Pupil notes

The Cardiovascular System

The cardiovascular system includes:

The heart, a muscular pump

The blood, a fluid connective tissue

The blood vessels, arteries, veins and capillaries

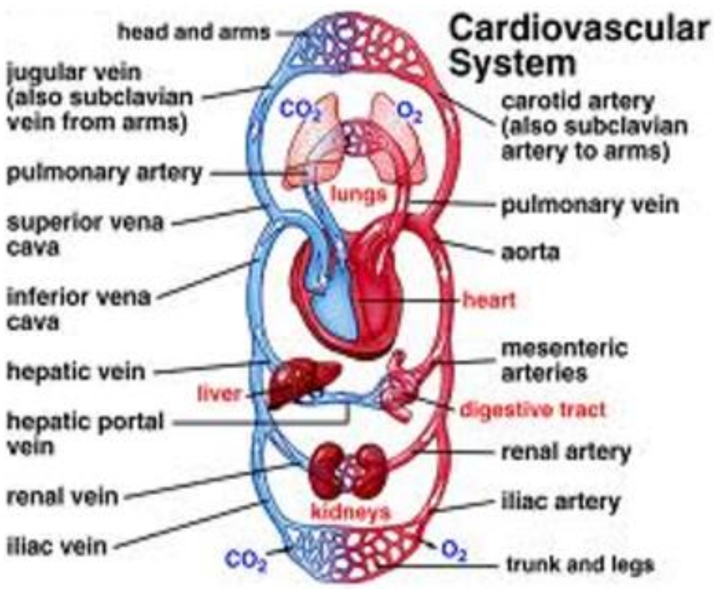
Blood flows <u>a</u>way from the heart in <u>a</u>rteries, to the capillaries and back to the heart in the veins

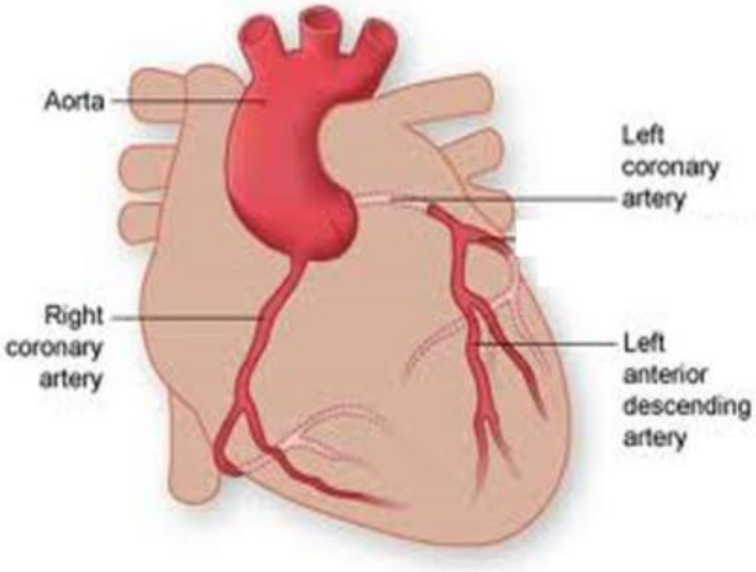
There is a decrease in blood pressure as the blood travels away from the heart

Arterial branches of the aorta supply oxygenated blood to all parts of the body

Deoxygenated blood leaves the organs in veins

Veins unite to form the vena cava which returns the blood to the heart

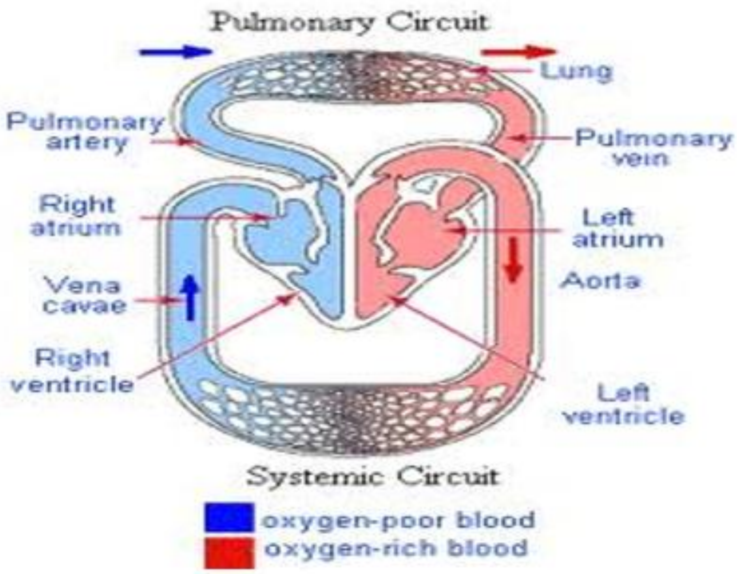




Pulmonary System

This is the route by which blood is circulated from the heart to the lungs and back to the heart again

The pulmonary system is exceptional in that the pulmonary artery carries deoxygenated blood and the pulmonary vein carries oxygenated blood



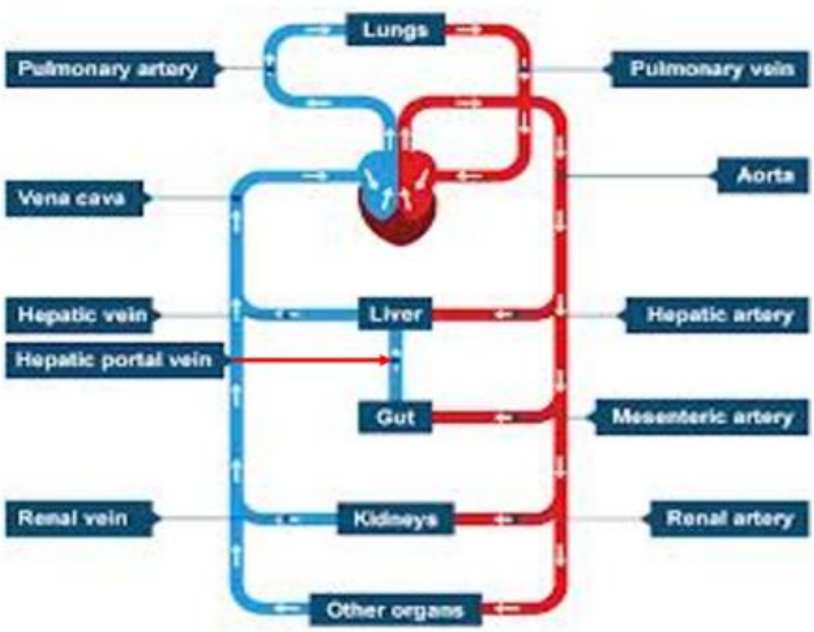
Hepatic Portal Vein

There is another exception in the circulatory system – the hepatic portal vein

Veins normally carry blood from an organ back to the heart

The hepatic portal vein carries blood from the capillary bed of the intestine to the capillary bed of the liver

As a result, the liver has three blood vessels associated with it



Arteries and Veins

The central cavity of a blood vessel is called the lumen

The lumen is lined with a thin layer of cells called the endothelium

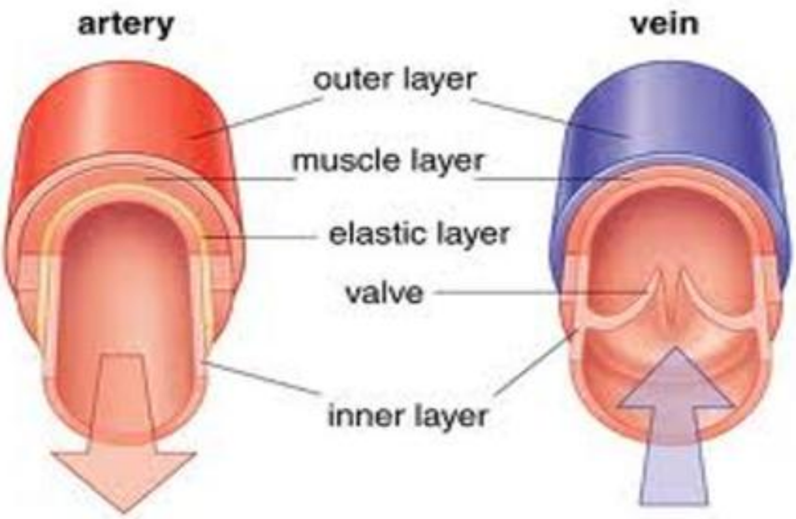
The composition of the vessel wall surrounding the endothelium is <u>different</u> in arteries, veins and capillaries

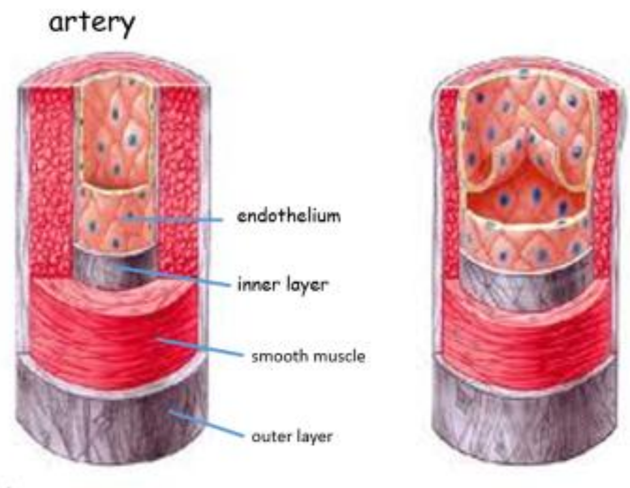
<u>A</u>rteries carry blood <u>a</u>way from the heart

Arteries have a thick middle layer of smooth muscle

They have an inner and outer layer of elastic fibres

Elastic fibres enable the artery wall to pulsate, stretch and recoil, thereby accommodating the surge of blood after each contraction of the heart





Smooth muscle can contract or become relaxed

This contraction or relaxation brings about vasodilation or vasoconstriction to control blood flow

During strenuous exercise the arterioles leading to the muscles undergo vasodilation – the circular muscle in the arteriole wall is relaxed and the lumen is wide

This allows an increased blood flow to the skeletal muscles

At the same time, the arterioles leading to the small intestine undergo vasoconstriction

The circular muscles are contracted and the lumen is narrow

As a result, this reduces the blood flow to the gut

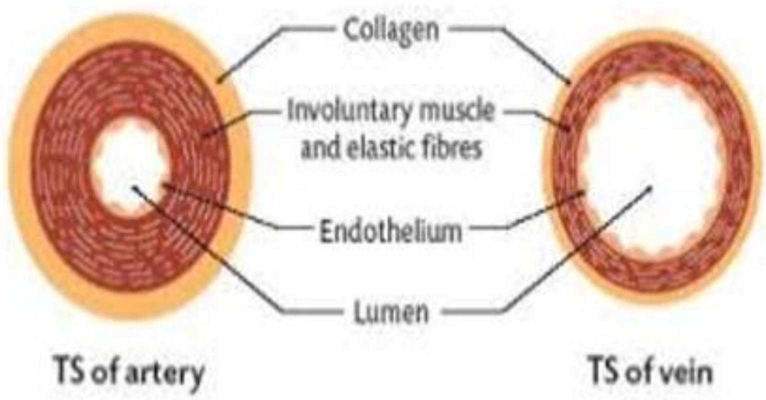
Veins carry blood back to the heart

The muscular layer and layers of elastic fibres in the vein wall are thinner than those in an artery because blood flows along a vein at low pressure

The lumen of a vein is wider than that of an artery

Valves are present in veins, to prevent the backflow of blood

Following two slides compare an artery and vein

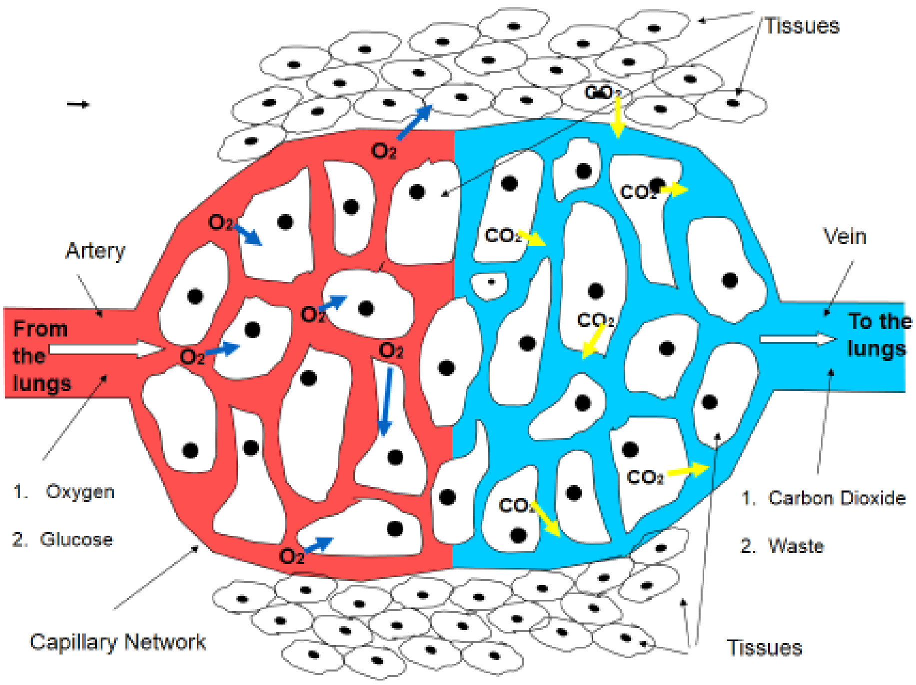


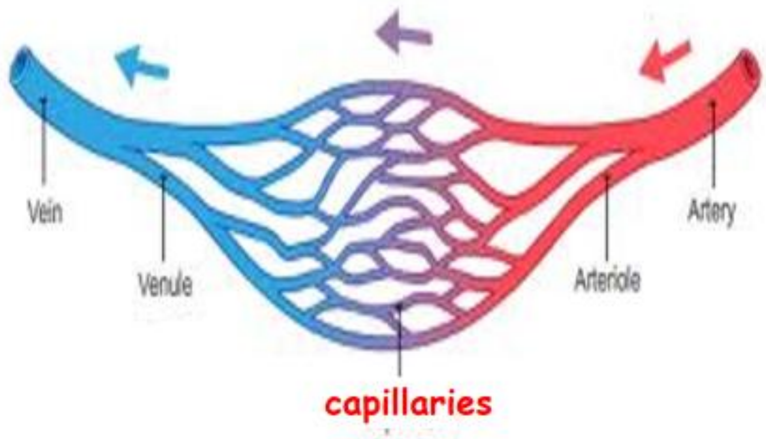
Capillaries and Exchange of Materials

Blood is transported from arterioles to venules by passing through a dense network of blood vessels called capillaries

All exchanges of substances between blood and living tissue takes place through capillary walls

Capillary walls are composed of endothelium and are only one cell thick





Plasma is a watery yellow fluid containing dissolved substances such as glucose, amino acids, blood cells, platelets and plasma proteins

Blood arriving at the arteriole end of a capillary bed is at a higher pressure than blood in the capillaries

As blood is forced into the narrow capillaries, it undergoes pressure filtration and much of the plasma is squeezed out through the thin walls

This liquid is called tissue fluid

The only difference between plasma and tissue fluid is that plasma has proteins

Tissue fluid contains a high concentration of dissolved food, oxygen, useful ions etc.

These diffuse, down a concentration gradient, into the surrounding cells

Carbon dioxide and other metabolic wastes diffuse out of the cells, down a concentration gradient, into the tissue fluid to be excreted

Tissue fluid and Lymph

Much of the tissue fluid returns to the blood in the capillaries at the venule end of the capillary bed

This is brought about by osmosis

Tissue fluid lacks plasma proteins so it has a higher water concentration than the blood plasma

Some of the tissue fluid does not return to the blood in the capillaries

This excess tissue fluid is absorbed by thin-walled lymphatic vessels

When the tissue fluid is in the lymphatic vessel it is called lymph

Tiny lymph vessels unite to form larger vessels

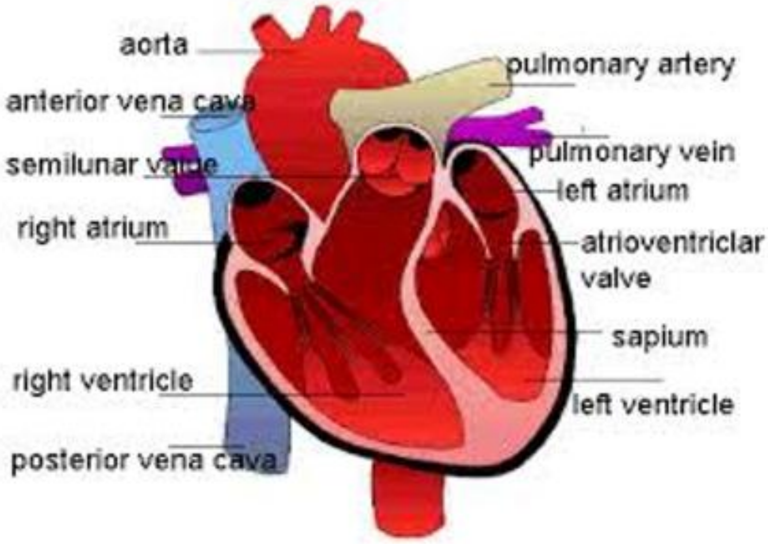
Flow of lymph is brought about by the vessels being compressed when muscles contract during breathing, movement etc.

Larger lymph vessels have valves to prevent backflow

Lymph vessels return their contents to the blood via two lymphatic ducts

These enter the veins coming from the arms

Structure and Function of the Heart



Continuous circulation of blood is maintained by a muscular pump, the heart

The heart is divided into 4 chambers, two atria and two ventricles

The right atrium receives deoxygenated blood from all parts of the body via the vena cavae

Deoxygenated blood passes into the right ventricle before leaving the heart through the pulmonary artery

The pulmonary artery divides into two branches, each leading to a lung

Oxygenated blood returns to the heart by the pulmonary veins

It flows from the left atrium to the left ventricle before leaving the heart by the aorta

The wall of the left ventricle is more muscular and thicker than that of the right ventricle

The left ventricle is required to pump blood all around the body

The right ventricle only pumps blood to the lungs

Valves between the atria and ventricles are the atrio-ventricular (AV) valves

Valves prevent the backflow of blood

The presence of valves ensures the blood flows in one direction through the heart

Semi-lunar valves are present at the origins of the pulmonary artery and the aorta

These valves open during ventricular contraction allowing flow into the arteries

When arterial pressure exceeds ventricular pressure, they close

Cardiac Function

At each contraction the right ventricle pumps the same volume of blood through the pulmonary artery as the left ventricle pumps through the aorta

Heart rate (pulse)

This is the number of heart beats per minute

Stroke volume

This is the volume expelled by each ventricle on contraction

Cardiac output is the volume of blood pumped out of a ventricle per minute

It is summarised by the following equation –

CO = HR X SV

HR is heart rate, SV is stroke volume

Pulse, health indicator

If a person is fit, the quantity of cardiac muscle present in their heart wall is greater and more efficient than that of an unfit person

A very fit person tends to have a lower pulse rate than an unfit person – the fit person's heart is larger and stronger

A fit person's stoke volume is greater

A fit person's heart does not need to contract as often to pump an equal volume of blood round the body

Chapter 12.

The Cardiac Cycle

Term 'cardiac cycle' refers to the pattern of contraction (systole) and relaxation (diastole) during one complete heart beat

The average length of time of one cardiac cycle is 0.8 seconds

Atrial and Ventricular Diastole

During atrial and ventricular diastole, the blood returning in the vena cavae and pulmonary veins causes the volume of blood in the atria to increase

When atrial pressure exceeds the pressure in the ventricles, the AV valves are pushed open and the blood enters the ventricles

Atrial systole

During atrial systole, the two atria contract simultaneously and sends the remainder of the blood into the ventricles – the ventricles are still in a state of ventricular diastole

Atrial systole is followed about 0.1 seconds later by ventricular systole

Ventricular Systole

This stage involves the contraction of the ventricles and the closure of the AV valve

The pressure exerted on the blood in the ventricles causes the SL valves to be pushed open

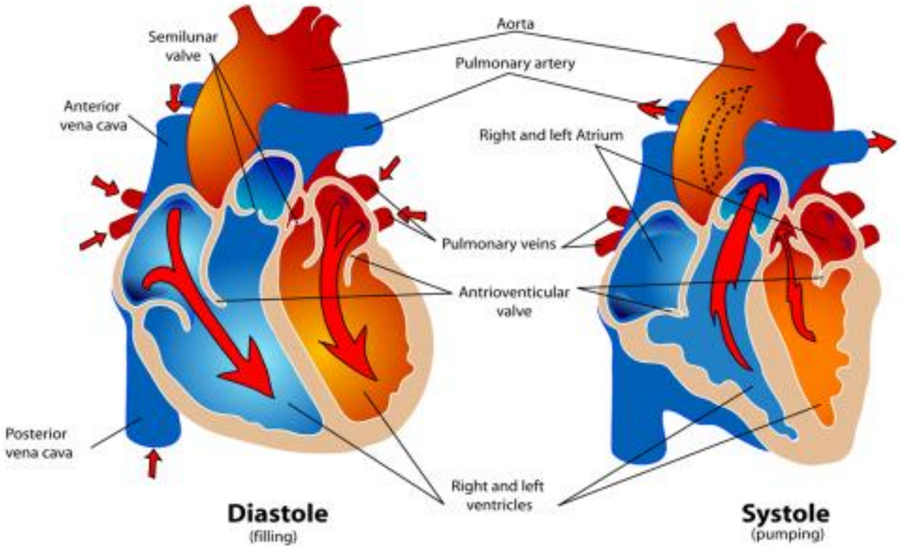
Blood is pumped out of the heart into the aorta and pulmonary arteries

Atrial and ventricular diastole

The higher pressure of the blood in the arteries leaving the heart close the SL valves again

The next cardiac cycle begins

Atrial and ventricular diastole → atrial systole → ventricular systole → diastole → and so on



The opening and closing of the AV and SL valves are responsible for making the heart sounds that can be heard with a stethoscope

When ventricular pressure exceeds atrial pressure this forces the AV valve to close

This produces the heart sound 'lubb'

When ventricular pressure exceeds aortic pressure, this forces open the SL valve

When the ventricular pressure then falls below the aortic pressure this causes the SL valve to close producing the 'dupp' sound

Cardiac conducting system

The heart beat is brought about by the activity of the pacemaker and the conducting system of the heart

The pacemaker, known as the sino-atrial node (SAN) is located in the wall of the right atrium

The region is composed of autorhythmic cells that exhibit spontaneous excitation

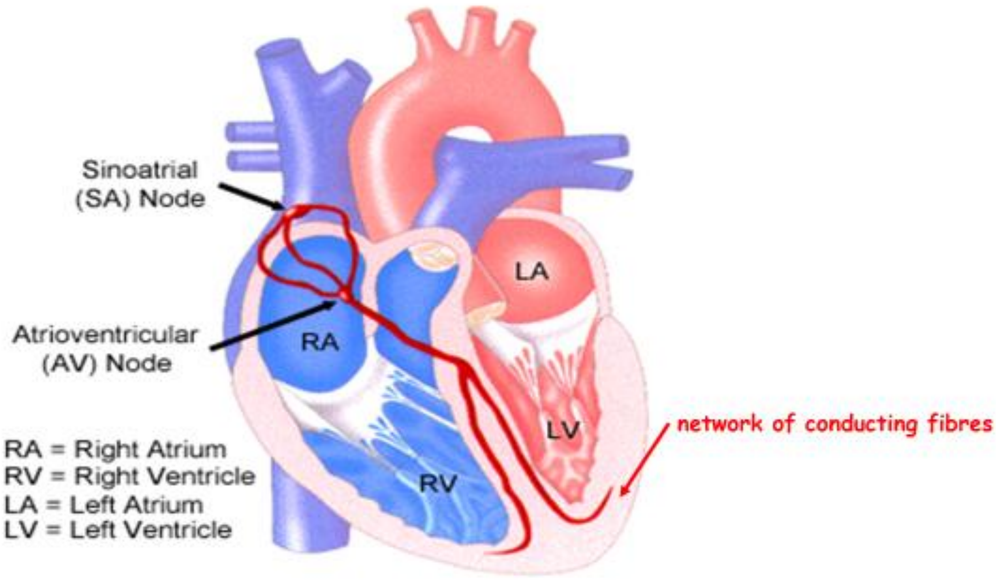
A wave of excitation originating in the SAN spreads through the muscle cells in the wall of the two atria

This makes them contract simultaneously, atrial systole

The impulse is then picked up by the atrio-ventricular node (AVN) located near the base of the atria

The impulse passes from the AVN into a bundle of conducting fibres

Stimulation of conducting fibres in the ventricular walls causes the simultaneous contraction of the two ventricles, ventricular systole



The medulla of the brain regulates heart rate

The cardio-accelerator centre sends nerve impulses via the sympathetic nerve to the heart

An increase in the number of nerve impulses arriving at the pacemaker via the sympathetic nerve results in an increase in heart rate

The cardio-inhibitor centre in the medulla sends its information via a parasympathetic nerve to the heart

An increase in the number of impulses arriving at the ASN from the parasympathetic nerve results in a decrease in heart rate

Under certain circumstances, such as stress or exercise, the sympathetic nervous system acts on the adrenal glands making them release the hormone adrenaline (epinephrine)

On reaching the SAN, the hormone makes the pacemaker generate cardiac impulses at a higher rate – bringing about an increase in heart rate

Electrical activity of the heart generates tiny currents that can be picked up on the skin surface

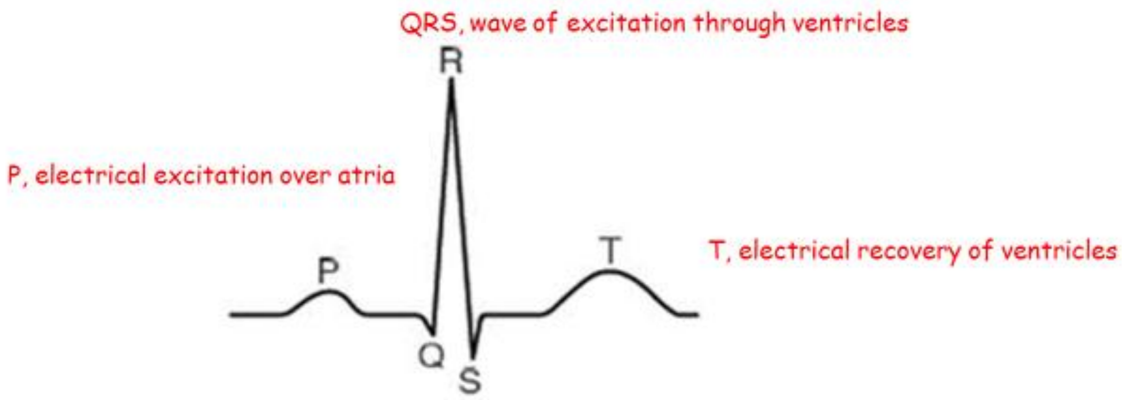
The electrical signals produce a pattern called an electrocardiogram (ECG)

The normal ECG consists of three distinct waves, normally referred to as P, QRS and T

P corresponds to the wave of electrical excitation spreading over the atria from the pacemaker

QRS represents the wave of excitation through the ventricles

T corresponds to the electrical recovery of the ventricles at the end of ventricular systole



Blood pressure is the force exerted by blood against the walls of blood vessels

It is generated by the contraction of ventricles

The highest value is in the Aorta and Pulmonary Artery

During ventricular systole the blood pressure in the Aorta rises to 120mm Hg

During ventricular diastole it drops to about 80mm Hg

There is a progressive decrease in pressure as blood travels round the circulatory system – almost zero when it reaches the right atrium again

Sphygmomanometer, below, measures systolic and diastolic pressure

Sphygmomanometer use

Step 1 - the cuff is inflated until the pressure it exerts stops the blood flowing through the arm artery

Step 2 - cuff allowed to deflate until pressure in artery exceeds pressure in cuff

Blood can be heard spurting through artery and pulse can be felt

The pressure at this stage is a measure of Systolic Pressure

Step 3 - more air is released until spurting blood and pulse cannot be heard, this is a measure of the Diastolic Pressure

Hypertension is prolonged elevation of the blood pressure when at rest

High blood pressure usually involves values >140/>90 mm Hg

Hypertension is a major risk for Coronary Heart Disease and Stokes

It is commonly found in people with unhealthy lifestyles

Overweight

Not enough exercise

Fatty diet

Too much salt

Excessive alcohol

Continuous stress

Chapter 13

Cardiovascular Disease

Atherosclerosis is the formation of plaques, or atheromas, beneath the inner lining in the wall of an artery

Atheromas are originally composed of fatty material, cholesterol, but in time they become enlarged by the addition of fibrous materials, calcium and more cholesterol

Larger atheromas lead to -

Reduction in the diameter of the artery lumen

Restriction of blood flow to capillary bed served by the artery

An increase in blood pressure

Larger plaques may become hardened by calcium deposits and this causes arterial walls to become thicker and lose their elasticity – often called 'hardening of the arteries'

In summary, atherosclerosis can lead to –

Coronary heart disease

Strokes

Heart attack

Peripheral vascular disease

Coronary heart disease refers to any disease that results in the restriction or blockage of the coronary blood supply

<u>Angina</u>

Angina is caused by the coronary arteries becoming narrowed by atherosclerosis

It causes pains in the centre of the chest radiating out into the left arm and up into the neck and jaw

Clotting of blood

In the presence of damaged cells, an inactive plasma enzyme called prothrombin becomes an active enzyme called thrombin

Thrombin promotes the conversion of a soluble plasma protein called fibrinogen into insoluble fibrin threads – eventually becomes a blood clot

Fibrinogen --- thrombin --- > <u>Fibrin</u> threads

Thrombosis is the formation of a blood clot in a blood vessel

How does this happen?

As an atheroma becomes enlarged it may burst through the inner lining of the blood vessel and this 'wound' gets sealed by a blood clot, thrombosis

If the thrombosis breaks loose it is called an embolus

An embolus is carried along by the blood until it blocks a narrow blood vessel

Coronary thrombosis

This is the blockage of the coronary artery by a thrombosis

It deprives the heart muscle of oxygen and may lead to a heart attack (myocardial infarction)

Stroke

A thrombosis that causes a blockage in an artery in the Brain may lead to a stroke

Peripheral Vascular Disorders

Peripheral arteries are arteries except the Aorta, Coronary and Carotid

Peripheral vascular disease happens when peripheral arteries are affected by atherosclerosis

PVD most commonly affects leg arteries

Pain is felt in the leg muscles because they are receiving an inadequate supply of oxygen

Deep Vein Thrombosis

This is the formation of a thrombosis (blood clot) in a vein, commonly in the calf muscle of the lower leg

Pulmonary Embolism

A clot may block a small arterial branch of the Pulmonary Artery

This results in chest pain and breathing difficulties

Atheroma present in blood vessel wall

Atheroma enlarges

Atheroma bursts through lining causing 'wound'

Wound sealed by blood clot, thrombosis

Thrombosis breaks loose and is called embolus

Embolus is carried in blood and can cause a blockage . . . .

Cholesterol and C.V.D.

Cholesterol is an important substance –

It is a precursor for the synthesis of steroids such as sex hormones

It is a basic component of cell membranes

Lipoproteins are present in the plasma and transport lipids around the body

Low-density lipoproteins

These are produced by the liver and they transport cholesterol to body cells

Most cells make LDL receptors which become inserted in the cell membrane

LDL carrying cholesterol (LDL-cholesterol) becomes attached to a receptor

The cell then engulfs the LDL-cholesterol

The cholesterol is released for use by the cell

When the cell has enough cholesterol for its needs, the synthesis of new LDL receptors is inhbited

People who eat a diet rich in saturated fat, and

People with an inherited condition called Familial Hypercholesterolaemia have LDL-cholesterol circulating in their bloodstream

Cholesterol can become deposited in an atheroma in an artery wall

LDL – cholesterol molecules are sometimes called 'bad cholesterol'

(Another molecule, High-density lipoprotein- cholesterol is sometimes called 'good cholesterol')

Some excess cholesterol is taken from body cells to the liver by high-density lipoproteins

This usually prevents a high level of cholesterol accumulating in the bloodstream

HDL-cholesterol is not taken into artery walls, therefore does not contribute to atherosclerosis

These benefits depend on a 'Healthy Balance' between the LDL-cholesterol molecules and the HDL- cholesterol molecules

A high ratio of HDL to LDL results in a decrease in blood cholesterol and a reduced chance of atherosclerosis and cardiovascular disease

A lower ratio of HDL to LDL results in an increase in blood cholesterol and an increased chance of atherosclerosis and cardiovascular disease

HDL levels may be raised by eating less fat

Statins –

Drugs such as statins reduce cholesterol levels in the blood

They inhibit an enzyme essential for the synthesis of cholesterol by liver cells

Molecules of LDL-cholesterol bind to LDL receptors on cell membranes

Sufferers of FH have a mutated gene that causes a decrease in the number of LDL receptors in the cell membrane

Molecules of LDL-cholesterol are unable to unload the cholesterol in cells

Sufferers have very high LDL-cholesterol in their bloodstream

If left untreated, large quantities of cholesterol are deposited in the walls of arteries

Statins work by inhibiting the enzyme needed for the synthesis of cholesterol by liver cells

Blood glucose levels and Vascular Disease

Normally blood plasma contains glucose at a concentration of 5 millimoles per litre

A person suffering from untreated diabetes can have a value of 30 millimoles per litre

Cells lining blood vessels absorb far more glucose than normal

This can lead to damage to blood vessels and to peripheral vascular disease, cardiovascular disease and stroke

Microvascular (small vessel) Disease

When lining cells of a small blood vessel such as an arteriole take in more glucose than normal they become weaker

They lose strength and may burst and bleed (haemorrhage) into surrounding tissues

A tissue may be affected by being flooded with leaked blood of by not receiving enough oxygen

Microvascular disease can -

Damage the retina, affecting vision

Damage the kidneys, causing renal failure

Affect the nerves in the extremities

The body obtains glucose when food is eaten

To guarantee a regular supply of glucose in the bloodstream the body employs a system of negative feedback control

About 100g of glucose is stored in the liver as glycogen

A rise in blood glucose concentration above the normal is detected by receptor cells in the pancreas

These cells produce insulin

Insulin is transported to the liver and glucose is converted to glycogen

This brings about a decrease in glucose levels to normal

When glucose concentration drops, between meals or during the night different receptor cells detect the change

Glucagon is released and is transported to the liver

An enzyme is activated that catalyses the reaction –

Glycogen → glucose

Glucose is released from liver cells to the blood and glucose concentration is normal again

During 'fight or flight reactions' the body needs extra glucose quickly, the adrenal glands secrete an increase quantity of adrenaline – this promotes the breakdown of glycogen to glucose

<u>Type 1</u>

First occurs in childhood or early teens

Ability of pancreatic cells to produce insulin is absent

Cells in the liver have the normal number of insulin receptors on their surface

They can therefore respond to insulin if given as a treatment (insulin injections)

<u>Type 2</u>

Adult onset, sufferer overweight or obese

Pancreatic cells able to produce insulin

Decreased number of insulin receptors, normal conversion of glucose to glycogen is prevented

Treatment includes weight loss, diet control and in some cases insulin

Both types of diabetes, if left untreated, results in a rapid increase in blood glucose levels following a meal

The kidney filtrate is so rich in glucose that much is not reabsorbed

Glucose is excreted in the urine

Glucose in the urine is an indicator of diabetes

Glucose tolerance tests are used to diagnose diabetes

After fasting, a person has their blood glucose level measured

They then consume a known mass of glucose, glucose load

Blood glucose level is monitored (2hours) and glucose tolerance curve produced

A 'normal' person's glucose level rises to a maximum then drops quickly well within the time period

Insulin production is normal

Obesity is characterised by the accumulation of excess body fat

BMI = body mass/height squared

Most common cause of obesity is excessive consumption of foods rich in fats and lack of physical activity

Increased exercise brings about –

Reduction in risk factors associated with CVD

Increase in level of HDL-cholesterol in the blood stream

Decrease in hypertension and stress

This concludes Notes for Unit 2, Higher Human Biology for CFE