Recap

We learnt about common examples of monosaccharides and polysaccharides that are used in plants and animals. This included looking at the functions of starch and cellulose in plants, as well as glycogen in animals.

1.3 Lipids

Lipids

- **Lipids (fats) have a variety of functions**. They are involved in various biological processes ranging from providing structure to a cell, to metabolism, to even playing a role in animal immune systems. Therefore, understanding the biochemistry of lipids is very important for understanding later topics in biology.

- **Lipids are organic molecules**. Therefore they contain large amounts of carbon and hydrogen within their chemical structures.

- **Lipids contain fatty acids with hydrocarbon chains**. Lipids contain fatty acids, which consist. Hydrocarbon chains are extremely long networks of carbons and hydrogens covalently bonded to each other.

AQA Specification

Triglycerides and phospholipids are two groups of lipids.

In biology, as well as for your exams, we are concerned primarily with two major classes of lipids: **triglycerides** and **phospholipids**.

Structure of Triglycerides

- **Triglycerides consist of 1 glycerol and 3 fatty acids.** Triglycerides are a special class of lipids which consist of one molecule of **glycerol** which is covalently bonded to three molecules of **fatty acids**.

AQA Specification

Triglycerides are made by condensation of a glycerol and three fatty acid molecules.

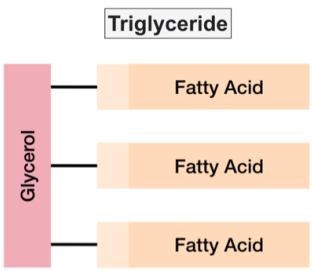

Fig 1. The Structure of a Triglyceride.

Glycerol

- **Glycerol is an alcohol.** Glycerol is a type of organic molecule referred to as an alcohol because of the presence of **hydroxyl (OH) groups** in its structure.

Fatty Acids

- **Fatty acids contain a carboxyl group and a hydrocarbon tail.** The fatty acid hydrocarbon tail (Figure 2) can be of variable length. Fatty acids are highly hydrophobic and insoluble in water.

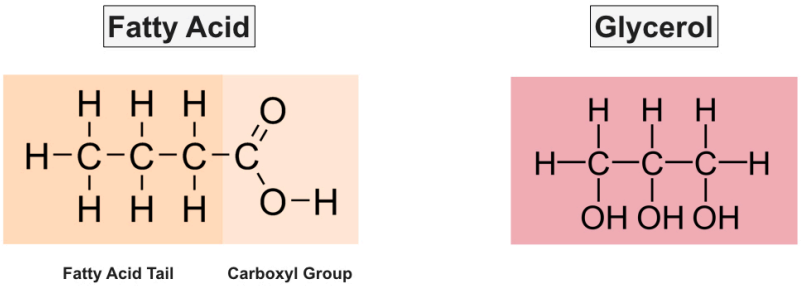

Fig 2. The Structure of a Fatty Acid Molecule (Butanoic Acid) and the Structure of a Glycerol Molecule.

AQA Specification

The R-group of a fatty acid may be saturated or unsaturated. Recognise, from diagrams, saturated and unsaturated fatty acids.

The **R-group** of a fatty acid can be saturated or unsaturated:

- **Saturated** fatty acids have **no double bonds** between carbons. They are hydrocarbons in which all the carbons are bonded to each other via a single bond. There is the maximum number of hydrogens for a given number of carbons.

- **Unsaturated** fatty have **at least one double bond** between carbons. They are hydrocarbons in which one or more carbons are bonded to each other through either double or triple bonds, or a combination of both, in addition to single bonds.

AQA Specification

A condensation reaction of glycerol and a fatty acid (RCOOH) forms an ester bond.

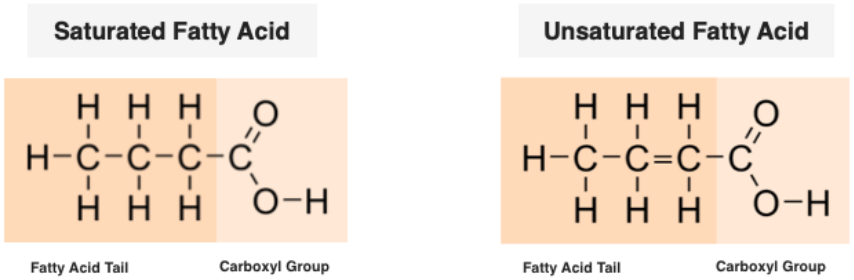

Fig 3. Structure of a Saturated Fatty Acid and an Unsaturated Fatty Acid.

- **Triglycerides are formed via a condensation reaction between** one molecule of glycerol and three molecules of fatty acids.
- **An ester bond is formed.** It is important to remember that the glycerol is bonded to each fatty acid chain by a "carbon-oxygen-carbon" or "**C-O-C**" bond. This bond is known as an **ester bond**.
- **Triglycerides can be broken down via hydrolysis.** As with everything else we have learned so far, a triglyceride can be broken down into one glycerol and three fatty acids through hydrolysis.

Knowledge Recall

1. *What are triglycerides made from?*
2. *Define an unsaturated fatty acid?*
3. *What is the name of the bond framed between glycerol and each fatty acid?*

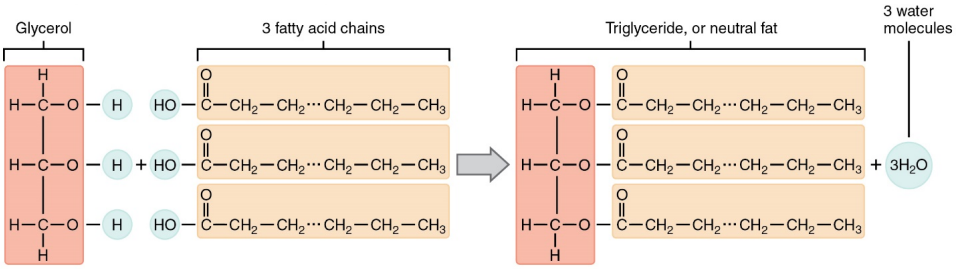

Fig 4. A Condensation Reaction Forming a Triglyceride. Note that three water molecules are released because in effect three condensation reactions are occurring using the three fatty acids.

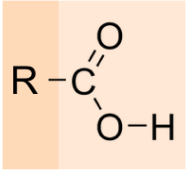

Fig 5. The General Structural Formula For a Triglyceride. The R group denotes the hydrocarbon chain.

Study Mind Tip

If you draw a fatty acid in the exam, you can just use the letter 'R' to denote the fatty acid hydrocarbon chain, which can be of variable length.

Structure of Phospholipids

The second major class of biologically relevant lipids that you should familiarise yourself with are **phospholipids**.

- **Phospholipids have one glycerol, two fatty acids and a phosphate group**. These lipids are very similar to triglycerides in that they have one molecule of glycerol and two molecules of fatty acids connected to the glycerol via ester bonds. However, the third fatty acid chain is replaced by what is called a phosphate group which is covalently bonded to the glycerol.

- **One of the fatty acid chains is unsaturated**. Furthermore, one of the fatty acid chains is saturated, whereas the second fatty acid chain is unsaturated.

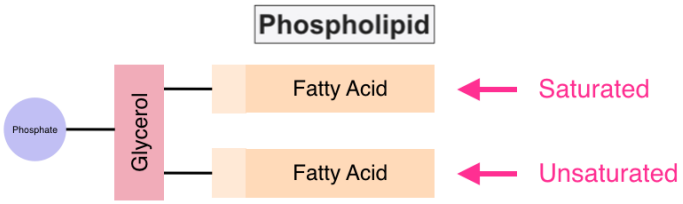

Fig 6. General Structure of a Phospholipid. A phospholipid has a similar structure to triglyceride, but with only 2 fatty acids and a phosphate in addition.

AQA Specification

In phospholipids, one of the fatty acids of a triglyceride is substituted by a phosphate-containing group.

- **Phospholipids are amphipathic.** This means that they have both hydrophobic (repelled from water) and hydrophilic (attracted to water) regions. The **fatty acid chains** on a phospholipid are **hydrophobic tails**, and the **phosphate group** is referred to as the **hydrophilic head**.

- **The phosphate groups can have extensions**. The phosphate groups of different phospholipids can have additional structures attached to them, which give unique properties to unique phospholipids. To illustrate this diversity in chemical structures, we simply designate this with an "R" connected to the phosphate and call this a variable "R" group.

AQA Specification

Understand that the different properties of triglycerides and phospholipids related to their different structures. Be able to explain these properties.

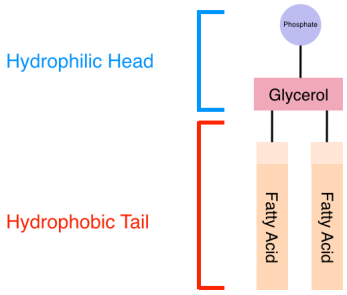

Fig 7. General Structure of a Phospholipid Molecule. Note the hydrophobic head and hydrophilic tail.

Functions of Triglycerides and Phospholipids

Triglycerides

- **Used as energy storage molecules**. Triglycerides are primarily used as energy storage molecules. During metabolic processes, such as respiration, the fatty acid chains of triglycerides can be broken down, in order to release very large amounts of stored chemical energy.

- **Triglycerides are adapted to energy storage**.

  - **Long hydrocarbon chains**. The presence of long hydrocarbon chains in the fatty acids allows for a lot of chemical energy to be stored in them.

  - **Insoluble**. The hydrophobic fatty acid chains arrange themselves to 'hide away' from water (Figure 8). Therefore triglycerides don't affect the osmotic potential of cells, and do not cause swelling due to influx of water.

Knowledge Recall

1. *What is the main function of triglycerides in humans?*
2. *How are triglycerides adapted to energy storage?*
3. *What does amphipathic mean?*

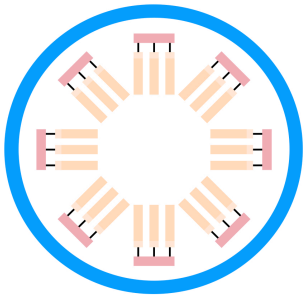

Fig 8. The arrangement of triglyceride molecules. The long fatty acid tails (in beige) face inwards, with the glycerol (in pink) pointing out.

Knowledge Recall

1. *What does an "R" in a molecular structure denote?*
2. *Where can phospholipids be found in the body?*
3. *How many fatty acid molecules does one phospholipid molecule contain?*

- **Triglycerides are the main food store in humans**. Triglycerides are so efficient at storing energy that triglycerides are able to store nearly twice as much energy as carbohydrates. Because of this, our bodily readily consumes carbohydrates and simple sugars for rapid energy boosts, and stores most of our consumed food in the form of fat.

Phospholipids

- **Phospholipids are found in cell membranes.** Phospholipids are the core component of most cell membranes of most organisms. Because cell membranes are the organelle which give structure to a cell, as well as control what goes in and out of cells, it can be argued that phospholipids are one of the most important biological molecules

- **Their amphipathic property is crucial.** Remember, the fatty acid chains are hydrophobic tails and the phosphate group, along with the glycerol component, make up the hydrophilic heads.

- **The hydrophilic heads point outwards in cell membranes.** How do phospholipids form cell membranes? When phospholipids are added to water, their hydrophilic heads face outwards, and their hydrophobic tails face inwards, forming a near circular barrier that has an internal space. This occurs spontaneously.

Knowledge Recall

1. *What do phospholipids arrange themselves into in the presence of water?*
2. *What makes up the hydrophobic component of a phospholipid?*
3. *What makes up the hydrophilic component of a phospholipid?*

- **A phospholipid bilayer is formed.** The barrier formed is known as the phospholipid bilayer, which is another name for a **cell membrane**. The middle of the barrier is **hydrophobic**, so aqueous (water-soluble) molecules cannot simply diffuse through (like they can through the cell wall) - they need to move via an ion channel.

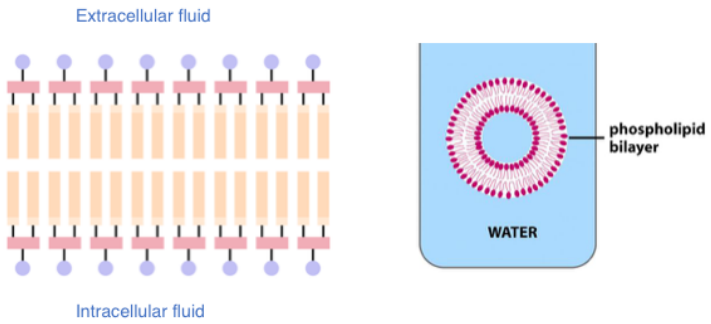

Fig 9. Phospholipid Bilayer. Diagram shows the formation of the phospholipid bilayer in water.

AQA Specification

The Emulsion Test for lipids.

Emulsion Test: Lipids

In the previous chapter (1.2 Carbohydrates) we studied the Benedict's Test for reducing and non-reducing sugars, and the Iodine Test for starch. Now we will consider the Emulsion Test for lipids.

1. **Add ethanol and shake**. Add ethanol to the sample, and vigorously shake for one minute.

2. **Pour the solution into water**. Next, pour the entire solution into a test tube containing water.

3. **Check for formation of a milky white emulsion.** Because lipids are insoluble in water, they will become immiscible, meaning they will not mix with the water. As a result, any lipids present in your sample will float to the top and form a milky white emulsion. The greater the concentration of lipids in your sample, the more apparent the milky colour will become.

Knowledge Recall

1. *Describe what is formed as a result of a positive test for lipids?*
2. *Why does this occur?*
3. *What does immiscible mean?*

Fig 10. Test Tube Showing a Positive Emulsion Test for Lipids.