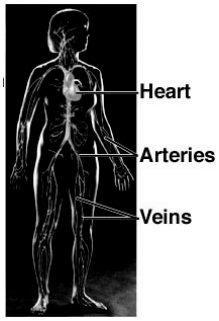
The Vertebrate Circulatory System



Transportation

- Respiratory
  - Erythrocytes (red blood cells) transport oxygen from lungs to tissues
  - Hemoglobin of red blood cells is transporter
  - CO_2 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

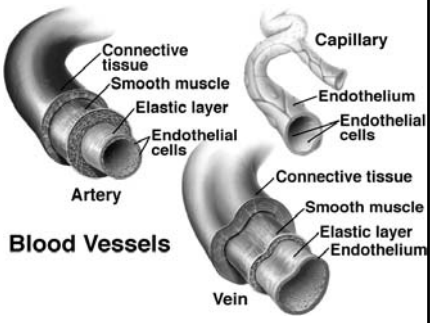
- Hormone transport
  - Hormones produced in endocrine glands - transported to target tissues throughout body
- Temperature regulation
  - Warm-blooded vertebrates are homeotherms
  - Heat distributed by circulating blood
  - Temperature adjusted by directing flow to or from extremities

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

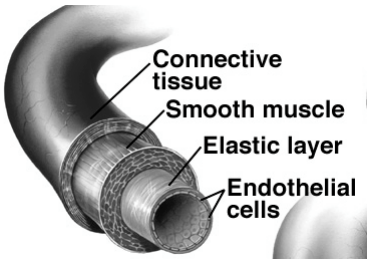
Blood Vessels

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

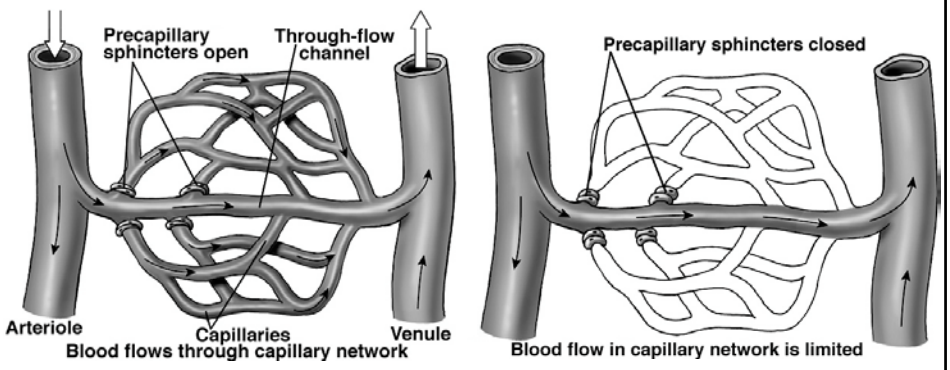


elastic fibers allow large arteries to expand and recoil when receiving blood from heart - helps to buffer effect of pulsing on capillary beds
smaller arteries and arterioles are less elastic, but have thicker smooth muscle - allows change in diameter
small diameter arteries and arterioles cause greatest 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

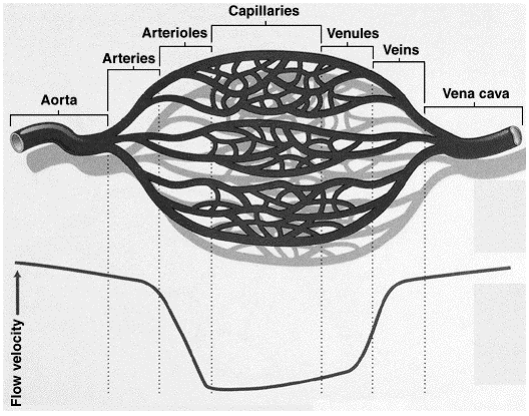
Average capillary 1 mm long, 8 μm diameter, slightly larger than a red blood cell

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

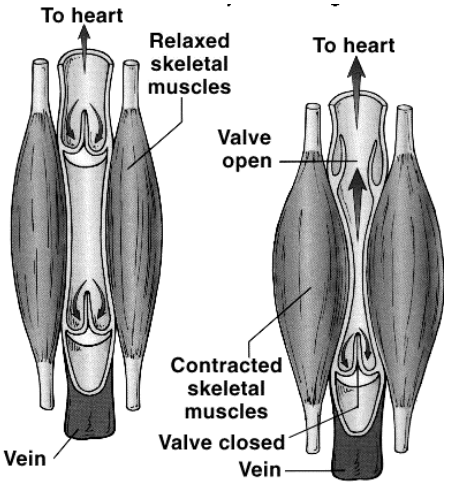


Venules and Veins

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

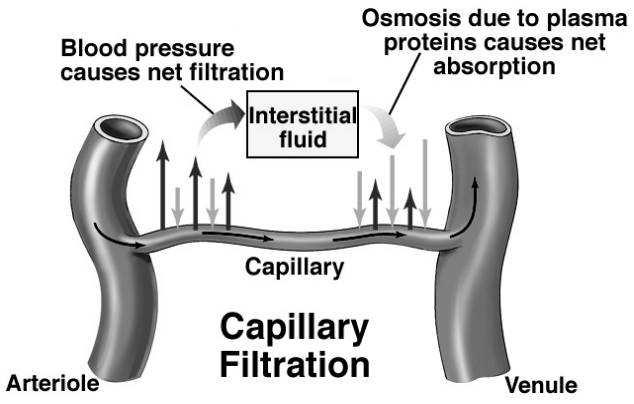
- Venous pressure is insufficient to return blood to heart from feet - aided by contraction of skeletal muscles
- One-way venous valves direct flow toward heart

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

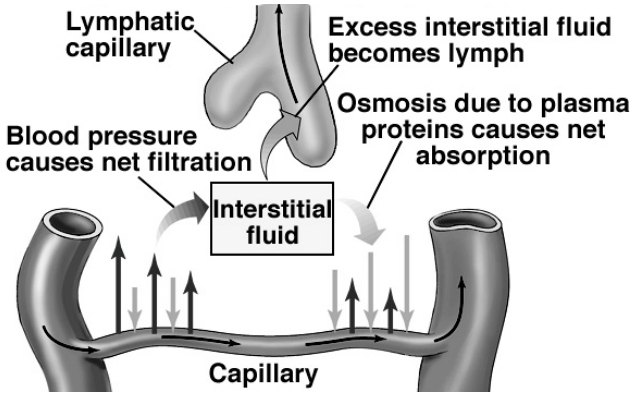


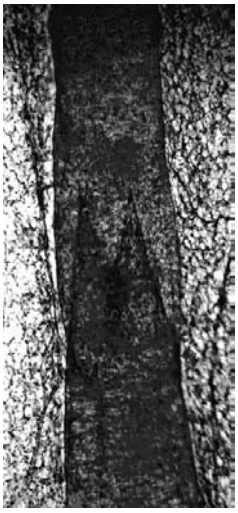
Circulatory system delivers by diffusion through capillary walls
Filtration driven by pressure of blood - supplies cells with nutrients
Most fluid returned by osmosis due to concentration of protein in blood
High capillary blood pressure causes production of too much interstitial fluid - "edema" - a 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



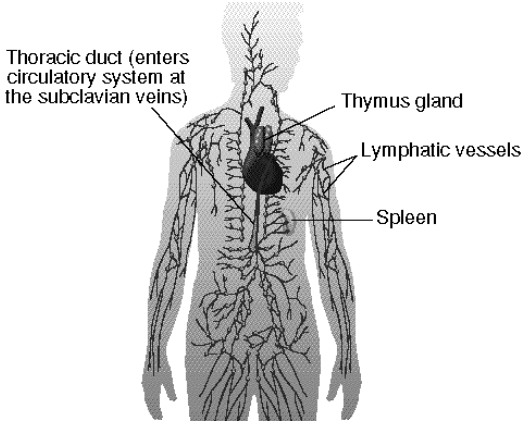
The lymphatic system recovers lost fluid and returns it to blood
Composed of lymphatic capillaries, lymphatic vessels, lymph nodes and lymphatic organs like spleen and thymus
Fluid in tissues diffuses into blind-end lymph capillaries

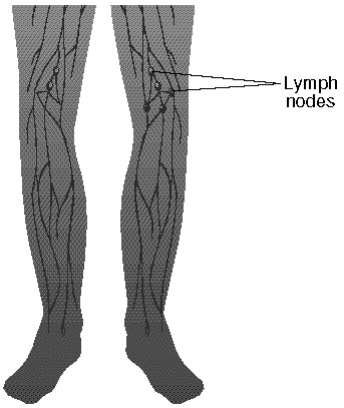




Lymph passes into larger vessels
Lymphatic vessels also contain one-way valves

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

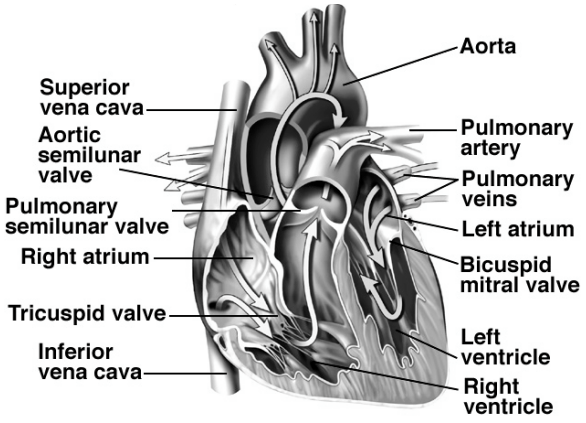
Semilunar valves lie between ventricles and main arteries

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

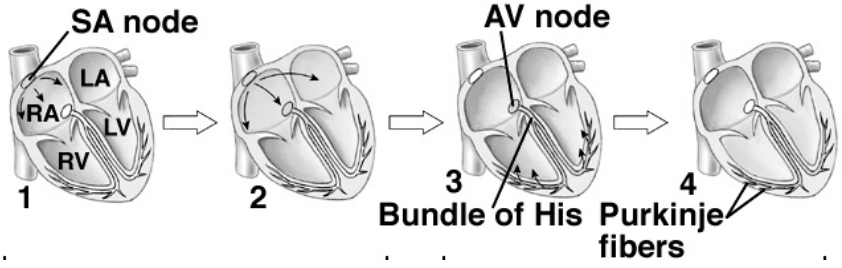
cardiac cells are "electrically" coupled by gap junctions

Atria contract first - ventricular depolarization delayed by ~ 0.1 sec

Separated by nonconductive connective tissue

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

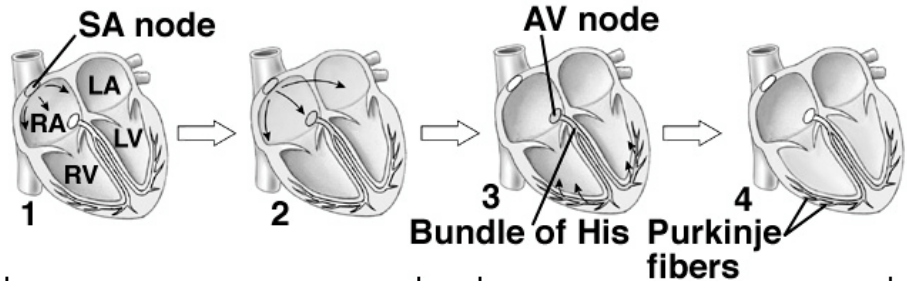
Delay permits atria to empty before ventricles contract



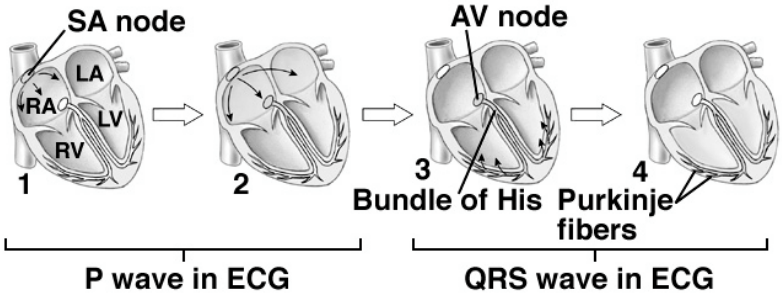
Ventricles contract together - signal carried through atrioventricular bundle of fibers - “Bundle of His”

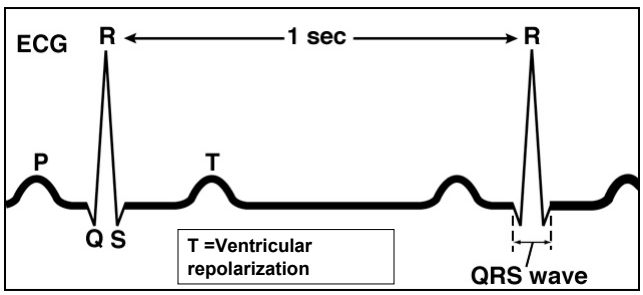
Signal transmitted by Purkinje fibers to bottom of ventricles stimulates ventricular cells to contract

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