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Key Takeaways

1. Sexual dimorphism
2. Male reproductive system
3. Male external genitalia
4. Male internal genitalia
   - Penis
   - Scrotum
5. Male accessory glands and ducts
6. Journey of sperm
7. Semen
8. Hormonal control in male
9. Male sex act

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17 Mammary glands

Lactation 18

19 Hormonal control of female reproductive system

20 Gametogenesis

Spermatogenesis

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Spermatocytogenesis

22 Structure of sperm

Spermiogenesis

23 Oogenesis

Fate of graafian follicle and secondary oocyte

24 Ova development in embryo

Folliculogenesis

25 Fertilisation

26 Journey of ovum

27 Sexual intercourse

28 Journey of sperm

29 Capacitation

30 Fusion of gametes

31 Embryonic development

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33 Gender determination

41 Post implantation events

Placenta 42

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45 Foetal ejection reflex

Parturition 46

47 Lactation

Menstruation 35

36 Ovarian cycle

Uterine cycle 37

38 Lack of menstruation

Menstruation cycle 39

40 Menstrual care

Summary

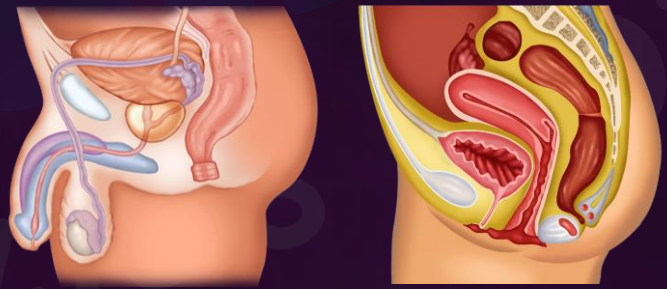
Sexual Dimorphism

Di = Two **Morphism** = Forms

Distinct male and female individuals exhibiting different characteristics

Male Female

Morphological dimorphism:
Differences in external features



Male Female

Anatomical dimorphism:
Differences in internal features

- These internal and external features lead to behavioural changes i.e., the way men and women think, act, etc.
- Many of these are hormone driven.
- However, some of them also depend on the society we live in and our upbringing.

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Male Reproductive System

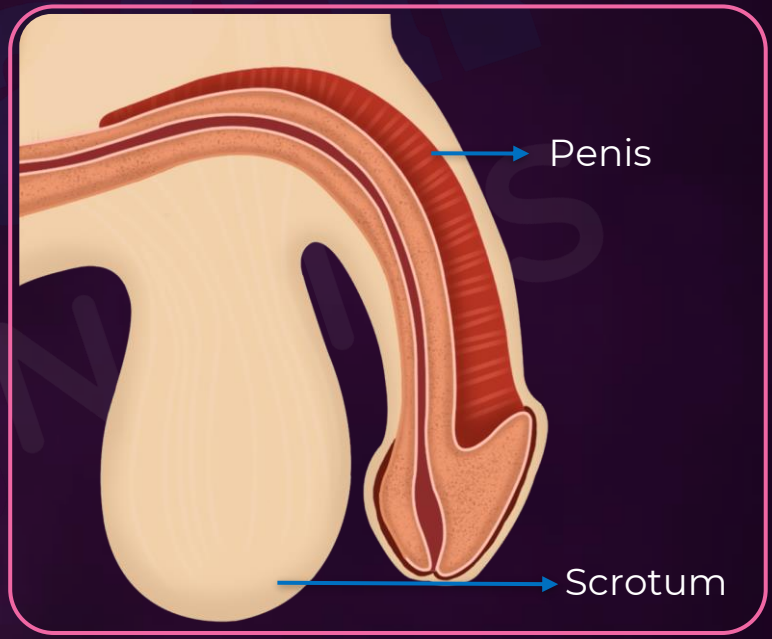
Male reproductive system

Primary sex organs (Gonads)

- They are directly involved in the process of gamete production.
- They also produce sex hormones.
- Male gonads are testes

Secondary sex organs

- They help in transportation, maturation and storage of gametes.



It includes penis and scrotum.

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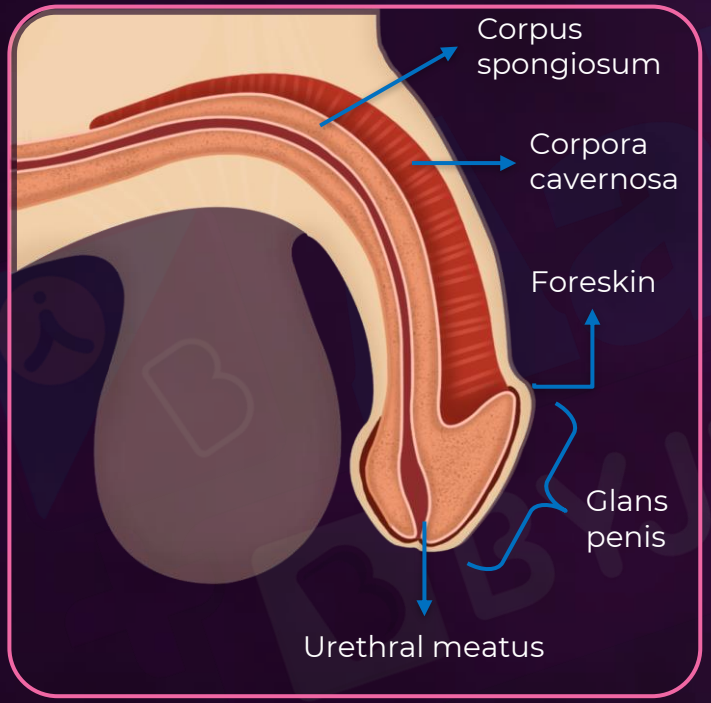
Male External Genitalia



Penis

- Conducts urine and sperm
- Has erectile tissue to transfer sperm into the female genital tract
- Has an opening called urethral meatus
- Has an enlarged end called glans penis
- Covered by a sheath known as foreskin
- Erectile tissues surrounding the urethra in penis aid in process of penis becoming hard and erect.

Erectile tissues

- Corpus spongiosum
- Corpora cavernosa

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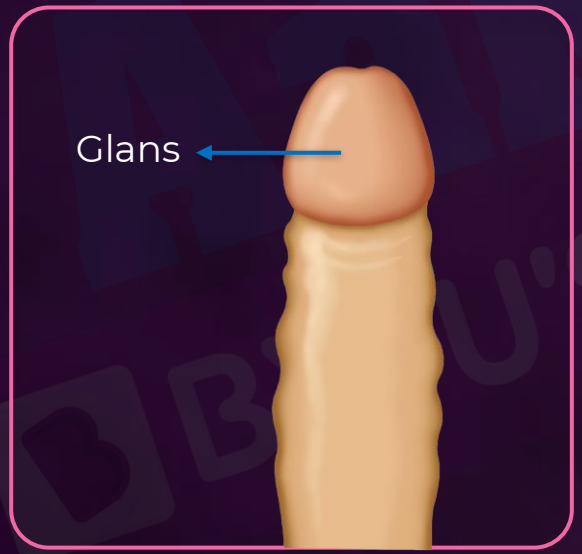
Did you Know?

- Removal of the foreskin is an elective procedure called circumcision.
- Circumcised men have lower risk of HIV infection.



Circumcised penis

Uncircumcised penis

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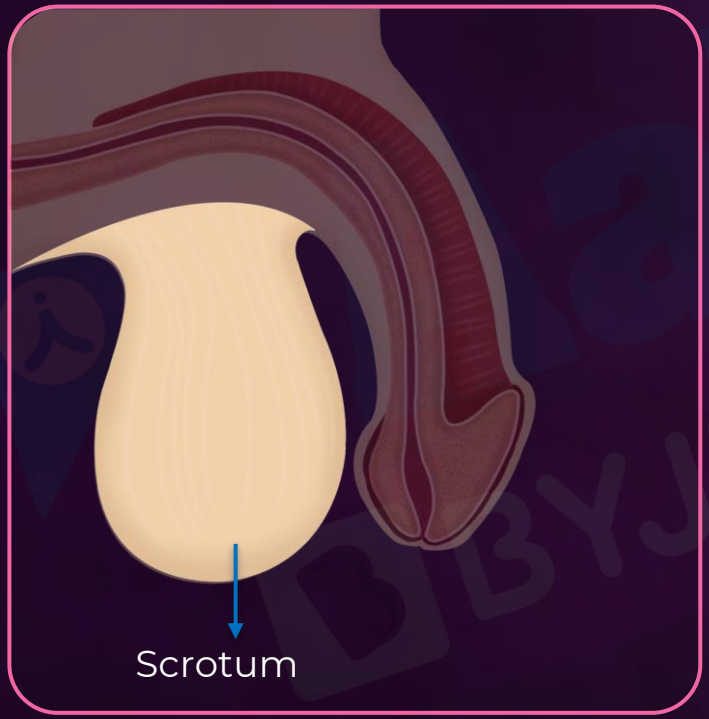
Male External Genitalia



Scrotum

- Present outside the abdominal cavity
- Sac like structure
- Contains testes
- 2-2.5°C lower than body temperature: Ideal for sperm production and viability
- Testes hang in scrotum with the help of spermatic cord
- Spermatic cord consists of blood vessels, lymph vessels, nerves and cremaster muscles.

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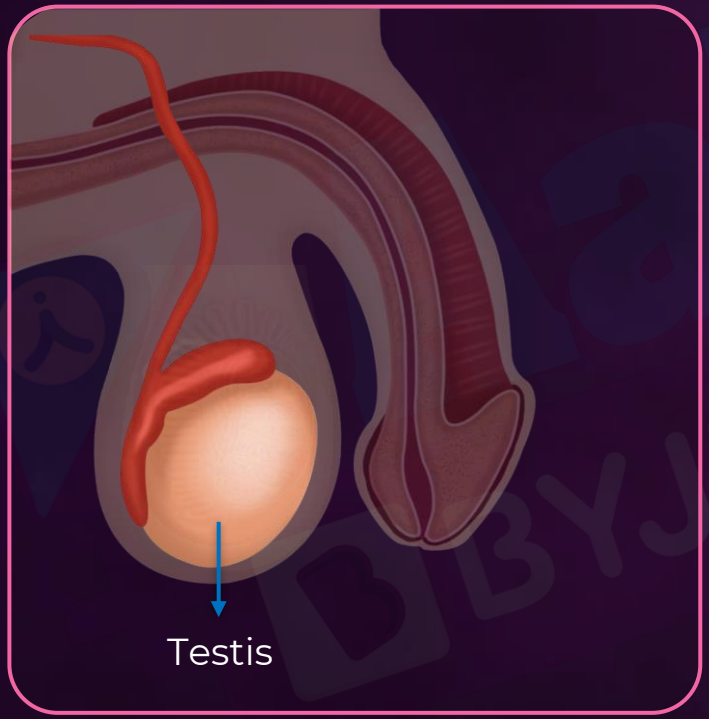
Male Internal Genitalia



Testes

- 4-5 cm long, 2-3 cm wide
- Function: Production of sperms and secretion of androgens (male sex hormones)
- Extra-abdominal in most of the mammals (because sperm production, maturation, storage and survival requires 2-2.5℃ lower temperature than that of body temperature)
- Intra-abdominal in egg laying mammals (prototherians), elephants, whales, dolphins (located in main body cavity).

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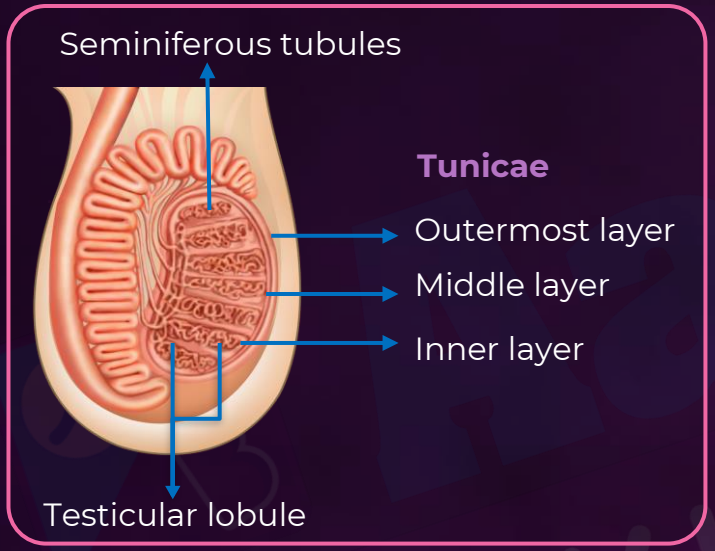
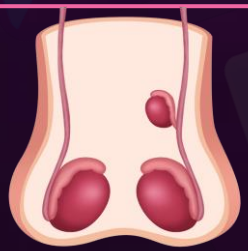
Male Internal Genitalia




Polyorchidism

Presence of more than two testes is a very rare congenital anomaly

Testes

- Surrounded by three layers called tunicae
- Each testes has about 250 compartments called testicular lobules
- Each lobule contains one to three seminiferous tubules
- Testes of male baby are formed during 7^{th} to 8^{th} week of pregnancy and are intra-abdominal
- Testes migrate to scrotum during 7^{th} to 8^{th} month of pregnancy.

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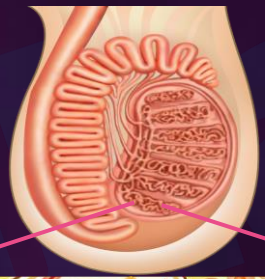
Male Internal Genitalia

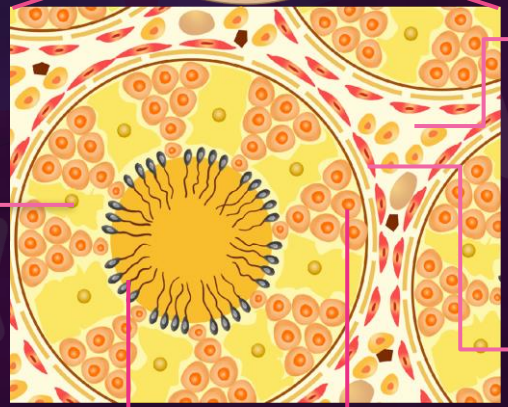
Seminiferous tubules



- One seminiferous tubule is about 70 cm long.

Sertoli cells

- Extend from basement membrane to lumen of tubule
- Provide structural support, nutrition and protection to developing sperms
- They secrete
  - Androgen binding protein (ABP)
  - Inhibin
  - Mullerian inhibiting substance (MIS)



Interstitial space

- Regions outside the seminiferous tubules

Leydig cells

- Synthesise and secrete male sex hormones called androgens

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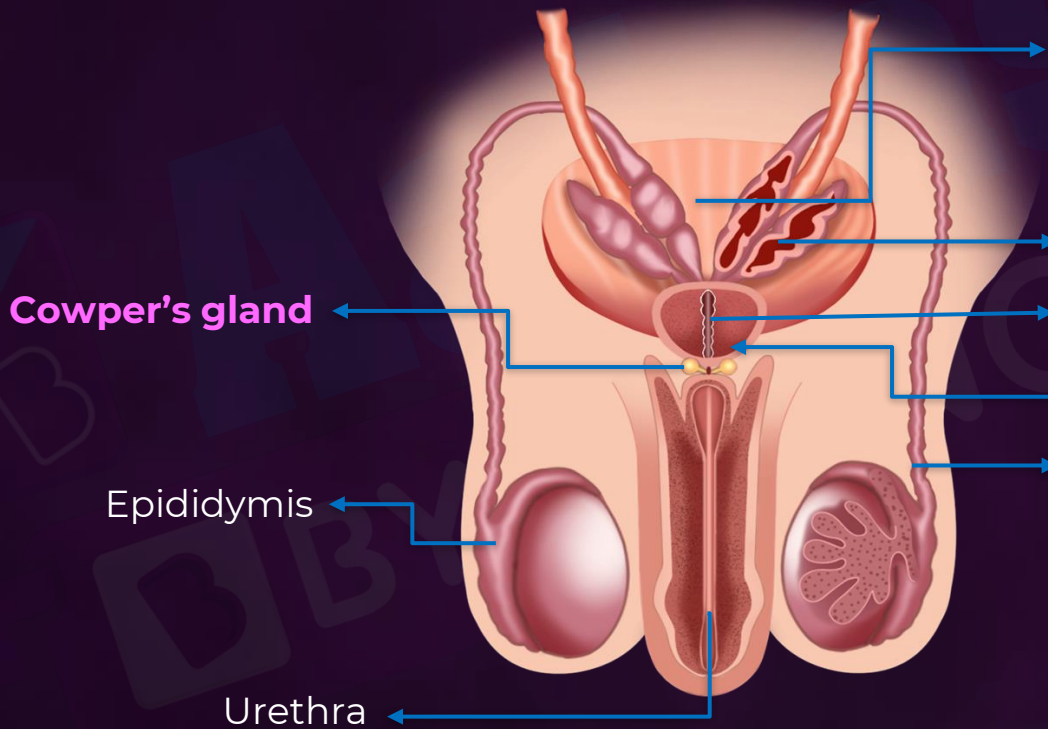
Male Accessory Glands and Ducts



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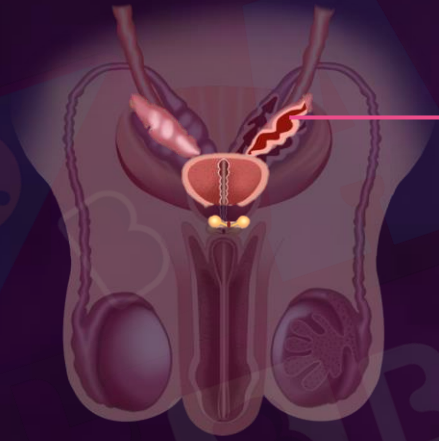
Accessory Glands of Male Reproductive System



Seminal vesicle

- Present at the behind the bladder
- Alkaline secretion: To neutralize male and female tracts
- Secretions contribute 60% of semen
- Contains:
  - Fructose and calcium
  - Prostaglandins
  - Inositol

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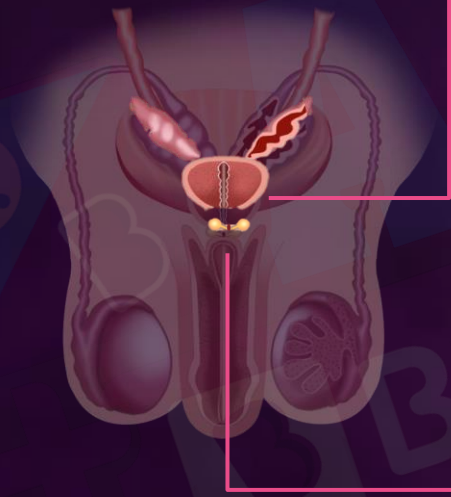
Accessory Glands of Male Reproductive System



Prostate

- Single gland surrounding the urethra
- Contains calcium, phosphate ions, clotting enzymes and fibrinolysin
- Contributes alkaline secretions

Cowper's glands

- Also called bulbourethral glands
- Present on either side of urethra
- Alkaline secretion
- Secretes viscous mucus to lubricate glans penis

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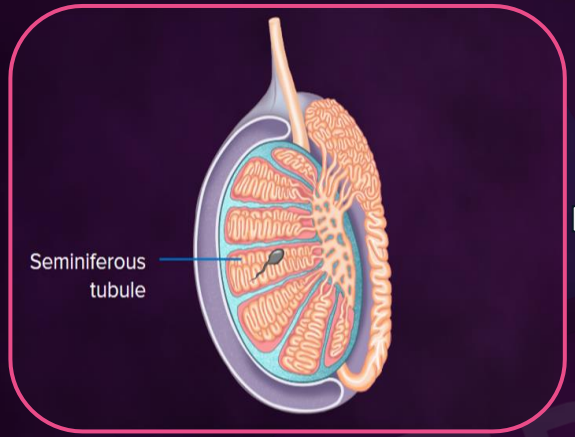
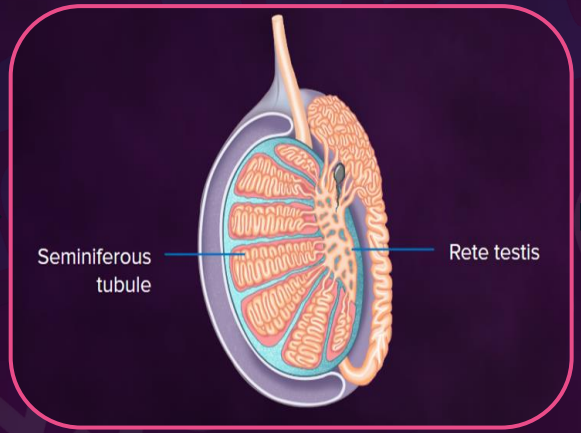
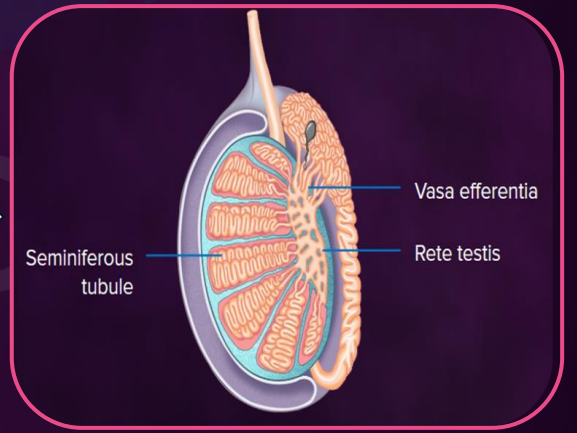
Journey of Sperm



Sperm is produced in the seminiferous tubules.



It passes through rete testis.



It reaches the vasa efferentia.

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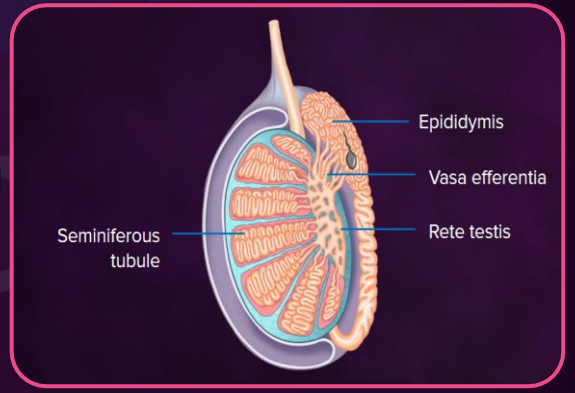
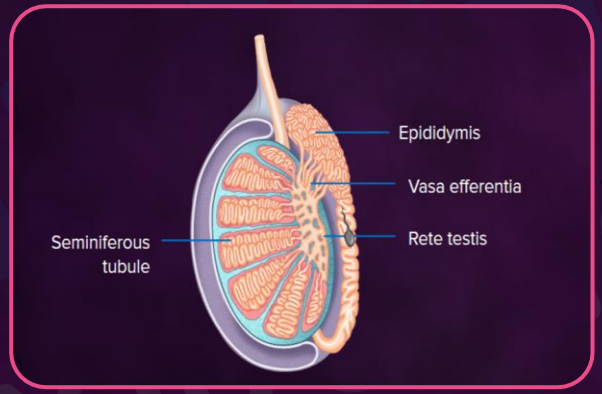
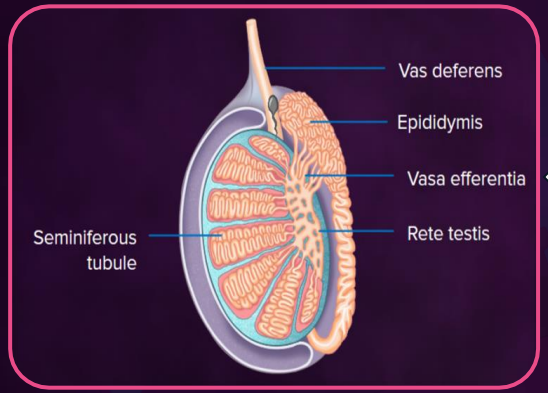
Journey of Sperm



It then leaves the testes to travel through the epididymis



Epididymis is located along the posterior surface of each testis.



Epididymis leads to the vas deferens.

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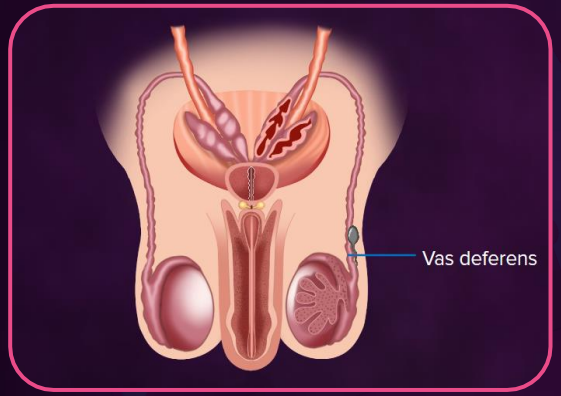
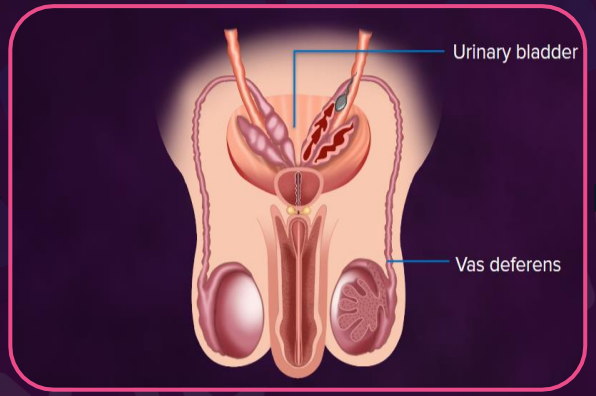
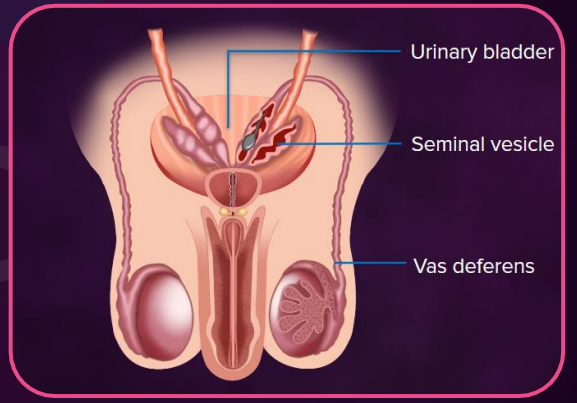
Journey of Sperm



The vas deferens ascends to the abdomen.



It loops over the urinary bladder.



It receives a duct from the seminal vesicles.

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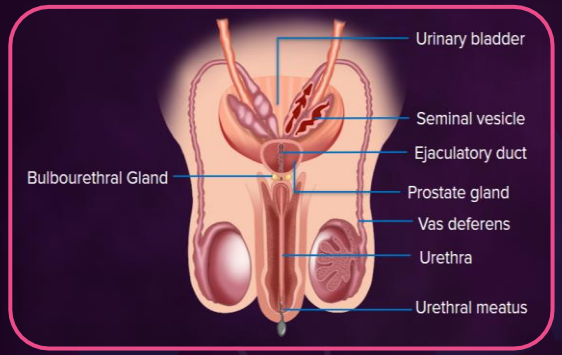
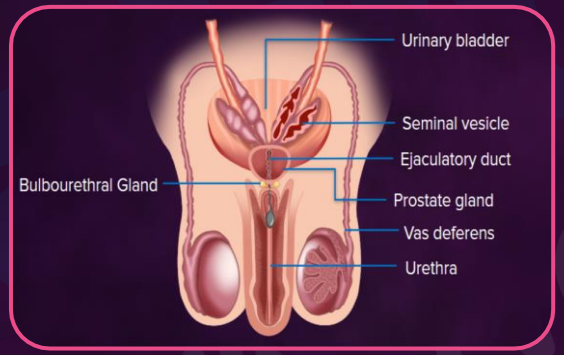
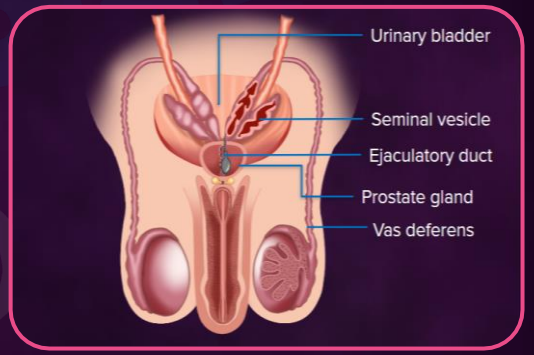
Journey of Sperm



It travels further along the urethra and exits from the external opening called urethral meatus in the penis.



Sperm then reaches the urethra which is a common duct for urine and semen. Here, it receives secretions from the bulbourethral glands.



It travels further along and enters the ejaculatory duct, where it receives secretions from the prostate gland.

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Semen

- Seminal plasma + sperm = semen
- Alkaline
- Ejected from penis during ejaculation

Seminal plasma consists of secretions from

- Seminal vesicle
- Prostate gland
- Bulbourethral gland

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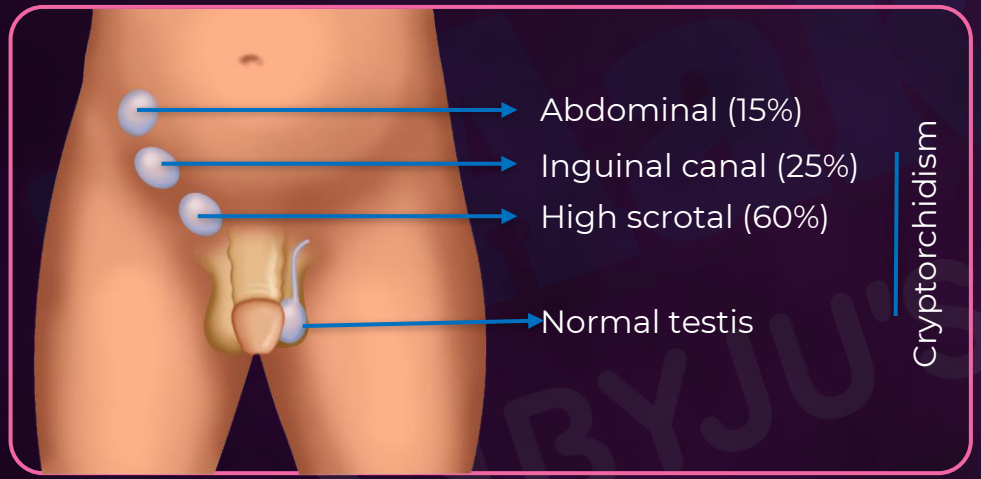
Did you know?

Cryptorchidism



- Failure of testes to descend into scrotum
- Can be due to deficiency of testosterone
- Causes sterility as the testes are not at optimum temperature
- 15% of cryptorchidism is abdominal, 25% inguinal and 60% cases are high scrotal
- Orchidopexy- Surgery performed to correct cryptorchidism.

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Hormonal Control in Male

Hypothalamus increases the secretion of GnRH → **GnRH stimulates anterior pituitary gland** → **Anterior pituitary gland increases the production of ICSH and FSH**

- Sperm production generally begins at teenage when a male enters puberty.
- This is due to a significant increase in the secretion of gonadotropin releasing hormone (GnRH).

Interstitial cell stimulating hormone (ICSH) or luteinising hormone (LH) → **Acts on** → **Leydig cells**

Follicle stimulating hormone (FSH) → **Acts on** → **Sertoli cells**

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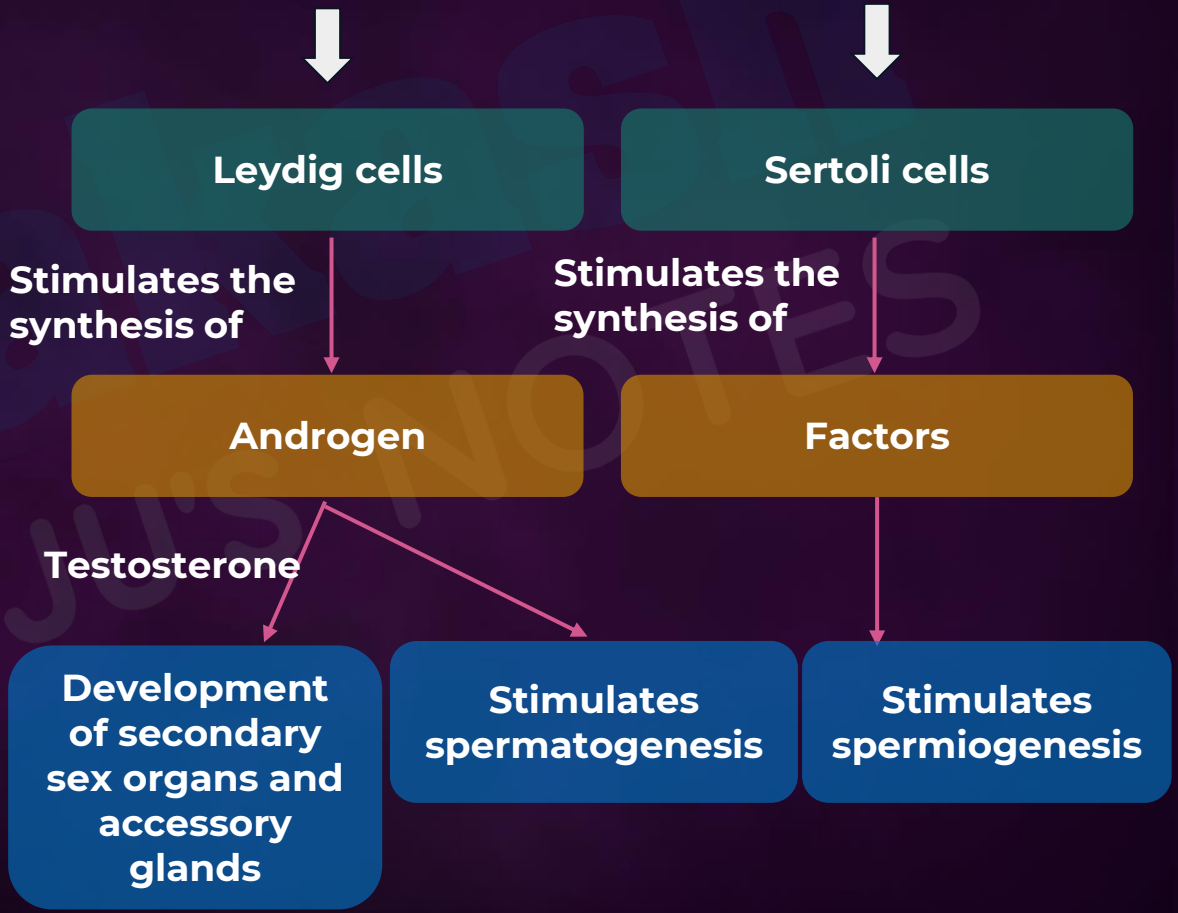
Hormonal Control in Male

- Androgens are sex hormones.
- The major sex hormone in men is testosterone which is produced mainly in the testes.
- Androgens stimulate the process of spermatogenesis.
- Sertoli cells help in the process of spermiation.



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Male Sex Act

1. Erection of penis
   - Rush of blood into sinuses
   - Penis becomes stiff due to hydraulic pressure
2. Copulation
   - Penis discharges the sperm into the vagina by wavelike contractions
   - At the peak of sexual stimulation orgasm occurs
3. Subsidence of erection
   - Arterioles in the penis contract
   - Blood flow to the penis reduces, which subsides the erection

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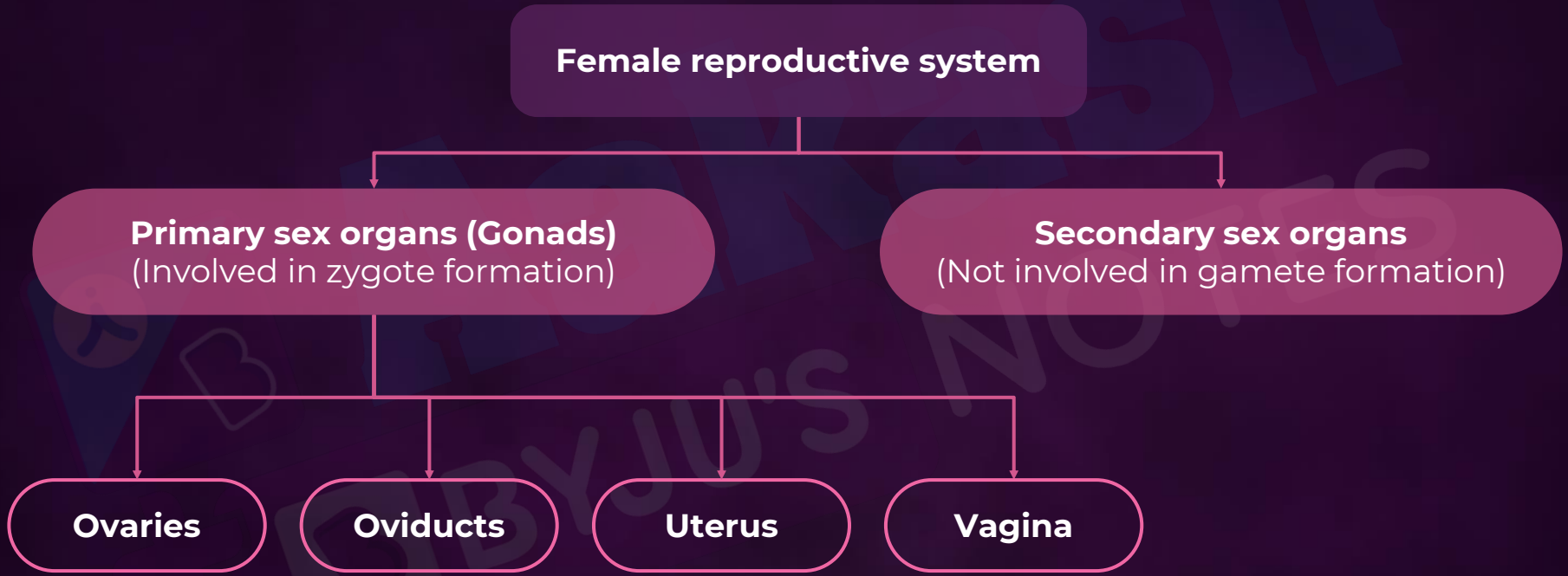
Female Reproductive System



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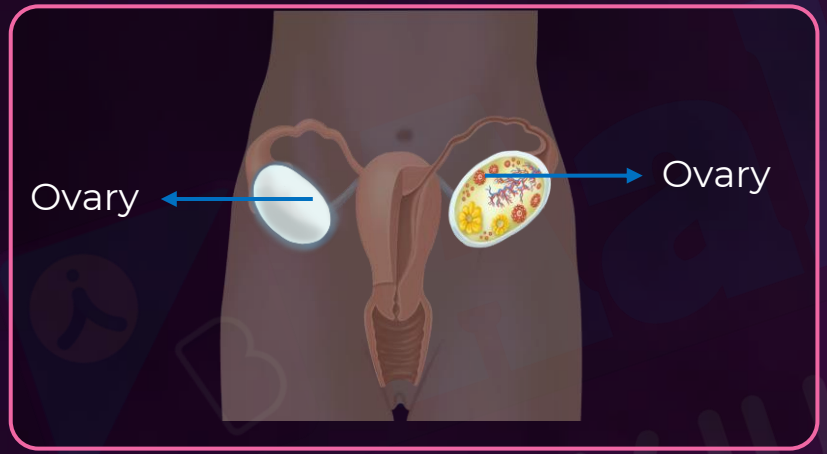
Ovaries



- They are the primary female sex organs.
- They are paired structures.
- They are located in the upper pelvic cavity.
- They produce female gametes called ova.
- They secrete female sex hormones.
- Each ovary contains a point of entry and exit for blood vessels and nerves known as hilum.

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Ovaries

Layers and parts

Germinal epithelium

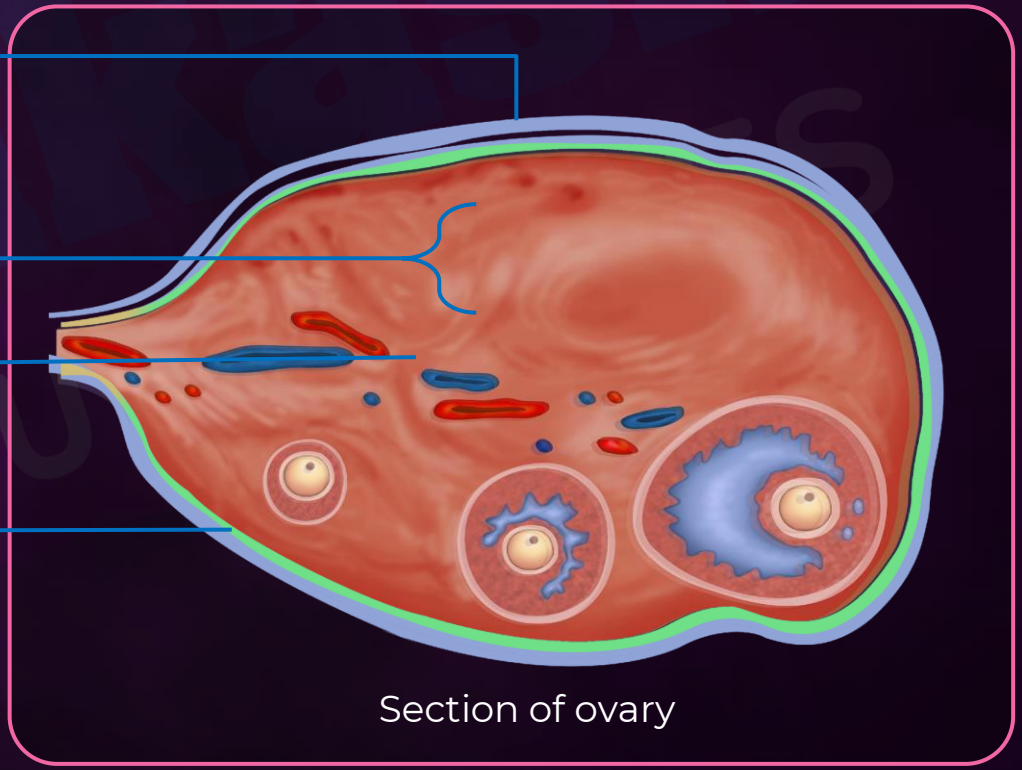
Each ovary is covered by the cuboidal germinal epithelium

Ovarian stroma

- Cortex
- Medulla

Tunica albuginea

Layer of connective tissue present beneath epithelium



Section of ovary

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Ovaries

- Cortex - It is a region inner to the tunica albuginea.
  - It consists of ovarian follicles surrounded by dense, irregular connective tissue that contains collagen fibers and fibroblast-like cells known as stromal cells.
- Medulla - It is a region inner to the ovarian cortex.
  - Medulla consists of more loosely arranged connective tissue.
  - It also contains blood vessels, lymphatic vessels, and nerves.
- The border between the cortex and medulla is indistinct.

Functions

- Gametogenic function
  Involves production of gametes
- Endocrine function
  Involves production of hormones

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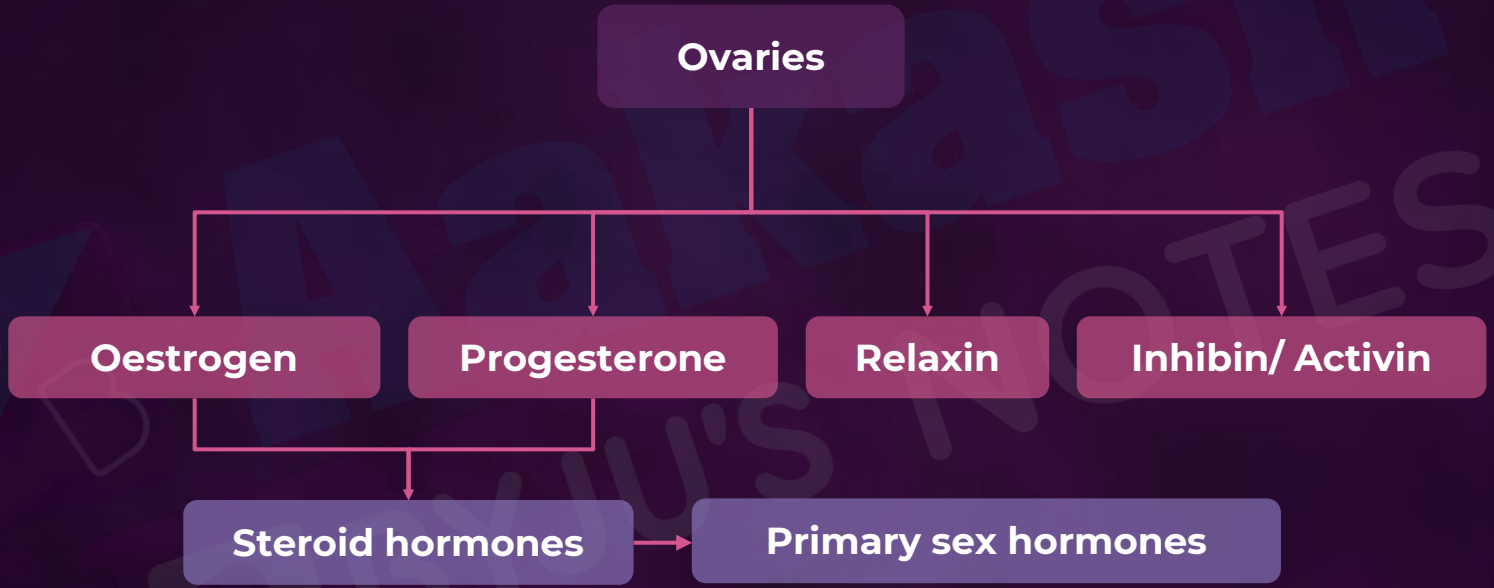
Ovaries



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Ovaries

Hormones of the ovary

Progesterone

- It stimulates the development of uterine epithelium.
- It is also secreted by the placenta and supports pregnancy.
- It maintains the endometrium.

Estrogen

- Estradiol is the principal estrogen.
- It is responsible for development of ovaries.
- It also regulates the menstrual cycle.
- It also controls the development of secondary sexual character.

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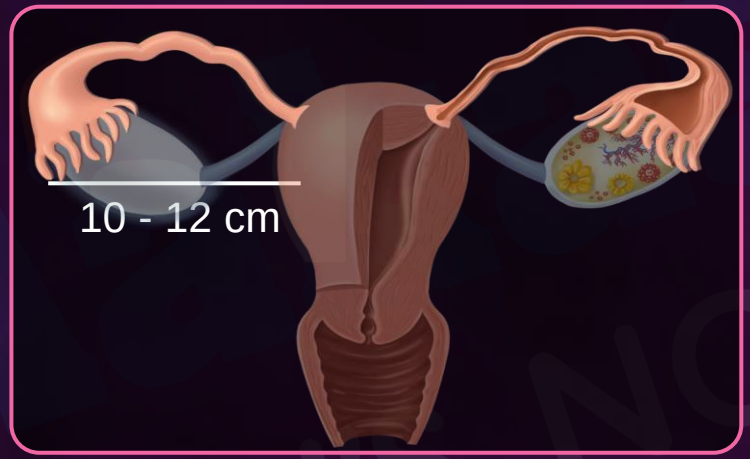
Oviducts



- Extend from the periphery of each ovary to the uterus
- Ciliated, muscular and tubular structures
- Connect ovaries to the uterus
- Each fallopian tube is about 10-12 cm long
- Suspended via mesosalpinx

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Oviducts

Structure

Isthmus -

- A short, narrow, thick-walled portion that joins the uterus

Ampulla -

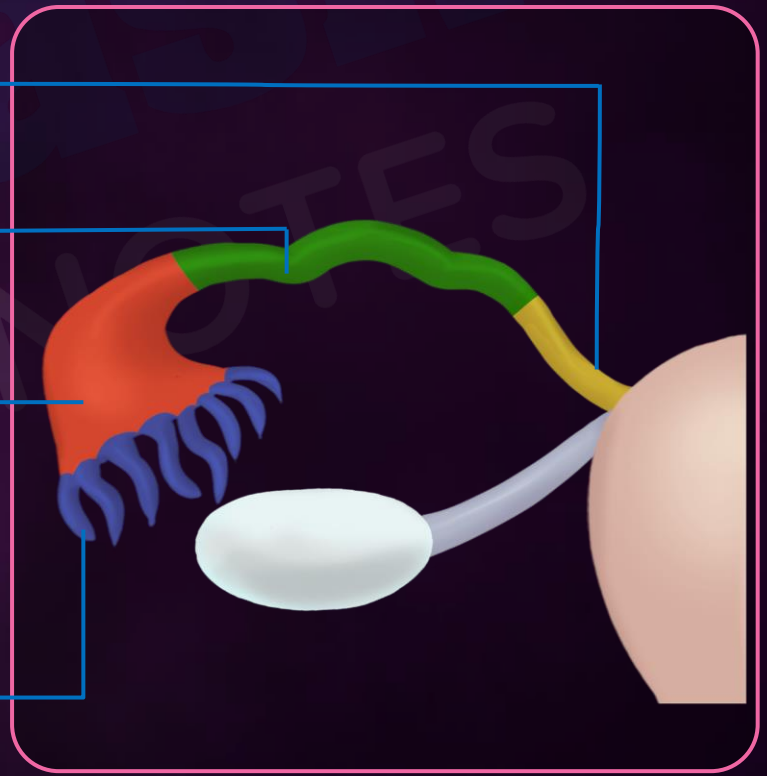
- The widest and longest portion that makes up about the lateral two-third of the oviduct's length
- Site of fertilisation

Infundibulum -

- The funnel shaped portion of each tube
- Close to the ovary

Fimbriae -

- Finger-like projections
- Terminal part of the ovary
- Helps in the collection of ovum



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Oviducts

Functions

- Transportation of sperms
- Capture of oocyte
- Movement of oocyte
- Site of fertilisation
- Nutrition to fertilised oocyte
- Transportation of embryo

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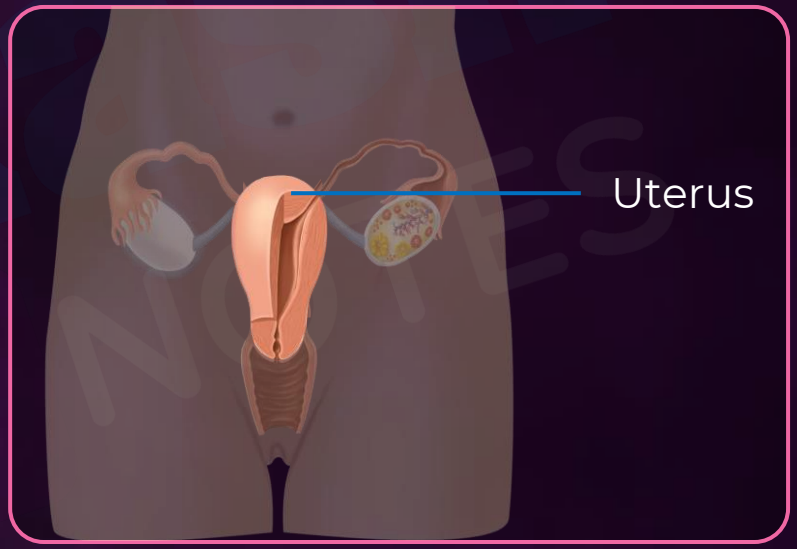
Uterus/Womb

- It is a single, hollow, muscular structure.
- It has the size and shape of an inverted pear.
- It is present in the pelvic cavity.
- It is supported by the ligaments attached to the pelvic wall.
- It is smaller in women who have not been pregnant.
- It is larger in females who have been pregnant, and smaller (atrophied) when the sex hormone levels are low.
- It is suspended by the mesometrium.



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Uterus/Womb

Structure

Fundus

It is the upper dome shaped part of the uterus which lies above the opening of fallopian tubes. Implantation occurs here.

Cornua

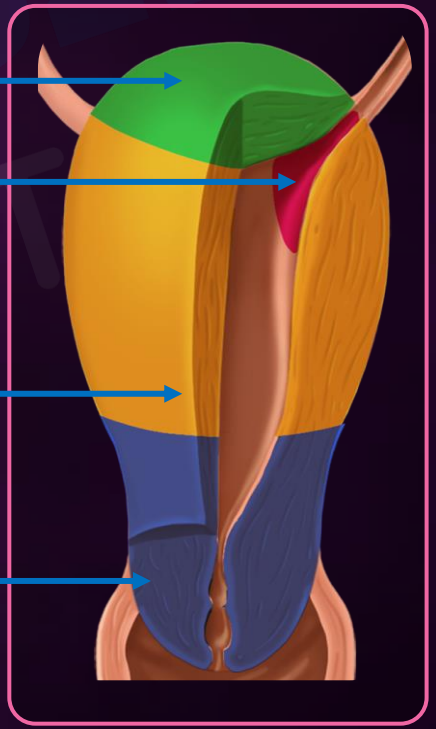
It is the upper corner from which the fallopian tubes open into the uterus.

Body

It is the main part of the uterus.

Cervix

It forms the connecting link between the uterus and the vagina. Its cavity is known as cervical canal which forms the birth canal.



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Uterus/Womb

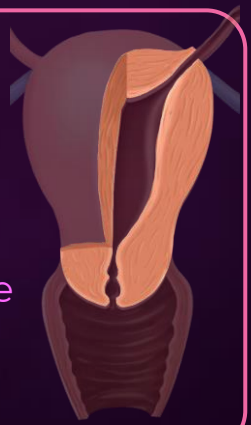
3) Histology

Perimetrium/Serosa

- It is the outermost thin layer.
- It is composed of the simple squamous epithelium and areolar connective tissue.

Myometrium

- It is the middle layer.
- It consists of three layers of smooth muscle fibres.
- These fibers are thickest in the fundus and thinnest in the cervix.
- During labour and childbirth, coordinated strong contractions of the myometrium in response to oxytocin from the posterior pituitary helps expel the foetus from the uterus.



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Uterus/Womb

Endometrium

- It is highly vascularised innermost layer.
- It is rich in glands and undergoes cyclic changes.
- Endometrium has three components:
  - An innermost layer composed of simple columnar epithelium (ciliated and secretory cells)
  - An underlying endometrial stroma
  - The endometrial (uterine) glands

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Uterus/Womb

Functions

It serves as part of the pathway for sperm deposited in the vagina to reach the uterine tubes.

It is also the site of :

- Implantation of blastocyst
- Development of the foetus during pregnancy
- Labour

During reproductive cycles, when implantation does not occur, the uterus is the source of menstrual flow.

It protects and nourishes the embryo.

- It supplements the energy needs of sperms.
- It protects sperms from phagocytes.
- It plays a role in capacitation.

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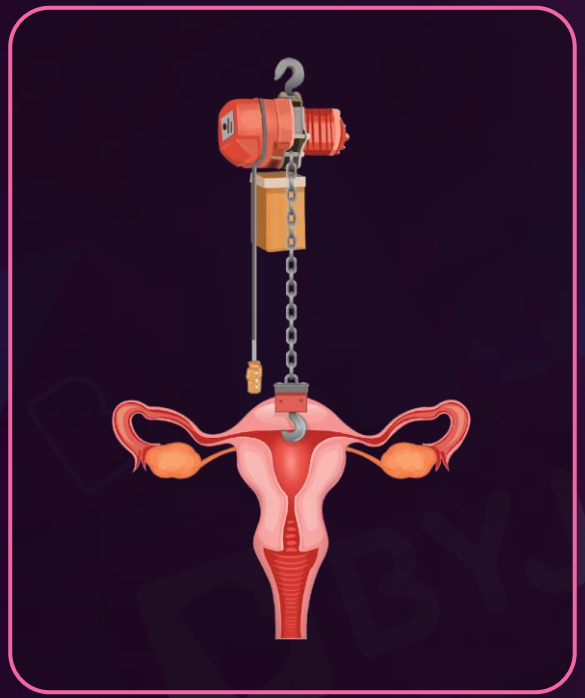
Did you Know?



Uterus has enough strength to bear the weight of a new life

The uterus of a pregnant women has the longest muscle fibers.

It also has a great tensile strength that gives it the ability to not break under high tension of contraction during the time of birth of a baby.

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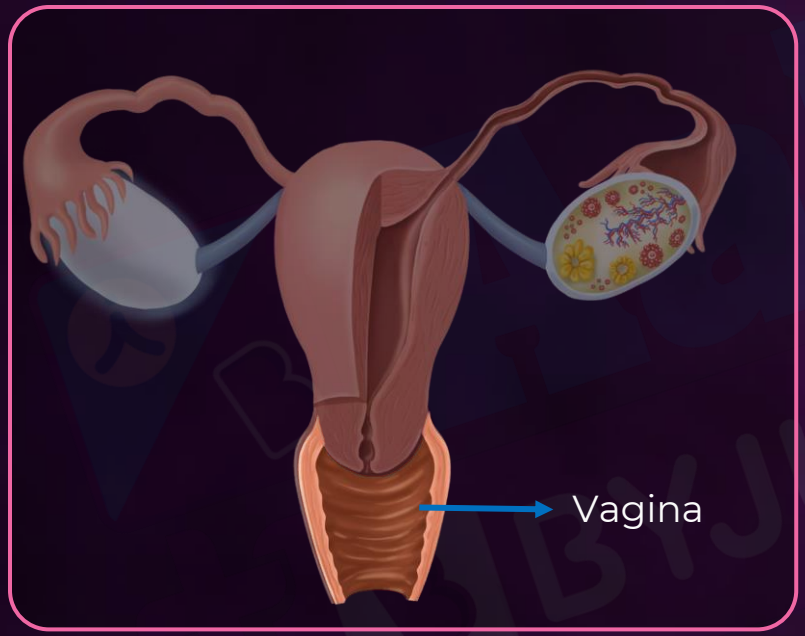
Vagina



- It is a tubular, 8.5 cm long, fibromuscular canal lined with mucous membrane.
- It extends from the exterior of the body to the uterine cervix.
- It stretches or expands to:
  - Accommodate the penis during intercourse
  - Allow the child delivery during parturition
  - Allow menstrual flow
- It acts as a passageway for childbirth.
- It forms birth canal along with cervix.

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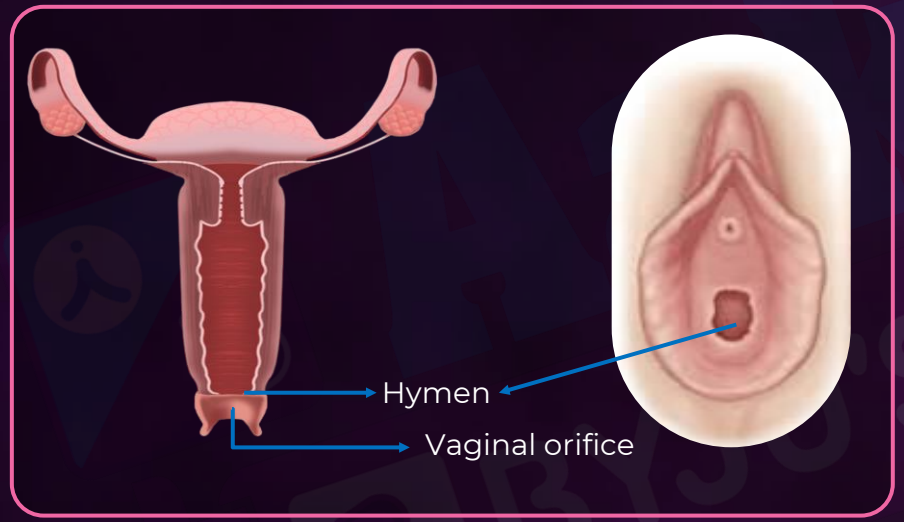
Vagina

Hymen



- The opening of the vagina is called vaginal orifice.
- The opening of the vagina is often covered partially by a membrane called hymen.
- Hymen is perforated to allow flow of menstrual blood.
- After its rupture, usually following the first sexual intercourse, only remnants of the hymen remain.

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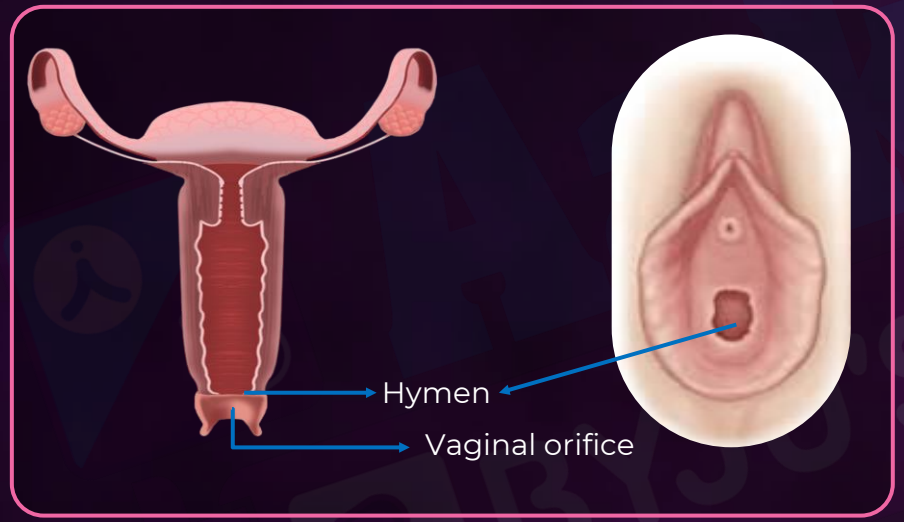
Vagina

Hymen



- It can also rupture because of:
  - Vaginal infection
  - Cycling
  - Horse riding or swimming
  - Vigorous athletic activities
- It, sometimes, completely covers the orifice, a condition called imperforate hymen.
- Surgery may be needed to open the orifice and permit the discharge of menstrual flow.
- Hymenoplasty is the surgery to reconstruct ruptured hymen.

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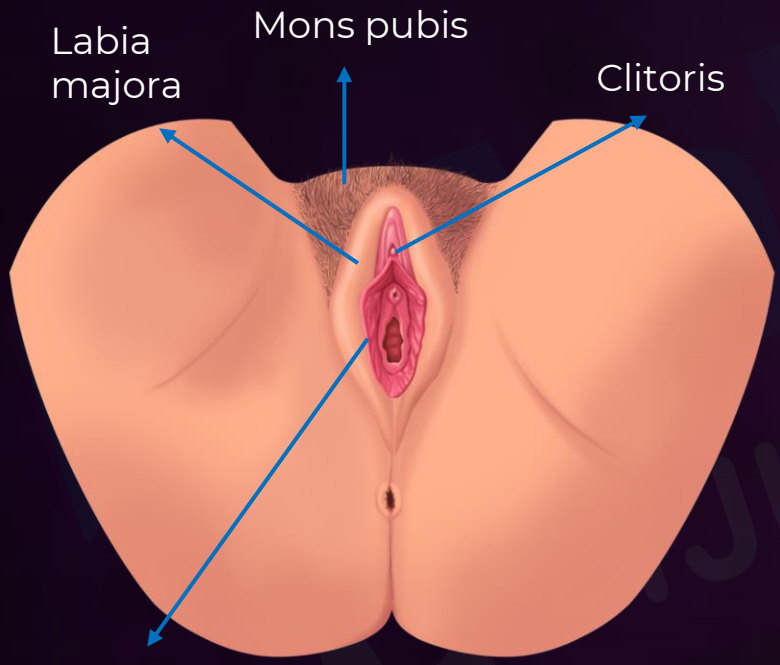
Female External Genitalia



- It is also called vulva

Vulva/ pudendum

01 Mons pubis

02 Labia majora

03 Labia minora

04 Clitoris

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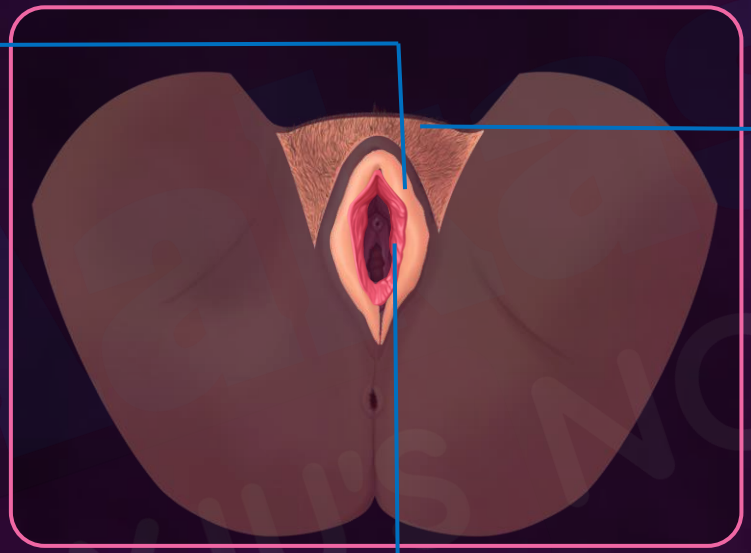
Female External Genitalia

Labia majora

- These are two large fleshy skin folds extending from mons pubis.
- They form the boundary of vulva.
- They are covered by pubic hair (partly).
- They contain abundant sebaceous (oil) glands



Mons pubis

- It is the anterior most part.
- It is a cushion of fatty tissue or adipose tissue layer.
- It is covered by skin and coarse pubic hair.

Labia minora

- These are two smaller thin skin folds without pubic hair and fat.
- They lie under the labia majora.
- They contain numerous sebaceous glands but very few sweat glands.

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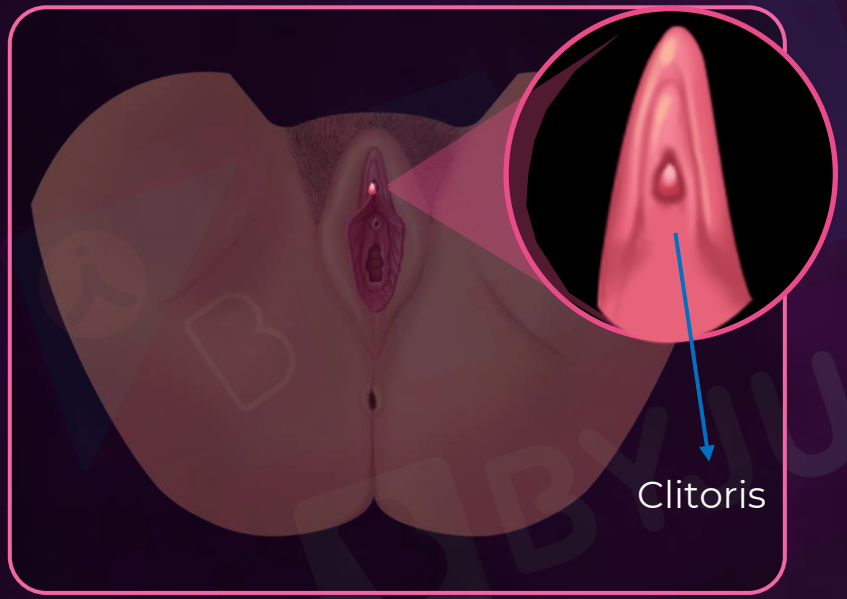
Female External Genitalia

Clitoris



- The clitoris is a tiny finger-like structure which lies at the upper junction of the two labia minora, above the urethral opening.
- The finger-like or small cylindrical mass is composed of:
  - Two small erectile bodies i.e. corpora cavernosa
  - Numerous nerves and blood vessels
  - Covered by a skin fold called prepuce

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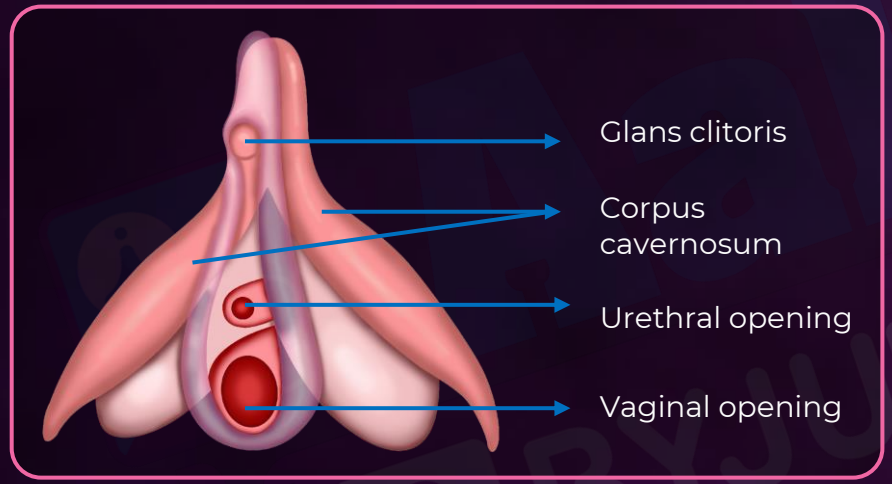
Female External Genitalia

Clitoris



- It contains erectile tissue.
  - When sexually stimulated, the corpus cavernosum or the erectile tissue gets swollen due to blood flow in the tissue.
  - This is similar to the erection of male penis.
- The exposed portion of the clitoris is called glans clitoris; homologous to glans penis.

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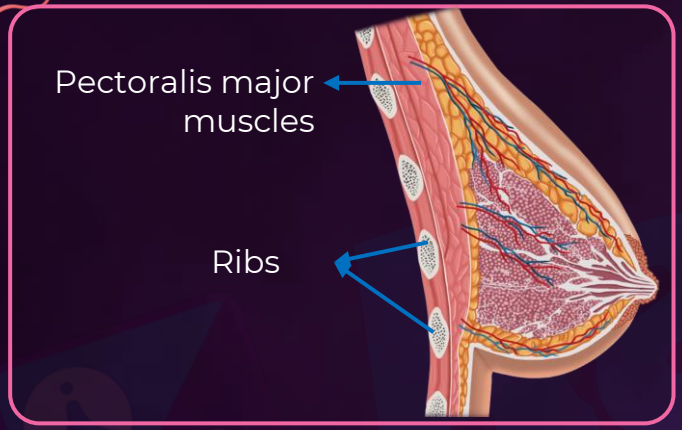
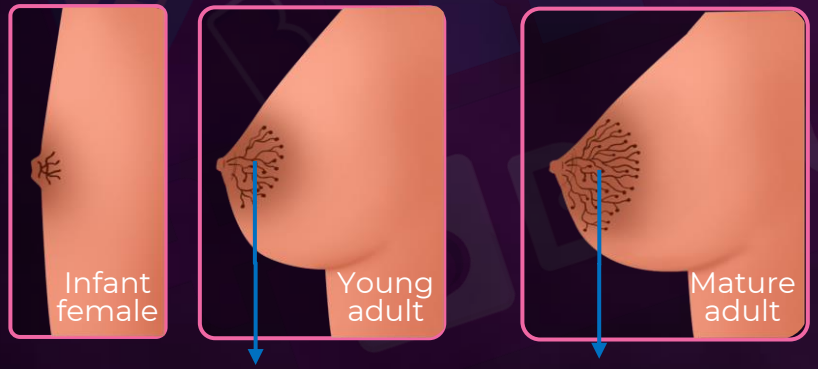
Mammary Glands



- A functional mammary gland is characteristic of all female mammals.
- It helps in nourishing the young ones with the milk produced by mammary gland, in lactating mothers.
- Each breast is a hemispheric projection of variable size lying over or anterior to the pectoralis major muscle on the front wall of the chest.



- In females, mammary glands are undeveloped until puberty.
- At puberty, they begin to develop under the influence of estrogen and progesterone hormones.

Estrogen stimulates duct growth

Progesterone stimulates formation of secretory alveoli

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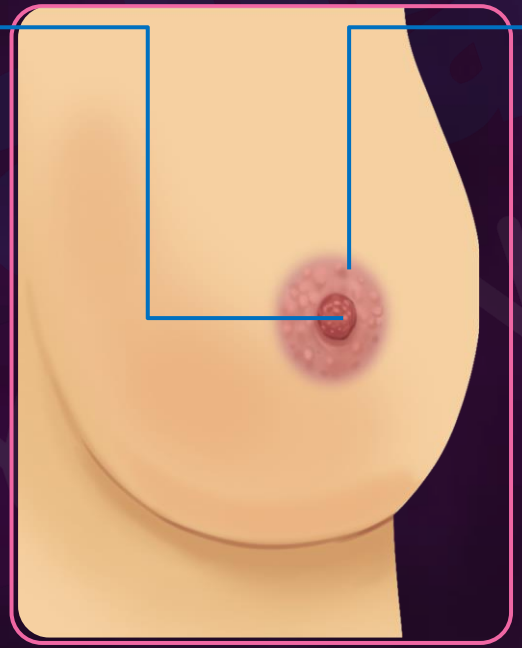
External Structure of Breast

Nipple

- Each breast has one pigmented projection, called the nipple.
- It has a series of closely spaced openings of ducts called lactiferous ducts, from where milk emerges.



Areola

- The circular hyperpigmented area of skin surrounding the nipple is called the areola.
- It appears rough because it contains modified areolar (oil) glands.

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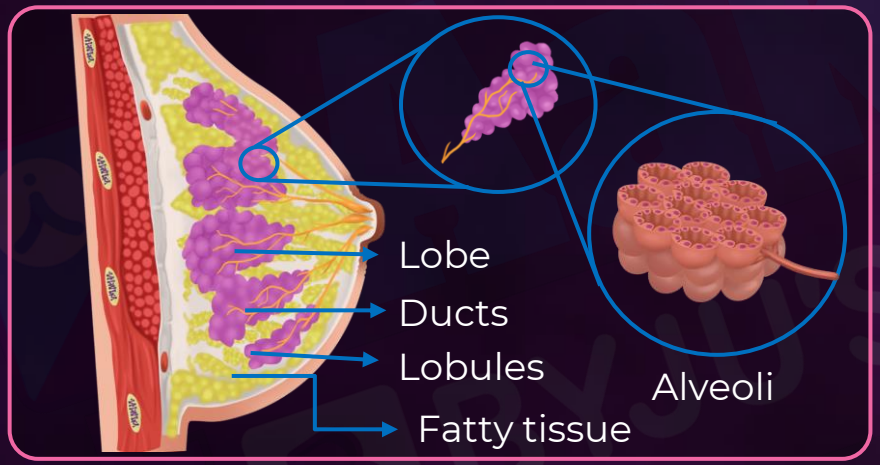
Internal Structure of Breast

Glandular tissue



- Each mammary gland has 15 – 20 mammary lobes or compartments separated by a variable amount of adipose tissue containing
  - clusters of milk secreting structures – alveoli embedded in fibrous connective tissue
  - cavities (lumen) of alveoli which store milk

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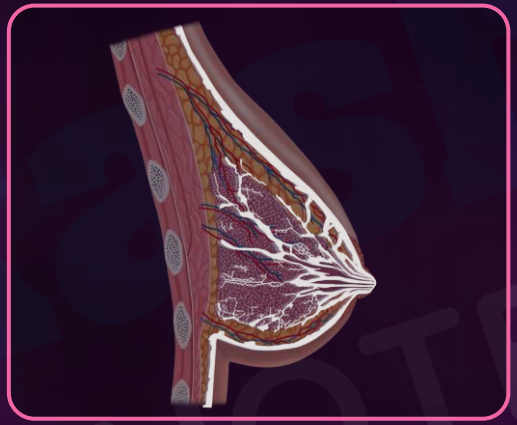
Internal Structure of Breast

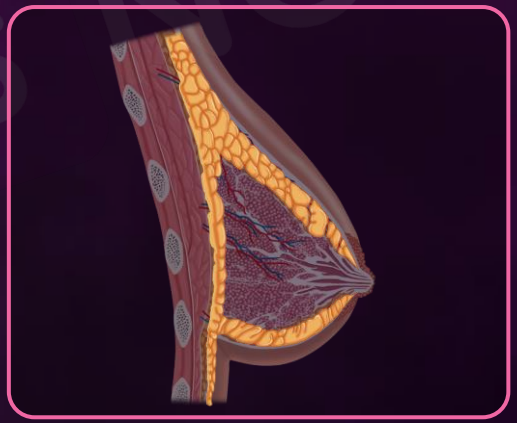
Fibrous (Connective) tissue

- It supports alveoli and ducts.



Fatty (Adipose) tissue

- It is present between the lobes.
  - It covers the surface of mammary glands.
- The fatty or adipose tissue is present in variable amounts and determines the size of breasts.



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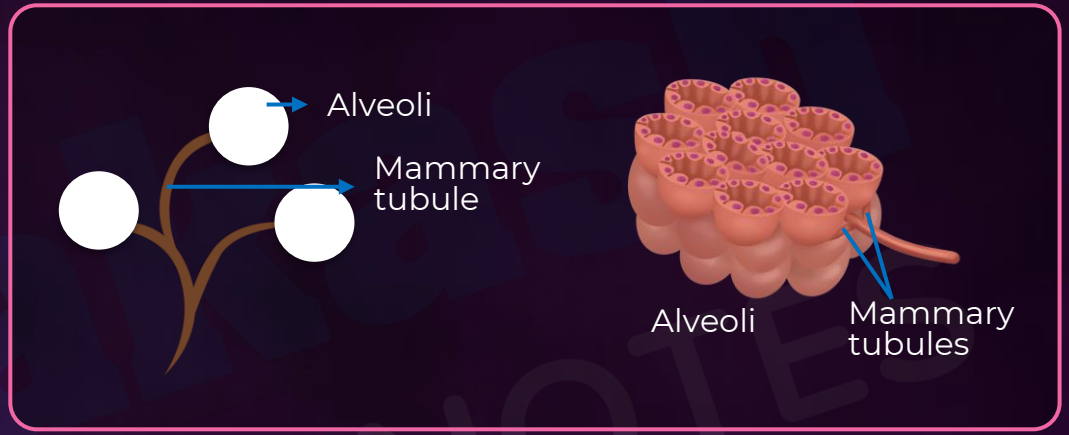
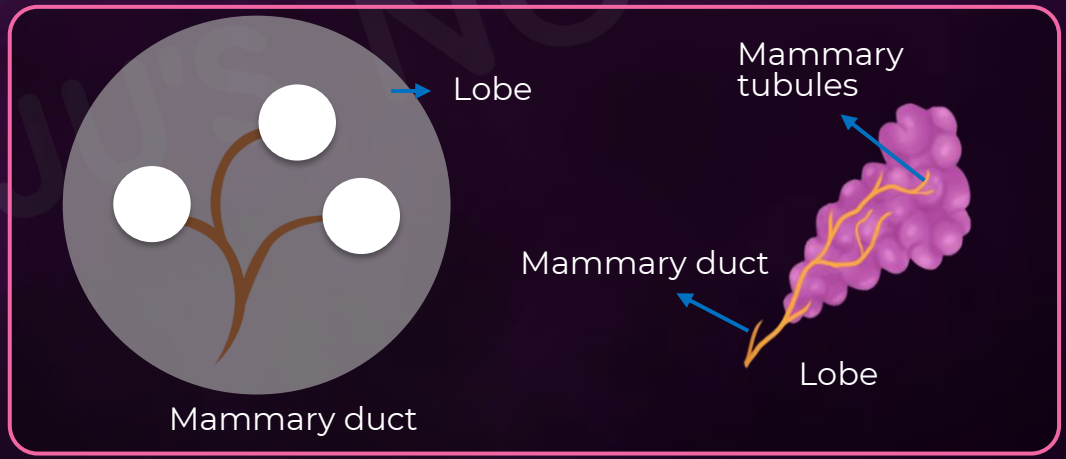
Internal Structure of Breast

Alveoli

- Each alveoli opens into mammary tubules.



- The tubules of each lobe join to form a mammary duct.



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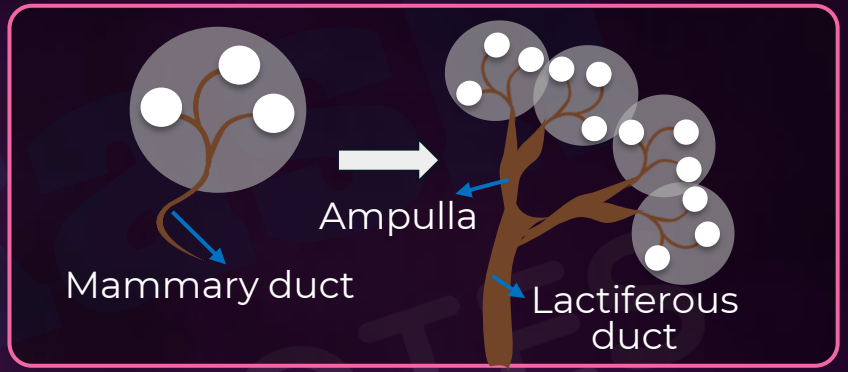
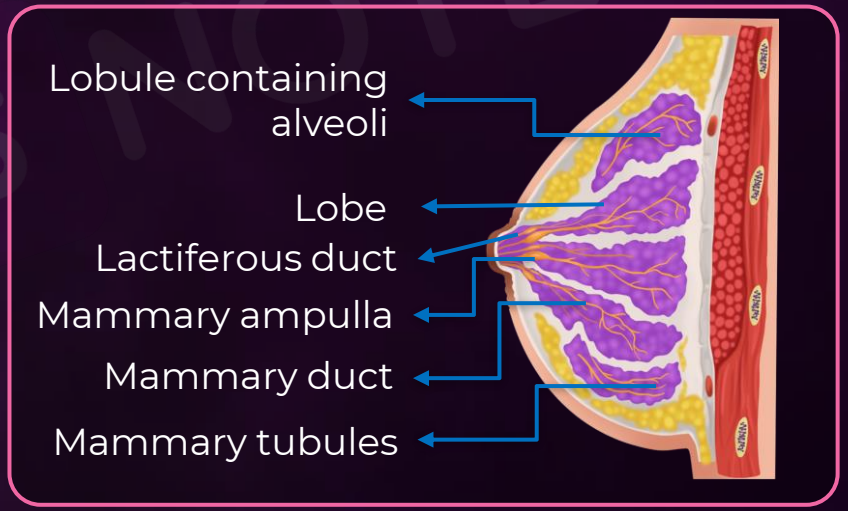
Internal Structure of Breast

- Several mammary ducts join to form a wider mammary ampulla which is connected to lactiferous duct through which milk is sucked out.





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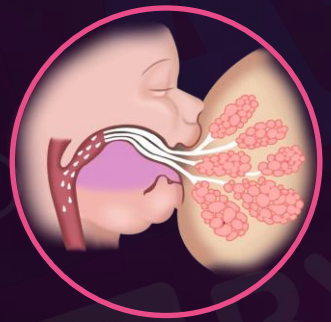
Functions of Breast

Lactation



- Secretion and ejection of milk
- Associated with pregnancy and childbirth

Milk production

Anterior lobe of pituitary gland

Prolactin

Production of milk by breast

Milk ejection

Posterior lobe of pituitary gland

Oxytocin

Ejection of milk from breast

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Lactation

- Lactation is the secretion and ejection of milk from the mammary glands.
- A principal hormone in promoting milk synthesis and secretion is prolactin (PRL), which is secreted from the anterior pituitary gland.
- Even though prolactin levels increase as the pregnancy progresses, no milk secretion occurs because progesterone inhibits the effects of prolactin.
- After delivery, the levels of estrogen and progesterone in the mother's blood decrease, and the inhibition is removed.
- The principal stimulus in maintaining prolactin secretion during lactation is the sucking action of the infant.

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Love/Cuddle Hormone

Oxytocin

- When a doctor places a newborn on its mother's chest in the moments after birth, oxytocin is released.
- The mother's body temperature rises to create a warm, comforting place for the baby to snuggle.
  - Skin-to-skin contact calms new babies and often helps them cry less.
- Oxytocin causes a newborn to seek out and latch on to its mother's breast. The hormone floods the body during breastfeeding.

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Male Mammary Glands

Male with gynecomastia

Normal male

- Mammary glands are also present in males but only in rudimentary form
- Sometimes, male breast tissue swells due to reduced male hormones (testosterone) or increased female hormones (estrogen) - Gynecomastia.

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Hormonal Control of Female Reproductive System

Pituitary gland

Produces FSH (Follicle-stimulating hormone)

At the time of puberty

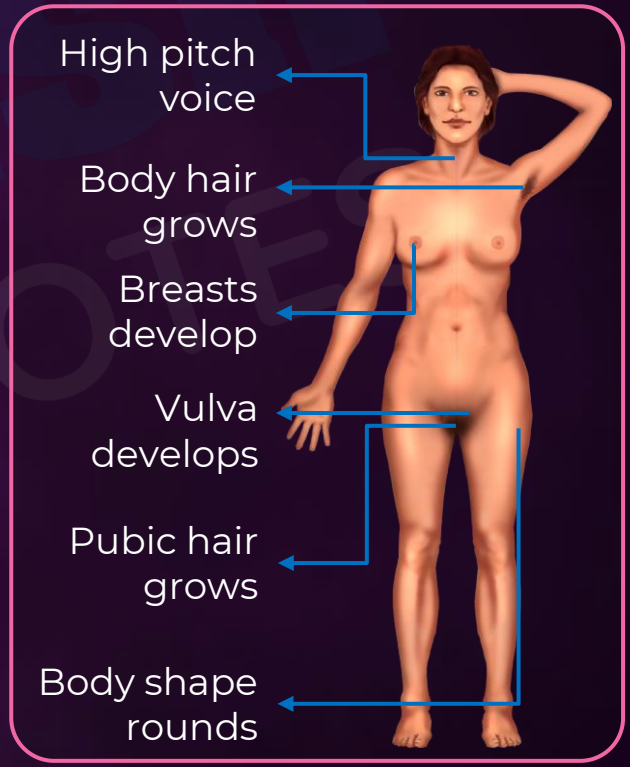
Development of ovaries

Estrogen

Development of secondary sexual characters

Estrogen induces development of secondary sexual characters, including:

- Changes in voice
- Development of external genitalia and breasts, body hair, pubic hair
- Widening of pelvis
- Deposition of fat in thighs buttocks and face



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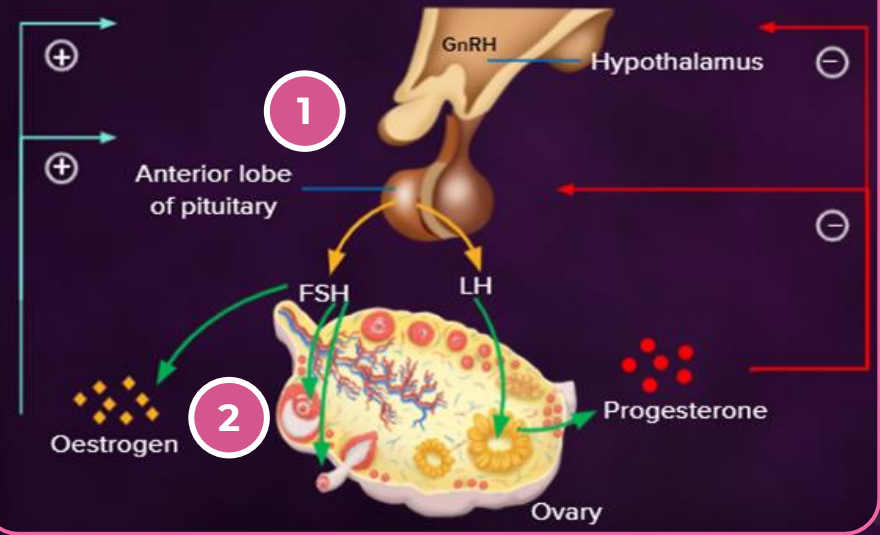
Hormonal Control of Female Reproductive System



1

- GnRH is secreted by the hypothalamus.
  - It stimulates anterior lobe of pituitary to secrete FSH and LH.
- FSH and LH stimulate the ovary.

2

- FSH stimulates:
  - Growth and development of ovarian follicles
  - Development of the egg or oocyte
  - Formation of estrogen
- Estrogen in turn stimulates the secretion of GnRH.
- FSH also stimulates other hormones from the anterior lobe of the pituitary gland.

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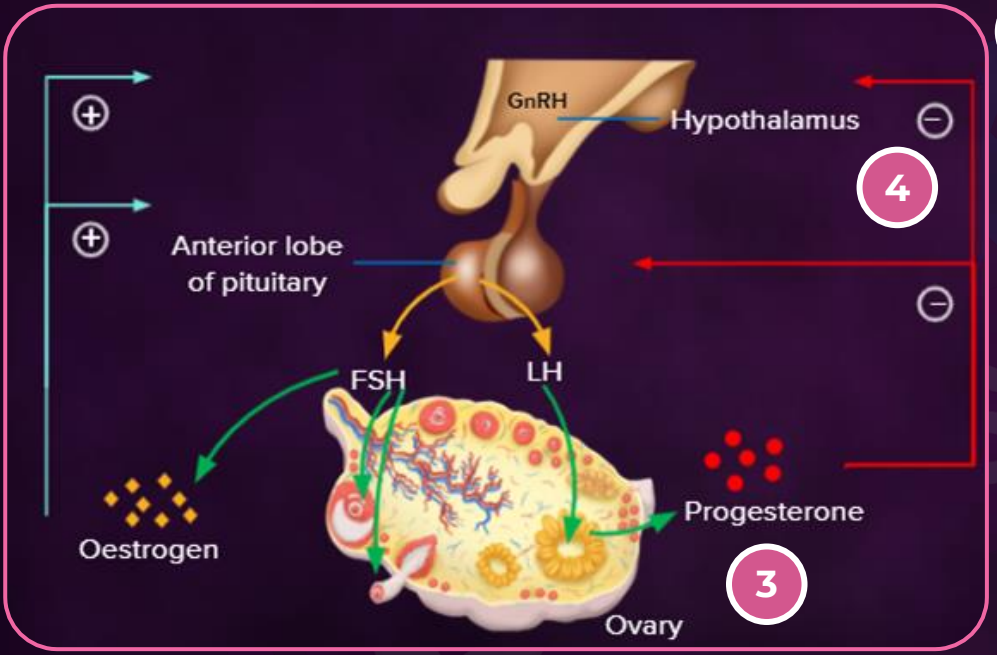
Hormonal Control of Female Reproductive System



3

- LH stimulates the corpus luteum to secrete progesterone.

4

- Increasing levels of progesterone inhibit the release of GnRH, which in turn inhibits the release of FSH, LH and progesterone itself.

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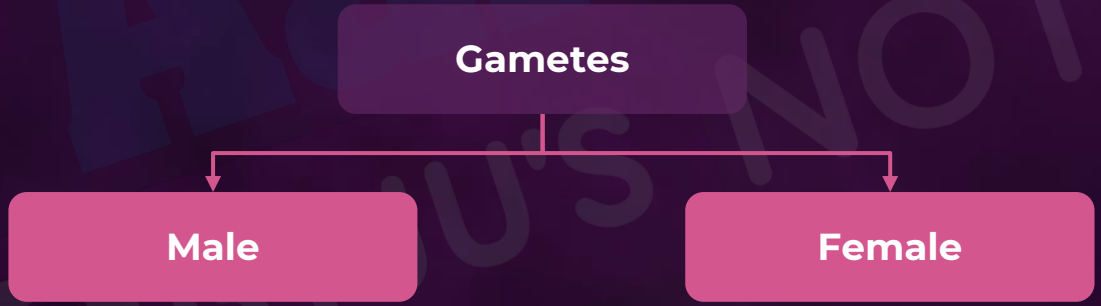
Gametogenesis

- Gametogenesis is the process of production of male and female sex cells (gametes), which are necessary for the development of new offspring.



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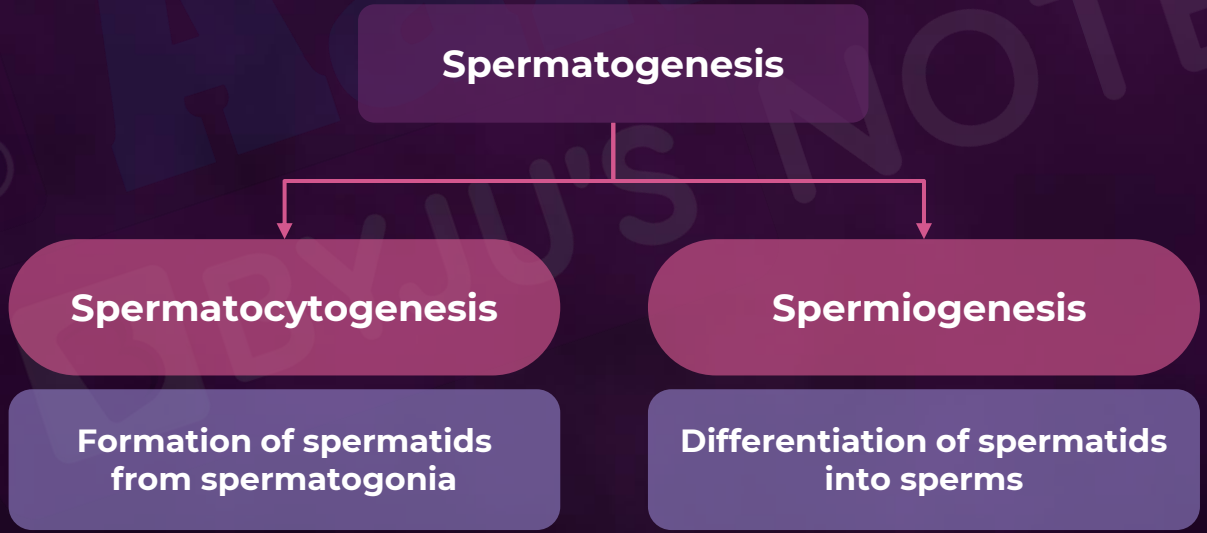
Spermatogenesis

- Process of formation of sperms
- Begins during puberty
- Continues till death
- With advancing age, the number and quality of sperms reduces



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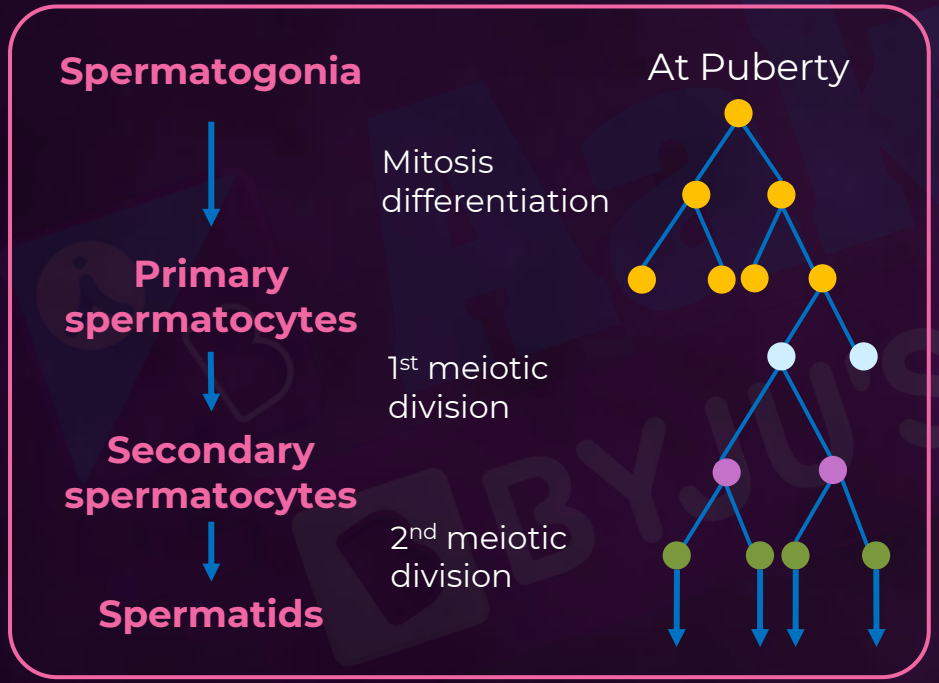
Spermatogenesis

Spermatocytogenesis



- Spermatogonia or the germ cells multiply by mitotic division to form primary spermatocytes.
- Each spermatogonia is diploid and contains 46 chromosomes.
- Primary spermatocyte then undergoes the first meiotic division to form two haploid cells called secondary spermatocytes, which have only 23 chromosomes each.
- Secondary spermatocytes undergo second meiotic division to produce four equal, haploid spermatids.

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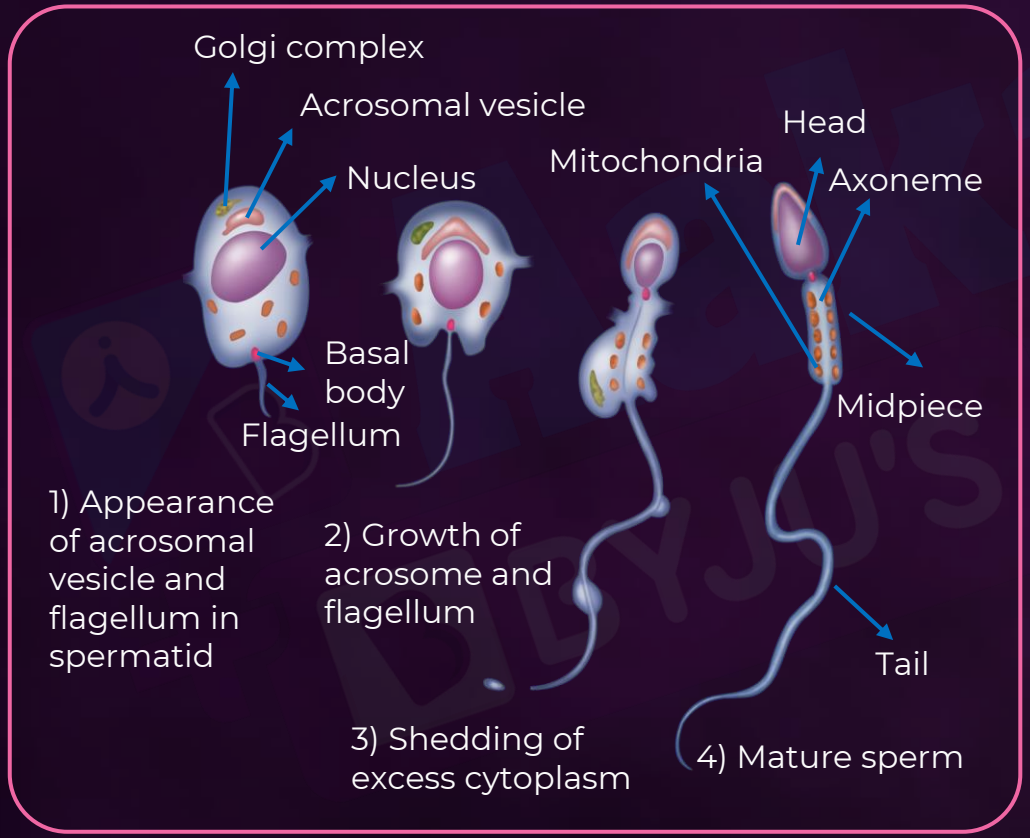
Spermatogenesis

Spermiogenesis



- Differentiation of spermatids into spermatozoa happens next.
- After spermiogenesis, sperm heads become embedded in the Sertoli cells to form specialized sperms.
- These sperms are finally released from the seminiferous tubules by the process called spermiation.

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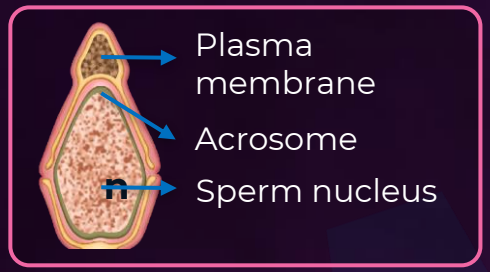
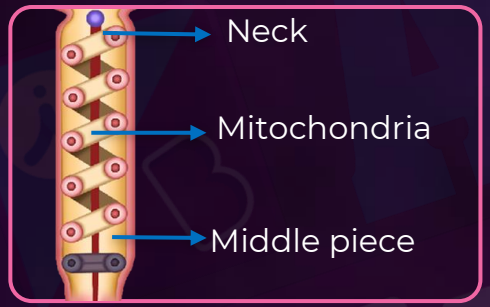
Structure of Sperm





Head

- Plasma membrane is the outer layer of head
- Acrosome is a cap like structure which contains enzymes
- Nucleus is haploid i.e. contains 23 chromosomes

Middle Part

- Contains numerous mitochondria which produce energy for motility which is essential for fertilisation.

Tail

- Tail helps sperm to move and to travel long distance.

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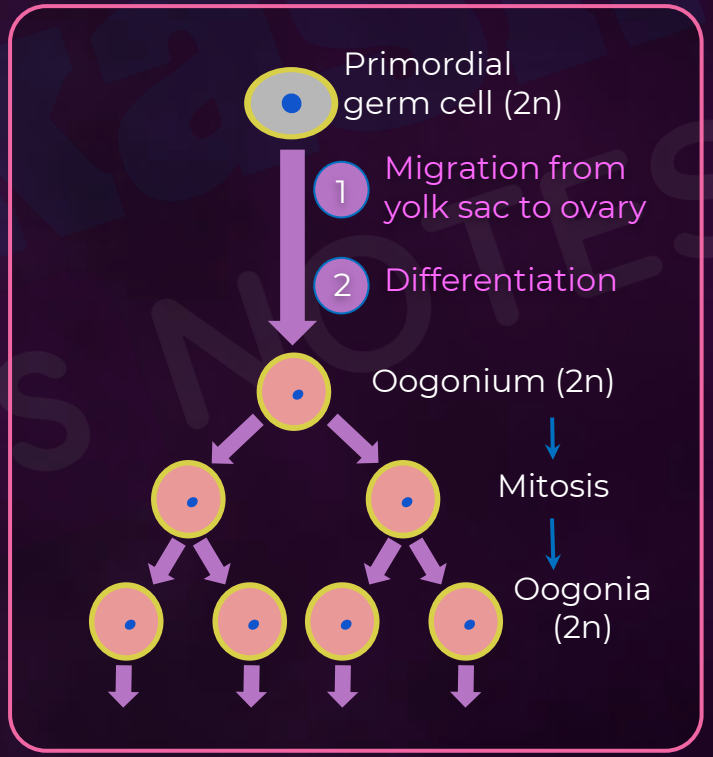
Oogenesis

The process of formation of a mature female gamete is called oogenesis.

Ova development in embryo

- It begins in females before they are even born i.e. during their embryonic life.
- During early foetal development, primordial germ cells migrate from the yolk sac to the ovaries.
- The germ cells differentiate within the ovaries into oogonia (singular is oogonium).



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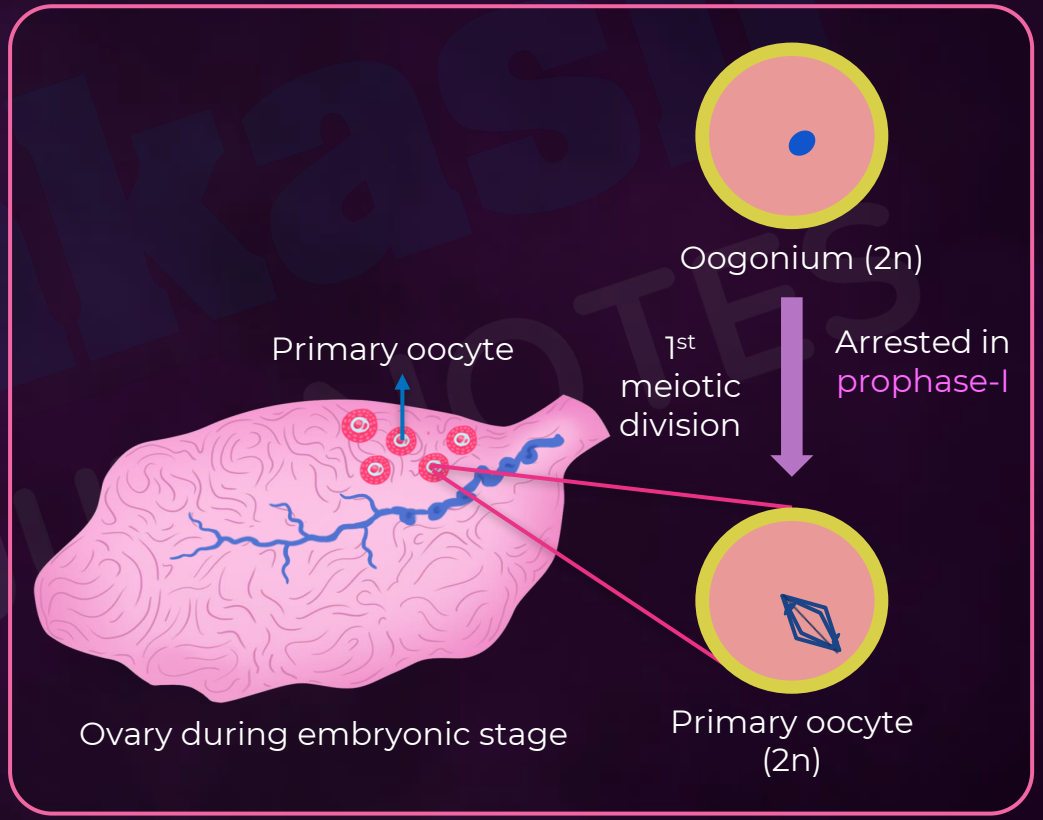
Oogenesis - Ova Development in Embryo

- Oogonia are diploid (2n) stem cells that divide mitotically to produce millions of germ cells.
- The gamete mother cells (oogonia) then undergo first meiotic division but get arrested at prophase - I and are called as primary oocytes.



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Oogenesis

Folliculogenesis

- It is the process of formation of follicles in the ovary.
- Follicular development happens in four stages:
  - Primary follicle
  - Secondary follicle
  - Tertiary follicle
  - Graafian follicle

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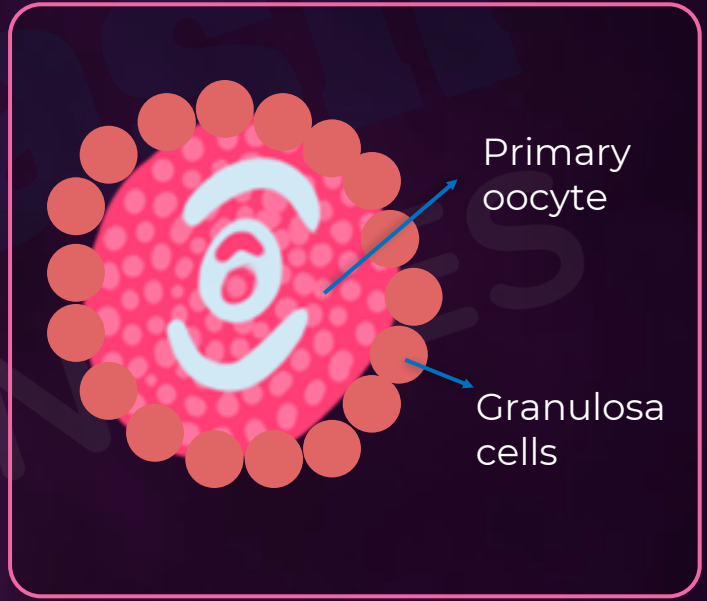
Folliculogenesis

1) Primordial follicle

- These are newly formed follicles containing primary oocyte.
- The primary oocyte is surrounded by single layer of flattened granulosa cells.
- Granulosa cells guide the development of oocyte and protect it.

Primary oocyte + Granulosa cells = Primary follicle



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Folliculogenesis

2) Secondary follicle

- With continuing maturation, a primary follicle develops into a secondary follicle.
- With maturation, an envelope or sheath of connective tissue called theca surrounds the granulosa cells.
- Granulosa cells rest on a basement membrane and the surrounding stromal cells form theca folliculi.

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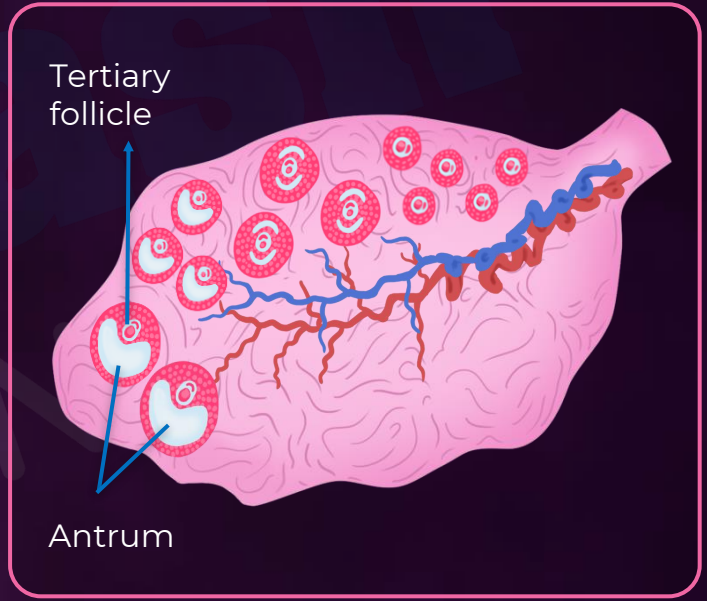
Folliculogenesis

3) Tertiary follicle

- The secondary follicles transform into tertiary follicles by developing a fluid filled cavity called antrum.
- The presence of antrum signifies the formation of tertiary follicle.
- The fluid of antrum is referred to as liquor folliculi.
- The theca gradually organizes into:
  - Internal – theca interna
  - External – theca externa



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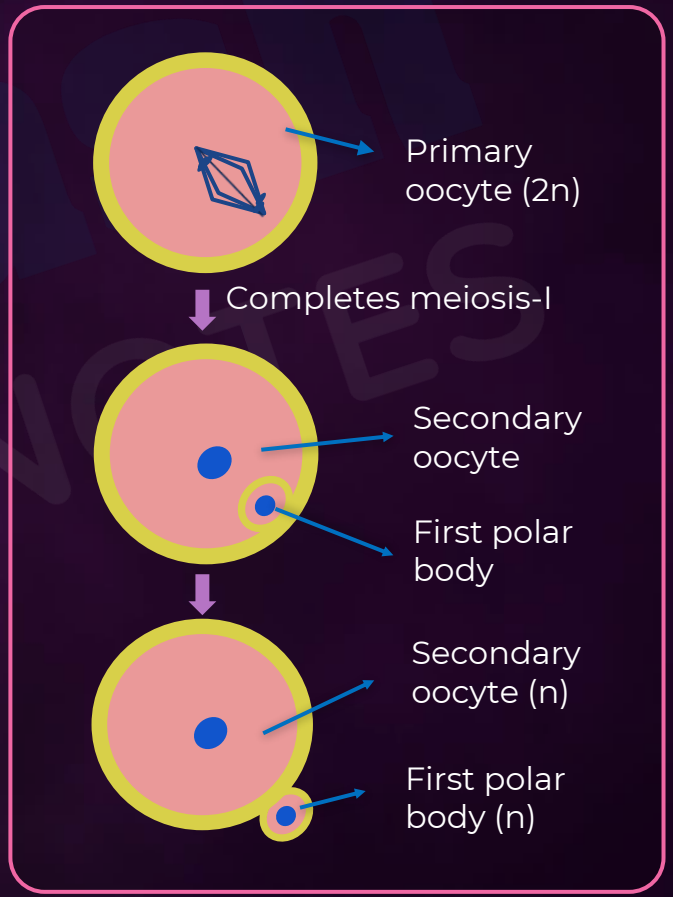
Folliculogenesis

Oocyte development in tertiary follicle

- During puberty in females, the arrested primary oocyte starts growing and completes its first meiotic division inside tertiary follicle.
- This reduction division occurs unequally to form
  - a large secondary oocyte
  - a tiny first polar body
- The secondary oocyte is haploid in nature and contains rich cytoplasm of primary oocyte.
- The fate of first polar body is unknown.
- Polar body is known to have no function.



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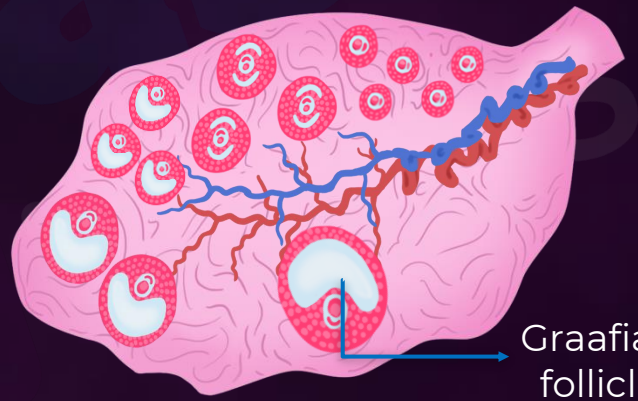
Folliculogenesis

4) Graafian follicle

- Tertiary follicles further grow and become Graafian follicles.
- It is final mature follicle which undergoes ovulation.
- Its diameter is 2.5 cm.



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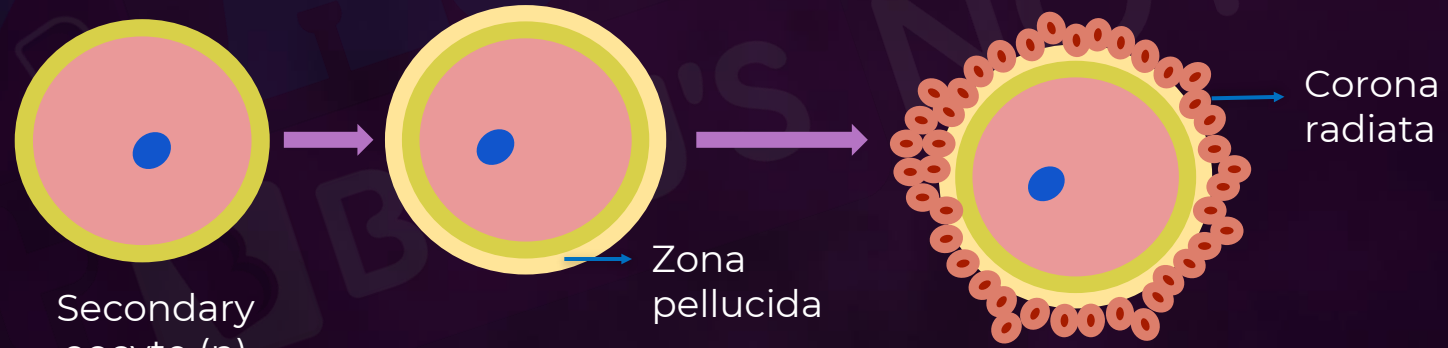
Stages of Development of Secondary Oocyte

- Inside the Graafian follicle, a membrane develops around secondary oocyte called zona pellucida.

- Before ovulation, a layer of cells, that provide vital proteins, develop around the oocyte and are called corona radiata.



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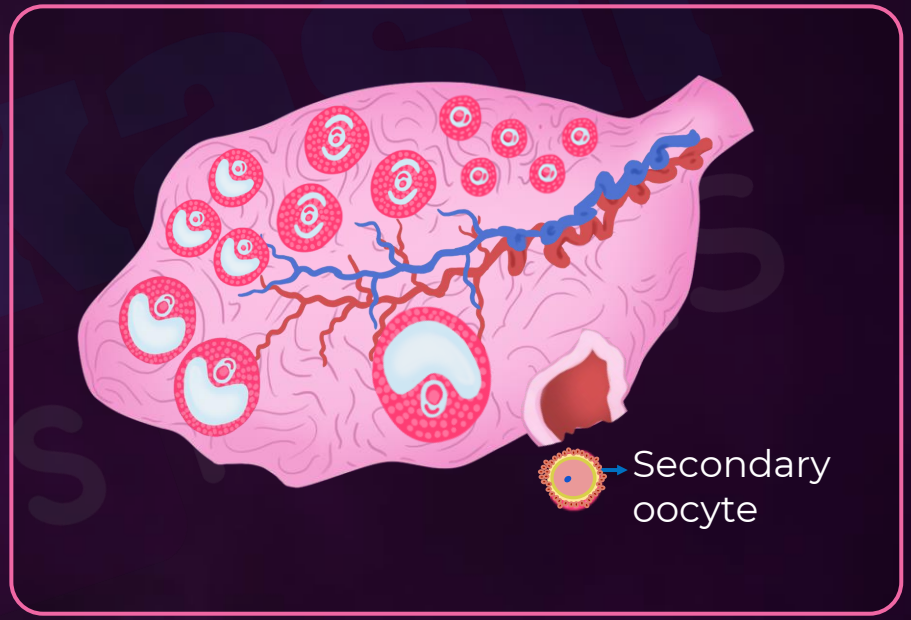
Fate of Graafian Follicle and Secondary Oocyte

1) During Ovulation

- Graafian follicle ruptures and releases the secondary oocyte (ovum).
- The process of releasing an ovum (secondary oocyte) by Graafian follicle is called ovulation.



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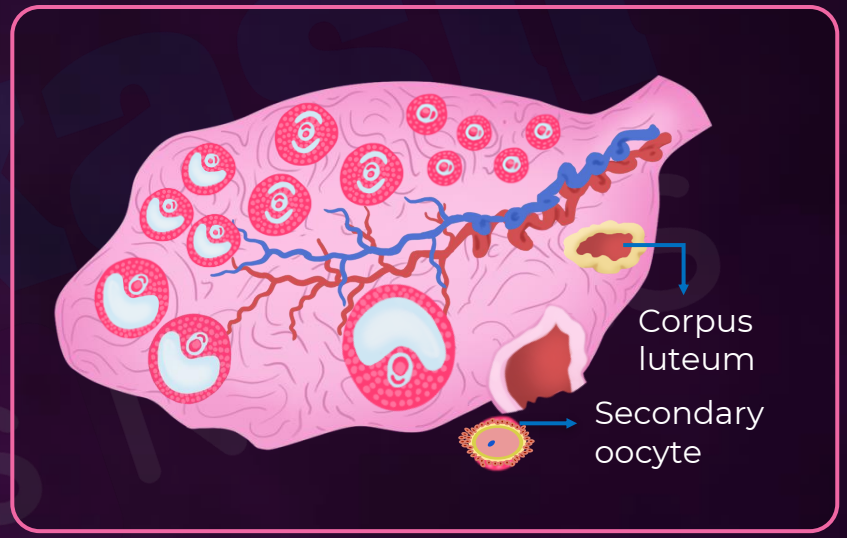
Fate of Graafian Follicle and Secondary Oocyte

2) Post - Ovulation

- Graafian follicle transforms into corpus luteum.
- Corpus luteum maintains the layer of uterus by secreting progesterone.
- The secondary oocyte undergoes meiosis-II but stops at metaphase-II.
- During fertilisation, it completes meiosis-II to produce a mature ovum and a tiny second polar body.



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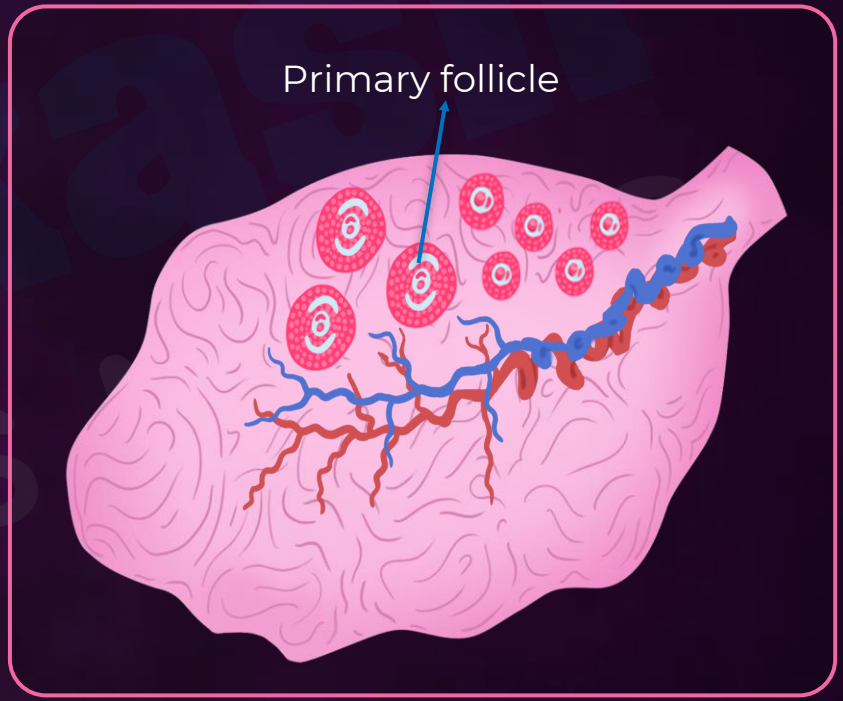
Did you Know?

Follicular degeneration

- No more oogonia are formed or added after birth.
- A large number of primary follicles get degenerated during development of a girl child.
- Follicular degeneration is a genetically programmed process.
- Before birth, lakhs of follicles are present in both ovaries, but at puberty only 60,000-80,000 follicles are left in each ovary.



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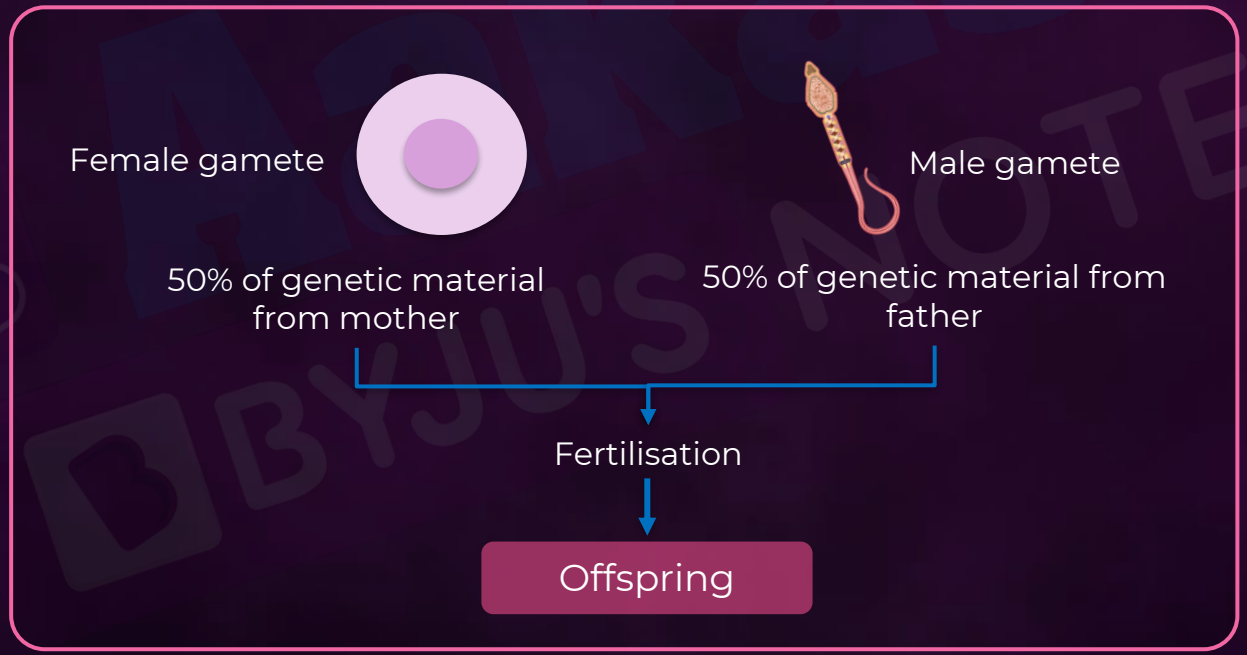
Fertilisation

- Fertilisation is the fusion of male and female gametes to produce a single celled zygote, which gives rise to a new organism.



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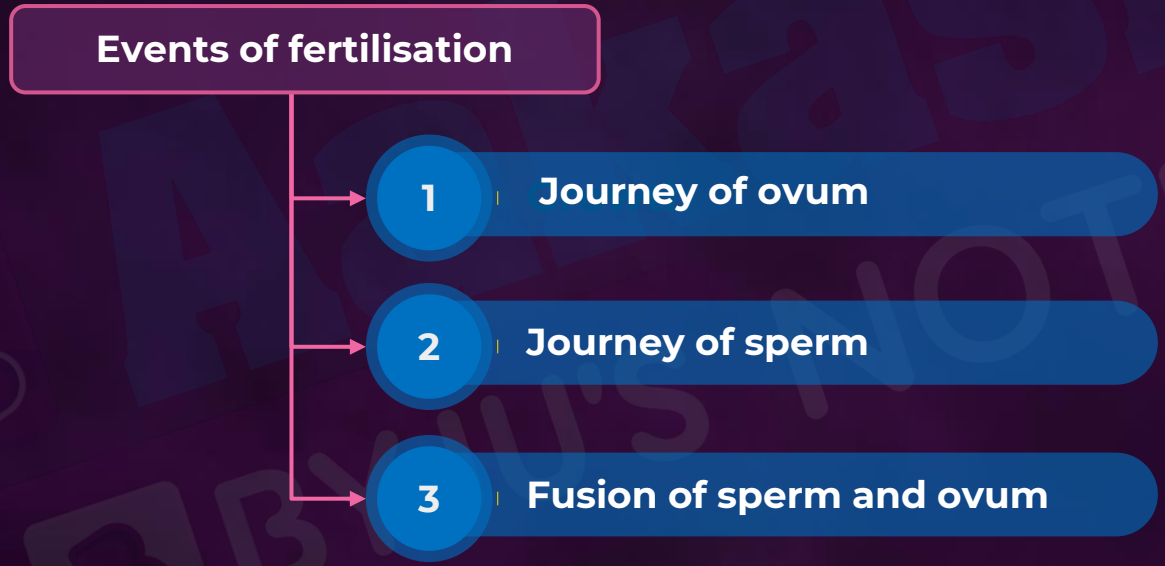
Fertilisation



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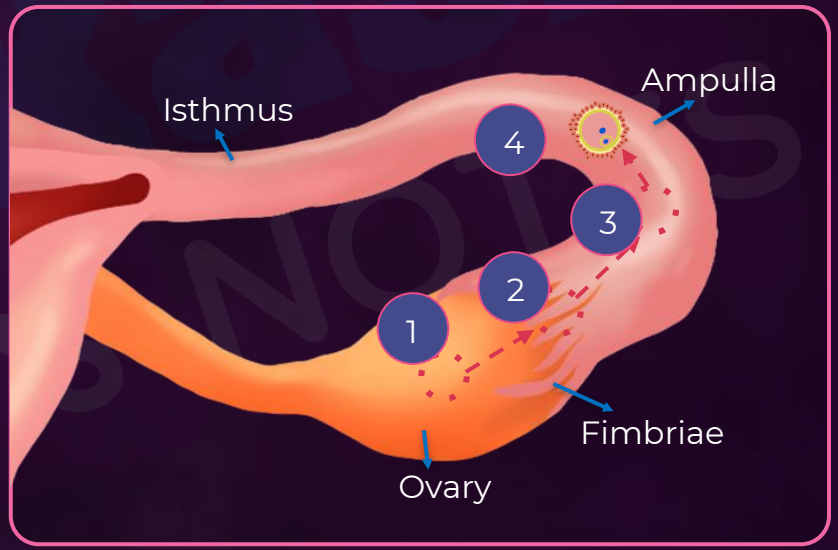
Journey of Ovum

1. The secondary oocyte released from the ovary is carried away towards the fallopian tube.
2. The secondary oocyte is picked up by finger like ends of the fallopian tube called **fimbriae**.
3. With the help of cilia, secondary oocyte moves forward to reach **ampulla region**.
4. At the ampulla region, the secondary oocyte awaits sperm for fusion.



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Sexual Intercourse

Step 1: Erection

The penis becomes **erect and stiff** due to the **rush of blood** into the sinuses.
Following this, penis is inserted into the female vagina.

Step 2: Stimulation

Insertion of penis inside vagina causes stimulation.
At the peak of sexual stimulation, a sensation called **orgasm** occurs. This is required for ejaculation to occur. Stimulation helps in releasing **lubricating fluid** from **both penis and vagina.**

Step 3: Ejacuation

Peak stimulation leads to ejaculation.
During ejaculation, the **penis discharges the sperm** outside by **wavelike contractions.**

Step 4: Insemination

During insemination, millions of sperms are deposited in the vagina.

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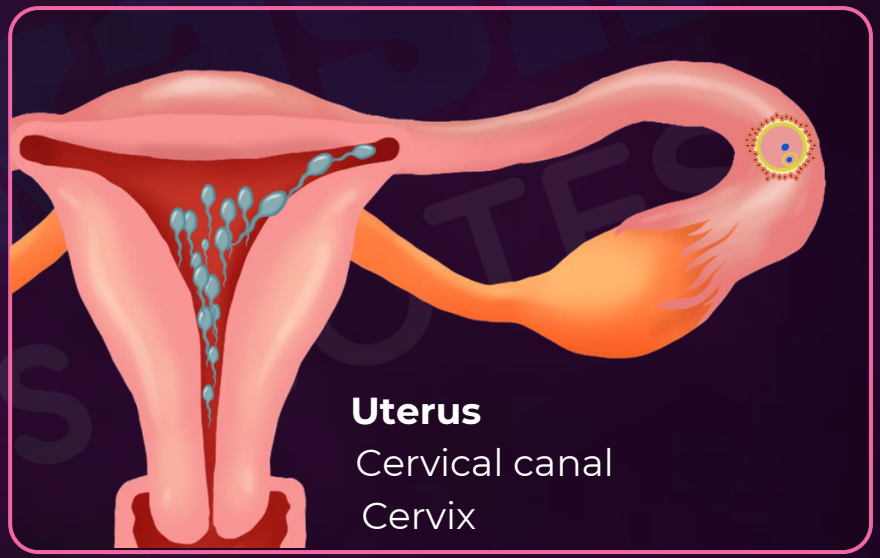
Journey of Sperm

- These motile sperms swim rapidly inside the vagina.
- Some of these sperms die due to following conditions in vagina:
  - Acidic environment
  - Mucus secretion of vagina
- The sperms pass through
  - The cervix
  - Enter cervical canal
  - Move towards the uterus
  - Then enter fallopian tubes
- Inside the uterus, the contractions of the uterus assist the journey of the sperms further.



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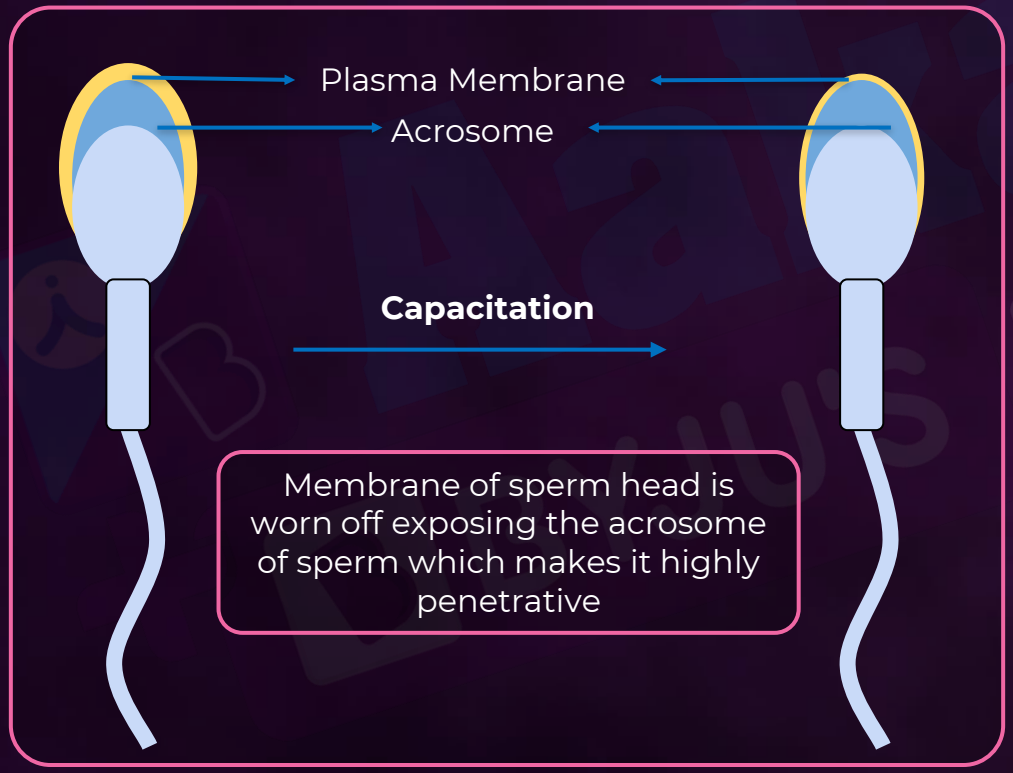
Capacitation

Before reaching the fallopian tube, sperm undergoes certain modifications known as **capacitation.**



- Capacitation refers to the modifications in sperm which increases its ability to penetrate and fertilise ovum.
- During capacitation, the medium inside the uterus wears off the plasma membrane of sperm head to expose the acrosome.
- The hydrolytic enzymes in the exposed acrosome helps the sperm to penetrate ovum.

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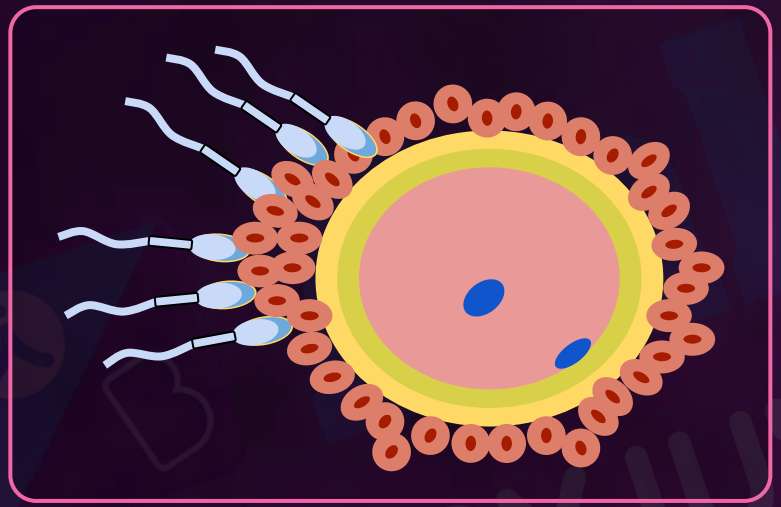
Fertilisation - Fusion of Gametes



- Pregnancy is most likely to occur if intercourse takes place during a 3-day window—from 2 days before ovulation to 1 day after ovulation.

- Fertilisation normally occurs in the ampulla of uterine (Fallopian) tube within 12 to 24 hours after ovulation.
- Sperms can remain viable for about 72 hours after deposition in the vagina, although a secondary oocyte is viable for only about 24 hours after ovulation.

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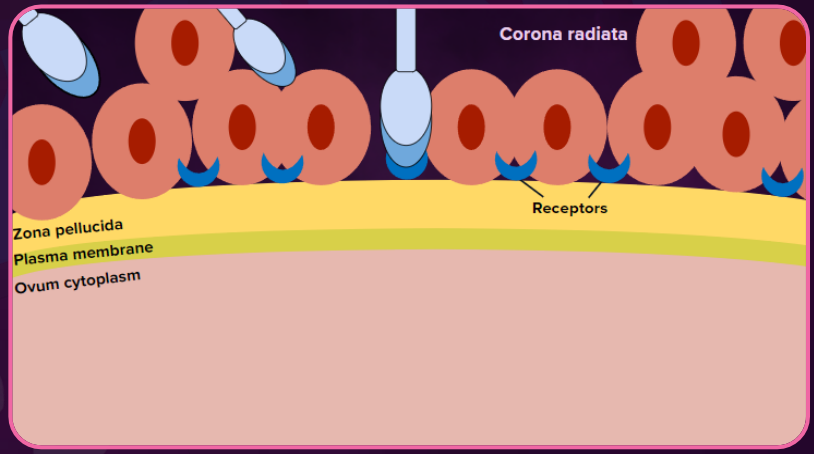
Penetration of Oocyte

- Monospermy occurs - Entry of only one sperm into cytoplasm. Polyspermy is avoided.
- For fertilisation to occur, a sperm cell must penetrate the following layers first:
  - Granulosa cells
  - Corona radiata
  - Zona pellucida



Among many sperms that reach ovum, one of the sperm passes between cells of corona radiata to reach zona pellucida layer.

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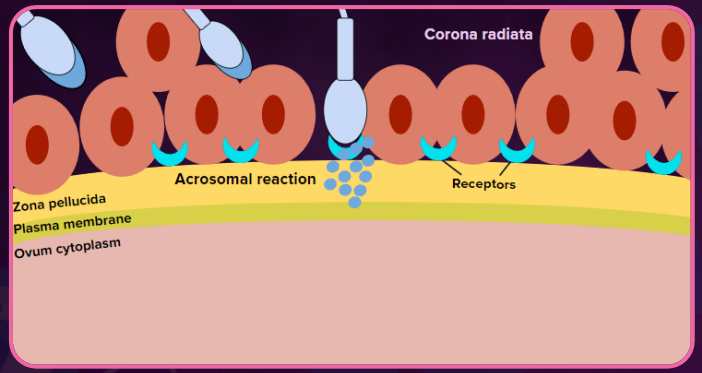
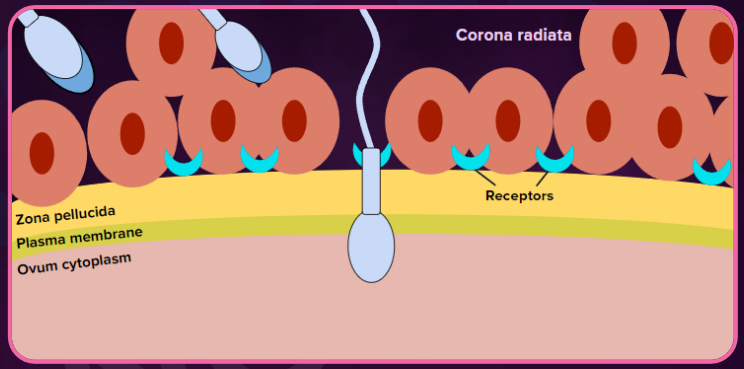
Penetration of Oocyte





- Once the sperm reaches zona pellucida, it binds to receptors on the zona pellucida and undergoes an acrosomal reaction.

- The hydrolytic enzymes/ digestive enzymes degrade zona pellucida.
- This enables the sperm to penetrate zona pellucida layer and plasma membrane of ovum.

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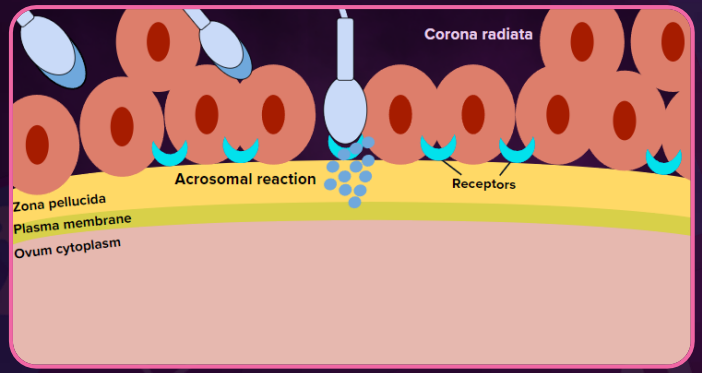
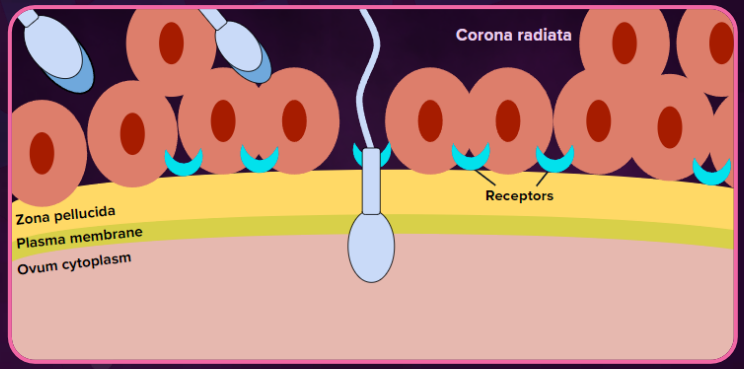
Penetration of Oocyte

Once a sperm penetrates the ovum, all the receptor sites for sperms, on the oocyte, are blocked. This ensures that polyspermy is avoided. This is referred to as depolarisation.





- As the sperm enter ovum cytoplasm, ovum releases chemicals.
- These chemicals block the receptors on zona pellucida of ovum, thereby blocking the entry of other sperms.
- The sperm's tail and body detaches from the head and disintegrates.
- The sperm head travels towards the nucleus of the oocyte.

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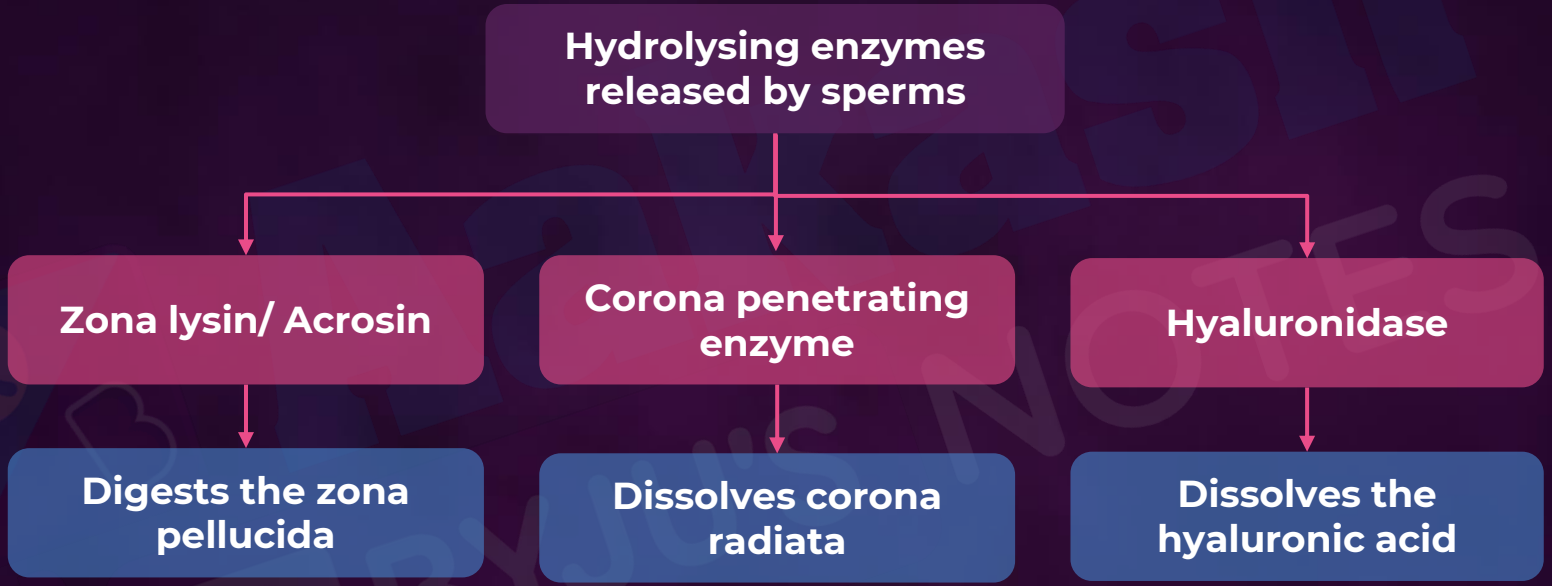
Penetration of Oocyte



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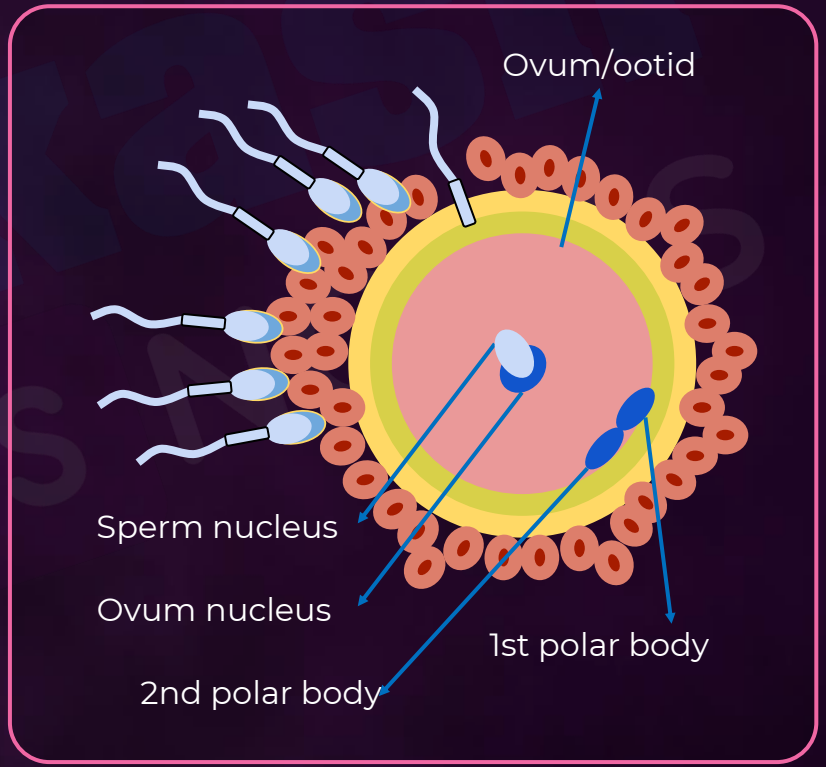
Fusion of Gametes

- Once a sperm cell enters a secondary oocyte, the oocyte must complete meiosis II first.
- It divides into a larger ovum and a smaller second polar body that fragments and disintegrates.
- The pronucleus of both the sperm head and the ovum fuse.
- A single diploid nucleus containing 46 chromosomes is formed.
- The fertilised ovum now is called a zygote.



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Embryonic Development

It includes cleavage, blastulation, implantation, gastrulation and organogenesis.

Cleavage

- First cleavage is completed after 30 hours of fertilization. Meridional plane completely divides the zygote into two blastomeres, which is known as holoblastic cleavage.
- Second cleavage is completed after 60 hours of fertilization.

Blastulation

- Cleavage results in a solid ball of cells called morula having 8-16 cells.
- As morula enters uterus, outer peripheral cells enlarge and flatten to form trophoblast or trophoectoderm.
- Trophoblast cells secrete a fluid into the interior creating a cavity called blastocoel.
- With the formation of blastocoel morula is converted into blastocyst.

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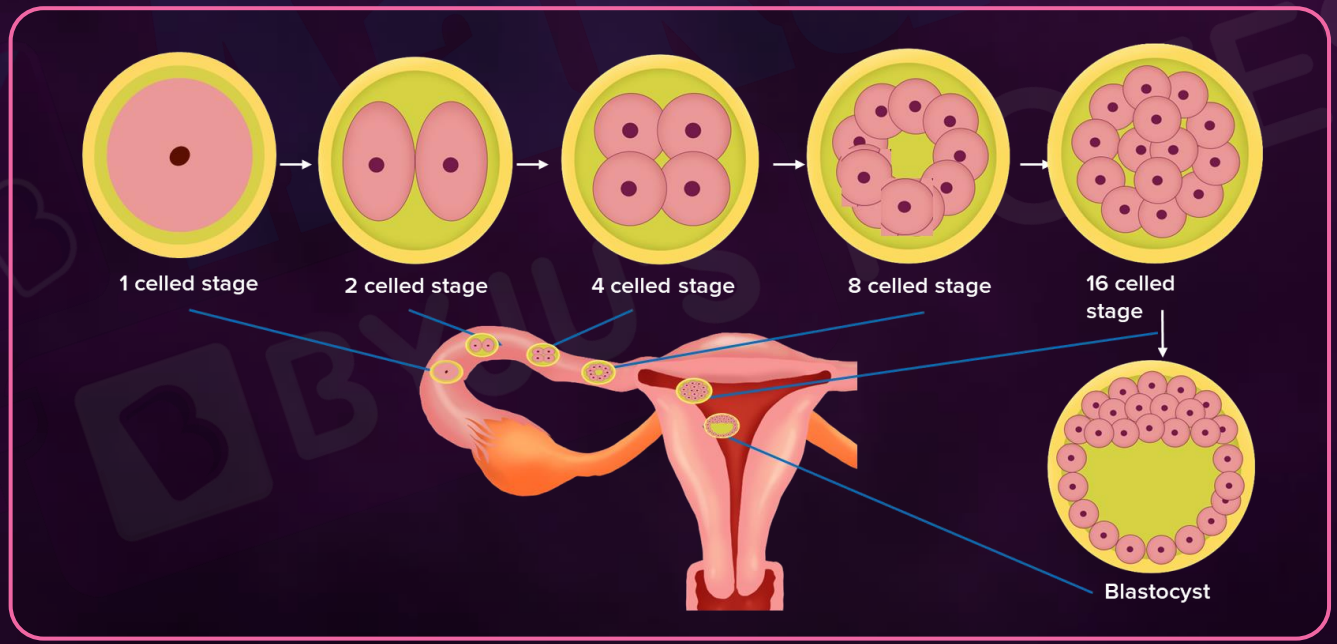
Embryonic Development

Implantation

Implantation is the process by which embryo attaches to the endometrial surface of the uterus.

- By day 4-5, the early blastocyst starts developing villi and implants itself into the uterus at the end of 7^{th}-8^{th} day of fertilisation.



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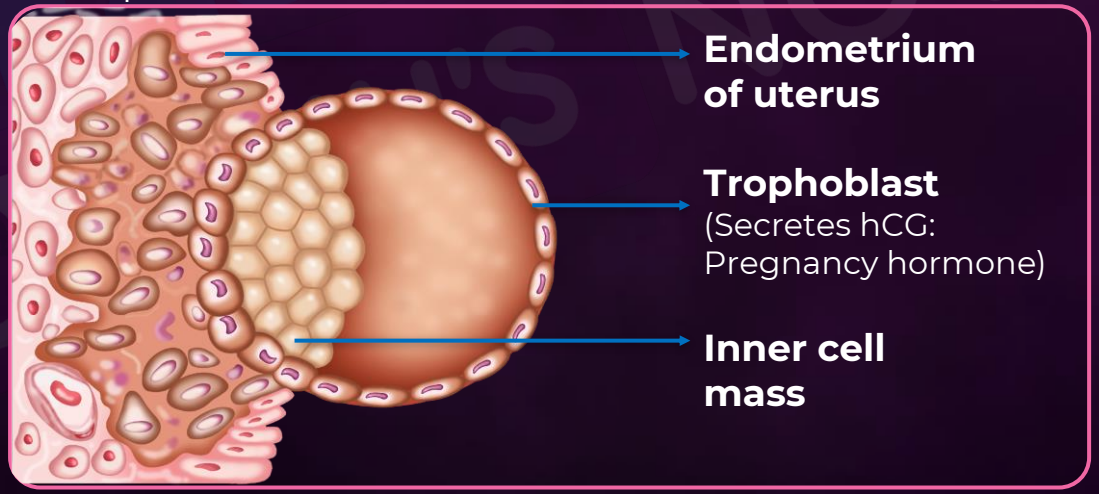
Embryonic Development

- Implantation causes nutrient enrichment, enlargement of cells and formation of uterine part of placenta called decidua, which has three regions: decidua basalis, decidua capsularis and decidua parietalis.
- During implantation, endometrium of uterus thickens to support implantation.
- After attachment of blastocyst, the uterine cells divide rapidly and cover the blastocyst.
- As a result, the blastocyst becomes embedded in the endometrium of the uterus. This completes implantation.



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Embryonic Development

Gastrulation

- Transformation of blastula into multilayered and multidimensional structure (Gastrula) is known as gastrulation.
- Cells of inner cell mass rearrange to form a flat embryonic or germinal disc.
- The latter differentiates into two layers, an outer layer epiblast and inner hypoblast.
- Epiblast is the source of all germ layers in the embryo.

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Post Fertilisation Event

- After fertilisation, rapid mitotic cell divisions of the zygote, called cleavage, takes place.
- Each daughter cell formed as a result of cleavage is called a blastomere.
- The first division of the zygote begins about 24 hours after fertilisation and is completed about 6 hours later.
- By the third day after fertilisation, the second cleavage is completed, and four cells are formed.
- By day four, 8-celled stage called morula is achieved.
- By the end of day 4 or day 5 beginning, morula transforms into a 16-celled structure. By this time morula also reaches the uterus.

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Post Fertilisation Events

- The early blastocyst structure consists of :
  - an inner cell mass concentrated at one end
  - a layer of trophoblast lining the inner cell mass
- The early blastocyst structure then matures into the late blastocyst structure and becomes completely merged with the endometrium.
- Inner cell mass starts receiving nutrients from the endometrium.

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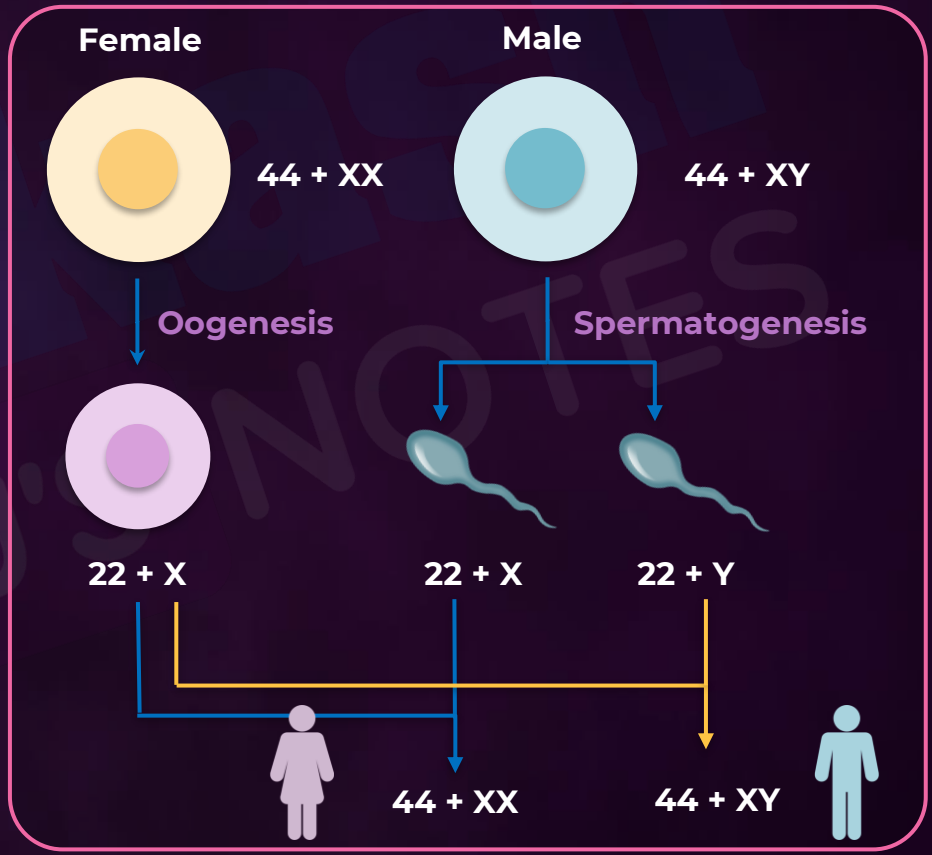
Gender Determination

- Gender of a child is determined by the sex chromosome contributed by the father during fertilisation.
- Mother, having a pair of x chromosomes, can only contribute the x chromosome to the progeny.
- However, father having x and y for sex chromosomes can contribute either of the two.
- If the father contributes y chromosome, then a boy is born.
- If the father contributes x chromosome, then a girl is born.



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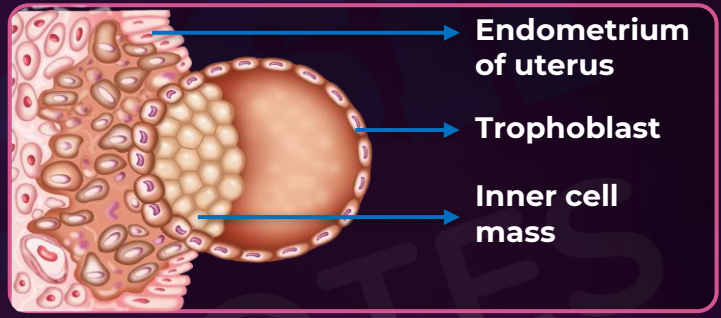
Post Implantation Events

- The blastocyst has two types of cells:
  - Outer trophoblast
  - Inner cell mass or embryoblast



Trophoblast + **Endometrium** → **Placenta**

Inner cell mass → (**Gastrulation**) → **Germinal layers**

- During the post implantation event, the trophoblast along with the endometrial lining contributes to the formation of placenta.
- The inner cell mass further divides to give rise to the germinal layers.

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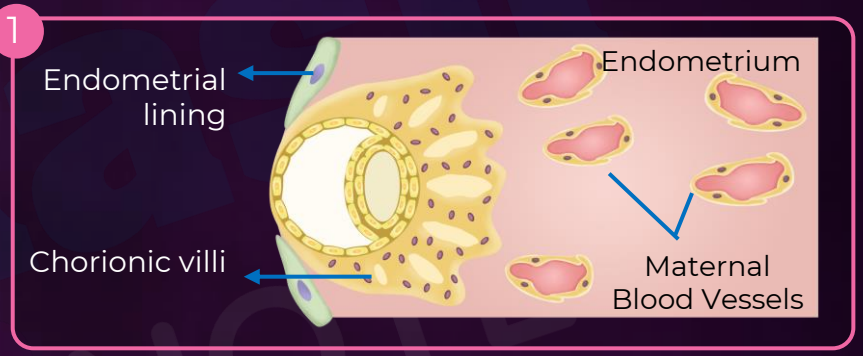
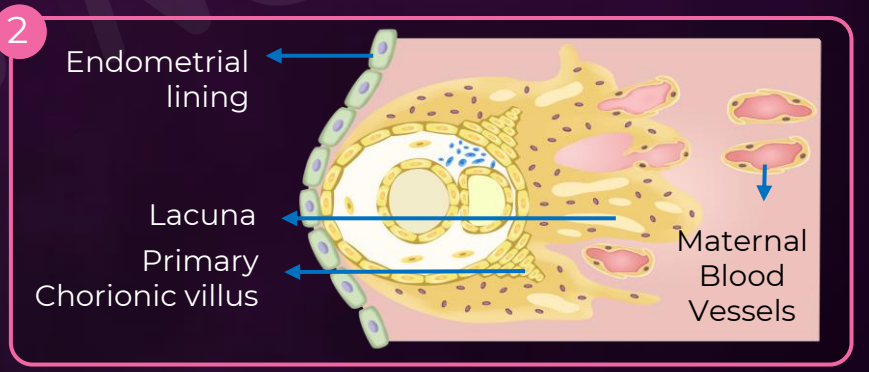
Post Implantation Events

To nourish the embryo, the endometrium prepares itself before implantation.

1
- It thickens due to the supply of lots of blood vessels.
- After the implantation, the trophoblast gives rise to the chorionic villi that comes in contact with the maternal blood vessels of the endometrium.



2
- The space between the villi growing from trophoblast is known as lacuna.
- The maternal blood vessels come in contact with these empty spaces.
- The cells developing from the trophoblast also have the foetal blood vessel.



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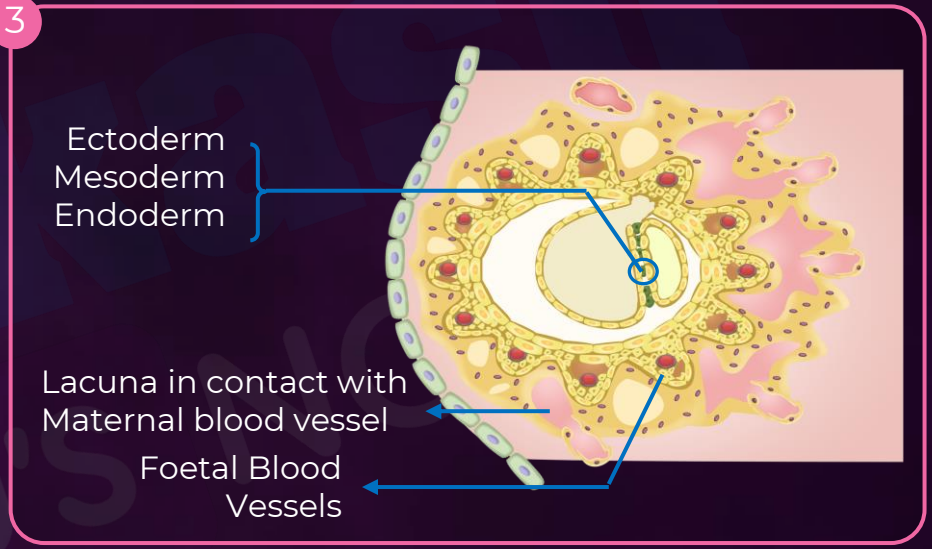
Post Implantation Events

3

- The maternal blood vessels and the foetal blood vessels give rise to the placenta.
- Simultaneously, there are also changes happening to the inner cell mass.
- The inner cell mass eventually gives rise to the germinal layers: ectoderm, mesoderm, and endoderm.



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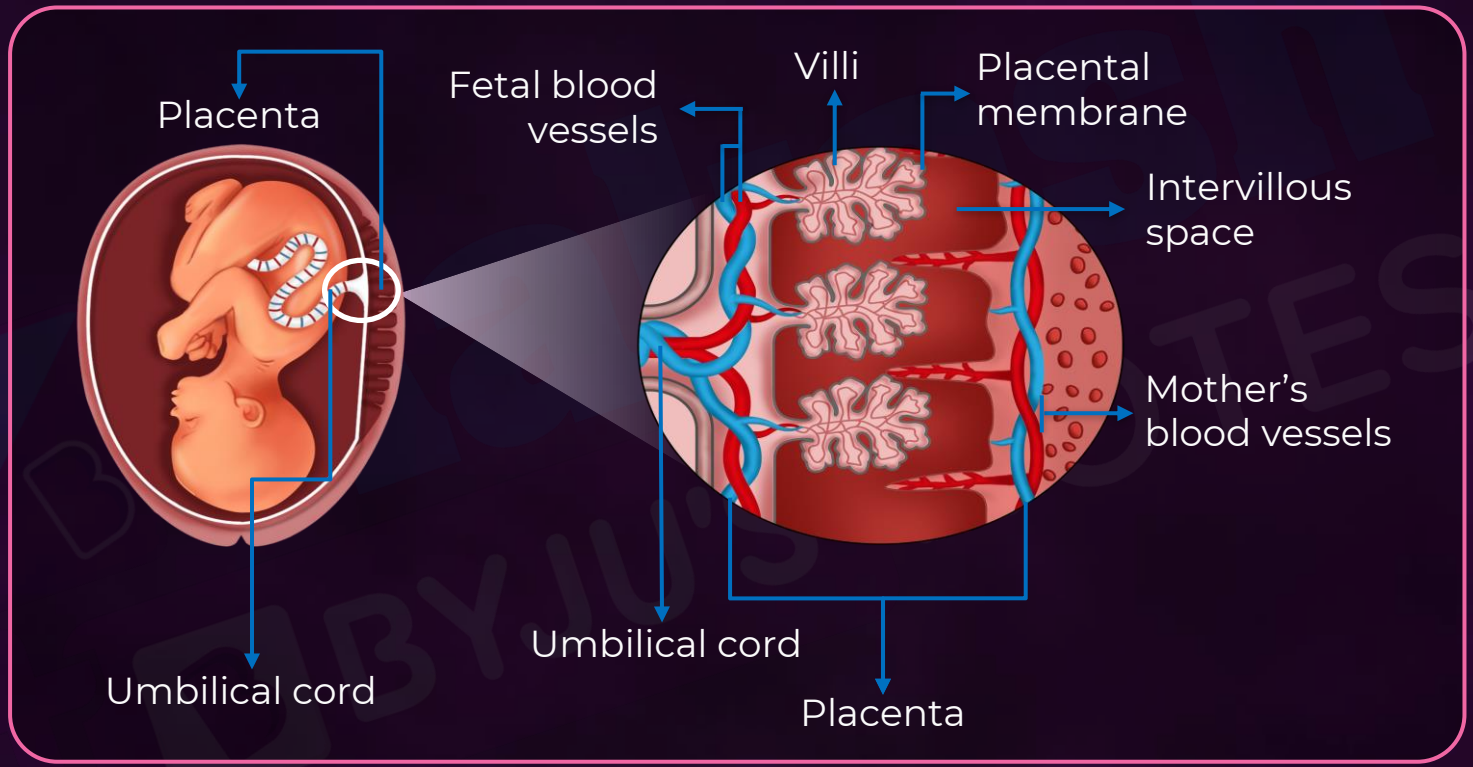
Placenta - Formation



The developing foetus is connected to the placenta via umbilical cord

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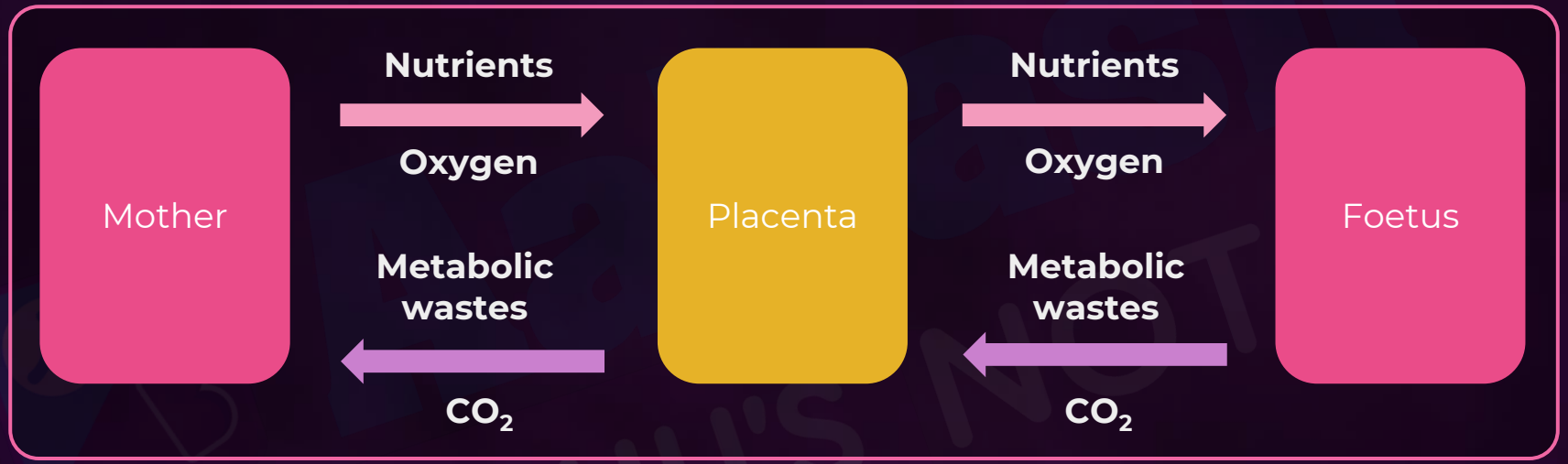
Placenta - Function



Nutrients from the mother are supplied to the foetus via placenta.

- Mother is the source of oxygen for the developing foetus.
- Foetus also returns carbon dioxide and excretory products to the mother.
- These products are then excreted out of the mother's body.

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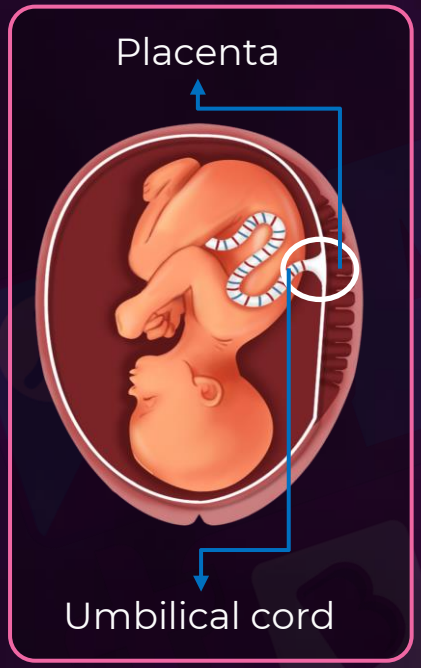
Placenta - Function



- Placenta confers passive immunity to the foetus by transferring antibody IgG. These antibodies work against diphtheria, scarlet fever, smallpox, measles, etc.
- Placenta acts as a protective barrier.
  - It protects the foetus from germs and pathogens circulating in the mother's blood.
- Placenta also stores glycogen and acts as a food reserve for the foetus.

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Placenta – Temporary Endocrine Gland

- The placenta releases several hormones only during pregnancy. Thus, it acts as a temporary endocrine gland. Various hormones include:

hCG

- Human chorionic gonadotropin (hCG) promotes progesterone secretion by corpus luteum
- It helps in maintaining the pregnancy

hPL

- Human placental lactogen (hPL) breaks down fats in mother to supply energy to the foetus

Relaxin

- Relaxin helps in relaxing the ligaments of pelvis
- It helps in widening of the cervix
- It helps in childbirth
- It is also produced by ovary

Estrogen and Progesterone

- Estrogen stimulates growth of myometrium
- Progesterone makes endometrium viable for implantation

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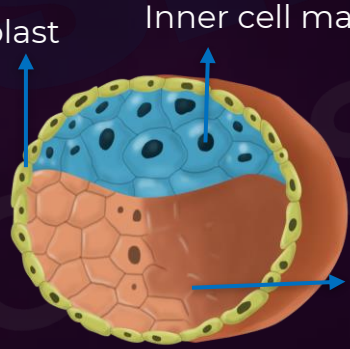
Gastrulation

Gastrulation is the process by which the inner cell mass gives rise to a structure called gastrula that has various germinal layers.

1. While the formation of the placenta takes place, simultaneously gastrulation also takes place.
2. The blastocysts have inner cell mass, which help in the structural changes and formation of cylindrical cells.

2. The cells start dividing from the bottom and separate from the top. Consequently, two types of cells are formed:
   - Epiblast on the top
   - Hypoblast in the bottom
   - Epiblast + Hypoblast = Embryonic disc

1



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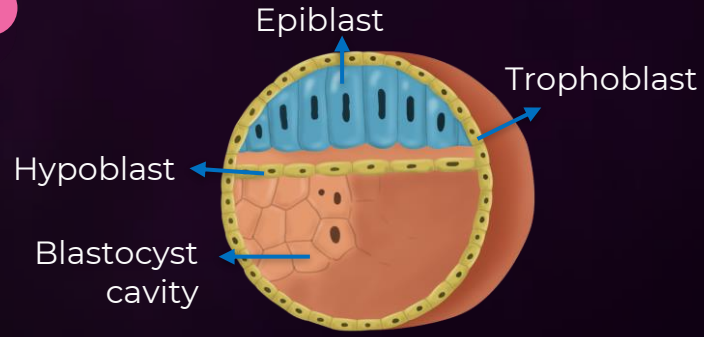

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Gastrulation

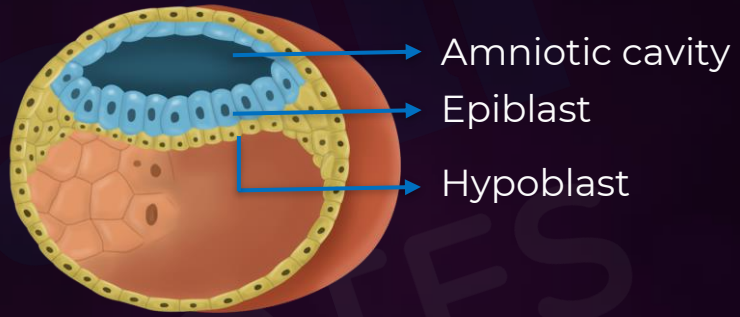
3

- The fluid starts accumulating in between the epiblast, forming a cavity known as an amniotic cavity, which is filled with a fluid known as amniotic fluid.
- The amniotic fluid acts as a shock absorber, protects the developing foetus and prevents desiccation of foetus.

4

- The hypoblast undergoes division and gives rise to the three germinal layers.
  - Ectoderm, mesoderm, and endoderm
- The structure formed is known as gastrula.

3



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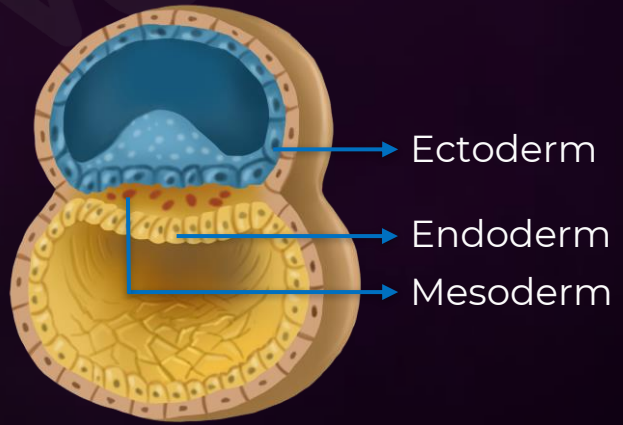

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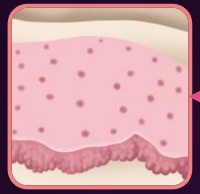
Gastrulation

Ectoderm (external layer)

- Skin cells of epidermis

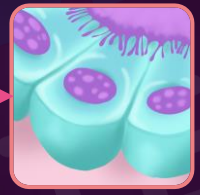


- Neuron

- Pigment cells

Endoderm (internal layer)

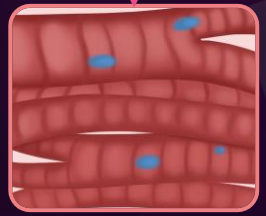
- Lung cells (alveolar cell)



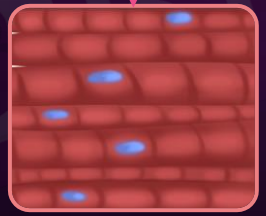
- Thyroid cells

- Digestive cells (pancreatic cell)

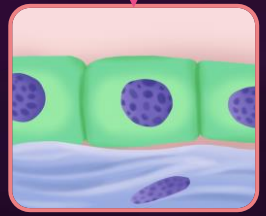
Mesoderm (middle layer)



Cardiac muscle cells

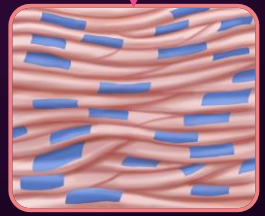


Skeletal muscle cells



Tubule cells of the kidney

Red blood cells



Smooth muscle cells (in gut)

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Gestation Period/ Pregnancy

TRIMESTER	MONTH	WEEK
1st 	1	0 - 4
	2	5 - 8
	3	9 - 13
2nd 	4	14 - 17
	5	18 - 22
	6	23 - 27
3rd 	7	28 - 31
	8	32 - 35
	9	36 - 40

- The first four weeks of the pregnancy includes ovulation, fertilization, implantation and gastrulation.
- Post gastrulation, development of different organs and organ systems in the embryo occurs.

Gestation period/ Pregnancy – 40 weeks

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Changes in the Embryo

1st trimester | 4 weeks | 1st month

- Baby is about strawberry seed size
- Major organ systems begin to form
- Baby grows rapidly
- Heart is formed

1st trimester | 8 weeks | 2nd month

- Limbs and digits begin to develop

1st trimester | 12 weeks | 3rd month

- Placenta becomes fully functional and takes over hormone production
- External genital organs and limbs are formed

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Changes in the Embryo

2nd trimester | 16 weeks | 4th month

- Ability to hear develops
- Ability to taste develops

2nd trimester | 20 weeks | 5th month

- Placenta is fully developed
- Reproductive system is fully developed
- First movement is seen
- Hair appears on head

2nd trimester | 24 weeks | 6th month

- Body is covered with fine hair
- Grease like protective covering develops on skin
- Eyelids separate
- Eyelashes are formed

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Changes in the Embryo

3rd trimester | 28 weeks | 7th month

- Frequency of eye movement increases
- Growth of brain occurs rapidly

3rd trimester | 32 weeks | 8th month

- Sleep wake cycle is regularised

3rd trimester | 36 weeks | 9th month

- The foetus turns upside down with its head near the cervix

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Foetal Ejection Reflex

- The foetal ejection reflex involves uterine contractions that are generated by the placenta when the foetus is fully developed.
- This reflex is seen during the time of parturition.
- The foetal ejection reflex involves the interaction between the female reproductive system and the brain.

- The pain is a result of a fully developed foetus.

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Foetal Ejection Reflex

Fully developed foetus

Pushes down into the birth canal

Stretching of cervix

Nerve impulses

Hypothalamus

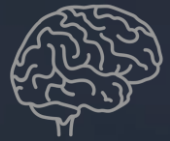
Releases oxytocin into the blood

Posterior Pituitary

Contraction of myometrium

Parturition

Female Reproductive System



Brain

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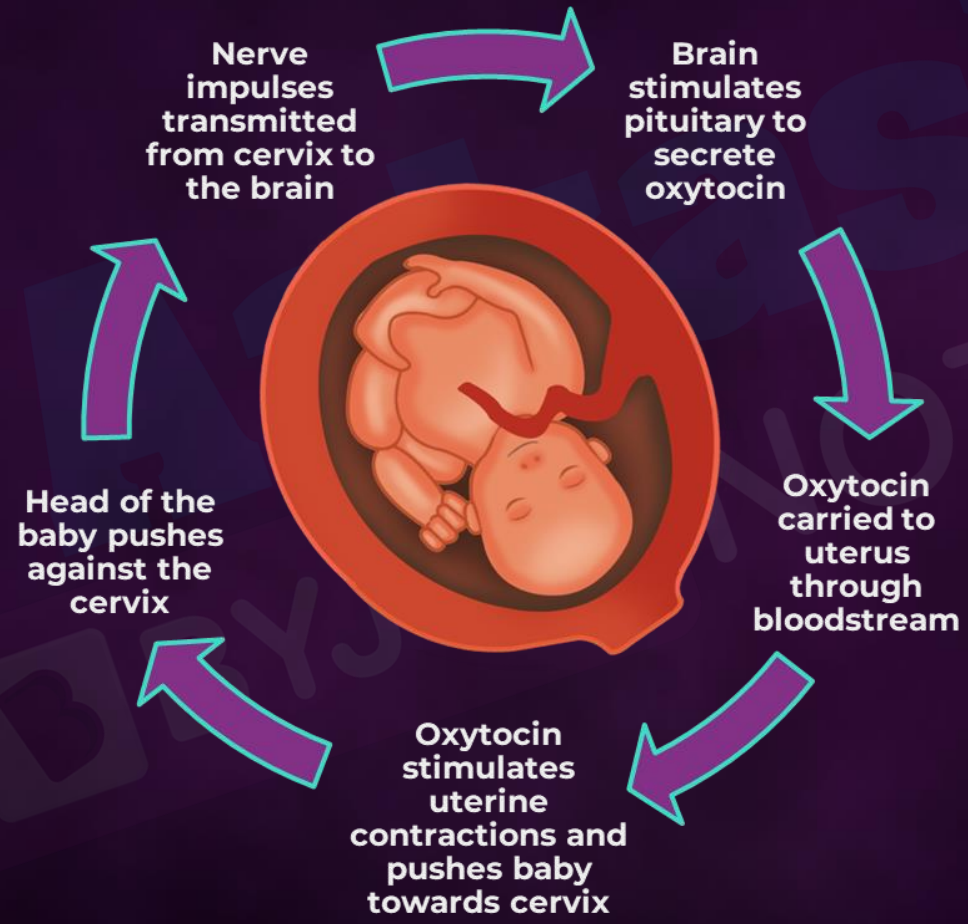
Positive feedback loop during Parturition



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Parturition

- Parturition is the process of delivery of foetus.
- The delivery of foetus is followed by expulsion of placenta.
- It is caused as a result of foetal ejection reflex.

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Lactation

- The mammary glands produce milk towards the end of pregnancy
- Breast- feeding – process of feeding the milk to the baby which is produced by the mammary glands
- Colostrum – milk produced in the initial days of lactation
- Colostrum is rich in antibodies especially IgA

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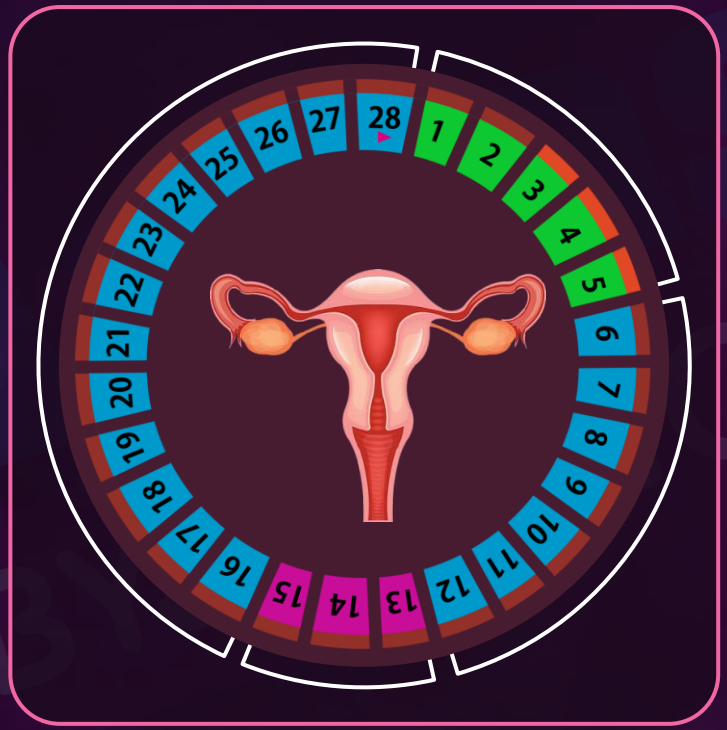
Menstruation



It is regular discharge of blood and mucosal tissue (known as menses) from inner lining of the uterus through vagina.

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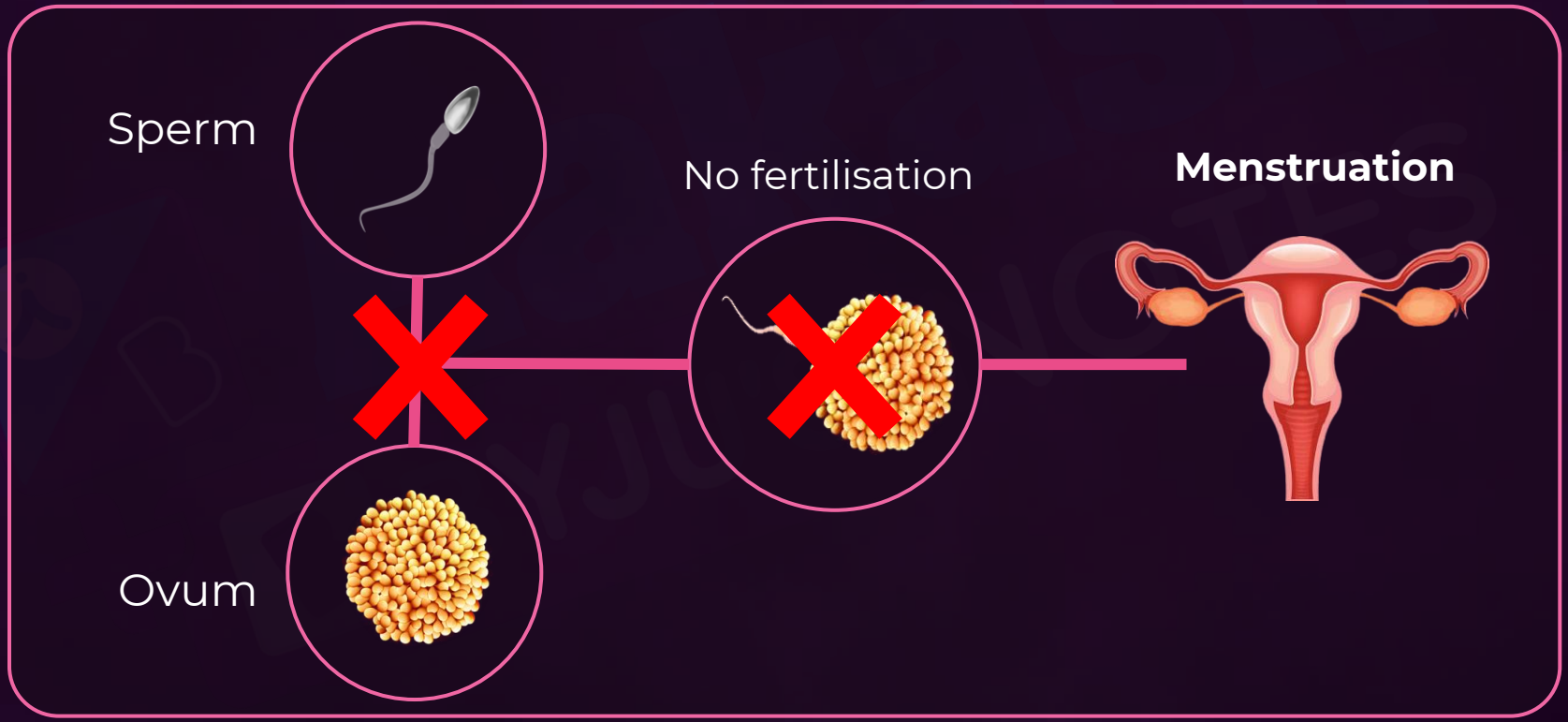
Menstruation

- In the absence of fertilisation, the uterus enters the menstrual phase.



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Menstruation

- Menstrual phase marks the onset of a menstrual cycle.
- On an average, a menstrual cycle lasts 28 days.
- Bleeding/menstruation usually lasts around 3 to 4 days.
- In the span of 28 days, there are two cycles that happen simultaneously:
  - Ovarian cycle in the ovary
  - Uterine cycle in the uterus
- Besides human beings, other close primates like monkeys and apes also menstruate.

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Ovarian Cycle

Follicular phase

1 - 3 days

- The secretion of FSH is stimulated by GnRH.
- FSH stimulates the follicular growth and the oocyte development inside the follicle.

4 - 7 days

- There is a gradual increase in the levels of FSH and LH during the first seven days.
- The growth and the development of the follicle and the oocyte continues.

8 - 13 days

- Graafian follicle containing the secondary oocyte matures.

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Ovarian Cycle

Ovulatory phase

14th day

- A steep increase in the LH levels is known as LH surge leads to the rupture of the Graafian follicle to release the secondary oocyte (ovulation).

- An over-the-counter home test that detects a rising level of LH can be used to predict ovulation a day in advance (OPKs - Ovulation predictor kits).
- It can detect LH in urine, released due to LH surge.

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Ovarian Cycle

Luteal phase

15 - 20 days

- After ovulation, formation of corpus luteum (yellow body) from the remnants of the follicle is stimulated by LH.
- Post that, there is a reduction in FSH and LH levels.

20 - 28 days

- FSH and LH levels further decrease.
- Corpus luteum degenerates in the absence of fertilisation to form corpus albicans (white body).
  - The duration of the luteal phase is always fixed in human females and it is about 14 days.
  - Hence, ovulation is expected on 26^{th} day of the menstrual cycle.

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Uterine Cycle

Proliferative phase

- Duration: From the last day of menstruation up to the 14th day of the menstrual cycle.
- Hormonal levels:
  - Rise in estrogen levels due to secretion from growing follicles
  - Low progesterone levels
- The proliferation of endometrium stimulated by estrogen takes place.
- There is an increase in number of the uterine glands and the blood vessels with the thickening of endometrium.

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Uterine Cycle

Secretory phase

- Duration: 15th - 28th day of the menstrual cycle
- Corpus luteum secretes large amount of progesterone.
- The progesterone maintains the endometrium, preparing for future implantation.
- Endometrium further thickens due to estrogen also secreted by corpus luteum.
- Estrogen and progesterone inhibit the release of FSH and LH.
- In the absence of fertilisation, corpus luteum degenerates.
- One menstrual cycle ends and the next starts with the onset of menstruation

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Uterine Cycle

Menstrual phase

- Duration: 3-5 days (1^{st}-5^{th} day of the menstrual cycle)
- The disintegration of corpus luteum decreases the level of progesterone which leads to menstruation.
- The endometrial lining of the uterus disintegrates along with its blood vessels.

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Lack of Menstruation

There can be some underlying causes for the lack of menstruation.

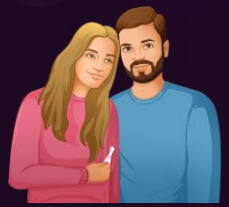
Weight changes

Profound stress

Illness

Medications

Extreme exercise



Pregnancy

Menarche

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Menstruation Cycle

BIRTH

PHASE 1

Pre - Menarche

MENARCHE

It is the onset of menstruation at puberty in a female.

PHASE 2

Post – Menarche / Pre - Menopause

MENOPAUSE

It is the ceasing of menstruation at old age in a female.

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Menstrual Care

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Menstrual Hygiene

Tampons

- It is for one-time use only.
- It is inserted into the vagina during menstruation to absorb blood and vaginal secretions.

Menstrual cup

- It is a reusable and eco-friendly cup made of medical grade silicone to collect menstrual blood inside the vagina.
- It needs to be washed and sterilised after every use.

Sanitary pad

- It is designed for one-time use only.
- It needs to be discarded every 4-5 hours.

Cloth pad

- It is a reusable pad made up of cloth.
- It is eco-friendly.

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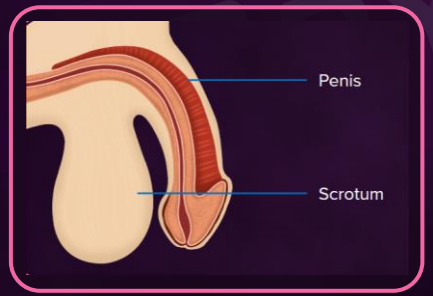
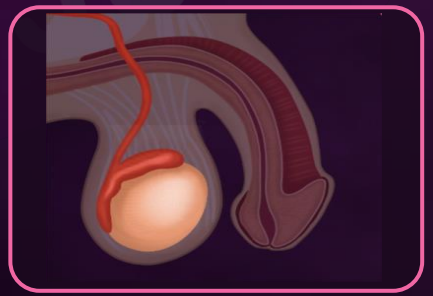
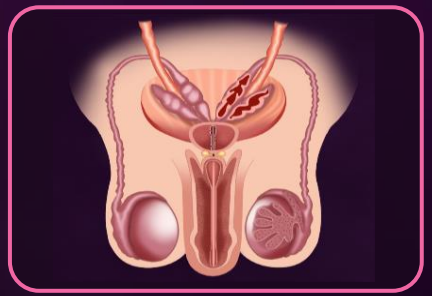
Summary

Male reproductive system

Male external genitalia	Male internal genitalia	Accessory ducts and glands
It includes scrotum and penis.	It includes testes.	It includes sperm ducts and glands.
		

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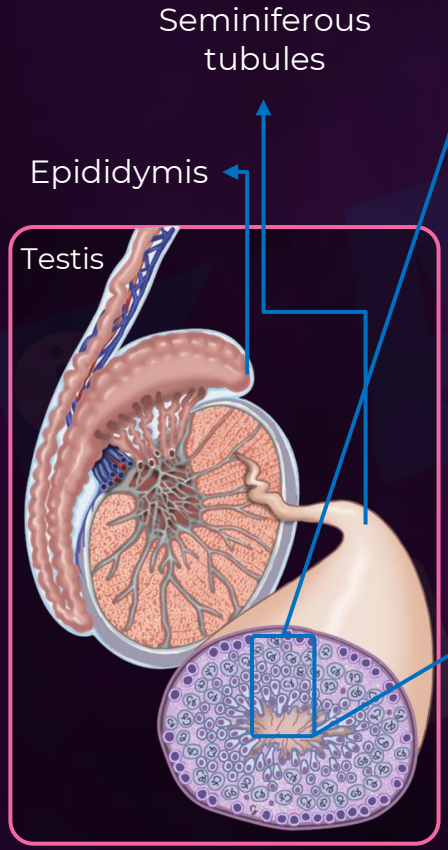
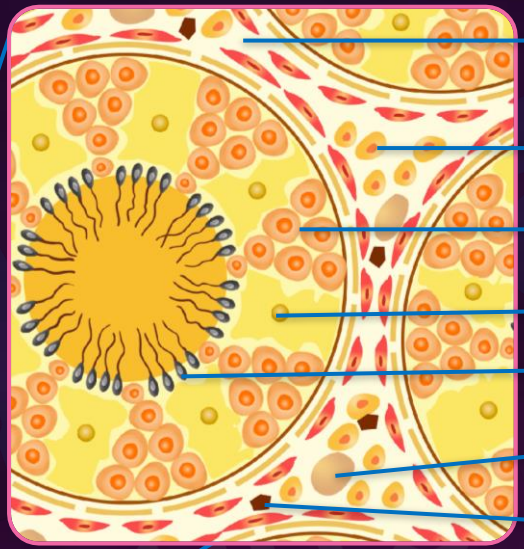
Summary





Interstitial space
(Regions outside the seminiferous tubules)

Leydig cells (synthesise and secrete male sex hormones called androgens)

Spermatogonia (Immature male germ cells)

Sertoli cells (Nourishes the germ cells)

Spermatozoa (Mature sperm)

Blood vessels

Immune cells

Testes

- Primary sex organs in human males
- Associated with the production of
  - Sperms
  - Male sex hormones

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Summary

Sperm produced in seminiferous tubule

↓ It passes through

Rete testis

↓ And reaches

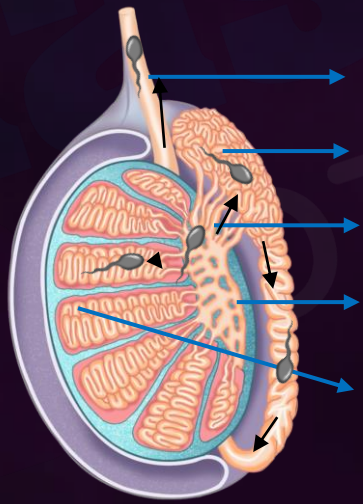
Vasa efferentia

↓ It leaves testes to travel through

Epididymis

↓ That leads to

Vas deferens



Movement of sperms within the testis

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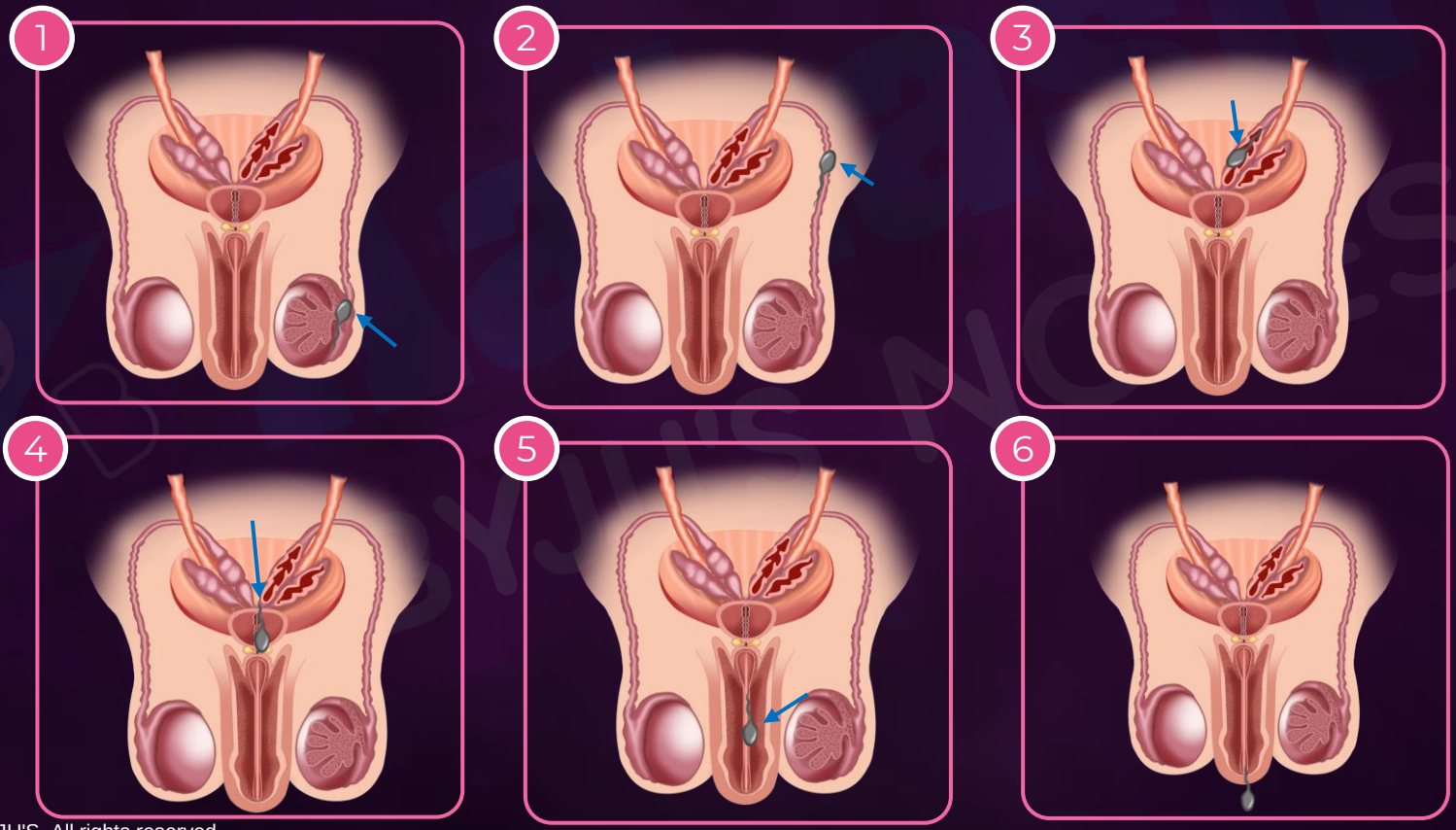
Summary

Sperms travel from testis to the penis and eject out of it during coitus.



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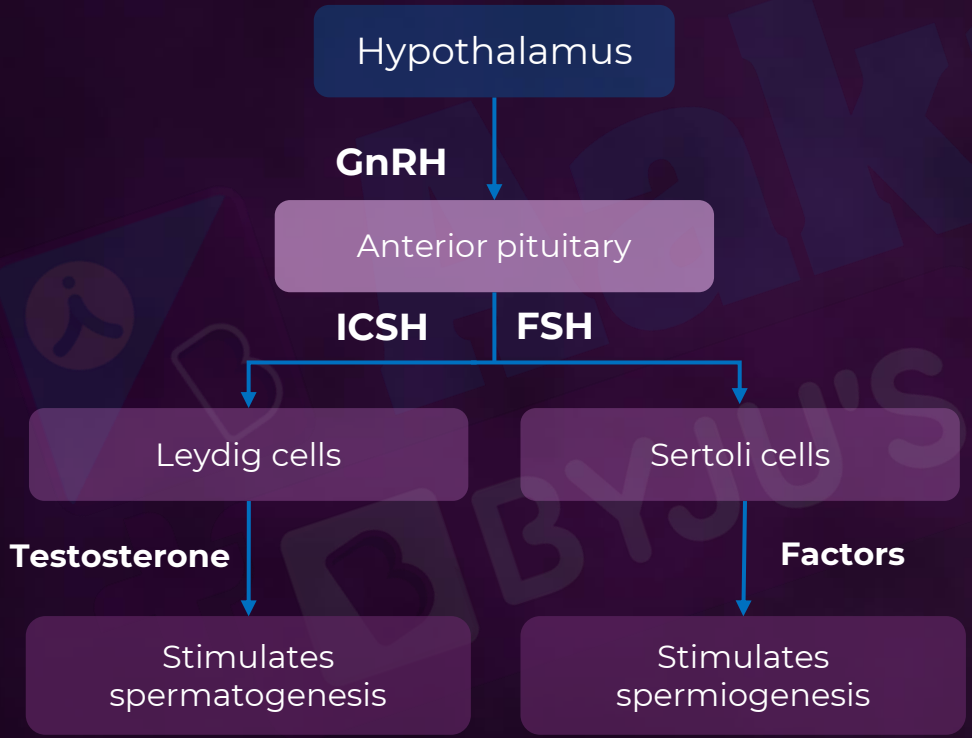
Summary

Hormonal control in males



Male sex act

1. **Erection of penis**
   Penis becomes stiff due to hydraulic pressure

2. **Copulation**
   The penis discharges the sperm into the vagina by wavelike contractions called ejaculation

3. **Subsidence of erection**
   The arterioles in the penis contract reducing blood flow to the penis, which subsides the erection

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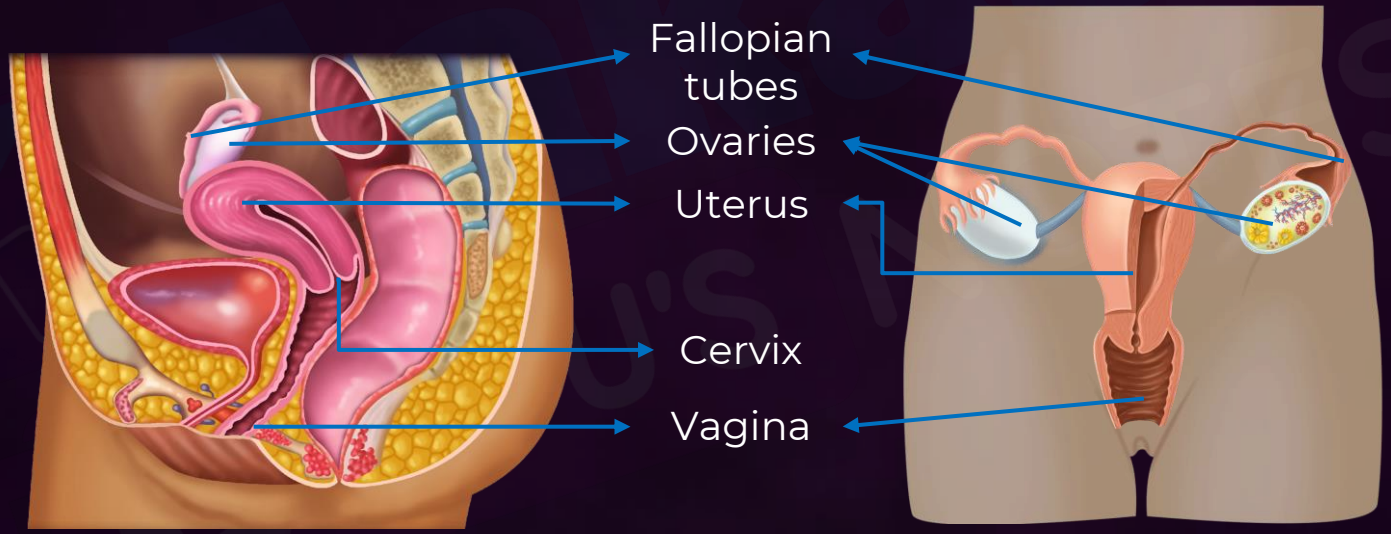
Summary

Female reproductive system



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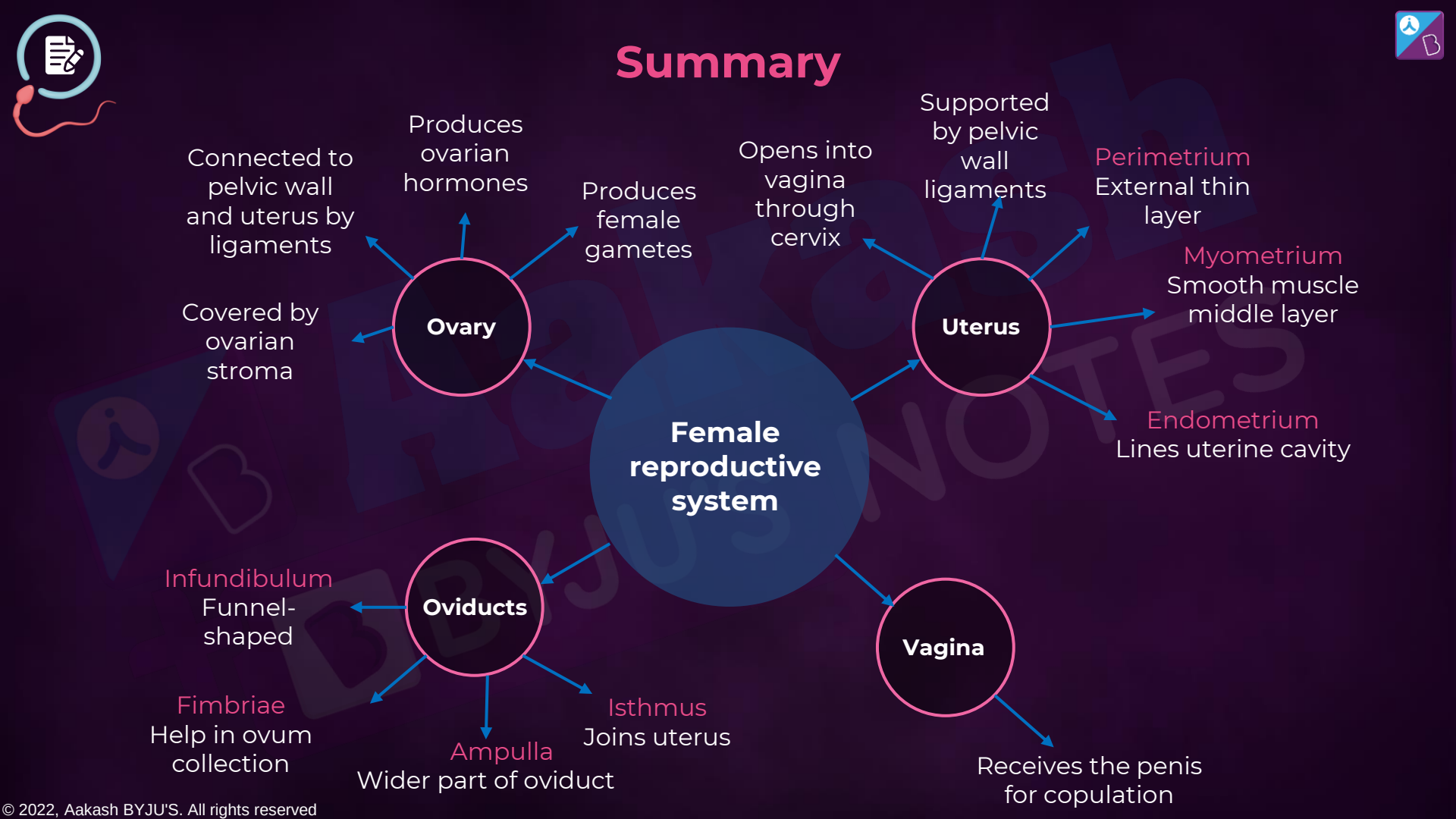

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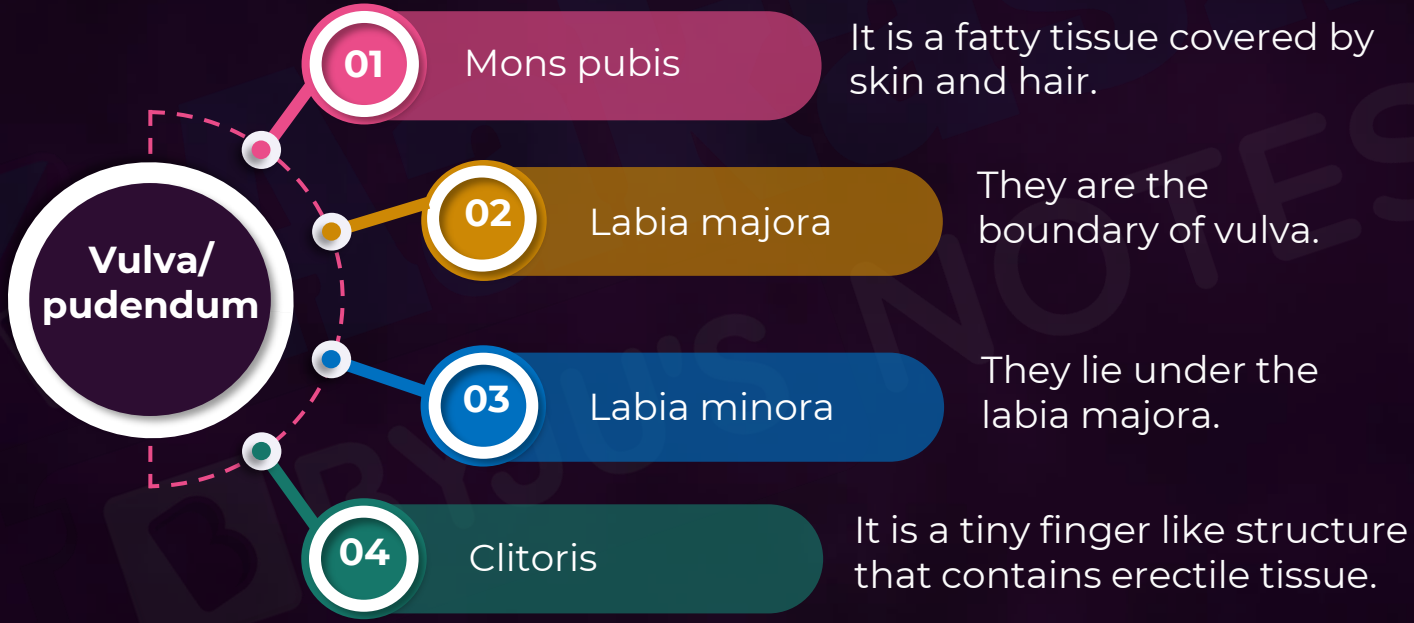

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Summary

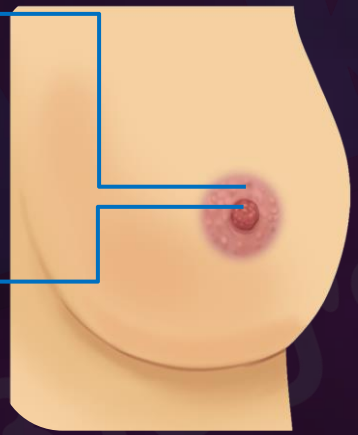
External structure of breast

Areola

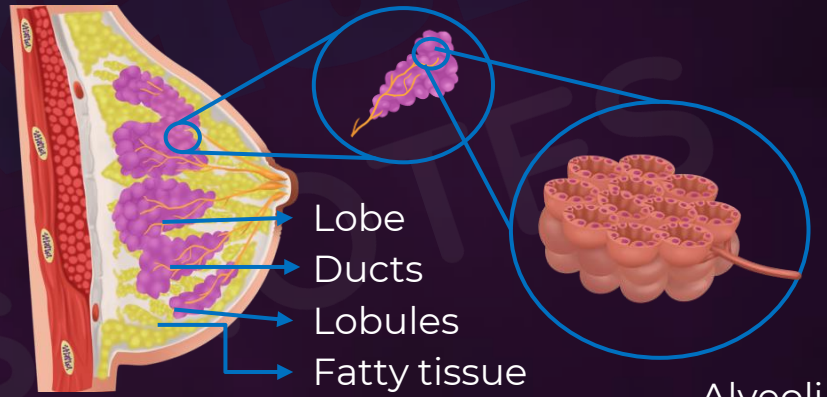
- It contains modified sebaceous (oil) glands.

Nipple

- It has a series of closely spaced openings of ducts called lactiferous ducts.



Internal structure of breast



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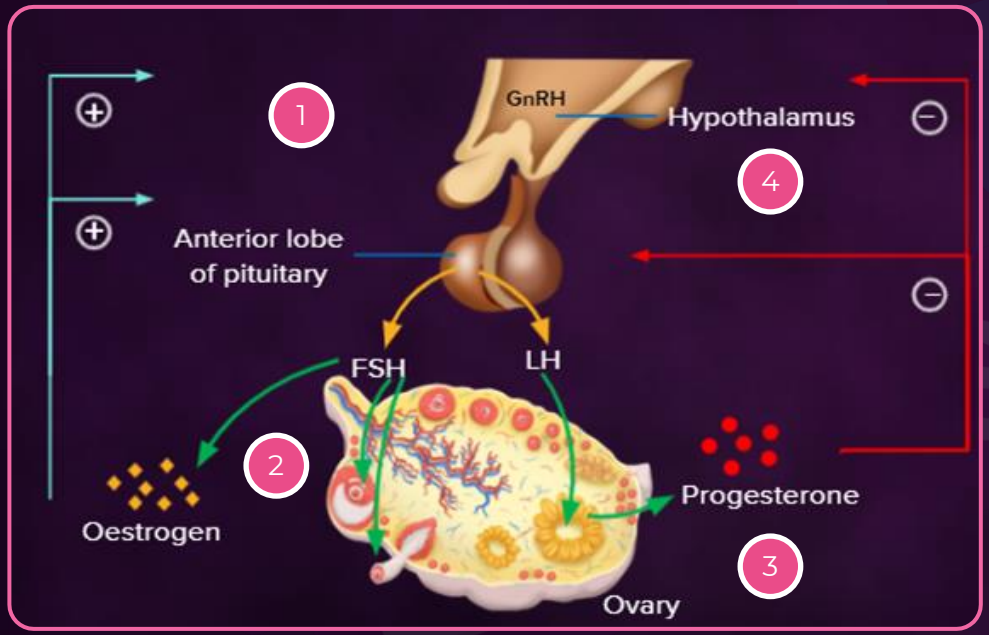
Summary

Hormonal control of female reproductive system



1. GnRH is secreted by the hypothalamus which stimulates anterior lobe of pituitary to secrete FSH and LH.

2.
- FSH mainly stimulates the formation of estrogen.
- This in turn stimulates the secretion of GnRH.

3. LH stimulates the corpus luteum to secrete progesterone.

4. Increasing levels of progesterone inhibits the release of GnRH, which in turn inhibits the release of FSH, LH and progesterone itself.

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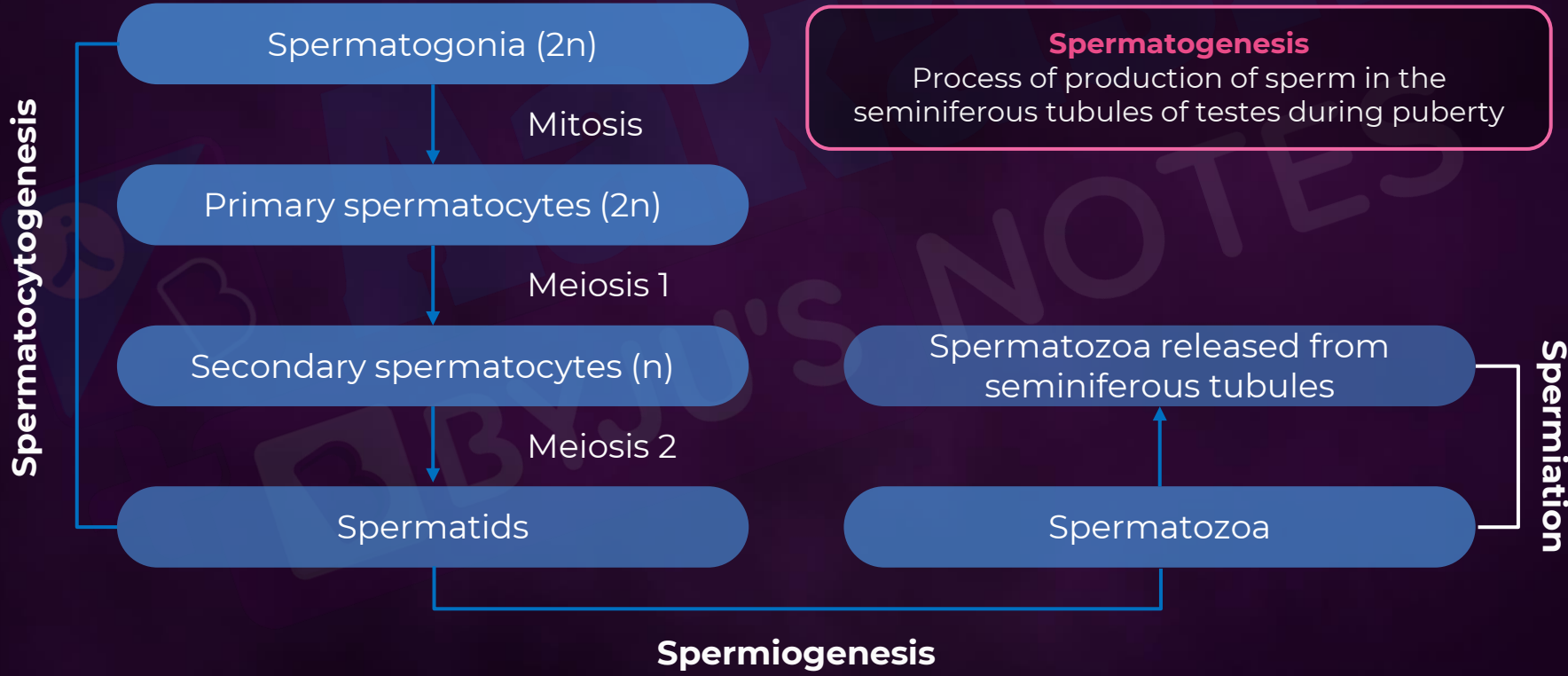
Summary

Spermatogenesis



Spermatogenesis
Process of production of sperm in the seminiferous tubules of testes during puberty

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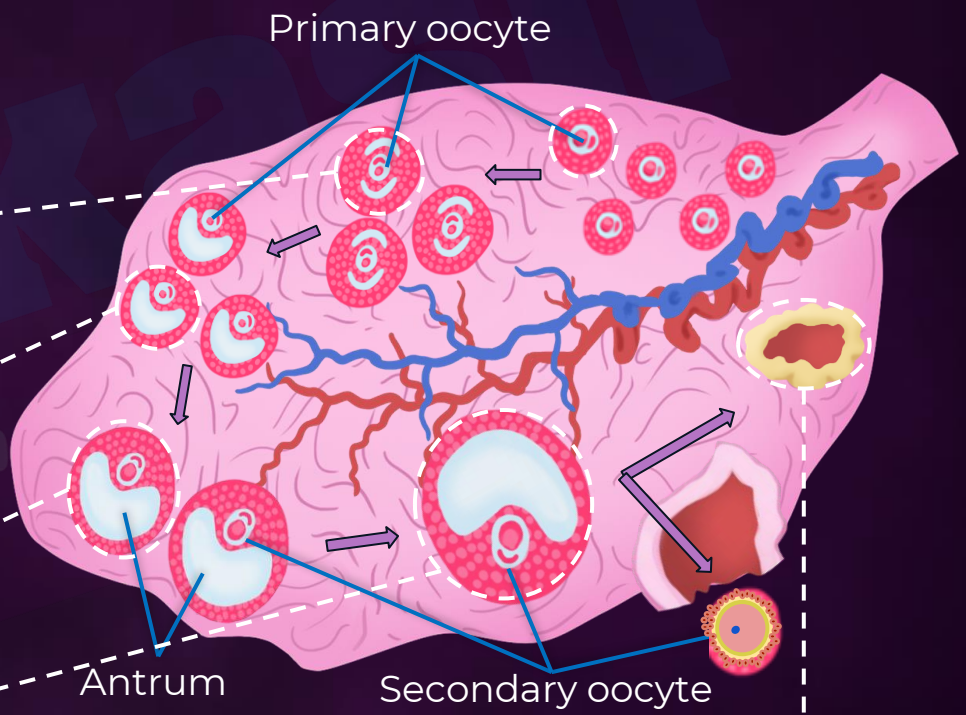
Summary

Folliculogenesis

1. **Primary follicle**
   Enlarged primary oocyte surrounded by granulosa cells
2. **Secondary follicle**
   Matured primary follicle with differentiation of theca
3. **Tertiary follicle**
   Mature follicle having a fluid filled cavity (antrum)
4. **Graafian follicle**
   Final mature follicle which undergoes ovulation



6. **Corpus luteum**
   Transformed Graafian follicle post-ovulation

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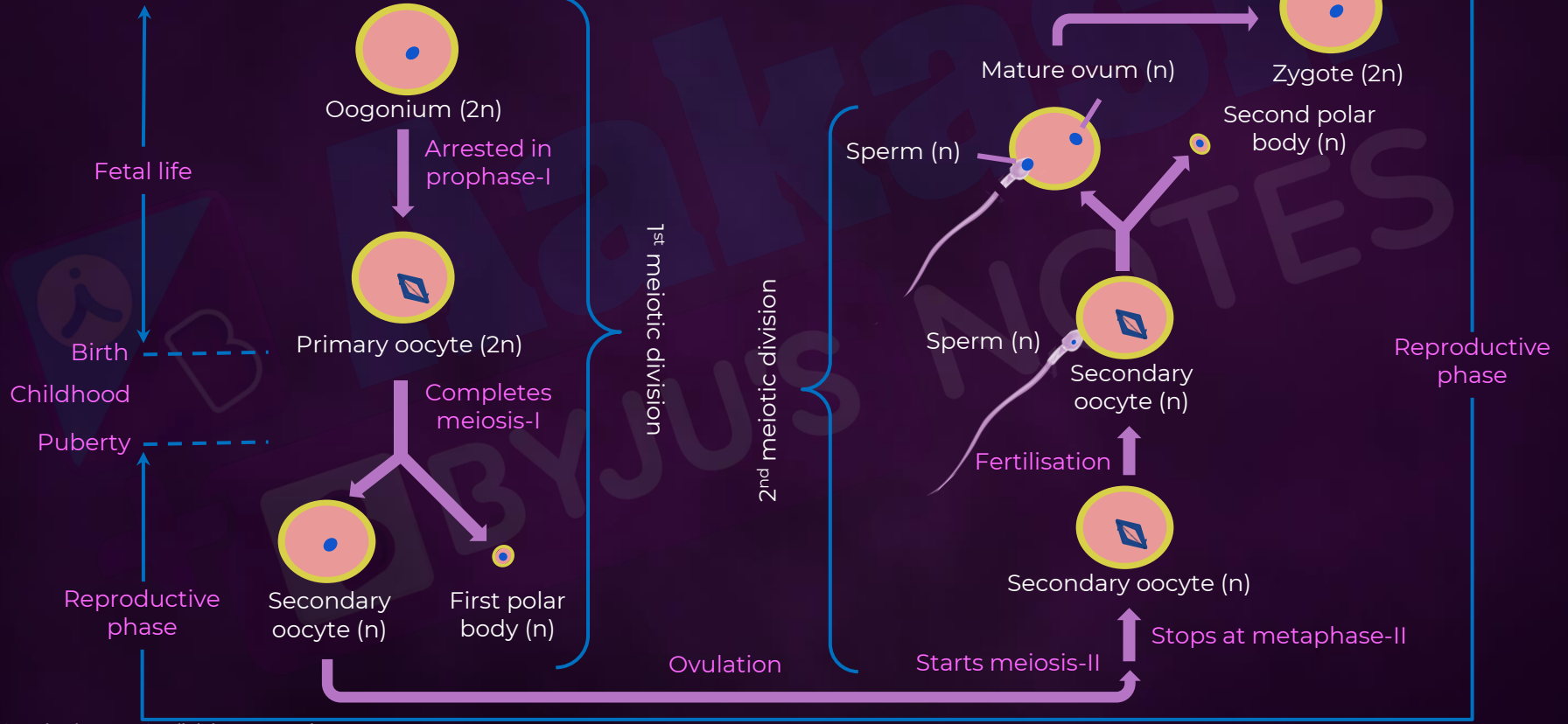
Summary

Oocyte formation and developmental stages



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Summary

Spermatogenesis vs oogenesis

Spermatogenesis	Oogenesis
Contains five stages	Contains four stages
Spermatogonia	Oogonia
Primary spermatocyte	Primary Oocyte
Secondary spermatocyte	Secondary Oocyte
Spermatids	Ovum
Spermatozoa	

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Summary

Spermatogenesis vs oogenesis

Spermatogenesis	Oogenesis
Meiosis produces cells of equal size	Meiosis produces unequal cells (small polar bodies and large ovum)
Gametes are formed by meiosis	Gametes are formed by meiosis
Release of gametes begins at puberty	Release of gametes begins at puberty

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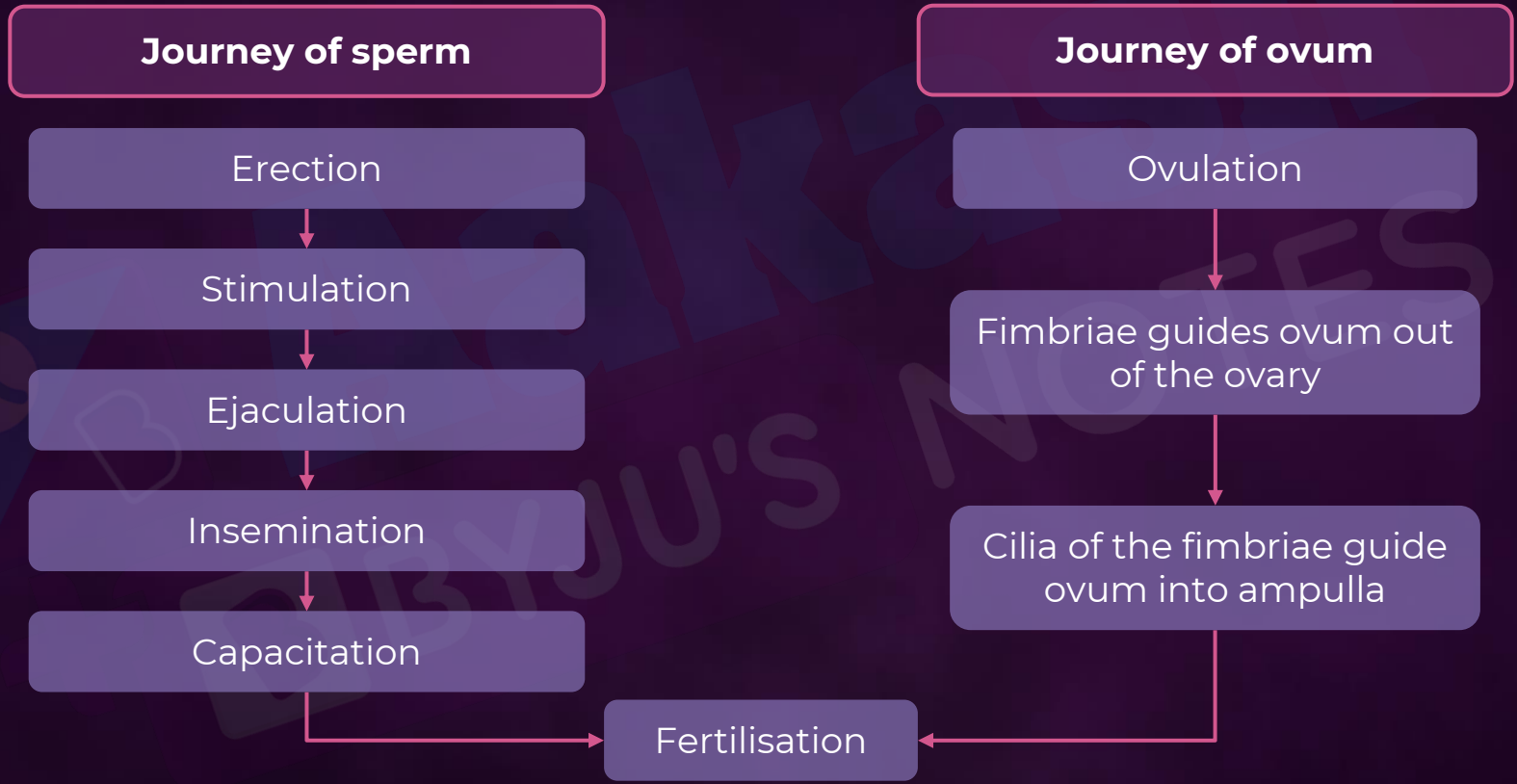

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Summary

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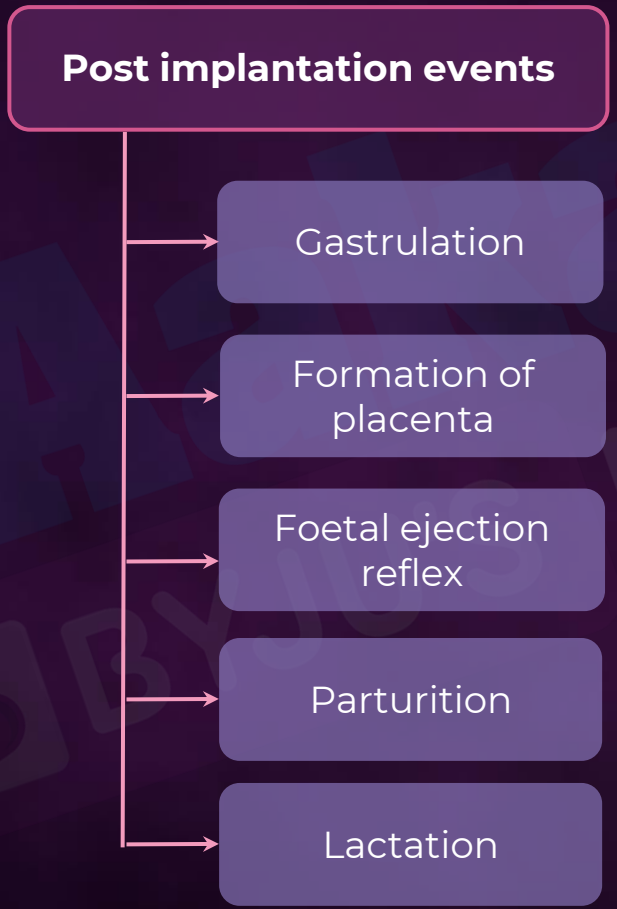

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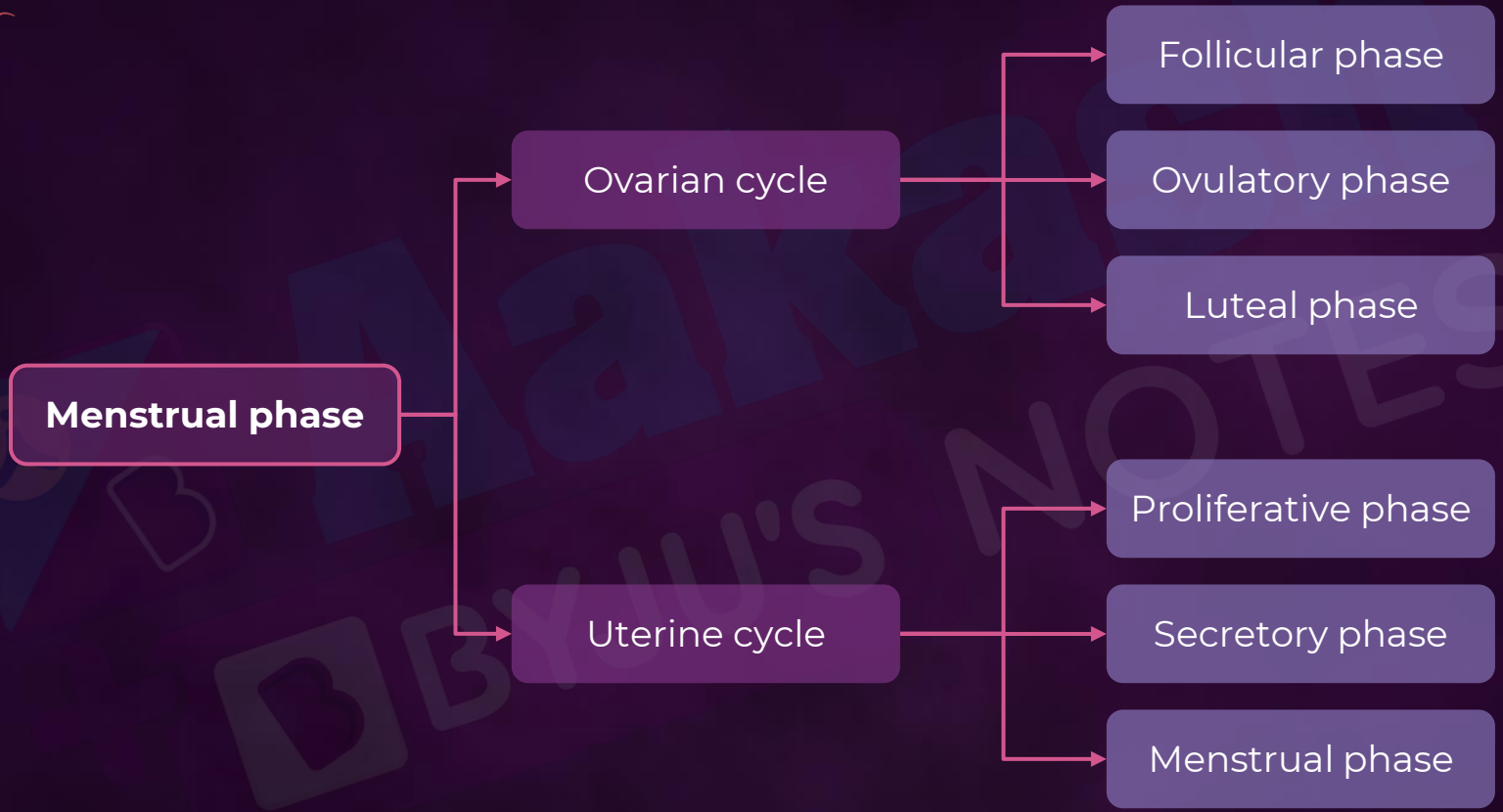

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Summary

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