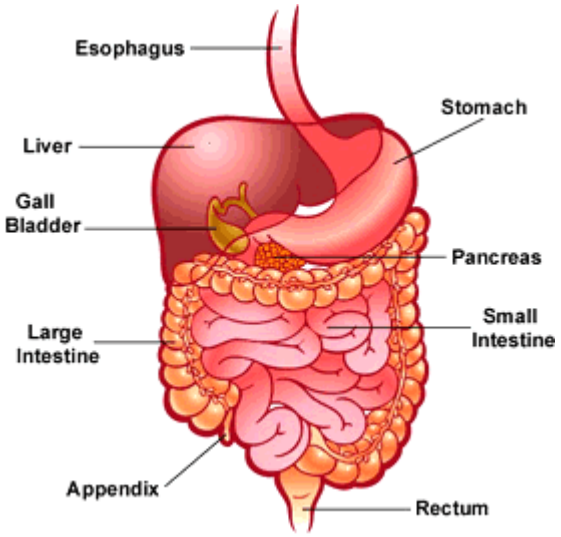
Section 2.1: Enzymes and Digestion

- Glands produce enzymes that are used to break down large molecules into smaller ones that are ready for abortion.

- The digestive system provides an interface between the body and the environment because it allows food to pass through it.

Major parts of the digestive system



- The **Oesophagus** is made up of a thick muscular wall and is adapted so that food can pass down it easily from the mouth to the stomach. Therefore it used for transport, as appose to digestion.

- The **stomach** is a muscular sac with an inner layer that produces enzymes. Its roles are to store and digest food (especially proteins). There are glands within it that produce enzymes to digest protein. Mucus is also produced in the stomach by glands. The mucus prevents the stomach being digested by its own enzymes.

- The **small intestine** is a long muscular tube. Food is further digested by enzymes in the small intestine. The enzymes enter the small intestine through its walls and through glands. The inner walls of the small intestine are folded into villi, giving them a larger surface area. The surface area of villi is further increased by millions of tinier projections called microvilli. The microvilli are found on the epithelial cells of each villus. This adapts the small intestine so that it can absorb substances into the blood stream.

- The **large intestine** absorbs water. Often the water is reabsorbed by the secretion of digestive glands. Because there is little water within the large intestine, the food becomes drier, thus forming faeces.

- The **rectum** is where faeces are stored before it is removed through the anus in a process called **egestion.**

- The **salivary glands** are positioned near the mouth. They pass there secretion via a duct into the mouth. This secretion will contain the enzyme amylase.

- The **pancreas** is a large gland situated near the stomach. It secretes pancreatic juice. This contains protease, lipase and amylase.

There are two stages of digestion; physical breakdown and chemical absorption.

Physical breakdown

Large pieces of food are broken down into smaller pieces by processes such as chewing and the churning of food in the stomach. This makes it possible to not only absorb food but to increase its surface area, thus making it easier for chemical absorption.

Chemical digestion

Chemical digestion is the process of breaking down large molecules into smaller ones so that they can be absorbed. This is carried out by enzymes. Enzymes function by **hydrolysis**. Hydrolysis is the process of splitting up molecules by adding water to the bonds that hold them together. The general term for these enzymes is **hydrolases.** Because enzymes are specific, more than one is needed to break down a large molecule. Usually, an enzyme will break down a molecule into smaller sections. These smaller sections are then hydrolysed into even smaller molecules by additional enzymes.

Carbohydrases break starch molecules down until they become monosaccharides.
Lipase breaks down lips into glycerol and fatty acids.
Protease breaks protein down to amino acids.

Once these molecules have been broken down to become even smaller molecules such as monosaccharides, they are absorbed into the body and are often built up again to form larger molecules again. These new molecules are incorporated into body tissue or are used in processes within the body. This is called **assimilation.**

Section 2.2: Carbohydrates – Monosaccharides

- Carbohydrates are carbon molecules (carbo) combined with water molecules (hydrate).

Life based on Carbon

- Carbon atoms are able to readily form bonds with other carbon atoms
- Life on earth is based on the versatile carbon atom.

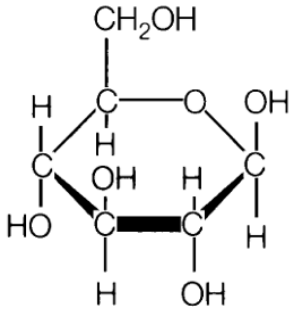
The making of large molecules

- Carbohydrates are long chains made up of individual molecules called monosaccharides.
- A pair of monosaccharides is called a disaccharide and several monosaccharides joined together are called a polysaccharide.

Monosaccharides

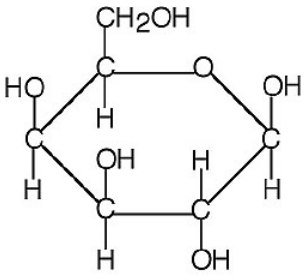
- Monosaccharides are soluble and have the general formula $(CH_20)_n$. N can be any number from 3 -7.
- Glucose is a hexose because it has 6 carbon atoms and has the formula $C_6H_{12}O_6$
- Even though it has the same chemical formula, the hydrogen and oxygen atoms can be arranged in many different ways:

Glucose



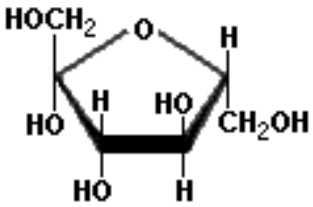
Glucose is the most common sugar. Although its molecular arrangement is often shown as a straight line, its atoms form a ring.

Galactose



Galactose has the same chemical formula as glucose. However on the left of the diagram you can see how the Hydroxide and hydrogen atoms are arranged differently to glucose.

Fructose



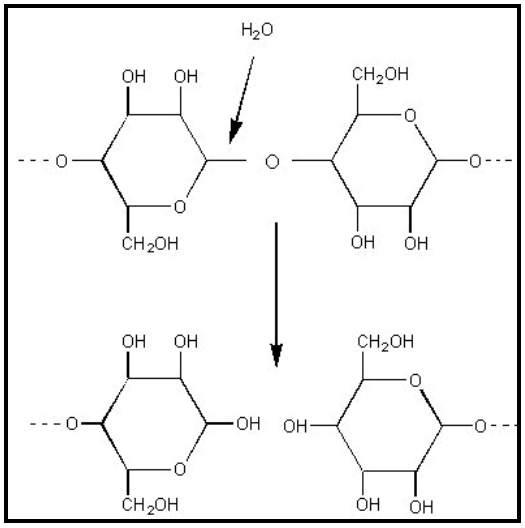
Fructose has a very different structure to glucose and is often used as a sweetener.

Section 2.3: Carbohydrates – disaccharides and polysaccharides.

Disaccharides

When combined in pairs, monosaccharides form disaccharides.

- Glucose with glucose forms maltose
- Glucose with fructose forms sucrose
- Glucose linked with Galactose forms lactose.



- When two monosaccharides join together, a water molecule is removed. This is called a **condensation reaction**.
- In order to break the bond, water is added to the molecule in a process called **hydrolysis**.
- The bond holding the two monomers together is called a **glycosidic bond**.
- A glycosidic bond involves an oxygen atom.

Polysaccharides

- Polysaccharides are long chains of monosaccharides combined together through glycosidic bonds.
- Because they are very long molecules, they are often insoluble. This means that they are very suitable for storage.
- When hydrolysed, polysaccharides break down into disaccharides or monosaccharides.
- Some polysaccharides such as cellulose are not used for storage, but instead are used to give support to plant cells.

Test for non-reducing sugars

To test for a non reducing sugar it must first be hydrolysed then added to Benedict's reagent.

Test for starch

To test for starch, add iodine solution (iodine dissolved in the solution of potassium iodide). If starch is present, the iodine will turn from yellow/brown to blue-black.

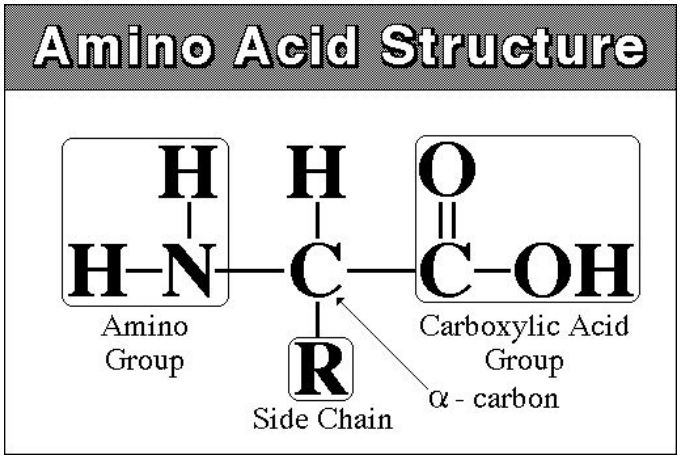
Section 2.4 – Carbohydrate digestion

- It usually takes more than one enzyme to break down a large molecule.
- Food is physically broken down by teeth to increase surface area.
- Normally one enzyme breaks a large molecule into smaller sections, and then other enzymes break these down to monomers.
- Firstly the enzyme “amylase” is produced in the mouth by salivary glands, where the pH is kept at neutral by mineral salts.
- This enzyme breaks starch into maltose by hydrolysing the glycosidic bonds holding the molecule together.
- Once the food is swallowed, the enzyme is destroyed by the stomach acid where the pH is around 2. This means that no more starch can be digested.
- After the stomach, food passes into the small intestine where it mixes with pancreatic juices.
- The pancreatic juice contains pancreatic amylase which hydrolyses the remaining starch.
- Alkaline salts are produced by the intestine wall and the pancreas to maintain the pH at neutral so that the enzymes can work efficiently.
- The epithelial lining of the intestine produces the enzyme maltase. This breaks maltose into glucose.
- Sucrase which is produced by the epithelial lining breaks down sucrose into fructose and glucose.
- People who are lactose intolerant do not produce enough lactase to break down the lactose found in milk.
- When undigested lactose enters the small intestine, bacteria digest it and produce lots of gas.
- This can cause stomach cramps, nausea and diarrhoea.
- For new born babies, milk makes up the majority of their diet. To overcome the problem of lactose intolerance amongst children, lactose can be pre-digested before consumption.

Section 2.5 – Proteins

- Each organism has numerous proteins that differ from species to species.
- The structure of one protein molecule differs from that of all other protein molecules.
- Proteins are the most important molecules for life.

Structure of amino acids



There are 4 main parts that make up the general structure of an amino acid. There is:

The amino group (NH2) this is a basic part of the molecule where it gets the name amino.
The carboxyl group (COOH) this is an acid group.
The hydrogen atom (H)
The r group, this can be a variety of chemicals. Each amino acid has a different r group.

The formation of a peptide bond

Through the same process by which monosaccharides join to make disaccharides and polysaccharides, amino acids can join together to form dipeptides.

They create a water molecule by combining the OH from the carboxyl group of one amino acid with the hydrogen atom of another amino acid.

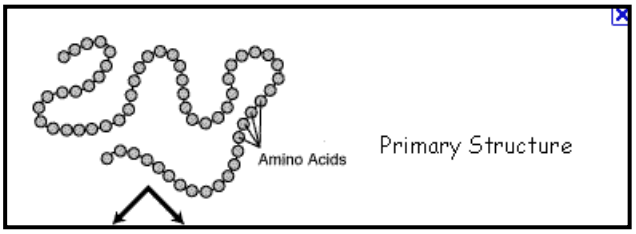
When there is a repeating sequence of amino acids joined by a peptide bond, it is called a polypeptide chain.

Primary Structure

After many condensation reactions (removal of water molecules to form a peptide bond), many monomers are joined together in a process called polymerisation.

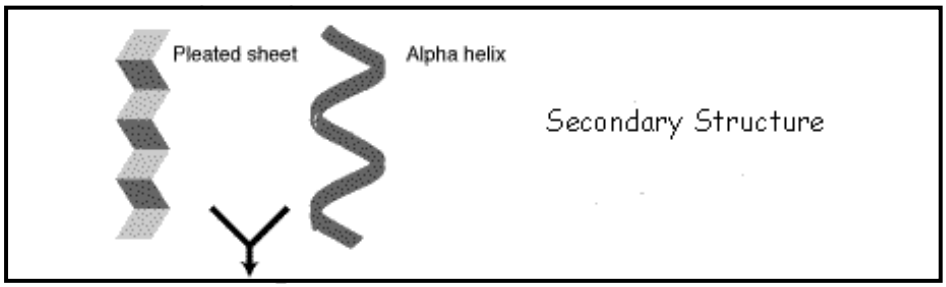
The chain of many amino acids is called a polypeptide.

This repeating sequence of amino acids in a polypeptide chain is known as the primary structure.



Secondary structure

The secondary structure is formed when the -C=O (which has an overall negative charge) is attracted to the hydrogen atom (which has an overall positive charge). This causes the long chain to twist in on its self creating a coil known as an alpha helix.



Tertiary Structure

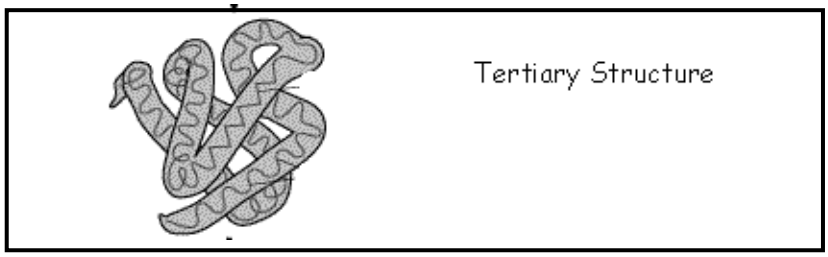
The secondary structure, which is an alpha helix can be further twisted and folded forming a unique 3D structure for each protein.

It is formed by several different types of bonds.

Disulphide bond – fairly strong, not easily broken down.

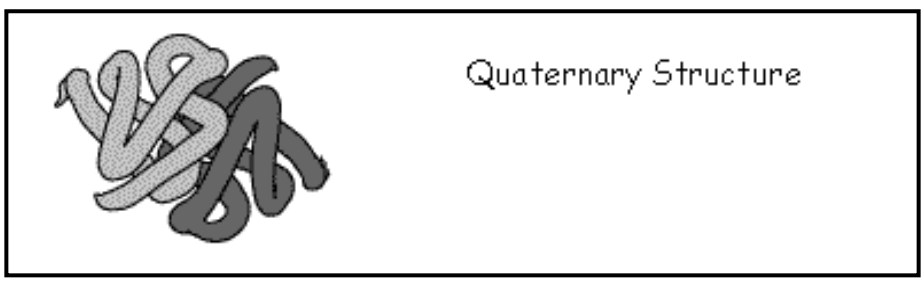
Ionic bonds – formed by the carboxyl and amino groups. They are weaker than disulphide bonds. A change in pH can affect an ionic bond.

Hydrogen bonds – there are many of these however they are easily broken down.



Quaternary Structure

This structure appears when a number of complex molecules containing polypeptide chains that are linked in various ways are associated with non-protein molecules called prosthetic groups.



Section 2.6 – Enzyme action

- All enzymes are globular **proteins** → spherical in shape
- Control biochemical reactions in cells
- They have the suffix "-ase"
- **Intracellular enzymes** are found **inside** the cell
- **Extracellular enzymes** act **outside** the cell
- Enzymes are **catalysts** → speed up chemical reactions
- **Reduce activation energy** required to start a reaction between molecules
- **Substrates (reactants)** are converted into products
- Reaction may not take place in absence of enzymes (each enzyme has a **specific** catalytic action)
- Enzymes catalyse a reaction at maximum rate at an optimum state.
- The substrate and the enzyme must collide with sufficient **energy**.
- Enzymes work by lowering the activation energy required to start a reaction.
- Once the substrate is inside the active site, the enzyme changes shape slightly, distorting the molecule in the active site, and making it more likely to change into the product.
- It's a bit more complicated than that though. Although enzymes can change the speed of a chemical reaction, they cannot change its direction, otherwise they could make "impossible" reactions happen and break the laws of thermodynamics.
- When a substrate (or product) molecule binds, the active site changes shape and fits itself around the molecule, distorting it into forming the transition state, and so speeding up the reaction. This is sometimes called the induced fit mechanism.

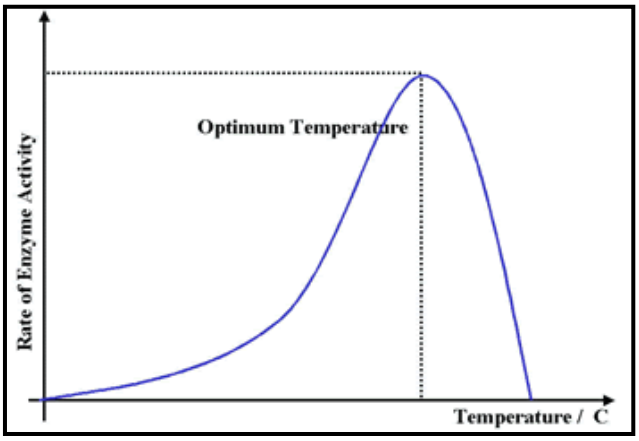
Section 2.7 – Factors affecting enzyme action

Measuring enzyme-catalysed reactions

- To measure the progress of an enzyme-catalysed reaction, its time course is measured. This is how long it takes to run its course.
- The two "events" most frequently measured are the volume of gas produced during a reaction and the disappearance of a substrate.

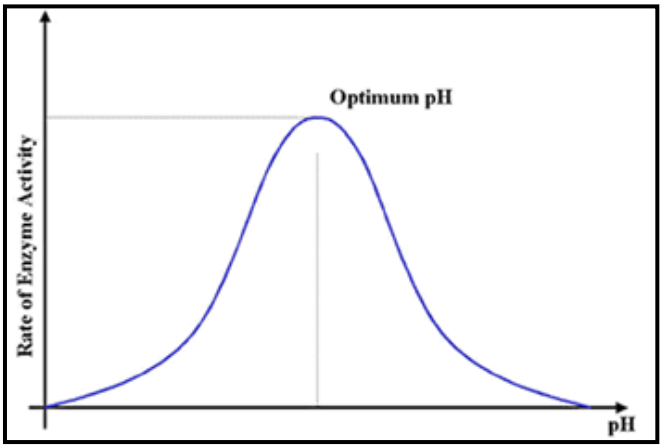
Effect of Temperature

- Enzymes have an optimum temperature at which they work fastest. For mammalian enzymes this is about 40°C, but there are enzymes that work best at very different temperatures, e.g. enzymes from the arctic snow flea work at -10°C, and enzymes from thermophilic bacteria work at 90°C.
- The rate of reaction doubles, approximately almost every ten degrees.
- The rate of reaction will increase as temperature increases. Then, once it reaches its optimum temperature it will begin to decrease as the temperature rises due to the active site being denatured.
- The thermal energy breaks the hydrogen bonds holding the secondary and tertiary structure of the enzyme together, so the enzyme (and especially the active site) loses its shape to become a random coil.



Effect of pH

- Enzymes have an optimum pH at which they work fastest.
- For most enzymes this is about pH 7-8 (physiological pH of most cells), but a few enzymes can work at extreme pH, such as protease enzymes in animal stomachs, which have an optimum of pH 1.
- The pH affects the charge of the amino acids at the active site, so the properties of the active site change and the substrate can no longer bind. For example a carboxyl acid R groups will be uncharged a low pH (COOH), but charged at high pH (COO^-).

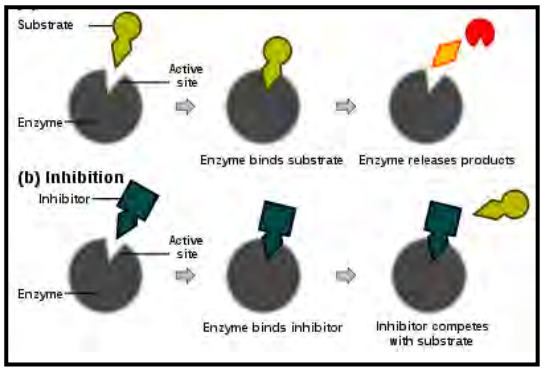


Section 2.8 – Enzyme inhabitation

Inhibitors inhibit the activity of enzymes, reducing the rate of reactions. They are found naturally, but are also used artificially as drugs, pesticides and research tools. There are two kinds of inhibitors.

Competitive inhibitor

- A competitive inhibitor molecule has a similar structure to the normal substrate molecule, and it can fit into the active site of the enzyme.
- It therefore competes with the substrate for the active site, so the reaction is slower.
- It is the difference between the concentration of the inhibitor and the concentration of the substrate that determines the affect it has on the enzymes activity.



- The inhibitor is not permanently bonded to the active site so once it leaves a substrate molecule can take its place.
- Eventually all the substrate molecules will be in the active sites. However, depending on the concentration of the inhibitor, the longer this will take.

Non-competitive inhibitors

- Non-competitive inhibitors do not fit into the active site but instead they bind to another part of the enzyme molecule, changing the shape of the whole enzyme, including the active site, so that it can no longer bind substrate molecules.
- Inhibitors that bind fairly weakly and can be washed out are sometimes called reversible inhibitors, while those that bind tightly and cannot be washed out are called irreversible inhibitors. Poisons like cyanide, heavy metal ions and some insecticides are all non-competitive inhibitors.
- Non-competitive inhibitors therefore simply reduce the amount of active enzyme (just like decreasing the enzyme concentration).