SESSION 10: TRANSPORT SYSTEMS IN MAMMALS (HUMANS) 1

KEY CONCEPTS:

In this session we will consider the following:

- Blood circulation system
- Direction of blood flow and circulation
- Mechanism for controlling cardiac cycle & heart rate

X-PLANATION:

- All living cells require nutrients and oxygen to survive. Cells produce metabolic waste, which must be removed and excreted.

Circulation takes place as follows:

- Unicellular organisms - diffusion
- Coelenterates - central gastrovascular cavity
- Coelomates - vascular system and a simple heart structure
- Arthropods and molluscs: haemocoel filled with blood that bathes the major organs
- Vertebrates: complex circulatory system with blood, blood vessels and a heart to pump the blood

Open Blood System:

- Blood system where blood pumped from heart to body cavities and the blood may re-enter blood system. Organs and tissues are thus surrounded by blood

Closed Blood System:

- Blood pumped from heart to blood vessels throughout the body and back to the heart. Blood does not usually leave blood vessels. Tissues and cells surrounded by tissue fluid.

The Human Circulatory System:

All mammals have a closed blood circulatory system - blood always flows inside blood vessels.

A double circulatory system = blood passes through the heart twice:
1. **Pulmonary circulation:**
   The blood is pumped from the heart to the lungs to oxygenate the blood and then back to the heart.

2. **Systemic circulation (to all the systems):**
   The blood is pumped from the heart to all parts of the body and back to the heart again.

**External Structure:**

[Image of the external structure of the heart with labeled parts]

**Internal Structure:**

[Image of the internal structure of the heart with labeled parts]
• The Heart

All vessels that flow Away from the heart are called Arteries (Aorta, Pulmonary artery).

All blood vessels entering the heart are called Veins (Inferior and Superior vena cava, Pulmonary vein).

The terms artery and vein are not determined by what the vessel transports (oxygenated blood or deoxygenated) but by whether the vessel flows to or from the heart.

• The Cardiac Cycle

The top half of the heart works as one unit.

The bottom half of the heart works as one unit.

The sino-atrial node (pacemaker) starts and regulates the process.

To understand the cardiac cycle, note the following:

– The duration of one heartbeat is approximately 0,8 seconds.
– Normal heartbeat rate is approximately 72–75 beats per minute.
– The contraction of the heart muscle is called systole (think ‘S’ for stressed).
– The relaxing of the heart muscle is called diastole.
Phase 1: Atrial Systole – atria Contract

- The blood from the pulmonary veins (left atrium) and the superior and inferior vena cava (right atrium) flows into the atria.
- The atria both **contract** at the same time.
- This contraction lasts for about 0,1 seconds.
- The blood is forced through the artio-ventricular valves (bicuspide on the left and tricuspid on the right) and into the ventricles.

Phase 2: Ventricular Systole – Ventricles Contract

- To fill up, the ventricles must be **relaxed**.
- As they fill, pressure inside the ventricles increases.
- The ventricles begin to **contract**.
- The contraction lasts for about 0,3 seconds.
- This contraction forces the blood upwards.
- It causes the bicuspid and tricuspid valves to **close** = LUBB sound.
- The blood can only pass out through the pulmonary artery (on the right) and through the aorta (on the left).
- The atria are relaxed during ventricular systole.
Phase 3: General Diastole – General Relaxation of the Heart

- The ventricles begin to relax so less pressure exists to push blood out.
- To prevent the blood from flowing back into the ventricles, the semi-lunar valves in the aorta and the pulmonary artery close = dubb sound.
- The atria are relaxed.
- This general state of diastole lasts for about 0.4 seconds.
- The next cycle can now begin.
- The stroke volume is the amount of blood that is pumped through the heart, during each cardiac cycle.
- When one exercises, the stroke volume will increase, because the skeletal muscles need more oxygen and glucose to produce energy.
- The fitter you are, the greater your stroke volume becomes.

Heartbeat

- When you listen to the heartbeat, there are two distinct sounds - the first sound is loud (LUBB) and the second sound is softer (dubb).
- The lubb sound is when the atrio-ventricular valves close when the ventricles contract.
- The dubb sound is when the semi-lunar valves close in the aorta and pulmonary artery. This prevents the flow of blood back into the ventricles as the ventricles relax.
- A doctor listens to the heart with an instrument called a stethoscope.
- A person’s pulse can be felt when pressing any of the fingers (not the thumb), against the wrist at the brachial artery or at the neck against the carotid artery.
- The pulse is a result of pressure caused by the blood, as it is forced out through the aorta.
Regulation of Heartbeat

- Heart and lungs functioning is regulated by the **medulla oblongata** in the brain.
- Nerve impulses are sent from medulla oblongata to the **sino-atrial node** (pacemaker) of the heart.
- The sino-atrial node controls the **systole and diastole** of all the cardiac cells – ensures that the whole heart works as one unit.
- An increase in the CO\textsubscript{2} level in the blood stimulates **chemoreceptors** in the aortic arch and the carotid arteries.
- Chemoreceptors convert the stimuli into impulses -**relayed** to the medulla oblongata.
- The medulla oblongata sends impulses to stimulate the sino-atrial node = heart will beat faster.
- The medulla oblongata will also stimulate the rate at which O\textsubscript{2} is inhaled into the lungs.
- So, an increase in the heartbeat **automatically increases** the breathing rate.
- The medulla oblongata is regulated by the hypothalamus and the **autonomic nervous system**.
Pulmonary Circulation:

Right ventricle (DeO₂) ---pulmonary arteries ---lungs ----oxygenation ----
pulmonary veins ---left atrium ---bicuspid valve ----left ventricle

Systemic Circulation:

Left ventricle----aorta -----tissues of body ----deoxygenation----veins ----inferior & superior venae cava ----right atrium ----tricuspid valve ----right ventricle
Hepatic Portal Circulation:

Organs of abdomen (DeO$_2$) -----hepatic portal vein -----liver ----deamination, detoxification ----hepatic vein -----ivc-----right atrium -----tricuspid valve ----right ventricle
Blood Pressure (Bp)

- Blood pressure is the result of the **pumping action** of the heart and the **size** of the blood vessels.
- Results in **pressure build-up** in the arteries.
- Pressure is important, because this keeps the blood flowing to all the parts of the body.
- Blood pressure can be increased by:
  - **smoking and excess alcohol intake**
  - **stress**
  - **adrenalin surges**
  - **water retention**
  - **poor diet and high cholesterol**
  - **obesity**
  - **lack of exercise**
- A healthy person’s blood pressure is measured in units of mercury at **120/80**.
- 120 is the **systolic pressure** (ventricles have contracted) and the 80 is the **diastolic pressure** (when general diastole occurs).
- **Hypotension**: lower blood pressure than normal
- **Hypertension**: higher blood pressure than normal
- High blood pressure can be aggravated by diet like too much salt can cause hypertension.
- High blood pressure can sometimes go undetected and may eventually lead to death –called the ‘silent killer’.
- A **sphygmomanometer** is an instrument used to measure blood pressure.

![Blood Pressure Diagram](image-url)
X-AMPLE QUESTIONS:

Question 1:

Diagrams showing the heart during the cardiac cycle:

Question 2:

The following diagrams show the heart during the cardiac cycle. The arrows represent the flow of blood. Study the diagrams and answer the questions that follow:

Diagrams showing the heart during the cardiac cycle:
2.1. Identify the structures labelled A and B respectively. (2)

2.2. Name and explain what happens in each of the phases of the cardiac cycle represented in:
   a) Diagram I (3)
   b) Diagram II (4)
   c) Diagram III (4)

2.3. Loss of a lot of blood, vomiting and diarrhoea often causes a decrease in blood volume. As a result, blood cannot move normally around the body, as blood vessels are not completely full. The tissues do not get enough blood, leading to possible death of cells and hence damage to organs.
   a) Explain why severe vomiting and diarrhoea would cause a decrease in the blood volume. (2)
   b) What is the relationship between blood volume and blood pressure? (2)

**Question 3:**

Read the passage below and then answer the questions based on it:

When the ventricles of the heart pump blood into the arteries, the pressure of the blood in the arteries is high. This is called systolic pressure (average 120 mm Hg). When the heart muscle relaxes, the pressure in the arteries is much less. This is called diastolic pressure (average 80 mm Hg). The average blood pressure of a healthy person is 120 over 80.

It is normal for a person’s blood pressure to differ slightly from the average. If blood pressure is too high or too low there are medication that can be used to control this. High blood pressure is called ‘hypertension’ and low blood pressure is called ‘hypotension’.

There are several contributing factors to heart disease, namely hypertension, strokes, lack of exercise, smoking, rich fatty diets, obesity and diabetes. Research has shown that 25% of the South African population suffer from hypertension and that this is on the increase.

The treatment for hypertension is expensive and has a great impact on the health system and on the economy.

3.1. Explain what causes the pressure in the arteries to rise and fall. (4)
3.2. Why is it essential that blood pressure in the capillary vessels be much lower than that in the artery? (4)
3.3. List THREE reasons why heart disease is on the increase in South Africa. (3)
3.4. Suggest ONE way in which the government could reduce the number of people with heart disease. (2)