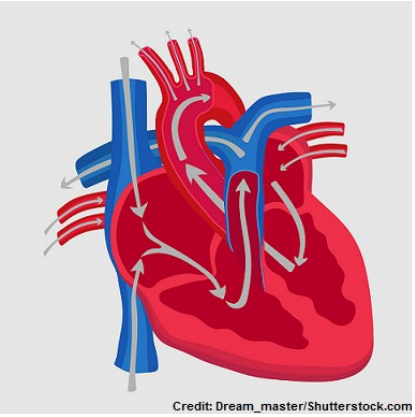
Fetal Circulation and the Transition to Newborn Circulation

Fetal circulation is the flow of the baby's circulatory system while it's in utero. Fetal circulation will change once the baby is born and adapts to life outside the womb.

Therefore, you want to be familiar with the following about fetal circulation:

- Three fetal shunts in the circulatory system
    - Name of each shunt
    - Function of each shunt
    - Location of each shunt
- Function of the Placenta
- Umbilical Vein and Arteries (number of each and what type of blood each carry…. oxygenated or deoxygenated)
- Blood flow to and from the placenta to the baby
- Fetal circulation BEFORE and AFTER birth (the changes)



Fetal Circulation Review

Before we discuss fetal circulation, you must be familiar with how the blood flows normally through the heart when a baby is OUTSIDE of the uterus. Remember the lungs and heart work together to perfuse the body. Therefore, let's quickly review:

Right Side of the Heart

Goal of right side: to get the blood RIGHT to the lungs so it can become oxygenated.

1. The un-oxygenated blood (this is blood that has been "used up" by your body and needs to be resupplied with oxygen) enters the heart through the **SUPERIOR AND INFERIOR VENA CAVA**.
2. Blood enters into the **RIGHT ATRIUM**
3. Then it is squeezed through the **TRICUSPID VALVE**
4. Blood then enters into the **RIGHT VENTRICLE**
5. Then it is squeezed into the **PULMONIC VALVE**
6. Blood is then shot up through the **PULMONARY ARTERY** and then enters the lungs for oxygen

Left Side of the Heart

Goal of the left side: to get the richly, oxygenated blood that LEFT the lungs to the body to feed the brain, tissue, muscles, organs etc.)

7. Blood enters from the lungs through the **PULMONARY VEIN**
8. Blood then enters the **LEFT ATRIUM**
9. Down through the **BICUSPID VALVE (**also called mitral valve)
10. Then blood is squeezed into the **LEFT VENTRICLE**
11. Up through the **AORTIC VALVE**
12. Lastly up through the **AORTA**, where it pumped throughout the body

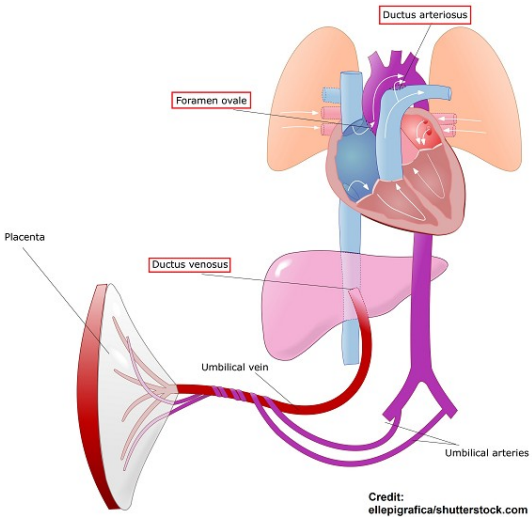
Important things to remember:

- The circulation in the heart OUTSIDE of the uterus does NOT have any shunts (*more about the shunts below*) that help push or pull blood away from the lungs.

Placenta and Umbilical Cord

The **placenta** is an amazing organ that is vital for the growth and development of the baby. It attaches to the wall of the uterus and pulls nutrients and oxygen from the mom's circulation to the baby's and helps remove the build-up of waste from the baby's circulation. If the placenta is unhealthy the baby's growth and development will be hindered.

Therefore, the role of the placenta is to supply the baby (from mom's circulation) with nutrient-rich oxygenated blood and remove the build-up of waste from baby's circulation to mom's circulation, who will clear the build-up.



The placenta attaches to the baby via the umbilical cord. The umbilical cord is made up of **TWO umbilical arteries** that carry ***deoxygenated*** blood from the baby to the placenta, and **ONE umbilical vein** that carries oxygenated blood from the placenta to the baby.

Shunts to Remember in Fetal Circulation

The word shunt means to "push or pull". These shunts do just that! Two of the three shunts push

blood away from the lungs, and the other one pushes blood from the liver to the inferior vena cava. The three shunts are:

1. ***Ductus Venosus***: found at the liver and umbilical vein that helps shunt oxygenated blood to the inferior vena cava.
2. ***Foramen Ovale***: found in the wall between the right and left atrium that allows oxygenated blood from the right atrium to flow into the left atrium (hence shunting blood AWAY from the lungs so it won't go in the right ventricle then to the pulmonary artery).
3. ***Ductus Arteriosus***: found connecting the pulmonary artery and aorta. It helps shunt mixed (oxygenate and deoxygenated) blood away from the lungs…instead it flows directly into the aorta (specifically to the descending aorta) where it will eventually travel to the umbilical arteries and back to the placenta.

Fetal Circulation BEFORE Birth

Remember that the baby doesn't breathe yet. The resistance in the lungs is HIGH due to being filled with fluid. The high resistance creates a higher pressure on the right side of the heart compared to the left, which helps play a role with shunting blood away from the lungs. Remember that blood from a higher resistance easily flows to a lower resistance. NOTE: this resistance changes after birth once the baby starts breathing and is responsible for closing off some of the shunts.

Now, let's walk step-by-step through fetal circulation BEFORE birth (shunt locations are bolded in RED):

- The placenta pulls nutrient-rich oxygenated blood from mom's circulation to the **UMBILICAL VEIN**.
- This blood flows down to the liver where some will go to the liver's circulation through the hepatic portal vein (the liver is NOT fully functional yet), but most will be **SHUNTED** by the **DUCTUS VENOSUS** to the **INFERIOR VENA CAVA** (IVC).
    - Therefore, rich oxygenated blood enters the IVC. Note: the IVC is also draining back deoxygenated blood just like it does in "normal" heart circulation as described at the beginning of this review.
- The blood from the IVC enters the **RIGHT ATRIUM**. Majority of this **oxygenated** blood will be **SHUNTED** through the **FORAMEN OVALE** (note: some of oxygenated blood will go down into the right ventricle). *Majority of the oxygenated blood needs to get to the body…there is no need for it to go through the rest of the right side of the heart because the lungs are NOT functioning yet.
    - So, this oxygenated blood flows from the **RIGHT ATRIUM** to the **LEFT ATRIUM**, down in the **LEFT VENTRICLE**, up through the aorta, and to the rest of the body.

- Also, draining into the right atrium is deoxygenated blood from the **SUPERIOR VENA CAVA** (SVC) and IVC. This deoxygenated blood along with some of the oxygenated blood from the umbilical vein will flow down into the **RIGHT VENTRICLE**. The blood is now mixed (contains oxygenated and deoxygenated blood).
- The mixed blood flows up through the **PULMONARY ARTERY** and is **SHUNTED** from the pulmonary artery to the AORTA (specifically the descending aorta) via the **DUCTUS ARTERIOSUS**.
- This blood flows down through the descending aorta. The descending aorta branches off into many arteries. Some of this blood will go to lower extremities and some will go via the internal iliac arteries.
- At the internal iliac arteries, the blood will flow into the **UMBILICAL ARTERIES** where it will leave the baby and go back to the placenta. Mom's circulation will clear the build-up of waste and re-supply it will fresh oxygen and nutrients.
- This cycle continues over and over!

Fetal Circulation AFTER Birth

When the baby is born, the umbilical cord is clamped off, and it starts breathing, the shunts begin to close or seal off. They are NO LONGER needed because the placenta is now non-functional, and the lungs are now functioning.

When the umbilical cord is clamped this stops blood flow through the umbilical vein. Therefore, the ductus venous is no longer needed and it seals off. Oxygenated blood will NOT enter the IVC.

When the placenta is no longer functioning, the levels of prostaglandins drop. In addition, when the baby starts breathing, the fluid in the lungs is removed and the alveoli sacs open up (this is the place where gas exchange occurs). The baby's blood oxygen levels start to increase. Furthermore, the resistance in the lung decreases, which in turn will decreases the pressure on the right side of the heart compared to the left side.

This causes the foramen ovale to close along with the ductus arteriosus. The ductus arteriosus is very sensitive to prostaglandin and when the levels drop the structure seals off. This change will be important to know when we discuss different cardiac disorders.

Vital Signs:

Heart Rate/ Heart Murmurs

A. normal: 110-160 beats/min (always listen one full minute)
B. Immediately after birth 175-180 beats/min
C. Often irregular (immaturity of cardiac regulatory center in medulla)
D. Transient murmurs – provided by turbulent blood flow
    1. Majority from incomplete closure of fetal circulation early in neonatal life

2. 90% are not associated with anomalies

E. Cardiac Apex – 3rd to 4th intercostal space in midclavicular line
F. Should feel peripheral pulses in all extremities

Blood Pressure

A. increased immediately after birth
B. lowest level at 3 hours of age
C. by 4-6 day B/P increases and plateaus
D. readings
    1. 1st 12 hours – vary with birth weight
    2. full term 60-80/40-50
    3. premature 50-70/35-45
E. crying may increase by 20 mm/Hg in both systolic and diastolic
F. best reading – use doppler and 1-2 inch cuff with stethoscope on brachial artery

Blood volume

A. 80-85 ml/Kg
B. varies based on amount of placental transfusion received
C. early cord clamp 78 ml/Kg
    1. 3rd day – 82.3 ml/Kg
    2. increases because of placental transfusion, decreased intake and diminished extracellular fluid volume
D. late cord clamp 98.6 ml/Kg
    1. 3rd day – 92.6 ml/Kg

Hematology:

RBC – erythrocytes

A. 5-7 million/ mm3
B. high count in utero prevents hypoxia
C. Oxygen from placenta provides 50% O2 sat.
D. Once proper lung oxygenation is established – the need for increased RBC's is diminished

WBC

A. 10,000 – 30,000 /mm3
B. trauma of birth stimulates higher production of neutrophils for first weeks of life – non-pathogenic
C. lymphocytes eventually become predominant until 4-5 years old
D. first few days after delivery – considerable drop in total count

Hemoglobin

A. primarily fetal Hgb (HgF) result of
    1. placental transfusion

2. low oral intake
3. diminished extracellular fluid volume

B. 70-90%
C. HgF eventually replaced by HgA after few weeks
D. Capable of maintaining increased oxygen saturation at lower pressure
E. Can carry as much as 20-30% more oxygen than maternal blood
F. Hgb level decrease gradually over 3 months the increase slowly

Hematocrit

A. concentrate about 50% higher than mother

By the first week fetal levels decrease progressively creating a phenomenon known as <u>physiologic anemia of infancy</u>

A. factors influencing:
    1. nutritional status of neonate – supplies of vitamin E, folic acid, and iron may be inadequate for growth
    2. Hgb values fall from decrease in red cell mass
    3. Red cell survival lower in neonates than adults (90 days vs. 120 days), red cell production is less