Model Answer

B.Sc Vth Semester Exam , Paper: LZT-503, Reproductive and Developmental Biology

1. i) c ii) c iii) c iv) a v) a vi) a

vii) a viii) a ix) b x) b.

2. Spermiogenesis is the maturation process in which spermatid is converted into mature spermatozoa. Because a sperm is a very active and mobile cell, it undergoes specialized modification suitable for mobility. The developing spermatozoa discard superfluous material and became more lighter required for swimming. Specialised parts such head and tail are formed by following methods:

i) Formation of head of spermatozoon:

The two major parts of the sperm head i.e the nucleus and acrosome, undergo following changes to form the sperm head:

a) Changes in the Nucleus:

Nucleus in the spermatid losses its entire fluid contents, all its RNA, nucleolus and most of its protein. In some cases, protein associated with DNA i.e Histone is replaced by an unusual class of small, basic proteins called protamines. The general shape of the sperm nucleus also changes from usual spherical to elongated and narrow structure. These shapea are an obvious adaptation for propulsion in water.

b) Acrosome Formation:

The acrosome of a spermatozoon is derived from the golgi apparatus of a spermatid. The golgi apparatus of an aearly spermatid consist of a series of cisternae arranged concentrically around an aggregation of small vacuoles. During acrosome formation, one or more vacuole start enlarging and inside the vacuole appears a small dense body the preacrosomal granule. The vacuole or acroblast enlarges in its volume by fusing with other small vacuoles containing proacrosomal granule and increase further and becomes the acrosomal granule which forms the core of the acrosome. The vacuole then gradually loss its liquid contents and its wall spread over the acrosomal granule and front half of the nucleus covering them with the double membranous sheath- the cap of spermatozoon. The remaining part of the golgi apparatus are gradually reduced and ultimately discarded from sperm as ‘Golgi rest” together with some cytoplasm.

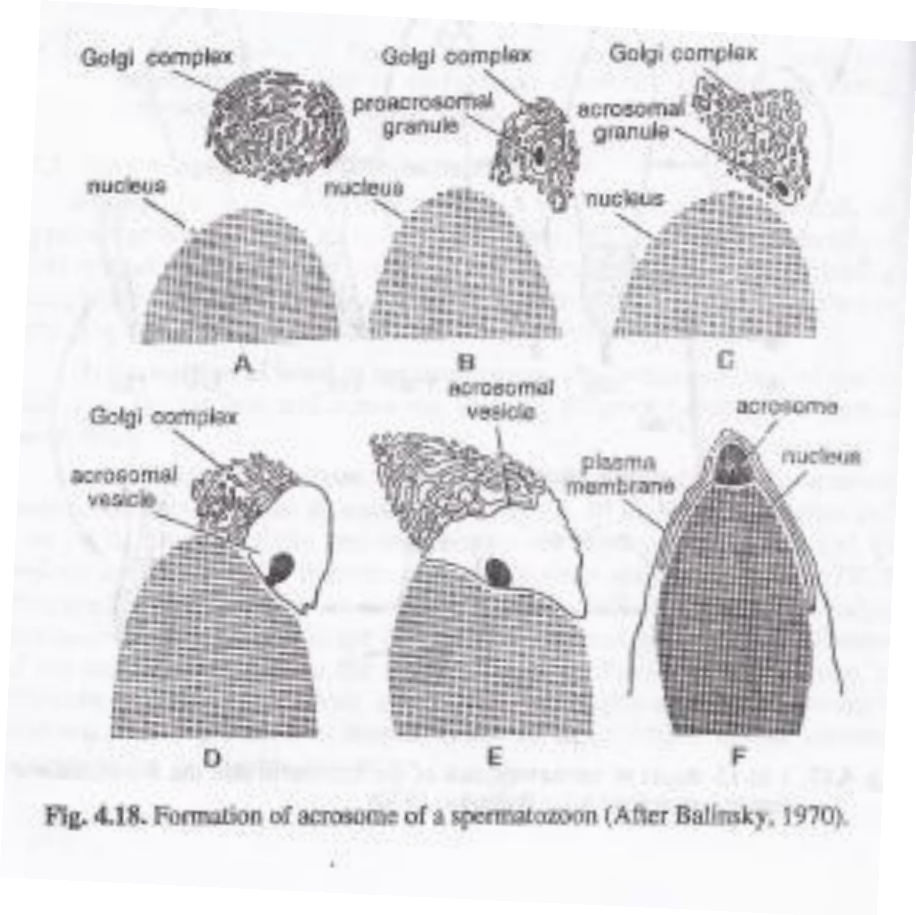
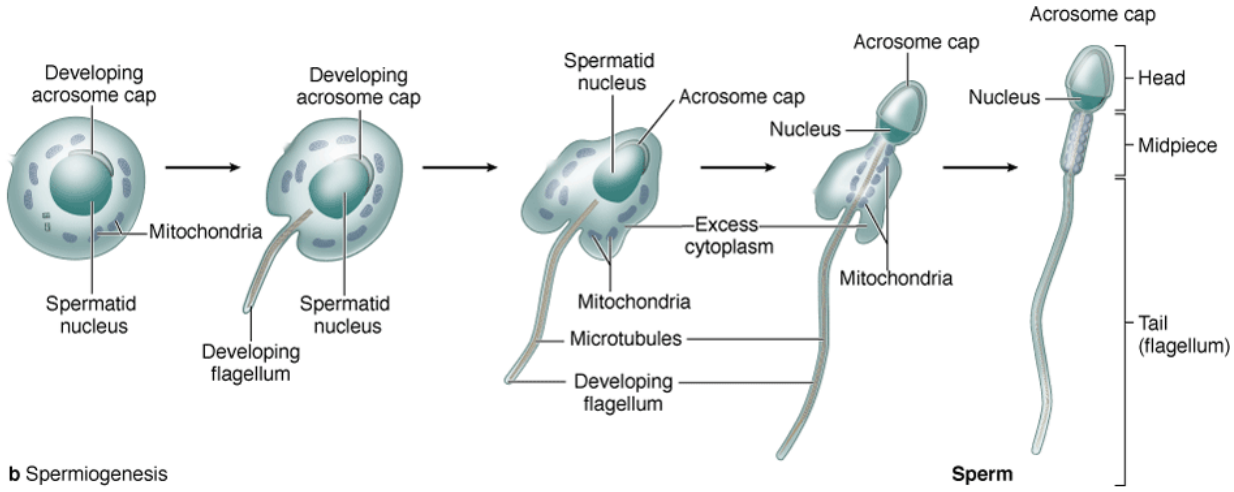


Fig. 4.18. Formation of acrosome of a spermatozoon (After Balinsky, 1970).

In the spermatozoa which have the axial body or acrosomal cone, the latter appears in between the acrosomal granule and nucleus, protruding itself from the behind into the acrosomal granule in the direction of the main axis of the spermatozoon.



ii) Formation of the tail of spermatozoon:

The centrosome of a spermatid after the second meiotic division consists of two centrioles which have the structure of two cylindrical bodies, lying at right angles to each other. During early stages of spermiogenesis, the two centrioles move to a position just behind the sperm nucleus. A depression is formed in the posterior surface of the nucleus and one of the centriole is placed in the depression with its axis approximately at right angle to the main axis of the spermatozoon. This is proximal centriole of the spermatozoon; the other centriole, the distal centriole, takes up a position behind the proximal centriole with its axis coinciding with the longitudinal axis of the spermatozoon. The distal centriole gives rise to the axial filament of the flagellum of the spermatozoon for which it serves as basal granule.

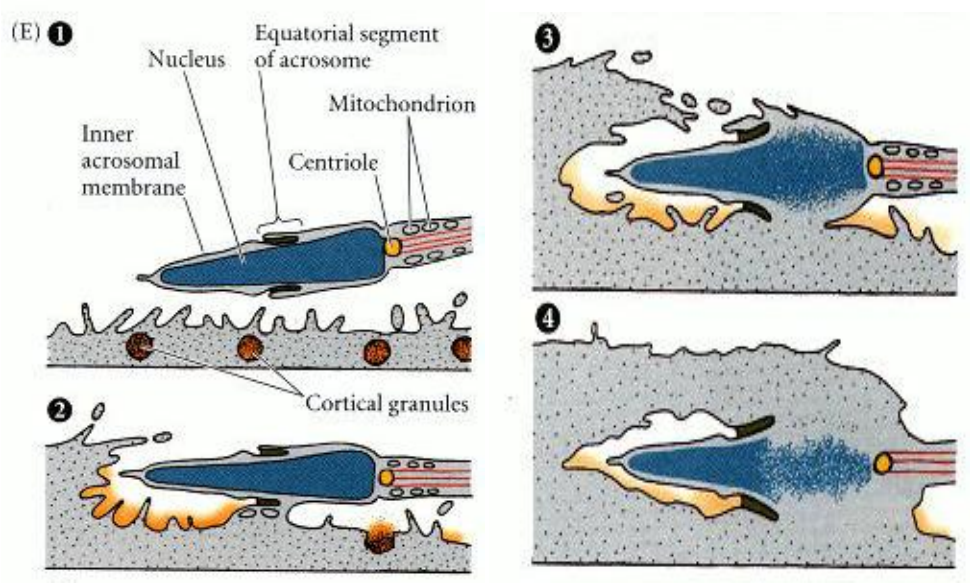
Most of the mitochondria of spermatids concentrate around the distal centriole and proximal part of the axial filament and form the neck and mid-piece of the tail of the spermatozoon. In the mid-piece of the sperm, the mitochondria lose their individuality by fusing to become either spirally arranged or form large mitochondrial bodies. The tail of sperm comprises an axial filament which remains differentiated into a principal piece and a tail piece.

Thus, much of the cytoplasm of the spermatid becomes redundant in the spermatozoon and it is simply discarded. With the formation of the acrosome at the posterior end of the spermatid nucleus, the cytoplasm flows away from it in the opposite direction, leaving only a thin layer with the plasma membrane covering the acrosome and the nucleus. The bulk of the cytoplasm is then attached to prospective middle piece of the spermatozoon, while the tail is growing out at the posterior end. After the mitochondria have arranged themselves around the base of the axial fillamnet of the flagellum, the remainder of the cytopplasm is simply pinched off from the spermatozoon, leaving a thin film of cytoplasm around the mitochondria of middle piece. The detached part of the cytoplasm disintegrates.

3. of acrosomal fluid containing the hydrolytic enzymes required for penetration of egg plasma membrane occurs through a process called acrosomal reaction.

Acrosomal Reaction and Contact of sperm and Ovum:

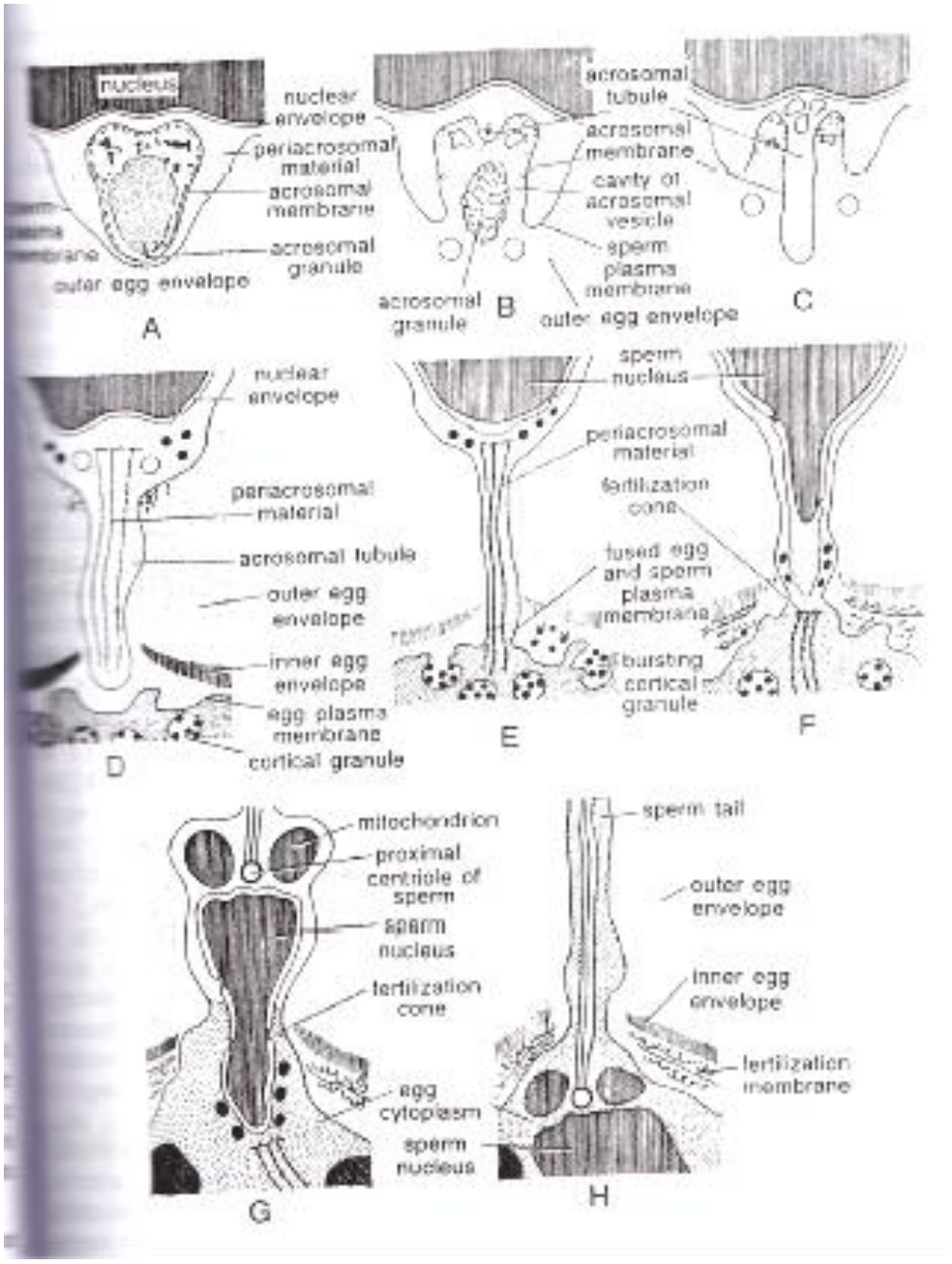
The first reaction of the sperm when it come in contact with constituent of the egg surface, involves the acrosome. Onset of the acrosomal reaction takes place when there are optimal physiological conditions such as optimum pH, Ca^{2+}, Mg^{2+} ions concentration and temperature. The presence of calcium condition for acrosomal reaction.



The acrsomal reaction involves breakdown of membrane of acrosomal vesicle, release of acrosomal enzymes, formation of acrosomal tubule and fusion of plasma membranes of sperm and egg. Acrosomal reaction has been studied in variety of animals such as echinoderms, annelids, saccoglosus and mammals.

1. Trigger mechanisms for breakdown of acrosome:

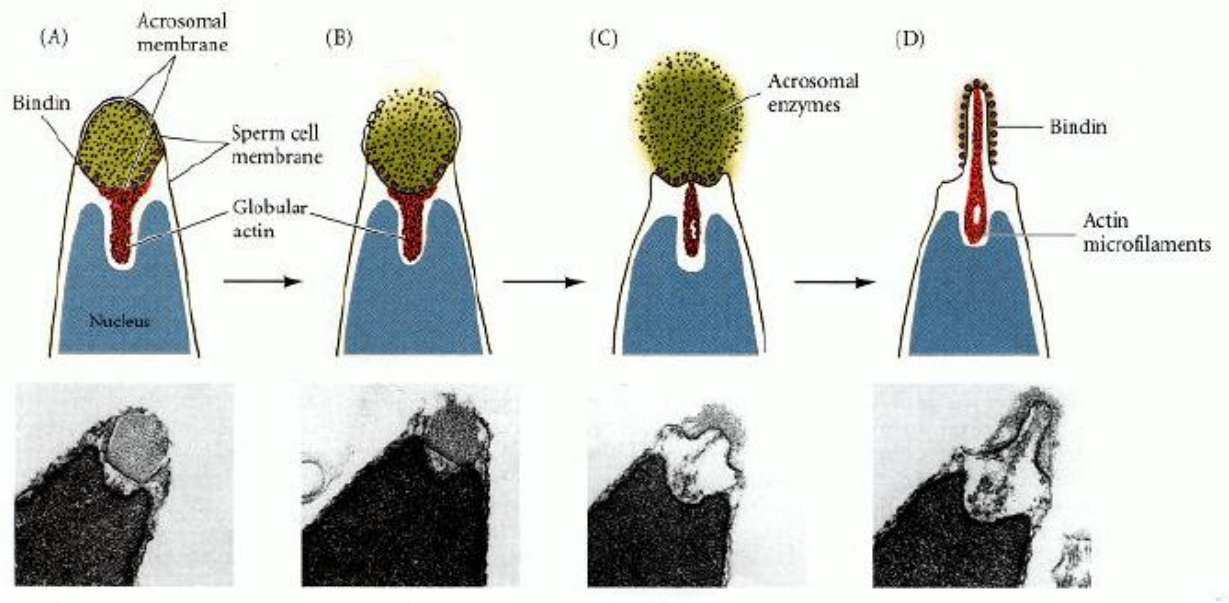
The apical part of the sperm plasma membrane and underlying outer acrosomal membrane undergo dehiscence. The severed edge of the two membranes fuse to form an opening through which the contents of the acrosomal vesicles are released. Inner acrsomal membrane grows into one or many acrosomal tubules which in some case may be almost as long as the entire spermatozoa. The acrosomal membrane first contact with the egg jelly, vitelline membrane and plasma membrane.



2. Release of acrosomal contents:

The trigger mechanism releases lytic enzymes located in the acrosome. The lysins are of wide occurrence and help the sperm penetrate the egg envelops by liquefying them locally, without affecting the egg plasma membrane. In sea urchin, the acrosomal reaction results in the liberation of a species specific egg binding protein, bindin ans a protease or lysine called acrosomin. The bindin plays a role in causing adhesion of eggs of the same species. Acrosomin is responsible for the initial digestion of the vitelline membrane that covers the unfertilized egg.

In human female and other mammals, sperm need to penetrate the multiple layers of the follicular cells which are attached to the outer side of the ovum, forming the corona radiata. The follicular cells of the corona radiate are held together by an adhesive cementing substance called hyaluronic acid. The sperm entry through the corona radiate and zona pellucda require hyaluronidase and proteolyitic enzymes released by the acrosome of the sperm. The hyaluronidase dissolves the cement between the follicular cells of the corona radiata and thus penetrates the egg.



3. Formation of Acrosomal Tubules:

The apical part of the sperm plasma membrane extends forward to form an acrosomal tubule. It project through the egg envelope to reach the oolemma. The shape and size of the acrosomal tubules varies from species to species. Inside the acrosomal tubules in most cases occurs a rigid substance called axial rod. The rod may either be completely formed from the precursor materials at the time of the acrosomal reaction.

4. The splitting or division of an activated egg by a series of mitotic division into a multitude of cells which become the building units of future organism is called as cleavage or cellulation. The cleavage has two important function: the first is to produce many cells and the second is to lay foundation of differences and prepares the ground for differentiation and morphogenesis.

PATTERNS OF CLEAVAGE:

Most animal eggs incorporate an organization pattern and this plays a far more important role in conditioning cleavage than does whatever amount of yolk may be present. The pattern of cleavage due to organization of egg may be of following types:

1. Radial Cleavage:

The radial cleavage occurs when the successive cleavage planes cut straight through the egg, at right angles to one another and resultant blastomere become symmetrically disposed around the polar axis. When such an egg is viewed from either pole, the blastomeres are formed to be arranged in a radially symmetrical form, e.g., all animal having holoblastic cleavage such as synapta, paracentrous et.

2. Biradial Cleavage:

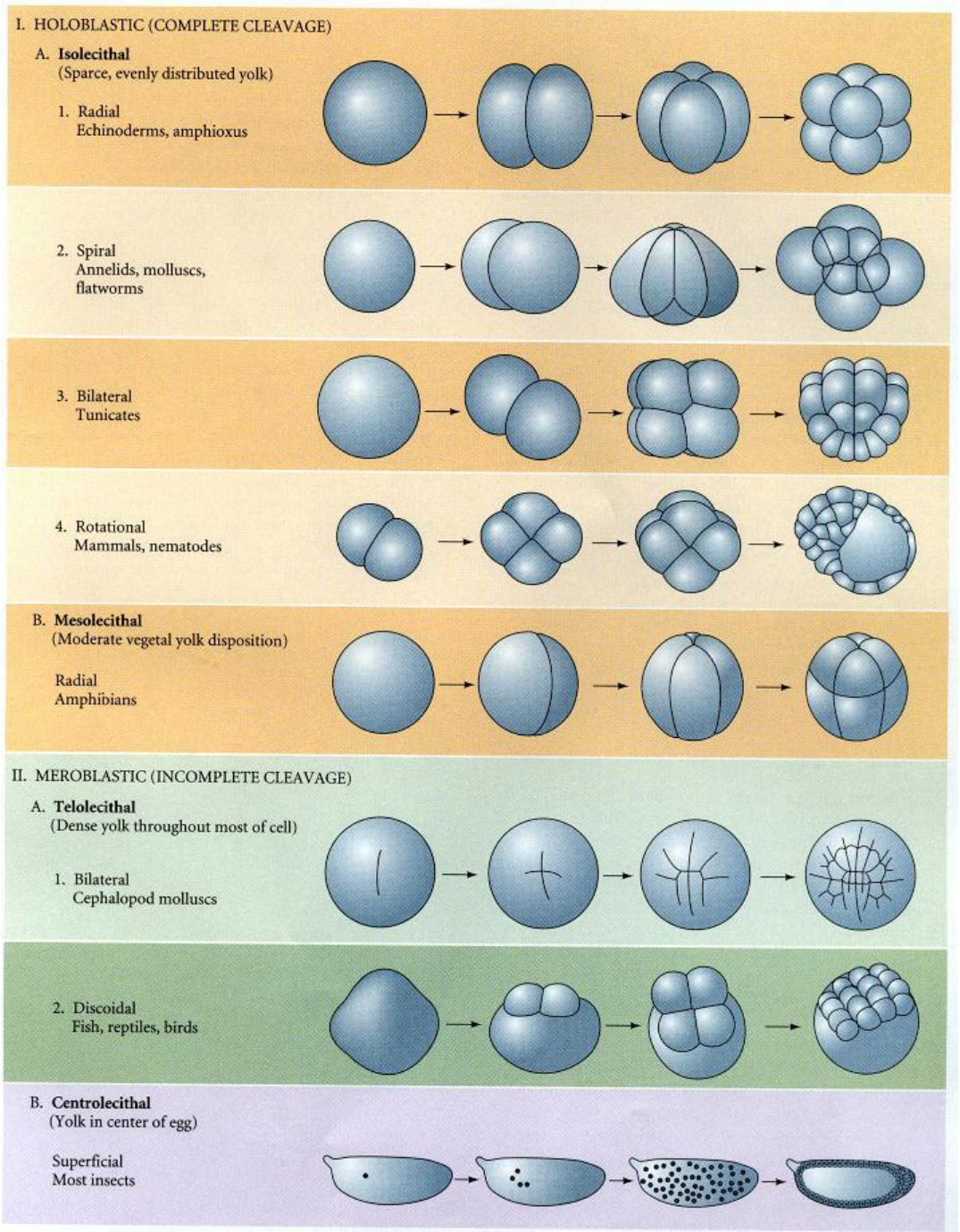
Biradial cleavage patterns arises when the three first division planes do not stand at right angle to each other e.g., Acoela like Ctenophora.

3. Spiral Cleavage:

The spiral cleavage is found in those forms in which there is a rotational movement of cell parts arounf the egg axis leading to a displacement or inclination of the mitotic spindles with respect to the symmetrically disposed radii. The spiral cleavage results because of the of the oblique position of the mitotic spindles in the blastomeres, therefore also called oblique cleavage. In successive cleavages, the rotational movements are characterised by a regular alteration in clockwise or anti-clockwise direction. The first case is called dexiotropic or dextral spiral cleavage while the second case is called sinistral spiral cleavage. Exp. Rotifer, annelid and all mollusks.

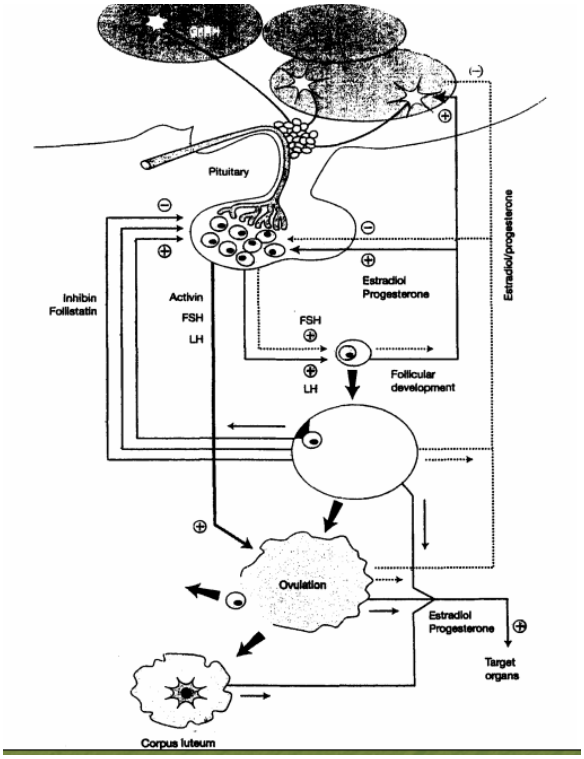
4. Bilateral Cleavage:

In bilateral cleavage, the mitotic spindles and cleavage planes remain bilaterally arranged with reference to a plane of symmetery which coincides with the median plane of the embryo. e.g., Tunicata, amphioxus, amphibian and all mammals.



5. Gametogenesis is the general process of gamete formation in both males and females. Meiosis, the process by which gametes are formed, can also be called gametogenesis, literally "creation of gametes". The type of meiosis in male organisms from a spermatogonium to a primary spermatocyte, a secondary spermatocyte, a spermatid and finally, a spermatozoid, is called spermatogenesis, while the process of meiosis in female organisms from an oogonium to a primary oocyte, a secondary oocyte and then an ovum (egg cell), is called oogenesis. Primordial

germ cells, once they have populated the gonads, proliferate into sperm (in the testis) or ova (in the ovary). The decision to produce either spermatocytes or oocytes is based primarily on the genotype of the embryo. In rare cases, this decision can be reversed by the hormonal environment of the embryo, so that the sexual phenotype may differ from the genotype.



1. The pulsatile liberation of GnRH, as well as FSH and LH

2. The long-loop feedback – effect of estrogen and progesterone on the hypothalamic – hypophysial – system

Early hormonal control helps the follicle to develop and forces oogenesis to occur in a cycle in a certain time period. The control begins in the hypothalamus which produces gonadotropin-releasing hormone (GnRH). GnRH is received by receptors in the anterior pituitary gland, which responds by releasing Foliclle Stimulating Hormone (FSH) and Luteinizing Hormone (LH), in a pulsatile manner approximately every 90 minutes. At the beginning of development, the granulosa cells express FSH receptors, which stimulate growth of the follicle. Theca cells express receptors for LH, which stimulates growth of the corpus luteum. Theca cells also produce androgens, which the granulosa cells convert to estrogen. Estrogen act back on the anterior pituitary gland to further FSH and LH surges, and also supports the growth of the endometrium. At some point, the dominate follicle begins to secrete inhibin, which acts back on the anterior pituitary gland to stop producing FSH. Only the dominant follicle, which is now

FSH independent, will continue to grow during further development, the granulose cells increase their FSH receptors and express LH receptors, while the theca cells increase their LH receptors. This surge in hormone reception results in ovulation. The mean interval between maximal E2 production of the Graafian follicle and maximal pituitary LH release is approximately 24 hours. Ovulation follows on average 8-10 hours later. Midcycle serum E2 concentration is approximately 250 pg/mL. After ovulation, if fertilization occurs, the corpus luteum secretes progesterone that supports the further growth of the endometrium. If, however, fertilization does not take place, then the hormone levels drop, the corpus luteum breaks down, no longer secreting progesterone, so that the endometrium sloughs off producing menstruation.

It is estimated that less than 1% of all follicles reach the stage of the Graafian follicle, with 99% of follicles degenerating by apoptosis. Programmed cell death is an energy-dependent process accompanied by DNA degradation. In addition to an adequate FSH level, survival of a follicle also depends on growth factors such as epidermal growth factor (EGF), transforming growth factor b (TGF-B), fibroblast growth factor (b FGF), insulin-like growth factor (IGF-I) and estrogens. Besides the sex steroids (estradiol and progesterone), which exert a regulatory influence on the function of GnRH producing nerve cells, catecholamines and endogenous opiates are also involved in the regulation of GnRH secretion. The corpus luteum develops out of the ruptured follicle immediately following ovulation.

The most important morphological characteristic of the corpus luteum is the vascularisation of the previous avascular follicular epithelium. With its integration into the circulatory system and the expression of low-density lipoprotein (LDL) receptors, the follicular epithelial cells are able to take up cholesterol from the periphery and use it for progesterone biosynthesis. Serum progesterone values reach a peak of approximately 15 ng/mL at 6-8 days post-ovulation.

Q. 6. Ans

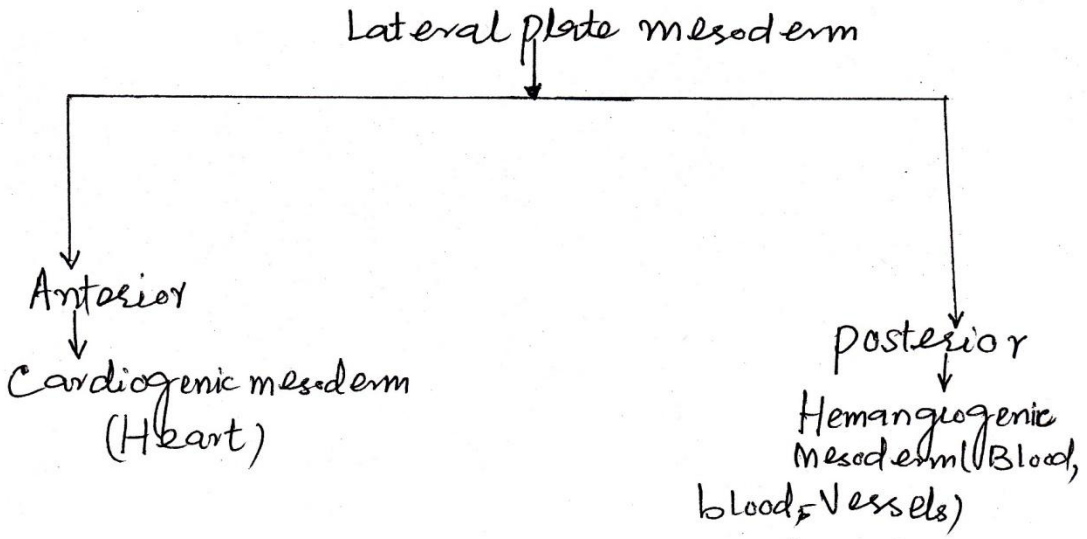
Development of Heart in Mammals.

(Cardiovascular System includes heart, blood cells and blood vessels. The circulatory System provides nourishment to the developing Vertebrate embryo. The Circulatory System is the first functional unit in the developing embryo, and heart is the first functional organ. The development of Vertebrate heart arises from two regions of Splanchic mesoderm - one on each side of the body.)

1. Specification of heart tissue :- In amniote Vertebrates, the (The embryo is formed as a flattened disc) and the lateral plate mesoderm doesn't Completely encircle the yolk Sac. (The presumptive heart cells originate in the early primitive Streak, these cells migrate through the streak and form two groups of cells. These two groups of cells are called the cardiogenic mesoderm (or cardiac Crescent). These cells then forms the atrial and Ventricular musculature, cells of the valves, the purkinje Conducting fibers and endothelial lining of the heart are generated from these two clusters.)

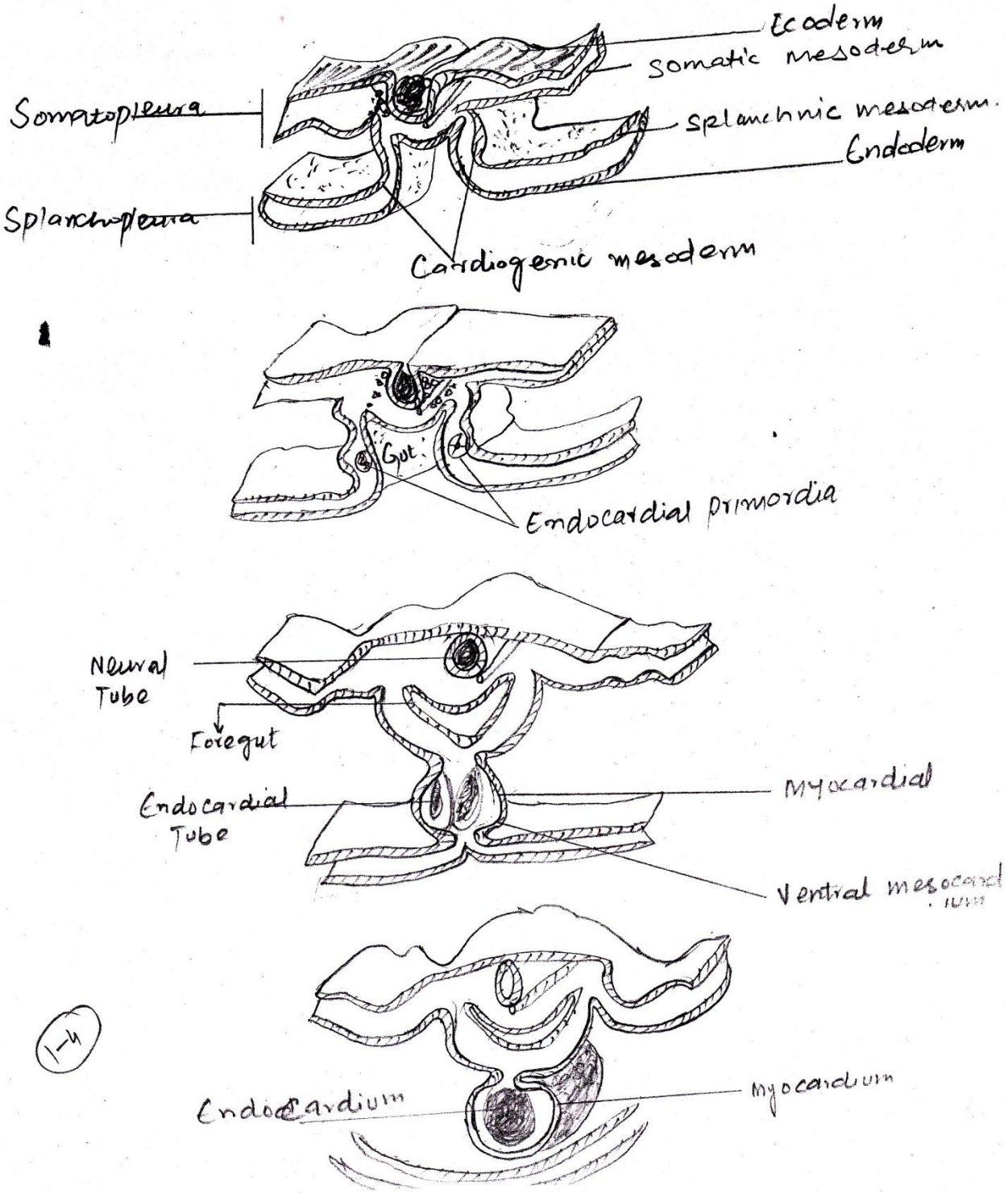
2. Specification of Cardiac Precursor Cells :- The Specification of the Cardiogenic mesoderm cells is mediated (induced) by the endoderm adjacent to the heart through the BMP and

FGF Signaling pathways) The endodermal Signal appears to be mediated by BMPs, especially Bmp2. BMP from the endoderm promote both heart and blood development. The endodermal BMPs also Induce Fgf8 synthesis in the endoderm directly beneath the cardiogenic mesoderm, and Fgf8 appears to be critical for the expression of heart proteins (Aslan and Schultheiss 2002)



Migration of the cardiac precursor cells:- (When the embryo is about 18-20 hours old, the presumptive heart cells move anteriorly between the ectoderm and the endoderm towards the middle of the embryo, remaining in close contact with the endodermal surface. When these cells reach the lateral walls of the anterior gut tube, migration ceases) The

direction to this migration is appears to be mediated to be provided by the foregut endoderm.

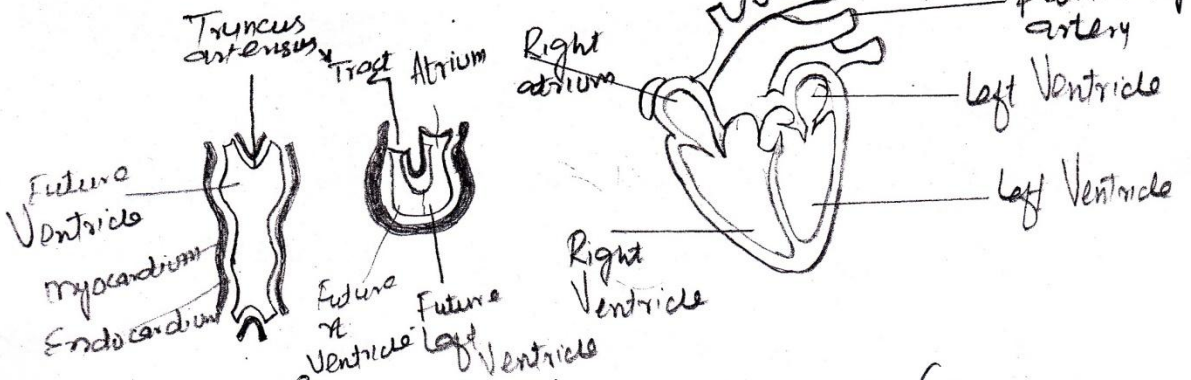


(1-4)

Establishment of Anterior and posterior Cardiac Domains:- When the Cardiac precursor cells migrate, the posterior region becomes exposed to increasingly higher concentrations of retionic acid produced by the posterior mesoderm. Rationic acid is critical in specifying the posterior Cardiac precursor cells into becoming the inflow or "Venous," portions of the heart, the Sinus Venous and atria.

x Intial Cell differentation:- Number of the genes are responsible for the development of the heart. GATA4 is first seen in the precardia cells of the mice, as these cells emerge from the primitive streak. GATA4 expression is retained in all the cells making up the heart field on both sides. This transcription factor is necessary for the activation of numerous specific genes; It also activates the expression of the N-cadhesin gene responsible for the fusion of the two heart rudiment into one tube. BMP pathway is critical in inducing the synthesis of the NKx2-5 transcription factor in the migrating Cardiogenic mesoderm, actually NKx2-5 instructs the mesoderm to become heart tissue. The Tbx family of genes is also critical for the heart development

Fusion of the heart rudiments:- The fusion of the two heart primordia occurs at about 3 Weeks in human gestation. The myocardia unite to form a single tube. The two endocardia lie within this common tube for a short while, but they also fuse. The infused posterior portions of the endocardium becoming the openings of the Vitelline Veins into the heart. These Veins will carry nutrients from the yolk sac into the Sinus Venous



Looping and formation of heart Chambers:- In 5-week human embryos, the heart is a two chambered tube, with one atrium and one Ventricle. Looping of the heart converts the original anterior-posterior polarity of the heart tube into the right-left polarity seen in the adult organism. (When this looping (rightward) is completed, the portion of the heart tube destined to become the right Ventricle lies anterior to the portion that will become the left Ventricle.)
lies

Q. 8. Ans:

C. Histological Types of Placenta

On histological basis, following types of mammalian placentae have been recognised :

1. Epithelio-chorial placenta. The epithelio-chorial type placenta is most primitive type placenta and it is found in marsupials, ungulates (pig, horse, sow, cattle, etc.) and lemurs. In such a case, no fewer than six tissues or membranes (called **barriers**) lie between the foetal and maternal blood streams, therefore, the molecules of nutrients and oxygen, for instance, in going from the mother to foetus would pass through in this order—(1) the endothelium of the maternal blood vessel ; (2) endometrial connective tissue (mesenchyme) ; (3) uterine epithelium ; (4) the ectoderm of the chorion or chorionic epithelium ; (5) chorionic connective tissue (foetal mesenchyme) ; and (6) the endothelium of foetal blood vessels. Because, the immediate contact of the two halves of the placenta involves chorionic epithelium and uterine epithelium, this type of placenta is called **epithelio-chorial placenta**. The villi of an epithelio-chorial placenta push in the wall of uterus and later lie in the pocket-like depressions of the uterine wall.

2. Syndesmo-chorial placenta. In the ruminant ungulates (cattle, sheep), the foetal and maternal components are fused so intimately as to result in a destruction of the uterine epithelium, thus, bringing the chorion into contact with the connective tissue of the uterine mucosa. Only five barriers, therefore, lie between the two, (*viz.*, foetal and uterine blood streams). This type of placenta is called **syndesmo-chorial placenta.**

3. Endothelio-chorial placenta. In carnivores (dogs, cats, bears, etc.), the uterine mucosa is reduced and the chorionic epithelium comes in contact with the endothelial wall of the maternal (uterine) blood vessels. In such a case, therefore, there lie only four barriers between the foetal and maternal blood streams. This type of placenta is called **endothelio-chorial placenta.**

4. Haemo-chorial placenta. In the haemo-chorial placenta of primates, insectivores (moles, shrews), and chiropterans (bats), a reduction of the barriers to three occurs. In such case, the endothelial walls of maternal (uterine) blood vessel also disappear and the chorionic epithelium is bathed directly in maternal blood. Actually, the chorionic villi are surrounded by spaces (sinuses) devoid of endothelial lining, into which maternal blood enters through the arteries of the uterus and from which the blood flows into the uterine vein.

5. Haemo-endothelial placenta. In haemo-endothelial placenta of mouse, rat, guinea pig, rabbit, the number of barriers between the maternal and foetal blood streams is reduced to just two. In them, the chorionic villi lose their epithelial and mesenchymal layers to such a degree that, in most places, the essentially bare endothelial lining of their blood vessels alone separates the foetal blood from the maternal sinuses.

smooth. The rosettes or patches of villi are called **cotyledons**, and the placenta of this type is found in ruminants (cud-chewing) ungulates such as cattle, sheep and deer.

Camel and giraffe have an intermediate type of placenta in which villi are arranged in cotyledons as well as are scattered.

3. Zonary placenta. In a zonary placenta, the villi are developed in the form of a belt or girdle-like band around the middle of their blastocyst or chorionic sac, which is more or less elliptical in shape. Such a placenta occurs in carnivores (*e.g.*, cats, dogs, etc.). Raccoon has incomplete zonary placenta.

4. Discoidal placenta. In a discoidal placenta, the villi are restricted to a circular disc or plate on the dorsal surface of blastocyst. Such a placenta occurs in insectivores, bats, rodents (rat, mouse), rabbit and bear.