HUMAN REPRODUCTION

Introduction

Humans are sexually reproducing and viviparous organisms. Their reproductive events include formation of gametes (gametogenesis), i.e., sperms in males and ovum in females, transfer of sperms into the female genital tract (insemination) and fusion of male and female gametes (fertilization) leading to formation of zygote. This is followed by formation and development of blastocyst and its attachment to the uterine wall (implantation), embryonic development (gestation) and delivery of the baby (parturition). You have learnt that these reproductive events occur 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.

Formation of Testes and Ovary

- Gonads of males and females are similar in appearance for the first forty or so days of development. At this stage, the embryonic structures have the potential to become either testes or ovaries.
- The substance that promotes their conversion to testes has been called the **Testes Determining Factor (TDF)** coded by a particular gene known as SRY (for sex-determining region of Y).
- This gene is found in the Y chromosome of all mammals and is highly conserved, meaning that it shows little variation in structure over evolutionary time.

The Male Reproductive System

- The male reproductive system is located in the pelvic region. It includes a pair of **testes**, **accessory ducts, accessory glands** and the **external genitalia.**
- Besides male reproductive system there are certain secondary sexual characters which are evident in males such as facial & chest hairs, broad shoulders, narrow hips, Adam's apple (low pitch voice), abdominal breathing and high BMR.
- In males puberty is attained at 13-16 year.

Resonate the Concept
The **primary sex organs** are **testes** in males and **ovaries** in females (mesodermal origin). Besides producing gametes, they also secrete sex hormones. The growth of gonads, their maintenance and functions are regulated by **gonadotropins** (FSH, LH) of the anterior lobe of pituitary. The other reproductive organs which perform important functions in reproduction but neither produce gametes nor secrete sex hormones, are called **secondary sex organs.** These include the prostate, seminal vesicles, vas deferens and penis in males, and the fallopian tubes, uterus, vagina and mammary glands in females.

Testes:

- The testes (singular, testis) are paired oval structures of 4-5 cm length and 2-3 cm width.
- They develop on the embryo's posterior abdominal wall and usually begin their descend into the pouch like scrotum which is situated outside the abdominal cavity in the seventh month of foetal development.
- This descent is promoted in the presence of the hormone testosterone. Hence, the testes of adult human males are **extra abdominal.**

Scrotum:

- The two testis are each held in a fleshy sac called the scrotum.
- The scrotum helps in maintaining the low temperature of the testes (2 – 2.5^0 C lower than the normal internal body temperature), which is necessary for spermatogenesis.
- The two muscles that regulate the temperature of the testes are the dartos and cremaster muscles:

Dartos Muscle:

- The dartos muscle is a layer of smooth muscle fibers in the subcutaneous tissue of the scrotum (surrounding the scrotum). This muscle is responsible for wrinkling up the scrotum, in conditions of cold weather, in order to maintain the correct temperature for spermatogenesis.

Cremaster Muscle:

- It is a thin strand of skeletal muscle associate with testes and spermatic cord. It is responsible for raising and lowering the testes to keep them at the correct temperature.

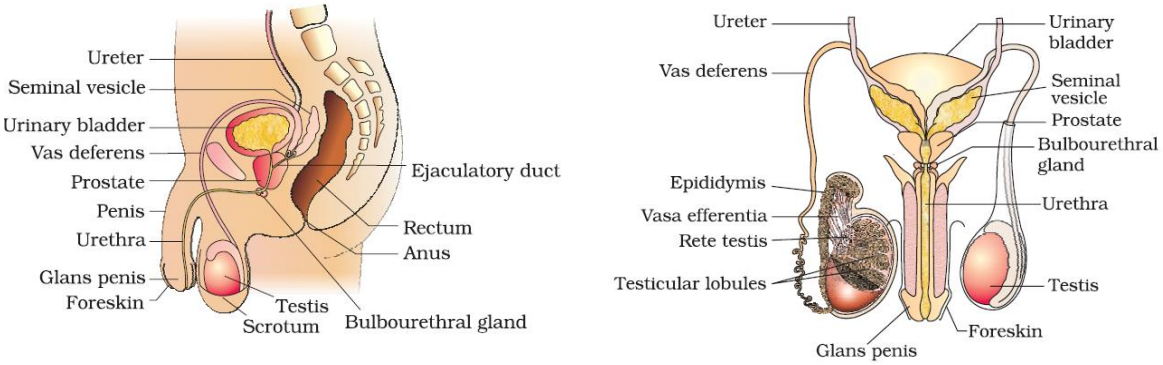


Fig. : (A) Diagrammatic sectional view of male pelvis showing reproductive system,
(B) Diagrammatic view of male reproductive system (part of testis is open to show inner details)

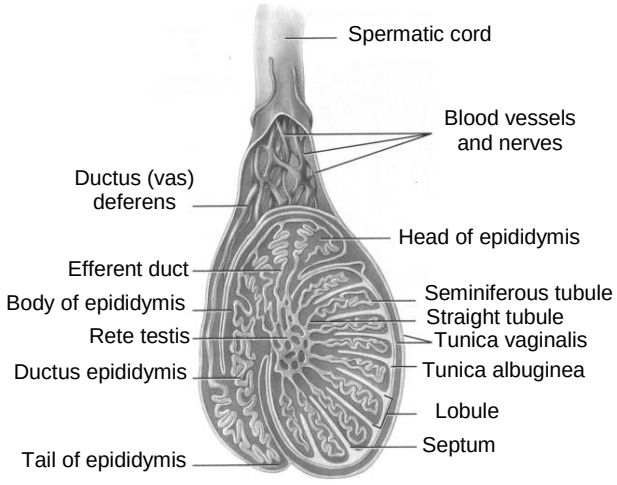


Fig :Sagittal section of testis showing seminiferous tubules

Resonate the Concept
1. If one or both the testes in human male fail to descend into the scrotum, the condition is called **cryptorchidism.** If both the testes fail to descend, it results in sterility. Orchiopexy is surgery to correct it. 2. There are certain mammals in which the testes remain permanently in the abdomen and does not cause any defect. Examples are elephant, aquatic mammals like whales, dolphins, seal and prototherians or egg laying mammals like *Ornithorhynchus.* 3. In mammals which breed seasonally, the testes descend into scrotum only during the breeding season, example Rat, Bat and Otter.

Coverings of Testis:

1. Tunica vaginalis: Composed of parietal and visceral layer. Absent on posterior surface (entry for spermatic cord, nerves, and blood vessels).
2. Tunica albuginea: **Dense, white fibrous connective tissue covering** all around testis, posterior border thicken to form vertical septum called mediastinum and divide the testis in two lobes dorsal and ventral. This layer divide testis into 250 lobules
3. Tunica vasculosa: Innermost, vascular, line testicular lobules.

Internal structure of testes:

Seminiferous Tubules:

- Each testes is divided into 250 testicular lobules, each lobules have 1-3 highly coiled seminiferous tubules (70-80 cm in length).
- These tubes are in form of loops and open at both ends and are lined by cuboidal epithelia.
- It contain two types of cells.

(i) Sertoli Cells:

- Sertoli cell (a kind of sustentacular cell) is a 'nurse' cell of the testes which is a part of a seminiferous tubules.
- Sertoli cells secrete a protein called **androgen-binding protein (ABP)** into the lumen of the seminiferous tubules, which binds to testosterone and there by concentrates it within the tubules.
- Sertoli cells main function is to nurture the developing sperm cells through the stage of spermeiogenesis, it is also called as "mother cell". It provides both the secretory and structural support.
- The junction of sertoli cells form the **blood-testis barrier**. During the time of sperm maturation, large sertoli cells nourish the immature sperm and filter out harmful things before they reach sperm.

(ii) Male germ cell:

- Originate in extra – embryonic mesoderm, then migrate to yolk sac endoderm & finally reach to testes.
- It undergo meiotic divisions, finally leading to sperm formation.
- Out of seminiferous tubules two type of cells are present –

(iii) Interstitial cells or Leydig's cells:

- In between seminiferous tubules within the testes are interstitial cells or cells of Leydig. They are responsible for secreting the male sex hormones (i.e., testosterone).

(iv) Some immunologically competent cells are also present.

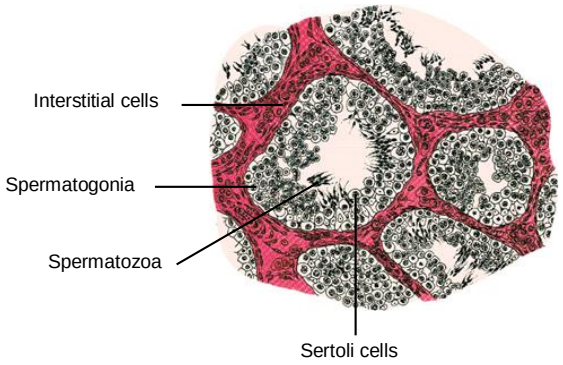


Figure : Diagrammatic sectional view of seminiferous tubule

Testicular duct system

(i) Tubuli recti: ends of seminiferous tubules are straight and form tubuli recti.

(ii) Rete testis: Channels lined by cuboidal epithelium, present on posterior side behind mediastinum.

(iii) Vasa efferentia: 10 – 20 fine tubules originating from rete testis, ending in epididymis.

(iv) Epididymis:

- Epididymis is located along the posterior surface of testis. It is developed from the **wolfian duct of embryo.**
- The epididymis is about 20 feet long, coiled tube. Epididymis is divided into three parts, upper caput epididymis (highly coiled), middle corpus epididymis (narrow in size) and lower cauda epididymis (less coiled).
- Within epididymis the sperm complete their maturation and their flagella become functional, if sperms are not ejaculated then they are phagocytized after one month of storage.
- Smooth muscle in the wall of the epididymis propels the sperm into the vas deferens.

(v) Vas Deferens or Ductus Deferens:

- The ductus (vas) deferens, also called sperm duct or spermatic deferens, developed from wolfian duct.
- It extends from the epididymis in the scrotum on its own side into the abdominal cavity through the inguinal canal.
- The inguinal canal is an opening in the abdominal wall for the spermatic cord (a connective tissue sheath) that contains the ductus deferens, testicular blood vessels and nerves.
- Terminal part dilated to form ampulla which stores the sperms and form loop over urinary bladder.
- The smooth muscle layer of the ductus deferens contract in waves of peristalsis during ejaculation.
- Vasectomy is the process of male sterilization, in which vas deferens is cut, the semen ejaculated will be without sperms.

(vi) Ejaculatory ducts: There are two ejaculatory ducts. Each receives sperm from the ductus deferens and the secretions of the seminal vesicles on its own side. Both ducts empty into the single urethra. It also store sperms.

(vii)Urethra: The urethra, originates from urinary bladder, is the last part of the urinary tract. Urethra pass through the corpus spongiosum part of the penis and its opening is known as the urethral meatus which lies on the tip of the glans penis. It is both a passage for urine and for the ejaculation of semen.

Accessory Glands

Seminal Vesicles (Uterus masculinus): One pair of seminal vesicles are posterior to the urinary bladder. They secrete fructose, citric acid, **prostaglandins** and fibrinogen. The duct of each seminal vesicle joins the vas deferens on that side to form the ejaculatory duct. Its secretion makes 60-70% of semen. pH of secretion is 7.3.

Prostate Gland:

This gland is present only in mammals and is single in number. The prostate gland is a muscular gland that surrounds the first inch of the urethra as it emerges from the bladder and is divided into 5 lobes. The smooth muscle of the prostate gland contracts during ejaculation to contribute to the expulsion of semen from the urethra. its secretion forms 20% of semen. its secretion is milky white in colour. pH is 7.2, secretion contain Ca^{++}, citrate ion, phosphate ion, profibrinolysin and acid phosphatase.

Bulbourethral Glands or Cowper's glands:

The bulbourethral glands also called Cowper's glands are located below the prostate gland and empty into urethra. The alkalinity of fluid from cowper's gland helps neutralize the acidity of urethra (due to urine) and vaginal acidity and permits sperm mobility in what might otherwise be an unfavorable environment. Its secretion is clear, viscous and alkaline. This secretion also contain some sperms, that's why *coitus interuptus* is not so successful. Its secretion also helps in lubrication of penis.

Semen= 60% seminal fluid +30% prostatic fluid +10% sperms + small amount of secretion from Cowper's glands.

Seminal plasma is rich in fructose, calcium and certain enzymes.

Penis:

- The penis is an external genital organ. it is cylindrical in shape and consists of a root, a body and the glans penis.
- The root of the penis is the attached portion whereas the body of penis is composed of three cylindrical masses of spongy tissue, two dorsolateral masses called as **corpora cavernosa** and the smaller midventral mass called as **corpus spongiosum** which contains the urethra. All three masses are enclosed by fascia (a sheet of fibrous connective tissue) and skin and consists of erectile tissue permeated by blood sinuses.
- The distal end of the penis is called the glans penis which is an elongation of corpus spongiosum and is covered with a fold of skin called the prepuce or foreskin.
- Removal of prepuce is called as Circumcision. In whale, bat, rat penis contains a bone called **bacculum** and such penis is called as **Os-penis**.

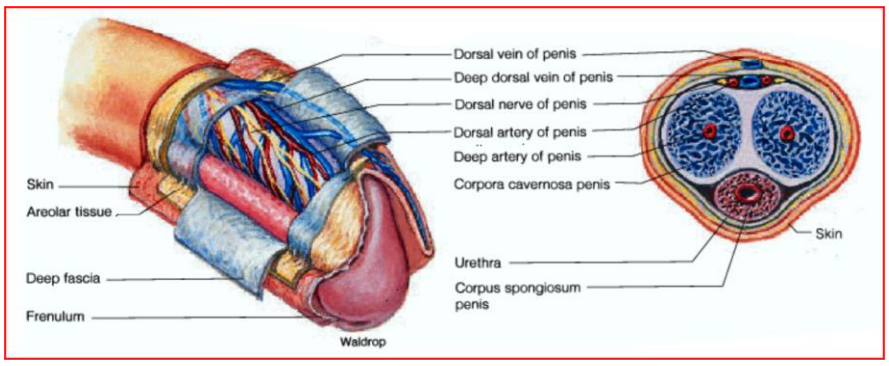


Figure: The structure of the penis. The attachment, blood and nerve supply, and arrangement of the erectile tissue are shown in both longitudinal and cross section.

Resonate the Concept
• **Castration** is removal of testes. It causes failure of development of secondary sex organs and characters and removes the ability to reproduce due to deficiency of testosterone. Choir boys were often castrated in medieval Europe to retain their high-pitch voice for singing. Castration often changes the aggressive bull into a docile ox. • **Erection of penis-** parasympathetic nervous system • **Ejaculation of semen**- sympathetic nervous system. • **Micturition**- parasympathetic nervous system • Emission is movement of semen in male genital tract.

Spermatogenesis:

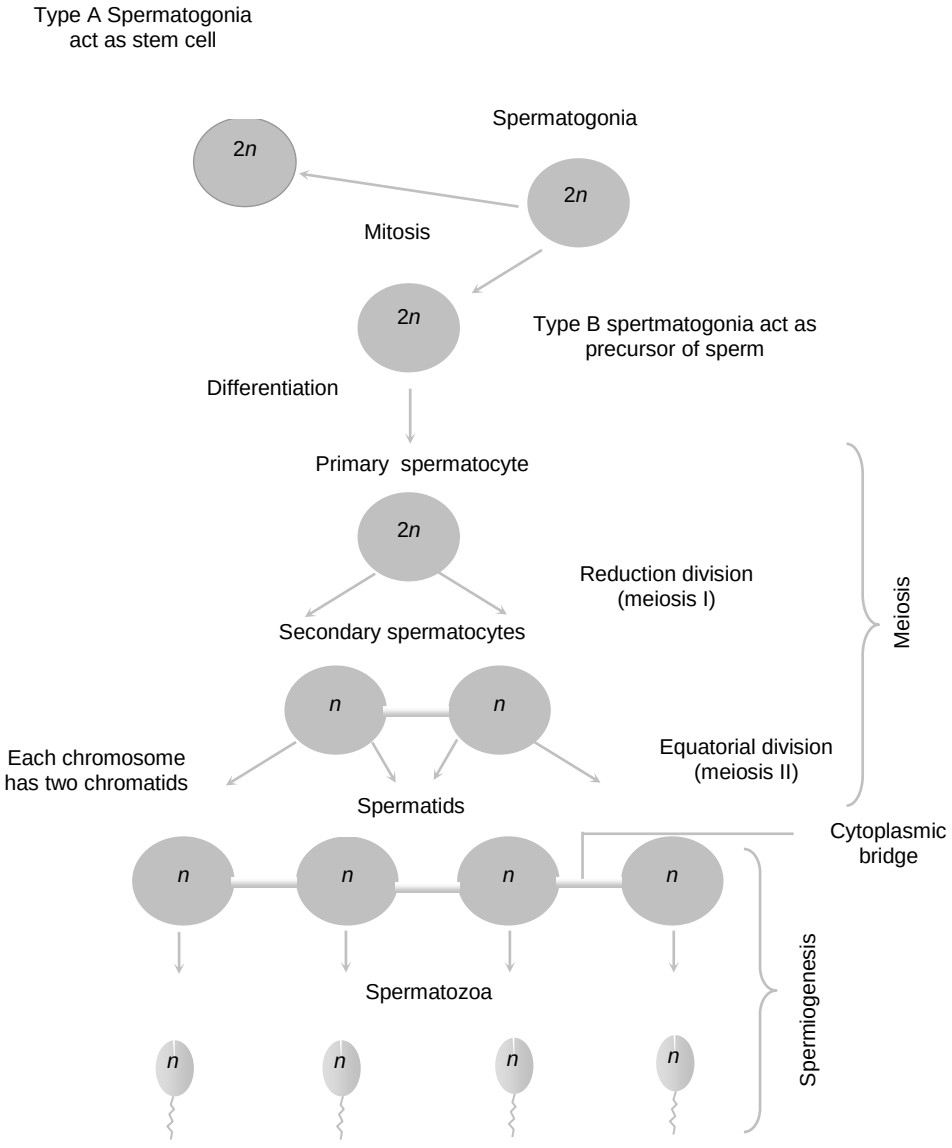


Fig- Events in spermatogenesis

- The process by which the seminiferous tubules of the testes produce sperm is called spermatogenesis, which begins at puberty.
- Spermatogonia divides several times during the process of development. The entire process of sperm formation and maturation takes about 9-10 weeks.
- It occurs in four stages: spermatocytogenesis, meiosis I, meiosis II and spermiogenesis

(i) Spermatocytogenesis (Multiplication phase): In spermatocytogenesis, the **spermatogonia** present on the inside wall of the seminiferous tubules multiply by mitotic division and increase in numbers. Each **spermatogonia** is **diploid** containing **46 chromosomes.** Some spermatogonia undergo changes they grow, increase in size by accumulating nourishing materials and are called **primary spermatocytes** which periodically undergo meiosis and others remain as **spermatogonia cells.** After multiplication phase two types of spermatogonia are formed, type A serve as stem cells while type B are precursor of sperms.

(ii) Maturation division

(a) Meiosis – I: A primary spermatocyte is diploid, (2n) with 44 + XY (total 46) chromosomes. It completes the first meiotic division (reduction division) leading to the formation of two equal, haploid cells called **secondary spermatocytes,** which have only 23 chromosomes each i.e. 22 + X or 22 + Y. During this division four chromatids of each homologous pair twist around one another for crossing over. This event of crossing over result in genetic recombination, as a result the sperm produced are genetically unlike one another and unlike the parent cell that produced them.

(b) Meiosis – II: In meiosis II there is no further replication of DNA. The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid spermatids. The number of chromosomes in each spermatid is 23.

(iii) Spermiogenesis: The spermatids are transformed into spermatozoa (sperms) by the process of metamorphosis called **spermiogenesis/spermateliosis/spermiosis.** During spermiogenesis the sperm heads become embedded in the **Sertoli cells,** and are finally released from the seminiferous tubules by the process called **spermiation.**

Resonate the Concept
• Amoeboid sperm is present in ***Ascaris***. • Primordial germ cell develops in extra embryonic mesoderm which later on migrates to yolk sac endoderm and finally settle in gonads. • Androgens include two hormones testosterone and Dihydro epiandrosterone (DHEA). • Although male ejaculate has 200 to 300 million sperms, very few of them reach the site of fertilization. Most sperms are killed by the acidic environment of the female reproductive tract. So many sperms are needed to increase the likelihood of fertilization.

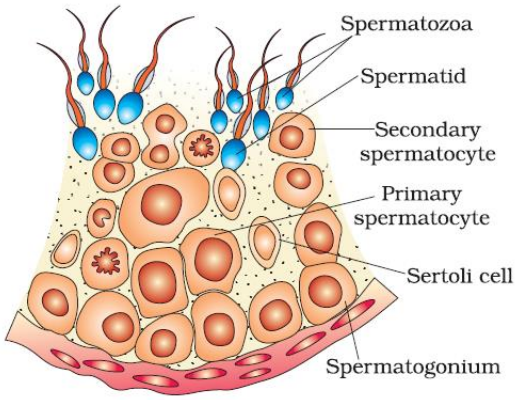


Fig.: Diagrammatic sectional view of a seminiferous tubule

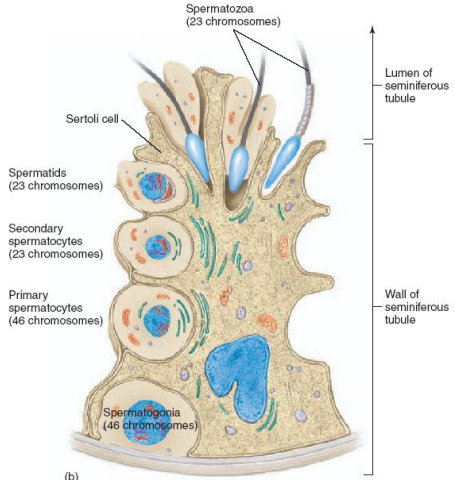


Fig.: In spermatogenesis from one primary spermatocyte four haploid sperms are formed.

Structure of Mature Sperm

- Mature sperm cell consists of a **head,** a **neck**, a **middle piece** and a **tail.**
- A plasma membrane envelops the whole body of sperm except the last part of tail.
- The sperm **head** contains a very little cytoplasm, an elongated haploid nucleus, the anterior portion of which is covered by a cap-like structure, **acrosome.**
- 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 cell to enter the ovum.
- Sperm lysins include hyaluronidase, corona penetrating enzyme and zona lysins.
- **Acrosome** is derived from **Golgi apparatus.** Its membrane extends down the outer surface of nucleus.
- The **short neck,** contains two distinct granules – the **proximal and distal centrioles.** 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 25 to 30 mitochondria arranged spirally which produce energy for the movement of tail that facilitates sperm motility essential for fertilization, that is why it is called as 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.
- The sperms move by **swimming** at the rate of 1.5 to 3 mm per minute to reach the site of fertilization within 30 minutes.

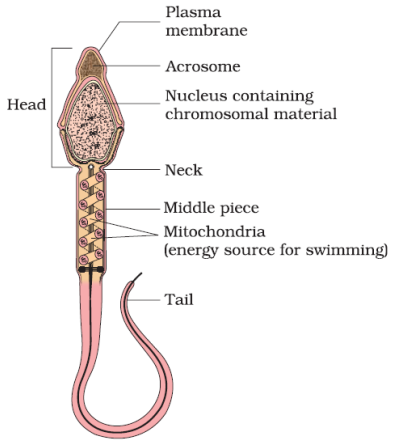


Fig. : Structure of a sperm

- The human male ejaculates about 3.5 ml semen in female tract during coitus, containing 200 to 300 million sperms. **For normal fertility, at least 60 percent of these sperms must have normal shape and size and at least 40 percent of them must show vigorous motility.**
- Sperm survives for one month in male genital tract while 24-48 hour in female reproduction tract.
- Oligospermia- Sperm count less than 20 million/ml of semen
- Necrospermia- More than 50% dead sperms
- Azoospermia- No sperms in semen
- Asthenospermia- Highly decreased motility
- Tetratozoospermia- Defective morphology of sperm.
- Aspermia – Absence of semen.

Hormonal control of Male Reproductive system

- At the onset of puberty, neurosecretory cells in the hypothalamus increase their secretion of **gonadotrophin-releasing hormone (GnRH)**. This hormone. in turn, stimulates the anterior pituitary to increase its secretion of **Luteinizing hormone (LH)** and **Follicle-stimulating hormone (FSH)**.
- LH stimulates Leydig cells to secrete **Testosterone**, synthesized from cholesterol and is a principal androgen.
- Testosterone acts in a negative feedback manner to suppress secretion of LH by anterior pituitary and GnRH by hypothalamic neurosecretory cells.
- Androgens stimulate process of spermatogenesis.
- FSH acts on sertoli cells & stimulate secretion of some factors, which help in process of spermiogenesis.
- 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. The seminal plasma along with the sperms constitute the semen. The functions of male sex accessory ducts and glands are maintained by the testicular hormones (androgens).
- In some target cells, such as in external genitals and prostate, an enzyme converts testosterone to other androgen called **dihydrotestosterone (DHT)**. DHT and testosterone act together to stimulate spermatogenesis. Once the degree of spermatogenesis required for male reproductive functions has been achieved, Sertoli cells release inhibin, a hormone which inhibits secretion of FSH by anterior pituitary. Here are some other effects produced by androgens

  (i) Prenatal development: Before birth, testosterone stimulates the male pattern development of reproductive system ducts and the descent of testes. DHT stimulates development of external genitals.

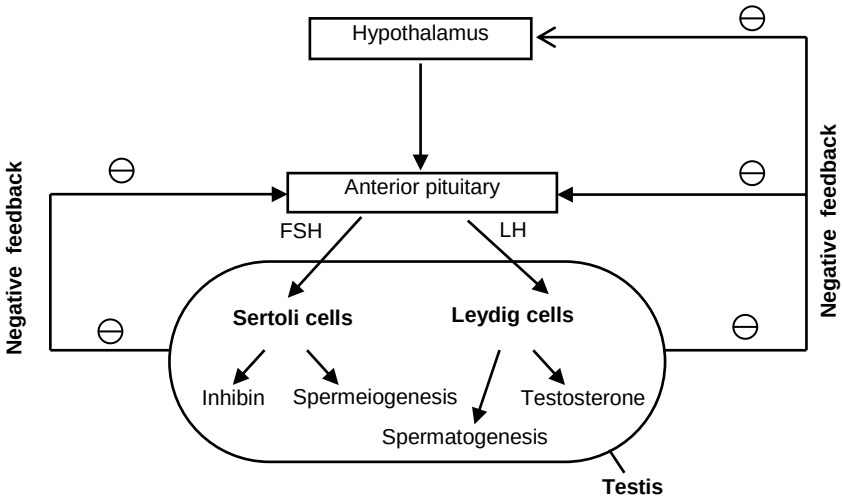
  (ii) Development of male sexual characteristics: At puberty, testosterone and DHT bring about development and enlargement of male sex organs and the development of masculine secondary sexual characteristics.

  (iii) Development of sexual functions: Androgens contribute to male sexual behavior and spermatogenesis and to sex drive (libido) in males.

  (iv) Stimulation of anabolism: Androgens are anabolic hormones; that is, they stimulate protein synthesis. This effect is obvious in the heavier muscle and bone mass of most men as compared to women.

Significance of spermatogenesis

- Maintain number of chromosomes in zygote equal to that in parental cells.
- During meiosis- I, crossing over takes place, which brings variation.
- Similar pattern of spermatogenesis take place in many animals. Which establish their common origin.



Hormonal control of the testis

Test your Resonance with concept

1. Movement of sperms in male reproductive tract is called.
(1) Ejaculation (2) Emission (3) Insemination (4) Micturition

2. Which of the following spongy tissue will be present at glans penis?
(1) Single corpus spongiosum (2) Single corpora cavernosa
(3) Two corpus spongiosum (4) Both corpus spongiosum & corpora cavernosa

3. For normal fertility, at least ___x___ percent of the sperms must have normal shape and size and at least ___y___ percent of them must show vigorous motility.
(1) x = 60, y = 40 (2) x = 40, y = 60 (3) x = 50, y = 40 (4) x = 40, y = 50

4. **Assertion:** Sertoli cells and spermatogonia are sibling cells as they are originated from same embryonic tissue in gonads.
Reason: Relation between sertoli cells & spermatogonia is similar as between oogonia and germinal epithelia of ovary.
(1) (2) (3) (4)

5. Gubernaculum cordis is a contractile structure that
(1) Pulls down the testis during breeding season into the scrotal sac
(2) Allows daily migration of the testis from the abdominal cavity into the scrotum
(3) Facilitates ejaculation of spermatozoa from the testis
(4) Keeps the testis in position

Answers

1. (2) **2.** (2) **3.** (1) **4.** (4) **5.** (4)

The Female Reproductive System

- The organs of female reproductive system include the ovaries, fallopian tubes or oviducts, uterus, vagina and external organs which are collectively called the **vulva** or **pudendum**. These parts of the system along with a pair of the mammary glands are integrated structurally and functionally to support the processes of ovulation, fertilization, pregnancy, birth and child care.
- Average age of puberty in females is 12-13 years and is subdivided with the development of different organs such as **Thelarche** is development of breasts, **Pubarche** is development of pubic hair and **Menarche** is beginning of menstrual cycle. Besides all these characters females develop broad hips, thoracic breathing predominantly and low BMR.

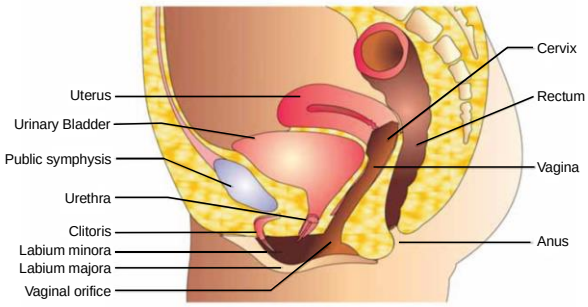


Fig. : Diagrammatic sectional view of female pelvis showing reproductive system

Ovaries

- The ovaries are paired organs that produce secondary oocytes and hormones such as progesterone, estrogen (the female sex hormone), inhibin and relaxin.
- The ovaries arise from the same embryonic tissue as the testes and they are the size and shape of unshelled almonds. Length of ovary is 2- 4 cm.
- One ovary lies on each side of the pelvic cavity, held in place by ovarian ligaments attached to the uterus wall and attached to peritoneal ligament by mesovarium. Blood vessels and nerves enter by mesovarium.
- Ovary is covered by visceral peritoneum (cuboidal in shape), inside to it germinal epithelium is present which are also called as primordial germ cells. Below germinal epithelium, a layer of connective tissue is present called as **tunica albuginea**. Internal to epithelia the ovarian stroma is divided into peripheral dense cortex and inner less dense medulla. Cortex consists of ovarian follicles and medulla contains blood vessels and nerves.

  Accessory organs: Similar to testis there are different accessory organs which play important role in female reproductive system. They are as follows;

(i) Oviduct:

- The oviduct is also known as **fallopian tube** or **uterine tube**. Females have a pair of uterine tube that extends laterally from the uterus and transport the secondary oocytes from the ovaries to the uterus.
- They are 10-12 cm long and along with ovaries they are also attached to peritoneal ligament.
- Fallopian tube is divided into three parts **infundibulum**, **ampulla** and **isthmus**. Infundibulum is funnel shaped end of each tube which lies close to ovary but is open to the pelvic cavity and ends in a fringe or finger like projections called **Fimbriae**. The infundibulum leads to a wider part called Ampulla and last part of oviduct is isthmus, has a narrow lumen and joins the uterus.

- Fertilization occurs at ampullary-isthemic junction. Oviduct is internally lined by ciliated columnar epithelia. After ovulation, fimbriae sweep the secondary oocyte into the uterine tube. Ovum is transported to Uterus by peristaltic movement in fallopian tube

(ii) Uterus:

- The uterus is also called as womb or hystera or metra. It is situated between the urinary bladder and the rectum and is shaped like an inverted pear.
- Uterus is divided into different parts, the dome shaped portion superior to the uterine tubes called **fundus**, the tapering central portion called the **body** (corpus) and the narrow portion opening into the vagina is called **cervix**. The interior of the body of the uterus is called the **uterine cavity**.
- Cervix joins anterior wall of vagina and open into it. Cervix communicate with upper part of uterus by an aperture internal os and to vagina by another aperture external os. Cervix along with vagina forms birth canal.
- It is supported by ligaments attached to the dorsal side of pelvic wall. The uterus wall is divided into three distinct layers; the outermost layer at the periphery is called as **perimetrium** (visceral peritoneum). The middle muscular layer the **myometrium**, which consists of smooth muscle (strongest, thickest and longest smooth muscle) and forms the bulk of the uterine wall. During childbirth, coordinated contractions of uterine muscles help expel the foetus. The innermost epithelial is **endometrium**, is made up of stratum basale and a more superficial stratum functionale. It consists of tubular glands for the secretion of mucous. The endometrium contains many endometrial glands whose secretions nourish sperm and the zygote. **It nourishes a growing foetus or is shed each month during menstruation if fertilization does not occur.**

(iii) Vagina:

- The vagina is a tubular canal that extends from the exterior of the body to the uterine cervix. It is the receptacle for the penis during the sexual intercourse, the outlet for menstrual flow and the passageway for childbirth, which is made of smooth muscles.
- It is approx. 8 cm long muscular tube, internally lined by non-keratinized stratified squamous epithelia.
- The mucosa of the vagina contains large stores of glycogen, the decomposition of which by *Lactobacillus* bacteria produces organic acids, resulting in acidic environment (pH=3.5), retards microbial growth and is also harmful for sperm.
- There is a thin fold of mucous membrane called the **hymen** partially covering the **vaginal orifice**, the vaginal opening. Vagina is devoid of glands.

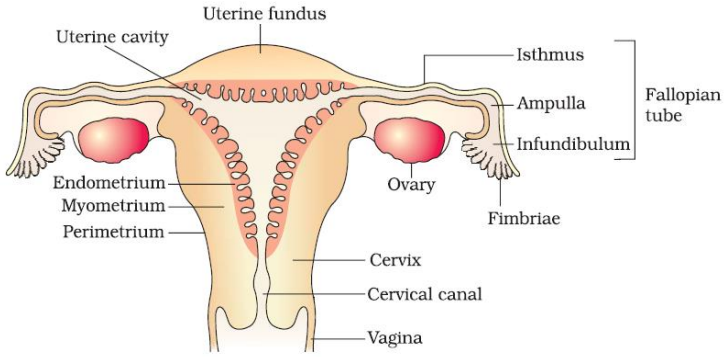


Fig. : Diagrammatic sectional view of the female reproductive system

Resonate the Concept

Removal of oviduct is called as tubectomy, which is also a process of sterilization (Salpingectomy). Removal of uterus is **hysterectomy**.

(iv) External Genitalia:

- The term vulva or pudendum, refers to the external genitals of the female.
- The mons pubis is an elevation of adipose tissue covered by coarse pubic hair, which cushions the pubic symphysis.
- From the mons pubis, two longitudinal folds of skin, the labia majora extend down and back, it is developed from the same embryonic tissue that the scrotum develops from in males. The labia majora contain adipose tissue and sebaceous (oil) and sudoriferous (sweat) glands, and covered by pubic hair like mons pubis.
- Medial to the labia majora are two folds of skin called the labia minora. The labia minora do not contain pubic hair or fat and have few sudoriferous (sweat) glands, they do contain numerous sebaceous (oil) glands.
- At the anterior junction or labia minora there is a small, cylindrical mass of erectile tissue and nerves called as clitoris is present. A layer of skin called the prepuce also known as the foreskin, is formed at a point where the labia minora unite and cover the body of clitoris.
- The region between the labia minora is called the vestibule. Vestibule consists of hymen (if present), vaginal orifice (posterior) and external urethral orifice (anterior)

Female accessory reproductive Glands:

(i) **Bertholin / Greater vestibular glands**: 1 pair on each side of vagina. Homologous to cowper's gland of male. Secretion is clear, alkaline and viscous.

(ii) **Skene's/Paraurethral/Lesser Vestibular Glands**- Many in number, open on each side of vagina. Homologous to prostate gland of male.

Resonate the Concept

- Like the penis, the clitoris is capable of enlargement upon sexual stimulation.
- The male's prostate develops from the same embryonic tissue as the female's paraurethral glands.
- Greater vestibular glands are equivalent to bulbourethral glands in males.
- The **clitoris** is covered with stratified squamous epithelium and is homologous to the male's glans penis.
- **Labia majora** are homologous to male scrotum. Labia minora is homologous to penile urethra of male.
- **Hymen** is often torn during the first coitus (intercourse). However, it can also be broken by a sudden fall or jolt, insertion of vaginal tampon, active participation in some sports like horseback riding, cycling etc. In some females, hymen persists even after coitus. In fact, the presence or absence of hymen is not a reliable indicator of virginity or sexual experience.

(iii) Mammary Gland:

- The mammary glands, located in the breasts which are modified sudoriferous (sweat) glands that produce milk. Each breast has a pigmented projection, the nipple, surrounded by circular pigmented skin called as areola.

- Internally each mammary gland consists of 15-20 lobes arranged radially and separated by adipose tissue and strands of connective tissue called suspensory ligaments of the breast (Cooper's ligaments), which supports the breast. Each lobe is divided into smaller lobules, in which milk secreting glands called alveoli are found. The cells of the alveoli secrete milk, which is stored in the cavities (lumen) of alveoli. The alveoli. The open into mammary tubules. The tubules of each lobe join to form a mammary duct. Several mammary ducts join to form a wider mammary ampulla which is connected to lactiferous duct through which milk is sucked out.
- At birth, the mammary glands are underdeveloped and appear as slight elevations on the chest, which develops with the onset of puberty under the influence of estrogens and progesterone. The duct system matures and fat is deposited which increases the breast size, subsequently areola and nipple also enlarge and become more darkly pigmented.
- The functions of mammary gland is the synthesis, secretion and ejection of milk; these functions are called **Lactation**, and are associated with pregnancy and childbirth. Nipples are vestigial in males.
- Gynaecomastia is the development of breast in male (due to hyposecretion of DHEA from adrenal cortex).
- Pathway of milk secretion

  Alveoli → Mammary tubules → Mammary duct → Mammary Ampulla → Lactiferous ducts.

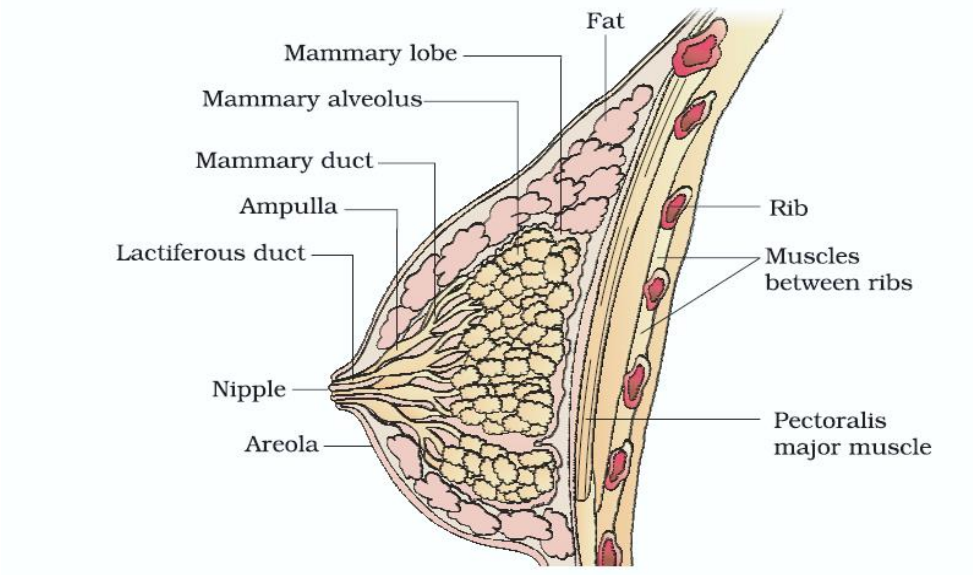


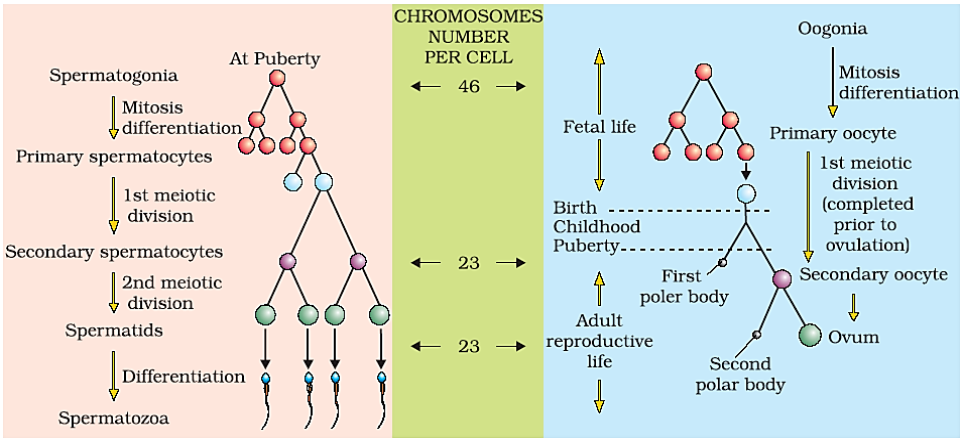
Fig. A diagrammatic sectional view of mammary gland

Resonate the Concept

- A woman's reproductive life generally ends at menopause, due to exhaustion of ovarian follicles which occurs at the age of around 50 years.
- A man's reproductive life never ends, unless disability or disease renders him unable to become father of children. About male produce 100 to 200 million sperms each day and can continue doing so throughout their life.

Oogenesis

- The process of formation of a mature female gamete is called **oogenesis** which is markedly different from spermatogenesis.
- Unlike spermatogenesis, which begins in males at puberty, oogenesis is initiated during the **embryonic** development stage when 2 million gamete mother cells (**oogonia**) are formed within each foetal ovary; no more oogonia are **formed** or **added** after birth. Scattered ovarian follicles are embedded in the stroma of cortex.



(a) (b)

Fig.: Schematic representation of (a) Spermatogenesis; (b) Oogenesis

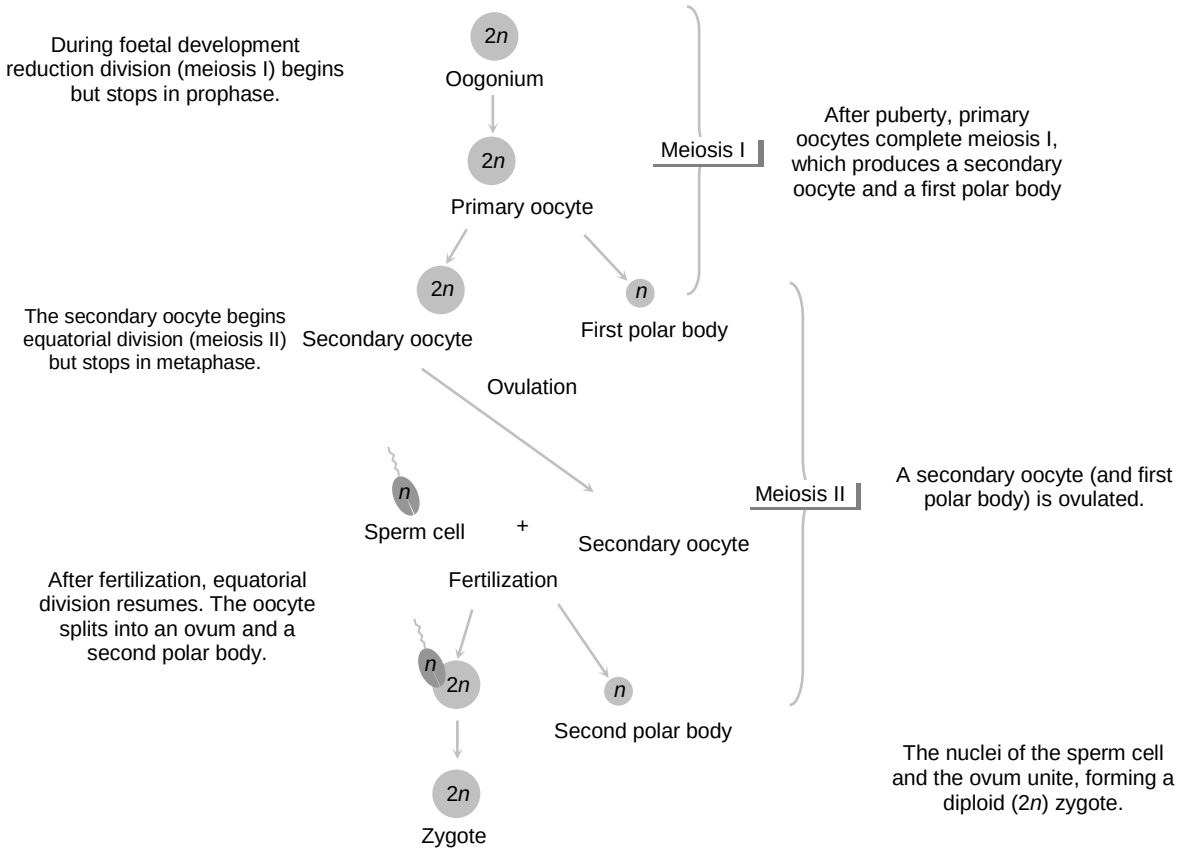


Fig.: Events is oogenesis

Ovarian Follicle:

- The primordial germ cells develop from extra embryonic mesoderm that migrate into the ovaries during early embryonic development multiply, by about 5 months of gestation (prenatal life) the ovaries contain approximately 2 million oogonia.
- An ovarian follicle consists of an oocyte, surrounded by one or more layers of follicular (flat epithelial) cells, the granulosa cells.
- The oogonial cells start division and enter into diplotene of prophase-I of the meiotic division, and get temporarily arrested at this stage called primary **oocytes.** Each primary oocyte gets surrounded by a layer of **granulosa** cells and then called **primary follicle.**
- A large number of these follicles degenerate from birth to puberty. Degeneration of ovarian follicles is called **follicular atresia** and their disposal is done by phagocytes. Therefore, **at puberty only 60,000 to 80,000 primary follicles are left in each ovary.** Follicular atresia can happen due to deficiency of vitamin E.
- With the onset of puberty, around one dozen primary follicle begins to mature with each ovarian cycle. The follicular cells becomes cuboidal, divide by mitosis to form a stratified epithelium, the granulosa layer. So, the primary follicles get surrounded by more layers of granulosa cells and a new theca, called **secondary follicles. Granulosa** cells rest on a basement membrane and the surrounding stromal cells form theca folliculi.
- The **secondary follicle** soon transforms into a **tertiary follicle** which is characterized by a fluid filled cavity **antrum**, which appears between the granulosa cells. Initially, the antrum is crescent shaped, but with time it greatly enlarges. The fluid of antrum is **liquor folliculi.**
- Theca layer soon differentiates into inner layer of endocrine cells – theca interna & outer layer of fibroblast like cells theca externa.
- The maturing oocytes adhere to the wall of the follicle through a pedicel/stalk, **cumulus oophorus,** formed by granulosa cells, and remains suspended in liquor folliculi. Theca interna is composed of cells having characteristics of steroid secretion, rich in blood vessels and theca externa gradually merges with ovarian stroma.
- The **primary oocyte** within the tertiary follicle grows in size and **completes** its **first meiotic division** at puberty. It is an unequal division resulting in the formation of a large **haploid secondary oocyte** and a tiny first polar body. The secondary oocyte retains the bulk of nutrient rich cytoplasm of the **primary oocyte.** The tertiary follicle changes into the mature follicle or **Graafian follicle (is present in mammals only).**
- The secondary oocyte forms a new membrane called **Zona pellucida** surrounding it. This thick coat of zona pellucida is composed of glycoproteins and synthesized by oocyte. Later the granulosa cells lying in close vicinity of the ovum and zona pellucida, become elongated to form the **corona radiata.** In the presence of LH hormone, the **Graafian follicle** now ruptures to release the secondary oocyte developing (ovum) from the ovary by the process called **ovulation.** After ovulation the ruptured follicle left in the ovary is converted to a structure called corpus luteum, **which secretes** mainly **progesterone** but some amounts of estrogen and relaxin are also secreted.

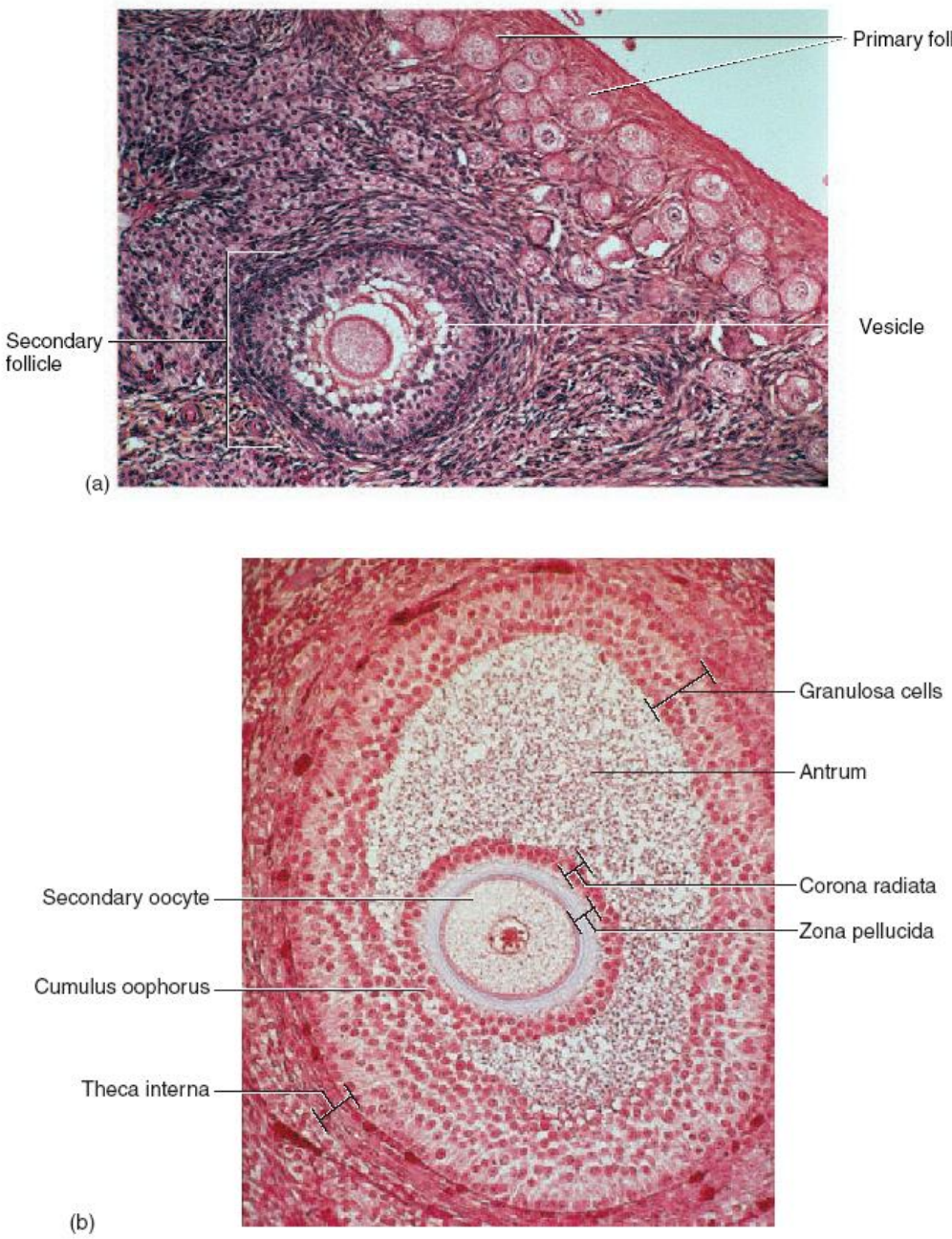


Fig.: Photomicrographs of the ovary.

(a) Primary follicles and one secondary follicle and (b) a graafian follicle are visible in these sections.

Resonate the Concept
• Generally, only one ovum is liberated in each menstrual cycle (average duration 28 days) by alternate ovaries. Each ovary releases six ova in one year. Only about 400 to 450 ova are produced by human female over the entire span of her reproductive life which lasts about 35 to 40 years. • 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.

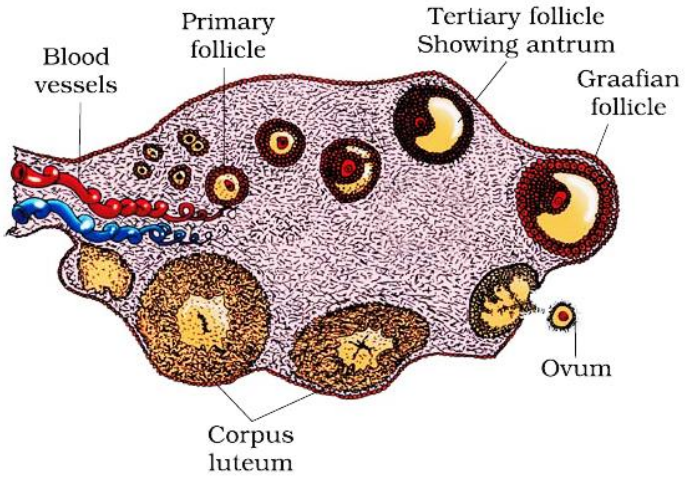
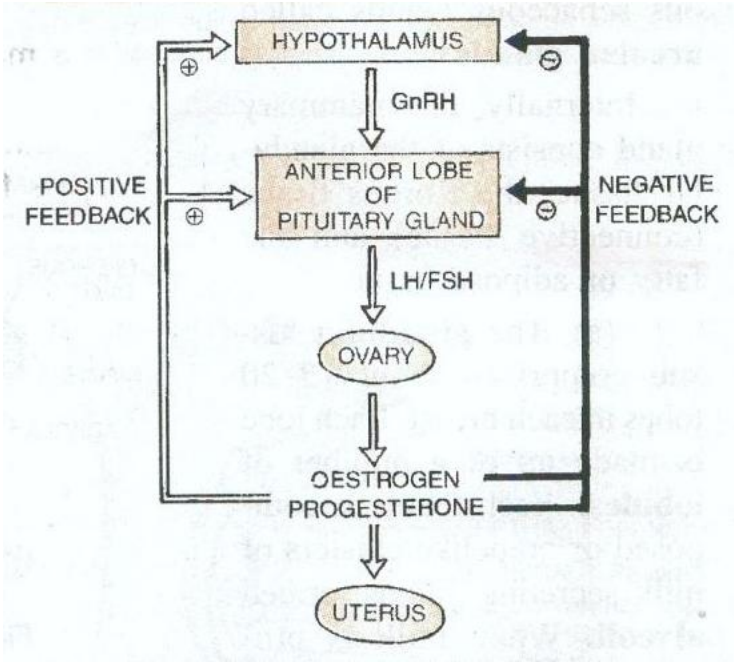


Fig.: Diagrammatic sectional view of ovary

Hormonal Control of Female Reproductive System



GnRH is secreted by the hypothalamus which stimulates the anterior lobe of pituitary gland to secrete LH and FSH. FSH stimulates the growth of the ovarian follicles and also increases the development of egg /oocyte within the follicle to complete the meiosis I to form secondary oocyte. FSH also stimulates the formation of oestrogens. LH stimulates the corpus luteum to secrete progesterone. Rising level of progesterone inhibits the release of GnRH, which, in turn, inhibits the production of FSH, LH and progesterone.

Test your Resonance with concept

1. The layer of cells immediately surrounding the ovum but outside the zona pellucida is called
(1) Corona radiata (2) Membrana granulosa
(3) Theca interna (4) Germinal epithelium

2. In female mammals Bartholin's glands open into the
(1) Vestibule and release a lubricating fluid in the vagina
(2) Uterus and release a lubricating fluid during the birth of young ones
(3) Urinary bladder and assist in release of urine
(4) Fallopian tubes and release a secretion which makes sperms motile

3. Part of oviduct closer to the ovary is .....(i)..... . that leads to a wider part of the oviduct called .....(ii)..... and the last part of the oviduct is called ..... (iii) ..... which opens in uterus. (i), (ii) and (iii) are respectively-
(1) Ampulla, Isthmus, infundibulum (2) Isthmus, Ampulla, infundibulum
(3) infundibulum, Ampulla, Isthmus (4) infundibulum, Isthmus, Ampulla

4. Which of the following is the group of external genitalia in human female?
(1) Labium minora, labium majora, uterus
(2) Labium minora, labium majora, clitoris
(3) Labium minora, labium majora, oviduct
(4) Labium minora, labium majora, cervix

5. Oogonia reach their maximum number at
(1) Five months of foetal life
(2) Birth
(3) Puberty (13 years of age)
(4) Adolescence (16 -20 years of age)

Answers
1. (1) **2.** (1) **3.** (3) **4.** (2) **5.** (1)

Reproductive Cycle

Estrous cycle:

- This type of cycle occur in non-primates and new world monkeys.
- The ovulation cycle in these animals go into estrus (heat) in approximate synchrony with ovulation.
- During estrus they use behaviors and other signals, such as pheromones, to indicate that they are sexually receptive. Estrus lasts, depending on the species, for a few hour to few days during each cycle.
- Based on frequency of cycles in a year, estrous animals can be of two types-
  (i) Monoestrous: Dog, Fox, Deer, Bat.
  (ii) Polyestrous: Mouse, Squirrel, Cow, Sheep, Pig, Horse etc.

- The whole cycle is divided into four phases (1) Pre-estrous (first step, oogenesis starts), (2) Estrous (Heat period, pheromones produced, (3) Meta Estrous (Pseudopregnancy, if fertilization occurs then lasts up to parturition) and (4) Anestrous/Diestrous (Interphase). Anestrous phase is longer in monoestrous as compared to polyestrous.

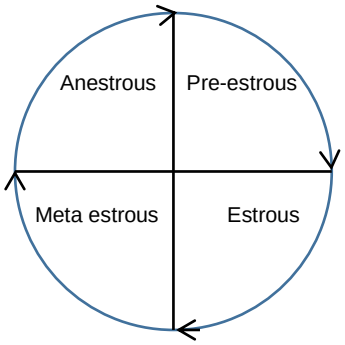


Fig.: Estrous Cycle

Menstrual Cycle

- The reproductive cycle in the female primates (e.g., old world monkeys, apes and human beings) is called **menstrual cycle.**
- The first menstruation begins at puberty and is called **menarche.** In human females, menstruation is repeated at an average interval of about 28/29 days (lunar month), and the cycle of events from one menstruation till next one is called the **menstrual cycle**.
- One ovum is released (ovulation) during the middle of each menstrual cycle of 28 days. The major events of the menstrual cycle are shown in the figure.

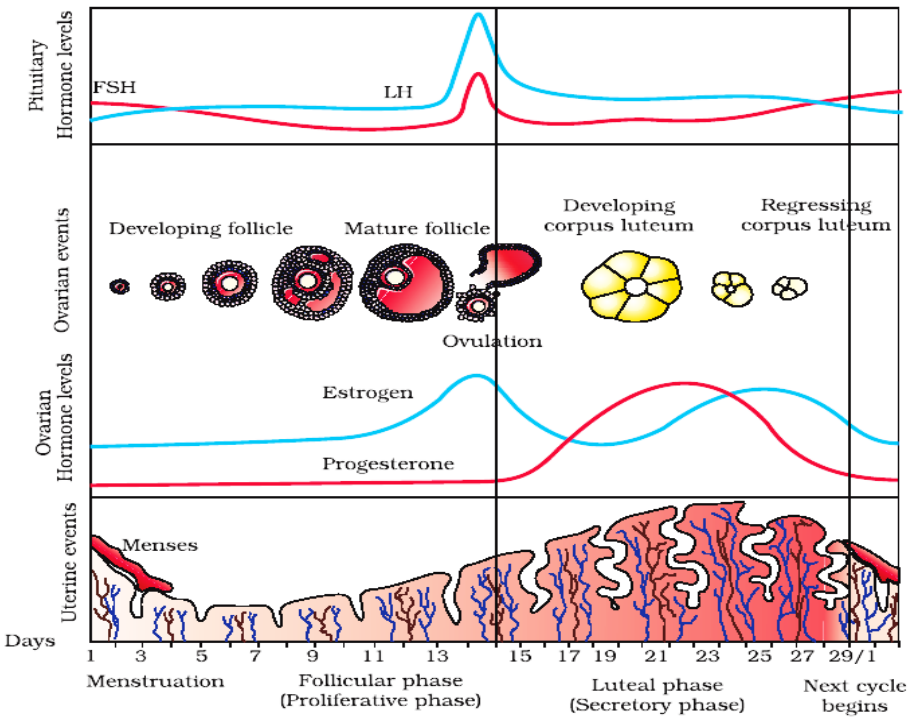


Fig.: Diagrammatic presentation of various events during a menstrual cycle

Phases of menstrual cycle

Menstrual phase

- Menstrual flow occurs in this phase and it lasts for 3 to 5 days.
- Due to decreased production of LH from anterior pituitary, secretion of progesterone & estrogen is reduced.
- This flow results due to the breakdown of endometrial lining of the uterus and its blood vessels which forms a liquid and flows out through the vagina. Menstruation usually occurs about 14 days after ovulation, if the released ovum is not fertilized. Lack of menstruation may be indicative of pregnancy.
- The total amount of blood discharged in one cycle is 30 to 50 ml. This blood forms clot in the uterus, later fibrinolytic enzyme form the uterus dissolves the clot so the blood in the menses always remains in liquid state.

Resonate the Concept

Certain environmental factors, such as stress, poor health, poor diet, prolonged strenuous exercise, can also affect the menstrual cycle and lead to lack of menstruation. These factors can influence hormone levels i.e.. secretion of gonadotropins by anterior lobe of pituitary and secretion of ovarian hormones, thus disrupting one or more phases of cycle

i. Follicular phase

- The menstrual phase is followed by the follicular phase. Follicular phase is also called as proliferative phase phase and occurs between day 6 to day 13 of menstrual cycle.
- During this phase, primary follicles in ovary grow to become a fully mature **Graafian follicle** and simultaneously the endometrium of uterus regenerates through proliferation.
- These changes in the ovary and the uterus are induced by changes in the levels of pituitary **gonadotropins** and **ovarian hormones.**
- Secretion of gonadotropins (FSH) increases gradually during the follicular phase, and stimulates follicle growth. The follicular cells secrete estrogen, a sex hormone that also aids in the growth of the follicle. Estrogen hormone stimulates mitotic divisions of the cells in the lining of uterus, and helps to repair the broken tissue and blood vessels. It also causes the thickening of the endometrium.
- Both FSH and LH attain a peak level in the middle of each cycle, on 14^{th} day of 28 day cycle. During this phase, the estrogen level in the blood continues to rise until it reaches the peak and the Graafian follicle moves to the surface of ovary.
- The elevated estrogen levels acts as positive feedback mechanism by stimulating the anterior lobe of pituitary to secrete luteinizing hormone (LH), which initiates the next stage of menstrual cycle. Rapid secretion of LH reaching to its maximum level during the mid-cycle called as **LH surge** induces the rupture of Graafian follicle and thereby the release of ovum (ovulation)

ii. Ovulation

- Both LH & FSH attain peak level in mid of cycle, LH surge results in rupture of Graafian follicle & induces ovulation which usually occurs on 14^{th} day in the 28 days cycle. The Graafian follicle ruptures and secondary oocyte (ovum) is released.
- Day of ovulation = Number of days in menstrual cycle –14.
- At time of ovulation body temperature rises by 0.5^0 C due to LH surge.

iii. Luteal phase/Secretory phase

- The ovulatory phase is followed by luteal phase and last from day 13 to day 28 of the menstrual cycle.
- In this stage an egg is swept into the fallopian tube, where it awaits fertilization as it travels through the tube towards uterus. The egg has stored nutrients to survive about 24 hours.
- The ovulatory phase is followed by luteal phase during which the remaining parts of Graafian follicle transform as **Corpus luteum** in the ovary. **Corpus luteum** secretes large amounts of progesterone which is essential for **maintenance** of endometrium which is thickened by estrogen.
- In luteal phase, the endometrium further thickens due to progesterone hormone secreted by corpus luteum. LH hormone causes the cells of the ruptured follicle to form corpus luteum.
- Corpus luteum (contain lutein/carotene pigment) is a yellowish mass of follicular cells that functions like an endocrine structure. LH hormone also stimulates the corpus luteum to secrete estrogen and progesterone.
- Estrogen and progesterone inhibit the release of FSH and LH. This prevents the development of new follicles during the luteal phase. Progesterone also inhibit uterine contraction.
- Luteal phase lasts for 14 days. During this phase, the levels of estrogen and progesterone will rise, while FSH and LH levels drop. Low level of LH causes, degeneration of corpus luteum leading to sudden decline in progesterone level that causes menstruation.
- Maintenance of endometrium by progesterone is necessary for implantation of the fertilized ovum and maintenance of pregnancy. During pregnancy all the events of the menstrual cycle stop and there is no menstruation due to high level of progesterone.
- In the absence of fertilization, the corpus luteum degenerates; the level of progesterone hormone will fall. This causes **disintegration of** the **endometrium** leading to menstruation, marking a new cycle.
- In human beings menstrual cycles ceases around 50 years of age, termed as **menopause.** Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.

Resonate the Concept

- Cryptomenorrhoea: Occurrence of Menstrual cycle without any external symptoms or bleeding.
- Dysmenorrhoea: Painful menstruation.
- Menorrhagia: Increased duration of menstrual cycle and blood flow more than 100 mL.
- Polymenorrhoea: Also called epimenorrhoea, increased frequency of menstrual cycle (decreased duration).
- Menopause is a senile (age related) change which occurs in the ovaries around the age of 50 years. At this time, a woman no longer ovulates and thus moves out of childbearing phase. All the ovarian follicles have degenerated and there is deficiency of estrogen and progesterone hormone. FSH and LH are being produced by anterior lobe of pituitary, but now ovary is not responding to these hormones.
- Just after menopause urinary excretion of FSH increases.

Fertilization and Zygote formation:

- During copulation (coitus) semen is released by the penis into the vagina of female, called insemination. Once the sperms are released, they swim through the vagina, cervix, uterus and finally reach the ampulla of the **fallopian tubes.**
- The ovum released by the ovary is also transported to the **ampulla where fertilization occurs.**

- Fertilization 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 fertilization and pregnancy.
- First mitosis after fertilisation is actual mixing of male & female chromosomes.

Movement of Sperms:

- Only a few thousand sperms make their way to fallopian tube.
- Contraction of uterus and fallopian tube assist in movement of sperms. The average speed of sperm is 1.5 to 3 mm/min.
- Flagellar movement is secondary to contractions which help the sperm movement.
- Leucocytes of vaginal epithelia engulf millions of sperms. These sperms can survive in female genital tract for 24-48 hr.

Arrival of secondary oocyte:

- Secondary oocyte is released from the ovary into the abdominal cavity from there it is collected by fimbriae of fallopian tube and propelled by peristaltic movements of fallopian tube towards ampulla.
- Secondary oocyte can be fertilized within 24 hour of its release.

Capacitation of Sperms:

- Capacitation is the process by which the sperms are activated in the vaginal duct. It is done by secretions of female genital tract.
- Cholesterol layer is removed from acrosomal surface of sperm to expose its receptors. Acrosomal receptors bind to ZP2 and ZP3 (zona protein) receptors of ova.
- It takes around 5-6 hour for capacitation. Alkaline medium make sperm more active.
- Sperm can survive in female genital tract for 24-48 hours.

Physio-chemical events of fertilization:

- The process of fusion of a sperm with the ovum is called fertilization. Before fusion of a spermatozoa with the egg, the spermatozoa has to penetrate a few barriers, the egg membranes, which cover the egg. The secretions of **acrosome** help the sperm to enter into the cytoplasm of ovum through zona pellucida and the plasma membrane. All the chemicals are contained in the acrosome located at the tip of the sperm head and the collectively called **sperm lysins** (e.g. corona penetrating enzyme (CPE), Zonalysin (acrosin), Hyaluronidase). For successful acrosomal reaction optimum pH Ca^{2+} & Mg^{2+} concentrations are required. In absence of Ca^{2+} fertilization doesn't occur.
- Usually, only one sperm is successful in penetrating an egg. Electrical changes or depolarization, occurs in an egg's cell membrane after a sperm enters the egg, helps to keep away other sperm from penetrating the egg, this process is called as **fast block**, it is due to influx of Na^{+}. **Slow block** is the process in which cortical granules present below plasma membrane of ovum release their contents between plasma membrane and zona pellucida. The enzymes harden zona pellucida which prevent polyspermy.

Fertilizin-Antifertilizin concept :

- This concept was proposed by F. R. Lillie in 1914 based on sea urchin.
- Egg secrete fertilizin which is a glycoprotein. On the other hand sperm secrete antifertilizin which is a protein and composed of acidic amino acids.
- Binding of fertilizin and antifertilizin is called agglutination.

Sperm entry:

- At the point, first sperm contact secondary oocyte, it develop fertilization cone/ cone of reception.
- **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.**

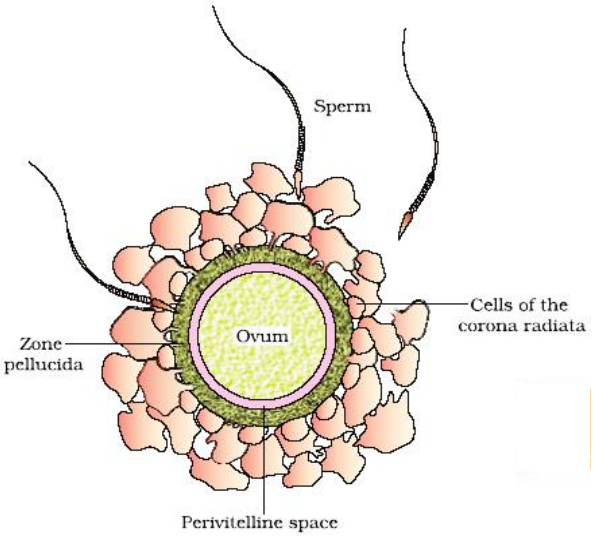


Fig. Ovum surrounded by few sperms

Each gamete contains 23 chromosomes, the haploid (n) number. Thus fusion of a sperm nucleus and an egg nucleus makes a zygote that have 46 chromosomes, thus restoring the diploid (2n) number.

Resonate the Concept
Sex of the baby is decided during fertilization. The chromosome pattern in human female is XX and that in the male is XY. Therefore, all the haploid gametes produced by the female (ova) have the sex chromosome X, whereas in the male gametes (sperms) the sex chromosome could be either X or Y, hence 50 percent of sperms carry X chromosome while the other 50 percent 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 has fertilized 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 and Implantation

- Within few hours after fertilization (while zygote is still in the fallopian tube), the zygote begins a series of mitotic divisions known as **cleavage** and forms 2,4,8,16 daughter cells **blastomeres.**
- The embryo with 8 to 16 blastomeres is called **morula.** A solid ball of cells whose size is same as that of zygote. The cells of morula continue to divide and transforms into blastocyst as it moves further into the uterus. Size of morula is same as that of zygote.
- At the end of 4^{th} day embryo reaches to uterus.

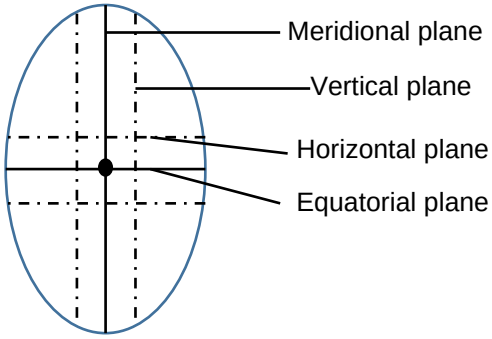


Fig.: Planes of cleavage

Cleavage in human

- Begins in fallopian tube.
- Holoblastic Indeterminate, Bilateral

Zygote

↓ 1st Cleavage 30 — Meridional plane

2 Blastomeres

↓ 2nd Cleavage 40 hr. — Meridional plane (right angle to first)

4 Blastomeres (Transient 3 cell

↓ 3rd Cleavage 72 hr. — Horizontal plane

8 Blastomeres (4 megamere,

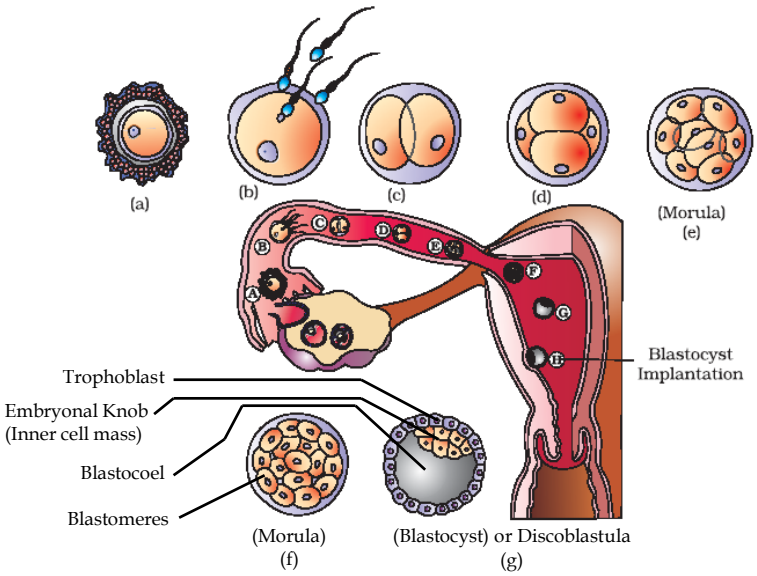
↓ Undefined pattern

16 Blastomeres

Resonate the Concept

1. All cleavage divisions are mitotic and resultant daughter cells are blastomeres.
2. During cleavage, there is no growth in the resulting blastomeres and the total size and volume of the embryo remains the same, becomes in cleavage divisions interphase is without growth phase.
3. During cleavage, the size of blastomeres keeps on decreasing, as there is no growth of blastomeres. Zona pellucida remains intact throughout the cleavage divisions.
4. During cleavage, there is no increase in mass of cytoplasm of the developing embryo. However, there is marked increase in the DNA containing chromosomal materials.

- A **Blastocyst** is a ball of almost 64 cells with a large, fluid-filled cavity called **blastocoel.** The **blastomeres** in the **blastocyst** are arranged into an outer layer called **trophoblast** and inner mass of cells (attached to trophoblast) called the **inner cell mass.**
- Side of blastocyst where inner cell mass is present is called embryonic pole, while opposite to it is abembryonic pole.
- Zona pellucida is broken on 5th day, blastocyst is implanted on 7th day.
- Cells of trophoblast, which are in contact with inner cell mass are called cells of Rauber.



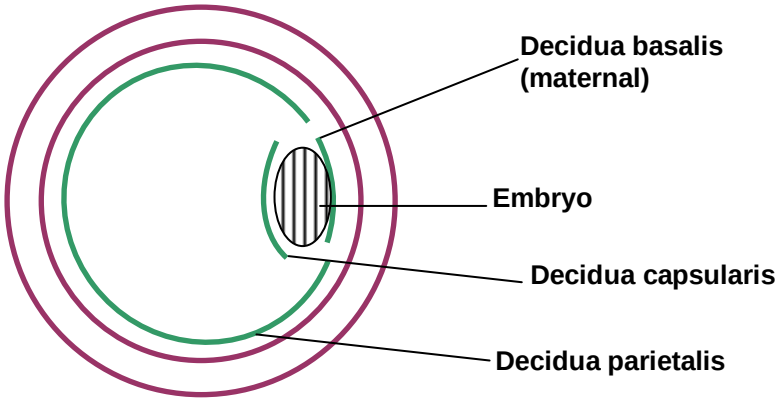


Fig.: After implantation

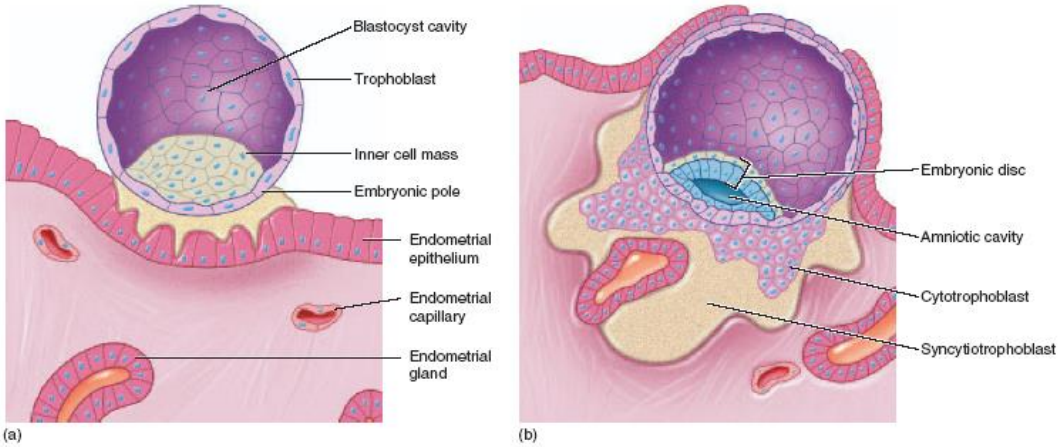


Fig.: Implantation of the blastocyst.
(a) A diagram showing the blastocyst attached to the endometrium on about the sixth day
(b) Implantation of the blastocyst at the ninth or tenth day

- Zona pellucida breaks down after the formation of blastocyst exposing the highly sticky, plasma membrane for implantation, because implantation cannot occur with it.
- Trophoblast or trophoectoderm does not take part in the formation of embryo proper. It forms foetal portion of the placenta which provides food to the developing embryo.
- Cells of inner mass are destined to form the body of the developing embryo. So, the trophoblast layer gets attached to the endometrium and the inner mass gets differentiated as embryo. After attachment, the uterine cells divide rapidly and covers the blastocyst.
- Approximately, **one week** after fertilization, the blastocyst embeds itself in the thickened wall of the uterus, a process called **implantation**, and pregnancy is established.

Implantation

Implantation is the attachment of the blastocyst to the uterine wall. It occurs after 7 days of fertilization. About 8 days after fertilization, the trophoblast develops into two layers in the region of contact between the blastocyst and endometrium. These layers are (a) **syncytiotrophoblast** that contains non-distinct cell boundaries and (b) **cytotrophoblast** between the inner cell mass and syncytiotrophoblast that is composed of distinct cells. The portion of the blastocyst where the inner cell mass is located lies against the endometrium of the uterus. The blastocyst sinks into a pit formed in the endometrium and gets completely burried in the endometrium. The embedded blastocyst forms villi to get nourishment.

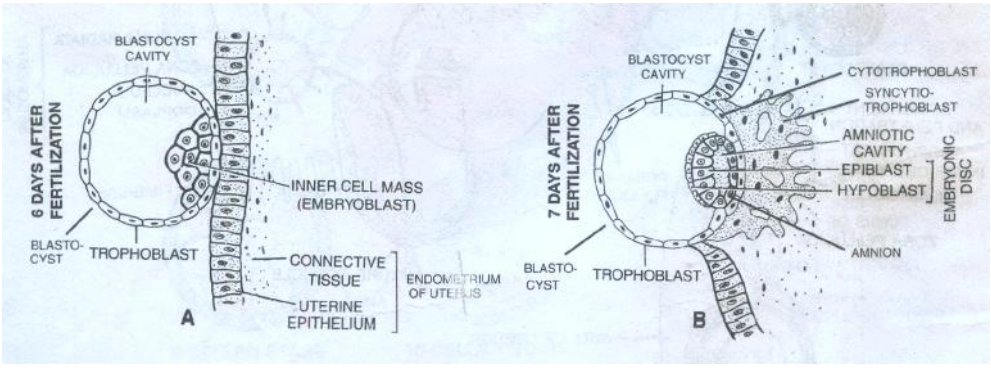


Fig.: Implantation of blastocyst

The cells of the inner cell mass differentiate into two layers.
(a) a layer of small, cuboidal cells known as the hypoblast layer; and
(b) a layer of high columnar cells, the epiblast layer. Both the hypoblast and epiblast form a flat disc called the embryonic disc.

Role of Zona Pellucida. Occasionally the blastocyst implants close to the internal os. The function of the zona pellucida is to prevent the implantation of the blastocyst at an abnormal site. It does not expose the sticky and phagocytic cells of the trophoblast till the blastocyst reaches the proper implantation site. As the blastocyst is formed, zona pellucida becomes thinner and finally disappears.

Role of Human Chorionic Gonadotropin (HCG). The trophoblastic cells secrete human chorionic gonadotropin hormone which has properties similar to those of luteinizing hormone (LH) of the pituitary gland. It takes over the job of pituitary LH dering pregnancy. The HCG maintains the corpus luteum and stimulates it to secrete progesterone. The latter maintains the endometrium of the uterus and causes it to grow throughout pregnancy. This also prevents menstruation. Progesterone also causes increased secretion of mucus in the cervix of the uterus that forms a protective plug during pregnancy.

Decidua (L. *deciduus* = falling off)

If implantation occurs, a portion of the endometrium of the uterus becomes modified and is called the decidua. The decidua is shed when the foetus is delivered. There are three kinds of **decidua**.

(i) **Decidua basalis**. It is the portion of the endometrium between the chorion and the myometrium of the uterus. The decidua basalis becomes the maternal part of the placenta.

(ii) **Decidua capsularis**. It is the portion of the endometrium between the embryo and uterine cavity.

(iii) **Decidua parietalis**. It is the portion of the modified endometrium that lines the entire pregnant uterus, except for, the area where the placenta is forming.

Test your Resonance with concept

1. All copulations do not lead to fertilization and pregnancy because

(1) All mating does not result in transport of sperm and ovum simultaneously at ampulla.

(2) Survival duration of both sperm and ovum is same

(3) Number of sperms and ovum varies

(4) Receptors on ovum are not sufficient to attract sperms

2. Find the incorrect statement.

(1) The embryo with 8 to 16 blastomeres is called as a morula

(2) The interaction of fertilizin of an ovum with antifertilizin of sperm is species specific

(3) Sex of a baby is determined by the father and not by the mother

(4) Nucleocytoplasmic ratio does not change as cleavage progresses

3. It is generally said Zona pellucida prevents implantation of blastocyst at an abnormal site. The most appropriate reason is

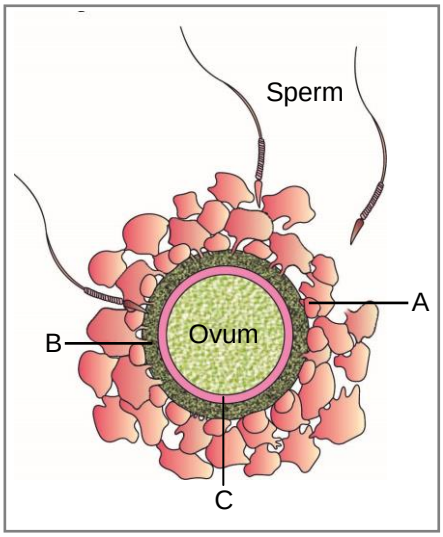
(1) It prevents the exposure of sticky and phagocytic trophoblast cells

(2) It is repelled by uterine wall

(3) Zona pellucida does not have any glycoproteinaceous sticky substance to attach with uterus

(4) Zona pellucida do not have receptors to recognize uterine wall for attachment

4. Given below is a structure of ovum surrounded by few sperms. Choose the correct option w.r.t. the identification of labelled structures A, B and C and the enzymes used to dissolve these structures.



(1) **A** → Corona radiata → Acrosin

(2) **B** → Zona pellucida → Zona lysin

(3) **A** → Zona pellucida → Corona penetrating enzyme

(4) **C** → Perivitelline space → Sperm lysin

Answers

1. (1) **2.** (4) **3.** (1) **4.** (2)

PREGNANCY AND EMBRYONIC DEVELOPMENT

- 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**.

Resonate the Concept

- Human placenta is called derived from chorion and maternal decidua basalis.
- Human placenta is Metadiscoidal, deciduate and haemochorial.
- Umbilical cord has 2 umbilical arteries & 1 umbilical vein.
- Myeloid tissue- Wharton's jelly

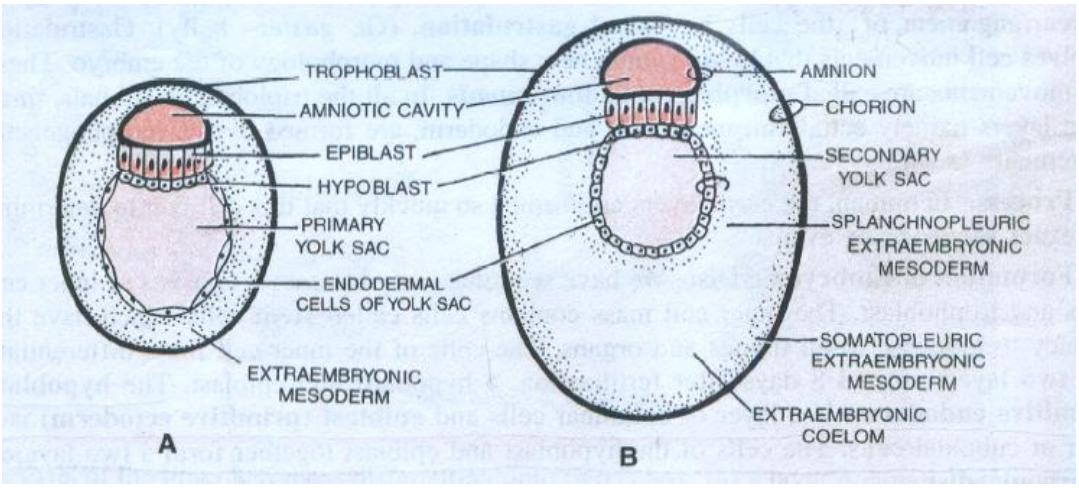


Fig.: Diagrams showing formation of extra-embryonic mesoderm and extra-embryonic coelom.

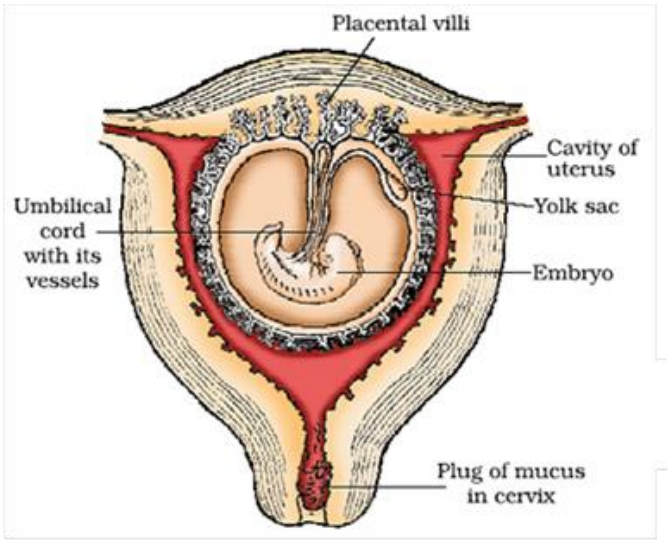


Fig.: The human foetus within the uterus

- The placenta facilitate the supply of oxygen and nutrients to the embryo and also removal of carbon dioxide and excretory/waste materials produced 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)** also called **chorionic somatomammotropin, chorionic corticotropin, estrogens, progestogens,** etc.
- In the later phase of pregnancy, a hormone called relaxin is also secreted by the ovary.

Resonate the Concept

Developing placenta begins to secrete a hormone called hCG, early in the second week after fertilisation. In early stages of pregnancy, hCG stimulates and maintains the corpus luteum that produces progesterone. Thus uterine endometrium and the pregnancy is retained. After 3 months, placenta begins to secrete sufficient progesterone, which will take over the ovarian progesterone for maintanance of uterine endometrium.

- hCG, hPL, chorionic corticotropin and relaxin are produced in women only during pregnancy. During initial stages of pregnancy relaxin and progesterone inhibits myometrial contraction and stabilizes the pregnancy. **Relaxin** hormone is a proteinaceous hormone produced by the ovary. It facilitates parturition by softening the connective tissue of pubic symphysis. 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.
- 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.
- After the formation of three layers, the embryo is called **gastrula.** 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 organs.
- The human pregnancy lasts 9 months. The gestation period of dog is 60-65 days, elephant is 607-641 days and cat is 52-65 days.

1. In human beings, after one month of pregnancy, the embryo's heart is formed. The first sign of growing foetus may be noticed by listening to the heart sound carefully through the stethoscope, placed on the abdomen of the mother (neural tube is first organ to be formed, heart is first organ which become functional).
2. By the end of the second month of pregnancy, the foetus develops limbs and digits.
3. By the end of 12 weeks (first trimester), most of the major organ systems are formed, for example, the limbs and external genital organs are well-developed (Time for sex determination by ultrasonography).
4. The first movements of the foetus (Quackening) and appearance of hair on the head are usually observed during the fifth month.
5. By the end of 24 weeks (second trimester), the body is covered with fine hair, eye-lids separate, and eyelashes are formed.
6. By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

Resonate the Concept

During the first trimester of pregnancy, the basic structure of the baby is formed. During this period, the developing baby called foetus, is very sensitive to anything that interferes with the steps involved. TORCH infecting (toxoplasmosis and other rubella, cytomegaloviruses and herpes simplex are the major cause of miscarriage. Thalidomide was used to treat the symptoms of morning sickness during pregnancy, it led to non-formation of long bones. Such condition is called Phocomelia/Oligomeromelia.

Parturition

- The average duration of human pregnancy is about 9 months which is called the **gestation period.**
- Neagle's formula- E.D.D.= first day of last menstrual cycle + 9 month and 7 days.
- Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus.
- This process of delivery of the foetus (child birth) is called **parturition.**
- Parturition is induced by a complex neuroendocrine mechanism. It involve signals from stretch receptors in myometrium of uterus by fully developed placenta and foetus, increased chorionic corticotropin and increase in estrogen : progesterone ratio.
- The signals for parturition originate from the fully developed foetus and the placenta which induced mild uterine contractions called **foetal ejection reflex.** This triggers **release of oxytocin from the maternal pituitary**.
- Oxytocin acts on the uterine myometrium 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.
- This leads to expulsion of the baby out of the uterus through the birth canal–parturition. Soon after the infant is delivered, the placenta is also expelled out of the uterus.
- Just after birth infant's lungs expand and it begins breathing. This requires a major switchover in the circulatory system. Blood flow through the umbilical cord, ductus arteriosus and foramen ovale ceases; the adult pattern of blood flow through the heart, aorta and pulmonary arteries begins. In some infants, the switchover is incomplete, and blood flow through the pulmonary arteries is inadequate. Failure to synthesize enough nitric oxide (NO) is one cause.
- Along with the drip, doctors inject oxytocin (or Pitocin) to increase uterine contractions. Oxytocin is also administered just after parturition to contract smooth muscles and prevent excessive bleeding which occur after parturition.

Lactation

- The mammary glands of the female undergo differentiation during pregnancy an starts producing milk towards the end of pregnancy by the process called lactation. This helps the mother in feeding the newborn.
- Functional maturation of mammary gland occur by human placental lactogen and prolactin secreted during pregnancy period, yet lactation can't occur as level of progesterone is high.
- Prolactin is antagonist to FSH and LH so for initial six months following lactation, menstrual cycle doesn't occur.
- The milk produced during the initial few days of lactation is called **colostrum** which contains several antibodies (IgA) absolutely essential to develop resistance for the new-born babies.
- Breast-feeding during the initial period (at least 6 months) as infant grows is recommended by doctors for bringing up a healthy baby.

Test your Resonance with concept

1. Implantation is the attachment of blastocyst to uterine wall. It takes place about

(1) Seven days after fertilization (2) Seven days after reaching uterus

(3) Seven hours after fertilization (4) Seven weeks after fertilization

2. The first movement of the foetus and appearance of hair on the head are observed during which month of pregnancy?

(1) 3rd (2) 4th (3) 5th (4) 6th month

3. During implantation of blastula, cells of Rauber play important role. These cells are

(1) Trophoblast cells in contact with megamere cells of blastula.

(2) Cells lying in blastocoel

(3) Cells of inner cell mass.

(4) Uterine endothelial cells, which come in contact with blastula

4. Match the following with correct combination

(a)	Hyaluronidase	(i)	Acrosomal reaction
(b)	Corpus luteum	(ii)	Morphogenetic movements
(c)	Gastrulation	(iii)	Progesterone
(d)	Capacitation	(iv)	Mammary gland
(e)	Colostrum	(v)	Sperm activation

(1) (a)-(v), (b)-(ii), (c)-(iv), (d)-(i), (e)-(iii)

(2) (a)-(i), (b)-(iii), (c)-(ii), (d)-(v), (e)-(iv)

(3) (a)-(i), (b)-(ii), (c)-(iii), (d)-(iv), (e)-(v)

(4) (a)-(iv), (b)-(ii), (c)-(v), (d)-(iii), (e)-(i)

Answers

1. (1) **2.** (3) **3.** (1) **4.** (2)

ADDITIONAL INFORMATION

- Yolk is the reserved food material in the cytoplasm of egg. It may be formed of phospholipids, proteins, lipid and carbohydrates. The process of formation of yolk and its deposition in egg is called **Vitellogenesis**.

1. Based on amount of yolk, the eggs are 4 types

(i) Alecithal: Eggs without yolk e.g., human egg.

(ii) Microlecithal: The eggs with very little yolk, e.g., sea urchin, starfish.

(iii) Mesolecithal: The eggs containing moderate amount of yolk, e.g., frog.

(iv) Megalectithal or **Macrolecthal:** The eggs containing very large amount of yolk, e.g., reptiles, birds, insects.

2. **Based on distribution of yolk, the eggs are of three types:**
   - **(i) Isolecithal:** The yolk is uniformly distributed throughout the cytoplasm of egg, e.g., *Branchiostoma*, *Herdamina*.
   - **(ii) Telolecithal:** The eggs in which the yolk is concentrated towards one pole i.e., Vegetal pole and nucleus along with major part of cytoplasm is displaced is animal pole e.g., Amphibians.
   - **(iii) Centrolecithal:** Yolk concentrated in center of the egg with cytoplasm surrounding it, e.g. insects.
3. **On the basis of presence or absence of shell, the eggs can be :**
   - **(i) Cleidoic:** Shelled eggs e.g., Reptiles, Birds, Insects.
   - **(ii) Non cleidoic:** Shell-less eggs e.g., Human, Amphibians.

❖ There are three **types of egg membrane** around the eggs.

1. **Primary egg membrane:** It is formed around the plasma membrane of the egg and is secreted by ovum itself e.g., **Jelly envelop** (Echinoderms), **Vitelline membrane** (Mollusca, amphibian & birds), **Zona radiata** (Shark, some amphibians), **Zona pellucida** (Mammals).
2. **Secondary egg membrane:** It is formed around the egg by the follicle cells of the ovary e.g., chorion around egg of insect; corona radiata, granulosa and theca layers in human.
3. **Tertiary egg membranes:** These are formed by the oviducts and other accessory parts of maternal genital tract while the egg is passing from the ovary to the exterior, e.g., the albumin, shell membrane and outermost calcareous shell of reptiles and birds.

❖ **Cleavage** is sequence of repeated mitotic divisions which a **zygote** undergoes. These are **rapid** divisions with no significant growth, producing a cluster of cells and **blastomeres.**

Characteristic features of cleavage:

(i) During cleavage, no cell growth occurs because G_1 and G_2, both phases are absent.

(ii) Nucleus cytoplasmic ratio increases

❖ The mode of cleavage is determined by the amount of yolk and its distribution.

- **(a) Holoblastic:** The cleavage in which the segmentation lines pass through the entire egg, dividin it completely. It occurs in alecithal, microlecithal and mesolecithal eggs; e.g., frog, human egg etc.
- **(b) Meroblastic:** The lines of segmentation do not completely pass through the egg and remain confined to a part of the egg. Such type of cleavage is found in megalecithal eggs as the yolk provides resistance to the cleavage e.g., insects, birds reptiles. Meroblastic cleavage may be (i) **Superficial** which occurs in centrolecithal eggs of insects, or (ii) **discoidal** as found in eggs of birds.

❖ **Patterns of Cleavage**

Cleavage is the successive mitotic cell divisions of the egg and can be

- **(i) Radial cleavage:** Successive cleavage planes cut straight through the egg e.g., *Synapta paracentrotus.*
- **(ii) Biradial Cleavage:** When the three first division planes do not stand at right angles to each other e.g., Ctenophora.
- **(iii) Spiral Cleavage:** There is a rotational movement of cell parts around the egg axis leading to displacement of mitotic spindle with respect to symmetrically disposed radii e.g., turbellarians. nematoda, rotifera, annelida, all molluscs except cephalopods.

(iv) Bilateral Cleavage: Mitotic spindles and cleavage planes remains bilaterally arranged with reference to the plane of symmetry e.g., tunicates, Amphioxous, amphibia and higher mammals.

(v) Meridional Cleavage: When cleavage furrow bisects both the poles of egg passing through animal- vegetal axis, the plane of cleavage is called meridional cleavage.

- According to concept of potency, cleavage can be
  - **(i) Indeterminate/Regulative cleavage where,** the fate of different parts of egg or its blastomeres is not predetermined or blastomers have no characteristic position and have alterable fate e.g., echinoderms and vertebrates.
  - **(ii) Determinate/Mosaic cleavage where,** every part of fertilized egg has a definite fate so that the fate of every blastomere is determined from beginning. The complete embryo is formed only if all the blastomers remain togethers. e.g., Nematoda, Mollusca (Dentalium).

- Blastula is the embryonic stage next to morula. It contains a fluid–filled cavity called **blastocoel** surrounded by one or more layers of cells, the **blastomeres.**
  - **(a)** The blastula with blastocoel is called **coeloblastula**, e.g., Frog & Human.
  - **(b)** The certain animals, the blastula is solid and is termed **stereoblastula** e.g., Cnidaria, *Neries* & some molluscs.
  - **(c)** The blastula formed as a result of superficial cleavage is called **superficial blastula,** e.g., Insects.
  - **(d) Discoblastula** is disc shaped blastula formed as a result of discoidal cleavage, e.g., birds.

- **Gastrulation** is the process of formation of gastrula from the blastula. Gastrula is the embryonic stage of development in which the **germinal layers** have been been formed. Gastrulation involves movement from the original place to the site where they finally settle. The movements are called **morphogenic movements.**

They include:

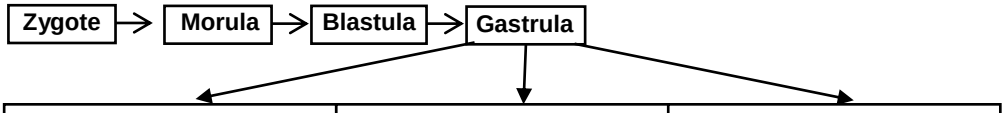
(i) Epiboly (descending of dividing cells to cover other cells).

(ii) Emboly (upward movement of dividing cells underneath the other cells).

- **(a) Involution** (inward migration of blastomeres to go into the blastocoel).
- **(b) Invagination** (tucking in of blastula wall)
- **(c) Delamination** (separation of a sheet of cells from blastula).

- **Archenteron** is the cavity which occurs inside the gastrula and is the future alimentary canal. It opens to the outside through **blastopore** which later on closes.
- The developing foetus becomes enclosed by three membranes i.e., **amnion, chorion** and **allantois.**
  - **(i) Amnion** is formed of **mesoderm** on outside and **ectoderm** inside. Space between amnion and foetus is called **amniotic cavity** and it contains **amniotic fluid.**
  - **(ii) Chorion** is formed of **ectoderm** externally and **mesoderm** inside. Along with the allantois, it participates in the formation of placenta. Space between amnion and chorion is extra **embryonic coelom.**
  - **(iii) Allantois** consists of **mesoderm** on outside and **endoderm** internally. It extends to fuse with chorion and forms **allanto-chorion** which gives rise to foetal part of placenta.

❖ **Fate of Germ Layers:**



Ectoderm	Mesoderm	Endoderm
Epidermis Cutaneous glands Nervous system (Brain and spinal cord) Eye (Retina, lens and cornea) Nasal epithelium Internal ear Pituitary Pineal gland Adrenal medulla	Dermis Muscular tissue Connective tissue Endoskeleton Vascular system (heart and blood vessels) Kidneys Gonads Urinary and genital ducts Coelom and coelomic epithelium Choroid and sclerotic cots of eye Adrenal cortex spleen	Gut Visceral organs Glands of stomach and intestine Tongue Lungs, trachea and bronchi Urinary bladder Liver and pancreas Thyroid glands Parathyroids Thymus Middle ear Eustachian tube

(a) On the basis of structure, the placenta is of following types :

- **Epitheliochorial:** Placenta with all the six barriers between foetal and maternal blood; e.g., Horse, Ass.
- **Syndesmochorial:** Uterine epithelium breaks down; only five barriers left; e.g., Cow, Buffalo, Sheep Goat, Camel.
- **Endotheliochorial:** Uterine epithelium and connective tissues eroded; only four barriers left; e.g., Tiger, Lion, Cat, Dog.
- **Haemochorial:** Placenta with only three barriers, the maternal part of placenta completely eroded; e.g., **Human**, Apes, Lemurs.
- **Haemo-endothelial:** All barriers except endothelium of foetal part of placenta get eroded; e.g., Rat, Rabbit.

(b) One the basis of nature of uterine wall after parturition, the placenta may be:

- **Non-deciduous –** No part of uterine portion of placenta is broken off, e.g., Horse, Ass.
- **Deciduous –** A portion of uterine tissue called **decidua** is detached and passed out at birth, e.g., **most of the mammals**.
- **Contra decidous –** Even the foetal part of placenta is retained and gets absorbed to provide nourishment, e.g., Talpa, Parameles.

(c) On the basis of distribution of villi on the surface, the placenta is of six types.

- **Diffuse placenta:** Villi distributed uniformly all over the surface, e.g., Horse, Pig.
- **Cotyledonary:** The villi form tufts which fit into corresponding areas, e.g., Cow, Buffalo, Sheep.
- **Intermediate:** Villi occur singly as well as in tufts, e.g., Camel, Giraffe
- **Zonary:** Villi arranged in tow transverse bands, e.g., Tiger, Lion, Cat, Dog, Elephant.
- **Discoidal:** When the villi are confined to a disc-like area, e.g., Rat, Rabbit, Bat.
- **Metadiscoidal:** The placenta in which the villi are initially distributed uniformly all over the surface but later on get confined to a disc-like area fitting into a corresponding depression on the uterine wall i.e., the placenta is diffuse first but later on becomes discoidal, e.g., **Human beings** and Apes.