# Implantation, Extraembryonic Membranes, Placental Structure and Classification

# Attachment and Implantation

Implantation is the first stage in development of the placenta. In most cases, implantation is preceded by a close interaction of embryonic trophoblast and endometrial epithelial cells that is known as **adhesion** or **attachment**.

Implantation also is known as the stage where the blastocyst *embeds* itself in the endometrium, the inner membrane of the uterus. This usually occurs near the top of the uterus and on the posterior wall.

Among other things, attachment involves a tight intertwining of microvilli on the maternal and embryonic cells. Following attachment, the blastocyst is no longer easily flushed from the lumen of the uterus. In species that carry multiple offspring, attachment is preceeded by a remarkably even spacing of embryos through the uterus. This process appears to result from uterine contractions and in some cases involves migration of embryos from one uterine horn to another (transuterine migration).

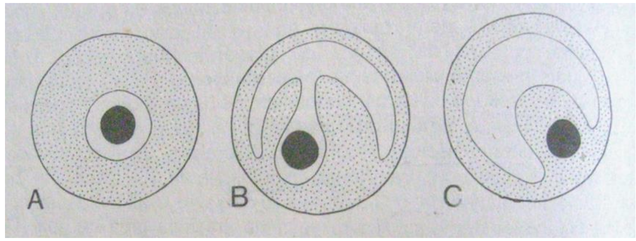
The effect of implantation in all cases is to obtain very close apposition between embryonic and maternal tissues. There are, however, substantial differences among species in the process of implantation, particularly with regard to **"invasiveness,"** or how much the embryo erodes into maternal tissue.

In species like horses and pigs, attachment and implantation are essentially equivalent. In contrast, implantation in humans involves the embryo eroding *deeply* into the substance of the uterus.

•**Centric:** the embryo expands to a large size before implantation, then remains in the center of the uterus. *Examples include* ***carnivores, ruminants, horses, and pigs.***

•**Eccentric:** The blastocyst is small and implants within the endometrium on the side of the uterus, usually opposite to the mesometrium. *Examples include* ***rats and mice****.*

•**Interstitial:** The blastocyst is small and erodes through endometrial epithelium into subepithelial connective tissue. Such implantation is often called nidation ("nest making"). *Examples include primates, including* ***humans, and guinea pigs.***



It has been difficult to attribute any particular advantage to the degree of invasiveness seen during implantation. One possible exception is that most species having highly invasive embryos have systems for prenatal **transfer of antibodies** from the mother to the fetus.

For eccentric and interstitial implantations, what allows the embryo to invade the uterine substance? In some species it appears that the blastocyst is a passive participant, and the underlying endometrium degenerates. In other cases, including carnivores and probably humans, the embryo seems to be the aggressor and trophoblast actively invades into the endometrium. It's likely that both tissues participate to some degree.

In species that undergo interstitial implantation, an interesting phenomenon called the **decidual** cell reaction occurs. This involves transformation of uterine stromal and endothelial cells into a tissue called the decidua, which becomes a substantial portion of the placenta and is expelled with the remainder of the placenta at the time of birth. The decidua is a prominent feature of the human placenta.

It is clear that steroid hormones from the ovary are necessary to prepare the endometrium for implantation and for the process of implantation itself. *In some species*, progesterone alone appears to be adequate, while in others, estrogen and progesterone are required for implantation.

In addition to the differences among species in the implantation process per se, there are also situations in which the timing of implantation varies. The usual case is for attachment and implantation to occur within a few days after the blastocyst reaches the uterus. In many animals, however, implantation can be delayed for substantial periods of time, during which the blastocyst enters a quiescent state called embryonic diapause. Delayed implantation seems to be a strategy used to regulate time of birth so that it occurs when environmental conditions are favorable.

Read it !

*Following hatching, the conceptus undergoes massive growth.*

**In the cow**, the blastocyst is about 3 mm in diameter around day 13, which undergoes maximum growth to 250 mm in length within the next four days and appears as a filamentous thread. By day 18 of gestation, the blastocyst occupies space in both uterine horns.

**In the sow**, the development of blastocyst is even more dramatic, where it grows from 2mm spheres on day 10 to about 200 mm in length in the next 24-48 h reaching lengths of 800-1000 mm by day 16 (growth is at a rate of 4-8 mm/h).

The dramatic growth of the conceptus is due largely to development of a set of membranes called the extraembryonic membranes.

**The pig**, sheep and cow are characterized as having filamentous or threadlike blastocysts prior to attachment.

**In the mare**, however, blastocysts do not change into a thread like structure but remain spherical.

As the hatched blastocyst begins to grow, it develops an additional layer called primitive endoderm just beneath, but in contact with the inner cell mass which continues to grow downwards eventually lining the trophoblast.

At the same time, it also forms an evagination at the ventral portion of the inner cell mass to form the yolk sac, a transient extra embryonic membrane that regresses in size as the conceptus develops.

As the blastocyst continues to expand, the newly formed double membrane (the trophoblast and mesoderm) becomes the chorion. Further development of the blastocyst causes the chorion to push upward in the dorso lateral region of the conceptus and begins to surround it.

The chorion begins to send “wing-like” projections above the embryo, the amnion begins to form. Fusion of the chorion over the dorsal portion of the embryo results in formation of a complete sac called amnion around the embryo.

The amnion is filled with fluid and serves to hydraulically protect the embryo from mechanical perturbations.

As an anti-adhesion material to prevent tissues in the rapidly developing embryo from adhering to each other.

The **amnionic vesicle** can be palpated in the **cow between days 30 and 45** and feels like a small, turgid balloon inside the uterus. The embryo, however, is quite fragile during this early period and amnionic vesicle palpation should be performed with caution.

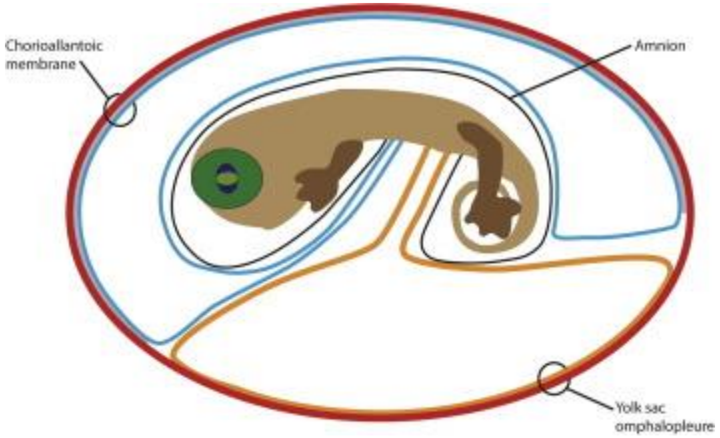
During the same time that the amnion is developing, a small evagination from the posterior region of the primitive gut begins to form. This sac-like evagination is referred to as the allantoic sac that collects liquid waste from the embryo.

As the embryo grows, the allantois continues to expand and eventually will make contact with the chorion.

When the allantois reaches a certain volume, it presses against the chorion and eventually fuses with it. When fusion takes place the two membranes are called the allantochorion. The **allantochorionic membrane** is the fetal contribution to the placenta and will provide the surface for attachments to the endometrium.

Read it !

# Extraembryonic Membranes



The embryos of reptiles, birds, and mammals produce **4 extraembryonic membranes**,

Amnion
Yolk sac
Chorion, and
Allantois

In birds and most reptiles, the embryo with its extraembryonic membranes develops within a shelled egg.
The amnion protects the embryo in a sac filled with amniotic fluid.
The yolk sac contains yolk — the sole source of food until hatching. Yolk is a mixture of proteins and lipoproteins.
The chorion lines the inner surface of the shell (which is permeable to gases) and participates in the exchange of $O_2$ and $CO_2$ between the embryo and the outside air.
The allantois stores metabolic wastes (chiefly uric acid) of the embryo and, as it grows larger, also participates in gas exchange

## Amnion

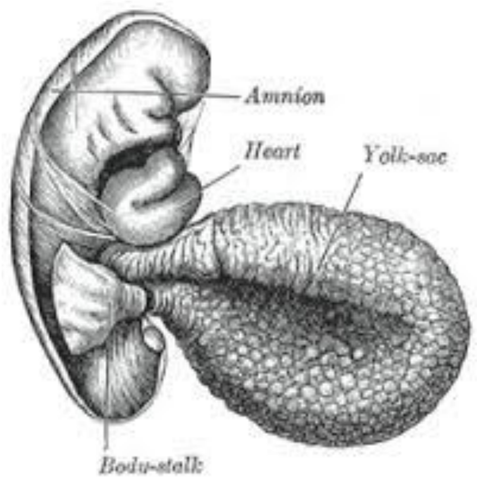
Amnionic membrane is two cell layers
1) epiblast derived extraembryonic ectodermal layer
2) thin non-vascular extraembryonic mesoderm
As the amnion enlarges it encompasses the embryo on the ventral side, merging around the umbilical cord.
Amnion forms the epithelial layer of the umbilical cord
With embryo growth the amnion obliterates the chorionic cavity
Amnionic sac is fluid filled called amnionic fluid: the embryo is bathed in the fluid

## Amnion Function

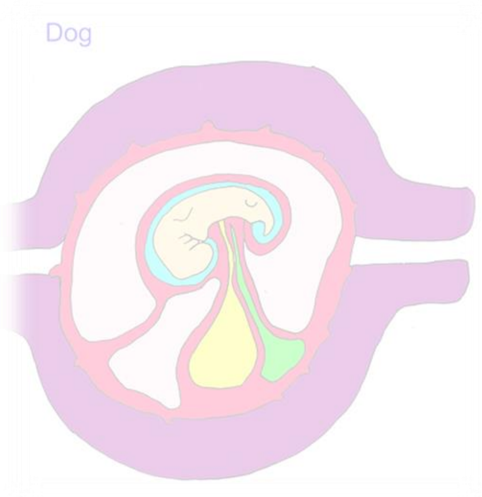
Mechanical protection: hydrostatic pressure
Allows free movement -which aids in neuromuscular development
Antibacterial
Allow for fetal growth
Protection from adhesions

# Yolk Sac

Hypoblast -the primary yolk sac or Heuser'smembrane.
Day 12 -Second wave of cell migration -forms definitive yolk sac
Composed of extrembryonic endoderm
Early nutrition (2-3 weeks) for the embryo -later shrinking -nonfunctional –*Meckels diverticulum* (outpocketing of small intestine)
Connects to midgut via the yolk sac stalk
Derivatives:
Early blood cells forms from blood islands
Primordial germ cells
The early gut, epithelium of the respiratory and digestive tracts



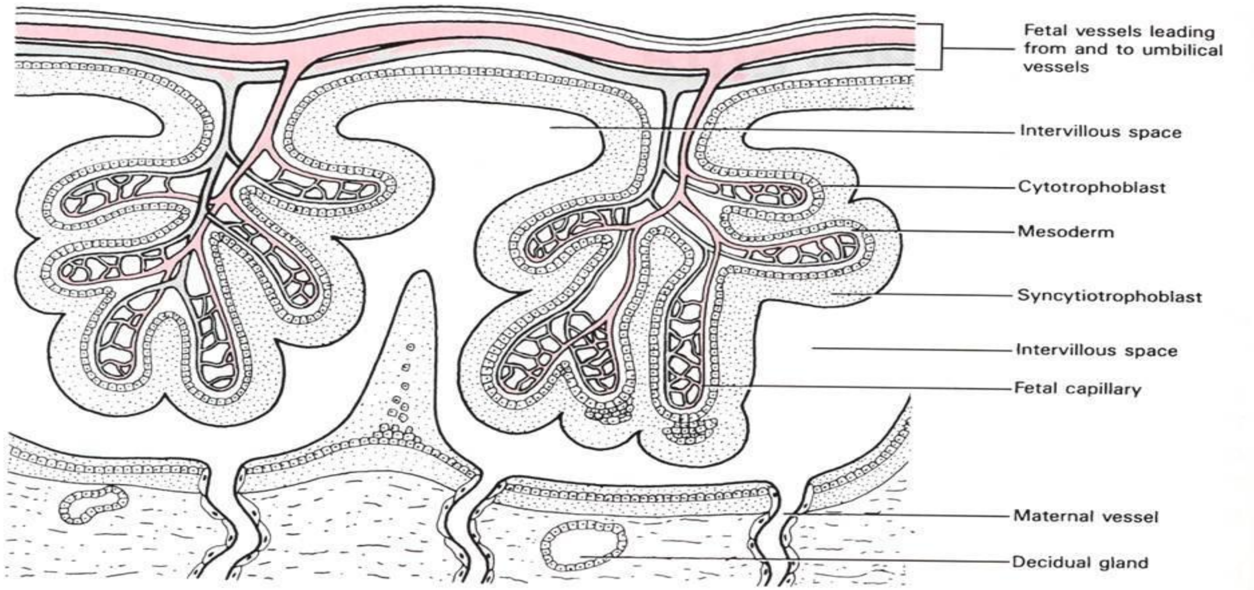
# Allantois




Endodermalorigin –caudal out pocketing of the yolk sac
Invades the connecting stalk (extraembryonicmesoderm) that suspends the embryo in the chorionic cavity
Involved in early hematopoiesis(up to 2 months)
The allanto is blood vessels -artery and vein -becomes the umbilical vessels
Remnants of Allantois becomes the urachusligament that connects the belly button to the bladder

# Chorion

Chorioniccavity (extraembryonic coelom)-lined with extraembryonic mesoderm
Chorionic cavity expands separating amnion from cytotrophoblast
Chorionicsac consist of:
Cytotrophoblastic layer
Syncytiotrophoblastic layer
Extraembryonic somatic mesoderm
The Chorion / maternal endometrium forms the placenta
Chorionforms stem villi




**Placental barrier** decreases with gestation

Placental Barrier –syncytiotrophoblast+ basal lamina, basallamin+ fetal capillary endothelium

Syncytiotrophoblasts –many microvilli, no major histocompatibility antigens

# Decidua

Decidua is the functional layer of endometrium which is shed during parturition.
Decidual Reaction–stromal cells –accumulate glycogen and lipid, called Decidual Cells
Decidua **basalis**-forms maternal component of the placenta; associates with the chorion frondosom
Decidua **capsularis**-superficallayer overlying the entire embryoblast-this layer eventually degenerates; associates with the chorion laeve
Decidua **parietalis**-all remaining parts of the endometrium-not associated with the embryo

# What is the Placenta ?

The placenta is a:

“Vascular (supplied with blood vessels) organ in most mammals that unites the fetus to the uterus of the mother.

It mediates the metabolic exchanges of the developing individual through an intimate association of embryonic tissues and of certain uterine tissues, serving the functions of nutrition, respiration, and excretion.”

(Online Britannica Encyclopaedia)

The placenta is also known as a hemochorical villous organ meaning that the maternal blood comes in contact with the chorion and that villi protrude out of this same structure.

As the fetus is growing and developing, it requires a certain amount of gases and nutrients to help support its needs throughout pregnancy. Because the fetus is unable to do so on its own, it is the placenta that carries out this function.

What are the main roles/functions of the placenta?

The placenta provides the connection between fetus and mother in order to help carry out many different functions that it is incapable to do alone. During pregnancy, the placenta has 6 main roles to maintain good health and a good environment for the fetus:

- Respiration
- Nutrition
- Excretion
- Protection
- Endocrine
- Immunity

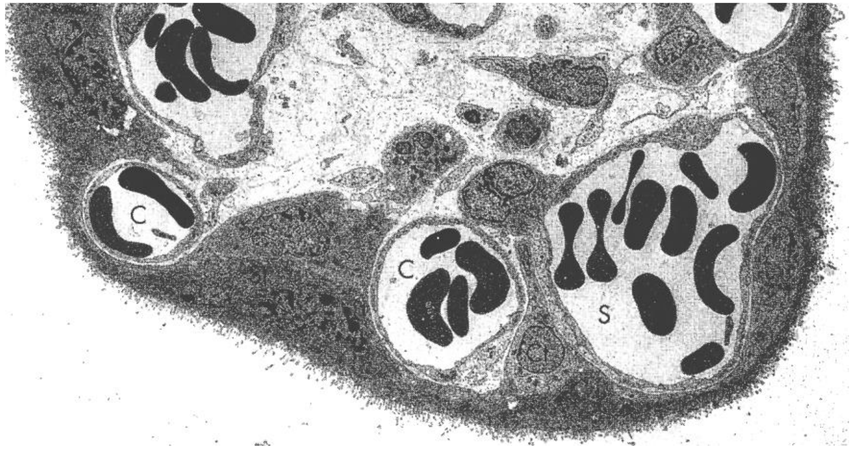
What passes across the placenta?

What stays behind?

How are wastes removed?

**IN**

$O_2$
$H_2O$
Fe
salts
carbohydrates, amino acids, lipids
vitamins, hormones, antibodies
drugs, alcohol
viruses (rubella, varicella-zoster, HIV)




**OUT**

$CO_2$
$H_2O$
salts
urea, uric acid
creatinine
bilirubin, hormones,
RBC antigens

The blood supply of the developing fetus is continuous with that of the placenta.
The placenta extracts food and oxygen from the uterus.
Carbon dioxide and other wastes (e.g., urea) are transferred to the mother for disposal by her excretory organs.

# Classification Based on Placental Shape and Contact Points

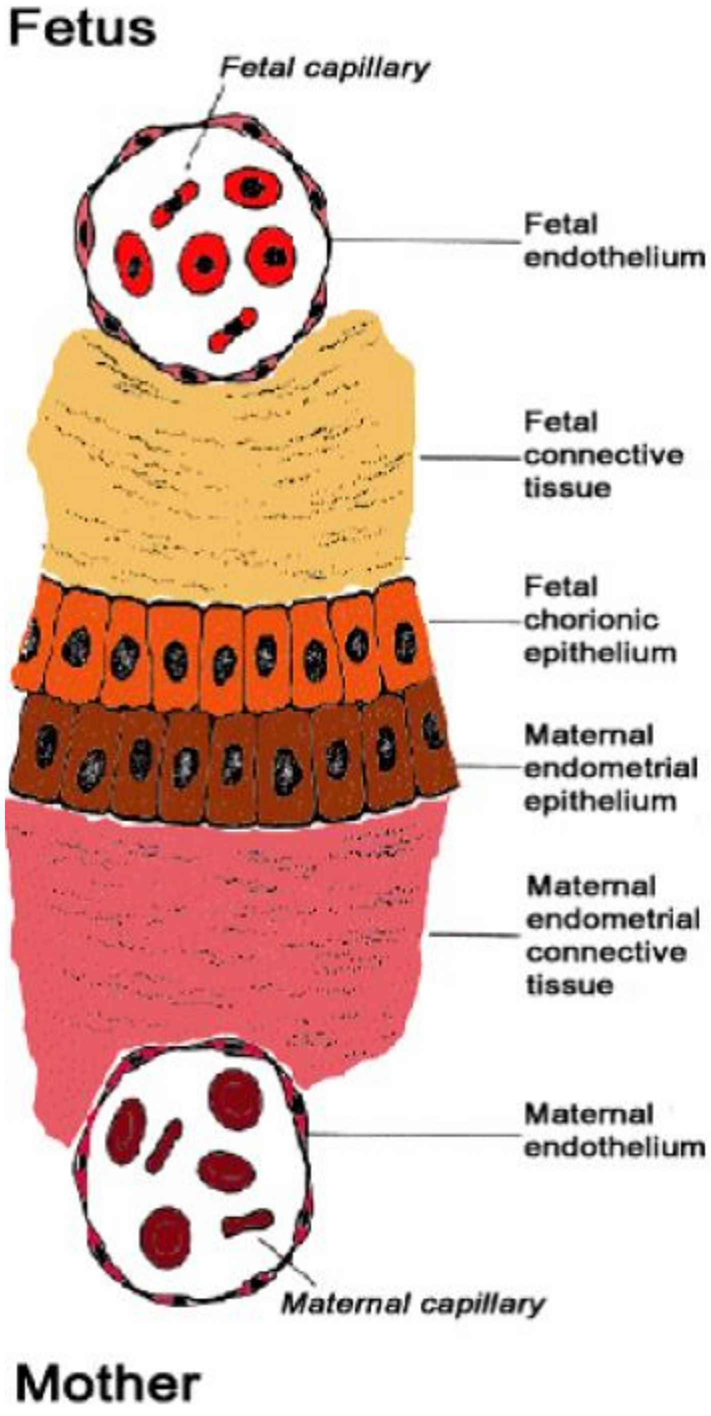
The placenta is composed of two different surfaces, the **maternal surface**, facing towards the outside, and the **fetal surface**, facing towards the inside, or the fetus. On the fetal surface, there is the umbilical cord, the link between the placenta and the fetus.

The placentas of all eutherian (placental) mammals provide common structural and functional features, but there are striking differences among species in gross and microscopic structure of the placenta. *Two characteristics are particularly divergent and form bases for classification of placental types*:

1.The gross shape of the placenta and the distribution of contact sites between fetal membranes and endometrium.

2.The number of layers of tissue between maternal and fetal vascular systems.

Differences in these two properties allow classification of placentas into several fundamental types.



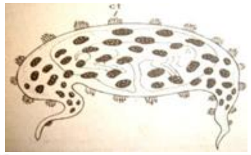
Examination of placentae from different species reveals striking differences in their shape and the area of contact between fetal and maternal tissue:

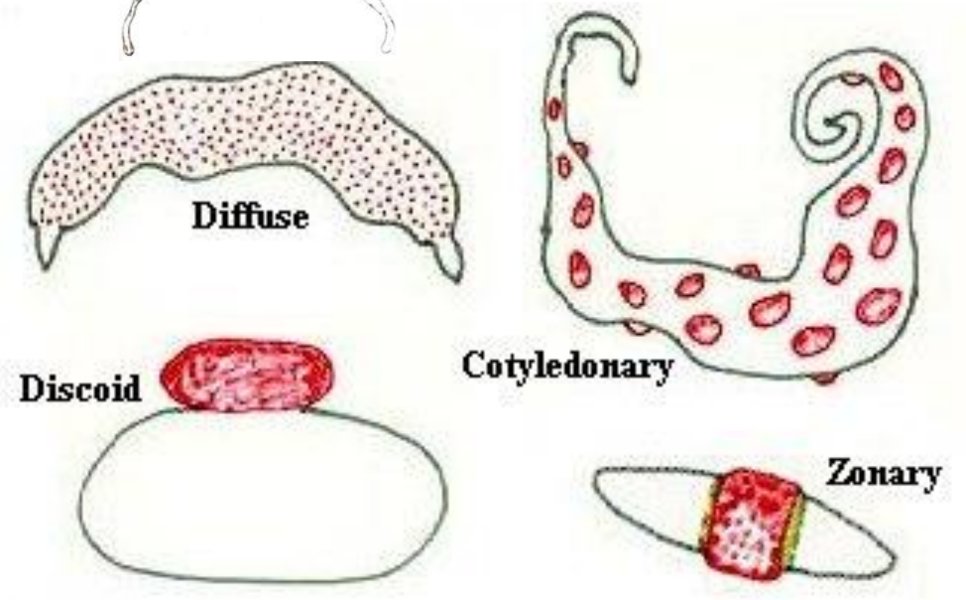
•**Diffuse**: Almost the entire surface of the allantochorion is involved in formation of the placenta. Seen in horses and pigs.

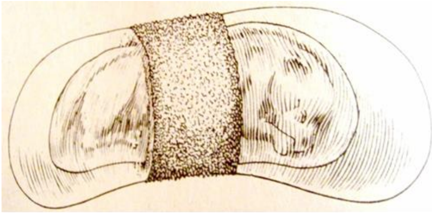
•**Cotyledonary**: Multiple, discrete areas of attachment called cotyledons are formed by interaction of patches of allantochorion with endometrium. The fetal portions of this type of placenta are called cotyledons, the maternal contact sites (caruncles), and the cotyledon-caruncle complex a placentome. This type of placentation is observed in ruminants.

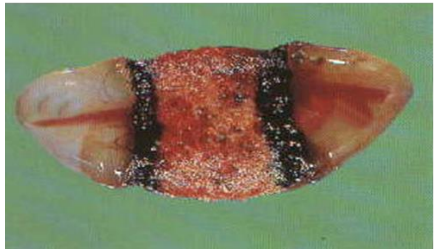
•**Zonary**: The placenta takes the form of a complete or incomplete band of tissue surrounding the fetus. Seen in carnivores like dogs and cats, seals, bears, and elephants.

•**Discoid**: A single placenta is formed and is discoid in shape. Seen in primates and rodents.

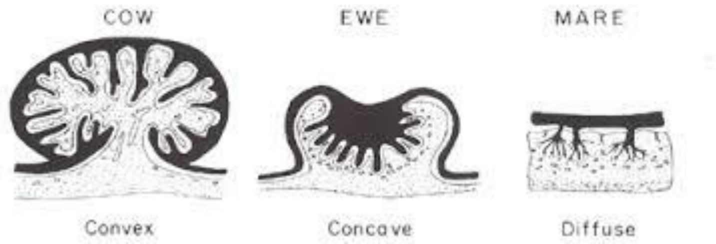






# Classification Based on Layers Between Fetal and Maternal Blood

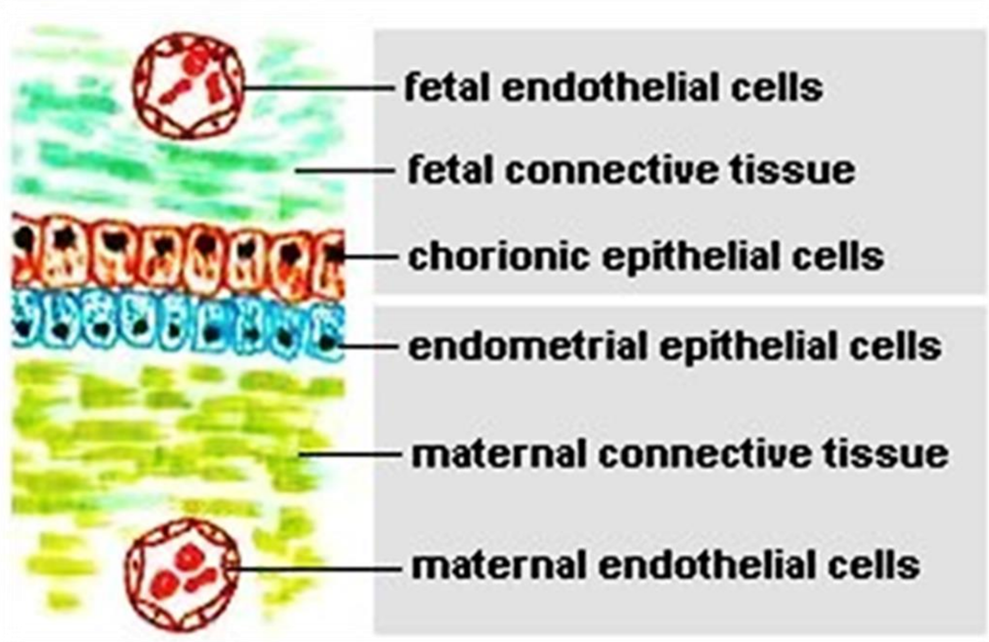


Just prior to formation of the placenta, there are a total of **six** layers of tissue separating maternal and fetal blood. There are three layers of **fetal extraembryonic membranes** in the chorioallantoic placenta of all mammals, all of which are components of the mature placenta:

1. Endothelium lining allantoic capillaries
2. Connective tissue in the form of chorioallantoic mesoderm
3. Chorionic epithelium, the outermost layer of fetal membranes derived from trophoblast

There are also three layers on **the maternal side**, but the number of these layers which are retained - that is, not destroyed in the process of placentation - varies greatly among species. The three potential maternal layers in a placenta are:

1. Endothelium lining endometrial blood vessels
2. Connective tissue of the endometrium
3. Endometrial epithelial cells

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One classification scheme for placentas is based on which maternal layers are **retained** in the placenta, which of course is the same as stating which maternal tissue is in contact with chorionic epithelium of the fetus.

Each of the possibilities is observed in some group of mammals.

| Type of Placenta | Maternal Layers Retained | | | Examples |
|---|---|---|---|---|
| | Endometrial Epithelium | Connective Tissue | Uterine Endothelium | |
| Epitheliochorial | + | + | + | Horses, swine, ruminants |
| Endotheliochorial | - | - | + | Dogs, cats |
| Hemochorial | - | - | - | Humans, rodents |

## Summary of Species Differences in Placental Architecture

The placental mammals have evolved a variety of placental types which can be broadly classified using the nomenclature described above slide. Not all combinations of those classification schemes are seen or are likely to ever be seen - for instance, no mammal is known to have a diffuse, endotheliochorial, or a hemoendothelial placenta. Placental types for "familiar" mammals are summarized below, with supplemental information provided for a variety of "non-familiar" species.

| Type of Placenta | Common Examples |
|---|---|
| Diffuse, epitheliochorial | Horses and pigs |
| Cotyledonary, epitheliochorial | Ruminants (cattle, sheep, goats, deer) |
| Zonary, endotheliochorial | Carnivores (dog, cat, ferret) |
| Discoid, hemochorial | Humans, apes, monkeys and rodents |

## The difference between marsupials & placentals

Although marsupials and placental animals are both mammals, there are several distinguishing features that differentiate the two groups.

The biggest difference between marsupials and placentals lies in the possession a placenta, the oxygen- and nutrient-rich organ that attaches growing embryos of placental mammals to their mothers. Marsupials, on the other hand, have no internal placenta and must therefore absorb nutrients from the yolk of their ovum; however, once the young are born, they spend a much longer time suckling than do placental young. Essentially, marsupials spend far more time nurturing and nursing their young after they are born than placentals, mammals that invest more time and energy in pregnancy.


## Summary of Species Differences in Placental Architecture ?

Placenta syndesmochorialis, adeciduata, villosa cotyledonata

<u>Ruminants (cattle, sheep, goats, deer)</u>

Placenta epithelio-chorialis, adeciduata, villosa diffusa incompleta

<u>Pig</u>

Placenta epithelio-chorialis, adeciduata, villosa diffusa completa

<u>Horse and donkey</u>

Placenta haemo-chroialis, deciduata, villosa discoidea

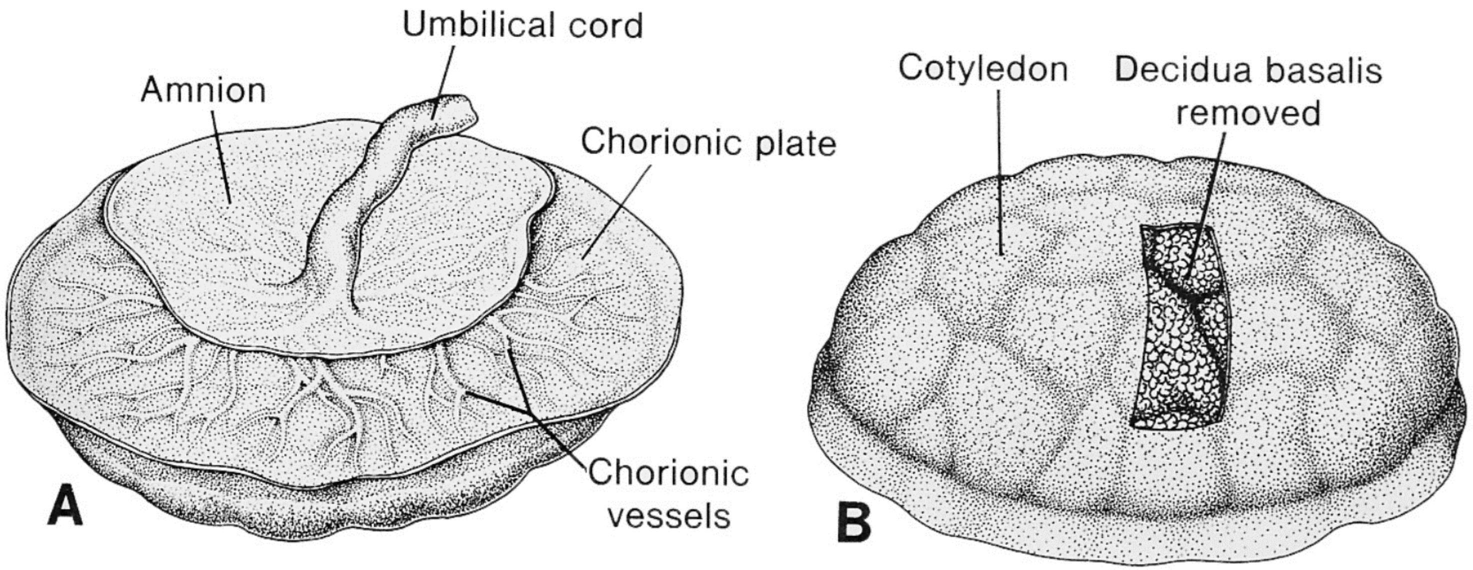
<u>Humans, apes, monkeys and rodents</u>

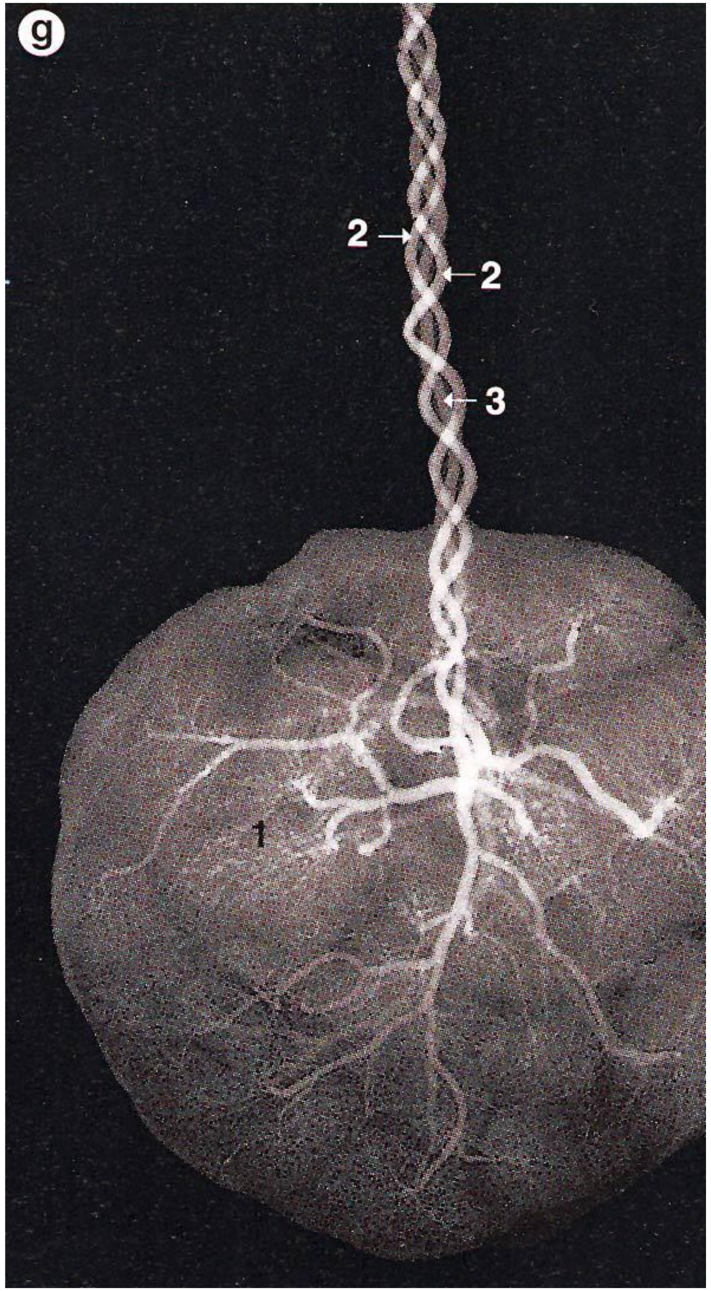
Placenta endothelio-chorialis, deciduata, villosa zonaria

<u>Carnivores (dog, cat, ferret)</u>

# Umbilical Cord

One umbilical vein, two umbilical arteries
Wharton's jelly –mucoid connective tissue surrounding vessels
Allantois
Yolk Stalk (vitellineduct) and vitelline vessels (early)
Intestinal loop –umbilical hernia (late)



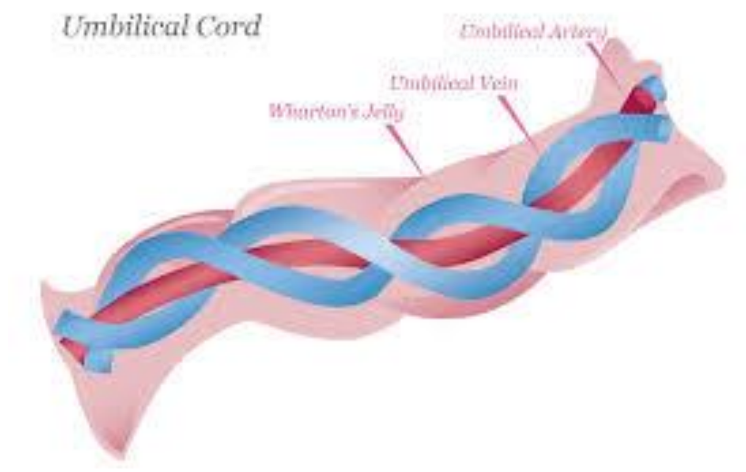



The umbilical cord emerges from the fetal side of the placenta (chorionic plate) to the belly button region of the fetus.

- The cord contains 2 arteries and 1 vein that are continuous with the fetal circulation. These vessels are longer then the cord and tend to twist and coil to add strength and protect against entanglement, compression and tension.

- The cord itself is composed of an extracellular matrix known as **Whartons jelly**, a specialized connective tissue. This substance helps to protect the vessels within the cord.

- The whole of the umbilical cord is incased by the continuous layer of the amnion that was covering the fetal surface of the placenta.



# Placental Circulation

Fetal –Contained within vessels
Umbilical Arteries –chorionic plate –branches to stem villi –capillaries in terminal villi –return via umbilical vein
Maternal –Free-flowing lake
Spiral arteries open into intervillous space and bath the villi
150 ml of maternal blood
Exchanged -3-4 times/minute
Reduced blood pressure in intervillous space
Oxygenated blood to the chorionic plate, return baths the villi

# references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