THE MALE REPRODUCTIVE SYSTEM

The male reproductive system consists of internal and external organs that work together to produce, mature, store, and deliver sperm for fertilization, while also producing key sex hormones like testosterone
The male reproductive system is located in the pelvis region (Figure 3.1a).

1. **External**: Scrotum, Testes, Penis
2. **Internal:** Epididymus, Vas differnese, Seminal Vesical, Prostate, Urethra

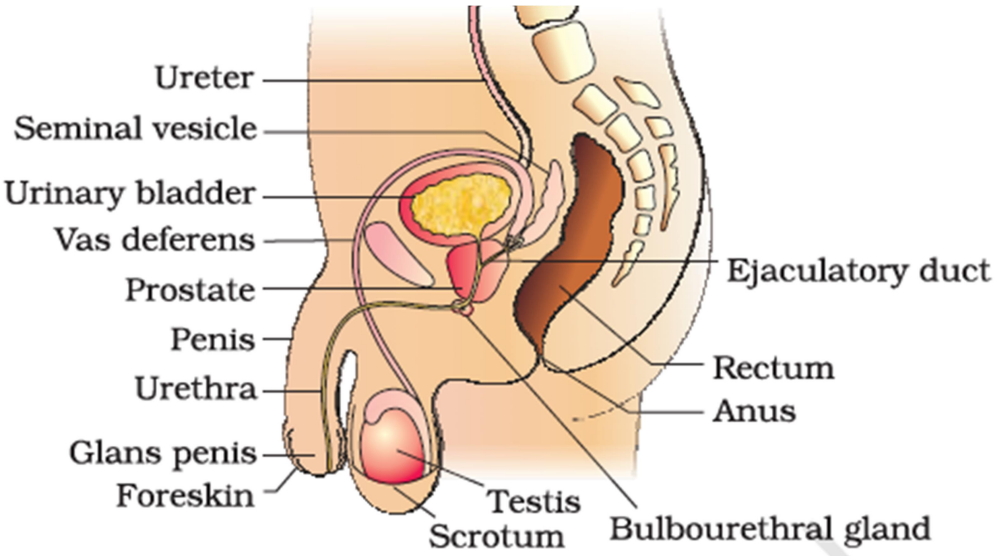


Figure 3.1(a) Diagrammatic sectional view of male pelvis showing reproductive system

External

1. 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 (2–2.5o C lower than the normal internal body temperature) necessary for spermatogenesis.

- Shape is Oval
- Length is 4 to 5 cm W
- Width of about 2 to 3 cm.
- It is covered by a dense covering.
- Each testis has about 250 compartments called **testicular lobules.**
- Each lobule contains one to three highly coiled **seminiferous tubules** in which sperms are
- produced.
- Each seminiferous tubule is lined on its inside by two types of cells called male germ cells **(*spermatogonia*)** and **Sertoli cells**.
- The male germ cells undergo meiotic divisions finally leading to sperm formation, while Sertoli cells provide nutrition to the germ cells.

- The regions outside the seminiferous tubules called **interstitial spaces**, contain small blood vessels and **interstitial cells or Leydig cells** (Figure 3.2). They are responsible for secreting the male sex hormones (i.e., testosterone) Testicular hormones called **androgens.** Other immunologically competent cells are also present.

1.1 Sertoli cell:

A Sertoli cell (a kind of sustentacular cell) is a 'nurse' cell of the testes which is part of a seminiferous tubule. It is activated by follicle-stimulating hormone, and has FSH-receptor on its membranes. Its main function is to nurture the developing sperm cells through the stages of spermatogenesis. Because of this, it has also been called the "mother cell." It provides both secretory and structural support. TOther functions During the Maturation phase of spermiogenesis, the Sertoli cells consume the unneeded portions of the spermatazoa.

2. **Penis:** The penis is an external genital organ. The distal end of the penis is called the glans penis and is covered with a fold of skin called the prepuce or foreskin. Within the penis are masses of erectile tissue. Each consists of a framework of smooth muscle and connective tissue that contains blood sinuses, which are large, irregular vascular channels.
3. **Scrotum**

It is a sac of thick skin that protects and surrounds the tests. It also controls temperature of the tests since they have to to be slightly at lower temperature than the body temperature for suitable sperm creation. The muscles in the wall allow the tests to hang far from the body or shrink to pull them closer for protection and warmth.

4. **Urethra:** The urethra, which is the last part of the urinary tract, traverses the corpus spongiosum and its opening, known as the meatus, lies on the tip of the glans penis. It is both a passage for urine and for the ejaculation of semen

Internal

1. **Epididymis**:

The seminiferous tubules join together to become the epididymis. The epididymis is a tube that is about 20 feet long that is coiled on the posterior surface of each testis. Within the epididymis the sperm complete their maturation and their flagella become functional. This is also a site to store sperm until the next ejaculation.

The epididymis has three parts-

1)head or caput epididymis- it is the proximal part of the epididymis. It caries the sperms from the testis.

2)body or corpus epididymis- it the highly convoluted middle part of the epididymis

3)tail or cauda epididymis

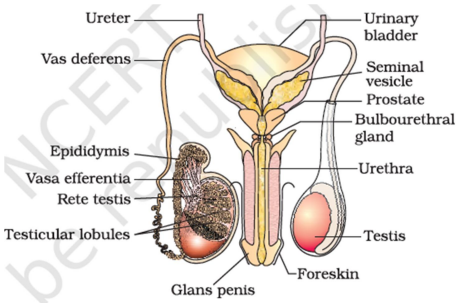
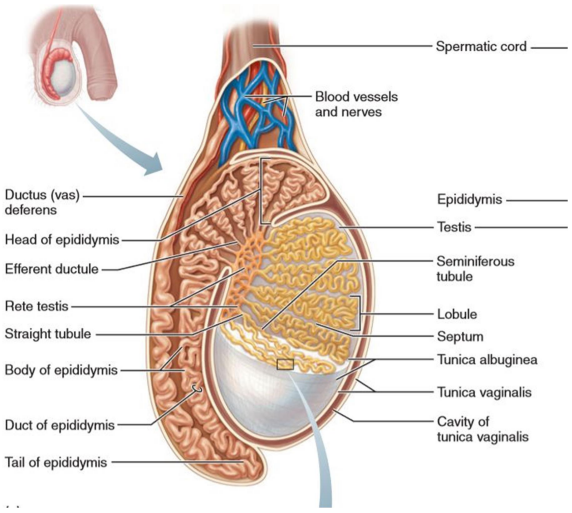


Figure 3.1(b) Diagrammatic view of male reproductive system (part of testis is open to show inner details)

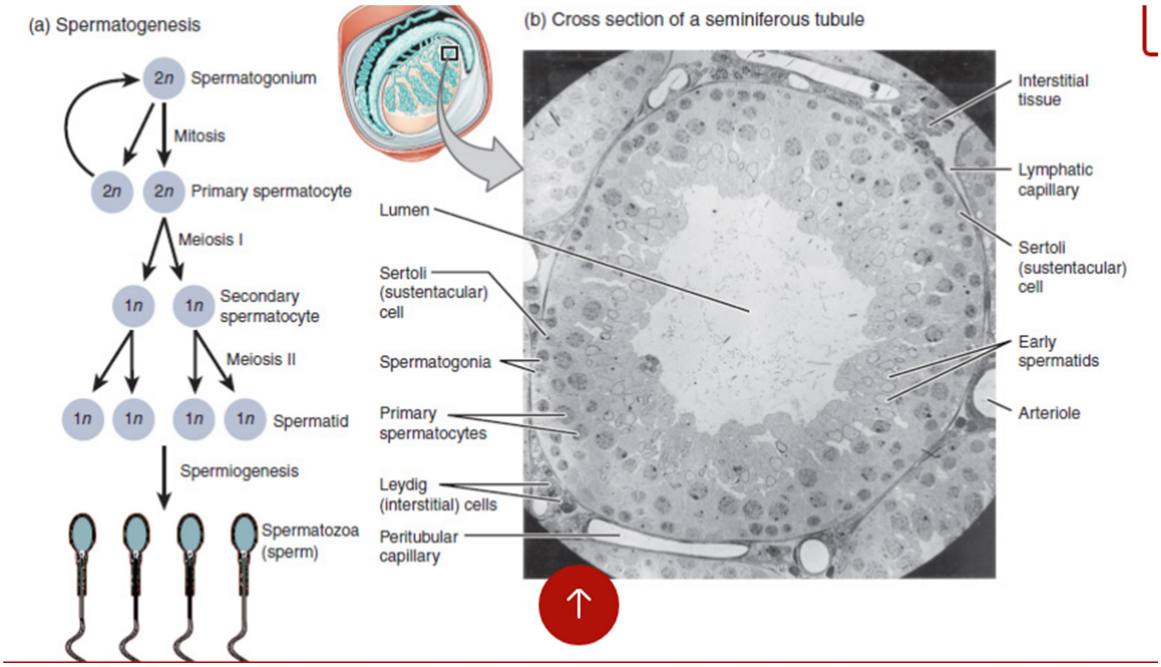
2. **The ductus (vas) deferens** : it is also called sperm duct, or, spermatic deferens, extends from the epididymis in the scrotum on its own side into the abdominal cavity through the inguinal canal. The inguinal canal is an opening in the abdominal wall for the spermatic cord (a connective tissue sheath that contains the ductus deferens, testicular blood vessels, and nerves. The smooth muscle layer of the ductus deferens contracts in waves of peristalsis during ejaculation.
3. **Seminal Vesicles:**
   The pair of seminal vesicles are posterior to the urinary bladder. They secrete fructose to provide an energy source for sperm and alkalinity to enhance sperm mobility. The duct of each seminal vesicle joins the ductus deferens on that side to form the ejaculatory duct.
4. **Ejaculatory Ducts:**
   There are two ejaculatory ducts. Each receives sperm from the ductus deferens and the secretions of the seminal vesicle on its own side. Both ejaculatory ducts empty into the single urethra.
5. **Prostate Gland**:
   The prostate gland is a muscular gland that surrounds the first inch of the urethra as it emerges from the bladder. The smooth muscle of the prostate gland contracts during ejaculation to contribute to the expulsion of semen from the urethra.
6. **Bulbourethral Glands**:
   The bulbourethral glands also called Cowper's glands are located below the prostate gland and empty into the urethra. The alkalinity of seminal fluid helps neutralize the acidic vaginal pH and permits sperm mobility in what might otherwise be an unfavorable environment.



FUNCTIONS:

- To produce, maintain, and transport sperm (the male reproductive cells) and protective fluid (semen)
- To discharge sperm within the female reproductive tract during sex
- To produce and secrete male sex hormones responsible for maintaining the male reproductive system

SPERMATOGENESIS



Spermatagonia divides several times during the process of sperm development. The entire process of sperm formation and maturation takes about **9-10 weeks.**

The separate divisions that take place and what happens in each are as follows:

1. **First division:** The first division is done by mitosis, and ensures a constant supply of spermatocytes, each with the diploid number of chromosomes.
2. **Second division:** Spermatocytes then undergo a series of two cell divisions during meiosis to become secondary spermatocytes.
3. **Third division:** Secondary Spermatocytes finally become spermatids.

- Spermatids, which are haploid cells, mature slowly to become the male gametes, or sperm.
- The sperm is the main reproductive cell in males.
- The sperms differ in that each carry a set of chromosomes dividing each into either a male, or female sperm.
- The females differ in that they carry a X gene, while the male sperm carry a Y gene. The female sperm also differ phenotypically in that they have a larger head in comparison to the male sperms.
- This contributes to the male sperm being lighter, and therefore faster and stronger swimmers than their female counterparts (although statistically there is still a 50% chance of an either XY or XX embryo forming.

NOTE: Spermatozoa are produced in the seminiferous tubules of the testes in a process called spermatogenesis. Round cells called spermatogonia divide and differentiate eventually to become spermatozoa. During copulation the vagina is inseminated, the spermatozoa move through chemotaxis to the ovum inside a Fallopian tube or the uterus.

STRUCTURE OF SPERM

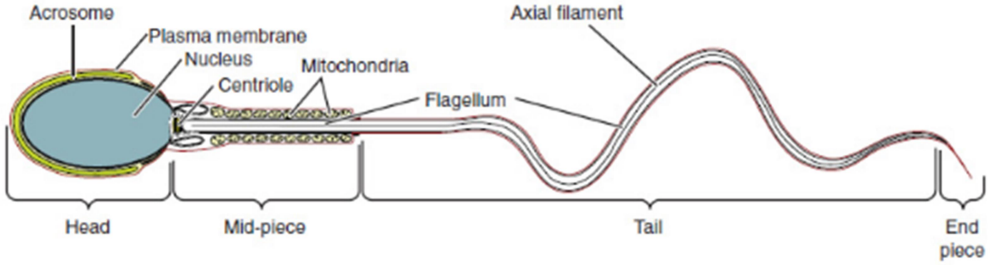


Figure 5. Structure of Sperm. Sperm cells are divided into a head, containing DNA; a mid-piece, containing mitochondria; and a tail, providing motility. The acrosome is oval and somewhat flattened.

FEMALE REPRODUCTIVE SYSYTEM

External Female Genitals

1. **Vulva:** The external female reproductive structures are referred to collectively as the **vulva**.
2. **Mons pubis:** It is a pad of fat that is located at the anterior, over the pubic bone. After puberty, it becomes covered in pubic hair.
3. **Labia majora** (labia = "lips"; majora = "larger") are folds of hair-covered skin that begin just posterior to the mons pubis.
4. **Labia minora** : The thinner and more pigmented **labia minora** (labia = "lips"; minora = "smaller") extend medial to the labia majora.
5. **Clitoris:** The superior, anterior portions of the labia minora come together to encircle the **clitoris** (or glans clitoris), an organ that originates from the same cells as the glans penis and has abundant nerves that make it important in sexual sensation and orgasm.
6. **Hymen** is a thin membrane that sometimes partially covers the entrance to the vagina. An intact hymen cannot be used as an indication of "virginity"; even at birth, this is only a partial membrane, as menstrual fluid and other secretions must be able to exit the body, regardless of penile–vaginal intercourse.

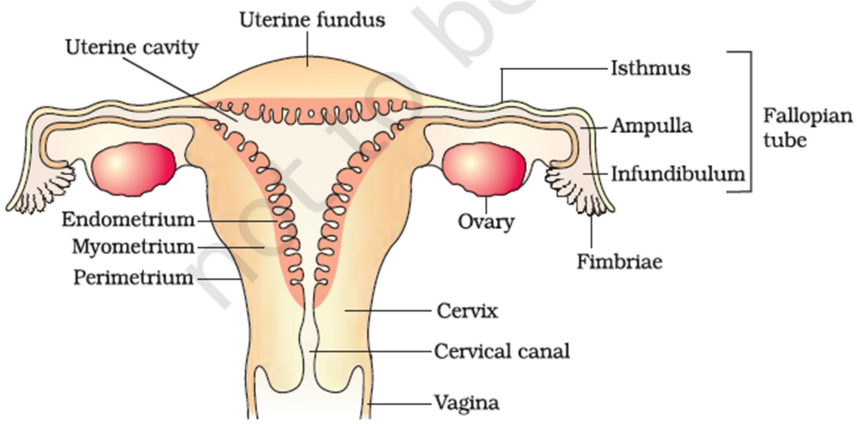
INTERNAL

1. **Bartholin's glands:** The vaginal opening is located between the opening of the urethra and the anus. It is flanked by outlets to the **Bartholin's glands** (or greater vestibular glands).

2. Vagina

- **Vagina** is a muscular canal (approximately 10 cm long) that serves as the entrance to the reproductive tract. It also serves as the exit from the uterus during menses and childbirth.
- The walls of the vagina are lined with an outer, fibrous adventitia; a middle layer of smooth muscle; and an inner mucous membrane with transverse folds called **rugae**.
- Together, the middle and inner layers allow the expansion of the vagina to accommodate intercourse and childbirth. The thin, perforated hymen can partially surround the opening to the vaginal orifice.
- The hymen can be ruptured with strenuous physical exercise, penile–vaginal intercourse, and childbirth. The Bartholin's glands and the lesser vestibular glands (located near the clitoris) secrete mucus, which keeps the vestibular area moist.
- The vagina is home to a normal population of microorganisms that help to protect against infection by pathogenic bacteria, yeast, or other organisms that can enter the vagina.
- In a healthy woman, the most predominant type of vaginal bacteria is from the genus *Lactobacillus*. This family of beneficial bacterial flora secretes lactic acid, and thus protects the vagina by maintaining an acidic pH (below 4.5).

Internal Structure



3. Ovaries

- The **ovaries** are the female gonads. Paired ovals, they are each about 2 to 3 cm in length, about the size of an almond. Ovaries are located within the pelvic cavity.
- The ovaries are small and oval-shaped, exhibit a grayish color, and have an uneven surface. The actual size of an ovary depends on a woman's age and hormonal status; the ovaries are approximately 3-5 cm in length during childbearing years and become much smaller and atrophic once menopause occurs.

- The ovary comprises of cortex is composed of a tissue framework called the ovarian stroma that forms the bulk of the adult ovary. Oocytes develop within the outer layer of this stroma. This grouping of an oocyte and its supporting cells is called a **follicle**.
- The ovaries are paired organs located on either side of the uterus within the mesovarium portion of the broad ligament below the uterine tubes. The ovaries are responsible for housing and releasing the ova, or eggs, necessary for reproduction. At birth, a female has approximately **1-2 million eggs, but only 300** of these eggs ever mature and are released for the purpose of fertilization.

4. **Uterus**

- The uterus is the inverted pear-shaped female reproductive organ that lies in the midline of the body, within the pelvis between the bladder and the rectum. It is thick-walled and muscular, with a lining that, during reproductive years, changes in response to hormone stimulation throughout a woman's monthly cycle.
- The uterus can be divided into 2 parts: cervix, and uterus
- The upper aspect of the uterus is dome-shaped and is called the fundus; it is typically the most muscular part of the uterus. The body of the uterus is responsible for holding a pregnancy, and strong uterine wall contractions help to expel the fetus during labor and delivery.
- Weight of Uterus: Nonpregnant 40-50 g. it have nerve, lymphatic and blood supply.

5. **Cervix**

The cervix is the inferior portion of the uterus, separating the body of the uterus from the vagina. The cervix is cylindrical in shape, with an endocervical canal located in the midline, allowing passage of semen into the uterus. The average length of the cervix is 3-5 cm.

6. Fallopian tubes

- The uterine tubes (also referred to as oviducts or fallopian tubes) are uterine appendages located bilaterally at the superior portion of the cavity.
- Their primary function is to transport sperm toward the egg, which is released by the ovary, and then to allow passage of the fertilized egg back to the uterus for implantation.
- Each tube is approximately 10 cm in length and 1 cm in diameter.
- The uterine tube has 3 parts. The first segment, closest to the uterus, is called the **isthmus**.
- The second segment is the **ampulla**, which becomes more dilated in diameter and is the typical place of fertilization.
- The final segment, furthest from the uterus, is the **infundibulum**. The infundibulum gives rise to the fimbriae, fingerlike projections that are responsible for catching the egg that is released by the ovary.

SEX HORMONES

1. INTRODUCTION

two types:

1. **Proteins:** These hormones weigh more than 5.000 daltons and therefore cannot penetrate the cells, they need membrane receptors.
2. **Steroids**: The steroids have a molecular weight of about 300 daltons, presenting thus a small size. Because of their size and lipo-solubility (soluble in fat), they can easily diffuse through target cells.

2. PROTEIN HORMONES

2.1 **Gonadotropins**

These hormones are produced by different tissues (pituitary and placenta) and their main function is gonadic regulation (ovaries and testicles). The gonadotropins include: FSH (folliculo-stimulating hormone), LH (luteinizing hormone) and hCG (human chorionic gonadotropin).

2.1.1 ***Folliculo-stimulating hormone (FSH)***

FSH is a glycoprotein produced by the pituitary gland and has a molecular weight of about 30.000 daltons.

Function

- To promote and sustain the ovarian follicular growth in women and the spermatogenesis in men.
- FSH stimulates also the synthesis of its own receptor on the granulosa and Sertoli cells and the LH receptor on granulosa cells.

2.1.2 ***Luteinizing hormone (LH)***

LH is a glycoprotein with a molecular weight of approximately 30.000 daltons, and produced by the hypophysis. Like FSH, LH is also present as a heterodimer with two different sub-units: a and b .

The principal functions of LH are:

1. Promoting the androgen synthesis in the interstitial cells of the testicles.
2. Inducing ovulation.
3. Maintaining the corpus luteum during the menstrual cycle.

2.1.3 Human chorionic gonadotropin (hCG)

hCG is a glycoprotein with a molecular weight of about 43.000 daltons.

Function: to maintain the corpus luteum of pregnancy and its progesterone secretion.

2.2 Prolactin (Prl)

Human prolactin is a non-glycosylated protein, which contains a simple polypeptide chain of 198 aminoacids.

Function: The principal biological function of prolactin in women is to control breast development and lactation.

3. THE STEROID HORMONES

3.1 Oestrogens

- Estrogen helps bring about the physical changes that turn a girl into a woman. This time of life is called **puberty**. These changes include:
- Growth of the breasts
- Growth of pubic and underarm hair
- Start of menstrual cycles
- Estrogen helps control the menstrual cycle and is important for childbearing.
- Estrogen also has other functions:
    - Keeps cholesterol in control
    - Protects bone health for both women and men
    - Affects your brain (including mood), bones, heart, skin, and other tissues

3.2 Progesterone (P4)

Progesterone is sometimes called the "hormone of pregnancy" and it has many roles relating to the development of the fetus:

- Progesterone converts the endometrium to its secretory stage to prepare the uterus for implantation.
- At the same time progesterone affects the vaginal epithelium and cervical mucus, making it thick and impenetrable to sperm.
- If pregnancy does not occur, progesterone levels will decrease, leading, in the human, to menstruation. Normal menstrual bleeding is progesterone-withdrawal bleeding. If ovulation does not occur and the corpus luteum does not develop, levels of progesterone may be low, leading to anovulatory dysfunctional uterine bleeding.
- During implantation and gestation, progesterone appears to decrease the maternal immune response to allow for the acceptance of the pregnancy.
- Progesterone **decreases contractility** of the uterine smooth muscle.
- In addition progesterone **inhibits lactation** during pregnancy. The fall in progesterone levels following delivery is one of the triggers for milk production.

3.3 Testosterone (T)

Men
Testosterone is the primary male sex hormone. It functions to develop a man’s primary and secondary sex characteristics.

Primary sex characteristics include:

- **Penis and testes size in adult men** – testosterone is responsible for developing the male genitals. Men who do not produce enough or any testosterone may maintain child-sized genitals;
- **Sperm production** – testosterone supports the final stages of sperm production and men who produce inadequate testosterone may be infertile ;
- **Libido** – testosterone regulates the male sex drive and inadequate testosterone production decreases libido;
- **Erectile function** – is also influenced by testosterone, which is important for the growth and development of erectile tissues (tissues in the penis which swell with blood in response to sexual stimuli and cause an erection). Testosterone also increases the activity of a molecule called nitric oxide synthase, which regulate the movement of smooth muscles (muscles which expand and contract involuntarily) in the penis. Increased nitric oxide synthase activity increases relaxation of smooth muscles in the penis and improve a man's ability to achieve and maintain an erection.

Secondary sex characteristics include:

- Hair growth – including the growth of pubic, body and facial hair;
- Deep voice;
- Heavier bones;
- Body composition – greater quantities of testosterone cause men to have a greater proportion of lean body mass and lower proportion of fat compared to women.

MENSTRUAL CYCLE

The menstrual cycle includes several phases. The exact timing of the phases of the cycle is a little bit different for every woman and can change over time.

Cycle days (approximate)	Events of the menstrual cycle
Days 1-5	The first day of menstrual bleeding is considered Day 1 of the cycle. Your period can last anywhere from 3 to 8 days, but 5 days is average. Bleeding is usually heaviest on the first 2 days.
Days 6-14	Once the bleeding stops, the uterine lining (also called the endometrium) begins to prepare for the possibility of a pregnancy. The uterine lining becomes thicker and enriched in blood and nutrients.
Day 14-25	Somewhere around day 14, an egg is released from one of the ovaries and begins its journey down the fallopian tubes to the uterus. If sperm are present in the fallopian tube at this time, fertilization can occur.
Days 25-28	If the egg was not fertilized or implantation does not occur, hormonal changes signal the uterus to prepare to shed its lining, and the egg breaks down and is shed along with lining. The cycle begins again on Day 1 menstrual bleeding.

The menstrual cycle has three phases:

1. Follicular Phase (Days 1-14)

- **Day 1-5 :** bright red bleeding.
- **Day 6-14:** After menstruation is over, in response to **increasing levels of estrogen** -> the lining of the **uterus (endometrium) becomes thicker.**
- **Pituitary gland** releases a hormone called **FSH**, causes several ‘follicles’ to rise on the surface of the ovary.

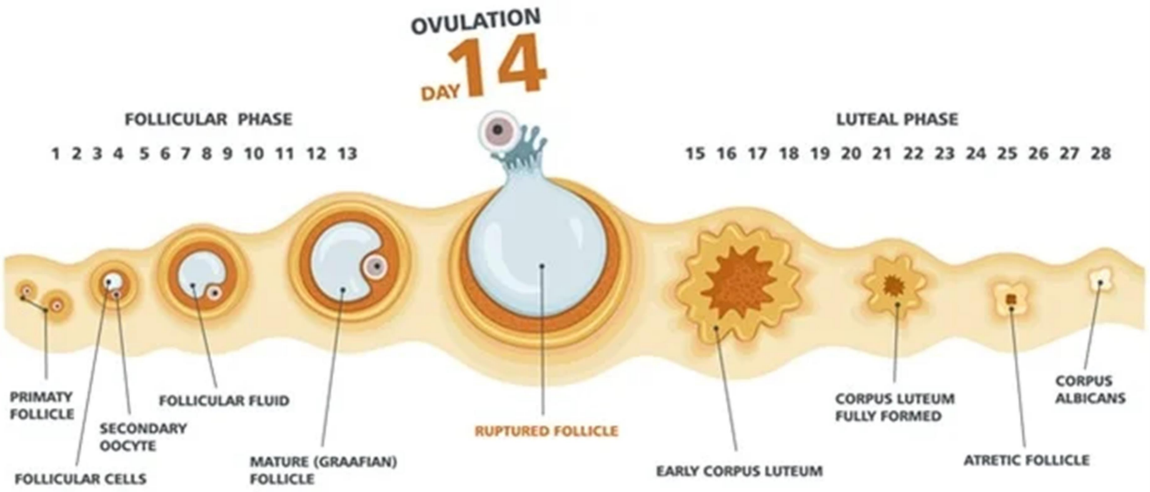
- These **fluid filled "bumps**" each contain an egg. Eventually, one of these follicle becomes dominant and within it develops a single mature egg; the other follicles shrink back. If more than one follicle reaches maturity, this can lead to twins or more.
- The maturing follicle produces the **hormone estrogen,** which increases over the follicular phase and peaks in the day or two prior to ovulation.
- **High blood levels of estrogen** -> production of (GnRH) → secrete luteinizing hormone (**LH**).
- On about day 12, surges in LH and FSH cause the egg to be released from the follicle. The surge in LH also causes a brief surge in testosterone, which increases sex drive, right at the most fertile time of the cycle.

2. Ovulatory Phase (Day 14)

The release of the mature egg happens on about day 14 as a result of a surge in LH and FSH over the previous day. After release, the egg enters the fallopian tube where fertilization may take place, if sperm are present. If the egg is not fertilized, it disintegrates after about 24 hours. Once the egg is released, the follicle seals over and this is called the corpus luteum.

3. Luteal Phase (Days 14-28)

1. After the release of the egg, **levels of FSH and LH decrease**.
2. The **corpus luteum** produces **progesterone**.
3. If fertilization has occurred, the corpus luteum continues to produce progesterone which prevents the endometrial lining from being shed.
4. If fertilization has not occurred, the corpus luteum disintegrates, which causes progesterone levels to drop and signals the endometrial lining to begin shedding.



Difference b/w Spermatogenesis and Oogenesis

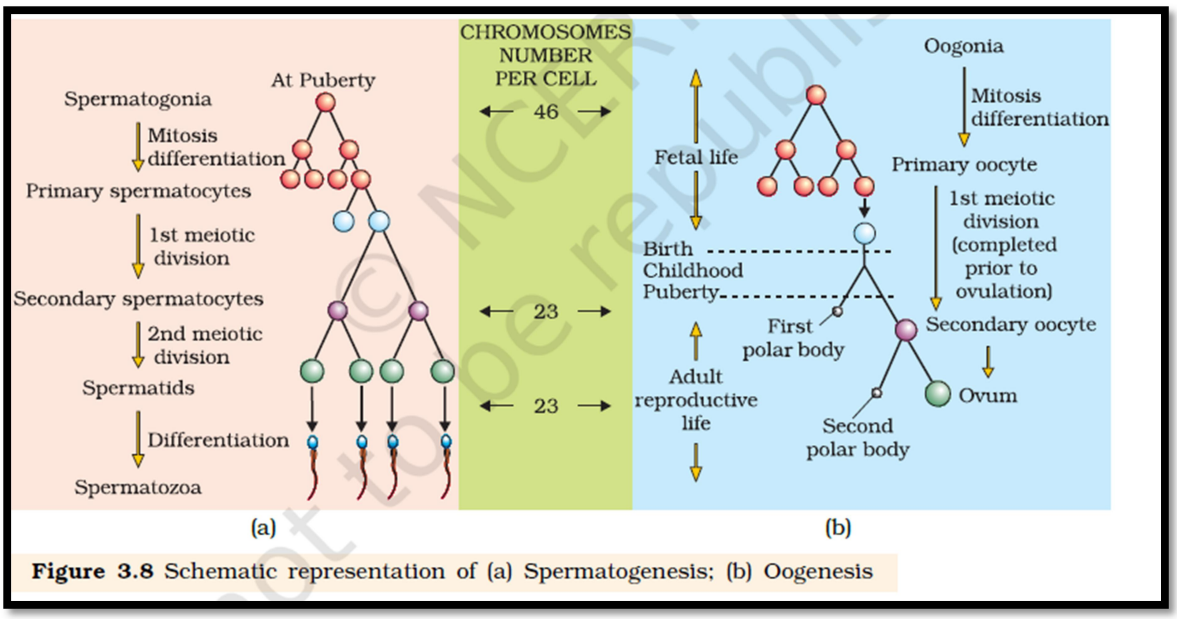


Figure 3.8 Schematic representation of (a) Spermatogenesis; (b) Oogenesis

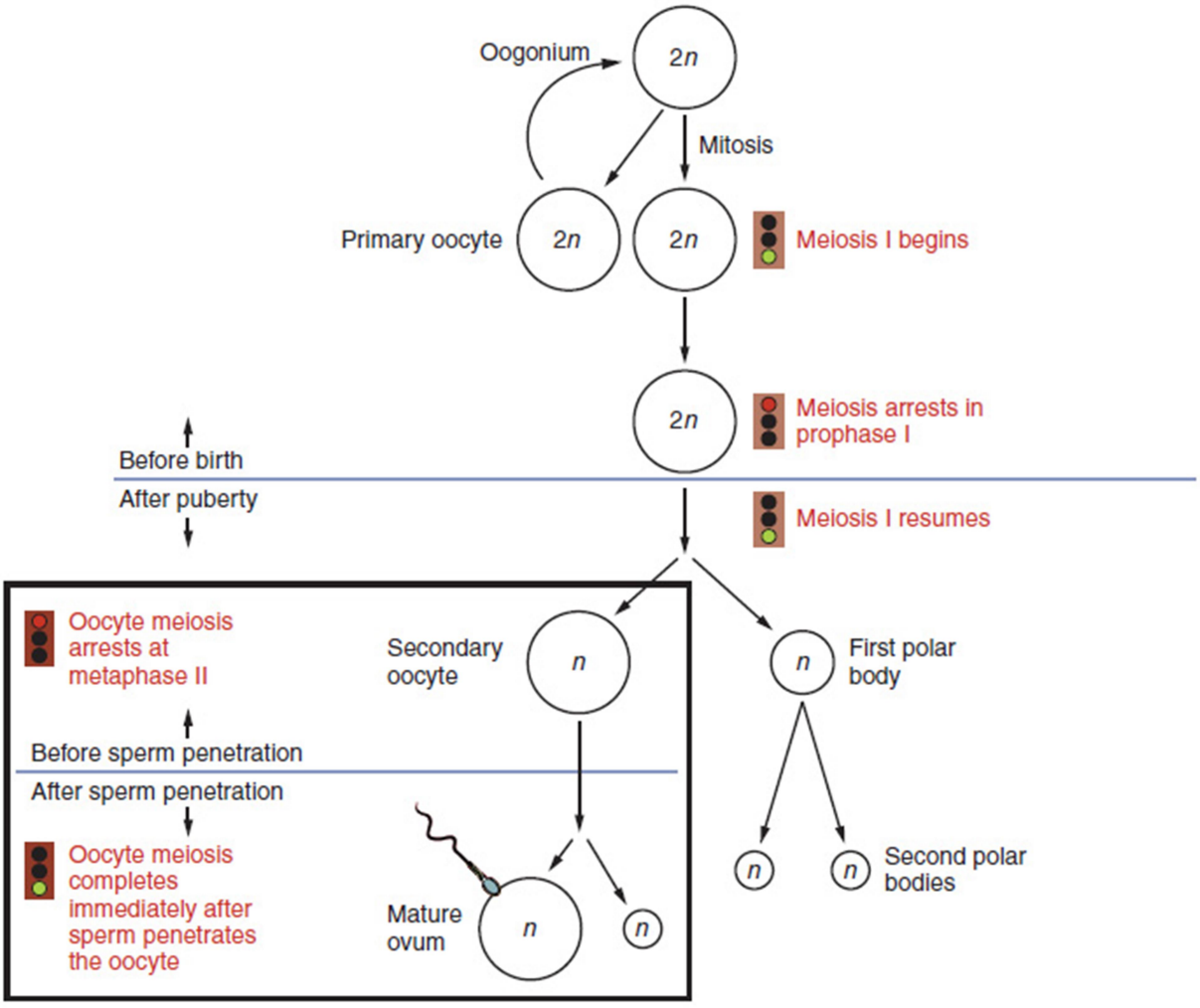


Fig. Process of Oogenesis

PREGNANCY

Pregnancy occurs when the sperm fertilizes the egg, and the zygote is formed.

The zygote gets implanted in the wall of the uterus.

As soon as the implantation takes place, the need for nourishment and care arises as the growth of the zygote develops into an embryo which further grows into a baby.

This responsibility is taken up by a layer formed between the baby and the mother, called the placenta.

The placenta is formed by finger-like projections called chorionic villi and the uterine tissue.

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

1. Providing nutrients and oxygen to the growing fetus.
2. It also removes the waste materials given out by the fetus substituting the function of the digestive system and the excretory system.
3. The placenta releases hormones like **human placental lactogen, progesterone, estrogen, human chorionic gonadotropin and relaxin** which are necessary for the growth of the fetus.
4. The umbilical cord that connects the fetus to the placenta helps in transportation of substances required for growth from the mother to the fetus.
5. As soon as the implantation takes place, the fertilized cell mass or embryo starts showing the triploblastic nature of human beings by dividing into the three layer of cells.
6. This gives rise to different organs during development – ectoderm, mesoderm, and endoderm.
7. All these steps after implantation lead to the development of the baby and it takes nine months in humans.
8. The development is very gradual and steady. At first, the heart of the embryo is formed, followed by limbs, major organs, the appearance of hair and so on. By the end of 9 months, the fetus is completely developed.

THREE TRIMESTERS

First trimester (Weeks 1–12)

- This crucial phase begins at conception (when a sperm fertilizes an egg). The embryo implants into the uterus and rapidly develops major organs, including the brain and spinal cord. The heart starts beating and Mother feels some following symptoms.
- Common symptoms include

    1. Missed period
    2. Nausea or morning sickness
    3. Fatigue
    4. Breast tenderness
    5. Frequent urination

Second trimester (Weeks 13–26)

This is also called the "honeymoon period", many early symptoms like nausea usually fade. For the mother, this time brings weight gain and other visible skin changes, such as the *linea nigra* (a dark line down the belly).

- The baby grows quickly.
- The mother may start feeling the baby's movements (called "quickening").
- Many people experience less nausea and more energy.

Third trimester (Weeks 27–40)

The final push toward birth is marked by the fetus gaining most of its weight. The mother may experience physical discomforts like lower back pain, frequent urination, and trouble sleeping as the baby drops lower into the pelvis in preparation for labor.

- The baby's lungs and brain continue to mature.
- The baby gains weight rapidly.

PARTURITION

1. Definition:

It is the expelling of the fully formed young from the mother's uterus after the gestation period (about 280 days or 40 weeks in human female) i.e., of about 9.5 months.

2. Mechanism:

- Parturition is induced by a complex neuroendocrine mechanism which is triggered by fully formed foetus and the placenta called **foetal ejection complex**.
- A developing **foetus secretes hormones** from its adrenal glands. These **hormones diffuse into the maternal blood** and accumulate to stimulate the **release of oxytocin** (birth hormone) from the mother's posterior pituitary.
- **Oxytocin** causes the forceful contraction of smooth muscles of myomefrium, called labour pains, which pushes the young gradually out through the **dilated cervix (caused by relaxin)** and vagina, with the head foremost. **Uterine contraction, in turn, stimulates further secretion of oxytocin**.
- The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in stronger and stronger contractions.
- It is aided by a reflex (whose centre lies in the lumbar region of spinal cord) and voluntary contraction of abdominal muscles. In the **beginning, the labour pains** occur once every half or quarter of an hour, called **mild ejection reflex**, but soon become more frequent.
- The foetal membranes burst and amniotic fluid is released but foetal membranes remain behind.
- This **expulsion stage lasts about 20 minutes to one hour**. It is followed by placental stage of 10-45 minutes during which the umbilical cord, placenta and foetal membranes are expelled as decidua or after birth.
- It is because after the child birth, the uterus reduces in size causing detachment of placenta.

- **Umblical cord is tied and then cut which finally shrinks into a depressed scar called umblicus or navel**. Sometimes, the foetus fails to come out then the baby is delivered by a surgical procedure. Such a baby is called cesarean.

3. Control of Parturition is controlled by hormones:

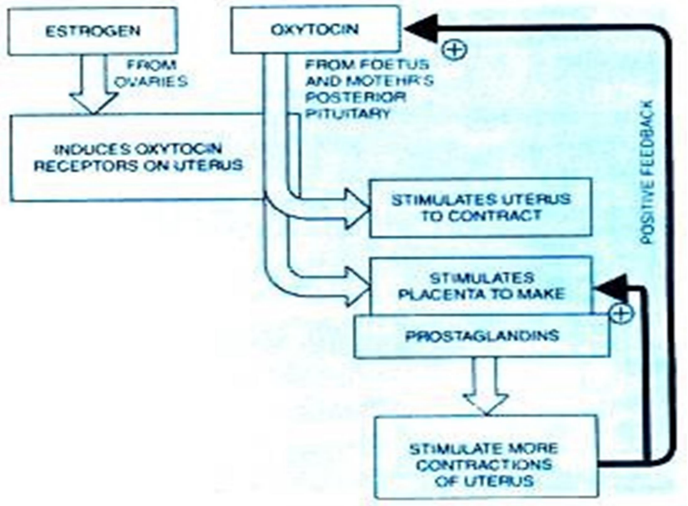


Fig. 3.35. Hormonal induction of labour

Oxytocin:

Causes powerful contractions of myometrium during parturition.

Relaxin:

Causes widening of pelvis by relaxing the pubic symphysis of the pelvic girdles

Lactation

It is the process of production of milk by the mammary glands at the end of pregnancy. The milk produced initially by the glands is called colostrum. This milk is crucial for the baby as it provides the child with the initial immunity.