Chapter 02 Human Reproduction

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Humans are sexually reproducing and viviparous organisms. Their reproductive events include –

Gametogenesis → Formation of gametes, i.e., sperms in males and ovum in females

Insemination → Transfer of sperms into the female genital tract

Fertilisation → Fusion of male and female gametes leading to formation of zygote

Implantation → Formation and development of blastocyst and its attachment to the uterine wall

Gestation → Embryonic development

Parturition → Delivery of the baby

- These reproductive events starts after puberty.
- There are remarkable differences between the reproductive events in the male and in the female, for example, sperm formation continues even in old men, but formation of ovum ceases in women around the age of fifty years.

(i) **Primary sex organs:-** Forms the gametes and also secretes sex hormones.
Ex: **Testes in males & ovaries in females**

(ii) **Secondary sex organs :-** They are responsible for nutrition, storage and transport of gametes.
- They neither produce gametes nor secrete hormones.
- In male this includes epididymis, vas deferens, seminal vesicles, prostate, cowper's glands & penis. While in female - Fallopian tube, uterus & vagina.

(iii) **Secondary/accessory sex characters: -** They appear first at the time of puberty in the influence of sex hormones and distinguish between male and female.
Ex. - Breast in females.

THE MALE REPRODUCTIVE SYSTEM

- The male reproductive system is located in the pelvic region.
- It includes a pair of testes along with accessory ducts, glands and the external genitalia.

TESTES:

- The testes are situated outside the abdominal cavity **(Extra-abdominal)** within a pouch called scrotum. which helps in maintaining the low temperature of the testes (2–2.5° C lower than the normal internal body temperature) necessary for spermatogenesis.
- Each scrotum is connected to the abdominal cavity through a passage termed as **inguinal-canal**.

- Through this canal, the testis descends down into the scrotal-sacs at the time of birth.
- In adults, each testis is oval in shape, with a length of about 4 to 5 cm and a width of about 2 to 3 cm.

DETECTIVE MIND

- Each testis is attached to the inner walls of the scrotal-sac through flexible, elastic fibres called **Gubernaculum**.
- Each testis is attached to the dorsal body wall of the abdominal-cavity through **Spermatic-cord**. Spermatic cord in males passes through the inguinal canal.
- Spermatic- cord contains vas deferens, blood vessels and nerves.

- Testes is covered by a tough fibrous coat called tunica albuginea.
- Each testis has about 250 compartments called **testicular lobules**.
- Each lobule has 1 to 3 highly coiled **seminiferous tubules,** these are structural and functional unit of testis and they produce sperms.
- Total number of seminiferous tubules in each testis is about 250 to 750.
- Each seminiferous tubule is lined by two type of cells-
  - **(i) Male Germ Cells (spermatogonia) : –** Spermatogonia give rise to spermatozoa which are released into the lumen of the tubule.
  - **(ii) Sertoli cells (Nurse cells)**

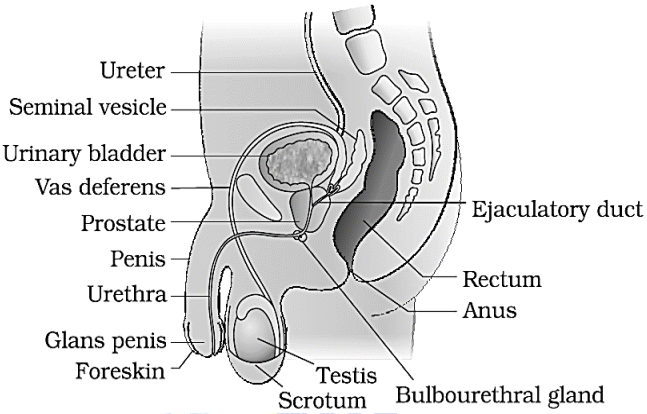


Fig. Diagrammatic sectional view of male pelvis showing reproductive system

Functions of Sertoli cells :-

(i) Provide nutrition to the developing sperms
(ii) Secrete inhibin hormone that checks FSH activity to prevent over production of sperms.
(iii) Secretes Androgen Binding Protein (ABP)
(iv) To release anti Mullerian factor (AMF) to prevent development of Mullerian duct/oviduct in male.

- The region outside the seminiferous tubule called interstitial space, contains small blood vessels & **interstitial cells or leydig cells**, which synthesis and secrete testicular hormones called **Androgens** into the blood. Other immunologically competent cells are also present.

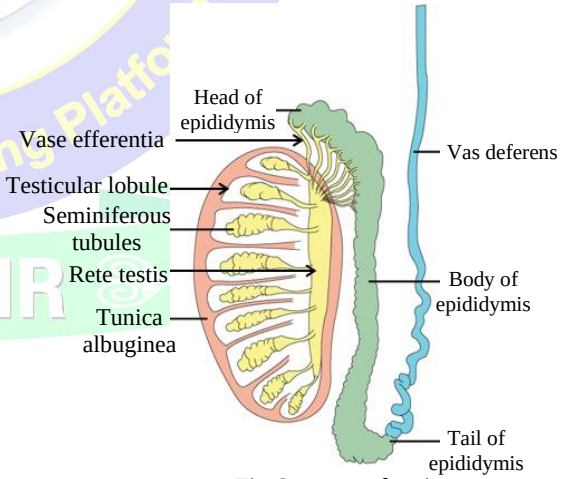
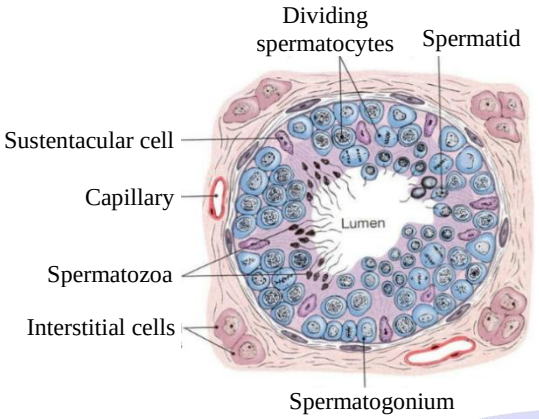


Fig. Structure of testis

Male accessory duct

- **The male accessory ducts include rete testis, vasa efferentia, epididymis and vas deferens.**
- Seminiferous tubules opens into vasa efferentia through rete testis.
- These vasa efferentia come out from upper dorsal surface of testis & open into **epididymis.**
- The epididymis store sperm and is responsible for **functional maturation** of sperm. It is located along the posterior surface of each testis.



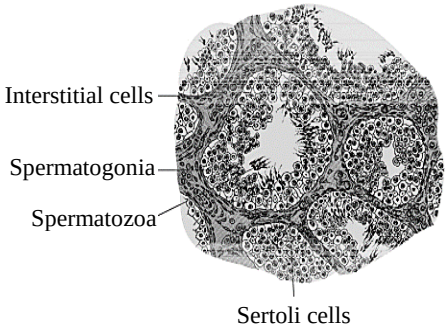


Fig. Diagrammatic sectional view of seminiferous tubule

DETECTIVE MIND

Epididymis has 3 parts:

(i) Caput epididymis - Upper, highly coiled part
(ii) Corpus epididymis - Middle part
(iii)Cauda epididymis - Basal, least coiled part

- Epididymis, enters inside the abdominal-cavity from the scrotal-sac in the form of **Vas deferens.**
- Vas deferens runs upward & enter into the abdominal cavity.
- Terminal dilated part of vas deferens are called **ampulla**. It stores sperms just prior to ejaculation.
- Ampulla of each side receives the duct of seminal vesicle of that side and forms ejaculatory duct and opens into prostatic urethra.

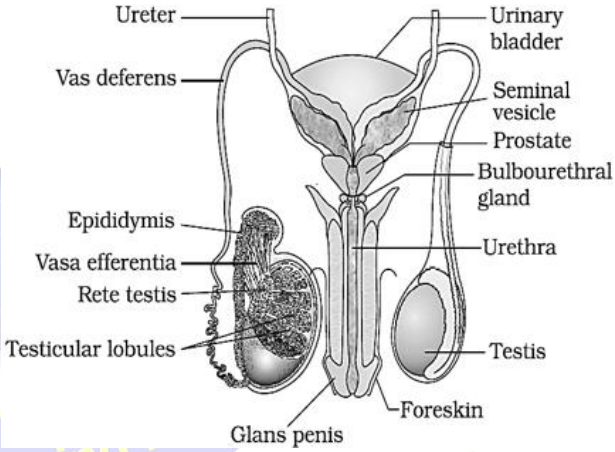


Fig. Diagrammatic view of male reproductive system (Part of testis is open to show inner details)

Urethra :

- Male urethra provides a common pathway for the flow of urine and semen.
- It is much longer in male than in female, measuring about 20 cm.
- The urethra receives the ducts of the prostate and Cowper's glands, passes through the penis and opens outside, through and external opening called **urethral meatus**.

PENIS:

- It is external genitalia & copulatory structure in male.
- It is a cylindrical, erectile organ suspended from pubic region in front of scrotum.
- Terminal part of penis is bulging, it is called as **Glans penis**, which is covered by a movable skin called as **prepuce or foreskin.**
- Penis is composed of **three** longitudinal cylindrical cords of erectile tissue.
- These cords are the **right & left corpora cavernosa & a median corpus spongiosum**, Urethra runs through corpus spongiosum.
- Erection of penis is purely vascular phenomenon and is controlled by ANS.

- It occurs due to increase of blood supply, dilation of penile arteries causes enlargement and hardening of penis.

Accessory Reproductive Glands of Male:

The substances secreted by the accessary reproductive glands help in events of reproduction. These glands are–

1. Seminal vesicle:

- These are paired, tubular, coiled glands situated behind the bladder.
- Which secretes seminal fluid, which is lubricating, transparent & jelly like substance, and **makes 60–70% part of semen.**
- It is slightly alkaline (pH 7.3).
- **Fructose** is found in seminal fluid; it acts as fuel to sperm.
- Fibrinogen, prostaglandin, citrate and several proteins are also present in semen.

2. Prostate gland:

- This gland is located below the urinary bladder. It is **unpaired** and secretes slightly alkaline prostatic fluid which is milky, thick, sticky or jelly like.
- It makes about 30% part of semen and helps in sperm activation.
- In the secretion of prostate-gland **citric acid, Calcium phosphate, clotting enzyme and pro-fibrinolysin** are present.

3. Cowper's glands (bulbourethral gland) :

- It is a pair of glands found on lateral side of urethra and helps in lubrication of the penis.

DETECTIVE MIND

Semen: Semen = Sperm + Accessory reproductive gland fluid (Seminal Plasma)

- Volume = 3 to 4 ml.
- pH = 7.2 - 7.7 (Slightly alkaline)
- Normal sperm count 20 to 120 million/ml.
- Oligospermia < 20 million/ml.
- Azoospermia – either absence or near absence of sperms.

→ **Path of Sperm through the Male Body:**

Seminiferous tubules → Rete testis → Vasa efferentia → Epididymis→ Vasa deferens → Ejaculatory duct → Urethra

THE FEMALE REPRODUCTIVE SYSTEM

- The female reproductive system consists of a pair of **ovaries,** a **duct system** consisting of a pair of fallopian tubes (oviducts), a uterus, cervix, vagina and the external genitalia that is located in pelvic region.
- A pair of **mammary glands** are **accessory reproductive glands.**

Ovaries :

- Ovary is the **primary female sex organ**.
- It produces ova and secretes the female sex hormones, estrogens and progesterone which are responsible for the development of secondary female sex characters and cause marked cyclic changes in the uterine endometrium.
- The human ovaries are small, almond-like flattened bodies, about 2 to 4 cm in length and is connected to the pelvic wall and uterus by ligaments.

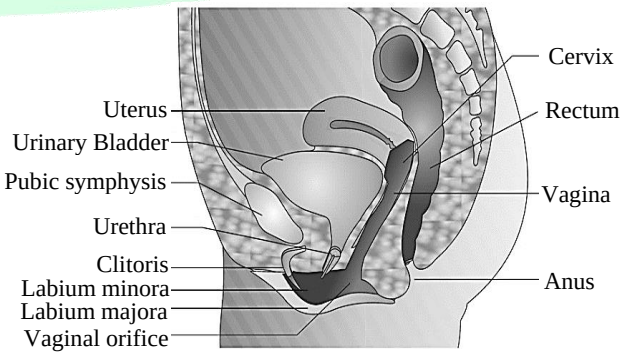


Fig. Diagrammatic sectional view of female pelvis showing reproductive system

Location:

Ovaries are located near kidneys and remain attached to the lower abdominal cavity.

Structure:

- Outer most layer of ovary is called germinal epithelium while the inner layer is called Tunica albuginea which is made up of White fibrous connective tissue.
- The inner part of ovary is called as **stroma**. Which is consists of follicular cells, connective tissues, blood vessels & lymphatics. It is differentiated into 2 parts; outer peripheral part is **cortex** & inner part is called **medulla**.

Fallopian Tubes (Oviducts) :

- These are one pair of long (10 to 12 cm), ciliated muscular and tubular structures which extend from the periphery of each ovary to the uterus.
- Fallopian tube is differentiated into three parts:

Fallopian Tube

Infundibulum

- Anterior funnel shaped part that is close to ovary
- Have finger-like projections called fimbriae which help in collection of oocyte after ovulation.

Ampulla

- It is the site of fertilization

Isthmus

- Links to the uterus
- Peristalsis and ciliary action takes place

Uterus (Hystera/Womb):

- It is a large hollow, muscular, highly vascular and inverted pear-shaped structure present in the pelvis between the urinary bladder and rectum.

It has the following three parts:

(i) **Fundus:** It is upper, dome-shaped part above the opening of fallopian tubes.
(ii) **Corpus/Body:** It is the middle and main part of uterus.
(iii) **Cervix:** It is lower, narrow part which opens in body of uterus by internal and in vagina through external .

- The cavity of cervix is called Cervical canal which along with vagina forms the **birth canal.**

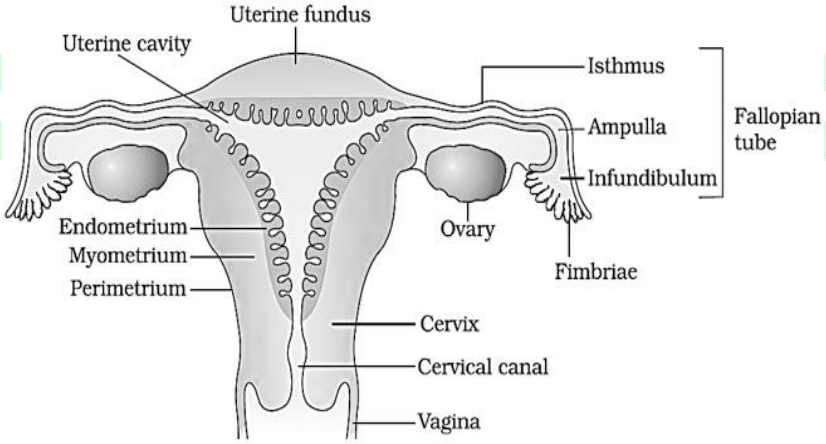


Fig. Female reproductive system

Wall of uterus: The wall of uterus is formed of three layers:

(i) Perimetrium: - Outer thin peritoneal layer**.**

(ii) Myometrium: - Middle muscular layer made up of smooth muscle fibers, which exhibits strong contraction during delivery of the baby at the time of parturition.

(iii) Endometrium: - Inner highly vascular and glandular layer.

- The **endometrium** undergoes cyclical changes during menstrual cycle.
- Implantation of embryo occurs in **uterine fundus.**
- It is the site of fetal growth during pregnancy.
- It also takes part in placenta formation and expulsion of the baby during parturition.

Vagina :

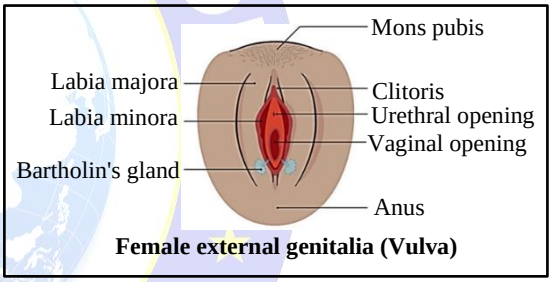
- It is a long (8.5 cm), fibro-muscular tube.
- It is lined with stratified squamous epithelium (Non Keratinized).
- Vagina acts both as copulation canal (as it receives the sperms from penis during copulation) and as birth canal along with cervix (during parturition).

Vaginal orifice :

- It is partially closed by a septum of mucous membrane called **hymen.**
- The hymen is often ruptured during the first coitus (intercourse).
- However, it can also be broken by a sudden fall or jolt, insertion of a vaginal tampon, active participation in some sports like horseback riding, cycling etc.
- In some women the hymen persists even after coitus, **in fact, the presence or absence of hymen is not reliable indicator of virginity or sexual experience.**

External genitalia (Vulva) :

- They include mons pubis, labia majora, labia minora, clitoris, vestibule.



Female external genitalia (Vulva)

1. Mons pubis:

- It is a cushion of fatty tissue, lying in front of pubis & covered by skin and pubic hairs in adult female.

2. Labia Majora (Homologous to the scrotum):

- Vulva is bounded on each side by the elevation and folds of skin & subcutaneous tissue.
- Its inner surface is hairless. Outer surface is covered by sebaceous gland, Sweat gland & hair follicles.

3. Labia Minora:

- There are two thin folds of skin present just within the labia majora.

4. Clitoris (Homologous to the penis):

- Small cylindrical & erectile body made by fusion of two labia minora, situated in the most anterior part of vulva.
- It is also made up of two erectile bodies (corpora cavernosa).

5. Vestibule:

- At the terminal part of vagina the urethra opens separately, so they form a common chamber called **vaginal vestibule or urinogenital sinus.**

DETECTIVE MIND

- The vestibule has following openings:

(a) Urethral opening – Lies on anterior end

(b) Vaginal orifice – Lies on posterior end.

- **Bartholin glands** are found on lateral side of vaginal orifice. It secretes slimy alkaline, watery fluid which make alkaline medium in vaginal passage.

MAMMARY GLANDS (Breasts):

- They are a pair of rounded prominences present over the **pectoralis major** muscles on the front wall of the thorax.

- They remain in rudimentary form in male. In females, they remain undeveloped till puberty.
- At puberty, they start developing under the influence of **oestrogen and progesterone hormones**.
- In the external side, each breast has a projection, known as **'nipple' which is** surrounded by rounded hyperpigmented area called **areola** and appear deep pink or light brown.
- Each breast contains glandular tissue and variable amount of fat.
- The **glandular tissue** comprises about 15-20 lobes (Mammary lobes) in each breast.
- Each lobe is made up of a number of **lobules.**
- Each lobule is composed of grapes like clusters of milk secreting cell termed **alveoli.**
- The cells of alveoli secrete milk which is stored in the cavity of alveoli.
- When milk is produced, it passes from the alveoli in to the mammary tubules and then into the **mammary ducts.**
- Near the nipple, mammary ducts expand to form mammary ampulla (lactiferous sinuses) where some milk may be stored before going to **lactiferous ducts.**
- Each lactiferous duct typically carries milk from one of the lobes to exterior.

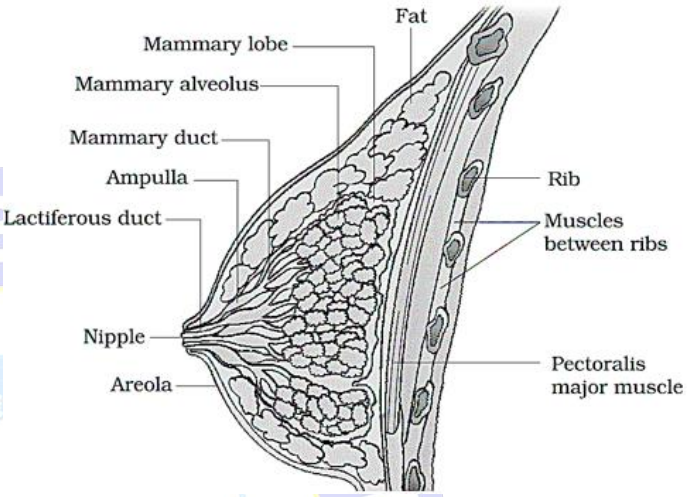


Fig. A diagrammatic sectional view of Mammary gland

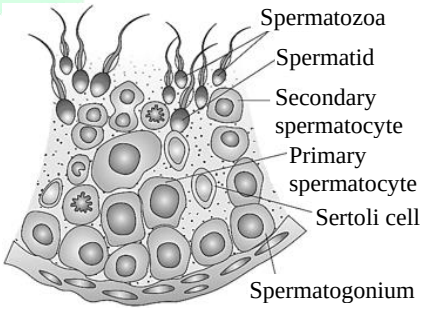
Mammary alveoli → mammary tubule → Mammary duct → Mammary ampulla → Lactiferous duct → Nipple

GAMETOGENESIS:

- Formation of gametes is called gametogenesis.
- The primary sex organs the testes in males and the ovaries in the females produce gametes (sperm and ovum) respectively.
- It starts at puberty & regulated by GnRH of hypothalamus, FSH & LH of pituitary gland.
- Gametogenesis is divided in three stages:
  (i) Multiplication phase
  (ii) Growth phase
  (iii) Maturation phase.
- **Spermatogenesis** is the formation of spermatozoa, whereas **oogenesis** is the formation of ova.

SPERMATOGENESIS:

- In testis (specifically), the immature male germ cells (spermatogonia) produce sperms by spermatogenesis which begins at puberty & remains continue even in old age
- Seminiferous tubules contains some special types of cells called **primordial germ cells,** these cells start spermatogenesis. Besides these cells, germinal epithelium contains some large sized cell called **sertoli cells**.
- **Occurrence of sertoli cells is the unique feature of mammalian testis**.
- Sertoli cells provide nutrition to developing sperm.
- Sperms are embedded in cytoplasm of sertoli cells and absorb nutrition.
- After maturation sperms comes out from sertoli cells and liberate in seminiferous tubules.



Diagrammatic sectional view of a seminiferous tubule (enlarged)

DETECTIVE MIND

- Liberation of sperms from Sertoli cells or seminiferous tubule is called **spermiation.**
- Liberation of sperms from testes is called **semination.**
- Liberation of sperms from body of male is called **ejaculation.**
- Transfer of sperm into female genital tract is called **Insemination**.

- Mainly two phases are present in spermatogenesis:

(1) Spermatocytogenesis (Mitosis)
(2) Spermiogenesis

- Spermatozoa are formed in the wall of the seminiferous tubules of the testes.
- The various cell- stages in spermatogenesis are as follows

I. The **spermatogonia** *(type A) or germ cells* (44+XY) divide mitotically, to give rise to more spermatogonia.
II. The *spermatogonia (type B)* (44 + XY) enlarge, to form **primary spermatocytes.**
III. The *primary spermatocytes* (44 + XY) now divide by meiosis into two **secondary spermatocytes**. This is the first meiotic division: it reduces the number of chromosomes to half (reduction division). Secondary spermatocytes are haploid cells which have 23 chromosomes.

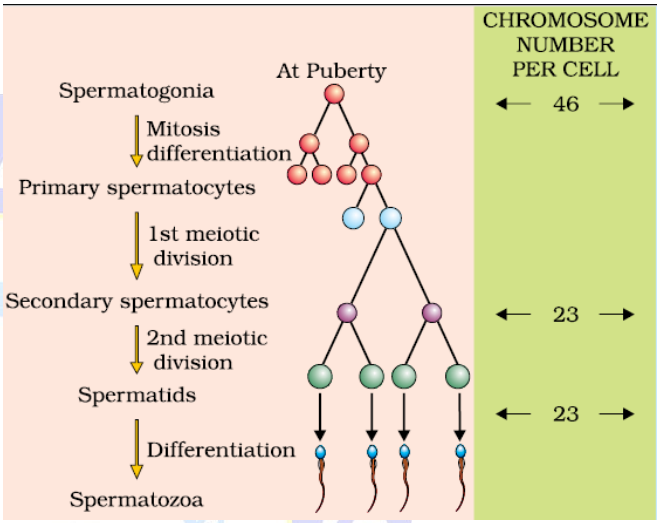


Fig. Schematic representation of spermatogenesis

IV. Each *secondary spermatocyte has* (22 + X) or (22 + Y) chromosomes. It divides to form two **spermatids**. This is the second meiotic division and this time there is no reduction in chromosome number.
V. Transformation of spermatid into sperm is termed **spermiogenesis**.
   - A spermatid is non-motile and heavy.
   - It has organelles like mitochondria, Golgi bodies, centrioles, nucleus etc.
   - After spermiogenesis the sperm head become embedded in the Sertoli cells, and are finally released from the seminiferous tubules or sertoli cells by the process called **spermiation.**

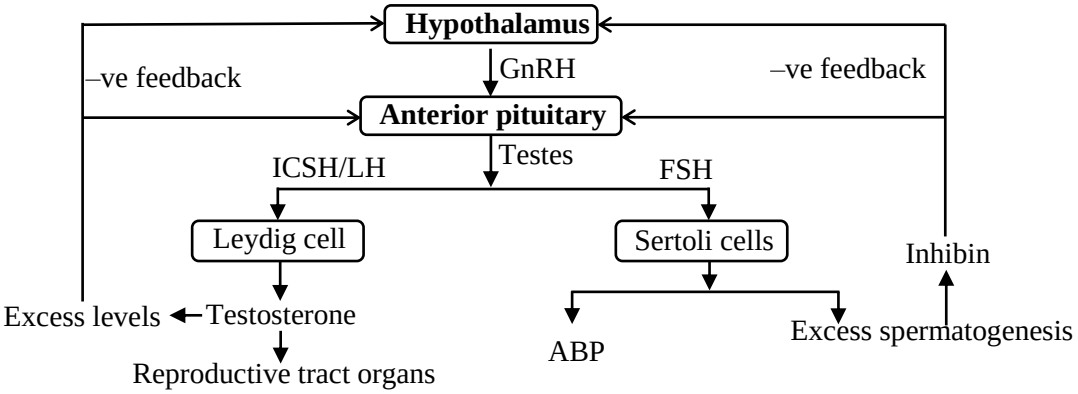
MALE REPRODUCTIVE HORMONES:

- Spermatogenesis starts at the age of puberty due to significant increase in the secretion of gonadotropin releasing hormone (GnRH). (hypothalamic hormone).
- The increased levels of GnRH then acts at the anterior pituitary gland and stimulates secretion of two gonadotropins – luteinising hormone (LH) and follicle stimulating hormone (FSH).
- **FSH:-** FSH acts on spermatogenic cells to stimulate to spermatogenesis in seminiferous tubules. It also regulates activity of Sertoli cells.
- **LH:-** It acts at the Leydig cells and stimulates synthesis and secretion of androgens mainly testosterone. Therefore, It is also called **Interstitial Cells Stimulating Hormone (ICSH)**
- **Testosterone:-**

(i) Stimulates spermatogenesis.
(ii) Development of secondary sexual characters in males (e.g: Facial hair)

- FSH and Testosterone are necessary for normal sperm production in human males

- **Inhibin:-** Excess of FSH also stimulate secretion of Inhibin from Sertoli cells. It suppresses secretion of GnRH and FSH to prevent excess production of sperms.



STRUCTURE OF SPERM:

- Mature sperm cell consists of head, neck, middle piece and tail (longest part).
- A plasma membrane envelops the whole body of sperm.
- The **sperm head** contains a very little cytoplasm, an elongated **haploid nucleus**, the anterior portion of which is covered by a cap-like structure called, **acrosome (Derived from Golgi apparatus)**.
- Nuclear part of head of spermatozoa consist of chromatin (mostly DNA) that is extremely condensed.
- The acrosome is filled with enzymes that help in fertilization of ovum.
- These enzymes called **sperm lysins** that dissolve the membranes enveloping the ovum and help the sperm to enter the ovum.
- Its membrane extends down the outer surface of nucleus.
- The short neck, contains two distinct granules- **the proximal and distal centrioles**.

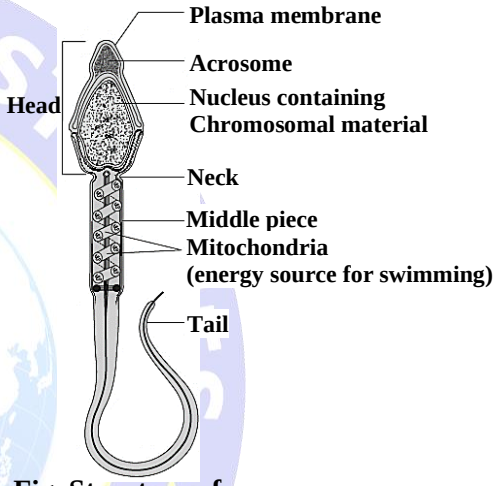


Fig. Structure of a sperm

- The proximal centriole plays a crucial role during the first cleavage of the fertilized ovum.
- The distal centriole gives rise to the axial filament of the long tail of the sperm.
- The middle piece possesses spiral sheath of numerous **mitochondria** (25 to 30 arranged spirally) called **Mitochondrial or Nebenkern sheath,** which produce energy for the movement of tail that facilitates sperm motility which is essential for fertilization, that's why it is called the **'power house of the sperm.'**
- The tail is made up of a central axial filament surrounded by a small amount of cytoplasm and cell membrane as external sheath.
- **Sperms move by the help of tail.**
- The human male ejaculates about 200 to 300 million sperms during a coitus of which, **for normal fertility, at least 60 per cent sperms must have normal shape and size and at least 40 per cent of them must show vigorous motility.**
- Sperms released from the seminiferous tubules, are transported by the accessory ducts.
- Secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for maturation and motility of sperms.
- Semen = Seminal plasma + sperms
- The functions of male sex accessory ducts and glands are maintained by the testicular hormones (androgens).

OOGENESIS:

- The process of formation of a mature female gamete is called **oogenesis**.
- It is initiated during the embryonic development stage when a couple of million gamete mother **cell (oogonia)** are formed with in each foetal ovary, **no more oogonia are formed after birth.**

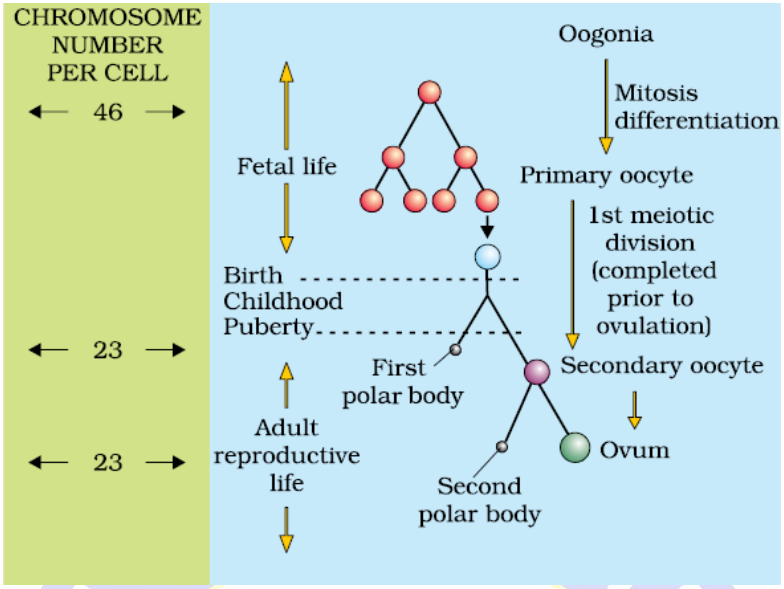


Fig. Schematic representation of Oogenesis

- Oogenesis process can be divided into three stages:
  (A) Multiplication phase **(B) Growth phase** **(C) Maturation phase**

(A) Multiplication phase :

- In this stage primordial germ cells or ovum mother cells repeatedly divide by mitosis to form large number of diploid oogonia.
- This process completes in embryo stage of female in most higher animals.

(B) Growth phase :

- Like spermatogenesis, in this process oogonia grow in size and form primary oocytes.

(C) Maturation phase :

- By the time the foetus is 25 weeks old, all the oogonia that she will ever produce, are already formed by mitosis. These cells start division & enter into prophase I of meiotic division & get temporarily arrested at the stage called primary oocyte.

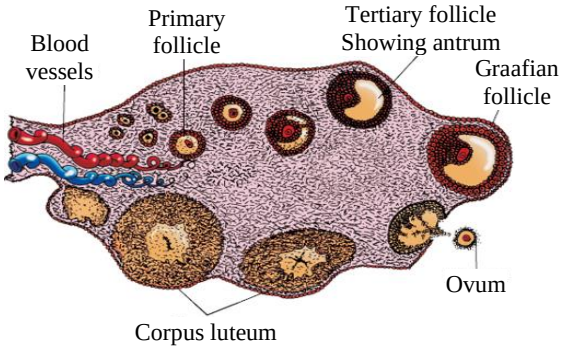
SPOT LIGHT

- Some important differences between oogenesis and spermatogenesis are

(i) Whereas one primary spermatocyte gives rise to four spermatozoa, one *primary oocyte* forms only one ovum.

(ii) When the primary spermatocyte divides, its cytoplasm is equally distributed between the two secondary spermatocytes formed. However, when the primary oocyte divides, almost all its cytoplasm goes to the daughter cell which forms the *secondary oocyte*. The other daughter cell *(first polar body)*, receives half the chromosomes of the primary oocyte, but almost no cytoplasm. The first polar body is, therefore, formed merely to get rid of unwanted chromosomes.

➢ **The stages in formation of Graafian follicle are as follows-**



Diagrammatic section view of ovary

- Each primary oocyte gets surrounded by a layer of follicular cells & after surrounding it is known as **primary follicle.**
- At puberty only **60000 to 80000** primary follicles are left in each ovary.
- Generally, only one ovum is liberated in each menstrual cycle, by alternate ovaries.
- Under the influence of FSH, the follicular cells proliferate now to form several layers of cells to form the membrane granulosa. These cells are now called granulosa cells.
- As the follicle expands, the stromal cells surrounding the membrane granulosa become condensed to form a covering called the theca Interna. Afterwards the cells of theca interna (Thecal cells) secrete a hormone called oestrogen. Outside the theca interna some fibrous tissue become condensed to form another covering called theca Externa. Now, this is called **secondary follicle.**
- A cavity appears within the membrane granulosa. which is called the **antrum.** With the appearance of this cavity, the **Tertiary follicle** is formed.
- **Presence of antrum (Follicular cavity) is characteristic feature of Tertiary follicle.**
- Secondary oocyte forms a new membrane called **zona pellucida** in tertiary follicle.
- The granulosa cells lying in the close vicinity of the ovum (secondary oocyte) and zona pellucida, become elongated to form the **corona radiata**.
- Mature tertiary follicle which is ready to ovulate is called **Graafian follicle** as it was first seen by the scientist **De Graaf**.
- After 13 days of menstrual cycle (on 14th day when cycle is ideally for 28 days) Graafian follicle is ruptured & egg is released. (**ovulation**)
- In human female ovulation occurs in presence of FSH & LH.

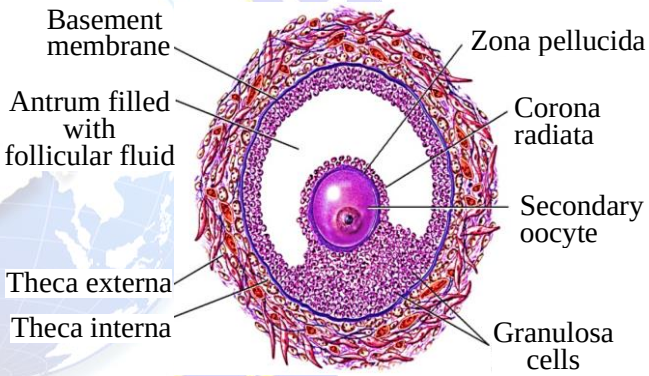


Fig-Mature (Graafian) follicle

- After ovulation the ruptured Graafian follicle is called **corpus luteum**. It is the main source of progesterone.
- Progesterone hormone maintains pregnancy and repairs the wall of uterus to make its surface adhesive to help in implantation.
- If fertilization occurs in fallopian tube, then corpus luteum becomes stable for next nine months.
- If fertilization does not occur then the corpus luteum starts degenerating after about 9 days of its formation.
- The degeneration is completed by 14 days to form **corpus albicans**, which gradually disappears.

DETECTIVE MIND

- The total number of follicles in the two ovaries of a normal young adult woman is about **four lakhs**.
- A large number of these follicles degenerate from birth to puberty.
- Degeneration of ovarian follicle is called **follicular atresia** and their disposal is done by phagocytes.
- Only about 450 ova are produced by a human female over the entire span of her reproductive life which lasts till about 40-50 years of age.
- Sometimes, two or more follicles reach maturity in one month or cycle, so more than one oocyte may be ovulated.
- This is the commonest cause of multiple births. In such cases the siblings are **fraternal**, not identical.

MENSTRUAL CYCLE:

- Duration – 28/29 days ideally
- The reproductive cycle in the female primates (e.g. monkeys, apes and human beings).
- The first menstruation begins at puberty and is called **menarche**.
- One ovum is released (ovulation) during the middle of each menstrual cycle.

Menstrual cycle has three main phases :

(i) Bleeding phase or menstruation phase.
(ii) Proliferative/pre ovulatory/ follicular phase or oestrogenic phase.
(iii) Secretory/post ovulatory/luteal phase or progesteronic phase.

(i) Bleeding Phase / Menstruation phase :

- The cycle starts with bleeding phase in its first 3 to 5 days.
- Endometrium gets shed off due to destruction of corpus luteum & **rapid decline of progesterone.**
- Total loss of blood per day is about 20 ml, so an average of 40 to 80 ml blood is lost/ cycle.
- This blood can not clot due to presence of **Fibrinolytic enzymes**.

(ii) Preovulatory/Proliferative phase/Follicular phase:

- After first four or five days, this phase begins.
- During this phase, due to release of GnRH, Pituitary secretes **FSH** and **LH** to stimulate the development of ovarian follicle.
- Developing follicle secrets high amount of **oestrogen.**
- The rising level of oestrogen causes thickening and proliferation of endometrium.
- Hypothalamus releases more of GnRH, this GnRH induces the pituitary to release more of FSH.
  The rising FSH levels now cause:
  (i) Growth and development of ovarian follicle to form Graafian follicle
  (ii) Release of **oestrogen from the theca interna** of this developing follicle.
- As the oestrogen level goes on rising, by the end of 10 day the extreme levels of oestrogen (which have by then caused maturation of Graafian follicle and growth of endometrium) now give a **positive feedback of** high concentration of oestrogen causing a rise in GnRH and LH secretion but due to **release of inhibin by graafian follicle**, FSH is not comparatively raised therefore the LH secretion from the pituitary goes on rising.
- This abrupt rise **(on 11th to 13th day)** in LH concentration in blood is called as **LH surge**.
- This LH now causes the Graafian follicle to rupture after partial completion of II meiotic division in oocyte and thus the secondary oocyte (metaphase stage) released.
- The release of egg (secondary oocyte) which occurs around 14 day is called as **ovulation**.

(iii) Post ovulatory/secretory phase/ Luteal Phase :

- The period between ovulation and next menstrual bleeding (post ovulatory period) is always constant (i.e. 14 days). However, the ovulation date may vary (causing a change in pre-ovulatory period).
- During this phase the **level of Estrogen and progesterone will rise** while **FSH and LH levels drop**.
- Remaining part of graffian follicle converts into corpus luteum.
- **Corpus luteum secrets large amount of progesterone** which is essential for maintenance of endometrium, which is necessary for implantation of fertilized ovum & for other events of pregnancy.
- During pregnancy all events of menstrual cycle stops & there is no menstruation.
- If pregnancy does not occur after ovulation, progesterone level rise, its rising levels inhibits the release of GnRH from hypothalamus by **negative feed back**.
- Due to this FSH, LH secretion by pituitary falls and thereby progesterone secretion by the corpus luteum (which was due to influence of LH) also now falls.
- As the progesterone level drops, the corpus luteum begins to degenerate and transform in **corpus albicans** (which can not secrete progesterone).

- Due to the lack of progesterone, the overgrown endometrium now begins to break and separate from the inner uterine wall causing bleeding. This is again the beginning of next menstrual or bleeding phase.

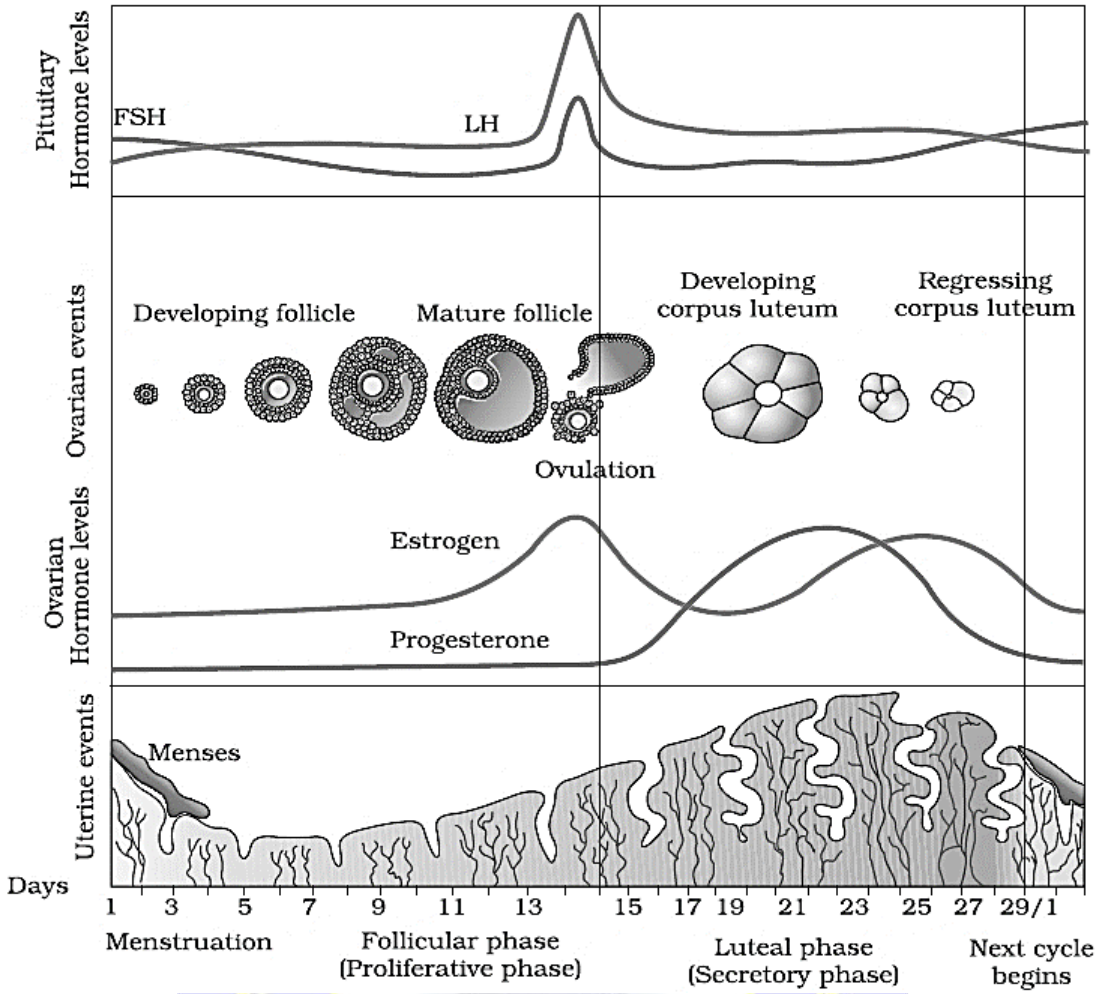


Fig. Diagrammatic presentation of various events during a menstrual cycle

- In human beings, menstrual cycle ceases around 50 years of age, and extends between menarche and menopause termed as **menopause**.
- Cyclic menstruation is an indicator of normal reproductive phase.

Mammalian egg and egg membranes:

- Oocyte is surrounded by membranes termed as the egg-membranes.
- **Egg = Ovum / Oocyte + Egg membrane.**
- Mammalian eggs have very less amount of yolk, so the eggs are oligolecithal and isolecithal or microlecithal and homolecithal.
- The egg has 2 egg-membranes :-

(1) Zona pellucida :-

- This is a transparent membrane like covering and is a primary membrane secreted by the Secondary oocyte.

(2) Corona radiata :-

- This is a layer of follicular cells" and these cells are attached to the surface of egg through " hyaluronic acid" This is a secondary membrane, which is secreted by the ovary.
- These eggs don't have tertiary membrane.

FERTILIZATION AND IMPLANTATION:

- The process of fusion of a sperm with an ovum is called **fertilization**.

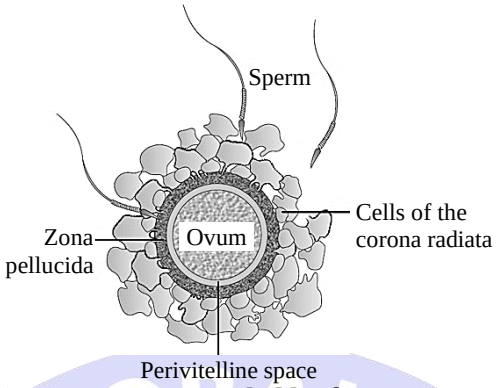


Fig : Ovum surrounded by few sperms

- Following events occurs during fertilisation:

1. During copulation (coitus), semen is released by the penis into the vagina of female, called **insemination**.

2. Sperm swim through the vagina, cervix, uterus and finally reach the **ampulla** of the fallopian tubes, ovum reaches to ampulla, (site fertilization) by the ciliary action of ciliated columnar epithelial lining of oviduct.

3. Fertilisation can only occur if the ovum and the sperms are transported simultaneously to the ampulla. This is the reason why **not** all copulations lead to fertilisation and pregnancy.

4. A number of sperms adhere to the surface of egg (Agglutination). The acrosome starts releasing its hydrolytic enzymes of **sperms lysins** which include:

(a) Hyaluronidase : Dissolves the hyaluronic acid responsible for cementing of follicle cells or granulosa cells.

(b) Corona penetrating enzyme (CPE) : Dissolves corona radiata.

(c) Zonalysin /Acrosin: Digests the zona pellucida.

(d) Lysozyme : Dissolves plasma membrane of oocyte.

5. **The entry of sperm into the ovum induces completion of the meiotic division of the secondary oocyte**. The second meiotic division is also unequal and results in the formation of a second polar body and a haploid ovum (ootid). Soon the haploid nucleus of the sperm and that of ovum fuse together to form a **diploid zygote.**

6. At the point of contact with sperm and plasma-membrane of egg a cone-like structure is formed called **reception cone**. After sometime, reception cone sinks in egg cytoplasm along with sperm (entry of sperm is a type of phagocytosis).

- When a sperm comes in contact with zona pellucida layer of the ovum, it induces changes in the membrane that block the entry of additional sperms.
- With the entry of sperm all the cortical granules burst and secrete a membrane around the egg is called **fertilization membrane (cortical reaction)**.
- Function of perivitelline fluid and fertilization membrane is to prevent the entry of additional sperm in egg.
- So normally only one sperm enters inside the egg (monospermy).
- Sometimes, more than one sperm enter inside the egg **(polyspermy)**.

7. **Fate of sperm in egg :**

- In majority of animals, only head and middle piece enter inside the egg and tail is left outside.
- The centriole of egg itself degenerates at the time of second maturation division.
- So proximal centriole of sperm starts division.
- The chromosome pattern in the human female is XX and that in the male is XY.
- Therefore, all the haploid gametes (ova) produced by the female have the sex chromosome X whereas in the male gametes (sperms) the sex chromosome could be either X or Y, hence, 50 per cent of sperms carry the X chromosome while the other 50 per cent carry the Y.

- After fusion of the male and female gametes, the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum.
- The zygote carrying XX would develop into a female baby and XY would form a male.
- That's why, **scientifically it is correct to say that the sex of the baby is determined by the father and not by the mother!**

CLEAVAGE

- Fertilized egg undergoes repeated cell divisions which occur rapidly producing a multicellular structure without changing its size. All these rapid **mitotic cell divisions are** called **cleavage**.
- Due to the process of cleavage, a single celled zygote, through a successive mitotic cell divisions changes into a complex multicellular structure.
- Cells produced as a result of cleavage are termed as **blastomeres**.
- The total size of the embryo remains the same.
- **Interphase stage** is very short in cleavage as **only 'S' phase is present, G_1 & G_2 phases are absent.**
- In humans cleavage is **equal holoblastic** (complete egg divides into blastomeres).
- There is no change in shape and size of developing embryo till blastula stage comes. Till then it remains just like undivided egg in shape and size.
- As a result of cleavage, unicellular zygote changes into multicellular structure.

PREGNANCY AND EMBRYONIC DEVELOPMENT

General Stages of Embryonic Development:

1. **Morula:**
   - As a result of cleavage activities, unicellular zygote changes into a solid ball like multicellular structure. This stage has 8-16 blastomeres.
   - Zona pellucida still forms the outer cover.
2. **Blastocyst Formation:**
   - Morula continues to divide and transform into **Blastocyst**, because blastula is in the form of a cyst.
   - **Cleavage ends with completion of Blastula.**
   - The blastomeres in the blastocyst are arranged into an outer layer called **trophoblast** and an inner group of cells attached to trophoblast called the **inner cell mass.**
   - The trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the embryo**.**
   - Cell of trophoblast just above the embryonal knob are called **cells of Rauber**.
   - A cavity is formed in between inner cell mass and trophoblast called **albumin cavity (Blastocoel)**.
   - It is filled with nutritive fluid absorbed from the wall of uterus. So, albumin cavity is also **nutritive-cavity**.
3. **Implantation:**
   - Blastocyst comes out from zona pellucida & get attached with the wall of uterus. Zona pellucida prevent implantation of the blastocyst at an abnormal site.
   - After attachment, the uterine cells divide rapidly and covers the blastocyst.
   - As a result, the blastocyst becomes embedded in the endometrium of the uterus. This is known as implantation which leads to pregnancy.

- In human being the blastocyst gets attached with the uterine endometrium in about four days after entering in uterus.
- At the same time, the cells of endometrium of implantation area separate out and adhere with embryonic cells with the help of certain enzymes secreted by the cells of trophoblast.
- In human, the site of implantation is generally **mid-dorsal/fundus part of uterus.**
- Implantation of blastocyst takes about **7-8 days** after fertilization in human and by **12th day** it is completely buried in the wall of the uterus.
- After implantation, the wall of uterus is called as **decidua**, instead of endometrium.
- Decidua also comes out from uterus at the time of parturition.
- The trophoblast has the property of being able to stick to the uterine (or other) epithelium and its cells have the capacity of eat up other cells.

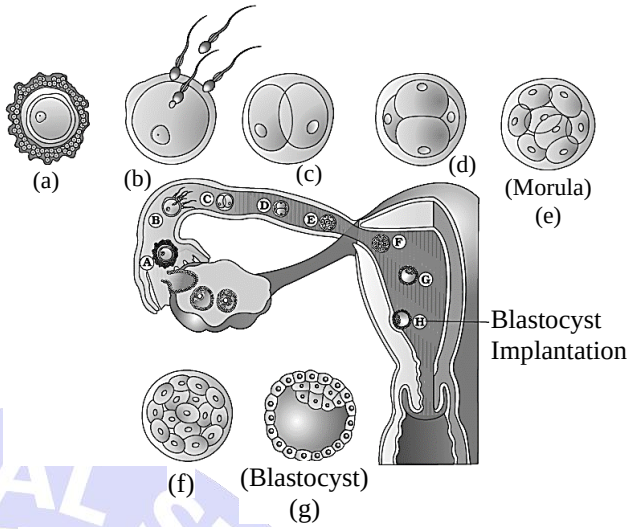


Fig. : Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

4. Gastrulation(Gastrula) :

Gastrula stage is the most important stage in embryonic development because two main events take place during gastrula stage.

- **Differentiation of blastomere:**
  - Immediately after implantation, the inner cell mass (embryo) differentiates into an outer layer called **ectoderm** and an inner layer called **endoderm**.
  - A **mesoderm** soon appears between the ectoderm and the endoderm.
  - These three layers give rise to all tissues (organs) in adults.
  - It needs to be mentioned here that the inner cell mass contains certain cells called **stem cells** which have the potency to give rise to all the tissues and organs.
  - Formation of three germinal layers is the significance of gastrula stage.
  - All the preparation of differentiation of blastomere are completed in late blastula stage.

5. Organogenesis :

- After one month ⟶ heart is formed & starts beating.
- End of second month ⟶ limbs & digits are developed.
- End of 12 weeks (first trimester) ⟶ Most of the major organs are formed.
- Fifth month ⟶ First movement & appearance of hair on head
- End of 24 (second trimester) ⟶ Fine body hairs, eye lids separate and eye lashes are formed.
- End of nine month ⟶ Foetus is ready for delivery

PLACENTA

- After implantation, finger-like projections appear on the trophoblast called **chorionic villi** which are surrounded by the uterine tissue and maternal blood.
- The chorionic villi and uterine tissue become interdigitated with each other and jointly form a structural and functional unit between developing embryo (foetus) and maternal body called **placenta.**

Functions of placenta :

- The placenta facilitates the supply of oxygen and nutrients to the embryo and also removal of carbon dioxide and excretory/waste materials produced by the embryo.
- The placenta is connected to the embryo through an umbilical cord which helps in the transport of substances to and from the embryo.
- Placenta also acts as an endocrine tissue and produces several hormones like **human chorionic gonadotropin** (hCG), **human placental lactogen** (hPL), **estrogens, progestogens,** etc.
- In the later phase of pregnancy, a hormone called **relaxin** is also secreted by the placenta.
- **hCG, hPL** and **relaxin** are produced in women only during pregnancy.
- In addition, during pregnancy the levels of other hormones like estrogens, progestogens, cortisol, prolactin, thyroxine, etc., are increased several folds in the maternal blood.
- Increased production of these hormones is essential for supporting the fetal growth, metabolic changes in the mother and maintenance of pregnancy.
- The antibodies for measles, chickenpox, polio etc. present in the blood of mother reach the embryo through placenta.
- Pathogenic viruses may also enter in embryo through placenta.
- If a female takes some harmful chemicals, liquor, drugs etc. during pregnancy, these may cross the placenta and on reaching into foetus may cause deformity during organogenesis. (e.g. Thalidomide)

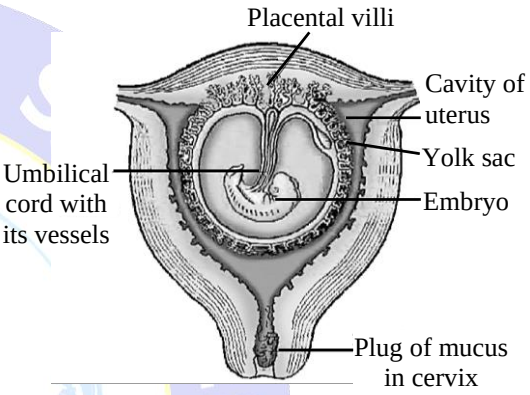


Fig. : The human foetus within the uterus

PARTURITION AND LACTATION:

- The average duration of human pregnancy is about 9 months which is called **gestation period**.

PARTURITION:

- Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus.
- This process of delivery of the foetus (childbirth) is called **parturition**.
- It is induced by a **complex neuroendocrine mechanism**.
- The signals for parturition originate from the **fully developed fetus** and the **placenta** which induces mild uterine contractions called **fetal ejection reflex.**
- This triggers release of oxytocin from the maternal pituitary.
- **Oxytocin** acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin.
- The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions.
- The labour pain during child birth, is due to this hormone.
- **Oxytocin is the main parturition hormone**.
- **Relaxin** hormone is secreted by the placenta and the ovary of pregnant female. It relaxes the pubic symphysis i.e. the joint between the pelvic girdles. That provides more spaces for foetus to come out.
- Soon after the infant is delivered, the placenta is also expelled out of the uterus.

LACTATION:

- The mammary glands of the female undergo differentiation during pregnancy and starts producing milk towards the end of pregnancy by the process called **lactation**.
- This helps the mother in feeding the newborn.
- Estrogen and progesterone are responsible for the physical development of the breasts during pregnancy, and prolactin hormone promotes secretion of milk.
- This hormone is secreted by the mother's anterior pituitary gland and its concentration in the blood rises steadily from the fifth week of pregnancy until birth of the foetus.
- Milk ejection is caused by a combined neurogenic and hormonal reflex that involves the posterior pituitary hormone **oxytocin.**
- The oxytocin is carried through the blood to the breasts where it causes contraction in **myoepithelial cells** (that surround the outer walls of the alveoli), which results in expelling the milk from the alveoli into the ducts.
- The milk produced during the initial few days of lactation is called **colostrum** which contains several antibodies absolutely essential to develop resistance for the new-born babies.
- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

DETECTIVE MIND

- Human placenta is deciduate (shedding at birth) and haemochorial i.e. the chorionic villi comes in direct contact with uterine blood of mother.
- **Gynecomastia** : Development of breast in the male.
- **Amenorrhea** : Absence of menstruation cycle.
- **Hysterectomy** : Surgical removal of uterus.
- **Oophorectomy** : Removal of ovaries.
- **Ectopic Pregnancy** : It is the case of implantation of fertilized egg outside the uterus.