THE CIRCULATORY SYSTEM

Prof.Dr.Alaa A.Sawad

Introduction

The **circulatory** system is comprised of the heart, veins, capillaries, arteries, lymph vessels, and lymph glands, which work together to **supply** the body tissues with **nourishment** and **collect waste** materials.

Functions of the circulatory system:

Distribute **nutrients**,

Transport and exchange **oxygen** and **carbon dioxide**,

Remove **waste** materials,

Distribute **secretions** of endocrine glands,

Prevent excessive **bleeding**,

Prevent **infection**, and

Regulate body **temperature**.

Anatomy of the Heart

The **heart** is a funnel-shaped, hollow, muscular organ that is responsible for pumping blood to all parts of the body.

The heart is located near the center of the **thoracic** cavity between the lungs and is contained in the pericardial sac.

The pericardial sac supports the heart and contains some fluid for lubrication.

The broad end, or base, of the heart is also supported by large **arteries** and **veins**.

The pointed end, or apex, of the heart is directed toward the abdomen.

The wall of the heart consist of three layers.

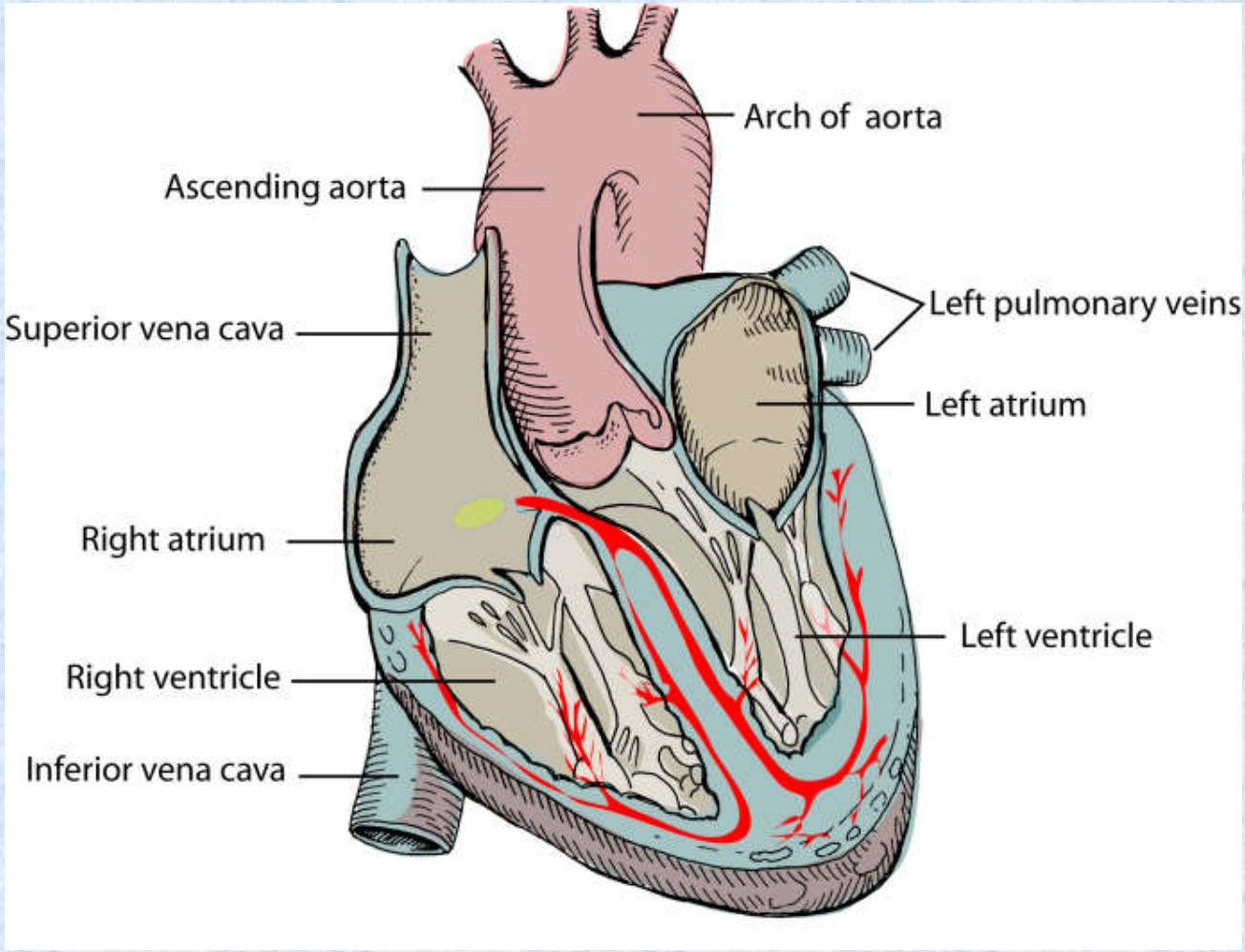
- **Epicardium** – outer layer of heart wall, which is also the inner layer of epicardial sac;
- **Endocardium** – inner layer that consists of endothelial cells, which line the heart, covers the heart valves, and lines the blood vessels.

- **Myocardium** – middle layer composed of cardiac muscle.

  The **cardiac** muscle is an **involuntary**, striated muscle with fibers that intertwine.

In mammals and birds, the heart is divided into a right and left side and each side is divided into an **atrium** and **ventricle**.

Therefore, the heart is said to have **four chambers** (right atrium, right ventricle, left atrium, and left ventricle).


Arch of aorta
Ascending aorta
Left pulmonary veins
Superior vena cava
Left atrium
Right atrium
Left ventricle
Right ventricle
Inferior vena cava

The **atrioventricular valves** (AV valve) separate the atrium and ventricle on each side of the heart.

The AV valves have flaps of tissues, called leaflets or cusps, which open and close to ensure that the blood flows only in one direction and does not backflow into the atriums.

The AV valve on the right side of the heart is called the **tricuspid** valve because it has three leaflets (cusps).

The AV valve on the left side of the heart is called the **bicuspid** valve (or mitral valve) because it has two leaflets.

The **pulmonary** valve and the **aortic** valve prevent blood from back-flowing into their respective **ventricles**.

The **pulmonary valve** is located between the right ventricle and the pulmonary artery.

The **aortic valve** is located between the left ventricle and the aortic artery.

Following the path that the blood takes as it flows through the heart and lungs is the best way to understand the heart's operation.

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A group of cells called the **sinoatrial node** (SA node) control the beat of the heart by sending out electrical signals to make the heart pump.

Anatomy of the Vascular System

The **vascular** system is made up of three types of blood **vessels**:

- Capillaries, and
- Arteries,
- Veins

Blood Vessels

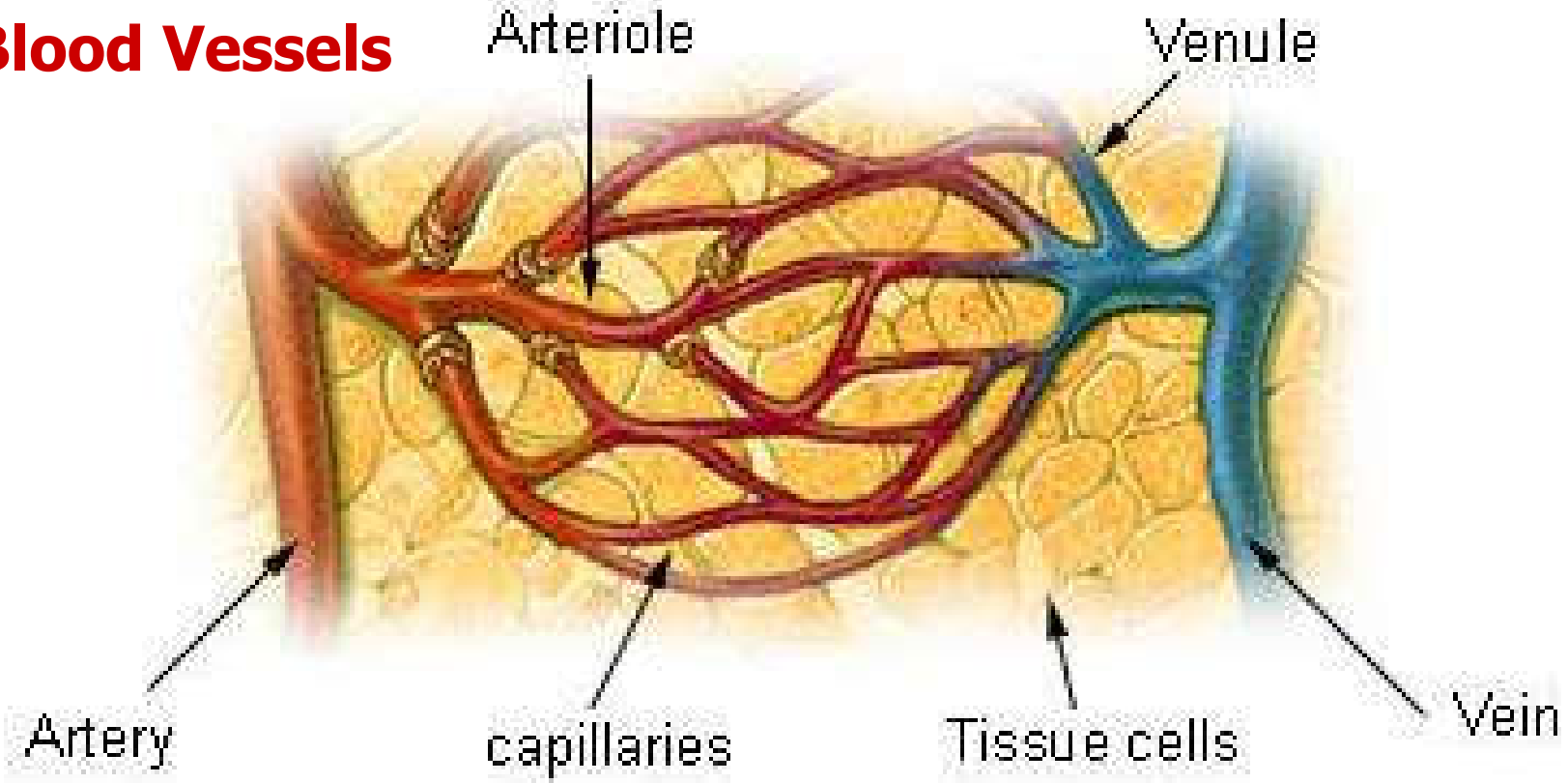


Photo from U. S. Federal Government courtesy of Wikipedia.

Arteries are blood vessels that carry blood, rich in oxygen, from the heart to other parts of the body.

The large arteries have thick walls of elastic-like tissue that enables them to withstand the blood pressure created by the heart's beating.

As the arteries extend away from the heart, they branch out into smaller arteries called **arterioles**.

The smaller arteries' walls are composed of large amounts of smooth muscle instead of the elastic tissue.

Arterioles branch into smaller vessels called **capillaries**.

At this junction, the arterioles have an especially thick layer of smooth muscle in their walls that carefully controls the amount of blood each capillary receives.

Blood pressure for the entire circulatory system is maintained by the tension at the end of the arterioles.

Shock is a serious condition that occurs when the arterioles dilate (relax) and allow a large volume of blood into the capillary beds.

The reduced blood flow that occurs with shock jeopardizes vital organs.

Capillaries are tiny, thin-walled blood vessels that connect arteries to veins and are located in all body tissues.

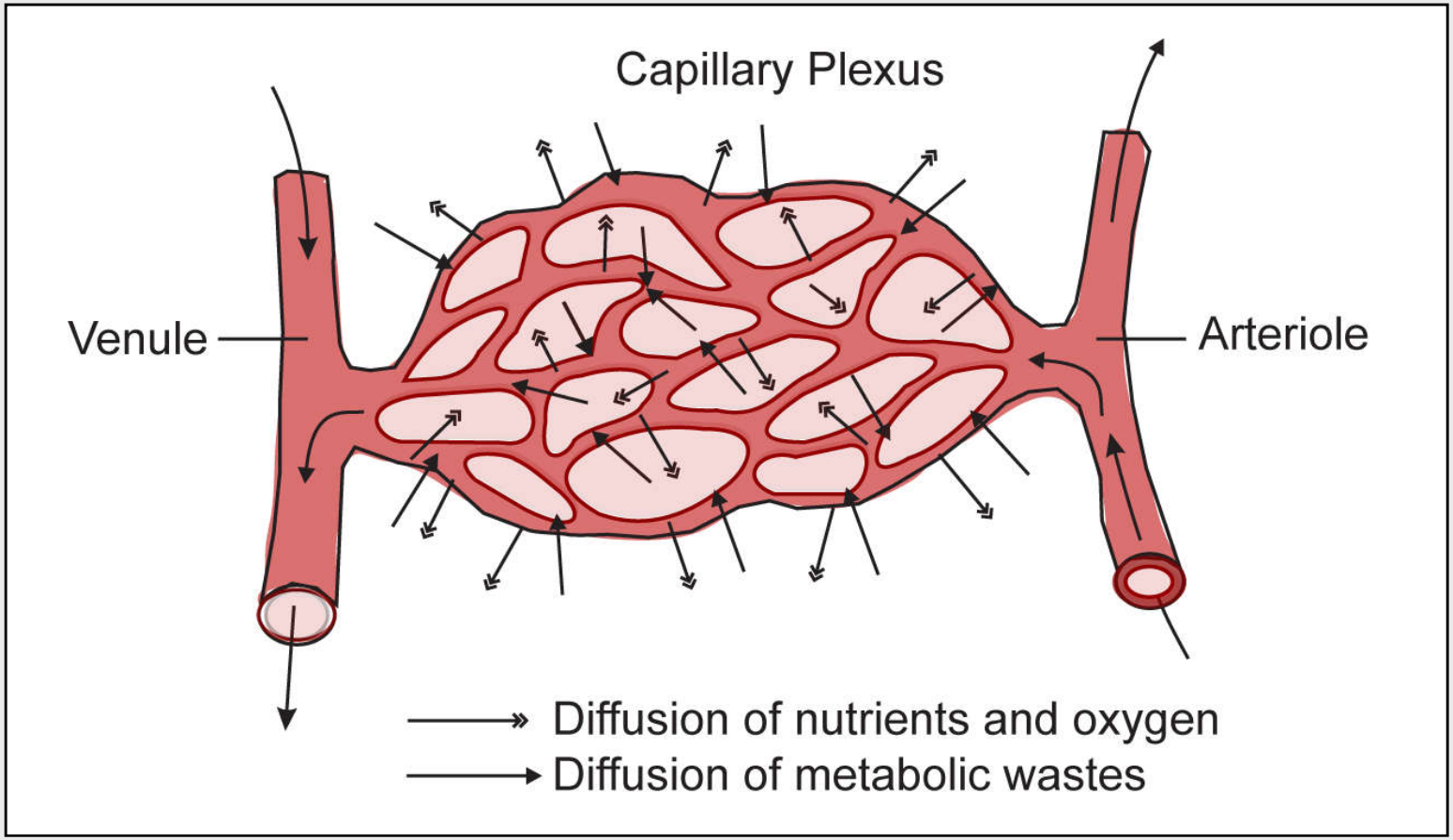
Capillaries are so small in diameter that blood cells pass through in a single file.

The semi-permeable membrane of capillary walls allows **nutrients**, **oxygen**, and **water** to diffuse from the blood to the tissues.

Waste products, like **carbon dioxide**, diffuse from the tissues into the blood.

Capillary Bed

Interaction of molecules flowing in and out of blood at a capillary bed.



Larger tubular connectors, which also connect arterioles to venules, are located within the capillary beds.

These tubules allow more blood to flow through an area, help warm tissues, and increase the return of blood pressure to the heart.

Once **blood** passes through the capillary beds, it begins its return to the heart.

Veins are the blood vessels that return blood to the heart from all parts of the body.

Capillaries unite to form small veins called **venules**.

The venules join together to form larger **veins**, which have thin walls and are collapsible.

For each artery, there is a much larger vein counterpart.

Veins have valves that aid the return flow of blood and prevent the blood from reversing flow.

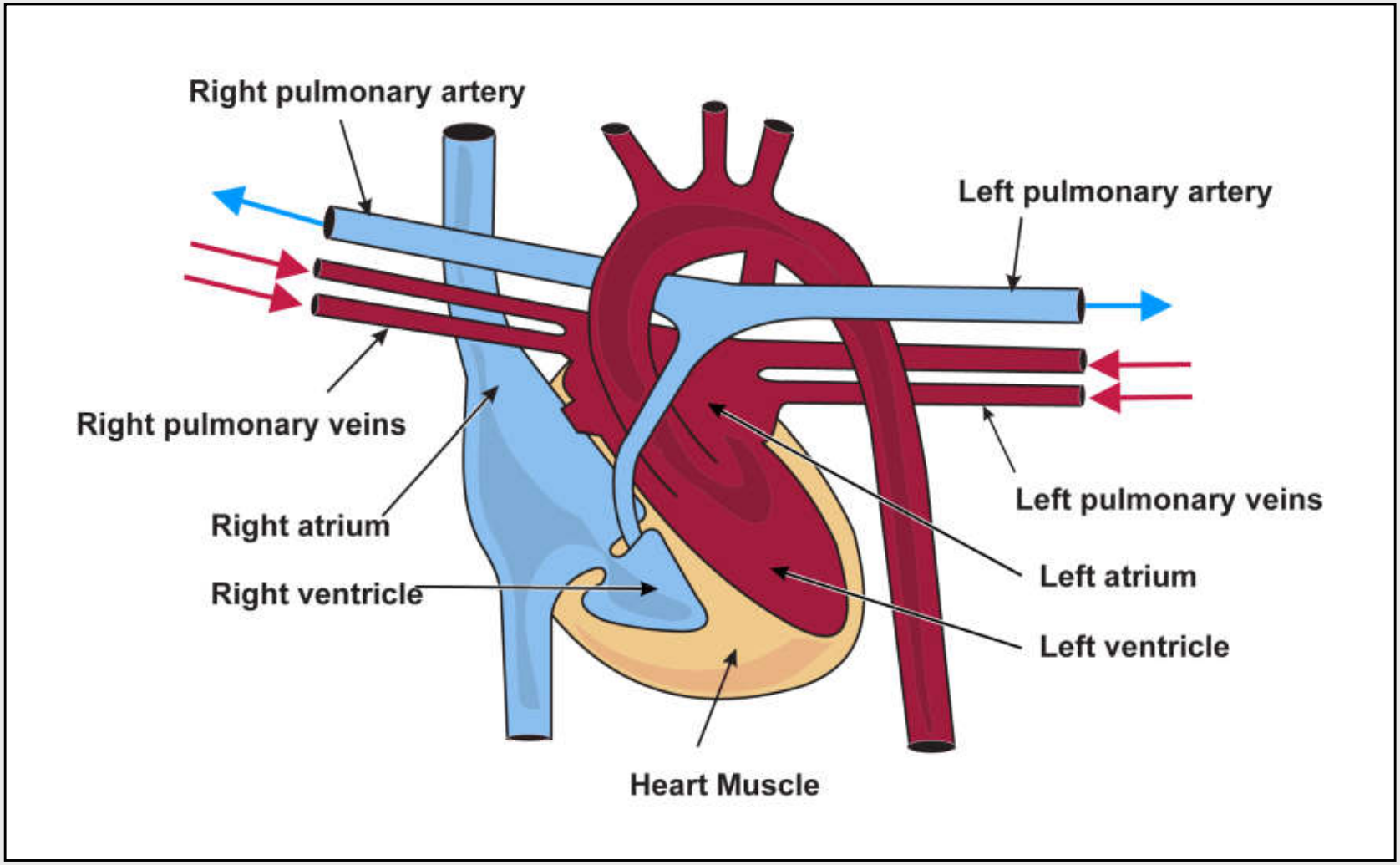
These valves allow for muscle contractions and movement of body parts.

The valves also assist the return flow of blood to the heart when blood pressure is low.

The total **circulatory system** is divided into two main parts:

- **Pulmonary** circulation, and
- **Systemic** circulation.

Pulmonary Circulation System



Red portion of heart and red blood vessels carry oxygen-rich blood.

Blue portion of heart and blue blood vessels carry oxygen-poor blood.

Pulmonary circulation is the part of the circulatory system that takes the blood from the heart to the lungs, where it is oxygenated, and returns it to the heart.

The main parts of the pulmonary circulation system include the heart, pulmonary arteries, capillaries of the lungs, and pulmonary veins.

Flow of Blood in Pulmonary Circulation

Blood that is low in oxygen returns to the heart through two large veins called the superior (or cranial) vena cava and the inferior (or caudal) vena cava.

The un-oxygenated blood enters the **right atrium** of the heart.

The blood then passes through the right atrioventricular (**tricuspid**) valve into the right ventricle.

The **right ventricle** pumps the blood through the **pulmonary valve** into the **pulmonary artery**.

The pulmonary artery quickly divides into two branches.

Each branch of the pulmonary artery carries blood to a **lung**.

In the lungs the pulmonary arteries branch into **capillaries** that surround the **alveoli**.

Through diffusion, carbon dioxide moves from the blood into the alveoli and oxygen moves from the alveoli into the blood.

The oxygenated blood then returns to the heart through the **pulmonary vein** into the **left atrium**.

From the **left atrium**, the blood flows through the left atrioventricular (**bicuspid**) valve into the **left ventricle**.

The thick-walled **left ventricle** pumps the blood through the **aortic valve** into the **aorta**.

The amount of pressure that is required for pulmonary circulation is much less than what is required for systemic circulation.

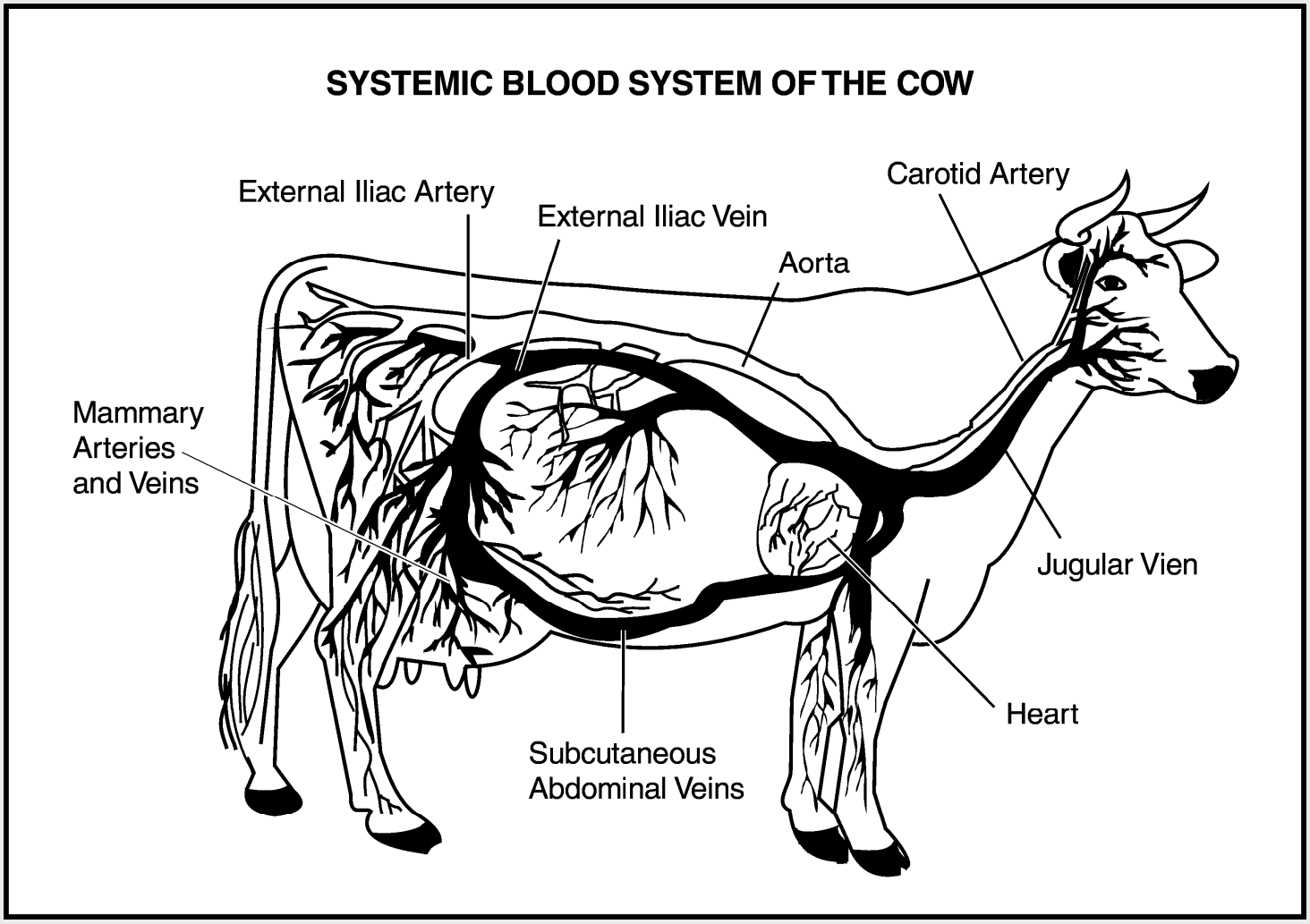
Therefore, the muscle mass developed in the right ventricle is much less that of the left ventricle**.**

Un-oxygenated blood is dark or brownish red, while oxygenated blood is bright red.

In the pulmonary system, un-oxygenated blood is carried by the pulmonary arteries and oxygenated blood is carried by pulmonary veins.

In the systemic system, arteries carry oxygenated blood and veins carry un-oxygenated blood.

The Systemic Circulation System



The **systemic circulation** includes the flow of oxygenated blood from the heart to the tissues in all parts of the body and the return of un-oxygenated blood back to the heart.

The **blood vessels**, including the **arteries**, **capillaries**, and **veins**, are the main parts of systemic circulation.

Through systemic circulation, oxygen and nutrients are delivered to the body tissues via the arteries.

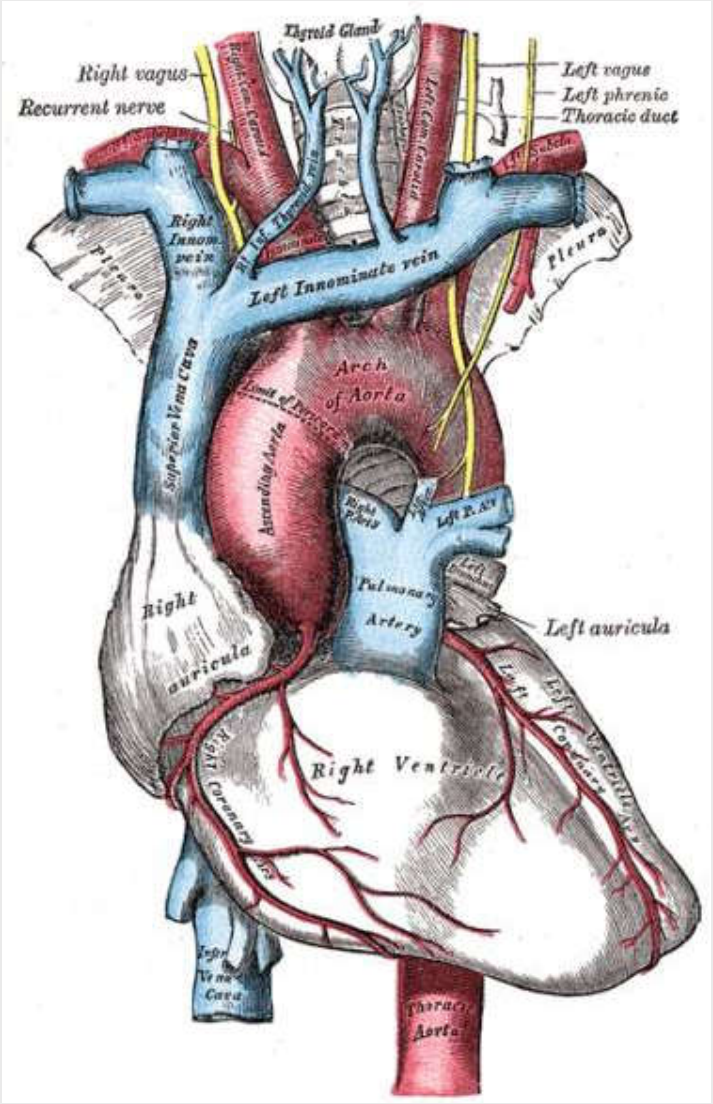
Blood is filtered during systemic circulation by the **kidneys** (most of the waste) and **liver** (sugars).

The systemic circulatory system is complex and its functions vary.

The systemic circulatory system is divided into subsystems for particular regions of the body.

The Flow of Blood Through the Systemic Circulatory System

Oxygenated blood leaves the left ventricle of the heart through the **aorta**, the largest artery in the body.



The left and right **coronary arteries** immediately branch from the aorta and carry fresh blood to the heart muscle itself.

The **coronary veins** quickly return that blood back to the heart.

The **brachiocephalic trunk** is the next branch from the aorta.

The **carotid arteries** branch off the brachiocephalic trunk and carry oxygenated blood to the neck and head region.

Blood from the neck and head region returned by the **jugular veins**.

The left and right **brachial arteries** also branch from the brachiocephalic trunk to supply blood to the shoulders and forelegs.

The **thoracic aorta** refers to the portion of the aorta that goes from the heart, through the thoracic cavity to the diaphragm.

The portion of the aorta that goes from the diaphragm, through the abdominal region, to the last lumbar vertebrae is called the **abdominal aorta**.

Branches from the thoracic aorta supply oxygenated blood to the lungs (via bronchial arteries), esophagus, ribs and diaphragm.

The **celiac artery** branches from the aorta immediately past the diaphragm and itself branches into the gastric, splenic, and hepatic arteries.

The **gastric artery** supplies blood to the stomach.

The **splenic artery** supplies blood to the spleen.

The **hepatic artery** supplies blood to the liver.

The cranial and caudal **mesenteric arteries** branch from the abdominal aorta and carry blood to the small and large intestines.

The **renal arteries** are next to branch from the abdominal aorta.

The renal arteries have two important functions:

- supply blood to the kidneys, and
- carry large volumes of blood to the kidneys for filtration and purification.

From the renal arteries arise arteries that supply blood to the testicles in males (**internal spermatic arteries**) and parts of the reproductive system in females (**uteroovarian arteries**).

The abdominal aorta ends where it branches into the internal and external iliac arteries.

The **internal iliac artery** supplies blood to the pelvic and hip region.

The **external iliac artery** branches into the femoral arteries.

The **femoral arteries** and their branches supply oxygenated blood to the hind legs.

Veins normally accompany arteries and often have similar names.

Veins are always larger than the arteries and are sometimes more visible than arteries because they are closer to the skin surface.

Most veins eventually empty the un-oxygenated blood into the vena cavas.

The **cranial veins** return the blood from the head, neck, forelegs, and part of the thoracic cavity to the right atrium of the heart via the **superior vena cava**.

These cranial veins include the **jugular vein**, **brachial veins**, **internal thoracic veins**, and the **vertebral veins**.

The **caudal veins** return blood from the **iliac**, **lumbar**, **renal**, and **adrenal veins** to the right atrium of the heart via the **inferior vena cava**.

Before blood is returned to the heart from the stomach, pancreas, small intestine, and spleen, it goes through the liver for filtration.

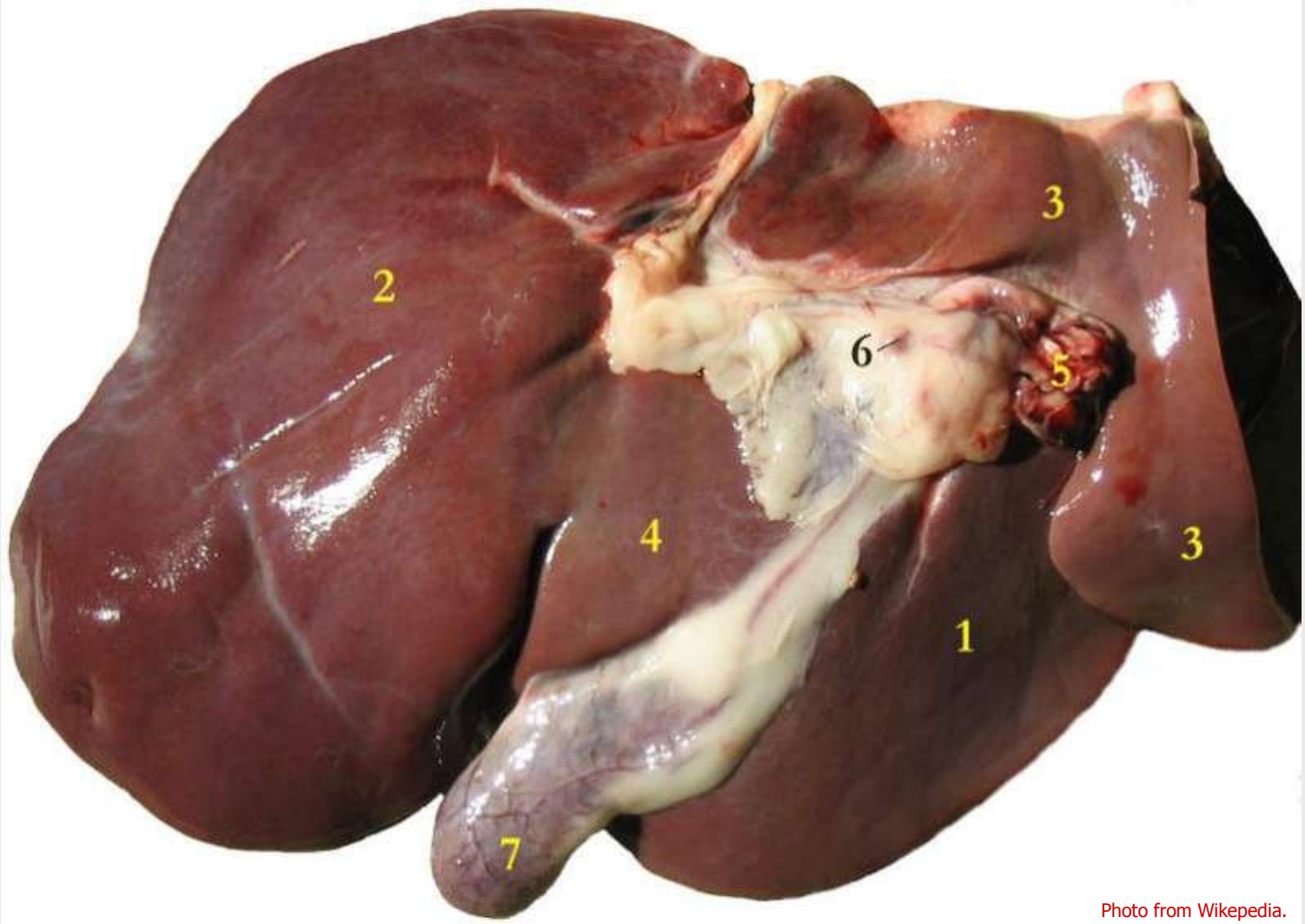
This portion of the systemic system is known as the hepatic portal system.

The **gastric vein** (stomach), **splenic vein** (spleen), **pancreatic vein** (pancreas), and **mesenteric veins** (small intestines) empty into the **portal vein** that carries the blood to the liver.

In the liver, the portal vein branches into smaller venules and finally into capillary beds.

In the capillary beds of the liver, nutrients are exchanged for storage and the blood is purified.

The capillaries then join into venules that empty into the **hepatic vein**, which carries blood to the inferior (caudal) vena cava.



Liver of a sheep: (1) right lobe, (2) left lobe, (3) caudate lobe, (4) quadrate lobe, (5) hepatic artery and portal vein, (6) hepatic lymph nodes, (7) gall bladder.

Anatomy of Lymphatic System

The **lymphatic system** is part of the immune system and acts as a secondary (accessory) circulatory system.

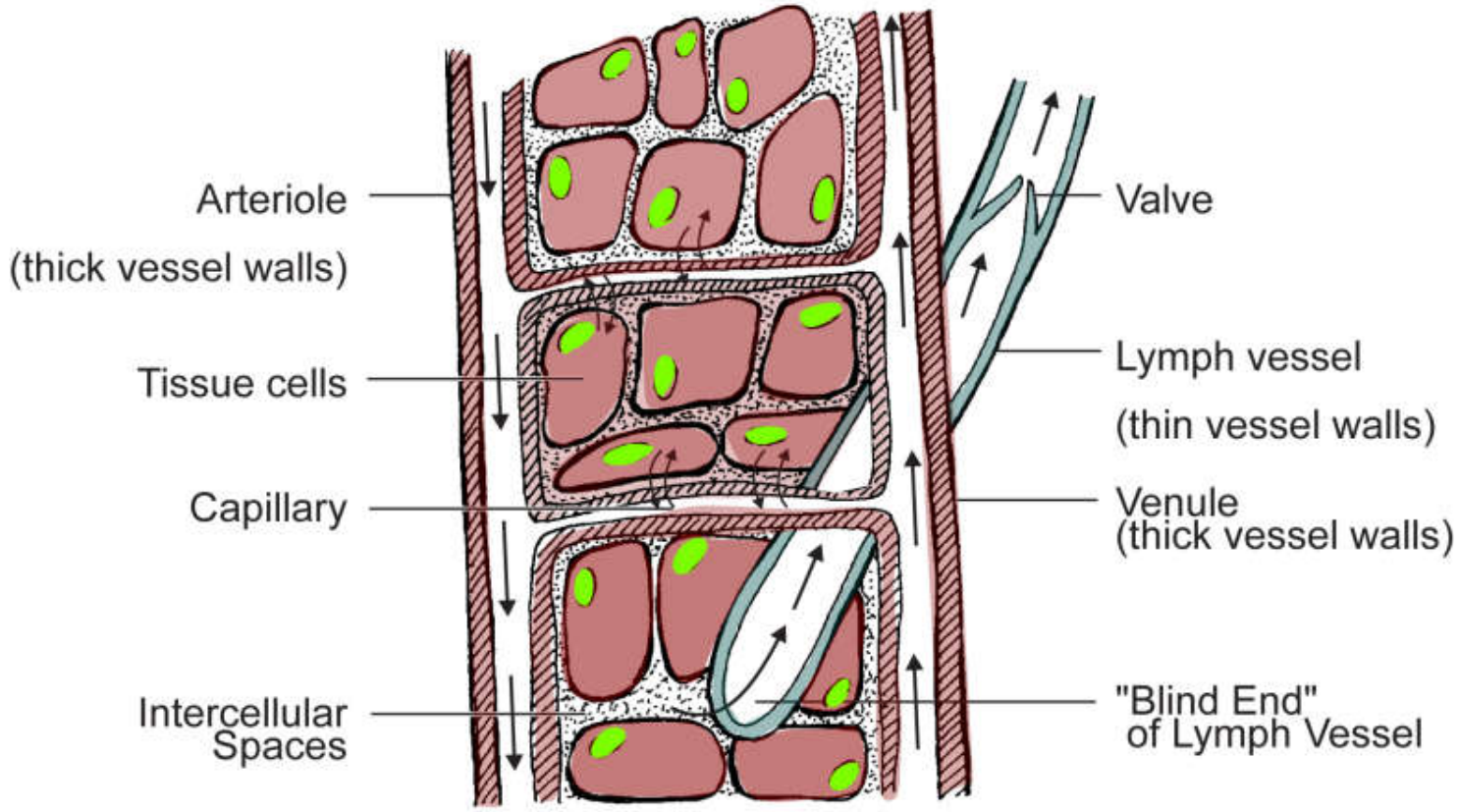
Functions of the lymphatic system:

- remove excess fluids from body tissues,
- absorb fatty acid and transport fat to circulatory system, and
- produce immune cells (lymphocytes, monocytes, and plasma cells).

Blood fluid escapes through the thin-walled capillaries into spaces between body tissue cells.

Lymph vessels, which have very thin walls, pick up these fluids called **lymph**.

Flow of Blood & Lymph Within Tissue



The lymph vessels join to form larger ducts that pass through **lymph nodes** (or glands).

Each lymph node has a fibrous outer covering (capsule), a cortex, and a medulla.

Lymph Node Structure

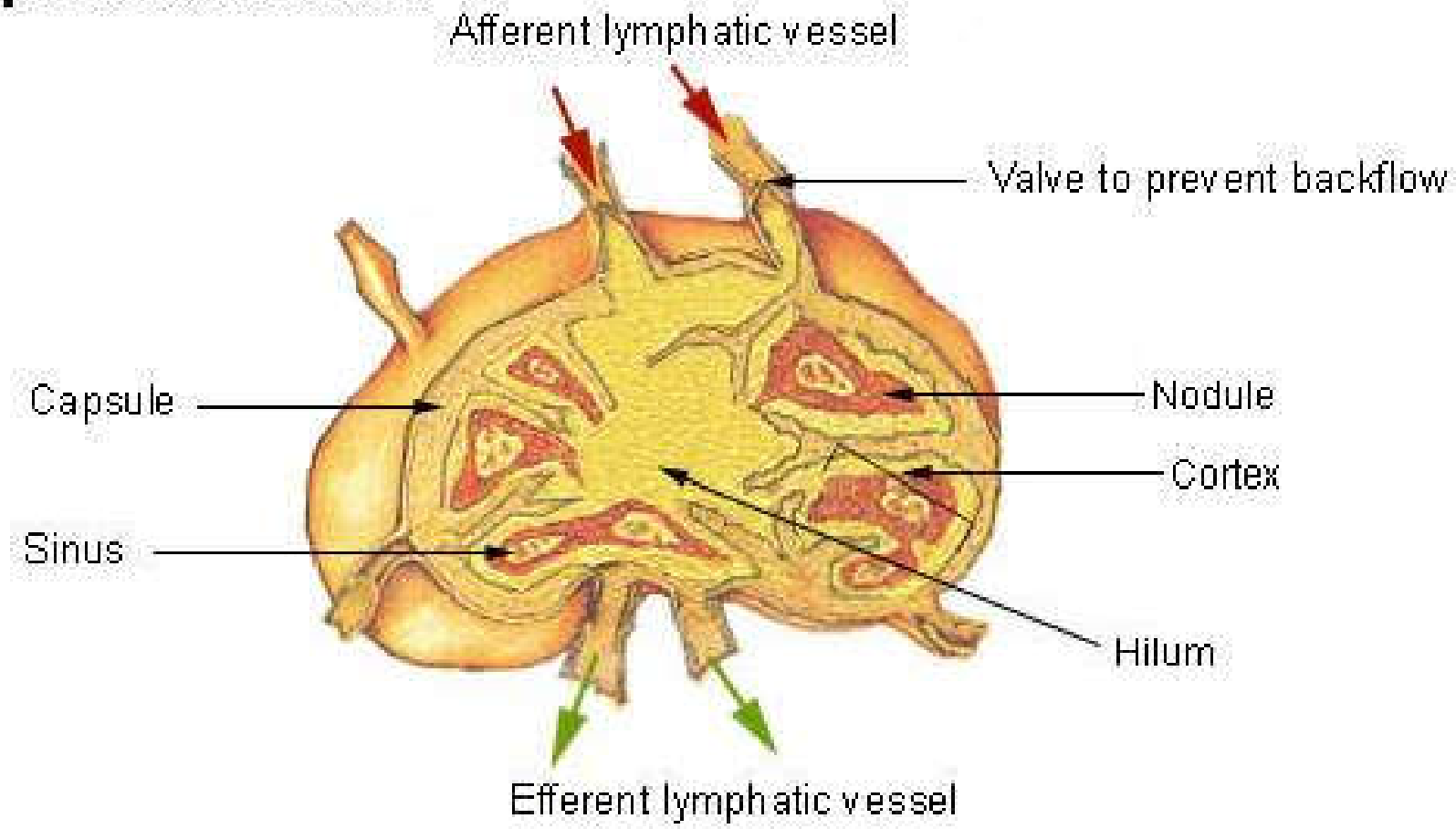


Photo from U. S. Federal Government courtesy of Wikipedia.

Lymph nodes filter foreign substances, such as bacteria and cancer cells, from the lymph before it is re-entered into the blood system through the larger veins.

Lymph nodes, which are scattered among the lymph vessels, act as the body's first defense against infection.

Lymph nodes produce the following cells:

- **Lymphocytes** – a type of white blood cell,
- **Monocytes** – a leukocyte that protects against blood-borne pathogens, and
- **Plasma cells** – produce antibodies.

Each lymph node has its own blood supply and venous drainage.

The lymph nodes usually have names that are related to their location in the body.

When a specific location gets infected, the lymph nodes in that area will enlarge to fight the **infection**.

If the lymph node closest to an infected area is unable to eliminate the infection, other lymph nodes in the system will attempt to fight the infection.

This is particularly critical in the case of **cancer**, which can be spread from its point of origin to all parts of the body through the lymphatic system.