Natural Polymers

Natural macromolecules

Large molecules in food

- We need food to give us energy and to keep making new cells in our body
- The main classes of food molecules that give us energy are carbohydrates and fats
- Proteins are needed for growth and other essential functions
- Proteins and some carbohydrates such as starch are macromolecules
- Fats are large molecules which usually contain three ester linkages

The structure of proteins

- Proteins have the same amide linkage as nylon
- But instead of being made from two different monomers, proteins are made up from twenty
- These monomer are amino acids
- All amino acids gave the amine $(-NH_2)$ and carboxylic acid $(-COOH)$ groups in common
- The side chains in each of the 20 amino acids are different
- When proteins are made, an amide link is formed by the reaction of the amine group of one amino acids with the carboxylic acid group of the next amino acid
- This is an example of a condensation reaction
- Water is eliminated
- The order of the amino acids in the protein do not follow any regular pattern

From proteins to amino acids

- Proteins in our food are broken down to amino acids with the help of hydrochloric acid in the stomach
- Enzymes catalyze this reaction
- In the laboratory we can break down proteins to amino acids by heating them with hydrochloric acid

$$protein + water \longrightarrow amino\ acids$$

- We call this a hydrolysis reaction
- In a hydrolysis reaction, a compound reacts with water and breaks down to form two or more products
- We often use acid or alkali to help the hydrolysis
- If we use acid we call the reaction 'acid hydrolysis'
- When proteins are hydrolyzed, the amide linkages are converted to carboxylic acid and amine functional groups- the reverse of the polymerization reaction
- You can use paper chromatography to identify the amino acids formed by the hydrolysis of a protein

Fats and soaps

The structure of fats

- Animal fats and vegetable oils form part of our diets
- Oils are liquid fats

- Oils and fats have similar structures-they are both esters
- Esters are formed by reacting carboxylic acids with alcohols
- We make fats and oils in a similar way, although in our bodies, the reactions are complex
- The alcohol we use to make fats in glycerol
- The carboxylic acids we use have long hydrocarbon chains
- We can simplify their structure by writing them ^^^^^^^^^COOH, where ^^^^^^^^^^ is the alkyl group
- We often call these long-chained carboxylic acids fatty acids
- When we react glycerol with fatty acids, an ester linkage is formed
- In fats and oils, the ester linkage is the same as in Terylene
- But the units making up the fat are different
- A long chain is not formed in Terylene, fats are not polymers
- Three ester linkages are usually formed when a fat or oil molecule is made
- This is a condensation reaction because two molecules have reacted to form a larger molecules, and a small molecule, water has been eliminated

Making soaps

- we can hydrolyze fats and oils in a similar way to proteins- by using an acid
- When we hydrolyze an ester with an acid, the reaction does not go to completion
- This is because an equilibrium mixture is formed
- So we hydrolyze fats with concentrated sodium hydroxide solution
- We call this alkaline hydrolysis
- When fats or oils are hydrolyzed using alkaline hydrolysis, a soap and glycerol are formed

$$fat\ (or\ oil) + sodium\ hydroxide \rightarrow soap + glycerol$$

- A soap is the sodium salt of a fatty acid. The type of soap formed depends on the fat or oil used

Carbohydrates

- Carbohydrate literally means carbon and water
- So the empirical formula for a carbohydrate is: $C_x(H_2O)_y$
- But even simple carbohydrates are quite complex molecules
- We can simplify the structure of glucose to show only those groups which react to form glucose polymers
- We give the name monosaccharides to simple sugars such as glucose: mono means 'one' and saccharide means sugar
- We can join monosaccharide monomers together to make polymers called polysaccharides
- You can see that this is a condensation polymerization
- The monosaccharide monomers have joined together and the water has been eliminated
- The linkage in these sugar polymers is called a glyosidic linkage
- The general formula for a polysaccharide made from glucose is $(C_6H_{10}O_5)_n$- glucose with water removed
- Two common sugar polymers found in plants are starch and cellulose:
    - Starch is found in rice, pasta and potatoes. It provides us with most of the carbohydrate in our diet. Starch is made of glucose monomers arranged either in long chains or branched chains

- Cellulose is found in the cell walls of plants. It is also a polymer of glucose. But the glucose molecules are arranged in a different way

<u>The hydrolysis of carbohydrates</u>

- When we heat polysaccharides with hydrochloric acid they are hydrolyzed to simple sugars
- When starch is hydrolyzed the glyosidic linkages break and simple sugars are formed
- The hydrochloric acid acts as a catalyst in the reaction
- In our bodies, starch is hydrolyzed to glucose using different enzymes

<u>Identifying hydrolysis products</u>

- The simple sugars formed by the hydrolysis of polysaccharides can be identified using paper chromatography
- Because sugars are colorless, we have to use a locating agent so they show up on a chromatogram
- We spray the chromatogram with a mixture of tin (II) chloride and a chemical called N-phenylenediamine
- We then warm the chromatogram in an oven to develop the color
- You cannot always identify a sugar or an amino acid from a chromatogram by simple chromatography
- This is because some compounds have the same or similar Rf values
- We overcome this by using two-dimensional chromatography:
- We carry out the chromatography as usual
- We allow the paper to dry hen turn it around 90° and carry out chromatography using a different solvent
- Only then do we spray the chromatogram with a locating agent

<u>Fermentation</u>

- Nearly all chemical reactions in living things are catalyzed by enzymes
- Enzymes are particular types of protein that act as biological catalysts
- But unlike inorganic catalysts they are very sensitive to changes in temperature
- They work best between 30°C and 40°C
- If the temperature is too low they work more slowly
- If the temperature is too high they lose their structure and don't work
- We say they are denatured
- Most enzymes will not work above a temperature of about 50°C
- Bacteria and yeast produce enzymes that catalyze fermentation reaction in organic materials
- Fermentation us the breakdown of organic material with effervescence and release of heat
- For thousands of years, ethanol has been made by fermentation
- Ethanol is an excellent solvent and a good fuel, as well as being an important starting point for making other chemicals

<u>Fermentation of glucose</u>

- A wide range of vegetable material can be fermented
- The most commonly used substances for making ethanol are sugars and starch

- The bacteria and yeast that cause fermentation are found on the surface of many plants, as well as in air
- When we carry fermentation to produce ethanol, we use a particular form of yeast so that unwanted reactions do not occur
- The fermentation of glucose produces ethanol and carbon dioxide
- The reaction tales place in the absence of air- it is anaerobic
- The reaction will occur until about 14% ethanol is present in the mixture
- If the ethanol concentrations gets much higher than this the yeast will die
- The ethanol is separated from the reaction mixture by fractional distillation

<u>Comparing methods</u>

<u>Ethanol from fermentation</u>	<u>Ethanol from ethene and steam</u>
Simple method	More complex method
Needs a lot of very large tanks	Needs smaller-scale equipment to produce the same amount of ethanol
Uses a batch process: you have to start again from the beginning once you have removed the solution in the tank	A continuous process: the ethanol is removed continuously and the ethene and steam are fed into the apparatus continuously
Rate of reaction slow	Rate of reaction fast
Ethanol needs further purification by distillation	Produces ethanol of high purity
Uses renewable resources	The ethene is made from a non-renewable resource- petroleum

<u>Ethanol as a fuel</u>

- Ethanol can be made by fermentation using a variety of plant sources
- Sugar cane waste is fermented to ethanol for use as a fuel for cars
- It is either mixed with petrol to form a fuel called a gasohol or used by itself
- Ethanol is a cheaper fuel than petrol- it does not produce as much pollution
- The ethanol made by fermentation comes from a renewable resource
- It is potentially ‘carbon neutral’: the carbon dioxide released into the atmosphere by burning the ethanol is balanced by the carbon dioxide absorbed from the atmosphere by sugar cane during photosynthesis