Embryology of the Foetal Membranes and Placenta

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The foetal membranes include all the extraembryonic structures which are derived from the primitive blastomeres and do not enter into the formation of the embryo itself. The membranes are the amnion, the yolk sac and the chorion.

The Amnion

Continuous with the ectodermal germ layer, the amnion is the membrane which bounds the amniotic cavity. It starts to appear on day 7 of development as small intercellular clefts between the ectodermal cells and the trophoblast. The clefts unite together to form a small space between the trophoblast and the ectoderm. This is the amniotic cavity. The cavity enlarges in size and becomes roofed by a layer of flattened amnioblasts, which develop from the inner surface of the trophoblast. After the formation of the extraembryonic mesoderm and the development of the extraembryonic coelom the roof of the amniotic cavity becomes separated from the trophoblast by a mass of extraembryonic mesoderm known as the connecting stalk, or body stalk. The amniotic cavity is now bounded by a membrane formed of amnioblasts and extraembryonic mesoderm and is termed the amnion (Fig. 3.1).

As pregnancy proceeds, the amniotic cavity enlarges rapidly and by the third month surrounds the embryo almost completely. The amnion eventually comes in contact with the chorion, thus obliterating the extraembryonic coelom (Fig. 3.2).

Secreted by the amnioblasts, the amniotic cavity is filled with amniotic fluid. It also receives urine secreted by the foetal kidney. By the end of pregnancy, the cavity will contain approximately 1.5 L of fluid. The amniotic fluid acts as a watery protective cushion around the embryo, protecting against trauma and external pressure. It prevents adhesions between the embryo and the amnion and helps maintain a constant temperature around all parts of the body of the embryo. The amniotic cavity and fluid provide a space for the embryo to freely move, which encourages muscle development. It also acts as a reservoir for the accumulation of foetal urine and meconium. The foetus will swallow the amniotic fluid, which helps develop the suckling reflex.

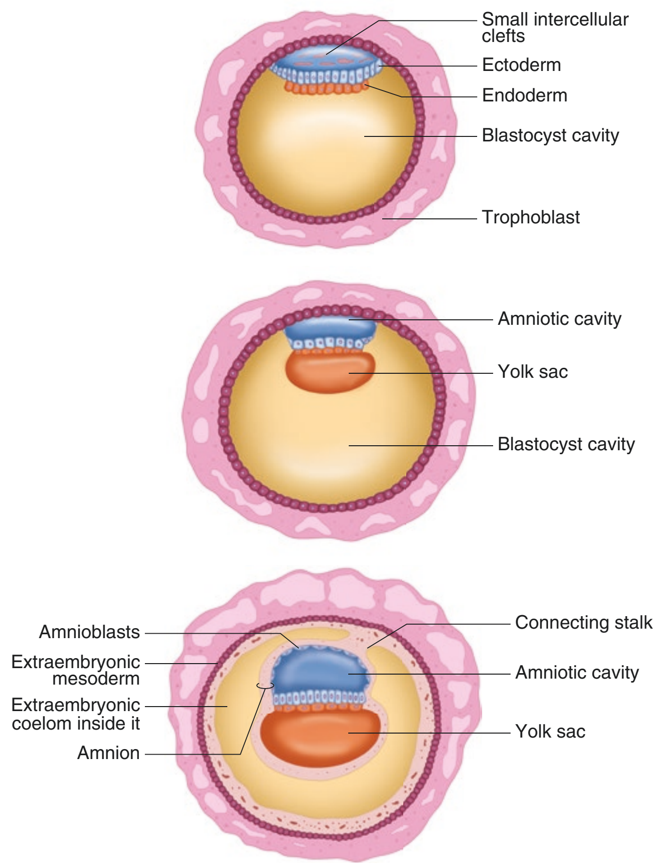

Fig. 3.1 Formation of the amnion and amniotic cavity

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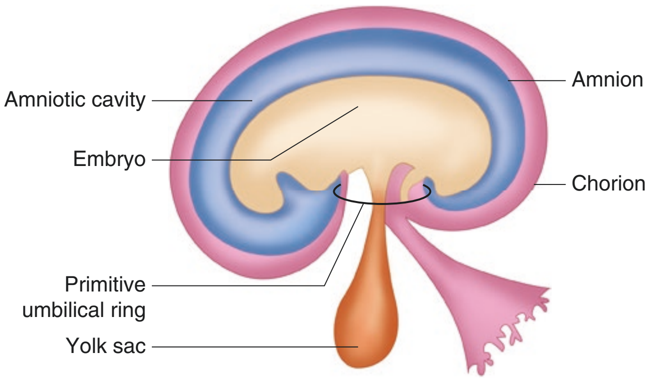

Fig. 3.2 Enlargement of the amniotic cavity and obliteration of the extra embryonic coelom

Oligohydramnios is the condition arising when the volume of amniotic fluid is less than half a litre. This may lead to adhesions between the embryo and the amnion. The opposite condition, polyhydramnios, when the volume of fluid is more than 2 L may lead to premature rupture of the amnion.

The Yolk Sac

Development of the yolk sac begins at around day 9 when the endoderm of the embryonic disc grows down on the inner surface of the trophoblast forming a membrane called Heuser's membrane. The primary yolk sac is roofed by the endodermal germ layer, while the rest of its wall is formed of Heuser's membrane with its covering extraembryonic mesoderm. The primary yolk sac later separates from the trophoblast by the development of the extraembryonic coelom.

The secondary yolk sac begins development at the end of the second week when the terminal end of the primary yolk sac becomes cut-off. The secondary yolk sac is covered by the splanchnic layer of the extraembryonic mesoderm, and a network of vitelline vessels develop in the mesoderm covering the secondary yolk sac (Fig. 3.3).

As a result of folding of the embryo, the roof of the secondary yolk sac becomes enclosed inside the body of the embryo. The secondary yolk sac becomes divided into three parts:

1. The primitive gut: the part inside the body of the embryo. This will eventually subdivide to form the foregut, midgut and hindgut.

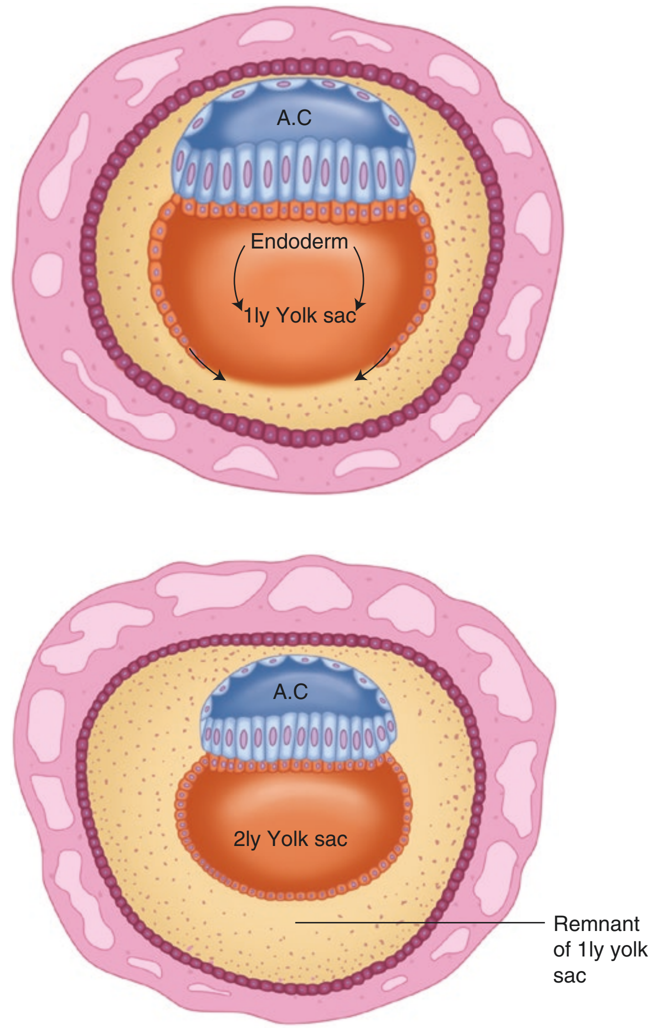

Fig. 3.3 Development of the primary and secondary yolk sac

2. The definitive yolk sac: the part of the yolk sac lying outside the embryo but inside the umbilical cord. This grows very slowly, never exceeding 0.5 cm in diameter, and eventually shrinks to form a small body within the cord.
3. The yolk sac stalk or vitello-intestinal duct: this connects the primitive gut with the definitive yolk sac. This disappears later in development (Fig. 3.4).

During week 3, a tubular invagination from the caudal part of the secondary yolk sac which extends into the connecting stalk develops into the allantois. When the hindgut is formed, the allantois becomes connected to the ventral aspect of the cloaca. The allantois has two parts, an intra-embryonic part which forms the urachus, connecting the urinary bladder to the umbilicus, and an extraembryonic part inside the umbilical cord which becomes obliterated.

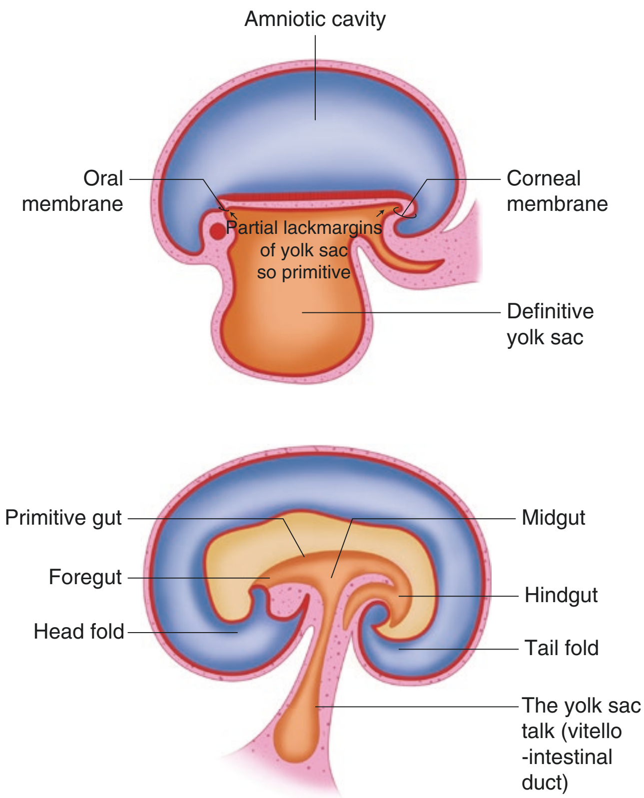

Fig. 3.4 Development of the definitive yolk sac

The yolk sac has no nutritive function in the human. As well as a role in the development of the primitive gut and the allantois, it has several other important functions. The primordial germ cells arise from the caudal wall of the yolk sac and then migrate to enter the developing gonads of the embryo. Blood is formed in the mesoderm of the wall of the yolk sac between weeks 4 and 6 of development. The vitelline vessels of the yolk sac will go on to form some of the embryonic vessels.

The Chorion

The chorion forms from the trophoblast after the formation of the extraembryonic mesoderm from its inner surface. At implantation, the trophoblast differentiates into an outer syncytiotrophoblast layer and an inner cytotrophoblast. The cytotrophoblast develops a layer of extraembryonic mesoderm on its inner surface which later splits into somatopleuric and splanchnopleuric layers. Both the trophoblast and the somatopleuric mesoderm are called the chorion, and the blastocyst is now termed the chorionic vesicle.

At the end of the second week of development, formation of the placenta proceeds with the appearance of the primary chorionic villi. These first appear at the embryonic pole of the chorionic vesicle and increase in number at the beginning of week 3. Each primary villus is formed of a central core of cytotrophoblast covered by a layer of syncytiotrophoblast (Fig. 3.5).

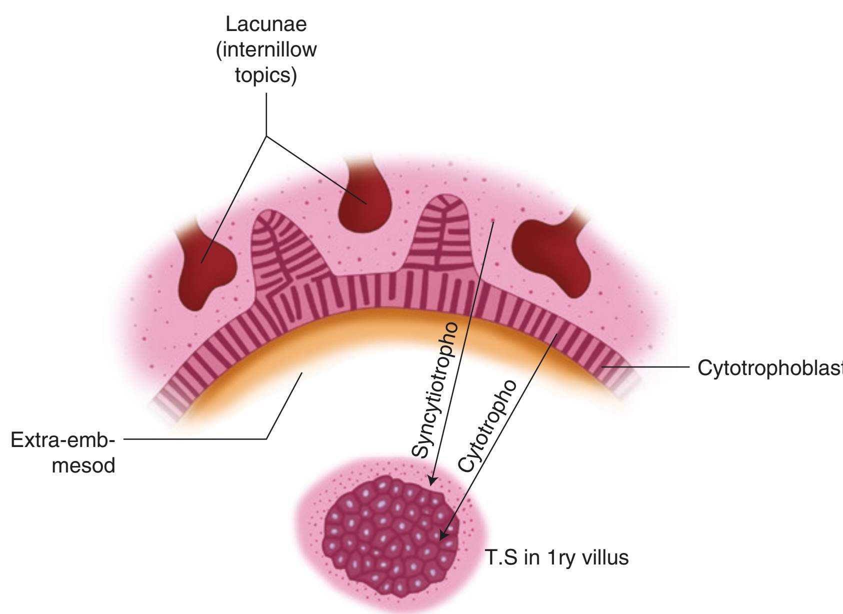

Fig. 3.5 Primary villus with central core of cytotrophoblast covered with syncytiotrophoblast during week 3 of development

Cells from the extraembryonic mesoderm which line the cytotrophoblast start to penetrate the primary villi to form the secondary chorionic villi. Each villus now consists of a central core of extraembryonic mesoderm, a middle zone of cytotrophoblast and an outer layer of syncytiotrophoblast (Fig. 3.6).

By the end of the third week, a loop of an afferent and an efferent capillary appears in the mesodermal core of the secondary villi, transforming them into tertiary villi. The afferent capillary loop is connected to the umbilical artery, while the efferent is connected to the umbilical vein. The tertiary villi branch in the intervillous spaces and oxygen and nutrients diffuse from the maternal blood in the intervillous space to the capillary loop in the tertiary villus (Fig. 3.7).

By the end of the third week, the embryo and embryonic structures appear as show in (Fig. 3.8).

The tertiary villi branch extensively to form a villous tree. The majority of these branching villi are free and surrounded by maternal blood. A few villi penetrate into the decidua basalis and fix the chorionic vesicle to the wall of the uterus; these are the anchoring villi (Fig. 3.9).

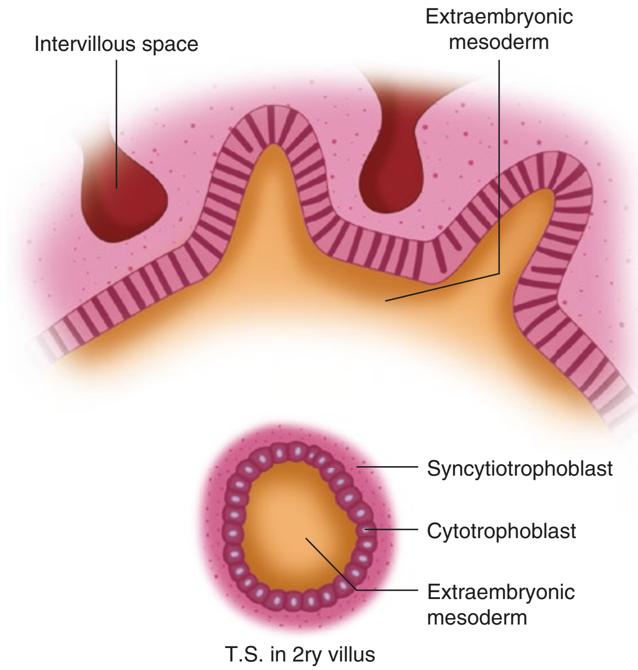

Fig. 3.6 Secondary villus with the development of a central core of mesoderm

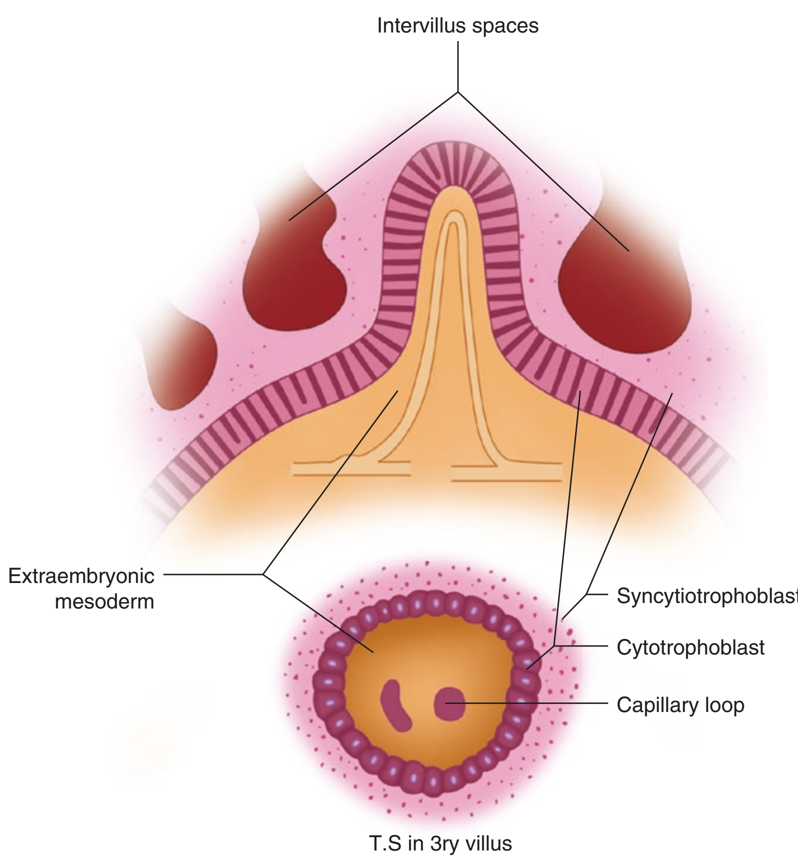

Fig. 3.7 Formation of the tertiary villi, the functional villi which allows diffusion of nutrients and oxygen from the maternal blood

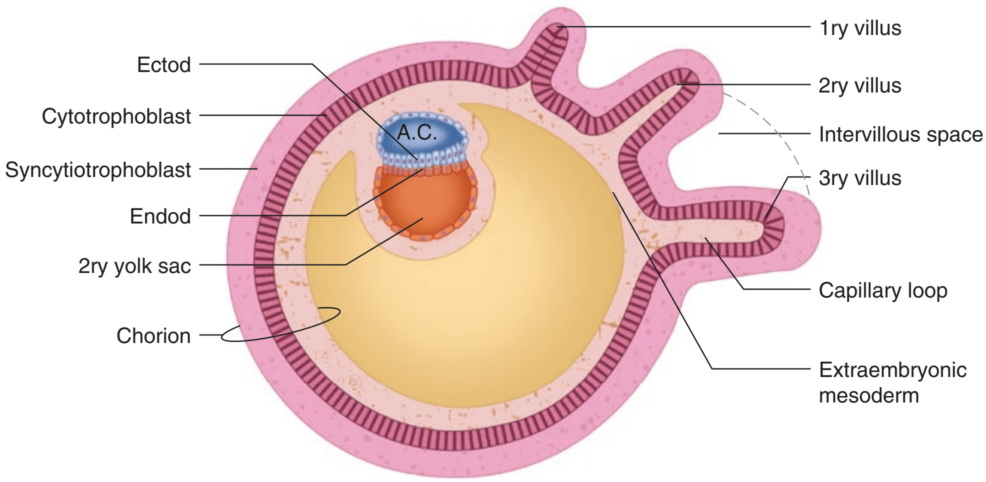

Fig. 3.8 The fully formed chorionic villi at week 3 of development

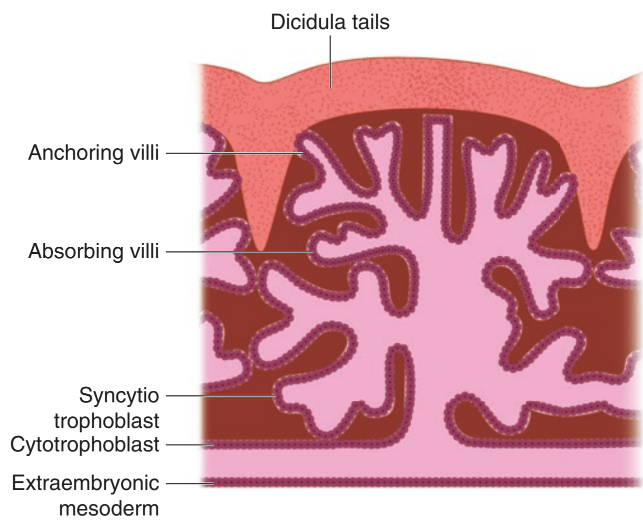

Fig. 3.9 The villous tree—the main structure of the placenta which anchors the placenta to the wall of the uterus

In the early weeks of pregnancy, the chorionic villi cover the whole surface of the chorionic vesicle. As pregnancy advances, the following changes occur: The chorionic villi which lie over the embryonic pole become more numerous and well developed giving this part of the chorion a leaflike appearance. For this reason, this part of the chorion is termed the chorion frondosum and is the only functioning part of the chorion. The villi that lie over the remaining part of the chorionic vesicle begin to degenerate by the end of the third month. This part of the chorion becomes smooth, having no villi, and is termed the chorion laeve.

The Placenta

The placenta is a vital organ of connection between the foetus and mother allowing physiological exchange between foetal and maternal circulations. It acts as a nutritive, respiratory, excretory and endocrine organ for the foetus during intrauterine life. The placenta is formed of two parts, a foetal part, the chorion frondosum, described above, and the decidua basalis, the maternal part (Fig. 3.10).

After implantation, the endometrium is termed the decidua. According to its relation to the chorionic vesicle, it can be divided into three parts. The decidua basalis is the part which lies over the embryonic pole of the chorionic vesicle, i.e. the part facing the chorion frondosum. The thin layer of decidua which covers the abembryonic pole of the chorionic vesicle is termed the decidua capsularis, as it is covering the chorion laeve forming a thin capsule. The rest of the lining of the uterine cavity is termed the decidua parietalis (Fig. 3.11).

At first, the different parts of the decidua are similar in structure. As the embryo grows, the decidua basalis develops and remains functional to form the maternal

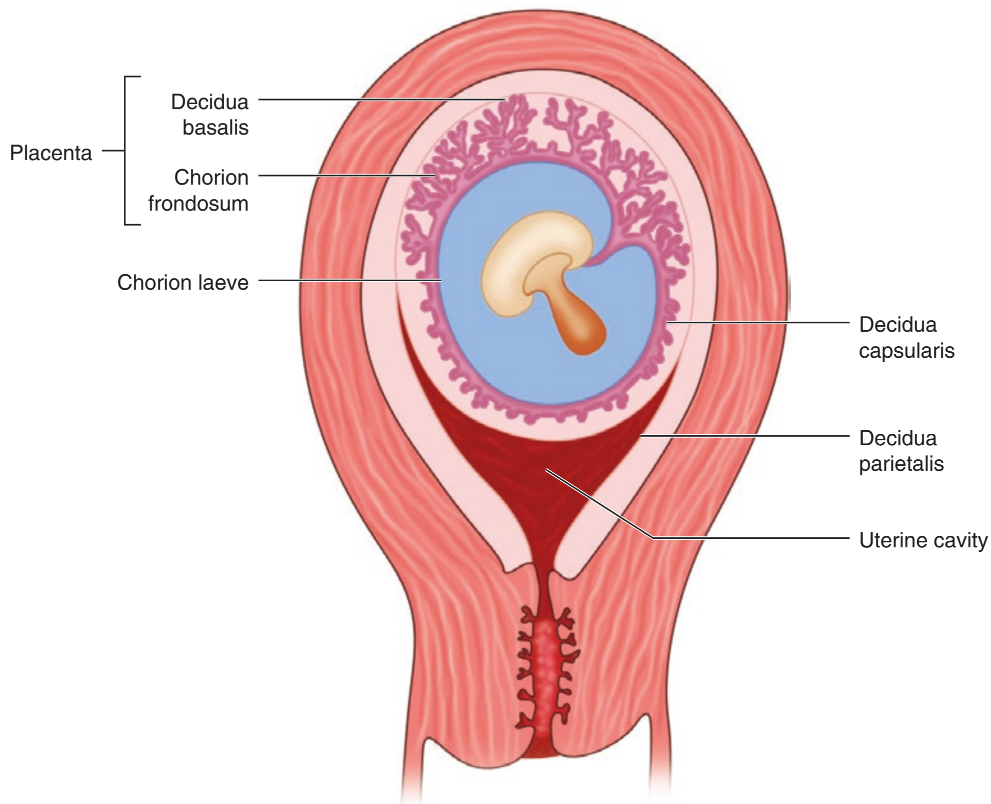

Fig. 3.10 The foetal and maternal contributions to the placenta

part of the placenta, and the capsularis and parietalis fuse together and eventually degenerate.

The placenta has several components:

1. The chorionic villi

   As described above, the tertiary villi contain a central core of extraembryonic mesoderm and blood vessels. The villi are connected to the chorion at the chorionic plate by the anchoring villi.
2. Intervillous space

   The space between the basal plate (forming its roof) and the chorionic plate (forming its floor) is filled with maternal blood coming from the maternal arteries (Fig. 3.12).
3. Cytotrophoblastic shell

   Lying in the roof of the intervillous space, this is formed at the basal plate by fusion of the cytotrophoblast of the adjacent anchoring villi to form a continuous sheet (Fig. 3.13).
4. Placental septa and cotyledons

   The septa are fingerlike processes which project from the roof of the intervillous space but do not reach the chorionic plate. The bases of the septa correspond to grooves on the outer surface of the decidual basalis bounding elevated masses of tissue called cotyledons.

The placental barrier consists of the layers of the villous wall which separates the foetal blood in the capillary loop of the floating villus from the maternal blood in the intervillous space. In early pregnancy, the barrier is formed of four layers, the endothelial lining of the capillary loop in the villus, the extraembryonic core of mesoderm in the villus, a layer of cytotrophoblast and a layer of syncytiotrophoblast. After the fourth month, the placental barrier becomes reduced in thickness to allow easier exchange of gases and nutrient substances and is composed of only the endothelial layer of the capillary loop and the syncytiotrophoblast layer.

The placenta is fully formed by the third month of pregnancy. After this, it grows in size by elongation of the villi and widening of the intervillous spaces which increase the thickness of the placenta. Its diameter increases secondary to the growth of the uterine wall. During the final month of pregnancy, the placenta undergoes degeneration which is manifested by fibrosis of the villi resulting in reduction of

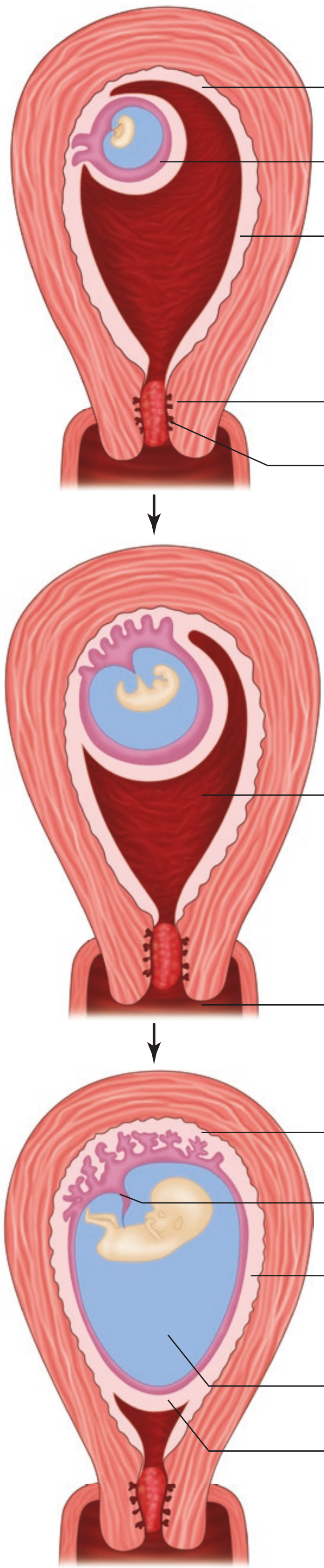

Fig. 3.11 Decidual components of the forming placenta

placental function, and the placenta begins to separate from the wall of the uterus.

Maternal blood (oxygenated) passes from the spiral arterioles of the decidua basalis to the intervillous spaces between the villi and then leaves via numerous thin-walled decidual veins. The deoxygenated blood from the foetus reaches the placenta via the branches of the two umbilical arteries. Blood flows through the arterioles where exchange of gases takes place. Oxygenated blood returns to the foetus via venules and veins which drain into the umbilical vein (Fig. 3.14).

Abnormalities of the Placenta

Size and Shape Anomalies

Placenta membranacea or diffuse placenta is seen when the placenta lines the greater part of the uterine cavity. It is due to persistence of the chorionic villi of the chorion laeve. Placenta succenturiata is when the placenta has one or more accessory lobes which are completely separate from the main placenta. Placenta accreta is the condition where there is abnormal fixation of the placenta to the wall of the uterus. This is caused by extensive invasion of the stem villi to the myometrium and can cause an increased risk of haemorrhage at the time of placental delivery.

Abnormalities of Position

Normally, implantation occurs in the posterior wall of the fundus, and the placenta develops in the upper part of the uterus. If implantation occurs in the lower part of the uterus, the placenta will develop in the lower uterine segment; this is known as placenta previa. Depending on the relation of the placenta to the internal os of the cervix, placenta previa is classified into three types:

1. Placenta previa lateralis—where the placenta encroaches on the lower uterine segment but does not reach the internal os
2. Placenta previa marginalis—where the margin of the placenta overlies the internal os of the cervix
3. Placenta previa centralis—where the centre of the placenta overlies the internal os of the cervix

Placenta previa is a dangerous abnormality leading to premature separation of the placenta from the uterine wall before labour. This can result in haemorrhage.

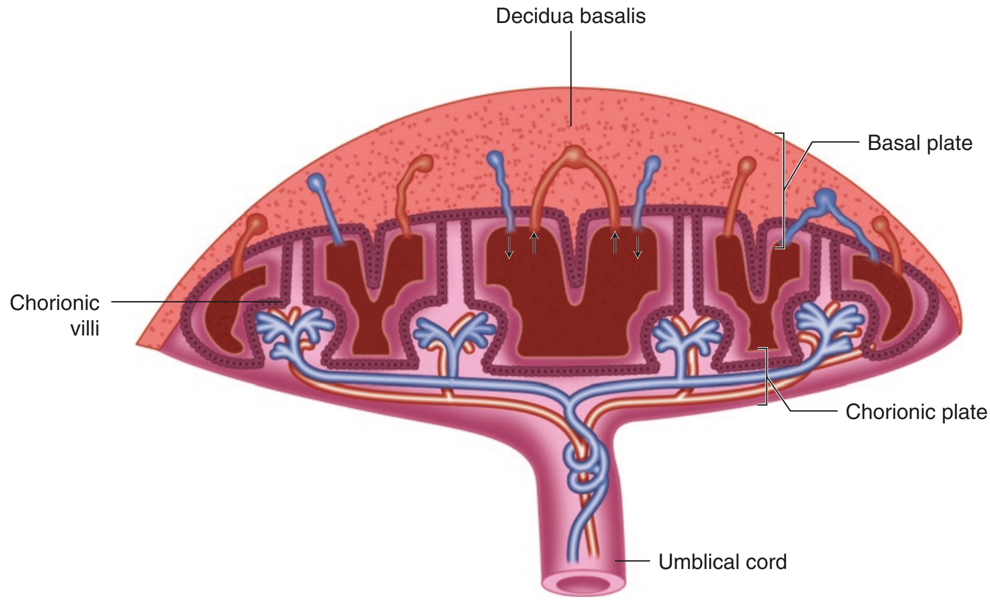

Fig. 3.12 Arrangement of the chorionic villi within the placenta

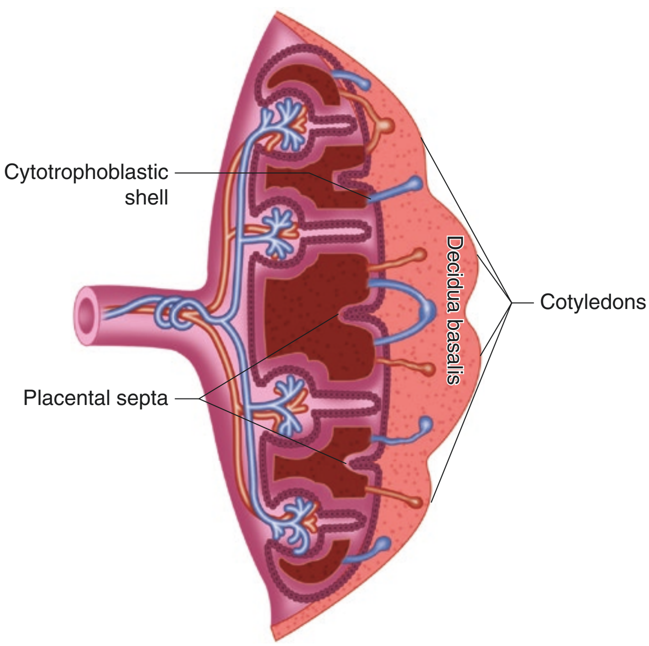

Fig. 3.13 Placental septa and cotyledons

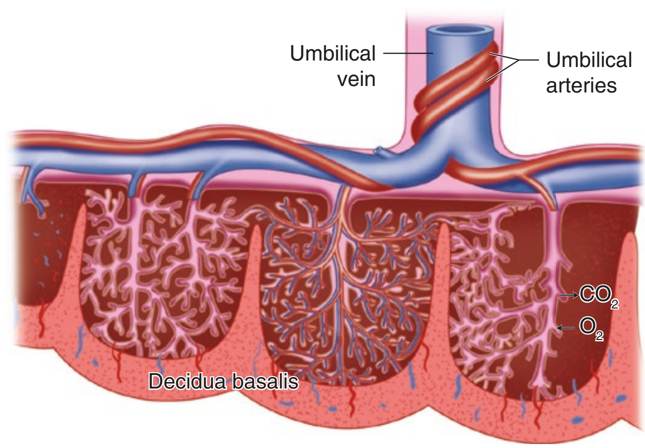

Fig. 3.14 Maternal and foetal circulation in the fully formed placenta