Circulatory system of mammals

- Explain the cardiac cycle and its initiation
- Discuss the internal factors that control heart action

Blood flows through the heart as a result of pressure differences

Blood moves via mass flow which is movement of material from high to low pressure

The Heart

What is the Cardiac Cycle

Refers to the sequence of contraction and relaxation of the heart chamber during one heartbeat

Systole: heart muscle is contracted
Diastole: heart muscle is relaxed

Cardiac output is the amount of blood flowing from the heart:

Stroke volume (Volume of blood) x Number of beats in a given time (Heart Rate)
Three Stages of the Cardiac Cycle

1. Atrial and ventricular diastole
2. Atrial systole
3. Ventricular systole

Atrial and Ventricular Diastole

- It describes how blood flows from veins to atria
  Both atria and ventricles are relaxed
- Atria pressure lower than in veins so blood moves into atrium, which is achieved when atria muscle relaxes and the volumes in the atria increases with a corresponding lowering of pressure

Atrial and Ventricular Diastole

- Pressure begins to rise in the atria which reduces volume
- As blood enters the atria, there is a higher pressure in the atria as opposed to the ventricles
- Blood will flow from the atria into the ventricles pushing open the atroventricular valves

Atrial Systole

- Blood flows from the atria into the ventricles
- The atria muscles contract while ventricle muscles relax
- Blood pushed from atria into ventricles, atroventricular valves open and the semilunar valves remain shut
**Ventricular Systole**

- Blood flows from the ventricles into the arteries
- The ventricular muscles contract and atrial muscles relax
- Blood will flow from the ventricles into arteries since the pressure in the ventricles is much higher than in arteries

A further increase in pressure occurs when the thick ventricle muscles contract

- This causes a decrease in the volume in the ventricles and an increase in pressure thereby forcing the atrioventricular valves shut
- The papillary muscles also contract to prevent the valves from bursting open under this high pressure
- As blood flows into the arteries, the aortic and pulmonary valves (semilunar valves) are pushed open which ensures that blood flows in one direction out of the heart

- The cycle repeats itself
The Heart Beat

• Ventricular pressure rises at 0.1s and repeated at 0.9s
• Length of heartbeat = 0.8s
• Therefore in 1 min = 0.8/60 = 75 bpm
• Between 0s and 0.1s, the pressure is higher in the atrium than the ventricle, so blood flows from atrium to ventricles
• The higher pressure in the atrium is due to contraction of the atrium at atrial systole, but is much lower than ventricular pressure

Pressure & Volume Changes in the left side of the heart

• At 0.1s, pressure rises in the ventricle due to contractions of the muscle during ventricular systole
• This forces the atrioventricular valves shut which produces the first heart sound (atrioventricular valves shutting)
• At 0.7s, the pressure in the ventricles has risen higher than that in the aorta, pushing aortic valves open
• This continues until the pressure in the ventricles fall below that in the aorta at 0.4s
• Blood then drops back from the aorta forcing the valves shut, producing the second heart sound (semilunar valves shutting)

Summary of Events
Summary of Events
- The pressure is lower in the atrium than the ventricle from 0.1s until 0.47s due to atrial diastole.
- From 0.25 to 0.47s, the pressure rises as blood enters the atrium from veins.
- NB. No sound is made when valves open, only when they shut.
- As blood passes from atrium to ventricle, the pressure falls slightly in the atrium and rises in the ventricle so pressure lines get closer (Atrial and Ventricular diastole).
- At about 0.8s, the atrium contracts at atrial systole and forces any remaining blood into the ventricles and the cycle starts again.

Electrocardiograms
The image is a detection of the voltage within the heart against time and is known as an electrocardiogram (ECG).
- P is the excitation of the atrial walls.
- Q, R, S are the ventricle wall excitation.
- T is the ventricle walls recovery.

How is the Cardiac Cycle coordinated
- Cardiac muscle is initiated at regular intervals without nervous or hormonal stimulation i.e. Myogenic Muscle.
- The human heart beats about 70 bpm in adults and this depend on the requirements of the body.
- This rate is can also be controlled by nerves of hormones based on the body’s needs.
The heart muscles are myogenic, meaning they contract and relax on their own. They are stimulated by two nodes, the sino-atrial node (pace maker) and the atrio-ventricular node. The sino-atrial node is a modified muscle cell collection that sends out regular electrical impulses to the atrial walls. The electrical impulse from the SAN causes the left and right atria to contract simultaneously.

Collagen tissue prevents the electrical impulses from the atria to the ventricles.

The atrio-ventricular node picks up the excitation waves as it spreads across the atria, and after a delay of 0.1 seconds it passes it on to conducting fibres, called the Purkyne tissue which runs down the septum between the ventricles where it spreads outwards and upwards through the ventricle walls. This purkyne tissue causes the ventricles to contract simultaneously from the bottom up, squeezing blood upwards and into the arteries.

If the heart loses control, and the excitation wave becomes chaotic, this is known as fibrillation, and it will feed back on itself and re-stimulate areas inappropriately. This can be due to a heart attack or an electric shock. This fibrillation, since the blood is not being pumped properly, is nearly always fatal, but an electric shock can kick the heart back into sequence.
Myogenic Control of Heart

- It is interesting to note that the ventricles contract about 0.16 - 0.20s after the atria contract, so giving sufficient time for blood to be fully squeezed out into the ventricles from the atria, before they start contracting.
- The cardiac muscle requires no stimulation externally and the branching fibres ensure that all parts of atrium and ventricle contract simultaneously.
- The coronary arteries provide raw materials for respiration and continue to contract without fatigue (i.e. long refractory period).

Nervous Control of Heart

Hormonal Control of Heart
Chemoreceptors and control of heart

Role of chemoreceptors
Chemoreceptors are sensitive to chemicals in the blood. They are called chemoreceptors and are found in the walls of the aorta and in the carotid arteries. These include receptors sensitive to the levels of carbon dioxide and oxygen in the blood. (Figure 10.15)

During exercise, the rate of respiration increases and so does the production of carbon dioxide. Carbon dioxide dissolves in plasma to form carbonic acid which then increases in hydrogen ions and acidity. This increase in hydrogen ions is detected by the chemoreceptors in the carotid arteries and the aorta. Once stimulated, these chemoreceptors cause impulses to be sent to the cardiovascular center in the medulla. This triggers impulses along the sympathetic nervous system to the heart, so increasing the heart rate. An increase in the heart rate speeds up the transport of blood to the lungs, where carbon dioxide is removed and oxygen is added. Thus the level of carbon dioxide is lowered back to a normal level.

This is an example of a negative feedback mechanism, where any increase in the level of carbon dioxide is detected and changes are brought about to lower the level of carbon dioxide back to its normal level.

Baroreceptors and control of heart

Role of pressure receptors (baroreceptors)
These are receptors sensitive to changes in pressure. The baroreceptors in the carotid arteries and the aorta respond to changes in blood pressure. (Figure 10.15)

High blood pressure stretches and stimulates the baroreceptors and impulses are sent to the medulla. The medulla responds by firing off impulses along the vagus nerve, which is part of the parasympathetic nervous system, to the heart.

This causes a decrease in heart rate, by slowing down the frequency of impulses from the SNS, so reducing the blood pressure. Once again, this is an example of a negative feedback mechanism, as an increase in blood pressure brings about changes that reduce it.

Low blood pressure means that the baroreceptors are not stretched and stimulated and fewer impulses are sent to the brain. As a result, the medulla sends impulses along sympathetic nerves to the heart leading to an increase in the heart rate. Impulses from the medulla also cause vasoconstriction of arterioles. This narrowing of the blood vessels also increases the blood pressure, so bringing it back to normal.

Session Ends