Chapter 3

Human Reproduction

Introduction to Human Reproduction

What is Reproduction?

Reproduction is the process of giving birth to their young ones which are identical to their parents. As we all are aware of, the process of reproduction in humans is sexual reproduction, which involves internal fertilization by sexual intercourse.

How do Humans Reproduce?

Human reproduction is any form of sexual reproduction resulting in human fertilization. It typically involves sexual intercourse between a man and a woman. During sexual intercourse, the interaction between the male and female reproductive systems results in fertilization of the woman's ovum by the man's sperm.
Humans reproduce sexually. They are viviparous, i.e. giving birth to the young ones. The process of reproduction in humans comprises a number of sequential steps:

1. Gametogenesis- production of male (sperm) and female (ovum) gametes
2. Insemination- transfer of male gamete to female genital tract
3. Fertilization- the fusion of gametes to form a zygote
4. Blastocyst development- the continuous mitotic division in zygote
5. Implantation- attachment of blastocyst to the endometrium of the uterine wall
6. Gestation- embryonic development (9 months in human)
7. Parturition- childbirth

Embryology is the branch of biology which deals with the study of all those processes, which take place during the development of the fetus.

Sexual Dimorphism in Human Beings

When male and female individuals are differentiated externally, the phenomenon is called **sexual dimorphism.** Human beings show sexual dimorphism. The characters which distinguish the males and females externally are known as secondary sex characters.

Primary sex organ :

- Essential organs form the gametes.
- In males, the gamete-forming organs are the testes.
- In females, the corresponding organs are ovaries.
- The male gamete is a spermatozoon.
- The female gamete is the ovum.

Secondary sex organ :

- These organs form the passage for the gametes to help the union of male & female gametes.
- In males, these include the epididymis, vas deferens, seminal vesicles, prostate, bulbourethral glands & penis etc.
- In females, these organs are the fallopian tube, uterus and vagina, Bartholin gland etc.

Primary Reproductive Organs	**Accessory Reproductive Organs**
The primary reproductive organs produce sex cells.	The accessory reproductive organs help in the transfer and meeting of two kinds of sex cells leading to fertilization.
The primary reproductive organs do not help in the development of the baby.	The accessory organs help in the growth and development of egg up to the birth of a baby.
Example: Testes in males and ovaries in females.	Example: penis in males, Uterus, vagina in female.

Development of Sex organs:

- During intrauterine life (IUL) testis & ovary develop from the mesoderm.
- They develop in the abdominal cavity.
- At the time of birth, testes descend down into the scrotal sac but ovaries remain in the abdominal cavity.

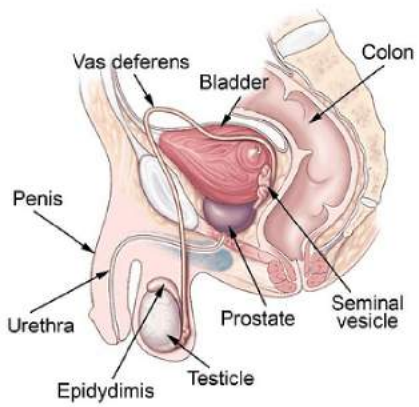
The Male Reproductive System

Human Male Reproductive System

It consists of the following parts:

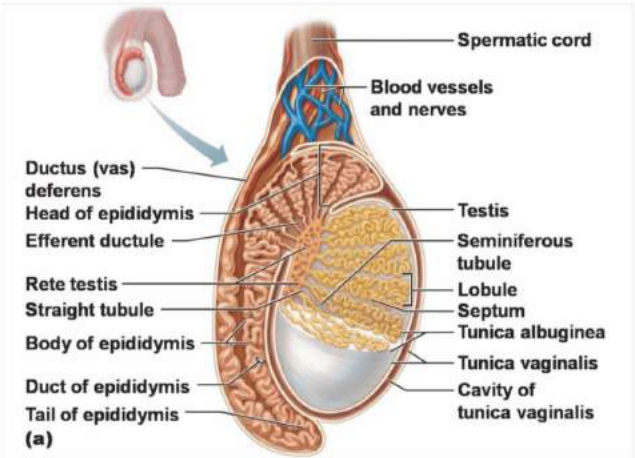
1. Scrotum

- It is a pouch of deeply pigmented skin divided into two separate sacs.
- Each sac contains one testis.
- The normal temperature of the testes in the scrotum is about 20-2.5°C lower than the internal body temperature.
- This temperature is the ideal temperature for developing sperms.
- When the body is chilled, the smooth muscle contracts and brings the testes closer to the pelvic cavity.
- When the temperature drops, the movement towards the pelvic cavity allows the testes to absorb heat from the rest of the body so that the sperm cells do not become chilled.
- The scrotum remains connected with the abdomen or pelvic cavity by the inguinal canals.
- The spermatic cord, formed from the spermatic artery, vein and nerve bound together with connective tissue into the testis through the inguinal canal.



2. Testes

- The primary sex organ in males.
- During early fetal life, the testis develop in the abdominal cavity but during the seventh month of the development, they descend into the scrotum through inguinal canals.
- There is a pair of testis that are suspended in the scrotum by the spermatic cords.
- A fibrous cord that extends from the caudal end of the testis to the scrotal wall is called the gubernaculum.
- Each testis is oval in shape with a length of about 4 to 5 cm and a width of about 2 to 3 cm.
- The peritoneum, called mesorchium supports the testis.

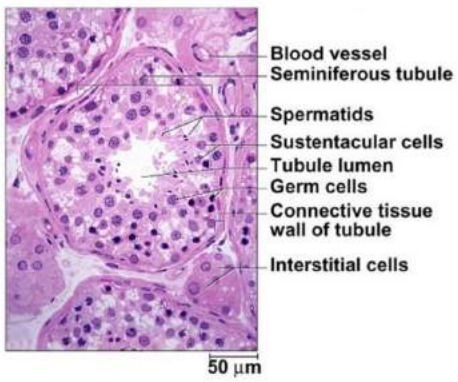


Lateral view of Male Testis

(i) Protective Coverings (Tunicae): The testis is surrounded by three layers.
(a) The tunica vaginalis is the outer covering of the testis.
(b) The tunica albuginea is a fibrous covering surrounding the testis situated under the tunica vaginalis.
(c) The tunica vasculosa consists of a network of capillaries supported by delicate connective tissue which lines the tunica albuginea.
(ii) Testicular Lobules: Each testis has about 250 compartments called testicular lobules.
(iii) Seminiferous Tubules:

- Each testicular lobule of the testis contains one to three highly coiled seminiferous tubules.

- The Wall of each seminiferous tubule is formed of a single-layered germinal epithelium.
- The majority of cells in this epithelium are cuboidal called male germ cells (spermatogonia) and at certain places, there are present tall Sertoli or sustentacular cells.
- These cells support developing germ cells and provide them with nutrition especially spermatids.
- Sertoli cells secrete androgen binding protein (ABP) that concentrates testosterone in the seminiferous tubules.
- Sertoli cells also secrete another protein called inhibin which suppresses FSH synthesis.
- The cuboidal cells undergo mitosis to produce spermatogonia.
- Spermatogonia grow into primary spermatocytes which undergo meiosis, producing haploid cells, first secondary spermatocytes and then spermatids.
- The latter convert into spermatozoa (sperms). Sertoli cells provide nutrition to the developing sperms.



Anatomy of Male Reproductive Organ

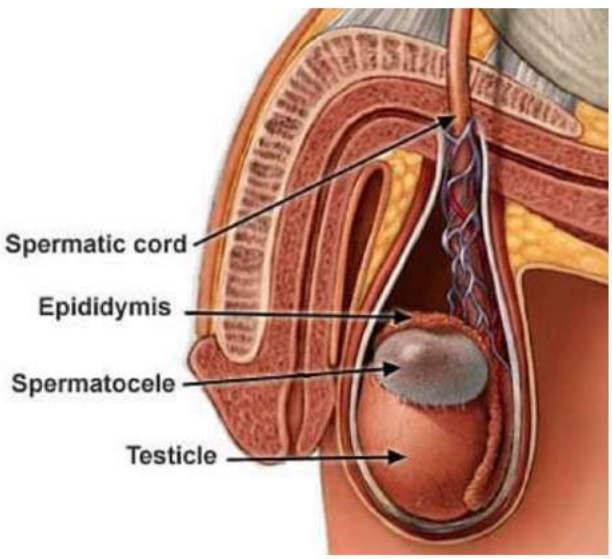
(iv) Interstitial Cells or Leydig's Cells (Endocrine portion of the testis): In between the seminiferous tubules in the connective tissue, there are present small groups of rounded interstitial or **Leydig's cell male sex hormones,** which secrete androgens (e.g.. testosterone i.e. male sex hormone)

(v) Rete testis and efferentia: The seminiferous tubules are closed at one end but on the other side, they join to a network the rete testis from where fine ciliated ductules, the vasa efferentia arise.

Thus testes perform two functions- production of sperms and secretion of male sex hormones.

3. Epididymis

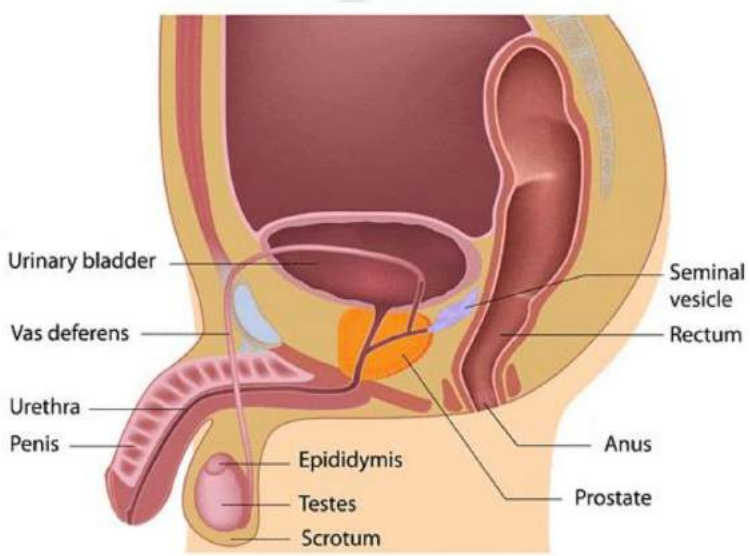
- The epididymis is a mass of long narrow closely coiled tubules which lie along the inner side of each testis.
- At the anterior end of the testis, it is called **caput epididymis**, in which the vasa efferentia opens.
- The middle part of the epididymis is known as **corpus epididymis.**
- The posterior end of the epididymis is called **cauda epididymis**.
- The epididymis stores the sperms and also secretes a fluid that is considered to nourish the sperms.



4. Vasa deferentia

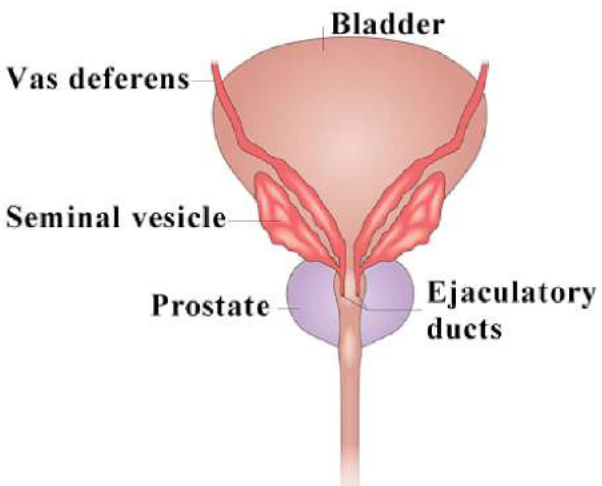
- A vas deferens emerges from the cauda epididymis on each side and leaves the scrotal sac and enters the abdominal cavity through the inguinal canal.
- The vas deferens loops over the urinary bladder where it is joined by a duct from the seminal vesicle to form the ejaculatory duct.
- **Vasa deferentia carry sperms.**

Vasa Efferentia	Vasa Deferentia
1. They arise from the rete testis.	1. They arise from the cauda epididymis.
2. They vary from 15 to 20 in number.	2. They are only. 2 in number.
3. Vasa efferentia are fine.	3. Vasa differentia arc thick.
4. Their lining bears many ciliated cells.	4. Their lining has many stereocilia.
5. It carries spermatozoa from the rete testis to the epididymis.	5. It carries spermatozoa from cauda epididymis to the ejaculatory duct.



5. Ejaculatory ducts

- The ejaculatory ducts are two short tubes each formed by the union of the duct from a seminal vesicle and a vas deferens.
- They pass through the prostate gland and join the prostatic part of the urethra.
- The ejaculatory ducts are composed of the fibrous, muscular and columnar epithelial tissue.
- Ejaculatory ducts carry sperms and secretion of seminal vesicles.



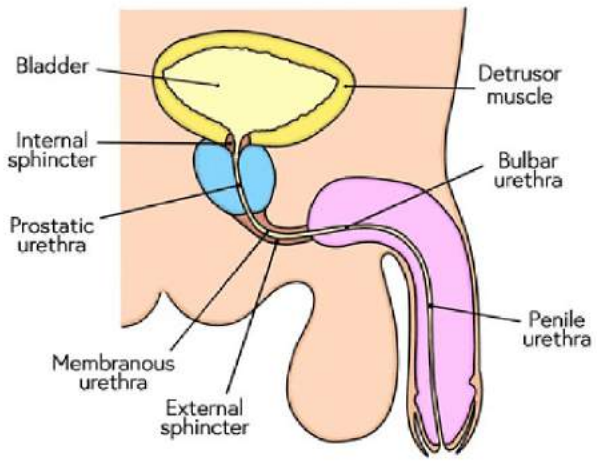
6. Urethra

- The male urethra provides a common pathway for the flow of urine called semen.
- It is much longer in males than in females, measuring about 20 cm.
- The urethra includes three parts

  (i) The first part is surrounded by the prostate gland and is called the prostatic urethra which arises from the urinary bladder and carries urine only.

  (ii) The second part is the membranous urethra which is situated behind the lower part of the pubic symphysis. The membranous urethra is the smallest urethra.

  (iii) The third part is the penile urethra which is situated in the penis. There are two urethral sphincters. The internal sphincter consists of smooth muscle fibres situated at the neck of the bladder above the prostate gland. The external sphincter consists of striated muscle fibres surrounding the membranous part of the urethra.
- The membranous urethra and penile urethra carry both urine and semen. The external opening of the urethra is called the **urethral meatus**.

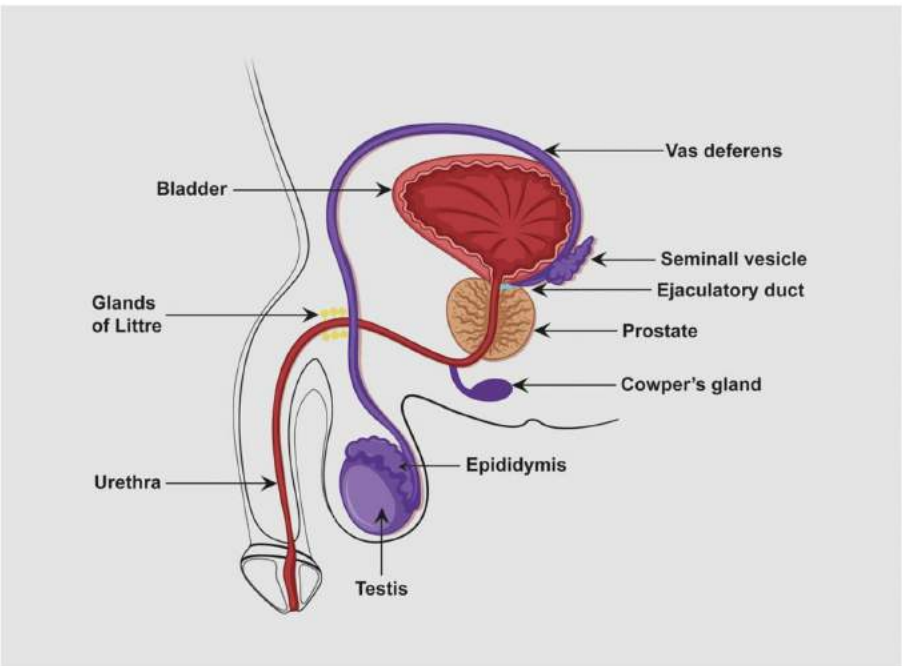


7. Penis

- The penis is male genitalia (male copulatory organ).
- At the tip of the glans penis is the slit-like opening called the external urethral orifice or urinogenital aperture.
- The penis in addition to conducting urine from the body transfers semen into the reproductive tract of the female during sexual intercourse.

- The penis contains three cylindrical masses of erectile tissue two dorsal corpora cavernosa and one ventral corpus.
- These bodies are surrounded by fibrous tissue.
- The corpus spongiosum contains the penile urethra, the end of the penis to form the glans penis.
- The penis is covered by a loose fold of skin, the prepuce or foreskin sexual arousal the three bundles of tissue in the pep become engorged with blood.
- The penis carries both urine and semen.

8. Male Accessory glands



Male Accessory

Glands(i) The seminal vesicles are one pair of sac-like structures near the base of the bladder.

- Their ducts join the vasa deferentia to form the ejaculatory ducts.
- They produce an alkaline secretion that forms 60% of the volume of semen.
- The pH of seminal fluid is 7.4.
- The secretion of the seminal vesicles contains fructose, hormone-like prostaglandins, and clotting proteins that are different from those in blood.

- Fructose is a source of energy for the sperm.
- The prostaglandins stimulate uterine contractions and thus may help the sperm to be contractions and thus may help the sperm to be energy moved towards the female's oviducts when fertilization takes place.
- The clotting proteins help semen coagulate after ejaculation.
- The alkaline nature of the seminal fluid helps to neutralize the acidic environment of the male urethra as well as that of the female reproductive tract which otherwise would inactivate and kill sperms.

Fructose, which is produced by the seminal vesicles, is not present anywhere else in the body, provides a forensic test for rape. The presence of fructose, in females genital tract confirms sexual intercourse.

(ii) The prostate gland is a single large gland that surrounds the urethra.

- It produces a milky secretion with pH 6.5 which forms 25% of the volume of semen.
- This secretion contains citric acid (a sperm nutrient) and enzymes (acid phosphatase, amylase, pepsinogen) and prostaglandins.
- Due to the presence of citric acid, it is slightly acid.
- A number of small ducts carry fluid from the prostate to the urethra.
- Secretion of the prostate gland nourishes and activates the spermatozoa to swim.

(iii) A pair of bulbourethral glands or Cowper's glands are present on either side of the membranous urethra.

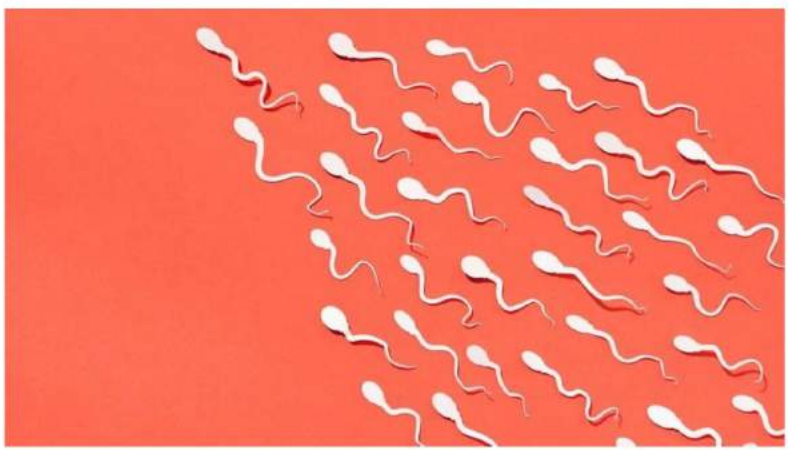
- These glands secrete an alkaline fluid.
- Their ducts open into the membranous urethra carrying the fluid that neutralizes acids from urine in the urethra.
- They also secrete mucus that lubricates the end of the penis and the lining of the urethra.
- This decreases the number of sperm damaged during ejaculation.

Secretions of these glands constitute the seminal plasma which is rich in fructose, calcium and certain enzymes as mentioned above. The secretion of bulbourethral glands also helps in the lubrication of the penis.
Secretion of bulbourethral glands carries some spermatozoa (sperms) released before ejaculation. This is one of the reasons for the high failure rate of the withdrawal method of birth control.

Functions of Male Reproductive System

1. Spermatogenesis. The germinal epithelial cells of seminiferous tubules produce sperms.
2. Male Sex hormones. Leydig's cells (interstitial cells) produce male sex hormones (e.g., testosterone).
3. Transfer of Sperms. The copulatory organ (e.g.. penis) transfers sperms into the vagina of the female during copulation.

Semen



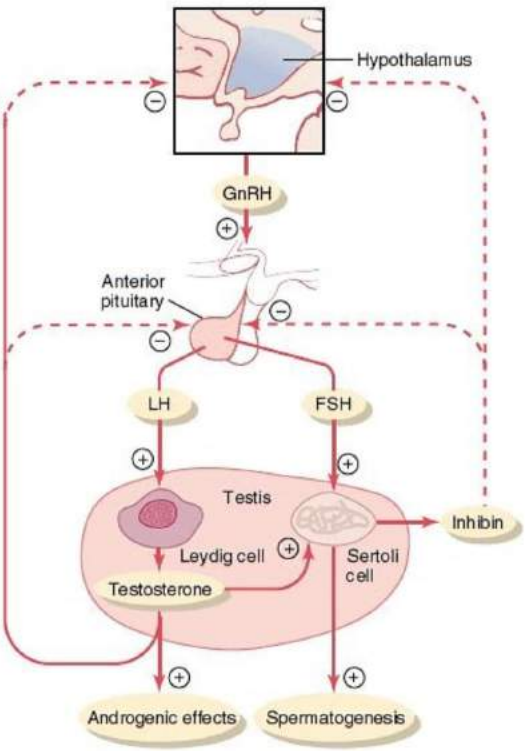
Semen

- Semen is a collection of secretions from the seminal vesicles, prostate gland and Cowper's glands and sperms from testes.
- Semen is ejected from the penis during ejaculation. A single ejaculation may contain 200 to 300 million spermatozoa (sperms) of which at least 60% of sperms must have normal shape and size and at least 40% of them must show vigorous motility for normal fertility.
- Semen has a pH of 7.35 to 7.50; its alkalinity helps to neutralize the acidity of the urethra left from the passage of urine and protects the sperms from the acidity of the vagina. In fact, the fluid part of semen is called **seminal plasma.**

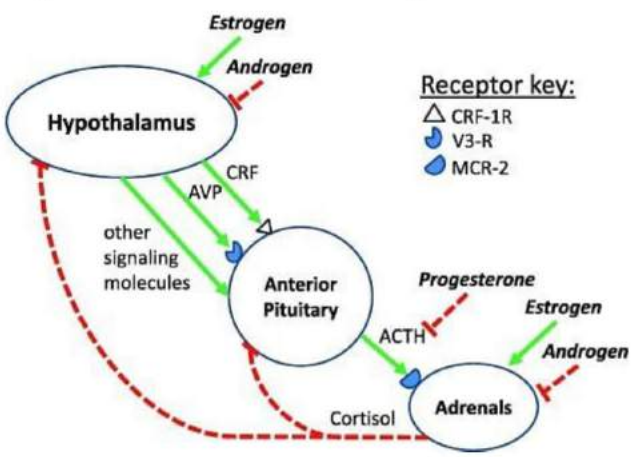
Hormonal Control of Male Reproductive System

- The growth, maintenance and functions of the male reproductive organs are under hormonal control as described below.
- GnRH is secreted by the hypothalamus. It stimulates the anterior lobe of the pituitary gland to secrete LH and FSH.
- In males, LH is called interstitial cells stimulating hormone (ICSH) because it stimulates interstitial cells. (Leydig's cells) of the testes to secrete androgens.

- Testosterone is the principal androgen, FSH stimulates Sertoli cells of the testes to secrete an androgen-bind ing protein (ABP) that concentrates testosterone in the seminiferous tubules.
- Sertoli cells also secrete a protein hormone called inhibin which suppresses FSH synthesis.
- FSH acts directly on spermatogonia to stimulate sperm production.



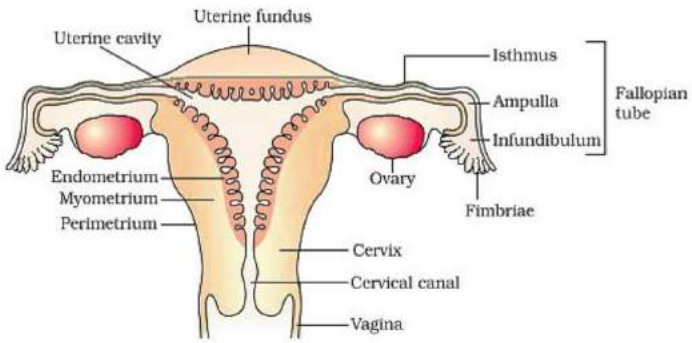
The onset of Puberty in Human Male Puberty



- Puberty is a period when reproductive organs start functioning.
- Puberty in human males is attained between 13-16 years.
- The hormone testosterone plays a significant role in the onset of puberty.
- Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus, which stimulates the anterior lobe of the pituitary gland to secrete luteinizing hormone (LH) and follicle-stimulating hormone (FSH).
- In males, LH may be called interstitial cells stimulating hormone (ICSH) because it stimulates the interstitial cells (Leydig's cells) of the seminiferous tubules of the testes to secrete androgens.
- Testosterone is the principal androgen that brings about the growth of the secondary sex organs and the development of secondary sexual characters. This is the onset of puberty in human males.

The Female Reproductive System

The female reproductive system consists of the **pair of ovaries, uterine tubes, uterus**, **vagina**, and **external genitalia**. The breasts, or **mammary glands**, are structurally and functionally integrated to support the processes of **ovulation**, **fertilisation**, **pregnancy**, **birth**, & **child care**.

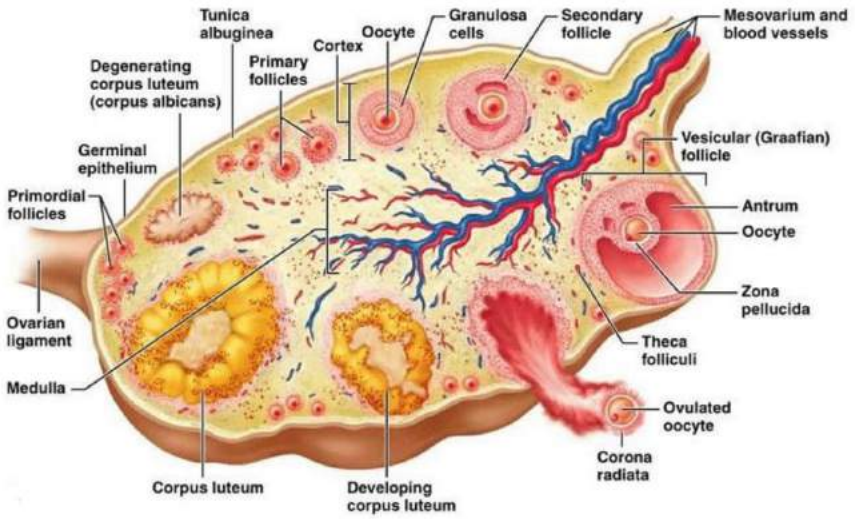


The Female Reproductive System

1. The Ovaries

- In females, the ovaries are the primary sex organs.
- Ovaries are located one on each side of the **lower abdomen**.
- Each ovary is about **2 to 4 cm long** and shaped like an unshelled almond.
- The ovarian ligament connects the ovary to the uterus.
- Each ovary has a thin epithelium that encloses the ovarian stroma. The stroma is split into two sections: the **peripheral cortex** and the **inner medulla**.

- The ovaries, as we will see later, are in charge of producing female sex hormones and ova.

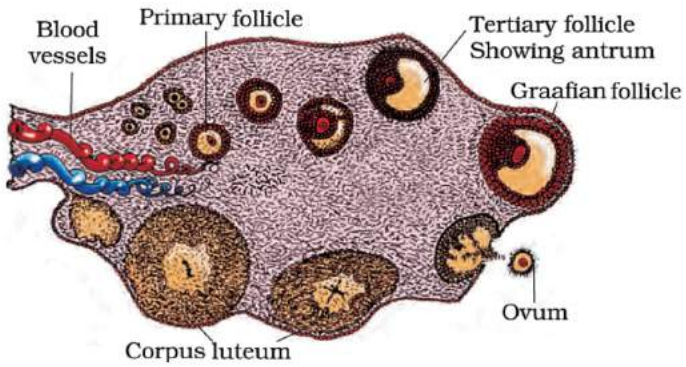


The ovary is made up of the following parts:

(i) The ovary is covered by a layer of cubical epithelium called the **germinal epithelium.** The germinal epithelium is covered by the visceral peritoneum.
(ii) Beneath the epithelium is the tunica albuginea- a layer of connective tissue and underlying it is the ovarian stroma.
(iii) The ovarian stroma contains a dense inner portion called the **medulla** and less dense outer layer called the **cortex**.
(iv) No more oogonia are formed and added after birth.

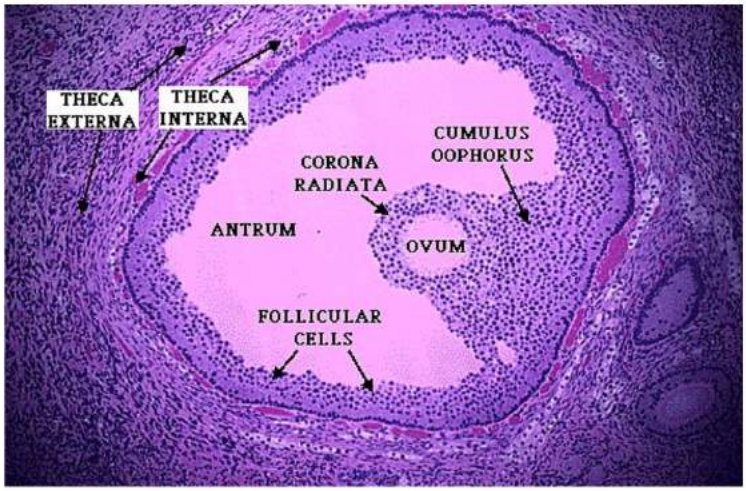
- Oogonia (egg mother cells) divide by mitosis forming **primary oocytes.**
- Each primary oocyte then gets surrounded by a layer of **granulosa cells** called **primary follicles**.
- A large number of these follicles degenerate during the phase from birth to puberty.
- Therefore, at puberty, only 60,000-80,000* primary follicles are left in each ovary.
- The primary follicles are surrounded by more layers of granulosa cells and called **secondary follicles**.
- The secondary follicle soon changes into a **tertiary follicle** which is characterized by a fluid-filled cavity called follicular antrum (Gr. antrona cave).

- The tertiary follicle is further converted into a mature follicle or Graafian follicle

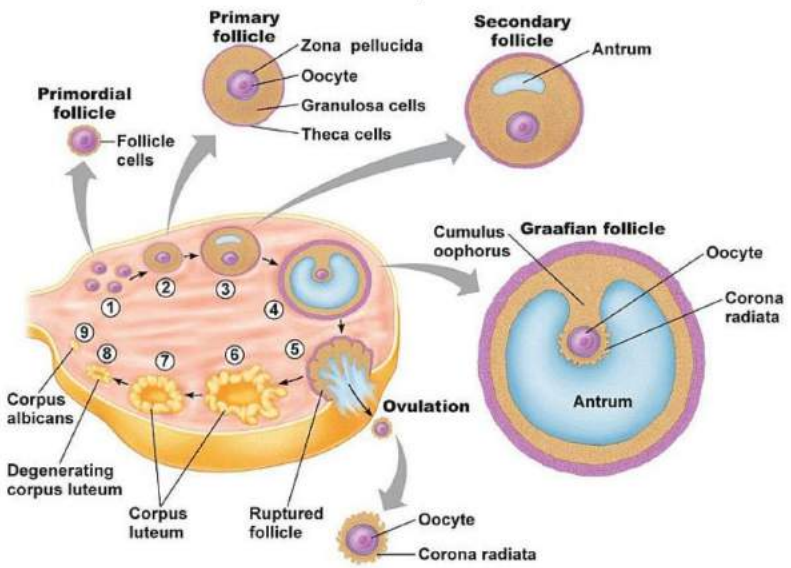


(v) Interspersed throughout the cortex are many ovarian follicles (also called Grafian follicles) in different stages of development. The ovarian follicle comprises the following parts:

- A follicle consists of an oocyte covered by a homogenous membrane the zona pellucida.
- When the surrounding cells form a single layer they are called **follicular cells**. Later in development when they form several layers, they are referred to as **granulosa cells**.
- The surrounding cells nourish the developing oocyte and begin to secrete **estrogens** called **membrana granulosa**.
- The follicle has an eccentric follicular cavity or follicular antrum filled with a fluid, the **follicular fluid** or **liquor folliculi**.
- A solid mass of the follicular cells that surrounds the developing ovarian follicle is called the **cumulus oophorus** formed by granulosa cells.
- It projects into the follicular cavity (**follicular antrum**).
- Later, the granulosa cells lying in close vicinity of the oocyte and zona pellucida, become elongated to form the **corona radiata**.
- The membrana granulosa is surrounded by the **theca interna** (theca - cover) and **theca externa**.



- The **total number** of follicles in each ovary of a normal young adult woman is about **60,000** to **80,000**.
- Many ovarian follicles (during the primary oocyte stage) undergo **degeneration**.
- This degenerative process of follicles is called **follicular atresia** and such follicles are known as **atretic follicles**.
- The release of secondary oocytes from the ovary is called **ovulation**.
  - It occurs due to the rupturing of the ovarian follicle and the wall of the ovary.



Process of Ovulation

- Generally, one secondary oocyte is released in each menstrual cycle (average duration 28 days) by alternate ovaries.
- Only about 450 secondary oocytes (ova) are produced by a human female over the entire span of her reproductive life which lasts about 40-50 years of age (in some cases 45-55 years).
- In addition to releasing an oocyte, the follicle also produces hormones.
- While the follicle is maturing, some of the follicular cells produce estrogens, mainly estradiol.

(vi) After ovulation many of the follicular cells remain in the collapsed follicle on the surface of the ovary.

- The antrum (cavity) of the collapsed follicle fills with a partially clotted fluid.
- The follicular cells enlarge and fill with a yellow pigment, **lutein**.
- Such a follicle is called a **corpus luteum**- literally, **yellow body**.
- The lutein cells secrete a small amount of **estradiol hormone** and a significant amount of **progesterone hormone**.
    - The Corpus luteum also secretes the **relaxin hormone**.

	Graafian Follicle	Corpus Luteum
Definition	Graafian follicle is a specialised follicle that contains the secondary oocyte.	Corpus luteum is the yellow coloured structure formed after the release of the secondary oocyte from the graafian follicle.
Parts Consists of	Consists of an oocyte (secondary), zona pellucida and cellular membranous ganulose surrounded by the theca internal and external.	Consists of luteam cells, fibrin and blood clot.
Hormone Secreting	Estrogen	Progesterone
Formed By	Formed by the germinal epithelium of the ovary	Formed after the release of the secondary oocyte from the Graafian follicle.
Hormones helping development and maintenance	FSH	HCG

(vii) Degenerated part of the corpus luteum is called **corpus albicans**, literally meaning white body. In fact, it is a white scar-like area.

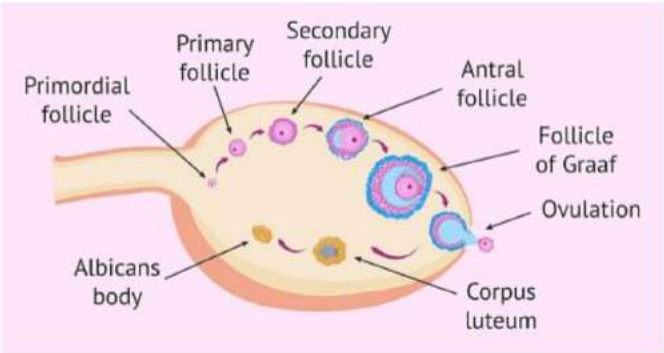


Image showing degeneration corpus luteum into corpus albicans

Functions of Ovaries: Production of **ova** and secretion of **female sex hormones.** Two Fallopian tubes (oviducts), uterus and vagina constitute the **female accessory ducts**.

2. Fallopian tubes consist of the following parts:

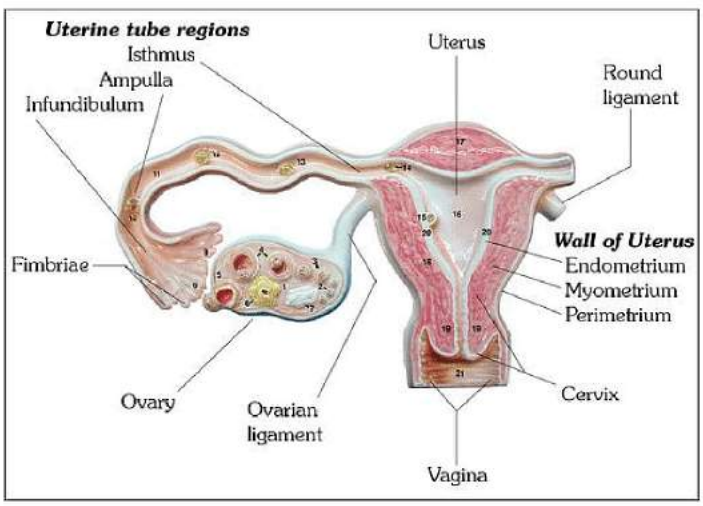
(i) The infundibulum is a dilated trumpet-like portion opening into the peritoneal cavity. The end of the tube has **finger-like projections** called **fimbriae** which help in the collection of the ovum after ovulation.

(ii) The ampulla is the widest and **longest part** of the Fallopian tube.

(iii) The isthmus is the short, narrow thick-walled portion that follows the ampulla.

(iv) The uterine part passes through the uterine wall and communicates with the uterine cavity.

(v) Uterus is single and known as **Womb.**



Functions of Fallopian Tubes: The Fallopian tube conveys the ovum from the ovary to the uterus. It is done by peristalsis. Fertilization of the ovum generally takes place in the upper portion of the Fallopian tube (ampulla).

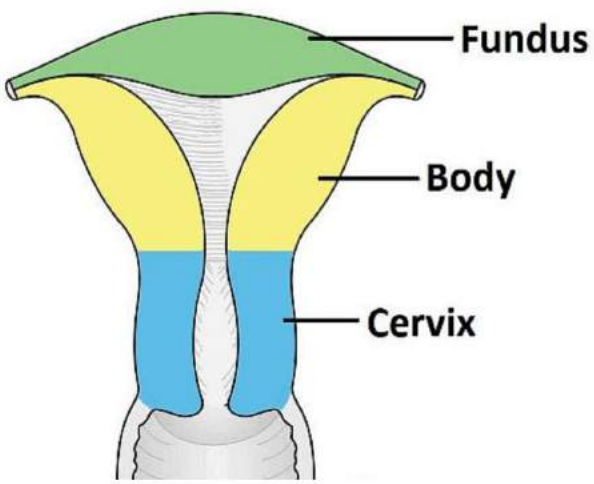
3. Uterus (Metra or Hystera or Womb)

- The uterus is a hollow muscular and **inverted pear-shaped** structure. It lies in the pelvic cavity between the **urinary bladder** and the **rectum**.
- It comprises three parts:

  (i) The **fundus** is the upper dome-shaped part of the uterus above the openings of the uterine parts of the Fallopian tubes.

  (ii) The **body** (corpus) is the main part that is narrowest inferiorly where it continues with the cervix. It is the usual site of implantation of blastocyst.

  (iii) The **cervix** is the part that joins the anterior wall of the vagina and opens into it. The cavity of the cervix is called the cervical canal. The cervix communicates above with the body of the uterus by an aperture called internal os and with the vagina below by an opening, the external os.



- The uterine walls are made up of three layers of tissue.

  (i)The **perimetrium** is the peritoneum's thin outer covering.

  (ii)The **myometrium** is a thick layer of smooth muscle fibres in the middle of the uterus that contracts strongly during childbirth.

  (iii)The **endometrium** is the uterine cavity's inner glandular layer. During the menstrual cycle, the endometrium undergoes cyclical changes.

ENDOMETRIUM	MYOMETRIUM
Mucous membrane lining the uterus, which thickens during the menstrual cycle in preparation for possible implantation of an embryo	Middle, smooth muscle tissue of the uterus
Made up of simple columnar epithelium, endocrine glands, and connective tissue	Made up of smooth muscles
Three layers are stratum compactum, stratum spongiosum, and stratum basalis	Three layers are the longitudinal muscles, crisscrossing muscle, and circular muscles
Undergo cyclic changes of the menstrual cycle and provide a site for the implantation of the blastocyst and the development of placenta	Responsible for the muscular movement of the uterus during parturition

Differences between Endometrium and Myometrium

Functions of Uterus: After **puberty**, the uterus goes through the **menstrual cycle**. If the fertilization has taken place, the embryo gets attached to the uterine wall where it is nourished and protected. At the end of the gestation period, **labour** begins and concludes when the child is born known as Parturition.

4. Vagina

- The vagina is a tube, about **10 cm** long, that extends from the cervix to the outside of the body.
- It is easily stretched.
- The opening of the vagina, called the **vaginal orifice** (vaginal opening), is partially covered by a membrane called the **hymen**.

Functions of Vagina: It provides a passageway for the **menstrual flow**, serves as the receptacle for sperm during intercourse, and forms part of the birth canal during **labour**.

The hymen is often torn during the first coitus (intercourse). However, it can also be broken by a sudden fall or jolt, active participation in some sports like horseback riding, bicycling, etc. In some women, the hymen remains even after coitus. In fact, the presence or absence of a hymen is NOT a reliable indicator of virginity.

5. External Genitalia (Vulva): Vulva means external genitalia of the female. It includes mons veneris, labia majora, labia minora, clitoris, hymen, vestibule & related perineum.

(i) Mons veneris (mons pubis): It is a cushion of fatty tissue or of subcutaneous connective tissue, lying in front of the pubis & is covered by **pubic hairs** in the adult female.

(ii) Labia majora: Vulva is bounded on each side by the elevation and fleshy folds of skin & subcutaneous tissue. Its inner surface is hairless. The outer surface is covered by the **sebaceous gland, Sweat gland & hair follicles**. It is homologous with the scrotum in the male.

(iii) Labia minora: They are two thin folds of skin present just within the labia majora. The lower portion of the minora fuses across the midline & form a fold of skin called a **fourchette**.

(iv) Clitoris: It is a tiny finger-like structure that lies at the upper junction of the two labia minora above the urethral opening. It is made up of two erectile bodies (corpora cavernosa). The skin which covers the glans of the clitoris is called a prepuce. At the terminal part of the vagina, the urethra opens separately, so they form a common chamber called the vaginal vestibule or urogenital sinus.

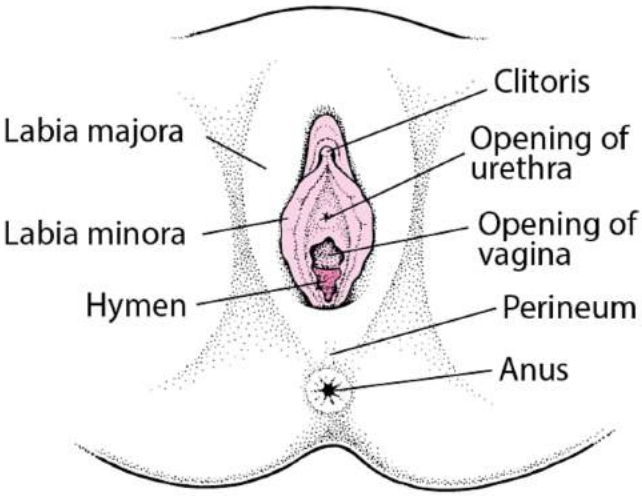
The vulva has the following openings:

(a) Urethral opening: Lies on the anterior end

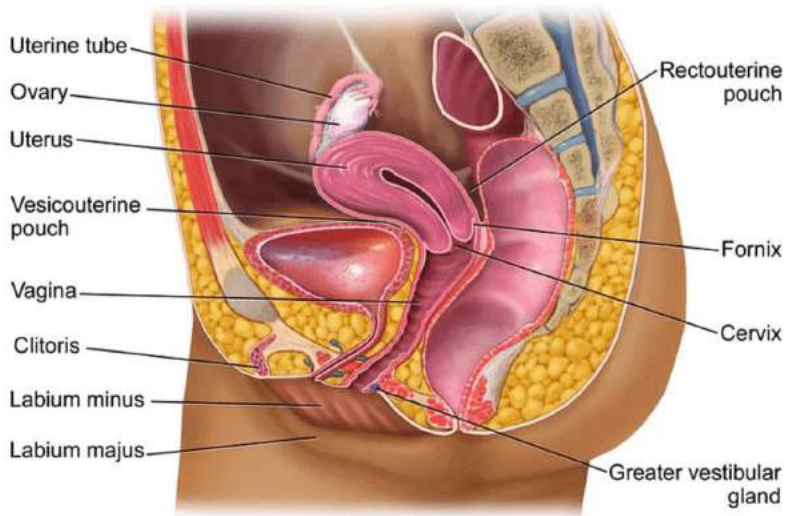
(b) Vaginal orifice: Lies on the posterior end.

It is incompletely closed by a septum of mucous membrane called the hymen, but it may not be a true sign of virginity.

(c) Opening of Bartholin's ducts: These are opening of one pair of bartholin's/greater vestibular glands situated on the lateral side of the vagina. They secrete alkaline fluid during sexual excitement.



(v) Perineum: It is the area that extends from the fourchette to the anus.



Lateral view of Female Reproductive System

6. Breasts

- The **mammary glands** are paired structures (breasts) that contain glandular tissue and a variable amount of fat.
- The glandular tissue of each breast is divided into **15-20 mammary lobes** containing clusters of cells called **alveoli.**
- The cells of alveoli secrete **milk**, which is stored in the cavities (lumens) of alveoli.
- The alveoli 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 the **lactiferous duct** through which milk is sucked out.

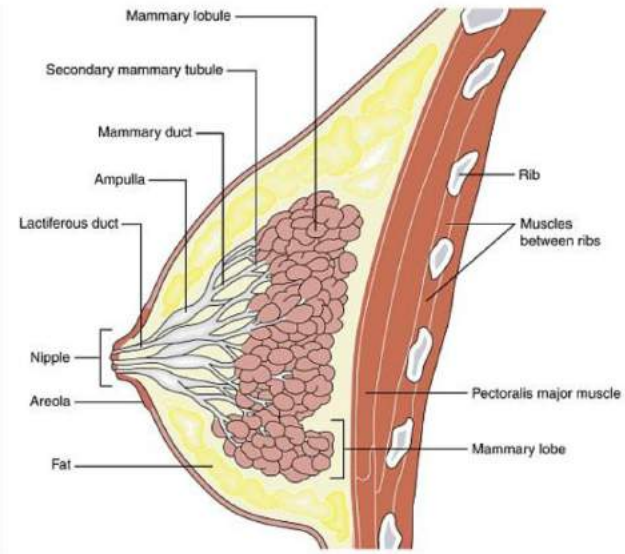


Image of mammary gland

Structure of a Lobe

Many alveoli or acini
↓
Many mammary tubules
↓
Many mammary ducts
↓
One mammary ampulla
↓
One lactiferous duct which opens on surface of nipple

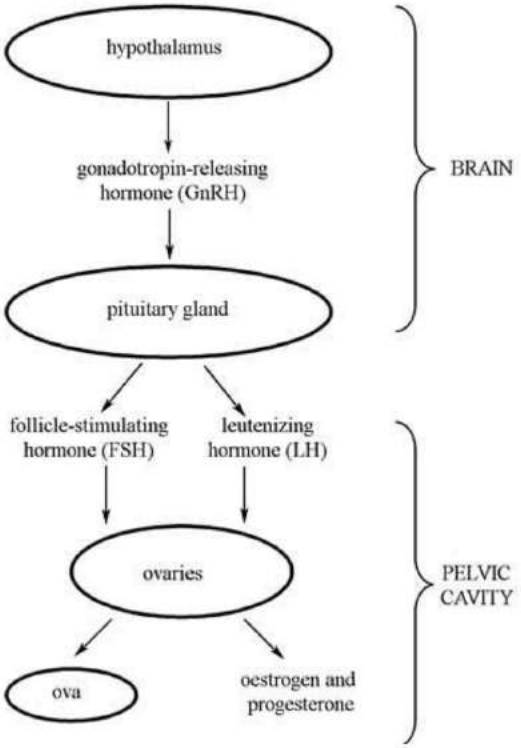
- Mammary glands produce a nutritive fluid, milk for the nourishment of young ones.
- Milk protects the young ones from various infections up to some months after birth.
- The mammary glands of the female undergo differentiation during pregnancy and start producing milk towards the end of pregnancy by the process called lactation.
- This helps the mother in feeding the newborn.

- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

Human milk consists of water and organic and inorganic substances. Its main constituents are **fat** (fat droplets), **casein** (milk protein), **lactose** (milk sugar), **mineral salts** (sodium, calcium, potassium, phosphorous, etc.) and **vitamins**. Milk is poor in iron content. Vitamin C is present in very small quantities in milk. The process of milk secretion is regulated by the nervous system. It is also influenced by the psychic state of the mother. The process of milk production is also influenced by hormones of the pituitary gland (already mentioned), the ovaries and other endocrine glands. A nursing woman secretes **1 to 2 litres of milk per day**. Milk contains an inhibitory peptide. If the mammary glands are not fully emptied the peptide accumulates and inhibits milk production.

Female Reproductive System Hormonal Control

- The **hypothalamus** secretes **GnRH**, which stimulates the anterior lobe of the pituitary gland to secrete luteinizing hormone **(LH) and FSH.**
- FSH promotes the growth of ovarian follicles as well as the development of egg/oocytes within the follicle to complete meiosis I and form secondary oocytes.
- FSH also promotes the production of **estrogens**.
- The corpus luteum is stimulated by LH to secrete **progesterone.**
- Rising progesterone levels inhibit GnRH release, which in turn inhibits the production of FSH, LH, and progesterone.



The Onset of Puberty in the Human Females

- Females reach puberty around the age of **thirteen.**
- The pituitary gland starts producing follicle-stimulating hormones around this time (FSH).
- FSH stimulates the development of the ovaries, which results in the production of the hormone estrogen.
- This hormone is in charge of the development of female secondary sex characteristics such as **voice change** and the **development of external genitalia, breasts, body hair, pubic hair,** and **feminine shape.**
- This shape is characterized by a widening of the pelvis and fat deposits in the thighs, buttocks, and face.

Functions of Female Reproductive System

1. Germinal epithelial cells of the ovary produce ova (**oogenesis**).
2. Fertilization takes place in the **Fallopian tube** (ovíduct).
3. After puberty the uterus goes through the menstrual cycle.
4. **Implantation** and **prenatal growth** take place in the uterus.
5. The vagina receives the seminal fluid during **copulation.**

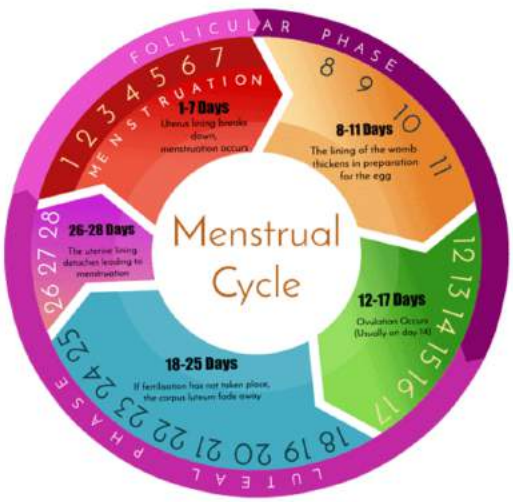
6. **Parturition** (the process of the birth of a child) is also an important function of the female reproductive system.
7. Mammary glands of the female secrete milk after parturition.

Menstrual Cycle: Introduction, Duration & Phases

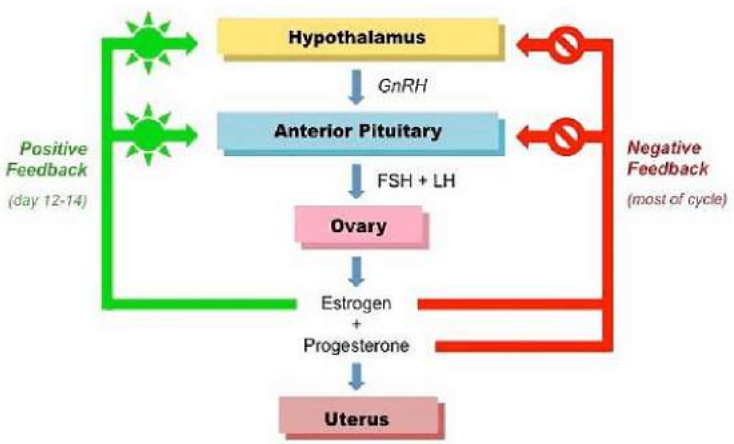
Menarche (Gr. men-month, arche- beginning)

The beginning of menstruation or first menstruation is called menarche. The beginning menstruation varies. It usually occurs between 12 and 15 years.

Menstrual cycle



his is exhibited by the primate group of animals. In this cycle, the female body prepares itself for a possible pregnancy. If the pregnancy does not occur then the body aborts all preparation done and restarts the preparation for pregnancy again in a monthly cyclic manner.

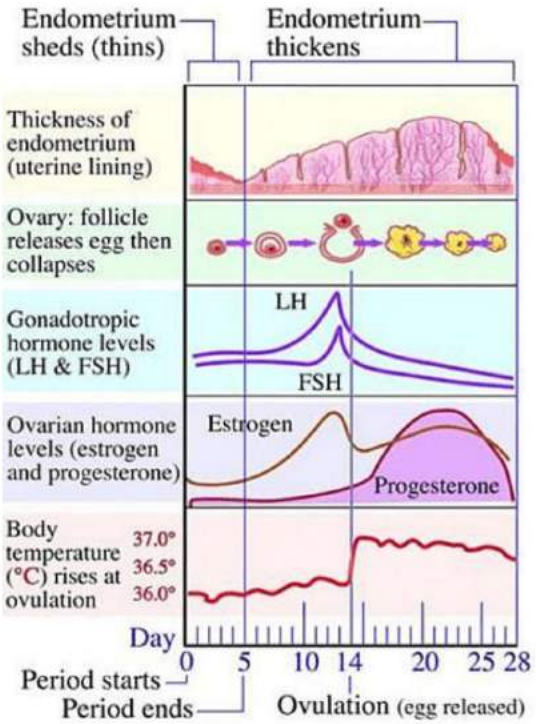


Flow Chart of the Menstrual Cycle

The menstrual cycle has three main phases:

- Bleeding phase or menstruation phase.
- Proliferative/preovulatory/follicular phase or oestrogenic phase.

Secretary/post-ovulatory/luteal phase or progesterone phase.



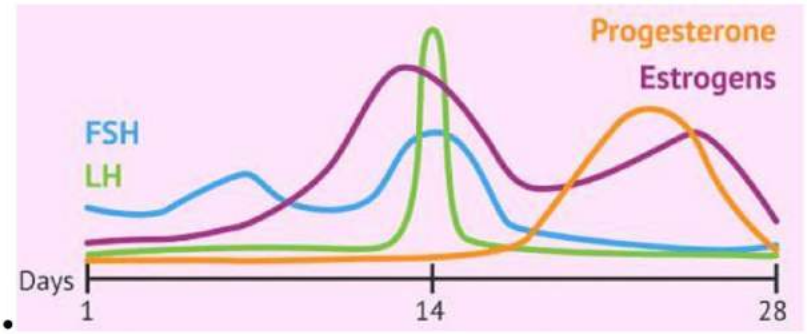
Schematic Diagram of Menstrual Cycle

Bleeding Phase

The cycle starts with the bleeding phase in its first **four** to **five** days. During this bleeding, the part of the layer of the endometrium gets shed off. The total loss of blood per day is about 20 ml, so an average of 40 to 80 ml blood/cycle is lost. This blood can not clot.

Preovulatory/Proliferative Phase

- After the first four of five days this phase begins. During this phase, due to the release of some GnRH, the Pituitary secretes some FSH to stimulate the ovarian follicle. The ovarian follicle now begins to develop.



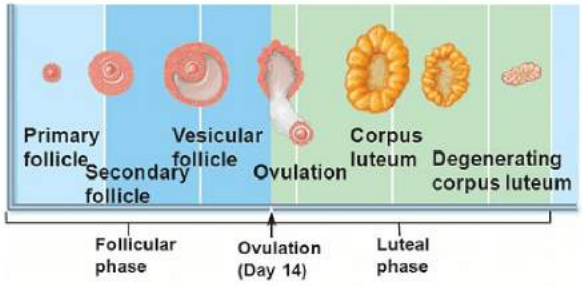
Level of Hormones during Menstruation

- Developing follicle now starts secreting an increasing amount of estrogen. The rising level of estrogen causes the endometrium to **proliferate** and **thicken**.
- It also causes an increase in the vascularity and granularity of the endometrium. The rising level of estrogen also activates the hypothalamus.
- Due to this, the hypothalamus releases more **GnRH**. This GnRH induces the pituitary to release more of FSH. The rising FSH levels now cause :
  (i) Further growth and development ovarian follicle to form Graafian follicle
  (ii) Even further release of estrogen from the theca interna of this developing follicle.
- As the estrogen level goes on rising, by the end of 10 days the extreme levels of estrogen (which have by then caused maturation of Graafian follicle and growth of endometrium) now give positive feedback of high concentration of estrogen causing a rise in LH secretion but due to release of inhibin by graffian follicle, FHS falls secretome falls, therefore, the LH secretion from the pituitary goes on rising.
- This abrupt rise (on the 11th to 13th day) in LH concentration in blood is called an **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 released. The release of an egg (secondary oocyte) which occurs around 14 days is called **ovulation**.

Post Ovulatory/Secretory Phase

- After ovulation, the ruptured Graafian follicle transforms into the corpus luteum. The granulosa and theca cells of the ruptured Graafian follicle (which is now called corpus luteum) are found only in mammals and contain yellow lutein or **carotene pigment**.

- In case of absence of pregnancy, this corpus luteum will get degenerated after 14 days of its formation. The degenerated corpus luteum is called corpus Albicans (white body).
- Stimulated by the rising levels of LH, the **corpus luteum secretes the progesterone hormone**.
- The progesterone facilitates the preparation of the endometrium for receiving the embryo and its implantation. Progesterone inhibits the contractions of the uterus so that the pregnancy could be maintained.
- Progesterone also **inhibits the** development of the next new **ovarian follicle**. If pregnancy occurs then the corpus luteum persists and secretes progesterone.
- Progesterone is important to maintain the pregnancy and it is thus called the **pregnancy hormone**.
- By the fourth month of pregnancy, the **placenta** has developed completely.
- This placenta now takes over the job of further progesterone secretion.
- Ovary also secretes some amount of **relaxin** at the time of **parturition**.
- If pregnancy does not occur after ovulation, then as the progesterone level rise, its rising levels inhibit the release of GnRH from the hypothalamus. Due to this FSH, LH secretion by the pituitary falls and thereby progesterone secretion by the corpus luteum (which was due to the 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.
  1) The overgrown endometrium now **begins to break** and separate from the inner uterine wall causing bleeding.
  2) The **uterine contraction** (which was till now inhibited due to the presence of progesterone) now starts.
- Thus the separated endometrium along with blood is now being passed out via the vaginal route.
- This is again the beginning of the next menstrual or bleeding phase.
- The period between ovulation and the next menstrual bleeding (post-ovulatory period) is always constant (i.e. 14 days).
- However, the ovulation date may vary (causing a change in the pre-ovulatory period).
- After ovulation, the ovum is viable only for two days, while sperms introduced into the vagina can survive for a maximum of four days.
- On the basis of the above data, the safe period method for family planning is calculated.
- Normally it is considered to be day 1 to day 8 and then from day 20 to day 28.



Phases of Menstrual Cycle

Brief description of different phases of Menstrual Cycle:

	Proliferative/ follicular phase	Secretory/luteal phase			Menstrual phase
Actions of pituitary hormones	Ovarian follicle growth stimulated by FSH	Estrogen stimulates LH surge at beginning of secretory phase, inducing ovulation & development of the corpus luteum			
Events in the ovary	Ovarian follicles grow and dominant follicle completes its maturation	Ovulation	Corpus luteum forms	Corpus luteum degenerates	
Major ovarian hormone	Estrogen produced by ovarian follicles acts on vagina, uterine tubes, and uterus	Progesterone produced by the corpus luteum acts on the uterus		Progesterone production stops	
Effects on endometrium	Basal layer proliferates to give rise to a new functional layer	Endometrium reaches its maximal thickness, endometrial glands become active and coiled in appearance, stroma becomes edematous			Functional layer is sloughed, basal layer is retained

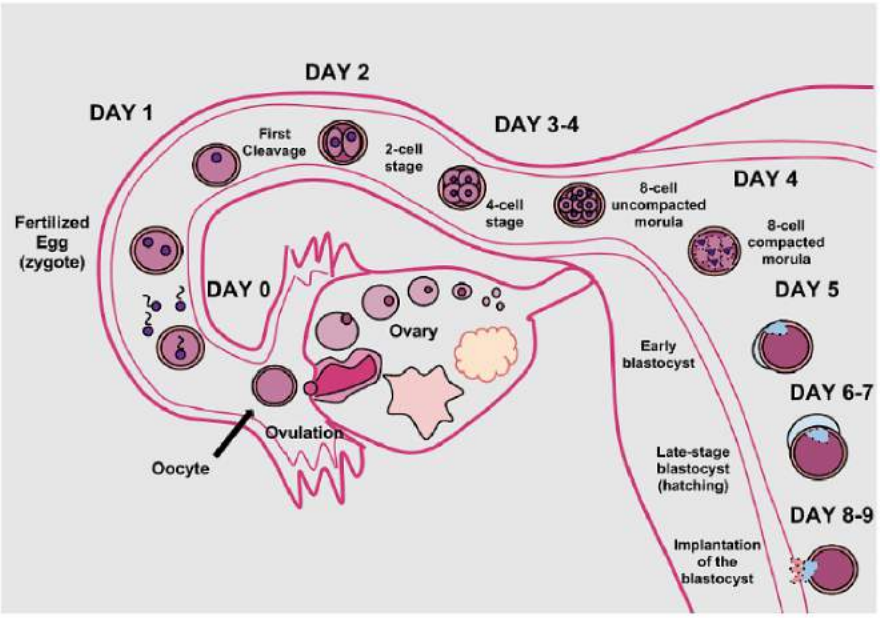
Menopause (Gr. men = month, pausis = cessation)

It is a medical term that refers to the cessation of menstruation. It is the period in a woman's life when ovulation and menstruation cease. Period. It occurs between the ages of 45 and 55. Some women experience irregular menstrual cycles for months or years before menopause. Others simply discontinue menstruation abruptly. **Symptoms.** The uterus and vagina gradually deteriorate (decreased work). During menopause, women may experience temporary depression, hot flashes, and other physiological and psychological issues. The majority of these symptoms can be alleviated by taking hormones prescribed by a doctor. However, due to some negative side effects, hormone replacement therapy is not recommended.

Implantation & Placenta

Implantation

The attachment of developing embryo to the appropriate body layer or surface to obtain nutrition is called implantation. This phenomenon is a common event in most mammals **(except prototheria)** in which embryo (blastocyst stage) after reaching in uterus attaches itself with the wall of the uterus. In other animals like fishes, reptiles, birds, prototherian mammals etc., this nutritive connection is established with the yolk present in egg. In higher mammals including men, the blastocyst on its contact with endometrium of uterus gets completely buried in the wall of the uterus.



Process of Implantation

Mechanism of Implantation

Initially the oocyte after its release from ovary, comes into falopian tube where the process of fertilization is completed. Just after fertilization, embryonic development starts and a blastocyst is formed after cleavage and morulation. 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. **The place of entry through which the embryo enters into the wall, is completely closed by a fibrous and cellular plug, known as closing coagulum.**

Types of Implantation

On the basis of the position of attachment in the uterus, implantation is of three types-

1. Central or Superficial implantation- In this type the blastocyst attaches superficially with the wall of uterus, and remains suspended in the lumen of the uterus.

Example: cow, pig, dog etc.

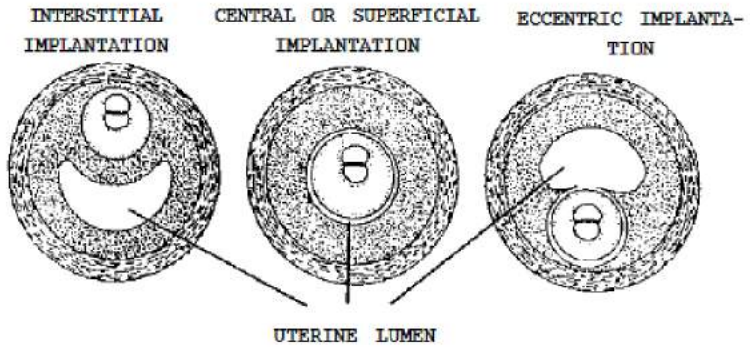


Fig: Types of implanatation

2. Interstitial implantation- The blastocyst is buries deeply inside the wall of uterus and covered by the endometrial tissues lying under epithelium. This type of implantation occurs in human being.

3. Eccentric implantation- It occur in rat, squirrel etc. In this type of implantation, the blastocyst settles in in the folds of epithelium of uterus. After some time it is completely surrounded by these folds.

Summary of developmental stages in human

Day 1 - **Fertilization**; the diameter of fertilized egg is about **0.15 mm**.
Day 2 - **Two cell stage**
Day 3 - **16 cell stage**, morula
Day 4 - **Entry of blastocyst in the lumen of uterus**, disappearance of zona pellucida, diameter of blastocyst is about 0.3 mm.
7-8 Days - **Partial entry of blastocyst** inside the endometrium of uterus; implantation
Day 12 - **Complete entry of blastocyst** into endoderm, extra-embryonic mesoderm, amnion and yolk sac.
Day 14 - **primitive streak formation**.
Day 18 - **Formation of 3-5 pairs of somites**

Fig: Embryonic development in human

Day 19 – **Neural groove, neural plate, notochordal plate, and 6-8 pair of somites formed.**

Day 24 – Indication of the **formation of head and tail region;** 21-23 pairs of somites formed,formation of heart continues at ventral side.

Day 28 – **Heart starts beating**, neural tube formed, 3 pairs of visceral arch and 30-31 pairs of somites formed. Blood islands appear

Day 32 – 30-39 pairs of somites formed.

7 Weeks – Jaws, fingers and external ears begin to appear. The CR length(**crown-rump length**; the length from head to the bottom of hips) is 19-20 mm.

8 Weeks – The embryo is completely surrounded by amnion, fingers and toes clearly visible, almost all organs formed with continuing development, at the end of 8thweek the embryo appears like a little human, now called as foetus; **C-R length is 28 to 30 mm.**

5 months – Blood formation starts in bone marrow Decidua capsularis and parietalis connect together, hairs appear.

9 months – placenta attains maximum size, nails on fingers appear. In the next 10 days the foetus is ready to born as a little baby.

The above mentioned timing are approximate time periods. Some times, due to some reasons, certain babies are born before stipulated time. The babies born in 7th month may also survive as normal babies.

EXTRA EMBRYONIC MEMBRANES AND PLACENTA

Extra embryonic membranes

In chordates like reptiles, birds and prototherian mammals, blastula is a disc shaped **structure called as blastodisc.**

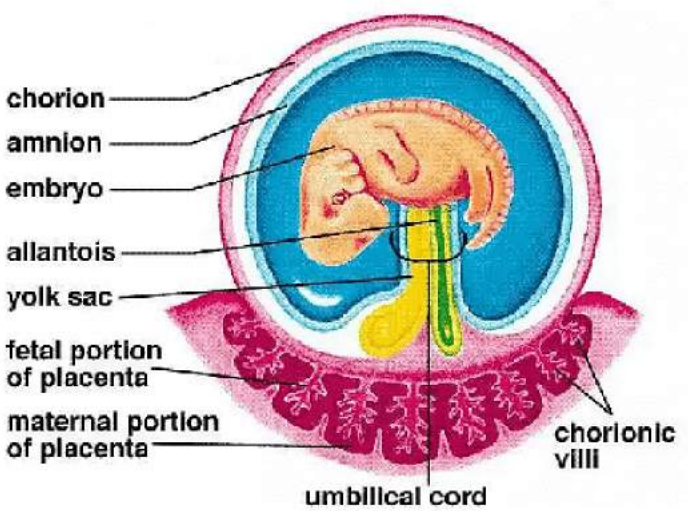


Fig: Extraembryonic membrane in human

The cellular layer formed of blastomeres remains as blastoderm. **The central part of blastoderm gives rise to embryo proper, while the peripheral portion does not take part in the formation of embryo.** This peripheral part is known as **extra embryonic region**. This region takes part in the formation of certain membranes called extra embryonic membranes. These extra embryonic membranes provide facilities for nutrition, respiration and excretion to the embryo. Extra embryonic membranes are of four types-

1. Amnion
2. Chorion
3. Yolk sac
4. Allantois

On the basis of presence or absence of amnion, two groups of vertebrates are categorized

1. Amniota - This group is characterized with the presence of amnion in the embryos of its members.
For example members of class Reptilia, Aves and Mammalia.
2. Anamniota - Animals of this group are devoid of amnion in their embryos. For example class cyclostomata, pisces and amphibia.

Extra embryonic membranes in human

The process of gastrulation in embryo results into the formation of endoderm or hypoblast, ectoderm or epiblast, amniotic cavity, yolk sac, extra embryonic parietal and visceral mesoderm, connecting stalk etc. Extra embryonic membranes are also formed during this process. Each extra embryonic membrane is derived from two layers.

1. Amnion- It is formed by the layer of amniogenic cells present around the amniotic cavity and the extra embryonic mesoderm. Extra embryonic mesoderm layer surrounds the amnion. The connecting stalk is also attached with it. With a gradual increase in size the amnion covers the embryo from all sides. **After about eight weeks of fertilization, amnion is completely incorporated into connecting stalk, which finally forms the umbilical cord.** Embryo, in this stage, is called as foetus remains hanging in amniotic fluid.

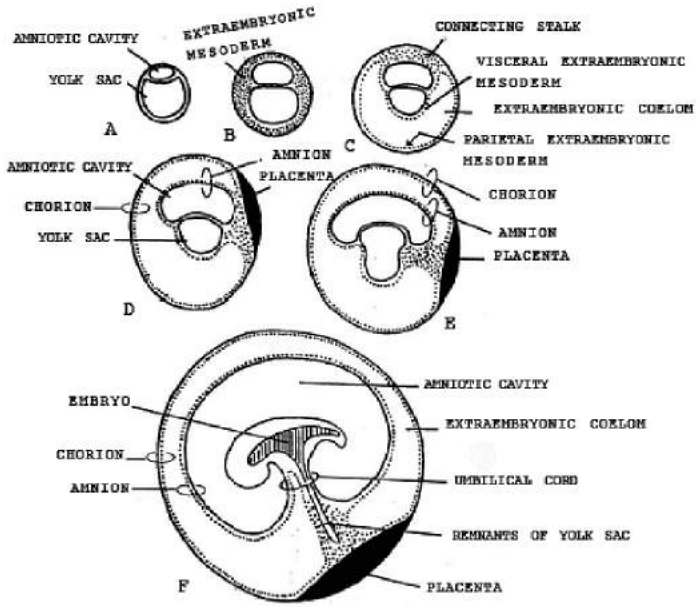


Fig: Formation of extraembryonic membrane in human2. Chorion- It is formed by the extra embryonic parietal layer of mesoderm and the cell of trophoblast. **After implantation of blastocyst, the trophoblast gives out several finger like processes, the chorionic villi which get embedded into uterine endometrium Mesoderm also contributes in the formation of these villi.** After a period of four month these villi disappear from all parts except the connecting stalk where they grow rapidly and participate in the formation of placenta.

3. Yolk sac- Yolk sac is formed by the cells of extra embryonic visceral mesoderm and endoderm. Initially the size of yolk sac is larger as compared to that of the embryo. **About eight weeks after fertilization, the yolk is reduced in size and changes into a tubular structure**. Ultimately a placenta is developed with the incorporation of yolk sac and mesodermal connecting stalk with the amnion and chorion.

4. Allantois- It is a solid and cylindrical mass formed by embryonic mesoderm. A small cavity lined by endodermal cells develops in it. The mesoderm of allantois forms many small blood vessels in this region. These vessels connect the embryo with placenta and ensure nutritional and respiratory supply to embryo. **In human, allantois does not function to store the excretory wastes as it does in reptiles and birds**.

PLACENTA

The eggs of viviparous animals are unable to develop into their embryos outside the uterus independently. This is because of the very little or negligible amount of yolk present in these eggs, which can not fulfill the nutritional and other physiolgical

demands of a developing embryo. Here **the embryo depends upon maternal tissues for shelter, nutrition, respiration etc.** These animals therefore, have developed adaptation, respiratory and other physiological requirements from mother's body.
Placenta is found in all viviparous (except **sub-class-prototheria; oviparous**) animals.

Structure of Placenta
Placenta is not a simple membrane.It is made up of the tissues from two different sources
Maternal tissue - These include **uterine epithelium, connective tissues and blood capillaries.**
Embryonic tissue - These include **extra embryonic membranes (mainly chorion).** Yolk sac and allantois may also take part in placenta formation. Embryonic connective tissues and blood capillaries are also constituents of it.

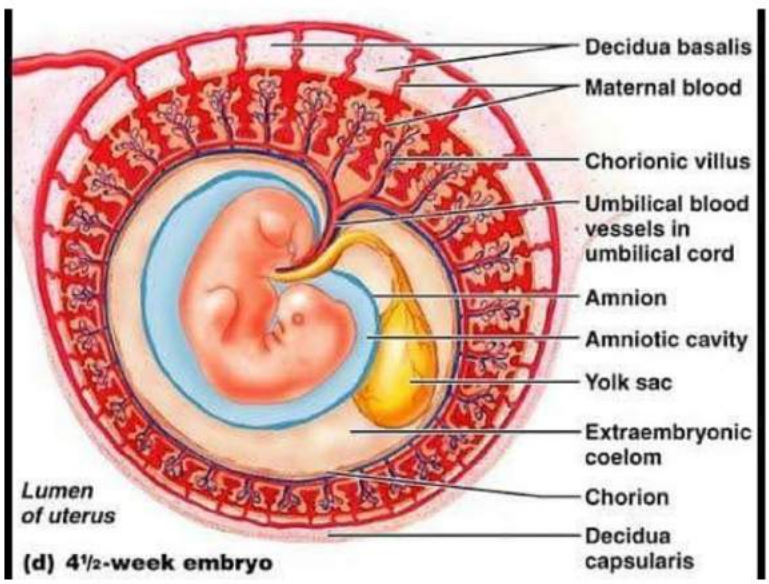


Fig: The placental villi embryology

On the basis of extra embryonic membranes, the placenta is of three types.
1. Yolk sac placenta- It is formed by yolk sac and uterine epithelium.For example, Elasmobranchs (Sharks), **Mustelus** etc.
2. Chorio-vitelline placenta- It is formed by chorion and yolk sac combinedly. Hence it is called as choriovitelline placenta. For example, **Didelphis**, **Macropus** and other metatherian mammals.
3. Chorio-allantoic placenta- This type of placenta is formed by embryonic chorion and allantoic membranes.

It is also referred to as a true placenta. It is found in **eutherian mammals**.

Chorio-allantoic placenta in mammals.

1. In this type of placenta, **allantoic mesodern and the mesoderm of umbilical cord jointly form the blood vessels of umbilical cord**. The endodermal part of the allantois remains as a very small cavity.

2. To obtain nutrition from maternal blood several finger like processes or villi are formed by chorion which penetrate deeply into the crypts of uterus.Initially the villi are scattered over the whole surface of chorion but later they become restricted in the decidua besalis region . The chorionic villi on the remaining surface disappear shortly. The part of chorion, which helps in placenta formation is known as **chorionic frondosum**.

Classification of Placenta

On the basis of different characters, the placenta are classified in following manner:-

1. On the basis of intimacy After implantation, the wall of uterus is called as **decidua,** instead of endometrium. The part of decidua, where placenta is formed is called **decidua basalis** whereas, the part separating the embryo from lumen of uterus is called **decidua capsularis**. The remaining part of lumen of uterus is called **decidua parietalis**. Decidua also comes out from uterus at the time of parturition. On the basis of intimacy between embryo and uterine wall the placenta is classified into three classes

(i) Non-deciduate or Semi placenta- In this type of placenta, **there is no close and rigid association between embryo and the wall of uterus**. Hence, at the time of parturition, there is no bleeding as the chorionic villi are easily pulled out from the crypts of uterus. For example, cow, buffalo, horse, pig.

(ii) Contra-deciduate placenta- There is a close association between embryonic and maternal tissues. However at parturition, the damaged maternal and embryonic tissues along with the part of placenta remain inside the uterus which are absorbed in situ by leukocytes.

For example- Parameles, Talpa etc.

(iii) Deciduate placenta- This type of placenta is found in human, dog, hare etc.**It is characterized with a very close association between chorionic villi and uterine wall**. At the time of birth, the mucosal covering of the uterus is also damaged and discarded outside. This results in an extensive bleeding at child birth. This placenta is known as a **true placenta**.

2. On the basis of implantation

Three types of placenta are found on the basis of implantaion.

(i) Superficial- When the placenta is situated in the lumen of uterus. For example, Parameles, pig, cow, cat etc.

(ii) Eccentric- The placenta is situated in the fold or pocket of the cavity of uterus. For example- rat, Squirrel etc.
(iii) Interstitial- This type of placenta is found in man, guinea pig, apes etc. **The chorionic sac (placenta) penetrates deep inside the wall of uterus**. Hence, the association between embryo and maternal part becomes very close.

3. On the basis of distribution of villi
On this basis, the placenta are of four types.
(i) Diffused placenta- The villi are scattered on the whole surface of placenta. For example pig, horse, lemur etc.
(ii) Cotyledonary placenta- The villi are distributed in small isolated groups on the chorionic surface. These groups of villi are called as **cotyledons**. For example, cow, buffalo, sheep, deer etc.
(iii) Zonary placenta- This type of placentae have the villi distributed in a belt shaped zone which is large sized and circular.
Zonary placenta is of two types-
(a) Complete Zonary placenta - The belt of villi is complete and ring shaped init. For example- dog, cat, lion etc.
(b) Incomplete Zonary placenta- The belt of villi is incomplete in it. For example- racoon.
(iv) Discoidal placenta- In this type of placenta, whole of the chorionic surface is covered by villi in initial stage, but the villi disappear later from most area except the region of implantation, that is only a disc like region is left with villi.
Discoidal placenta is also of two types–
(a) Mono discoidal placenta– The villi are present only on dorsal surface in a single circular disc like area.
For example- human, hare etc.
(b) Bidiscoidal placenta- If the villi are distributed in two disc like areas, the placenta is called as bidiscoidal,
Example: monkeys.

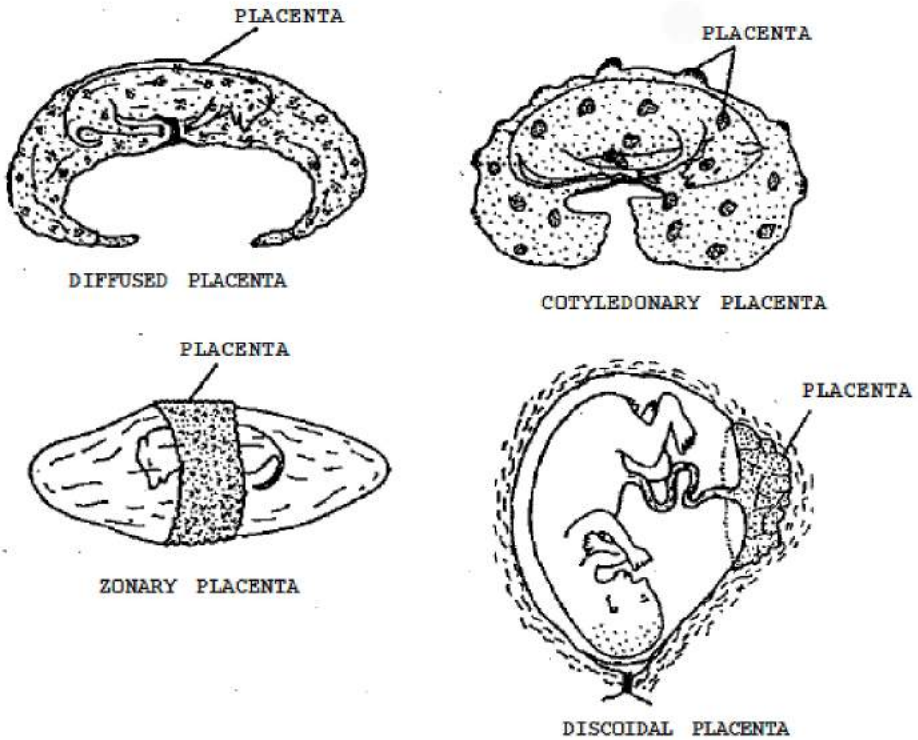


Fig: Different types of placenta

Types of placenta on the basis of distribution of villi

4. On the basis of histology

The blood of maternal and embryonic do not mix together through placenta. The blood circulations of the two sides are kept separated by one or more layers described below–

1. Maternal endothelium
2. Uterine connective tissue } Maternal layers
3. Uterine epithelium
4. Trophoblast / Chorion
5. Chorionic connective tissue } Foetal layers
6. Endothelium of embryonic blood vessels

The transportation of various materials takes place by diffusion through these six layers. **The intimacy between maternal and embryonic tissues in different mammals is determined by the presence or absence of these layers in placenta.** Therefore, on the basis of presence of above layers, the placenta is of five types.

1. Epitheliochorial- It is the most primitive type of placenta in which all the six layers, mentioned earlier, remain intact.
For example - pig, horse etc.
2. Syndesmochorial- In this type of placenta the uterine epithelium is eroded by chorionic villi, so only two maternal layers remain functional. Therefore, along with three foetal layers, total five layers are present in this placenta.
For example - sheep, goat, cow etc.
3. Endotheliochorial- Here uterine connective tissue layer is also damaged along with uterine epithelial layer. Therefore only four layers (3 foetal and one maternal) are found in this placenta
For example - dog, cat, etc.
4. Haemochorial- All the three maternal layers are penetrated in this placenta. The chorionic epithelium comes in direct contact with uterine blood sinusoids.
For example- man, monkey, bat etc.

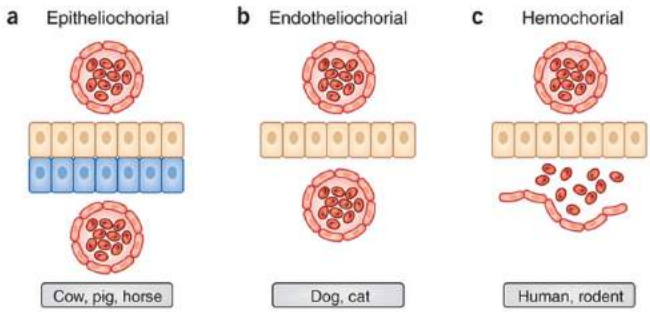


Fig: Classification of placenta

5. Haemo-endotheliochorial/Haemo-endothelial : it is the most typical placenta in which the tropho-blastic epithelium of embryo is also eroded along with all three maternal layers. The foetal capillaries are in direct contact with maternal blood.
For example: rat, guinea pig, rabbit etc.

Hormones of Human Placenta
The placenta of human mainly secretes two steroid hormones like **estradiol** and **progesterone**, and two protein hormones like **human chorional gonadotropin** HCG and **human placental somatomammotropin HCS.** Large amount of HCG hormone is secreted, during early pregnancy, from the placenta. Because of this reason its quantity increases in the urine of pregnant lady. On the basis of this fact, pregnancy test is performed. The above hormones are also held responsible for keeping the **corpus luteum active, protection of embryo, prevention of abortion and growth of mammary glands.**

Functions of placenta
1. Exchange of important materials between foetal and maternal blood.

2. The essential materials are exchanged by diffusion, pinocytosis or active transport.
3. The small molecules like O_2, CO_2, H_2O etc. and other inorganic substances like chlorides, phosphates, sodium, potassium, magnesium etc. are also diffused through placenta.
4. Large molecules like lipids, polysaccharides, carbohydrates, proteins etc. are obtained by pinocytosis process.
5. The nutritional substances are supplied to embryo from the mother through placenta.
6. Placenta also serves as a respiratory medium for exchange of O_2 and CO_2 between embryo and mother.
7. The nitrogenous and metabolic wastes from foetus are released into the blood of mother by diffusion through placenta.
8. The antibodies for measles, chickenpox, polio etc. present in the blood of mother reach the embryo through placenta.
9. Pathogenic viruses may also enter in embryo through placenta.
10. 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 organo genesis.(eg. Thallidomide)
11. Placenta itself secretes some hormones like progesterone, estrogen, lactogen, HCG, HCS etc.
12. Progesterone, maintains and supports the foetus during the whole pregnancy period . At the time of parturition, relaxin is secreted by placenta which lubricates, and widens the birth canal to facilitate child birth.

HISTORY : -

Aristotle is known as "Father of Embryology" he first studied the development in chick and other embryos. He gave its description in his book "Historia Animalia".

Leeuwenhoek (1671)
(a) He observed and described human sperm for the first time.
(b) According to Hartsoeker and Leeuwenhoek there is a small model of developing animal present in the head of the sperm of that animal. This small model is called homunculus. Both these scientists are called spermists, and this theory is called **"Theory of spermist"**.

Swammer Dame, Haller, Bonette & Malpighi:- According to these scientists, small model of animal is always present in the egg. These scientists are called Ovists, and their theory is known as 'Ovists theory'

Schleiden & Schwann:- Both the scientists established the cellular structure of egg and sperm.

Pander:- He described the presence of three germinal layers in chick embryo.

Fredrich Wolff:- He first presented the **"theory of epigenesis"**.

Muller :- He gave the recapitulation theory.

Haeckel :- He gave the details of Recapitulation theory and named it as the **bio-genetic law**. - **Bio-genetic Law :-** According to this each organism during its embryonal development, passes through all stages, through which its species has evolved or embryo repeats its ancestry. i.e. Ontogeny recapitulates its Phylogeny.

"Carl Ernest Von Baer":- He is known as the "father of modern embryology." He gave the Baer's Law which in turn proves the recapitulation theory.
According to this law, during embryonal development, the development of general structures takes place earlier and specific structures develop at last or later on.

A. Weismann:- He gave the **theory of germplasm** or **the theory of continuity of germplasm**. According to him, there are 2 types of protoplasm in the body of animals :-
(a) Somatoplasm
(b) Germplasm.
Somatoplasm dies but the germplasm is never destroyed, rather it is transferred to the progenies.

Wilhelm:- He studied embryonal development in frog and gave the mosaic theory.
He said that there are some presumptive areas in the eggs of frog. These areas form specific structures during embryonal development. This is termed as "Promorphology". and these type of eggs are termed as the mosaic eggs.

Hans Driesch:- He studied embryonal development in sea-urchin and gave the regulative theory. - In the eggs of Sea-Urchin presumptive areas are not found i.e. promorphology is not found. So, each part of the egg is capable of forming the complete embryo. These type of eggs are termed as regulative eggs.

Boveri & Child:-

They gave the gradient theory to explain the mosaic development in eggs.
According to them, a metabolic gradient is present inside the eggs.
Different parts of the egg have different metabolic rates.
The rate of metabolism is faster at the animal- pole of the egg and is slower at the vegital pole of the egg.
Due to different metabolic rates, different structures are formed from different parts of the egg.

Spemann:- He gave the **"Theory of organizers".** -
(a) According to it embryo has some special type of tissues, which induce development of some specific structures.
(b) These are termed as the **organizers**.
(c) These organizers secrete some special chemicals called **evocators** which induce the formation of specific structures.
(d) Spemann got the Nobel prize for his theory of organizers.

R.V. Graff:-
He studied a follicle in human ovary and termed it as "**Graafian follicle**".

Phases of Cleavage

Cleavage (Cellulation or Segmentation)

- The term 'Cleavage' was given by "Von Baer".
- In fertilized egg or activated egg, the egg undergoes repeated cell divisions which occur rapidly producing a multicellular structure without changing its size.
- All these rapid mitotic cell divisions are collectively called **cleavage or segmentation.**
- Due to the process of cleavage, a single-celled zygote, through successive mitotic cell divisions changes into a complex multicellular structure.
- Cells produced as a result of cleavage are termed **blastomeres.**

Process of cleavage

- About thirty hours after fertilization, the newly formed zygote divides into two cells, the blastomeres, in the upper portion of the Fallopian tube.
- This is the first cleavage. The next division occurs within forty hours after fertilization. The third division occurs about three days after fertilization.

- During these early cleavages, the young embryo is slowly moving down the Fallopian tube towards the uterus.
- At the end of the fourth day, this solid mass of cells is known to reach the uterus.
- It has 8-16 blastomeres and (little mulberry) as it looks like a mulberry.
- When the blastomeres divide completely the cleavage is called holoblastic.

Early Embryonic Development

Significance of Cleavage

Cleavage brings about:
(i) the distribution of the cytoplasm of the zygote, amongst the blastomeres,
(ii) increased mobility of the protoplasm, which facilitates morphogenetic movements necessary for cell differentiation, germ layer formation and the formation of tissue and organs,
(iii) the restoration of the cell size and the nucleo-cytoplasmic ratio characteristic of the species.
(iv) Unicellular zygote is converted into a multicellular embryo.

CLEAVAGE	CELL DIVISION
Act or state of splitting or dividing of a cell, particularly during the telophase of (animal) cell division	Process by which a parent cell divides into two or more daughter cells
Occurs only in animal cells	Occurs in both animal and plant cells
Also called cytokinesis in animal cells	Two steps are kayokinesis and cytokinesis
Division of the cytoplasm of the parent cell between the two daughter nuclei	Division of the parent nucleus into two daughter nuclei and then, the division of the cytoplasm
Follows nuclear division	Follows G2 phase of the cell cycle
Involves actin filaments, myosin filaments, and contractile ring	Involves mitotic spindle made up of microtubules

Cleavage V/S Cell Division1. Morula -

- As a result of segmentation or cleavage activities, a unicellular zygote changes into a solid ball-like multicellular structure.

- In the later stage of cleavage, clusters of sticky, cohering, protruding (outside) blastomeres are produced, which look like mulberry.
- This stage is termed as morula stage.
- The mitotic division starts as the zygote moves through the isthmus of the oviduct called cleavage towards the uterus and forms 2, 4, 8, 16 daughter cells called blastomeres.
- The embryo with 8 to 16 blastomeres is called a morula.

2. Blastulation -

- The morula continues to divide and transform into a blastocyst.
- **Blastocyst** - Blastula of eutherian and metatherian mammals is called blastocyst because blastula is in the form of a cyst.
- The **blastomeres** in the blastocyst are arranged into an outer layer called the trophoblast and an inner group of cells attached to the 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.
- Initially, the oocyte after its release from the ovary comes into the fallopian tube where the process of fertilization is completed.
- Just after fertilization, embryonic development starts and a blastocyst is formed after cleavage and morulation.
- In human beings, the blastocyst gets attached to the uterine endometrium about four days after entering the uterus.
- At the same time, the cells of the endometrium of the implantation area separate out and adhere with embryonic cells with the help of certain enzymes secreted by the cells of the trophoblast.
- In humans, the site of implantation is generally the mid-dorsal/fundus part of the uterus.
- Implantation of blastocyst takes about 7–8 days after fertilization in humans and by the 12th day, it is completely buried in the wall of the uterus.
- The place of entry through which the embryo enters into the wall is completely closed by a fibrous and cellular plug, known as closing coagulum.

The function of the zona pellucida -

- It prevents implantation of the blastocyst at an abnormal site.
- The trophoblast has the property of being able to stick to the uterine (or other) epithelium and its cells have the capacity to eat up other cells.

Interstitial implantation– The blastocyst is buried deep inside the wall of the uterus and covered by the endometrial tissues lying under the epithelium. This type of implantation occurs in human beings. After implantation endometrium is known as **decidua.**

Morula	Blastula
Morula is a solid ball of cells resulting from division of a fertilized ovum, and from which a blastula is formed	Blastula is a hollow sphere of cells surrounding the blastocoele produced during the development of an embryo
Forms 4-5 days after fertilization	Forms 5-10 days after fertilization
A solid cell mass	A hollow structure
Consists of a ball of small, spherical cells formed by the rapid cleavage of the zygote	Consists of a spherical cell layer of blastomeres and a fluid-filled cavity called blastocoel
Consists of more than a hundred of cells	Consists of hundred and twenty-three cells
Develops into the blastula in a process called blastulation	Develops into the gastrula in a process called gastrulation

Morula V/S Blastula

3. Gastrulation -

- In the gastrula stage rate of cleavage division is slow and ultimately stops at the end of the gastrula.
- Gastrula the stage is the most important stage in embryonic development because two main events take place during the gastrula stage.

(a) Differentiation of blastomere: As a result of differentiation of blastomere; three germinal layers i.e. ectoderm, mesoderm and endoderm are formed.

- The formation of three germinal layers is the significance of the gastrula stage.

- All the preparation of differentiation of blastomere is completed in the late blastula stage.

(b) Morphogenetic Movements: During the gastrula stage blastomere performs amoeboid movement and reaches their definite place in the embryo because after the gastrulation organogenesis has to start in the embryo.

- Morphogenetic movement requires enormous energy.
- So respiratory activity of the egg increases.

Method of Gastrulation :

(a) **Epiboly:** Movement of ectoderm forming blastomere
(b) **Emboly:** Movement of mesoderm and endoderm forming blastomere.

- In the same animal's new cavity is formed in the gastrula this is called gastrocoel or archenteron cavity.
- Immediately after implantation, the inner cell mass (embryo) differentiates into ectoderm endoderm and mesoderm (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.**

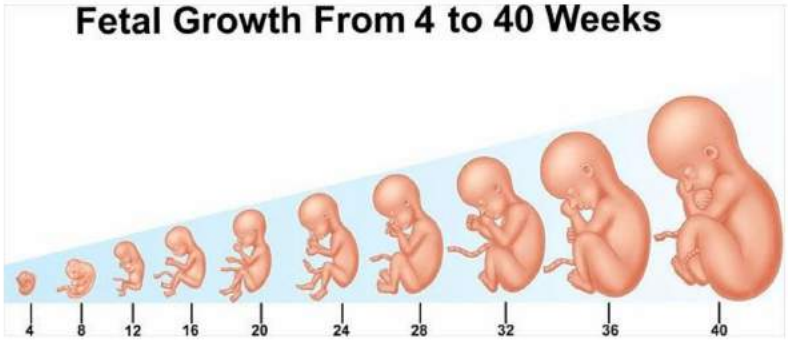
Blastula	Gastrula
Blastula is an animal embryo at the early stage of development when it is a hollow ball of cells	Gastrula is an embryo at the stage following the blastula, when it is a hollow cup-shaped structure having three layers of cells
Formed from the morula in the process called blastulation	Formed from the blastula in the process called gastrulation
Results from rapid mitotic cell division	Results from slow mitotic cell division
A single-layered, hollow structure	A three-layered, hollow structure
Cells in the morula do not show any movement during the formation	Cell masses are migrated from the surface of the blastula during the formation
Contains 128 cells	Contains more cells than blastula
Contains undifferentiated cells	Contains differentiated cells
Comprises of a zona pellucida	Lacks a zona pellucida

Blastula v/s Gastrula

Pregnancy & Embryonic Development

What is Pregnancy?

Pregnancy occurs when the sperm fertilizes the egg, and the zygote is formed. The zygote gets implanted in the wall of the uterus. As soon as the implantation takes place, the need for nourishment and care arises. The zygote develops into an embryo which further grows into a baby. This responsibility is taken up by a layer formed between the baby and the mother, called the placenta. The placenta is formed by chorion and the uterine tissue.



Phases of Pregnancy

This layer plays many roles during pregnancy, which are briefly discussed as follows:-

1. Providing nutrients and oxygen to the growing fetus.
2. It also removes the waste materials given out by the foetus, substituting the function of the digestive system and the excretory system.
3. The placenta releases hormones like human placental lactogen, progesterone, estrogen, human chorionic gonadotropin and relaxin which are necessary for the growth of the foetus.
4. The umbilical cord that connects the foetus to the placenta helps in transportation of substances required for growth from the mother to the fetus.

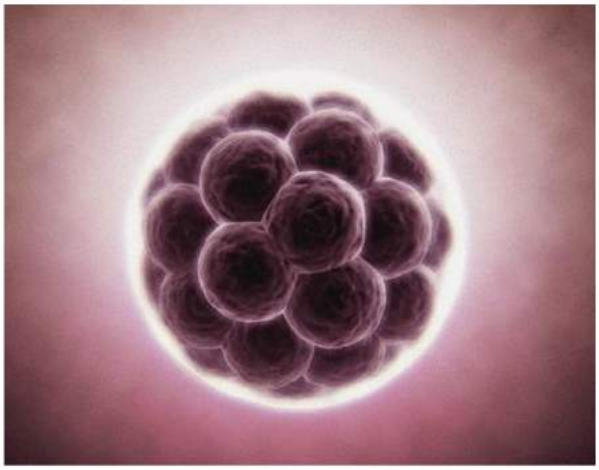
As soon as the implantation takes place, the fertilized cell mass or embryo starts showing the triploblastic nature of human beings by dividing into the three layers of cells. This gives rise to different organs during development – ectoderm, mesoderm, and endoderm.

All these steps after implantation lead to the development of the baby and it takes nine months in humans. The development is very gradual and steady. At first, the heart of the embryo is formed, followed by limbs, major organs, the appearance of hair and so on. By the end of 9 months, the fetus is completely developed.

General Stages of Embryonic Development

Morula

As a result of segmentation or cleavage activities, unicellular zygote changes into a solid ball like multicellular structure. In the later stage of cleavage, clusters of sticky, cohering, protruding(outside) blastomeres are produced, which look like mulberry.

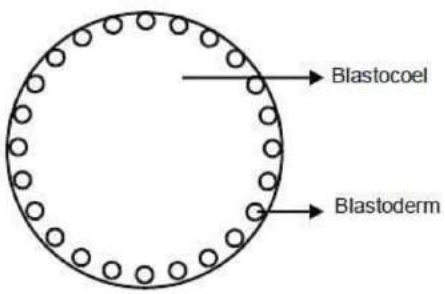


Morula

This stage is termed as **morula stage.**

Blastulation

Cleavage continues in solid ball like morula and new formed blastomeres start rearranging themselves. **Cell - aggregation starts in blastomeres, due to the movement of these blastomeres a cavity appears in the embryo, it is called as blastocoel**. This cavity is schizogenous cavity in origin i.e. it is formed by the separation of cells. Cell aggregation is also known as cohesion. Blastomeres arrange themselves in the form of a layer around the blastocoel, this layer is termed as **blastoderm.** The embryonic stage is now called **blastula**, and its formative activities is called **blastulation**.



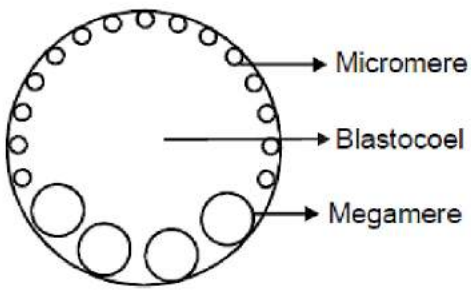
Coeloblastula

Types of blastula

The shape of blastula depends on so many factors e.g. **size of eggs, amount of yolk, distribution of yolk in the eggs, frequency of cleavage and number of cleavage divisions**. According to these factors, we can classify blastula of different animals indifferent categories.

(a) Coeloblastula
(b) Stereoblastula / solidblastula
(c) Discoblastula
(d) Blastocyst
(e) Superficial blastulaor Periblastula

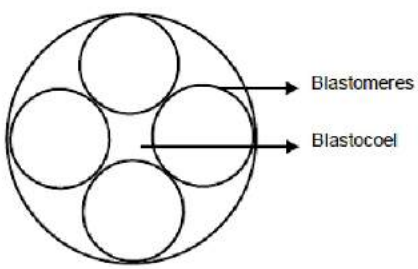
(a) Coeloblastula: Blastocoel is wide and clear in this blastulation, it is completely surrounded by blastomeres on all the sides i.e., blastocoel cavity is situated totally inside the embryo. **Blastomeres are very small in size as compared to blastocoel.**



Amphiblastula

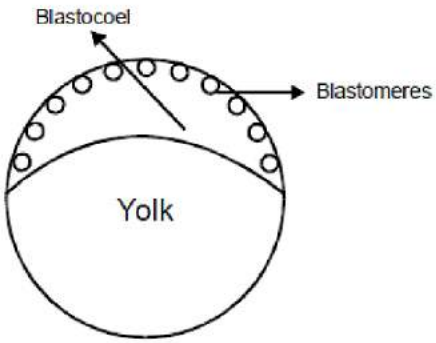
Example: eggs of Amphioxus, Coelenterata, amphibia, sponges etc.
Coeloblastula of amphibians is called amphiblastula because in it blastocoel cavity is accentric in position and s more towards the animal pole (amount of yolk is more towards the vegetal pole). Amphiblastula of sponges is a free swimming larva, its blastomeres are flagillated. This larva swims freely with the help of these flagella. It is a unique feature in sponges.

(b) Stereoblastula :- In this blastula, blastocoel is very narrow or obliterated. Blastomeres are large as compared to blastocoel.



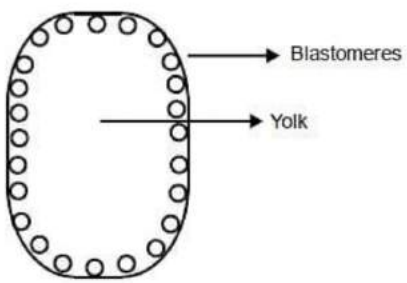
Stereoblastula

Example: eggs of Neries, Phylum Mollusca.
(c) Discoblastula: It is found in those animals which have discoidal eggs. **There is a cavity present in between blastomeres and yolk, it is called the sub-germinal cavity**. It is a type of cavity, which is surrounded by yolk on one side and by blastomeres on the other side.
Examples: eggs of reptiles, birds and Prototheria.



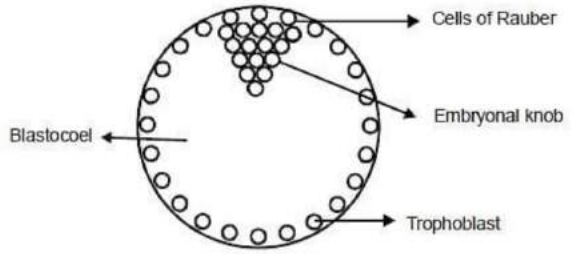
Discoblastula

(d) Superficial blastula or periblastula: In centrolecithal eggs, cleavage occurs only in peripheral region. The layer of blastomeres surrounds the centrally situated yolk. **Blastocoel is absent in this type of blastula.**
Example - Eggs of insects.



Periblastula

e) Blastocyst - Blastula of Eutherian & Metatherian mammals is called blastocyst, because blastula is in the form of a cyst.



Blastocyst

Blastula - of mammals is called a blastocyst. In blastocyst all the embryonal cells occur in the form of solid mass called embryonal knob. **Embryonal knob (inner cell mass) is covered by protective layer called trophoblast and it's cell just above the embryonal knob are called cells of Rauber (amniogenic cells).** There occurs a cavity in between embryonal knob 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.

Gastrulation

Gastrula : In gastrula stage rate of cleavage division is slow and ultimately stops at the end of gastrula. Gastrula stage is the most important stage in embryonic development because two main events take place during gastrula stage.

(a) Differentiation of blastomere: As a result of differentiation of blastomere; three germinal layers i.e. **ectoderm, mesoderm and endoderm** are formed. Formation of three germinal layers is the significance of gastrula stage. All the preparation of differentiation of blastomere are completed in late blastula stage.

(b) Morphogenetic Movements: During gastrula stage blastomere perform amoeboid movement and reach to their definite place in embryo because after the gastrulation organogenesis has to start in embryo.

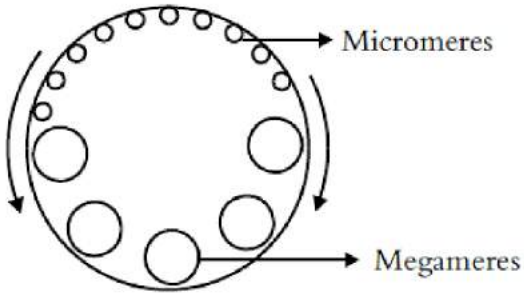
Morphogenetic movement requires enormous energy. So respiratory activity of egg increases. Embryo consumes maximum O_2 during gastrula stage.

Method of Gastrulation:

(a) Epiboly: Movement of ectoderm forming blastomere

(b) Emboly: Movement of mesoderm and endoderm forming blastomere.

(a) Epiboly: In epiboly, ectoderm forming blastomere undergoes division to form new blastomere. New blastomeres perform amoeboid movement and cover the embryo from outside. **Epiboly is clearly visible in animal with amphiblastula**. In amphiblastula ectoderm is derived from outer most layer of dividing micromeres.



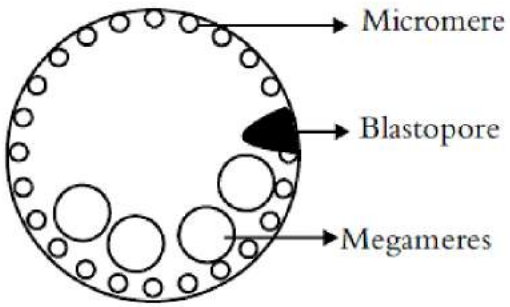
Gastrulation

These micromeres perform amoeboid movement and cover the megamere from outside. Megameres without any movement establish inside the embryo because they are heavily filled with yolk . **At one definite place in embryo micromeres do not perform any movement to cover the megameres this place occurs in the form of depression is called gastrulation slit or future blastopore**. It is formed in grey crescent area.
In some animals there occur special type of epiboly is called Apiauxis. In this process ectoderm forming micromere are received from two sources.
(1) By the division of micromere
(2) By budding of megamere. (Eg-Ctenophora. Annelida, Mollusca and Fishes)

(b) Emboly : Mesoderm and endoderm forming blastomere perform movement and establish inside the
embryo. There are three methods of emboly.
(i) Invagination: Emboly mainly takes place by invagination in animal with simple coeloblastula. In coeloblastula a part of blastoderm invaginate in embryo, as a result blastocoel cavity degenerates and new cavity forms outside to inside called archenteron. **Opening of archenteron is called blastopore**. Archenteron forms alimentary canal .Blastopore forms mouth in protostomia animals and anus in deuterostomia animal. As a result of invagination blastomere which fill the blastocoel form mesoderm and endoderm. Blastomere of outer layer form ectoderm i.e. all the three germinal layer are formed by emboly in coeloblastula. **Epiboly is absent in coeloblastula.**

(ii) Involution : Involution i.e. rolling movement of blastomere. Emboly mainly takes place by involution in animal with amphiblastula. In amphiblastula micromeres move from different directions towards future blastopore,this movement is called **convergence**. After convergence, second step is **involution** (i.e. blastomere perform rolling movement and enter in blastocoel with the help of future blastopore) now all the blastomeres move in different direction in blastocoel, this is called divergence. As a result of divergence blastocoel cavity degenerates and

new cavity called archenteron is formed. **Opening of archenteron is called blastopore.** All the involuted blastomeres are collectively called **'Chorda mesoderm'**. At the end of gastrula, outgrowth occurs in some megamere i.e. megameres evaginate outside and close the blastopore temporarily (yolk-pluge stage) yolkpluge stage indicates completion of gastrulation.



Involution

(3) Poly-invagination or ingression: Emboly mainly takes place by poly-invagination in discoblastula, periblastula.

Gastrulation in discoblastula:

In discoblastula, gastrulation takes place by two methods:

(i) Delamination : In delamination all the blastomere of blastoderm undergoes division. As a result new blastomere form and new blastomere fall on the floor of subgerminal cavity. So embryo become double layered. **Upper layer of blastomere is called epiblast and lower-layer of blastomere is called hypoblast.** Hypoblast differentiates in endoderm.

Delamination- the splitting of one sheet of cells into two parallel sheets of cells

(ii) Polyinvaginations : All the blastomere of epiblast undergo division to form new blastomere and new blastomere fall in sub-germinal cavity form different direction and fill the sub-germinal cavity. **Blastomere which fill the sub-germinal cavity are collectively called chorda-mesoderm.** (chorda mesoderm forms mesoderm) Blastomeres which are left outside i.e. blastomere of epiblast form ectoderm. In such blastulas no new cavity is formed during gastrula stage i.e. archenteron formation does not occur during gastrula stage.

SPECIAL POINTS

1. **The growth phase is the longest phase during male gametogenesis. But in human oogenesis, maturation phase is longest.**
2. The acrosome of sperm are produced by golgibodies.
3. The smallest sperm is of crocodile and its size is 0.02 mm & largest sperm is of Discoglossus (2mm)
4. 74 days are required to complete the cycle of spermatogenesis in human being.
5. **In 1 ml of semen, 20 to 120 millions of sperms are present in human being.**
6. Deficiency in the number of sperms result in sterility which is known as **oligospermia**.
7. Absence of sperms in semen is known as **azoospermia**.
8. Formation of yolk in oogenesis takes place in the growth phase.
9. **Largest egg is of Ostrich (16 cm long with its shell).**
10. Although normal number of sperm are present in semen but if these are completely non motile. This condition is known as necrospermia.
11. Smallest egg in birds is of humming bird.
12. Due to high mortality rate in lower animals, the production of egg is more.
13. Sequence of egg production is as follows.

Mammals < Aves < Reptiles < Amphibian < Pisces.

14 Cat and rabbit both are induced ovulator.
15. The life span of eggs in female reproductive organs in human being is 48 hrs.
16. The nucleus of egg is known as germinal vesicle.
17. **At the age of 45-50 yrs. in female the ovulation process will stop which is known as menopause.**
18. The spermiation (release of sperms from sertoli cells) in all sertoli cells occurs simultaneously.
19. Cortical granules are absent in rat.
20. **Mosaic type of cleavage is found in the parasite *Echinococcus* granulosus.**

Special features of some animals :

(a) Sperms of some animals are not having flagella : eg.
(1) *Ascaris* - sperm is amoeboid
(2) Cray fish - star shaped, tail less sperm
(3) In crab and lobster the sperm are tail less and have three sharp processes.
(b) Biflagellated sperm :
eg. In toad fish ***(Opsansus)*** head of many sperms unite together and form sperm boats.

In Gastropods, the sperms are hexaflagellated.
Smallest sperm - Crocodile (0.02 mm)
Largest sperm - ***Discoglossus*** (2 mm) in chordates and Drosophila in entire animal kingdom.

Shape of head part of sperms :

(i) Spherical - eg Teleostei
(ii) Lance shaped - eg Amphibia and Reptiles
(iii) Spiral end - eg. Birds
(iv) Spoon shaped - eg. Mammals (in man)
(v) Hook like - eg. Rat.

Germinal layers and their derivatives

The following description gives an account of the respective organs formed by the three germ layers. Most of the organs are the product of combination of more than one germ layers.

Organs derived from ectoderm

1. Skin(epidermis) and their pigment cells.
2. Mucosal membrane of lips, cheek, gums, basal portion of mouth, some part of palate, nasal apertures.
3. Lower part of anal canal.

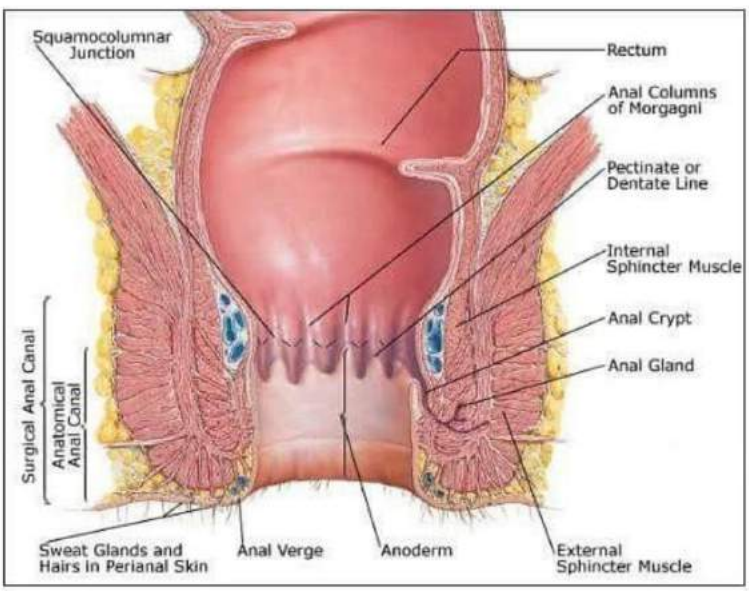


Fig: View of Anal canal

4. Glans penis.
5. Labia majora and outer part of labia minora.
6. Anterior epithelium of cornea, epithelium of conjunctiva, ciliary body and iris of eyes.
7. Outer face of tympanic membrane, epithelium of labyrinth.
8. Glands:

(i) Exocrine-

(A) Sweat glands
(B) sebaceous glands
(C) parotid glands
(D) mammary glands
(E) lacrimal glands;

(ii) Endocrine-

(A) Hypophysis cerebri
(B) adrenal medulla

9. Hairs, nails, enamel of teeth
10. Lens of eyes.
11. Nervous system.

Derivatives of mesoderm

1. Connective tissues, superficial and deep fascia, ligaments, tendons, dermis of skin. (from dermatome)
2. Specialized connective tissues like adipose tissue, reticular tissues, bones, cartilages.
3. Teeth.
4. All muscles.
5. Heart, all blood vessels and blood cells.
6. Kidneys, ureters, urinary bladder, posterior urethra of female, upper glandular part of prostate.
7. Ovaries, uterine tubes.
8. Testes, epididymis, vas deferens and seminal vesicle, ejaculatory duct.
9. Pleural cavities, peritoneal cavity and pericardial cavity.
10. Joints.
11. Cornea, sclera, choroid ciliary body and iris related material.
12. Microglia, duramater etc.

Derivatives of endoderm

1. Epithelial part of mouth, some part of palate, tongue, tonsils, pharynx, oesophagus, stomach, small and large intestine, upper part of anal canal.

2. Pharyngo-tympanic tube, middle ear, inner face of tympanic membrane.
3. Respiratory tract.
4. Gall bladder, pancreatic duct.
5. Major portion of urinary bladder, complete urethra of female except posterior part, complete urethra of male except anterior and posterior part.
6. Whole inner part of vagina including inner face of labia minora.
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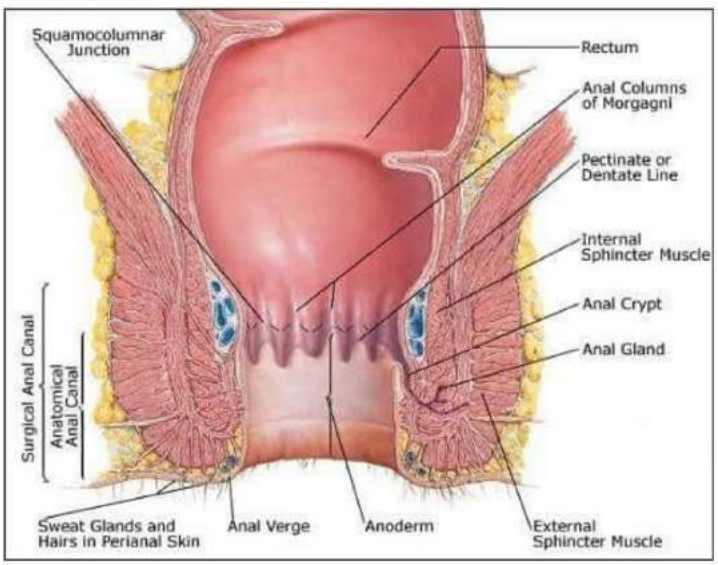

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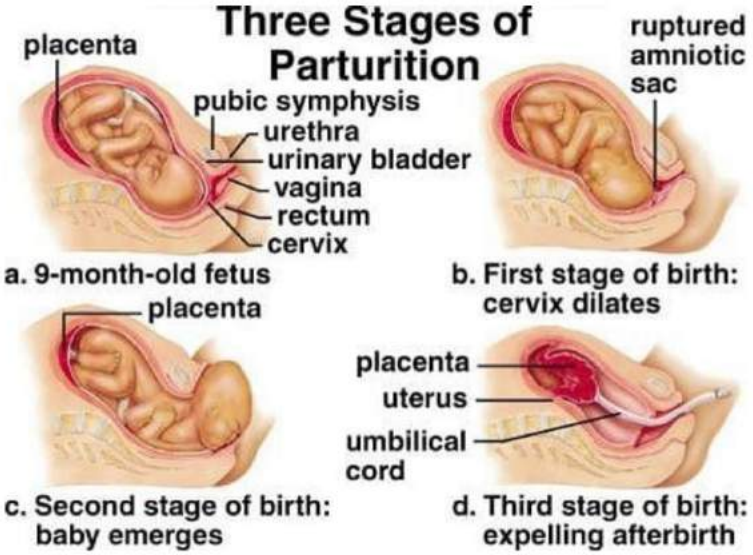
Parturition & Lactation

Parturition

Parturition is a **hormonal process**. Many hormonal changes take place during it.



1. The progesterone secretion stops, so the **placenta dissolves** and the foetus is separated from the walls of the uterus.
2. The pituitary gland secretes **Oxytocin** in more amount. This hormone induces intense contractions in the uterus.
Due to these contractions, the foetus starts moving towards the vagina.
The **labour pain** during child-birth is due to this hormone. **Oxytocin** is the main parturition hormone. After parturition, Oxytocin stimulates milk-let down by **milk ejection reflex.**
3. **Relaxin hormone** is secreted by the placenta and the ovary. This hormone relaxes the **pubic-symphysis** i.e. the joint between the pelvic-girdles. So more space is available to the foetus to move out.

GESTATION PERIOD

1. The time from fertilization to parturition is termed as **gestation-period**. Rabbit has gestation-period of **28-30 days**. In one time 4-6 young-ones are born in rabbit (Maximum = 8). The group of young-ones born at the same time are called **Litter**. At the time of birth, the young ones of a rabbit are blind, deaf and uncovered with fur.

Types of Oestrus, Oestrus cycle length, Gestation period and Act of Parturition in domestic animals

Animal	Type of Oestrus	Oestrus cycle length	Gestation period	Act of Parturition
Cow	Poly estrus	21 days	282 days	Calving
Buffalo	Poly estrus	17-24 days	310 days	Calving
Goat	Seasonal poly estrus	19 days	150 days	Kidding
Sheep	Seasonal poly estrus	17 days	152 days	Lambing
Camel	Seasonal poly estrus	28 days	410 days	Calving
Mare	Seasonal poly estrus	21 days	320-362 days	Foaling
Sow	Poly estrus	21 days	115-122 days	Farrowing
Bitch	Mono estrus	6-7 months	62-64 days	Whelping

2. They become normal in next 4-5 days. The young-ones of Hare are normal at the time of birth. In humans, the actual gestation period is **9 months+7 days**.
3. In human expected date of delivery (**EDD**) = Ist day of last menstrual cycle+ 9 months + 7 days.

What is Lactation?

"Lactation is the process of milk secretion from the mammary glands of a female after childbirth."

Lactation is the process of milk secretion from the mammary glands of a mother soon after childbirth. The milk, thus produced provides nutrition and immunity to the young one. Galactopoiesis is the stage that maintains milk production and requires prolactin and oxytocin.

Preparation for Lactation

The female is ready to produce milk during the fifth or sixth month of pregnancy. During the later stages of pregnancy, the female enters the first stage of lactogenesis. At this stage, the breasts make colostrum, a thick, yellow fluid, also known as the first milk a baby receives.Colostrum is highly rich in immunoglobulin A that boosts the immunity of the newborn. It prevents any pathogens from invading the baby's body and also prevents food allergies.

Lactation Process

1. Due to the impact of ovarian hormones and placental hormones, breast growth begins during the period of pregnancy and it continues to get larger in size after the childbirth.
2. During this period, a certain amount of milk is produced in the breast.
3. The milk secretion increases only after the baby's birth.
4. During the process of lactation, the milk is secreted from the mammary glands.

Lactation Hormones

- Usually hormones like estrogen, placental lactogenic, progesterone, prolactin and oxytocin are involved in the process of lactation.
- Estrogen hormone helps in increasing the size of the breast during pregnancy causing the growth of breast tissue.
- The presence of a placental lactogenic hormone is higher during pregnancy as this hormone helps in stimulating the growth of the nipple, areola and breast tissue.
- Progesterone hormone helps in increasing the size of the breast tissue along with boosting milk production. During the post-pregnancy period, the progesterone hormone level tends to decrease, which stimulates milk production.
- Prolactin hormone helps in differentiating the cells that perform their own specific functions. The alveoli, which is responsible for producing milk after the baby's birth is active mainly because of the prolactin hormone. The prolactin hormone is produced once exposed to cortisol hormone.
- Once the nipples are stimulated, the oxytocin hormone is released, causing the alveoli to contract. These help in squeezing the milk out into the duct system. The entire process is called as a letdown. The letdown process begins only when the nerves of breasts are stimulated.

Can Lactation Happen without Pregnancy?

There are three hormones, which play an important role in stimulating the milk production in mammary glands of a lactating mother. Consuming medicines of these three hormones in the form of supplements would help women to produce breast milk in their mammary glands without pregnancy.

There are certain other natural tendencies were lactation happens without pregnancy. These include:

1. Imbalance of hormone.
2. Side effects from drugs/medicines.
3. Health disorders.
4. Nerve irritation in the breast region.
5. Overproduction of prolactin hormone in the brain.

Properties of milk

1. The milk produced in an initial stage of lactation varies from the milk after maturation viz. produced when lactation is well established.
2. The early milk produced in the initial stage of lactation is known as colostrum.
3. The composition of milk changes gradually after childbirth. The colostrum changes to transitional milk within four-five days from the childbirth.
4. After 14 to 15 days of childbirth, matured milk is produced in mammary glands.

The termination of lactation slowly stops with the reduced demand from the baby.