Grade 11 Biology

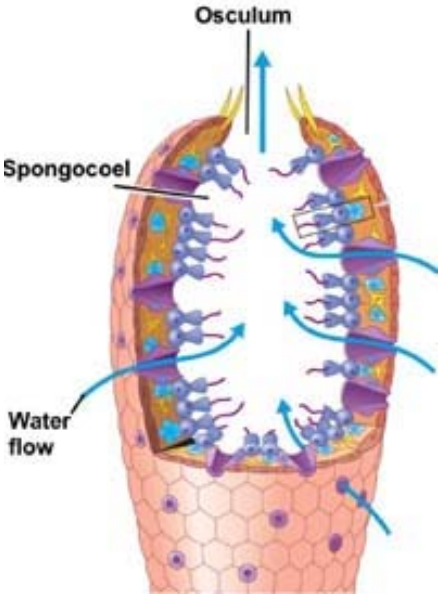
Animals – Structure and Function

Class 13

Circulatory System

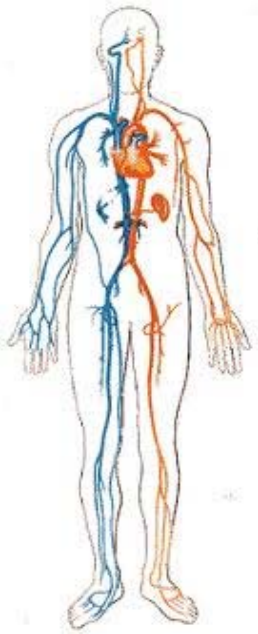
- **Components:**
  - Heart
  - Blood
  - Blood Vessels (Arteries, Veins, Capillaries)
- **Functions:**
  - To deliver nutrients to all cells in the body
  - To eliminate waste products from cells
  - To carry chemical messages from cells to target tissue
  - To distribute heat throughout the body
  - To defend against invading organisms

Simple Organisms



- Simple organisms do not need a circulatory system
- Sponges have two cell layers which allow oxygen and nutrients to absorb and eliminate wastes
- Flagella circulate water in the central cavity to bring in nutrients and oxygen

Multicellular Organisms



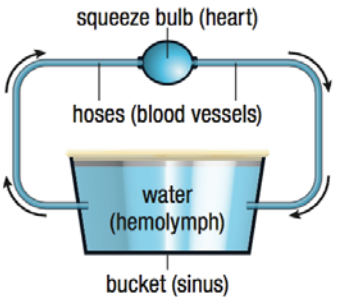
- Multicellular organisms have a middle layer that is not in contact with the circulating fluids
- Diffusion is inefficient for the body to get the necessary nutrients and oxygen therefore they need a circulatory system

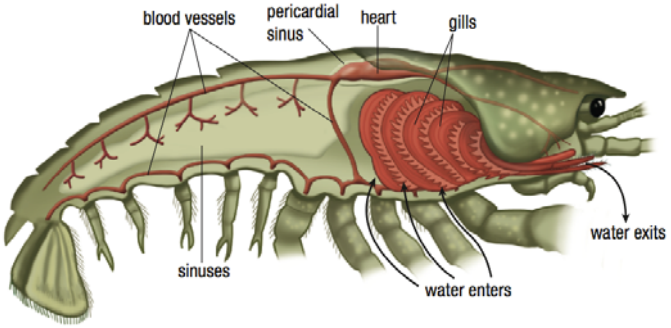
Types of Circulatory Systems

- All circulatory systems have:
  - A fluid that transports and circulates materials throughout the body
  - A network of tubes in which the fluid circulates
  - A pump that pushes the fluid through the tubes
- Types:
  - Open Circulatory System
  - Closed Circulatory System

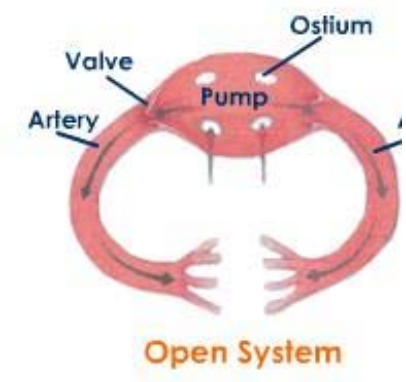
Open Circulatory Systems

- Found in most invertebrates such as snails, insects, and crustaceans
- Circulating fluid (hemolymph) is pumped into body cavities or sinuses to bathe the cells directly





OPEN

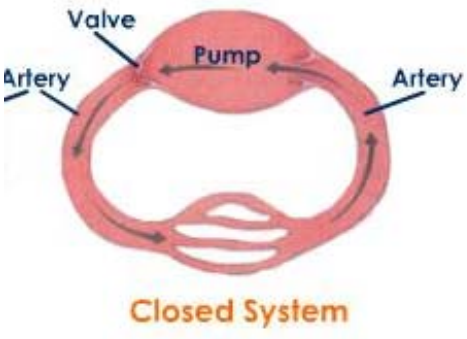


- **No distinction between blood and interstitial fluid**

- Hemolymph is under low pressure and circulates slowly
- Appropriate for animals with low metabolic rates since blood flow is slow
- Main function is to transport nutrients to cells and eliminate waste products out of cells

Closed Circulatory System

CLOSED



- **Blood and interstitial fluid is separated**

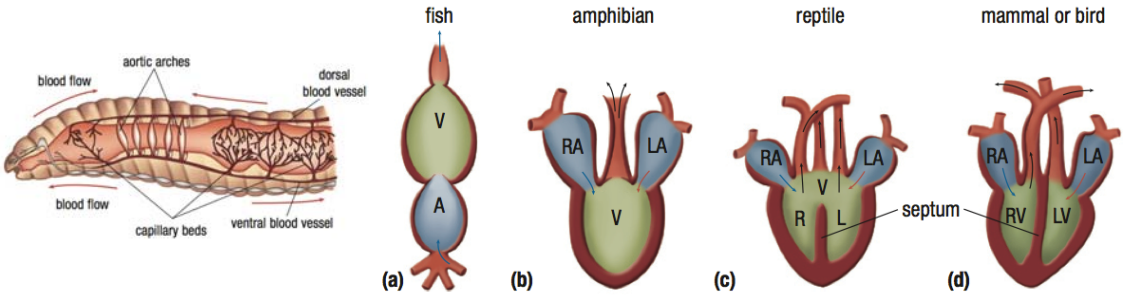
- Found in vertebrates and some invertebrates like earthworms, squid and octopus
- Blood is separated from the interstitial fluid by the blood vessels

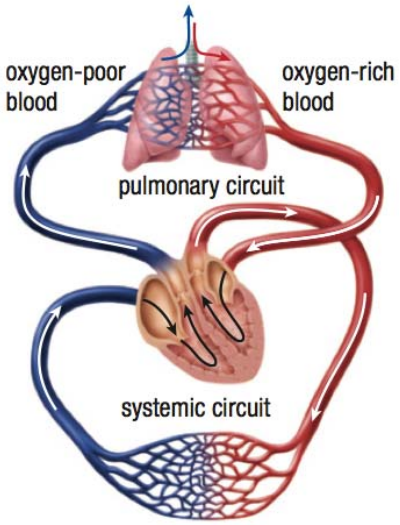
Pros and Cons of the Systems

OPEN	CLOSED
✓ Direct exchange of materials	✓ Faster circulation
✓ Less energy to distribute	✓ Regulated blood flow to farther distances
✓ For smaller bodies	✓ For larger bodies
✗ Slower circulation	✗ Takes more energy to distribute and exchange materials
✗ Less regulated	
✗ Slow oxygen uptake	

Evolution of the Circulatory System

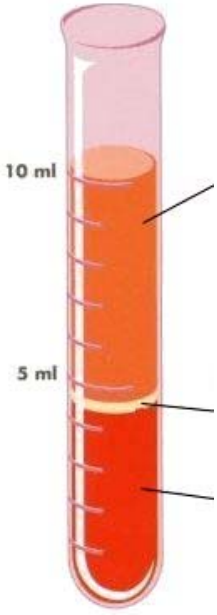
- Earthworm has five pairs of aortic arches to pump blood
- Fish has two chambers which connect in one loop to bring oxygenated blood from the gills to the body





- Amphibians have 3 chambers
- Mammals and birds have 4 chambers and a two-circuit circulatory system to separate the circulation to the lungs with the rest of the body
  - **Pulmonary circuit** – circulates blood to the lungs for gas exchange
  - **Systemic circuit** – circulates blood around the body to deliver oxygen, nutrients and to pick up carbon dioxide and waste

Blood



- Human body contains 4-5L of blood

Intercellular Matrix (55% of blood volume)

Plasma (55% of blood volume)

90% of plasma is water

7% are blood proteins

2% are nutrients, hormones, salts, waste

Cellular Components (45% of blood volume)

Leukocytes and Platelets (less than 1%)

Erythrocytes

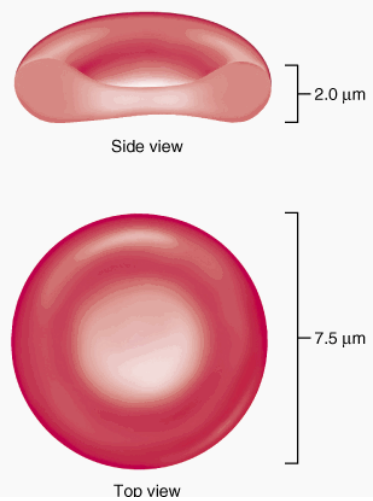
Plasma

- Protein-rich liquid containing mostly water
- Dissolved materials:
  - Oxygen and carbon dioxide
  - Nutrients (glucose, minerals, vitamins)
  - Waste products
  - Dissolved ions (Na^+, K^+, Ca^{2+}, Cl^- and HCO_3^-)
  - Proteins

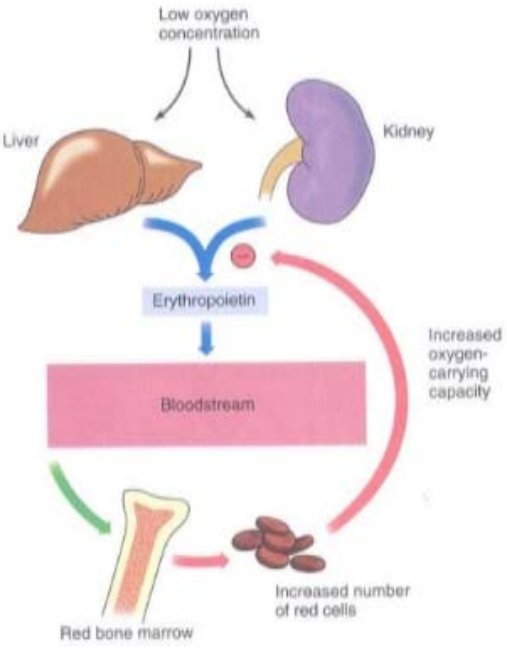
- Plasma proteins:
  - Albumin – concentration determines the amount of water entering or leaving the blood by osmosis
  - Globulins – transport lipids, cholesterol, fat-soluble vitamins and minerals
  - Fibrinogen – blood clotting

- Serum – fluid that results when cell, platelets, and fibrinogens have been removed

Erythrocytes (Red Blood Cells)



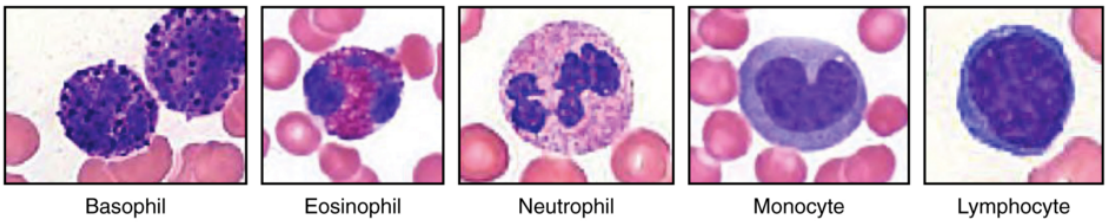
- Made in the bone marrow and stored in the spleen
- Structure:
  - Biconcave to maximize surface area
  - No nucleus, no mitochondria
  - Contains hemoglobin
- Function:
  - Carry oxygen from the lungs to the body and eliminate carbon dioxide from the body to the lungs



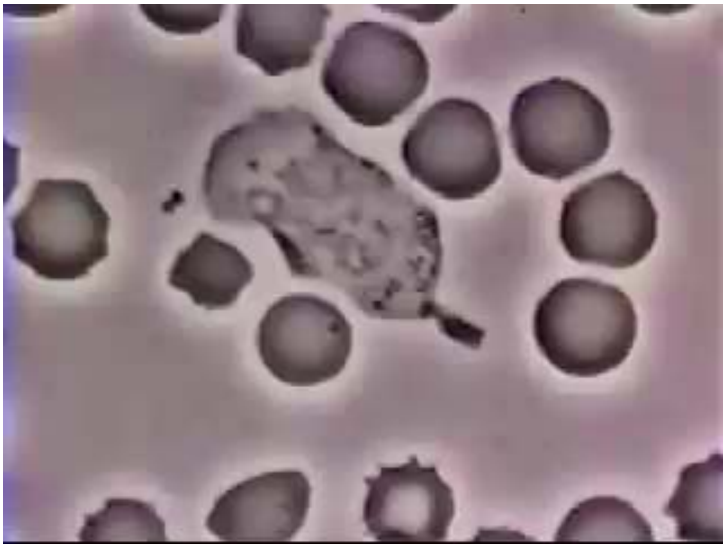
- After 120 days in circulation, erythrocytes die and are removed by the liver and spleen
- 2-3 million erythrocytes and produced each second to replace those that are removed
- If oxygen levels falls, brain signals the production of erythropoietin (EPO) in the kidneys to stimulate additional erythrocytes

Leukocytes (White Blood Cells)

- Formed in the bone marrow
- Structure:
  - Contain nuclei, many types
  - Granular Leukocytes: neutrophils, eosinophils, basophils attach foreign material
  - Agranular Leukocytes: lymphocytes, monocytes engulf bacteria via phagocytosis

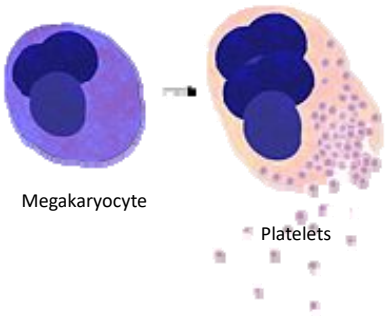


- Function:
  - Protect body from disease and infection
  - Recycle dead or damaged cells



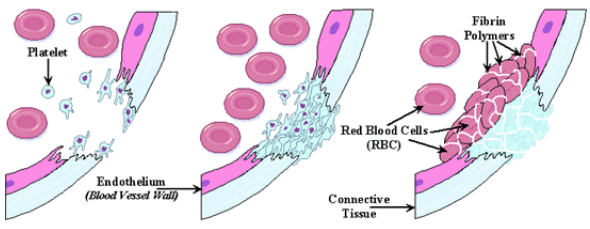
Platelets

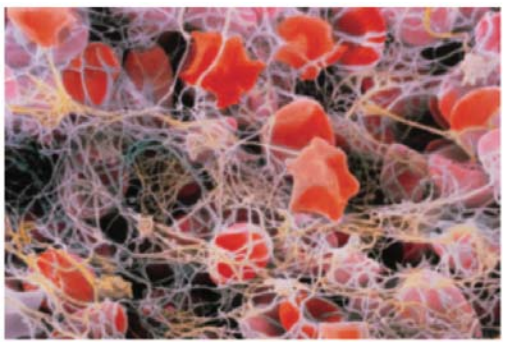
- Produced in the bone marrow
- Structure:
  - Cell fragments broken off from a megakaryocyte in the bone marrow
  - No nucleus



- Function:
  - Aggregate at the wound to initiate blood clotting (coagulation)

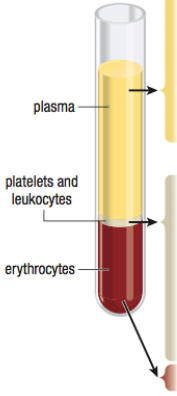
- When a blood vessel is broken, platelets stick to the collagen fibres in the blood vessel
- Fibrinogen in the plasma converts to fibrin to form a mesh that traps more platelets and blood cells
- Forms a clot that is eventually absorbed by the body



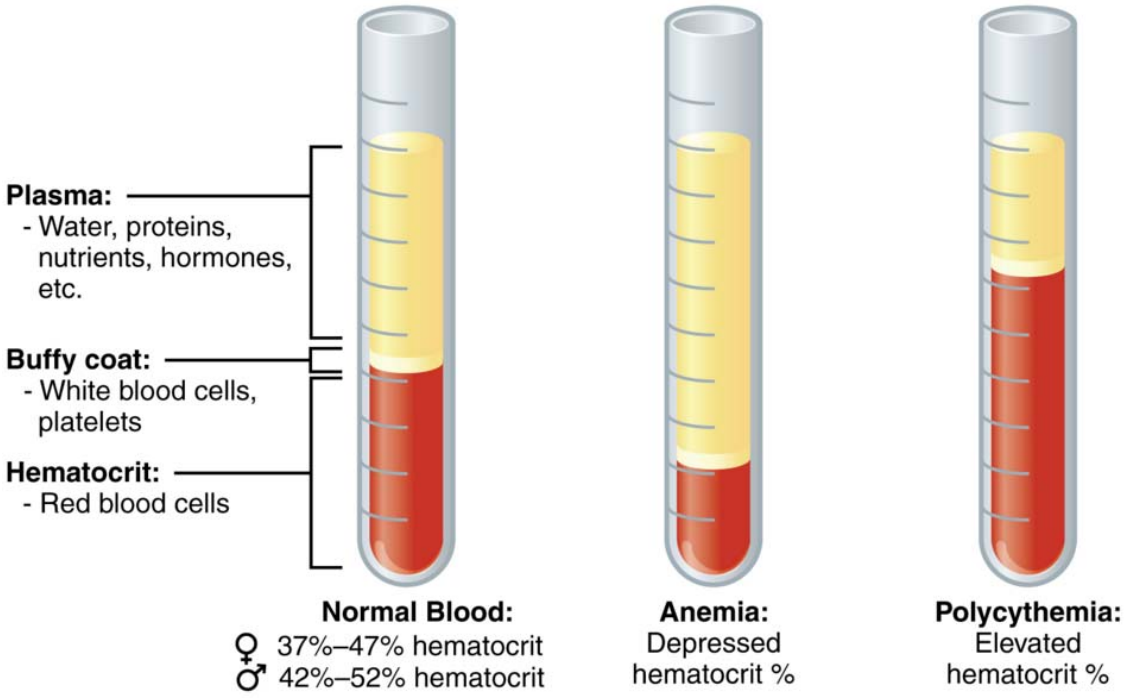


Counting Blood Cells

- Hemocytometer estimates the number of erythrocytes, leukocytes and platelets in a blood sample

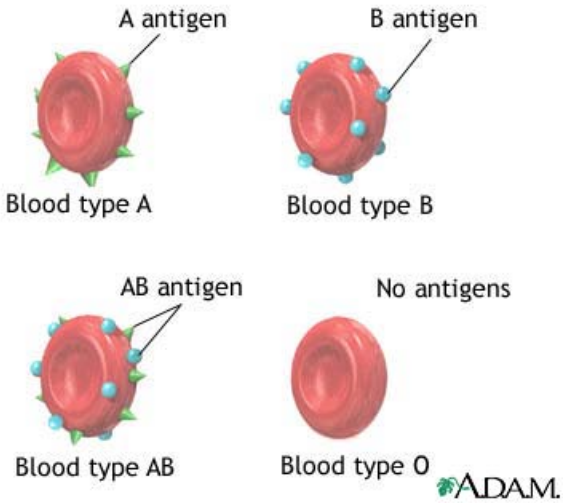


Components	Relative amounts	Functions
Plasma portion (55 %–58 % of total volume):		
Water	91 %–92 % of plasma volume	Solvent
Plasma proteins (albumin, globulins, fibrinogen, and so on)	7 %–8 %	Defence, clotting, lipid transport, roles in extracellular fluid volume, and so on
Ions, sugars, lipids, amino acids, hormones, vitamins, dissolved gases, urea and uric acid (metabolic wastes)	1 %–2 %	Roles in extracellular fluid volume, pH, eliminating waste products, and so on
Cellular portion (42 %–45 % of total volume):		
Platelets	250 000–300 000 per microlitre	Roles in clotting
Leukocytes (white blood cells) Neutrophils Lymphocytes Monocytes/macrophages Eosinophils Basophils	 3000–6750 1000–2700 150–720 100–360 25–90	 Phagocytosis during inflammation Immune response Phagocytosis in all defence responses Defence against parasitic worms Secrete substances for inflammatory response and for fat removal from blood
Erythrocytes (red blood cells)	4 800 000–5 400 000	Oxygen, carbon dioxide transport



Blood Types

- Blood types are determined by the presence or absence of markers called antigens on their membrane



Blood Transfusions

- If you transfuse Type A blood into a Type B person, the Type B person's immune system will see the A antigens, tag it as foreign and attack it with antibodies
- Antibodies will cause clumping of the blood cells, block capillaries and prevent oxygen delivery → Death

Canadian Blood Services
it's in you to give

Blood Transfusions

Blood Type	Can accept from:	Can donate to:
A	A, O	A, AB
B	B, O	B, AB
AB	A, B, AB, O	AB
O	O	A, B, AB, O

- Type AB blood = universal **acceptor**
- Type O blood = universal **donor**

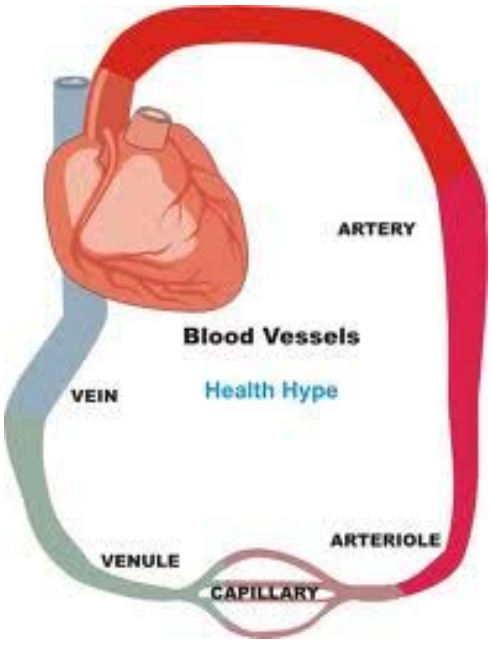
Rhesus Factor

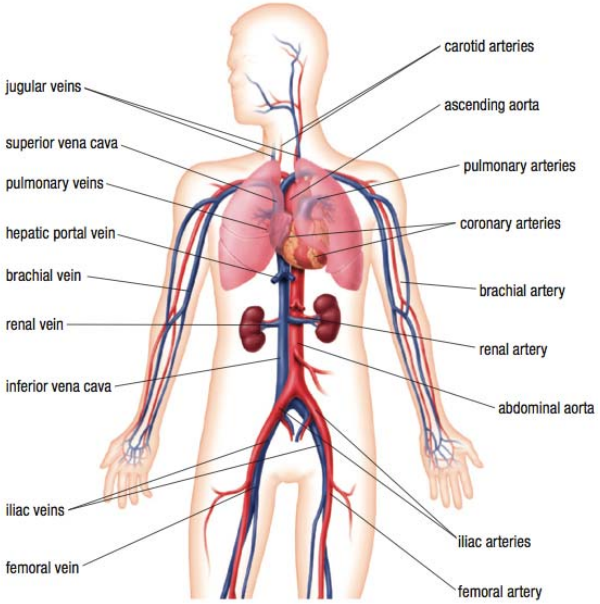
- Discovered in the blood of rhesus monkeys
- An antigen on erythrocyte membrane
- Rh-positive individuals have the rhesus antigen and make up 85% of the population
- Rh-negative individuals do not have the rhesus antigen
- Rh-negative can donate to Rh-positive but cannot receive blood from Rh-positive

Blood Substitutes and Artificial Blood

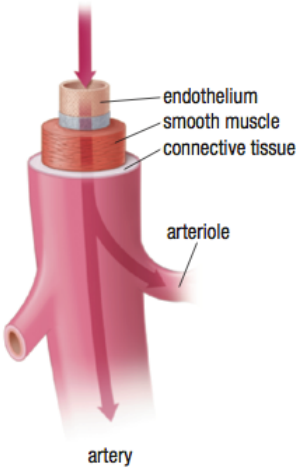
- Hemoglobin-based oxygen carriers (HBOCs) contains human or cow blood
  - Hemoglobin is exposed which is toxic to the kidneys
- Perfluorocarbon emulsions (PFCEs) was used as an artificial blood however there were adverse side effects so it was removed from market in 1994

Blood Vessels





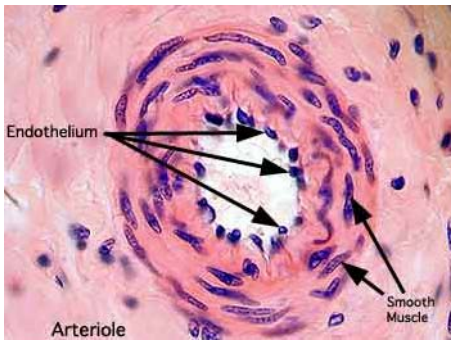
Arteries



- Structure:
  - Outer layer of connective tissue and elastin fibres to stretch and recoil and to withstand high pressure
  - Middle layer of smooth muscle tissue
  - Inner layer of epithelial cells (endothelium) to minimize friction
- Function:
  - Bring blood **away** from the heart

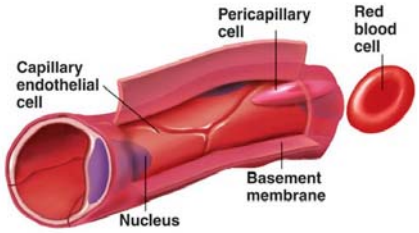
Arterioles

- Smaller arteries with smooth muscle in the walls and nerves that control blood flow
- Vasodilation – increased diameter of the smooth muscles in the arterioles to allow heat loss
- Vasoconstriction – decreased diameter of the smooth muscles in the arterioles to prevent heat loss

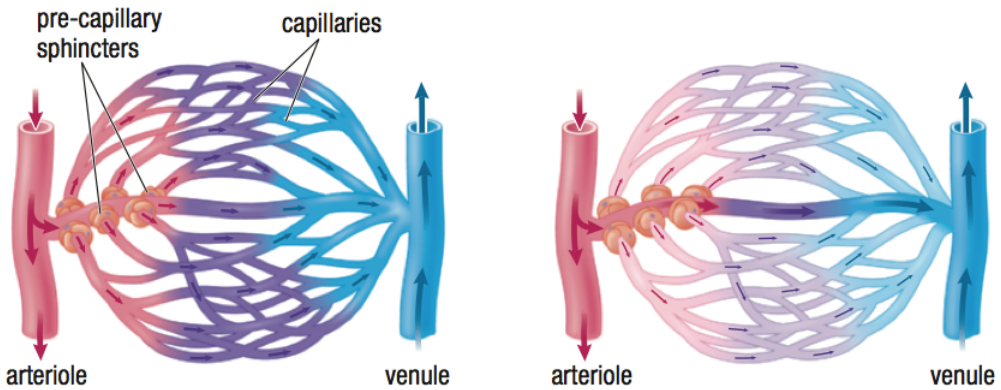


Capillaries

- Structure:
  - Small vessels made of a single layer of cells
  - Red blood cells squeeze through in a single file
  - High surface area
  - Slows blood circulation down
- Function:
  - Diffusion of nutrients, waste and gases
  - Diffusion of fluids

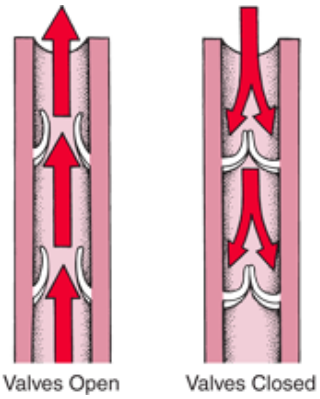


- Capillaries have pre-capillary sphincters which can contract and reduce blood flow
- During exercise, sphincters are fully relaxed to allow blood flow to the muscles

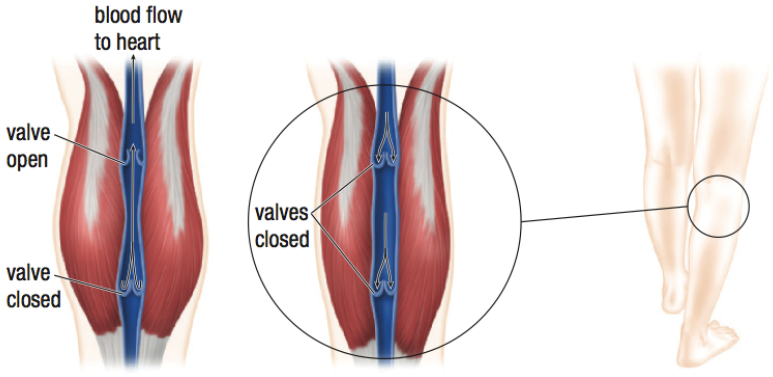


Venules and Veins

- Structure:
  - Contains valves to prevent backflow of blood
  - Muscle contractions help to squeeze the veins to move the blood back to the heart
  - Walls are thinner than arteries
  - Blood pressure is lower
- Function:
  - Holds blood
  - Brings blood back **to** the heart

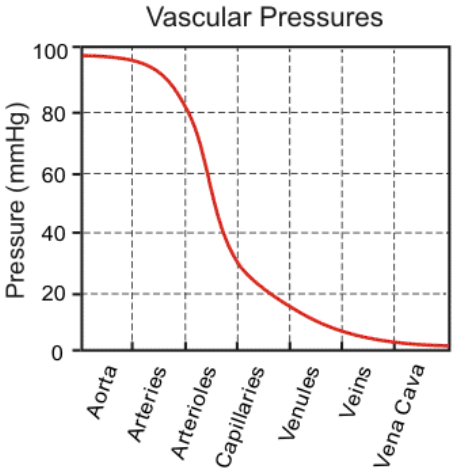


- If valves fail to close or there are few muscle contractions, blood can pool in the lower extremities
- Blood pooling can lead to fainting, clot formation and varicose veins



Blood Pressure

- The pressure exerted or the walls of the arteries
- Blood pressure decreases the further you move away from the heart



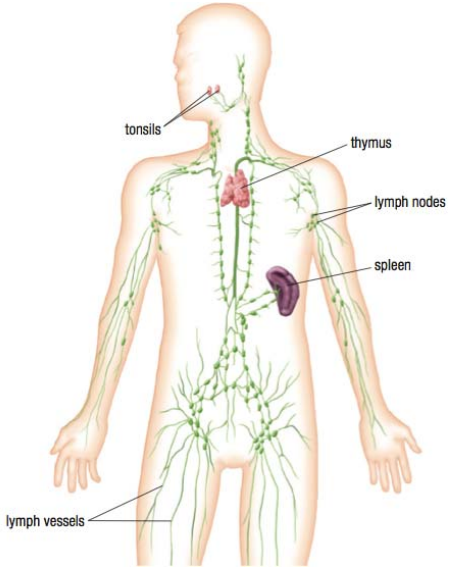
- Blood pressure is measured with a sphygmomanometer

  - Cuff is inflated until the blood flow is stopped
  - As pressure is released, pressure sensors in the cuff detect the vibrations of the blood flowing through the artery
  - **Systolic Pressure** – pressure in the artery when heart contracts; normal is 120 mmHg
  - **Diastolic Pressure** – pressure in the artery when heart relaxes; normal is 80 mmHg

Hypertension

- High blood pressure that is consistently 140/90 mmHg or above
- Causes:
  - How much water and salt is in your body
  - Stress and age
  - Kidney disease
- Symptoms:
  - No symptoms until a heart attack or stroke occurs
  - Can cause ruptured blood vessels in the kidneys and eyes

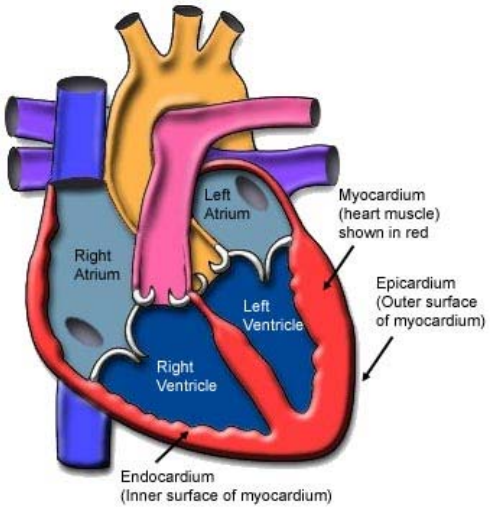
Lymphatic System



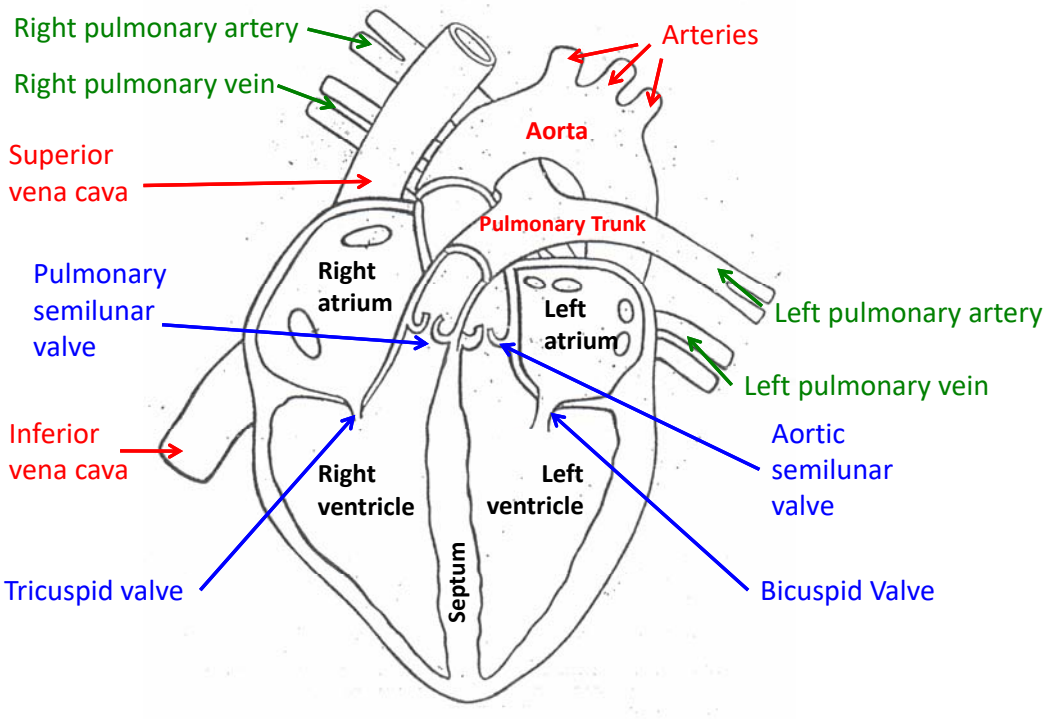
- Function:
  - Ensures that the blood volume is maintained by collecting excess interstitial fluid in lymph vessels
  - Filters out bacteria and other components from the blood at the lymph nodes
  - Spleen filters the lymph and produces leukocytes and erythrocytes when necessary

The Heart

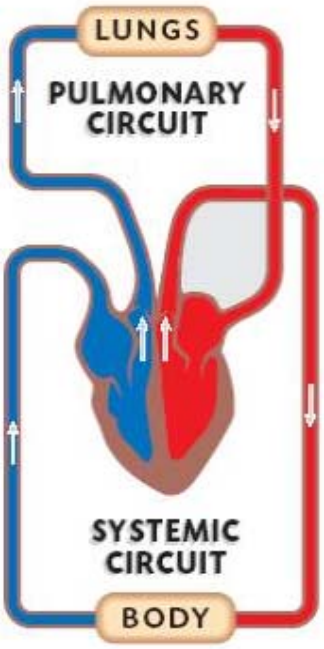
- Tissue Structure



- **Myocardium**: The heart's muscular wall consisting of myogenic muscle fibres
- **Epicardium**: The outer surface
- **Endocardium**: The inner lining
- **Pericardium**: Fluid filled membrane that surrounds the heart to prevent friction from the epicardium and the connective tissue encasing the heart



Circulation

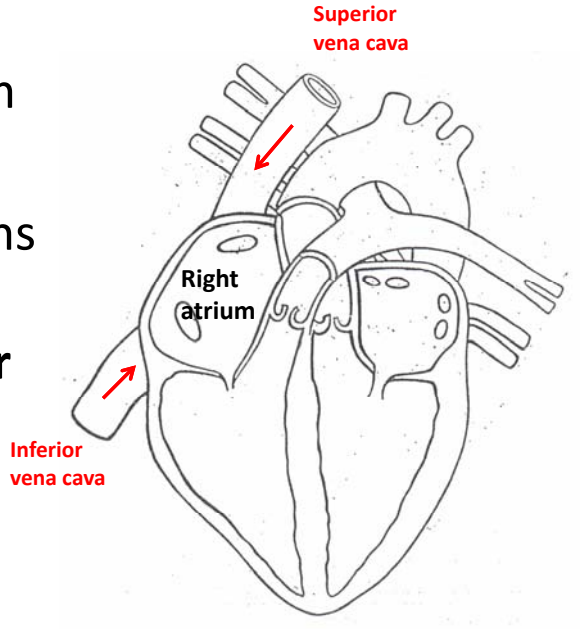


- How does blood flow through the heart?
- Two parts:
  1. The Pulmonary Circuit – blood flows through the **lungs**
  2. The Systemic Circuit – blood flows through the **body**

The Pulmonary Circuit

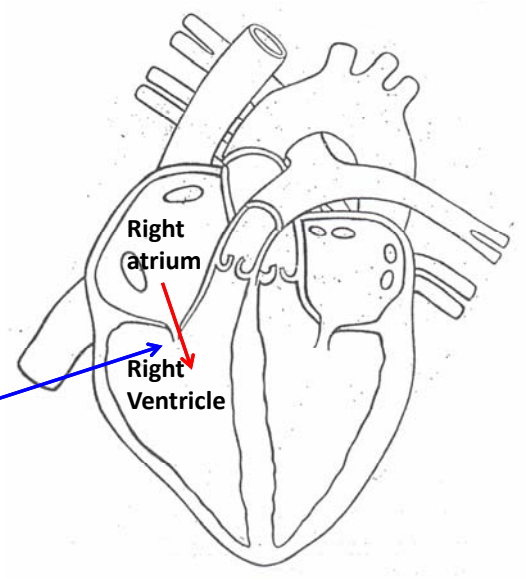
- A low pressure system

1) Deoxygenated blood from the body returns to the heart via the **superior** and **inferior vena cava** into the **right atrium**



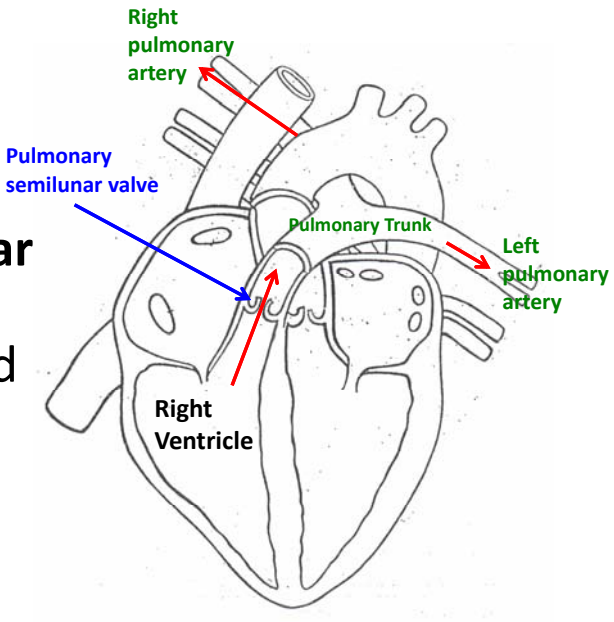
The Pulmonary Circuit

2) Blood then flows through the **tricuspid valve** and into the **right ventricle**



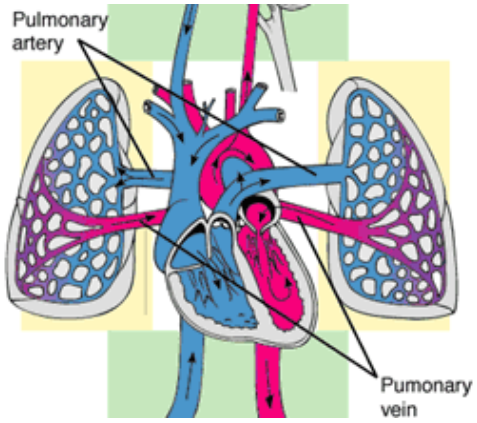
The Pulmonary Circuit

3) **Right ventricle** contracts sending blood through the **pulmonary semilunar valve** into the pulmonary trunk and out of the heart through the left and right **pulmonary arteries**



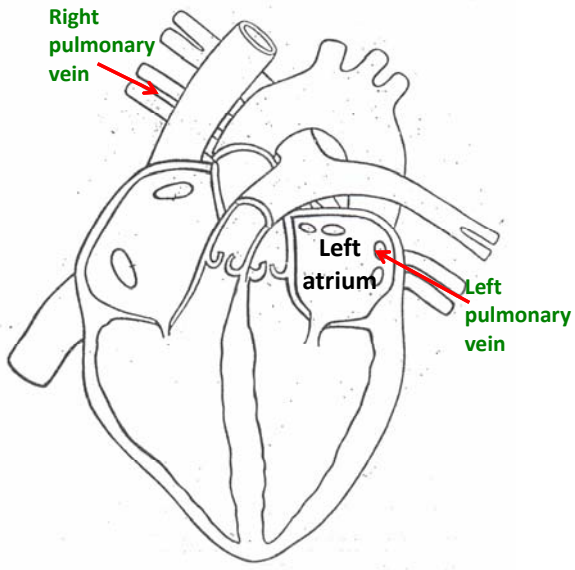
The Pulmonary Circuit

4) The deoxygenated blood then enters the lungs where it picks up oxygen and releases carbon dioxide



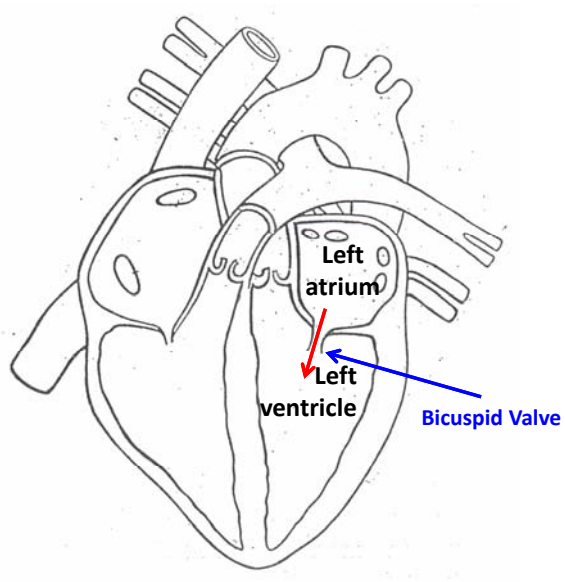
The Pulmonary Circuit

5) The oxygenated blood then returns to the heart's **left atrium** via the right and left **pulmonary veins**



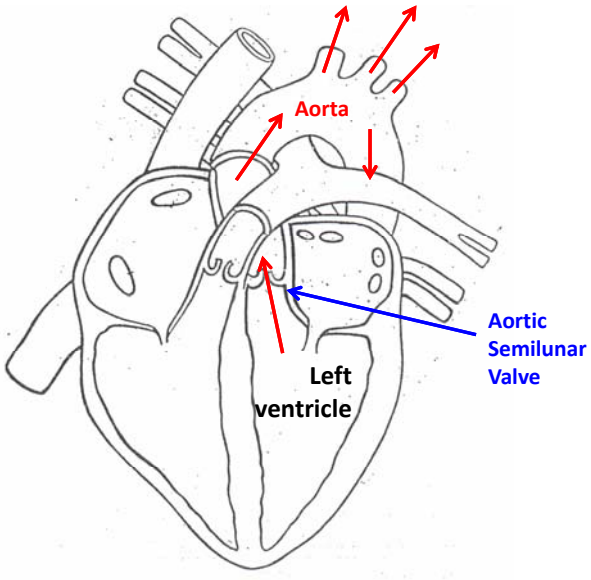
The Pulmonary Circuit

6) It then passes through the **bicuspid valve** (mitral valve) and enters the **left ventricle**

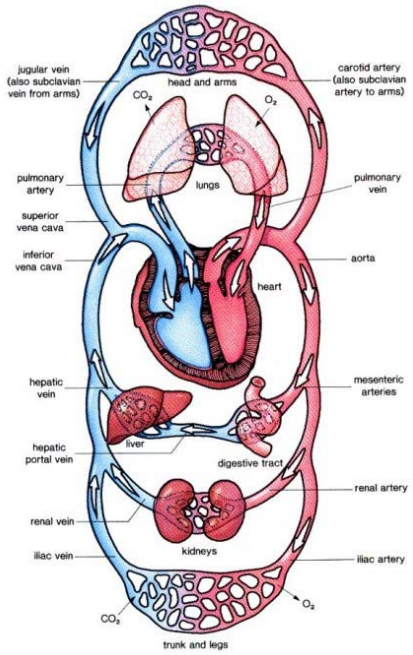


The Pulmonary Circuit

7) The **left ventricle** then contracts and blood is forced through the **aortic semilunar valve** into the **aorta**



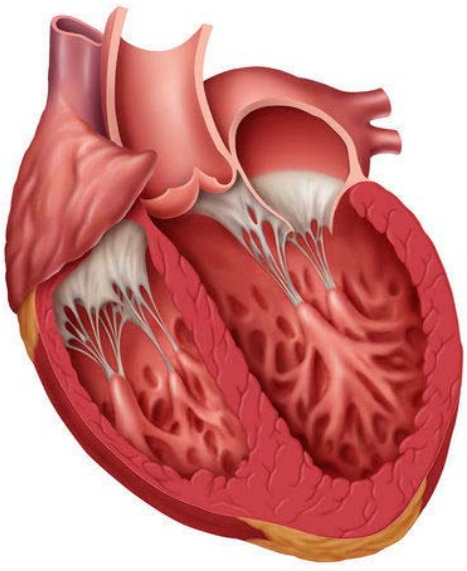
The Pulmonary Circuit



8) It then enters the systemic circuit where it passes through capillary bed through the whole body for gas exchange

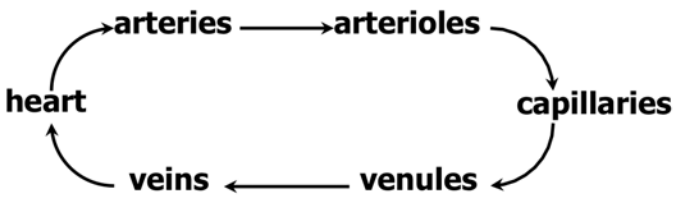
The Systemic Circuit

- A high pressure system
- Blood must leave the heart with enough force to travel to far distances
- The left ventricle is more muscular than the right ventricle



The Systemic Circuit

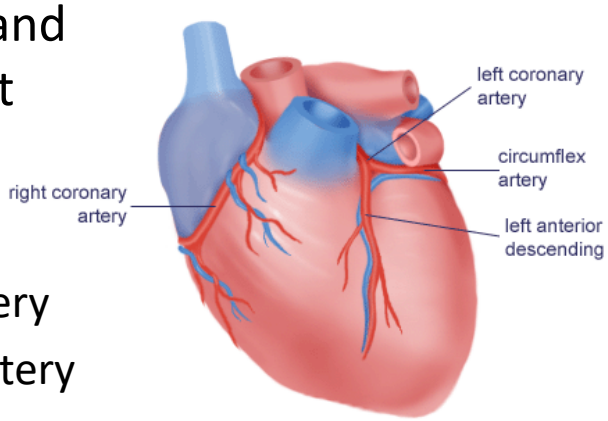
- Aorta = largest artery in the body



- Deoxygenated blood from the upper body returns to the heart via the **superior vena cava**
- Deoxygenated blood from the lower body returns to the heart via the **inferior vena cava**

The Coronary Circulation

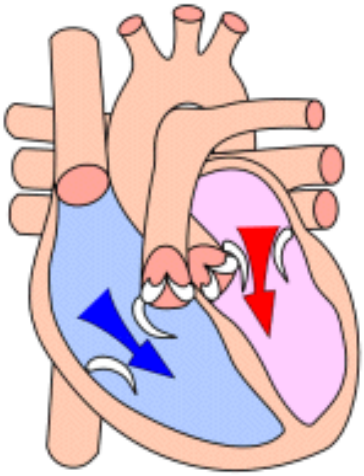
- Delivers nutrients and oxygen to the heart muscle
- Consists of:
  1. Left coronary artery
  2. Right coronary artery



Cardiac Cycle

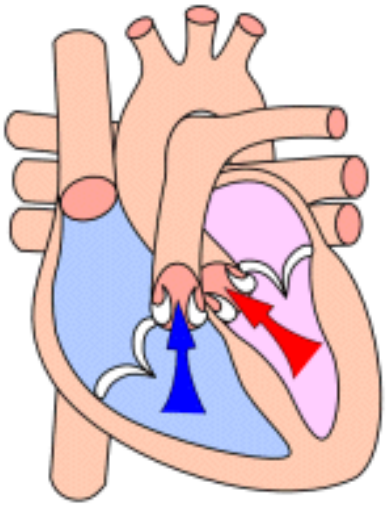
- The contractions and relaxations of the heart muscles during a complete heartbeat
- Normal conditions, cardiac cycle takes 0.8 s
- Two main components:
  - Diastole
  - Systole

Diastole

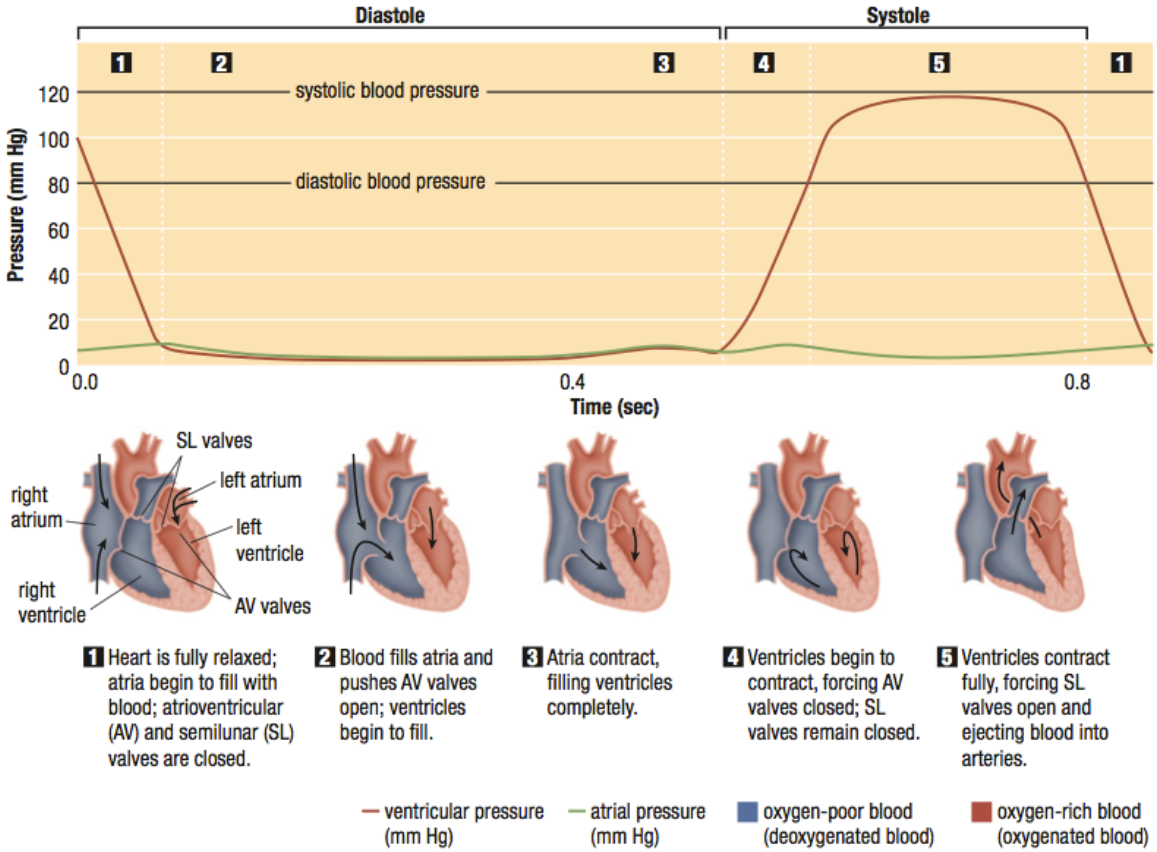


- Heart is relaxed and the cavities are filled with blood
- Tricuspid valves and bicuspid valves are open to allow blood to flow into ventricles
- Semilunar valves are closed
- Blood pressure decreases

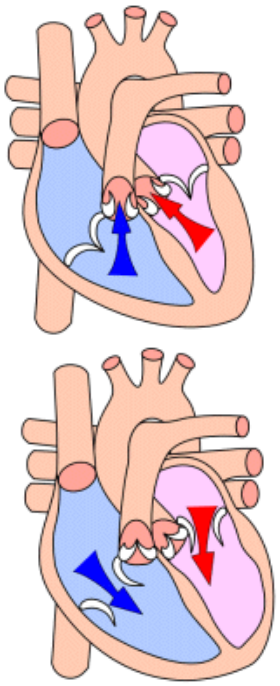
Systole



- Heart is contracted and blood is pushed out of the heart
- Tricuspid valves and bicuspid valves close
- Semilunar valves open
- Blood pressure increases



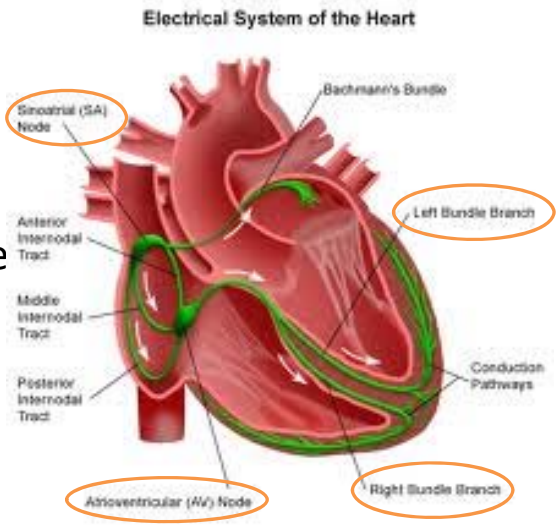
Heart Sounds



- "Lub-dub" sound comes from closing of the heart valves
- "Lub" occurs during systole when the tricuspid and bicuspid valves close
- "Dub" occurs during diastole when the semilunar valves close

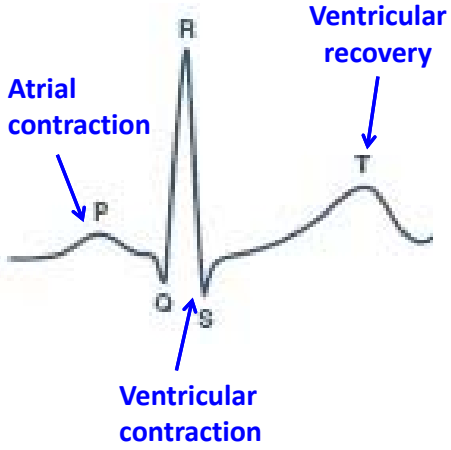
Heart Rhythm

- Heart contains myogenic muscle – muscle that contracts without external nerve stimulation
- Heart's rhythm is set by the sinoatrial node (SA node), which acts as a pacemaker
- Nerve impulses from the SA node contract the atrium→ Atrioventricular node (AV node) → Purkinje fibres to contract the ventricles

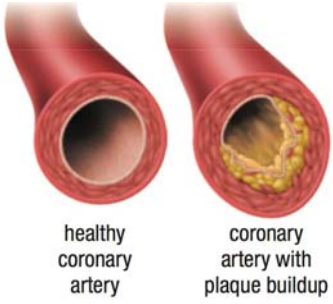


Electrocardiograms (ECG)

- Test that records the electrical activity of the heart by placing electrodes on the skin



Arteriosclerosis



- Hardening of the arteries due to the presence of plaque (fat, cholesterol, calcium)
- Causes a condition called atherosclerosis

Risk Factors:

- High blood pressure, high cholesterol, diabetes, obesity, smoking, physical activity, gender, genetics, age

- Cholesterol is produced in the liver and carried in the blood; used in cell membranes and hormones
- Transported by special carriers called lipoproteins
  - High-density lipoprotein (HDL) – "good cholesterol", carries cholesterol to the liver to be removed
  - Low-density lipoprotein (LDL) – "bad cholesterol", causes plaque buildup in the arterial walls

Symptoms:

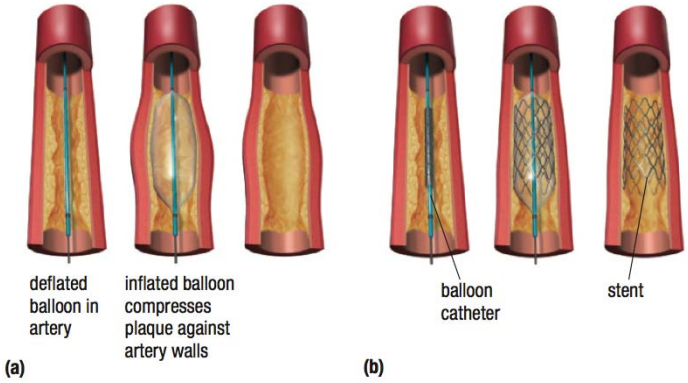
- Angina – pain in the chest area, left shoulder, arm, neck; caused by reduced blood supply to the cardiac muscles
  - Treated with nitroglycerin which is a vasodilator

Treatment:

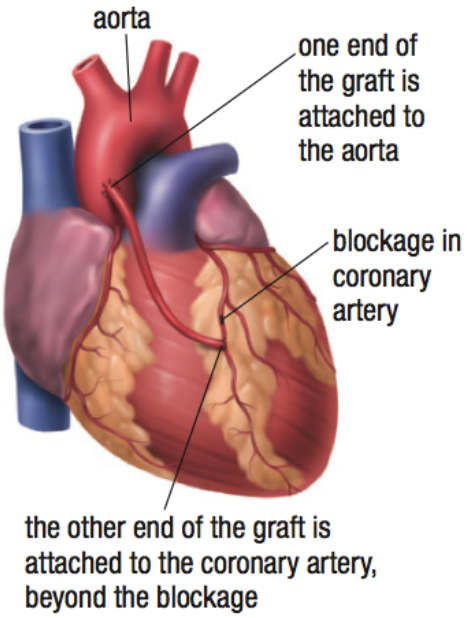
- Lifestyle changes – regular exercise, healthy diet, quit smoking
- Angioplasty
- Bypass surgery

Angioplasty

- Opens up a blocked artery by inflating a small balloon at the point of blockage
- A stent may be placed at the site of the blockage to ensure that the artery remains open



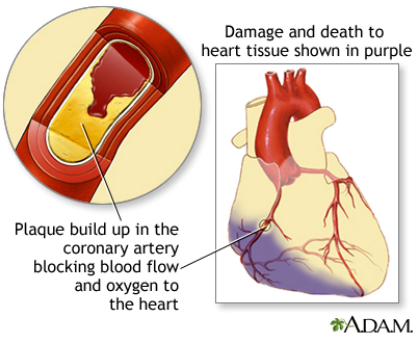
Bypass Surgery



- Reroute blood around clogged coronary arteries
- Take arteries or veins from another part of the body to graft and bypass the blocked artery

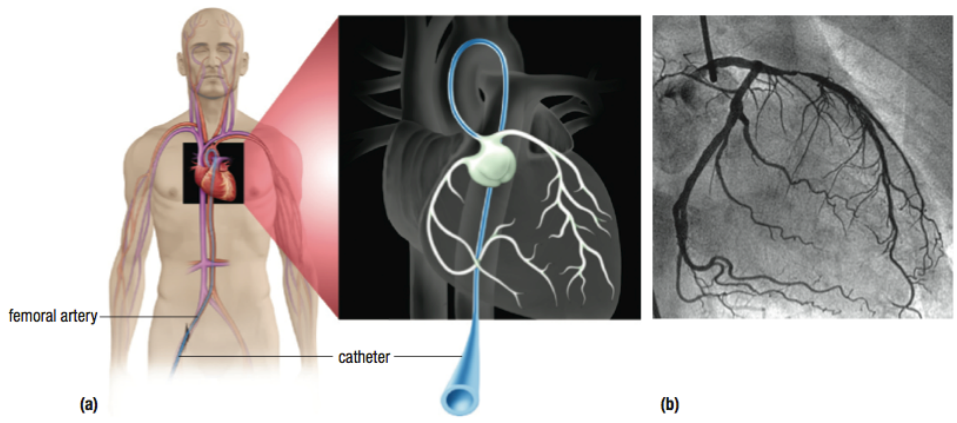
Myocardial Infarction

- Aka: Heart Attack
- Death of an area of heart muscle tissue to due oxygen deprivation
- Symptoms:
  - Chest pain
  - Difficulty breathing
  - Pain in the arm, back, jaw
  - Nausea, vomiting and sweating



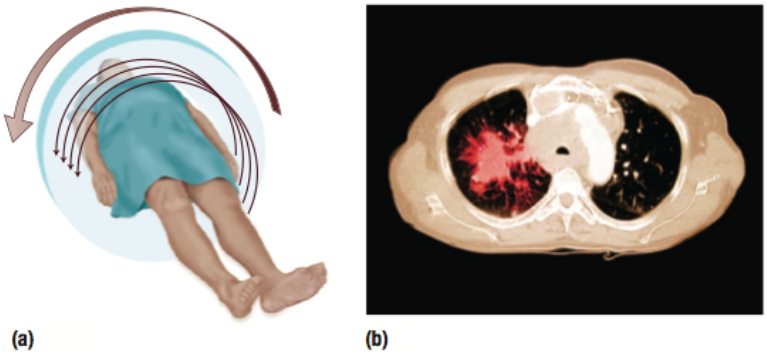
Cardiac Catheterization

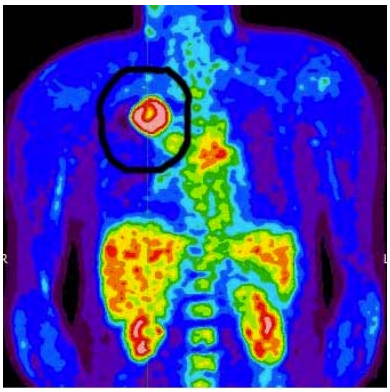
- Insertion of a catheter into a large blood vessel and a contrast dye is injected to show the circulation through X-rays



CT and PET Scans

- Computerized tomography (CT) scans produces cross-sectional images of a 3-D object
- Able to capture soft tissue





- Positron emission tomography (PET) scan uses gamma rays instead of X-rays
- Patients need to swallow or inject a radioactive tracer
- Exposes patient to radioactive materials
- Overexposure can damage cells and increase the risk of developing cancer

MRI Scan

- Magnetic Resonance Imaging (MRI) scan – uses radio waves and a large magnet to produce still and video images
- Safer to use than X-rays, CT scans and PET scans however MRI machines are very expensive to purchase and operate