Edexcel IAL Biology A Level

Topic 1 : Molecules, transport and health

Notes

Water

Water as a solvent

- In water the hydrogen atoms are more positive than the oxygen atom, causing one end of the molecule to be more positive than the other.
- This causes water to have a permanent dipole - an uneven distribution of charge within the molecule, making water a polar molecule.
- Many substances, such as inorganic ions, can dissolve in water thanks to these positive and negative charges within the molecule.
- When substances dissolve in water, they can move, allowing chemical reactions to occur.

Carbohydrates

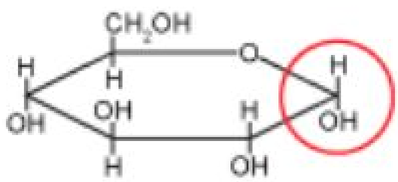
Carbohydrates are molecules which consist only of carbon, hydrogen and oxygen and they are long chains of sugar units called saccharides.

There are three types of saccharides - monosaccharides, disaccharides and polysaccharides. Monosaccharides can join together to form disaccharides and polysaccharides by glycosidic bonds which are formed in condensation reactions.

Monosaccharides

- These are the monomers of carbohydrates.
- They are soluble in water and small, simple molecules.

KEY EXAMPLE: Glucose
One of the most common monosaccharides is glucose, it contains six carbon atoms in each molecule, it is the main substrate for respiration therefore a very important biological molecule. Its structure is shown:



Disaccharides

- 2 monosaccharides join together in a condensation reaction to form a disaccharide.

- Maltose is a disaccharide formed by condensation of two glucose molecules.
- Sucrose is a disaccharide formed by condensation of glucose and fructose.
- Lactose is a disaccharide formed by condensation of glucose and galactose.

Polysaccharides

These are formed from many monosaccharides of glucose joined together and are used as energy stores:

- They are a large molecule with a compact shape - there are many glucose molecules within a small space.
- They can be easily hydrolysed to glucose - glucose can then be broken down in respiration to release energy.
- They are insoluble - so have no osmotic effect in cells.

KEY EXAMPLE: Glycogen

Glycogen is the main energy storage molecule in animals and it's formed from many molecules of glucose joined together by 1,4 and 1,6 glycosidic bonds. It has a large number of side branches meaning that energy can be released quickly. Moreover, it is a relatively large but compact molecule thus maximising the amount of energy it can store.

KEY EXAMPLE 2: Starch

Starch is the primary energy store in plants and it is a mixture of two polysaccharides called amylose and amylopectin:

- Amylose – amylose is an unbranched chain of glucose molecules joined by 1,4 glycosidic bonds. As a result of this amylose is coiled and thus it is a very compact molecule meaning it can store a lot of energy.
- Amylopectin - amylopectin is branched and is made up of glucose molecules joined by 1,4 and 1,6 glycosidic bonds, due to the presence of many side branches it is rapidly digested by enzymes therefore energy is released quickly.

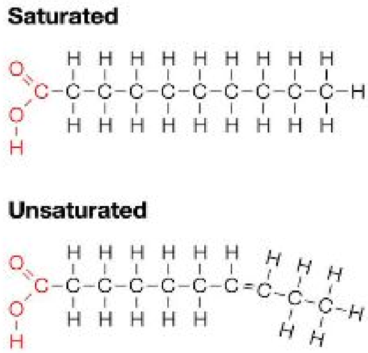
Joining monosaccharides to form disaccharides and polysaccharides

Monosaccharide monomers such as glucose and galactose can join together through condensation reactions - reactions that join 2 molecules together through the release of a small molecule (often water). The bond formed between 2 monosaccharides is known as a glycosidic bond and contains a single oxygen atom.

To break apart polysaccharides these glycosidic bonds have to be broken, this time through a hydrolysis reaction where a water molecule is added, splitting a polysaccharide into 2 smaller molecules, or a disaccharide into 2 monosaccharides.

Lipids

Lipids are biological molecules that have many different functions within an organism such as energy storage, organ protection, thermal insulation and making cell membranes. They are non-polar molecules, so insoluble in water, but soluble in organic solvents. Lipids can be saturated, or unsaturated:

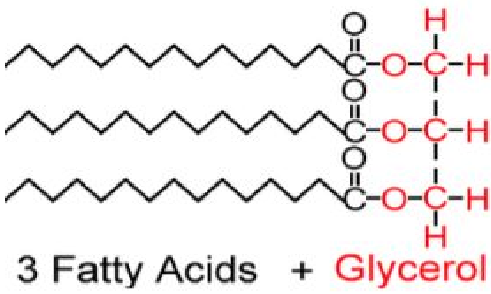


- Saturated lipids (such as those found in animal fats) – saturated lipids don't contain any carbon-carbon double bonds
- Unsaturated lipids (these can be found in plants) – unsaturated lipids contain carbon-carbon double bonds and melt at lower temperatures than saturated fats.

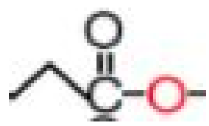
Triglycerides are one of the most important lipids

Triglycerides are made of one molecule of glycerol and three fatty acids joined by ester bonds formed in condensation reactions. There are many different types of fatty acids, they vary in chain length, presence and number of double bonds. Also, some triglycerides contain a mix of different fatty acids. Triglycerides are used as long term energy reserves in plant and animal cells.

One triglyceride molecule:



An ester bond



Mass transport

Why we need a transport system

Diffusion in single-celled organisms can occur directly between the external environment and the cell, this is known as simple diffusion as it occurs only through the cell membrane. Exchange of substances, such as oxygen for these organisms occurs very quickly as they have a very large surface area to volume ratio. For larger organisms, like us humans, we have a low surface area to volume ratio, meaning diffusion would be too slow to supply all cells with the nutrients they need and this is why larger organisms have mass transport systems that supply all cells with vital substances.

Circulatory system

The mammalian circulatory system is comprised of the heart and three types of blood vessels: arteries, veins and capillaries. Each blood vessel is adapted to its role in the circulation of the blood.

Arteries

- Arteries take oxygenated blood Away from the heart
- This vessel has thick walls containing muscles and elastic that expand and recoil with each heartbeat to withstand the high pressure of the blood
- They have a relatively small lumen (hole in the centre through which the blood passes)
- Arteries contain no valves
- Its inner lining is folded to allow it to stretch
- Arteries split into smaller blood vessels called arterioles which split into capillaries
- They are lined with smooth endothelium to reduce friction and ease flow of blood

Capillaries

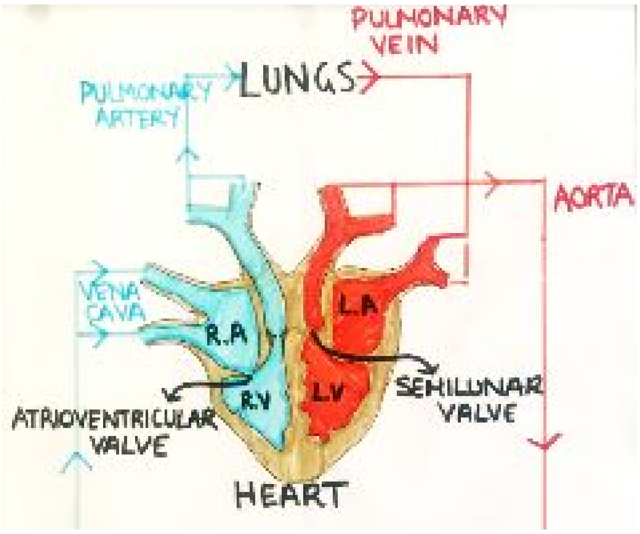
- Arterioles branch into these to supply cells with substances from the blood
- They are numerous and highly branched so have a large surface area
- Their walls are one cell thick to allow quick diffusion
- Very narrow diameter to reach close to every cell

Veins

- Capillaries join back up to form these, so veins carry deoxygenated blood back to the heart
- Carry blood a low pressure so have thin walls
- Have a wide lumen to maximise blood flow to the heart
- Have valves to prevent backflow (blood flowing in the wrong direction).

Structure of the heart

The heart is comprised of 4 chambers: the left and right ventricles (which receive blood into the heart), and the left and right atria (which push blood out of the heart and into arteries to go to the lungs or the body).



Between the ventricles and the atria are the atrioventricular valves which prevent blood flowing back from the ventricles and into the atria; between the ventricles and the arteries leaving the heart are the semilunar valves which prevent backflow of blood from the arteries into the ventricles.

Mammals are described as having a '**double circulatory system**', this is because the blood flows through the heart twice in each circulation. Blood first enters the heart into the right atrium through the largest vein in the body - the vena cava. The first time it leaves the heart it travels from the right ventricle via the pulmonary artery to the lungs where it becomes oxygenated, the blood then returns to the heart via the pulmonary vein into the left atrium. The second time the blood leaves the heart is from the left ventricle via the aorta, where blood now flows to the rest of the body.

The cardiac cycle

The movement of blood through the heart is carefully controlled by the contracting and relaxing of heart muscles. The cardiac cycle has three stages as follows:

1. Atrial systole – the atria contract and this forces the atrio-ventricular valves open and blood flows out of the atria and into the ventricles. Pressure in the atria is greater than in the ventricles, so blood is forced out.
2. Ventricular systole – the ventricles then contract, causing the atrio-ventricular valves to close and semi-lunar valves to open. Thus allowing blood to leave the left ventricle through the aorta and right ventricle through the pulmonary artery.
3. Cardiac diastole – the atria and ventricles relax, elastic recoil of the heart lowers the pressure inside the heart chambers and blood is drawn from the arteries and veins. Thus causing semilunar valves in the aorta and pulmonary arteries to close, preventing backflow of blood.

Transport of gases in the blood

Haemoglobin

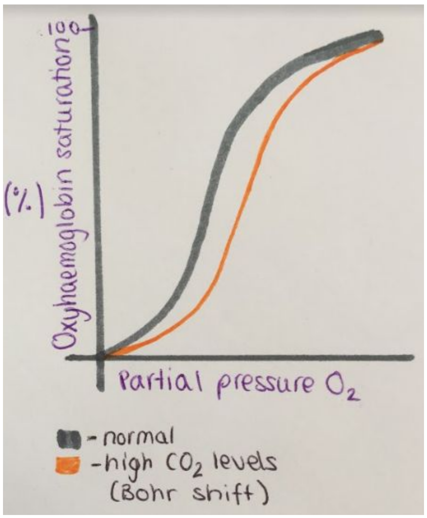
Haemoglobin is a water soluble **globular protein** found in **red blood cells,** which consists of two beta polypeptide chains, 2 alpha polypeptide chains and 4 haem groups. Each of the 4 polypeptide chains is bound to a haem group (Fe2+ ion) to which 1 oxygen molecule can bind. This means each molecule of haemoglobin can carry **4 oxygen molecules**. The oxygen binds with haemoglobin to form **oxyhaemoglobin**, and can unbind when needed in **respiring cells** and tissues.

Transport of oxygen and carbon dioxide

The **affinity** of oxygen for haemoglobin (how easily oxygen loads onto haemoglobin) varies depending on the **partial pressure of oxygen,** which is a measure of oxygen concentration. The greater the concentration of dissolved oxygen in cells the greater the partial pressure. Therefore, as partial pressure increases, the affinity of haemoglobin for oxygen increases. This means that oxygen binds to haemoglobin **more readily.** This occurs in the lungs in the process known as **loading**. During respiration, oxygen is used up therefore the partial pressure decreases, decreasing the affinity of oxygen for haemoglobin. As a result of that, oxygen is released from haemoglobin in respiring tissues where it is needed; this is known as **unloading**.

As oxygen diffuses into respiring tissues for respiration, carbon dioxide diffuses out and into the capillaries. Here, in the **low partial pressure** of oxygen environment, carbon dioxide binds to haemoglobin to form **carboxyhaemoglobin**. The **deoxygenated blood** returns to the lungs where carbon dioxide unloads from haemoglobin, which binds to oxygen again.

Dissociation curves



Dissociation curves illustrate the **change in haemoglobin saturation as partial pressure changes.** The saturation of haemoglobin is affected by its **affinity for oxygen**, therefore in the case where partial pressure is **high**, haemoglobin has **high affinity** for oxygen and is therefore **highly saturated**, and vice versa.

Factors resulting in different affinities:

- **Saturation** - saturation can also have an effect on affinity. As after binding to the first oxygen molecule, the affinity of haemoglobin for oxygen **increases** due to a **change in shape**, thus making it easier for the other oxygen molecules to bind.

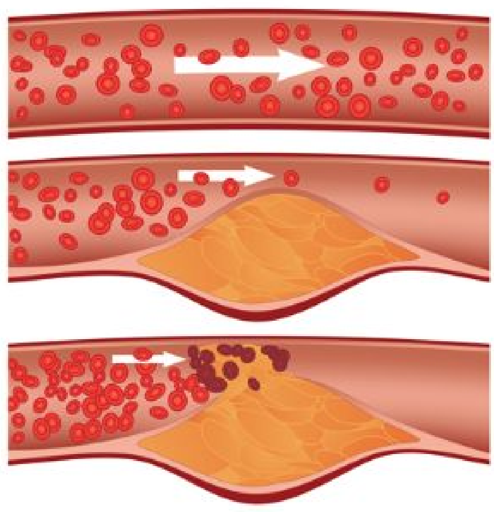
- **Fetal haemoglobin** - The haemoglobin present in foetuses has a different affinity for oxygen compared to adult haemoglobin, as it needs to be **better** at absorbing oxygen because by the time oxygen reaches the **placenta**, the oxygen saturation of the blood has **decreased**. Therefore, fetal haemoglobin must have a **higher affinity** for oxygen in order for the foetus to survive at **low partial pressure.**

- **The Bohr effect** - The affinity of haemoglobin for oxygen is also affected by the partial pressure of **carbon dioxide**. Carbon dioxide is released by respiring cells, which require oxygen for the process to occur. Therefore, in the presence of carbon dioxide, the affinity of haemoglobin for oxygen **decreases**, thus causing it to be released.

Cardiovascular Diseases (CVD)

Atherosclerosis

Atherosclerosis is the **hardening** of arteries caused by the build-up of **fibrous plaque** called an **atheroma**. Atheroma formation is the cause of many **cardiovascular diseases** and occurs as following:



1. The **endothelium** which lines the arteries is **damaged**, for instance by high cholesterol levels, smoking or high blood pressure.

2. This increases the risk of **blood clotting** in the artery and leads to an **inflammatory response** causing **white blood cells** to move into the artery.

3. Over time, white blood cell, cholesterol, calcium salts and fibres **build up and harden** leading to **plaque formation.**

4. The build-up of fibrous plaque leads to **narrowing** of the artery and **restricts blood flow** thus **increasing the blood pressure** which in turn damages the **endothelial lining** and the process is repeated.

Blood clotting

Blood clots are formed to **minimise blood loss** from damaged vessels, and also to **prevent pathogens** entering the bloodstream. Blood clots are important to **preventing damage** to the body, however when they form on the inside of blood vessels, they can **restrict blood flow** through the vessel and cause a **blockade**. This is known as **thrombosis** and can cause cardiovascular disease. Blood clots are formed as follows:

1. Platelets come into contact with a damaged blood vessel wall and change shape from flattened discs to spherical shapes with thin outward projections which form a temporary plug by clumping together.

2. The platelets and damaged tissues release clotting factors such as thromboplastin which causes prothrombin to change to thrombin.

3. This enzyme catalyses the conversion of fibrinogen to insoluble fibrin, whose strands form a mesh, trapping bundles of blood cells. More platelets attach to this, forming the clot.

Risk factors for cardiovascular disease

Risk is defined as the chance of something unfavourable occurring. There are a number of factors that increase the risk for cardiovascular diseases, some within a person's control and down to their lifestyle choices, others outside of their control.

- Genetics - certain genes can increase the risk, sometimes indirectly for instance by having genes for a higher blood pressure. Family history of the disease also increases your risk.

- Diet - diets high in cholesterol and certain fats increase the build-up of plaque on arteries.

- Age - prevalence of CVD increases with age.

- High blood pressure - this can narrow and damage arteries or cause an aneurysm, both of which increase the risk of CVD

- Smoking - smoking damages the lining of arteries and can cause the formation of atheromas.

- Inactivity - has been linked with an increase in blood pressure

Thus risk of CVD can be reduced by stopping smoking, regular exercise, reducing consumption of alcohol, dietary changes and maintaining healthy body weight.

Dietary antioxidants

Oxidative stress is an imbalance of antioxidants and free radicals of oxygen in the body. Free radicals of oxygen are oxygen atoms with an uneven number of electrons, making it highly reactive and meaning it can cause damaging chains of chemical reactions in the body. Antioxidants can donate electrons to make the oxygen radical stable, without making itself unstable. It's thought that this oxidative stress can contribute towards the cause of cardiovascular disease, so the intake of additional antioxidants in the diet should help prevent some cases of cardiovascular disease and at least lessen the risk.

Blood cholesterol levels and CVD

Cholesterol is transported in your body in **high-density lipoproteins (HDLs)** or **low-density lipoproteins (LDLs)**, they each have a different effect on cholesterol levels and are found in different types of food.

High-density lipoproteins

- Transports cholesterol to the liver to be **expelled**
- **Reduces** cholesterol levels
- The **more** of this you have in your body, the **better**
- Formed from **unsaturated fats** and **proteins**

Low-density lipoproteins

- Transports cholesterol to the **arteries** where it can **build up** and form **plaque**
- **Increases** cholesterol levels
- The **less** you have of this in your body, the **better**
- Formed from **saturated fats** and **proteins**

There is a **positive correlation** between ingestion of saturated fats and an increase in cholesterol level. Since increased cholesterol levels cause a build-up of plaque on artery walls, there is a **causal relationship** between saturated fats (LDLs) and cardiovascular disease.

Treatment of cardiovascular diseases

Antihypertensives

These are drugs that are used to **lower blood pressure.**

- Pros - generally **effective** on most patients and **inexpensive**.
- Cons - different types of drugs have different **side effects**, although most aren't severe and are irreversible.

Statins

These are a class of drugs used to **lower cholesterol levels** and so **reduce** the build-up of plaques on artery walls.

- Pros - mostly **effective,** also help relax blood vessels leading to a **lower blood pressure,** also helping to prevent CVD
- Cons - can cause **nausea, vomiting and aches in muscles and joints**, as well as more severe but less common side effects such as **diabetes.** The side effects often go away over time.

Anticoagulants

These are drugs that help **prevent blood clots**.

- Pros - Reduce the risk of internal blood clots that can sometimes cause **thrombosis** and **reduce blood flow** in the artery.

- Cons - If damage to the blood vessel does occur, then excessive bleeding can happen and lead to a **haemorrhage**, since blood clots take longer to form.

Platelet inhibitors

These are drugs that **interrupt the cascade** through which blood clots are formed, commonly through **stopping thrombus formation** and so **preventing blood clots** from forming.

- Pros - can help prevent the formation of blood clots in certain arteries that anticoagulants are ineffective at preventing.
- Cons - Can, like anticoagulants, also lead to excessive bleeding and **haemorrhage** due to **slow** clot formation.

Obesity indicators

The public's understanding of cardiovascular disease and its causes has increased greatly over the years and a number of measurements can now be used to look at obesity, which is a cause of cardiovascular disease. Being aware you are overweight or obese can help encourage a change in diet and increase in exercise to reduce the risk of CVDs.

Body mass index (BMI)

BMI is a value calculated using the following equation:

Body mass in Kilograms ÷ (body height in metres)^2

The value generated can be compared to a chart which classifies you under the following:

- Under 18.5 - underweight
- 18.5 - 25 - normal
- 25 - 30 - overweight
- Over 30 - obese

Waist to hip ratio (WHR)

WHR is another way to view if someone is overweight and can also be used to view their risk of **developing certain diseases**. You are classified as obese if as a male you have a value greater than 0.9 and as a female have a value greater than 0.85.

Perceived risk

Risk is the chance of something unfavourable occurring. Statistical chance of something occurring can be supported using data obtained by scientific research. Whereas a **perceived risk** varies from person to person and is based on **factors,** such as approval of activity. Therefore, as a result of that, the perceived risk can **vary greatly from the actual risk,** thus leading to **underestimating or overestimating** the probability of occurrence of an unwanted event or outcome.

Exam Technique

From the specification: "students should be able to analyse and interpret **quantitative data** on illness and **mortality rates** to determine health risks, including distinguishing between **correlation** and **causation** and recognising conflicting evidence"

- Quantitative data - Data that can be represented with **figures**. For instance, your weight.
- Correlation - correlation describes **the relationship between 2 variables**. A value of 1 means a perfect positive correlation (as one increases, the other also increases). A value of 0 is no correlation and a value of -1 is perfect negative correlation (as one increases, the other equally decreases). For instance, there is a positive correlation between cholesterol levels and the number of cases of CVD.
- Causation - This is when **one variable causes another,** and is different to correlation. 2 values can have a correlation, but that does not mean they cause each other. For instance, an increase in cholesterol levels can cause an increase in plaque formation (causation and correlation); or correlation only - the average temperature in 2 places both increase over 2 months, this is correlation, but one has not caused the increase in the other, so there is no causation.

Evaluating studies

In order to make conclusions from scientific studies they must have been carried out appropriately to **avoid bias** and to be **representative** of the whole population.

Sample selection must be done **randomly** to avoid bias, it must be a **large** enough sample size to be representative of the whole population and must also be sampled across different areas. For instance a nationwide study couldn't sample from one city only.

A reliable study has **statistical analysis** and **peer review** from other scientists. Any trials involving patients and doctors should have a **control group, a placebo, and be blind - or ideally double-blind**.