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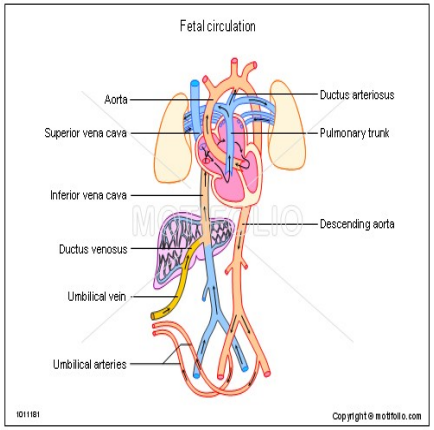
FACULTY OF NURSING

FETAL CIRCULATION



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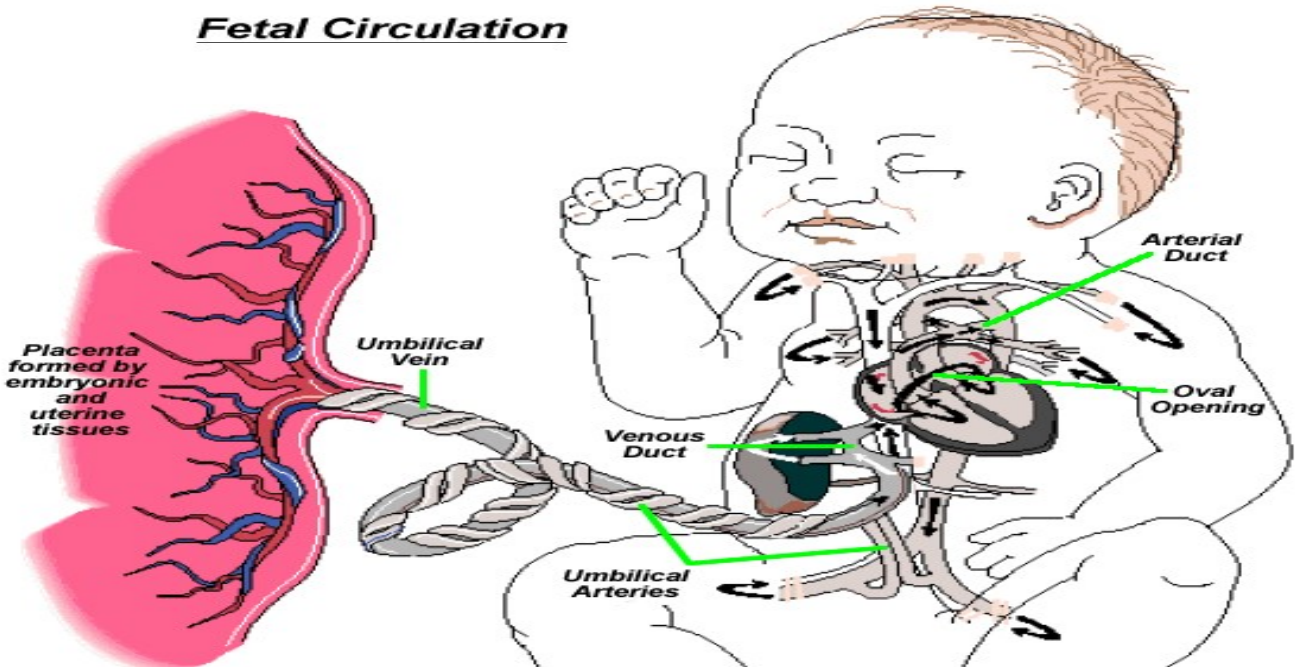
INTRODUCTION

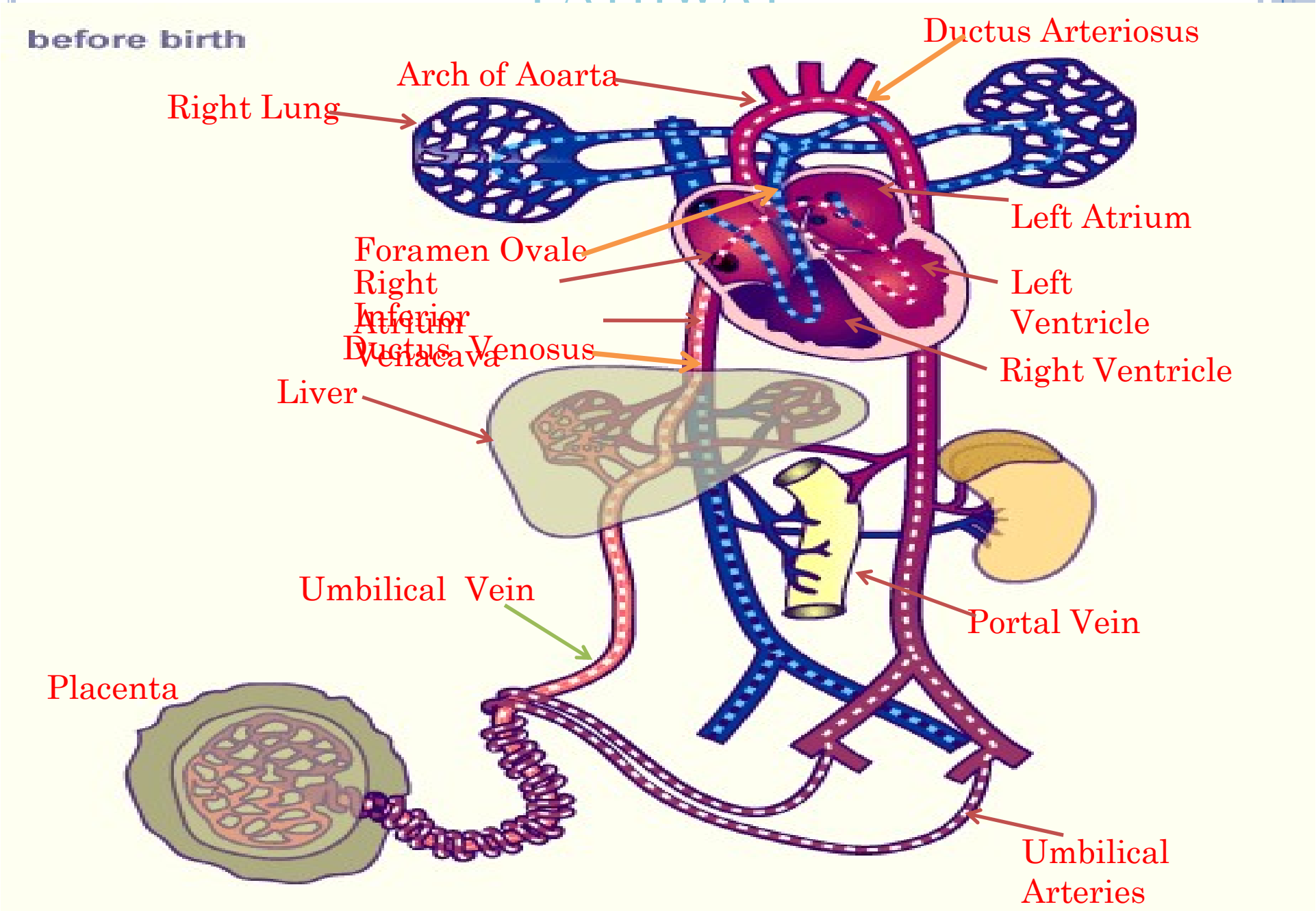
- In the fully developed human, the heart serves two main purposes.
- The right heart pumps blood to the lungs for oxygenation and the left heart pumps oxygenated blood to rest of the body.
- In the embryo and fetus, the lungs do not oxygenate the blood.
- Fetal circulation is consequently quite different than that of a breathing baby or adult.
- When a baby is born and takes its first breathes, the ducts close and blood is rerouted to the lungs.

DEFINITION

The **fetal circulation** is the circulatory system of a human fetus, often encompassing the entire fetoplacental circulation which includes the umbilical cord and the blood vessels within the placenta that carry fetal blood.



PATHWAY


before birth
Ductus Arteriosus
Arch of Aoarta
Right Lung
Left Atrium
Foramen Ovale
Right
Inferior
Atrium
Left
Ventricle
Ductus Venosus
Venacava
Right Ventricle
Liver
Umbilical Vein
Portal Vein
Placenta
Umbilical
Arteries

Umbilical Cord

- 2 umbilical arteries:

  return non-oxygenated blood, fetal waste, CO_2 to placenta

- 1 umbilical vein:

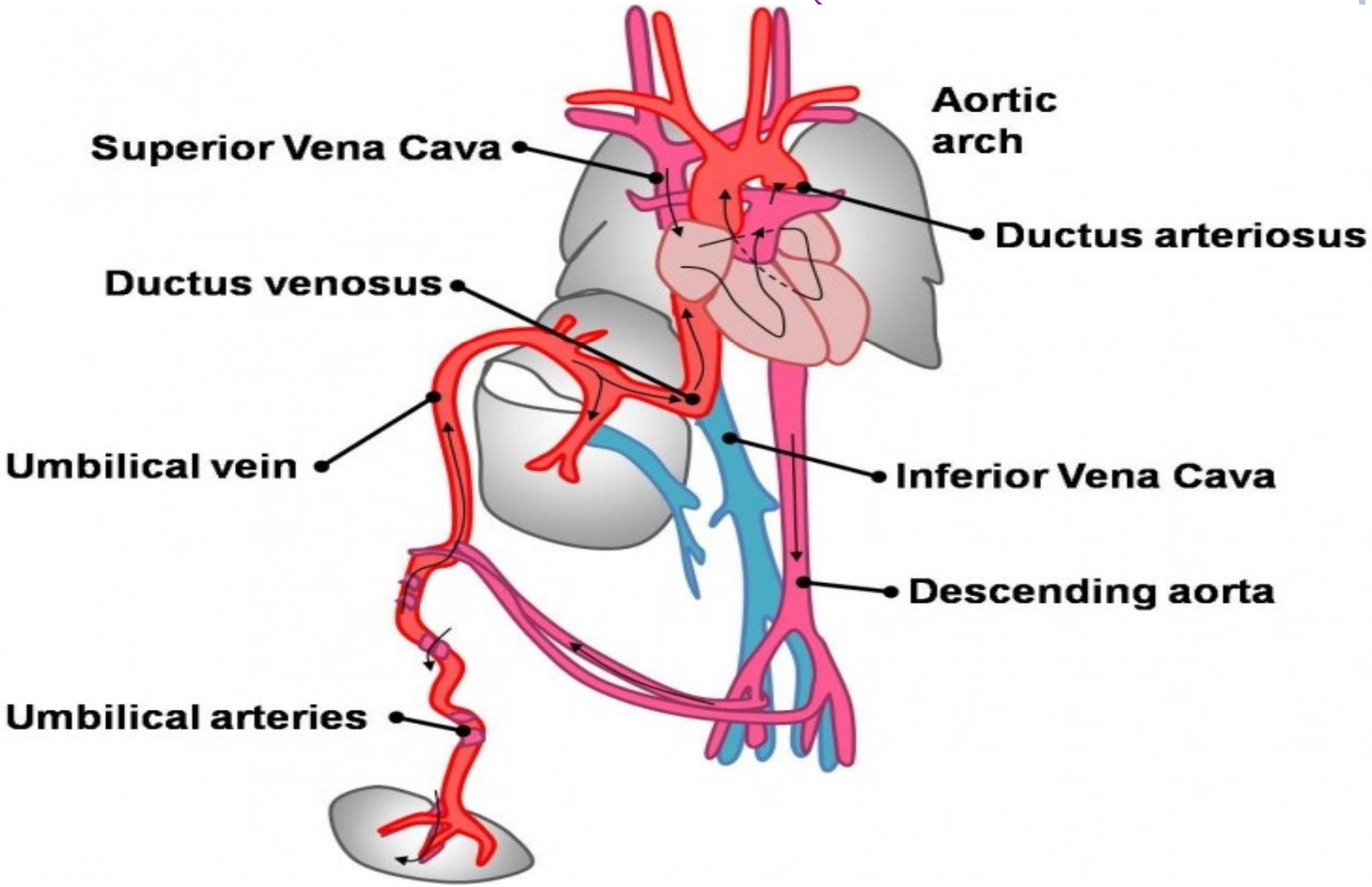
  brings oxygenated blood and nutrients to the fetus

Foetal circulation consequently differs from the adult one predominantly due to the presence of 3 major vascular shunts:

Three shunts are present in fetal life:

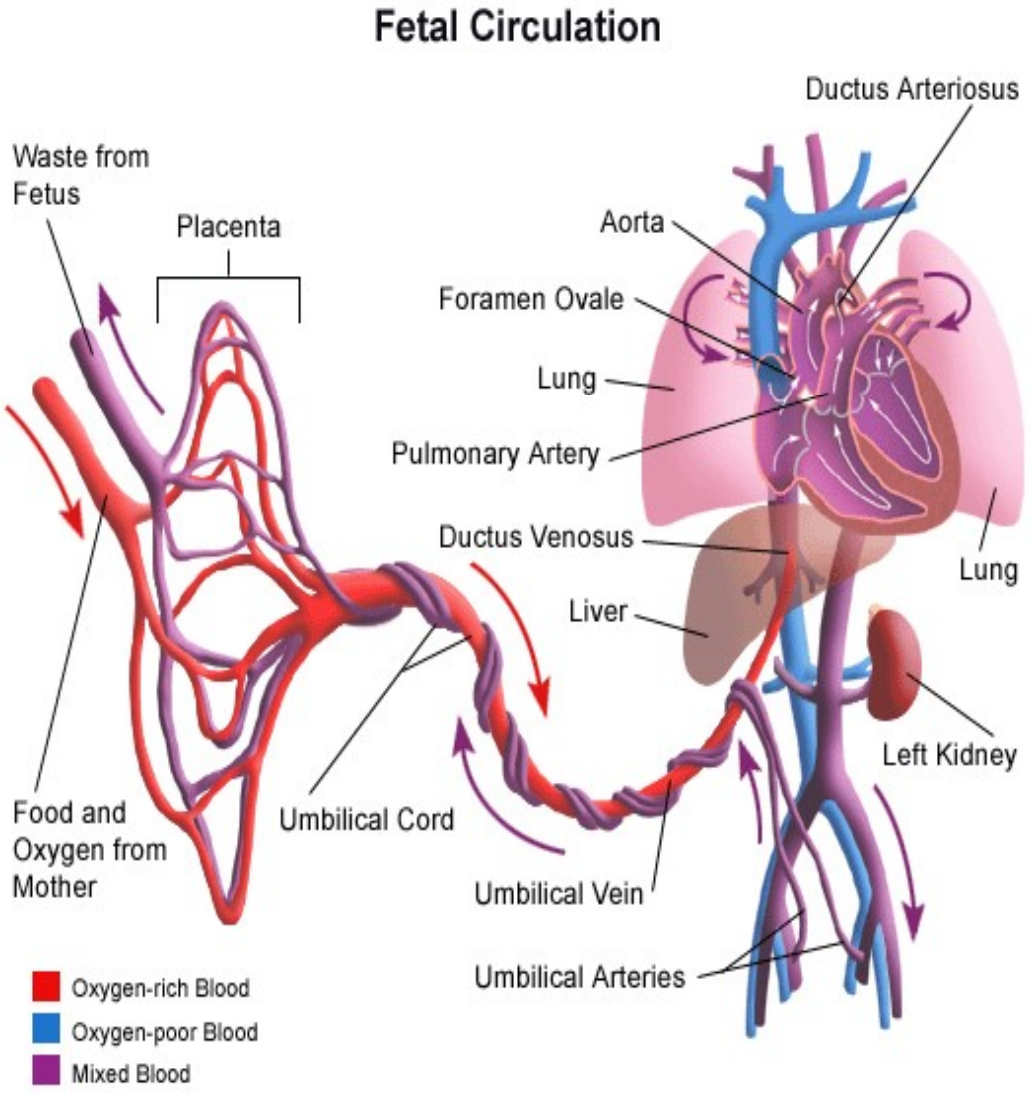
1. Ductus venosus: connects the umbilical vein to the inferior vena cava
2. Ductus arteriosus: connects the main pulmonary artery to the aorta
3. Foramen ovale: anatomic opening between the right and left atrium.

THE MAIN FUNCTION OF THESE SHUNTS IS TO REDIRECT OXYGENATED BLOOD AWAY FROM THE LUNGS, LIVER AND KIDNEY (WHOSE FUNCTIONS ARE

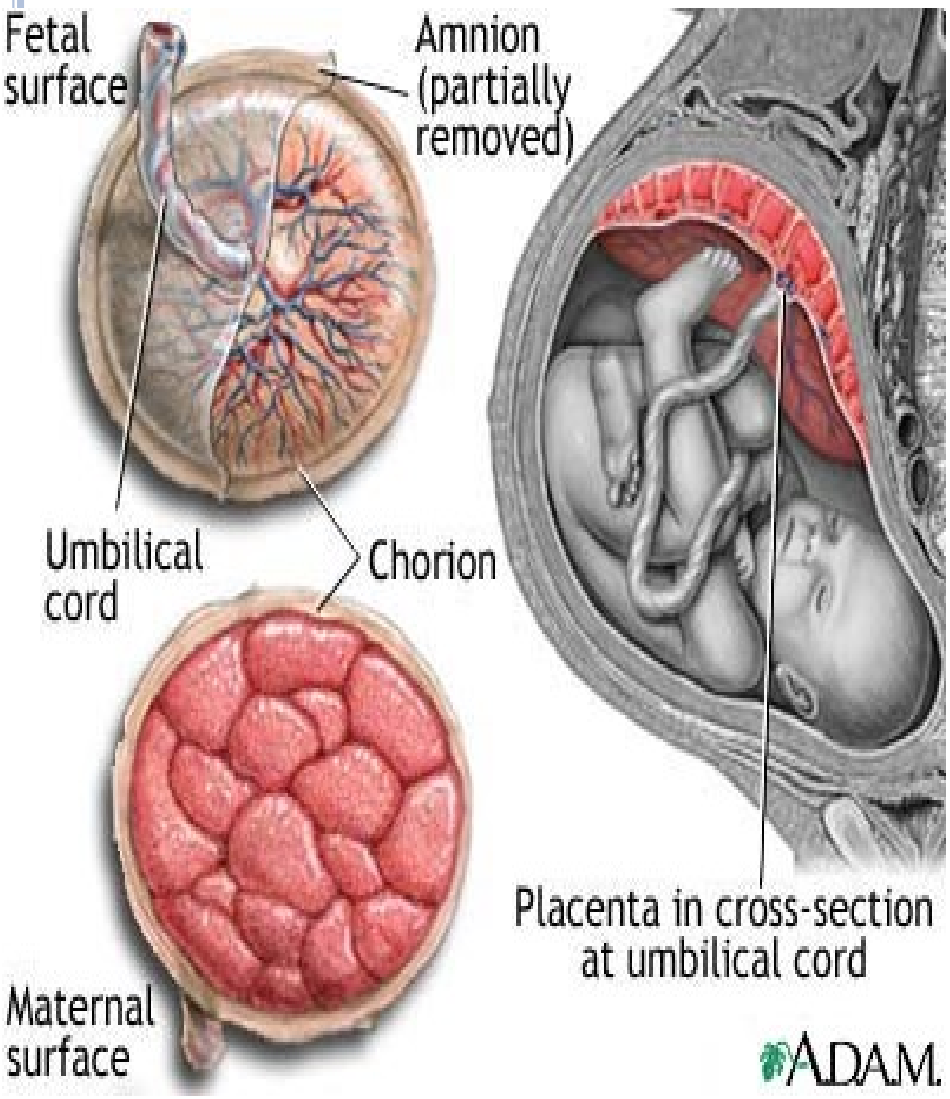


Umbilical Circulation

- Pair of umbilical arteries carry deoxygenated blood & wastes to placenta.
- Umbilical vein carries oxygenated blood and nutrients from the placenta.



The Placenta



- Facilitates gas and nutrient exchange between maternal and fetal blood.
- The blood itself does not mix.

PLACENTAL ROLE

The core concept behind fetal circulation is that fetal hemoglobin has a higher affinity for oxygen than does adult hemoglobin, which allows a diffusion of oxygen from the mother's circulatory system to the fetus.

The circulatory system of the mother is not directly connected to that of the fetus, so the placenta functions as the respiratory center for the fetus as well as a site of filtration for plasma nutrients and wastes.

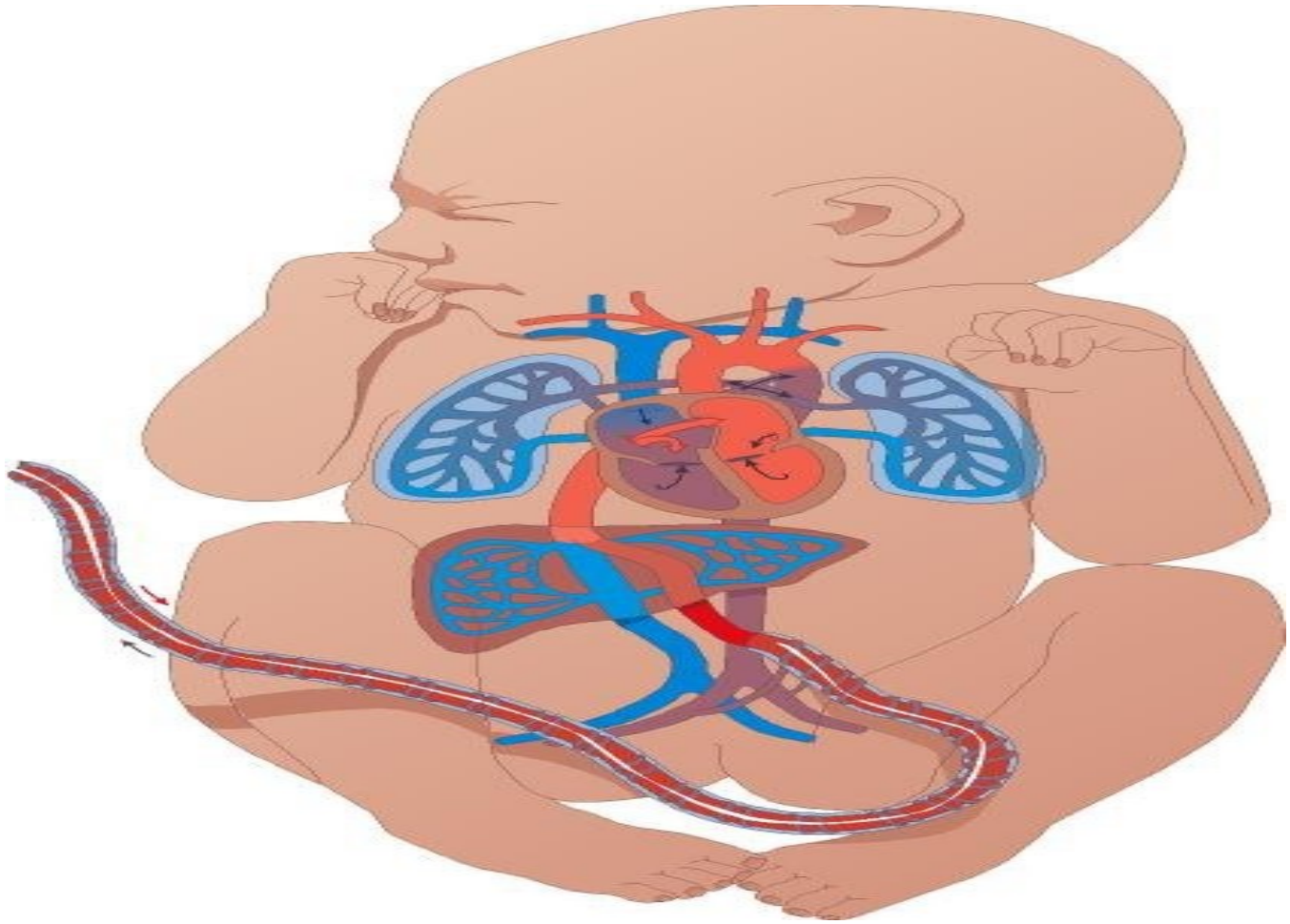


Image depicts fetal circulation. Note the areas of oxygenated blood (red) and deoxygenated blood (blue) mixing (purple) through fetal shunts

PATHWAY

Oxygenated blood from the placenta

↓ through umbilical vein

fetus

↓

liver

↓

Receives deoxygenated blood from the portal vein

↓ through **ductus venosus**

Inferior vena cava

↓

Right atrium of heart

↓ through **foramen ovale**

Left atrium of the heart

↓

Left ventricle of the heart

During ventricular systole

Left ventricular blood

pumped

Ascending aorta and distributed by their branches to the heart, head,neck,brain,arms.

Right ventricular blood

with < o2 content

is discharged

Pulmonary arteries

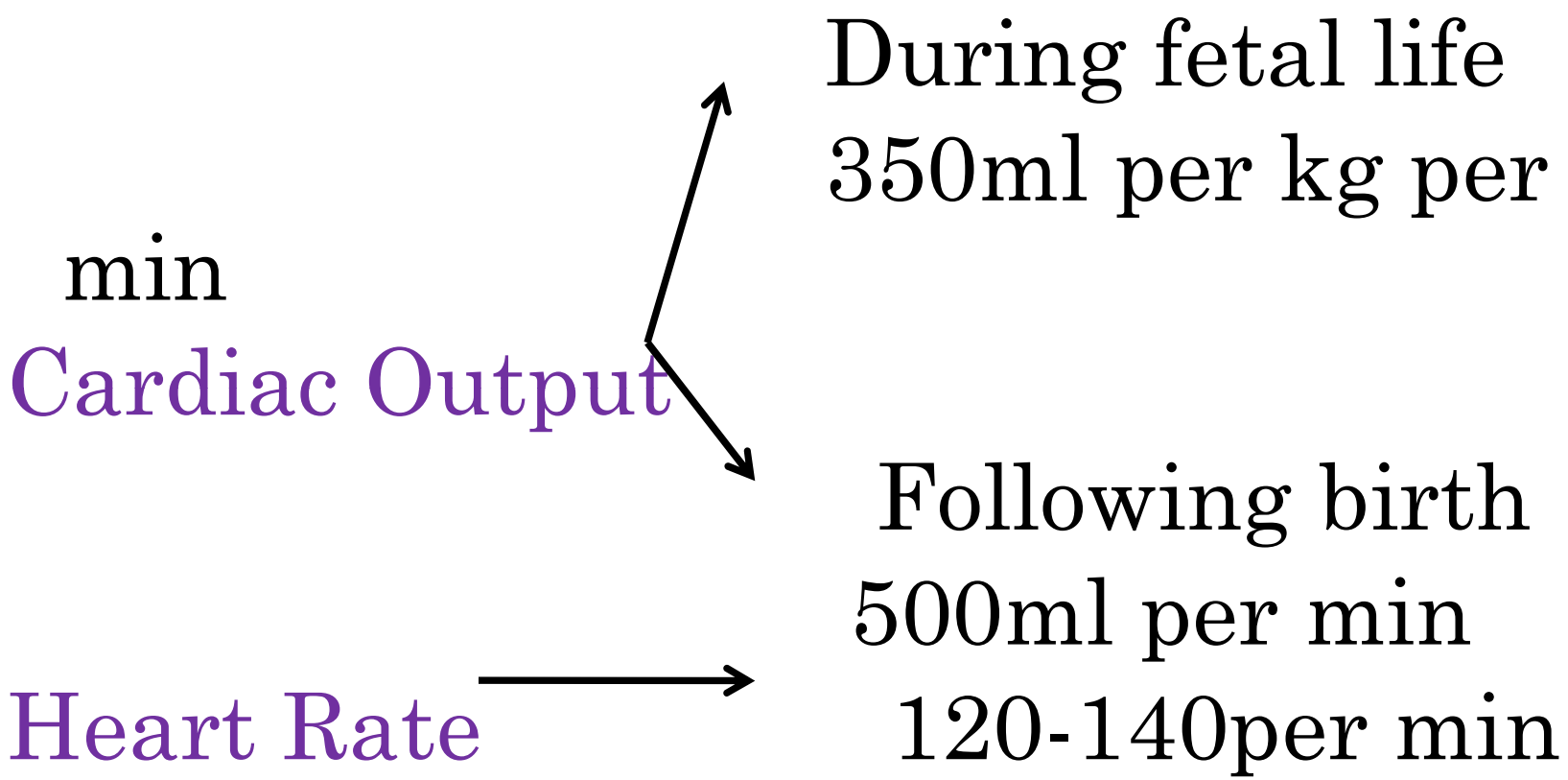
Ductus arteriosus

Descending aorta

Hypogastric arteries

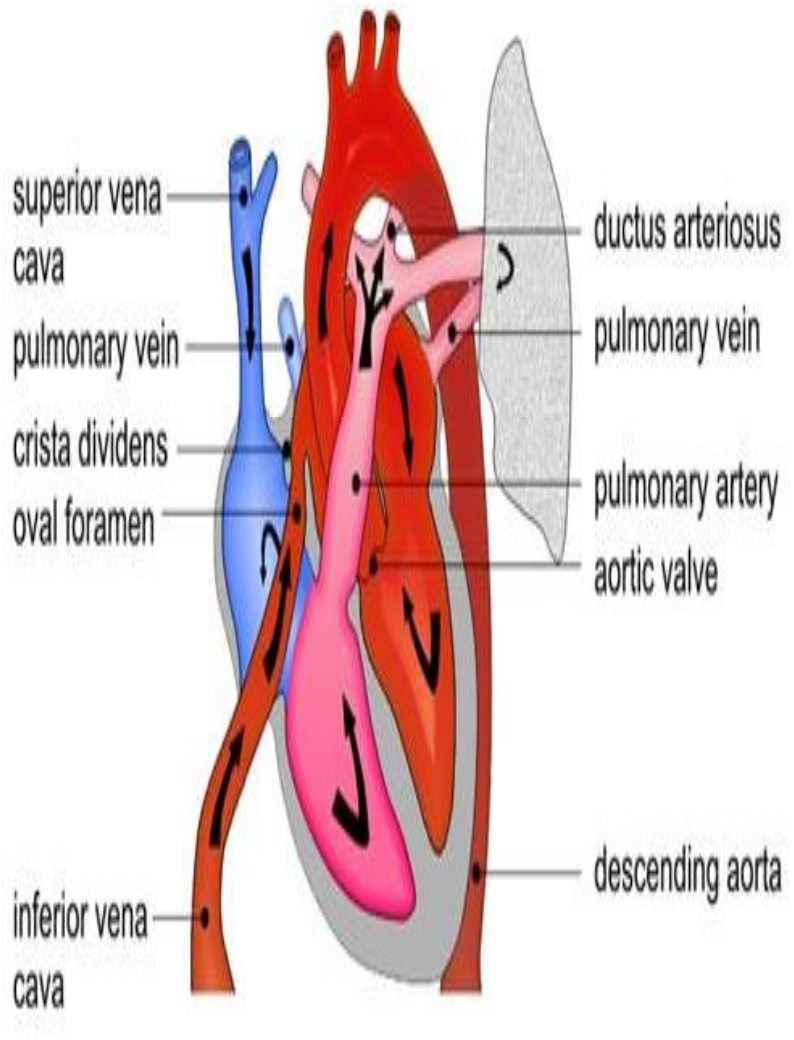
Umbilical arteries

Placenta


During fetal life
350ml per kg per
min
Cardiac Output
Following birth
500ml per min
Heart Rate
120-140per min

Fetal Circulation

- By the third month of development, all major blood vessels are present and functioning.
- Fetus must have blood flow to placenta.
- Resistance to blood flow is high in lungs.

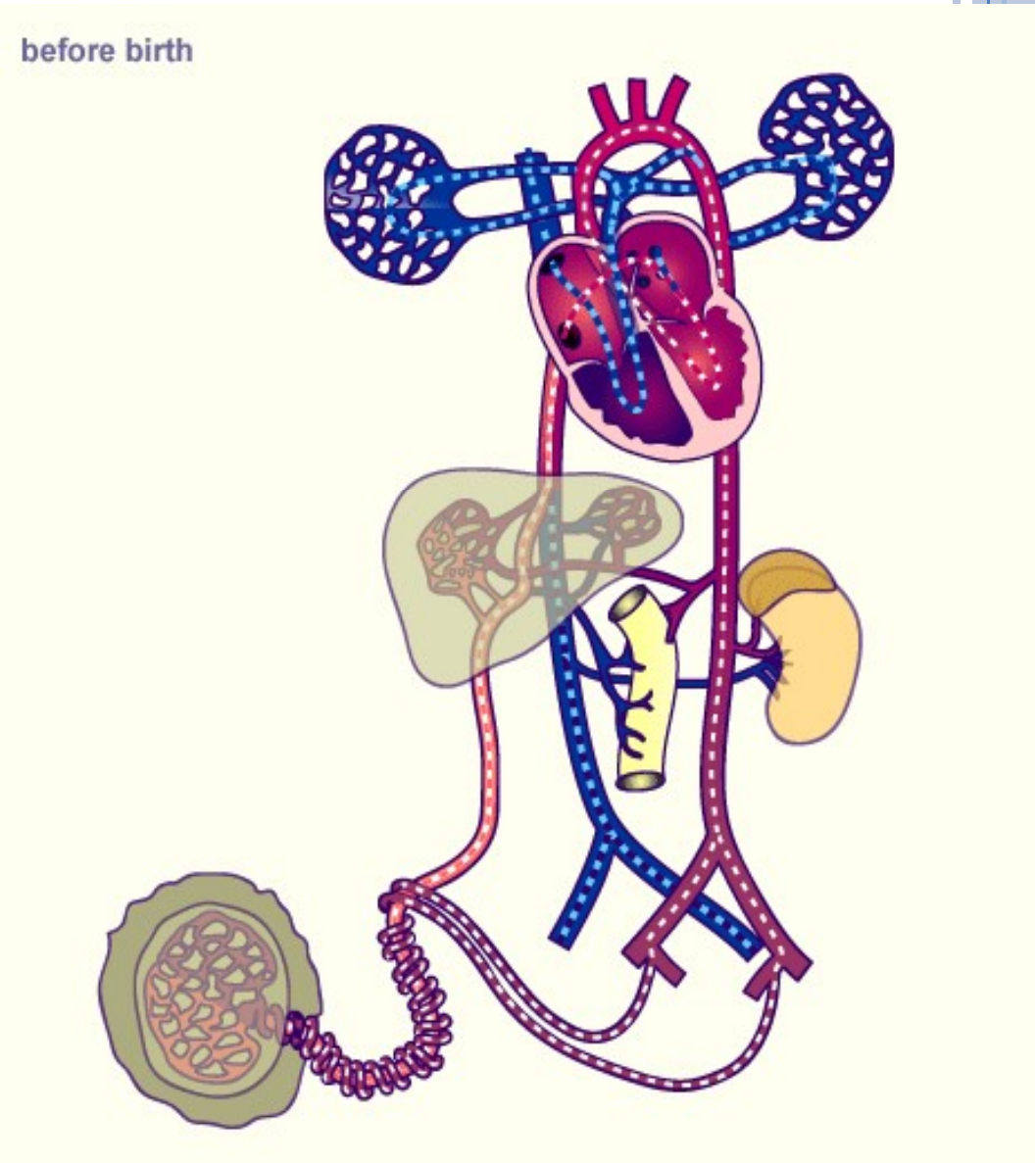


Difference between Adult and Fetal Circulation

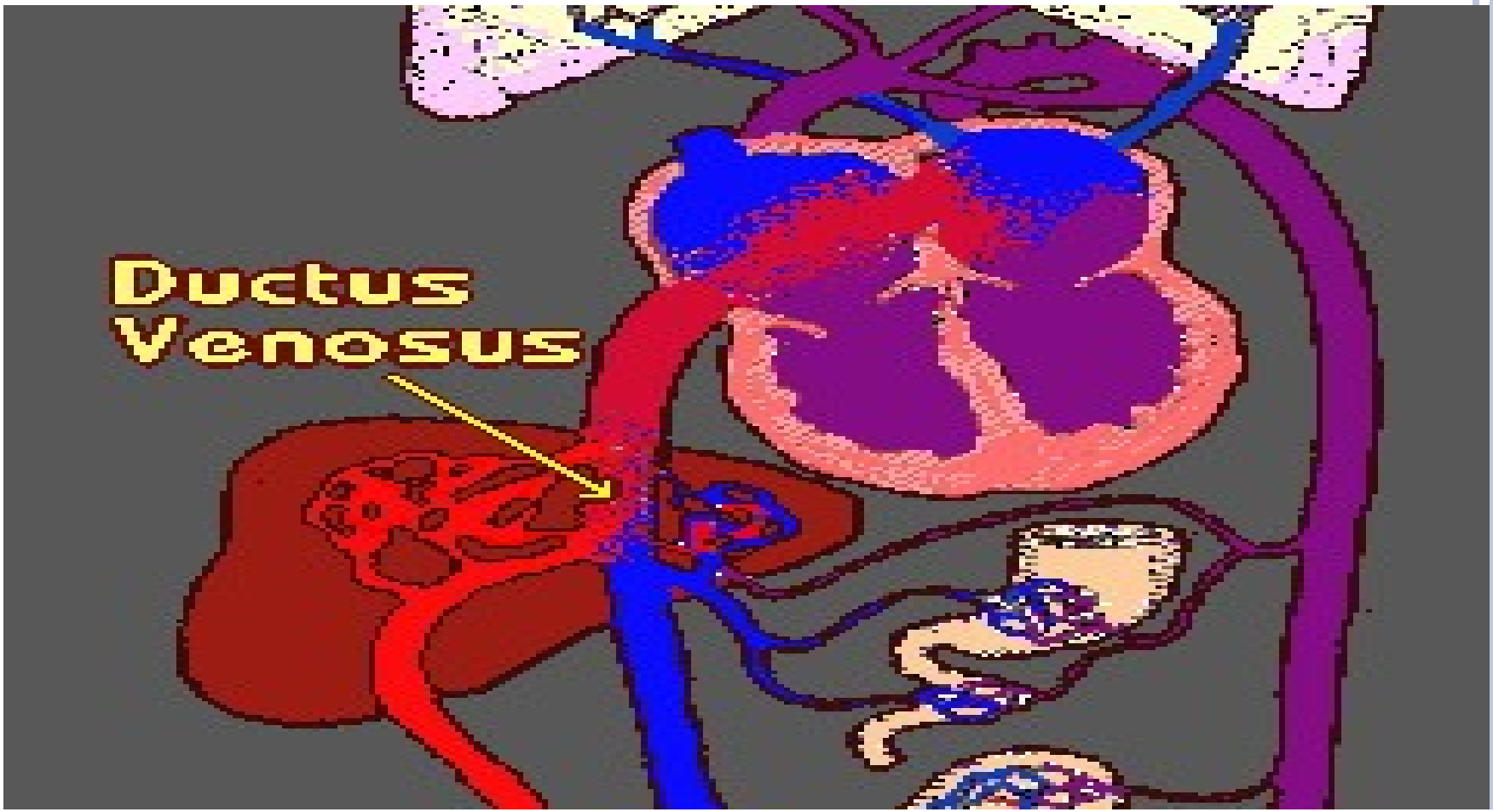
Criteria	Adult Circulation	Fetal Circulation
Artery	Carries oxygenated blood away from the heart	Carries Non-oxygenated blood away from the fetal heart
Veins	Carries non-oxygenated blood towards the heart	Carries oxygenated blood back to the heart
Exchange of Gases	Takes places in the lungs	Takes place in the placenta
Pressure	Increase pressure on the left side of the heart	Increase pressure on the right side of the heart

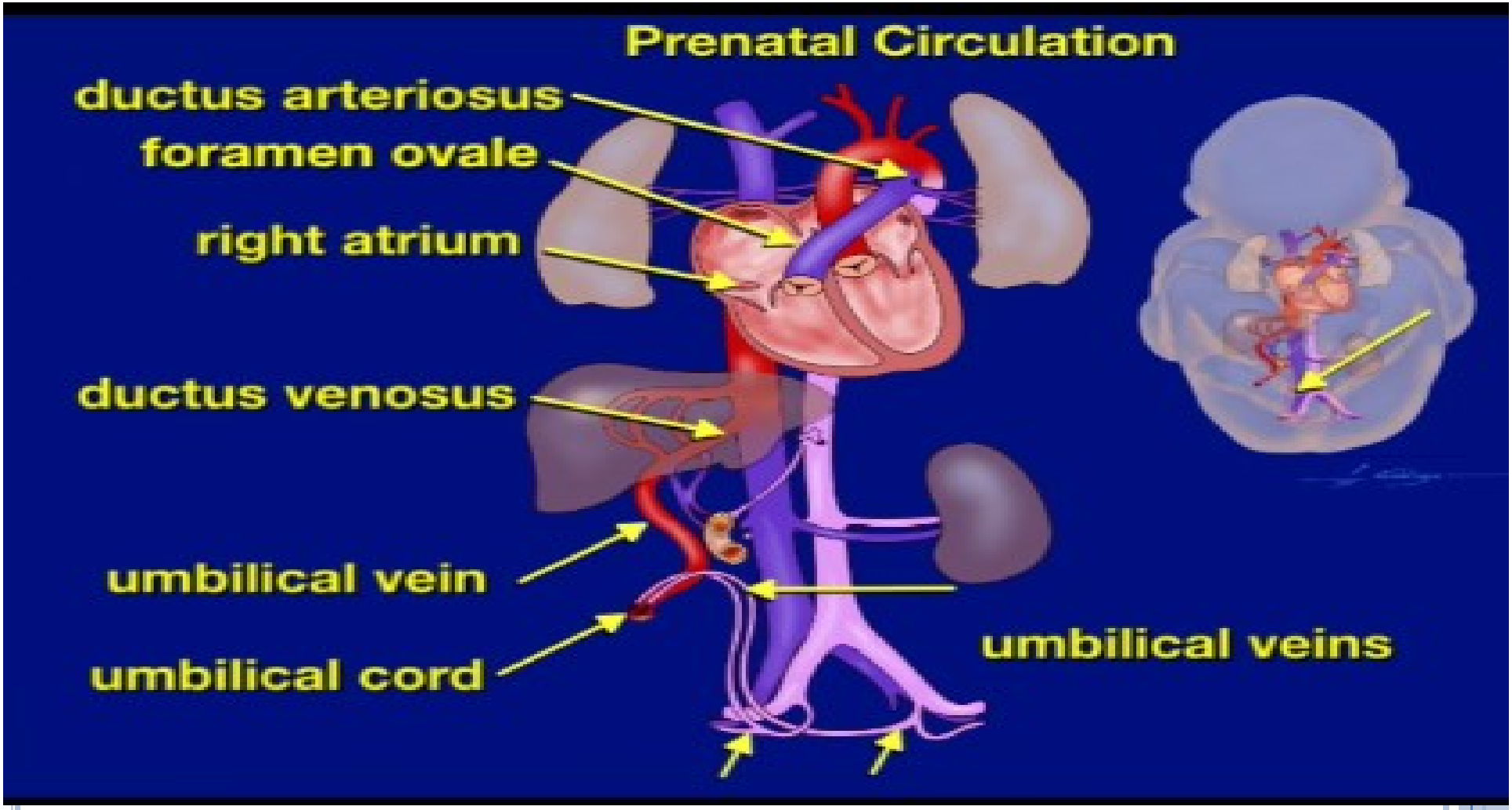
Fetal Circulation Sequence

Exchange of gases occurs in the placenta. Oxygenated blood is carried by the umbilical vein towards the fetal heart.



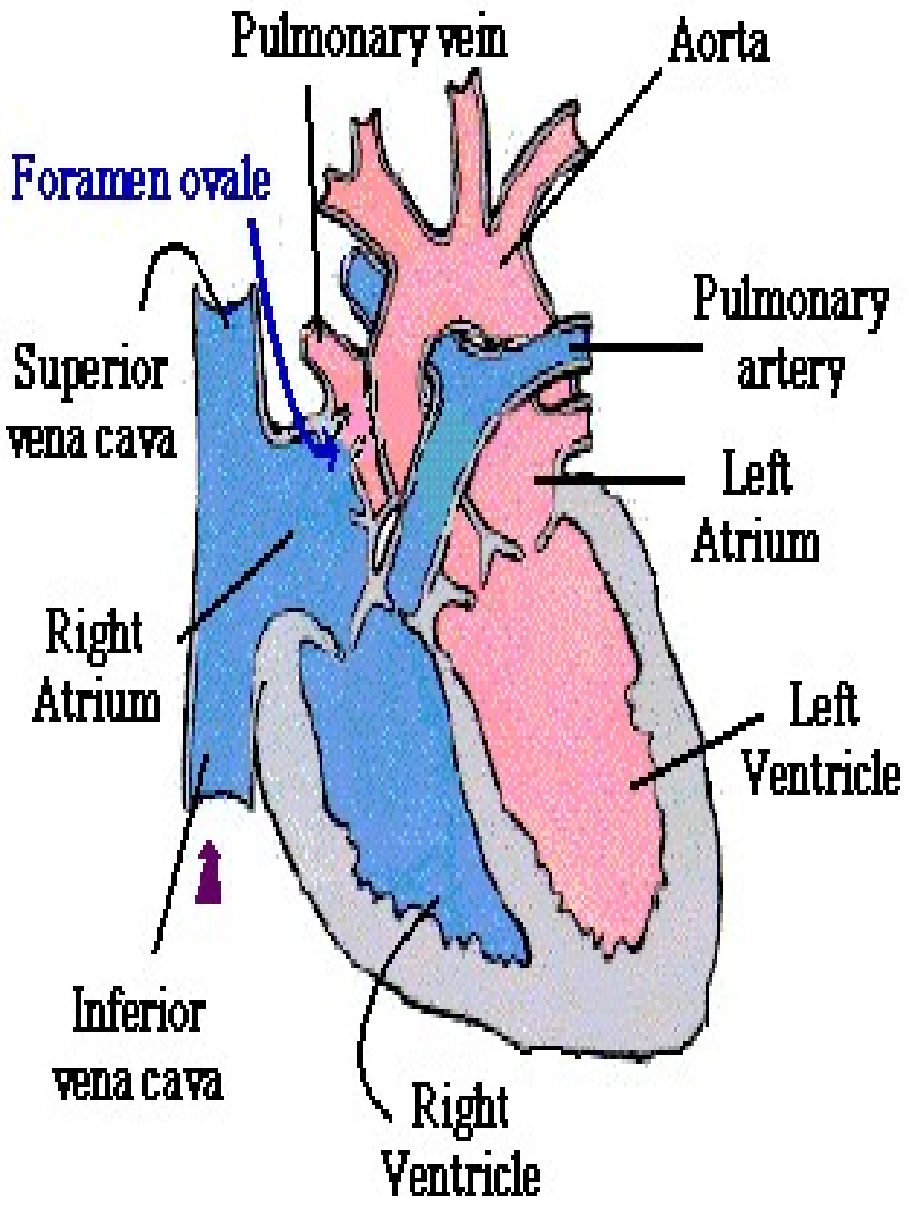
The ductus venosus directs part of the blood flow from the umbilical vein away from the fetal liver (filtration of the blood by the liver is unnecessary during the fetal life) and directly to the inferior vena cava.



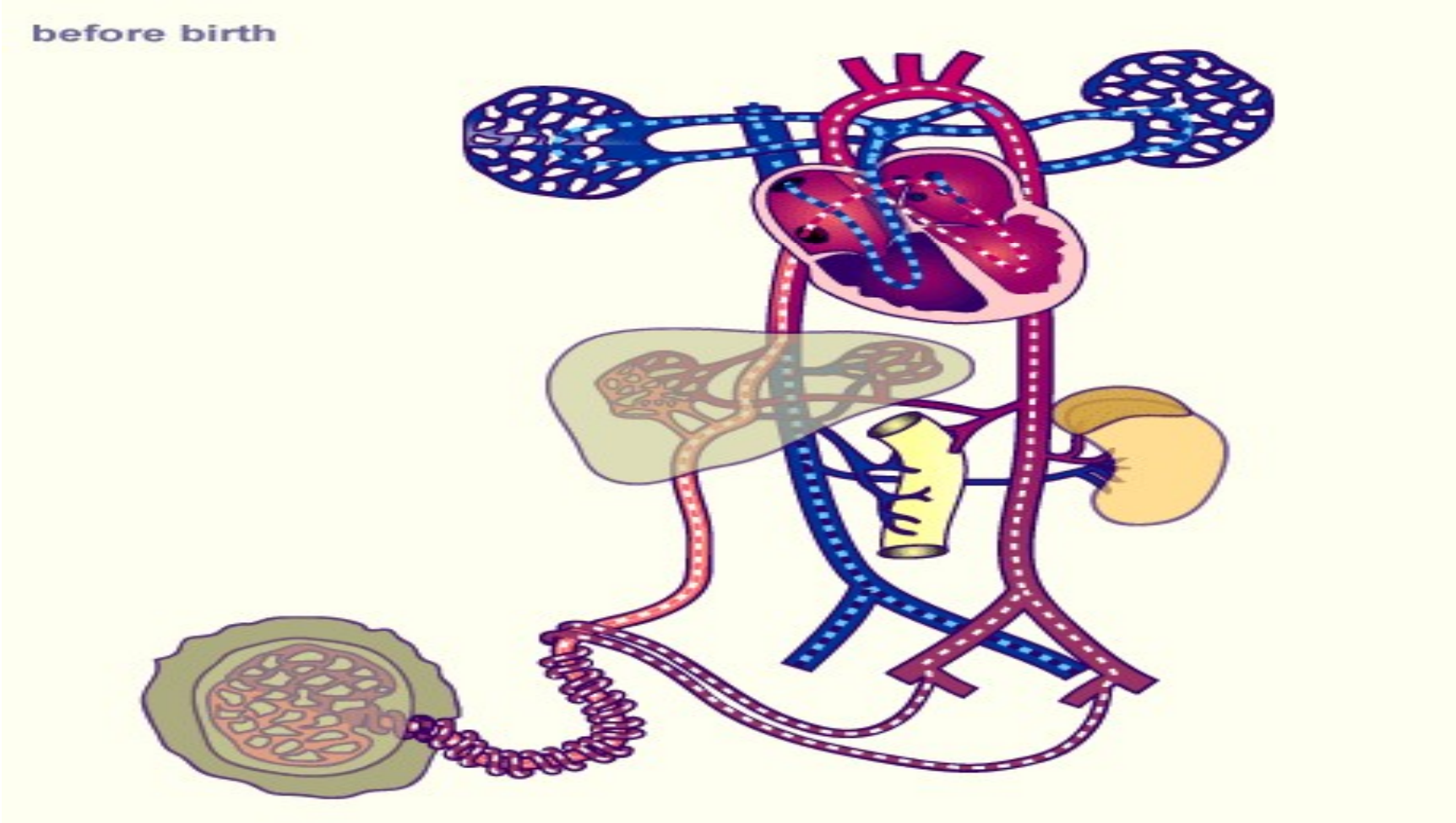


Blood from the ductus venosus enters to the inferior vena cava. Increase levels of oxygenated blood flows into the right atrium.

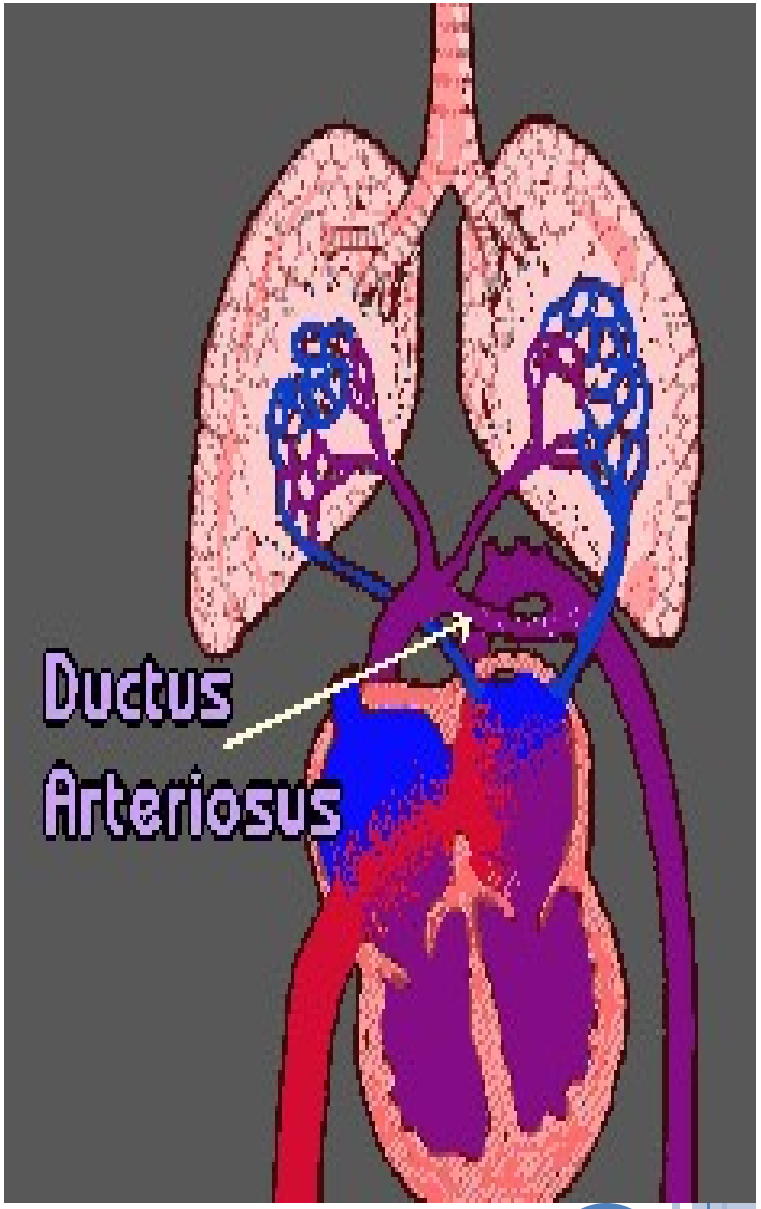
In adults, the increase pressure of the right atrium causes the tricuspid valve to open thus, draining the blood into the right ventricle. However, in fetal circulation most of the blood in the right atrium is directed by the foramen ovale (opening between the two atria) to the left atrium.



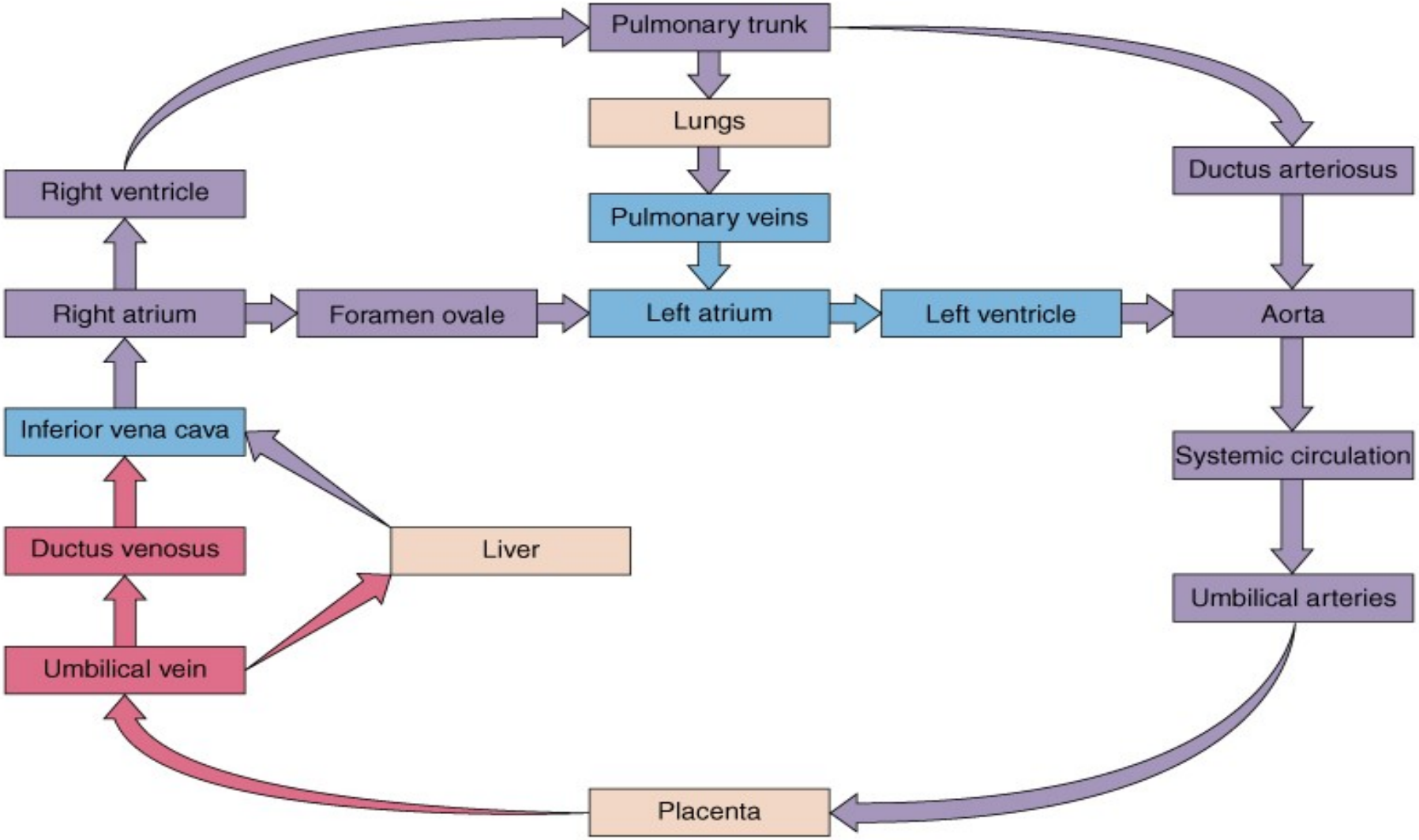
The portion of the blood that drained into the right ventricle passes to the pulmonary artery.



As blood enters the pulmonary artery (carries blood to the lungs), an opening called ductus arteriosus connects the pulmonary artery and the descending aorta. Hence, most of the blood will bypass the non-functioning fetal lungs and will be distributed to the different parts of the body. A small portion of the oxygenated blood that enters the lungs remains there for fetal lung maturity.



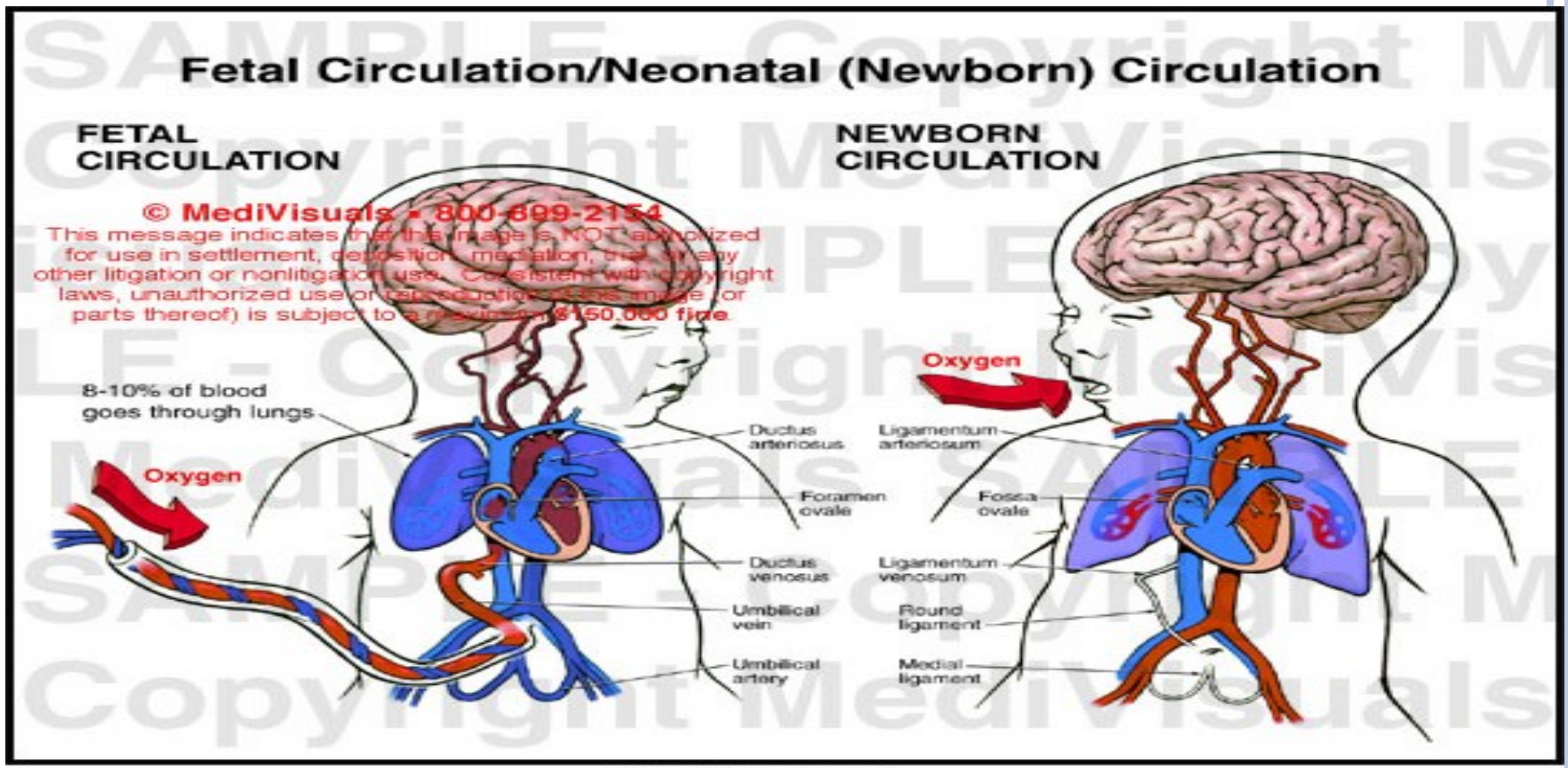
Flow Chart of Fetal Circulation



(c) Scheme of fetal circulation

WHY IS THE PULMONARY CIRCULATION REDUCED IN THE HUMAN FETUS?

Pulmonary circulation is reduced in the human fetus because the baby gets its oxygen from its mother and does not breath



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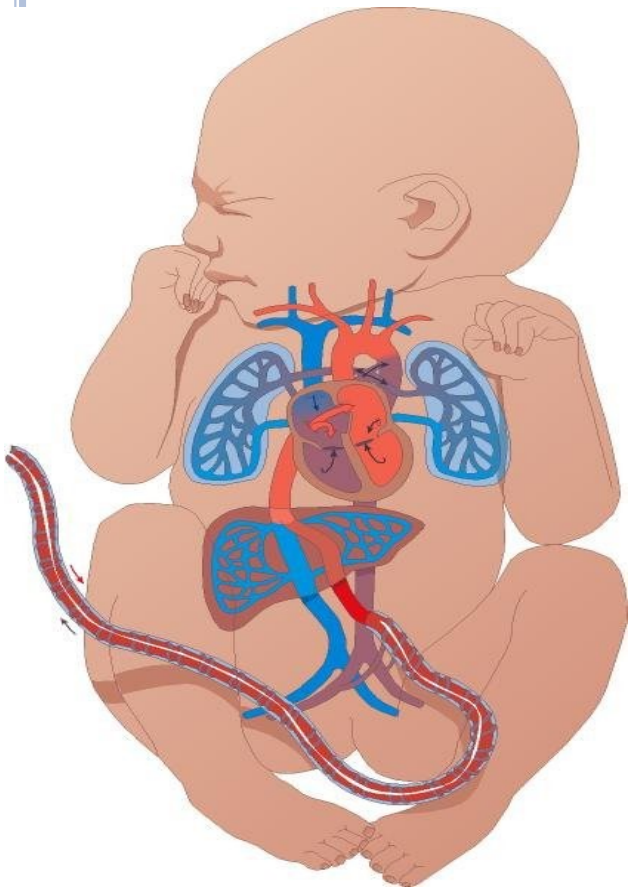
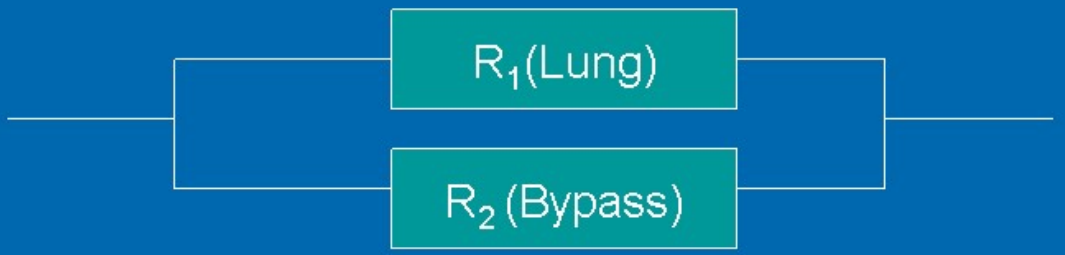
POSTNATAL CHANGES IN CIRCULATION

WHAT HAPPENS AT BIRTH?

- **The change from fetal to postnatal circulation happens very quickly.**
- **Changes are initiated by baby's first breath.**



Fetal and Neonatal Circulation



$$1/R_{eq} = 1/R_1 + 1/R_2$$

Before birth R_1 is high. Thus most of blood bypasses the lung.

After birth R1 decreases and blood is directed through the lungs.

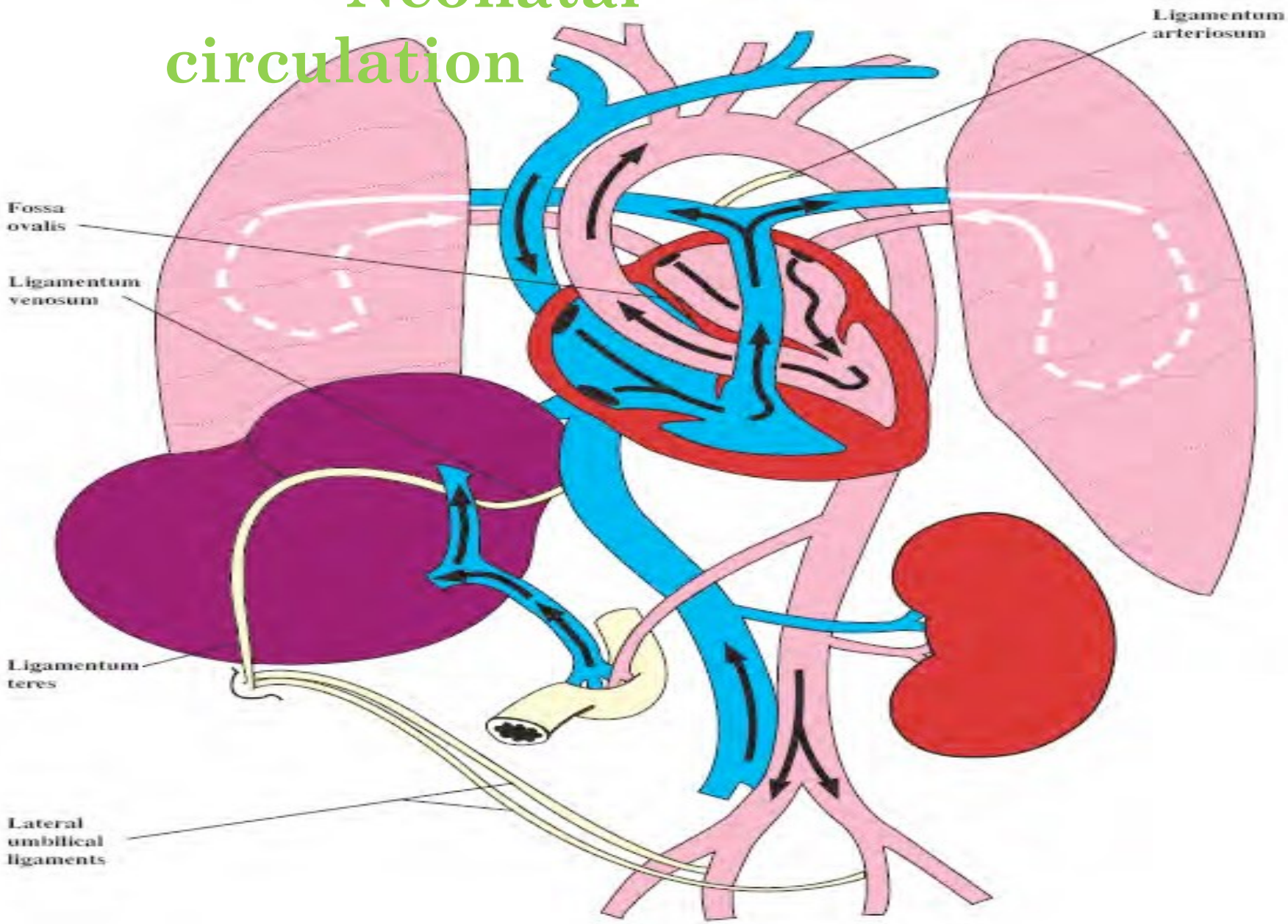
POST NATAL CHANGES

- Gas exchange function is transferred from placenta to the lungs.
- Separation of systemic and pulmonary circulations
- Increased metabolism to maintain body temperature and hence increased cardiac output.

At birth

- Clamping the cord shuts down low-pressure system
- Increased atmospheric pressure(increased systemic vascular resistance) causes lungs to inflate with oxygen
- Lungs now become a low-pressure system

Neonatal circulation

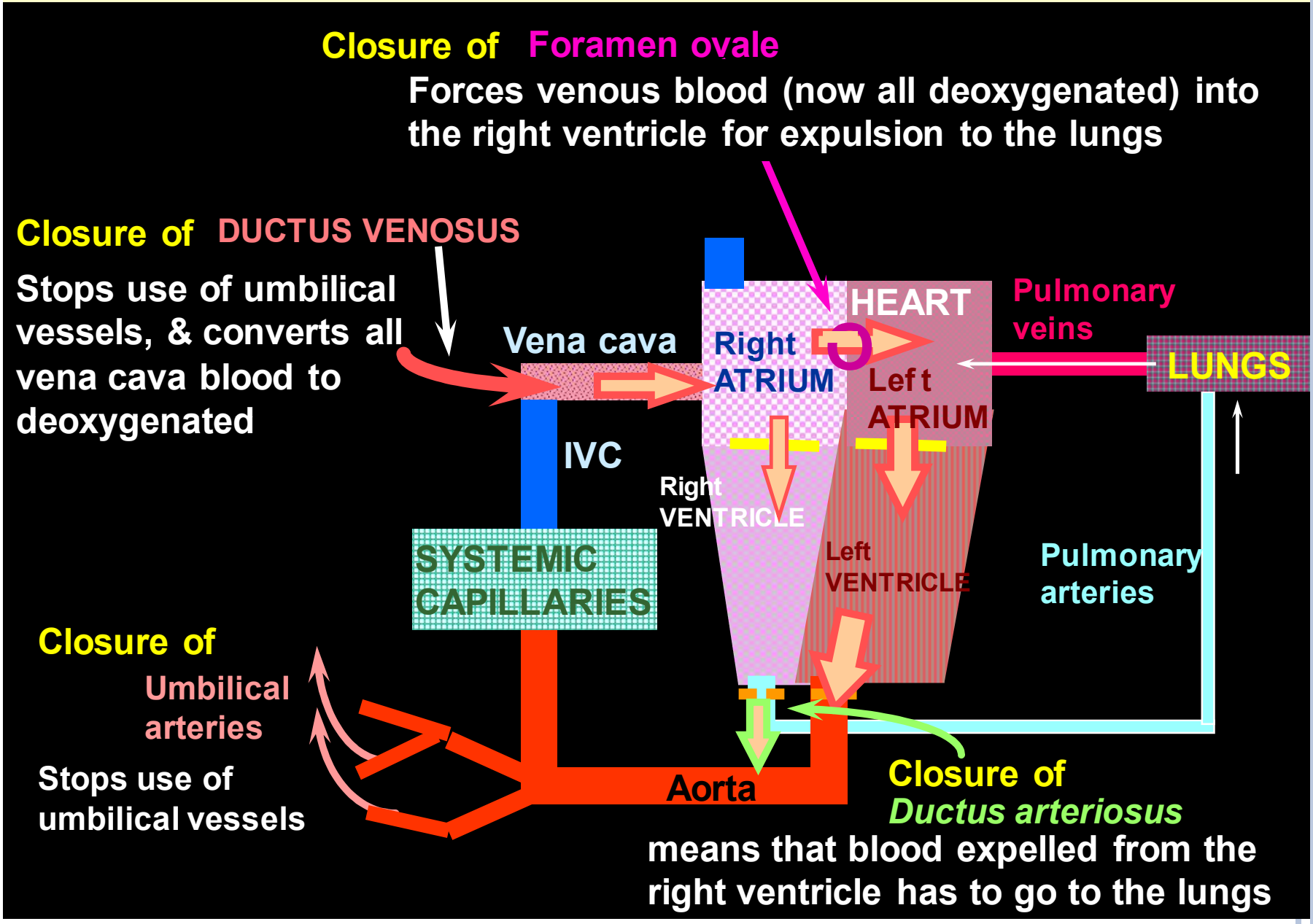


Changes in the Fetal Circulation after Birth

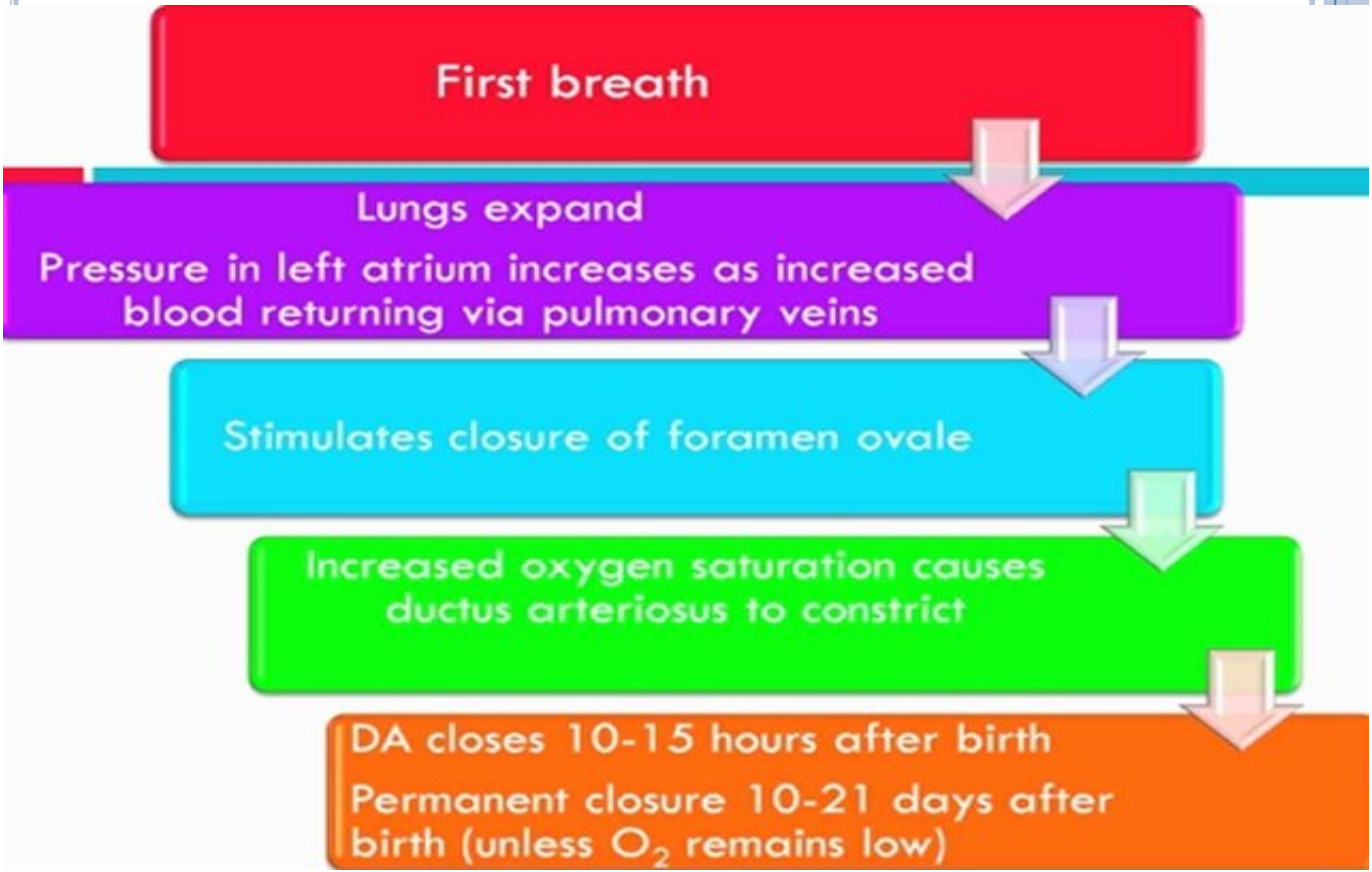
Shunt	Functional closure	Anatomical closure	Remnant
Ductus arteriosus	10 – 96 hrs after birth	2 – 3 wks after birth	Ligamentum arteriosum
Formamen ovale	Within several mins after birth	One year after birth	Fossa ovalis
Ductus venosus	Within several mins after birth	3 – 7 days after birth	Ligamentum venosum

- Umbilical vein → Ligamentum teres

FETAL CIRCULATION VIII: Conversion to post-natal*



Foramen ovale	Closes shortly after birth, fuses completely in first year.
Ductus arteriousus	Closes soon after birth, becomes ligamentum arteriousum in about 3 months.
Ductus venosus	Ligamentum venosum
Umbilical arteries	Medial umbilical ligaments
Umbilical vein	Ligamentum teres


First breath
Lungs expand
Pressure in left atrium increases as increased blood returning via pulmonary veins
Stimulates closure of foramen ovale
Increased oxygen saturation causes ductus arteriosus to constrict
DA closes 10-15 hours after birth
Permanent closure 10-21 days after birth (unless O_2 remains low)

Problem with persistence of fetal circulation

- Patent (open) ductus arteriosus and patent foramen ovale each characterize about 8% of congenital heart defects.
- Both cause a mixing of oxygen-rich and oxygen-poor blood; blood reaching tissues not fully oxygenated. Can cause cyanosis
- Surgical correction now available, ideally completed around age two.
- Many of these defects go undetected until child is at least school age.

ADULT DERIVATIVES OF FETAL VASCULAR STRUCTURES

S.No	FETAL STRUCTURE	ADULT STRUCTURE
1.	FORAMEN OVALE	FOSSA OVALIS
2.	UMBILICAL VEIN	LIGAMENTUM TERES
3.	DUCTUS VENOSUS	LIGAMENTUM VENOSUM
4.	DUCTUS ARTERIOSUM	LIGAMENTUM ARTERIOSUM
5.	UMBILICAL ARTERY AND ABDOMINAL LIGAMENT	MEDIAL UMBILICAL ARTERY AND SUPERIOR VESICULAR ARTERY

Fetal Vs Infant Circulation

Fetal	Infant
• Low pressure system • Right to left shunting • Lungs non-functional • Increased pulmonary resistance • Decreased systemic resistance	•High pressure system •Left to right blood flow •Lungs functional •Decreased pulmonary resistance •Increased systemic resistance

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