Origin and significance of mammalian Placenta (Paper 105; Unit IV)

The term placenta in its broadest sense refers to any region in a viviparous organism where maternal and embryonic tissues of any kind are closely apposed, and which serves as a site for physiological exchange between parent and embryo (Kent, 1987). The placenta can be defined as a temporary organ which is formed jointly by the extra-embryonic membranes of the foetus and maternal tissue. The developing embryo or foetus of viviparous mammals obtains its nourishment from the maternal uterine tissue. The mode of formation and fusion of the placenta to the uterine wall is called placentation.

The phenomenon of placentation is invariably related with the viviparity of the organism. In all viviparous animals, the development of the young takes place inside the uterus of the mother because the amount of stored yolk of egg does not remain sufficient for the development of an embryo which can lead an independent mode of existence, therefore, the developing embryo has to depend on the mother in lesser or greater degree for nourishment, oxygen supply and other physiological assignments. Such embryos which develop inside the uterus of the mother often get attached with uterine wall to draw necessary substances from the maternal (uterine) circulation by means of a organ called placenta. The placentae are not found exclusively in mammals but appear also in animals belonging to various groups of the animal kingdom such as in *Peripatus* (Protracheata), *Salpa* (Tunicata), *Mustelus laevis* (Elasmobranchii) and certain lizards (Reptilia). The nature of the tissues entering into the formation of the placenta is not the same in all cases. For example, in placental fishes and reptiles, the yolk sac comes in close relation with the maternal blood stream and vitelline circulation carries the materials to and from the embryo. However, the placentae of mammals have following mode of origin, structure, type and physiology.

Mode of origin and Types of mammalian placentae

A mammalian placenta, typically, is a structure produced by the apposition or fusion of the extra-embryonic membranes (i.e., chorion) with the endometrium of uterus for the purpose of physiological exchange. It, therefore, follows that the placenta from the point of view of its origin, consists of two parts: a foetal placenta, furnished by the extra-embryonic membranes and a maternal placenta, furnished by the uterine endometrium. Now, it would be obvious that while on the maternal side a single component, the endometrium is involved; on the foetal side, one has to consider the prospective roles of four elements – amnion, chorion, yolk sac and allantois. The first of these, the amnion, may be ruled out immediately, as it is making no direct contribution to the placenta. This leaves the other three, of which the chorion, because of its most external position, is the membrane making immediate contact with the endometrium. In mammals, there are two possible sources of chorionic vascularisation – the vitelline circulation provided by the yolk sac and allanotic circulation, provided by the allantois. Thus, it can be said that in mammals, there exists two essentially different main types of placentae – **the chorio-vitelline placenta** and the **chorio-allantoic placenta**.

A. Chorio-vitelline Placenta or Chorionic Placenta or Yolk-sac Placenta In some marsupials (*Didelphys, Macropus*), the allantois remains relatively small and never makes contact with the chorion. Whereas the yolk sac becomes very large and fuse broadly with the chorion. In these forms, the chorion gains its blood supply from the network of vitelline blood vessels of yolk sac. Such a placenta is called yolk sac placenta or chorio-vitelline placenta. In such a foetal placenta, the chorion never advances beyond a smooth membrane is close apposition with the vascular uterine lining, the

endometrium. The chorio-vitelline placenta also occurs as a temporary structure in insectivores, rodents and horse (eutherians).

B. Chorio-allantoic Placenta or Allantoic Placenta In some marsupials (e.g., *Parameles, Dasyurus*), and all eutherians the yolk sac remains rudimentary and the allantois becomes well developed and vascularised to fuse with chorion and to furnish the latter the blood supply. Such a foetal placenta is called chorio-allantoic placenta. In this kind of placenta, the chorion is not smooth, but bears root-like, vascular processes, the villi, which grow out from the chorion into the adjacent maternal tissue. Thus, in chorio-allantoic placenta, the chorion lined with allantois becomes associated with the uterine wall during the gestation period. In it the allantoic (umbilical) vessel transports the materials. As the embryonic body develops, it separates from various membranes until only the umbilicus cord connects the foetus with the placenta. The final part of the placenta consists of chorionic villi formed of outer chorionic ectoderm, inner allantoic endoderm and in between these is a highly vascularised mesodermal connective tissue of double origin– somatic or chorionic and allantoic or splanchnic. The ectodermal cells have mircovilli to increase the absorptive surface. The trophoblast that give rise to villi often becomes syncytial on its outer border towards endometrium (syncytiotrophoblast). The maternal part of placenta consists of the epithelium of endometrium and the stroma of endometrium with its glands and the uterine blood vessels.

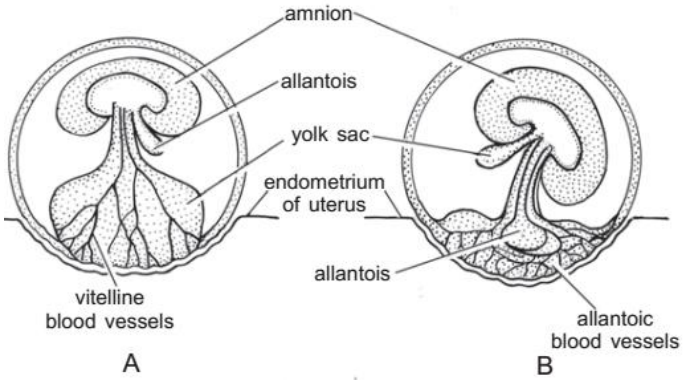


Figure 1 A. Yolk Sac Placenta B. Allantoic Placenta

Classification of chorio-allantoic placenta

The chorio-allantoic placenta has been classified into various types on the basis of its morphology, arrangement of villi, histology and electron microscopy.

A. Morphological Classification of Placenta

On the basis of closeness of foetal and maternal tissues, placentae may be of the following three types :

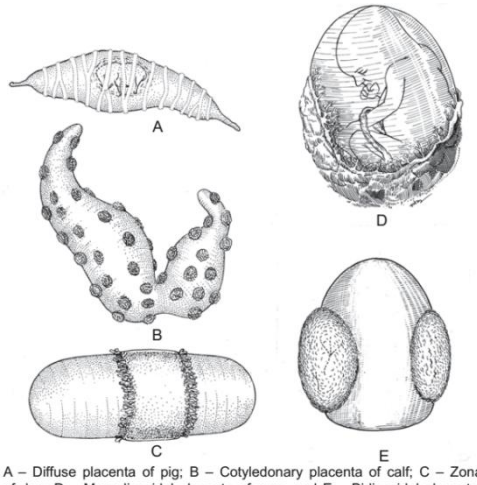
1. Non-deciduous placenta or semiplacenta. In most mammals, the implantation is superficial, i.e, the blastocyst lies in the cavity of the uterus in contact with the uterine wall. The contact may be made more intimate by the surface of the blastocyst by forming finger-like outgrowths which penetrate into depressions in the wall of the uterus. Such outgrowths are intially formed by the trophoblast (i.e., the epithelial layer covering the blastocyst), but later on the connective tissue and blood vessels invade the outgrowths. These outgrowths are called chorionic villi, the blood vessels of chorionic villi are the branches of allantoic blood vessels in case of chorio-allantoic placenta. (In chorio-vitelline placenta, vitelline blood vessels give their branches to chorionic villi). At the time of birth, when parturition (the separation of the foetus and its membranes from the mother's body) occurs, the chorionic villi are simply drawn out from the depressions in the wall of the uterus and, thus, maternal and foetal tissues are separated without further damage to the uterine wall and no bleeding occurs. This type of placenta is called non-deciduate or nondeciduous placenta and is found in pigs, cattle and some other mammals. Further, the chorionic villi of a non-deciduate placenta,

because lie in apposition with the endometrium, but, do not fuse with it, so such a placenta is also called semiplacenta.

2. Deciduous placenta or placenta vera. In other mammals, however, the degree of intimacy between maternal and foetal tissues becomes further increased. The wall of the uterus becomes eroded to various degress through the action of the trophoblast and the embryonic tissues penetrate into the uterine wall, establishing a more intimate contact and facilitating the passage of substances from the mother to the foetus and from the foetus to the mother. Here because the chorionic villi fuse with the eroded uterine mucosa, such placenta is called placenta vera (true placenta). At the end of pregnancy the uterine wall is no longer intact and when the foetus with its membranes including the chorion is removed, more or less extensive haemorrhage from the uterine wall ensues (i.e., at birth, when such placenta is discharged, the uterine lining also tears away with some bleeding). Such a type of placenta found in higher eutherian mammals and is called deciduate or deciduous placenta. The maternal tissues which are expelled at birth in the case of deciduate placenta are called deciduae. The haemorrhage at parturition is normally stopped by the same mechanism as serves for the expulsion of the newborn, the contraction of the muscular wall of the uterus constricts the blood vessels and, thus, slows down the flow of blood, until clotting of the blood stops the haemorrhage altogether.

3. Contra-deciduate placenta. In Perameles and Talpa (mole), somewhat modified type of deciduate placenta occurs, which is called contra-deciduate placenta. In such case, not only there is a loss of maternal tissue but also of the foetal portion of the placenta, both of which absorbed in situ by maternal leucocytes.

B. Classification of Placentae According to the Distribution of Villi on Chorion In different mammals the pattern of distribution of villi varies from species to species and accordingly following kinds of placentae have been recognised :



A – Diffuse placenta of pig; B – Cotyledonary placenta of calf; C – Zonary placenta of dog; D – Monodiscoidal placenta of man; and E – Bidiscoidal placenta of monkey.

1. Diffuse placenta. In some mammals (e.g., ungulates, pig, sow, mare, horse, lemur, etc.) the chorionic villi remain scattered all over the surface of the chorion and their placentae are correspondingly expensive. Such placentae are called diffuse placentae.

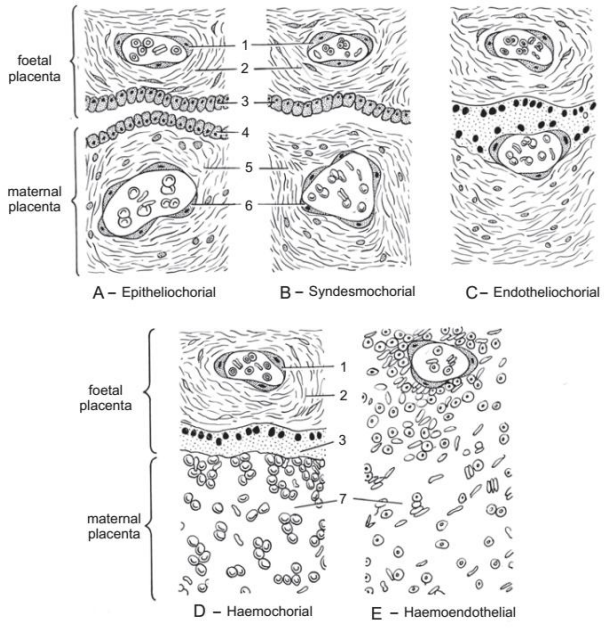
2. Cotyledonary placenta. In a cotyledonary placenta, the villi are found in groups or patches, while the rest of the chorion surface is smooth. The rosettes or patches of villi are called cotyledons, and the placenta of this type is found in ruminants (cud-chewing), ungulates such as cattle, sheep and deer. Camel and giraffe have an intermediate type of placenta in which villi are arranged in cotyledons as well as 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 insctivores, bats, rodents (mouse, rat, rabbit, etc.) and bear, the villi are restricted to a circular disc or plate on the dorsal surface of blastocyst.

5. Metadiscoidal placenta. In primates also discoidal placenta is found but of special type, i.e., chorionic villi are at first scattered but later on become restricted to one or two discs. Thus, in man the placenta has a single disc-shaped villous area and is called monodiscoidal placenta. In the monkeys, the placenta consists of two disc-shaped villous areas and such a placenta is called bidiscoidal placenta.

C. Classification of Placenta According to Histology On histological basis, following types of mammalian placentae have been recognised :



40.3. Mammalian placental types arranged in a series to show the progressive elimination of barriers between the maternal and foetal circulation. 1. Endothelium of foetal blood vessel; 2. Chorionic connective tissue; 3. Chorionic epthelium; 4. Uterine epithelium; 5. Endometrial connective tissue (mucosa); 6. Endothelium of maternal blood vessel; 7. Maternal blood pool.

1. Epithelio-chorial placenta. The epithelio-chorial type placenta is most primitive type and it is found in marsupials, ungulates (pig, horse, sow, cattle, etc.) and lemurs. In this case, placenta is formed of six tissue or membranes : (i) the endothelium of the maternal blood vessels; (ii) endometrial connective tissue (mesenchyme); (iii) uterine epithelium; (iv) the ectoderm of the chorion or chorionic epithelium; (v) chorionic connective tissue (foetal mesenchyme) and (vi) 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 lie in 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 or tissues, 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 also reduced and the chorionic epithelium comes in contact with endoethelial walls of the maternal (uterine) blood vessels. In such a case, therefore, there lies 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, i.e., the endothelial walls of maternal (uterine) blood vessels also disappear and the chorionic epithelium is bathed directly in maternal blood sinuses. Actually, the chorionic villi are surrounded by spaces (sinuses) devoid of endothelial lining, into which maternal blood enters through the uterine arteries flows out through the uterine veins.

5. Haemo-endothelial placenta. In haemo-endothelial placenta of higher rodents (rat, guinea pig, rabbit), the number of barriers between the maternal and foetal blood streams is further reduced

to two. In them, the chorionic villi lose their epithelial and connective tissue layers to such a degree that, in most places, the bare endothelial lining of their blood vessels alone separates the foetal blood from the maternal blood sinuses.

D. Classification of Placentae According to the Mode of Implantation

The relation of the chorionic sac to the uterine wall varies greatly among placental mammals. In general, following three types of implantation may be distinguished, although transitional conditions occur:

1. Superficial implantation. Growth of the chorionic sac brings it into contact with the lining of the main uterine cavity. This type of implantation is called central implantation, e.g., ungulates, carnivores, monkey.

2. Eccentric implantation. The chorionic sac lies for a time in a fold or pocket which looses off from the main cavity, e.g., beaver, rat, squirrel.

3. Interstitial implantation. The chorionic sac penetrates into the substance of the uterine lining, e.g., hedgehog, guinea pig, some bats, ape and man.

Physiology of placenta

Placentation is the mechanism by which the foetal and maternal blood circulations are brought very close together for conducting various metabolic functions such as respiration, excretion and nutrition of foetus. In all histological types of placentae, there exists a placental barrier which may include two to six kinds of tissues. Due to the placental barrier, the blood of foetus and mother is never mixed. Physiologically, the placental barrier is like a ultrafilter or semipermeable membrane. Accordingly, there is a relationship between placental transmission and molecular size, smaller molecules passing more readily through placental barrier than the larger ones. This means that water, oxygen, carbon dioxide, soluble inorganic materials as chloride and phosphates of sodium, potassium and magnesium and soluble organic substances as monosaccharides, hormones, vitamins and urea pass by diffusion. Macromolecules of polysaccharides, lipids and proteins may be absorbed by trophoblast cells by pinacocytosis. Exchange of substances also occurs by active transport and leakage, i.e, by breaking the placental membrane.

1. Nutritive function of placenta. The foetus obtains its nutrients from the maternal blood and when the diet is inadequate, then by depletion of maternal tissue storage occurs. Thus, to avoid the depletion of maternal tissue storage a rich diet is essential for the pregnant mother. Glucose which is the principal source of energy of foetus is transported to the foetus by facilitated diffusion. Lipids needed for foetal growth are transported from the mother to the foetus or synthesised in the foetus (e.g., triglycerides and fatty acids). Amino acids are transferred to the foetus by active transport and then proteins are synthesised in the foetal body. Water, sodium, potassium and chloride enter the foetal blood by simple diffusion. Whereas calcium, phosphorus (phosphate), iron and iodine enter the foetal blood by active transport. Water soluble vitamins are transported by active transport but the fat soluble vitamins enter the maternal blood by simple diffusion. Hormones like insulin, steroids from the adrenals, thyroid hormones and chorionic gonadotropin or placental lactogen cross the placenta at a very slow rate.

2. Respiratory function of placenta. Intake of oxygen and output of carbon dioxide occurs by simple diffusion, across the foetal membrane, i.e., oxygen from maternal blood diffuses into the foetal blood, whereas carbon dioxide from the foetal blood diffuses into the maternal blood.

3. Excretory function of placenta. Excretory wastes such as urea, uric acid and creatinine from the foetus are excreted to the maternal blood through placenta by diffusion. The kidneys of the mother eliminate these wastes of foetus along with her own waste products.

4. The placenta during first half of pregnancy is impermeable to bacteria and macromolecules. Therefore, it reduces the chances of appearance of maternal ill health on the foetus. But in the latter half of pregnancy, the placenta becomes more permeable and chances of passing the germs from mother to foetus become more. Certain pathogenic organisms and viruses can penetrate through the placental barrier and can infect the foetus, if the mother is infected by those pathogens. This is known to happen with syphilis, small pox, chicken pox, measles, and rubella or German measles.

5. The antibodies, which have developed in the blood of a mother who has acquired immunity to certain diseases, such as diphtheria, scarlet fever, small pox and measles, are passed to the foetus, which, thus, becomes passively immunised and unsusceptible to these illnesses in the first period after birth. Many drugs used medically may penetrate the placental barrier and sometimes cause most adverse effects on the embryo. Thus, it is believed that, the drug thalidomide, which was used as a sedative, when taken by women in early pregnancy (25 to 44 days), caused very extensive deficiencies in the development of limbs, the alimentary canal (non-perforation of the anus) and the heart. The children born to such mothers had flipper-like limbs (phocomelia) and were called thalidomide babies. Drugs like quinine and aspirin, exposure to X-rays and radium, alcoholic drinks and cigarette smoking, etc, are found to be potent teratogens.

6. Placenta as an Endocrine gland: placenta secretes many hormones such as estradiol, progesterone, chorionic gonadotropin and placental lactogen. In some animals, such as rabbit, the placenta is a significant source of relaxin, which is a protein hormone for the relaxation of the pelvic ligaments to facilitate the birth of the young. Human placenta produces a variety of protein and steroid hormones such as oestrogens, and progesterones. Protein hormones are chorionic gonadotropin, placental lactogen, chorionic thyrotropin and corticotropin and relaxin, etc.