

The Vertebrate Circulatory System

Transportation

Respiratory

Erythrocytes (red blood cells) transport oxygen from lungs to tissues

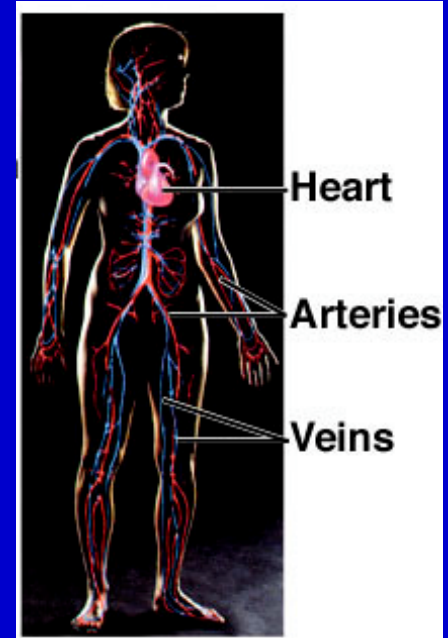
Hemoglobin of red blood cells is transporter
CO₂ is released by cells into blood - carried back to lungs

Nutritive

Nutrients enter blood through wall of intestine
Carried to liver and to all body cells

Excretory

Metabolic wastes carried to kidney for removal
Filtered through capillaries - Excreted in urine



Regulation

Hormone transport

Hormones produced in endocrine glands - transported to target tissues throughout body

Temperature regulation

Warm-blooded vertebrates are homeotherms

Heat distributed by circulating blood

Temperature adjusted by directing flow to or from extremities

Protection

Blood clotting

Protects against blood loss when vessels are damaged

Involves proteins in plasma and platelets

Immune defense

Leukocytes, white blood cells, provide immunity against disease agents

Are phagocytic, produce antibodies or have other actions

Blood Vessels

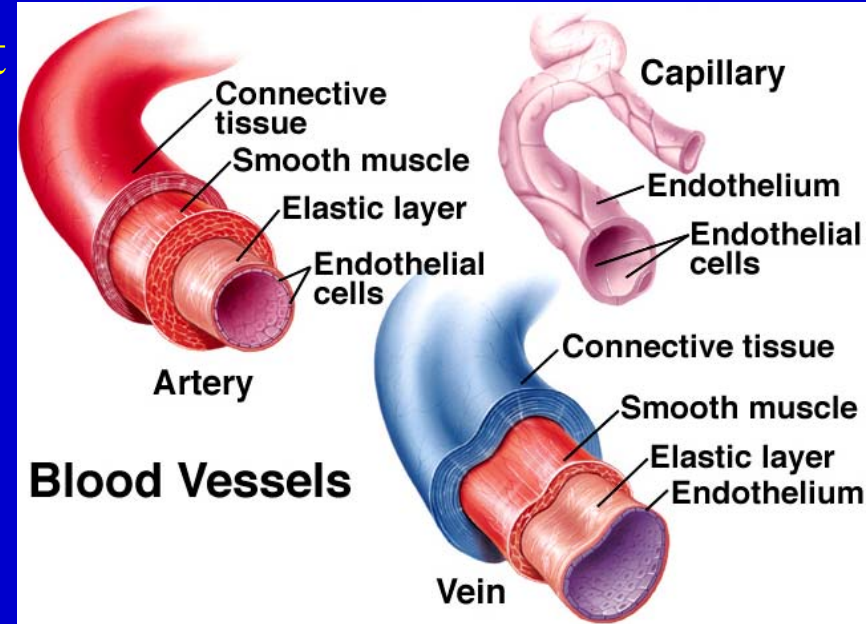
Arteries - carry blood away from heart

Arterioles - network of microscopic vessels of arterial tree

Capillaries - fine network of thin-walled tubes

Venules - small vessels that collect blood from capillaries

Veins - return blood to heart



Arteries, arterioles, veins and venules have similar structure
four layers of tissue

endothelium, elastic fibers, smooth muscle, connective tissue

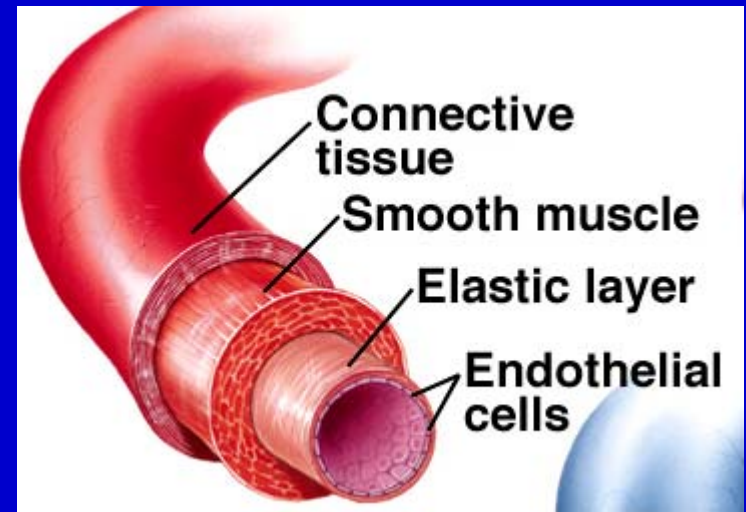
too thick to permit exchange of materials with surrounding tissues

Exchange with tissues occurs in capillaries, endothelium is only layer
molecules and ions leave blood plasma by filtration (pressurized)
travel through pores in capillary walls or transported through
endothelial cells

Arteries and Arterioles

elastic fibers allow large arteries to expand and recoil when receiving blood from heart - helps to buffer effect of pulsing on capillary beds

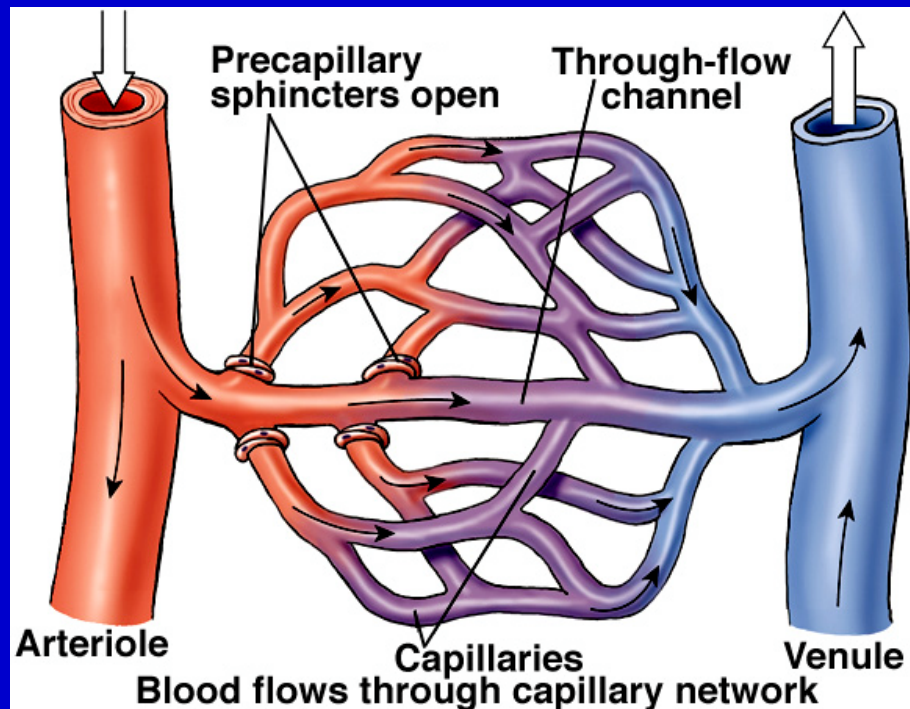
smaller arteries and arterioles are less elastic, but have thicker smooth muscle - allows change in diameter
small diameter arteries and arterioles cause greatest resistance to blood flow



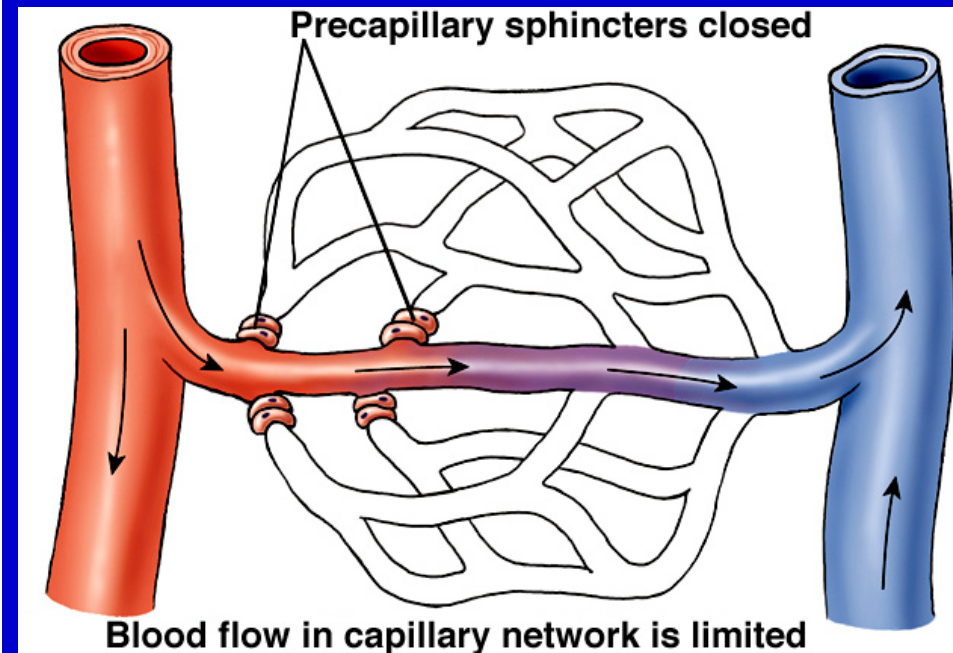
Vasoconstriction - through contraction of smooth muscle increases resistance, decreases flow volume

Vasodilation - through relaxation of smooth muscle decreases resistance, increases flow volume

Blood around some organs regulated by precapillary sphincters
rings of smooth muscle around arterioles at capillary bed
can regulate or stop blood flow to capillary bed
Example - close beds in skin to limit heat loss in cold environments



High tissue perfusion



Low tissue perfusion

Capillary Exchange

Heart provides sufficient pressure to pump against resistance of arterial tree and into capillaries

Every cell is within 100 μm of a capillary

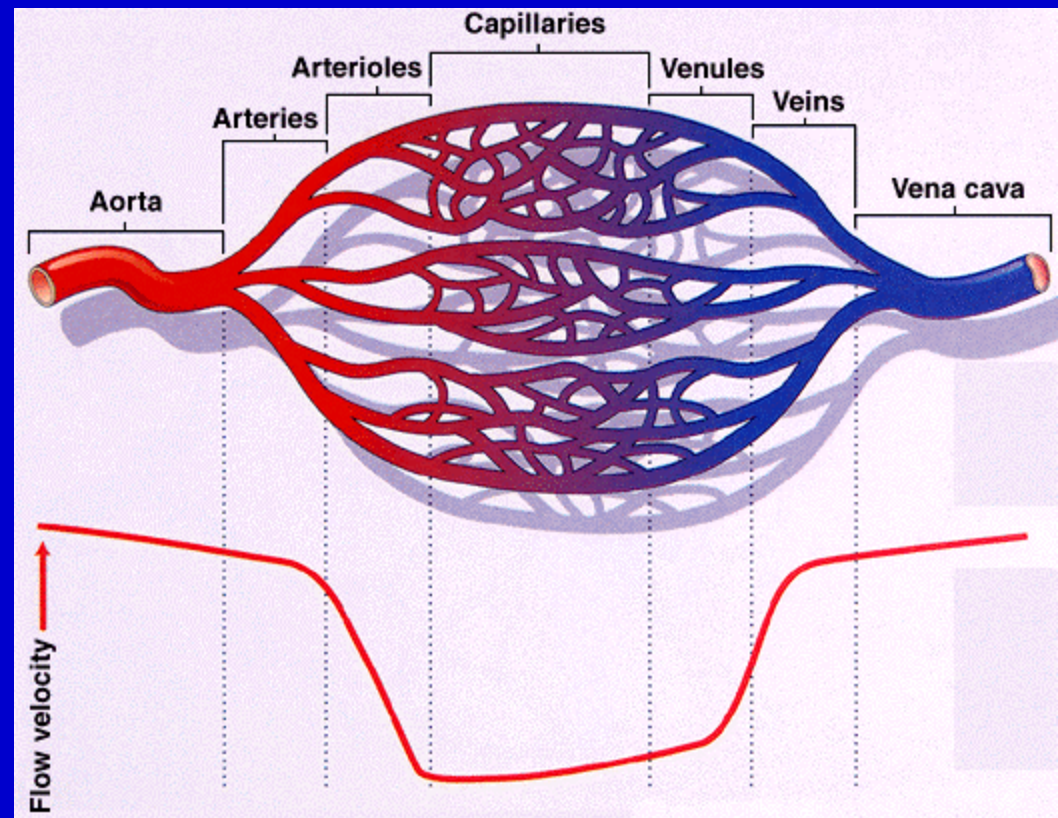
Average capillary 1 mm long, 8 μm diameter, slightly larger than a red blood cell

Capillaries have greatest cross-sectional area

Blood velocity decreases in capillary beds

Provides greater time for exchange of materials with tissues

Blood pressure is greatly reduced when blood enters veins



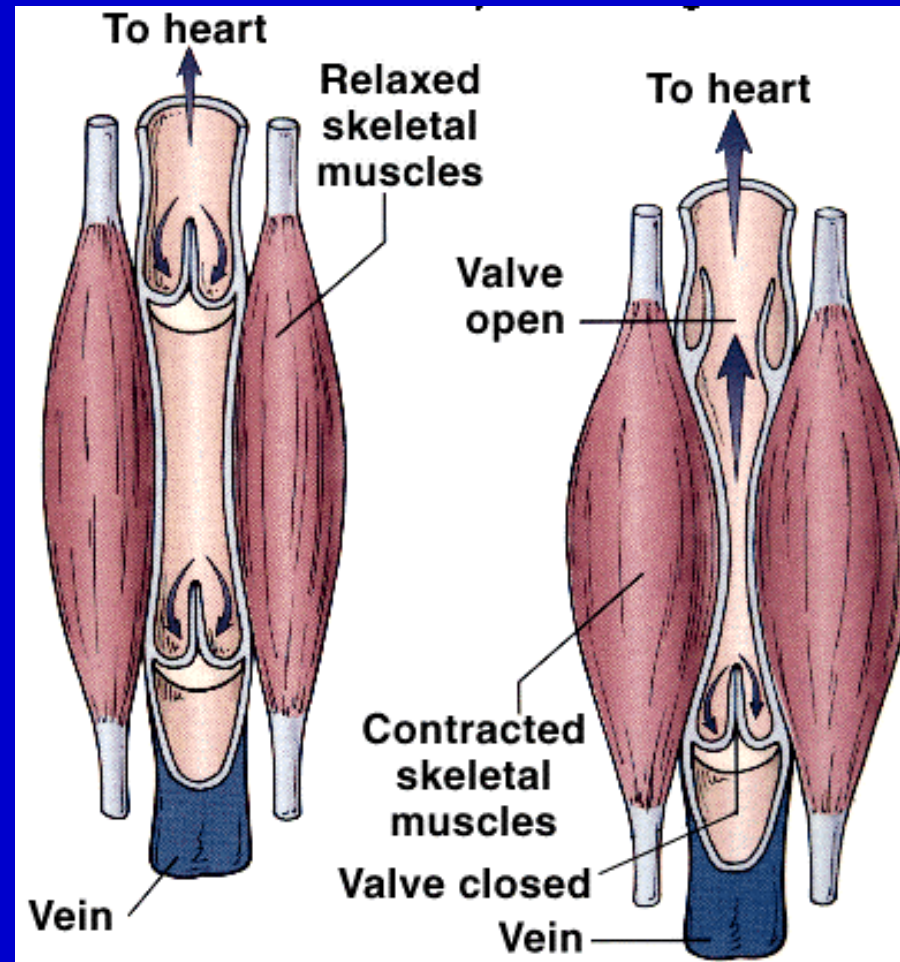
Venules and Veins

Veins and venules have thinner layer of smooth muscle than arteries
pressure one-tenth that of arteries
can expand to hold greater quantities - most blood in body is in veins

Venous pressure is insufficient to
return blood to heart from feet
- aided by contraction of
skeletal muscles

One-way venous valves direct
flow toward heart

Varicose veins - caused by blood
pooling in veins when valves
fail



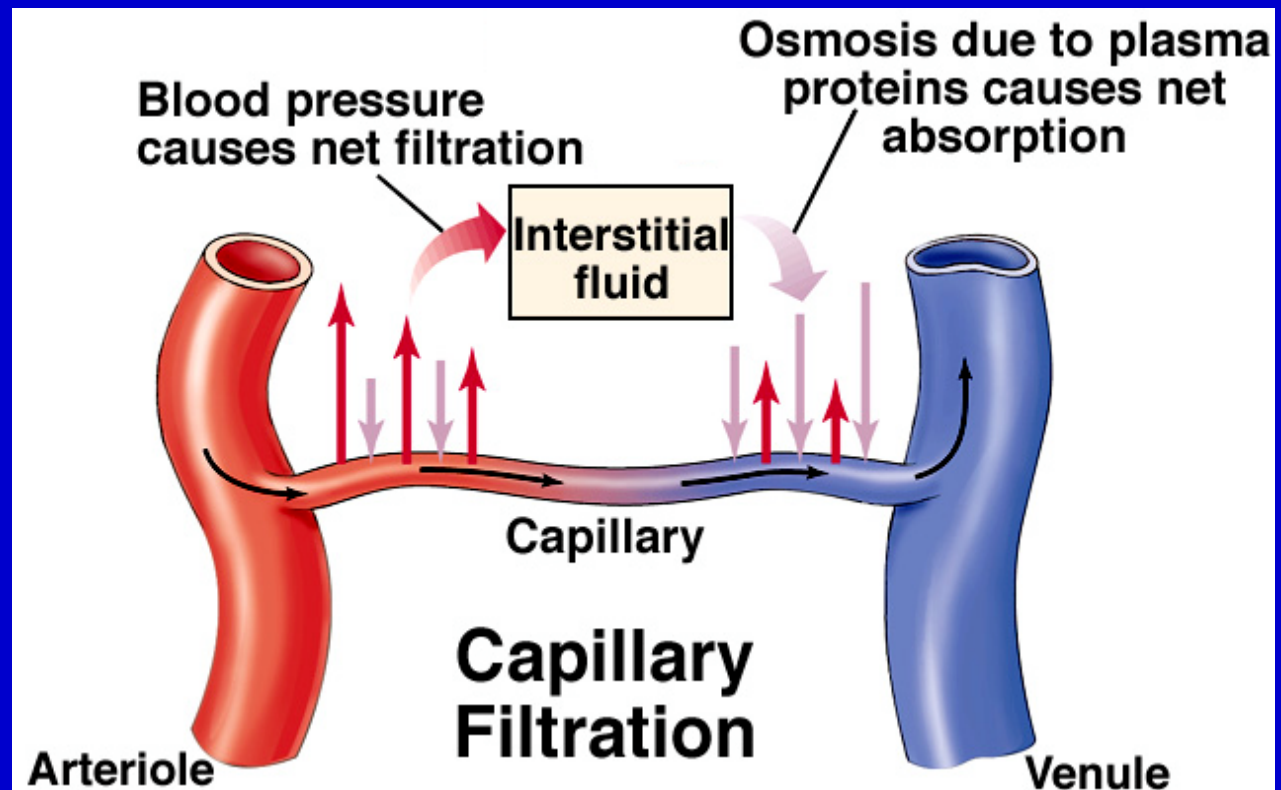
Circulatory system delivers by diffusion through capillary walls
Filtration driven by pressure of blood - supplies cells with nutrients
Most fluid returned by osmosis due to concentration of protein in blood

High capillary blood pressure causes production of too much interstitial fluid - “edema” - a swelling of tissues in extremities

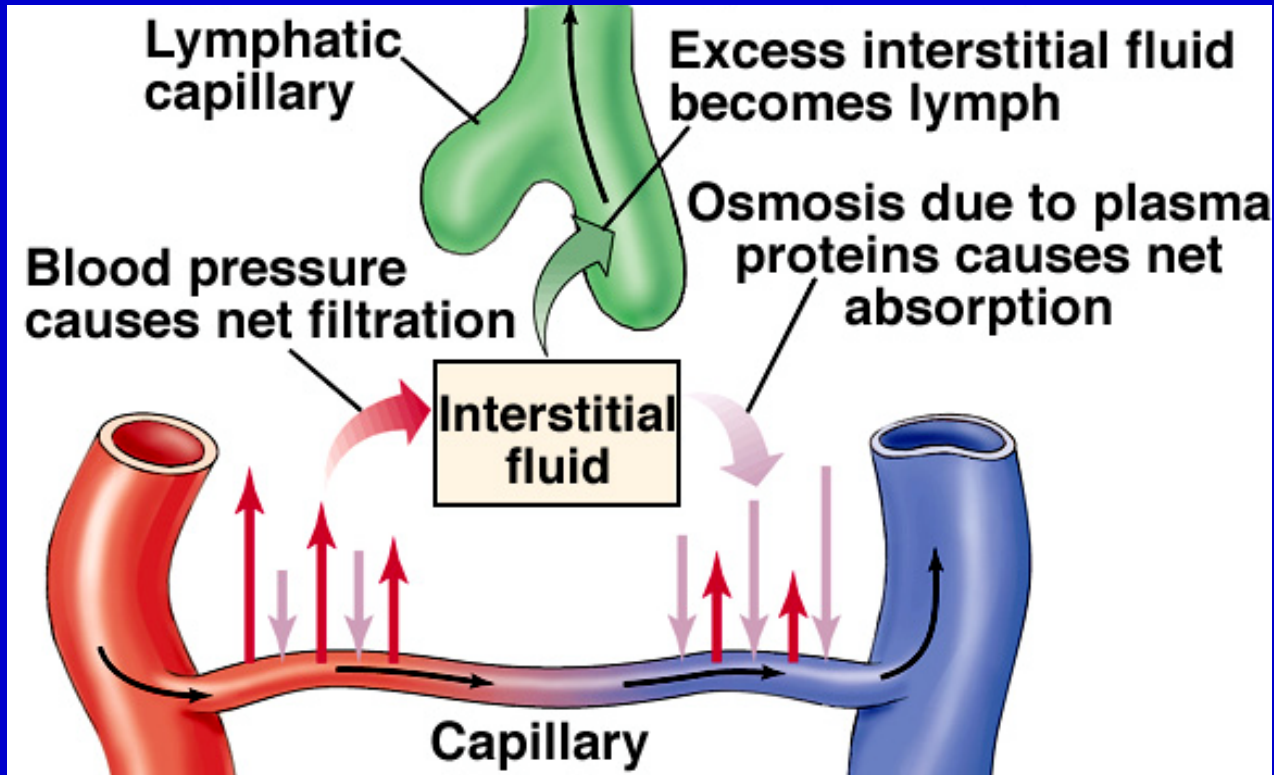
Edema commonly occurs in feet of pregnant women

Edema also results when plasma protein concentration is too low

May be caused by liver disease or protein malnutrition

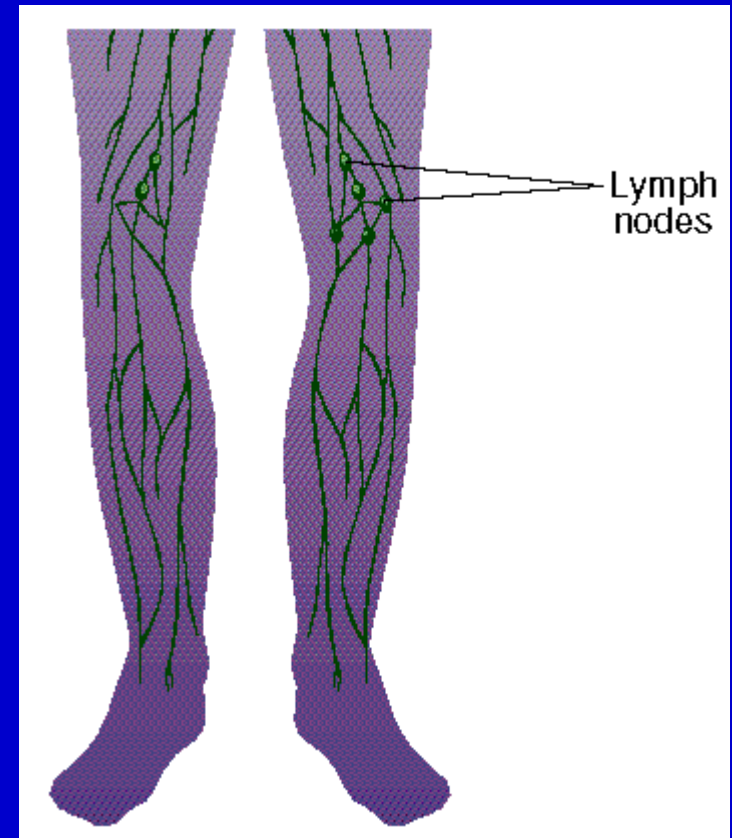
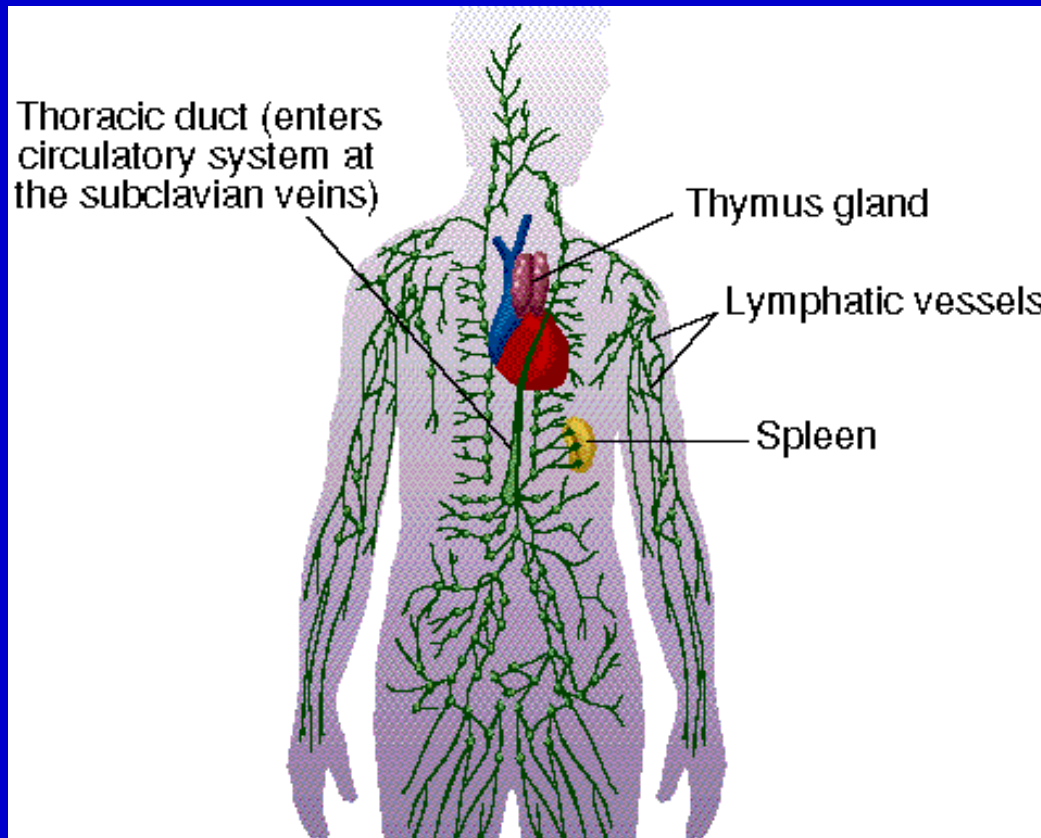


The lymphatic system recovers lost fluid and returns it to blood
Composed of lymphatic capillaries, lymphatic vessels, lymph nodes
and lymphatic organs like spleen and thymus
Fluid in tissues diffuses into blind-end lymph capillaries



Lymph passes into larger vessels
Lymphatic vessels also contain one-way valves

Major lymphatic ducts drain into veins on sides of neck
Lymph fluid movement assisted by movement of muscles
Some lymph vessels contract rhythmically
Lymph modified by phagocytic cells in lymph nodes and lymphatic organs



The Heart - has two pairs of valves

Atrioventricular (AV) valves lie between atria and ventricles

on right side - tricuspid valve

on left side - bicuspid or mitral valve

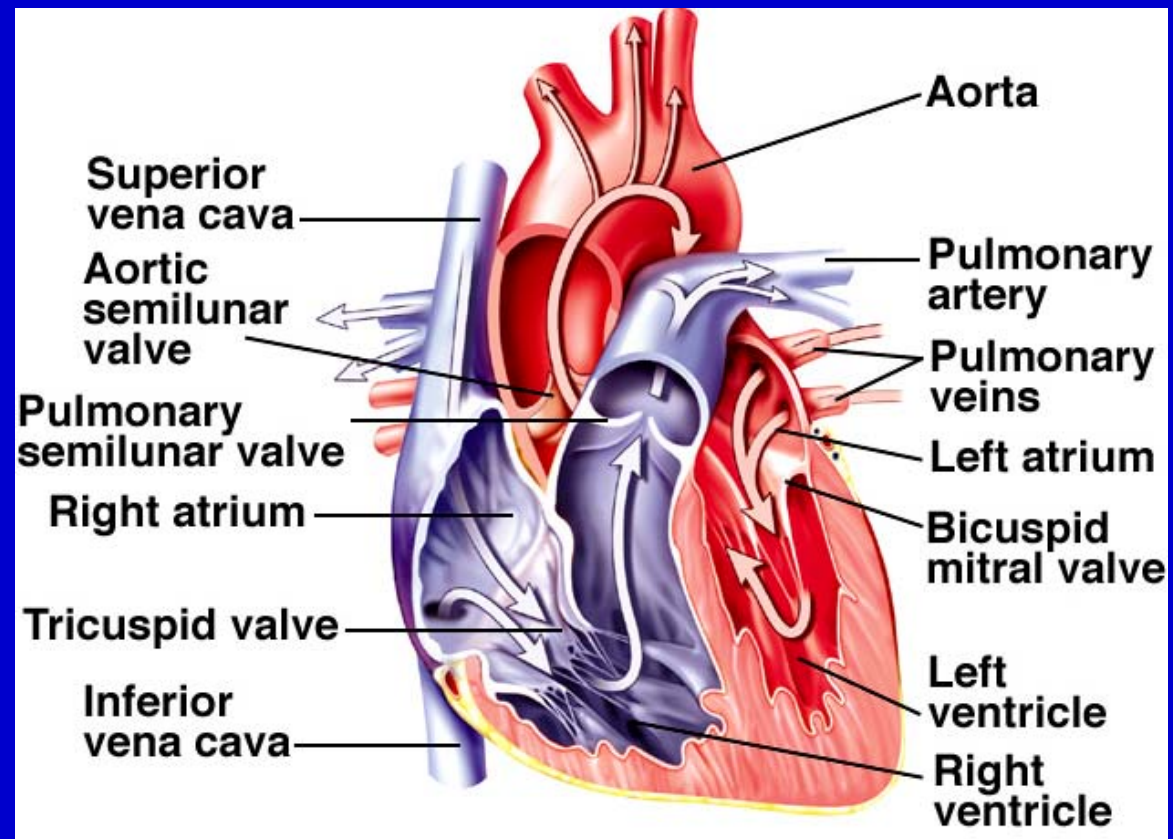
Semilunar valves lie between ventricles and main arteries

right - pulmonary valve

left - aortic valve

Right side sends
blood to lungs

Left side sends
blood to rest of
body



How the Heart Is Stimulated to Contract

Caused by transmission of membrane depolarization

triggered by **sinoatrial (SA) node** - the “pacemaker”

SA cells depolarize spontaneously with regular rhythm

depolarization passes from one cardiac muscle cell to another

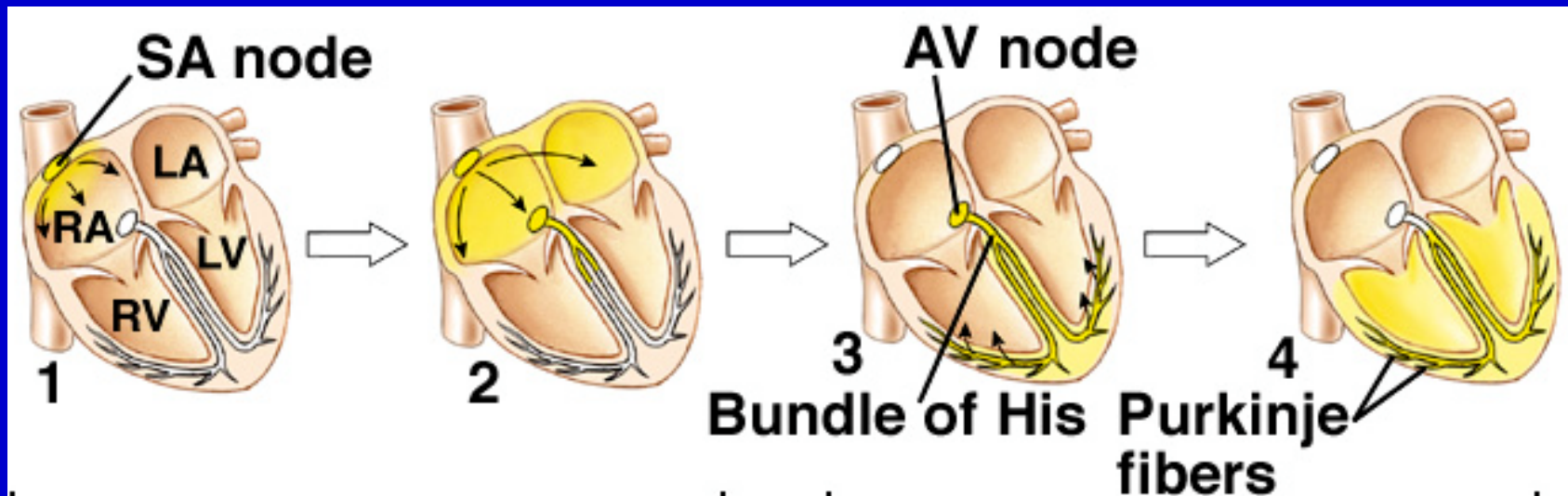
cardiac cells are “electrically” coupled by gap junctions

Atria contract first - ventricular depolarization delayed by ~ 0.1 sec

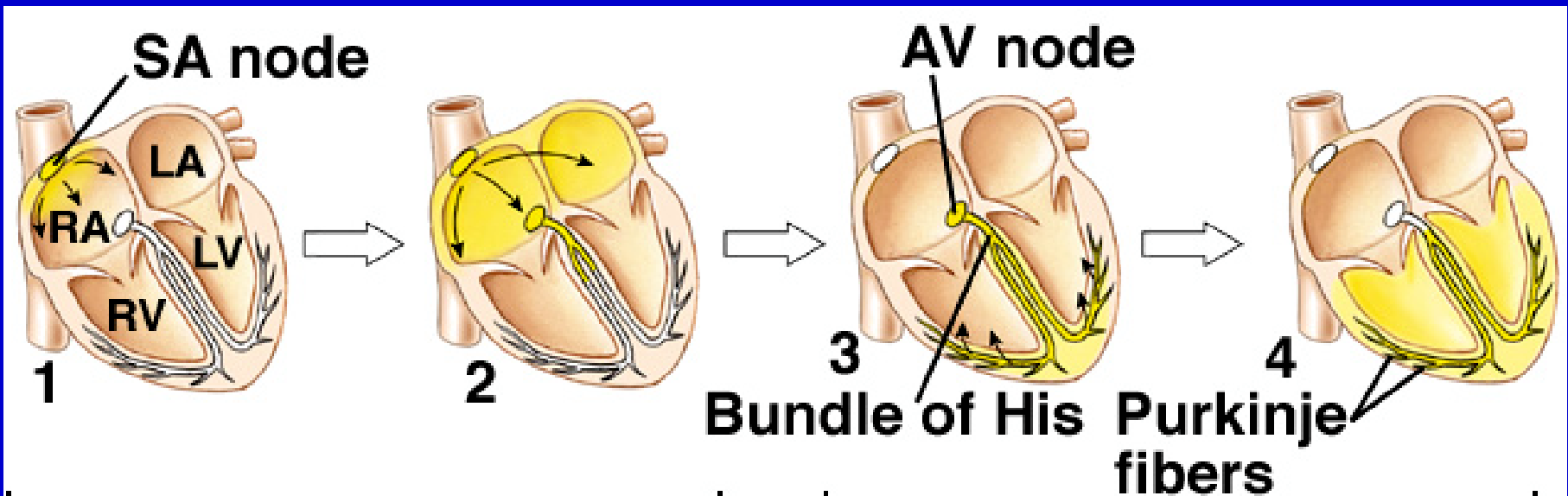
Separated by nonconductive connective tissue

Wave passes via **atrioventricular (AV) node**

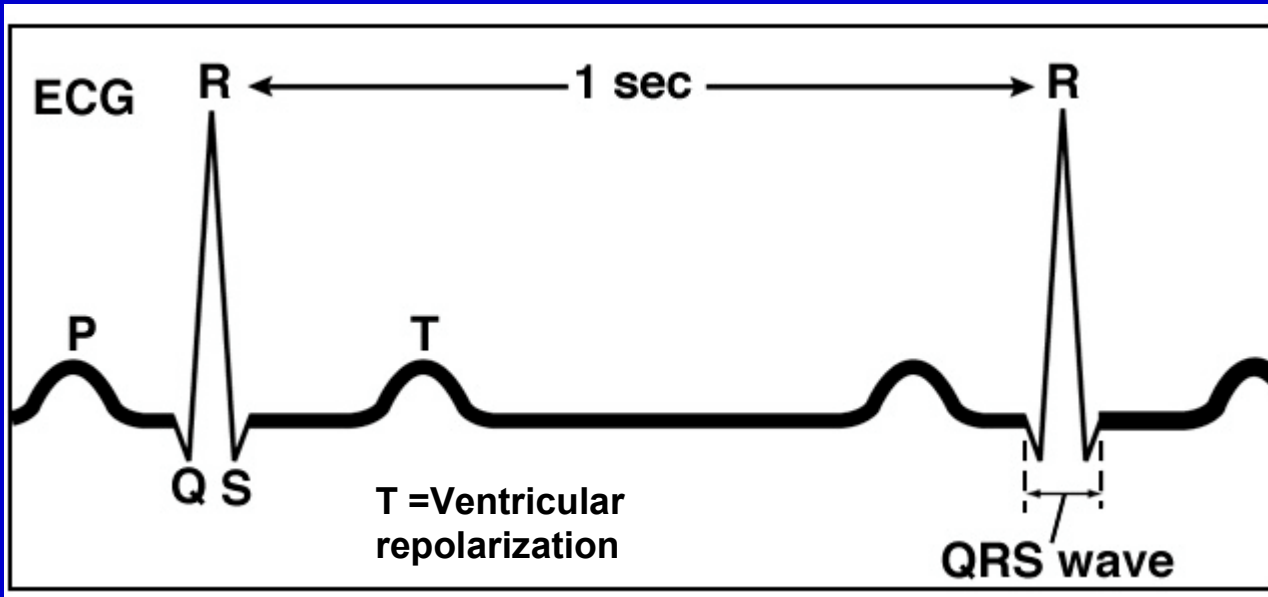
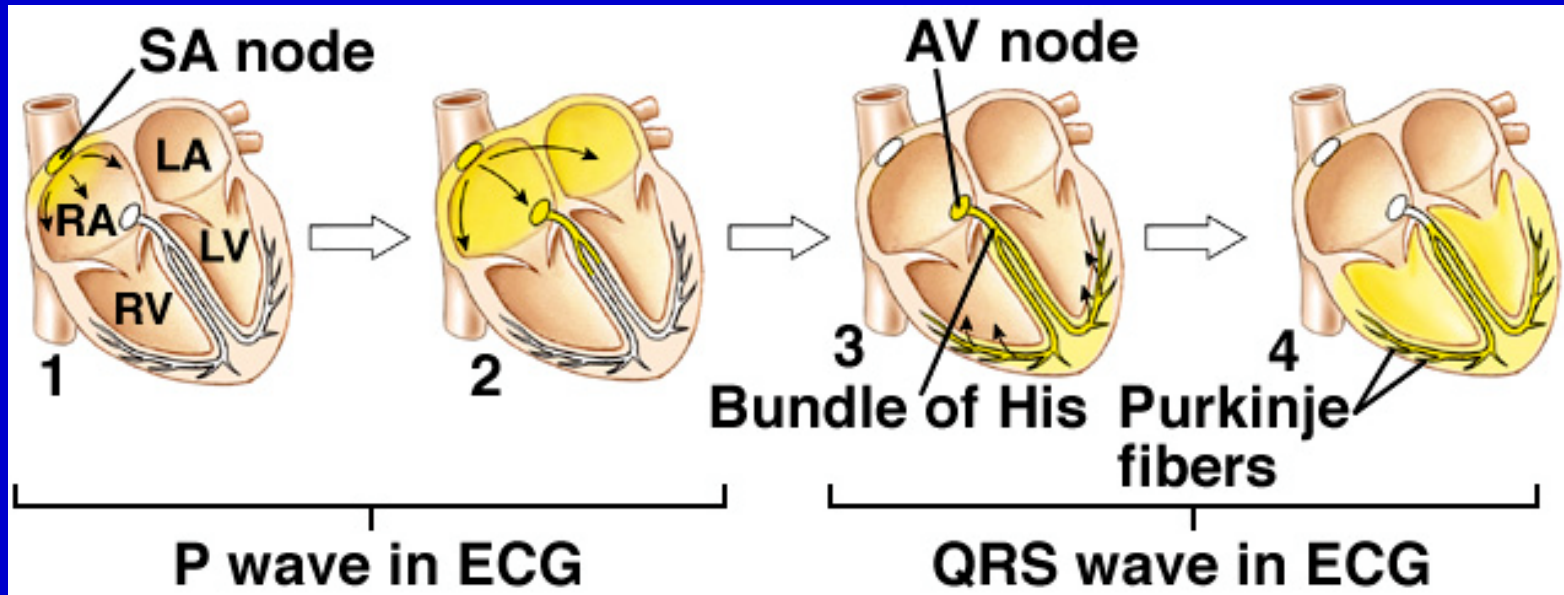
Delay permits atria to empty before ventricles contract



Ventricles contract together - signal carried through
atrioventricular bundle of fibers - “Bundle of His”
Signal transmitted by Purkinje fibers to bottom of ventricles
stimulates ventricular cells to contract
Right and left ventricles contract almost simultaneously from
bottom to top, emptying ventricles



ECG readings and contraction



Blood Pressure and the Baroreceptor Reflex

Arterial blood pressure depends on two factors

- Cardiac output - how much ventricles pump

- Resistance to flow

Increased blood pressure caused by

- Increased heart rate or blood volume or resistance

 - Vasoconstriction - produces increased resistance to flow

Blood pressure will fall if

- Heart rate slows or blood volume reduced or vasodilation

Baroreceptors are sensitive to changes in arterial blood pressure

- Located in walls of aortic arch and carotid arteries

- Connected to cardiovascular control center in medulla

When baroreceptors detect decrease in blood pressure

- Stimulates an increased heart rate and vasoconstriction of vessels in skin and viscera

- Raises blood pressure

Baroreceptors act to maintain blood flow to brain with rapid standing

Rapid standing changes venous pressure in lower body, reduces pressure above the heart

Increases volume of blood in lower body

Reduced return of blood to heart and reduced cardiac output

Low blood flow to brain can cause light-headedness or fainting

Reflex rapidly increases heart rate, constricts arterioles

Maintains normal blood pressure