BIOS1170: THE CARDIOVASCULAR SYSTEM

Role of the cardiovascular system: Oxygen delivery and carbon dioxide removal; delivery of nutrients and hormones; water and electrolyte balance; thermoregulation.

- A dual circulatory system: two loops through which blood circulates, one is oxygenated, the other is deoxygenated. It takes more energy to maintain it, but it is far more efficient.
  - ➔ Ensures tissues and muscles receive fully oxygenated blood rather than mixture of both
  - ➔ Blood pressurised twice so reaches a higher pressure. This is beneficial as blood loses pressure and flowrate at the lungs, so if it wasn't returned to the heart, it would continue to the tissues at much slower rate.
  - ➔ In large animals blood needs to be pumped with enough force to send it considerable distances
  - ➔ Animals with dual circulatory systems need blood supplied quickly due to high metabolite rates (rates of energy used in chemical reactions in the body).
  - ➔ Sufficient blood flow is required for homeostasis (large animals need blood flow to maintain relatively high body temperatures).

Location of the heart

- Located in the thorax, in the front of the mediastinum (heart and greater vessels, 2 pleural cavities). The three main structures behind the heart are the thoracic vertebrae, oesophagus and descending aorta.
- It is bounded laterally by lungs, inferiorly by diaphragm and anteriorly by sternum and left costal cartilage (sternocostal surface).
- It lies surrounded by a serous membrane, contained within a dense connective tissue sac (fibrous pericardium). This attaches the heart to the diaphragm.
- Thus the heart moves in the thorax during breathing because it attaches to the diaphragm, the main muscle of inspiration.
  - ➔ Apex: most inferior point of heart, major portion is left ventricle, located anteriorly, 5th left intercostal space
  - ➔ Base: superior, flat, largely comprised of left atrium
  - ➔ Sternocostal surface: formed by right atrium and ventricle, separated by the atrioventricular groove
  - ➔ Diaphragmatic surface is formed by left atrium and bit of right atrium.
  - ➔ When observing a radiograph, the right margin consists of right atrium, left margin of left ventricle.

The pericardium

- Fibrous pericardium:
  - The outer layer of pericardium, consisting of a dense network of collagen fibres.
  - Functions to stabilise the position of the heart, anchoring it in the mediastinum and to protect it.
- Serous pericardium
  - A slippery thin membrane that covers the surface of the heart, allowing it to pump.
  - The parietal layer lines the inner surface which surrounds the heart. It fuses with fibrous pericardium.
  - The visceral layer, the inner wall, adheres to the heart
  - In between the parietal and visceral surfaces is the pericardial cavity.
- Pericardial cavity
  - Air space caused by the heart pushing into the pericardium. Pericardial fluid is found here, which reduces friction between opposing surfaces as the heart beats.

Structure of the heart

- Epicardium: outer layer which attaches to the visceral layer of the serous pericardium.
- Myocardium: the muscular wall of the heart, forming the atria and ventricles. This contains cardiac muscle tissue, blood vessels and nerves.

- Endocardium: covers the inside surfaces of the heart including the valves. It is very thin (2 cells thick) and smooth so discourages clotting of blood.
- Chordae tendinae: strings anchored to the cusps of valves to prevent blood flow in the wrong direction. Tension is created in them so the cusps close. The contraction of the atria causes turbulent blood flow, which causes the chordae tendinae and the papillary muscles to contract.
- Papillary muscles: muscles at the base of the ventricles that attach to chordae tendinae and walls of ventricles, create tension to prevent valve backswings. Connective tissue originates here.
- Trabeculae carneae: muscular ridges and columns on the interior wall of the ventricles
- Musculi pectinate: muscular ridges on the interior surface of the auricles and part of the right atrial wall

Right atrium	▪ Receives blood from the systemic circuit through SVC and IVC ▪ SVC opens into posterior/superior portion, delivers blood from head, neck, chest, upper limbs ▪ IVC opens into posterior/inferior portion, delivering blood from lower limbs, rest of trunk.
Right ventricle	▪ Receives blood from the right atrium through the tricuspid valve ▪ Pumps blood through pulmonary semi-lunar valve→ pulmonary arteries→ deoxygenated blood→ lungs to be oxygenated ▪ The moderator band delivers stimuli for contraction to the papillary muscle→ tenses chordae tendinae→ right ventricle contracts (part of electrical conducting system).
Left atrium	▪ Receives blood from the left and right pulmonary veins ▪ The bicuspid valve permits blood flow from left ventricle and prevents backflow.
Left ventricle	▪ Receives blood from the left atrium once it has passed the bicuspid valve. ▪ Pumps blood through aortic valve to aorta then rest of the body. ▪ Thick walls enable it to develop sufficient pressure to push blood. No moderator band

- ➔ Atria are collecting chambers that pump blood to adjacent vessels (close proximity), they have similar structures since demands are similar.
- ➔ Ventricles must exert more pressure to pump blood further distances, so they are stronger and thicker cardiac muscles than the atria.
- ➔ The right ventricle is thinner than left as only has to pump blood to lungs in pulmonary circuit, so left exerts 4-6 times the pressure to pump same amount of blood.
- ➔ Note also the left ventricle has a round cross-section meaning when it contracts, the distance between base and apex decreases, so diameter decreases (allowing generation of greater pressure).
- ➔ Right and left side of heart separated by interventricular septum, ventricles by interventricular groove.

Components of the circulatory system

- **Arteries (conduit vessels):**
  - ➔ Efferent vessels, they carry blood away from the heart. Have a lot of elastic tissue and thick walls which promotes blood flow to the muscles. This is when blood flow is pulsatile.
  - ➔ Recoil after stretched, meaning pressure is increased as the vessels reduce in size. This helps keep the blood flow continuous (stored elastic energy maintains high pressure not generated by heart during diastole).
  - ➔ As they enter peripheral tissues, they branch repeatedly, smallest branches being arterioles
  - ➔ Elastic arteries have the thick elastic fibres in media tolerating large pressure changes.
  - ➔ Muscular arteries have very smooth muscle cells in media, easily distribute blood flow.
  - ➔ Aorta: receives blood from LV, pumping it to the rest of the body.
    - Brachiocephalic trunk: branches into right carotid (right side of neck and head) and right subclavian artery
    - Left common carotid: left side of head and neck
    - Left subclavian arteries: left upper limbs
  - ➔ Left and right coronary arteries originate at the base of the ascending aorta, at the aortic sinuses. Blood pressure here is highest in the systemic circuit.
  - ➔ Left coronary artery:
    - Supplies left ventricle, atrium and interventricular septum

- Anterior interventricular branch: major branch that extends inferiorly into anterior IV sulcus. Supplies blood to most of the anterior parts of the heart
- Circumflex branch: extends around to posterior side of heart in the coronary sulcus, supplying to posterior wall of the heart

➔ Right coronary artery:
- Supplies right ventricle, atrium and portions of the conducting system of the heart
- Posterior interventricular branch: lies in posterior interventricular sulcus and supplies blood to the posterior and inferior part of the heart
- Marginal branch: supplies blood to lateral wall of right ventricle
- Sinoatrial nodal branch: near SVC

- **Veins (conduit vessels):**
  - ➔ Afferent vessels, return blood to the heart. Elastic and smooth muscle, capable of contraction and dilation.
  - ➔ Also have relatively thin walls allowing them to hold the majority of blood volume. (thin media, thick externa to encourage blood flow).
  - ➔ Superior vena cava: deoxygenated blood from upper limbs, head, chest, neck and brain
  - ➔ Inferior vena cava: deoxygenated blood from body and lower limbs
  - ➔ Pulmonary veins: oxygenated blood from lungs and enters left atrium
- **Capillaries:**
  - ➔ Interconnect the smallest arteries and the smallest veins
  - ➔ Called exchange vessels because thin walls allows exchange of nutrients, dissolved gases, and wastes between blood and surrounding tissues. This is when blood is non-pulsatile.
  - ➔ The total cross sectional area is greatest in the capillaries.
  - ➔ Blood also flows quite slowly through the capillaries, allowing time for diffusion across the capillary walls.
  - ➔ Continuous capillaries: supply most regions of body, endothelium is complete lining, permit diffusion, but prevent loss of blood cells.
  - ➔ Fenestrated capillaries: contain pores that penetrate the endothelial lining, allowing rapid exchange of water and solutes between blood and interstitial fluid.
- **Arterioles:**
  - ➔ Known as resistance vessels because they contribute the most to total resistance of the circulation. This is because they change in response to sympathetic or endocrine stimulation.
  - ➔ Lots of smooth muscle and thick walls, control blood flow within organs
  - ➔ The largest pressure drop is across the arterioles.
- **Venules:**
  - ➔ Unite to form larger veins that return blood to the heart.
  - ➔ These are mainly connective tissue, small veins that collect blood from the capillaries, linking the capillaries to veins when blood is being transported back to the heart and lungs.
  - ➔ Lumen of venule is generally wider than equivalent arteriole to limit resistance
  - ➔ Have valves formed by folding of tunica interna.
    - **Intercalated discs**
  - ➔ Interconnect cardiac muscle cells. The interlocking membranes of adjacent cells are held together by desmosomes and linked by gap junctions
  - ➔ Transfer the force of contraction from cell to cell and propagate action potentials

Arteries	Veins
Usually round, relatively thick wall, which allows them to retain their circular shape	Usually flattened with relatively thin wall.
In the tunica intima, the endothelium is rippled due to vessel constriction. An internal elastic membrane is present.	Often smooth endothelium, and no internal elastic membrane
Tunica media is thick, dominated by smooth muscle cells and elastic fibres.	Thin tunica media, dominated by smooth muscle cells are collagen fibres

Helps resist arterial pressure generated by heart and are more resilient (elastic recoil)	
Tunica externa contains collagen and elastic fibres	Tunica externa contains collagen and elastic fibres, and smooth muscle cells
	Contain valves, internal structures that prevent backflow of blood towards capillaries