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 moving through 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.
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. It is composed of lymphatic capillaries, lymphatic vessels, lymph nodes, and lymphatic organs like the spleen and thymus. Fluid in tissues diffuses into blind-end lymph capillaries.

Lymph passes into larger vessels, and 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

P wave in ECG

QRS wave in ECG

ECG

R

1 sec

Q

S

T = Ventricular repolarization

QRS wave
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