

**B.Sc. 6<sup>th</sup> Semester**

**Subject: Physiology**

**Paper: C13T**

**Topics: Fetal circulation and its changes  
after birth**

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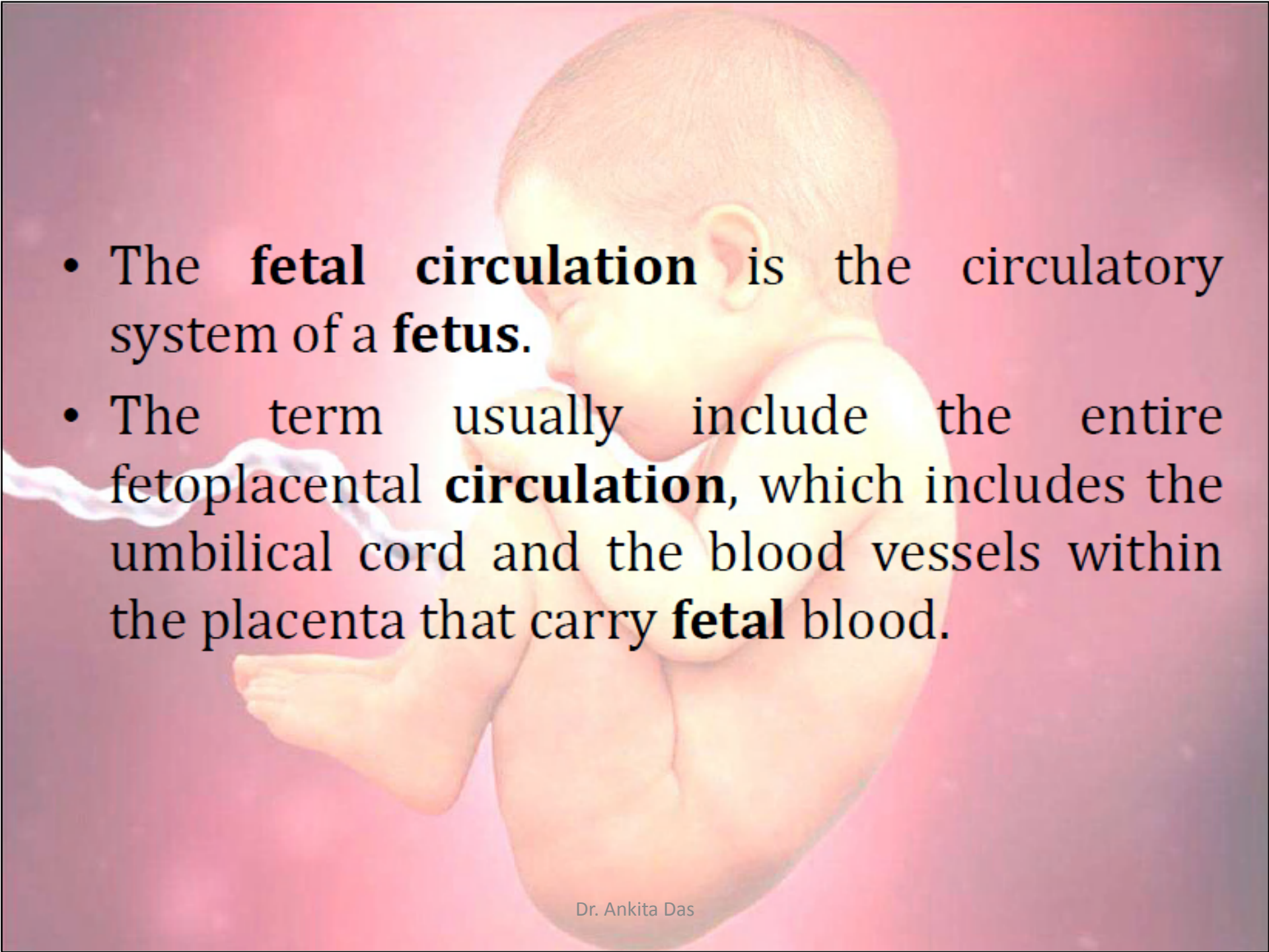


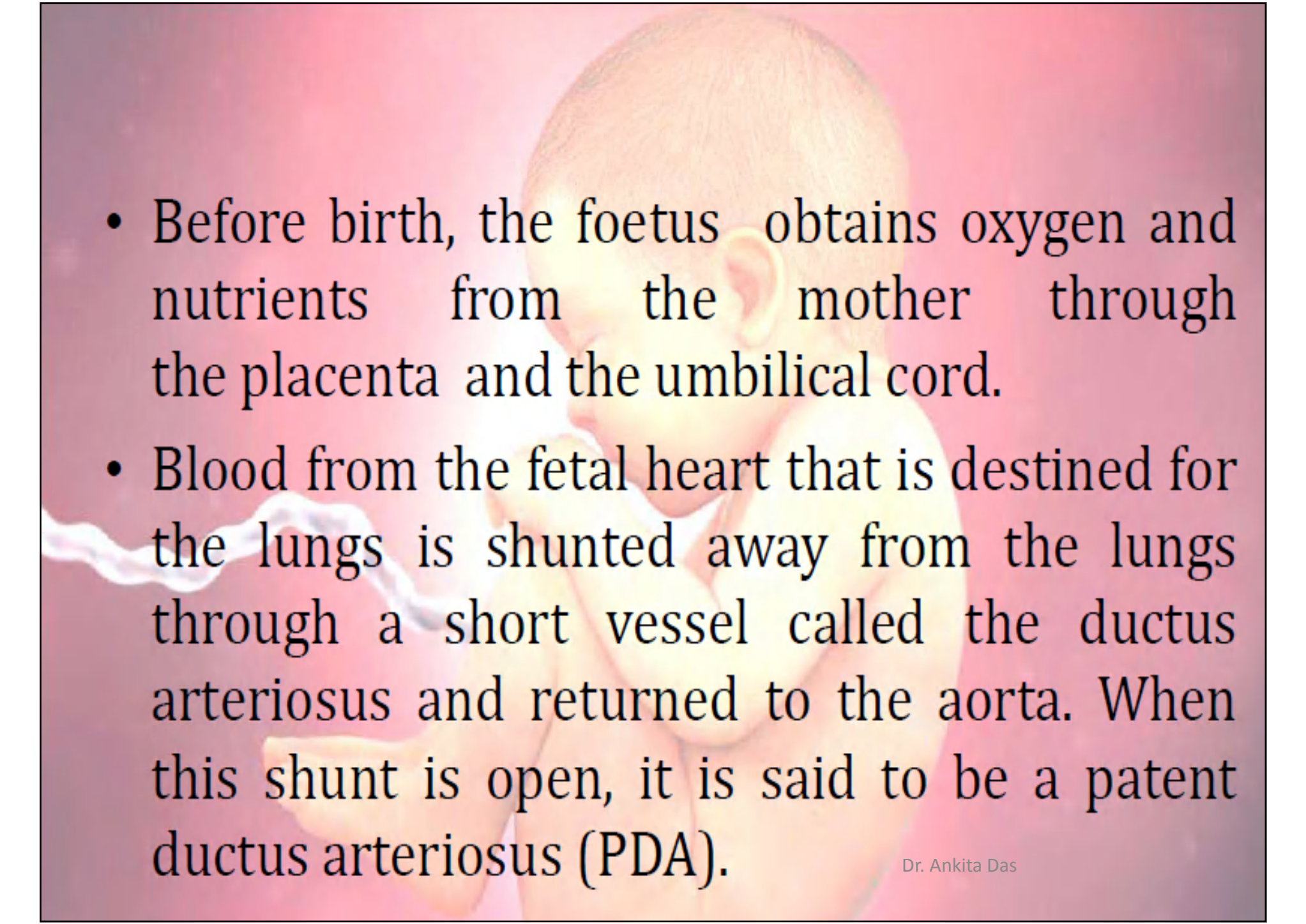
## • The Foetus:

It is the term used to refer to a prenatal mammal between it's embryonic state and it's birth.

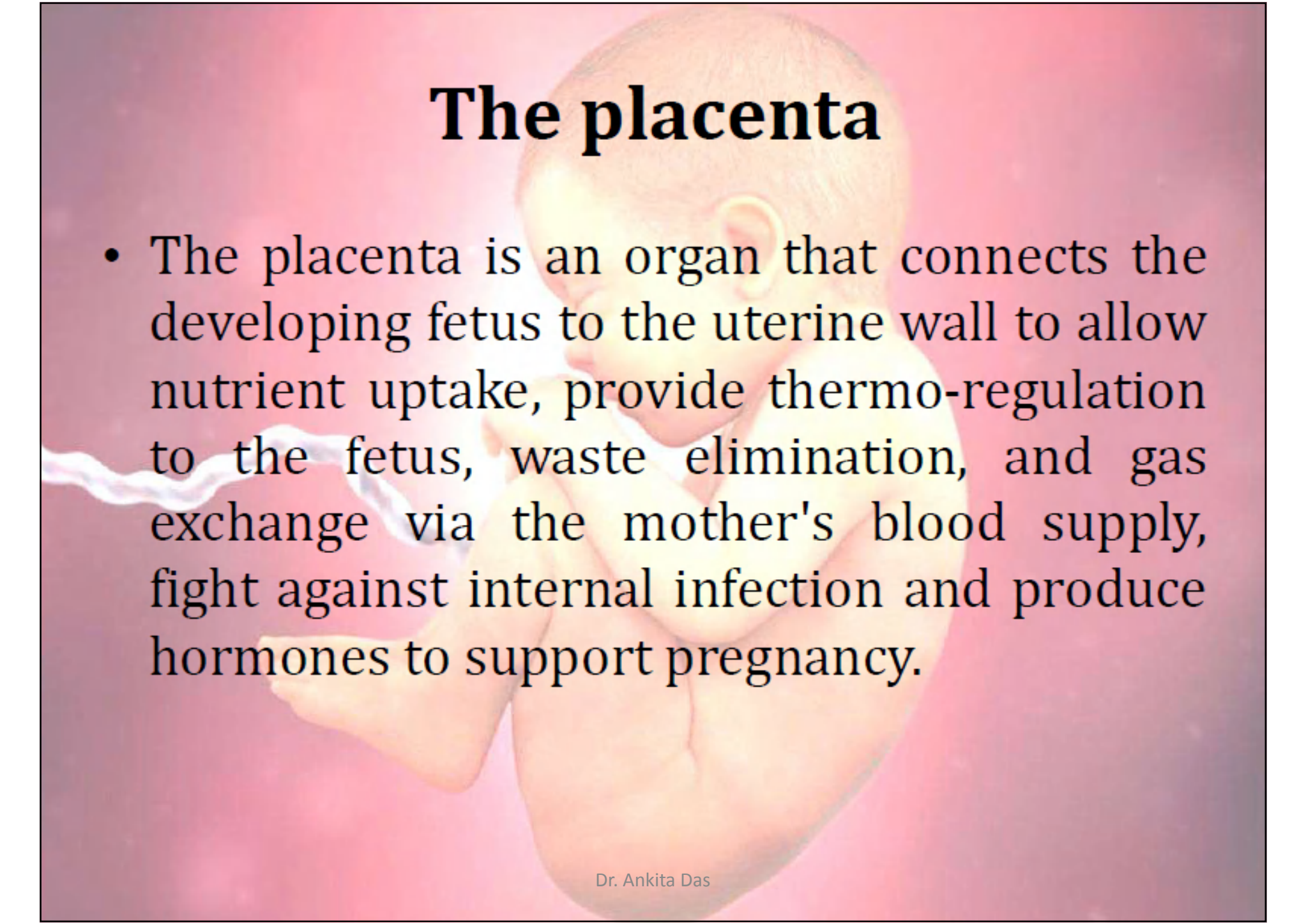
## • The Placenta:

The organ in human mother responsible for the supplying of oxygen and nutritive material to the fetus and for the elimination of CO<sub>2</sub> and nitrogenous waste out of the fetus.

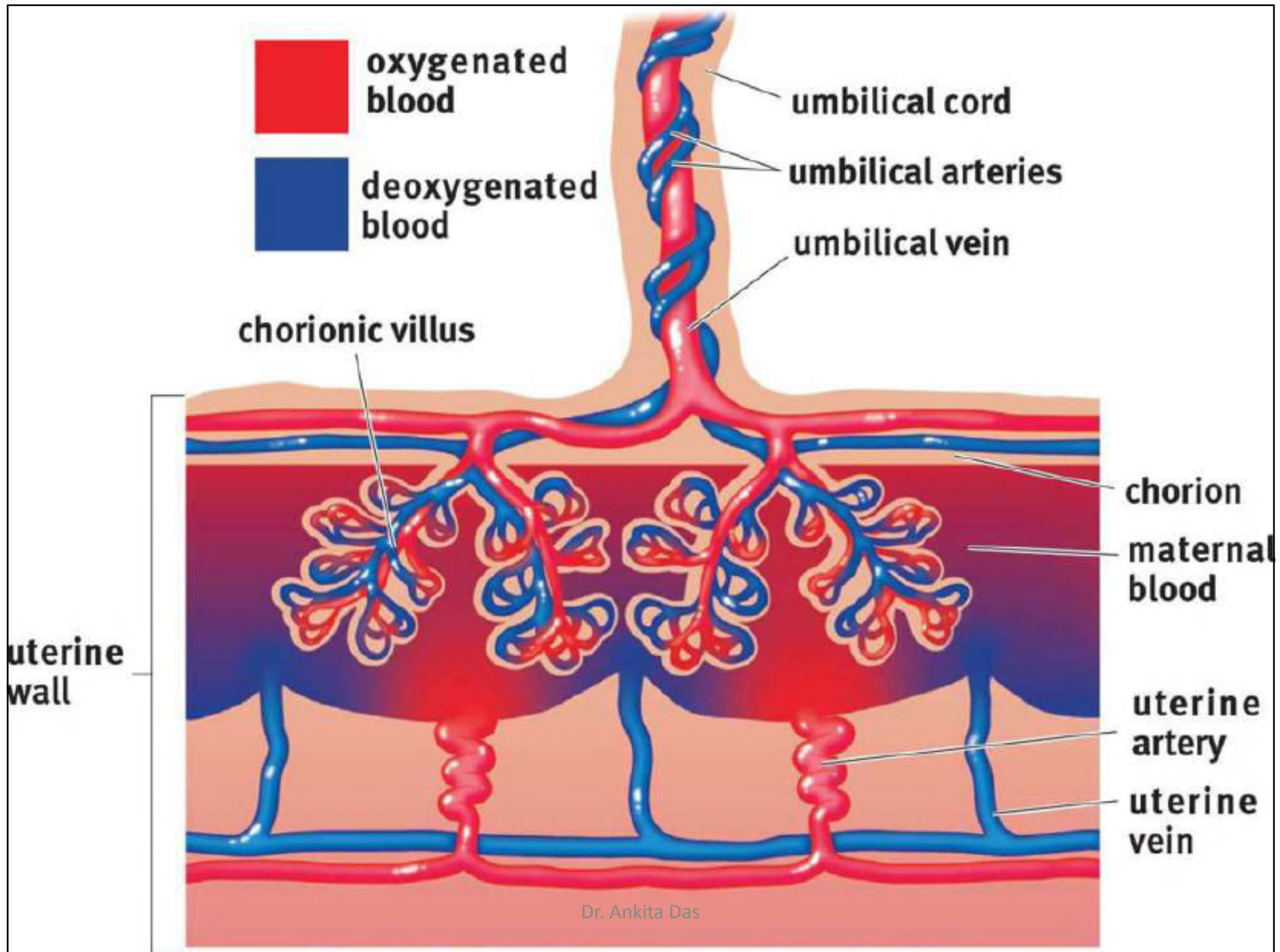
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- A medical illustration of a fetus in the womb, shown in profile. The fetus is curled, and the umbilical cord is highlighted in a light blue color, extending from the fetus towards the left side of the frame. The background is a soft, pinkish-red gradient.
- The **fetal circulation** is the circulatory system of a **fetus**.
  - The term usually include the entire fetoplacental **circulation**, which includes the umbilical cord and the blood vessels within the placenta that carry **fetal** blood.

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- Before birth, the foetus obtains oxygen and nutrients from the mother through the placenta and the umbilical cord.
  - Blood from the fetal heart that is destined for the lungs is shunted away from the lungs through a short vessel called the ductus arteriosus and returned to the aorta. When this shunt is open, it is said to be a patent ductus arteriosus (PDA).

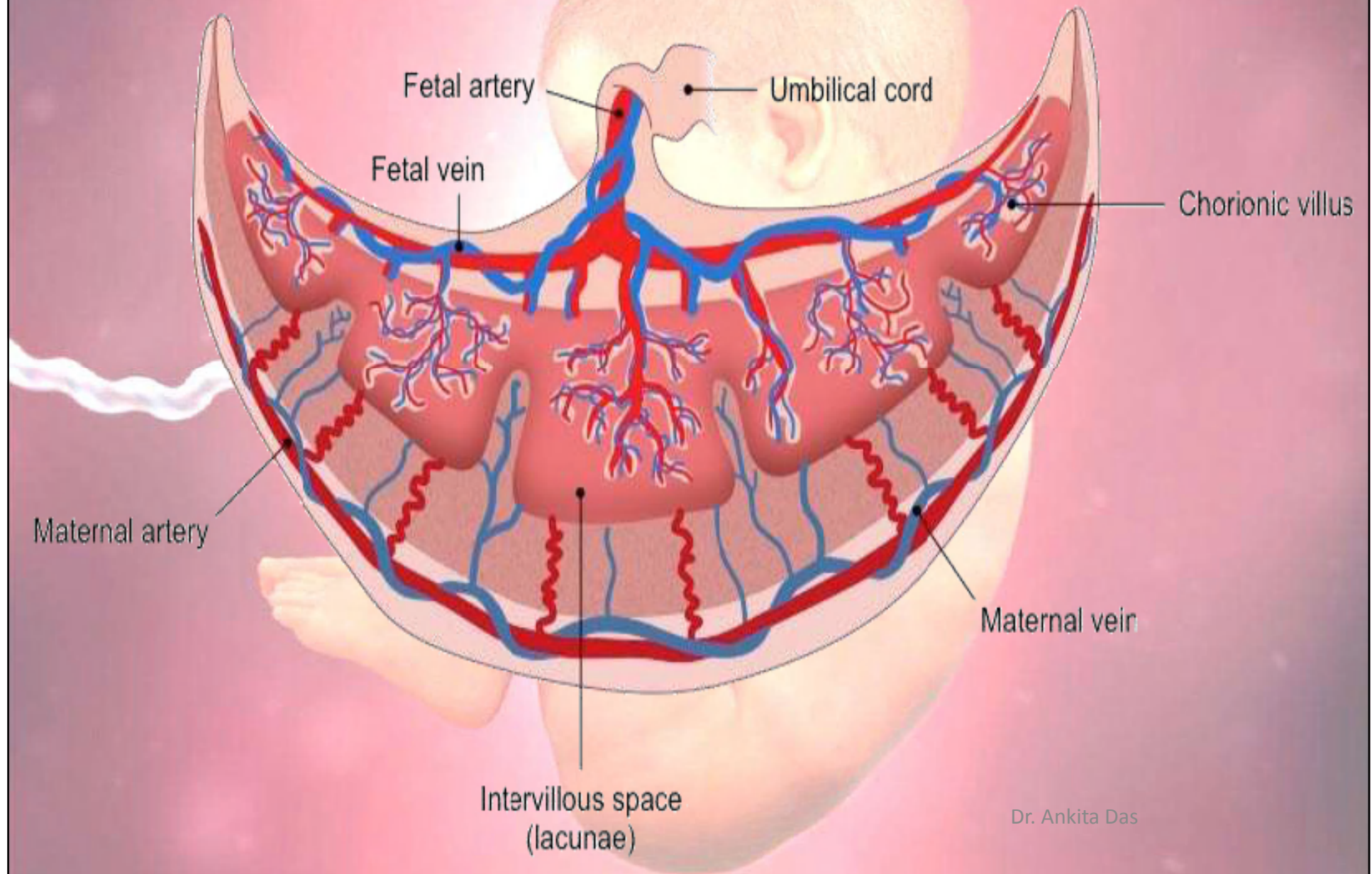
# The placenta



- The placenta is an organ that connects the developing fetus to the uterine wall to allow nutrient uptake, provide thermo-regulation to the fetus, waste elimination, and gas exchange via the mother's blood supply, fight against internal infection and produce hormones to support pregnancy.



# PLACENTA



# Placental Role

- The core concept behind foetal circulation is that **foetal 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 foetus.
- 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.**
- Water, glucose, amino acids, vitamins, and inorganic salts freely diffuse across the placenta along with oxygen.
- The **umbilical arteries carry blood to the placenta**, and the blood permeates the sponge-like material there. Oxygen then diffuses from the placenta to the chorionic villus, an alveolus-like structure, where it is then carried to the umbilical vein.

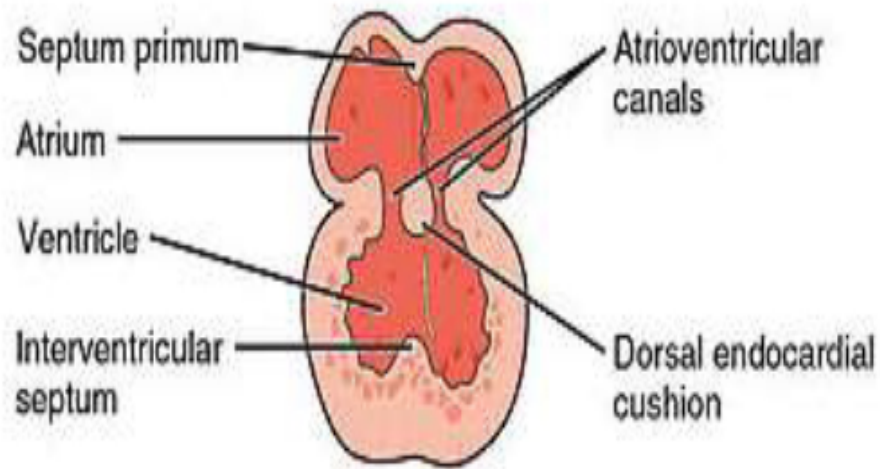


# Special Structures

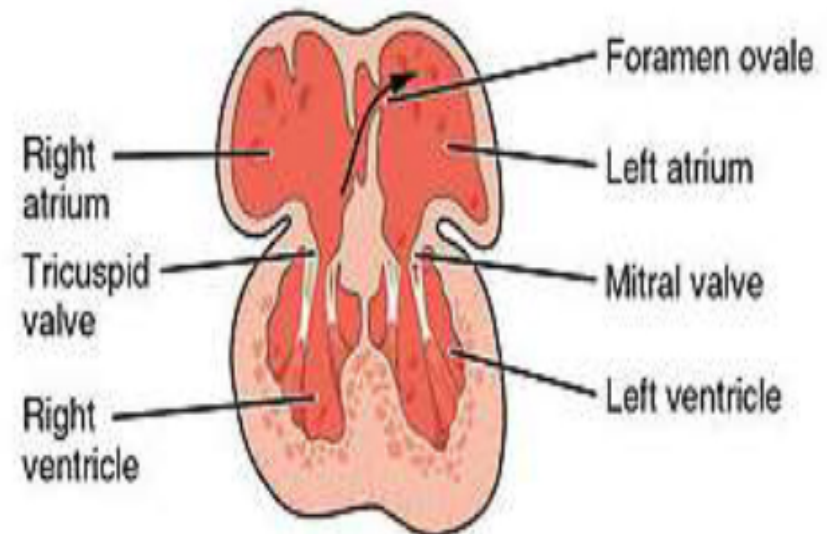
- Connection between the **right and left atria** via the **foramen ovale**
- Connection between the **truncus pulmonalis and the aorta** via the **ductus arteriosus**
- The **ductus venosus** shunts most of the left umbilical vein blood flow directly to the inferior vena cava. Thus, it allows oxygenated blood from the placenta to bypass the liver.
- The **hypogastric arteries** enter the umbilical cord and then known as the **umbilical arteries**.

# Foetus heart starts beating on 18<sup>th</sup> to 22<sup>nd</sup> day

## Partitioning of the heart into four chambers



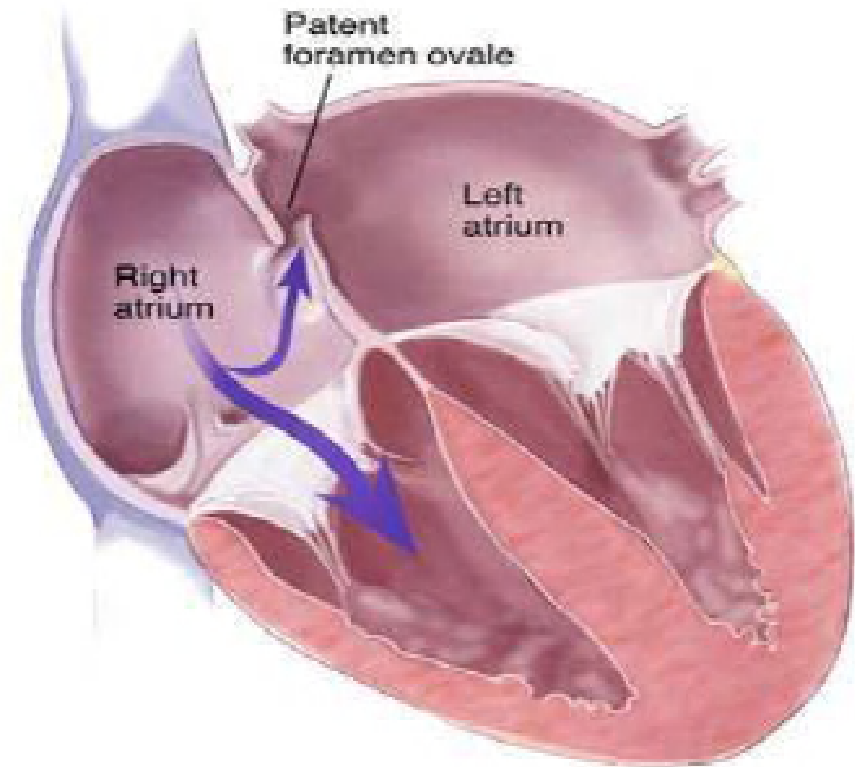
28 days



8 weeks

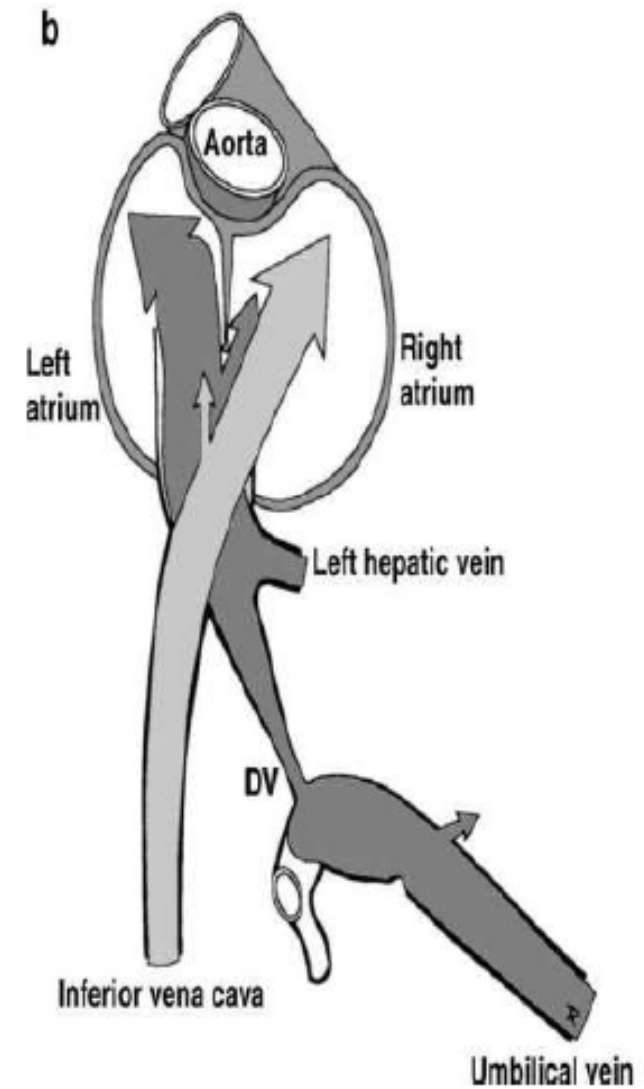
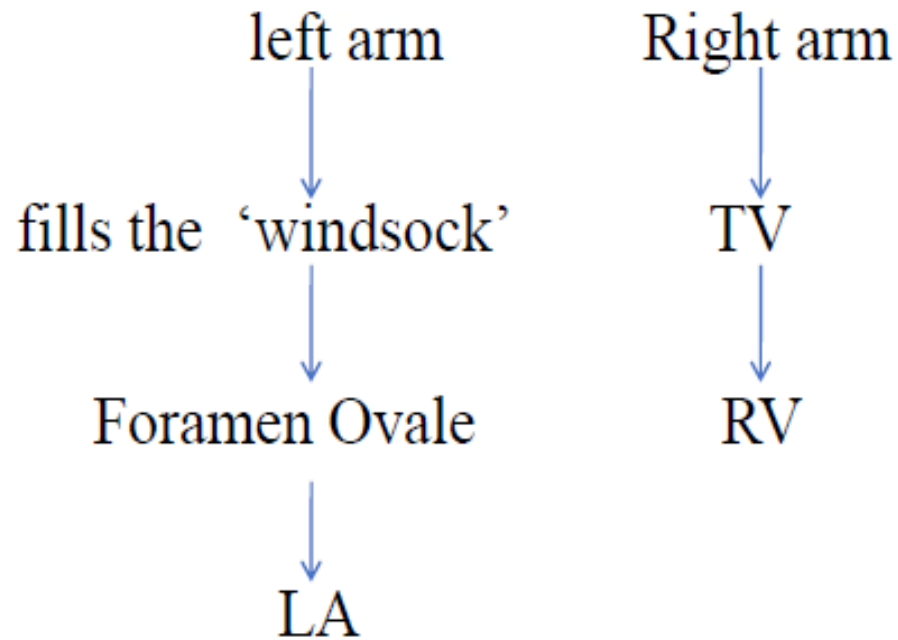
# Foramen Ovale

- Formed by the overlapping edge of the septum secundum against the ruptured upper portion of the septum primum.
- Acts like a flap valve for preferential blood flow from the right atrium to the left atrium.



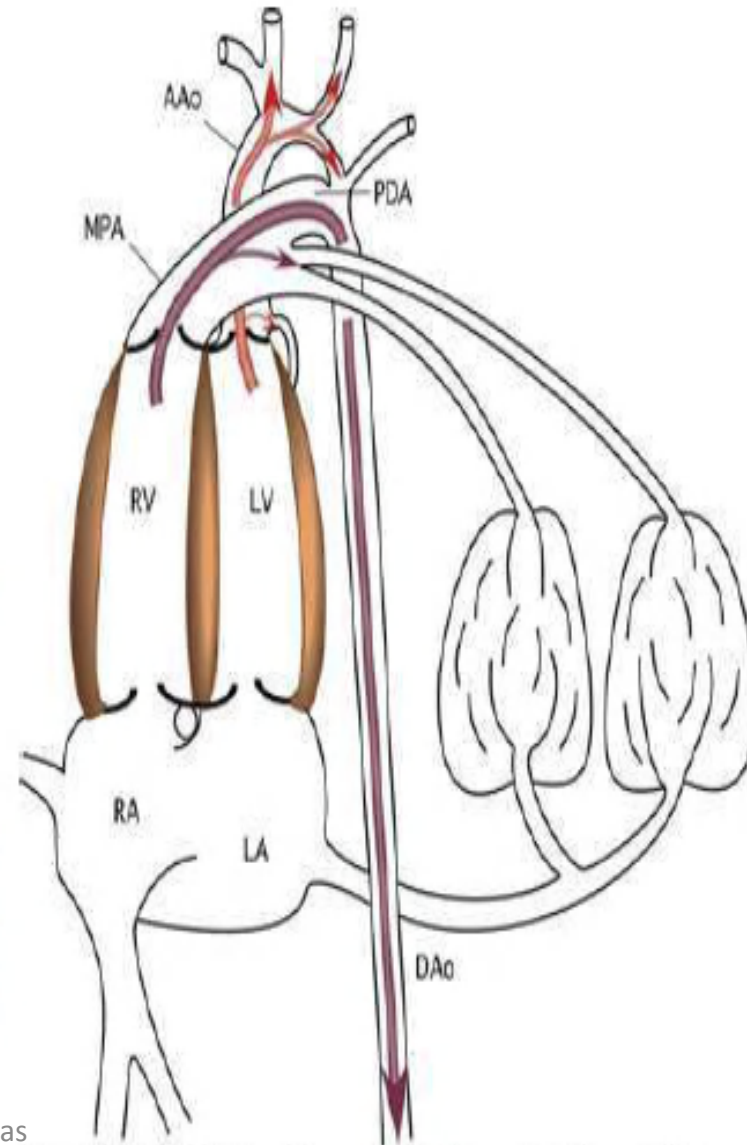
# • Foramen Ovale

- Blood column in IVC inlet (to RA)
- hits the interatrial ridge, the crista dividens



# Ductus Arteriosus

- Connects the left branch of the pulmonary trunk to arch of aorta(beyond the origin of left subclavian artery)
- It protects the lungs from circulatory overloading.
- Less oxygenated blood in Pulmonary artery flows through **Ductus Arteriosus** to descending aorta and then to placenta for oxygenation



# Vena-caval Circulation

## Superior Vena Cava

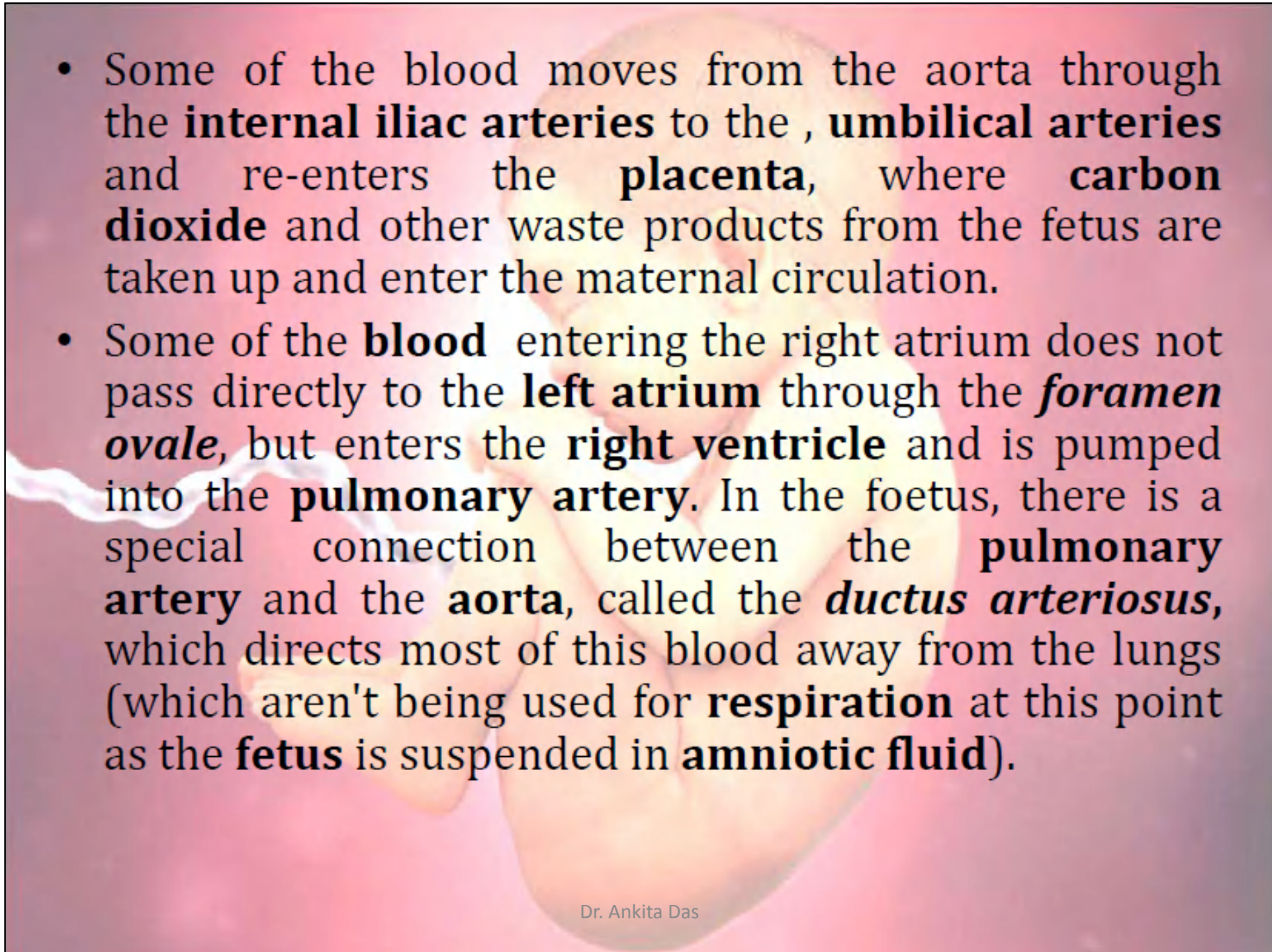
- Drains the upper part of the body, including the brain (15% of combined ventricular output).
- Most (95%) of SVC blood goes to the Right Ventricle.
- **SVC SpO<sub>2</sub>- 40%**

## Inferior Vena Cava

- Drains lower part of body and placenta (70% of combined ventricular output)
- Most of IVC blood is directed to the LA through Foramen ovale.
- **IVC SpO<sub>2</sub> -Inlet- 70%**  
**Distal- 35%**

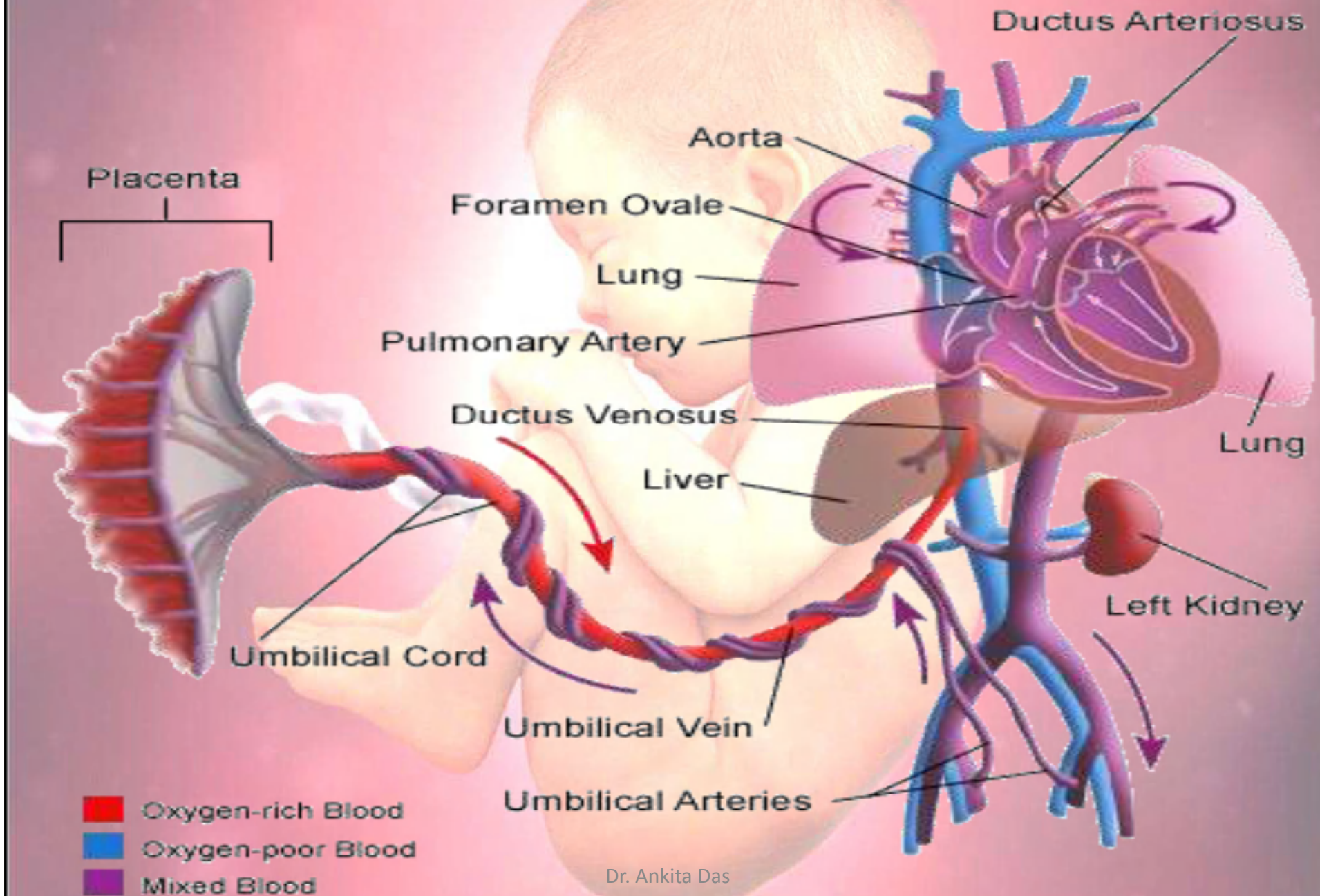
# Circuit

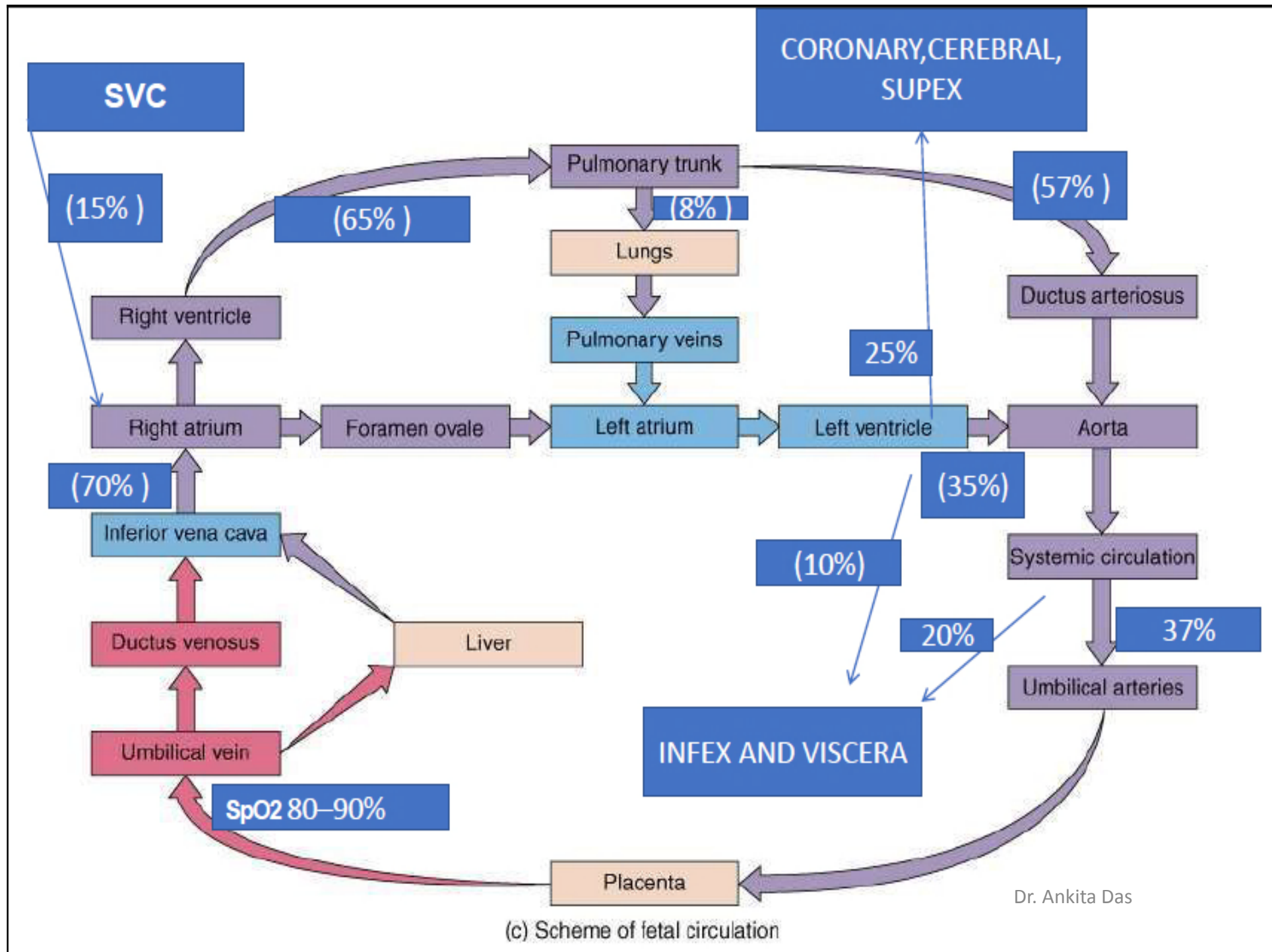
- Blood from the placenta is carried to the foetus by the umbilical vein. Less than a third of this enters the **foetal ductus venosus** and is carried to the **inferior venacava**, while the rest enters the liver proper from the inferior border of the liver.
- The branch of the umbilical vein that supplies the right lobe of the liver first joins with the portal vein. The blood then moves to the right atrium of the heart. In the foetus, there is an opening between the right and left atrium (the **foramen ovale**), and most of the blood flows through this hole directly into the left atrium from the right atrium, thus bypassing pulmonary circulation.
- The continuation of this blood flow is into the left ventricle, and from there it is pumped through the aorta into the body.

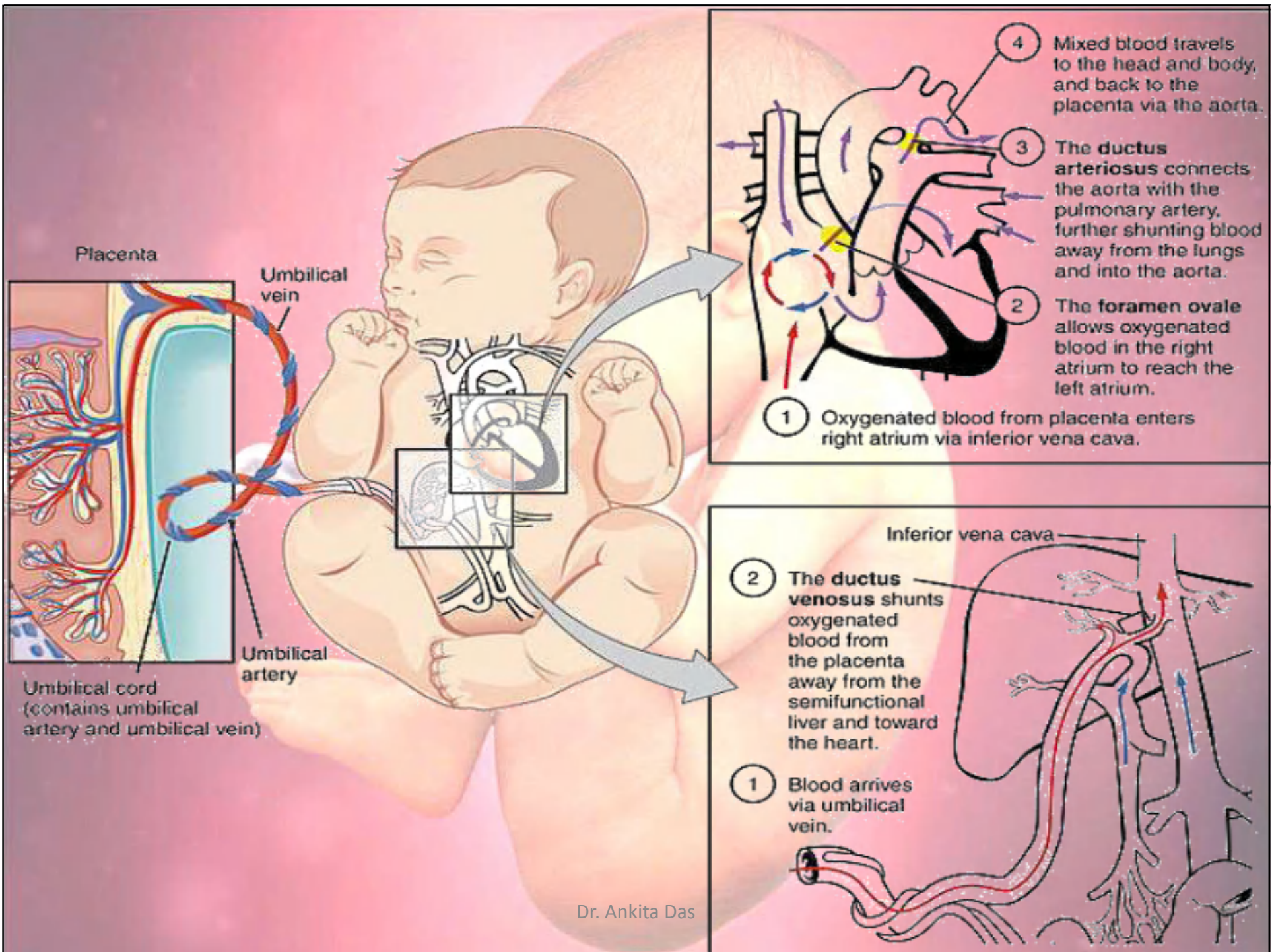
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- Some of the blood moves from the aorta through the **internal iliac arteries** to the , **umbilical arteries** and re-enters the **placenta**, where **carbon dioxide** and other waste products from the fetus are taken up and enter the maternal circulation.
  - Some of the **blood** entering the right atrium does not pass directly to the **left atrium** through the *foramen ovale*, but enters the **right ventricle** and is pumped into the **pulmonary artery**. In the foetus, there is a special connection between the **pulmonary artery** and the **aorta**, called the *ductus arteriosus*, which directs most of this blood away from the lungs (which aren't being used for **respiration** at this point as the **fetus** is suspended in **amniotic fluid**).



# Fetal Circulation







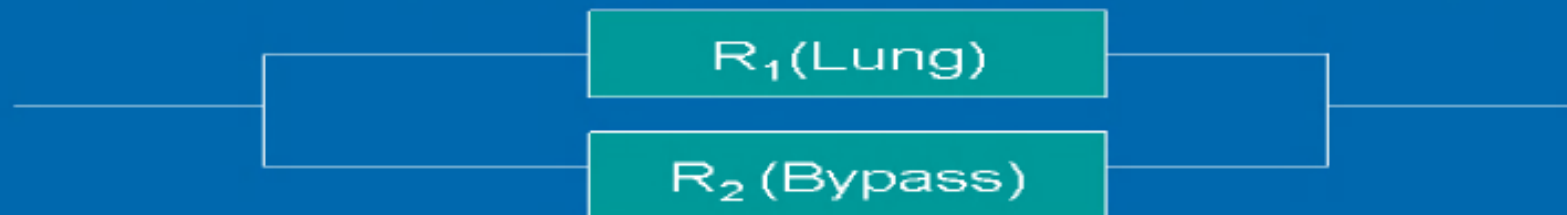
# What happens at birth?

## The change from fetal to postnatal circulation happens very quickly.

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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  $R_1$  decreases and blood is directed through the lungs.

A newborn baby is shown in a fetal position, curled up. The baby's head is turned to the left, and its hands are near its face. A white umbilical cord is visible on the left side of the baby's back, extending towards the left edge of the frame. The background is a soft, pinkish-red gradient. The text is overlaid on the left side of the image.

## 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

# The first breath:

Pulmonary alveoli open up:

- pressure in pulmonary tissues decrease.
- Blood from right heart rushes to fill the alveolar capillaries.
- Pressure in right side of heart ↓.
- Pressure in the left side of the heart ↑ (as more blood is returned from pulmonary tissue via pulmonary veins to the LA).

# Conversion of the fetal to the adult circulation requires

- Increase of pulmonary blood flow to a level necessary for adequate gas exchange
- Eliminating the umbilical-placental circulation
- separation of the left and right sides of the heart by closure of fetal channels.

# 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
Foramen 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 arteries → Umbilical ligaments
- Umbilical vein → Ligamentum teres



# Fetal Vs Infant Circulation

Fetal	Infant
<ul style="list-style-type: none"><li>• Low pressure system</li><li>• Right to left shunting</li><li>• Lungs non-functional</li><li>• Increased pulmonary resistance</li><li>• Decreased systemic resistance</li></ul>	<ul style="list-style-type: none"><li>• High pressure system</li><li>• Left to right blood flow</li><li>• Lungs functional</li><li>• Decreased pulmonary resistance</li><li>• Increased systemic resistance</li></ul>

	<b>FETAL</b>	<b>NEWBORN</b>
Gas exchange	Placenta	Lungs
RV,LV circuit	Parallel	Series
Pulmonary circulation	Vasoconstricted	Dilated
Fetal myocardium Contractility, Compliance	Less	Good
Dominant ventricle	Right	Left
Change in Structure	Umbilical vein Umbilical artery Ductus venosus Ductus arteriosus Foramen ovale	Ligamentum teres Medial umb ligament Ligamentum venosum Ligamentum arteriosum Fossa ovalis

## ☞ Closure of the Ductus Venosus:

1. Functional closure occurs within minutes of birth.
2. Structural closure occurs within 3 to 7 days.
3. After it closes, the remnant is known as ligamentum venosum.
4. Closure of ductus venosus is caused by strong contraction of muscle wall of ductus venosus, but the cause of this contraction is not revealed yet.

# ☞ Closure of the Ductus Arteriosus:

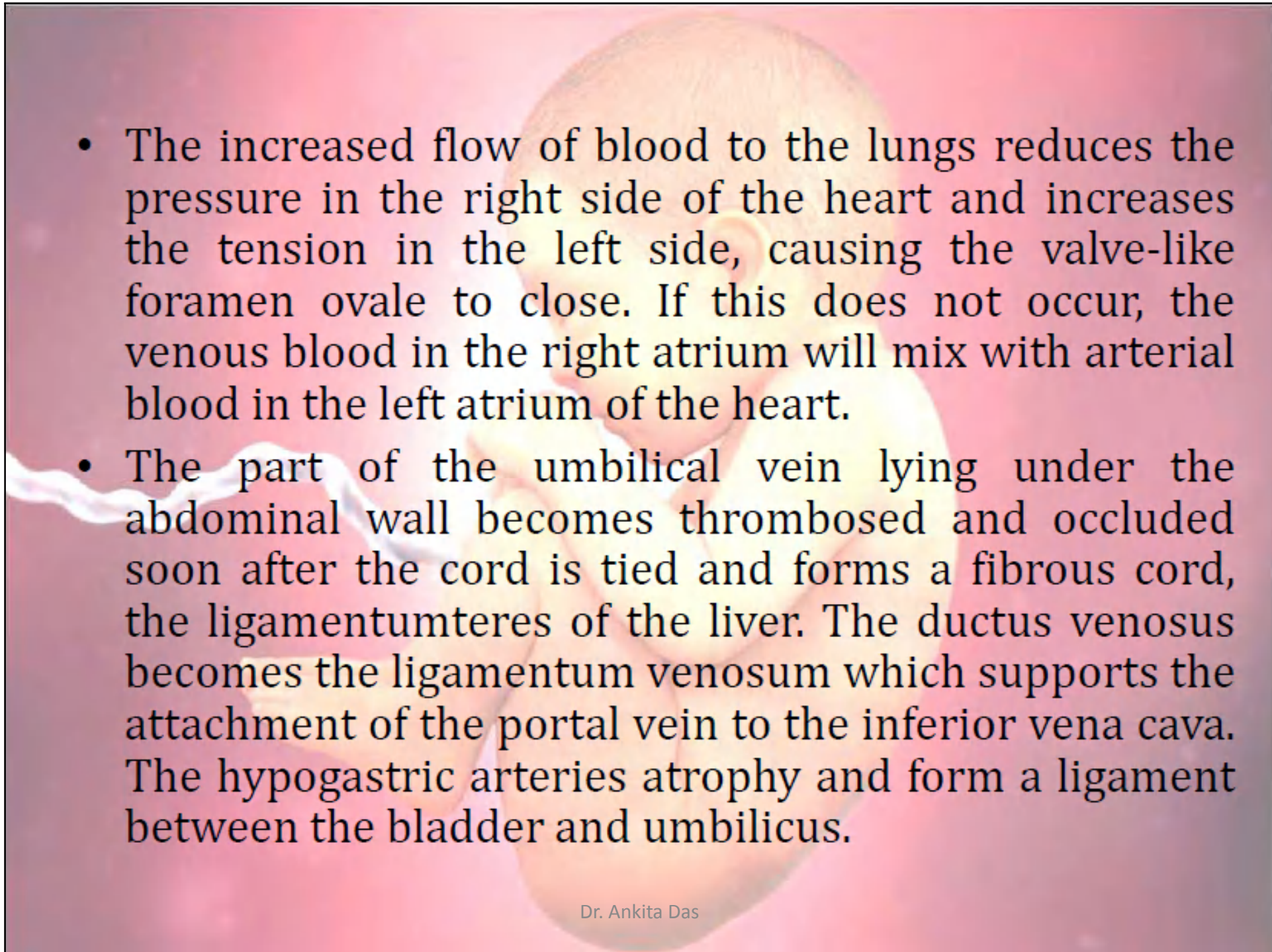
1. Closure of ductus arteriosus is by smooth muscle contraction.
2. It is further replaced by fibrous tissue, called ligamentum arteriosum.
3. At birth, opposite direction of blood flow from aorta to pulmonary artery supplies more oxygenated blood than before.
4. This contraction of smooth muscle occurs because of the increase in availability of oxygen.
5. The degree of smooth muscle contraction is highly dependant on more availability of oxygen.

# ☞ Closure of the Foramen Ovale:

1. Before birth the foramen ovale allows most of the oxygenated blood entering the right atrium from the Inferior Vena Cava to pass into the left atrium.
2. Closes at birth due to decreased flow from placenta and Inferior Vena Cava to hold open foramen.
3. More importantly because of increased pulmonary blood flow and pulmonary venous return to left heart causing the pressure in the left atrium to be higher than in the right atrium.
4. The increased left atrial pressure then closes the foramen ovale against the septum secundum (between right and left atrium).
5. The output from the right ventricle now flows entirely into the pulmonary circulation.

# Changes in the Circulation at Birth

- The changes which occur are not due to tying of the umbilical cord, but rather to establishment of respiration.
- When the infant cries, the lungs expand and their vascular field is increased; so the blood which has been passing through the ductus arteriosus to the aorta now flows through the pulmonary arteries to the lungs for oxygenation.
- Within a short period of from five to twenty minutes, the ductus arteriosus closes and eventually becomes a cardiac ligament. In a very small number of cases the ductus arteriosus remains patent.

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- The increased flow of blood to the lungs reduces the pressure in the right side of the heart and increases the tension in the left side, causing the valve-like foramen ovale to close. If this does not occur, the venous blood in the right atrium will mix with arterial blood in the left atrium of the heart.
  - The part of the umbilical vein lying under the abdominal wall becomes thrombosed and occluded soon after the cord is tied and forms a fibrous cord, the ligamentum teres of the liver. The ductus venosus becomes the ligamentum venosum which supports the attachment of the portal vein to the inferior vena cava. The hypogastric arteries atrophy and form a ligament between the bladder and umbilicus.

## Books to refer:

1. Medical Physiology, Guyton and Hall
2. Medical Physiology, Ganong
3. Marieb, Human Anatomy & Physiology
4. Tortora, Principles of Anatomy and Physiology: Organization, Support and Movement, and Control Systems of the Human Body



## **Practice Questions:**

1. Describe the special structures of the fetal circulation.
2. Draw and schematically describe the pathway of fetal blood flow.
3. Mention the role of placenta and the umbilical cord in fetal circulation.
4. Briefly explain the changes in fetal circulation after birth.
5. What phenomenon leads to the first breath of the newborn?
6. Differentiate between fetal and infant circulation.