FETAL CIRCULATION

I. FETAL CIRCULATORY ANATOMY AND REMNANTS AFTER BIRTH (Fig. 29.20a, b [29.21a,b]) These can be seen on the fetal pig and on the illustrations. The foramen ovale is seen on the illustration only (*). Observe the boldfaced remnant structures on the heart models and torso liver model also.

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II. THE FETAL CIRCULATION

A. Placenta (Fig. 29.4 [29.5]) Observe the illustrations.

The placenta is a vascular organ, genetically part maternal and part fetal. It enables maternal and fetal blood to flow close by one another, separated only by permeable membranes. Maternal and fetal blood do not mix, but the placenta allows for exchange of oxygen and carbon dioxide; the fetal lungs are of course nonfunctional. It is a source of nutrients to the fetus, and it removes wastes. It provides maternal antibodies to the fetus. In effect, the placenta serves as the lungs, digestive system, kidneys, and immune system of the fetus. It is also a major source of reproductive and other hormones during the pregnancy.

Fetal arteriole*  
Fetal venule*  
Umbilical veins*  
Umbilical arteries*  

*Note that the color of fetal blood is reversed in the fetal vessels.
B. **Fetal blood flow** (Fig.29.20a [29.21a]) Trace these pathways on the illustration.

1. Oxygenated (red) blood flows from the *placenta* via the *umbilical vein* in the *umbilical cord*.

2. Red blood from the umbilical vein continues as the *ductus venosus* within the liver, and joins the inferior vena cava. It mixes with “blue” blood within the vena cava. From this point the blood that oxygenates the fetal tissues is mixed blood. However, the fetal hemoglobin is able to pick up oxygen at a lower PO$_2$.

3. The lungs are collapsed and nonfunctional; they receive only enough blood for their own growth. Most of the blood bypasses the lungs in one of two ways:

   a. The *ductus arteriosus* is a short, wide artery that connects the pulmonary trunk artery with the aorta. This allows most blood to bypass the lungs, although some blood still enters the right and left pulmonary arteries. There is considerable resistance to blood flow into the lungs because they are collapsed.

   b. Before birth, the pressure in the right heart is higher than the pressure in the left heart. Because of this, the one-way valve, the *foramen ovale*, lets blood bypass the lungs by going from the right atrium to the left atrium.

4. Mixed arterial blood flows through the same arteries as in the adult to oxygenate the tissues. Used, “blue” blood leaves via the same veins as in the adult and enters the superior or inferior vena cava.

5. Mixed blood in the *internal iliac arteries* is sent out the two *umbilical arteries* through the *umbilical cord* to the *placenta*, where it becomes red, oxygenated blood. It also picks up nutrients and releases wastes.

6. The *umbilical vein* carries red blood from the placenta back to the fetus.
C. Birth and the stimuli for the first breath:

1. The sudden cooling as the child is born triggers the "gasp" reflex.
2. Hypoxia and hypercapnia may occur during the birth.
3. The breathing rhythm is immediate or begins after brief delay due to increased hypoxia. Delays of 8 minutes are maximum tolerable.

D. The first breaths

Much extra effort is needed for the first breath. The child can produce more than twice the effort needed. Normal compliance (ease of inflation) is established about 40 minutes after birth.

III. CIRCULATORY READJUSTMENTS AFTER BIRTH (Fig. 29.20b [29.21b])

A. Since blood no longer circulates in the placenta, blood volume in the child increases, causing increased pressure in the left ventricle, left atrium, and aorta.

B. Pulmonary resistance decreases five times as the lungs expand with air, because the blood vessels are less compressed. Also the extra O\textsubscript{2} causes vasodilation within the lungs. This decreases the pulmonary blood pressure, right atrial and right ventricular pressures.

C. Foramen ovale closure: This one-way valve between left and right atria closes because due to the increase in left heart pressure and the decrease in right heart pressure as outlined above. (It only allowed right to left blood flow before birth.) This occurs immediately, but it grows closed and becomes the fossa ovalis within months or years (or occasionally not at all; if this is the case, the higher pressure in the left atrium after birth keeps it closed).

D. Closure of the ductus arteriosus: The smooth muscle wall of the ductus arteriosus constricts due to the higher O\textsubscript{2} availability, and closes fully within one to eight days. Within one to four months, it is replaced with fibrous tissue. It persists for life as the ligamentum arteriosus.

E. Closure of the ductus venosus: This liver bypass conducts blood from umbilical vein to the inferior vena cava. When umbilical blood flow ceases immediately after birth, portal blood still bypasses the liver via the ductus venosus, until the ductus venosus contracts one to three hours after birth. This forces portal blood through the liver. The cause is unknown. The ductus venosus becomes the ligamentum venosum.
F. If it is not immediately cut, the **umbilical cord** may pulse for a few minutes after the birth but before the placenta detaches from the uterine wall. Even if the cord is not clamped, blood leakage from the cord will stop due to a gel within it that swells upon exposure to air.

G. The lack of blood flow to the wall of the **umbilical arteries and vein** causes fibrosis of them. The arteries become the lateral umbilical ligaments and the vein persists as the **round ligament of the liver**.

IV. REVIEW QUESTIONS

A. The fetal circulation

1. Which organ systems in the fetus are nonfunctional?

   __________________ __________________ _________ __________

2. What organ provides for their functions before birth? ____________

3. Which blood vessel takes red blood from the umbilical vein to the inferior vena cava? __________________ __________________

4. Name the two bypasses of the lungs. ____________ _________
   __________________ __________________

5. How many umbilical arteries are there? ______

6. They branch off from what other arteries? __________________

7. Do the umbilical arteries carry red, mixed, or “blue” blood? ______

8. Where do the umbilical arteries take the blood? ______________

9. How many vessels are in the umbilical cord? _____________

10. Is lung compliance high or low during the first breath? _________
B. Circulatory adjustments after birth

1. Before birth, the pressure in the right atrium is higher than in the left atrium. After birth, which side has higher pressure? _________

2. What happens at birth because of this pressure?

____________________________________________________________________________________

3. What causes the ductus arteriosus to close? _________________

____________________________________________________________________________________

4. What does it become after birth? ________________________

____________________________________________________________________________________

5. What does the umbilical vein become? _______________

____________________________________________________________________________________

Optional notes on the fetal circulation

1. Do you wonder why the fetus' tissues are nourished with mixed rather than fully oxygenated blood? Here's why: Only arterial blood is under enough pressure to leave the fetus and return to the placenta to pick up oxygen. If the arterial blood were already fully oxygenated, it could not load any more oxygen. But--only arterial blood nourishes the tissues, as is true after birth; therefore, the fetus gets mixed blood. The fetal hemoglobin compensates for this situation.

2. Patent ductus arteriosus occurs when the ductus arteriosus fails to close after birth. The blood recirculates from the aorta to the pulmonary trunk (higher pressure to lower), and causes more work for both sides of the heart. It may be corrected with medications, or may be surgically corrected.

3. A septal defect (a "hole in the heart") occurs when either the interatrial or interventricular septum has a congenital perforation. Interatrial septal defects are usually from a failure of the foramen ovale to close. An interventricular septal defect occurs early in development; there is no normal opening in the interventricular septum before birth. Because the pressure in the left heart is higher than in the right heart after birth, blood flows from the left side to the right side, increasing the work load on both sides of the heart.