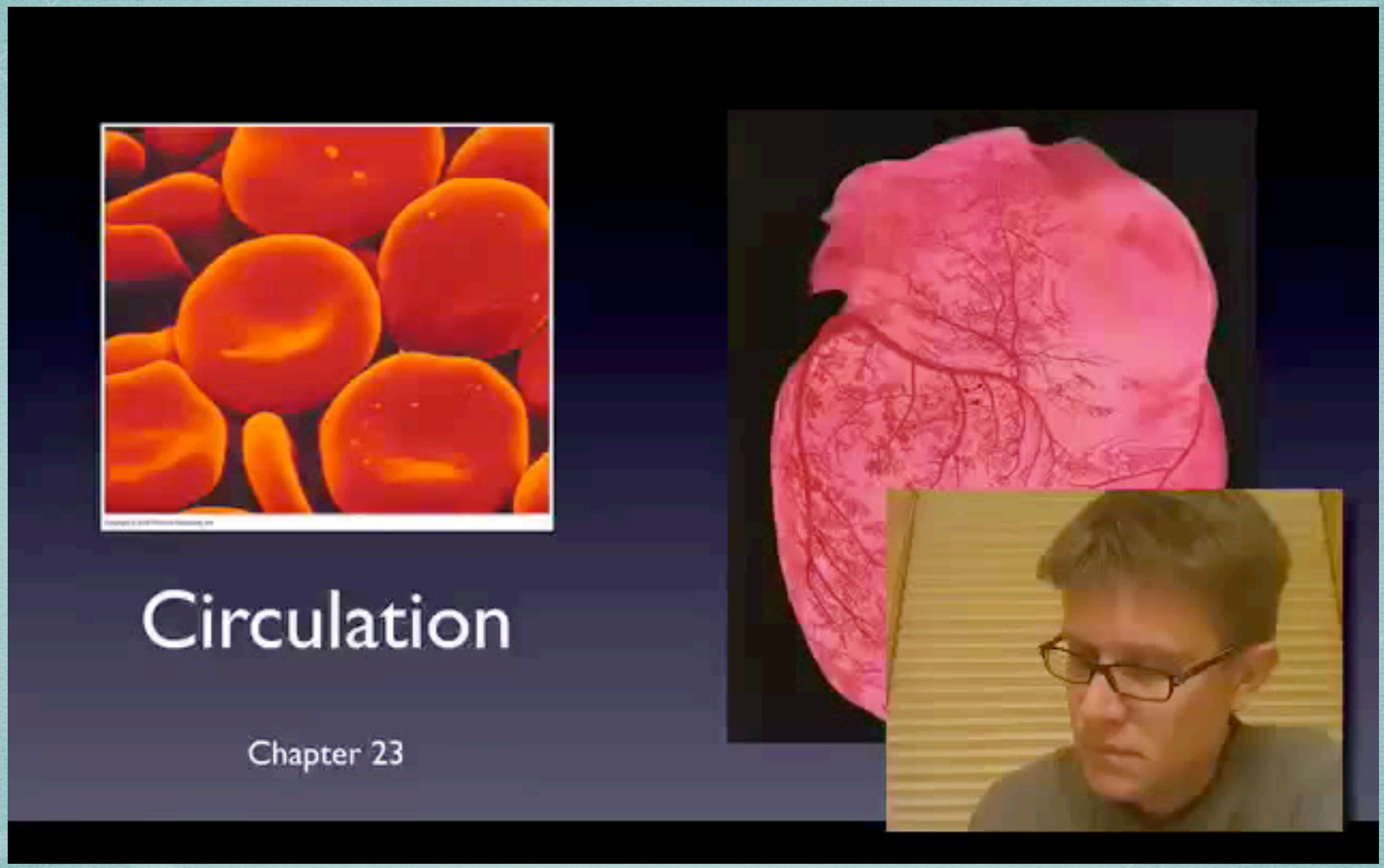
Circulatory System

Circulatory System



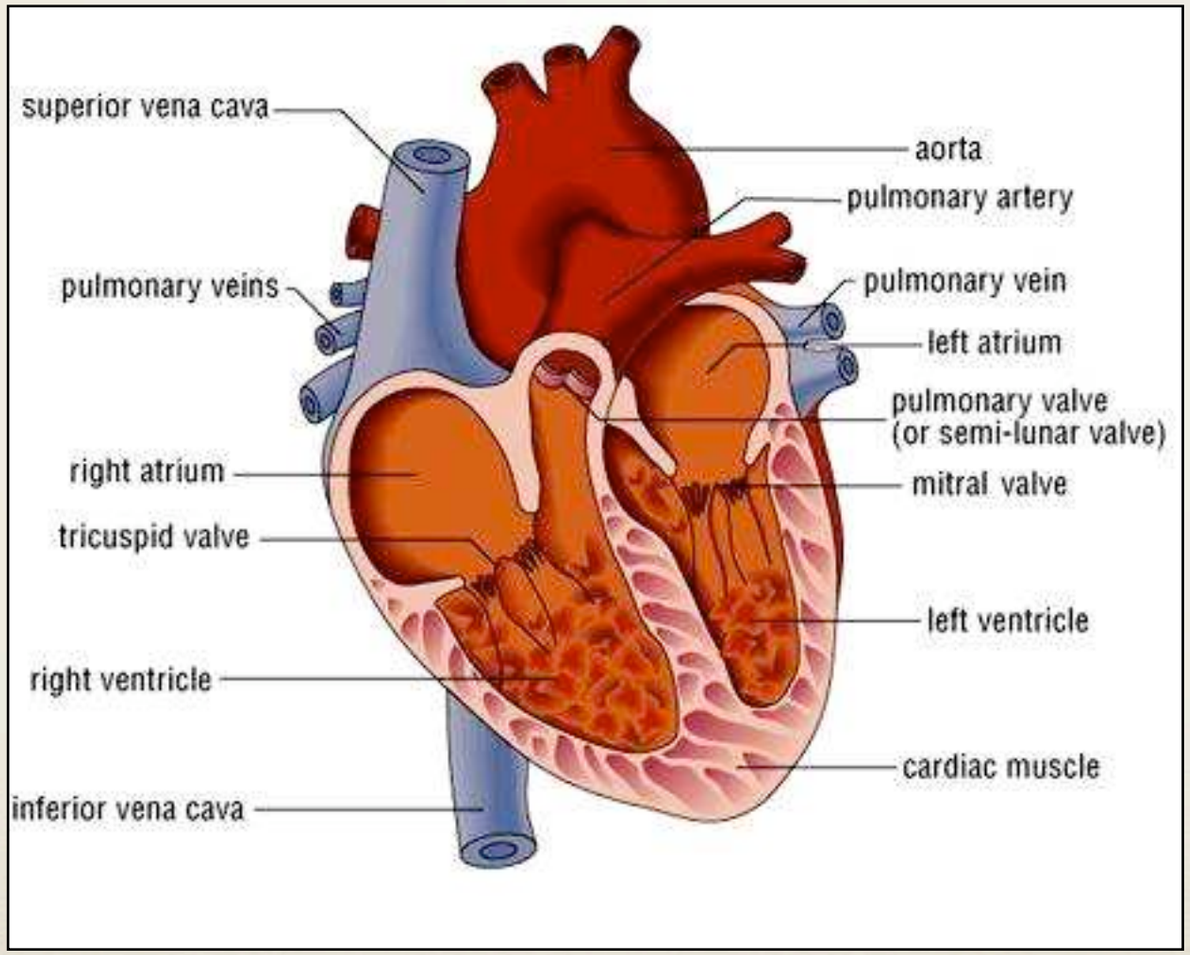
The Purpose of the Human Circulatory System

- The purpose of the circulation system is to act as the body's main **transport** system
- Items such as **nutrients**, **wastes, oxygen** and **carbon dioxide** are carried in the blood

The Heart

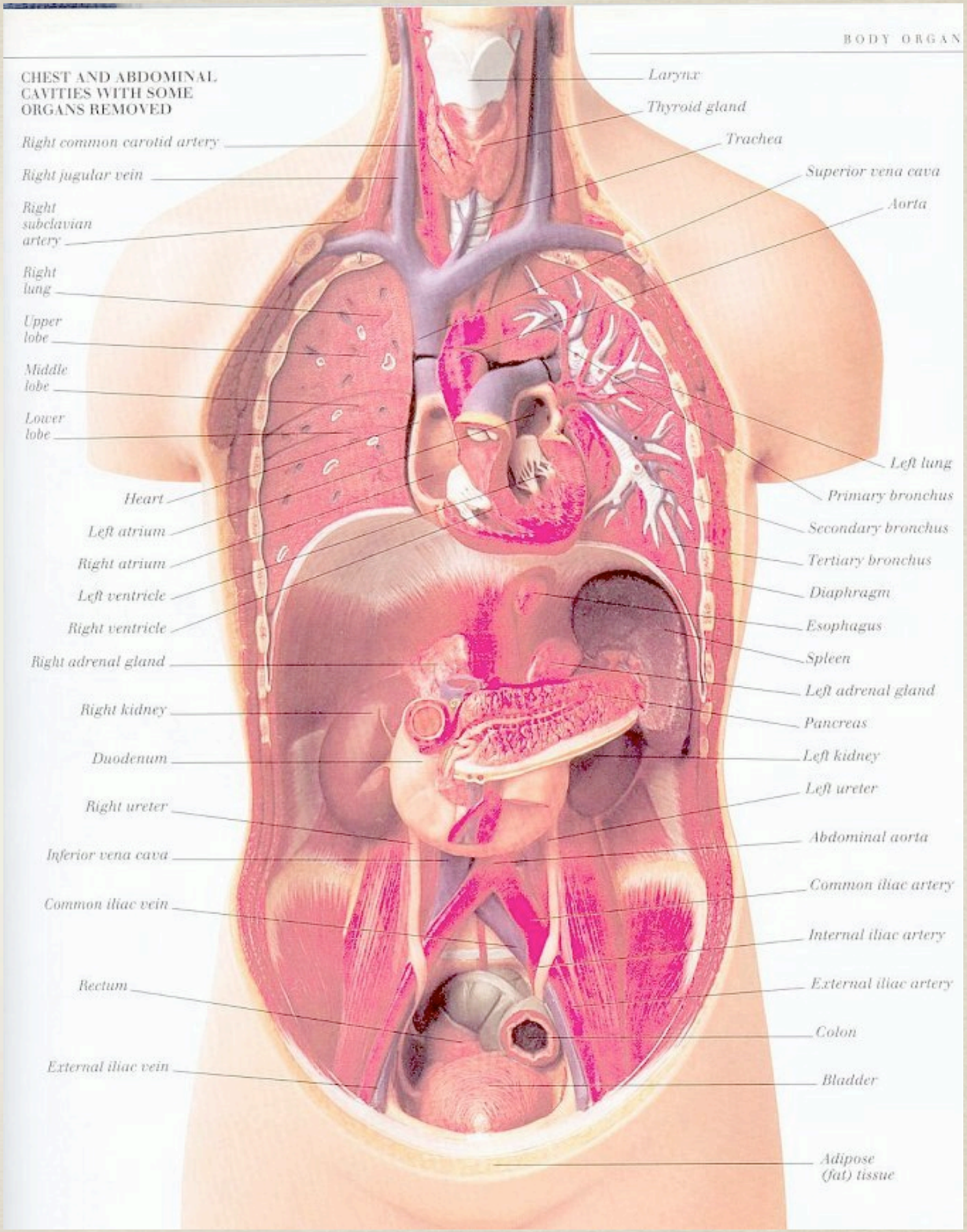
Function

- The acts as the **pump** of the circulatory system
- The heart forces blood through both the of the body's major circulatory circuits:
  - The **pulmonary** circuit (blood through the lungs)
  - The **systemic** circuit (blood through the body)



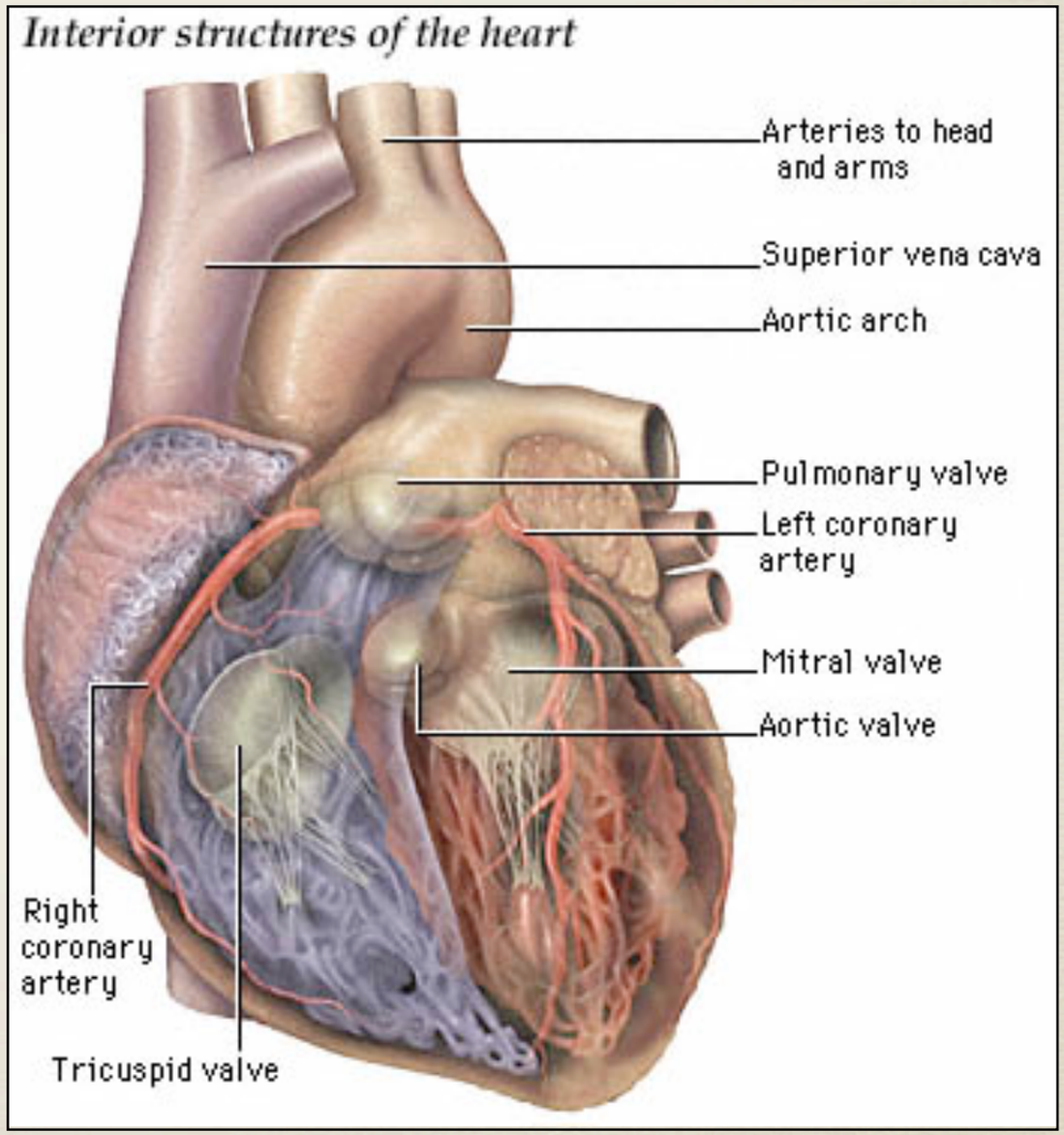
Structure

- The heart is a very **muscular** organ
- It is about the size of a fist
- The heart is located between the lungs, directly behind the sternum (breastbone)
- The heart is enclosed in within the **pericardium** which contains a small amount of fluid for lubrication



Heart Chambers & Walls

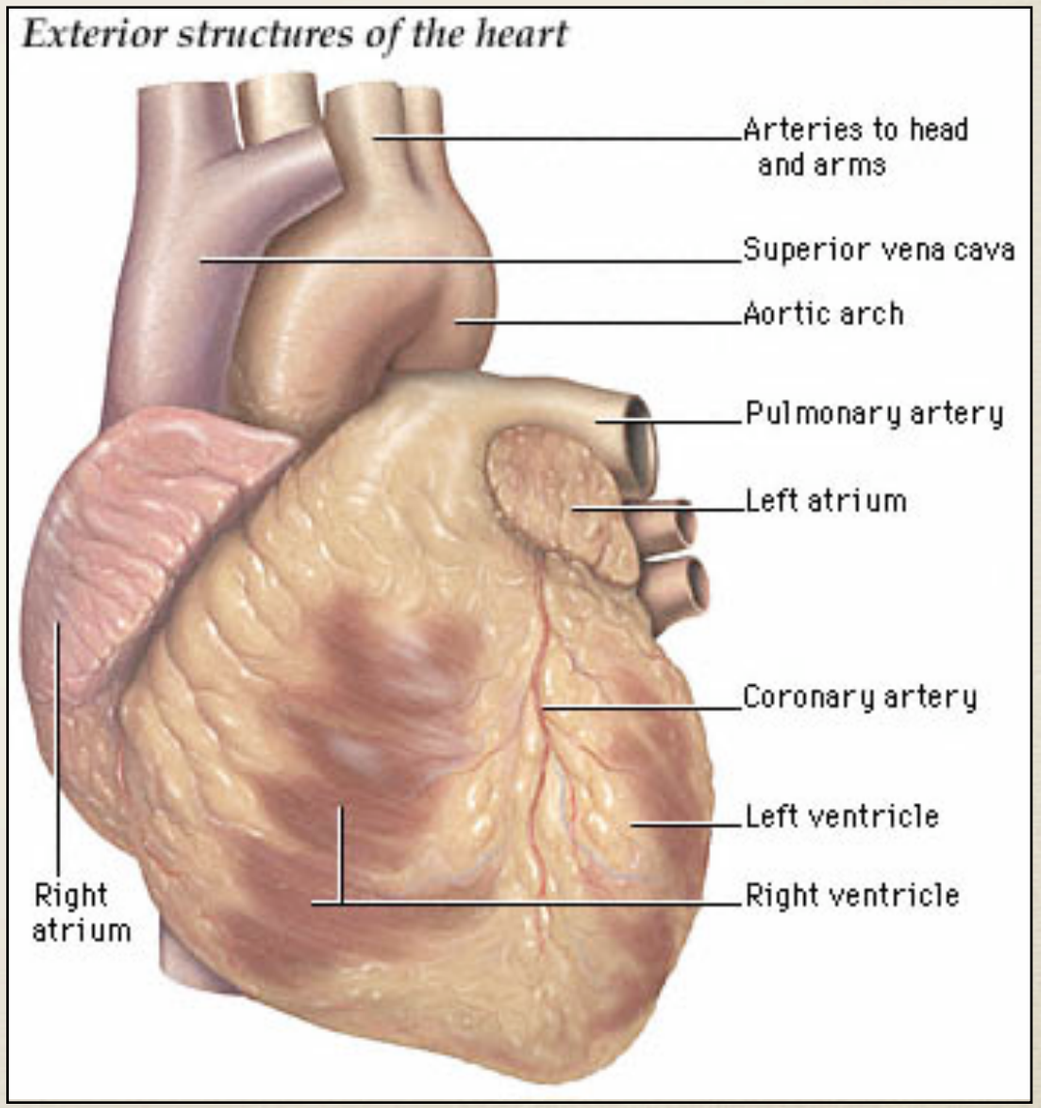
- The walls of the heart consist largely of **cardiac muscle** which gives the heart the ability to contract and pump blood
- A muscular wall called the **septum** separates the right side of the heart (deoxygenated blood) from the left side of the heart (oxygenated blood)
- There are four **chambers** in the heart:
  - Right **ventricle**
  - Right **atrium**
  - Left **ventricle**
  - Left **atrium**



- The walls of the **atria** are **thin** since they only have to move blood into the ventricles
- The walls of the **ventricles** are **thick** because they have to pump blood

- The **left ventricle** has the **thickest** walls since it has to pump blood through the **systemic** circulatory system (the body)

- The walls of the **right ventricle** are not as thick since it only has to pump blood into the **pulmonary** circulation (the lungs)



Heart Valves

- The heart has four **valves** which direct blood flow and prevent backward movement of blood
  - **Atrioventricular valves** lie between the atrium and the ventricle

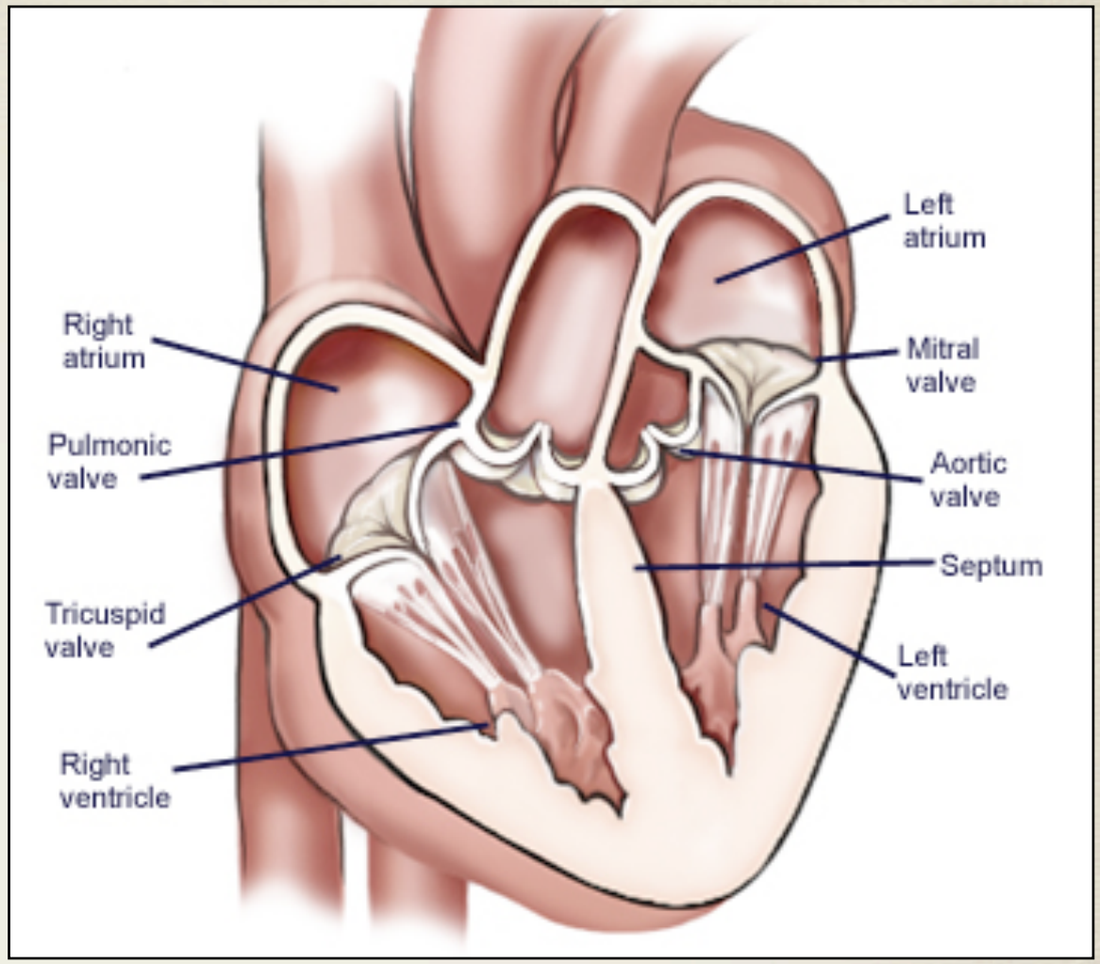
    The atrioventricular valve on the **right** side of the heart is called the **tricuspid valve** because it has three **cusps** or **flaps**

    The atrioventricular valve on the **left** side of the heart is called the **bicuspid** or **mitral valve** because it has two **cusps**

  - **Semilunar valves** lie between the ventricles and their attached vessels

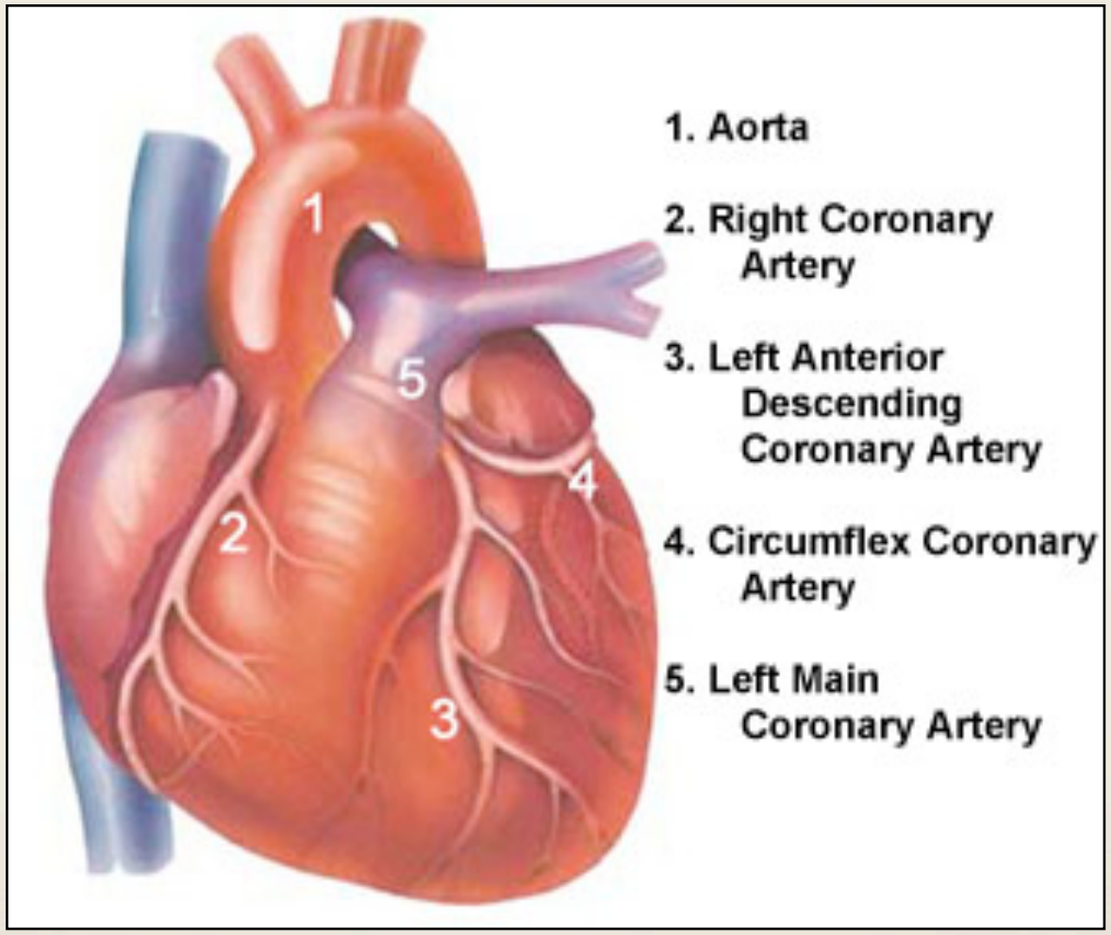
    The **pulmonary** semilunar valve lies between the **right** ventricle and the pulmonary trunk

    The **aortic** semilunar valve lies between the **left** ventricle and the **aorta**



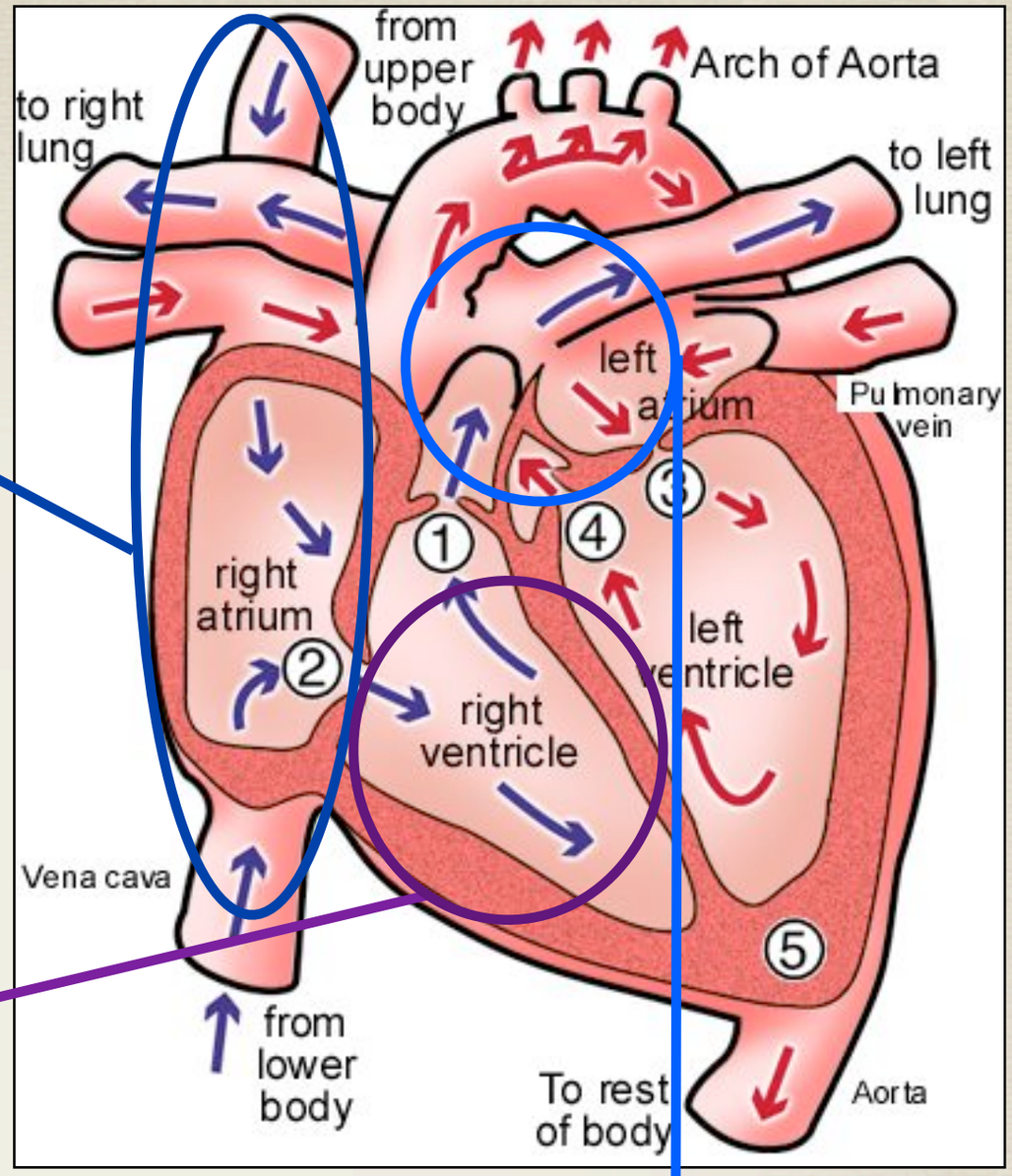
Coronary Arteries

- These are the arteries that supply the heart itself with blood
- They are embedded in the muscular walls of the heart
- The heart is NOT nourished by the blood in the chambers
- They are part of the **systemic** circulation



Flow of blood through the Heart

- Blood returning from the systemic circulation (which is now **deoxygenated**) enters the **right atrium** via the **superior** (top) **vena cava** and **inferior** (bottom) **vena cava**
    - Note- the vena cavae are the body's largest veins

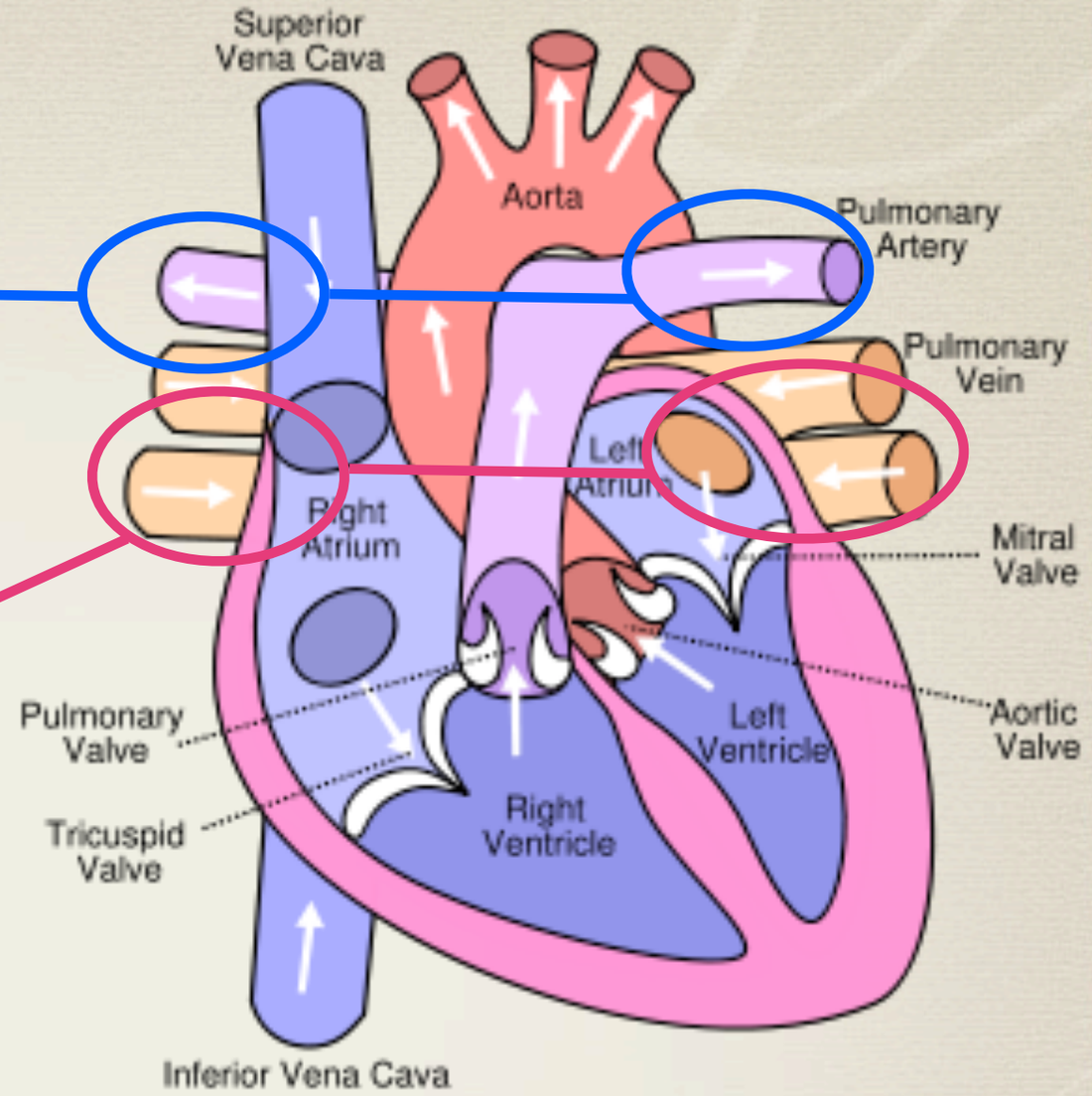


- The right atrium contracts, forcing blood through the **tricuspid valve** into the **right ventricle**
- The right ventricle contracts, forcing blood through the **pulmonary semilunar** valve into the **pulmonary trunk**

- The pulmonary trunk, divides into the **pulmonary arteries** which carry blood to the **lungs**

- At the lungs, **carbon dioxide** diffuses out of the blood and **oxygen** enters the blood

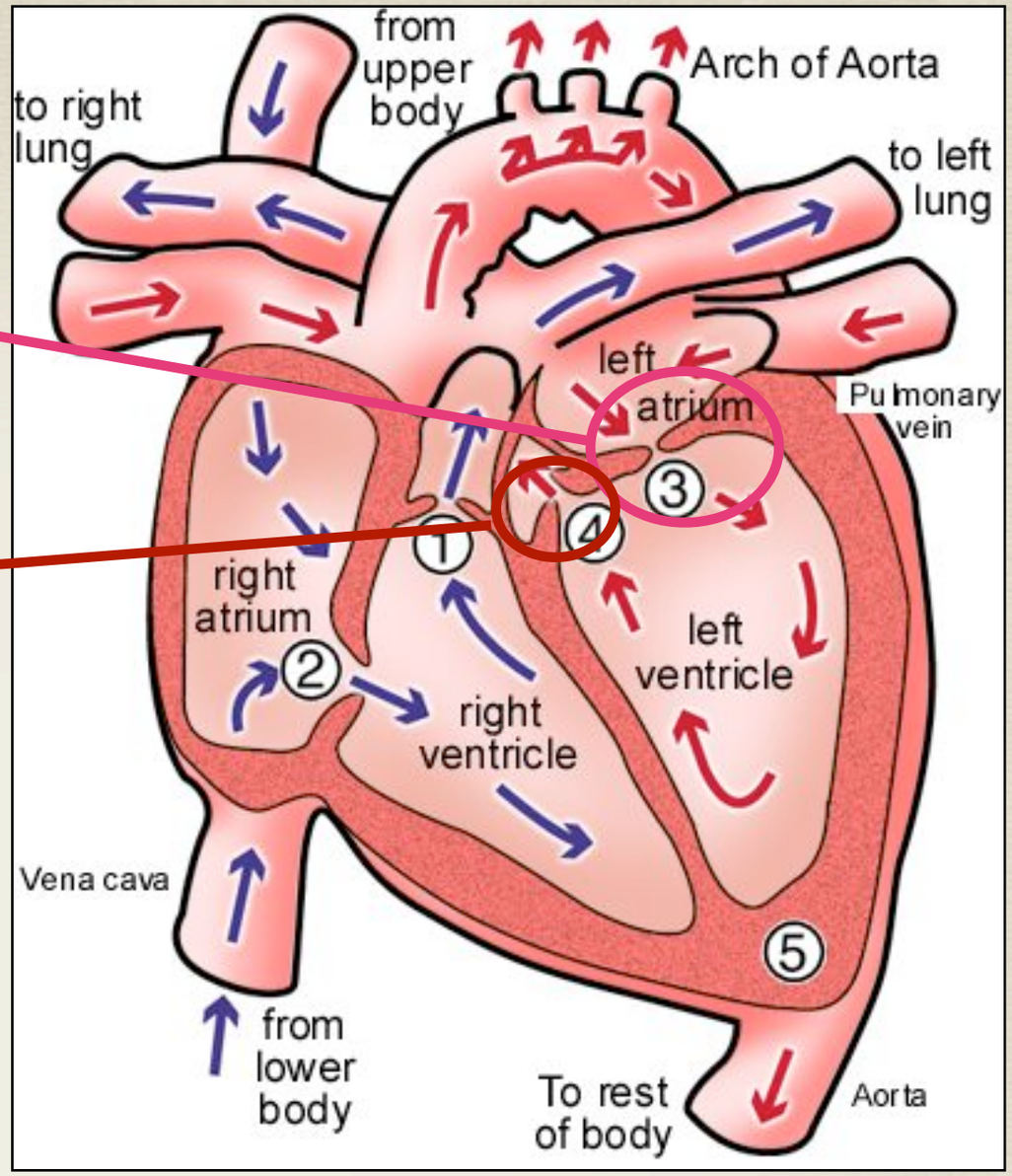
- **Oxygenated** blood enters the pulmonary veins which carries it back to the **left atrium**

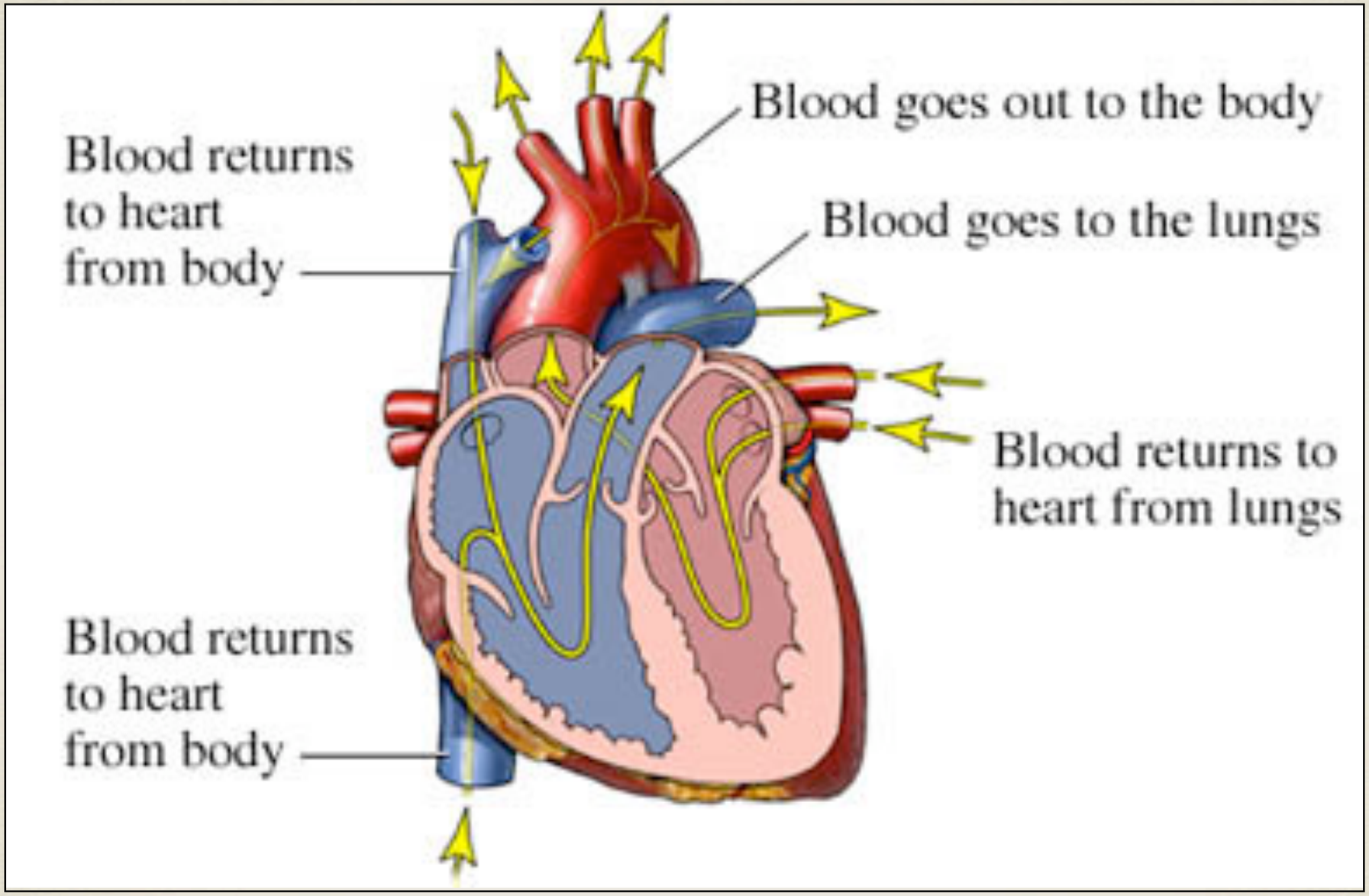


The left atrium contracts, forcing blood through the **bicuspid** valve and into the **left ventricle**

- The left ventricle contracts, forcing blood through the **aortic semilunar valve** and into the **aorta**

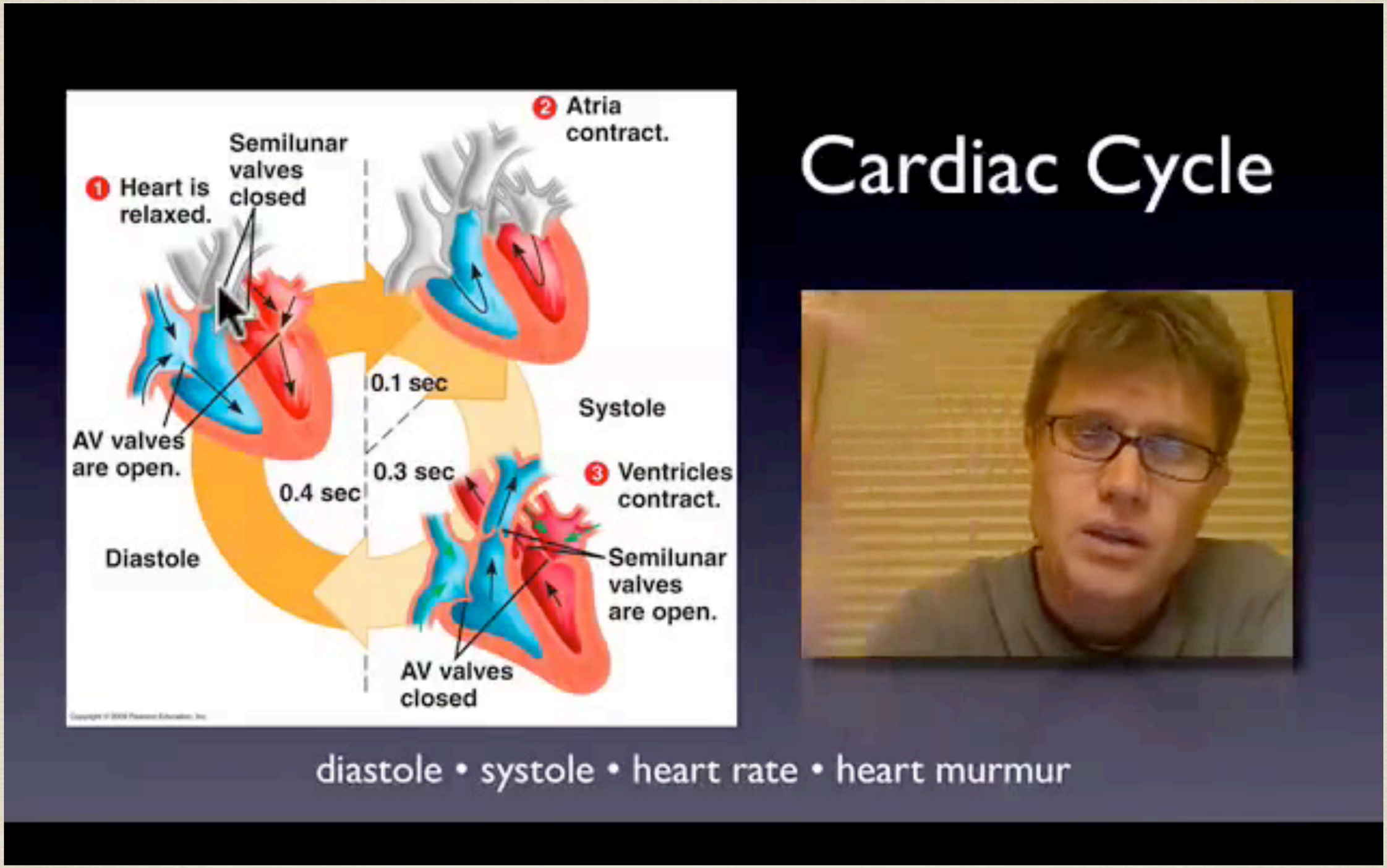
- The aorta divides into smaller **arteries** which carry oxygenated blood throughout the body




Blood goes out to the body
Blood returns to heart from body
Blood goes to the lungs
Blood returns to heart from lungs
Blood returns to heart from body

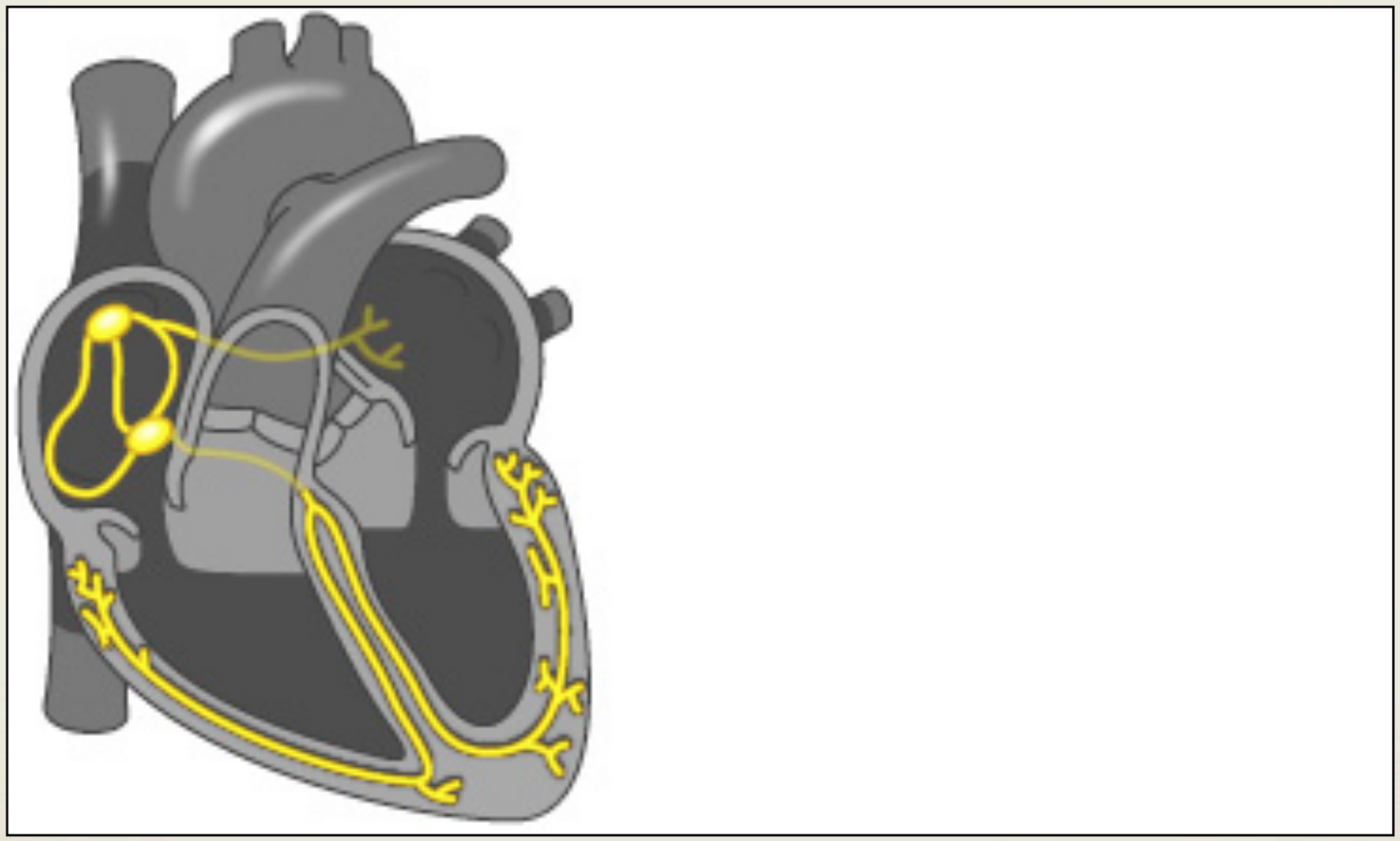
Nodal Tissue: The Heart's Conduction System (p 244)

Nodal Tissue: The Heart's Conduction System (p 244)

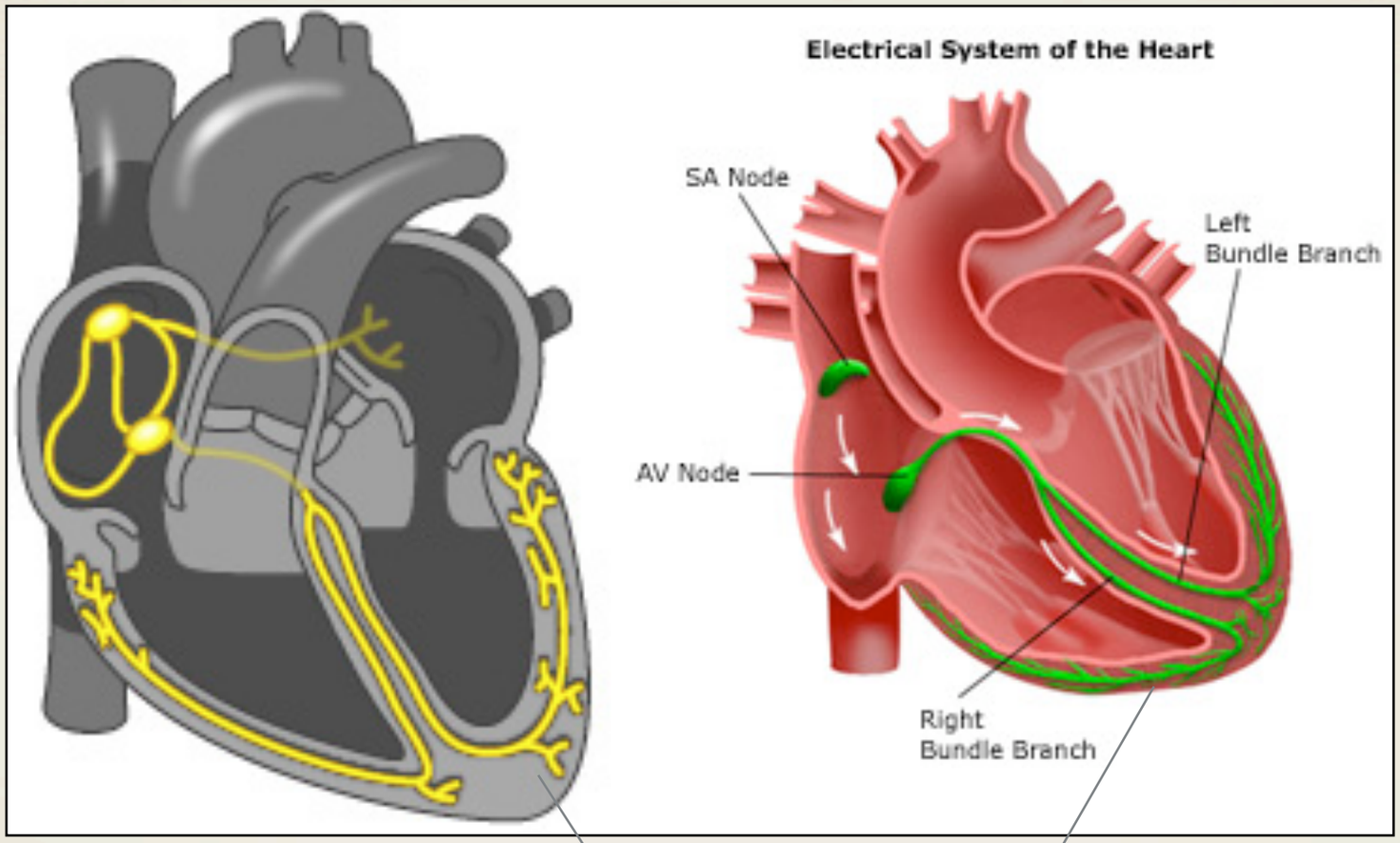


Nodal Tissue: The Heart's Conduction System (p 244)

- The **heart beat** is controlled by special tissue called **nodal tissue**
- **Nodal tissue** initiates and conducts impulses that cause the heart to contract
- This tissue has both **muscular** and **nervous** tissue characteristics



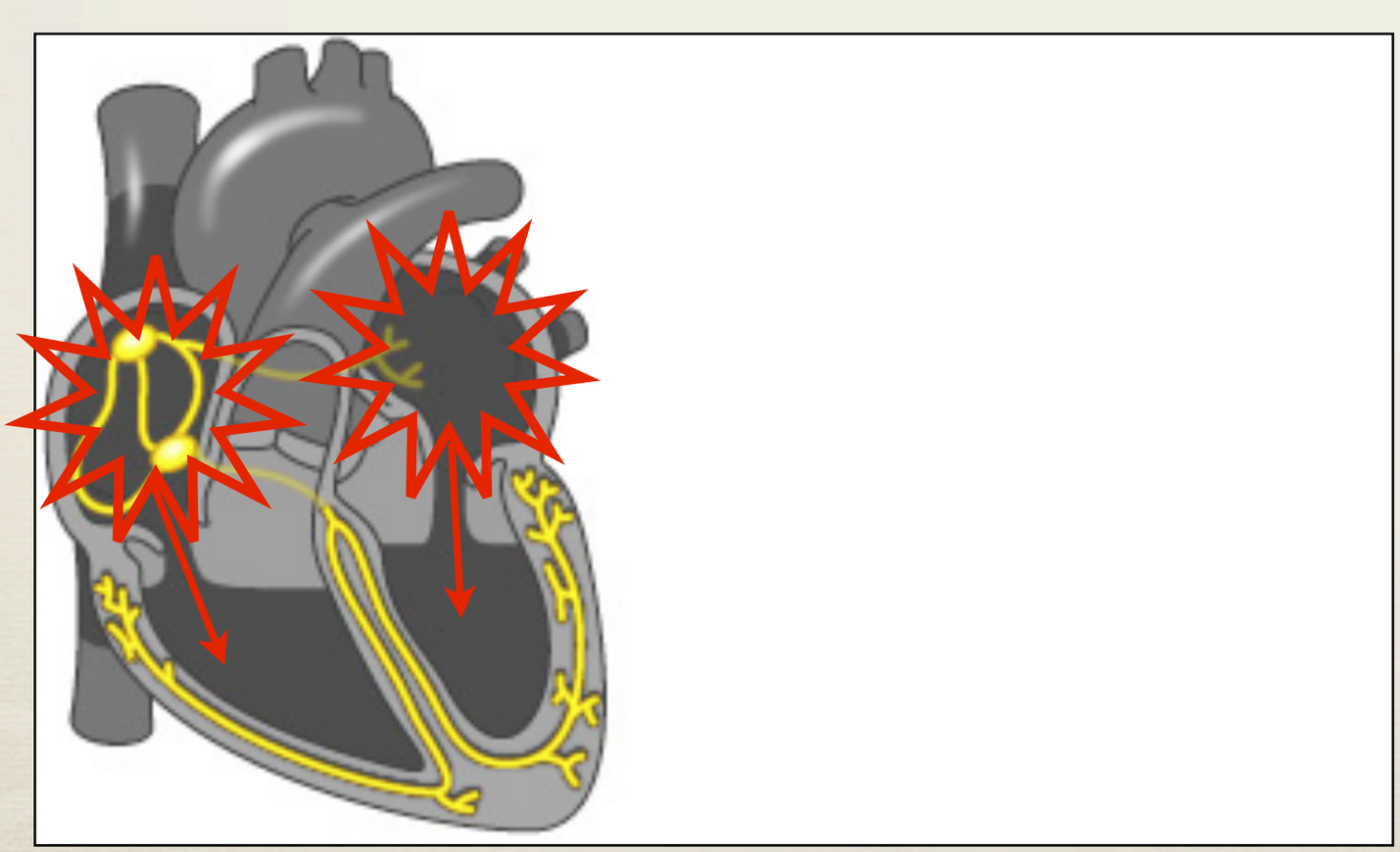
- Nodal tissue is located in two regions of the heart:
  - **SA (sinoatrial) node** is located in the upper wall of the right atrium
  - **AV (atrioventricular) node** is located in the base of the right atrium



Purkinje Fibres

Heart Beat- Cardiac Cycle

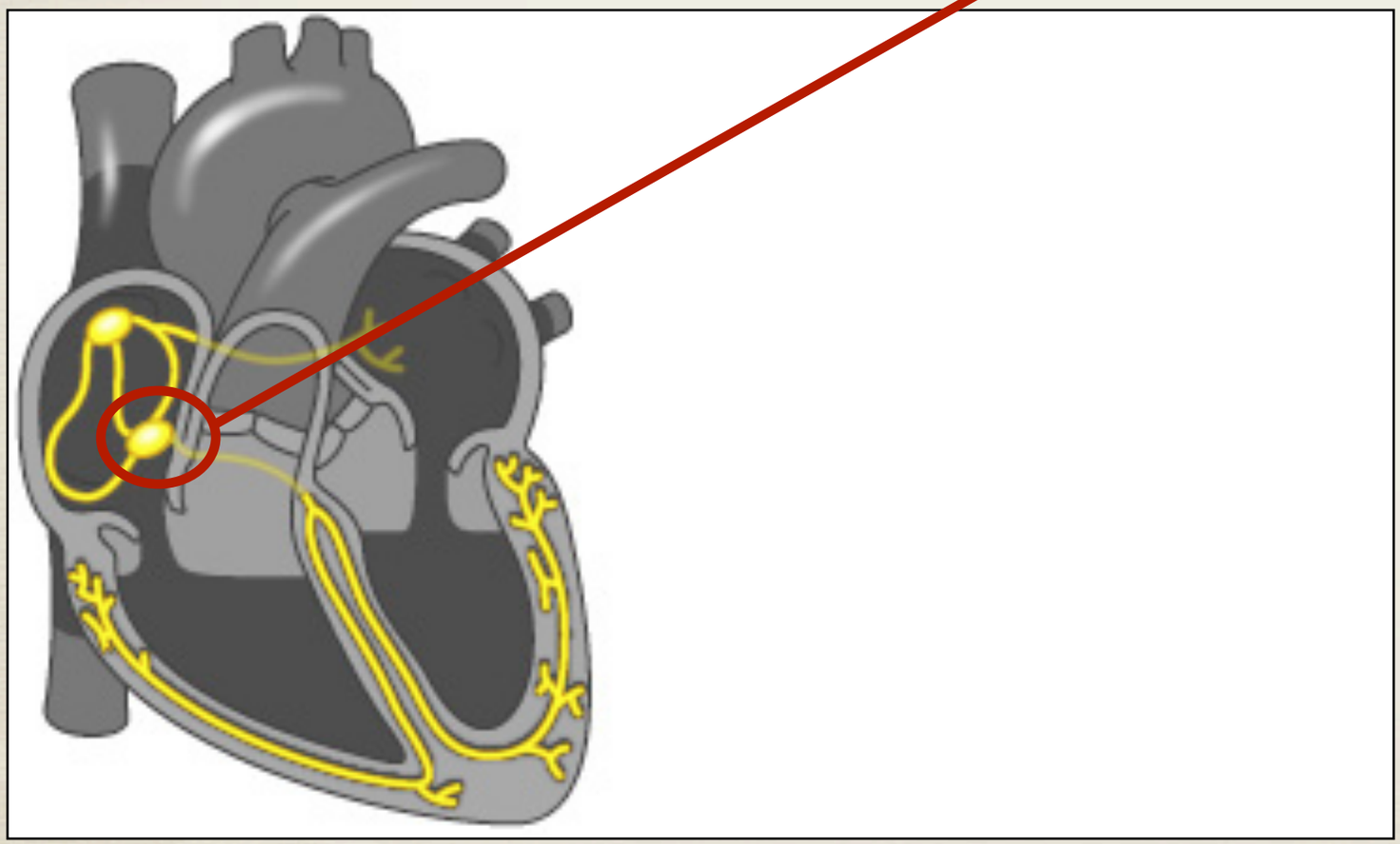
- The **cardiac cycle** describes how the **nodal tissue** of the heart controls the normal **heart beat**
- Since the normal heart beat is controlled by **nodal tissue** within the heart, this is known as **intrinsic control**
- The initiation of the heartbeat is due to an excitation impulse emitted by the **SA node** in the upper wall of the right atrium
- This impulse travels through the walls of the right and left atria causing them to **contract** simultaneously thus forcing blood from the atria into the ventricles



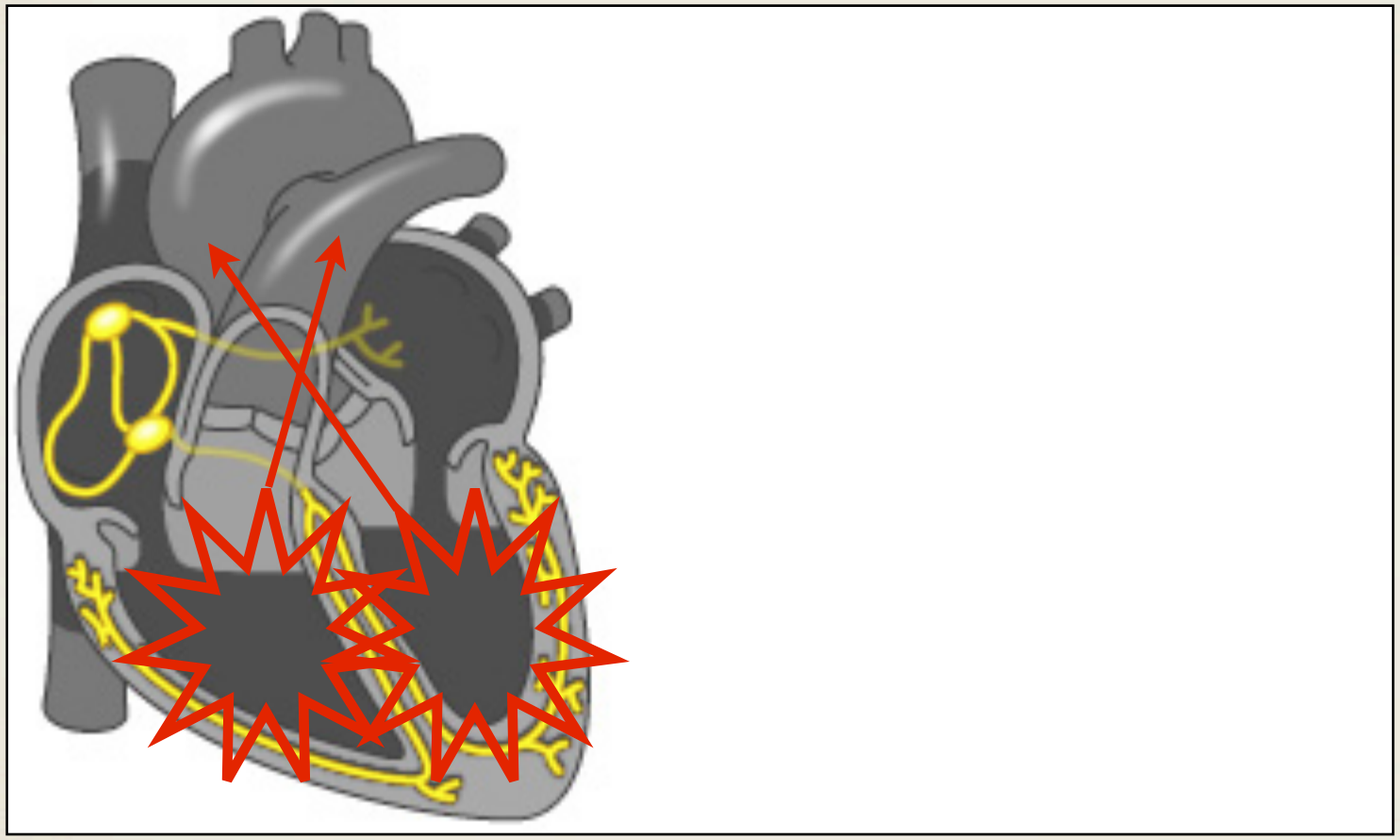
- When the atria contract, the ventricles are relaxed and filling with blood
  - Note-**systole** refers to **contraction** of heart muscle
  - Note-**diastole** refers to **relaxation** of heart muscle

It's kinda like the concept of peristalsis (Squeezing the toothpaste out of the tube).

- The impulse is then picked up by the **AV node** which is located at the base of the right atrium



- From the AV node, the impulse is conducted downward by the **AV bundle**
- The impulse is then picked up by the **Purkinje Fibres** which conducts it through the walls of both ventricles causing them to contract
- When the ventricles are contracting the atria are relaxed and filling with blood



Modification of the Normal Heartbeat

- Speeding up or slowing down of the normal heart beat can be achieved in two ways:
    1. Impulses from the **autonomic nervous system**
    2. Hormones from the **endocrine system**

- Since both of these originate **outside** of the heart, this is called **extrinsic control**

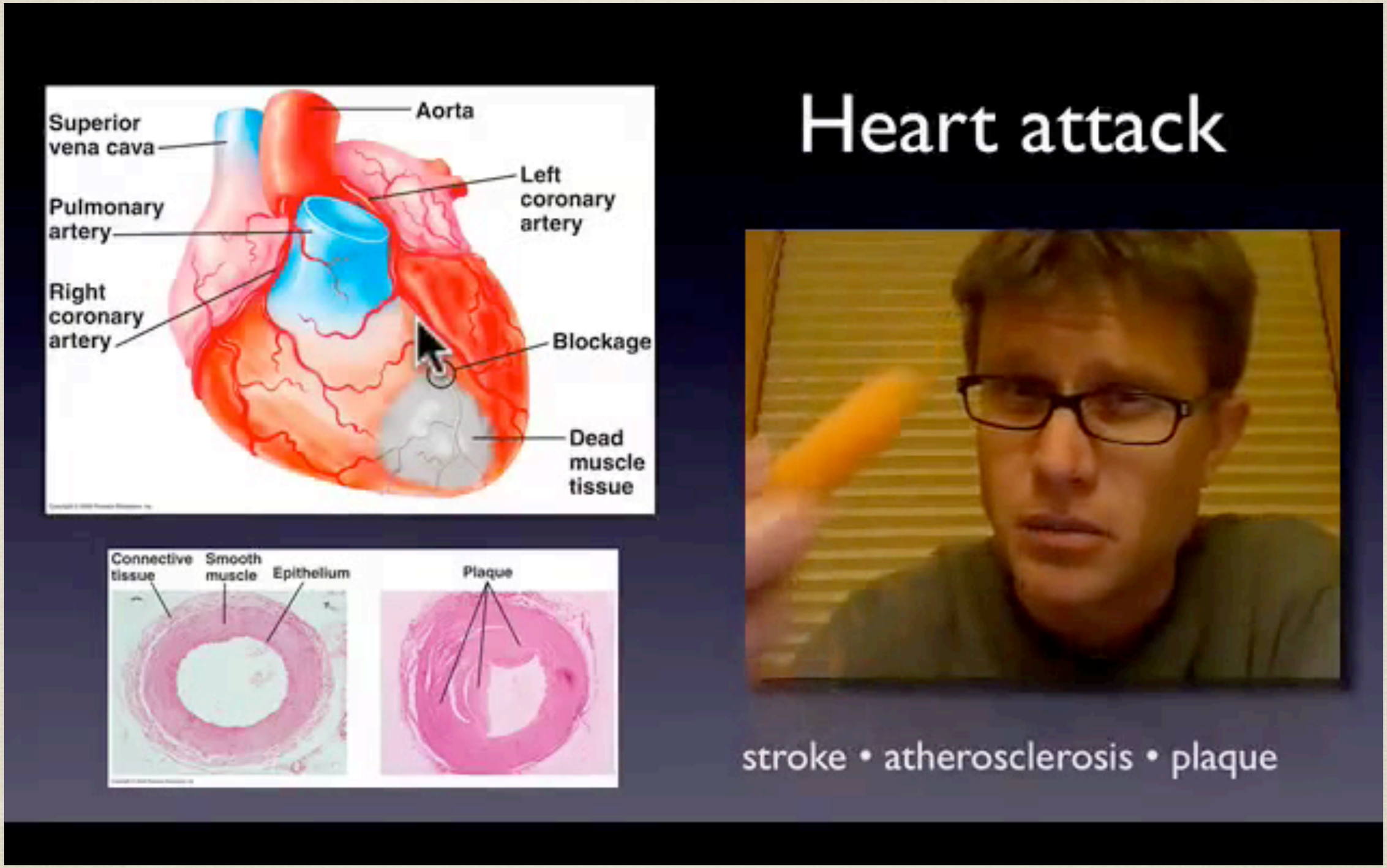
1. Autonomic Regulation by the Nervous System

- The autonomic nervous system has two divisions, the **sympathetic** and the **parasympathetic**
- The **medulla oblongata**, a portion of the brain that controls internal organs, can increase or decrease heart rate
- The **parasympathetic** division of the nervous system, which promotes functions associated with a resting state, ***decreases*** **SA** and **AV** node activity when we are inactive
- The **sympathetic** division of the nervous system, which brings about response associated with increased activity or stress, ***increases*** **SA** and **AV** node activity when we are active or excited

2. Hormonal Regulation by the Endocrine System

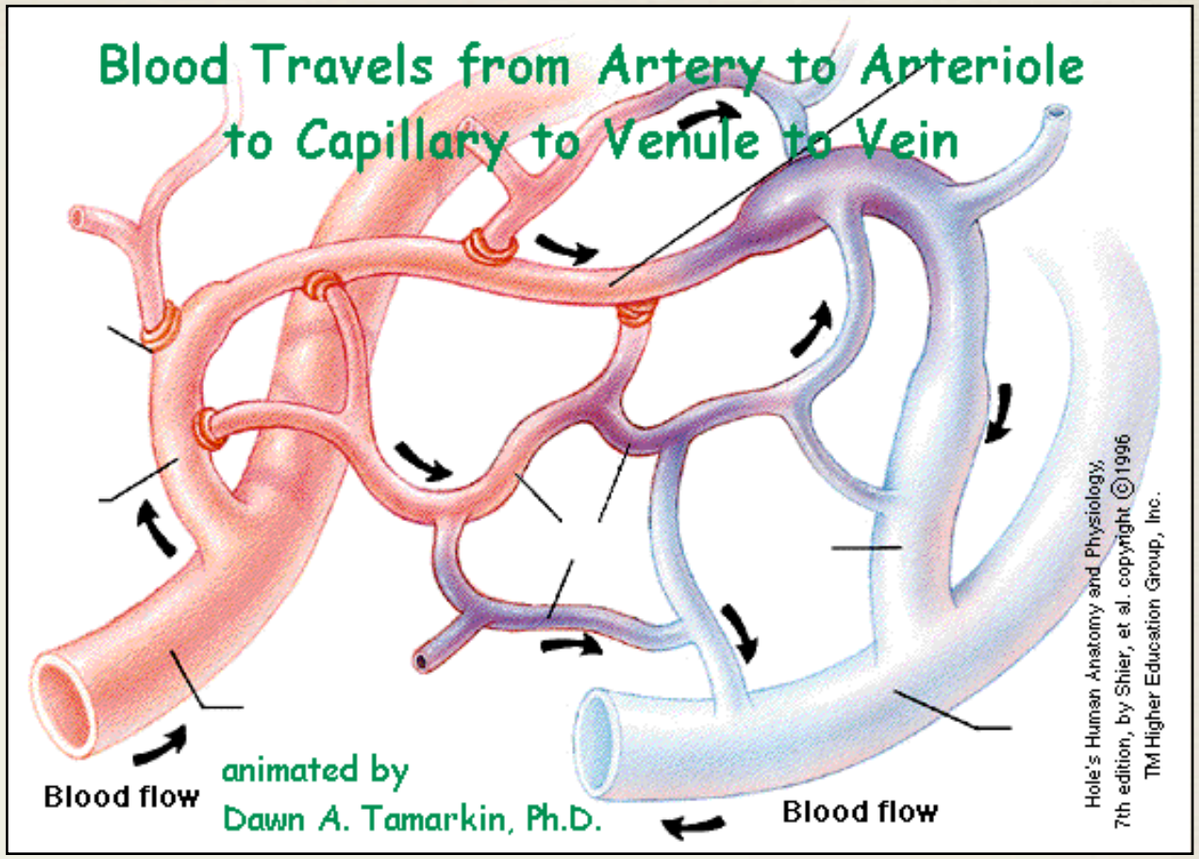
- The **adrenal medulla** releases the hormones **norepinepherine** and **epinephrine** into the blood
- These hormones travel to the heart where they **increase** heart rate

Blood Vessels and Vascular Pathways



Blood Vessels

- There are five types of blood vessels
  - Arteries
  - Arterioles
  - Capillaries
  - Venules
  - Veins



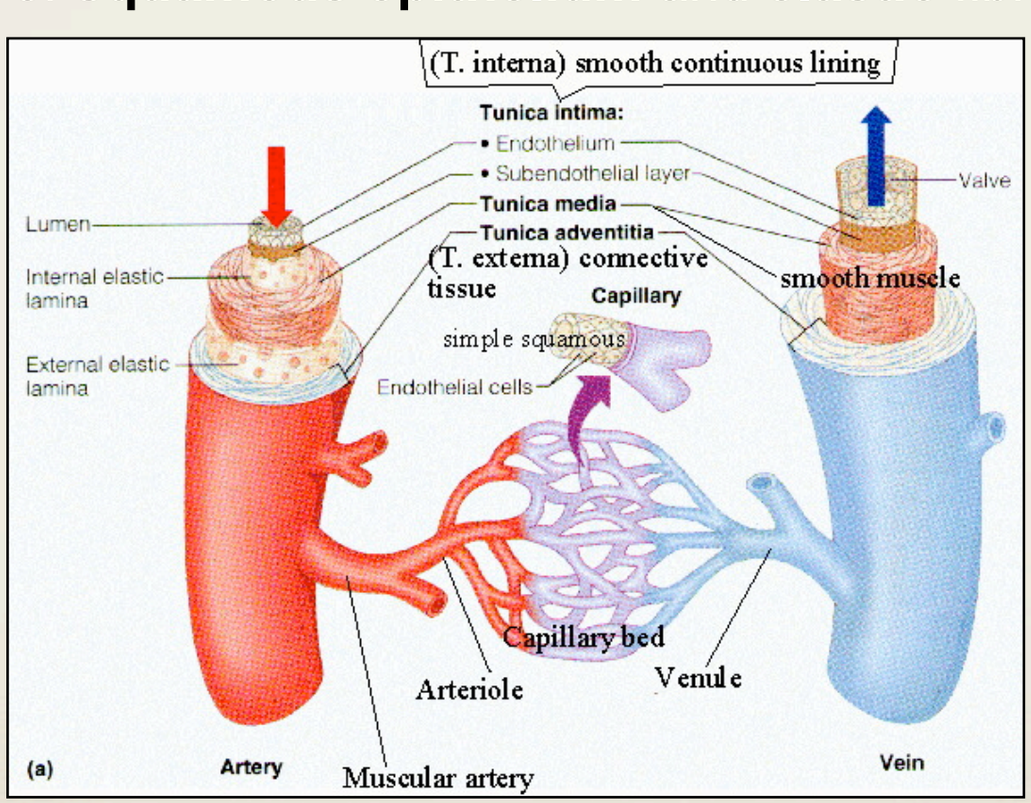
Arteries

Function

- The function of the arteries is to **carry blood away from the heart**

Structure

- The walls of the arteries are very **thick** and highly **muscular** which allows them to **contract** in response to changes in blood pressure and blood flow
- Artery walls consist of three layers:
  - An outer layer of **connective** tissues
  - A middle layer of **smooth muscle** and some **elastic** tissue
  - An inner layer of **squamous epithelium** and **elastic** fibres



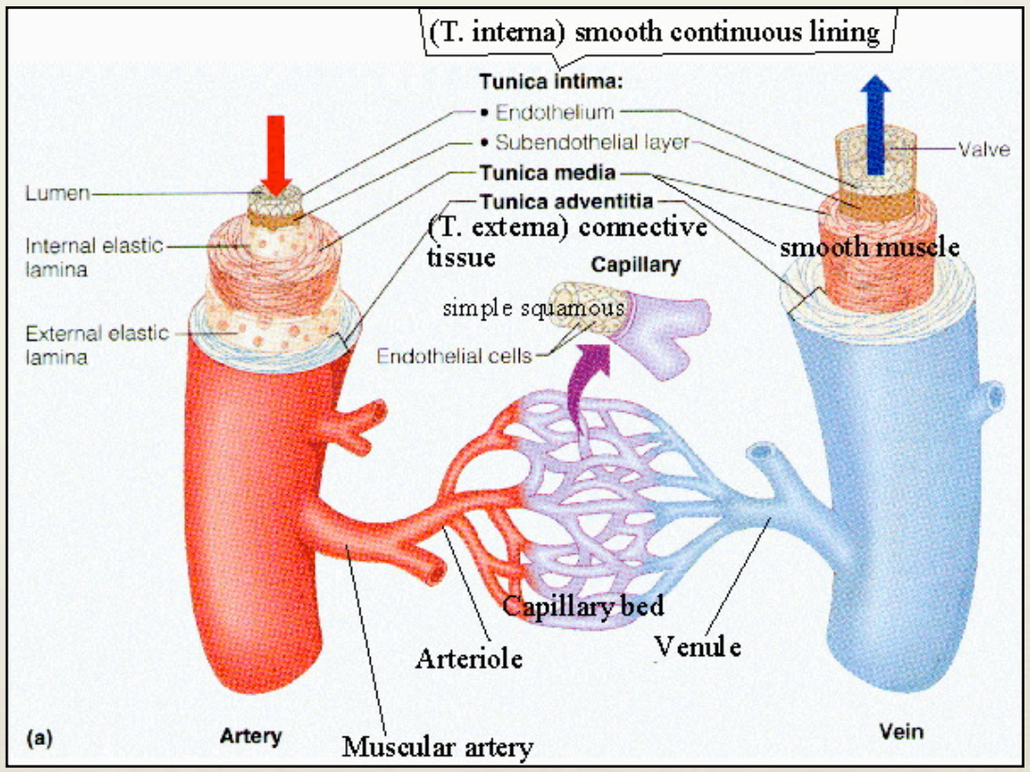
Arterioles

Function

- Arterioles carry blood away from the heart, in between the arteries and the capillaries
- Through the processes of **constricting** and **dilating** arterioles can change their **diameter** thus affecting **blood pressure**

Structure

- Arterioles walls have the same three layers as arteries but the middle layer is composed largely of **smooth muscle** with some **elastic fibres** that encircle the arteriole
- When muscle fibres **contract**, the diameter of the arteriole **decreases,** causing an **increase** in **blood pressure**
- When the muscle fibres are **relaxed**, the diameter of the arteriole **increases** causing a **decrease** in **blood pressure**



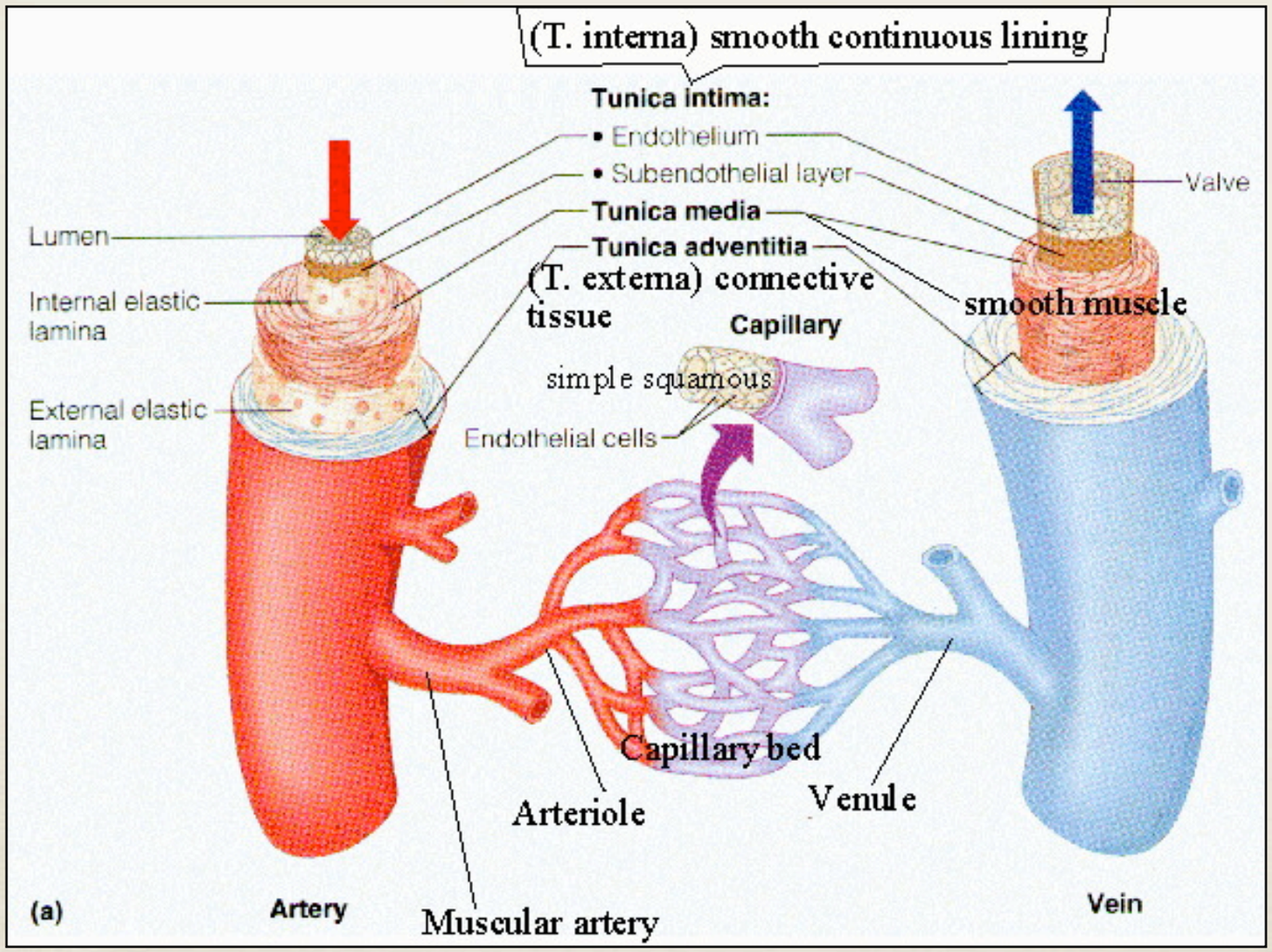
Capillaries

Function

- The function of the capillaries is to allow the exchange of **nutrients** and **wastes** and the exchange of the gases **oxygen** and **carbon dioxide** between the blood and various tissues through the process of **diffusion**

Structure

- Capillary walls are a **single cell** thick to allow molecules to pass through by diffusion
- The capillaries are highly **branched** and form networks called **capillary beds** which maximize **surface area** for **diffusion**



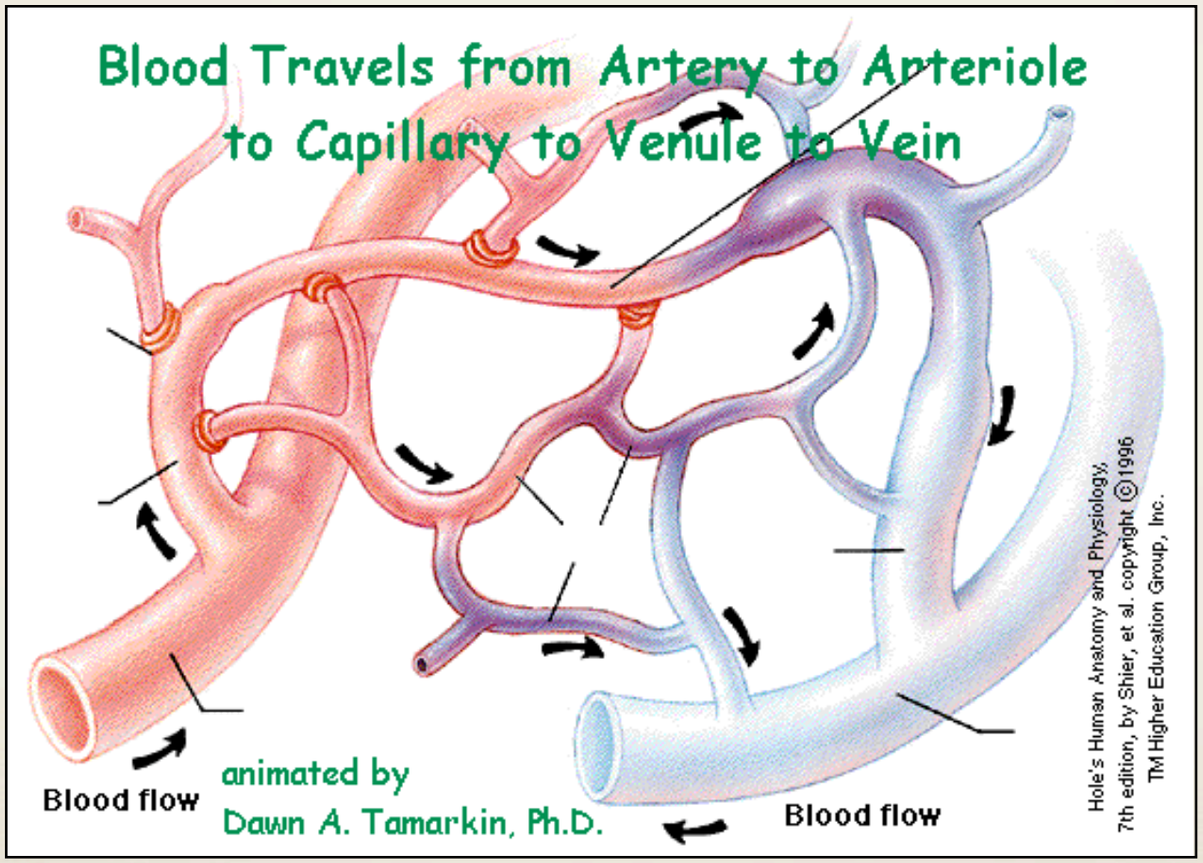
Venules

Function

- The function of the veins is to carry blood from the **capillary beds** to the **veins**

Structure

- Although the walls of the venules consist of the same layers, the middle layer is less developed causing the walls to be relatively thin
- As the blood pressure in venules is relatively low, their walls do not need to be particularly thick or muscular



Veins

Function

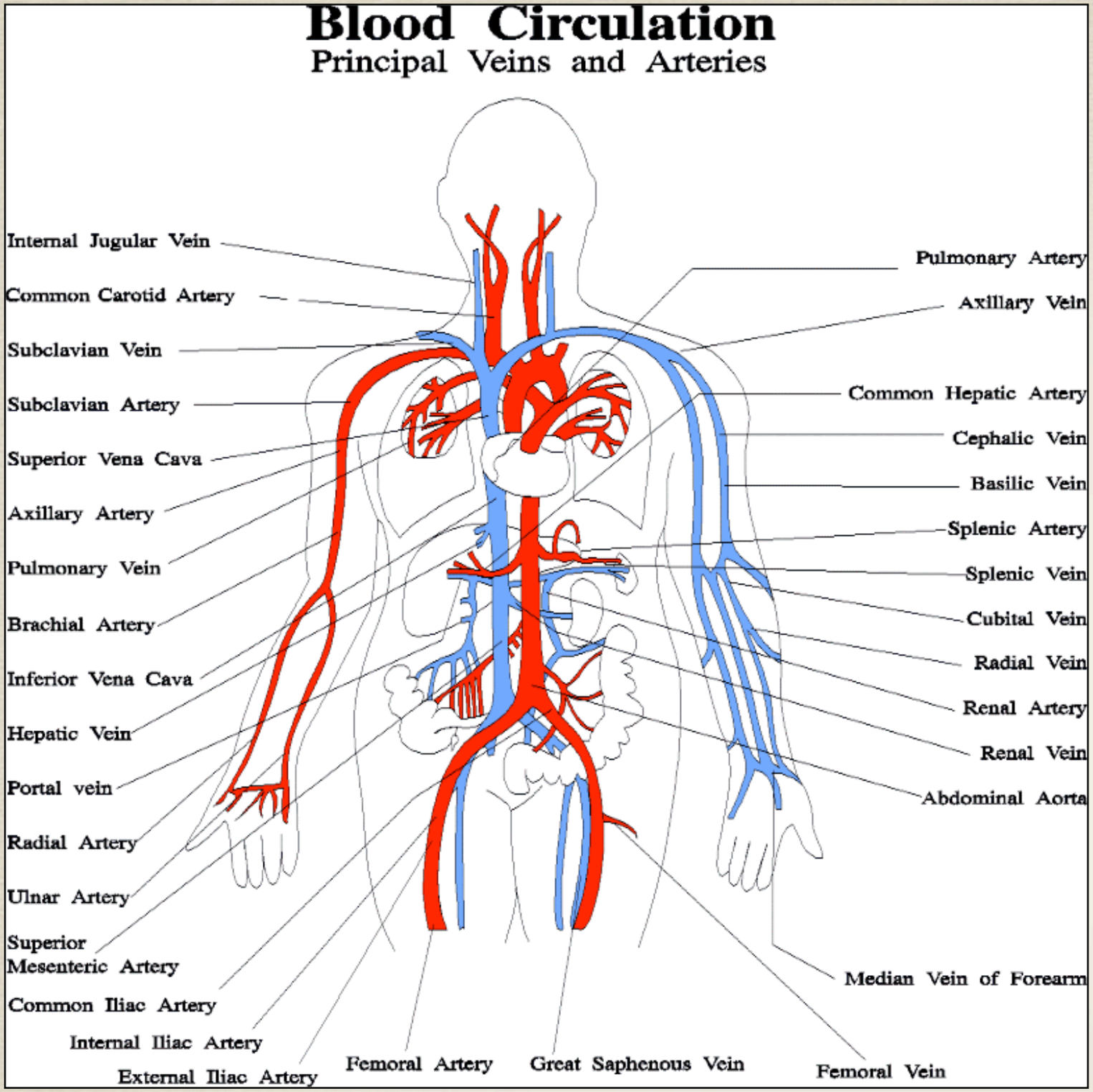
- Veins carry blood low in oxygen to the heart
- Major veins serve as blood **reservoirs** which, if blood pressure is too **low**, can constrict forcing more blood through the circulatory system thus maintaining blood pressure

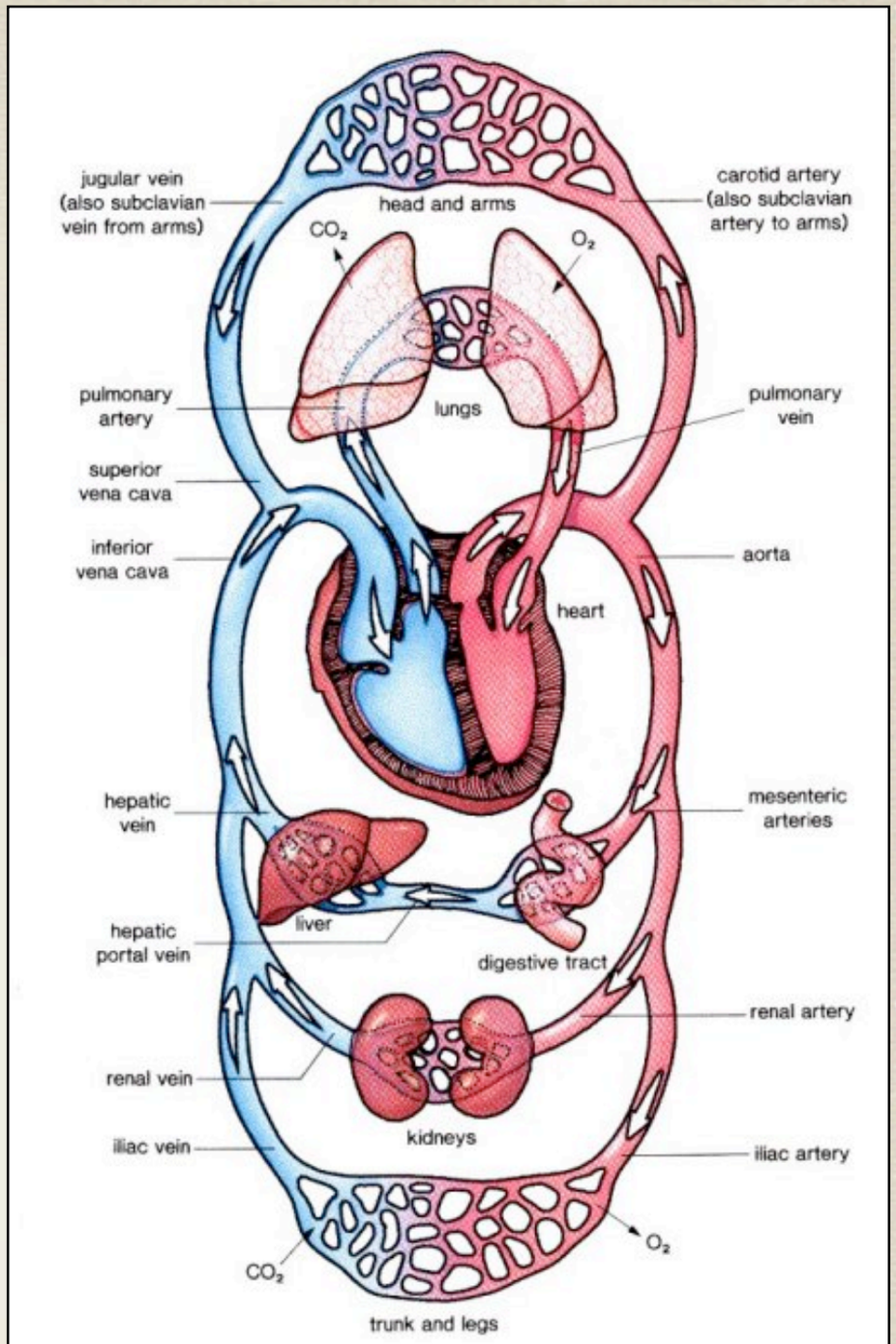
Structure

- Although the walls of the veins consist of the same layers, the middle layer of smooth muscle and elastic fibres in much **thinner** in veins than in arteries since the blood pressure is much lower
- Veins also have **one way valves** which allow blood to flow only towards the heart when open and prevent the backflow of blood when closed
- Although the walls of the venules consist of the same layers, there is **less** smooth muscle and connective tissue
- **Valves** are found in vessels carry in blood **against** the flow of gravity

Blood Circulation

Principal Veins and Arteries





Blood Pressure, Velocity and Cross Sectional Area

Blood Pressure

- Blood pressure is the force which the blood exerts on the walls of the blood vessels
- Blood pressure in **arteries** tends to **oscillate** from high to low in response to **ventricular systole** and **diastole**
- *As the blood moves further from the heart, blood pressure decreases*
- Therefore blood pressure is **highest** in the **aorta** and lowest in the **vena cava**

Blood Velocity

- Blood velocity is the **speed** at which blood moves through the blood vessels
- Like blood pressure, blood velocity oscillates in response to ventricular systole and diastole
- *As blood moves away form the heart, blood velocity **decreases**,* reaching the lowest speed in the capillaries and increasing again in the **venules** and **veins**

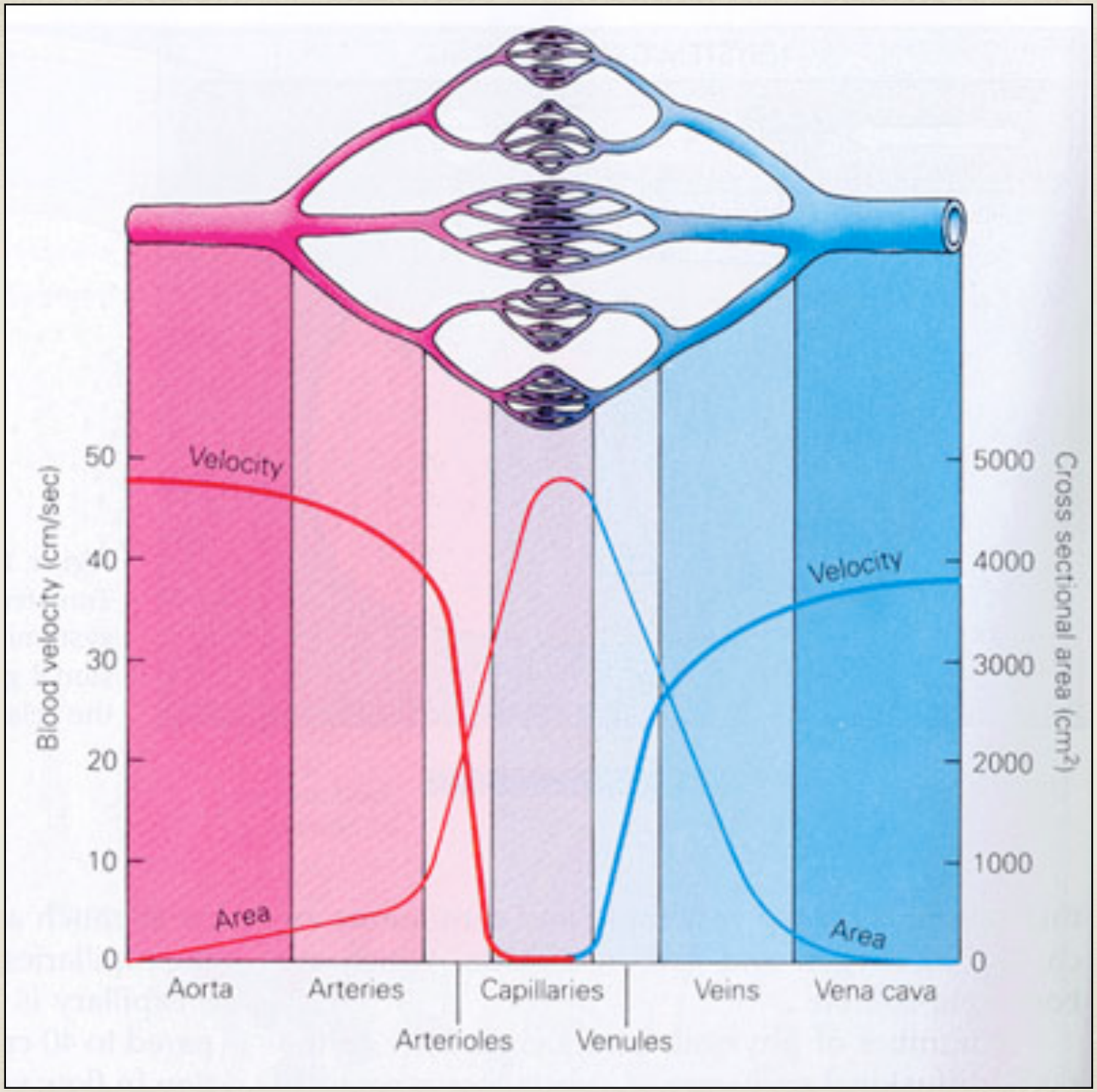
Blood Vessel Cross Sectional Area

- Blood vessel cross sectional area is the **total** cross sectional area of **all** blood vessel of a particular type
- Although the cross sectional area of individual arteries and veins is large, their total cross sectional areas are small since there is a relatively small number of arteries and veins in the circulatory system
- Although the cross sectional area of each individual capillary is small, their total cross sectional area is very large since there is such a large number of capillaries in the circulatory system
- Therefore, ***cross sectional area is highest in the capillaries and lowest in the arteries and veins***

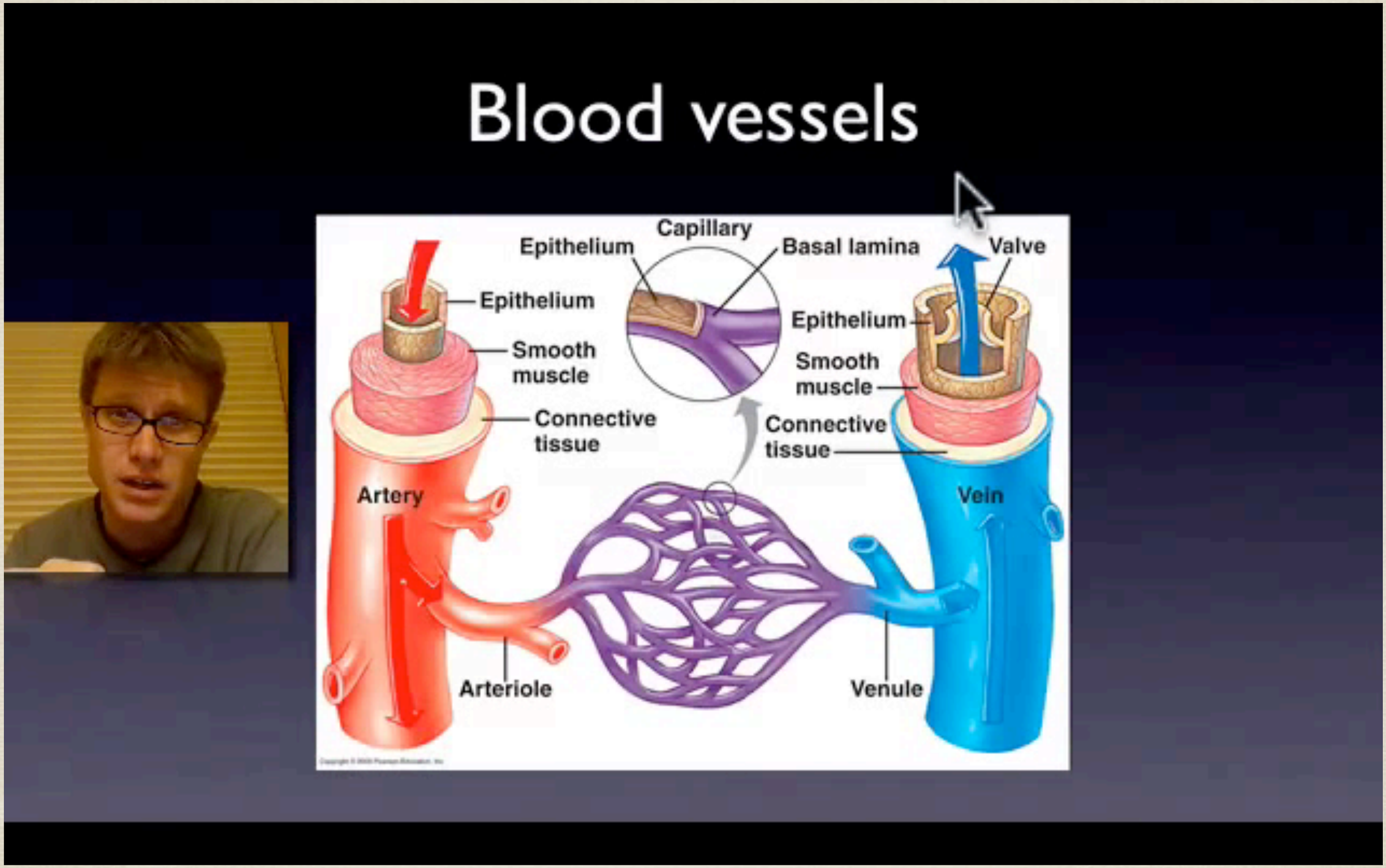
**All of these concepts are interrelated*

Relationships between blood pressure, velocity & cross sectional area

- Blood **pressure** and **velocity** oscillate from high to low in response to the contractions of the **left ventricle**
- As blood moves from the arteries to the arterioles and then to the capillaries, **blood pressure** and **velocity decrease** due to **increasing** cross sectional area of the blood vessels
- **Blood pressure** and **velocity** are at their **lowest** in the capillaries due to the very large **cross sectional area**
- **Blood pressure** in the **venules** and **veins** remains **low** due to the large distance between these vessels and the **heart**
- **Blood velocity increases** once again in the **veins** and **venules** due to the following
  - Contraction of skeletal muscle surrounding the veins
  - A decrease in cross sectional area as venules join to form veins
  - Expansion of the thoracic cavity which decrease external pressure on vessels leading back to the heart


Blood velocity (cm/sec)
50
40
30
20
10
0
Velocity
Area
5000
4000
3000
2000
1000
0
Cross sectional area (cm²)
Velocity
Area
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Vena cava

Heart Sounds, Pulse Rate, Blood Pressure...



Heart Sounds, Pulse Rate, Blood Pressure, Hypertension and Hypotension

Heart Sounds

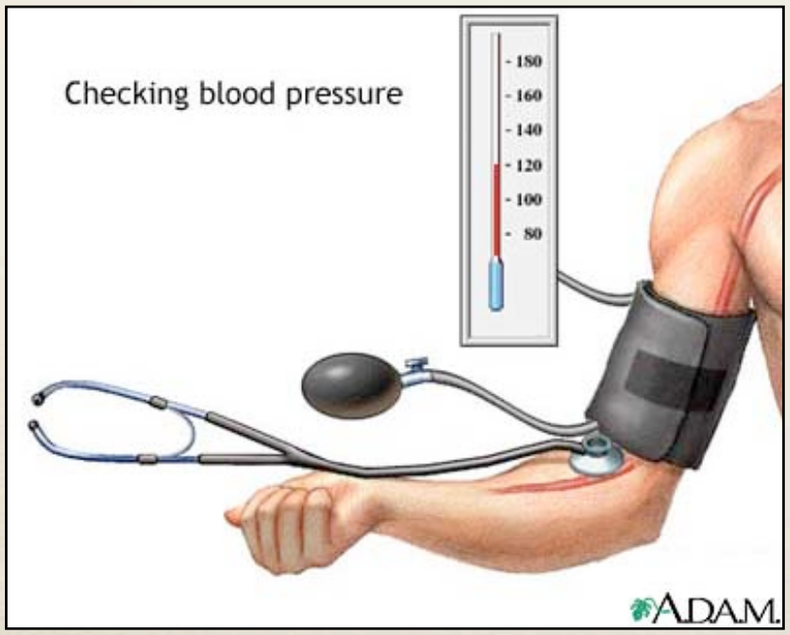
- The heart produces a “lub dub” sound
- The “lub” sound is due to the closing of the atrioventricular valves
- The “dub” sound is due to the closing of the semilunar valves
- Recall that the closing of these valves prevents the backflow of blood in the heart

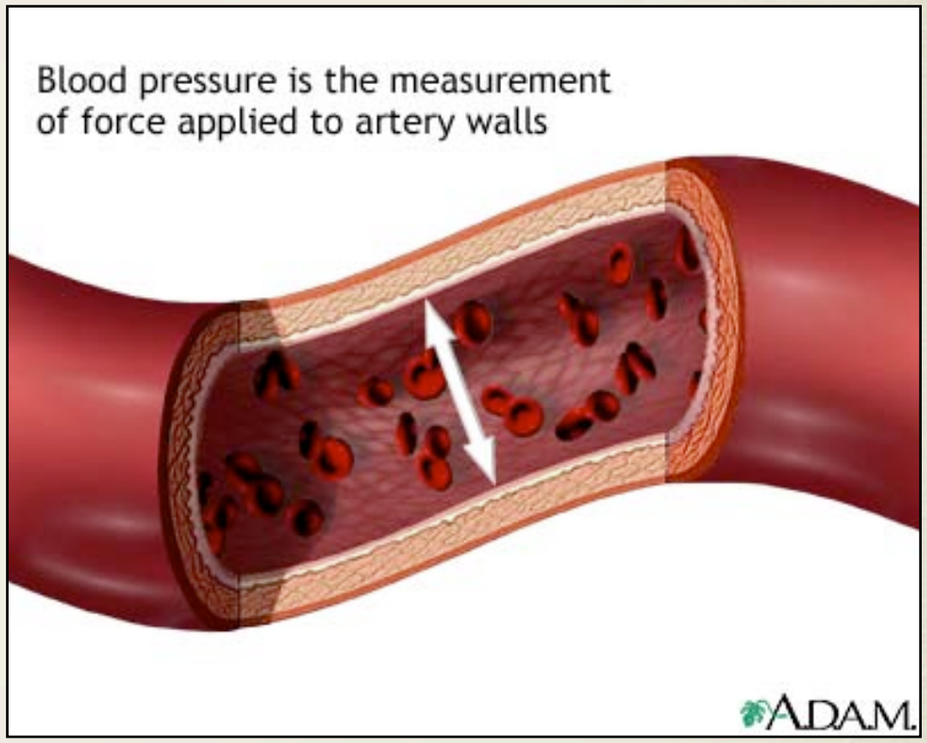
Blood Pressure

- Blood pressure can be measured using a **sphygmomanometer** and is measured in units of **mm Hg**
- Two blood pressure values called **systolic** and **diastolic** pressures are recorded
- **Systolic** pressure occurs when the arterial walls are **stretched**
- **Diastolic** pressure occurs when the arterial walls are **relaxed**
- Blood pressure is typically measured at the brachial artery of the inner arm just above the elbow
- The cuff of the **sphygmomanometer** is wrapped around the arm just above the elbow, with the head of the **stethoscope** against the inner arm

- The person taking the blood pressure listens through the stethoscope while inflating the cuff until no sounds are heard (~160 mmHg)
- The pressure of the cuff is then **slowly released** (by turning the valve on the pump) while the persons listens through the **stethoscope**
- The pressure when the first **tapping sound** is heard is the **systolic pressure**
- The pressure at the point where **no sounds** are heard is the **diastolic pressure**

- Average systolic pressure is 120 mm Hg and average diastolic pressure is 80 mm Hg



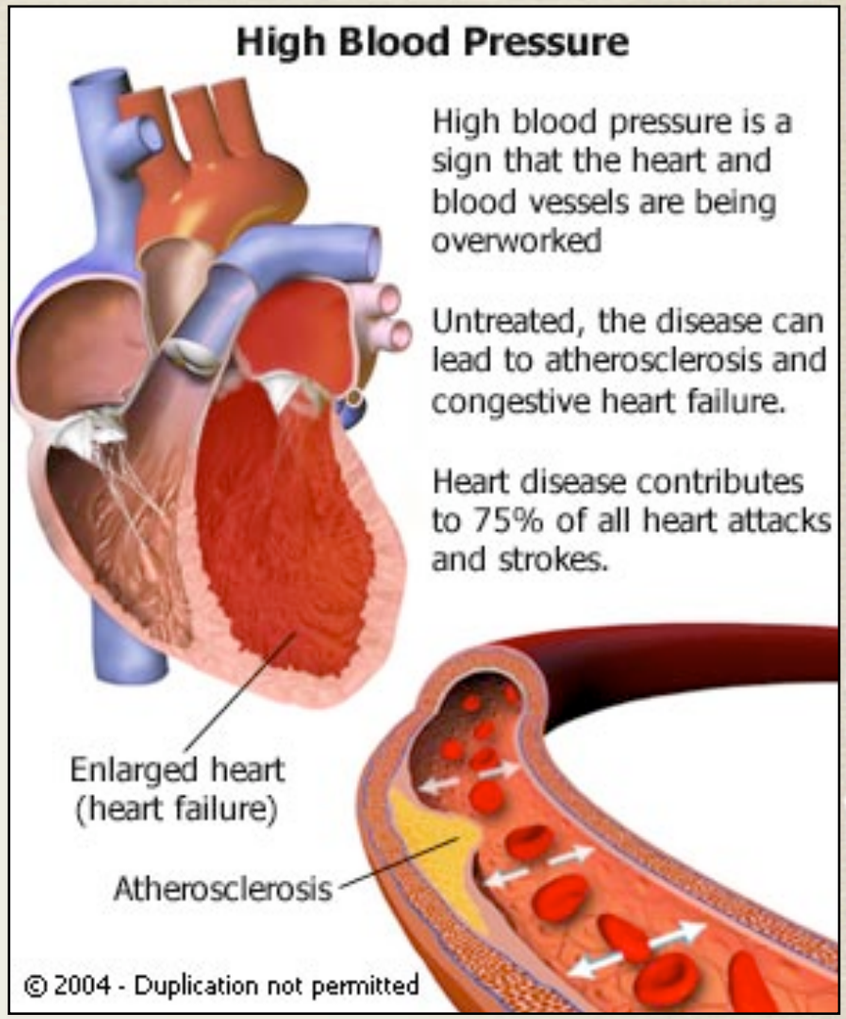


Normal Blood Pressure Fluctuations

- Blood pressure fluctuates normally in response to mechanisms which maintain **homeostasis**
- Such mechanisms include
  - **Dialation** of the peripheral blood vessels to promote **heat loss** and thus aid cooling in the body. This would cause a **decrease** in blood pressure
  - **Constriction** of peripheral blood vessels to **prevent heat loss** and thus aid in maintaining core temperature. This would cause an **increase** in blood pressure
  - Increased **heart rate** to supply cells with additional **oxygen** during times of strenuous exercise. This would cause an **increase** in blood pressure

Hypertension

- Hypertension is **prolonged** and **abnormally high** blood pressure
- Factors which can contribute to hypertension include:
  - Excessive fat and cholesterol in the diet, leading to **atherosclerosis** in which **cholesterol** deposits on the inner walls of the arteries/ vessels and impedes normal blood flow
  - Excessive **salt** intake in the diet which draws water into the blood increases the bloods **diastolic** pressure due to **increased blood volume**
  - **Nicotine** causes blood vessels to **constrict** thus increasing blood pressure
  - Certain types of **heart disease** can lead to **hypertension**



Hypotension

- Hypotension is **prolonged** and **abnormally low** blood pressure
- Factors which can contribute to hypotension include:
  - Excessive blood loss
  - Decreased ventricular output
  - Leaky heart valves would decrease blood pressure by allowing blood to escape and thus less blood is forced through the system

Circulation, Capillary Exchange & Lymphatic System

Pulmonary Circulation

- The function of the pulmonary circulation is to carry blood from the heart to the lungs and back to the heart to allow for **gas exchange**
- The **pulmonary pathway** is as follows:

Pulmonary trunk2 pulmonary arteries(to each lung) arterioles pulmonary capillaries (surrounding air sacs-aveoli) gas exchangevenulespulmonary veins (2 from each lung)heart

Systemic Circulation

- The function of the systemic circulation is to carry blood from the heart to all of the body's tissues and back to the heart to allow for **exchange of nutrients, wastes, carbon dioxide and oxygen**
- The systemic pathway begins with the aorta and branches into several **arteries** including:
  - Coronary arterycarries blood to heart tissue
  - Subclavian arterybranches into the carotid artery (to the head) and the brachial artery (to the arms)
  - Renal arteriesto the kidneys
  - Mesenteric arteriesto the digestive tract
  - Iliac arteries to the legs

- Each artery branches into arterioles which link up with the capillaries
- Exchange of nutrients, wastes O_2 and CO_2 takes place at the capillaries
- Blood moves from the capillaries to the venules and then into the veins which return blood to the heart
- Some of these **veins** include:
  - Renal veins from the kidneys to the inferior vena cava
  - Hepatic portal vein from the small intestine to the liver
  - **NOTE:** a **portal system** begins and ends in capillaries

    The **hepatic portal system** consists of capillaries from the villi of the small intestine which are linked to the capillaries of the liver by the hepatic portal vein
  - Hepatic vein blood from the liver to the inferior vena cava
  - Jugular veins blood from the head to the superior vena cava

Exchange between the Systemic Capillaries and the Tissues

- Exchange of materials occurs at the tissue capillaries
- There are two forces affecting movement of fluid through the capillary wall

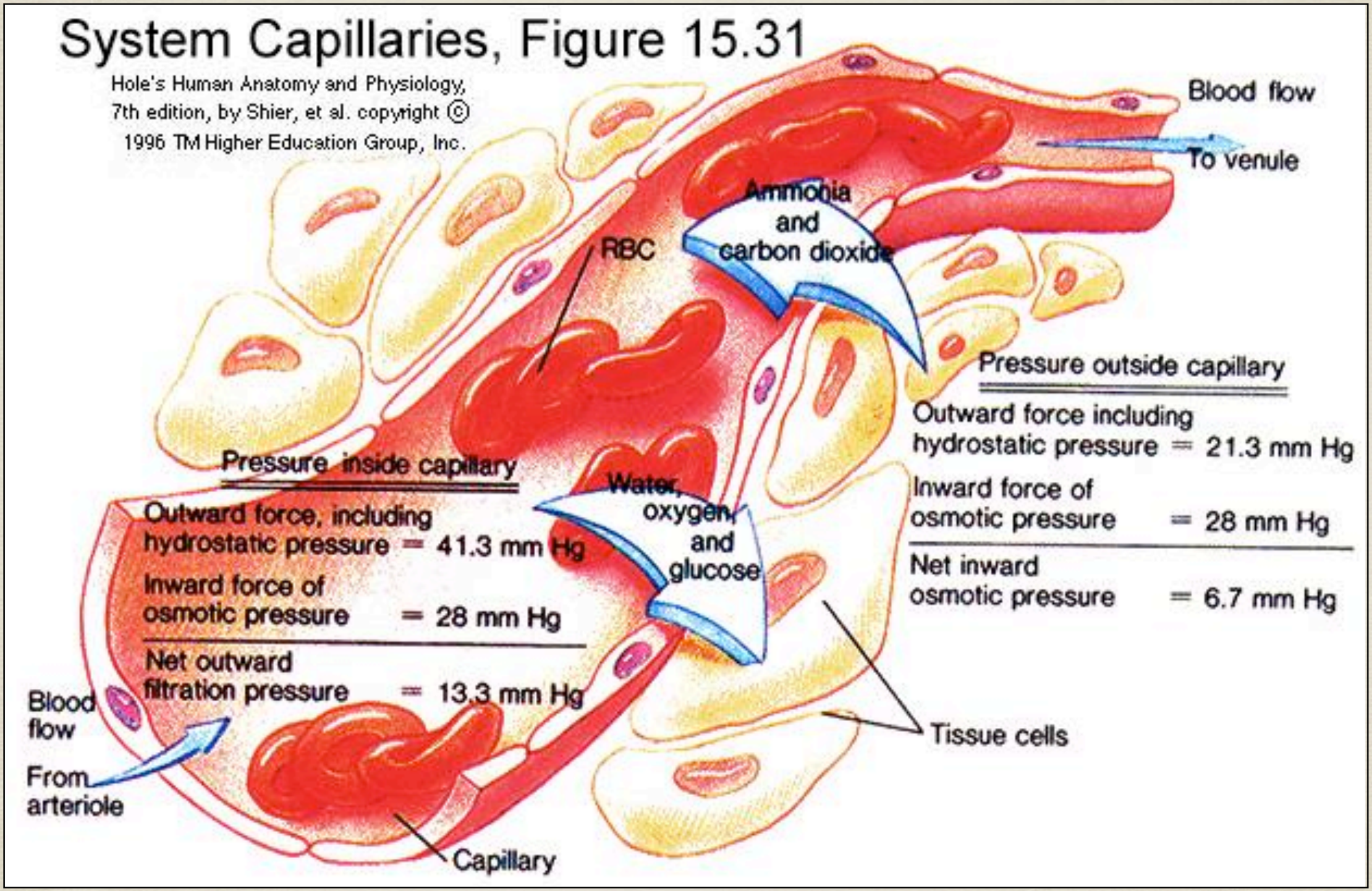
Osmotic Pressure

Blood (Hydrostatic)Pressure

- **Osmotic Pressure**
  - Measure of the tendency of water to move across a membrane
  - This acts as an inward force on the capillary

- **Blood (Hydrostatic Pressure)**
  - Pressure exerted by blood on the vessel walls
  - This acts as an outward force on the capillary

- The **net difference** in these two forces determines whether substances move out of (net hydrostatic force) or into (net osmotic force) the capillary



<u>At the arteriole end (beginning) of capillary bed</u>

- Blood pressure = 30 mmHg
- Osmotic Pressure = 21 mm Hg
- Net **blood** pressure = 9 mm Hg (out of the capillary)
    - ***blood pressure higher than osmotic pressure***

- Blood from arterioles enters capillary beds of various tissues. The blood is carrying oxygen (on the hemoglobin of Red Blood Cells) and nutrients like amino acids and glucose in the plasma.
- On the arteriole side of the capillary bed the blood pressure is higher than the osmotic pressure.
- The higher blood pressure pushes **fluid** containing oxygen, water and nutrients (amino acids and glucose) **into the tissues.**
- Large molecules like red blood cells and plasma proteins cannot cross into the tissues.

Midsection of capillary bed

- In the middle of the capillary bed, blood pressure and osmotic pressure are approximately **equal**
- Therefore movement in this region is due to **diffusion** of particles and depends on the concentration gradient of various particles
- Materials move into the capillary by diffusion
- eg: high concentrations in tissue fluid move to low concentrations in the cell and vice versa. For example:
  - Oxygen diffuses from the capillaries into the tissue fluid and then into the cells cell respiration uses the oxygen and produces carbon dioxide and water which diffuse out of the tissues, into the tissue fluid and eventually into the capillary bed.
  - Amino acids diffuse into the cell and are broken down producing amino groups. These amino groups are converted into ammonia which also diffuses out of the cell, into the tissue fluid and then into a capillary bed.

<u>At the venule side (end) of capillary bed</u>

- Osmotic pressure = 21 mm Hg
- Blood Pressure = 15 mm Hg
- Net **Osmotic** Pressure = 6 mmHg
    - ***blood pressure lower than osmotic pressure***

- Blood pressure is lower than osmotic pressure
- As a result osmotic pressure (The force that causes the flow from a high concentration to a low concentration) **fluid** is forced back **into** the **capillary**
- This bring additional amounts of waste materials (carbon dioxide and ammonia) into the capillaries

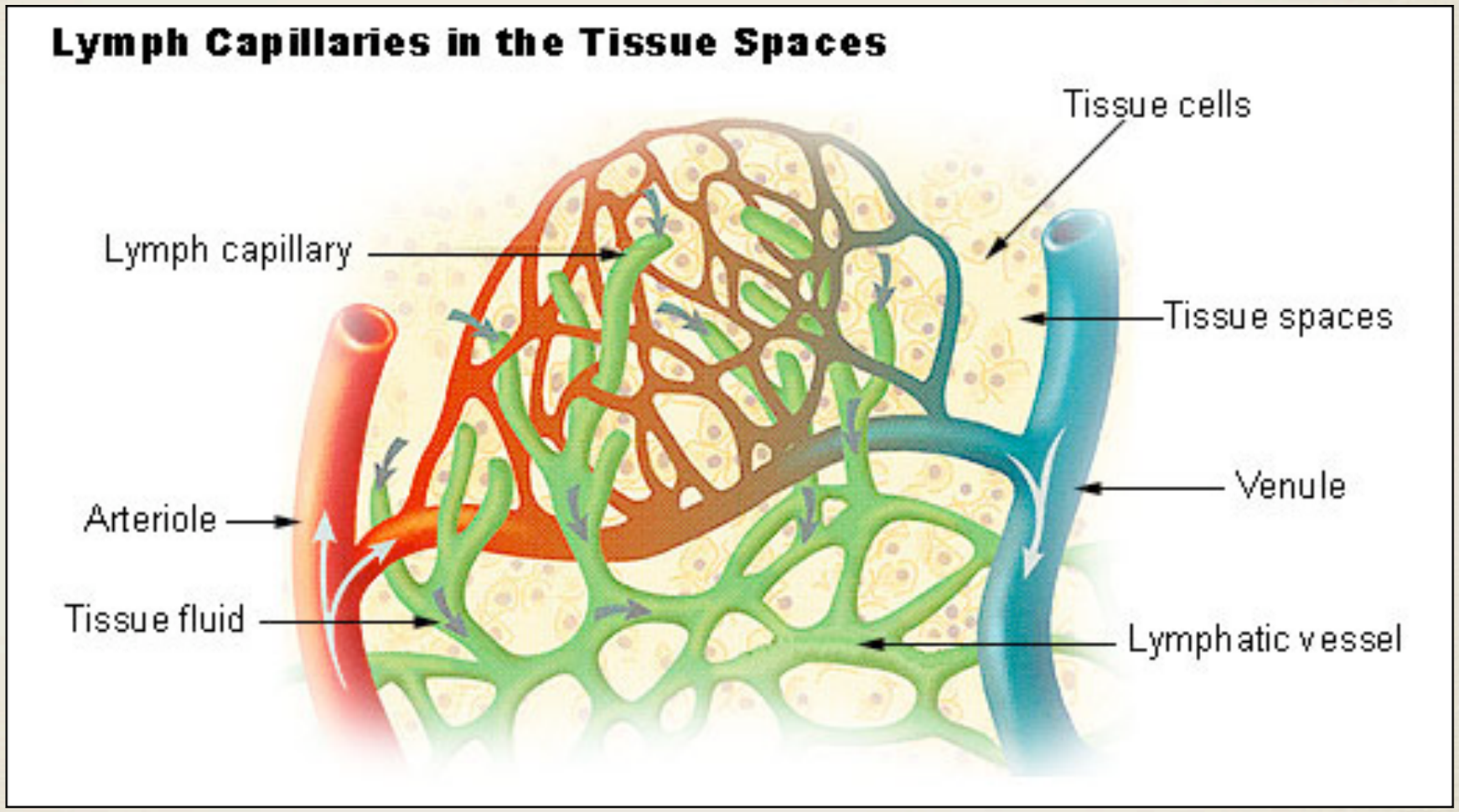
Lymphatic System

- The major **functions** of the lymphatic system are:
  - Take up **excess fluid** and return it to the blood stream
  - **Transport fat** from the digestive system to the blood stream
  - Work with the immune system to **fight disease**

- The components of the lymphatic system are:
  - Lymph
  - Lymphatic vessels
  - Lymph nodes
  - Lymph organs (immune function)

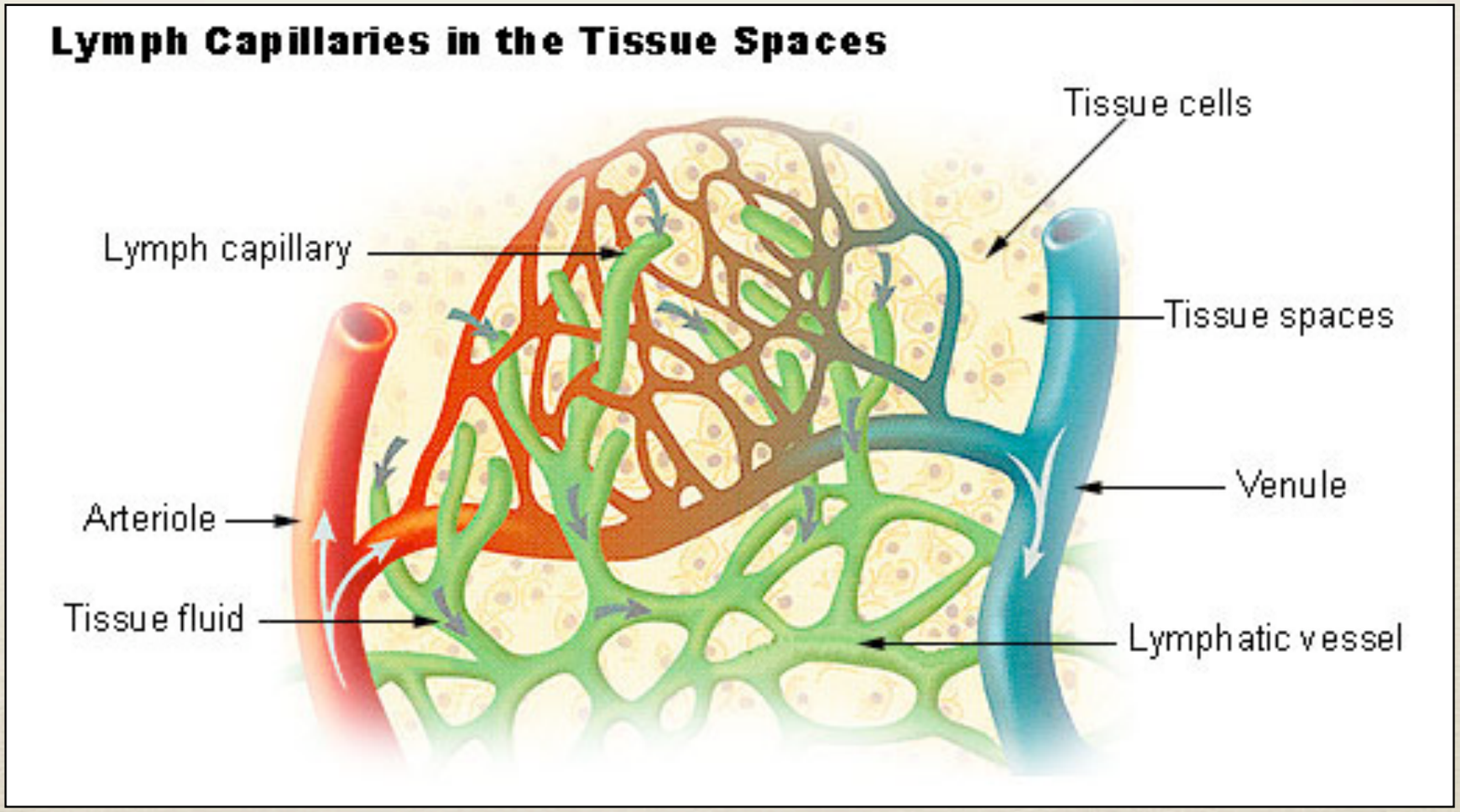
Lymph

- Lymph, which consists largely of **fluid** in which some small solute particles are dissolved, is the fluid which was not returned to the blood at the venule end of the capillary bed
- This fluid enters the lymph vessels



Lymph Vessels

- The lymphatic vessels include the lymphatic capillaries and vessels which form an extensive network throughout the body
- **Lymphatic capillaries** gather and conduct lymph fluid into the larger lymph vessels
- The **larger vessels** are similar in structure to veins and have one way **valves** to prevent the backflow of lymph
- The lymph vessels direct fluid to the **lymph ducts** which return the fluid to the cardiovascular system
- If too much tissue fluid is produced or not drained away, an **edema** can result (swelling due to fluid build up)



Lymph Nodes

- Lymph nodes are ovoidial structures surrounded by a capsule
- The interior of the lymph node is divided into the cortex and medulla
- Macrophages in the medulla work to cleanse the lymph fluid
- Lymphocytes congregate in the cortex to fight infection