Animal physiology-lecture (5)

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The Circulatory System

The circulatory system is extremely important in sustaining life. The functions of the circulatory system can be divided into **three broad areas:** transportation, regulation, and protection.

1. **Transportation**:

All of the substances essential for cellular metabolism are transported by the circulatory system. These substances can be categorized as **follows**:

A. **Respiratory**: Red blood cells, or erythrocytes, transport oxygen to the cells. In the lungs, oxygen from the inhaled air attaches to hemoglobin molecules within the erythrocytes and is transported to the cells for aerobic respiration. Carbon dioxide produced by cell respiration is carried by the blood to the lungs for elimination in the exhaled air.

B. **Nutritive**: The digestive system is responsible for the mechanical and chemical breakdown of food so that it can be absorbed through the intestinal wall into the blood and lymphatic vessels. The blood then carries these absorbed products of digestion through the liver to the cells of the body.

C. **Excretory**: Metabolic wastes (such as urea), excess water and ions, and other molecules not needed by the body are carried by the blood to the kidneys and excreted in the urine.

2. **Regulation**:

The circulatory system contributes to both hormonal and temperature regulation.

A. **Hormonal**: The blood carries hormones from their site of origin to distant target tissues where they perform a variety of regulatory functions.

B. **Temperature**: Temperature regulation is aided by the diversion of blood from deeper to more superficial cutaneous vessels or vice versa. When the ambient temperature is high, diversion of blood from deep

to superficial vessels helps cool the body, and when the ambient temperature is low, the diversion of blood from superficial to deeper vessels helps keep the body warm.

3. **Protection**: The circulatory system protects against blood loss from injury and against pathogens, including foreign microbes and toxins introduced into the body.

A. **Clotting**: The clotting mechanism protects against blood loss when vessels are damaged.

B. **Immune**: The immune function of the blood is performed by the leukocytes (white blood cells) that protect against many disease-causing agents (pathogens).

Major components of the circulatory system

The circulatory system consists of **two** subdivisions: the cardiovascular system and the lymphatic system. The **cardiovascular system** consists of the heart and blood vessels, and the **lymphatic system**, which includes lymphatic vessels and lymphoid tissues within the spleen, thymus, tonsils, and lymph nodes.

The term "**cardiac**" (as in cardiology) means "related to the heart". The **heart** is a four-chambered double pump. Its pumping action creates the pressure head needed to push blood through the vessels to the lungs and body cells. At rest, the heart of an adult pumps about 5 liters of blood per minute. At this rate, it takes about 1 minute for blood to be circulated to the most distal extremity and back to the heart. Blood vessels form a tubular network that permits blood to flow from the heart to all the living cells of the body and then back to the heart. The heart is composed of cardiac muscle, an involuntary muscle tissue that is found only within this organ. The cardiac muscle is self-exciting, meaning it has its own conduction system. This is in contrast with skeletal muscle, which requires either conscious or reflex nervous stimuli. The heart's rhythmic contractions occur spontaneously, although the frequency or heart rate can be changed by nervous or hormonal influence such as exercise or the perception of danger.

Arteries carry blood away from the heart, whereas **veins** return blood to the heart. Arteries and veins are continuous with each other through smaller blood vessels. Arteries branch extensively to form a "tree" of progressively smaller vessels. The smallest of the arteries are called **arterioles**.

Blood passes from the arterial to the venous system in microscopic **capillaries**, which are the thinnest and most numerous of the blood vessels. All exchanges of fluid, nutrients, and wastes between the blood and tissues occur across the walls of capillaries. Blood flows through capillaries into microscopic veins called **venules**, which deliver blood into progressively larger veins that eventually return the blood to the heart. As blood plasma (the fluid portion of the blood) passes through capillaries, the hydrostatic pressure of the blood forces some of this fluid out of the capillary walls. Fluid derived from plasma that passes out of capillary walls into the surrounding tissues is called **tissue fluid**, or **interstitial fluid**. Some of this fluid returns directly to capillaries, and some enters into lymphatic vessels located in the connective tissues around the blood vessels. Fluid in lymphatic vessels is called **lymph**. This fluid is returned to the venous blood at specific sites. Lymph nodes, positioned along the way cleanse the lymph prior to its return to the venous blood. The lymphatic system is thus considered a part of the circulatory system.

Pulmonary and Systemic Circulations

Blood whose oxygen content has become partially depleted and whose carbon dioxide content has increased as a result of tissue metabolism returns to the right atrium. This blood then enters the right ventricle, which pumps it into the pulmonary trunk and pulmonary arteries.

The **pulmonary arteries** branch to transport blood to the lungs, where gas exchange occurs between the lung capillaries and the air sacs (alveoli) of the lungs. Oxygen diffuses from the air to the capillary blood, while carbon dioxide diffuses in the opposite direction. The blood that returns to the left atrium by way of the pulmonary veins is therefore enriched in oxygen and

partially depleted of carbon dioxide. The path of blood from the heart (right ventricle), through the lungs, and back to the heart (left atrium) completes **one circuit:** the **pulmonary circulation**. Oxygen-rich blood in the left atrium enters the left ventricle and is pumped into a very large, elastic artery— the aorta. The aorta ascends for a short distance, makes a U-turn, and then descends through the thoracic (chest) and abdominal cavities. Arterial branches from the aorta supply oxygen-rich blood to all of the organ systems and are thus part of the **systemic circulation**. As a result of cellular respiration, the oxygen concentration is lower and the carbon dioxide concentration is higher in the tissues than in the capillary blood. Blood that drains from the tissues into the systemic veins is thus partially depleted of oxygen and increased in carbon dioxide content. These veins ultimately empty into two large veins—the superior and inferior venae cavae—that return the oxygen-poor blood to the right atrium. This completes the **systemic circulation**: from the heart (left ventricle), through the organ systems, and back to the heart (right atrium). The systemic and pulmonary circulations are illustrated in (figure 1).

Heart sounds closing of the atrioventricular (AV) valves and semilunar valves produces sounds that can be heard by listening through a stethoscope placed on the chest. These sounds are often verbalized as “lub-dub.” The “lub,” or first sound, is produced by closing of the AV valves during isovolumetric contraction of the ventricles. The “dub,” or second sound, is produced by closing of the semilunar valves when the pressure in the ventricles falls below the pressure in the arteries. The first sound is thus heard when the ventricles contract at systole, and the second sound is heard when the ventricles relax at the beginning of diastole.

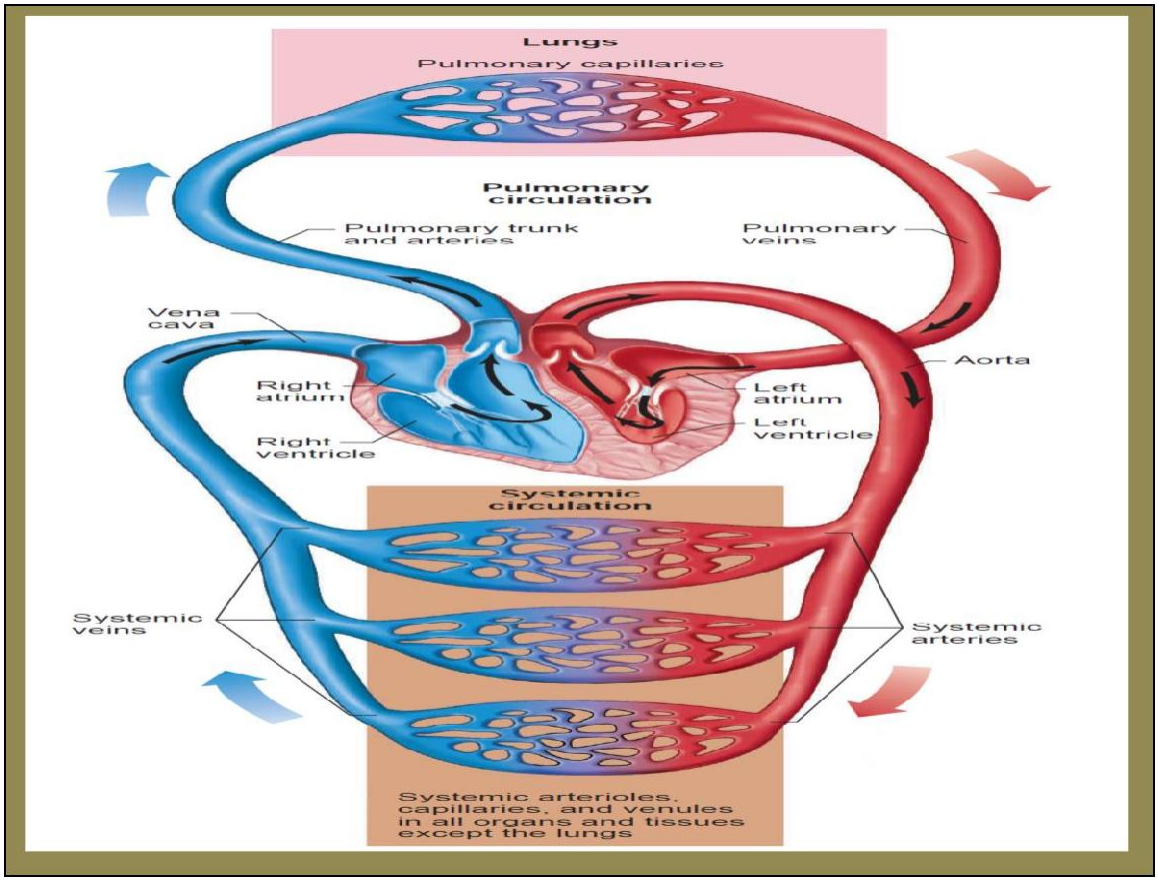

Figure 1: The systemic and pulmonary circulations. As depicted by the color change from blue to red, blood becomes fully oxygenated (red) as it flows through the lungs and then loses some oxygen (red to blue) as it flows through the other organs and tissues.