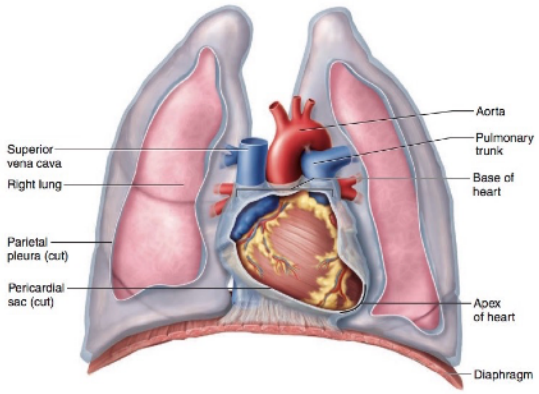
THE HEART AND BLOOD VESSELS

DEVELOPMENT OF THE HEART (EMBRYOLOGY)

- All invertebrates and chordates have a heart.
- The heart functions as a pump to overcome impossibly long diffusion distances.
  - It pumps from regions of high oxygen tension and nutrient concentration to the all the cells in the body.
- **First 3 weeks:** fetus is too big for diffusion to work.
  - The fluid filled space in the blastocyst keeps the cells close enough to cells with nutrients and oxygen.
- **Day 19:** embryo becomes a flat disk (with a head end and a tail end).
  - Heart develops in the **cardiogenic** area.
  - Blood vessels form through vasculogenesis around the cariogenic region.
  - Heart forms as an endocardial tube; 2 tubes on either side of cardiogenic area (fuse together at **day 20**).
- **Day 22:** tubular heart forms and the heart starts beating.
- **Day 23:** develops further with a venous end (incoming) and an arterial end (outgoing).
- **Day 28:** the heart has elongated and folded with both venous and arterial ends both at the top.
- **Last 4 weeks:** valves form and the chambers get divided.
- **Birth:** the circulation to the lungs and body is separated.

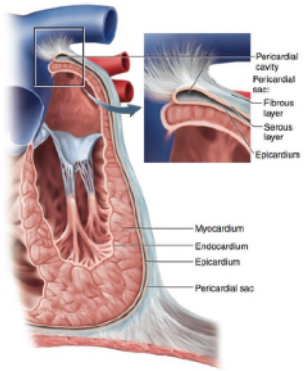
ANATOMY

- **Location:** between **lungs**, the **sternum** and **thoracic vertebra**; surrounded by ribs in a space called **mediastinum**.
- The heart sits in a **dense fibrous connective tissue bag** called the **pericardial sac**; it diffuses with the bases of the great vessels.
  - The heart bulges because it was well fixed in this sac.
  - The bottom of pericardium is fused to the diaphragm.
- The heart grows into a space called the **pericardial cavity** which is **obliterated after invagination** (once the heart enters).
- As heart grows, its outer lining fuses with the serous layer (secretes a fluid to allow the heart to move freely) of pericardium.
- Vessels and the heart is lined with simple squamous epithelium.



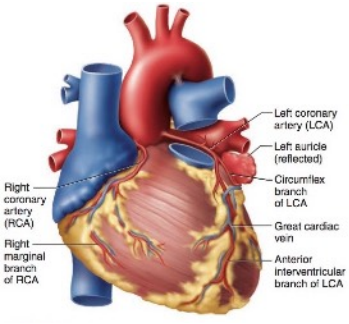
PERICARDIUM

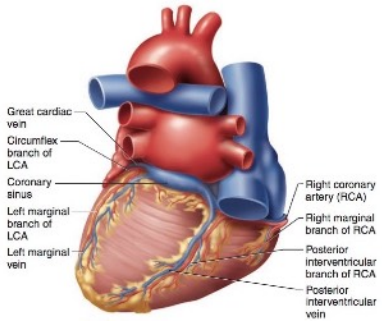
- Pericardium is a **double walled sac enclosing the heart**. It is anchored to the diaphragm.
  - **Fibrous pericardium** (dense irregular connective tissue): limits over-filling of the heart.
  - **Serous pericardium**:
    - ⟶ Parietal serous lines the fibrous sac.
    - ⟶ Visceral serous (epicardium) covers the surface of the heart.
- Fibrous pericardium > serous pericardium > parietal pericardium > visceral pericardium (continuous with the epicardium) > myocardium > endocardium.



CORONARY VESSELS

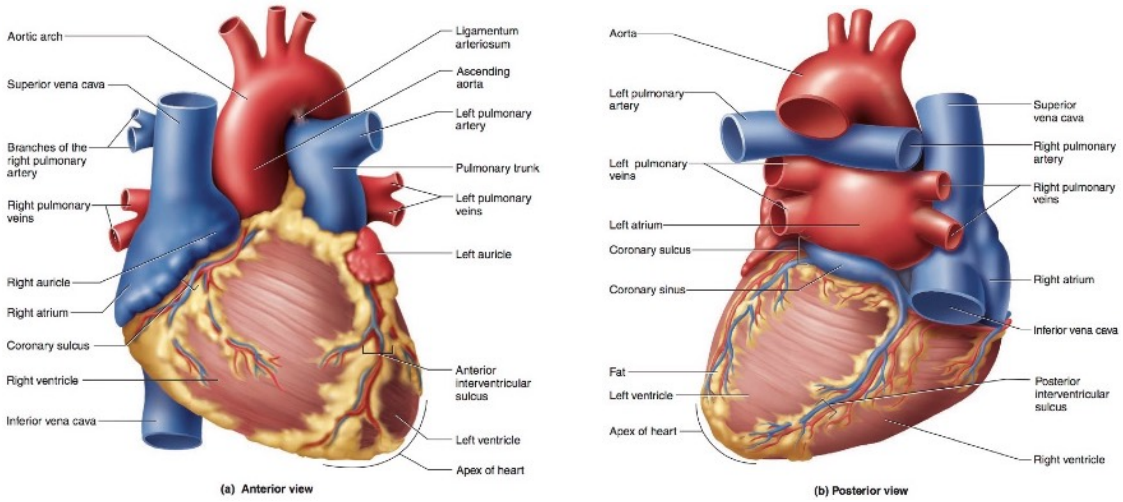
- The very first branches that come off the base of the aorta are the left and right coronary arteries. They run around in the atrioventricular sulcus.
  - **Left coronary artery** gives rise to the **anterior interventricular branch.**
  - **Right coronary artery** gives rise to the **posterior interventricular branch**.
- The **coronary sinus** enters the coronary sulcus and **empties into the right atrium**. These blood vessel branches **supply and drain the heart**.





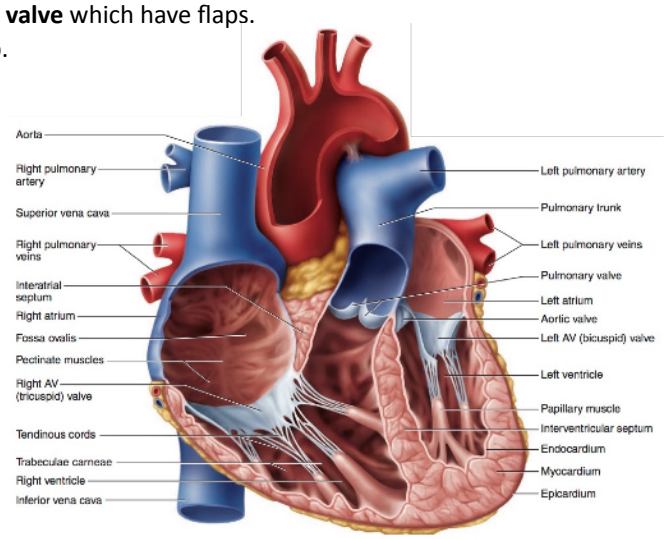
EXTERNAL FEATURES OF THE HEART

- The **pulmonary trunk** is a common vessel leaving the left ventricle which splits into **right and left pulmonary arteries** and the **4 pulmonary veins** which are coming back from the lungs (open into the left atrium).
- The heart has 4 chambers; left and right atrium and left and right ventricles.
- The **left ventricle** has a **thicker muscle** as it **pumps blood to the rest of the body** but the right ventricle only pumps blood around the heart.
- Between the atria and the ventricles (form most of the substance of the heart) is the **atrioventricular sulcus (coronary sulcus)** which is a groove filled with fat that runs all the way round the heart.
- Between the right and left ventricles there is a **posterior interventricular sulcus**.
- Inferior and superior **vena cava enter** into the **right atrium**.
- The **blood drains from the heart via** the **coronary sinus** (opens into the right atrium).



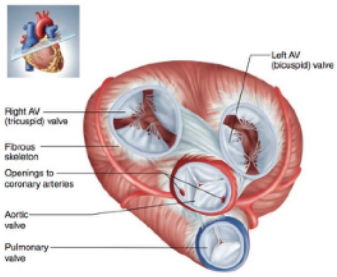
INTERNAL FEATURES OF THE HEART

- Between each atrium and ventricle there is an **atrioventricular valve** which have flaps.
  - When the ventricle contracts, it tries to force the valve flap.
  - **Papillary muscles** contract to put tension on **chordae tendinae** to prevent flaps from turning inside out during ventricular contraction.
  - The **pulmonary trunk** and **pulmonary semilunar valves** arise from the right ventricle and close under the pressure of blood.
  - The **blood tries to flow back when the heart relaxes**.
- Vessels close to the heart are elastic. When the heart contracts they can expand and when the heart relaxes, the elastic recoil tries to squeeze the blood back into the heart, the valves close and the blood is passed on.



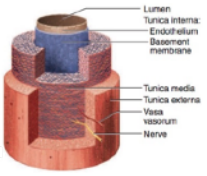
HEART SKELETON

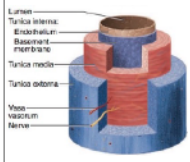
- **Dense fibrous connective tissue** with some **fibrocartilage**.
- Gives a basis for each of the **valves**. **Pressure stops them from spreading**.
- Provides an **anchor** for the heart muscle. The heart muscle, from having being attached to the fibrous skeleton, spirals off around the heart. So when the muscle contracts, it has a wringing action.
- The **ring shape** is **effective at squeezing blood out of the heart**.
- It provides electrical insulation (delay between contractions).

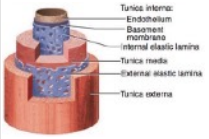


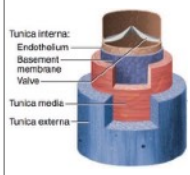
BLOOD VESSELS

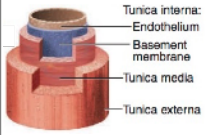
- **Arteries** carry blood **away** from the heart. **Veins** carry blood **towards** it.
- Blood vessels as a whole have a standard structure. They have 3 tunics:
  - **Tunica interna**: always has a layer of endothelium. May also have connective tissue and elastin.
  - **Tunica media:** has smooth muscle, collagen and variable amount of elastic tissue (thicker in arteries).
  - **Tunica externa** (adventitia): connective tissue and collagen fibres (thicker in veins).

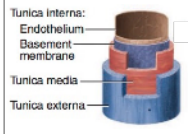
<table>
<tr><th>Arteries
(average pressure is up to 120mmM)</th><th>Veins
(average pressure is up to 10mmM)</th></tr>
<tr><td><u>Conducting large arteries:</u>
 

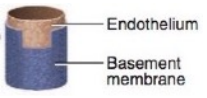
- Thick wall vessels near to the heart.
- They maintain blood flow and smooth out blood pressure.
- Thick elastic wall absorbs pressure from contractions of the heart by stretching.
- When the heart relaxes, the elastic recoil pushes the blood on.</td><td><u>Large veins:</u>
 

- Soft wall with larger lumen.
- Contain 64% of blood volume at rest.
- Media is thinner with smooth muscle.
- Externa is thicker than of the large artery.
- Have some muscle in externa and media allowing contraction in length and width.
- Example: vena cava, renal veins etc.</td></tr>
<tr><td><u>Distributing muscular arteries:</u>
 

- Smaller vessels can change diameter.
- Under autonomic NS control (vasomotor).
- Maintain blood pressure.
- Deliver blood to the organs.
- Have less elastic fibres. Instead, they have internal and external elastic lamina.</td><td><u>Medium veins:</u>
 

- Have some sub-endothelial tissue.
- Media has some muscle.
- Externa is thicker than the medium artery.
- Veins are paired around deep blood vessels.
- Endothelium forms flaps (valves) which increase blood flow back to the heart.</td></tr>
<tr><td><u>Resistance small arteries:</u>
 

- May control flow into capillaries.
- Can contract a bypass and reduce the amount of blood thats going into a capillary in a particular area.</td><td><u>Venules (small muscular veins):</u>
 

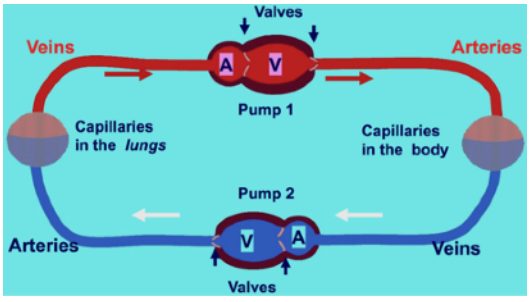
- Some have muscles, others are endothelium.
- Similar to capillaries.
- They are very leaky where a lot of fluid can leak out of the post-capillary venules.</td></tr>
<tr><th colspan="2">Capillaries</th></tr>
<tr><td colspan="2"> 

- Capillaries join arteries and veins. It is where the exchange between the tissues occurs.
- Endothelium and basement membrane.
- Can be continuous with tight junctions (found everywhere), fenestrated with windows (found in the kidneys) or sinusoidal with large holes (found in the liver and spleen).
- Endothelial cells are wrapped around and have specialised junctions between them.
- Thin walls allow rapid gas exchange.</td></tr>
</table>

THE CARDIAC CYCLE

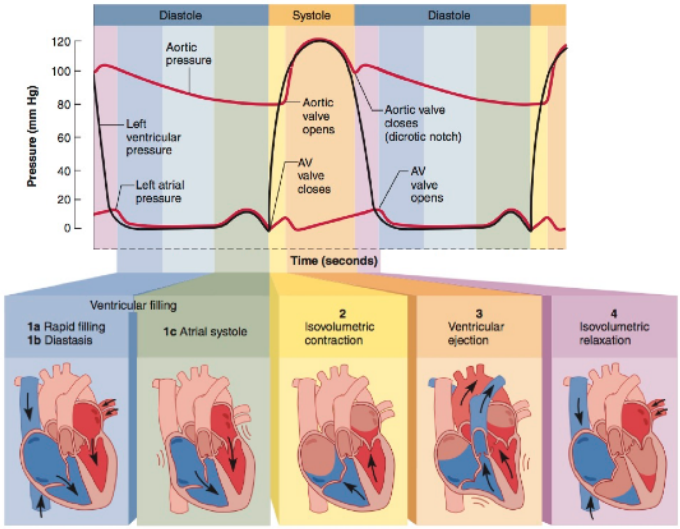
BASIC PLAN

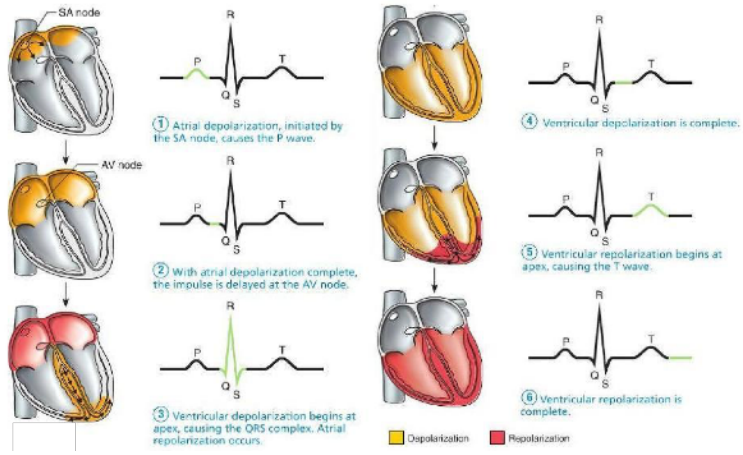
- The heart consists of **two pumps** in which **blood flows in a single direction** due to the **valves** in the pumps.
  - First pump represents blood going to a capillary bed in the body where gas exchange takes place.
  - Deoxygenated blood is brought back to the second pump which pumps via arteries to capillaries. The deoxygenated blood then returns to the first pump.
  - The **volume is the same in both pumps** in the circuit.
  - Each pump has a small atrium (small with thinner walls) and a large ventricle (larger with thicker walls).
  - Left ventricle pushes blood to the body.



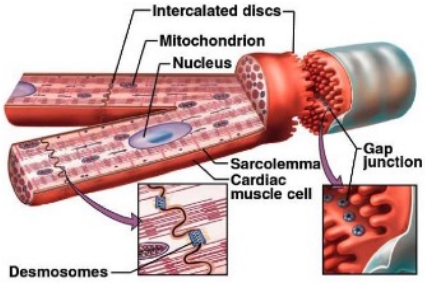
  - **Pathway of blood in the heart:** right atrium > right ventricle > pulmonary trunk > branches into pulmonary arteries (to lungs) > pulmonary beings (coming back into the heart) > left atria > left ventricle > out of aorta.
- **Systolic** blood pressure is **120mmHg** and **diastolic** is **80mmHg**.

Cardiac Cycle The heart cycle costs of alternating periods of contraction (systole) and relaxation (diastole). Ventricular pressure determines when valves open; AV valves opens in low pressure and semilunar valves open in high pressure.	
Ventricular Diastole	- **Arteriole diastole:** chambers are relaxed and **most of the ventricular filling occurs** (70-80%). Ventricular pressure in lower than atrial press so the AV vales open. - **Arteriole systole:** the atria contracts and **pushes the last 20 to 30% of blood**. Even if the atria does not contract, the ventricles have enough blood to pump around.
Isovolumetric Contraction (Systole)	- **Ventricles contract** (tension in the muscles). - Ventricular pressure begins to rise above atrial pressure causing **AV valves to close** to prevent blood flowing back into the atria. - **Semilunar valves remain closed** as pressure is still not high enough. - Contraction occurs with increasing pressure but there is no blood movement. The **volume is constant** as all valves are closed.
Ventricular Ejection (Systole)	- Ventricular pressure rises enough above the aortic pressure causing **semilunar valves to open**. - Blood to be forced out by **ventricular ejection**.
Isovolumetric Relaxation (Diastole)	- The ventricle relaxes where pressure decreases. - Some blood pours back down into the pulmonary trunk closing the semilunar valves. - Blood that tries to flow back in causes AV valves (cup shape) to flatten. **AV valves will remain closed** until ventricular pressure is less than atrial pressure.





CONTROL OF THE HEART



<u>CARDIAC MUSCLE</u>

- Cardiac muscle is **involuntary**. It has large amounts of **mitochondria**.
- The muscle cells tend to branch. Each cell has a single nucleus. The **cells are joined by intercalated discs** that consist of desmosomes and gap junctions (allows electrical conduction).
- Cardiac muscle cells **do not need stimulation for contraction**, it works as single unit. The cells have a **longer refractory period**.
- The heart is very sensitive to change in extracellular fluid concentrations.
- All cardiac cells have an **unstable membrane potential**. They are leaky in terms of K^+ concentration which allows inside of cell to become more positive to carry action potentials.
- Specialised autorhythmic cells form the cardiac conduction system which have lost the ability to contract.
- **Cardiac cells undergo spontaneous depolarisation** till an action potential occurs. This initiates **contraction**.
- The thickness of the cardiac muscle in the ventricle is larger in that of the atrium as the atrium only has to pass blood the ventricle which needs a stronger pump to pass the blood to valves and the body.