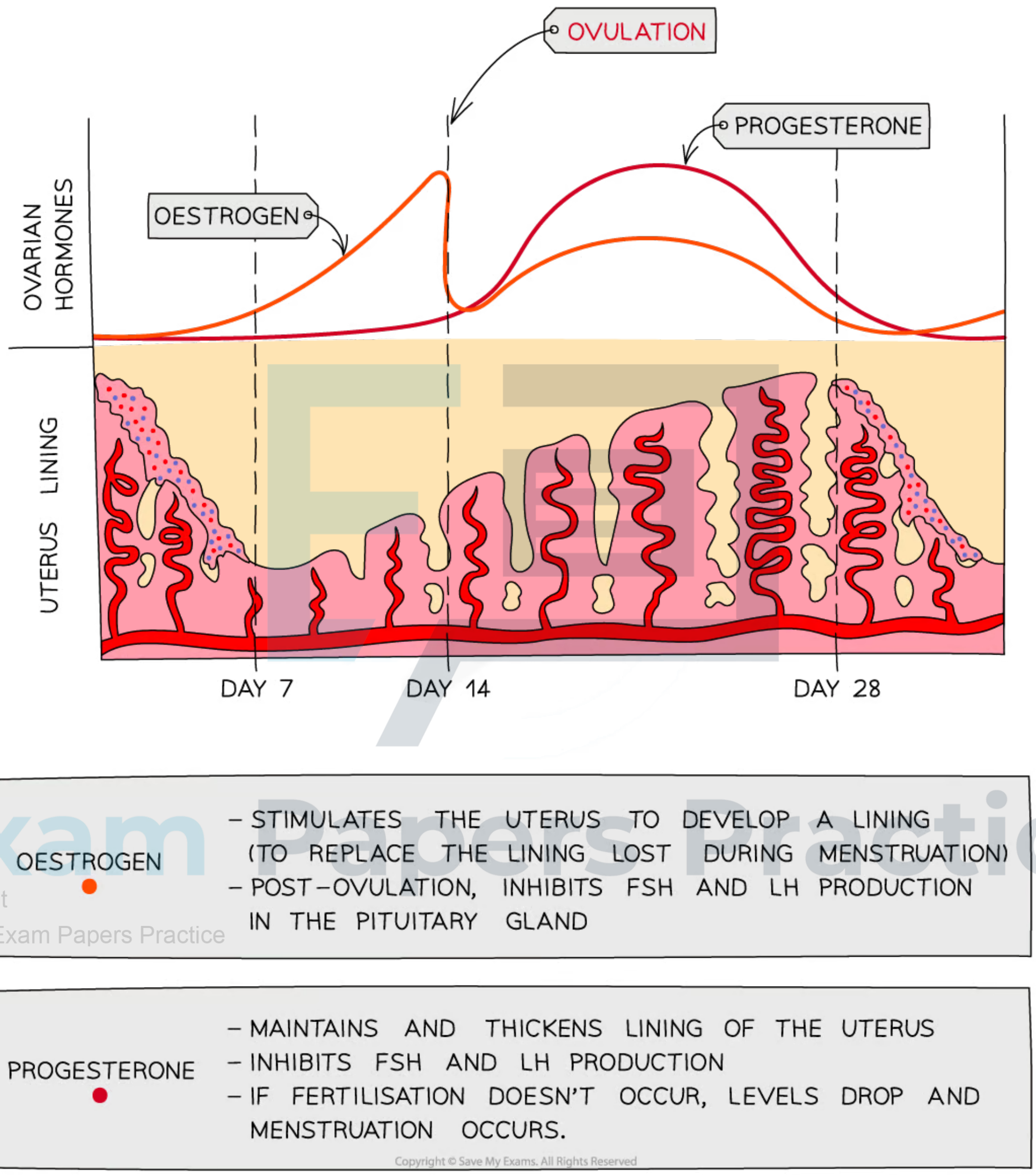


Changes in the levels of the pituitary hormones FSH and LH in the blood during the menstrual cycle

- The roles of oestrogen (also known as oestradile) and progesterone:

- **Oestrogen** levels rise from **day 1** to **peak** just before **day 14**
- This causes the **endometrium** to start **thickening** and the egg cell to **mature**
- The peak in oestrogen occurs just before the egg is released
- **Progesterone** stays low from day 1–14 and starts to rise once ovulation has occurred
  - Progesterone is produced by the corpus luteum
- The increasing levels of progesterone cause the endometrium to continue to thicken
- A fall in progesterone levels as the corpus luteum deteriorates causes the endometrium to **break down**, resulting in **menstruation**

Diagram to show the impact of oestrogen and progesterone on the menstrual cycle

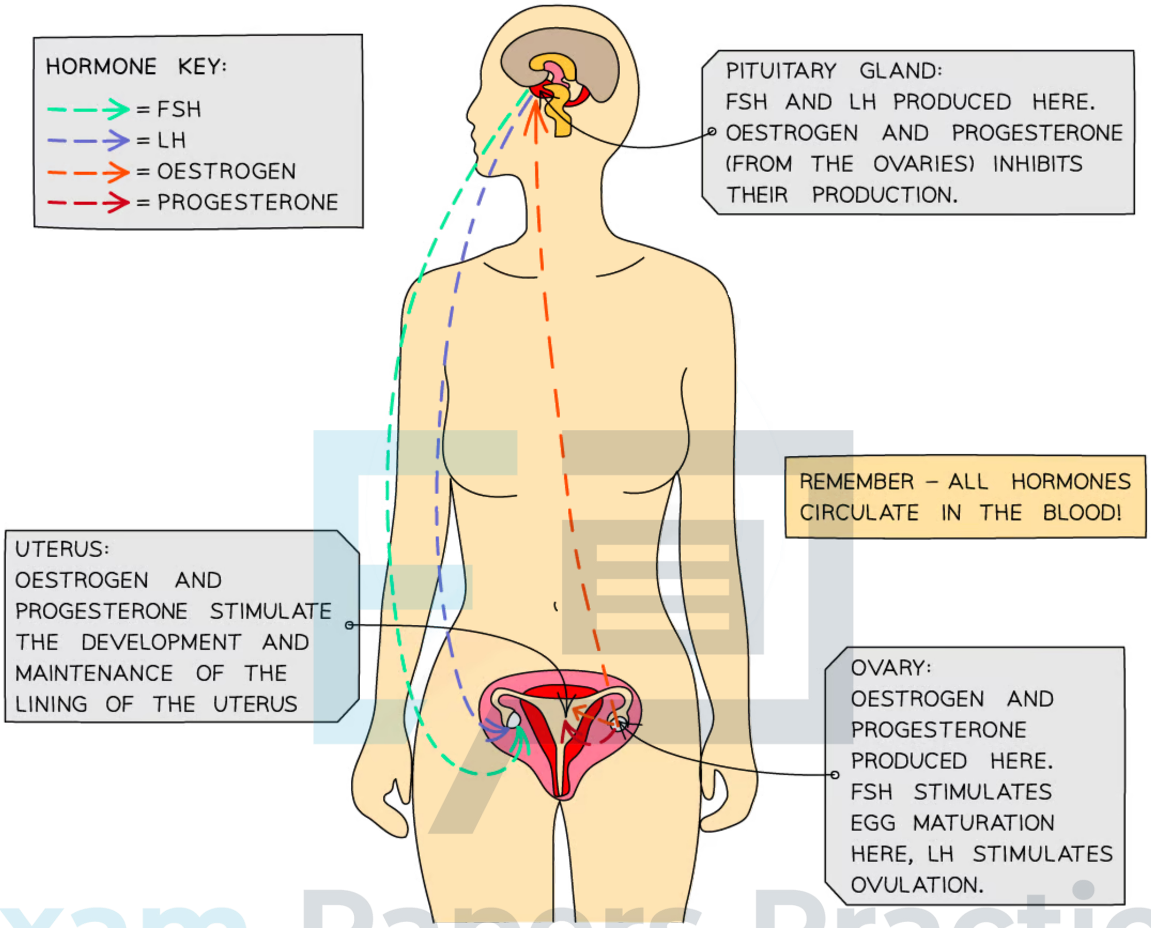


Changes in the levels of oestrogen and progesterone in the blood during the menstrual cycle

Negative and positive feedback mechanisms controlling the menstrual cycle

- The four hormones all **interact** to control the menstrual cycle via both negative and positive feedback
  - FSH and oestrogen
    - FSH stimulates the development of a follicle, and the follicle wall produces the hormone oestrogen; it can be said that **FSH stimulates the production of oestrogen**
    - As well as causing growth and repair of the endometrium, oestrogen also causes an **increase in FSH receptors;** this makes the follicles **more receptive to FSH** which, in turn, **stimulates more oestrogen production**
      - This is **positive feedback**
    - When oestrogen levels are high enough, it **inhibits the secretion of FSH**
      - This is **negative feedback**
    - LH and oestrogen
      - When oestrogen rises to a high enough level, it **stimulates the release of LH** from the pituitary gland, causing ovulation on around day 14 of the cycle
      - After ovulation, **LH causes the wall of the follicle to develop into the corpus luteum,** which **secretes more oestrogen**
        - This is **positive feedback**
      - LH and progesterone
        - **LH** stimulates the wall of the follicle to develop into the **corpus luteum,** which **secretes progesterone**
        - Progesterone thickens and maintains the endometrium but also **inhibits the secretion of FSH and LH** from the pituitary gland
          - This is **negative feedback**

Glands and hormones of the menstrual cycle diagram



Where hormones involved in the menstrual cycle are made and act – remember that hormones travel around the body in the bloodstream but only have an effect on a target organ

Hormones Involved With In Vitro Fertilisation Treatment

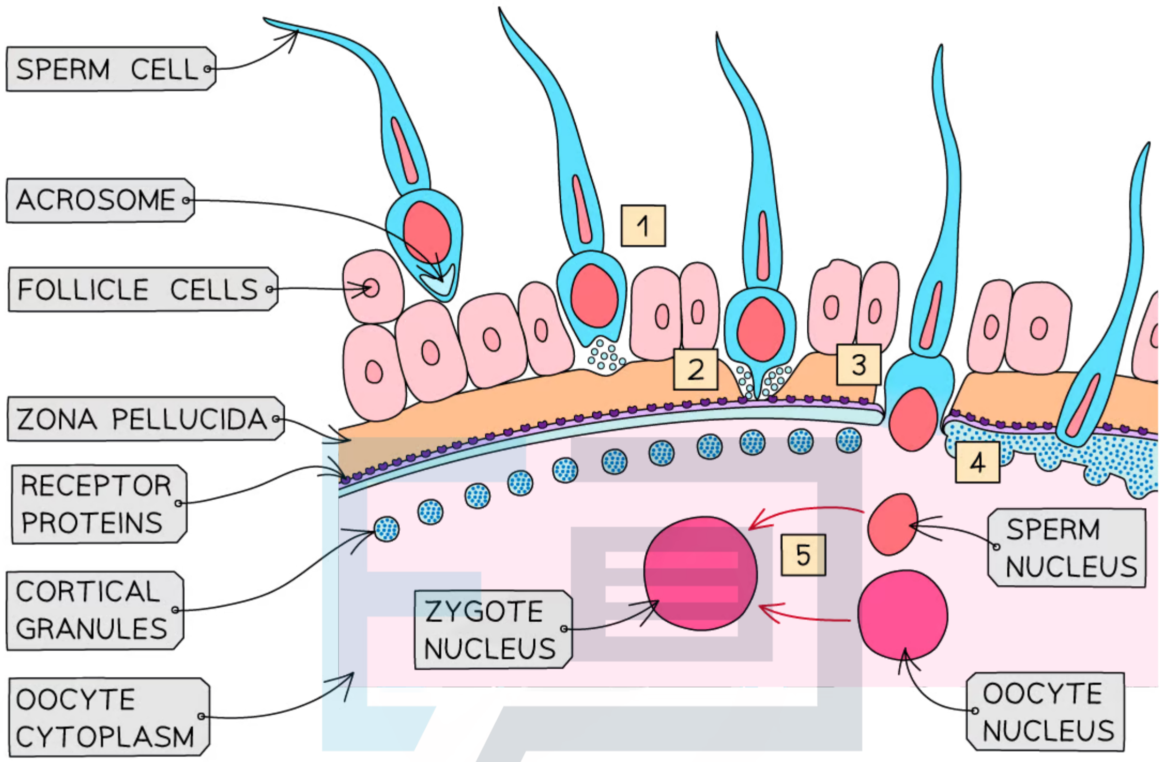
- A couple may find it difficult to conceive a baby **naturally**
- This can be due to **insufficient levels of reproductive hormones** affecting the development of egg and sperm cells, or as a result of **issues with the reproductive system of the male or female**
- One possible treatment is for eggs to be fertilised by sperm **outside the body** in carefully controlled laboratory conditions
  - This is known as *in vitro* **f**ertilisation, or **IVF**
- Although the process can vary, it normally follows the same main steps:
  - The first step involves stopping the normal secretion of hormones; the woman takes a drug to **inhibit the secretion of FSH and LH** from the pituitary gland
    - This also causes oestrogen and progesterone secretions to stop
  - This **temporarily halts the menstrual cycle**, allowing doctors to control the **timing** and **quantity** of **egg production** in the woman's ovaries
  - The woman is then given **injections of FSH and LH to stimulate the development of follicles;** as the injection gives a much higher FSH concentration than is present during a normal menstrual cycle, '**superovulation**' occurs
    - Many more follicles than normal begin to mature
  - The eggs are then collected from the woman and fertilised by sperm from the man in **sterile conditions in the laboratory**
  - The fertilised eggs develop into **embryos**
  - At the stage when they are tiny balls of cells, about **48 hours after fertilisation**, one or more embryos are inserted into the mother's uterus
  - Finally, **extra progesterone** is normally given to the woman to ensure the **endometrium** is **maintained**
- The success rate of IVF is low (~30%) but there have been many improvements and advancements in medical technologies which are helping to increase the success rate

Fertilisation

Human Fertilisation

- Fertilisation is the **fusion** of **one sperm cell** and **one ovum** (egg cell); this fusion of two haploid nuclei gives rise to a diploid zygote
- During sexual reproduction, **many sperm are released**, and the sperm cells are attracted towards the secondary oocyte by chemical signals
- When the sperm cells reach the secondary oocyte, the process that takes place at its cell surface **prevents more than one sperm from passing through its cell surface membrane**
  - The entry of more than one sperm into a single oocyte is known as **polyspermy**
- When the first sperm cell digests its way through the zona pellucida, it reaches the oocyte cell surface membrane; **complementary receptors on the head of the sperm bind with proteins on the oocyte cell surface membrane**, enabling the cell surface membranes of the two gametes to **fuse together** and the sperm nucleus to enter the oocyte
  - At this point **vesicles released from the egg destroy the sperm flagellum (tail) and its mitochondria**
- Inside the ovum haploid sets of chromosomes from the sperm and egg cell are both within the cytoplasm of the oocyte
- The paternal and maternal chromosomes form a pronucleus within which **DNA undergoes replication to prepare for mitosis**
  - The two haploid pronuclei come together and the temporary membranes dissolves to create a **diploid cell**, the zygote, fertilisation is now complete
  - Chromosomes undergo the first mitotic division of the now diploid cell, subsequent mitotic divisions take place to form a blastocyst

Fertilisation diagram



1. ENZYMES FROM THE ACROSOME DIGEST THE ZONA PELLUCIDA
2. THE SPERM BINDS TO RECEPTORS ON THE OOCYTE CELL SURFACE MEMBRANE
3. THE SPERM AND OOCYTE CELL SURFACE MEMBRANES FUSE AND THE SPERM NUCLEUS ENTERS THE OOCYTE
4. ENZYMES RELEASED FROM THE CORTICAL GRANULES DIGEST RECEPTOR PROTEINS AND HARDEN THE ZONA PELLUCIDA
5. FERTILISATION IS COMPLETED

Mechanisms during the process of fertilisation destroy the sperm tail and polyspermy is prevented

Plant Reproduction

Sexual Reproduction in Flowering Plants

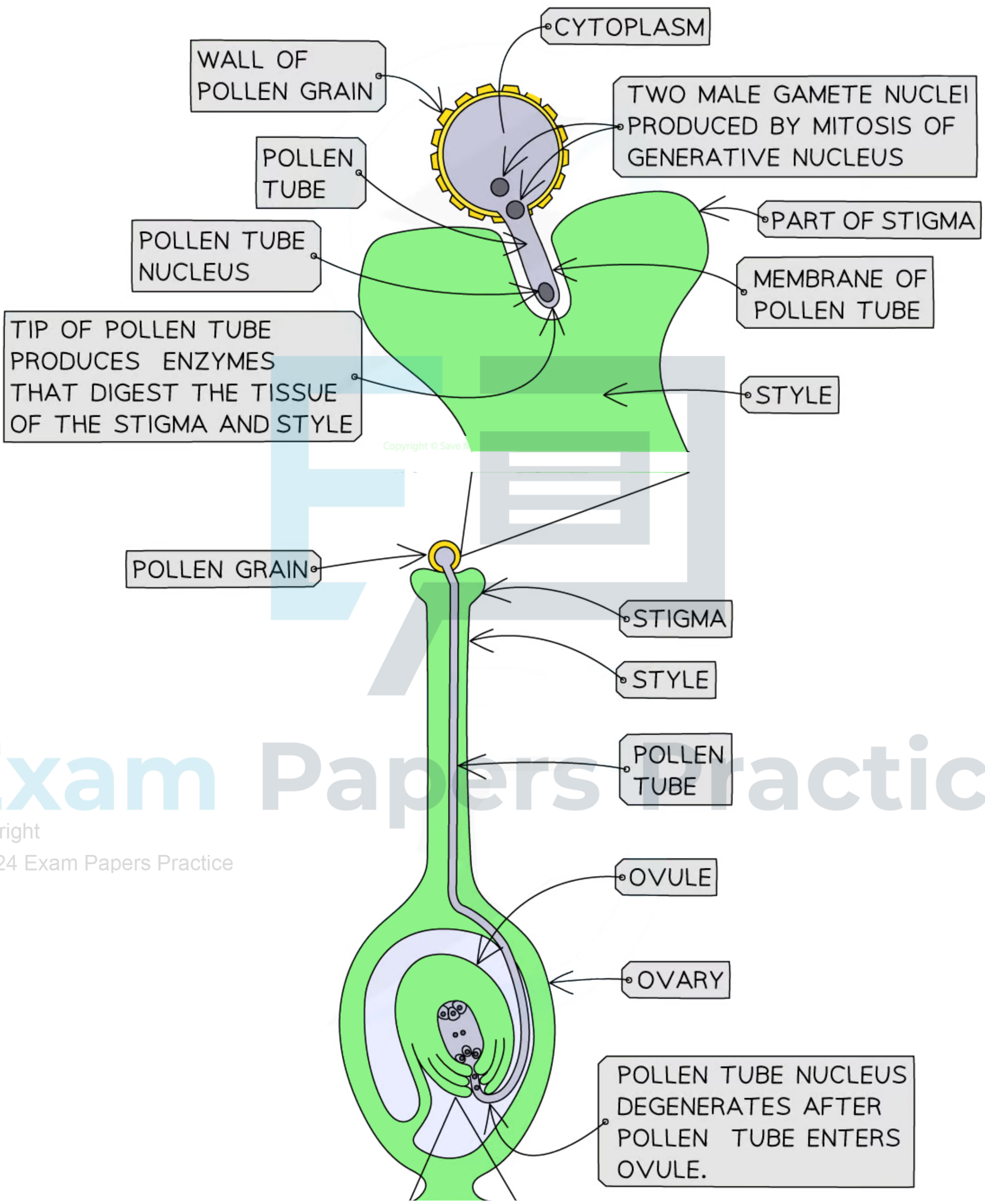
Production of Gametes

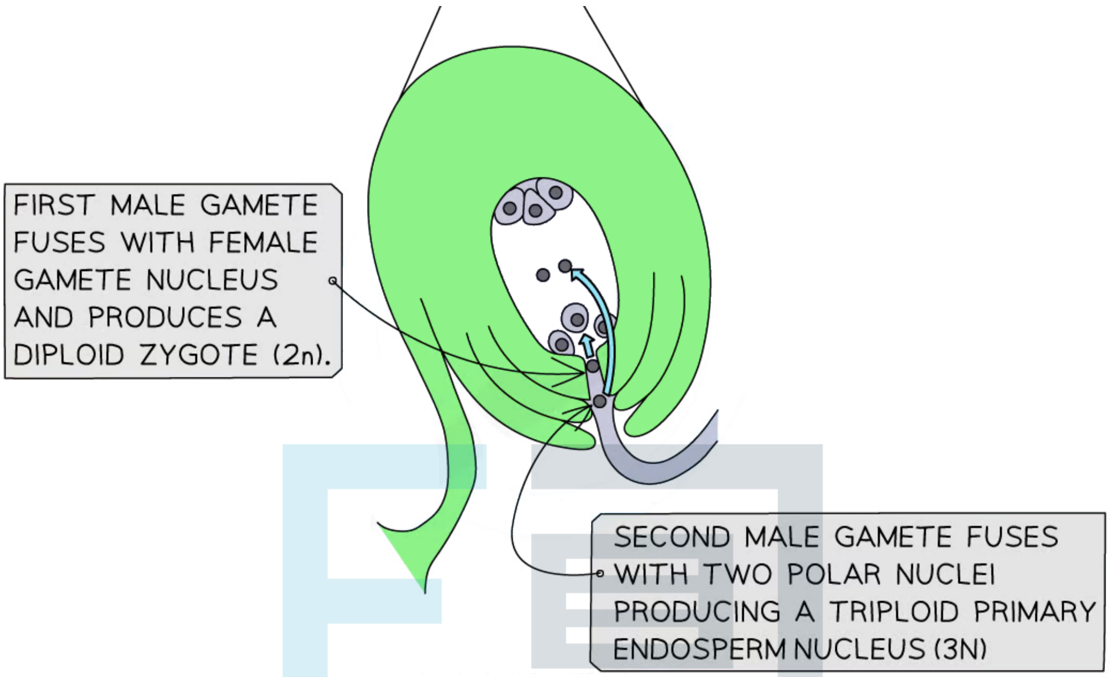
- In flowering plants, **male and female gametes are produced in the anther and ovule** (see diagram below for position of these structures), **respectively**
  - **Male gametes are contained within pollen grains**, which are released from the anthers
    - The anther contains pollen sacs
    - Each pollen sac contains a **diploid mother cell which undergoes meiosis** to form four haploid pollen grains (the gametes)
    - **Mitosis occurs** to produce more haploid male gametes
  - **Female gametes are made in the ovules**
    - A **single diploid cell within the ovule undergoes meiosis** to produce four haploid egg cells
    - Only one of these cells survives which undergoes **mitosis to produce female gametes**

Pollination and Fertilisation

- **Pollination** is the process of transferring pollen from the **anther** of one flower to the **stigma** of another
  - Some flowering plants are **hermaphroditic** which means they **contain both male and female parts**
    - **Self pollination** can occur in some of these species when pollen is transferred between different flowers on the same plant, or even from anther to stigma within the same flower
  - **Cross pollination** is the transfer of pollen from one plant to another
    - Flowers make use of a variety of methods, such as shape, colour and scent, to attract pollinators to aid with pollination
  - All pollination methods are forms of **sexual reproduction because the gametes are produced by meiosis so there is fusion of gametes** to form a diploid nucleus
- After pollination has occurred, a **pollen tube** grows from the **pollen grain** down the **style** to the **ovary** of the plant
- The **male nuclei** travel down the pollen tube to the female ovule
  - Two male nuclei travel down the pollen tube to the ovule; one will fuse with an ovule nucleus to form the zygote while the other will go on the form the plant embryo's food store
- **Fertilisation** occurs when the **haploid** male and female nuclei fuse and a **diploid zygote** is formed
  - After fertilisation, the **ovule** becomes a **seed** and the **ovary** develops into the **fruit**

Fertilisation in flowering plants diagram


CYTOPLASM
WALL OF POLLEN GRAIN
TWO MALE GAMETE NUCLEI PRODUCED BY MITOSIS OF GENERATIVE NUCLEUS
POLLEN TUBE
PART OF STIGMA
POLLEN TUBE NUCLEUS
MEMBRANE OF POLLEN TUBE
TIP OF POLLEN TUBE PRODUCES ENZYMES THAT DIGEST THE TISSUE OF THE STIGMA AND STYLE
STYLE
POLLEN GRAIN
STIGMA
STYLE
POLLEN TUBE
OVULE
OVARY
POLLEN TUBE NUCLEUS DEGENERATES AFTER POLLEN TUBE ENTERS OVULE.

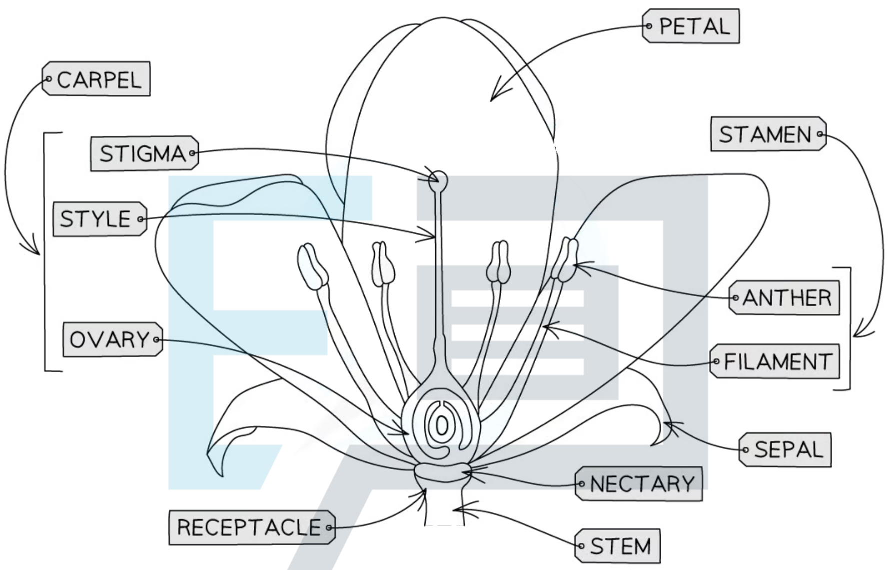


The process of fertilisation in a flowering plant to produce an embryo

Anatomy of an Insect-Pollinated Flower

- The development of flowers occurs in the **reproductive stage** of the plant life cycle
- Flowers contain all the necessary organs and tissues required for **sexual reproduction** by **pollination**
- Key structures of the flower include
  - The **anther** - where the male gamete, pollen, is found
  - The **stigma** - part of the female reproductive organ which receives the pollen
  - The **ovary** - where the female gametes are located

Insect pollinated flower diagram



The structure of an insect pollinated flower

Exam Tip

You should be able to draw diagrams annotated with names of structures and their functions of insect pollinated plants.

Flower structures and their functions table

Structure	Function
Sepal	Protecting the developing flower whilst inside the bud
Petal	Colourful to attract pollinators

Anther	Part of the stamen that produces the male gametes
Pollen	Contains the male nuclei for fertilisation
Filament	The stalk of the stamen that hold up the anther
Stigma	The top of the carpel, the female part of the flower, pollen lands here
Style	The part of the carpel that supports the stigma
Ovary	Contains the ovules
Ovule	The chamber within the ovary where female gametes develop

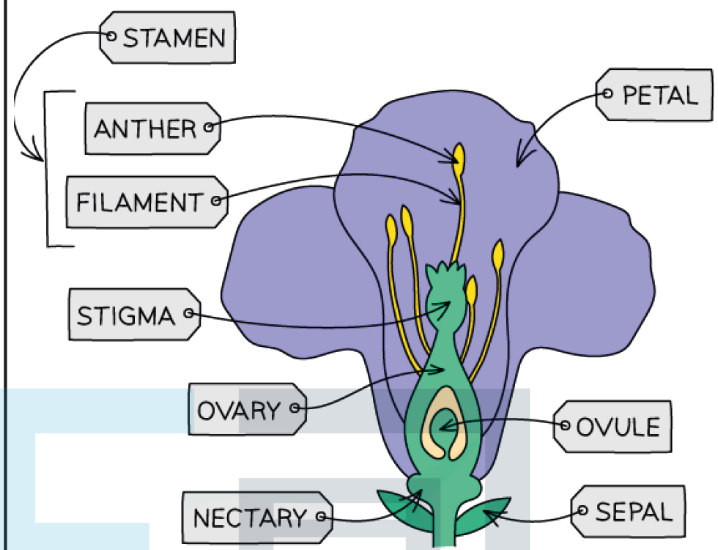
Pollination

Promoting Cross-Pollination

- Flowers are the **reproductive organ** of the plant
- They usually contain both male and female reproductive parts
- Plants produce **pollen** which contains a nucleus inside that is the **male gamete**
- Unlike the male gamete in humans (sperm), pollen is **not capable of locomotion** (moving from one place to another)
- This means plants have to have mechanisms in place to **transfer pollen from the anther to the stigma**
- This process is known as **pollination** and there are two main mechanisms by which it occurs: transferred by **insects** (or other animals like birds) or transferred by **wind**
- The structure of insect and wind-pollinated flowers are slightly different as each is adapted for their specific function

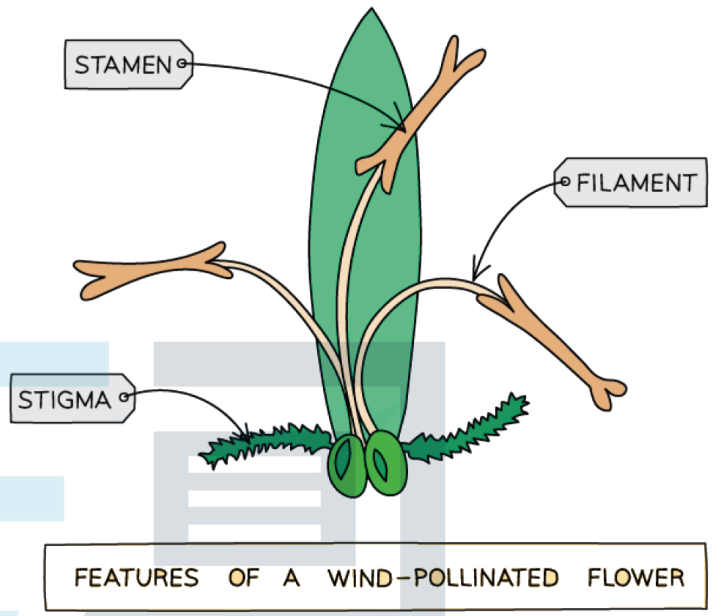
Insect-pollinated flower features

- For the flowers of many plant species, the **pollinating agents** are **insects** (e.g. bees)
- Insects often visit these flowers to collect **nectar** (a sugary substance produced by insect-pollinated flowers and the base of their petals, which provides the insects with **energy**)
- As an insect enters the flowers in search of nectar, it often brushes against the **anthers**, which deposit **sticky pollen** onto the insect's **body**
- When the insect visits another flower, it may brush against the **stigma** of this second flower and in the process, may **deposit** some of the pollen from the **first flower**, resulting in **pollination**
- The structures of an insect-pollinated flower ensure that the flower is well-adapted for pollination by insects

FEATURE	INSECT–POLLINATED
	 FEATURES OF AN INSECT–POLLINATED FLOWER
PETALS	LARGE AND BRIGHTLY COLOURED TO ATTRACT INSECTS
SCENT AND NECTAR	PRESENT – ENTICES INSECTS TO VISIT THE FLOWER AND PUSH PAST STAMEN TO GET TO NECTAR
NUMBER OF POLLEN GRAINS	MODERATE – INSECTS TRANSFER POLLEN GRAINS EFFICIENTLY WITH A HIGH CHANCE OF SUCCESSFUL POLLINATION
POLLEN GRAINS	LARGER, STICKY AND / OR SPIKY TO ATTACH TO INSECTS AND BE CARRIED AWAY
ANTHERS	INSIDE FLOWER, STIFF AND FIRMLY ATTACHED TO BRUSH AGAINST INSECTS
STIGMA	INSIDE FLOWER, STICKY SO POLLEN GRAINS STICK TO IT WHEN AN INSECT BRUSHES PAST

Wind-pollinated flower features

- For wind-pollinated flowers, the process of pollination is more **random** than it is for insect-pollinated flowers
- When ripe, the **anthers open** and **shed their pollen** into the open air
- The pollen is then either blown by the wind or carried by air currents until it (by chance) lands on the **stigma** of a plant of the same species, resulting in **pollination**
- The structures of a wind-pollinated flower ensure that the flower is well-adapted for pollination by the wind

FEATURE	WIND–POLLINATED
	
PETALS	SMALL AND DULL, OFTEN GREEN OR BROWN IN COLOUR
SCENT AND NECTAR	ABSENT – NO NEED TO WASTE ENERGY PRODUCING THESE AS NO NEED TO ATTRACT INSECTS
NUMBER OF POLLEN GRAINS	LARGE AMOUNTS – MOST POLLEN GRAINS ARE NOT TRANSFERRED TO ANOTHER FLOWER SO THE MORE PRODUCED, THE BETTER THE CHANCE OF SOME SUCCESSFUL POLLINATION OCCURRING
POLLEN GRAINS	SMOOTH, SMALL AND LIGHT SO THEY ARE EASILY BLOWN BY THE WIND
ANTHERS	OUTSIDE FLOWER, SWINGING LOOSE ON LONG FILAMENTS TO RELEASE POLLEN GRAINS EASILY
STIGMA	OUTSIDE FLOWER, FEATHERY TO CATCH DRIFTING POLLEN GRAINS

- Cross-pollination occurs when the **pollen from one plant** is transferred to the stigma of **another plant of the same species**
- This is the way most plants carry out pollination as it **improves genetic variation**
- Cross-pollination relies completely on the presence of **pollinators** and this can be a problem if those pollinators are **missing** (e.g. the reduction in **bee** numbers is of great importance to humans as bees pollinate a large number of food crops) - this doesn't apply to wind-pollinated plants
- In addition to the mechanisms described above for insect and wind pollinated plants, plants also have a variety of other **methods to ensure successful cross-pollination**
  - **Different maturation times** for the pollen and ovules of the same flower. This prevents self-pollination from occurring
  - **Self-incompatibility mechanisms** are used in some species that ensure if pollen lands on the stigma from the same plant the plant produces chemicals that ensure a pollen tube does not grow
  - Plants can produce flowers that only have **either male or female parts** or the whole plant is either male or female
  - Wind-pollinated plants are less likely to self-pollinate due to the **wind carrying the pollen far from the parent plant**

Preventing Self-Pollination

- The pollen from a flower can **land on its own stigma** or on the **stigma of another flower on the same plant** - this is known as self-pollination
- Self-pollination **reduces genetic variety of the offspring** as all the gametes come from the same parent (and are therefore genetically identical). this can lead to inbreeding
- Lack of variation in the offspring is a disadvantage if environmental conditions change, as it is **less likely that any offspring will have adaptations that suit the new conditions** well
- **Genetic mechanisms** in many plant species ensure male and female gametes fusing during fertilisation are from different plants
  - Each plant has a **set of genes that controls the growth of a pollen tube** so that when pollen lands on the stigma of a flower of the same plant protein interactions occur that **prevent the growth of a pollen tube**
  - This is an example of a **self-incompatibility mechanism**
  - The mechanism may include
    - A pollen grain fails to germinate into a pollen tube
    - A pollen grain germinates but does not enter the style
    - The pollen nuclei enters the ovule but it degenerates before fertilisation can occur
    - Fertilisation occurs but the embryo degenerates before growth is established

Seed Dispersal & Germination

Seed Dispersal & Germination

Seed dispersal

- **Seed dispersal** is then required in order to distribute the seeds away from the parent plant and **reduce competition** between the offspring and the parent plant
  - Methods of seed dispersal include
    - **Wind or water**
      - Parachute or wing shaped lightweight seeds will travel on the wind or float in water
    - **Animals**
      - Fleshy fruit is eaten by animals and seeds distributed through egestion
      - Sticky or hooked seeds catch on to the fur or feathers of passing animals
    - **Explosions**
      - Some pods explode propelling the seeds away from the parent plant
- Seed dispersal can often be confused with pollination
  - Pollination is the **transfer of pollen from anther to stigma**, while seed dispersal is the **distribution of mature seeds**. Both processes can involve wind, water, or animals.

Seed germination

- Once a seed has formed within the ovary of a flower they undergo a period of dormancy
- When conditions become favourable the seed may germinate
  - **Germination** is the **start of growth in the seed**

Requirements for germination

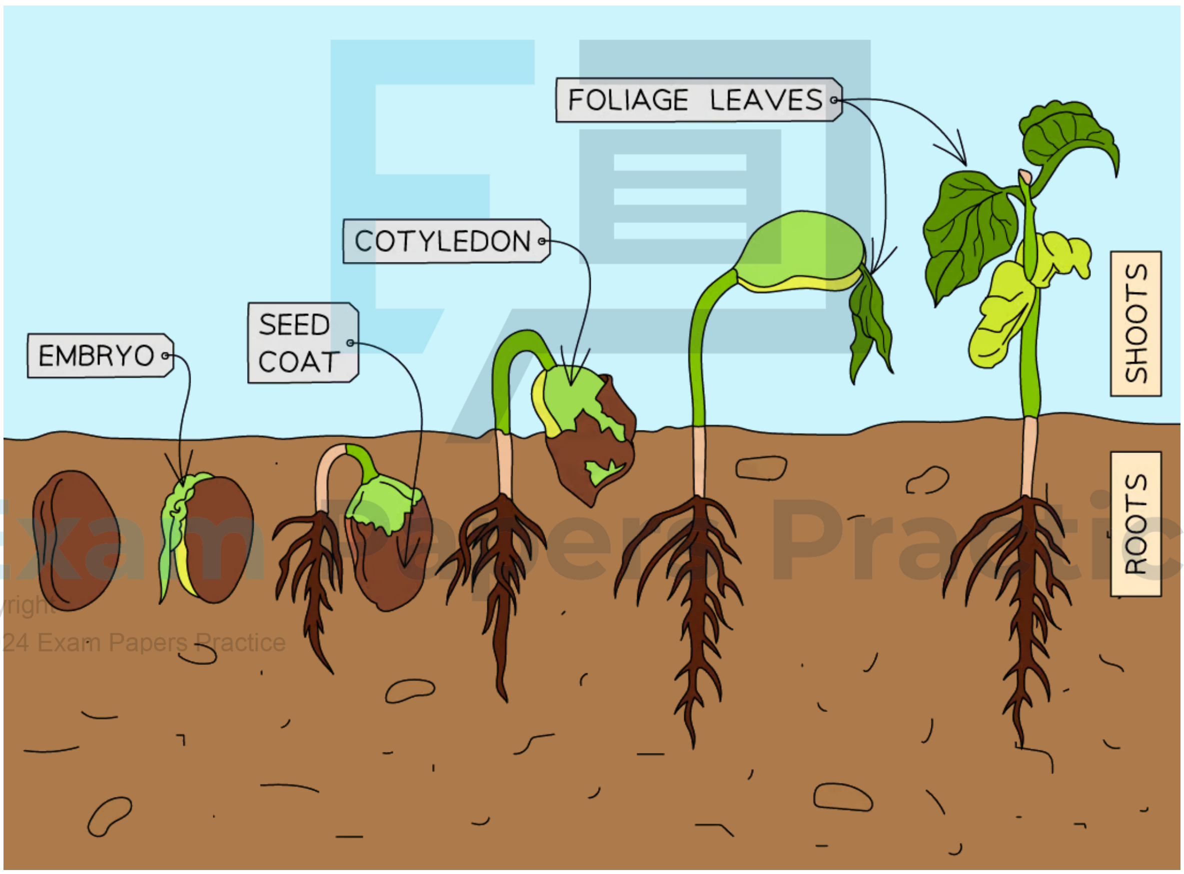
- Three factors are required for **successful germination**:
  - **Water** - allows the seed to **swell up**, which causes the **seed coat** (testa) to **burst**, allowing the growing embryo plant to exit the seed. Water also allows the enzymes in the embryo to start working so that growth can occur (**increases metabolic activity**)
  - **Oxygen** - required for **respiration**, so that **energy** can be released for germination
  - **Warmth** - germination improves as temperature rises (up to a certain point) as the reactions which take place are controlled by **enzymes**, which cannot function effectively when temperatures are **too low**

The process of germination

- A seed contains a plant embryo and **food reserves for its growth**
- The food reserves contain endosperm tissue which are transferred to the embryo through early leaf structures called **cotyledons**
- Seeds needs to **replenish water lost during dormancy and does so through a process called imbibition** which activates the biochemistry of the embryo

- The **rate of respiration and protein synthesis increases** and the embryo can prepare to emerge through the seed coat
- A **structure called the radicle is the first to emerge** and forms the initial root structure which responds to gravity and **grows downward** into the soil
- The **first structure to appear above ground is called the hypocotyl**, this is a curved portion of the plant shoot found below the cotyledons and **grows upwards**
- As the shoot grows the **first leaves begin to appear from the cotyledon and photosynthesis can begin**
- The root structure is also established and full plant growth can occur

Stages of germination diagram



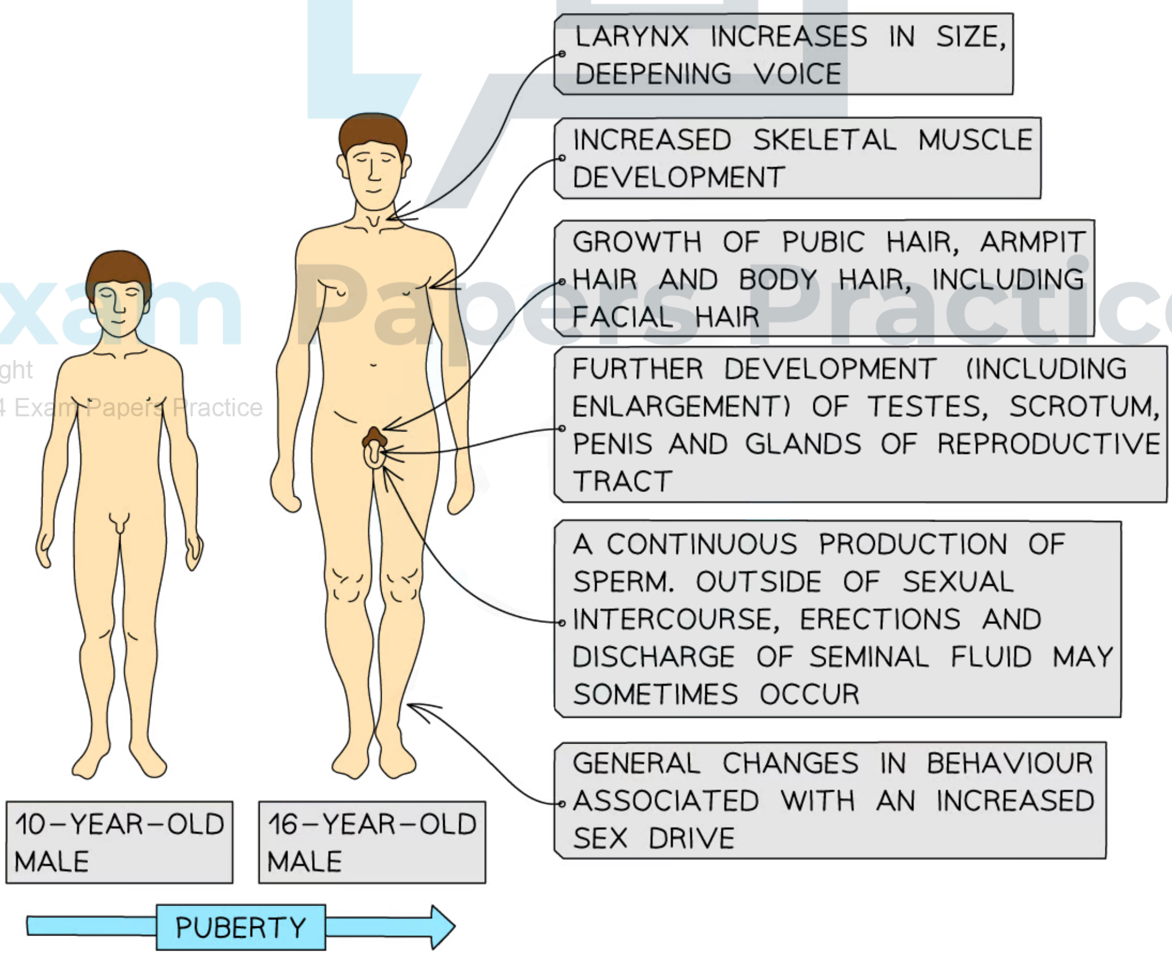
The process of germination in flowering plant showing the development of roots and shoots

Hormones & Puberty (HL)

Hormones & Puberty

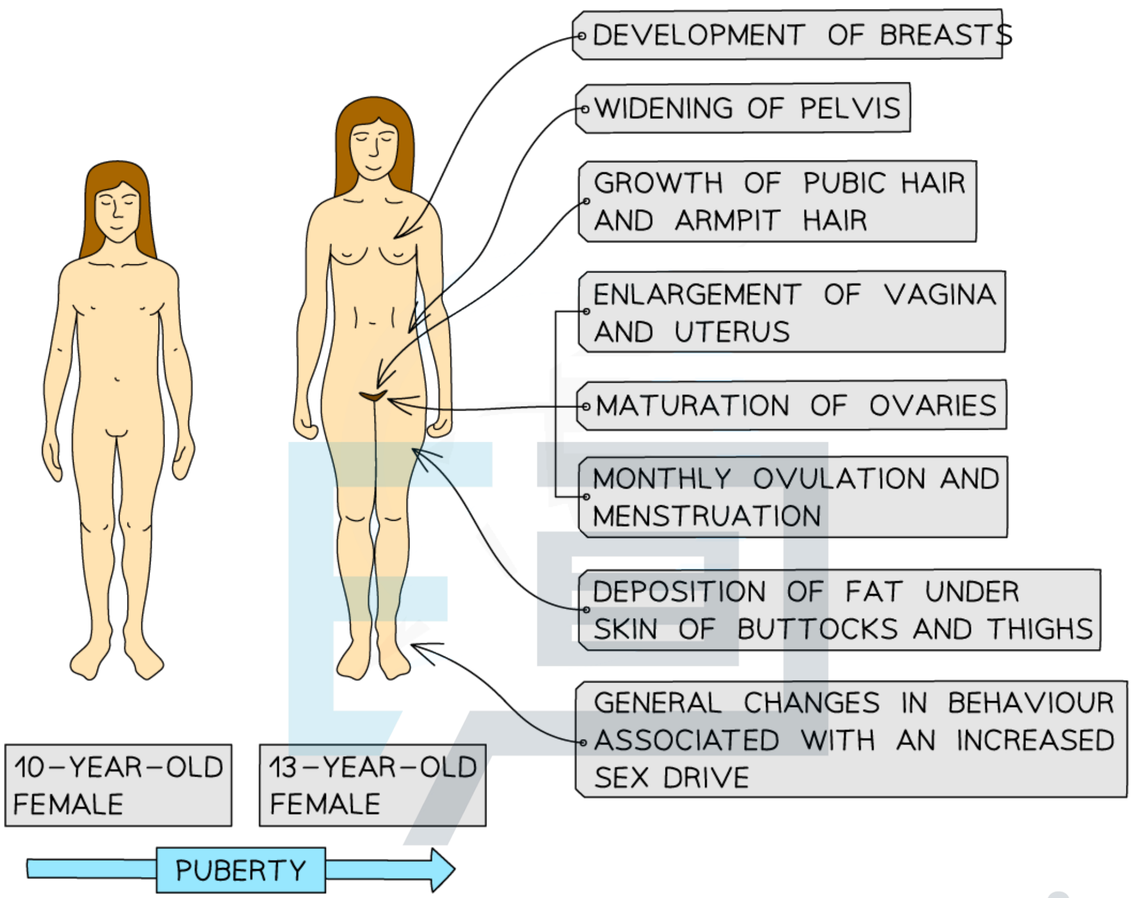
- During puberty, reproductive hormones cause secondary sexual characteristics to develop
- This is under the control of hormones, two types of sex hormones include
  - **Gonadotropin-releasing hormone** (GnRH)
  - **Steroid sex hormones** such as **oestrogen** (also known as oestradiol) and **testosterone**
- The increase in sex hormones production leads to the **changes associated with puberty**
  - The onset of puberty is triggered by the release of **hormones from the hypothalamus** in the brain which secretes GnRH
  - This is **detected by the pituitary gland** (situated underneath the hypothalamus) which in turn secretes two further hormones
    - **LH**
    - **FSH**
  - These hormones are produced in both females and males and they **enhance the effects of the sex hormones oestrogen and testosterone**
  - Following this the development of the **secondary sexual characteristics takes place**

Male secondary sexual characteristics



The development of male secondary sexual characteristics at puberty are under hormonal control

Female secondary sexual characteristics



The development of female secondary sexual characteristics at puberty are under hormonal control

Gametogenesis (HL)

Gametogenesis

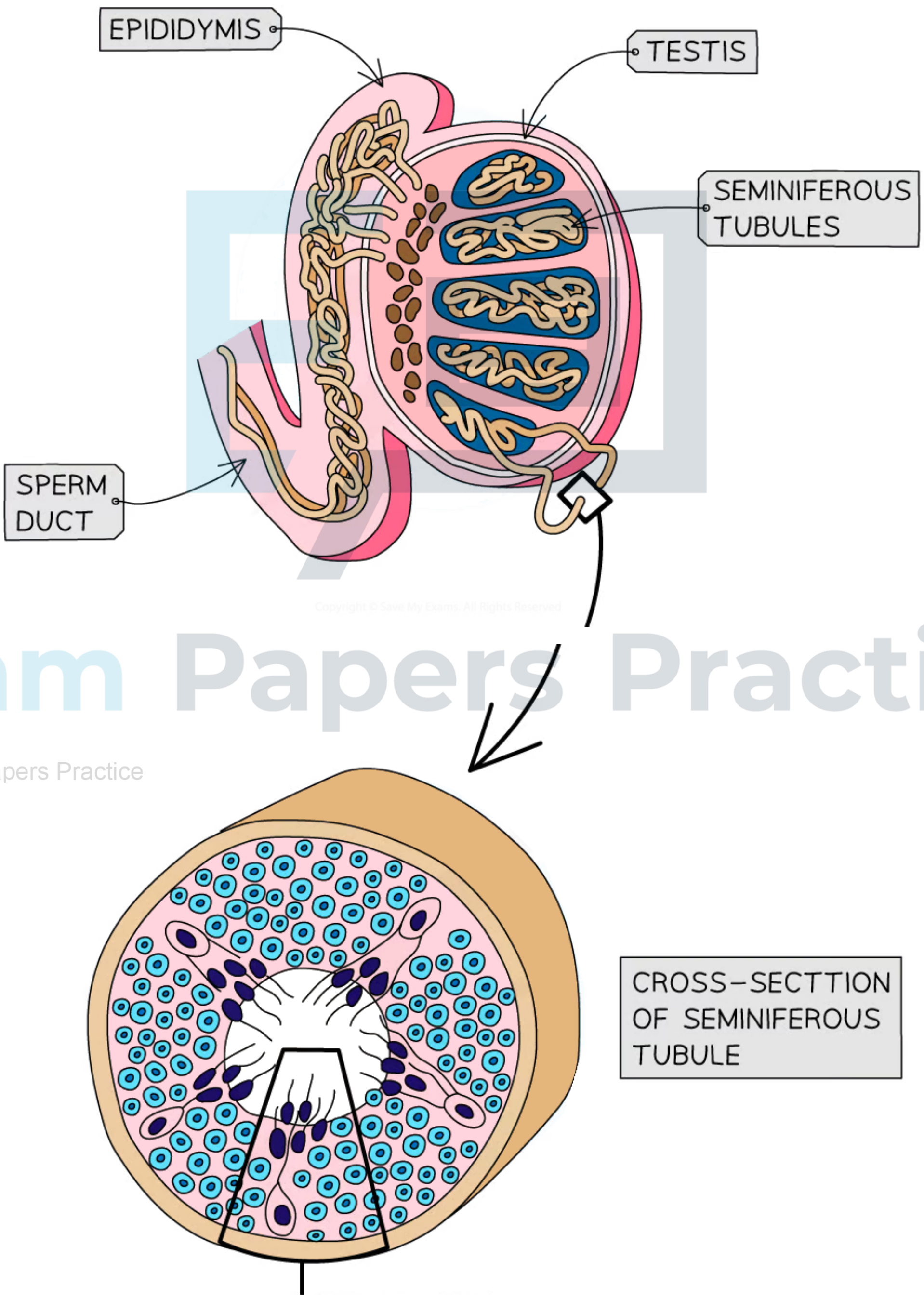
- **Sexual reproduction** involves **fertilisation**; the **fusion of sex cells**, or **gametes**, from two parents
  - Gametes are **specialised**, haploid cells
  - The fusion of gametes forms a zygote
- In animals, male gametes are **sperm** cells and female gametes are **ova** (singular ovum), also known as **oocytes**
- Gametes are produced in pairs of glands known as **gonads**
  - Sperm are produced in the male **testes** (singular testis)
  - Ova are produced in the female **ovaries** (singular ovary)
- The process of gamete formation is known as **gametogenesis**, and it involves both **mitosis** and **meiosis**
  - Specifically the production of sperm cells is **spermatogenesis** and production of ova is **oogenesis**
- Gametogenesis in both males and females involves the following stages:
  - Cells **dividing by mitosis** to produce many new cells, all of which have **the potential to develop into gametes**
  - Cells **growing** and differentiating
  - Cells **dividing by meiosis** to produce **haploid gametes**

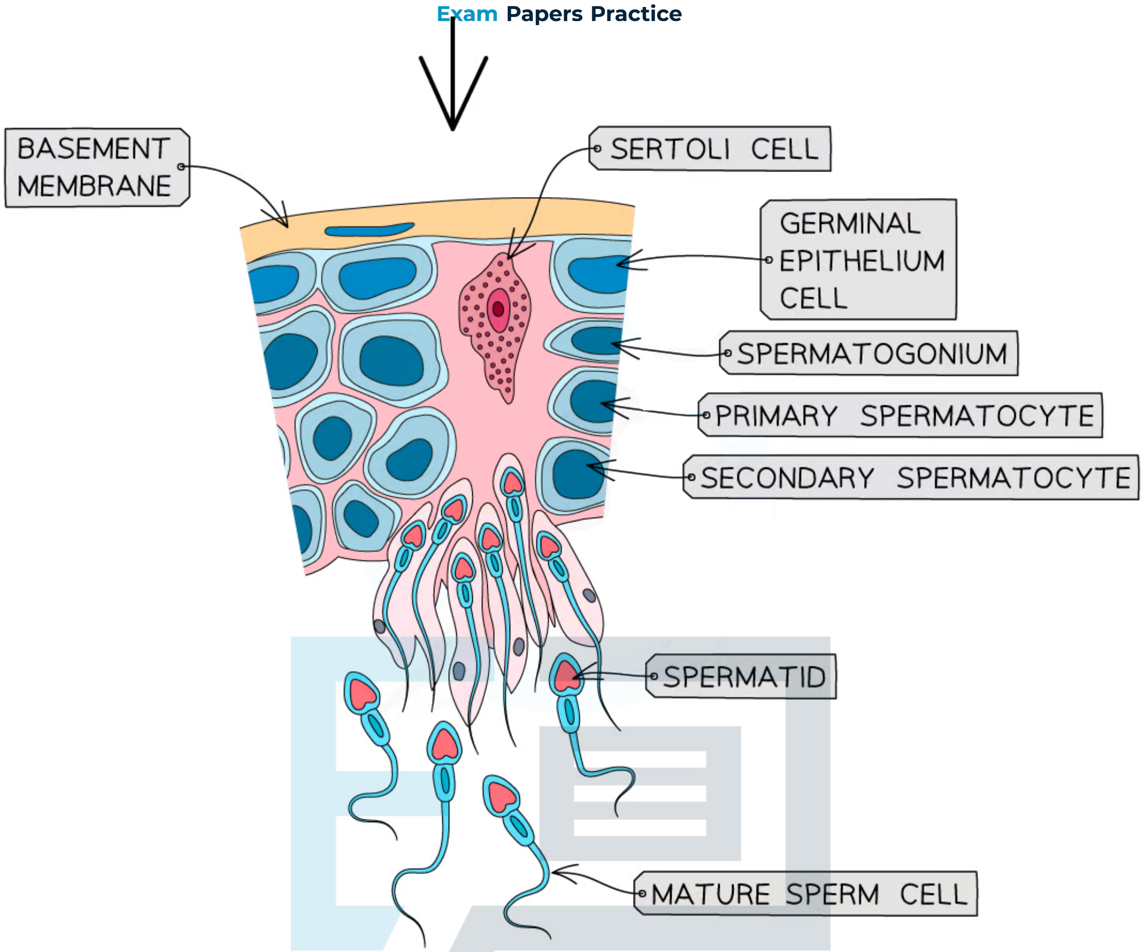
Spermatogenesis

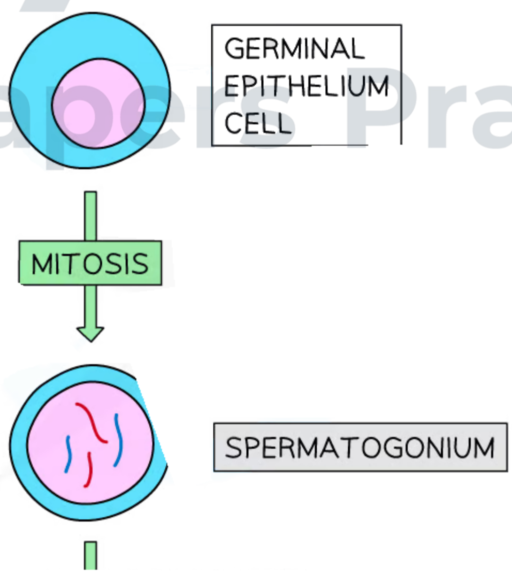
- The production of sperm takes place in the **testes** in males **from puberty onwards**
- The testes contain **many small tubes**, or **tubules**, known as **seminiferous tubules**
  - The gaps, or **interstices**, between the seminiferous tubules are filled with cells called **interstitial cells**, sometimes known as **Leydig cells**
  - The interstitial cells produce the male sex hormone **testosterone**
- Spermatogenesis begins in the **germinal epithelium**, a layer of cells that makes up the **outer layer** of the seminiferous tubules
- Cells in the germinal epithelium **divide by mitosis**, producing diploid cells called **spermatogonia** (singular spermatogonium)
  - Of the two daughter spermatogonia cells, one will go on to eventually become a sperm cell, while the other remains in the germinal epithelium where it can continue development
- Spermatogonia begin to migrate from the germinal epithelium towards the lumen of the seminiferous tubules; they do this by moving through the gaps between **Sertoli cells**
  - Sertoli cells form the **inner lining of the seminiferous tubules**
- Spermatogonia differentiate into immature sperm cells called **primary spermatocytes**
- Primary spermatocytes mature and **divide by meiosis**

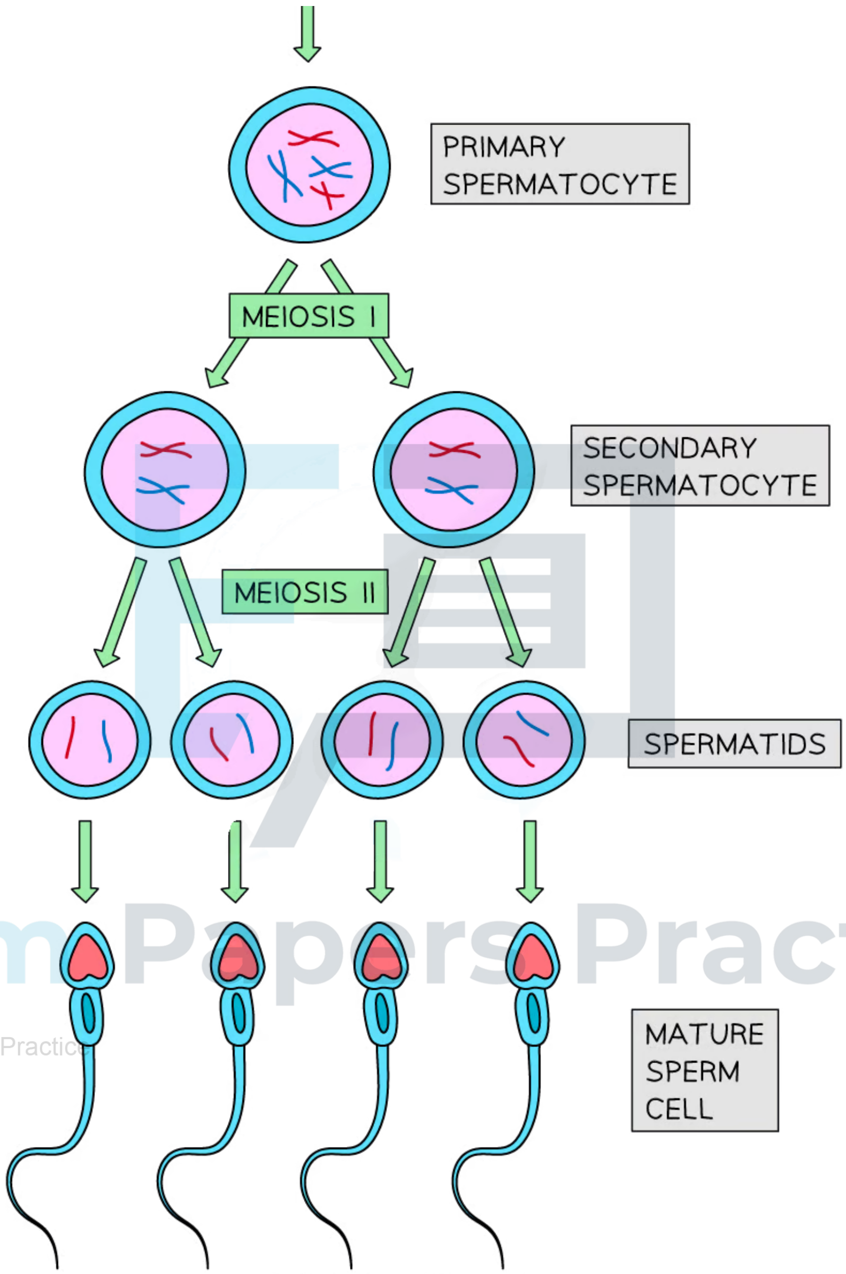
- **Meiosis I** forms **secondary spermatocytes**
- **Meiosis II** forms **spermatids**
- Spermatids formed during meiosis remain **associated with the Sertoli cells** as they **mature into sperm cells**, also known as **spermatozoa**
- Once fully matured, the sperm cells detach from the Sertoli cells and move **along the seminiferous tubule lumen towards the sperm duct**
  - On their way towards the sperm duct, the mature sperm pass through a coiled tube called the **epididymis**

Spermatogenesis diagram




BASEMENT MEMBRANE
SERTOLI CELL
GERMINAL EPITHELIUM CELL
SPERMATOGONIUM
PRIMARY SPERMATOCYTE
SECONDARY SPERMATOCYTE
SPERMATID
MATURE SPERM CELL


GERMINAL EPITHELIUM CELL
MITOSIS
SPERMATOGONIUM

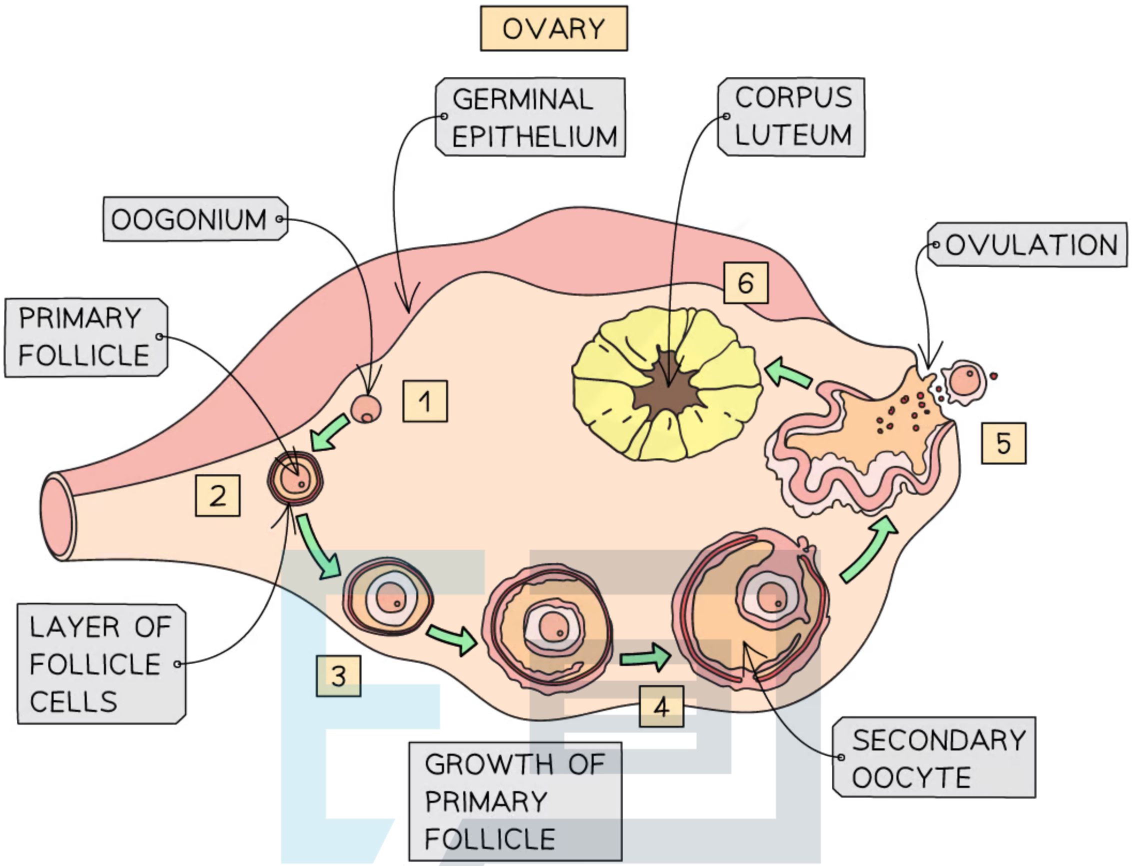


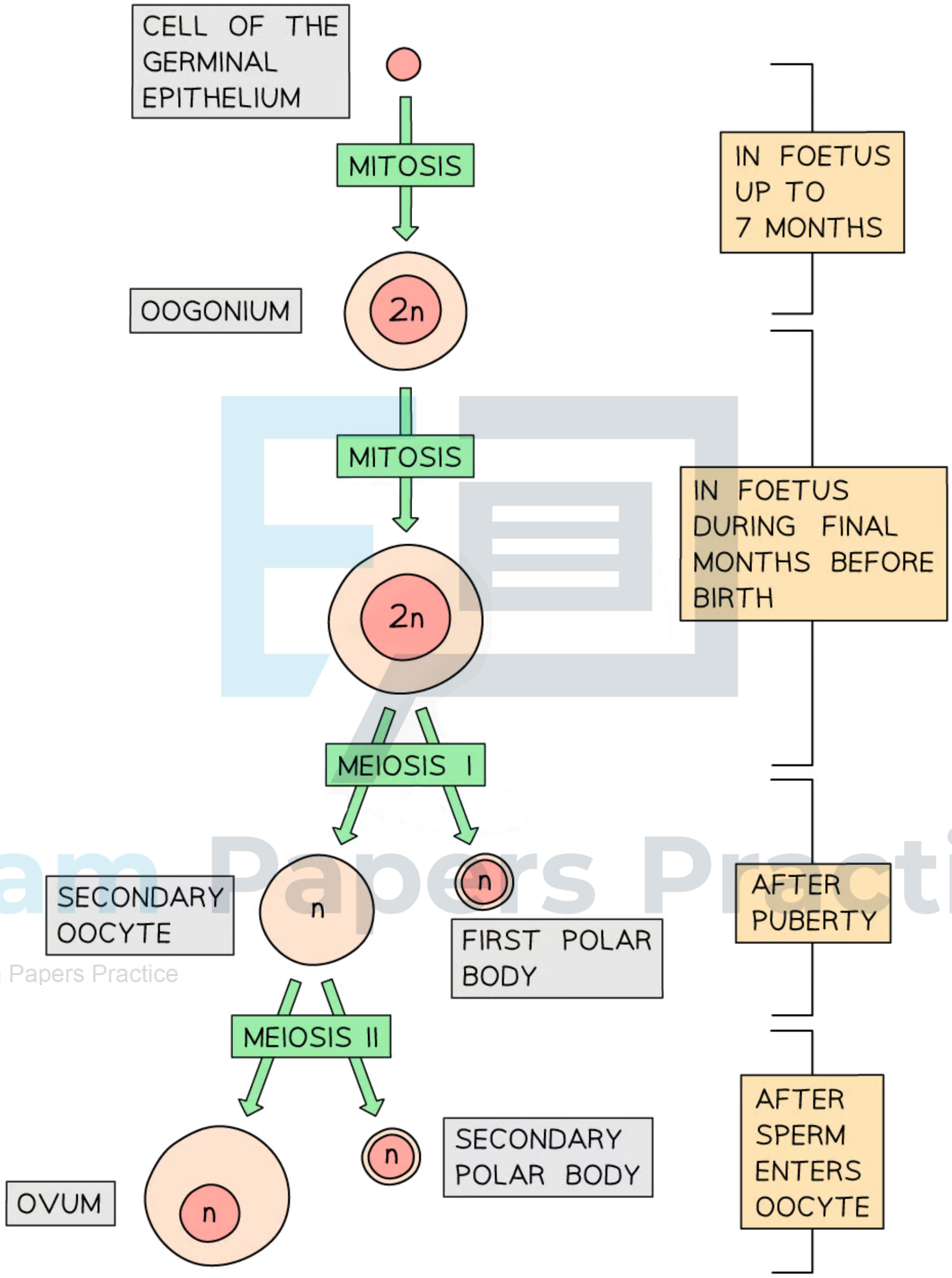
Spermatogenesis begins in the germinal epithelium of the seminiferous tubules and the new cells migrate towards the tubule lumen as they differentiate. Both mitosis and meiosis are involved.

Oogenesis

- The production of **ova** begins **in the ovaries of the female foetus** before birth
- The ovaries are surrounded by an **outer layer of cells** called the **germinal epithelium**; the cells in this layer **divide by mitosis** throughout the first 7 months of foetal development to form **diploid cells called oogonia** (singular oogonium)
  - The oogonia **migrate throughout the tissues of the ovaries**
  - This process of oogonia formation **stops after 7 months**, by which time several million oogonia have been produced
  - These are all the oogonia that the ovaries will produce in the female's lifetime
- During the **few months leading up to birth**, the oogonia in the foetus' ovaries **grow in size** and enter **meiosis I**, and a **layer of cells** called **follicle cells** develop around them
  - The partially divided oogonia together with their layer of follicle cells are known as **primary follicles**
- Once the oogonia have developed into primary follicles the **oogenesis process pauses** until the start of puberty
  - Although the ovaries contain several million primary follicles at birth, many of them degrade throughout a woman's life and never reach maturity
- When puberty begins, the hormone FSH stimulates the **continued development of several primary follicles** in the ovary
  - **Only one** of the stimulated follicles will reach **maturity**
- **Meiosis I continues** and the primary follicle divides to form **two new cells**
  - The division of cytoplasm is **not equal** and the result of meiosis I is a **secondary oocyte** along with a **very small cell** called a **polar body**
  - The polar body cell has **very little cytoplasm** and **does not mature further**
- The secondary oocyte formed at the end of meiosis I enters **meiosis II**; at this point, it leaves the ovary, together with its layer of follicle cells, in the process of **ovulation**
  - The remains of the follicle that are left behind in the ovary develop later into the **corpus luteum**
- The secondary oocyte **doesn't finish meiosis II until after a sperm cell enters it**, at which point meiosis II finishes **just before the nuclei fuse**
  - The secondary oocyte **becomes an ovum very briefly** between the end of meiosis II and the fusion of the two nuclei
  - A **second polar body** is produced at the completion of meiosis II

Oogenesis diagram


OVARY
GERMINAL EPITHELIUM
CORPUS LUTEUM
OOGONIUM
OVULATION
PRIMARY FOLLICLE
6
1
5
2
LAYER OF FOLLICLE CELLS
3
4
SECONDARY OOCYTE
GROWTH OF PRIMARY FOLLICLE



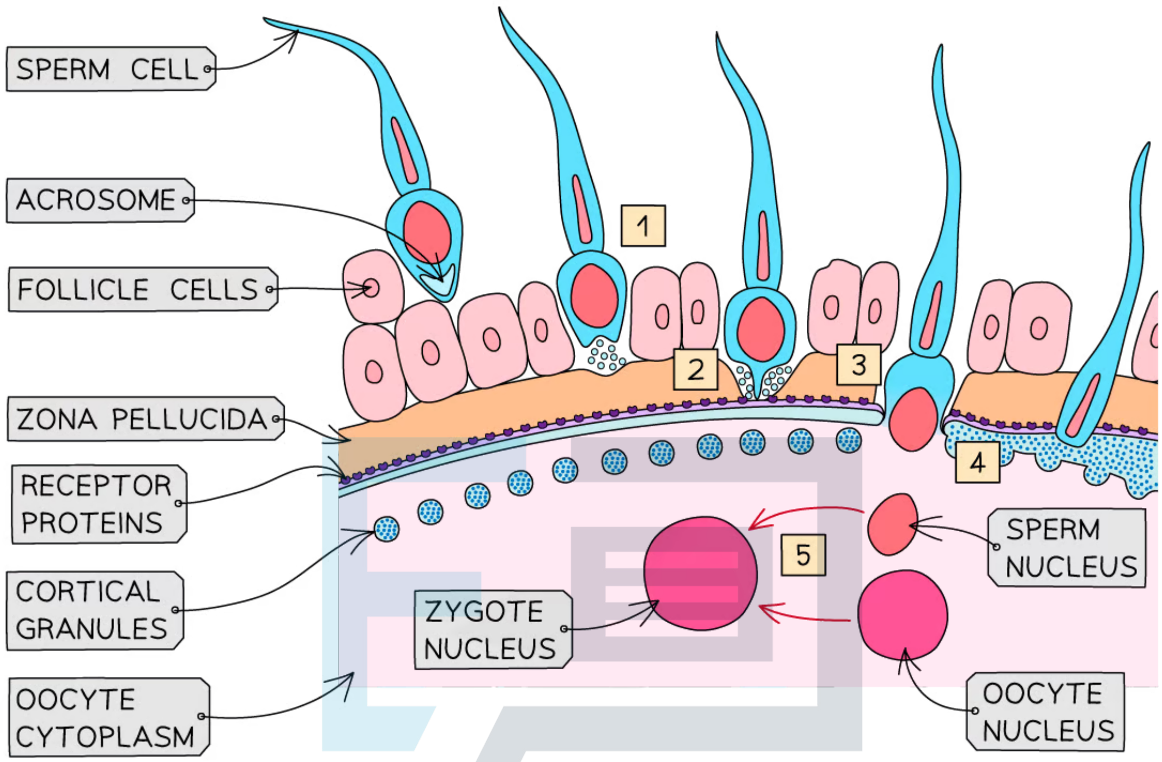
Oogenesis also begins in the germinal epithelium before new cells migrate through the tissues of the ovary. Both mitosis and meiosis are involved.

Fertilisation & Implantation (HL)

Preventing Polyspermy During Fertilisation

- Fertilisation is the **fusion** of **one sperm cell** and **one ovum**; this fusion of two haploid nuclei gives rise to a diploid zygote
- During sexual reproduction, **many sperm are released**, and the sperm cells are attracted towards the secondary oocyte by chemical signals
    - Remember that at this point in the oogenesis process, meiosis II has not yet been completed, so **the female gamete is still a secondary oocyte** and not yet an ovum
- When the sperm cells reach the secondary oocyte, the process that takes place at its cell surface **prevents more than one sperm from passing through its cell surface membrane**
    - The entry of more than one sperm into a single oocyte is known as **polyspermy**
- The oocyte is surrounded by a **layer of follicle cells**, as well as a layer of glycoproteins known as the **zona pellucida**
- The sperm cells need to **digest the glycoproteins of the zona pellucida** in order to reach the oocyte cell surface membrane; they do this by **releasing digestive enzymes from a structure called the acrosome**
    - This is known as the acrosome reaction
- When the first sperm cell digests its way through the zona pellucida, it reaches the oocyte cell surface membrane; **complementary receptors on the head of the sperm bind with proteins on the oocyte cell surface membrane**, enabling the cell surface membranes of the two gametes to **fuse together** and the sperm nucleus to enter the oocyte
    - At this point the process of meiosis II continues, leading to the release of the second polar body and the **formation of the mature ovum**
- The fusion of the two cell surface membranes triggers the **movement of a series of vesicles called cortical granules**; the vesicles move from the outer layer of the ovum cytoplasm to the cell surface membrane, **releasing enzymes that digest the binding proteins on the cell surface of the ovum** and that **cause the zona pellucida to harden**
    - This is the cortical reaction
    - The enzymes are released by the process of exocytosis
    - Once the binding proteins have been broken down and the zona pellucida has hardened, **no more sperm cells can enter** the ovum; **polyspermy is prevented**
- Inside the ovum the **male and female nuclei fuse** together and **fertilisation is completed**

Preventing polyspermy diagram



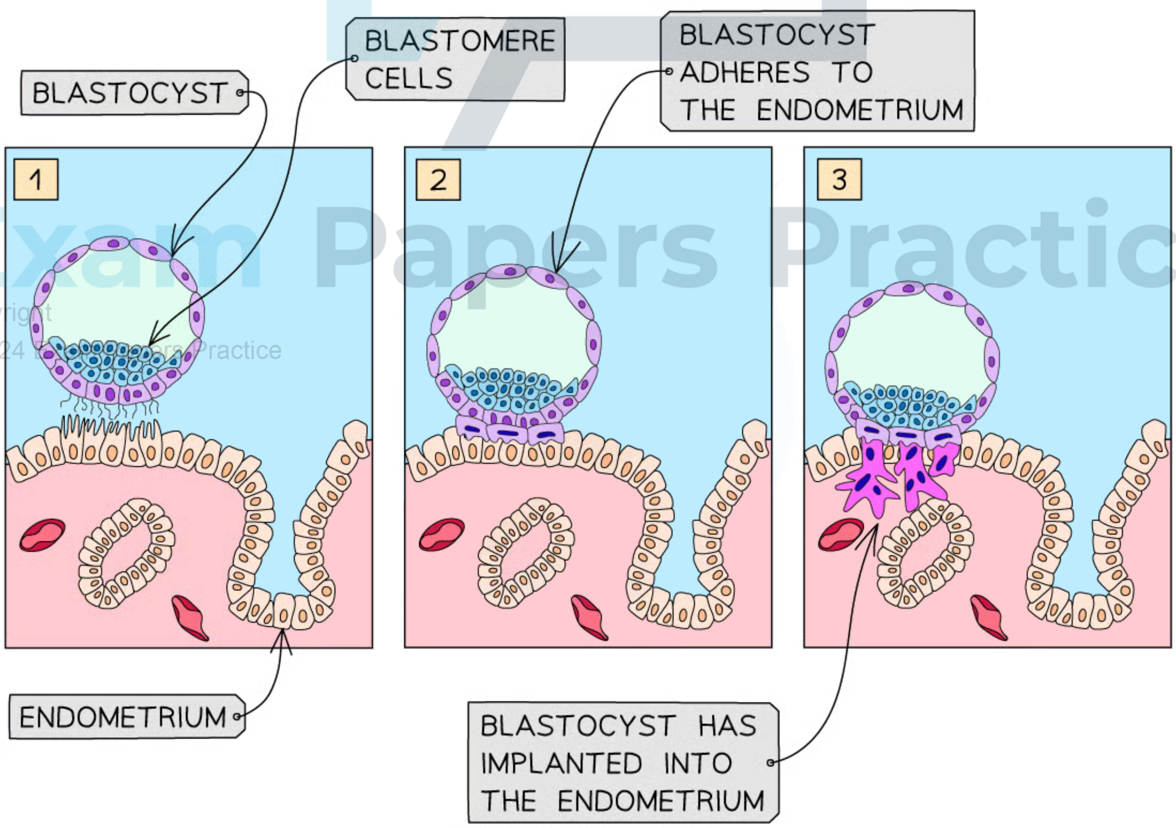
1	ENZYMES FROM THE ACROSOME DIGEST THE ZONA PELLUCIDA
2	THE SPERM BINDS TO RECEPTORS ON THE OOCYTE CELL SURFACE MEMBRANE
3	THE SPERM AND OOCYTE CELL SURFACE MEMBRANES FUSE AND THE SPERM NUCLEUS ENTERS THE OOCYTE
4	ENZYMES RELEASED FROM THE CORTICAL GRANULES DIGEST RECEPTOR PROTEINS AND HARDEN THE ZONA PELLUCIDA
5	FERTILISATION IS COMPLETED

Mechanisms during the process of fertilisation prevent polyspermy

Blastocyst Development & Implantation

- Following human fertilisation, the newly **fertilised ovum divides by mitosis** to form **two diploid nuclei** (i.e. each nucleus contains two sets of chromosomes) and the cytoplasm divides equally to form a two-cell embryo
- Mitosis continues to form a four-cell embryo and this process continues until eventually, the embryo takes the shape of a hollow ball called a **blastocyst** (with an internal group of cells called **blastomeres**)
  - Blastomeres will eventually develop into the **foetus**
- The embryo is now referred to as a blastocyst and up until this point is found **in the oviduct**
- After about seven days it consists of around 125 cells and will have reached the **uterus**
- During the embryo stage and up until this point the blastocyst is surrounded by a **protective extracellular coat** called the **zona pellucida**; at around seven days of age this coat breaks down and is lost
- The blastocyst has used up the nutrient supplies of the egg cell and now needs an external supply of **nutrients**, which it obtains by **implanting** into the **endometrium** (uterus lining)
- The outer layer of the blastocyst develops finger-like projections that allow it to **penetrate** the endometrium
- At this stage, there is already an **exchange of nutrients and oxygen with the mother's blood**
- The embryo continues to grow and develop rapidly after this point

Implantation of the blastocyst diagram



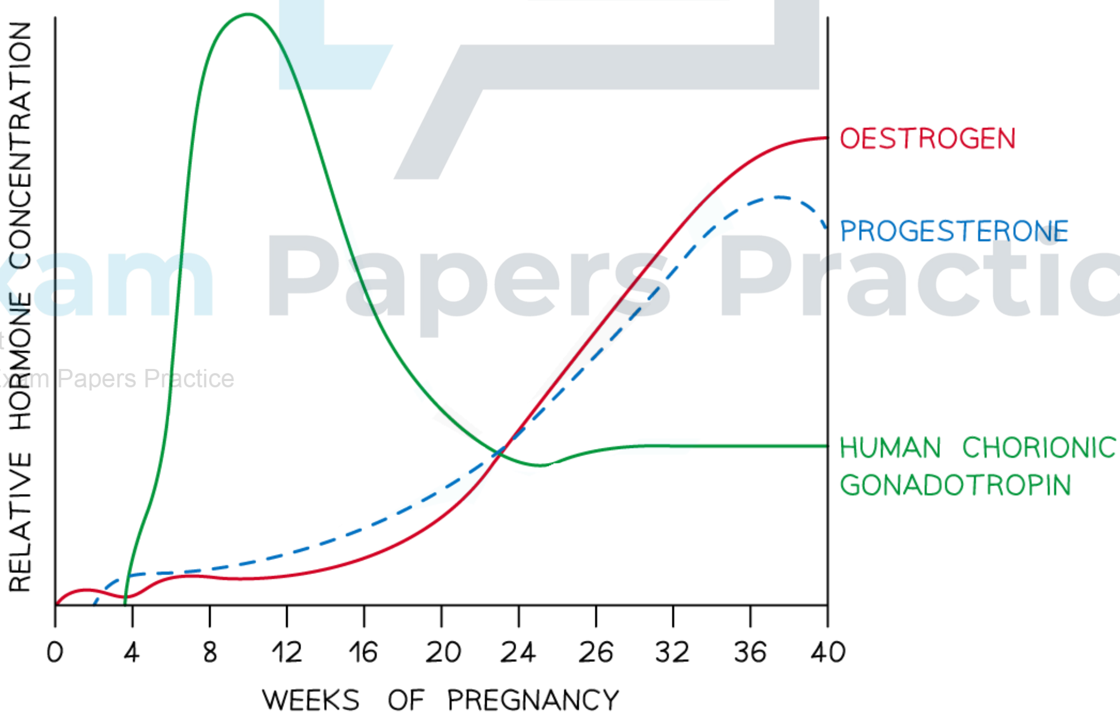
The blastocyst implants into the endometrium of the uterus

Hormones in Pregnancy (HL)

Human Chorionic Gonadotropin

- Shortly after the developing embryo implants into the endometrium it begins secretion of the hormone **human chorionic gonadotropin** (hCG)
- hCG is secreted during the first **8–10 weeks** of pregnancy
- The role of this hormone is to:
  - **Stimulate the corpus luteum** in the ovary to **maintain secretion of oestrogen and progesterone** (in order to continue the development of the endometrium)
  - **Stimulate** the **growth of the placenta** and **uterine enlargement**
  - **Inhibit menstruation**
- During the second trimester (after **12 weeks**) hCG **declines** and the placenta takes over the role of stimulating the secretion of oestrogen and progesterone
- Pregnancy tests detect the presence of hCG in the mother's urine and can be used to confirm a positive pregnancy

Hormone changes during pregnancy graph

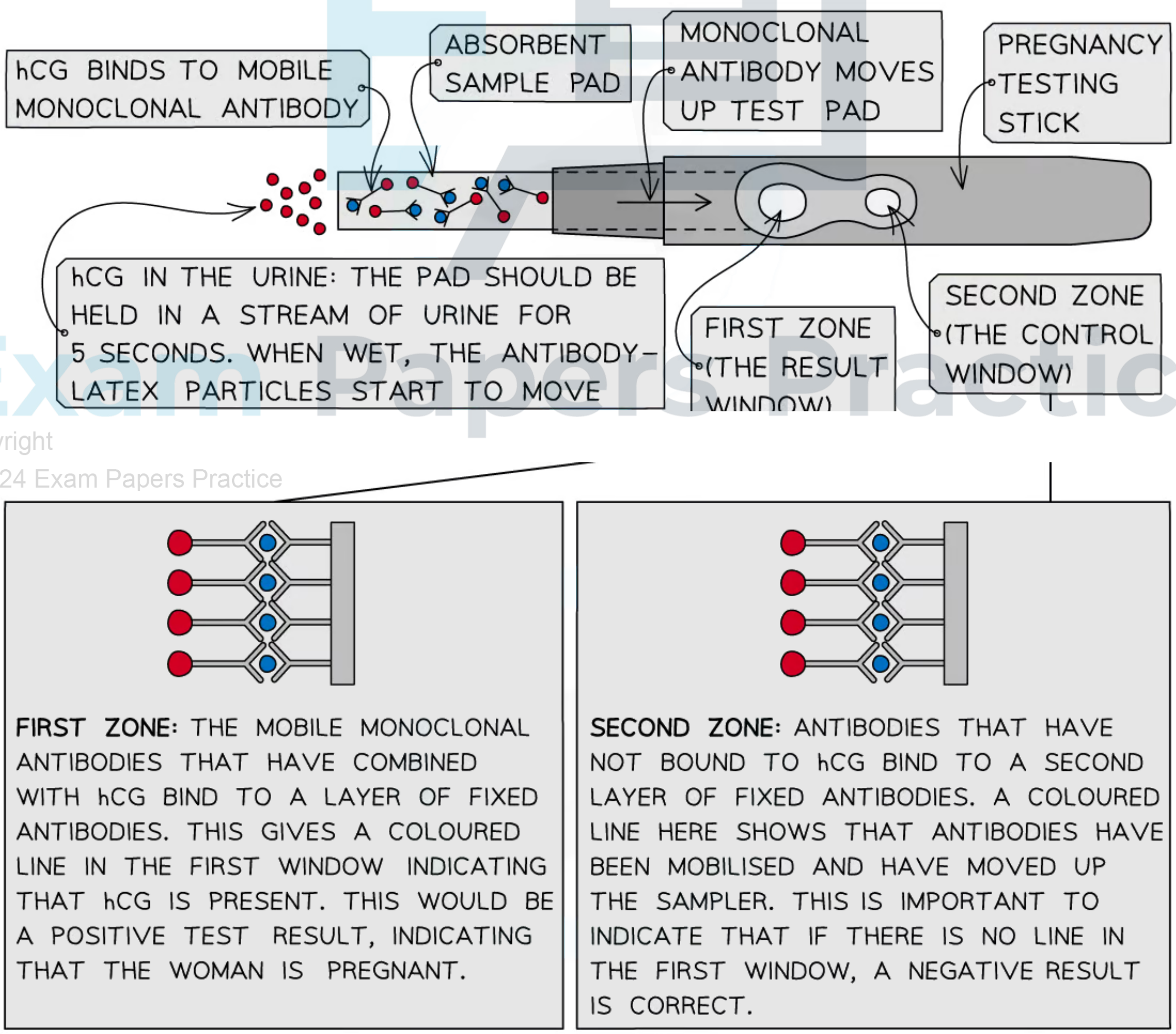


hCG increases during the first 12 weeks of pregnancy to stimulate the release of oestrogen and progesterone; after 12 weeks hCG declines as the placenta takes over

Pregnancy tests

- The confirmation of a pregnancy during the early stages can be through the **presence of hCG**
- This is detected in the the mother's blood and urine
- A pregnancy test kit makes use of a specific type of antibody called a **monoclonal antibody (mAb) which is used to detect the presence of hCG**
  - Monoclonal antibody is a **single antibody that can be used outside of the body and will react to a specific antigen, in this hCG**
  - When using a pregnancy test the mother will urinate onto the test strip, the **urine will contain higher levels of hCG** if the mother is pregnant
  - The urine, containing the hCG will travel along the test strip of the pregnancy test; the test strip contains the **monoclonal antibodies which bind to the hCG (if present) and lead to a colour change within the pregnancy test** which can be seen and inform the mother that she is pregnant
  - If there is no colour change it means that hCG is not present (in high enough concentrations) to bind to the monoclonal antibodies and give the colour change

Pregnancy test diagram



Monoclonal antibodies are used to detect the presence of the hormone hCG in the urine of pregnant women

Hormonal Control of Pregnancy & Birth

The role of progesterone

- The hormone progesterone is secreted by the placenta throughout pregnancy
- Progesterone **inhibits the production** of another hormone, **oxytocin**, by the **pituitary gland**
- Progesterone **inhibits contractions** of the **muscles** of the uterus wall (the **myometrium**), which could induce birth if not inhibited
- At the **end of pregnancy**, the **foetus** produces the hormone **oestrogen**, which signals to the placenta to **stop producing progesterone**, thereby **initiating the production of oxytocin** by the pituitary gland and the start of labour (and the start of the muscular contractions that eventually lead to the birth of the baby)

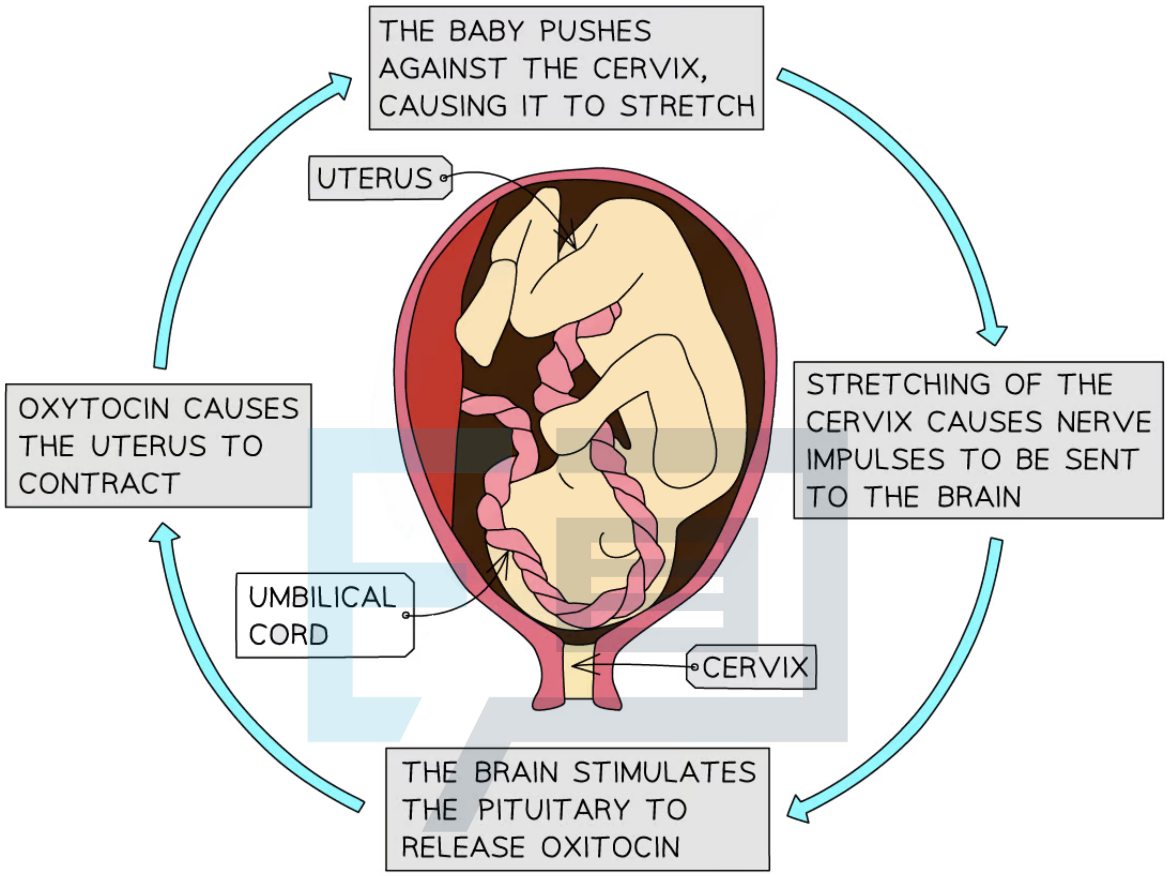
The role of oestrogen

- At the end of pregnancy, the hormone **oestrogen** is produced by the **foetus** and the **placenta**
- Oestrogen makes the **uterine wall more sensitive to oxytocin**
- **Progesterone** is also **inhibited** by oestrogen

Labour

- Oxytocin now stimulates **contractions** of the muscles in the **myometrium**
  - Oxytocin is released by the pituitary gland in the brain
- **Stretch receptors** in the **cervix** detect the contractions and signal the pituitary gland to **increase oxytocin secretion**
- More oxytocin creates **further contractions**, which in turn signal for **further release of oxytocin** in this **positive feedback loop**
- This process increases the contractions slowly and rhythmically

Positive feedback loop diagram



The positive feedback loop stimulates the release of oxytocin and causes the contraction of the uterus wall

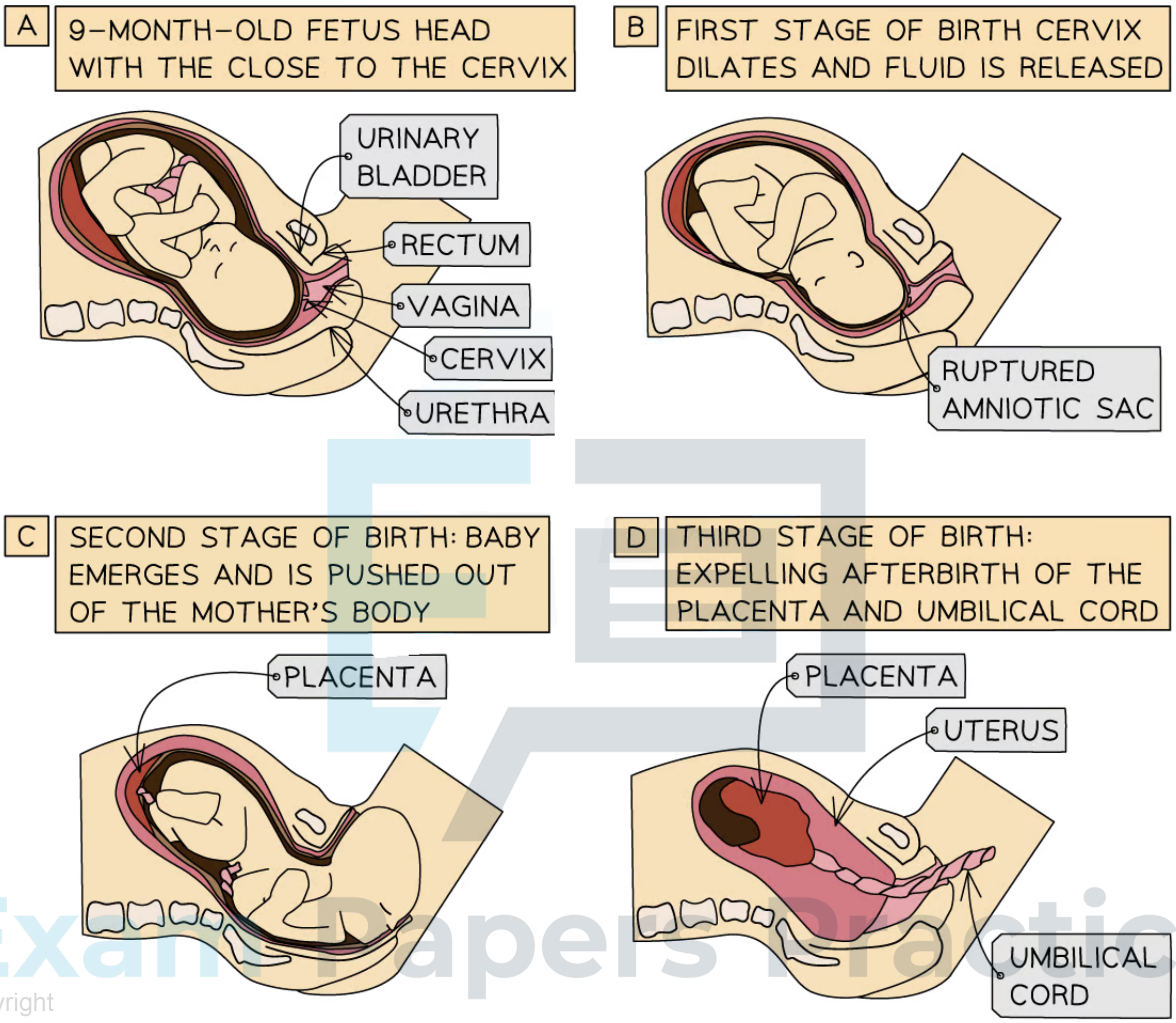
Birth

- **Relaxation** of the **cervix muscles** causes the cervix to **dilate** and **widen**
- Uterine contractions continue and cause the **amniotic sac to burst**, releasing the amniotic fluid through the open cervix
- The baby is **pushed out** through the **cervix** and **vagina** as contractions continue
- As the umbilical cord is cut, the baby is **physiologically separated** from the mother

Afterbirth

- After the baby has been delivered, **uterine contractions continue** and the placenta will separate from the uterine wall
- The mother will then **birth the placenta** and remains of the umbilical cord

Stages of birth diagram



The stages of birth, which are initiated by the hormone oxytocin

The Placenta (HL)

The Placenta & the Exchange of Materials

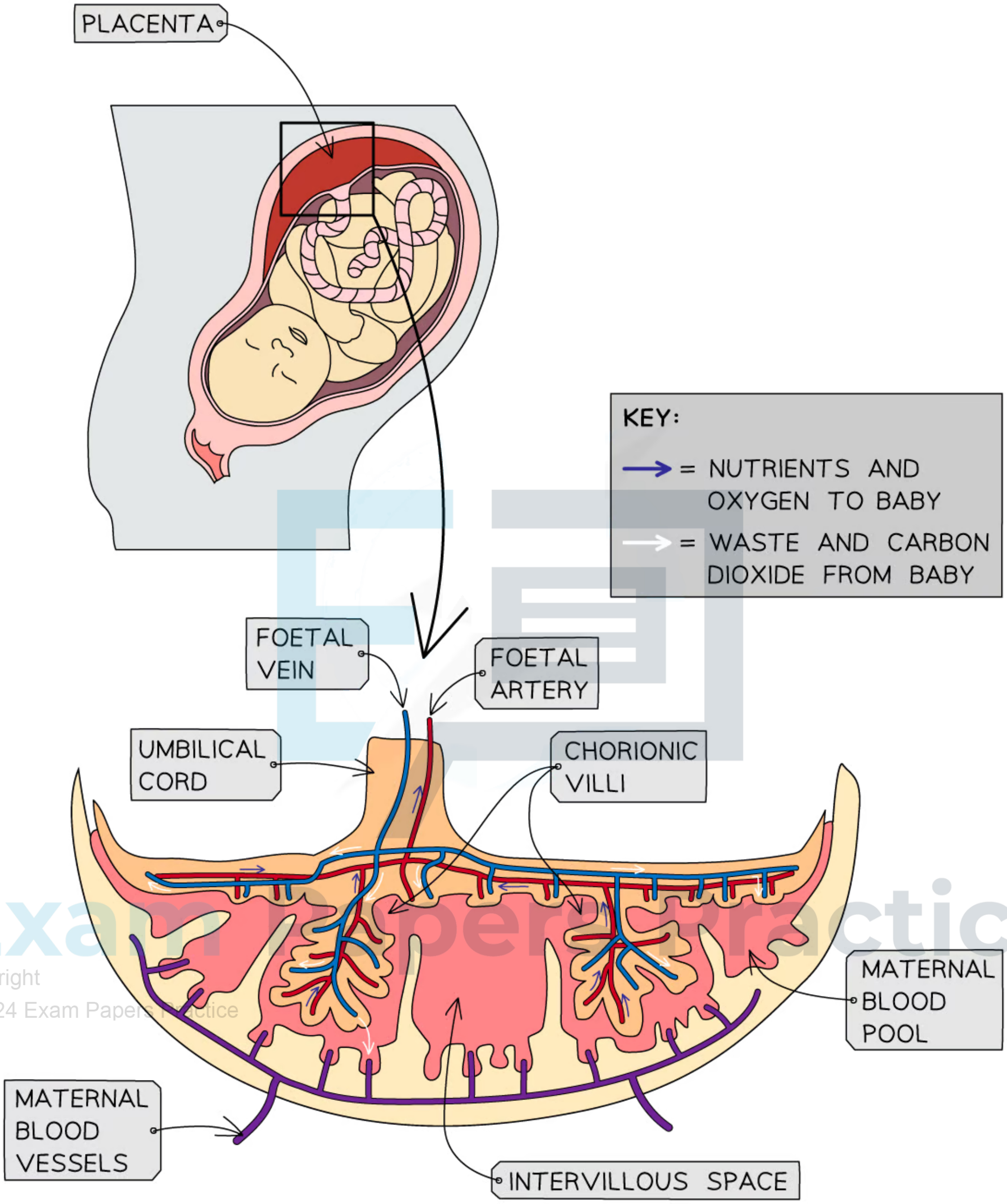
- Mammals can be split into different categories on the basis of their **mechanism for foetal nourishment**
  - **Placental** mammals, such as humans
  - **Monotremes**, or egg laying mammals, such as a platypus
  - **Marsupials,** such as kangaroos, whose offspring develop in a pouch
- **Placental mammals** rely on the complex system of **blood vessels** specially designed to maximise exchange of substances between mother and foetus without any direct connection between them
- The placenta is also responsible for **production of key pregnancy hormones** oestrogen and progesterone
- The foetus is connected to the placenta via the **umbilical cord** and is contained within the **amniotic sac** filled with **amniotic fluid** which protects the foetus

Structure of the placenta

- The placenta is an organ primarily made up of a complex arrangement of **blood vessels arranged into placental,** or **chorionic, villi** with maternal blood flow distributed around the villi
  - Throughout the course of the pregnancy, the number of villi increases to meet the demands of the growing foetus
- **Maternal blood and foetal blood never mix directly**, but flow either side of a layer of cells that make up the placental barrier; there is a very short distance between the maternal and foetal blood to allow **exchange of nutrients and gases**
  - The mother's blood flows **out of the mother's blood vessels** and forms pools in the spaces surrounding the placental villi; these spaces are known as the **inter-villous spaces**

- The **placental membrane,** or **barrier,** provides a selectively permeable barrier which restricts the exchange of substances between mother and baby
- Substances that move across the barrier **from mother to foetus** include
  - **Oxygen**
  - **Antibodies**
    - Antibodies cross the placenta using a mechanism called endocytosis
  - **Water**
  - **Glucose**
  - **Unwanted** or **harmful substances** may also cross the placental barrier, including alcohol, drugs or small pathogens such as viruses
    - Bacterial pathogens are too large to cross the barrier
- Substances that move across the barrier **from foetus to mother** include
  - **Carbon dioxide**
  - **Water**
  - **Urea**
- The placenta is connected to the growing foetus by the **umbilical cord**

The placenta diagram



The placenta brings the maternal and paternal blood systems close but without directly mixing

Exam Tip

You are not required to know details of placental structure apart from the large surface area of the placental villi. You should understand which exchange processes occur in the placenta and that it allows the foetus to be retained in the uterus to a later stage of development than in mammals that do not develop a placenta.

Hormone Replacement Therapy (HL)

Hormone Replacement Therapy & Coronary Heart Disease

- **Hormone replacement therapy** (HRT) is a treatment used to relieve the symptoms of the **menopause**
  - The menopause is when a **female stops having periods** for longer than 12 months. It's a natural part of ageing that usually happens between 45 and 55 years old
- During the menopause the ovaries have stopped releasing eggs (ovulating) and **stopped producing most of their oestrogen and progesterone**, this is in response to the ovaries no longer responding to FSH and LH, two hormones released from the pituitary gland in the brain
- Due to a decrease in oestrogen and progesterone there is no longer a nagative feedback loop from the ovaries to the pituitary gland and so **LH and FSH levels increase**
- These hormonal changes can cause many symptoms in the woman including
  - Hot flushes
  - Breast tenderness
  - Headaches
  - Sleep issues
  - Emotional changes
- HRT can be given to a woman experiencing the menopause
  - This **replaces the hormones oestrogen and progesterone**
  - Oestrogen has many effects all over the body including blood vessels, bone strength, the skin, the urinary tract, the uterus and the brain
  - Taking synthetic oestrogen, in the form of a tablet, patch, cream or gel, can help reduce the symptoms of the menopause

NOS: In early epidemiological studies, it was argued that women undergoing hormone replacement therapy (HRT) had reduced incidence of coronary heart disease (CHD) and this was deemed to be a cause-and-effect relationship. Later randomized controlled trials showed that use of HRT led to a small increase in the risk of CHD

- Almost 40 years ago, epidemiological observational study on the effect of HRT showed that the **use of HRT led to a small decrease in the risk of developing** coronary heart disease (CHD)
  - Women who took HRT had a lower risk of heart disease than those that did not
  - This lead to many women choosing, and being advised, to take HRT for this benefit
  - The effect was deemed to be a **cause-and-effect relationship**
- Randomised controlled trials in the 1990s showed that the **use of HRT may cause increased risk of heart disease**
- New evidence suggests the "timing hypothesis" has to be considered when investigating the link between HRT and CHD

    - HRT started in the early years of the menopause, does provide benefit to the heart with reduced risk of CHD
    - The timing hypothesis suggests that the difference from the early observational studies and the randomised trials is because the randomised trials included many women who were several years postmenopausal, whereas the observational studies included women who were in the early menopausal years
- The **correlation between HRT and decreased incidence of CHD is not actually a cause-and-effect relationship**
    - In general, women who take HRT are more educated, wealthier, have healthier lifestyles, and have fewer cardiovascular risk factors
    - A meta-analysis study showed that the previously observed reduced risk for CHD among HRT users was decreased when analysis included **socioeconomic status**