CHAPTER 6: PLACENTA

The placenta is an organ composed of both fetal tissue (chorion frondosum) and maternal tissue (decidua basalis). Its function is to support and nourish the growing fetus.

The placenta develops when the blastocyst (a multicellular mass derived from the division of the fertilized ovum) implants into the layer of tissue called the endometrium, which lines the uterine lumen. At this stage the embryo is composed of two main groups of cells: the inner cell mass, which develops into the fetus, and the trophoblast, which contributes to the placenta. Upon implantation the trophoblast differentiates into two layers called the cytotrophoblast and syncytiotrophoblast. The cytotrophoblast consists of mitotically active uninucleate cells that fuse to produce the syncytiotrophoblast. The latter therefore represents a syncytium (a multinucleated mass derived from the fusion of previously uninucleate cells). The syncytiotrophoblast has invasive properties. It grows into the endometrium and invades and erodes the walls of uterine glands and maternal blood vessels. Spaces called lacunae, which are present within the syncytiotrophoblast, gradually enlarge and fuse to form the maternal blood space, which receives maternal blood from the eroded uterine vessels. The syncytiotrophoblast thus forms an interface between fetal and maternal tissues. It lines all the placental surfaces that contact the maternal blood space (decidua basalis, chorionic villi, and chorionic plate). The cytotrophoblast, in contrast, is always separated from the maternal blood by the syncytiotrophoblast.

Stages in implantation are shown in the diagrams below.
Early in development, proliferation of the syncytiotrophoblast and cytotrophoblast forms structures known as villi that grow into the maternal blood space and begin to branch. In fact, the maternal blood space is also called the intervillous space because it lies between and surrounds the villi. The villi carry branches of the fetal umbilical arteries and vein. Some villi extend all the way from the chorionic plate to
the decidua basalis. In a section of placenta, any villus that is directly continuous with the chorionic plate is referred to as a stem villus. Any villus directly continuous with the decidua basalis is called an anchoring villus. You should realize however that all anchoring villi are in fact part of a stem villus. Side branches of stem villi that end in the intervillous space rather than extending all the way to the decidua basalis are known as terminal villi. The whole structure of a villus can be likened to that of a tree, where the stem villus (or main stem villus) is the trunk, the terminal villi are the side branches, and the anchoring villus is the crown or treetop.

At first the villi consist of an outer layer of syncytiotrophoblast that surrounds a solid core of cytotrophoblast, and are known as primary villi. Gradually the extraembryonic mesoderm that lies just deep to the cytotrophoblast (see the first figure on the previous page) grows into the villi transforming them into secondary villi, which by definition have a core of mesoderm surrounded by a layer of cytotrophoblast and an outer covering of syncytiotrophoblast. Finally fetal blood vessels grow into the mesodermal core of the villi, transforming them into tertiary villi. All of the villi on the laserdisk are already at the tertiary villus stage.

Tertiary villi undergo a process of maturation involving at least structural changes that decrease the diffusion distance between maternal blood and fetal blood vessels, thus improving gas exchange between mother and fetus. One of these changes involves the cytotrophoblast. Gradually the rate of mitosis in the cytotrophoblast decreases until it falls below the rate at which cytotrophoblast cells fuse with the syncytiotrophoblast. The result is that the cytotrophoblast becomes a discontinuous layer and then disappears once all of its cells have fused with the
syncytiotrophoblast. A second change involves the syncytiotrophoblast. The nuclei within this protoplasmic mass begin to cluster together in groups called syncytial knots, leaving a very thin layer of cytoplasm between knots, across which gases can more diffuse more rapidly. Finally the fetal capillaries, which are located within the cores of the villi, proliferate and move closer to the surface of the villus. All three of these changes contribute to forming the thinnest possible barrier between maternal and fetal blood.

Meanwhile on the maternal side of the placenta, invaginations of the decidua basalis form placental septa that divide the placenta into units called cotyledons (see figure on preceding page). Each cotyledon surrounds one or more stem villi. Maternal blood from the eroded uterine arteries (endometrial arteries) enters each cotyledon, bathes the stem villi thus allowing for transfer of oxygen to the fetal capillaries within the villi, and then drains back into endometrial veins. The oxygenated fetal blood is carried to the fetus by the single umbilical vein contained in the umbilical cord. Note the unusual situation, namely that oxygenated blood is carried to the fetus by a vein. This vessel has the morphology of a vein and is also a vein by definition since it carries blood toward the fetal heart (an artery carries blood away from the heart). The oxygenated blood circulates through the fetus and, once it has become deoxygenated, it returns to the placenta via the two umbilical arteries in the umbilical cord. The entire cycle of gas exchange then begins again.

Frame 39322
Tertiary Villus
H&E 80x

A tertiary villus is formed as soon as fetal blood vessels enter the mesenchymal core of the villus. The arrow indicates a fetal capillary that contains a red blood cell.

Frame 39367
Intervillous Space
H&E 80x

The surfaces of the villi are bathed by maternal blood in the intervillous space. Oxygenated maternal blood enters the intervillous space from endometrial arteries called spiral (helicine) arteries, and the deoxygenated maternal blood drains back into endometrial veins.

Frame 39325
Syncytial Knot
H&E 160x

This is a relatively mature tertiary villus because the cytotrophoblast is no longer present, most of the nuclei of the syncytiotrophoblast have clustered together to form a syncytial knot (arrow), and the fetal capillaries are abundant and close to the surface of the villus. In the large villus on the right side of the image can you see one pale-staining nucleus very near the surface of the villus? It is possible that this nucleus belongs to a cytotrophoblast cell. If so, electron microscopy would show that it is separated from the intervillous space by a thin layer of syncytiotrophoblast cytoplasm.
The solid mass of tissue filling most of this frame is the decidua basalis. Above it lie the intervillous space and some villi. The decidua basalis (maternal side of the placenta) can be distinguished from the chorionic plate (fetal side) by looking for decidual cells, which are present only on the maternal side. These large cells with abundant cytoplasm tend to occur in clusters. They are derived from endometrial stromal cells. Very similar cells (called peripheral cytotrophoblast cells) that are derived from the cytotrophoblast also occur in the decidua basalis. It is ordinarily not possible to distinguish between them. Note the fibrous eosinophilic material near the surface of the decidua. This extracellular material is known as fibrinoid, and tends to be more abundant on the maternal than on the fetal side of the placenta. Finally, notice the structure with a circular outline that resembles a villus, but is embedded in the decidua. This is in all likelihood an anchoring villus.

This higher magnification of the previous frame shows what may be decidual cells (arrow), fibrinoid, and an anchoring villus in the left half of the image. The intervillous space and villi are on the right. Decidual cells often have a pale cytoplasm since they frequently contain large amounts of glycogen. They produce placental prolactin as well as substances that nourish the blastocyst until the fetal circulation can be established. They may also help to limit the invasiveness of the trophoblast and form part of the interface where separation of placenta from uterus occurs at birth.

In addition to looking for syncytial knots, you can estimate the relative age of a placenta by looking at the abundance and size range of the villi. In an older placenta such as this the stem villi are highly branched with many small terminal branches that crowd the intervillous space. In this image there are many such small villi as well as a few that are much larger. The latter may be anchoring villi or stem villi, although technically you cannot say that for sure unless you can see the physical continuity of the villus with either the decidua basalis or the chorionic plate.

A number of important features of the placenta are not well illustrated in the images available on the laserdisk. By studying your glass slides, be sure that you can identify the cytotrophoblast, Hofbauer cells (macrophages found in the mesenchymal core of the villi), the chorionic plate containing large branches of the umbilical vessels, the amnion, and the umbilical cord (where you should be able to distinguish between umbilical arteries and umbilical vein).