[Topic 1] Reproductive System

1.1 Male Reproductive System

It includes a pair of testes, accessory ducts, glands and the external genitalia.

(*i*) **Testes** are located outside the abdominal cavity within a pouch called **scrotum**. Scrotum maintains the low temperature of the testes (2-2.5°C lower than the normal body temperature) required for spermatogenesis.

(a) Each testis is oval-shaped with a length of 4-5 cm width of 2-3 cm and covered by a dense covering called **tunica albuginea**.

(b) Internally it is divided into about 250 compartments known as **testicular lobules**.

(c) Each lobule contains 1-3 highly coiled structural and functional units of testis called **seminiferous tubules** in which sperms are produced.

(d) Seminiferous tubule is lined on its inside by two types of cells called **male germ cells** or spermatogonia and **Sertoli cells**.

(e) Male germ cells undergo meiotic divisions leading to formation of spermatozoa.

(f) Sertoli cells provide nutrition to the germ cells.

(g) Interstitial spaces are present in outside regions of seminiferous tubules, which contain small blood vessels and **Interstitial cells** or **Leydig cells**.

(h) Leydig cells synthesise and secrete the testicular hormones called **androgens** mainly testosterone.

(*ii*) **Male accessory ducts** include rete testis, vasa efferentia, epididymis and vas deferens.

(a) The intratesticular duct system starts with tubuli recti, which are short, straight end segments of the seminiferous tubules. These tubules connect the seminiferous tubules to the highly anastomosing, cuboidal epithelium-lined channels called **rete testis**.

(b) From rete testis, 10-25 fine tubules arise called **vasa efferentia** that leave the testis and open into the epididymis.

(c) **Epididymis** leads to vas deferens that ascends to the abdomen and loops over the urinary bladder. It receives a duct from the seminal vesicle to form **ejaculatory duct** that runs through the prostate and opens into urethra.

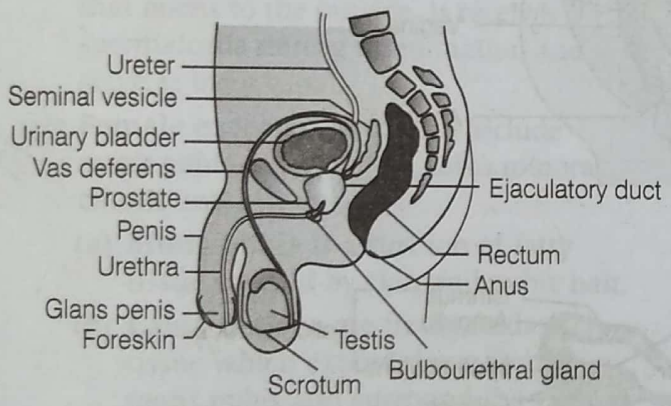


Figure 3.1

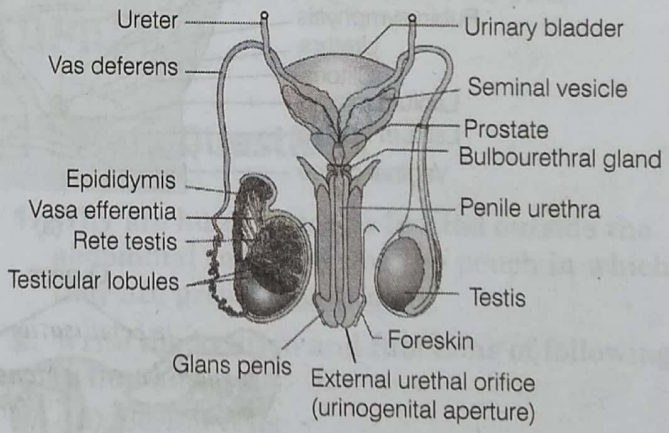


Figure 3.2

Figure 3.1 Diagrammatic sectional view of male pelvis showing reproductive system

Figure 3.2 Diagrammatic view of male reproductive system (part of testis is open to show inner details)

(d) Urethra receives the ducts of prostate gland and the bulbourethral gland (Cowper's glands) a little ahead and runs through the penis to its external opening called **urethral meatus**.

(*iii*) The **accessory glands** of male reproductive system include:

(a) A pair of **seminal vesicles**, a **prostate gland** and a pair of **bulbourethral glands** (Cowper's glands).

(b) The secretion of all these glands is called **seminal plasma**.

(c) Seminal plasma contains fructose, calcium and some enzymes. It is to provide nutrition to the spermatozoa, while travelling through female reproductive tract.

(d) Seminal plasma along with sperms is called **semen**.

(e) Secretion of bulbourethral glands also helps in the lubrication of the urogenital tract.

(*iv*) **External genitalia** is the penis. It is made up of special erectile tissue that helps in erection of the penis. The enlarged tip of the penis is called **glans penis**. It is covered by a loose fold of skin called **foreskin** or **prepuce**.

1.2 Female Reproductive System

It consists of a pair of ovaries, secondary sex organs, external genitalia and mammary glands.

(*i*) **Ovaries** are primary female sex organs, which produce female gametes called ova and secrete the female sex hormones.

(a) These are located one on each side of the lower abdomen.

(b) These are almond-shaped, 2-4 cm in length, 1.5 cm in width.

(c) Each ovary is connected to the pelvic wall and uterus by ligaments.

(d) Each ovary is covered by a thin epithelium which encloses the **ovarian stroma**.

(e) Ovarian stroma is divided into two regions, i.e. **peripheral cortex** and **inner medulla**.

(*ii*) The female **accessory ducts** constitute **oviducts** or Fallopian tubes, **uterus** and **vagina**.

(*iii*) Each Fallopian tube is about 10-12 cm long and extends from the periphery of each ovary to the uterus.

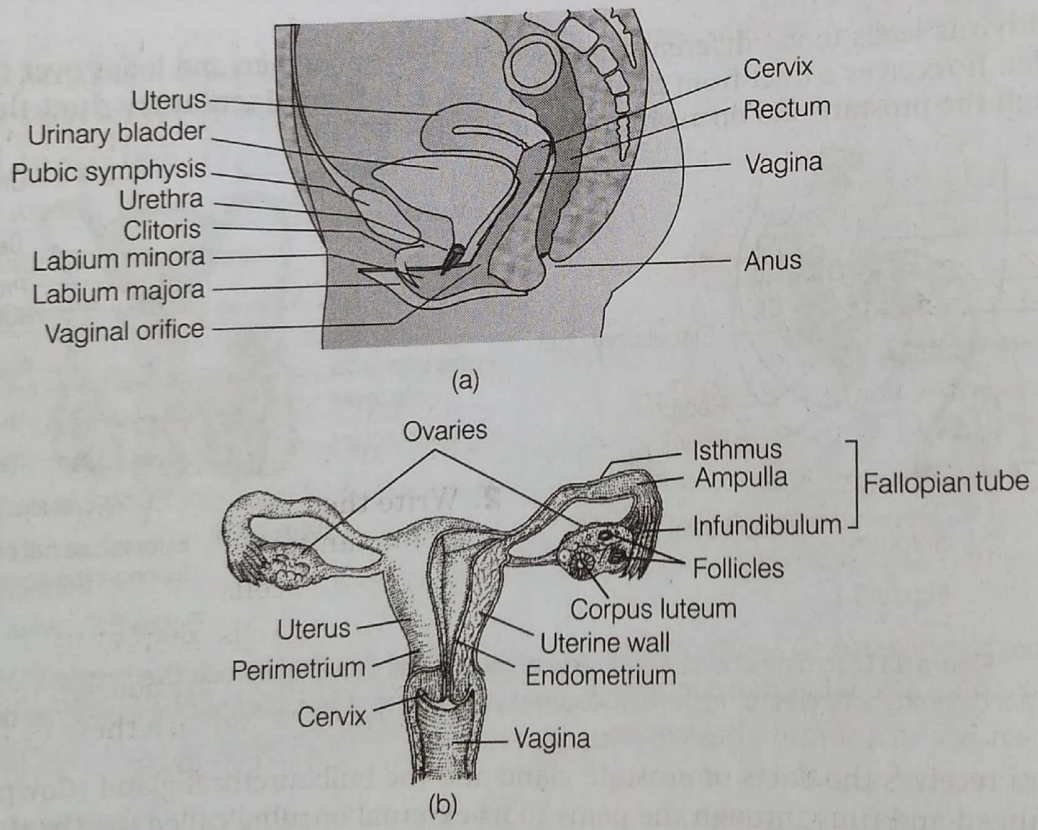


Figure 3.3 Female reproductive system (a) Lateral view (b) Sectional view

(a) The part of oviduct closer to the ovary is funnel-shaped **infundibulum**.

(b) The edges of infundibulum possess finger-like projections called **fimbriae**, which help in collection of the ovum after ovulation.

(c) Infundibulum leads to a wider part of the oviduct called **ampulla**.

(d) **Isthmus** is the last part of the oviduct, which has a narrow lumen and it joins the uterus.

(*iv*) **Uterus** or **womb** is a pear-shaped muscular organ. It is about 75 cm long and 5 cm wide. It is attached to the pelvic wall and supported by ligaments.

(a) Wall of the uterus has three layers of tissue.

(b) **Perimetrium** is the outermost thin membranous layer, **myometrium** is the middle thick layer of smooth muscles and **endometrium** is the innermost glandular layer which lines the uterine cavity.

(c) Uterus opens into the **vagina** through a narrow **cervix**, its cavity is called **cervical canal**, which along with vagina forms **birth canal**.

(d) Endometrium layer undergoes cyclic changes during menstrual cycle.

(e) Smooth muscles in myometrium contract during parturition to deliver the baby.

(*v*) **Vagina** is a muscular tube-like structure that opens to the outside. It receives spermatozoa during insemination and serve as birth canal.

(*vi*) **Female external genitalia** include mons pubis, labia majora, labia minora, clitoris and hymen.

(a) **Mons pubis** is a cushion of fatty tissue covered by skin and pubic hair.

(b) **Labia majora** are fleshy folds of tissue which extend down from the mons pubis and surround the vaginal opening.

(c) **Labia minora** are paired folds of tissue under the labia majora.

(d) **Hymen** is a membrane that covers the opening of vagina partially. It gets ruptured during vigorous physical activities or during the first coitus.

(e) **Clitoris** is a tiny finger-like structure, which lies at the upper junction of the two labia minora above the urethral opening.

(*vii*) **Mammary glands** (breasts) are paired structures that contain glandular tissue and variable amount of fat.

(a) Glandular tissue of each mammary gland is divided into 15-20 mammary lobes containing the cluster of cells called **alveoli**.

(b) The cells of alveoli secrete milk, which is stored in the cavities (lumen) of alveoli.

(c) Alveoli open into **mammary tubules**. The tubules of each lobe join to form a **mammary duct**.

(d) Several mammary ducts join to form a wider **mammary ampulla**, which is connected to lactiferous duct through which milk is sucked out.

[Topic 2] Gametogenesis

Gametogenesis is the process of producing gametes (sperms and ova by the testis and ovary respectively). It is of the following two types:

(*i*) Spermatogenesis (*ii*) Oogenesis

2.1 Spermatogenesis

It is production of sperms in males.

(*i*) In testis, the immature male germ cells (spermatogonia) produce sperms by **spermatogenesis** that begins at puberty.

(*ii*) **Spermatogonia** (sing. spermatogonium) present on the inside wall of seminiferous tubules multiply by mitotic division and increase in numbers.

(*iii*) Each spermatogonium is diploid and contains 46 chromosomes. Some of the spermatogonia called **primary spermatocytes** periodically undergo meiosis.

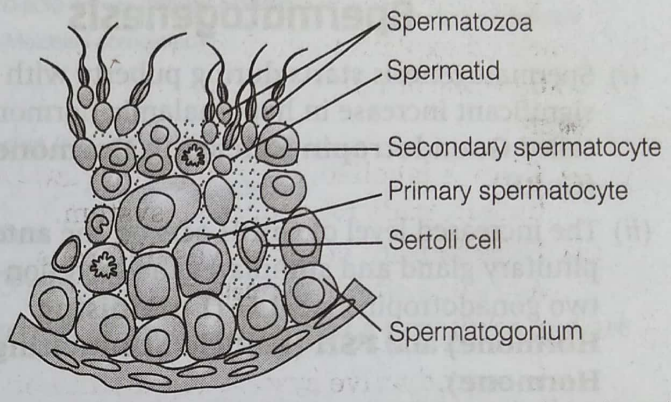


Figure 3.4 Sectional view of a seminiferous tubule (enlarged)

(*iv*) The primary spermatocytes undergo first meiotic division leading to two equal, haploid cells called **secondary spermatocytes**, which contains only 23 chromosomes each.

(*v*) The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid **spermatids** which contains only 23 chromosomes each.

(*vi*) The spermatids are transformed into spermatozoa (sperms) by the process called **spermiogenesis**. Thus, each sperm too contains only 23 chromosomes.

(*vii*) Sperm heads are embedded in the Sertoli cells and are finally released from the seminiferous tubules by the process called **spermiation.**

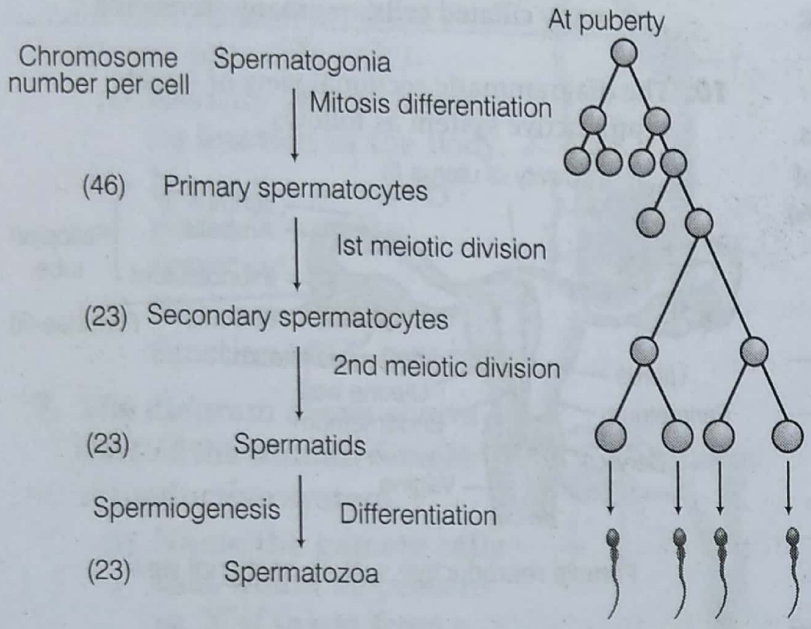


Figure 3.5 Spermatogenesis in human male

Role of Hormones in Spermatogenesis

(*i*) Spermatogenesis starts during puberty with the significant increase in hypothalamic hormone called **Gonadotropin Releasing Hormone** (GnRH).

(*ii*) The increased level of GnRH acts on the anterior pituitary gland and stimulates the secretion of two gonadotropins, i.e. **LH (Luteinising Hormone)** and **FSH (Follicle Stimulating Hormone)**.

(*iii*) LH acts on the Leydig cells and stimulates the synthesis and secretion of androgens, which in turn stimulate the process of spermatogenesis.

(*iv*) FSH acts on Sertoli cells and stimulates the secretion of some factors, which help in the process of spermiogenesis.

Structure of a Sperm

(*i*) A sperm is composed of a **head, neck**, a **middle piece** and a **tail**.

(*ii*) A plasma membrane encloses the whole body of sperm.

(*iii*) Head contains an elongated haploid nucleus, the anterior portion of which is covered by a cap-like structure called **acrosome.**

(*iv*) The acrosome is filled with enzymes that help in fertilisation of the ovum.

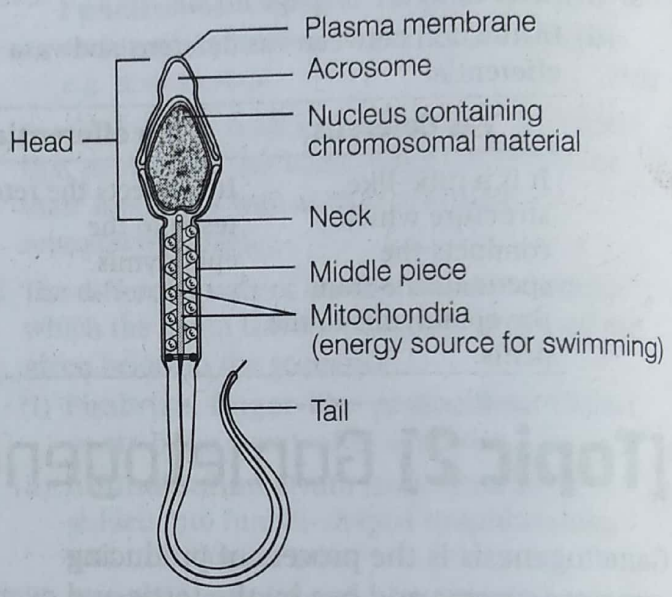


Figure 3.6 Structure of a sperm

(*v*) Neck contains two centrioles, a proximal centriole, which is necessary for first cleavage division of zygote and a distal centriole, that gives rise to axial filament of tail.

(*vi*) Middle piece possesses many mitochondria to produce energy for the movement of tail to facilitate sperm motility.

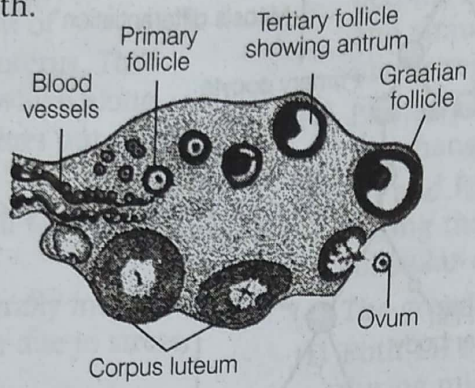
(*vii*) Tail of the sperm consists of an axial filament. Its role is to help movement inside the female reproductive tract towards the ovum for fertilisation.

2.2 Oogenesis

It is the process of formation of a female gamete or ova in the ovary.

(*i*) It starts during embryonic stage in a female.

(*ii*) About a million **oogonia** are formed in the ovary of the female foetus of 25 weeks. No new oogonia are formed after birth.



(*iii*) The oogonial cells start meiotic division, enter into prophase-I, get temporarily arrested at that stage and are called as **primary oocytes**.

(*iv*) Each primary oocyte then gets surrounded by a layer of granulosa cells called **primary follicle**.

(*v*) A large number of primary follicles degenerate during the phase from birth to puberty. As a result, about 60000-80000 primary follicles are left in each ovary at puberty.

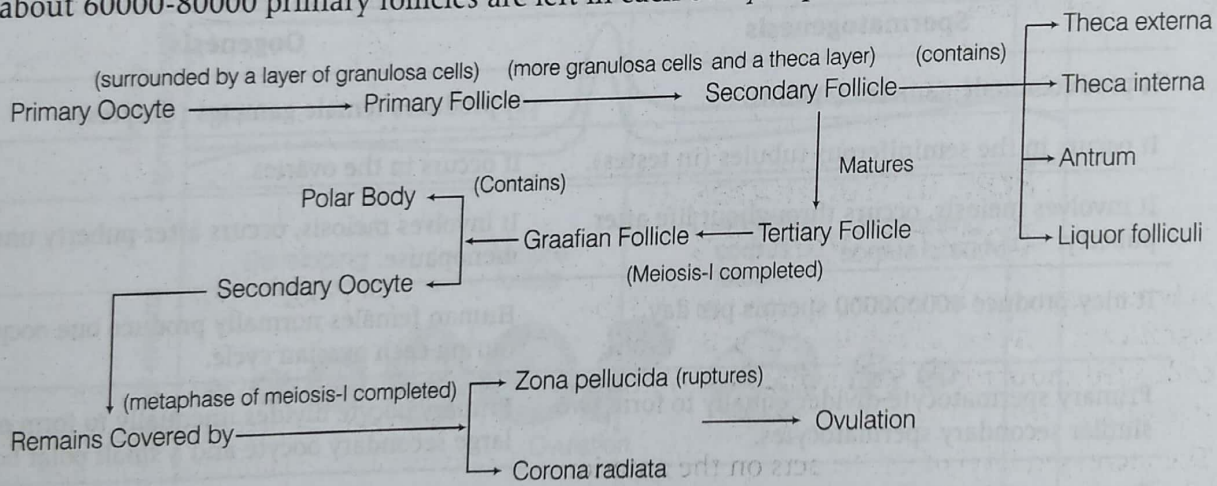


Figure 3.8 Stage of maturation of ova

(*vi*) The primary follicles get surrounded by more layers of granulosa cells and a new theca and are called **secondary follicles**.

(*vii*) The thecal layer in secondary follicles become organised into an outer theca **externa** and an inner theca **interna**. This stage is called **tertiary follicle**.

(*viii*) Tertiary follicle is characterised by a fluid-filled cavity called **antrum**.

(*ix*) At this stage, the primary oocyte within the tertiary follicle grows in size and completes its first meiotic division.

(*x*) The first meiotic division, which is unequal results in the formation of haploid **secondary oocyte** and tiny first polar body.

(*xi*) Secondary oocyte retains bulk of the nutrient rich cytoplasm of the primary oocyte.

(*xii*) The tertiary follicle develops into a mature follicle or **Graafian follicle**.

(*xiii*) The secondary oocyte forms a new membrane called **zona pellucida** surrounding it.

(*xiv*) The Graafian follicle ruptures to release the secondary oocyte (ovum) from the ovary by the process called **ovulation**.

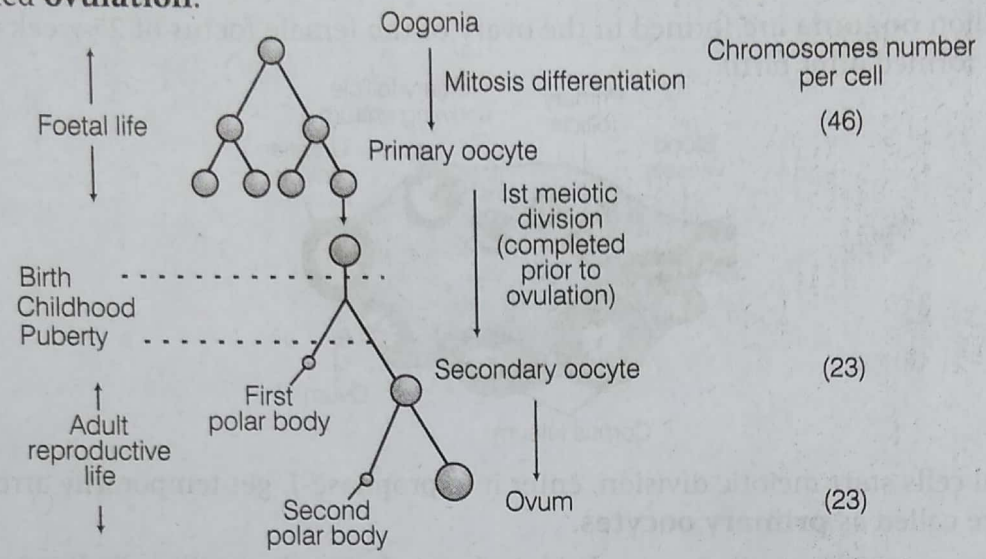


Figure 3.9 Oogenesis in human female showing formation of ovum

Differences between spermatogenesis and oogenesis

Spermatogenesis	Oogenesis
It produces male gametes (sperm).	It produces female gametes (oocytes).
It occurs in the seminiferous tubules (in testes).	It occurs in the ovaries.
It involves meiosis, occurs throughout life after puberty.	It involves meiosis, occurs after puberty until menopause.
It may produce 400000000 sperms per day.	Human females normally produce one oocyte during each ovarian cycle.
Primary spermatocyte divides equally to form two similar secondary spermatocytes.	Primary oocyte divides unequally to form one large secondary oocyte and a small polar body.
One spermatogonium produces four functional spermatozoa.	An oogonium produces one functional ovum and two non-functional polar bodies.

2.3 Menstrual Cycle

Menstrual cycle is a rhythmic change in the reproductive organs of the female primates (monkey, apes and humans).

(*i*) The first menstruation begins at puberty and is called **menarche**.

(*ii*) Average interval of menstruation in human female is about 28-29 days.

(*iii*) The cyclic events starting from one menstruation till the next one constitute one menstrual cycle.

(*iv*) The four phases of menstrual cycle are:

Menstrual Phase

(a) Cycle starts with this phase and the menstrual flow occurs for 3-5 days.

(b) It occurs due to breakdown of endometrial lining of the uterus. The blood vessels form liquid which along with unfertilised ovum comes out through the vagina.

(c) Menstruation occurs only if fertilisation does not takes place.

(d) Lack of menstruation generally indicates pregnancy, but may also be due to stress, poor health, diseases, etc.

Follicular or Proliferative Phase

(a) Menstrual phase is followed by the follicular phase.

(b) The primary follicle in the ovary grows to become a fully mature Graafian follicle and simultaneously the endometrium of uterus regenerates through proliferation.

(c) Pituitary and ovarian hormones induce the changes in ovary and uterus.

(d) LH and FSH levels increase gradually during this phase and stimulates follicular development.

(e) The growing follicles secrete oestrogens.

(f) Both LH and FSH attain highest level during mid-cycle (about 14th day).

Ovulatory Phase

(a) Rapid secretion of LH leading to its maximum level during the mid-cycle is called **LH surge**.

(b) The LH surge induces rupture of Graafian follicle, releasing the ovum called **ovulation**.

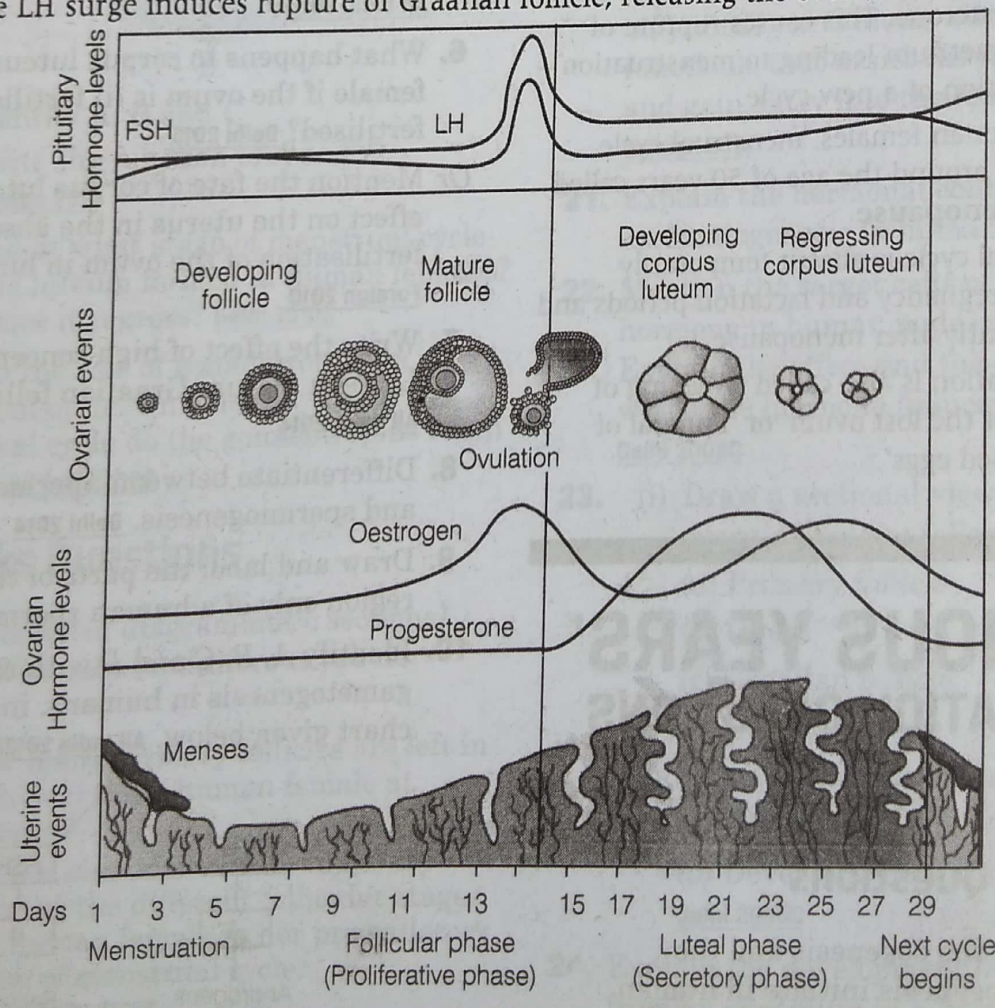


Figure 3.10 Diagrammatic representation of various events during a menstrual cycle

Luteal Phase/Secretory Phase

(a) Ovulatory phase is followed by the luteal phase.

(b) The remaining parts of the ruptured Graafian follicle changes into **corpus luteum**.

(c) Corpus luteum secretes large amounts of progesterone, which is required for the maintenance of endometrium.

(d) The thickened endometrium is necessary for the implantation of fertilised ovum and maintenance of pregnancy.

(e) During pregnancy, all the events of menstrual cycle stop and menstruation does not occur.

(f) In case of no fertilisation, the corpus luteum degenerates and now known as **corpus albicans**, which does not secret progesterone. This causes rupture of endometrium leading to menstruation – initiation of a new cycle.

(g) In human females, menstrual cycle stops around the age of 50 years called as **menopause**.

(*v*) Menstrual cycle is absent temporarily during pregnancy and lactation periods and permanently after menopause.

(*vi*) Menstruation is also called 'Weeping of uterus for the lost ovum' or 'Funeral of unfertilised eggs'.

[Topic 3] Fertilisation, Pregnancy and Embryonic Development

3.1 Fertilisation

The process of fusion of a sperm with an ovum is called Fertilisation.

(*i*) Semen of a male is transferred by the penis to the vagina of female during copulation (coitus) and is called **insemination.**

(*ii*) Spermatozoa move through the cervix, enter the uterus and reach the ampullary isthmic junction of Fallopian tube, where fertilisation takes place.

(*iii*) Fertilisation takes place only if the ovum released by the ovaries and sperms are transported simultaneously to the ampullary-isthmic junction of the Fallopian tube.

(*iv*) During fertilisation, a sperm comes in contact with **zona pellucida** layer of the ovum and induces changes in the membrane that block the entry of other sperms ensuring that only one sperm fertilises an ovum.

(*v*) The secretions of the acrosome help the sperms enter into the cytoplasm of the ovum through the zona pellucida and the plasma membrane.

(*vi*) This induces the completion of the meiotic division of the secondary oocyte which results into the formation of a haploid ovum (ootid) and a small **second polar body**.

(*vii*) The haploid nucleus of the sperms and that of ovum fuse together to form a **diploid zygote**.

(*viii*) After fusion of the male and female gametes, the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum. The zygote carrying XX would develop into a female baby and XY would form a male baby.

3.2 Implantation

The zygote implantation in uterus occurs in the following steps:

(*i*) The mitotic division within the zygote termed **cleavage** starts as the zygote moves towards the uterus through the isthmus of the oviduct.

(*ii*) It forms 2, 4, 8 and 16 daughter cells called **blastomeres**.

(*iii*) The embryo with 8-16 blastomeres is called a **morula.**

(*iv*) Morula continues to divide and transforms into **blastocyst** as it moves further into the uterus.

(*v*) Blastomeres in the blastocyst are arranged into an outer layer called **trophoblast**.

(*vi*) The inner group of cells attached to trophoblast constitute the **inner cell mass**.

(*vii*) Trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the embryo.

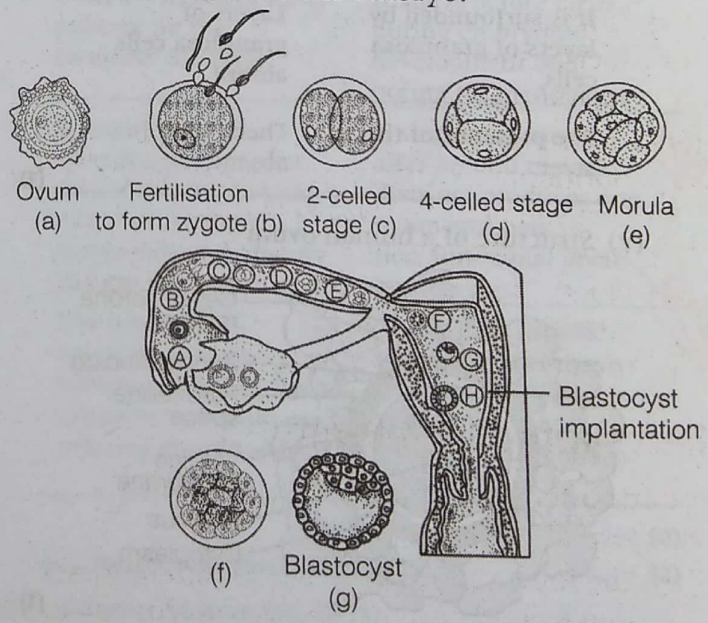


Fig 3.11 Implantation

(*viii*) After attachement, the uterine cells divide rapidly and covers the blastocyst. This leads to embedding of blastocyst in the endometrium of the uterus. This is called **implantation**.

3.3 Pregnancy

It starts after implantation. Following changes occur during pregnancy.

(*i*) The finger-like projections appear on the trophoblast called **chorionic villi**, surrounded by the uterine tissue and maternal blood.

(*ii*) Both the uterine tissue and chorionic villi become interdigitated with each other and jointly form a structural and functional unit between developing embryo and maternal body called **placenta**.

(*iii*) Placenta transports oxygen and nutrients to the foetus and removes carbon dioxide and excretory waste materials produced by the embryo.

(*iv*) Placenta also acts as an endocrine tissue and secretes hormones like human Chorionic Gonadotropin (hCG), human Placental Lactogen (hPL), oestrogen, progesterone, etc.

(*v*) A hormone called **relaxin** is secreted by the ovary, in later phase of pregnancy.

(*vi*) Umbilical cord connects the placenta with foetus and helps in transport of substances to and from embryo.

(*vii*) During pregnancy, the levels of other hormones like oestrogen, progesterone, cortisol, prolactin, thyroxine, etc., are increased many times in the maternal blood. These hormones support the foetal growth, maintenance of pregnancy and metabolic changes in mother.

Embryonic Development

It starts after pregnancy with the following changes:

(*i*) The inner cell mass (embryo) differentiates into an outer layer called **ectoderm** and an inner layer called **endoderm**.

(*ii*) Middle layer called **mesoderm** appears between the ectoderm and endoderm.

(*iii*) Primary germ layers give rise to all the tissues and organs of the adult. The inner cell mass contains certain cells called **stem cells**, which have the potency to give rise to all the tissues and organs.

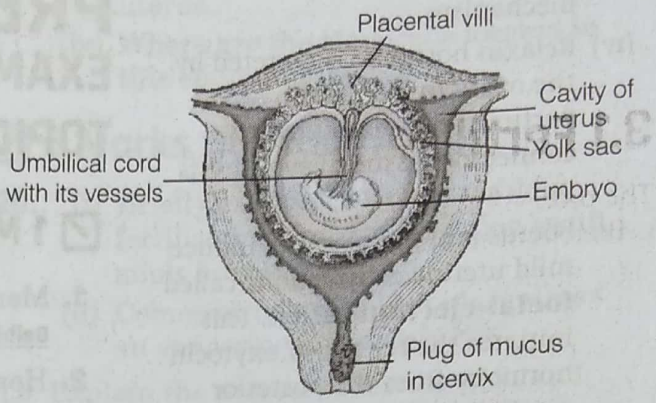


Figure 3.12 Human foetus within the uterus

(*iv*) In humans, after one month of pregnancy, the embryo's heart is formed. The sign of growing foetus can be ensured by listening the heartbeat.

(*v*) By the end of second month, limbs and digits develop.

(*vi*) By the end of third month (first trimester), most of the major organ systems are formed.

(*vii*) During the fifth month, the first movement of foetus and appearance of hair on the head are observed.

(*viii*) By the end of sixth months (second trimester), the body is covered with fine hair, eyelids separate and eyelashes are formed.

(*ix*) By the end of eight months, the testes in male foetus descend into the scrotum.

(*x*) By the end of nine months, the foetus is fully developed and ready for birth.

3.4 Parturition

The process of delivery of foetus (childbirth) is called **parturition**.

(*i*) The average duration of human pregnancy is about 9 months, which is called **gestation** period.

(*ii*) Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus.

(*iii*) Parturition is induced by complex neuroendocrine mechanism.

(*iv*) Relaxin hormone is secreted by the ovary to facilitate parturition by softening the connective tissue of symphysis pubica.

(*v*) Foetus and the placenta induce mild uterine contractions called **foetal-ejection reflex**. This initiates the release of oxytocin hormone from the posterior pituitary.

(*vi*) Oxytocin acts on uterine muscle to cause stronger contractions, which in turn stimulate further secretion of oxytocin. This causes more stronger contractions leading to the expulsion of the baby out of the uterus through the birth canal.

(*vii*) After the baby is delivered, the placenta is also expelled out of the uterus.

Lactation

Parturition is followed by the **lactation** which requires certain changes in the mother's body.

(*i*) Mammary glands of the female undergo differentiation during pregnancy.

(*ii*) By the end of pregnancy, these start producing milk by the process called **lactation**.

(*iii*) During the initial few days of lactation, the milk produced is called **colostrum**.

It contains several antibodies (IgA) and nutrients very essential to develop resistance in the newborn baby.