Chapter 2

Human Reproduction

Chapter Contents

Introduction

Humans are sexually reproducing and viviparous organisms. Their reproductive events include formation of gametes **(gametogenesis)**, i.e., sperms in males and ovum in females, transfer of sperms into the female genital tract **(insemination)** and fusion of male and female gametes **(fertilisation)** leading to formation of zygote. This is followed by formation and development of blastocyst and its attachment to the uterine wall **(implantation)**, embryonic development **(gestation)** and delivery of the baby **(parturition)**. You have learnt that these reproductive events occur after puberty. There are remarkable differences between the reproductive events in the male and in the female, for example, sperm formation continues even in old men, but formation of ovum ceases in women around the age of fifty years.

THE MALE REPRODUCTIVE SYSTEM

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

Did You Know?

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

The Testes

The testes are situated outside the abdominal cavity within a pouch called **scrotum**. The scrotum helps in maintaining the low temperature of the testes (2 – 2.5°C lower than the normal internal body temperature), which is necessary for spermatogenesis. The slightly cooler temperature of the scrotum is necessary for the development of normal sperm. The testes start their development in the abdominal cavity. But during the 7th month of the foetal life, they descend into the scrotal sacs in presence of testosterone hormone. Hence, the testes of human males are extra-abdominal. If they fail to descend, this condition is called **cryptorchidism** that leads to sterility. Scrotum remains connected with the abdomen or pelvic cavity by the **inguinal canal**. Blood vessels, nerves and conducting tubes pass through it. **Cremaster muscles** and connective tissues form spermatic cord and surround all structures passing through inguinal canal. Cremaster muscles and **dartos muscles** of the scrotal sac help in the positioning of testes. Whenever the outside temperature is low, these contract to move the testes close to the abdominal or pelvic cavity. When outside temperature is high, these relax moving the testes away.

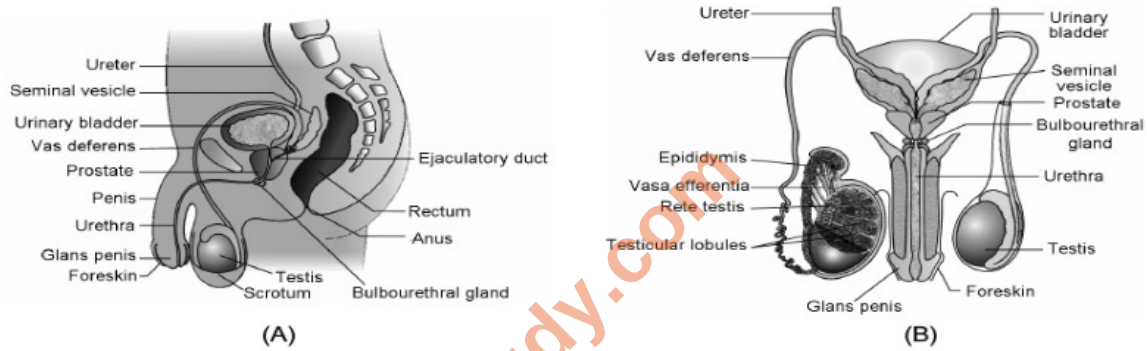


Fig. : (A) Diagrammatic sectional view of male pelvis showing reproductive system, (B) Diagrammatic view of male reproductive system (part of testis is open to show inner details)

Did You Know?

1. **Gubernaculum :** A fibrous cord that extends from caudal end of epididymis to scrotal wall.
2. **Inguinal canal :** Oblique passage through the lower abdominal wall. In males, it is the passage through which the testes descend into the scrotum and contains the spermatic cord.
3. There are certain mammals in which the testes remain permanently in the abdomen and does not cause any defect. Examples are elephant, aquatic mammals like whales, dolphins, seal and prototherians or egg laying mammals like *Ornithorhynchus*.
4. In mammals which breed seasonally, the testes descend into scrotum only during the breeding season, example bat and otter.

In adults, each testis is oval in shape, with a **length** of about **4 to 5 cm** and **width** of about **2 to 3 cm**. The testis is covered by a dense covering. They are enclosed in an outer tough capsule of collagenous connective tissue, the **tunica albuginea**. Each testis has about 250 compartments called **testicular lobules**, these compartments contain highly coiled tubules called **seminiferous tubules**.

Each lobule contains one to three **seminiferous tubules** in which the sperms are produced. Each seminiferous tubule is lined on its inside by two types of cells called **male germ cells** (spermatogonia) and **Sertoli cells**. Spermatogonia lining these tubules give rise to spermatozoa which are released into the lumen of the tubule.

In between spermatogenic cells, Sertoli or **sustentacular** or nurse cells are present which provide nourishment to developing spermatozoa and regulate spermatogenesis by releasing **inhibin** to check FSH over-activity. The other functions of sertoli cells are

(i) To absorb the parts being shed by developing spermatozoa.

(ii) To release anti mullerian factor (AMF) to prevent development of mullerian duct/oviduct in male.

(iii) To release Androgen Binding Protein (ABP).

(iv) To form blood-testis barrier.

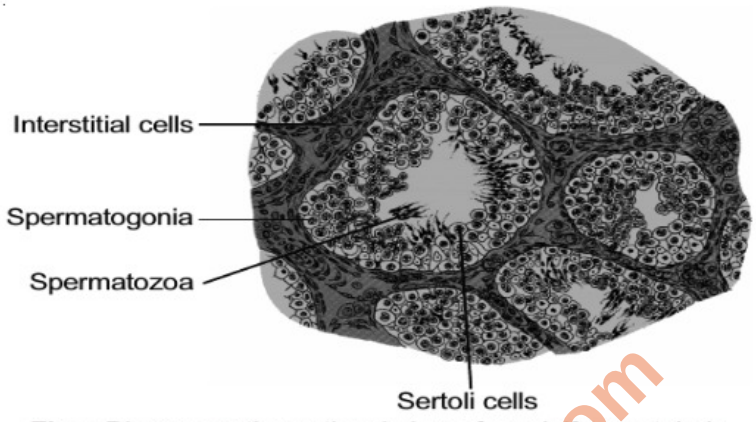


Fig. : Diagrammatic sectional view of seminiferous tubule

Did You Know?

Castration is removal of testes. It causes failure of development of secondary sex organs and characters and remove the ability to reproduce due to deficiency of testosterone. Choir boys were often castrated in medieval Europe to retain their high-pitch voice for singing. Castration often changes the aggressive bull into a docile ox. The latter lacks the male character of aggressiveness due to deficiency of testosterone. The docile ox can be conveniently used for ploughing and drawing of bullock carts. **Mullerian ducts** (or **paramesonephric ducts)** are paired ducts of the **embryo.** In the female, they develop to form the **Fallopian tubes, uterus, cervix** and the upper portion of the **vagina;** in the male, they degenerate. These ducts are made of tissue of **mesodermal** origin.

The **Wolffian duct** (also known as **archinephric duct, Leydig's duct, mesonephric duct,** or **nephric duct**) is a paired **organ** found in mammals including **humans** during **embryogenesis.** It connects the primitive kidney **Wolffian body** (or mesonephros) to the **cloaca.** In male, the Wolffian duct develops into the **trigone of urinary bladder,** a part of the bladder wall and vas deferens and in female the Wolffian duct develops into the **trigone of urinary bladder,** a part of the bladder. However, further development differentiates between the sexes in the **development of the urinary and reproductive organs.**

Groups of polyhedral cells called **Interstitial cells of Leydig**, are located in the connective tissue around the seminiferous tubules. They constitute the endocrine tissue of the testis. Leydig cells synthesise and secrete testicular hormones called **Androgens** into the blood. Seminiferous tubules unite to form several straight tubules called **tubuli recti** which open into irregular cavities in the posterior part of the testis which is a highly anastomosing labyrinth of cuboidal epithelium lined channels called **rete testis**. Several tubes called vasa efferentia arise from it and conduct spermatozoa out of the testis. Tubuli recti, rete testis and ductuli efferentes form the **intra-testicular genital duct system**.

The **extratesticular duct system** consists of tubes which conduct sperms from the testes to the outside. It starts with ducts known as vasa efferentia. From each testis, 10-12 vasa efferentia confluent to form a folded and coiled tube called **epididymis** behind each testis. The epididymis consists of three parts: (i) **Caput** (ii) **Corpus** (iii) **Cauda.**

The epididymis stores the sperms temporarily. From cauda epididymis, a partially coiled tube called **vas deferens** ascends into the abdomen through inguinal canal, passes over the urinary bladder, the ductus deferens/vas deferens dilates to form ampulla, which receives the duct from the seminal vesicle behind the urinary bladder and forms an **ejaculatory duct**. The final portion of ampulla passes through the prostate to open into the urethra shortly after its origin from the urinary bladder.

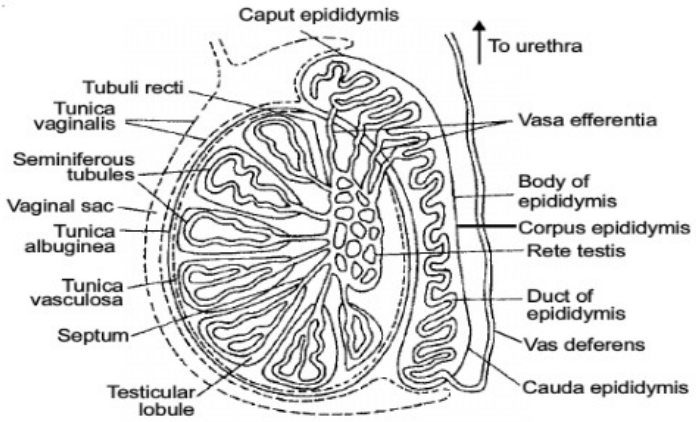


Fig. : Structure of Testis

Urethera : Male urethera provides a common pathway for the flow of urine and semen. It is much longer in male than in female, measuring about 20 cm.

(i) First part is surrounded by prostate gland and is called prostatic/glandular part of urethera.

(ii) Membranous urethera is the second part which is situated behind the lower part of pubic symphysis and is smallest.

(iii) Penile urethra is situated in the penis and is the longest part.

The urethra receives the ducts of the prostate and Cowper's glands, passes through the penis and opens to the outside.

Penis : This is the **copulatory organ** of man. It is a cylindrical, erectile, pendulous organ suspended from pubic region in front of scrotum. It remains small and limp (flaccid) but on sexual arousal, it becomes long, hard and erect, ready for copulation (coitus or intercourse). Erect human penis is, on an average, about 15 cm long.

The penile mass is itself encased in a fibrous sheath, called **tunica albuginea.** The interior of the penis is formed of three cylindrical cords of spongy, erectile (cavernous) tissues. Two of these cords are thicker and situated parallely on right and left sides, forming the thick part of penis that remains in front when penis is limp, but become superio-posterior when penis is erect. These two cords are called **corpora cavernosa.** The fibres of tunica albuginea surround both the cords jointly and also form a separate sheath around each cord. Some fibres form a partition called **septum penis** between these cords. The third, smaller cord forms that part of penis which remains inferio-anterior in erect penis. Urethra runs through this cord. Hence, this cord is called **corpus urethrae** or **spongiosum.**

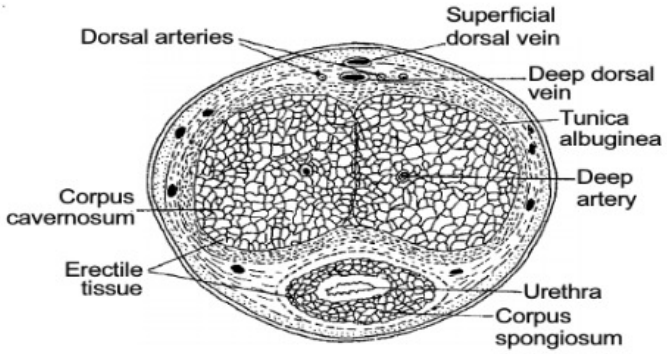


Fig. : T.S. of Penis

The extended part of corpus spongiosum is enlarged, forming a bulging, conical structure called **glans penis.** The surface of glans is formed of thin, smooth and shiny, hairless skin. The base line of glans is referred to as the **neck** of the penis. The loose skin of penis becomes folded here to form a loose, retractile skin covering upon the glans, called **foreskin or prepuce**. At the tip of glans penis is the slit like **external urethral orifice** or **meatus** by which urethra opens out and discharges urine or semen.

Tyson's gland or Preputial glands, present in the skin of penis neck, secrete a white sebaceous substance called **smegma.** Microbial infection in smegma can cause irritation due to inflammation.

Accessory Glands of male

1. **Seminal vesicles :** These are paired, tubular, coiled glands situated behind the bladder. They secrete viscous fluid which constitutes the main part of the ejaculate. Seminal fluid contains fructose, citric acid, inositol and prostaglandins.
2. **Prostate gland :** The prostate gland is a chestnut shaped gland and is a collection of 30-40 tubuloalveolar glands which lie at the base of the bladder and surrounds the first part of the urethra. It contributes an alkaline component to the semen. (Although, the alkalinization of semen is primarily accompalished through secretion from the seminal vesicles.)

   The alkaline secretions of prostate gland help the sperms to become active and counteract any adverse effects that the urine may have on the sperms. The prostatic fluid provides a characteristic odour to the seminal fluid. Prostate gland secretes citrate ions, calcium, phosphate ions and profibrinolysin.

   Prostatitis : Inflammation of prostate gland.
3. **Bulbourethral glands or Cowper's glands :** The two bulbourethral glands are pea sized structures lying adjacent to the urethra at the base of penis. They secrete a viscous mucus which acts as a lubricant.

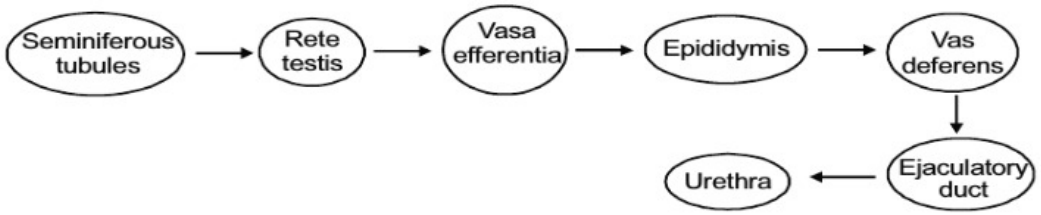
   The duct system, accessory glands and penis are secondary male sex organs. Their growth, maintenance and functions are promoted by testosterone, secreted by **Leydig cells**. On the other hand, the growth, maintenance and functions of **seminiferous tubules** and **Leydig cells** are regulated respectively by **FSH** and **ICSH** of anterior pituitary.

Semen

Semen is a mixture of sperms and seminal fluid, which is the liquid portion of semen that consists of secretions of the seminiferous tubules, seminal vesicles, prostate gland and bulbourethral glands. The average volume of semen in an ejaculation is 2.5 – 5 ml, with a sperm count (concentration) of 200 to 300 million sperms. Out of these sperms, for normal fertility, atleast 60 percent sperms must have normal shape and size and atleast 40 percent of them must show vigorous motility. When the number of sperms falls below 20 million/ml, the male is likely to be infertile.

Semen has a slightly alkaline pH of 7.2-7.7, due to the higher pH and larger volume of fluid from the seminal vesicles. The prostatic secretion gives semen a milky appearance whereas the fluids from the seminal vesicles and bulbourethral glands give it a sticky consistency. Semen provides sperms with transportation medium and nutrients. It neutralizes the hostile acidic environment of the male urethra (due to presence of urine) and the female vagina.

Path of Sperm through the Male Body



Delivery of Sperm : The urethra passes through the penis, an erectile copulatory organ that deposits the semen in the female reproductive tract. The penis is the male external genitalia, made up of three cylinders of special spongy tissue. Filling of blood in these tissue helps in erection of the penis that facilitate insemination. The enlarged end of the penis is called the **glans penis**, covered with a loose fold of skin called **foreskin** or **prepuce**. Semen is forcefully expelled from the penis by the contractions of smooth muscles that line the urethra. This process is ejaculation.

Example 1 : *Which of the following is not present in testicular lobule?*

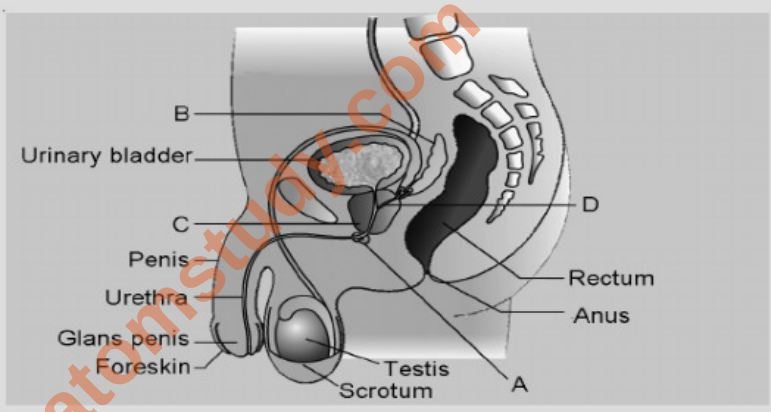
(1) Seminiferous tubules *(2) Leydig cells*

(3) Sertoli cells *(4) Theca cells*

Solution : (4) Theca cells

Try Yourself

1. Given below is a diagrammatic sectional view of male pelvis showing reproductive system. Select the correct set of names labelled A, B, C and D.



	A	B	C	D
(1)	Prostate gland	Bulbourethral gland	Vas deferens	Seminal vesicle
(2)	Bulbourethral gland	Seminal vesicle	Prostate gland	Ejaculatory duct
(3)	Bulbourethral gland	Prostate gland	Seminal vesicle	Ejaculatory duct
(4)	Prostate gland	Bulbourethral gland	Seminal vesicle	Ejaculatory duct

2. If the vas deferentia of both the sides is cut and tied by thread, then what would happen?

A. This will prevent gamete formation

B. This will block gamete transport and thereby prevent conception

C. Semen is without sperms

D. The production of testosterone will stop

Which of the following option is correct?

(1) A & D only (2) A & B only

(3) B & C only (4) B, C & D only

EXERCISE

1. Temperature in scrotum necessary for sperm formation should be
   (1) 2°C above body temperature (2) 2°C below body temperature
   (3) 8°C above body temperature (4) 8°C below body temperature
2. Cryptorchidism is
   (1) Non-development of testes (2) Nondescent of testes into scrotum
   (3) Removal of scrotum (4) Breaking connection of vas deferens
3. Tubuli recti of seminiferous tubules open into
   (1) Epididymis (2) Vasa efferentia
   (3) Vasa deferentia (4) Rete testis
4. Common duct formed by the union of vas deferens and duct of seminal vesicle is
   (1) Urethra (2) Tunica vasculosa
   (3) Ejaculatory duct (4) Spermatic duct
5. Accessory glands of male reproductive system are
   (1) Prostate and seminal vesicles
   (2) Prostate, Bartholin's and seminal vesicles
   (3) Seminal vesicles and Bartholin's
   (4) Prostate, Cowper's and seminal vesicles
6. Scrotal sacs of man are connected with the abdominal cavity by
   (1) Inguinal canal (2) Haversian canal
   (3) Spermatic canal (4) Rete testis
7. Sperms are stored and nourished inside
   (1) Cowper's gland (2) Epididymis
   (3) Seminiferous tubules (4) Vasa efferentia
8. Role of Leydig cells of testis is
   (1) Provide nourishment to sperms (2) Provide motility to sperms
   (3) Bring about maturation of sperms (4) Synthesis of testosterone hormone
9. Vas deferens arises from
   (1) Cauda epididymis (2) Caput epididymis
   (3) Corpus epididymis (4) Rete testis
10. Epididymis is
   (1) Network of sinuses between seminiferous tubules and vasa efferentia
   (2) Intermediate structure between rete testis and vasa efferentia
   (3) A long coiled tube between vasa efferentia and vas deferens
   (4) Connection between vas deferens and seminal vesicle

THE FEMALE REPRODUCTIVE SYSTEM

The female reproductive system consists of a pair of **ovaries**, a **duct system** consisting of a pair of fallopian tubes (oviducts), a uterus, cervix and vagina. A pair of **mammary glands** are accessory **genital glands.**

Ovaries

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

1. **Location :** Ovaries are located near kidneys and remain attached to the lower abdominal cavity through **mesovarium**.

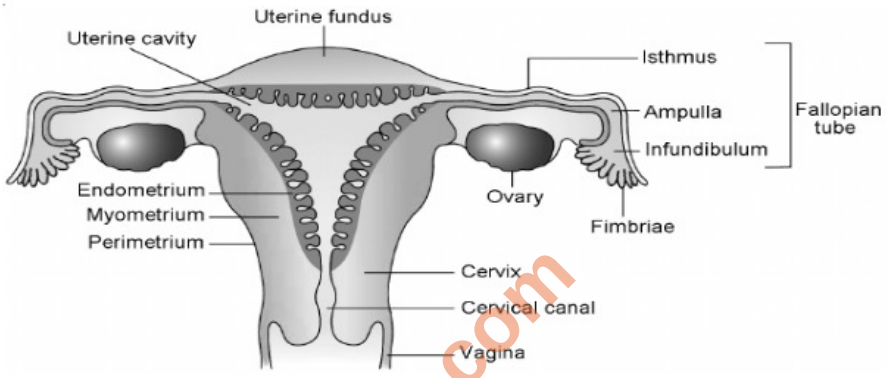


Fig. : Diagrammatic sectional view of the female reproductive system

2. **Structure :** The free surface of the ovaries is covered by a **germinal epithelium** composed of a single layer of cubical cells. This epithelium is continuous with the mesothelium lining called **peritoneum.** The epithelium encloses the ovarian stroma. The stroma is divided into two zones—a peripheral cortex and an inner medulla. Immediately below the germinal epithelium, the cortex is covered by a connective tissue called **tunica albuginea**.

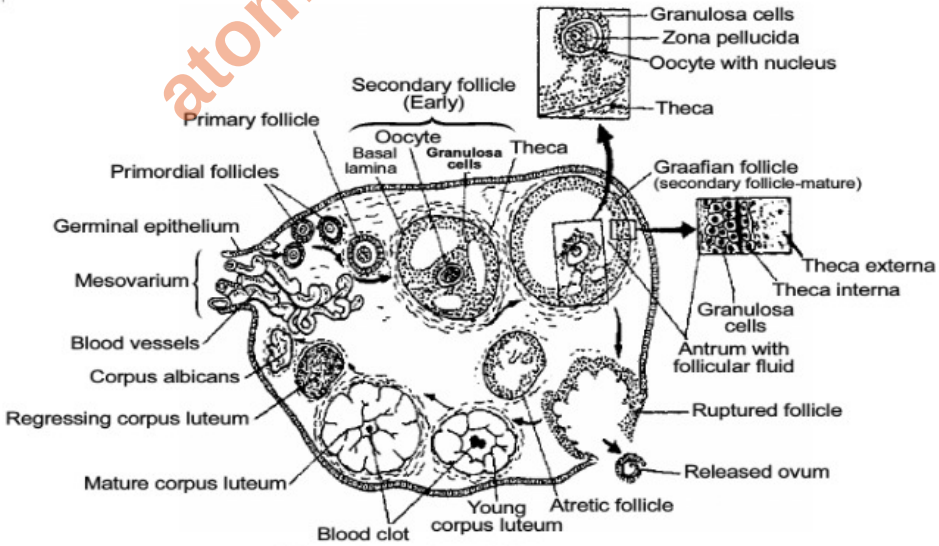


Fig. : A section of human ovary

The **cortex** contains numerous spherical or oval, sac-like masses of cells known as **ovarian follicles**. The **medulla** consists of loose connective tissue, elastic fibres, numerous blood vessels and some smooth muscle fibres.

Internal Structure :

(a) **Ovarian follicle :** The ovarian follicle contains a large, centrally placed ovum, surrounded by several layers of granular cells (**follicular granulosa** or discus proligerus or cumulus oophorus). It is suspended in a small cavity called the antrum. Antrum is filled with a fluid known as **liquor folliculi**. The secondary oocyte in the tertiary follicle also forms a new membrane called **zona pellucida**. The follicle bulges onto the surface of the ovary. Such a follicle is called the mature **Graafian follicle** (after **de Graaf**, who reported them in 1672 and considered them to be eggs).

(b) **Corpus luteum :** The ovum is shed from the ovary by rupture of the follicle. The shedding of the ovum is called **ovulation** and occurs nearly 14 days before the onset of the next menstrual cycle.

After the extrusion of the ovum, what remains in the Graafian follicle is called **corpus luteum (yellow body)**. The cytoplasm of the corpus luteum is filled with a yellow pigment called **lutein**. The corpus luteum grows for a few days and if the ovum is fertilized and pregnancy results, it continues to grow. But if the ovum is not fertilized, the corpus luteum persists only for about 14 days and during this period, it secretes progesterone and small amount of estrogen. At the end of its functional life, the corpus luteum degenerates and is converted into a mass of fibrous tissue called **corpus albicans (white body)**.

Fallopian Tubes (Oviducts)

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

(i) **Infundibulum :** The part of oviduct closer to the ovary is the funnel shaped infundibulum. The edges of infundibulum possess finger-like projections called fimbriae. Fimbriae help in the collection of the ovum after ovulation. Infundibulum opens into the abdominal cavity by an aperture called ostium.

(ii) **Ampulla :** The infundibulum leads to a wider part of the oviduct called ampulla.

(iii) **Isthmus :** It is the last and narrow part having narrow lumen that links to the uterus.

The tube is involved in conduction of the ovum or zygote towards the uterus by peristalsis and ciliary action. It is also the site of fertilization. (Fertilization occurs **at the junction of ampulla and isthmus**).

Uterus (Hystera/Womb)

It is a large hollow, muscular, highly vascular and inverted pear shaped structure present in the pelvis between the bladder and rectum. It is suspended by a mesentery, the **mesometrium**. It has the following three parts.

(i) **Fundus :** It is upper, dome-shaped part above the opening of fallopian tubes.

(ii) **Corpus/Body :** It is the middle and main part of uterus.

(iii) **Cervix :** It is lower, narrow part which opens in body of uterus by **internal os** and in vagina below by **external os**. **It is mainly formed of the most powerful sphincter muscles in the body.** The cavity of the cervix is called **Cervical canal** which along with vagina forms the **birth canal.**

Wall of uterus : The wall of uterus is formed of outer peritoneal layer, **perimetrium;** middle muscular **myometrium** of smooth muscle fibres, and inner highly vascular and glandular **endometrium**. The endometrium undergoes cyclical changes during menstrual cycle while myometrium exhibits strong contractions during delivery of the baby. Implantation of embryo occurs in uterine fundus.

It is the site of foetal growth during pregnancy. It also takes part in placenta formation and expulsion of the baby during parturition.

Vagina

It is a long (8.5 cm), fibro-muscular tube. It extends backward in front of rectum and anal canal from cervix to the vestibule. It is a highly vascular tube lined internally by mucus membrane which is raised into transverse folds called vaginal rugae. It is lined with stratified squamous epithelium (Non Keratinised). Vagina is devoid of glands. Vaginal orifice is covered partially by a membranous diaphragm called **hymen**. The hymen is often ruptured during the first coitus (intercourse). However, it can also be broken by a sudden fall or jolt, insertion of a vaginal tampon, active participation in some sports like horseback riding, cycling etc. In some women the hymen persists even after coitus, In fact, the presence or absence of hymen is not reliable indicator of virginity or sexual experience.

Vagina acts both as **copulation canal** (as it receives the sperms from penis during copulation) and as **birth canal** along with cervix (during parturition).

External Genitalia

The external genital structures of the female reproductive system are collectively called the **vulva**. The female external genitalia or vulva includes mons pubis, labia majora, labia minora, hymen and clitoris. **Mons pubis** is a cushion of fatty tissue covered by skin and pubic hair. The **labia majora** are fleshy folds of skin, which extend down from mons pubis and surround the vaginal opening. The **labia minora** are paired folds of tissue in the form of lips under the **labia majora**. The opening of vagina is often covered partially by a membrane called **hymen**. The clitoris is a tiny finger-like structure which lies at the upper junction of the two labia minora above the urethral opening. It is formed of two erectile bodies and is covered by skin fold called **prepuce**. It has a depression, the vestibule, in front of anus. Vestibule has **two apertures–upper external urethral orifice** and lower **vaginal orifice**.

Vestibule is bounded by two pairs of moist skin folds called **labia minora** and **labia majora. Labia majora is homologous to scrotum.** Labia minora fuse anteriorly to form a skin fold called **prepuce** in front of a small erectile organ, the **clitoris** which is homologous to penis as both are supported by corpora cavernosa. Labia minora also fuse posteriorly to form a membranous fold called **fourchette**. The area between the fourchette and the anus is called **perineum**. There is fleshy elevation above the labia majora and is known as **mons veneris (mons pubis)** which has pubic hair.

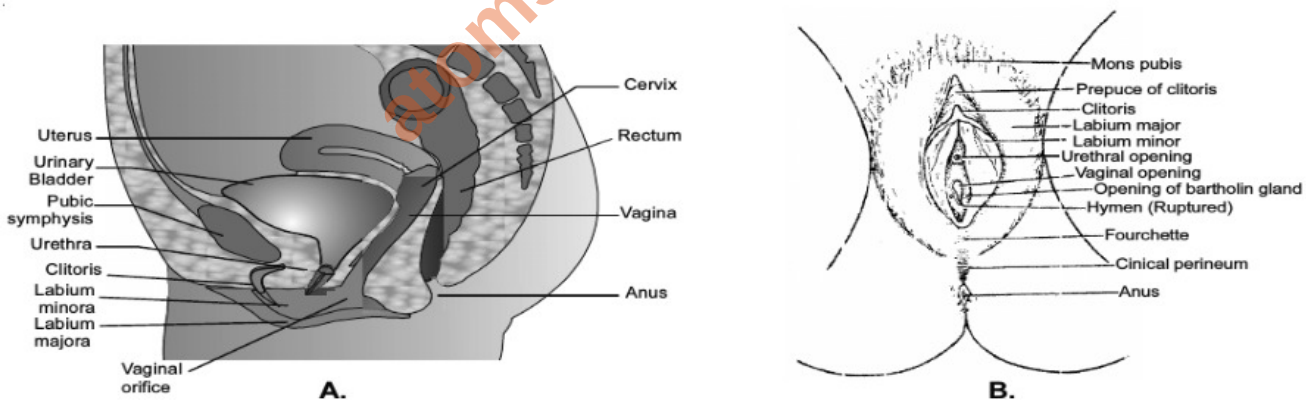


Fig. : A. Female pelvis showing reproductive system, **B.** The external genitalia in the female

Accessory Glands

Vestibular Glands : These are of two types-greater and lesser. Greater vestibular or **Bartholin's** glands are a pair of small reddish yellow glands on each side of vaginal orifice and secrete alkaline secretion for lubrication and neutralising urinary acidity. **Lesser vestibular glands** or paraurethral or **skene's** glands are small mucus glands present between urethral and vaginal orifices.

Mammary Glands/Breasts

There are a pair of rounded prominences present over the pectoralis major muscles on the front wall of the thorax. These remain in rudimentary form in male. In females, these remain undeveloped till puberty. At puberty, these start developing under the influence of oestrogen and progesterone hormones. On the external side, each breast has a projection, the 'nipple' surrounded by rounded hyperpigmented area called areola and appear deep pink or light brown. On the surface of the areola, numerous sebaceous glands, called areolar glands are present.

Internally, the breast consists of the glandular tissue forming mammary glands, the fibrous tissue (connective tissue) and the fatty or adipose tissue. Mammary glands are modified sweat glands.

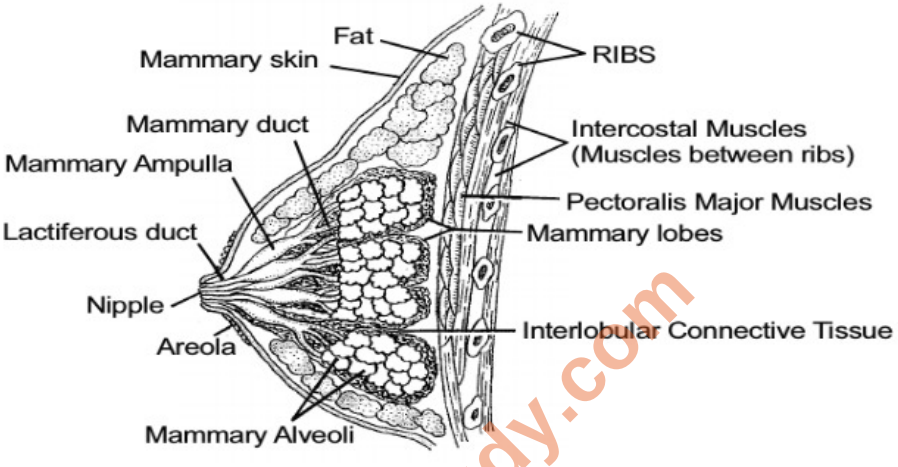


Fig. : Female's Breast in Sagittal Section

(a) The **glandular tissue** comprises about 15-20 lobes in each breast. Each lobe is made up of a number of **lobules**. Each lobule is composed of grapelike clusters of milk secreting glands termed **alveoli.** When milk is produced it passes from the alveoli into the **mammary tubules** and then into the **mammary ducts**. Near the nipple, mammary ducts expand to form **mammary ampullae** (= **lactiferous sinuses**) where some milk may be stored before going to **lactiferous ducts**. Each lactiferous duct typically carries milk from one of the lobes to exterior.

Mammary alveoli → Mammary tubule → Mammary duct → Mammary ampulla → Lactiferous duct.

(b) The **fibrous tissue** (connective tissue) supports the alveoli and the ducts.

(c) The **fatty** or **adipose tissue** is found between the lobes and covers the surface of the gland. The amount of the adipose tissue determines the size of the breasts.

Main functions of the mammary glands are secretion and ejection (release) of milk. These functions are called **lactation**. Lactation is associated with pregnancy and child birth. Milk production is stimulated largely by the hormone **prolactin** secreted by anterior lobe of the pituitary gland. The ejection of milk is stimulated by the hormone **oxytocin,** released from the posterior lobe of the pituitary gland.

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, phosphorus, etc) and vitamins. Milk is poor in iron content. Vitamin C is present in very small quantity 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.

Example 2 : *The wall of the uterus has three layers of tissue. The layer which undergoes cyclical changes during menstrual cycle is*

(1) Perimetrium

(2) Myometrium

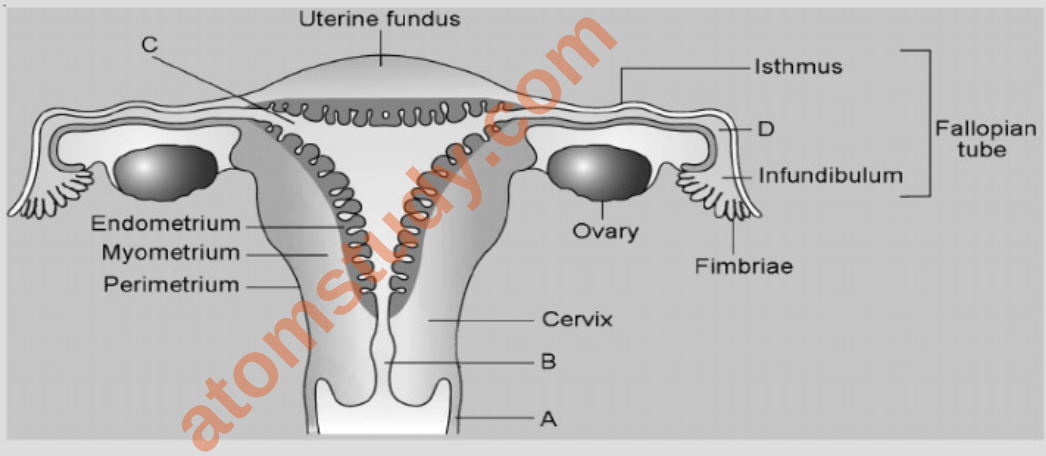
(3) Endometrium

(4) Both (2) & (3)

Solution : (3) Endometrium

Try Yourself

3. Locate the point at which sperms enter the female reproductive system illustrated in the figure given below :



Choose the correct option :

(1) A : Vagina

(2) B : Cervical canal

(3) C : Uterine cavity

(4) D : Ampulla

4. Ovum released from ovary and is transported to the fallopian tube for fertilisation. Trace the correct path the egg and embryo takes from ovary to uterus.

(1) Ovum → Abdominal cavity → Ampulla → Isthmus → Infundibulum → Uterus

(2) Ovum → Abdominal cavity → Infundibulum → Ampulla → Isthmus → Uterus

(3) Ovum → Abdominal cavity → Isthmus → Ampulla → Infundibulum → Uterus

(4) Ovum → Abdominal cavity → Fimbriae → Isthmus → Ampulla → Uterus

EXERCISE

11. Mesovarium is the peritoneal covering of
    (1) Ovary (2) Testis
    (3) Kidney (4) Liver
12. Ostium is an aperture present in
    (1) Ampulla part (2) Fallopian funnel
    (3) Ovisac (4) Cloaca
13. Lower narrow end of uterus is called
    (1) Urethra (2) Cervix
    (3) Clitoris (4) Vulva
14. Which group represents external genitalia of human female?
    (1) Labium minora, labium majora, vagina (2) Labium majora, labium minora, oviduct
    (3) Labium minora, labium majora, cervix (4) Labium majora, labium minora, clitoris
15. Layers of ovum from outside to inside are
    (1) Corona radiata, zona pellucida, vitelline membrane
    (2) Zona pellucida, corona radiata, vitelline membrane
    (3) Vitelline membrane, zona pellucida, corona radiata
    (4) Zona pellucida, vitelline membrane, corona radiata
16. In human females, ova are produced in
    (1) Ovary (2) Oviduct
    (3) Uterus (4) Vagina
17. Hormone responsible for ovulation and development of corpus luteum is
    (1) FSH (2) LH
    (3) LTH (4) ICSH
18. When egg is not fertilised, yellow coloured corpus luteum degenerates to form
    (1) Corpus albicans (2) Corpus callosum
    (3) Corpora bigemina (4) Corpora quadrigemina
19. In the absence of pregnancy, corpus luteum
    (1) Becomes active and secretes FSH and LH
    (2) Produces a lot of oxytocin and relaxin
    (3) Degenerates after some time
    (4) Is maintained by progesterone
20. Egg is liberated from ovary and enters the fallopian tube in
    (1) Secondary oocyte stage (2) Primary oocyte stage
    (3) Oogonial stage (4) Mature ovum stage

GAMETOGENESIS

The primary sex organs – the testis in the males and the ovaries in the females, produce gametes *i.e.* sperms and ovum respectively, by the process called **gametogenesis**.

Spermatogenesis

In testis, the immature male germ cells, spermatogonia produce sperms by a process spermatogenesis that begins at puberty. Spermatogenesis occurs in four stages: (i) **Spermatocytogenesis**, (ii) **Meiosis-I**, (iii) **Meiosis-II** and (iv) **Spermiogenesis**.

(i) Spermatocytogenesis : In spermatocytogenesis, the **spermatogonia** present on the inside wall of the seminiferous tubules multiply by mitotic division and increase in numbers. Each **spermatogonia** is **diploid** containing **46 chromosomes**. Some spermatogonia undergo changes they grow, increase in size by accumulating nourishing materials and are called **primary spermatocytes** which periodically undergo meiosis and others remain as **spermatogonia**.

(ii) Meiosis-I : A primary spermatocyte is diploid, (2n) with 44 + XY (total 46) chromosomes. It completes the first meiotic division (reduction division) leading to the formation of two equal, haploid cells called **secondary spermatocytes**, which have only 23 chromosomes each *i.e.* 22 + X or 22 + Y.

(iii) Meiosis-II : The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid spermatids. The number of chromosomes in each spermatid is 23.

(iv) Spermiogenesis : Transformation of spermatid into sperm is **termed spermiogenesis**. A spermatid is non-motile and heavy. It has organelles like mitochondria, Golgi bodies, centrioles, nucleus etc. During spermiogenesis, the weight of gamete is reduced along with the development of locomotory structures. Nucleus becomes compact forming the major part of head of spermatozoa. **Golgi complex of spermatid gives rise to acrosome**. **The two centrioles of the spermatids become arranged one after the other behind the nucleus**. **Mitochondria** from different parts of spermatid get arranged in **the middle piece around axial filament**. Much of the cytoplasm of a spermatid is lost. It forms a thin layer around middle piece. A typical mammalian sperm is flagellated, consisting of four parts namely **head**, **neck**, **middle piece** and **tail**. The human sperm was first seen by **Hamm** and **Leeuwenhoek**. After spermiogenesis the sperm heads become embedded in the **Sertoli cellls**, and are finally released from the seminiferous tubules by the process called **spermiation**.

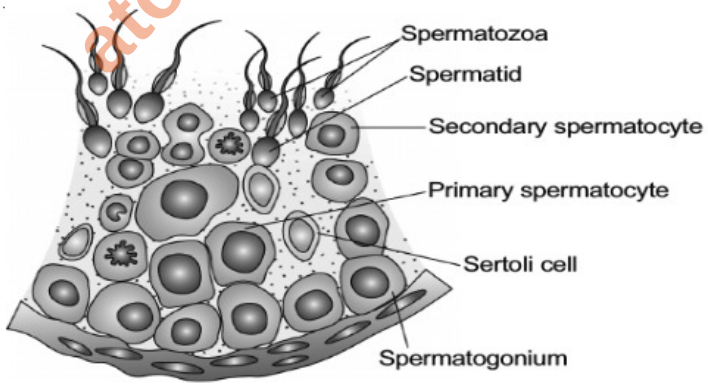


Fig. : Diagrammatic sectional view of a seminiferous tubule

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

Hormonal Control of Male Reproductive System : Spermatogenesis starts at the age of **puberty** due to significant increase in the secretion of gonadotropin releasing hormone (GnRH) from hypothalamus. The increased levels of GnRH then acts at the **anterior pituitary** gland and stimulates secretion of two gonadotropins – **luteinising hormone** (LH) and follicle **stimulating hormone** (FSH). LH acts at the Leydig cells and stimulates

synthesis and secretion of androgens. Androgens, in turn, stimulate the process of spermatogenesis. FSH acts on the Sertoli cells and stimulates secretion of some factors which help in the process of **Spermiogenesis**. Sertoli cells also secrete another protein, hormones called **inhibin**, which suppresses FSH synthesis. So, FSH along with testosterone stimulate the sperm production in the seminiferous tubules.

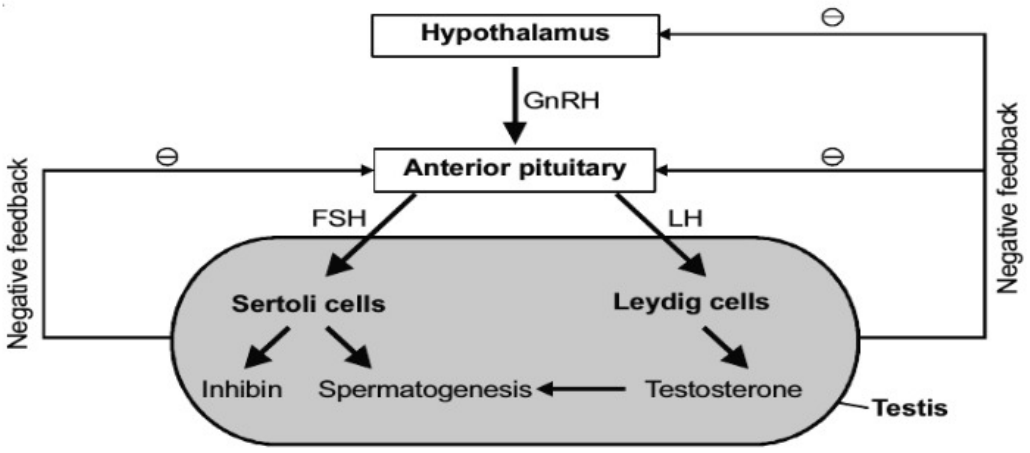


Fig. : Hormonal control of the testes

Did You Know?

1. A woman's reproductive life generally ends at menopause, due to exhaustion of ovarian follicles which occurs at the age of around 50 years. At what age men can no longer be father of children? A man's reproductive life never ends, unless disability or disease renders him unable to become a father. Adult male produce 100 to 200 million sperms each day and can continue doing so throughout their life.
2. Many different types of sperm abnormalities occur. A common classification scheme is based on the location of the abnormalities. Those that are located in the sperm head are classified as primary. Abnormalities associated with neck, middle piece or tail are classified as secondary abnormalities. Primary defects are more severe and are thought to originate while the sperm is still within the seminiferous epithelium of the testes. Secondary defects are less serious and are thought to arise during passage through the epididymis or by mishandling after ejaculation.
3. In *Ascaris*, the sperms are non-flagellated amoeboid sperms.

Structure of Mature Sperm: Mature sperm cell consists of a **head**, a **neck**, a **middle piece** and a **tail**. A plasma membrane envelops the whole body of sperm. The sperm **head** contains a very littile cytoplasm, an elongated haploid nucleus, the anterior portion of which is covered by a cap-like structure, **acrosome**. The acrosome is filled with enzymes that help in fertilisation of ovum. These enzymes called **sperm lysins** that dissolve the membranes enveloping the ovum and help the sperm cell to enter the ovum. **Acrosome** is derived from **golgi apparatus**. Its membrane extends down the outer surface of nucleus. The **short neck**, contains two distinct granules – the **proximal and distal centrioles**. The **proximal centriole** plays a crucial role during the first cleavage of the fertilised ovum. The **distal centriole** gives rise to the axial filament of the long tail of the sperm. The **middle piece** possesses numerous mitochondria (25 to 30 arranged spirally) which produce energy for the movement of tail that facilitates sperm motility essential for fertilisation, that is why it is called as the **power house** of the sperm. The **tail** is made up of a central axial filament surrounded by a small amount of cytoplasm and cell membrane as external sheath. The sperms move by **swimming** at the rate of 1.5 to 3 mm per minute to reach the site of fertilisation within 30 minutes.

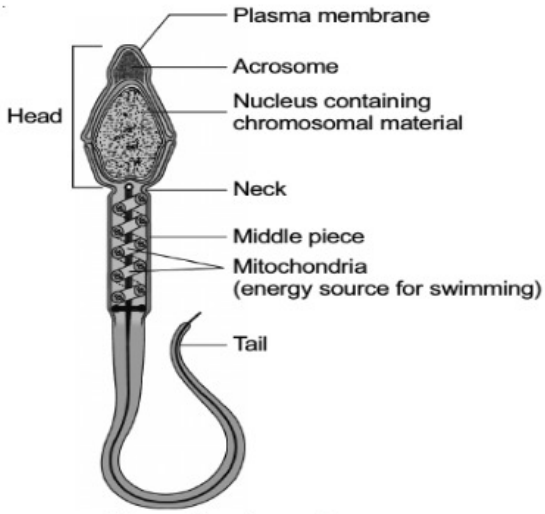


Fig. : Structure of a sperm

The human male ejaculates semen in female tract during coitus, containing 200 to 300 million sperms. **For normal fertility, at least 60 percent of these sperms must have normal shape and size and at least 40 percent of them must show vigorous motility.**

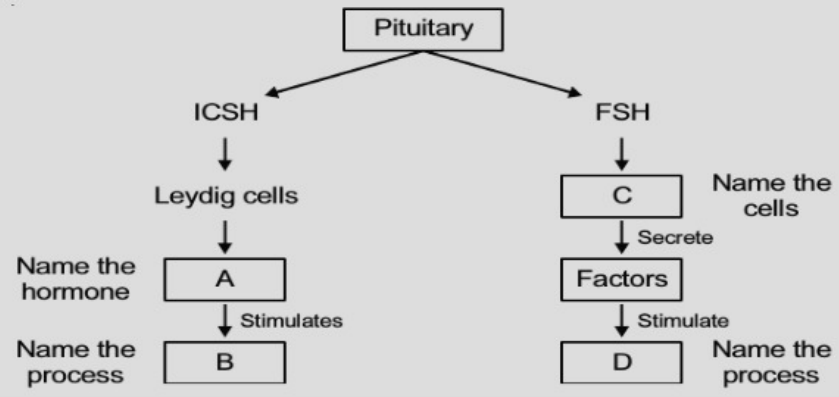
Sperms released from seminiferous tubules, are transported by the accessory ducts, secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for maturation and motility of sperms. **The functions of the male accessory ducts and glands** are maintained by the testicular hormones (androgens).

Did You Know?

Why are so many sperms produced by the male reproductive system? Although male ejaculate has 200 to 300 million sperms, very few of them reach the site of fertilisation. Most sperms are killed by the acidic environment of the female reproductive tract. So many sperms are needed to increase the likelihood of fertilisation.

Try Yourself

5. Given below is an incomplete flow chart showing the influence of hormones on testes in males. Observe the flow chart and fill the blanks marked as A, B, C, D respectively.



Choose one correct option for A, B, C and D :

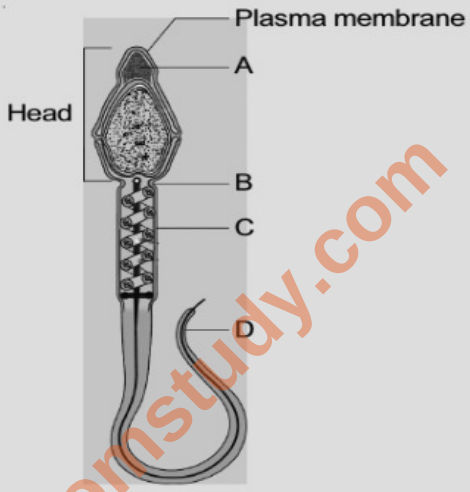
(1) A – Androgens B – Spermiation
C – Seminiferous tubules D – Spermatogenesis

(2) A – Inhibin B – Spermiogenesis
C – Sertoli D – Spermiogenesis

(3) A – Testosterone B – Spermatogenesis
C – Sertoli D – Spermiogenesis

(4) A – Testosterone B – Spermiogenesis
C – Sertoli D – Spermatogenesis

6. The diagram below shows a mature human sperm cell. Select the option which has correct explanation of any two structures labelled as A, B, C and D.



Choose the correct option :

(1) A : Acrosome which is filled with enzymes that help in fertilisation.
B : Neck has proximal centriole which forms the axial filament of tail.

(2) A : Acrosome which is filled with enzymes that help in fertilisation.
C : Middle piece, contain mitochondria which supply energy.

(3) C : Neck with two centrioles.
D : Tail for the movement of sperm.

(4) A : Nucleus containing chromosomal material.
C : Tail for the movement of sperm.

Oogenesis

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

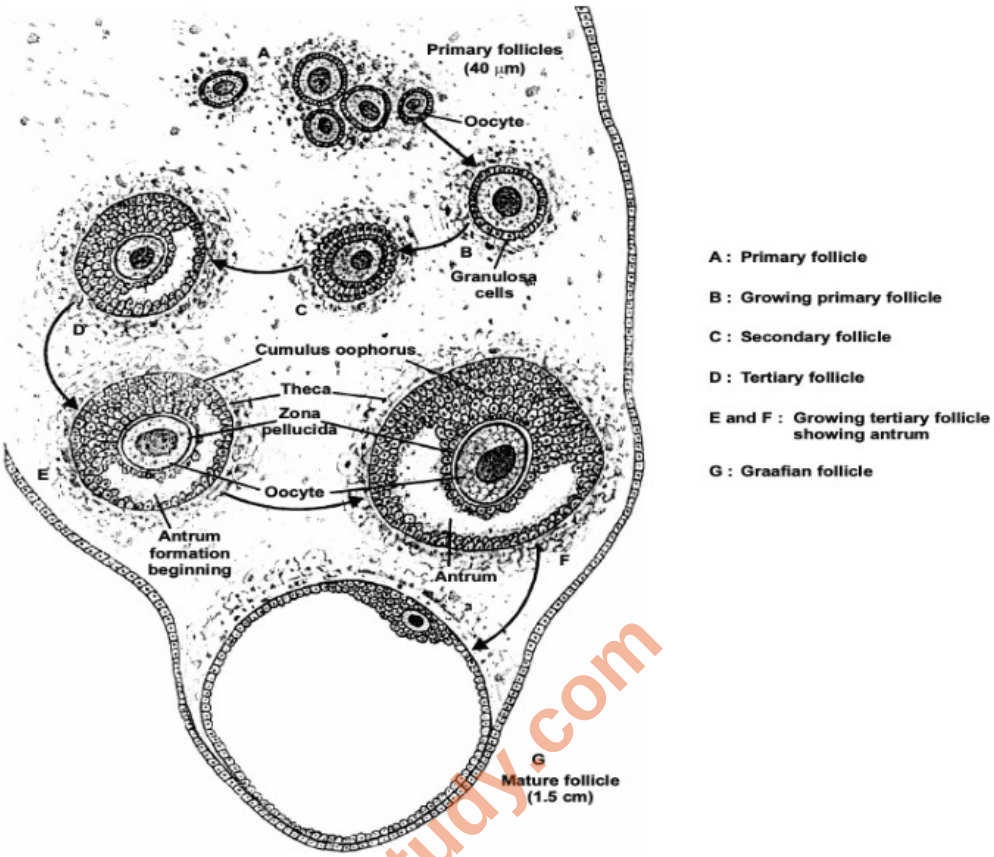


Fig. : Development of a human oocyte and ovarian follicle

An ovarian follicle consists of an oocyte, surrounded by one or more layers of follicular (flat epithelial) cells, the granulosa cells, which are derived from the germinal epithelium lining the ovary. The oogonial cells start division and enter into prophase-I of the meiotic division, and get temporarily arrested at this stage called **primary oocytes**. Each primary oocyte gets surrounded by a layer of **granulosa** cells and then called **primary follicle**.

A large number of these follicles degenerate from birth to puberty. Degeneration of ovarian follicles is called **follicular atresia** and their disposal is done by phagocytes. Therefore, **at puberty only 60,000 to 80,000 primary follicles are left in each ovary.**

With the onset of puberty, a primary follicle begins to mature with each ovarian cycle. The follicular cells become cuboidal, divide by mitosis to form a stratified epithelium, the granulosa layer. So, the primary follicles get surrounded by more layers of granulosa cells and a new theca, called **secondary follicles**. **Granulosa** cells rest on a basement membrane and the surrounding stromal cells form theca folliculi. The **secondary follicle** soon transforms into a **tertiary follicle** which is characterised by a fluid filled cavity **antrum**, which appears between the granulosa cells. Initially, the antrum is cresent shaped, but with time it greatly enlarges. The fluid of antrum is liquor folliculi. As the follicles grow, the theca folliculi become organised into inner layer of secretory cells, the **theca interna** and an outer layer of connective tissue cells containing fibroblast-like cells, the **theca externa**. The maturing oocytes adhere to the wall of the follicle through a pedicel/stalk, **cumulus oophorus**, formed by granulosa cells, and remains suspended in liquor folliculi. Theca interna is composed of cells having characteristics of steroid secretion, rich in blood vessels and theca externa gradually merges with ovarian stroma.

The **primary oocyte** within the tertiary follicle grows in size and **completes** its **first meiotic division** at puberty. It is an unequal division resulting in the formation of a large **haploid secondary oocyte** and a tiny first polar body. The **secondary** oocyte retains the bulk of nutrient rich cytoplasm of the **primary oocyte**. The tertiary follicle changes into the mature follicle or **Graafian follicle**.

The secondary oocyte forms a new membrane called **Zona pellucida** surrounding it. This thick coat of zona pellucida is composed of **glycoproteins** and synthesised by oocyte. Later, the granulosa cells lying in close vicinity of the ovum and zona pellucida, become elongated to form the **corona radiata**. In the presence of LH hormone, the **Graafian follicle** now ruptures to release the secondary oocyte developing (ovum) from the ovary by the process called **ovulation**. After ovulation the ruptured follicle left in the ovary is converted to a structure called **corpus luteum**, which secretes mainly **progesterone**.

- **What accounts for the large difference in the size of sperm and eggs?**

  During spermatogenesis excess cytoplasm of sperm is also absorbed by the sertoli cell during spermiogenesis. The difference in the sizes of sperm and eggs is due to the difference between the process of sperm formation (spermatogenesis) and egg formation (oogenesis). During spermatogenesis, equal divisions of the cytoplasm follow meiosis-I and meiosis-II, resulting in four equal-sized sperm cells having little cytoplasm. During oogenesis, unequal divisions of the cytoplasm follow meiosis-I and meiosis-II, resulting in formation of one large egg and two or three small polar bodies. Polar bodies later on degenerate.

- **Does the first polar body born out of first meiotic division divide further or degenerate?**

  In human beings and most vertebrates, the 1st polar body does not undergo meiosis-II, and usually dies. However, in some species 1st polar body undergoes meiosis-II.

- **Why is unequal division of cytoplasm seen in meiotic division?**

  Due to the unequal division of cytoplasm, the mature egg or ovum, retains most of the cytoplasm, which provides nutrients for the ovum during the early stages of development.

- In human beings from one primary oocyte, a single ovum and two polar bodies are formed. The ovum is released from the ovary in secondary oocyte stage after the release of 1st polar body.

Did You Know?

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

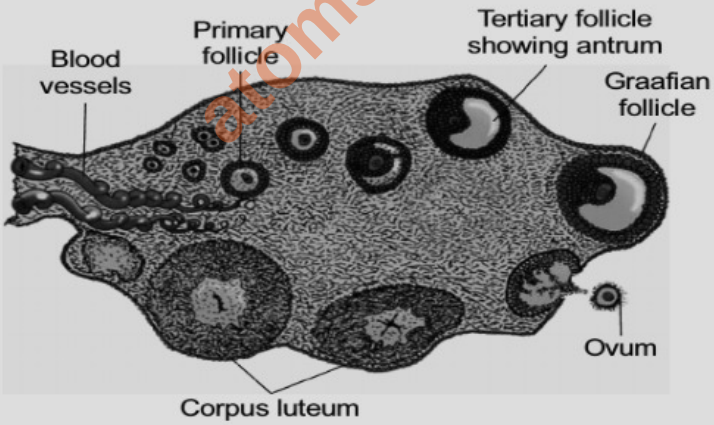


Fig. : Diagrammatic section view of ovary

Did You Know?

Sometimes, two or more follicles reach maturity in one month or cycle, so more than one oocyte may be ovulated. This is the commonest cause of multiple births. In such cases the siblings are **fraternal**, not identical.

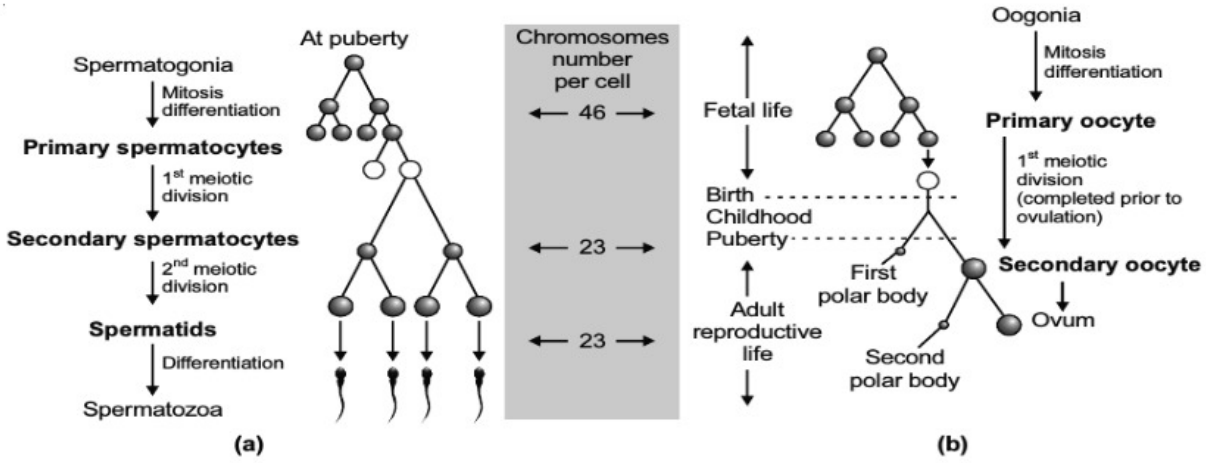


Fig. : Schematic representation of (a) Spermatogenesis; (b) Oogenesis

Example 3 : *At the time of ovulation, usually a single ovum is released. However, how many ova are released in case of identical twins and fraternal twins respectively?*

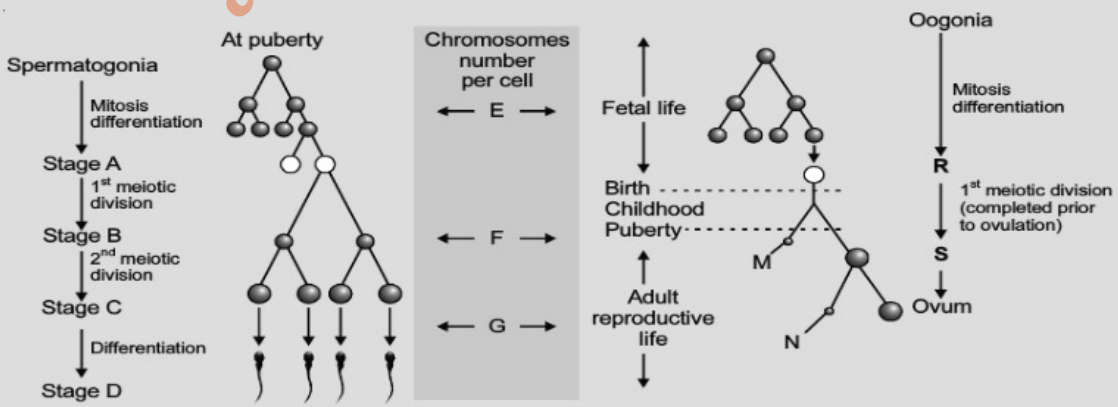
(1) 2, 2 *(2) 1, 1*

(3) 1, 2 *(4) 2, 1*

Solution : (3) 1, 2

Try Yourself

7. When do the egg cells of a human female begin meiosis?
   (1) Before she is born
   (2) During ovulation
   (3) At the start of puberty
   (4) During menstruation
8. From the given diagram of human gametogenesis, answer the following :



(i) Name the stages A, B, C and D.
(ii) Write the number of chromosomes in E, F and G.
(iii) What are M and N?
(iv) What does R and S represent?

EXERCISE

21. During spermatogenesis, meiosis occurs in
(1) Primary spermatocytes (2) Secondary spermatocytes
(3) Both (1) & (2) (4) Spermatogonia

22. Spermiogenesis changes
(1) Spermatogonium to primary spermatocytes
(2) Primary spermatocytes to secondary spermatocytes
(3) Secondary spermatocytes to spermatids
(4) Spermatids to sperms

23. In spermatogenesis, a primary spermatocyte produces four similar sperms while in oogenesis a primary oocyte forms
(1) Four similar ova (2) Three large ova and one polar body
(3) Two large ova and two polar bodies (4) One large ova and 2-3 polar bodies

24. Minute cells separating from ova are
(1) Primary oogonia (2) Polar bodies
(3) Secondary oogonia (4) Primary spermatogonia

25. What are the diploid stages in spermatogenesis?
(1) Spermatogonia and spermatids
(2) Spermatogonia and primary spermatocytes
(3) Spermatogonia and sperms
(4) Primary spermatocytes and secondary spermatocytes

26. Extrusion of second polar body from egg nucleus occurs
(1) After entry of sperm and before completion of fertilization
(2) After completion of fertilization
(3) Before the entry of sperm
(4) Without any relation with sperm entry

27. Spermatogenesis and sperm differentiation are under the control of
(1) FSH only (2) LH
(3) Testosterone and FSH (4) Parathyroid hormone

28. Middle piece of mammalian sperm possesses
(1) Mitochondria (2) Centriole only
(3) Acrosome (4) Nucleus and mitochondria

29. A change in ovum after penetration of sperm is
(1) Formation of first polar body (2) Second meiosis starts
(3) First meiosis (4) Formation of second polar body

30. Which of the following structures produces energy for the mobility of mature sperm?
(1) Nucleus in head region (2) Mitochondria in head region
(3) Axial filament in tail (4) Mitochondria in middle piece

MENSTRUAL CYCLE

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

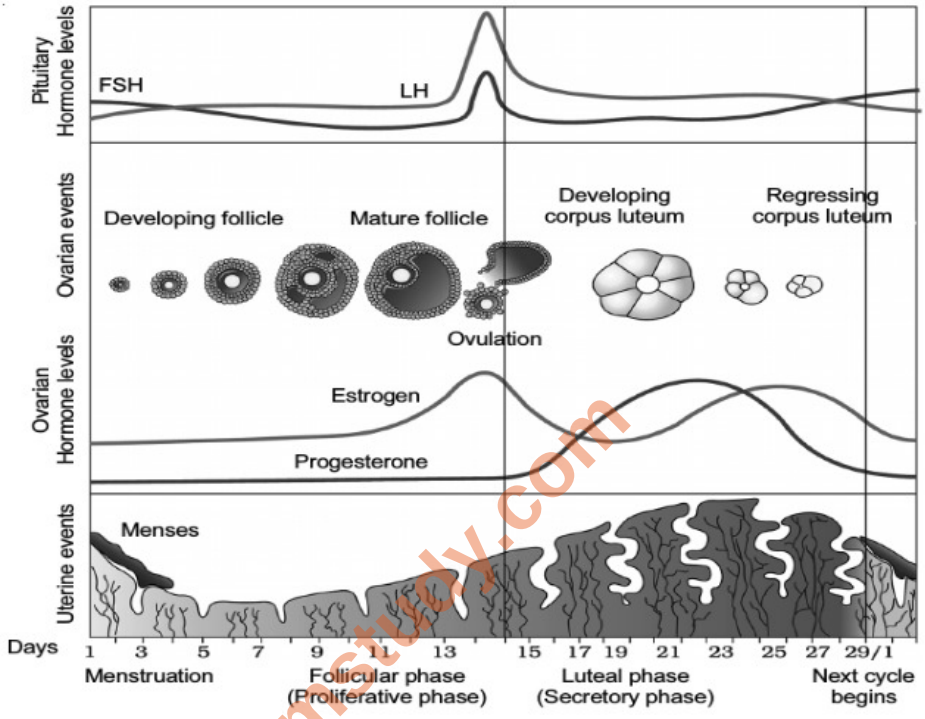


Fig. : Diagrammatic presentation of various events during a menstrual cycle

Phases of menstrual cycle

(i) Menstrual phase
(ii) Follicular phase
(iii) Ovulation
(iv) Luteal/Secretory phase

(i) Menstrual phase : Menstrual flow occurs in this phase and it lasts for 3 to 4 days. This flow results due to the breakdown of endometrial lining of the uterus and its blood vessels which forms a liquid and flows out through the vagina. Menstruation usually occurs about 14 days after ovulation, if the released ovum is not fertilised. Lack of menstruation may be indicative of pregnancy.

Did You Know?

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

The total amount of blood discharged in one cycle is 30 to 50 ml. This blood forms clot in the uterus, later fibrinolytic enzyme from the uterus dissolves the clot so the blood in the menses always remains in liquid state.

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

Did You Know?

What is ovarian cycle?

Series of events occurring in the ovary during menstrual cycle is called as the **ovarian cycle**. The **ovarian** cycle is regulated by hormones produced by hypothalamus and pituitary.

(iii) Ovulation : LH induces ovulation which usually occurs on 14th day in the 28 days cycle. The Graafian follicle ruptures and secondary oocyte (ovum) is released.

Day of ovulation = Number of days in M cycle – 14

(iv) Luteal phase/Secretory phase: Following ovulation, an egg is swept into the fallopian tube, where it awaits fertilisation as it travels through the tube towards uterus. The egg has stored nutrients to survive about 24 hours. The ovulatory phase is followed by luteal phase during which the remaining parts of Graafian follicle transform as **Corpus luteum** in the ovary.

Corpus luteum secretes large amounts of progesterone which is essential for **maintenance** of endometrium which is thickened by estrogen. In luteal phase, the endometrium further thickens due to estrogen hormone also secreted by corpus luteum. LH hormone causes the cells of the ruptured follicle to form corpus luteum. A corpus luteum is a yellowish mass of follicular cells that functions like an endocrine structure. LH hormone also stimulates the corpus luteum to secrete estrogen and progesterone. Estrogen and progesterone inhibit the release of FSH and LH. This prevents the development of new follicles during the luteal phase. Luteal phase lasts for 14 days. During this phase, the levels of estrogen and progesterone will rise, while FSH and LH levels drop. Low level of LH causes, degeneration of corpus luteum leading to sudden decline in progesterone level that causes menstruation.

Maintenance of endometrium by progesterone is necessary for implantation of the fertilised ovum and maintenance of pregnancy. During pregnancy all the events of the menstrual cycle stop and there is no menstruation due to high level of progesterone.

Did You Know?

• Sometimes women wish to postpone the menstrual bleeding for few days to participate, in some competitive sports or religious function, she should take progesterone like drugs. High level of progesterone maintains endometrium. • Menopause is a senile change which occurs in the ovaries around the age of 50 years. At this time, a woman no longer ovulates and thus moves out of childbearing phase. All the ovarian follicles have degenerated and there is deficiency of estrogen and progesterone hormone. FSH and LH are being produced by anterior lobe of pituitary, but now ovary is not responding to these hormones.

In the absence of fertilisation, the corpus luteum degenerates; the level of progesterone hormone will fall. This causes **disintegration of** the **endometrium** leading to menstruation, marking a new cycle. In human beings, menstrual cycles ceases around 50 years of age, termed as **menopause**. Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.

Example 4 : *Which of the following phases of the menstrual cycle is of shortest duration?*

(1) Menstrual phase

(2) Follicular phase

(3) Luteal phase

(4) Ovulatory phase

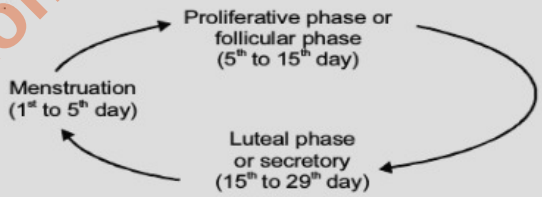
Solution : (4) Ovulatory phase

Knowledge Cloud

Estrous Cycle : The estrous cycle consists of cyclic changes in the female reproductive system of **non-primate** mammals. There is no menstruation at the end of estrous cycle. The estrogen level in blood increases resulting in a strong sex urge in the female. This is called "**period of heat**". The estrous cycles run only during breeding season. The estrous cycles remain suspended in female during non-breeding season. The suspension of estrous cycles is called **anestrum**. The animals that have only a single estrous cycle during the breeding season are called **monoestrous**, e.g., fox, deer, bat, etc. and animals that have a recurrence of estrous during breeding season are called **polyestrous**, e.g., Mouse, squirrel, cow, sheep, pig, horse etc.

Try Yourself

9. The events of the menstrual cycle are represented below. Answer the questions following the diagram:



(i) State the levels of FSH, LH and progesterone simply by maintaining high or low around 13^{th} and 14^{th} day and 21^{st} to 23^{rd} day.

(ii) In which of the above mentioned phases does the egg travel into the fallopian tubes?

(iii) Why there is no menstruation during pregnancy?

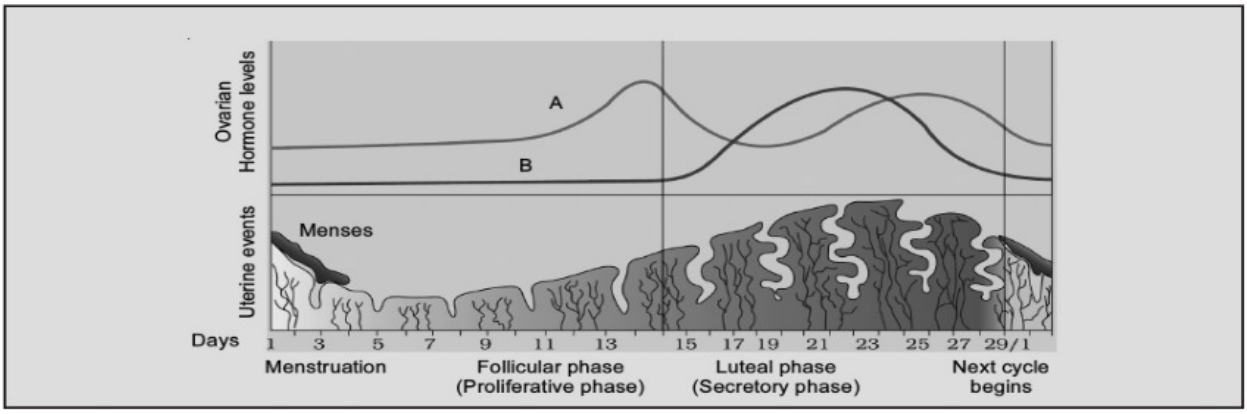
10. Read the graph given below and correlate the uterine events that take place according to the hormonal levels on

(i) 6^{th} to 15^{th} day

(ii) 16^{th} to 25^{th} day

(iii) 26^{th} to 29^{th} day if fertilisation does not occur

(iv) Specify the hormones labelled as A and B in the graph



EXERCISE

31. In menstrual cycle of 28/29 days, ovum is released during
    (1) Beginning of the cycle (2) Middle of the cycle
    (3) End of the cycle (4) Any time during the cycle
32. Loss of reproductive capacity in women after the age of 45 years is
    (1) Menstruation (2) Ageing
    (3) Menopause (4) Menarche
33. The correct sequence of hormones secreted from the beginning of menstrual cycle is
    (1) FSH, estrogen, progesterone (2) Estrogen, FSH, progesterone
    (3) FSH, progesterone (4) Estrogen, progesterone, FSH
34. Phase of menstrual cycle in human that lasts for 7-8 days is
    (1) Follicular phase (2) Ovulatory phase
    (3) Luteal phase (4) Menstruation
35. Menstrual cycle occurs in
    (1) All females (2) Mammalian females
    (3) Primate females (4) Rabbits
36. Withdrawl of which hormone is the immediate cause of menstruation?
    (1) Estrogen (2) FSH
    (3) FSH-LH (4) Progesterone
37. LH surge occurs during which phase of menstrual cycle?
    (1) Menstrual phase
    (2) Beginning of proliferative phase
    (3) Secretory phase
    (4) At the middle of the cycle

38. Estrous cycle is the characteristic of

(1) Human females (2) Mammalian females

(3) Mammalian females other than primates (4) Primate females

39. Monoestrous animals have

(1) One ovulation each month

(2) One heat period each month

(3) One breeding season in a year

(4) One menstrual cycle each month

40. Which hormone level reaches peak during the luteal phase of menstrual cycle?

(1) Luteinising hormone

(2) Progesterone

(3) FSH

(4) Estrogen

FERTILISATION AND IMPLANTATION

During copulation (coitus) semen is released by the penis into the vagina of female, called **insemination**. A human sperm can live for many weeks in male genital duct. Once ejaculated in the semen, it lives only for 48 to 72 hours outside the body. Sperms move in the liquid medium secreted by female genital tract at a speed of 1.5 - 3.0 mm/minute. Prostaglandins of semen help in the movement of spermatozoa.

Once the sperms are released **Capacitation** of sperm occurs in the female genital system and involves :

(1) Removal of membrane cholesterol present over acrosome, weakening the membrane cover.

(2) Dilution of decapacitation factors.

(3) Entry of Ca^{2+} into sperms causing rapid whiplash movements of the tail part. They swim through the vagina, cervix, uterus and finally reach the junction of the isthmus and ampulla called ampullary-isthmic junction of the **fallopian tubes**. The ovum released by the ovary is also transported to the **ampullary isthmic junction where fertilisation occurs**. Ovum is released in the secondary oocyte stage (arrested in metaphase-II). Due to ciliary current produced by fimbriae portion of oviduct, ovum is drawn in through ostium. It reaches ampulla, the site of fertilization, by the ciliary action of ciliated columnar epithelial lining of oviduct. Fertilisation can only occur if the ovum and the sperms are transported simultaneously to the ampullary isthmic-junction. This is the reason why **not** all copulations lead to fertilisation and pregnancy.

The process of fusion of a sperm with the ovum is called **fertilisation**.

Knowledge Cloud

The vacuum created in the uterine cavity in between successive contractions allows aspiration of the sperms passively from the vagina. During their ascent through the female genital tract, the spermatozoa are gradually reduced in number by the barriers provided by abrupt contractions at the cervix and uterine ostium of the tube. As a result 300-500 sperms appear at the site of fertilization. This is probably a method of natural selection so that only the compatible spermatozoa are allowed to enter the uterine tube.

Fusion of gametes/Syngamy : The various steps involved are :

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

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

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

(c) Zona lysin/Acrosin : Digests the zona pellucida.

Contact of acrosome stimulates development of an outgrowth by the oocyte called **fertilisation cone** or **cone of reception.**

Cortical and zona reactions : As the sperm head comes in contact with the fertilization cone, it causes opening of Na^+ channels to cause depolarisation of ovum membrane **(fast block to check polyspermy)** and Ca^{2+} move into the egg. Sperm and egg membranes dissolve. Complete sperm enters cytoplasm of egg and the envelope is left out. Ca^{2+} influx causes extrusion of cortical granules **(cortical reaction)** and **zona reactions** which make the zona pellucida impervious to second sperm by destroying sperm receptors.

Knowledge Cloud

Disintegration of cells of cumulus oophorus and corona radiata takes place by the liberation of hyaluronidase from the acrosomal cap. Zona pellucida is now exposed. The sperm head now binds to specific glycoprotein receptors ZP3 of zona pellucida and induces acrosome reaction to release **acrosin** which digests the zona pellucida. Now the sperm head appears in perivitelline space and fuses with the vitelline membrane. This is done by two disintegrin peptides carried by sperm head which open the gate for sperm to enter in the oocyte. As a result a calcium wave sets in throughout the oocyte cytoplasm. This initiates completion of second meiotic division of the secondary oocyte which results in formation of mature **ovum** with extrusion of second polar body.

Cortical reaction and zona reaction constitute **slow block to check polyspermy.**

The entry of sperm into the ovum induces completion of the meiotic division of the secondary oocyte. Entry of sperm causes breakdown of metaphase promoting factor (MPF) and turns on anaphase promoting complex (APC). This results in completion of meiosis-II. The second meiotic division is also unequal and results in the formation of a **second polar body** and a **haploid ovum** (ootid). Soon the haploid nucleus of the sperm and that of ovum fuse together to form a **diploid zygote**.

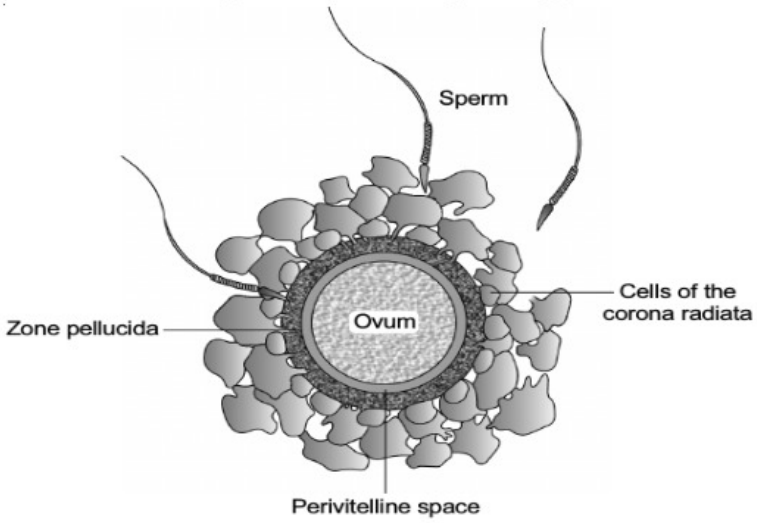


Fig. : Ovum surrounded by few sperms

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

Male and female pronuclei approach each other and finally mixing up of paternal and maternal chromosomes **(Amphimixis)** occurs resulting in the formation of **synkaryon/zygote.**

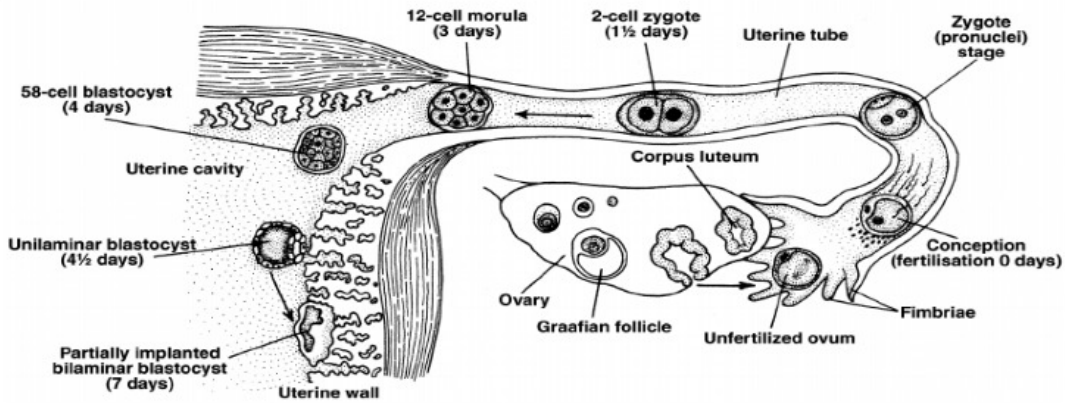


Fig. : Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

Knowledge Cloud

The genetic material of male and female pronuclei fuse. Their membranes dissolve, leaving no barriers between the male and female chromosomes. During this dissolution, a **mitotic spindle** forms between them. The spindle captures the chromosomes before they disperse in the egg cytoplasm. Upon subsequently undergoing mitosis (which includes pulling of chromatids towards centrioles in anaphase), the cell gathers genetic material from the male and female together. Thus, the first mitosis after the union of sperm and oocyte is the actual fusion of their chromosomes.

Did You Know?

Sex of the baby is decided during fertilisation. The chromosome pattern in human female is XX and that in the male is XY. Therefore, all the haploid gametes produced by the female (ova) have the sex chromosome X, whereas in the male gametes (sperms) the sex chromosome could be either X or Y, hence 50 percent of sperms carry X chromosome while the other 50 percent carry the Y. After fusion of the male and female gametes the zygote would carry either XX or XY depending on whether the sperm carrying X or Y has fertilised the ovum. The zygote carrying XX would develop into a female baby and XY would form a male. That's why, scientifically it **is correct** to say that the sex of the baby is determined by the father and not by the mother.

Embryonic Development

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

Cleavage : First cleavage is completed after 30 hours of fertilization. Cleavage furrow passes from animal-vegetal axis as well as centre of zygote (Meridional plane). It divides the zygote completely into two blastomeres (Holoblastic cleavage). Second cleavage is completed after 60 hours of fertilization. It is also meridional but at right angle to the first one. It is completed earlier in one of the two blastomeres resulting in a **transient 3-celled stage.** Third cleavage is horizontal forming 8 blastomeres. It is slightly unequal. Thereafter the rate and pattern of cleavage is non specific. In mammals, including humans, cleavage divisions are among the slowest in animal kingdom. Also, the cleavage divisons asynchronous. The number of resultant blastomeres increased following arithmetic progression.

Did You Know?

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

Morula : Cleavage results in a solid ball of cells, **Morula** having 8-16 cells. Zona pellucida still forms the outer cover. Morula undergoes compaction. The outer/peripheral cells are smaller/flat with tight junctions while the inner cell mass consists of slightly large, rounded cells with gap junctions. Morula descends slowly towards uterus in 4-6 days and corona radiata detaches during this period.

Blastulation or Blastocyst Formation : Endometrium secretes a nutrient fluid and its mucosal cells become enlarged with stored nutrients. As the morula enters uterus, it gets a rich supply of nutrients. Outer peripheral cells enlarge and flatten further. They form **trophoblast or trophoectoderm.** Trophoblast cells secrete a fluid into the interior creating a cavity called **blastocoel.** The **inner cell mass** now comes to lie on one side as **embryonal knob**. With the formation of blastocoel, morula is converted into **blastula** which is called **blastocyst** in mammals because of different nature of surface layer and eccentric inner cell mass.

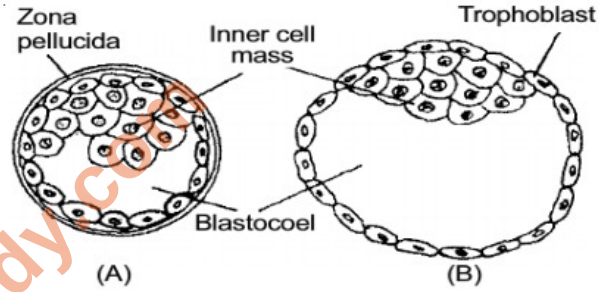


Fig. : Development of blastocyst

Due to pressure of growing blastocyst, a slit is produced in zona pellucida through which it squeezes out. The growing blastocyst comes out of this slit . At times, it gets broken into two parts which then gives rise to identical twins or **monozygotic twins**.

Trophoblast cells in contact with embryonal knob are called cells of Rauber. Area of embryonal knob represents **animal pole**. The opposite side is **abembryonal pole**. Soon embryonal knob shows rearrangement to form **embryonal disc**. Cells of trophoblast layer divide periclinally. This gives rise to two layers, outer **syncytiotrophoblast** and inner **cytotrophoblast**. The two layers later form chorion, amnion and foetal part of placenta.

Implantation : It is embedding of the blastocyst into endometrium of uterus. Blastocyst comes in contact with the endometrium in the region of embryonal knob or embryonic disc and adheres to it. The surface cells of trophoblast secrete lytic enzymes which cause corrosion of endometrial lining. They also give rise to finger-like outgrowths called **villi**. Villi not only help in fixation but also in absorption of nutrients. Implantation causes nutrient enrichment, enlargement of cells and formation of uterine part of placenta called **decidua** (L. deciduos-falling off).

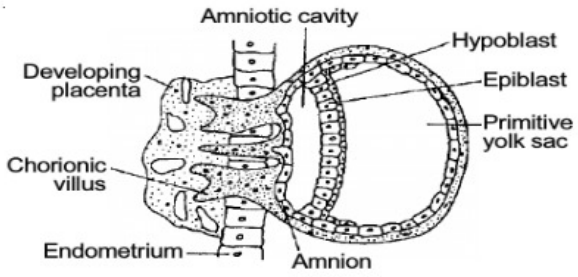


Fig. : Implanted blastocyst

Decidua has three regions : (i) **Decidua Basalis** - Part of decidua underlying the chorionic villi and overlying the myometrium). (ii) **Decidua Capsularis** - Lying between embryo and lumen of uterus and (iii) **Decidua Parietalis** the part of decidua that lines the uterus at places other than the site of attachment of embryo.

Trophoblast covering secretes a hormone called **human chorionic gonadotropin** (hCG). Detection of hCG in the urine is the basis of **pregnancy/Gravidex test.** hCG maintains the corpus luteum beyond its normal life time when it is called **corpus luteum of pregnancy**. It continues to secrete progesterone which prevents menstruation and maintains the uterine lining in nutrient rich state. Progesterone induces the cervical glands to secrete viscous mucus for filling the cervical canal to form a protective plug. Progesterone is also called **pregnancy hormone** as it is essential for maintenance of pregnancy. The hormone is secreted by placenta as well.

Gastrulation

It is characterised by movements of cells in small masses or sheets so as to form primary germinal layers. There are three primary germinal layers - endoderm, ectoderm and mesoderm. The cell movements that occur during gastrulation are called **morphogenetic movements** since they lead to initiation of morphogenesis. The product of gastrulation is called gastrula.

A space appears between the ectoderm (below) and the trophoblast. This is the amniotic cavity, filled by amniotic fluid. The roof of this cavity is formed by amniogenic cells derived from trophoblast.

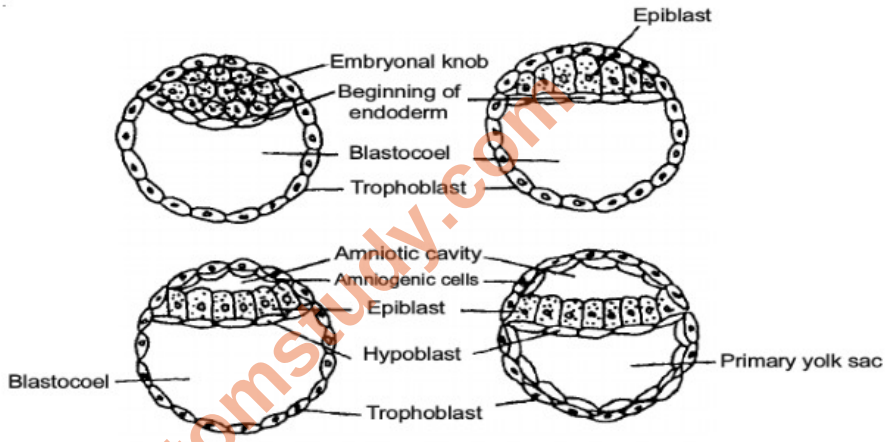
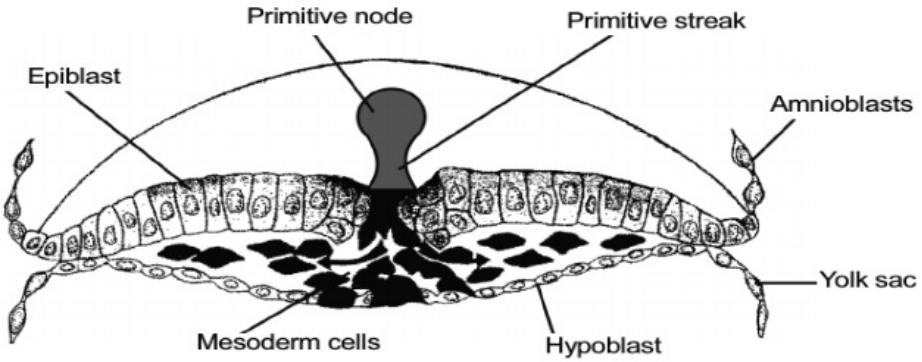


Fig. : Formation of endoderm and amniotic cavity

Formation of Primary Germinal Layers : Cells of the inner cell mass or embryonal knob get rearranged to form a flat **embryonic** or **germinal disc**. The latter differentiates into two layers, an outer **epiblast** of larger columnar cells and inner **hypoblast** of smaller cuboidal cells.

Gastrulation begins with the formation of primitive streak on the surface of the epiblast.



1. The diagram shows a cross section through the cranial region of the streak at 15 days showing movement of epiblast cells. The first cells to move inward displace the hypoblast to create the definitive endoderm.
2. Once definitive endoderm is established, inwardly moving epiblast forms mesoderm.
3. Cells remaining in the epiblast then form ectoderm. Thus **the epiblast is the source of all the germ layers in the embryo.**

Knowledge Cloud

Fate of Germ Layers :

Zygote → Blastula → Gastrula

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

Try Yourself

11. In which part of human female reproductive system implantation takes place?
12. From which part of blastocyst does an embryo develop?
13. Mention the fate of inner cell mass after implantation in uterus.
14. What is the other name of trophoblast cells lying over the embryonic disc?
15. Which germ layer forms nervous system, eye, pituitary gland and internal ear?

A **blastocyst** is a ball of cells with a large, fluid-filled cavity called **blastocoel**. The **blastomeres** in the **blastocyst** are arranged into an outer layer called **trophoblast** and inner mass of cells (attached to trophoblast) called the **inner cell mass**.

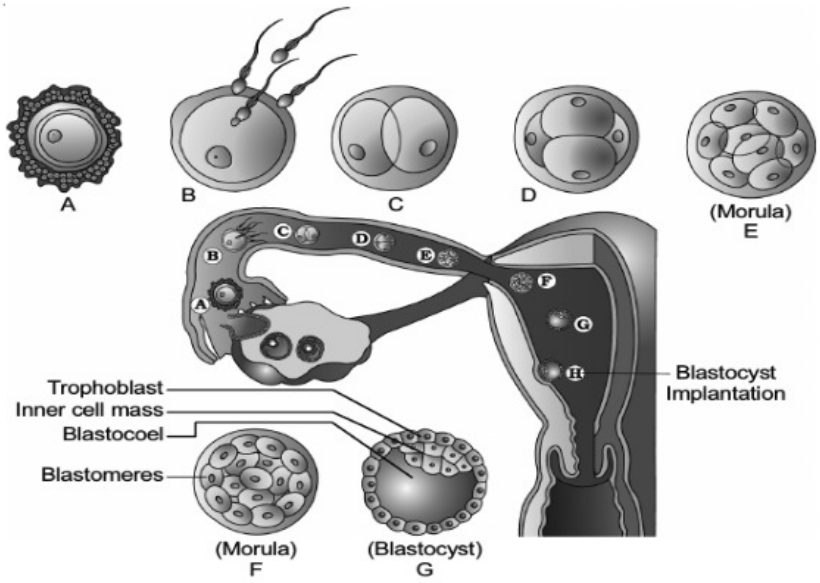
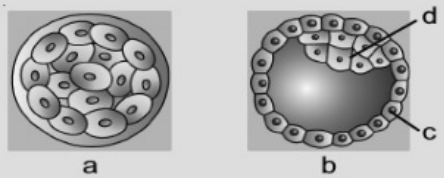


Fig. : Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

Did You Know?

The mitotic spindle of the first cleavage division appears in the cytoplasm of the fertilised ovum at right angle to an imaginary axis which runs through the ovum from animal pole to vegetal pole. Animal pole is that pole through which the polar bodies are extruded, and pole opposite to it is vegetal pole. The furrow divides the ovum into two daughter cells. The daughter cells are called **blastomeres**. The second cleavage furrow occurs at right angles to the first division, leading to the formation of 4-celled stage – an appearance suggestive of crossed dumb-bells as shown in figure (D). The third cleavage division is horizontal leading to the formation of 8-celled stage. Subsequent division are vertical and horizontal in alternate manner.

Try Yourself

16. 

(i) Identify the stage a and b.

(ii) Name the structures c and d.

(iii) In which stage implantation occurs.

17. Following fertilisation cleavage begins while the zygote is in :

(1) An ovary (2) The placenta

(3) The uterus (4) The fallopian tube

EXERCISE

41. Stage of embryo development at which implantation occurs in human female is
(1) Morula (2) Zygote
(3) Blastocyst (4) Transient 3-celled stage

42. In ectopic pregnancy, foetus grows in
(1) Fundus part of uterus (2) Fallopian tube
(3) Uterus (4) Both (1) & (3)

43. Which of the following statements is **incorrect**?
(1) Fertilization occurs in fallopian tube
(2) Fertilization is a physio-chemical process/event
(3) Cleavage produces morula
(4) Cleavage leads to increased mass of protoplasm

44. Cortical granules are associated with
(1) Oogenesis (2) Spermatogenesis
(3) Cleavage (4) Fertilization

45. Termination of gastrulation is marked by
(1) Closure of primitive gut (2) Obliteration of archenteron
(3) Obliteration of blastocoel (4) Closure of neural tube

46. Onset of pregnancy
(1) Stimulates testosterone secretion (2) Leads to degeneration of ovary
(3) Inhibits further ovulation (4) Inhibits fusion of egg and sperm nuclei

47. Site of fertilization in a mammal is
(1) Ovary (2) Uterus
(3) Vagina (4) Fallopian tube

48. Gastrulation comprises
(1) Morphogenetic movements (2) Differentiation of archenteron
(3) Differentiation of three germ layers (4) All of these

49. After a sperm has penetrated an ovum, the entry of other sperms is prevented by :
(1) Condensation of yolk
(2) Formation of pigment coat
(3) Development of vitelline membrane
(4) Development of fertilization membrane

50. Two offsprings developed in the same uterus from fertilisation of two different ova are
(1) Monozygotic twins (2) Dizygotic twins
(3) Fraternal twins (4) Both (2) & (3)

PREGNANCY AND EMBRYONIC DEVELOPMENT

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

Placenta is an organ which connects the foetus with uterine wall. It constitutes both maternal as well as foetal parts although there is no mixing of the maternal and foetal blood supplies. The placenta acts as an ultrafilter through which soluble inorganic and organic materials, nutrients, hormones, antibodies against diphtheria, small pox, scarlet fever and measles etc. can pass from the mother to the foetus.

Placenta also acts as an endocrine gland and synthesises large quantities of proteins and some hormones such as human chorionic gonadotropin (hCG), **chorionic thyrotropin, chorionic corticotropin**, **chorionic somatomammotropin or human placental lactogen** (hPL), estrogens and progesterone. The hCG stimulates corpus luteum of pregnancy to continue to secrete progesterone for a long time after its normal life time. In addition, it secretes some relaxin that facilitates parturition by softening the connective tissue of the pubic symphysis. The metabolic activity of the placenta is almost as great as that of the foetus itself. The **umbilical cord** connects the foetus to the placenta. During the first trimester (first 3 months) of pregnancy, the basic structure of the foetus is formed. This involves cell division, cell migration and the differentiation of cells into the many types found in the body. During this period, the developing baby called **foetus** is very sensitive to anything that interferes with the steps involved.

Virus infection of the mother *e.g.* by Rubella (German measles) virus or exposure to certain chemicals may cause malformations in the developing embryo. Such agents inducing malformations are called teratogens (monster forming agents). By 3 months, all the systems of the foetus have been formed, at least in a rudimentary way. From then on, development of the foetus is primarily a matter of growth and minor structural modifications. The foetus is less susceptible to teratogens after first trimester.

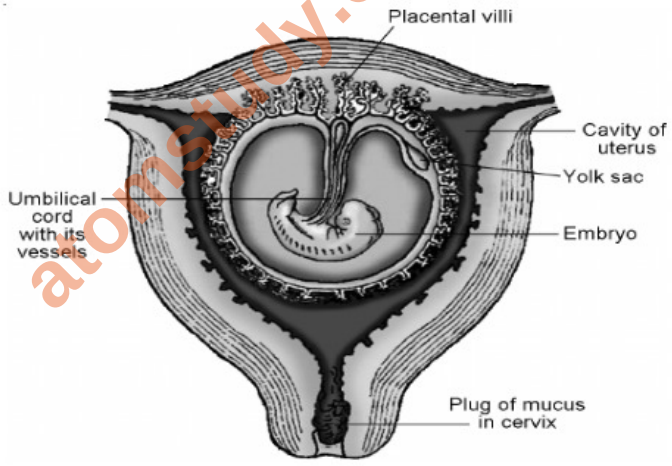


Fig. : The human foetus within the uterus

Did You Know?

During the first trimester of pregnancy, the basic structure of the baby is formed. During this period, the developing baby – called foetus – is very sensitive to anything that interferes with the steps involved. Torch infecting (toxoplasmosis and other rubella, cytomegaloviruses and herpes simplex are the major cause of miscarrage or abortion in first trimester. Such agents are called **teratogens**. Teratogens are infact drugs or chemicals that product abnormally in foetal development. Thalidomide was used to treat the symptoms of morning sickness during pregnancy, it lead to heart disorders and non-formation of long bones. Such as **Phocomelia, Amelia.**

Knowledge Cloud

Placenta banking refers to the collection and storage of **stem cells** from the **placenta,** in addition to those found in **cord blood,** after the **birth** of a human baby. Placental stem cells are those stem cells that are found only in the placenta and are collected after the blood from the umbilical cord is drawn. They are **non-embryonic stem cells,** as are those obtained from umbilical cord blood.

Both the **placenta** and **umbilical cord** are rich sources of stem cells. Banking stem cells from the placenta in addition to those found in cord blood significantly increases the number of prenatal stem cells that are collected and preserved.

Types of Placenta

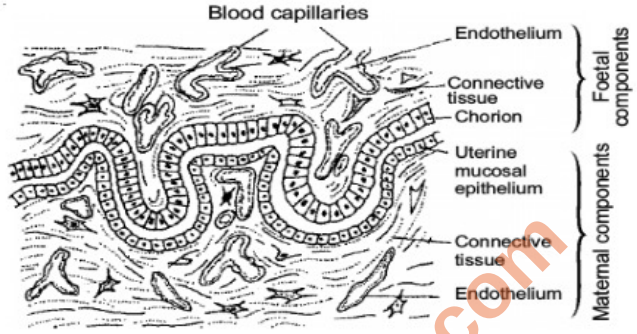


Fig. : Structure of typical placenta

As shown in the diagram, there are six barriers between the maternal and the foetal blood across the placenta.

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

(i) Epitheliochorial – Placenta with all the six barriers between foetal and maternal blood; *e.g.* Horse, Ass.

(ii) Syndesmochorial – Uterine epithelium breaks down; only five barriers left; *e.g.* Cow, Buffalo, Sheep, Goat, Camel.

(iii) Endotheliochorial – Uterine epithelium and connective tissues are eroded; only four barriers left; *e.g.* Tiger, Lion, Cat, Dog.

(iv) Haemochorial – Placenta with only three barriers, the maternal part of placenta is completely eroded; *e.g.* Human, Apes, Lemurs.

(v) Haemo-endothelial – All barriers except endothelium of foetal part of placenta get eroded *e.g.* Rat, Rabbit.

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

(i) **Non-deciduous** – no part of uterine portion of placenta is broken off, *e.g.* Horse, Ass.

(ii) **Deciduous**–a portion of uterine tissue called **decidua** is detached and passed out at birth, *e.g.* most of the mammals.

(iii) **Contra-deciduous**–even the foetal part of placenta is retained and gets absorbed to provide nourishment, *e.g. Talpa, Perameles*.

(c) On the basis of distribution of villi on the surface, the placenta are of six types :

(i) **Diffuse placenta**–Villi distributed uniformly all over the surface. *e.g.* Horse, Pig.

(ii) **Cotyledonary**–the villi form tufts which fit into corresponding areas, the **caruncles** in the uterine part of placenta, *e.g.* Cow, Buffalo, Sheep.

(iii) **Intermediate**–villi occur singly as well as in tufts, *e.g.* Camel, Giraffe

(iv) **Zonary**–villi arranged in two transverse bands, *e.g.* Tiger, Lion, Cat, Dog, Elephant.

(v) **Discoidal**–villi are confined to a disc-like area, *e.g.* Rat, Rabbit, Bat.

(vi) **Metadiscoidal**–villi are initially distributed uniformly all over the surface but later on get confined to a disc-like area fitting into a corresponding depression on the uterine wall *i.e.*, the placenta is diffuse first but later on becomes discoidal, *e.g.* Human beings and Apes.

The human pregnancy lasts 9 months. The gestation period of dog is 60-65 days, elephant is 607-641 days and cat is 52-65 days. In human beings, after one month of pregnancy, the embryo's heart is formed. The first sign of growing foetus may be noticed by listening to the heart sound carefully through the stethoscope. By the end of the second month of pregnancy, the foetus develops limbs and digits. By the end of 12 weeks (first trimester), most of the major organ systems are formed, for example, the limbs and external genital organs are well-developed. The first movements of the foetus and appearance of hair on the head are usually observed during the fifth month. By the end of 24 weeks (second trimester), the body is covered with fine hair, eye-lids separate and eyelashes are formed. By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

Knowledge Cloud

Important Developmental Events in the Human Embryo

Time from fertilization	Event
30 hours	Embryo reaches two-celled stage.
3 days	Morula stage.
7 days	Blastocyst begins to implant in the uterus.
2.5 weeks	Notochord and neural plate are formed; tissue that will give rise to heart is differentiating; blood cells are formed in yolk sac and chorion.
3.5 weeks	Neural tube formation; primordial eye and ear visible; pharyngeal pouches formed; liver differentiates; respiratory system and thyroid gland just begin to develop; heart tubes fuse, bend and begin to beat; blood vessels are laid down.
4 weeks	Limb buds appear; three primary vesicles of brain formed.
2 months	Muscles differentiate; embryo capable of movement; gonads distinguishable as testis or ovary; bones begin to ossify; principal blood vessels assume final positions; embryo becomes foetus; nervous system develops; bones enlarge.
3 months	Sex can be determined by external inspection; notochord degenerates; lymph glands develop.
4 months	Face begins to look human; lobes of cerebrum differentiate; eye, ear, and nose look more 'normal'; rapid growth.
Third trimester	Lanugo* appears, later it is shed; neurons become myelinated; tremendous growth of body.
266 days(from conception)	Birth

** **Lanugo** is the soft hairy covering of the foetus which begins to be shed before birth.*

PARTURITION

The average duration of human pregnancy is about 9 months or 38 weeks/266 days after fertilisation which is called the **gestation period**. Vigorous contraction of the uterus at the end of pregnancy causes expulsion/ delivery of the foetus. This process of delivery of the foetus (childbirth) is called **parturition**. Parturition is induced by a complex neuroendocrine mechanism. The signals for parturition originate from the fully developed foetus and the placenta which induce mild uterine contractions called **foetal ejection reflex.** This triggers the release of oxytocin from the maternal pituitary. Oxytocin acts on the uterine muscles and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin. The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions. This leads to expulsion of the baby out of the uterus through the birth canal. Soon after the infant is delivered, the placenta is also expelled out of the uterus.

Parturition includes three stages :

1. **Dilation Stage :** The uterine contractions start from top and occur after long intervals (once every thirty minutes). This forces the foetus outward, pushing its head against cervix. As a result, cervix gets dilated with vagina also showing a similar dilation. Dilation of cervix increases the stimulus for oxytocin secretion, further increasing the strength and frequency of contractions (1-3 every minute). With continued powerful contractions, the amnion ruptures and the amniotic fluid flows out through vagina.
2. **Expulsion Stage :** With further increase in the intensity of uterine and abdominal contractions, the foetus comes out through cervix and vagina, with head coming out first. Expulsion may take 20-60 minutes. Umbilical cord is cut. The infant's lungs expand and it begins breathing. This requires a major switchover in the circulatory system. Blood flow through the umbilical cord, ductus arteriosus and foramen ovale ceases and the adult pattern of blood flow through the heart, aorta and pulmonary arteries begins. In some infants, the switchover is incomplete and blood flow through the pulmonary arteries is inadequate. Failure to synthesise enough nitric oxide (NO) is one cause of this.
3. **Stage of After Birth :** Within 10-15 minutes after delivery, placenta and the remains of the umbilical cord which is called 'after birth' is expelled out.

LACTATION

Although estrogen and progesterone are essential for the physical development of the breasts during pregnancy, a specific effect of both these hormones is to inhibit **the actual secretion of milk.** Conversely, the hormone prolactin has exactly the opposite effect and promotes secretion of milk. This hormone is secreted by the mother's anterior pituitary gland and its concentration in the blood rises steadily from the fifth week of pregnancy until birth of the foetus (10 to 20 times the normal nonpregnant levels). In addition, the placenta secretes large quantities of **human chorionic somatomammotropin** which probably also has lactogenic properties, thus supporting the prolactin from the mother's pituitary during pregnancy. The fluid that is secreted first few days after parturition is called **colostrum,** slightly yellow in colour, rich in calories and antibodies (IgA). This antibody provides passive immunity to the child. It contains essentially the same concentrations of proteins and lactose as milk but almost no fat.

Ejection (or "Let-Down") Process in Milk Secretion

Milk is secreted continuously into the alveoli of the breasts but it does not flow easily from these alveoli into the duct system and therefore, does not continually leak from the breast nipples. Instead, the milk must be **ejected** from the alveoli into the ducts before the new born can obtain it. This is caused by a combined neurogenic and hormonal reflex that involves the posterior pituitary hormone **oxytocin.**

When the new born suckles on the breasts, sensory impulses are transmitted through somatic nerves from the nipples to the mother's spinal cord and then to her hypothalamus, initiating nerve signals that promote oxytocin secretion. The oxytocin is carried through the blood to the breasts where it causes myoepithelial cells (that surround the outer walls of the alveoli) to contract, thereby expelling the milk from the alveoli into the ducts.

Example 5 : *hCG is functionally similar to*

(1) LH *(2) FSH*

(3) GnRH *(4) Progesterone*

Solution : (1) LH

EXERCISE

51. Hormone administered for hastening child birth is meant for

(1) Stimulating the striped muscles (2) Raising blood pressure

(3) Increasing energy availability (4) Contraction of smooth muscles

52. Gestation period in human is

(1) 10 weeks (2) 28 weeks

(3) 32 weeks (4) 38 weeks

53. Extra-embryonic membrane amnion provides

(1) Cells to embryo (2) Protection to embryo

(3) Nutrition to embryo (4) Both (1) & (2)

54. Active inrolling of endodermal and mesodermal cells into interior of embryo is

(1) Ingression (2) Involution

(3) Inversion (4) Epiboly

55. Placenta is

(1) Channel for providing essential requirements for growth of embryo

(2) Storage organ

(3) Conductor for nerve impulse

(4) Meant for protection of embryo from shocks

56. During embryonic development, which of the following is formed first?

(1) Heart (2) Brain

(3) Neural tube (4) Skin

57. Which of the following are the derivatives of endoderm?

(1) Muscles and blood

(2) Alimentary canal and respiratory organs

(3) Excretory and reproductive organs

(4) Skin and nerve cord

58. Which of the following are mesodermal and endodermal in origin respectively?

(1) Urinary bladder – Kidney

(2) Kidney – Inner lining of urinary bladder

(3) Urinary ducts – Genital ducts

(4) Genital ducts – Urinary ducts

59. Find the **incorrect** match w.r.t. increase in the levels of following hormones

(1) Oxytocin – Uterine contraction during labour

(2) Prolactin – Lactation after child birth

(3) Progesterone – Uterine contraction

(4) Luteinising hormone – Stimulates ovulation

60. Kidneys, heart and gonads are formed from

(1) Ectoderm (2) Endoderm

(3) Inner cell mass (4) Mesoderm

Try Yourself

18. By the end of the first trimester, which of the following has occurred in the foetus?

(1) The fetus uses its lungs to breathe

(2) The brain of foetus is fully developed

(3) Most of the major organ system are formed

(4) The first movements of the foetus occur

19. There is no menstruation during pregnancy. This is due to high levels of _____.

(1) Estrogen (2) Progesterone

(3) Gonadotropins (4) GnRH

Did You Know?

Types of Egg

The eggs are classified on the basis of amount and distribution of yolk in them. Yolk is the reserved food material in the cytoplasm of egg. It may be formed of phospholipids, proteins, lipid and carbohydrates. The process of formation of yolk and its deposition in egg is called vitellogenesis.

1. **Based on Amount of Yolk:**

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

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

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

(iv) Megalecithal (or **Macrolecithal**) - The eggs containing very large amount of yolk, *e.g.,* reptiles, birds.

2. Based on distribution of yolk.

On the basis of distribution of yolk, the eggs can be

(i) Isolecithal : The yolk is uniformly distributed throughout the cytoplasm of egg, e.g., Branchiostoma, Herdmania.

(ii) Telolecithal : The eggs in which the yolk is concentrated towards one pole i.e., vegetal pole and nucleus along with major part of cytoplasm is displaced is animal pole e.g., amphibians.

(iii) Centrolecithal : Yolk concentrated in centre of the egg with cytoplasm surrounding it, e.g. insects.

Cleidoic Eggs

Eggs of reptiles and birds which are insulated from the environment by albumen, membranes and shell. The calcareous shell present around the eggs of birds is mainly made of calcium carbonate (94%) and is secreted by uterus (shell glands). **Chalazae** are the suspensory ligaments of the yolk in birds's eggs.

Egg Membranes : There are three types of egg membrane around the eggs.

(i) Primary egg membrane: It is formed around the plasma membrane of the egg and is secreted by ovum itself e.g, **Jelly envelope** (Echinoderms), **Vitelline membrane** (Mollusca, amphibians & birds), **zona radiata** (Shark, some amphibians), **Zona pellucida** (Mammals).

(ii) Secondary egg membrane : It is formed around the egg by the follicle cells of the ovary e.g., chorion around egg of insect; corona radiata, granulosa and theca layers in human.

(iii) Tertiary egg membranes : These are formed by the oviducts & other accessory parts of maternal genital tract while the egg is passing from the ovary to the exterior, e.g. the albumin, shell membrane and outermost calcareous shell of reptiles & birds.

Types of Cleavage

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

(a) Holoblastic : The cleavage in which the segmentation lines pass through the entire egg, dividing it completely. It occurs in alecithal, microlecithal and mesolecithal eggs; e.g. frog, human egg etc. It is of two types-equal holoblastic e.g., *Amphioxus,* Humans and Marsupials and unequal holoblastic e.g. lower fishes and amphibians.

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

Laws of Cleavage

(a) Sach's Laws (1877) :

(i) Cells tend to divide into equal daughter cells.

(ii) Each new division plane tends to intersect the preceding plane at right angles so as to maintain the spheroidal shape of blastomeres.

(b) Hertwig's Law (1881) :

(i) The nucleus and achromatic figures occupy the centre of 'protoplasmic density' of the egg or blastomeres in which it lies.

(ii) The axis of mitotic spindle occupies the longest axis of the protoplasmic mass in which it lies and division therefore tends to cut this axis transversely.

(c) Balfour's Law (1885) **:** The rate of cleavage is inversely proportional to the amount of yolk or deutoplasm.

(d) Pyfulger's Law : The mitotic spindle always elongates in the direction of least resistance.

Patterns of Cleavage

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

(a) Radial Cleavage : Successive clevage planes cut straight through the egg *e.g., Synapta paracentrotus.*

(b) Biradial Cleavage : When the three first division planes do not stand at right angles to each other : Ctenophora.

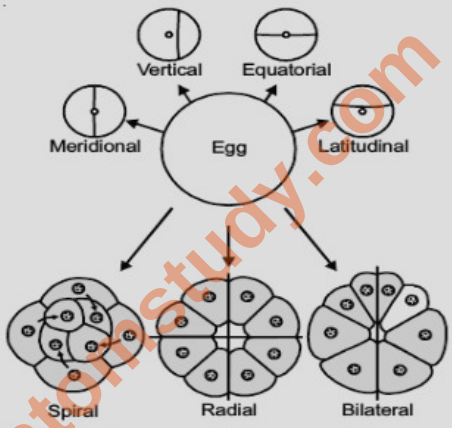


Fig. : Patterns and planes of cleavage

(c) Spiral Cleavage : There is a rotational movement of cell parts around the egg axis leading to displacement of mitotic spindle with respect to symmetrically disposed radii *e.g.,* turbellarians, nematoda, rotifera, annelida, all mollusc except cephalopods.

(d) Bilateral Cleavage : Mitotic spindles and cleavage planes remain bilaterally arranged with reference to the plane of symmetry *e.g.,* tunicates, cephalopods.

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

According to concept of potency, cleavage can be

(i) Indeterminate/Regulative cleavage where, the fate of different parts of egg or its blastomeres is not predetermined or blastomeres have no characteristic position and have alterable fate *e.g.,* echinoderms and vertebrates.

(ii) Determinate/Mosaic cleavage where, every part of fertilized egg has a definite fate so that the fate of every blastomere is determined from beginning. The complete embryo is formed only if all the blastomeres remain together. *e.g.*, Nematoda, Mollusca **(***Dentalium***)**.

Morula

Cleavage results in formation of solid mass of cells which is called Morula as it looks a mulberry.

Blastula

Blastula is the embryonic stage next to morula. It contains a fluid-filled cavity called **blastocoel** surrounded by one or more layers of cells, the **blastomeres.** The blastula with blastocoel is called **coeloblastula,** e.g. frog. In certain animals, the blastula is solid and is termed **stereoblastula** e.g., Cnidaria, Nereis & some molluscs**.** The blastula formed as a result of superficial cleavage is called **superficial blastula,** e.g. insects. **Discoblastula** is disc shaped blastula formed as a result of discoidal cleavage, e.g. birds.

Gastrula

Gastrula is formed by gastrulation. **Gastrulation** is the process of formation of **gastrula** from the blastula. Gastrula is the embryonic stage of development in which the **germinal layers** have been formed. Gastrulation involves movement from their original place to the site where they finally settle. The movements are called **morphogenic movements**. They include **epiboly** (descending of dividing cells to cover other cells), **emboly** (upward movement of dividing cells underneath the other cells), **involution** (inward migration of blastomeres to go into the blastocoel), **invagination** (tucking in of blastula wall), and **delamination** (separation of a sheet of cells from blastula).

Archenteron is the cavity which occurs inside the gastrula and is the future alimentary canal. It opens to the outside through **blastopore** which later on closes.

Foetal Membranes :

(i) **Amnion** is formed of **mesoderm** on outside and **ectoderm** inside. Space between amnion and foetus is called **amniotic cavity** and it contains **amniotic fluid.**

(ii) **Chorion** is formed of **ectoderm** externally and **mesoderm** inside. Alongwith the allantois, it participates in the formation of placenta. Space between amnion and chorion is extra **embryonic coelom.**

(iii) **Allantois** consists of **mesoderm** on outside and **endoderm** internally. It extends to fuse with chorion and forms **allanto-chorion** which gives rise to foetal part of placenta.

(iv) **Yolk sac:** It is formed of mesoderm on the outerside and endoderm on the innerside.

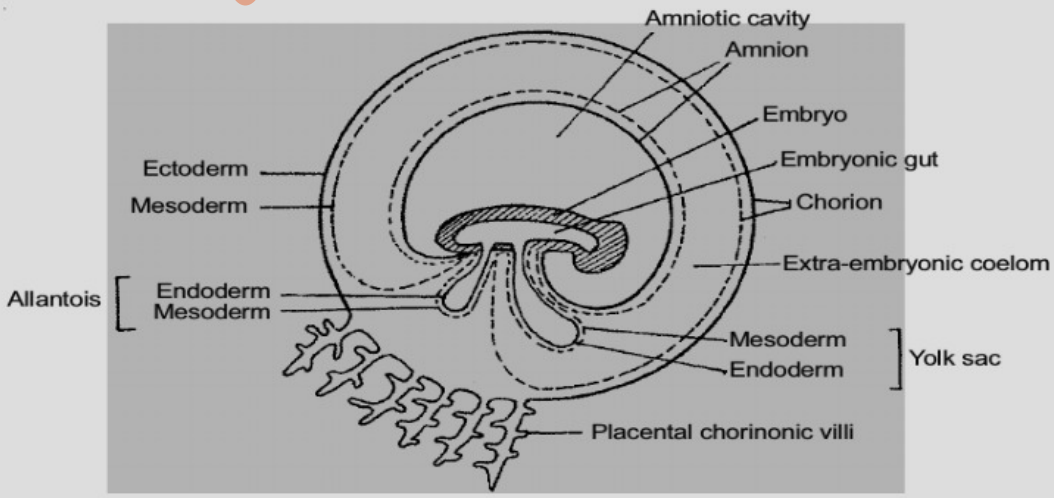


Fig. : Foetal membranes (diagrammatic)

Metamorphosis in Frog : It is a post embryonic extension of the developmental potentials and involves changes in habitat, habit, morphology, physiology and behaviour of larva. e.g. in frog, the tadpole shows following changes.

(a) Ecological Changes : Aquatic, herbivorous, tailed tadpole to terrestrial, non-tailed, carnivorous adult.

(b) Morphological change :

(i) **Retrogressive changes :** Ventral suckers, external gills, long tail with finfolds, gill clefts, peribranchial cavities, horny teeth of perioral disc, horny lining of jaws, lateral line sense organs are shed in adult.

(ii) **Progressive changes :** Forelimbs, middle ear, hyoid apparatus, tympanic membrane, tongue, hind limbs develop.

(iii) **Organs present in both but the changes in their differentiation :** Skin gets keratinized, intestine shortens and brain becomes highly differentiated in adult.

(c) Physiological and biochemical changes : Endocrine function of pancreas starts, increased role of liver in carbohydrate metabolism, ammonotelic nature changes to ureotelism, porphyropsin visual pigments change to rhodopsin, larval haemoglobin replaced by adult Hb. Overall 'degrowth' of frog takes place.

(d) Hormonal changes : The spacing of events is inherent in the genetic make up of tissue but timing of events is decided by hormones. When metamorphosis starts, thyroxine level increases steadily and suddenly reaches a high level when complete metamorphosis takes place.

Quick Recap

1. Humans are sexually reproducing and viviparous organisms. The male reproductive system is composed of a pair of testes, the male sex accessory ducts, the accessory glands and external genitalia. Each testis has about 250 compartments called testicular lobules, and each lobule contains one to three highly coiled seminiferous tubules. Each seminiferous tubule is lined inside by spermatogonia and Sertoli cells. The spermatogonia undergo meiotic divisions leading to sperm formation, while Sertoli cells provide nutrition to the dividing germ cells. The Leydig cells outside the seminiferous tubules, synthesise and secrete testicular hormones called androgens. The male external genitalia is called penis.
2. The female reproductive system consists of a pair of ovaries, a pair of oviducts, a uterus, a vagina, external genitalia, and a pair of mammary glands. The ovaries produce the female gamete (ovum) and some steroid hormones (ovarian hormones). Ovarian follicles in different stages of development are embedded in the stroma. The oviducts, uterus and vagina are female accessory ducts. The uterus has three layers namely perimetrium, myometrium and endometrium. The female external genitalia includes mons pubis, labia majora, labia minora, hymen and clitoris. The mammary glands are one of the female secondary sexual characteristics.
3. Spermatogenesis results in the formation of sperms that are transported by the male sex accessory ducts. A normal human sperm is composed of a head, neck, a middle piece and tail. The process of formation of mature female gametes is called oogenesis.
4. The reproductive cycle of female primates is called menstrual cycle. Menstrual cycle starts only after attaining sexual maturation (puberty). During ovulation, only one ovum is released per menstrual cycle. The cyclical changes in the ovary and the uterus during menstrual cycle are induced by changes in the levels of pituitary and ovarian hormones.

5. After coitus, sperms are transported to the junction of the isthmus and ampulla, where the sperm fertilises the ovum leading to formation of a diploid zygote. The presence of X or Y chromosome in the sperm determines the sex of the embryo. The zygote undergoes repeated mitotic division to form a blastocyst, which is implanted in the uterus resulting in pregnancy. After nine months of pregnancy, the fully developed foetus is ready for delivery.
6. The process of childbirth is called parturition which is induced by a complex neuroendocrine mechanism involving cortisol, estrogens and oxytocin. Mammary glands differentiate during pregnancy and secrete milk after child-birth. The new-born baby is fed milk by the mother (lactation) during the initial few months of growth.

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