

CHAPTER 9

Reproduction and Embryonic Development

Introduction

- Reproduction means "to multiply" or to increase in number. Reproduction is essential for the continuation of race or it is essential for maintaining the continuity of an individual species.
- Reproduction is of two types : **Asexual Reproduction** and **Sexual Reproduction**.

Asexual Reproduction

- In this fusion of male and female gametes does not take place and only a single parent is involved (uniparental). There is **no gamete formation, no fertilization, no meiotic division and variation** in asexual reproduction therefore, daughter organisms are genetically identical to the parent.
- It is of following types
 - (a) **Fission** During fission, the body of a single organism divides into two or more organisms.
 - (b) **Budding** In this, a daughter organism forms a small projection called as **bud**.
 - (c) **Fragmentation** In fragmentation the body of the parent may break into some pieces and then each piece develops into a whole animal.

Sexual Reproduction

- In this process, there is direct fusion of female gamete *ie*, egg (macrogamete) and male gamete *ie*, sperm (microgamete). It takes place by two methods : **Syngamy** and **Conjugation**
 - (a) **Syngamy**
 - It is the complete and permanent fusion of male and female gametes to form the zygote. Syngamy is of two types.
 - (i) **Exogamy** Exogamy or cross fertilization involves the fusion of two gametes, produced by different parents. Thus, it is biparental *eg*, Rabbit and other unisexual animals.
 - (ii) **Endogamy** It involves the fusion of two gametes of the same parent. Thus, it is uniparental *eg*, Tapeworm and other hermaphrodites.
 - Syngamy is also of two types on the basis of structure of fusing gametes.
 - (i) **Isogamy** It involves the fusion of two gametes of identical structure. Such gametes are called isogametes *eg*, *Monocystis*.
 - (ii) **Anisogamy (Heterogamy)** It involves the fusion of two dissimilar gametes. Such gametes are called **heterogametes**. It is found in frog, rabbit and humans.
 - (b) **Conjugation**
 - It involves temporary union of two parents of the same species which exchange their male pronuclei and then separate. It is somewhat cross fertilization and found in *Paramecium* and other ciliates.

Parthenogenesis

- Development of an unfertilized egg into a complete individual is known as parthenogenesis. It is of two types :

Complete Parthenogenesis

- It occurs in those animals which breed exclusively by parthenogenesis with no biparental sexual reproduction. There is no male and, therefore, such individuals are represented by females only *eg*, a lizard, *Lacerta saxicola arminicana*.

Incomplete Parthenogenesis

- In some animals, sexual reproduction as well as parthenogenesis occur collectively eg, In honey bee, fertilized egg (zygote) gives rise to queen and workers (both are females) and unfertilized eggs (ova) develop into drones (males) parthenogenetically.

MAMMALIAN REPRODUCTIVE SYSTEM

- Mammals are unisexual, it means male and female are separate, which has reproductive organs (gonads), reproductive ducts and accessory structures.

Male Reproductive System

Scrotum

- It is a pouch of deeply pigmented skin divided into two separate sacs. Each sac contains one testis.
- The normal temperature of testis in scrotum is about 2°C lower than internal body temperature, because it is ideal temperature for development of sperm.

Testes

- There is a pair of testes which are suspended in the scrotum by **spermatic cord**.
- Each testis consists of 200-300 lobules of seminiferous tubules.
- In testis, **Sertoli cells** or **Nurse cells** are present, which help in the nourishment of developing sperms.
- Sertoli cells secrete a glycoprotein hormone called **inhibin** which is involved in the negative feedback control of sperm production.
- In between the seminiferous tubules, small rounded **Leydig's** or **interstitial cells** are present which secrete **testosterone** (male sex hormone).

Epididymis

- Each testis contains a mass of long (about 4-6 mm) narrow closely coiled tubules, called the epididymis, which lies compacted along the testis from their upper end to lower back sides. Most of the epididymis consists of highly coiled duct with a true uncoiled length of 6 meter.
- It stores sperms and also secretes fluid which helps in nourishment of the sperms.
- **Wolffian duct** of embryo gives rise to epididymis in adult. Sperms achieve maturity and motility in epididymis.

Vas Deferentia

- These are two in number each of which joins with seminal vesicle and forms ejaculatory duct.
- Vas deferentia help in conduction of sperms.

Ejaculatory Ducts

- These are two short tubes approximately 2 cm long. Each formed by the union of a duct from seminal vesicle and a duct from vasa deferens.
- They pass through the prostate gland and join the prostatic part of the urethra.

Urethra

- Urethra is a tube-like structure, starts from urinary bladder and runs through the penis and opens to the outside at the tip of the penis. It includes three parts
 - (i) **Prostatic urethra**, carries urine only.
 - (ii) **Membranous urethra**, receives ducts from Cowper's glands.
 - (iii) **Penile urethra**, it lies inside corpus spongiosum.
- Urethra is a thick walled muscular duct and it is a common passage for both urine and semen and called **urinogenital duct**.

Penis

- Penis is composed of three cylinders of erectile spongy tissues-two dorsal **corpora cavernosa** and one ventral **corpus spongiosum**.
- The corpus spongiosum enlarges at the distal end of the penis which forms **glans penis**, that is more sensitive to stimulation.
- The penis is covered by a fold of skin, called the **foreskin** or **prepuce**.

Table 9.1 Male Reproductive System with Their Location and Function

Organ(s)	Description and location	Function
Testes	Primary sex organs; posterior to the penis within the scrotum	Produce spermatozoa (male gametes) and testosterone (male sex hormone)
Scrotum	Pouch of skin, posterior to the penis	Encloses and protects testes
Epididymis	Mass of tubules attached to the posterior surface of the testes	Site of sperm maturation; store spermatozoa
Ductus (vas) deferentia	Ducts extending from the epididymis to the ejaculatory ducts	Store spermatozoa; transport spermatozoa during ejaculation
Prostate	Walnut-sized gland at the base of the urinary bladder, surrounding the prostatic urethra	Secretes alkaline fluid that helps to neutralize acidic environment of the vagina; enhances motility of spermatozoa
Seminal vesicles	Club-shaped glands posterior to the prostate, attached to the ejaculatory ducts	Secrete alkaline fluid containing nutrients and prostaglandins
Bulbourethral glands	Pea-sized glands inferior of the prostate; empty into the membranous urethra	Secrete fluid that lubricates urethra and end of penis
Ejaculatory ducts	Short ducts between the ductus deferentia and the prostatic urethra	Receive spermatozoa and additives to produce seminal fluid
Penis	Pendant organ anterior to the scrotum and attached to the pubis	Convey urine and seminal fluid to outside of body, organ of coitus

Accessory Sex Glands

Seminal vesicles

- These are two in number and are sac-like structures situated near the base of the urinary bladder. Their ducts join the vas deferentia to form ejaculatory duct.
- The secretion of the seminal vesicle contains fructose, amino acids, proteins, ascorbic acids, citric acid and prostaglandins.
- Fructose is a source of energy for sperm and prostaglandins stimulate uterine contractions and thus, help in the movement of sperms towards the female's oviduct.
- Seminal vesicles contribute about 60% of the total volume of the semen.

Prostate gland

- It secretes a milky fluid which helps in sperm motility and nourishment.
- This fluid contains a small amount of citric acid, some lipids, few enzymes and bicarbonate ions, which give the semen to its alkaline pH.

Cowper's glands or Bulbourethral glands

- A pair of Cowper's glands is located in the floor of pelvic cavity.
- Their secretion which contains mucous for lubrication, enters the semen through the ducts.

Semen

- It contains secretions of seminal vesicles, prostate gland, Cowper's glands and sperms from testes.
- Each ejaculation contains about 400 million sperms in 2-6 mL of fluid.
- The pH of semen is slightly alkaline (7.35 to 7.50). This alkaline pH protects sperms from acidity in urethra (male) and vagina (female).

Female Reproductive System

Ovaries

- These are two in number, 3 cm long, 2 cm wide, 1 cm thick, almond-shaped female gonads.
- Internally ovary is consisted of **germinal epithelium**, **tunica albuginea**, **stroma** and **Graafian follicles** (ovarian follicles).
 - Germinal epithelium**
 - Outer covering of ovary which consists of cubical cells. It is covered by a layer of visceral peritonium.
 - Tunica albuginea**
 - It is present beneath the germinal epithelium. It is made up of connective tissues.
 - Stroma**
 - It is made up of dense outer layer called the **cortex** and a dense inner portion called the **medulla**.

(d) Graafian follicles (Ovarian follicles)

- Within the cortex, many ovarian follicles or Graafian follicles are present in different stages of development.
- Each follicle contains an **oocyte** which is covered by a **zona pellucida**, a homogenous membrane.
- A woman produces about **450 ova** in her entire reproductive life span.

Fallopian Tube (Oviduct)

- It is tube like passageway from an ovary to the uterus. It consists of following parts.
 - Uterine part** Which lies within wall of the uterus between the fundus and body.
 - Isthmus** It is a narrow and straight part which is present just lateral to the wall of uterus.
 - Infundibulum** It is a finger like cluster of fallopian tube that lies near contact with ovary.
 - Ampulla** It is the widest part of fallopian tube. It is present behind the infundibulum. Here **fertilization of ovum takes place**. The function of uterine tube is to carry the ovum from the ovary to uterus by **peristaltic movements**.
- The embryo develops upto **blastocyst stage** in fallopian tube.

Uterus

- Latin word meaning 'womb'. It is a hollow pear-shaped muscular structure which lies in the pelvic cavity.
- It sits above the urinary bladder and in front of the rectum and connects direct with the vagina.
- The wall of the uterus is composed of 3-layers of tissues.
 - Perimetrium** It is an outer covering of peritonium.
 - Myometrium** It forms the middle layers of smooth muscular fibres.
 - Endometrium** The inner lining of uterus. This lining has two layers, an underlying permanent layer and a functional transient layer, that is in contact with the uterine cavity. The functional layer grows and thickens each month, reading itself for the implantation of an embryo. If an embryo is not present, the functional layer is shed. This monthly development and shedding of the functional layer of the endometrium is called menstrual cycle.
- The attachment of developing **foetus** (trophoblast) with the wall of the uterus is known as **implantation**. Implantation takes place after seven days of fertilization (7-10 days in humans).

Vagina

- It is tube (9 cm long) like muscular passageway. It has following functions :
 - During sexual intercourse, it accepts the penis.
 - It is the place where sperms are released and deposited.
 - It is the lower portion of the birth canal during child birth.
 - It provides a passageway for the exit of the menstrual flow.

Clitoris

- Clitoris is a small organ consisting of erectile tissue and is homologous to the penis of the male.
- It is a solid structure, however male penis has urethra.

Table 9.2 Female Reproductive Organ with Their Function and Location

Organ(s)	Description and location	Function
Ovaries	Primary sex organ; upper pelvic cavity on both lateral sides of uterus	Production of ova (female gametes) and female sex hormones
Uterine tubes (fallopian tubes)	Open ended tubes that extend from the ovaries to the uterus	Convey ova towards uterus; site of fertilization, convey developing blastocyst to uterus
Uterus	Hollow, musculomembranous organ shaped like an inverted pear; maintained in position within the pelvic cavity by muscles and ligaments	Site of implantation; sustains life of embryo and foetus during pregnancy; plays active role in parturition
Vagina	Hollow, musculomembranous organ positioned between the urinary bladder and urethra anteriorly and the rectum posteriorly	Conveys uterine secretion to outside of body; receives erect penis and semen during coitus; passageway for foetus during parturition
Labia Majora	Two longitudinal folds of skin that extend from the mons pubis to the perineum separated longitudinally by the pudendal cleft	Form margins of pudendal cleft, enclose and protect other external reproductive organs
Labia Minora	Two longitudinal folds of skin medial to the labia majora, separated longitudinally by the vaginal vestibule	Form margins of vestibule, protect openings of vagina and urethra
Clitoris	Rounded projection at the upper part of the pudendal cleft, sheathed by a prepuce	Provides feeling of pleasure during sexual stimulation
Vestibular glands	Subcutaneous within the wall of the vaginal opening	Secrete lubricating fluid into the vestibule and vaginal opening during coitus
Mammary glands	Composed of lobes within the breasts	Produce and secrete milk for nourishment of an infant

The External Genitals

- The external genitals of a female are collectively called the **vulva**.
- The most anterior structure of vulva is the **mons pubis** refers to mound of fatty tissue which is covered with skin and pubic hairs.
- Two longitudinal folds of skin called the **labia majora** form the boundary of vulva. Labia majora covers two additional folds of skin called the **labia minora**.
- Labia majora and labia minora protect the vaginal and urethral opening. The labia minora, in addition to vaginal and urethral openings, also covers the openings of several tiny ducts that produce a mucous like secretion during sexual intercourse.

Mammary Glands

- There are two mammary or milk producing glands found in each normal female.
- Males also contain mammary glands but in rudimentary or vestigial form.
- Each mammary gland lies over the chest muscles.
- Externally, each mammary gland has a median nipple, surrounded by a pigmented area, called the **areola**.
- Several sebaceous glands, called the **areolar glands** are found on the surface of areola.
- These are modified **sweat glands**.

Types of Reproductive Cycles in Female

- Two main types of reproductive cycles are found in females of mammals.
 1. Estrous cycle — Found in non primate families.
 2. Menstrual cycle — Found in primate families.

Estrous Cycle

- Estrous cycle takes place in non-primate mammals eg, cow, dogs, cats etc.
- An estrous cycle is consisted of a short period of **estrous or heat**.
- During estrous period, the female is most receptive to male.
- Estrous period is followed by a **passive** or **anestrous** period during which the female becomes passive and does not receive the male.

Menstrual Cycle

- Cyclic changes occur in the uterus, extending approximately a month period.
- Average duration of menstrual cycle is 28 days. Follicle is matured after 14 days and **ovulation** takes place in between 14-21 days.
- Menstrual cycle has three phases ie, proliferative, secretory and menstrual phase.
 - (a) **Proliferative phase**
 - FSH stimulates follicle to secrete oestrogens.
 - This phase has a duration of 10-12 days.
 - It is also called follicular phase.
 - (b) **Secretory phase**
 - Corpus luteum secretes progesterone.
 - Phase has duration of 12-14 days.
 - (c) **Menstrual phase**
 - If ovum is not fertilized, the corpus luteum degenerate causing sudden fall in the progesterone level.
 - Breakdown of endometrium takes place which results in discharge of blood.
 - It is controlled by FSH, LH, oestrogen and progesterone.
 - The menstrual cycle and menstruation **remain** suspended during pregnancy and lactation.

Menopause

- Reproductive life of a girl begins from **menarche** (ie, first menstrual flow about 10-16 years age) and ends by **menopause**.
- Ovulation and menstrual cycle are stopped permanently in menopause.
- Menopause occurs around 45-50 years of age.
- In this stage, woman lose the ability to reproduce.

Gametogenesis (Gamete Production)

- The sexual reproductive process begins with the production of male and female gametes.

- The gametes are produced from specialized cells called **primordial germ cells**. These cells are found in the gonads (*ie*, testes and ovaries) and are designated to become the **germ cells**.
- The process of formation and maturation of gametes (ova and sperm) is called **gametogenesis**.
- **Spermatogenesis** is the formation and maturation of male gametes or spermatozoan.
- **Oogenesis** is formation and maturation of female gametes or ova.

Structure of Mature Sperm

- The human sperm was first seen by **Hamm** and **Leeuwenhoek** in 1677.
- A mature spermatozoan of sperm cell is a microscopic, tadpole shaped cell of about 2.5 μm in diameter and 60 μm long.
- It consists of an oval head, cylindrical body and an elongated tail.
- The **head** contains the **nucleus** having haploid number of chromosomes. It also contains the **acrosome**, a large lysosome which contains **hydrolytic enzymes**.
- Acrosome is involved in the penetration of the layers surrounding the egg immediately before fertilization.
- The **short neck** contains a pair of centrioles lying at right angle to each other, their microtubules form **axial filament**. The **middle piece** is the first part of the tail and is enlarged by the presence of many **mitochondria** arranged in a **spiral** around the axial filament.

Structure of Egg or Ovum

- Human egg or ovum is **non-cleidoic** (*ie*, without shell), **alecithal** (*ie*, yolk remains absent), microscopic with about 0.1–0.13 mm or 100 to 130 μm in diameter.
- The ovum possesses three coverings *ie*, inner **plasma membrane**, middle glycoproteinous **zona pellucida** and outer cellular **corona radiata** with radially elongated scattered cells held in mucopolysaccharide (hyaluronic acid).

Types of Eggs or Ovum

- On the basis of **amount of yolk**, the eggs are of the following types :
 - Alecithal eggs** do not contain yolk *eg*, human eggs.
 - Microlecithal eggs** contain a little amount of yolk *eg*, eggs of tunicates, *Amphioxus*, urchins etc.
 - Mesolecithal eggs** contain a moderate amount of yolk *eg*, eggs of frog, lung fish and toads.
 - Macrolecithal eggs** contain large amount of yolk *eg*, eggs of reptiles, birds, bony fishes, prototherial mammals.
- On the basis of **yolk distribution**, the eggs are of the following types :
 - Homolecithal eggs (isolecithal)** contain a homogenously distributed yolk *eg*, eggs of protochordates and echinoderms.
 - Telolecithal eggs** contain most of the amount of yolk at their vegetal pole, *eg*, eggs of amphibians.
 - Meiolecithal eggs** contain a very large amount of yolk which occupies nearly the entire ooplasm and leaving only a small disc like area of cytoplasm for the nucleus *eg*, eggs of reptiles, birds etc.
 - Centrolecithal eggs** contain centrally concentrated yolk *eg*, eggs of insects.
- On the basis of presence of **shell**, the eggs are of the following types :
 - Non-cleidoic eggs** does not contain a shell, *eg*, eggs of frog, human etc.
 - Cleidoic eggs** contain a water proof shell, *eg*, eggs of birds and reptiles.

Fertilization

- It involves the union of female ovum and male sperm which resulted in formation of a diploid **zygote**.
- **External fertilization** occurs in oviparous animals which lay egg in water, *eg*, frog.
- **Internal fertilization** occurs in ovoviviparous and viviparous animals, *eg*, *Echidna*, rabbit and man.
- **Fertilizins** are the substances emitted from mature eggs.
- **Antifertilizin** is present on the surface layer of the cytoplasm of spermatozoa.
- In **mammals** (rabbit and human beings), fertilization of the ovum occurs in **fallopian tube**.
- The fusion of male and female pronuclei is called **amphimixis** (syngamy).

Cleavage and Early Embryo Development

- Cleavage is a process of rapid mitotic divisions of the zygote.
- Cleavage involves cell division **without** growth in size because cells continue to be retained within the **zona pellucida**.
- In all animals, fertilized ovum develops in the sequence : zygote, cleavage, morula, blastula, gastrula and neurula.
- Development of a fertilized egg starts with cleavage.

Patterns of Cleavage

- (a) **Radial** — Sponges
- (b) **Spiral** — Annelida and Mollusca
- (c) **Bilateral** — Amphibia and higher mammals

Types of Cleavage

(a) **Holoblastic cleavage**

- Found in isolecithal eggs. In this cleavage, furrows extend completely through the egg. *eg.* echinoderms, tunicates, cephalochordates, nemerteans, most molluscs and several vertebrate animals (including human).

(b) **Meroblastic cleavage**

- Found in telolecithal eggs. In this type of cleavage pattern, the cleavage furrows can not cut through the heavy yolk. *eg.* reptiles and amphibians.

Morula Stage

- Zygote divides by repeated holoblastic cleavage and forms a **32-celled** structure, called the **morula**.
- Each cell present in morula embryo is called as **blastomere**.
- At the end of morula stage-embryo reaches the uterus.

Blastula Stage

- It is a **64 celled** stage which contains a fluid filled cavity called as **blastocoel**.
- This embryo is known as **blastocyst** and is comprised of an inner cell mass which is attached to embryonic or **animal pole** and an outer covering of cells called **trophoectoderm** or **trophoblast**.
- The opposite side of animal pole is known as **abembryonic pole**.
- Inner cell mass or embryoblast is the precursor of embryo and later gives rise to the embryo, while the nutritional requirement of developing embryo is fulfilled by trophoblast cells.
- In certain animals, the blastula is solid and called **stereoblastula** (*eg.* cnidaria, Annelida *ie.* *Nereis* and some molluscs). The blastula with blastocoel is called **coeloblastula** (*eg.* frog, *Amphioxus*). The blastula formed as a result of superficial cleavage is called **superficial blastula** (*eg.* insects) and blastula formed as a result of discoidal cleavage is called **discoblastula** (*eg.* birds)

Implantation of Blastocysts

- After one week of fertilization, implantation begins to start.
- During implantation, the trophoectoderm (trophoblast) comes in contact with the endometrium of the uterus and sinks into a pit formed in the endometrium and gets completely buried in the endometrium.
- Trophoblast cells form specialized structures, called **villi** which help in absorption of nutrient materials.

Gastrulation

- It is a dynamic process, which involves cell movements by which a hollow or flat blastula is transformed into a layered gastrula.
- Three germ layers are formed due to morphogenetic movements (in gastrula) from the inner cell mass of the blastocyst. These are **ectoderm** (out skin), **mesoderm** (middle skin) and **endoderm** (inside skin).

Table 9.3 Fate of Three Germ Layers

Ectoderm	Mesoderm	Endoderm
Epidermis, including glands, hairs, nails	Dermis of skin	Linings of alimentary canal except mouth and anal canal, vagina, urethra
Epithelial lining of sense organs, nasal cavity, sinuses, mouth, oral glands and anal canal	Connective tissue, mitochondria, cartilage, bone	Liver, pancreas and their ducts
Nervous tissue, pituitary gland, adrenal medulla, pigment cells, pineal body	Muscles	Gastric and intestinal glands
Retina, cornea, conjunctiva, lens of eye, internal ear	Body cavities, coelomic epithelium	Primordial germ cells
	Gonads, genital ducts	Thyroid, parathyroid, thymus
	Kidney, ureter	Middle ear and eustachian tube
	Lymphoid tissue and lymphatics	Urinary bladder
	Heart, blood vessels	Respiratory system
	Adrenal cortex	
	Blood and bone marrow	

Extra Embryonic or Foetal Membranes

- These are called extra embryonic membranes because they are not a part of the body of the embryo. These membranes play some role in the life support of pre-embryo, the embryo and the foetus.
- These membranes are formed from the **trophoblast** (the ring of cells surrounding the inner cell mass in a developing pre-embryo). These membranes include amnion, allantois, chorion and yolk sac.

Amnion

- It is a thin, fluid (amniotic fluid) filled sac that fully encloses the embryo. It provides an aqueous environment in which the embryo is protected from shocks and adhesion.

Allantois

- It is a tiny sausage shaped pouching which arises from the gut of the embryo near the yolk sac. In human, it supplies the blood vessels to the placenta. But in reptiles, birds and egg laying mammals, it helps in the exchange of oxygen and carbon dioxide.

Chorion

- It lies just beneath the egg shell. It completely encloses the developing embryo and extra embryonic tissues. The chorion is highly specialized to facilitate the transfer of nutrients, gases and wastes between the embryo and the mother's body.

Yolk Sac

- It is a membrane that surrounds the yolk. In mammals, it is reabsorbed before the embryo is borned. In others such as fishes, it remains attached to the free living larvae and is used as a food source until the fish can begin to feed itself.

Gestation Period

Table 9.4 Gestation Periods (average) in Mammals

Elephant	620 days	Woman	266 days
Rhinoceros	560 days	Lion	106 days
Giraffe	450 days	Panther	93 days
Camel	395 days	Dog	50-60 days
Horse	330 days	Rat	20 days
Cow	280 days		