Biological Molecules

Carbohydrates

Key points

A Carbohydrate is a molecule containing only Carbon, Hydrogen and Oxygen in the ratio C:2H:0. For example glucose is $C_6H_{12}O_6$; it has equal numbers of Carbon and Oxygen with twice as many Hydrogens.

Monosaccharides are single sugar molecules. They are generally used as fuel for respiration. At A level the 3 monosaccharides you need to be aware of are **Glucose**, **Fructose** and **Galactose**.

A Disaccharide is 2 single sugars joined together by a chemical (glycosidic) bond. For A level you need to know:

- Maltose = glucose + glucose
- Sucrose = glucose + fructose
- Lactose = glucose + galactose

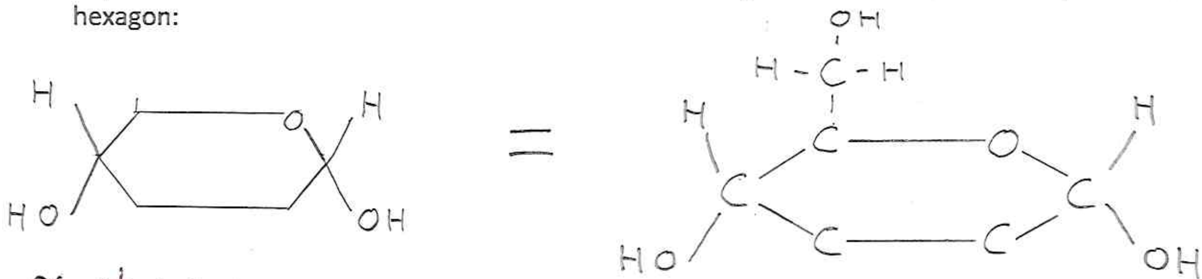
A Polysaccharide is a large number of single sugars joined together by chemical (glycosidic) bonds. At A level the 3 polysaccharides you need to know about are all made from glucose. They are:

- Glycogen (glucose storage in animals)
- Starch (glucose storage in plants)
- Cellulose (plant cell walls)

Sugar molecules can be joined to one another by Glycosidic bonds. Forming a glycosidic bond is a **condensation** reaction (water is removed). Breaking a glycosidic bond requires hydrolysis (water is put back into the molecule).

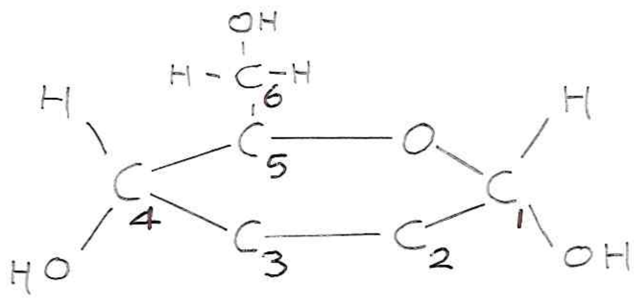
There are 2 food tests linked to carbohydrates – Iodine tests for starch and Benedicts reagent tests for reducing sugar.

You will never be asked to draw any molecule from scratch but you may need to recognise important features and show how bonds are formed / broken. Glucose is always shown as a hexagon:

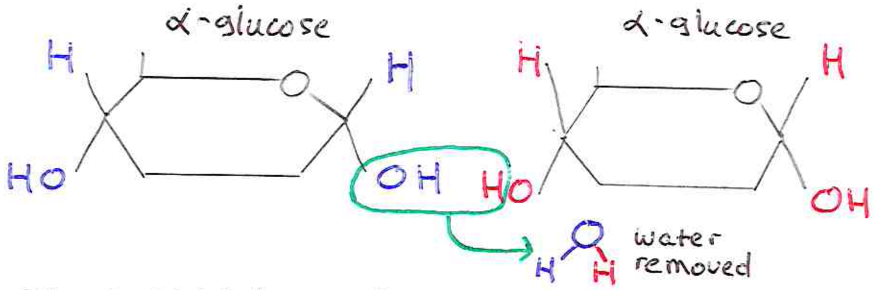


α-glucose:

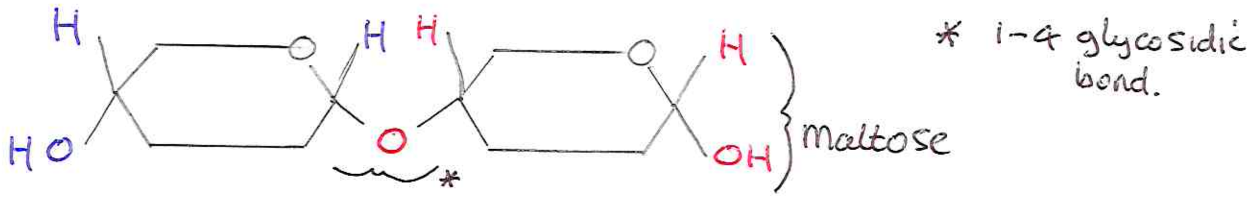
By convention, we start at the right-most Carbon and work round clockwise giving them numbers:



Don't be put off by how complicated some pictures of carbohydrates can be, we are only really interested in the –OH groups as they are used to form the bonds:



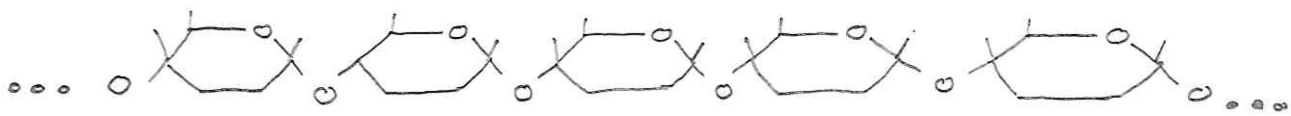
When 2 α (alpha) glucose molecules come together water can be formed from the –OH groups of Carbon 1 and Carbon 4. An Oxygen atom is left behind forming a 1-4 Glycosidic bond. At A level we always deal with α-glucose unless we are talking about cellulose which will be discussed later on.



A 1-4 glycosidic bond between 2 α-glucoses forms the disaccharide **Maltose**.

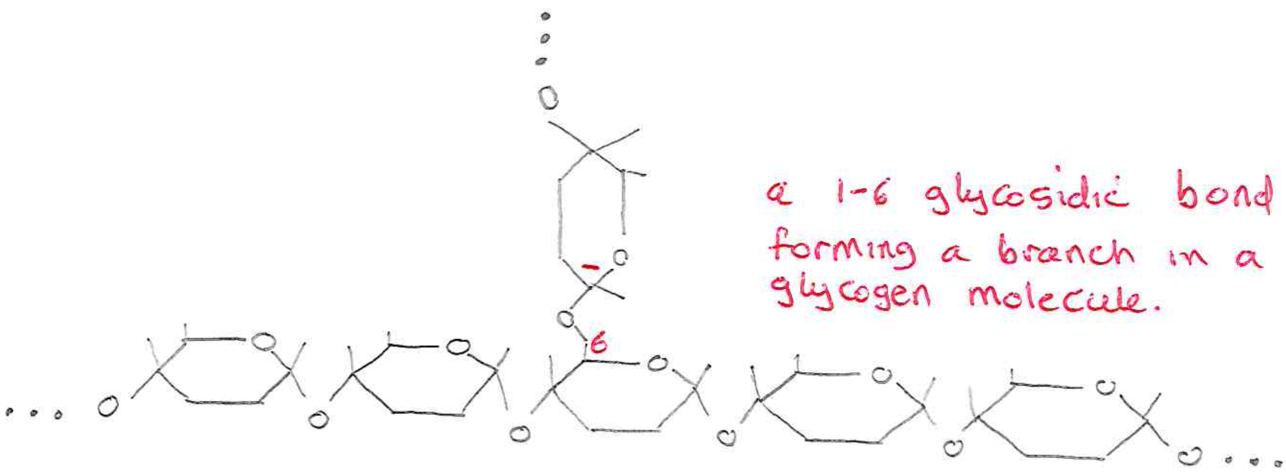
Polysaccharides

Both starch and glycogen are formed by joining lots of α-glucose together using 1-4 glycosidic bonds as shown earlier;



Starch is a spiral shape and therefore compact. Starch is also insoluble which means it does not have an effect on the water potential of cells and it does not diffuse away from the storage location. In actual fact, starch is also branched but you are not required to know this for AQA.

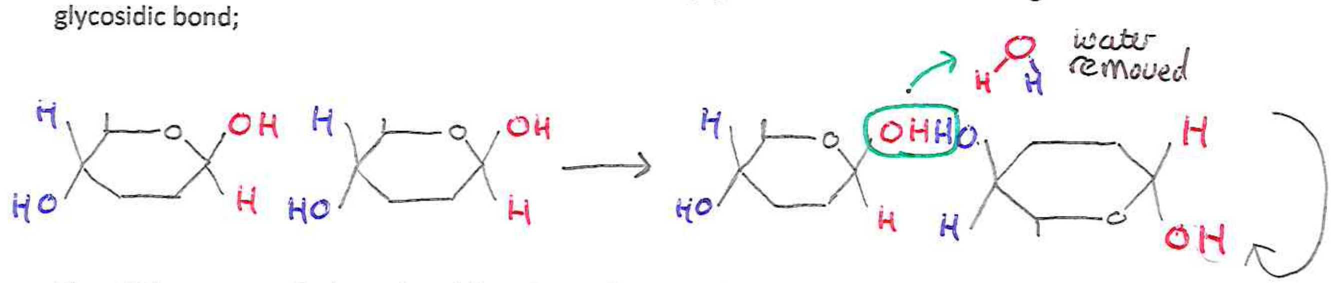
Glycogen: If you look at the diagram of glucose on page 1 you can see that Carbon 6 also has an –OH group. This allows for branching of glucose chains as glycosidic bonds can form between Carbon 1 of one glucose and Carbon 6 of the other;



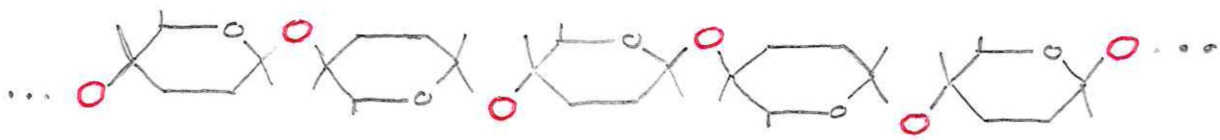
Glycogen is also insoluble therefore it does not diffuse away and does not affect the water potential of cells. In questions about how glycogen is adapted to its function you would also say that because it is branched it can be broken down (hydrolysed) into glucose more quickly. The enzymes that break down glycogen do so from the ends and more branching = more ends.

Cellulose is the polysaccharide plants use to build cell walls, it is the only example using β (beta) glucose on the A level syllabus.

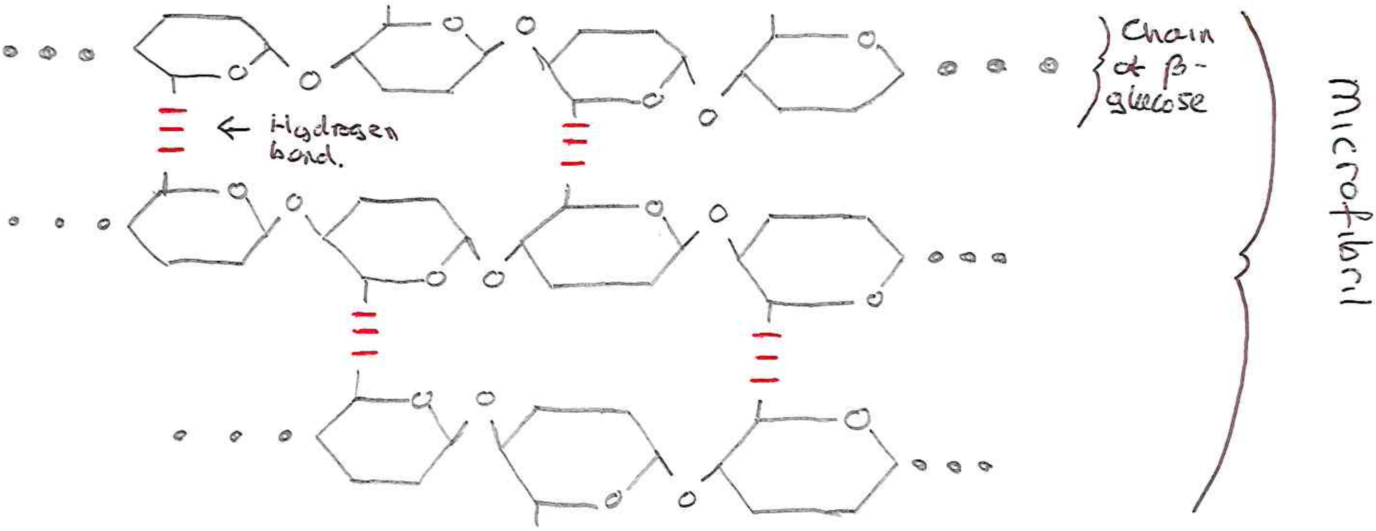
The diagram above shows the difference between α and β glucose. In β glucose the –H and –OH on Carbon 1 swap places. This causes a problem when 2 β-glucose molecules come together to form a glycosidic bond;



The –OH groups on Carbons 1 and 4 no longer line up. The solution is to turn the second β-glucose molecule upside down. You can recognise diagrams of cellulose on exam papers because the position of the glycosidic bonds will alternate up and down;



Relating the structure of cellulose to its function; Because every second glucose is upside down, in a chain of β-glucose you have Carbon 6 pointing both up and down. Remember that Carbon 6 has an –OH group on it; the O is slightly negative and the H is slightly positive. The –OH groups therefore allow **Hydrogen bonds** to form between different chains of β-glucose, forming microfibrils. This gives the cell wall strength.



Carbohydrates and food tests

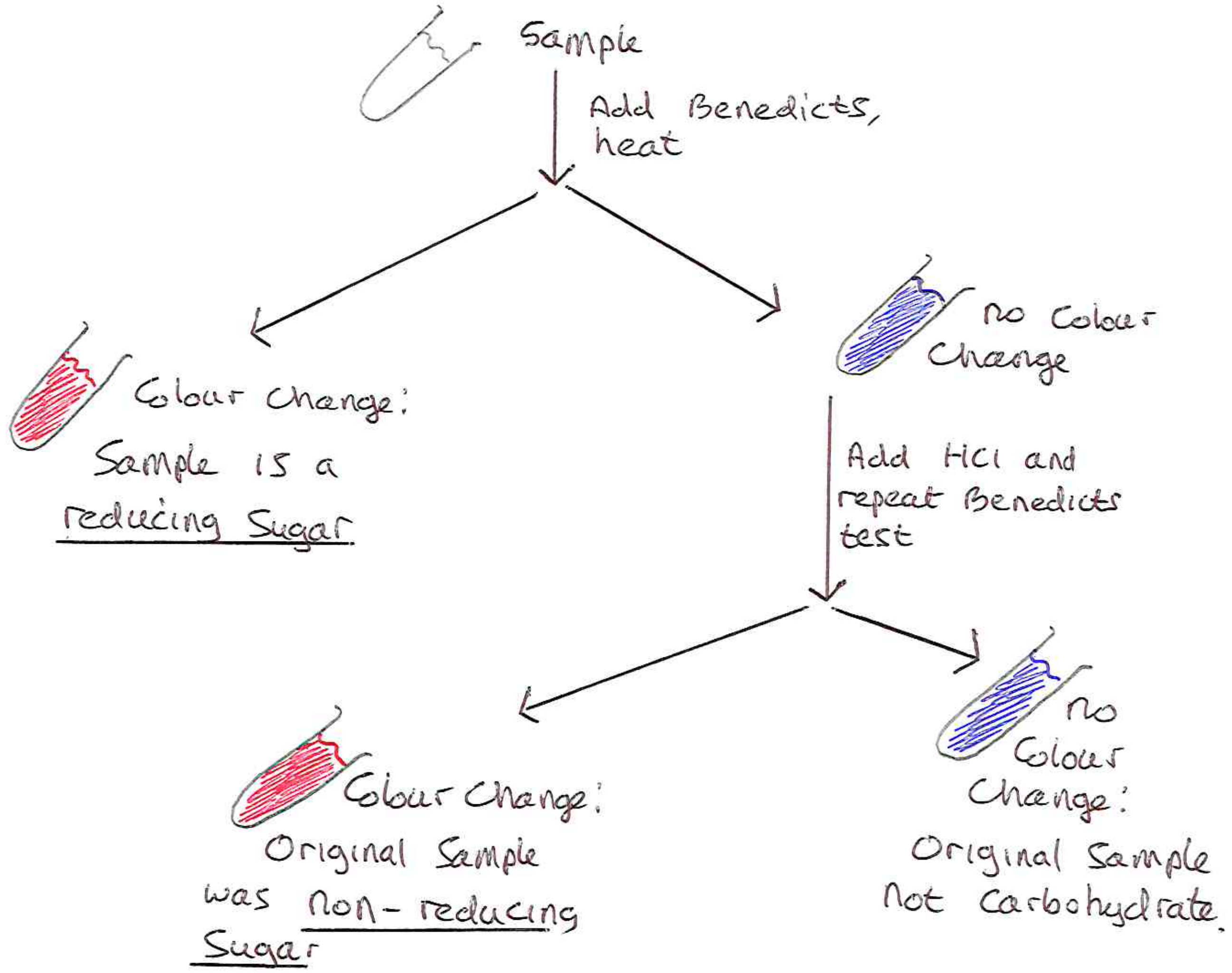
Test for starch; add Iodine in Potassium Iodide (often saying Iodine alone is not enough). If starch is present it will go from brown to blue/black.

Benedicts test for reducing sugar; A reducing sugar reacts with Copper ions in the Benedicts solution in order to produce a colour change. It is the Oxygen atom within the ring that is involved in the reaction and when sugars a joined together the position of the glycosidic bond can often prevent the Oxygen from reacting. For this reason;

- All monosaccharides are reducing sugars (there are no interfering glycosidic bonds)
- Some disaccharides are reducing sugars, some are not (it depends on the position of the glycosidic bonds)
- All polysaccharides are non-reducing sugars (due to the large number of glycosidic bonds)

The procedure is to add Benedicts solution to the sample and heat. If reducing sugar is present the sample will change from blue through green/yellow to red. The degree of colour change can be used to estimate the amount of reducing sugar in the sample (semi-quantitative).

If you carry out the Benedicts test and get a negative result it could mean that the sample contains no carbohydrate at all or that the sample is a non-reducing sugar (eg starch). In order to tell the difference we add HCl (hydrochloric acid). This will break any glycosidic bonds and turn any carbohydrate present into monosaccharides. Because monosaccharides are always reducing sugars if we repeat the Benedicts test we will get a colour change, showing that the original sample was a non-reducing sugar.



Protein

Key Points

Protein is a polymer of amino acids.

Amino acids all have the same basic structure – only there R groups are different.

The amino acids are joined by peptide bonds (a condensation reaction) to form the primary structure.

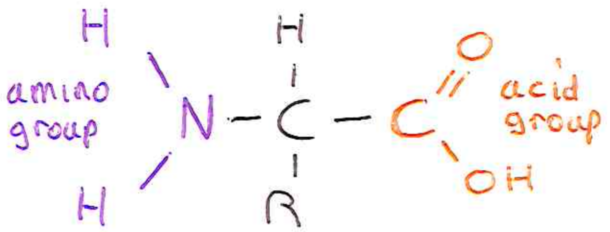
The primary structure can then fold into secondary, tertiary and quaternary structures.

The order of amino acids in the primary structure determines how the protein folds up and what shape it will be. It is the specific shape of the protein that gives it its properties.

Proteins can be Fibrous (insoluble and structural) or Globular (soluble and metabolic).

The test for protein is to add Biuret Reagent. If a purple colour develops the sample contains protein.

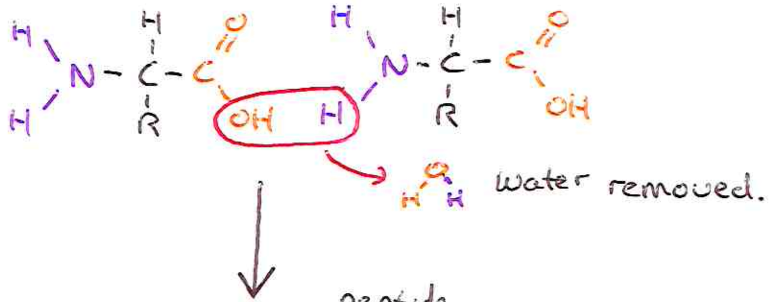
The basic structure of an amino acid is;

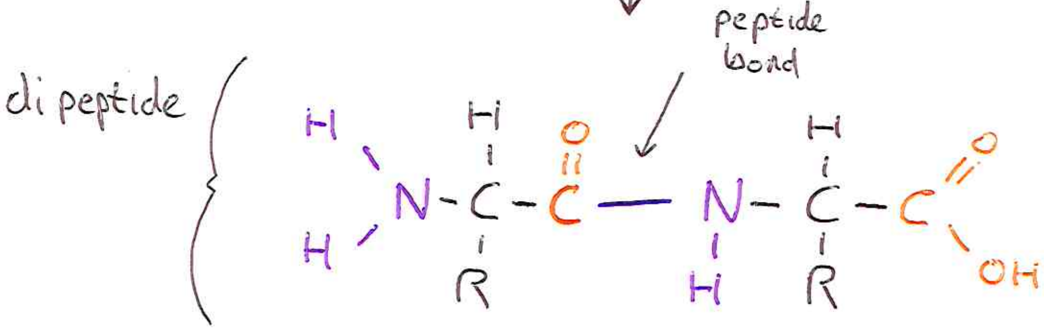


All amino acids share this structure. Only the R group is different. The R group is what gives different amino acids different properties and determines which amino acids will bond together when the tertiary structure forms.

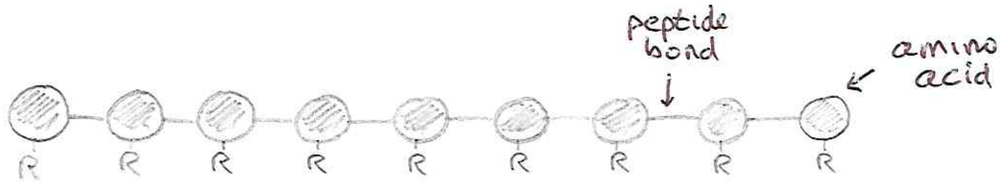
It is important that you can recognise an amino acid but you will not be expected to draw the structure or learn any of the R groups. The simplest amino acid is glycine, its R group is just a Hydrogen. The amino acid **cysteine** is worth remembering; its R group contains Sulphur (S). when 2 cysteines come together their groups can form a strong disulphide bond.

Peptide Bond formation:

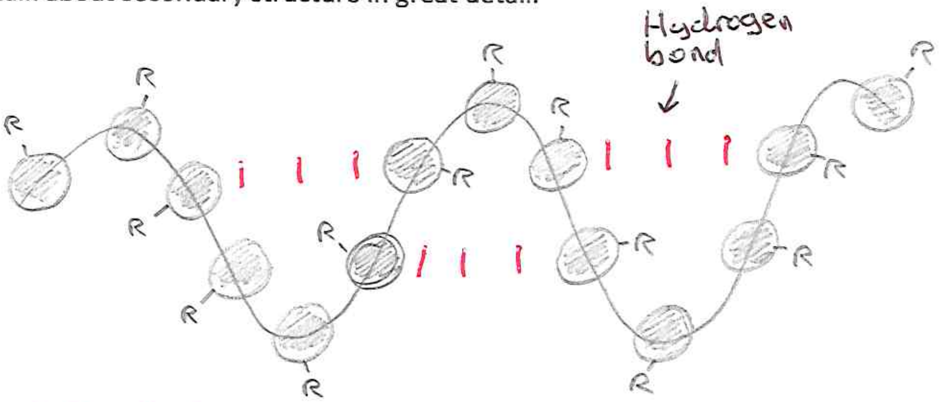




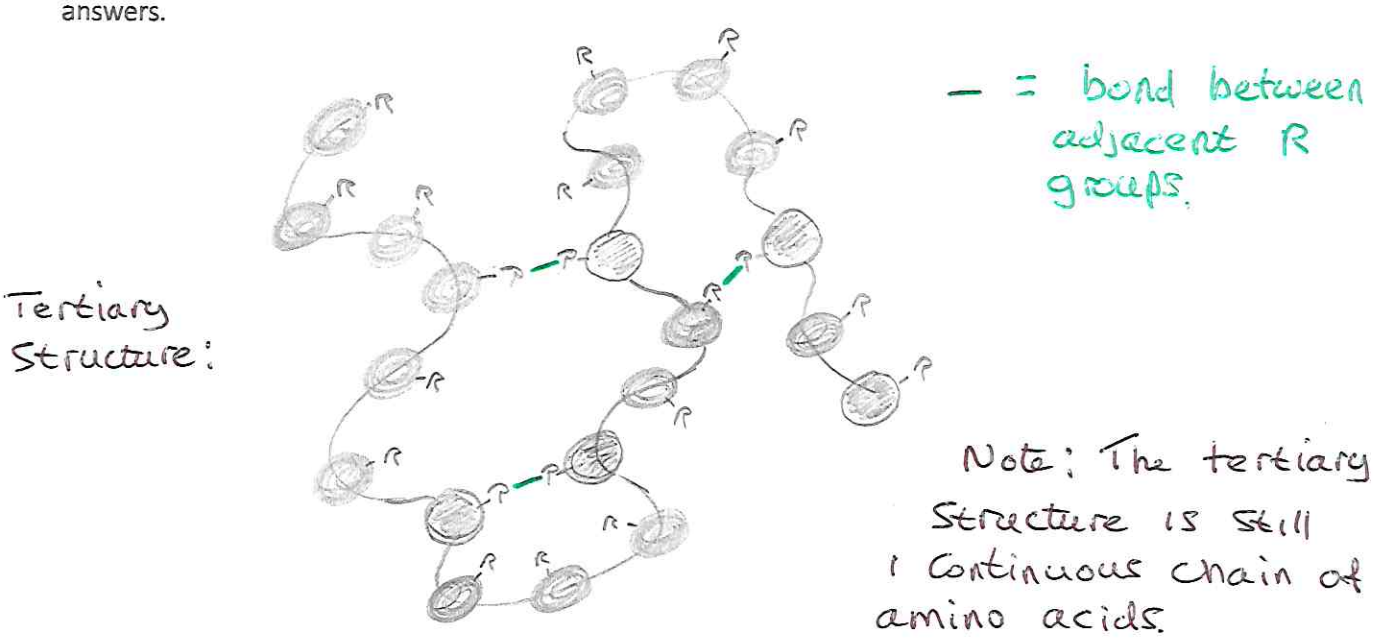
The primary structure is just a specific sequence of amino acids joined together by peptide bonds:



In the secondary structure the chain of amino acids coils up (eg into an α-helix). The secondary structure is held together by Hydrogen bonds and does not involve the R groups. You will not have to talk about secondary structure in great detail.

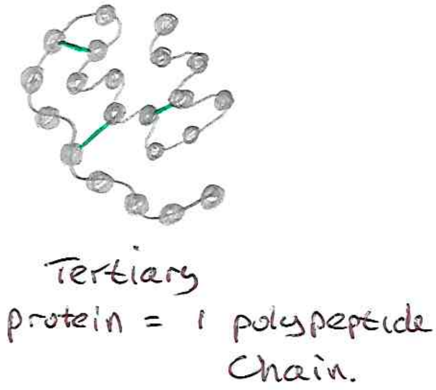


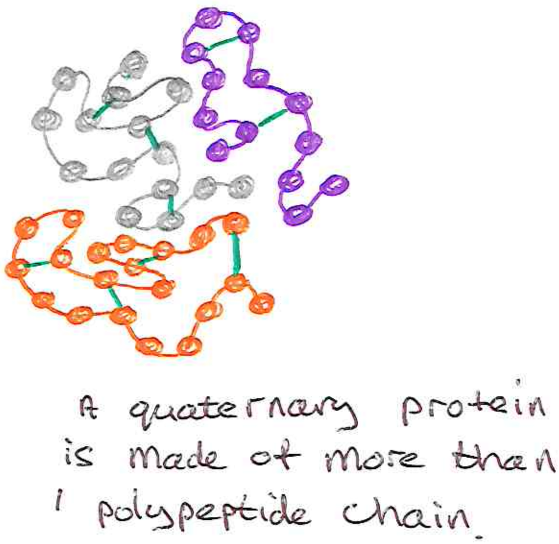
In the tertiary structure the secondary chain folds up into a 3-D shape. Different R groups (that may be nowhere near each other in the primary and secondary structures) are brought together and from bonds; Ionic, Hydrogen and Disulphide bonds are there ones you should talk about in exam answers.



It is important that amino acids are joined together in the correct order when building the primary structure. Otherwise the wrong R groups will come into contact in the tertiary structure and different bonds will form. The protein will have an incorrect shape; eg if it is an enzyme it may no longer be complementary to the substrate.

Quaternary proteins have more than one polypeptide chain, they should be easy to recognise in exam-paper diagrams. They can also contain non-protein elements known as prosthetic groups. For example haemoglobin has haem groups containing Iron.





Fibrous and Globular Proteins

Fibrous proteins tend to be insoluble and made from a limited number of different amino acids repeated over and over. They form long chains which bond together to give the protein strength. Examples of fibrous proteins are collagen (tendons) and keratin (hair).

Globular proteins are water soluble and (very) roughly spherical in shape. They have a wide variety of metabolic functions. For example all enzymes are globular proteins, as are antibodies and transport proteins.

Lipids

Key Points

You need to be familiar with 2 main types of lipid; Triglycerides and Phospholipids.

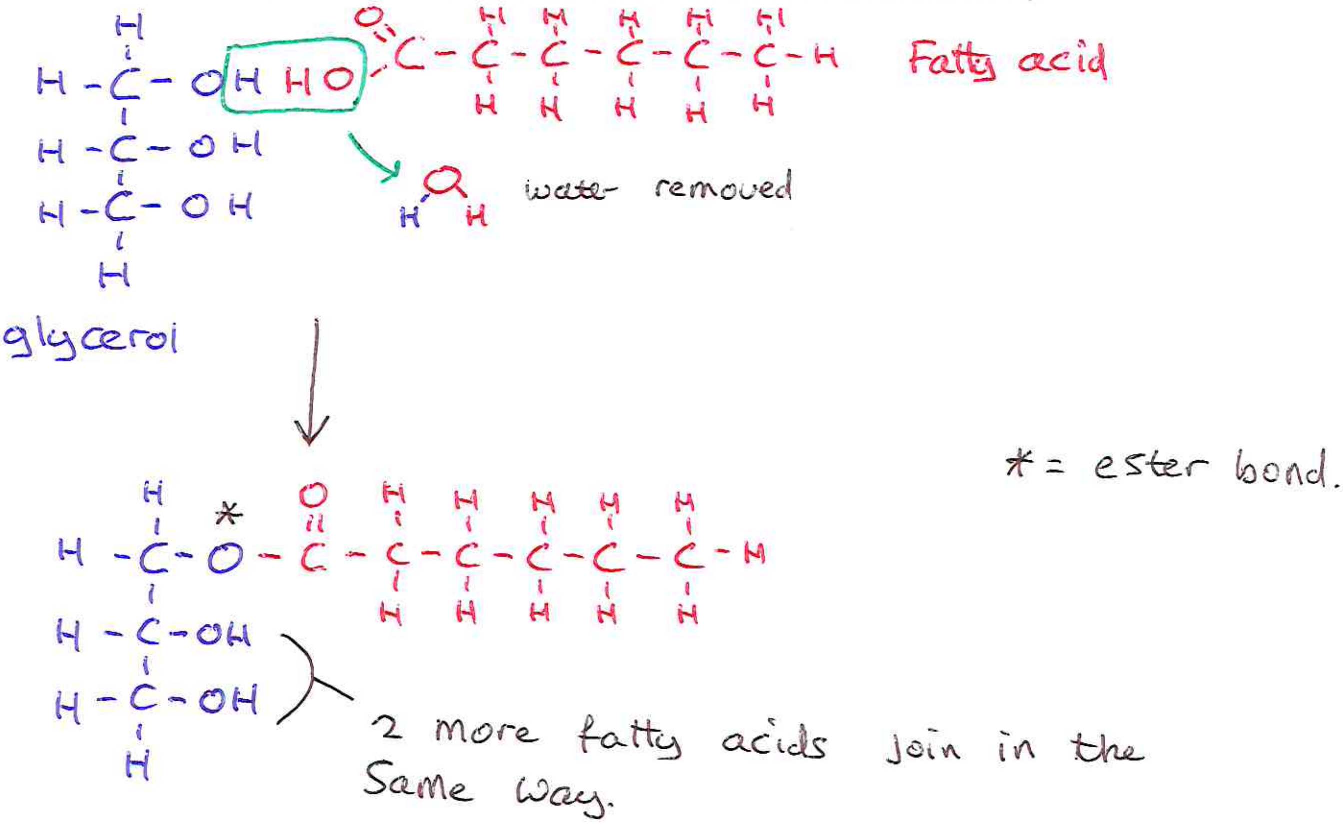
Triglycerides are used for energy storage, insulation, water proofing and protection. They are formed from a glycerol molecule joined to 3 fatty acids by ester bonds (a condensation reaction).

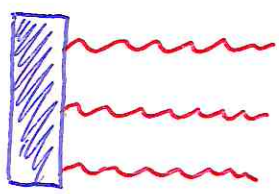
Phospholipids are made from a glycerol joined to 2 fatty acids and a phosphate. They bare the basis of cell membranes.

Fatty acids can be saturated or unsaturated depending on how the Carbon atoms are bonded together.

The food test for lipids is the emulsion test. Shake the sample with ethanol (to dissolve any lipid) and place into water. If the sample contains lipid the water will turn milky-white.

Triglycerides:
(note; the acid part of the fatty acid is the same as the acid part of an amino acid).

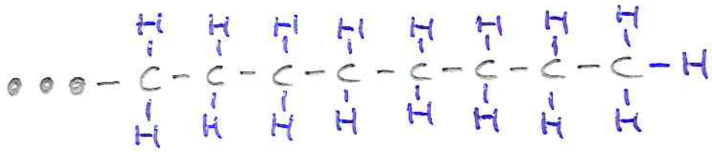




glycerol + 3x fatty acids = Triglyceride.

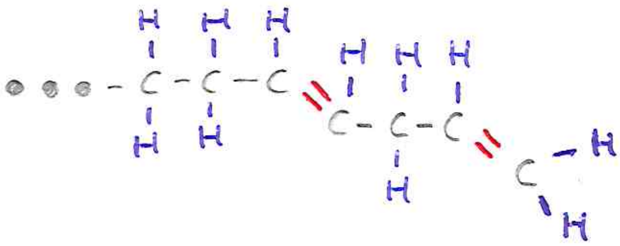
Saturated and Unsaturated fatty acids:

Carbon always has to make 4 bonds. In a saturated fat all the bonds between carbons are single.



No more Hydrogens can be added – therefore the molecule is saturated.

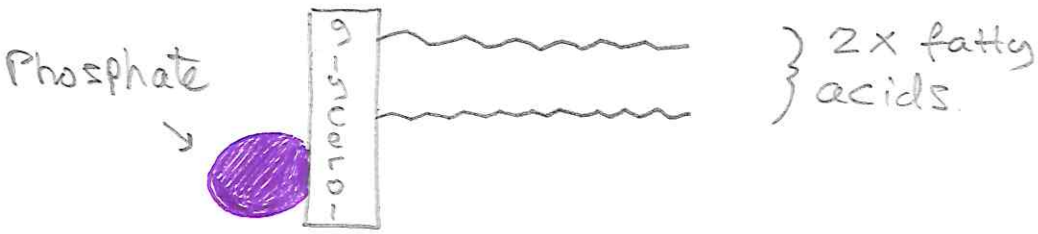
An unsaturated fat contains at least 1 double bond between the carbons.



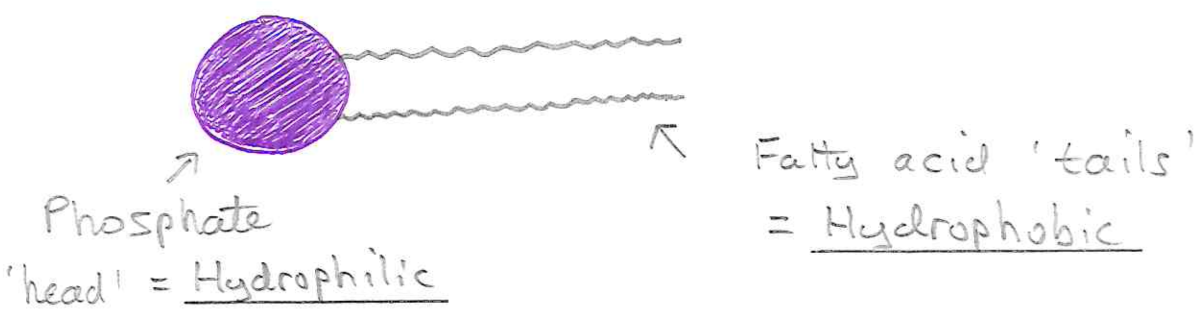
The 2 Carbons linked by a double bond are still making 4 bonds each but now there are fewer Hydrogens on the chain and it is said to be unsaturated. When describing fats as saturated or unsaturated in exam questions, always talk about the bonds between the Carbon atoms. Saturated fatty acids tend to be straighter chains than unsaturated ones. This means that saturated fats can pack together better to form solids (eg butter, lard). Unsaturated fats do not pack together as well because the double bond causes the chain to kink (bend). Unsaturated fats tend to be oils at room temperature.

Phospholipid

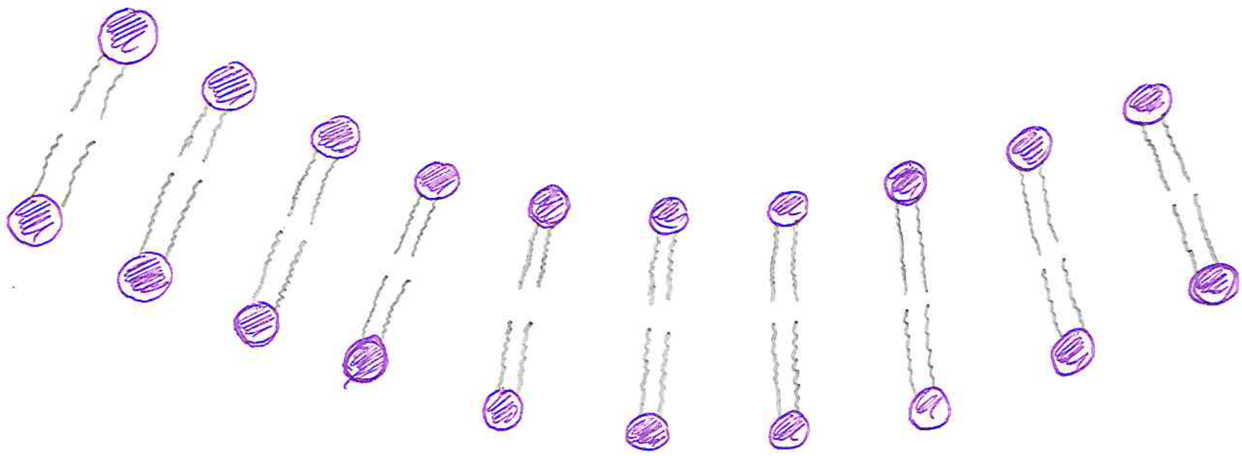
A phospholipid is different to a triglyceride in that it has 1 glycerol, 2 fatty acids and a phosphate in place of the third fatty acid. A phosphate consists of a Phosphorous atom joined to Oxygen atoms.



The phospholipid is often drawn to ignore the glycerol, resembling a tadpole with 2 tails;



The phosphate head part is hydrophilic or 'water loving' while the fatty acid tails are hydrophobic or 'frightened of water'. When phospholipids are put into water they form a bilayer. You can think of this like a football with the inside and outside surfaces made of phosphate heads. The fatty acid tails are hidden away in the middle and cannot be seen unless you slice through the football.



Biological Molecules Summary

Every time smaller molecules join together to form a larger one it is a condensation reaction (water is removed).

Every time larger molecules are split into smaller ones it is a hydrolysis reaction (water is added).

It is very unlikely that you will be asked to draw molecules from scratch but make sure you can recognise glycosidic, ester and peptide bonds.

Make sure you can indicate on a diagram which atoms are removed when glucoses, amino acids or glycerol + fatty acids join together.

Make sure you can alter a diagram of disaccharides, dipeptides or triglycerides to show how the molecules separate when hydrolysis happens.

Make sure you learn the food tests and the colour changes that happen when a result is positive.