

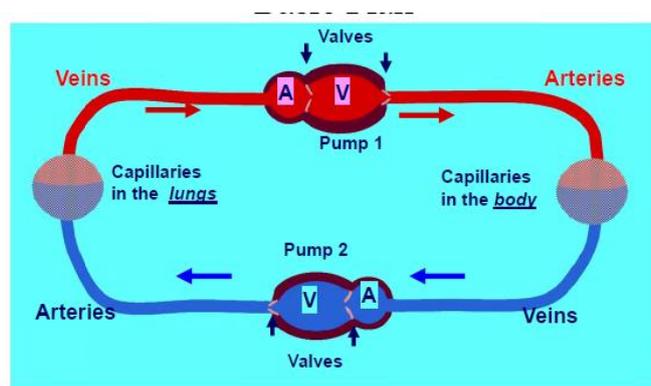
Cardiovascular System

The Cardiovascular System:

- The cardiovascular system includes the heart and its blood vessels
- Blood is an excellent means of moving materials about the body because of its fluid nature
- The cardiovascular system essentially keeps blood moving around the body
 - The movement of blood is driven by pressure generated by the heart
- Blood cannot be called pure or impure, it can only be referred to as oxygenated or deoxygenated, and nutrient rich or nutrient pure
 - Depending on whether or not it carries oxygen and/or nutrients
- Blood vessels are tubes of various sizes which carry blood around the body and regulate the pressure

The Base Plan of the Cardiovascular System:

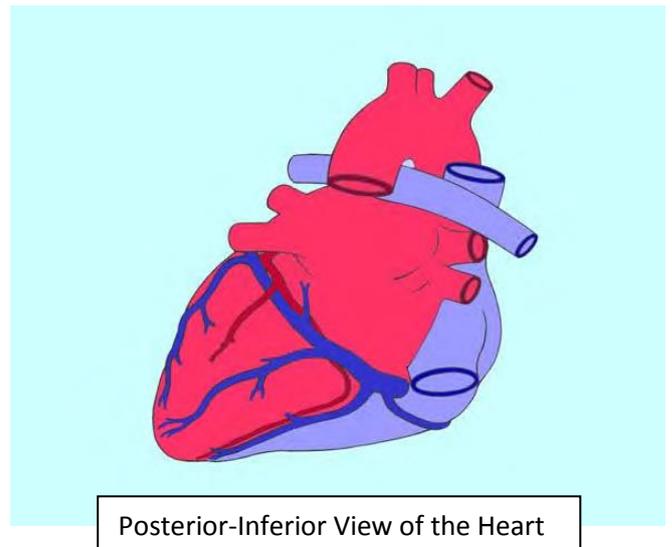
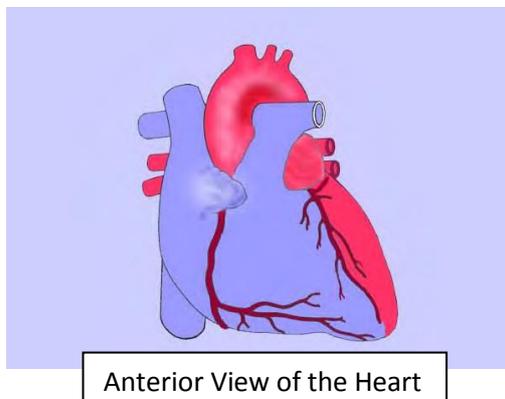
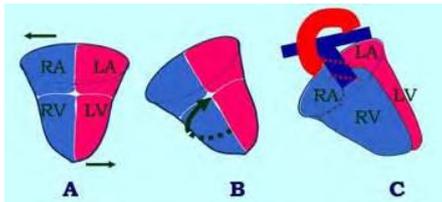
- Note that blood enters pump 1 or pump 2, the initial chamber does not have thick walls, but the second chamber does
- Also note that there are valves within the pumps to prevent the backflow of blood
- A blood vessel which brings blood toward the heart is called a vein, while a blood vessel which brings blood away from the heart is an artery



The Heart:

- The Heart was referred to as pump 1 and pump 2 previously
- The heart is inside the thorax between the two lungs in the mediastinum
- Surrounding the heart is a layer called the pericardium
 - The pericardium has several layers:
 - The visceral layer is attached to the heart
 - The parietal layer is attached to the surroundings
 - Between the two layers is a fluid
 - Surrounding the parietal layer is another layer made from fibrous connective tissue called the fibrous pericardium
- Functional perspective of the heart
 - Blood enters through the vena cavae to the right atrium
 - From the right atrium blood moves to the right ventricle
 - From the right ventricle blood is pumped through the pulmonary artery toward the lungs where it is re-oxygenated, then entering the pulmonary vein

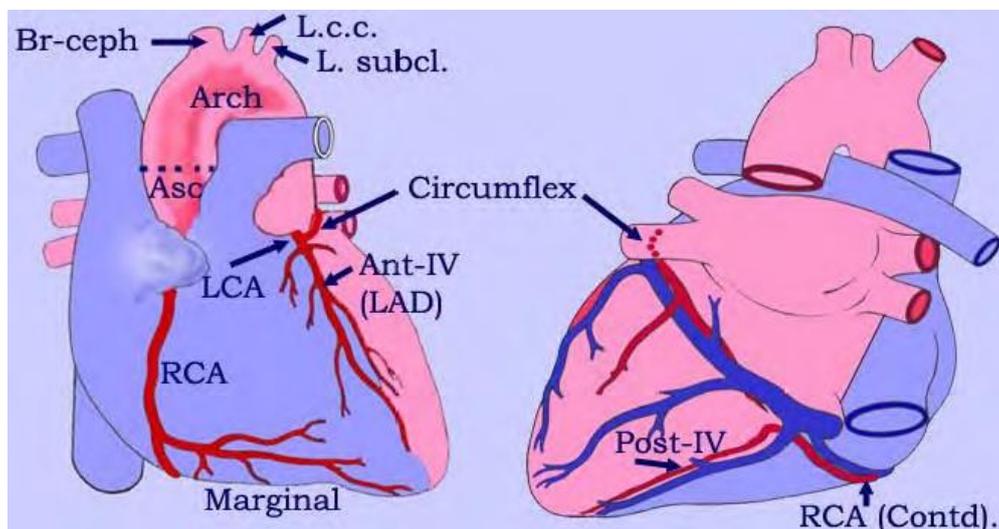
- From the pulmonary vein it re-enters the heart at the left atrium, then from the left atrium to the left ventricle
- From the left ventricle it is pumped through the aorta and through the body
- When the heart is viewed from an anterior position, the right atrium and ventricle appear on the left and toward the front. Dorsal to the right ventricle is the left ventricle with the left atrium not being visible
 - When viewed from a posterior-inferior angle, the left ventricle and atrium become visible as well as parts of the right atrium and ventricle



*right side of heart represented as blue and left side of heart represented as red

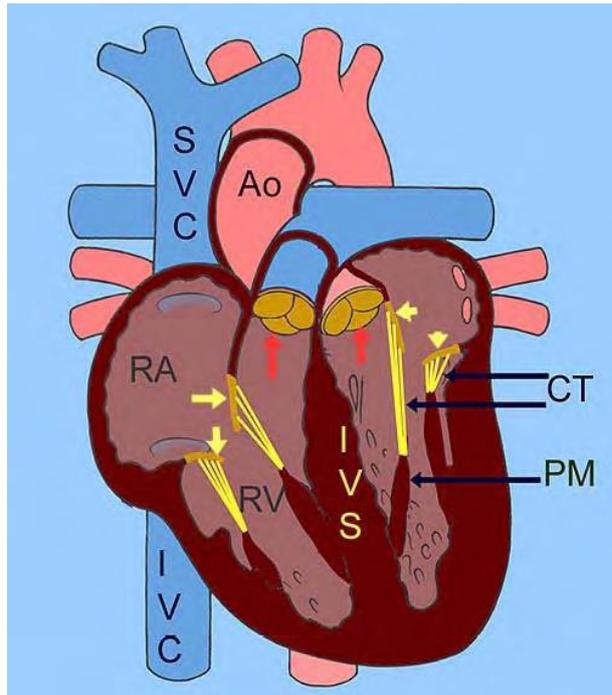
Coronary Vessels:

- The heart also needs a blood supply
- The heart has its own set of blood vessels: two arteries, one on the left and one on the right which go around the heart
 - These arteries form a ring around the heart giving them the name the coronary arteries



Internal Features of the Heart:

- The atria have thin walls and veins open into them. All deoxygenated blood must flow into the right atrium
- The ventricles when they contract generate enormous amount of pressure as the right ventricle must pump blood to the lungs to be oxygenated and the left must pump blood through the entire body
 - Valves within the heart prevent blood from flowing backward into the atria when the ventricles contract
- The pressure generated by the contraction of the ventricles is so great that the valves may be blown back into the atria
 - To prevent this inversion of the valves there are small columns of muscle inside the ventricles which attach to the valves with thin tendons
 - These tendons are known as chordae tendinae, the columns of muscle are called papillary muscle and primarily serve to prevent the valves from being blow back by ventricular contraction
- The valves are referred to as cusps in anatomical terms, 3 of the 4 valves have 3 cusps, the left atrio-ventricular valve is the only valve with 2 cusps
 - All valves lie in one plane and are encased in a fibrous tissue; a fibrous skeleton

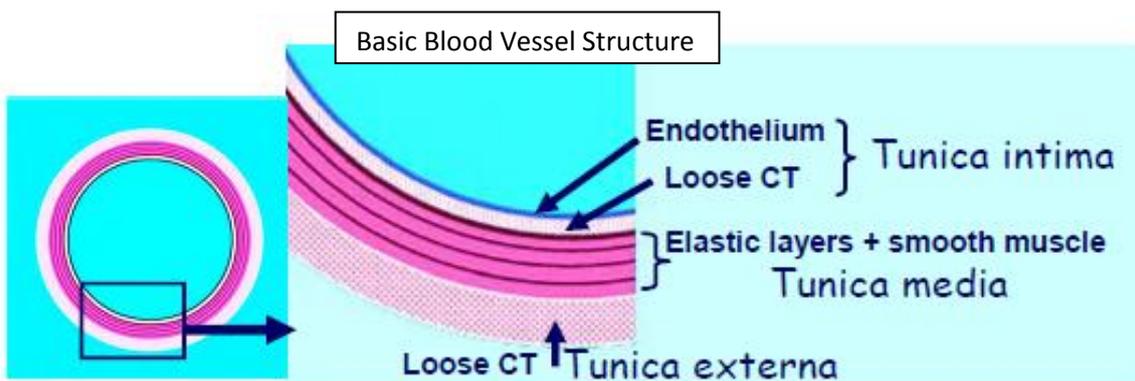


Development of the Heart:

- The heart begins as a single tube, but splits into two to form a right and left side
- The heart begins development in a very superior position of the embryo; above the brain
 - But as folding occurs, the heart is brought down to its final position
 - So folding at the head end of the embryo causes the heart to reach the thorax
- Produced by the folding as well is a tube; which is the heart, the head end will form the arteries and the tail end the veins
 - By the end of the third week of development, the heart begins to beat and will not stop until death
- The heart tube will bend as it continues to grow; due to there being limited space in the pericardium. As the heart bends, the atria become placed posteriorly and the ventricles anteriorly
 - At this moment the heart tube is still a single cavity
- From weeks 4 to 8 the heart begins to partition into left and right.
- As the lungs are not yet functional, blood flows from right atrium to left atrium

Blood Vessels:

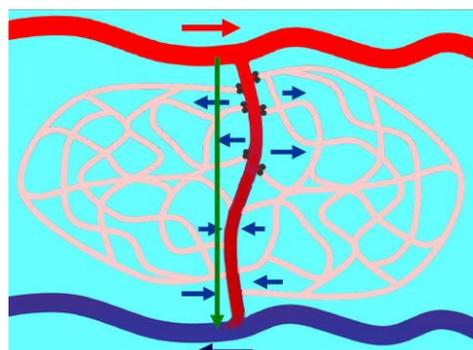
- Capillaries are microscopic blood vessels which form an enormous network. Capillaries have very thin walls, that allow the quick exchange of substances between blood and cells of the body
- All blood vessels have a common basic plan
 - They have a smooth inner epithelium (endothelium), as blood has the tendency to clot on a rough surface
 - Flow and pressure vary in blood vessels so blood vessels must be elastic
 - Control over flow (through diameter of blood vessel) through smooth muscle action
- Capillaries are designed for the slow movement of blood, so substances can be exchanged between blood and surrounding cells
- General statements for arteries include
 - Large arteries close to the heart require more elastic tissue
 - Medium sized arteries control distribution of blood and require more muscle
 - Arterioles reduce pressure for capillaries
- Capillaries are endothelial tubes with a single layer of supporting cells. They do not have any elastic tissue or muscle, they are responsible for the exchange of materials



- Capillaries form such a vast network, that if all capillaries remained open, there would be no blood left for circulation
 - So it is impossible for the body to have all capillaries open at once, and they open according to which areas requirement

How Arterioles Control Blood Flow:

- There is a main channel leading from the main arteriole to the main venule, and on the entrances from the main channel to the capillary network are bundles of smooth muscle
 - These bundles of smooth muscle allow the arterioles to act like a tap



- When all smooth muscle bundles are open, blood can flow from the main area into the capillary bed. When the smooth muscle closes on the left side, blood will not flow into the left side, when it closes on the right blood will not flow into the right side
 - If both sides are closed off blood will flow directly from arteriole to venule
- Though capillary beds are tiny, if thousand close off, a lot of blood can be diverted

Veins:

- As blood passing through the capillary has virtually no pressure, blood coming out will also have next to no pressure; so pressure in the veins are virtually close to zero
 - Low pressure results in the slow movement of blood
- Veins have valves similar to those found in the heart to prevent the backflow of blood
- Skeletal muscle contractions help push blood back to the heart
 - This especially happens in the legs (knee to ankle) as this is one of the most inferior parts of the body
- Veins tend to have thinner walls compared to arteries, but are often wider than their corresponding arteries

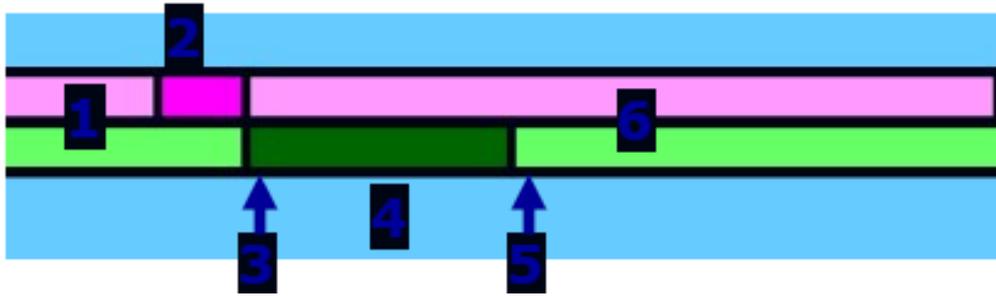
Electrical Activity in Muscle Cells:

- Cells have a resting membrane potential of -70mV
 - They are negative on the interior and remain in a polarised state if not activated
- If this potential is reversed momentarily, the inside becomes positive and outside negative, the muscle will contract
 - So when the potential is reversed it is referred to as an action potential (the muscle takes action)
- An action potential is the temporary depolarisation of the cell membrane
 - After the depolarisation the cell membrane will repolarise and return to its normal resting potential
 - For a fraction after activation, the cell cannot take action, this is known as the refractory period
 - In the heart this is also known as the refractory period, it is the time between contraction where the heart will resist any stimulation/change

The Cardiac Cycle:

- There are two periods in the heart: diastole and systole
 - Diastole is the when the heart is relaxed and systole when the heart contracts
 - These two events happen on average 72times/minute
 - During systole the ventricles do not completely empty, there is always a residual amount of blood remaining in it

- The cardiac cycle



- Phase 1:
 - All chambers of the heart are relaxed; blood flows from the veins into the atria, and from the atria to the ventricles
 - This is known as total cardiac diastole
- Phase 2:
 - The atria begin their contraction, which causes the ventricles to full fill
 - Known as atrial systole
- Phase 3:
 - The ventricles begin their contraction and the atria relax; the ventricular contraction is initially isovolumetric (volume does not change) as the pressure within the ventricles is less than the pressure in the arteries, the atria also resume filling in this phase
 - Ventricular systole and atrial diastole
- Phase 4:
 - Pressure in the ventricles becomes greater than pressure in the arteries causing blood to flow out of the ventricles and into the arteries; this is known as volumetric contraction as volume changes
 - The atrio-ventricular valves prevent the backflow of blood into the atria
 - The semi-lunar valves (between ventricle and artery) remain open until pressure of the ventricles drop below that of the arteries
- Phase 5:
 - When pressure of the ventricles drop below pressure of the arteries total cardiac diastole resumes. However it is initially isovolumetric as the pressure within the ventricles are initially greater than that in the atria
- Phase 6:
 - When the pressure of the atria become greater than that in the ventricles, the AV valves re-open and phase 1 of a new cycle begins

How does the Heart work?

- The heart muscle can contract on its own, but it requires co-ordination
 - There are specialised masses of heart muscle cell which aid in this co-ordination
- The first specialised mass is located in the right atrium and is located high up
 - This first mass is called the sinu-atrial node referred to as the SA node

- The SA node generates action potentials faster than anywhere else in the heart, so the entire heart responds to the SA node
 - This makes the SA node the pace maker of the heart
 - All the muscle cells in the atria respond to the action potentials generated by the SA node
- There is another node which lies between the atria and ventricles to prevent the atria and ventricles from contracting at the same time
 - This node is called the atrio-ventricular node, the AV node
- The AV node plays a role in innervating the ventricles, but more importantly, upon receiving impulse from the SA node, the AV node first holds the impulse for a time before propagating it
 - This delay is known as AV node delay
- The system of SA and AV nodes ensures that the heart beats regularly in co-ordination and is known as the conducting system of the heart
- The action potential which governs the contraction of the heart is called the cardiac impulse and it begins at the SA node
 - SA node -> atria and AV node -> PAUSE! -> AV bundles -> ventricles -> Purkinje fibres
- An Electrocardiograph detects electrical changes on the skin and records the direction and amplitude of the spread
 - It gives us information on the size of the heart chambers, rate and regularity of heart beats, blocks in conduction and if there are any damaged areas of the heart
 - The ECG
 - The P-wave shows the atria being depolarised
 - There is a small effect Q before the spike R wave, the Q dip indicates the repolarisation of the atria but is lost to the R-wave
 - The R-Wave shows the depolarisation of the ventricle, the R wave is significantly larger than the P wave as the ventricles are far larger
 - The T-wave is the repolarisation of the ventricles
 - It can be seen that after P-wave, there is a short period of inactivity; this period of inactivity is caused by the AV node; it is AV node delay
- Stroke volume is ~70mL/ventricle, each ventricle must pump the same volume of blood, if not the output would not match input
 - As this volume is the same stroke volume only refers to 1 ventricle
- Cardiac output = stroke volume x heart rate
 - Cardiac output is measured in volume/time
- An extremely fast heart rate becomes inefficient because the ventricles are unable to fill all the way

