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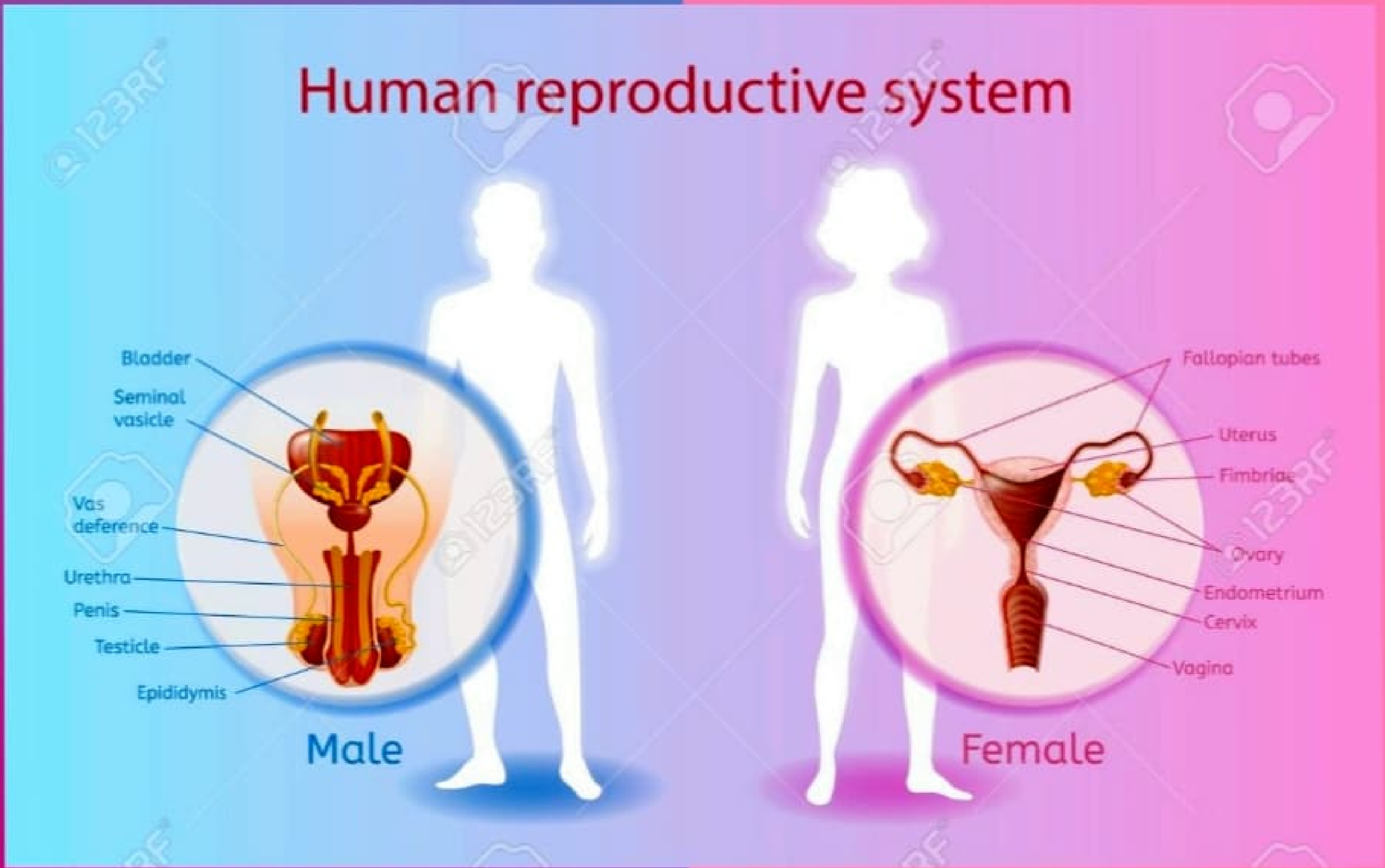


CHAPTER - 3

BIOLOGY

Class -12

EMBRYONIC DEVELOPMENT

A study of the development of an organism from fertilization to the formation of young one is known as embryogeny. In fact, embryogeny includes all changes by which a fertilized ovum (zygote) is transformed into an adult. Formation of sex cells or gametes is said to be **gametogenesis.** A special type of nuclear division, called **meiosis**, occurs during gametogenesis and as such gametes contain only half or haploid number of chromosomes. When male and female gametes unite at the time of fertilization, the resulting cell (zygote) again has the full or diploid number of chromosomes. Male germ cells (spermatozoa or sperms) are formed in male gonads (testes) by spermatogenesis. Similarly, female germ cells (ova) are produced by female gonads (ovaries) by oogenesis. The fertilized ovum passes through a series of dynamic changes and identifiable stages and eventually attains an adult organization. The structural changes in a zygote leading to the formation of adult form are thus said to be embryonic development.

FERTILIZATION

The fusion of the male (sperm) and the female (ovum) gametes to form zygote is called fertilization. In lower vertebrates (fish and amphibians), fertilization normally occurs outside the body of the female (generally in water) and it is called **external fertilization**. However, in higher vertebrates (reptiles, aves, mammals), fertilization occurs within the body of the female and it is known as **internal fertilization**. Fertilization brings together maternal and paternal chromosomes and thus restores the diploid number of chromosomes. The process is of genetic significance because by bringing together chromosomes from two different parents variability is introduced. It is also of considerable physiological importance as egg is activated by sperm to initiate its further development.

Fertilization in Mammals (Human as an Example)

In the human female, **fertilization takes place inside the fallopian tube**. The whole process of fertilization can be divided into the following five stages.

Maturation and capacitation of spermatozoa. The fully formed spermatozoa as pass through the male genital passage undergo the process of **maturation**. They acquire some motility only after they reach the epididymis. The secretions of the epididymis, seminal vesicles, and prostate have a stimulating effect on spermatozoa, but they become fully motile only after ejaculation. Spermatozoa acquire the ability to fertilize the ovum only after they have been in the female genital tract for sometime. This final step in their maturation is known as **capacitation**.

Structure of ovum. The ovum in humans is **alecithal**, i.e. it is almost devoid of yolk and has bulky cytoplasm and a centrally located nucleus. When shed from the ovary, it is not fully mature and is really a secondary oocyte. It measures approximately 100 μm in diameter and remains surrounded by a secreted transparent, non-cellular layer called **zona pellucida**. An investment of radially elongated follicle cells is present outside this layer which is known as **corona radiata**. Some cells of the corona radiata remain sticked to the outside of the zona pellucida. Between the cell membrane (vitelline membrane) and the zona pellucida, a distinct space, said to be **perivitelline space**, is present. The first polar body, which separates from the ovum during the first meiotic division, lies in this space *(Fig. 19)*. The region of the ovum which extrudes polar bodies and receives sperm is called **animal pole**. The pole of the ovum opposite to the animal pole is known as **vegetal pole**.

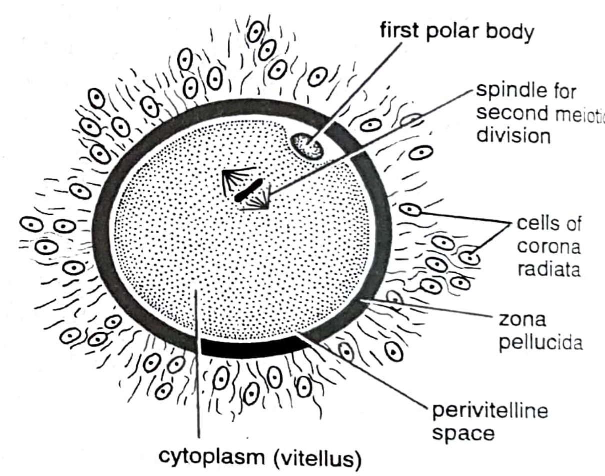


Fig. 19. Structure of ovum at the time of ovulation.

Coitus. The passageway for semen to the external world is urethra, a channel inside the penis that transfers spermatozoa from a male to the female. During coitus, the parasympathetic nerves of the penis are stimulated, that causes tremendous vasodilatation. At the same time the venous drainage is also obstructed. Arterial dilatation in conjunction with venous obstruction leads to the retention of blood within the penis, which in turn causes the penis to enlarge and to become hard, a phenomenon called **erection**. This facilitates the limp penis to penetrate the female vagina. The climax of the act is **orgasm**, which for the male entails the ejaculation or discharge of semen. During orgasm, the heart rate increases, blood pressure rises, and emotional excitement reaches a climax. Orgasm begins with emission, the movement of spermatozoa into the urethra by means of rhythmic contractions of muscles in the testes, epididymis and vasa deferens. At the same time the muscles of the prostate gland and seminal vesicles contract, pouring their secretions into urethra. When penis is filled with spermatozoa and secretions, contraction of muscles at its base causes ejaculation. After ejaculation the erection of the penis subsides. An enormous number of spermatozoa—about 400 million—are contained in an average ejaculation.

Passage of spermatozoa in female genital tract. During coitus, semen containing millions of spermatozoa is deposited in the vagina. Since the site of fertilization is fallopian tube, spermatozoa have to travel a great distance through the female genital tract beset with chemical hazards in the form of strong acid secretions. Actively motile spermatozoa move in the female genital tract usually at a speed of about 100 μm/sec. After introducing into vagina, spermatozoa reach uterine tubes much sooner than their own motility would allow, suggesting that contractions of uterine and tubal musculature also exert a sucking effect. In the normal acid reaction of vagina, spermatozoa cannot survive long (beyond few hours). Most of the spermatozoa die in the vagina and the surviving ones migrate upwards and enter the uterus through cervix. Creeping along the endometrial surface, the remaining spermatozoa try to reach the fallopian tubes (*Fig. 20*). In the favourable phase of the menstrual cycle, they can survive for about 72 hours in uterus and fallopian tubes. Only one spermatozoon, out of millions, reaches the ovum in the fallopian tube by overcoming with several mechanical obstacles during the course of its path.

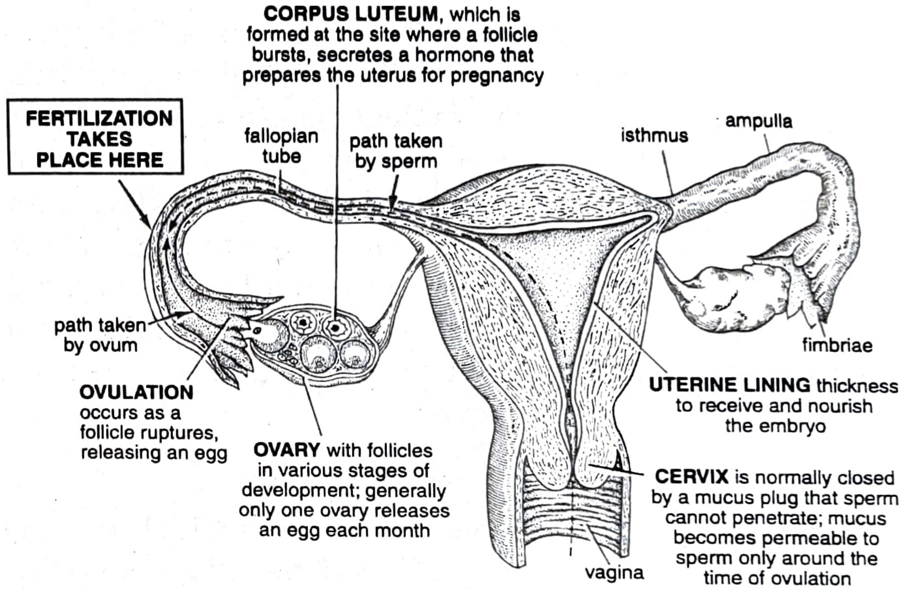


Fig. 20. Path taken by the sperm and ovum for fertilization.

Ovum-spermatozoa interaction in fallopian tube. The ovum at the secondary oocyte stage extrudes from the ovary and trickles down the fallopian tube being encircled by the follicle cells (corona radiata). The follicle cells are glued together by a mucopolysaccharide called **hyaluronic acid**.

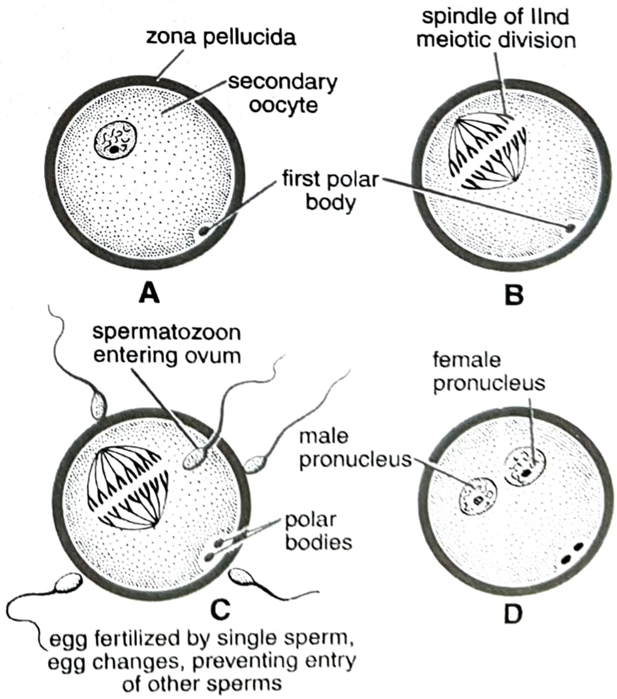


Fig. 21 A-D. Stages in the maturation of the ovum and fertilization : A. ovum just before ovulation; B. ovum at the time of ovulation; C. ovum at the time of fertilization; D. ovum just after fertilization.

Fertilization of the ovum occurs in the ampullary-isthmic junction of the fallopian tube (*Fig. 20*). On reaching the fallopian tube the spermatozoon undergoes some changes, which are collectively known as **sperm capacitation. Activation of sperm for fertilizing the egg is called**

capacitation. The phenomenon of sperm capacitation exhibits two important features : (i) entry of large number of calcium ions provided by the viscous fluid of the glands of fallopian tube increases the mobility of sperm tail, by which the gentle movement of the tail of the sperm changes into whip like movement, and (ii) the acrosomal membrane is lost so that the enzymes at the head region of the sperm are exposed. With the loss of the acrosomal membrane, the sperm releases an enzyme, **hyaluronidase** (sperm lysin), that helps in the removal of follicle cells from the ovum to facilitate the entry of the sperm into the ovum. The hyaluronidase also dissolves zona pellucida at the entry point. At this time the compatibility of sperms for ovum is checked. The ovum releases **fertilizin** (a chemical) which are complementary to antifertilizin released by sperm. Sperm can enter ovum only after this compatibility check up. As soon as the first sperm enters the ooplasm, zona pellucida changes chemically and becomes impermeable to other sperms. This is called **zona reaction** or **cortical reaction**. Hence, monospermy (entry of only one sperm into ovum) is maintained. This entry of sperm activates ovum which now completes its second meiotic division which was so far incomplete. As a result a second polar body is extruded and a mature ovum is formed. The chromatin of the ovum forms the female pronucleus (haploid) and the head of sperm which gets separated from middle piece and tail, becomes male pronucleus (*Fig. 21 A-B*). Eventually, both fuse together and a **zygote** (fertilized ovum) is thus formed. In the fertilized ovum the usual number of 46 chromosomes in a human cell is restored through equal contribution from the spermatozoon and the ovum.

From Egg to Embryo

Fertilization is a crucial biological process which includes an orderly series of physico-chemical events. It sets the ovum in the path of development of a new individual.

CLEAVAGE AND EMBRYONIC DEVELOPMENT

Cleavage. It is a series of repeated mitotic division that takes place in zygote. It inceases number of cells but does not result in growth due to short interphase. The resultant blastomeres become smaller which is called **compactation**. The volume and general shape of embryo does not change during cleavage. As a result of cleavage the zygote changes first into a solid ball - shaped **morula** and then into a hollow ball like **blastula (blastocyst)**.

In humans, the first cleavage division is vertical, that takes place in zygote, twenty four hours after fertilization. The zygote divides into two blastomeres. Forty hours after fertilization the second cleavage takes place, which is also vertical, but right angle to each other. As a result the embryo becomes four-celled. The third cleavage occurs about three days after fertilization and subsequent division follows one after another in an orderly manner, till the 16 - celled solid cricket ball - like structure called **morula** is formed.

Morula. It is so called because it resembles a mulberry fruit. It is still surrounded by zona pellucida and is about the same size as the zygote. It consists of centrally located cells called **inner cell mass** surrounded by a layer of cells called **trophoectoderm** or **trophoblast**. By the end of 4th day morula reaches uterus.

Blastulation. Formation of blastula from morula is called **blastulation. Blastula** is a hollow structure. In human and most of the mammals, it is called **blastocyst**. As soon as morula enters uterine cavity, the glands of uterine wall secrete uterine milk which enters morula and collect between trophoblast and inner cell mass, causing the formation of blastocyst cavity or blastocoel.

The appearance of blastocoel changes morula into blastocyst by 5th day after fertilization. The blastocoel now enlarges and pushes inner cell mass to one side. It forms a knob in blastocoel which is called **embryonal knob** that later gives rise to embryo and the cells of trophoblast help to provide nutrition to the embryo. Later the trophoblast forms the extra embryonic membranes namely **chorion** and **amnion** and the part of placenta. The side of blastocyst to which the inner cell mass is attached is called **animal pole** while the opposite side is the **embryonic pole**. The cells of the trophoblast which are in contact with the inner cell mass are called **cells** of **Rauber**. As blastocyst is formed zona pellucida becomes thinner and finally disappear.

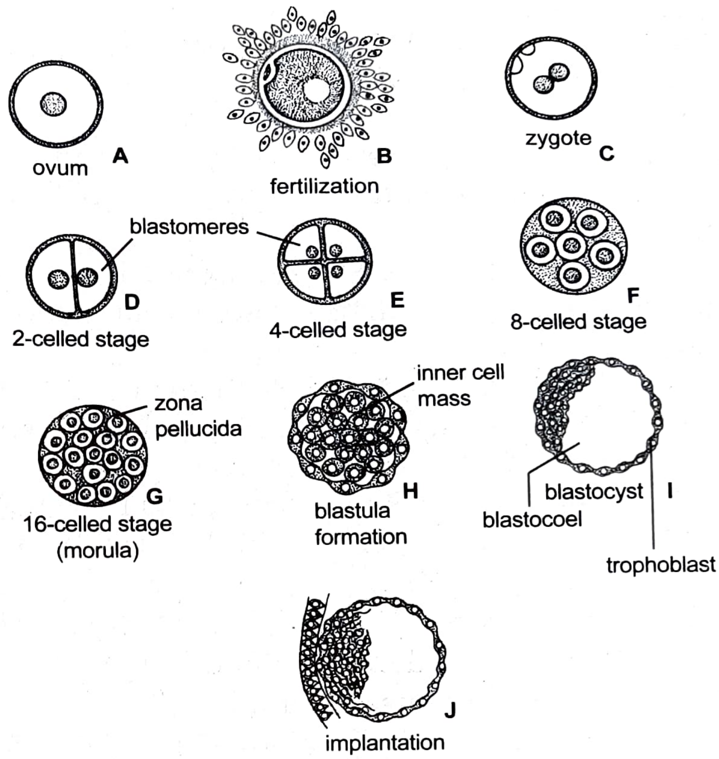


Fig. 22 A-J. Stages in the segmentation of fertilized ovum and formation of blastocyst.

Implantation. It is the attachment of blastocyst to the endometrium of uterine wall. It occurs after 7 days of fertilization, when blastocyst sinks into the pit formed in the endometrium and gets completely buried. The cells of trophoblast secrete lytic enzymes that help blastocyst to penetarate uterine wall. Finger like trophoblastic villi or chorionic villi of trophoblast interdigitate to establish intimate contact between blastocyst and endometrium. Progesterone helps in implantation by inducing uterine wall to secrete integrin and osteopontin molecules for adhesion. Implantation leads to pregnancy. Corpus luteum continues to produce progesterone which keeps endometrium thick and vascular and prevents menstruation.

Gastrulation. Gastrulation is the process of transformation of blastula into gastrula which contains three primary germ layers – **ectoderm, mesoderm** and **endoderm**. It occurs about 15 days after fertilization. All the organ systems of the body develop from these three germ layers.

Formation of chorion and amnion. During the course of differentiation of three germ layers, two important membranes—**chorion** and **amnion**—are formed (*Fig. 23*). **Chorion** is formed by the parietal extra-embryonic mesoderm (on the inside) and overlying to the trophoblast (on the outside), whereas **amnion** is developed by the amniogenic cells forming the wall of the amniotic cavity. Both of these layers play an important role in child birth (parturition).

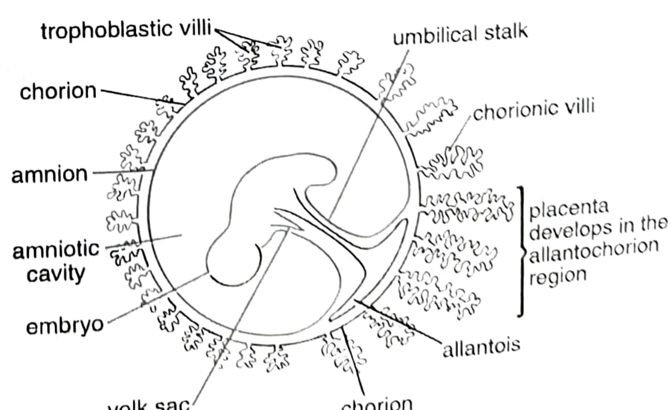


Fig. 23. Relationship between the human embryo and extra-embryonic membranes about five weeks ovulation.

Even before the complete closure of amniotic cavity, the endoderm layer from beneath the hinder end of embryo grows out as a sac or vesicle, and carries with it the overlying layer of splanchnic mesoderm. This vesicle is called **allantois** (*Fig. 23*). It rapidly grows and extends into extra-embryonic coelom between the amnion and chorion, and then over the embryo outside the amnion.

Fate of germ layers in embryonic development. Soon after the formation of germ layers, the phase of differentiation and specialization initiates. Each germ layer is destined to develop some specific organs.

1. **Derivatives of ectoderm.** The **ectoderm,** being the outermost layer of the embryo, differentiates into structures like skin, brain, spinal cord, and nerves. The main derivatives of ectoderm are as follows.
   (1) Epidermis and epidermal glands of the skin like sweat, sebaceous and parotid glands.
   (2) Mucous membrane of lips, cheeks, gums, parts of the floor of the mouth, part of palate, and nasal cavities.
   (3) Conjunctiva, lens, cornea, and retina of the eye.
   (4) Enamel of teeth.
   (5) Hair and nails.
   (6) Outer layer of tympanic membrane.
   (7) Pituitary and pineal glands and adrenal medulla.
   (8) Entire nervous system.
   (9) Terminal part of male urethra and outer surface of labia minora and whole of labia majora in females.
   (10) Mammary and lacrimal glands.
2. **Derivatives of endoderm.** The **endoderm**, the innermost layer of the embryo, differentiates into primitive gut (archenteron), which in turn forms various organs. The following are the main derivatives of endoderm.
   (1) Mucous epithelium of gut.
   (2) Epithelium of pharyngeo-tympanic tube, middle ear and inner layer of tympanic membrane.
   (3) Epithelium of respiratory tract.
   (4) All digestive glands (liver, pancreas, glands in the wall of gastro-intestinal tract, etc.).
   (5) Thyroid, parathyroid, thymus, islets of Langerhans.
   (6) Urinary bladder and urethra.
   (7) Lower part of vagina, vestibule and inner surface of labia minora.
3. **Derivatives of mesoderm.** The **mesoderm** , which is the middle layer, differentiates into a variety of structures listed below.
   (1) All types of connective tissue.
   (2) Dermis of skin.
   (3) Dentine of teeth.
   (4) All muscular tissues, except the musculature of iris (which is ectodermal in origin).
   (5) Heart, blood vessels and lymphatics.
   (6) Kidneys and ureter.
   (7) Reproductive organs (ovary, uterus, and uterine tubes in females and testis, epididymis, vas deferens, seminal vesicles and ejaculatory ducts in males).
   (8) Lining mesothelium of pleural, pericardial and peritoneal cavities.
   (9) Iris, sclerotic and choroid of eyes.
   (10) Adrenal cortex.

In human beings, the embryo's heart is formed after one month of pregnancy. The first sign of growing foetus is noticed by listening the heart sound 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. 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 and eye-lids separate. By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

Table 6. Major features of embryonic development at various months of pregnancy.

S. No.	Events	Month
1.	Human pregnancy (Gestation period).	9 months.
2.	Embryo's heart formed.	After one month of pregnancy.
3.	Development of lymph and digits of foetus.	End of second month of pregnancy.
4.	Most of the major organ systems formed, for example limbs and external genital organs well developed.	End of 12 weeks (first trimester).
5.	First movements of the foetus and appearance of hair on the head are usually observed.	During the fifth month.
6.	Body covered with fine hair, eyelids separate and eyelashes formed.	By the end of 24 weeks (end of second trimester).

PLACENTA

The intimate connection established between the foetal membrane and the uterine wall is known as placenta. The main task of the placenta is to permit the diffusion of nourishment from the mother's blood to the baby's and the disposal of waste products from the baby's blood to the mother's.

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** (*Fig. 24*). The embryo's own blood vessels grow into this network and embryonic fetal blood comes close to maternal blood, but the blood of the mother and the foetus never actually mix. The part of the placenta contributed by the foetus, i.e. chorionic villi, is called **foetal placenta**; and the part that is shared by the mother, *i.e.*, part of uterine wall, is known as **maternal placenta**.

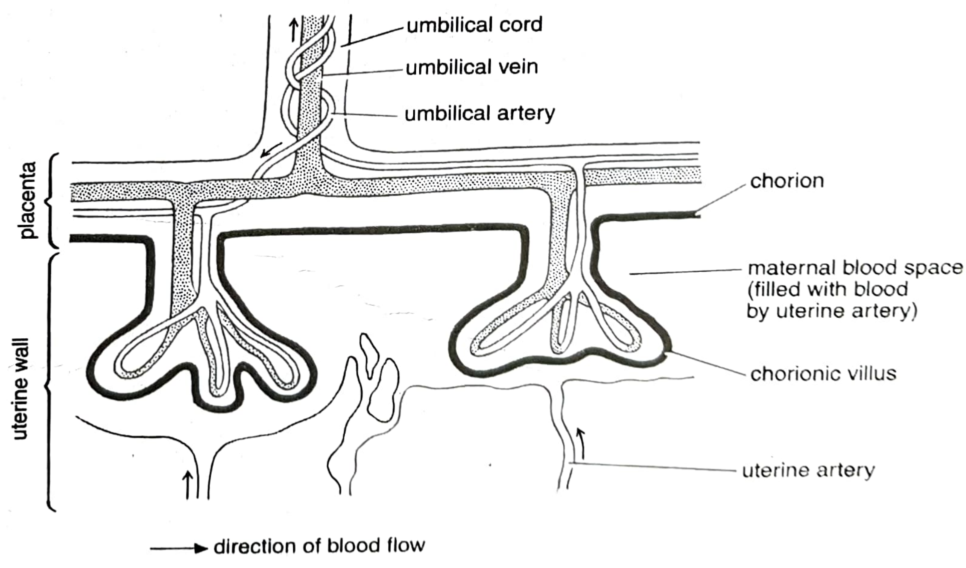


Fig. 24. The mammalian placenta.

Oxygen and nutritive substances can pass through the two layers of fetal cells separating maternal blood from the embryonic blood. The waste products can pass outward from the embryonic to the maternal to be carried away and disposed off through maternal lungs and kidneys.

The placenta does the work of several organs that the developing foetus possesses in only rudimentary form. It serves as a lung for the foetus, exchanging the foetus's carbon dioxide for the mother's oxygen. It serves as an intestine, absorbing food molecules from the mother's blood. It functions as a kidney, filtering urea and other waste products from the fetal blood and delivering it to the mother's for disposal. It serves as a liver, processing the mother's blood cells for the iron they contain; and as an endocrine gland (produces hormones like **human chorionic gonadotropin** (hCG), **human placental lactogen** (hPL), **estrogens**, **progestogens**, etc.) supplying the hormones that maintain the pregnancy, and prepare breasts for the production of milk after birth. The placenta also permits the passage of certain maternal immunoglobulins that provide protection against infection in the foetus and in the newborn too.

To perform its job, the placenta keeps on growing. Initially, it is bigger than the embryo. At four months, when the foetus is roughly 18 cm long from head to toe, the placenta is a disk about 7.6 cm in diameter. By the end of pregnancy, it grows to approximately 20 cm in diameter.

PARTURITION (CHILD BIRTH)

Parturition is the act of expelling the full-term foetus from the mother's uterus at the end of gestation. The length of time from conception to birth is termed **gestation period.** It is about 280 days in humans. During most of gestation, the uterus grows to accommodate the growing foetus. But near the end of pregnancy, its growth ceases and the uterine wall becomes stretched as the foetus continues to grow. When muscles are stretched, their power to contract increases.

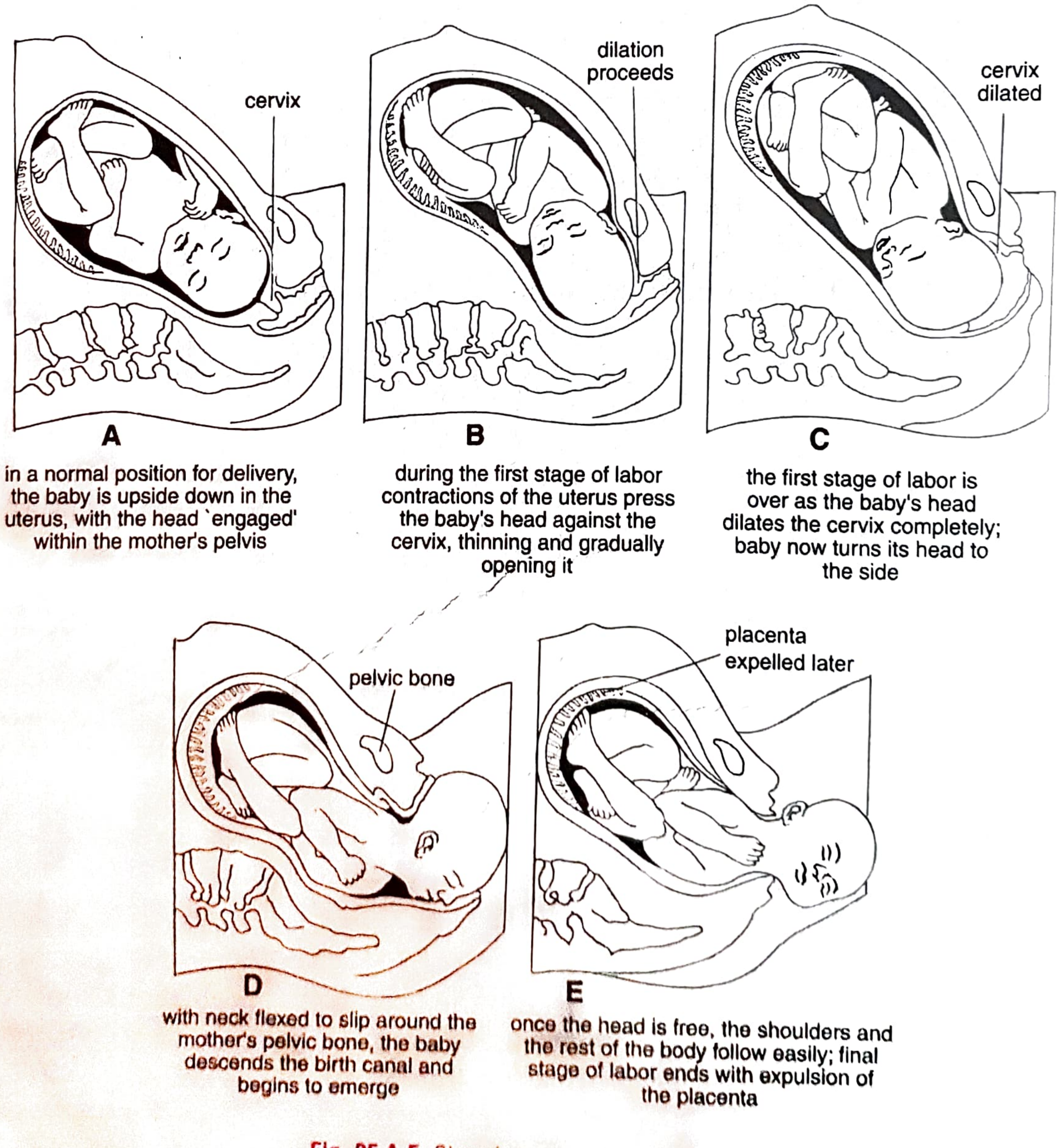


Fig. 25 A-E. Steps in a normal child birth.

Parturition is induced by a complex neuroendocrine mechanism. The signals for parturition originate from the fully developed foetus and the placenta which induce mild contractions called **foetal ejection reflex**. This triggers release of oxytocin from the maternal pituitary (mother's brain). This hormone is a very powerful stimulant of uterine contractions and labor begins when uterus responds to critical levels of this hormone in the blood. The onset of **labor** commences with the leaking of fluid from the amniotic sac. Labor during the first birth can last anywhere from 8 to 24 hours. The foetus is gradually expelled out together with the foetal part of the placenta *(Fig. 25 A-E)*. The latter remains attached to the young one by a rope-like cord called **umbilical cord.** The final stage of labor ends with the expulsion of the placenta. After birth, the umbilical cord is removed by operation.

LACTATION

The term **lactation** refers to the **secretion and ejection of milk by the mammary glands**. This helps the mother in feeding the new-born. A principal hormone in promoting lactation is **prolactin** from the anterior pituitary gland. It is released in response to prolactin releasing hormone **(PRH)** secreted by the hypothalamus. The principal stimulus in maintaining prolactin secretion during lactation is the sucking action of the infant. Sucking initiates nerve impulses from receptors in the nipples to the hypothalamus. The impulses decrease release of prolactin inhibiting hormone (PIH) and/or decrease release of prolactin releasing hormone (PRH), so more prolactin is released by the anterior pituitary gland. The sucking action also initiates nerve impulses to the posterior pituitary gland *via* the hypothalamus. These impulses stimulate the release of the hormone **oxytocin** from the posterior pituitary gland. Oxytocin induces the ejection of milk by compressing the alveoli.

1. What is parturition? Give a brief account.
2. Differentiate between Blastogenesis and Embryogenesis.
3. In man, testes lie outside the abdomen. Give reason.
4. Write down two functions of testes.
5. List four characteristics of cleavage.
6. List four functions of placenta.
7. List the functions of various parts of sperm.
8. Distinguish between spermatogenesis and oogenesis.
9. Give one function of each of the following :
   (a) Sertoli cells **(b)** Interstitial cells **(c)** Corpus luteum
10. **(a)** Define Menopause.
    (b) How many sperms are produced from two spermatogonia?
    (c) Define implantation.
11. **(a)** Testosterone is secreted by ____________ cells
    (b) Define puberty
    (c) Define spermiogenesis.
12. Define corpus luteum. Name two hormones secreted by it.
13. What is colostrum? Why is it preferred over normal milk?
14. Where are Leydig's cells present? What is their role in reproduction?
15. Define menstrual cycle. Name any two hormones which regulate this process.

List any four differences between sperm and ovum.

Draw a neat diagram of an oocyte and label.

(i) Corona radiata (ii) Zona pellucida (iii) Perivitelline space (iv) Cortical granules.

Draw a well labelled diagram of human sperm.

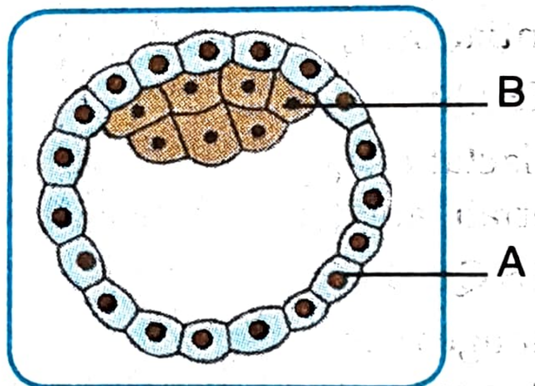
What is parturition? Which hormones are involved in the induction of parturition.

Define placenta and give its significance in human female.

Breast feeding during initial period of infant growth is recommended by doctors. Why ?

(a) In which part of human female reproductive system, following events occur:

(i) Fertilization (ii) Implantation (b) In Diagram of blastocyst, identify A and B:?



It is evident that it is the genetic make up of sperm that determines sex of child in human. Substantiate.

Mother's milk is considered essential for new born infants.

(a) Name the fluid secreted by mother's breast during initial days of lactation.

(b) Which type of immunity, it provides ?

How placenta is formed ?

What is menstrual cycle ? Name any two stages of menstrual cycle.

What is first milk which comes out from mother's mammary gland called ? State its importance.