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Teacher view



(https://intercom.help/kognity)



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B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

The big picture

? Guiding question(s)

- In what ways do variations in form allow diversity of function in carbohydrates and lipids?
- How do carbohydrates and lipids compare as energy storage compounds?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.



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Figure 1. The brain sends and receives about 100 trillion signals a day.

Credit: libre de droit, Getty Images (<https://www.gettyimages.com/detail/illustration/human-brain-activity-with-plexus-lines-royalty-free-illustration/1153710302>)

The brain is the only carbohydrate-dependent organ in the body. The brain exclusively uses glucose, a basic simple sugar carbohydrate, to function. As your brain cells need twice the energy of any other cells in your body, your body makes sure that it receives the required amount of glucose for you to function. Without this glucose, your brain would not be able to coordinate and respond to any changes in your environment (**Figure 1**). You would not be able to make decisions on what to eat, what to study, whom to talk to and the list goes on! Indeed, this simple glucose molecule is essential to your being.

But how does your body keep this supply of glucose to your brain constant? How does your brain continue to work even though you have not had breakfast yet?

The diversity of functions in living organisms arises from the unique combinations of molecular structures and the interactions between them. In this subtopic and in [subtopic B1.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/\)](https://study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/), you will begin to explore the wonder of molecular biology and the special processes that occur to make sure that you always have exactly what you need to function. By the end of this subtopic, you will gain a deeper appreciation for the intricate details of the molecules that we are composed of and sustain us.






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Prior learning

Before you study this subtopic make sure that you understand the following:

- Structure of a water molecule (see [subtopic A1.1](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43193/) )
- Nucleotide structure (see [subtopic A1.2](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/) )
- Structure of the plasma membrane (see [subtopic B2.2](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43532/) )

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Chemical bonding and polymerisation

B1.1.1: Chemical properties of the carbon atom B1.1.2: Production of macromolecules by condensation reactions

B1.1.3: Digestion of polymers by hydrolysis reactions

Learning outcomes

By the end of this section you should be able to:

- Describe the nature of a covalent bond and that a carbon atom can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements.
- Explain how macromolecules, such as polysaccharides, are formed by condensation reactions that link monomers to form a polymer.
- Explain that water molecules are split to provide the —H and —OH groups that are incorporated to produce monomers in a hydrolysis reaction.



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Before you embark on your journey to understand how the properties of molecules are essential to their function, you must first gain appreciation for the carbon atom. In this section, you will explore how the carbon atom is an essential component of these molecules. You will also learn about how molecules can be synthesised or broken down based on what your body needs.

Carbon and the covalent bond

Carbon compounds are commonly referred to as the building blocks of life (**Figure 1**). They are found in molecules that are essential to an organism's survival, such as carbohydrates, lipids, proteins and nucleic acids. What is it about carbon that makes it so special? Let's explore.

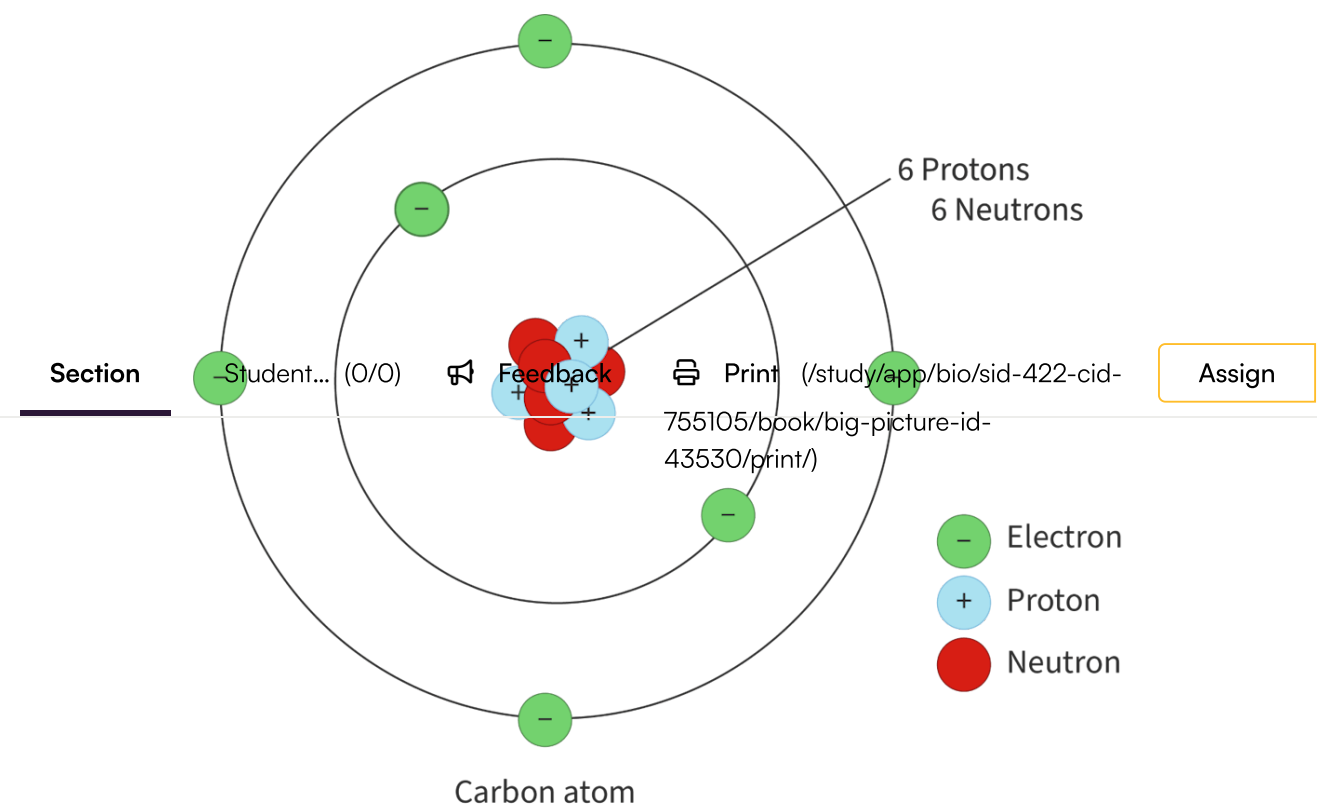


Figure 1. Diagram of a carbon atom.

More information for figure 1

This diagram illustrates the structure of a carbon atom. At the center is the nucleus, which contains 6 protons and 6 neutrons. The protons are depicted as light blue circles with a positive sign, while the neutrons are shown as red circles with no sign. Surrounding the nucleus are two electron shells. The



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electrons are represented by green circles with a negative sign. The first shell holds two electrons, and the second shell holds four electrons, completing the depiction of the carbon atom. Labels identify the electrons, protons, and neutrons, as well as the overall structure being a carbon atom.

[Generated by AI]

Carbon atoms can form four covalent bonds allowing a variety of stable compounds to exist (**Figure 2**). A covalent bond is a type of bond in which electrons are shared between two neighbouring atoms. The covalent bond is considered to be a stable bond and therefore, its presence gives stability to molecules. In addition, the fact that carbon can bind to four different atoms allows for formation of an array of diverse molecules in which carbon plays an important part.

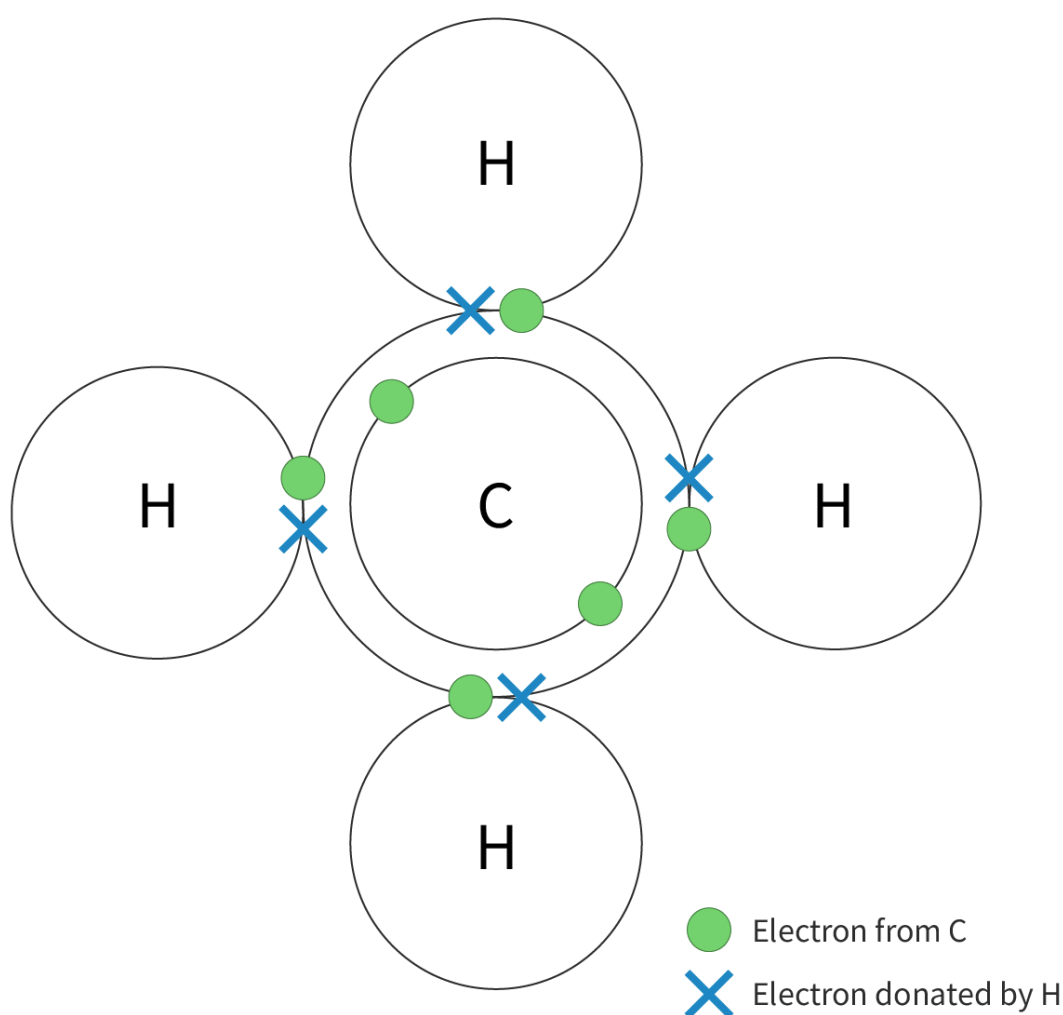


Figure 2. Carbon atoms form four covalent bonds.



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More information for figure 2

The diagram illustrates a carbon atom, represented by a central circle labeled 'C', forming covalent bonds with four hydrogen atoms, each represented by circles labeled 'H'. Lines connect the carbon atom to each hydrogen atom, indicating the shared electrons that constitute the covalent bonds. Green dots near the lines represent electrons from the carbon atom, while blue crosses represent electrons donated by the hydrogen atoms. This configuration demonstrates carbon's ability to form stable compounds by sharing electrons and forming covalent bonds with other atoms.

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Carbon—carbon bonds

Carbon—carbon bonds specifically are strong and stable; therefore, long-chained carbon compounds provide the basic framework for many molecules. The longer the chain of carbon—carbon bonds, the more stable the molecule, as there are more covalent bonds holding it together. In **Figure 3**, you can see how these carbon—carbon bonds are a distinct feature of a fatty acid. See [section B1.1.8–11 \(/study/app/bio/sid-422-cid-755105/book/properties-and-functions-of-lipids-id-44588/\)](/study/app/bio/sid-422-cid-755105/book/properties-and-functions-of-lipids-id-44588/) to learn more about fatty acids.

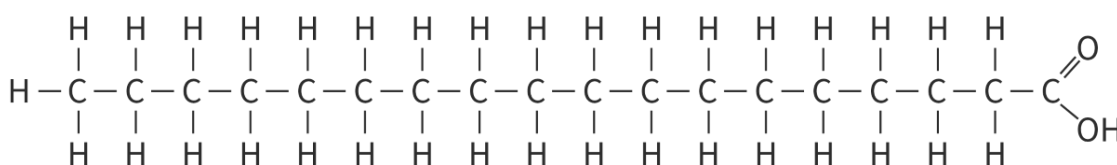


Figure 3. Fatty acids consist of many carbon atoms covalently linked together. Having many carbon atoms linked together provides stability for the fatty acid molecule.

More information for figure 3

The image is a diagram depicting the chemical structure of a fatty acid. It illustrates a long chain of carbon atoms (C) linked covalently, with hydrogen atoms (H) attached to them. The chain is linear and demonstrates a saturated fatty acid where all carbon atoms are single-bonded. At the end of the chain, there is a carboxyl group consisting of a carbon atom double-bonded to an oxygen atom (O) and single-bonded to a hydroxyl group (OH). This structural representation shows the stability provided by carbon—carbon bonds, typical in fatty acids.



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In addition to being found in chain form, carbons can also form rings and can also form branched structures. An example of carbon in ring form is the molecule glucose (see **Figure 4**), which you will learn more about in the next section.

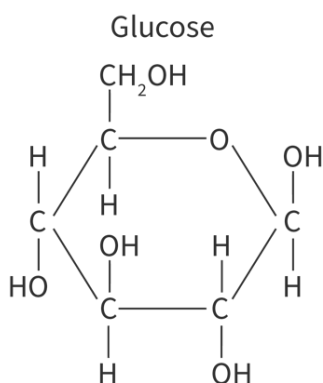


Figure 4. Glucose ($C_6H_{12}O_6$) is an example of carbon atoms joining together in ring form.

More information for figure 4

The image depicts the molecular structure of glucose, a simple sugar. Glucose features a six-carbon ring with the chemical formula $C_6H_{12}O_6$. In the diagram, each corner of the hexagon represents a carbon atom, denoted with the letter 'C'. The structure shows lines connecting carbon atoms, forming a closed ring. Outside the ring, hydroxyl groups (OH) and hydrogen atoms (H) are attached to the carbon atoms. Specifically, the top of the ring is connected to CH_2OH , indicating a carbon bonded to two hydrogen atoms and one hydroxyl group. Other carbon atoms are bonded to hydrogen and hydroxyl groups in varying arrangements, demonstrating how carbon can form multiple bonds with non-metals like oxygen and hydrogen, highlighting the versatility of carbon in organic molecules.

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As you can see from **Figure 4**, carbon binds not only to carbon but also to oxygen and hydrogen. Oxygen and hydrogen along with nitrogen, sulfur and phosphorus, are all examples of non-metallic elements that have the ability to bind with carbon. Carbon can bind to other carbon atoms or to non-metallic elements through either single or double bonds. The ability of carbon to bind to these elements is the basis of the formation of a diverse array of organic molecules such as nucleic acids ([subtopic A1.2 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/\)](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/)) and proteins ([subtopic B1.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/)).

Multiple carbon rings can also join together to form branched structures such as glycogen, which is a polymer of many glucose molecules joined together (**Figure 5**). There is more detail about glycogen in [section B1.1.4–7 \(/study/app/bio/sid-422-cid-755105/book/carbohydrates-id-44751/\)](/study/app/bio/sid-422-cid-755105/book/carbohydrates-id-44751/).

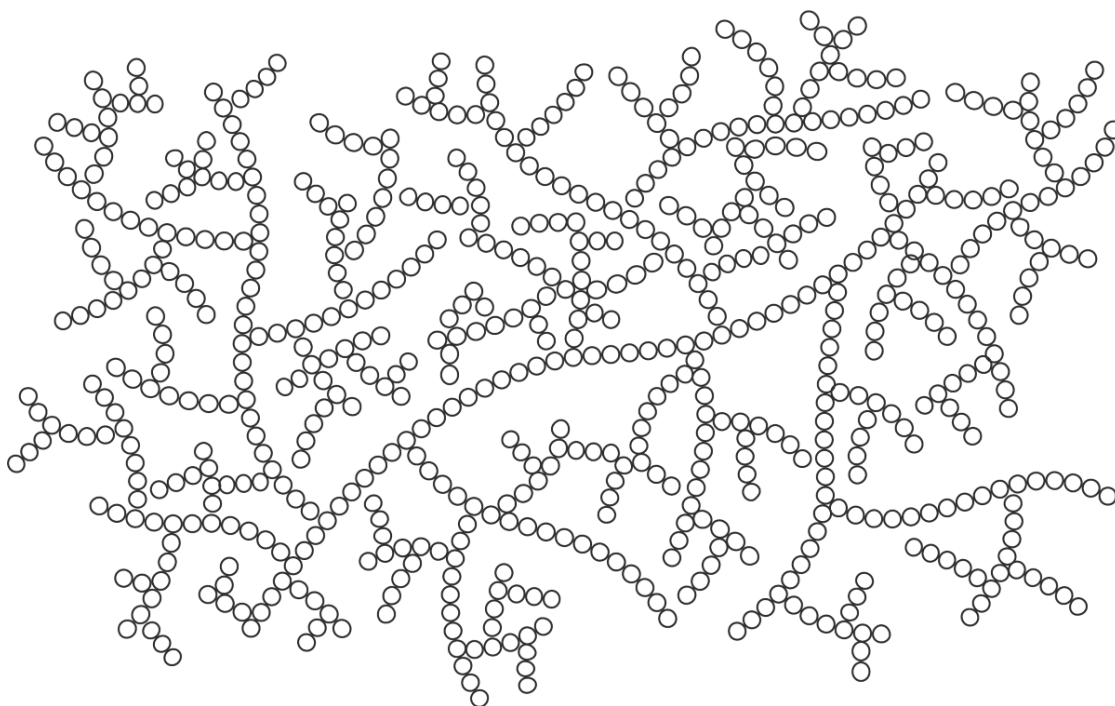


Figure 5. Glycogen is composed of thousands of glucose molecules and shows how carbon atoms can also be found in branched form.

 More information for figure 5

The image is a diagram showing a complex branched structure representing glycogen. It consists of numerous rings or circles that are connected in branching patterns, illustrating how glucose molecules link together to form a polymer. The diagram depicts multiple branches emanating from central glucose



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molecules, showing the way carbon atoms can form these branches. The structure is intricate, reflecting the large number of glucose units involved in forming glycogen.

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Aspect: Measurement

Observation, hypothesis, experimentation and analysis are all important principles in the nature of science. It is a methodological approach to understanding the world around us and relies on internationally recognised conventions that are based on international agreement. The SI metric unit prefixes 'kilo', 'centi', 'milli', 'micro' and 'nano' provide a standardised way to express quantities of measurement. These prefixes are used consistently in scientific research and communication.

By understanding the importance of these conventions, you can better appreciate the precision and rigour that is necessary in scientific inquiry, and you can develop the skills needed to conduct and communicate your own research effectively.

Macromolecules

Macromolecules are large molecules that are made up of smaller building blocks called monomers. Monomers are individual subunits that can be linked together to form longer chains called polymers. There are four main classes of macromolecules:

1. carbohydrates (see section B1.1.4–7 (/study/app/bio/sid-422-cid-755105/book/carbohydrates-id-44751/)))
2. lipids (see section B1.1.8–11 (/study/app/bio/sid-422-cid-755105/book/properties-and-functions-of-lipids-id-44588/)))



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3. proteins (see [subtopic B1.2 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/\)](/study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/))

4. nucleic acids (see [subtopic A1.2 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/\)](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/)).

Each of these macromolecules plays a crucial role in the structure and function of living organisms. Carbohydrates and lipids will be explored later in this subtopic.

Formation by condensation reactions

For macromolecules to be formed, specific monomers must join together by a type of chemical reaction called a condensation reaction. You may already be familiar with how a polymerisation reaction is used to form the sugar–phosphate backbone of DNA (see [subtopic A1.2 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/\)](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43236/)).

A condensation reaction is a polymerisation reaction in which two molecules join together (**Figure 6**). When two molecules join, one molecule loses a hydroxyl group (–OH) and the other loses a hydrogen atom (–H), forming a water molecule and resulting in formation of a new covalent bond. Condensation reactions are responsible for formation of macromolecules.

Glucose molecules join together through condensation polymerisation reactions to form larger carbohydrate molecules. In a condensation reaction between two glucose molecules, the –OH group on carbon 1 of one glucose molecule attaches to the –OH group on carbon 4 of the other glucose molecule. This results in formation of a covalent bond between the two glucose molecules, and the release of a molecule of water. The resulting covalent bond that links glucose molecules together is called a 1,4-glycosidic bond. In a glycosidic bond, an oxygen atom is shared between the two glucose molecules that are joined together. When two glucose molecules join together, they are given the name disaccharide.



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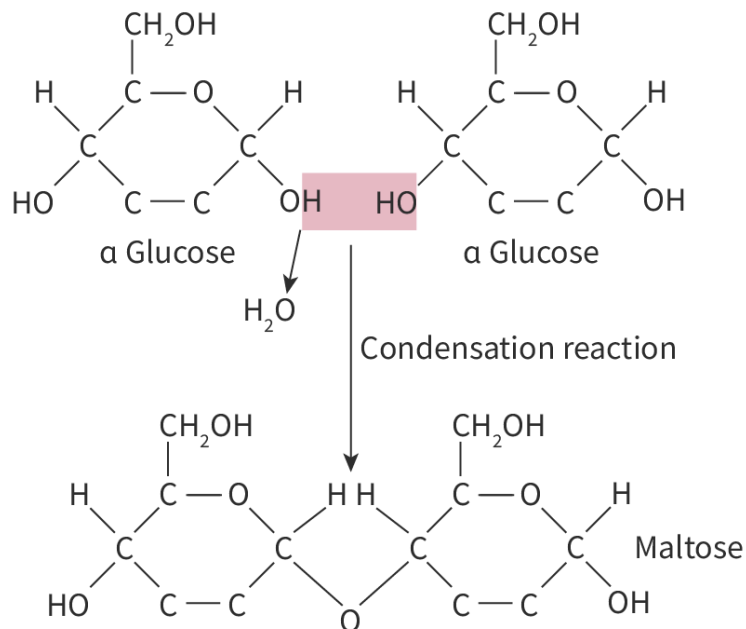


Figure 6. A condensation reaction between two glucose molecules forming the disaccharide, maltose.

More information for figure 6

The diagram illustrates the condensation reaction between two glucose molecules to form a disaccharide, maltose. At the top, two glucose molecules are shown with their molecular structures. Each glucose molecule has a six-membered ring with several hydroxyl groups (-OH). An arrow indicates the -OH group on carbon 1 of the first glucose molecule joining with the -OH group on carbon 4 of the second glucose molecule. This process involves the release of a water molecule, depicted as ' H_2O ' towards the middle of the diagram. Below this, the two glucose molecules are shown forming a covalent link through an oxygen atom, resulting in a 1,4-glycosidic bond. The newly formed structure is labeled as maltose. The overall diagram conveys the chemical changes happening during the condensation reaction, indicating both the structural transformation and the water by-product.

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When more than two glucose molecules join together, the product is called a polysaccharide. Starch and glycogen, which are important for storing glucose in plants and animals, respectively, are examples of polysaccharides. Cellulose, which



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is an important component of the cell wall, is also an example of a polysaccharide.

You will learn more about these important polysaccharides in [section B1.1.4–7](#)
([/study/app/bio/sid-422-cid-755105/book/carbohydrates-id-44751/](#)).

Breakdown by hydrolysis reactions

To stay alive, your body requires a constant supply of nutrients in the form of carbohydrates, fats and other macromolecules. However, these macromolecules are too large to be directly absorbed and used by your cells. Your body must break down these large polymers into their constituent monomers to use them for energy or to build new macromolecules that your body needs. This process of breaking down macromolecules into monomers is called hydrolysis. Hydrolysis is a reverse reaction for the condensation polymerisation reaction.

Hydrolysis is a chemical reaction in which water molecules are used to break the covalent bonds between the monomers that make up a polymer, such as the glycosidic bonds that join together glucose molecules. By doing so, this reaction breaks the larger polymer down into its individual monomers, making them available for biological processes.

For example, when the disaccharide sucrose (table sugar) undergoes hydrolysis, it will be broken down to its constituent monosaccharides, which are glucose and fructose. The –OH group of the water molecule will attach to one of the monosaccharides while the –H will attach to the other monosaccharide, breaking the glycosidic bond that was present in the disaccharide.

Watch **Video 1** to see an animation of how maltose is broken down to glucose by hydrolysis.



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Hydrolysis of Maltose



Video 1. How maltose is broken down to glucose by hydrolysis.

More information for video 1

The video presents a clear and concise animation of the hydrolysis process, focusing specifically on how one molecule of maltose is broken down into two molecules of alpha glucose. It begins with the display of the title "one molecule of maltose..." at the top of the screen, introducing the viewer to the molecular structure of maltose. Maltose is visually represented as two glucose units joined by an oxygen atom, known as a glycosidic bond. Below the structure, the phrase "+ one molecule of water" along with a water molecule (H_2O) below the text appears. The water molecule then moves below the glycosidic bond of the maltose, with a blue arrow in between, indicating the role of the water molecule (H_2O) in the upcoming chemical reaction. This sets the stage for understanding how hydrolysis operates on a molecular level. The animation then proceeds to demonstrate how the water molecule interacts with the glycosidic bond connecting the two glucose monomers. As the water molecule approaches, it is shown splitting into its two components: a hydrogen atom (H) and a hydroxyl group (OH). These components are incorporated into the maltose structure at the precise point where the glycosidic bond is located. The hydrogen attaches to one glucose molecule along with the oxygen molecule of the glycosidic bond, while the hydroxyl group binds to the other. The two monomers in the maltose, move apart, and the covalent bond linking the two glucose molecules is broken, effectively separating the maltose into its monomeric units. This step highlights the key feature of hydrolysis: the use of water to cleave covalent bonds in polymers. Once the hydrolysis is complete, the two resulting alpha glucose molecules are displayed side by side on the screen. Above them, the text "two molecules of alpha glucose..." is shown to emphasize the products of the reaction.



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Both condensation and hydrolysis are reversible processes that can create and break down polymers. These processes are essential for proper functioning of biological systems as they allow for recycling of monomers and synthesis of new polymers as needed for cellular processes.


Try the activity below to explore the 3D structures of different molecules.



Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills — Using search engines and libraries effectively
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual/group activity

MolView is a powerful online tool you can use to visualise and explore the 3D structures of different molecules. MolView allows you to search a database of over 50 000 molecules and view their structures in 3D.

Click on this [MolView](http://molview.org)  (<http://molview.org>) link to begin. Then you can start searching for a molecule of your choosing by keying the name into the search bar. MolView will display the structure and the 3D shape can be rotated and viewed from any angle. Find the Information card for the molecule in the Tools tab, which will have more information on the selected molecule, such as its chemical formula and molecular weight.

Some molecules you might consider exploring are alpha- and beta-glucose, sucrose, glycogen and the nucleotide bases (adenine, cytosine, thymine, guanine).

Here are some questions to help guide the activity:

- Can you use MolView to visualise the 3D structure of glucose? Extend your search to other monosaccharides, disaccharides and polysaccharides you have covered in this subtopic.
- Is it possible to view the nitrogenous bases of nucleotides using MolView?
- Can you manipulate the visualisation of molecules in MolView by zooming in and rotating the 3D structure?



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Once you are done, discuss your experience with your group. Here are some discussion questions for you to think about:

- What can you deduce as some of the advantages of using such software?
- Outline the structures of the molecules that you searched. Did you expect them to look like that?

5 section questions ▾

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Carbohydrates

B1.1.4: Form and function of monosaccharides B1.1.5: Polysaccharides as energy storage compounds

B1.1.6: Structure and function of cellulose B1.1.7: Role of glycoproteins in cell—cell recognition



Learning outcomes

By the end of this section you should be able to:

- Recognise monosaccharides (pentoses and hexoses) and know the properties of glucose (glucose is soluble, stable and can be oxidised).
- Outline the role of polysaccharides as energy storage compounds (i.e. glycogen, starch) and as structural components (i.e. cellulose).
- Explain the role of glycoproteins in cell—cell recognition (e.g. ABO antigens).

Carbohydrates are macromolecules that are essential to life. Section B1.1.1–3 (</study/app/bio/sid-422-cid-755105/book/chemical-bonding-andpolymerisation-id-44681/>) covers how carbohydrates and other macromolecules can be built up by



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condensation and broken down by hydrolysis. These processes are necessary for carbohydrates to be functional in living organisms.

In The big picture (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43530/), we asked you to think about:

- How does your body keep this supply of glucose to your brain constant?
- How does your brain continue to work even though you have not had breakfast yet?

In this section, you will learn about the structure of carbohydrates and how living organisms rely on carbohydrates for a variety of uses.

Form and function of monosaccharides

Introduction to monosaccharides

Monosaccharides are fundamental biological molecules that serve as a source of energy for cells and are involved in various cellular processes. A monosaccharide is the simplest form of a carbohydrate, consisting of a single sugar unit that cannot be broken down into smaller molecules by hydrolysis.

Types of monosaccharides

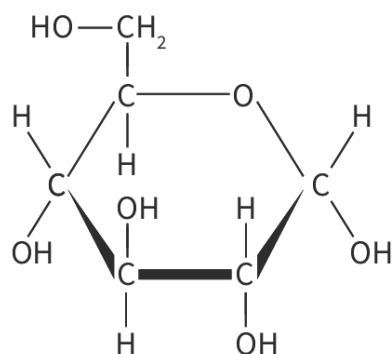
Monosaccharides are classified by the number of carbon atoms they contain. For example, pentoses have five carbon atoms such as ribose, whereas hexoses have six carbon atoms such as glucose, galactose and fructose (**Figure 1**). Fructose is a type of sugar naturally found in fruits, whereas galactose is a type of sugar that is commonly found in dairy products. Glucose is the most common monosaccharide found in nature and is an important source of energy for many organisms.



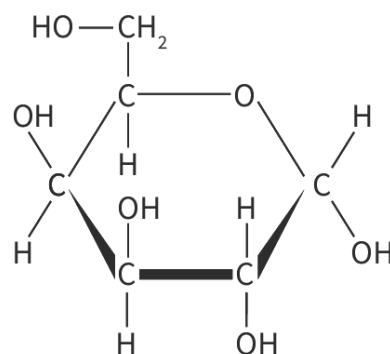
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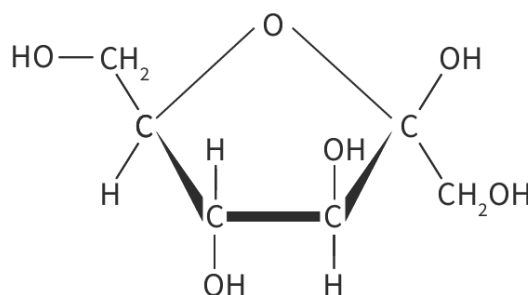
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Glucose



Galactose



Fructose

Figure 1. Glucose, galactose, and fructose are all examples of hexose sugars.

More information for figure 1

The image displays chemical structures of three hexose sugars: glucose, galactose, and fructose. Each structure is a diagram showing the arrangement of carbon (C), hydrogen (H), and oxygen (O) atoms.

1. **Glucose:** The structure of glucose is shown as a hexagonal ring with the chemical formula $C_6H_{12}O_6$. It includes hydroxyl (OH) groups attached to different carbon atoms and a CH_2OH group extending from one of the carbon atoms in the ring.
2. **Galactose:** Similar to glucose, galactose is presented as a six-membered ring, also with the chemical formula $C_6H_{12}O_6$. Its structure differs slightly from glucose, particularly in the arrangement of OH groups around the ring.
3. **Fructose:** The structure of fructose also forms a six-membered ring; however, the arrangement differs as it includes a five-membered ring with a CH_2OH group at both the first and sixth carbon.

These hexoses are known as monosaccharides, each with unique structural configurations leading to different chemical properties.

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Properties and uses of glucose

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Glucose is the most common monosaccharide found in nature. The properties of glucose are essential to its roles:

1. Glucose has two isomers: alpha-glucose (α -glucose) and beta-glucose (β -glucose).

These isomers vary in the orientation of the hydroxyl ($-\text{OH}$) group on the first carbon atom in the glucose molecule. In alpha-glucose, the $-\text{OH}$ group is oriented downwards, whereas in beta-glucose, it is oriented upwards as you can see in **Figure 2**.

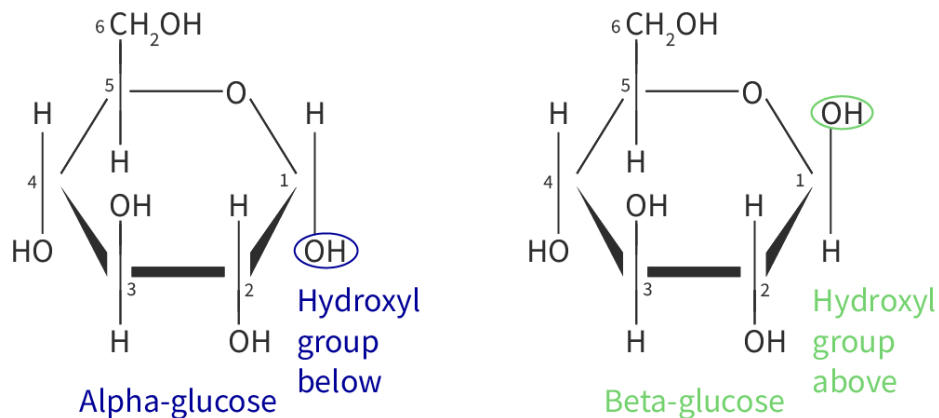


Figure 2. Glucose has two isomers: alpha-glucose and beta-glucose.

More information for figure 2

This diagram illustrates the structural difference between alpha-glucose and beta-glucose isomers. On the left, the alpha-glucose is depicted with a hydroxyl (OH) group on the first carbon atom oriented below the plane of the ring. On the right, beta-glucose is shown with the hydroxyl (OH) group on the first carbon oriented above the plane of the ring. Each glucose structure is represented as a six-membered ring composed of carbon and oxygen atoms, with hydrogen atoms and hydroxyl groups branching out. The positions of the carbon atoms are marked from 1 to 6, and the CH_2OH group is attached to carbon 6. The orientation of the hydroxyl group on the first carbon atom differentiates the two isomers and influences their roles in forming polysaccharides like starch, glycogen, and cellulose.

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The difference in orientation between these two isomers plays a critical role in the formation of polysaccharides such as starch, glycogen and cellulose. Different structures are a result of different combinations of the different isomers. Whereas glycogen and starch are composed of alpha-glucose molecules, cellulose is composed of beta-glucose molecules. You will learn more about these different polysaccharides later in this subtopic.

2. Glucose is a soluble molecule.

The solubility of glucose is due to its polarity. Glucose's polarity is due to its molecular structure as it contains several –OH groups, which are polar functional groups. In addition, the oxygen atom present in the glucose ring has a partial negative charge and therefore, the carbon–hydrogen (C–H) groups linked to it have a partial positive charge. This separation of charge within a molecule of glucose also contributes to its polarity.

In water solution, glucose is in equilibrium with the open-chain form, where the C1 atom is able to rotate, and the alpha and beta are randomly assigned. The molecule, at this point, is referred to simply as "glucose" without the alpha or beta labels. It is only in the formation of a polymer that the C1 atom becomes fixed, and we are able to assign the alpha and beta labels.

As glucose is a polar molecule, it can therefore dissolve in water. It can be easily transported in blood as it can dissolve in plasma (the liquid portion of blood). The –OH groups of glucose can hydrogen bond with the water present in plasma (see [subtopic A1.1 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43193/\)\)](/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43193/). Glucose transport in the blood is essential to ensure that all cells receive the glucose they need for cellular respiration.

3. Glucose is a stable molecule.



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Glucose is a cyclic molecule with the –OH groups situated in the equatorial regions of the molecule. This makes glucose a stable molecule chemically. The stability of glucose is a key feature for the structural role of the polysaccharide cellulose in plants, and for starch and glycogen in the storage of glucose in plant and animal cells, respectively. These molecules will be discussed later in this section.

4. Glucose can be oxidised.

Oxidation is a chemical reaction that involves the loss of electrons from an atom or molecule. In this reaction, the atom or molecule that loses electrons is said to be oxidised while the molecule that gains electrons is said to be reduced. Oxidation can occur through a variety of processes, including addition of oxygen to a molecule, removal of hydrogen atoms or loss of electrons to another molecule or ion.

Oxidation is an important process in many biological systems as it involves production of energy in the form of ATP through cellular respiration (**Figure 3**). During oxidation, glucose, a six-carbon molecule, is broken down by losing electrons to oxygen to produce carbon dioxide (CO₂) and water (H₂O). Energy released is used to generate ATP. There is more detail on cellular respiration and oxidation in subtopic C1.2 (</study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/>).

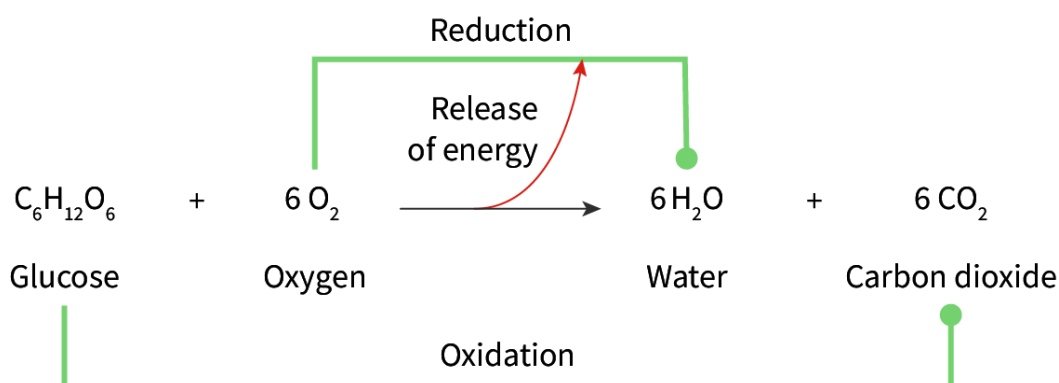


Figure 3. In cellular respiration, glucose is oxidised to release energy (see subtopic C1.2 (</study/app/bio/sid-422-cid-755105/book/big-picture-id-43538/>)).

More information for figure 3

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The diagram illustrates the process of cellular respiration, focusing on the oxidation of glucose and the concurrent reduction reactions. The chemical equation shown is: $\text{C}_6\text{H}_{12}\text{O}_6$ (glucose) + 6O_2 (oxygen) \rightarrow $6\text{H}_2\text{O}$ (water) + 6CO_2 (carbon dioxide). Arrows indicate the process flow, where glucose reacts with oxygen. Below the reactants, the term "Oxidation" is labeled, indicating the loss of electrons from glucose. On the upper part, an arrow labeled "Reduction" highlights the gain of electrons associated with oxygen turning into water. The diagram links the transformation of reactants to products outlined by the arrows, with "Release of energy" as a central labeled part of the process. The energy released is used to generate ATP in cells.

[Generated by AI]

Polysaccharides as energy storage compounds

The two types of polysaccharides that play a role in energy storage are starch in plants and glycogen in animals. Both starch and glycogen are composed of alpha-glucose molecules.

Starch

In plants, starch serves as the primary storage form of glucose. There are two types of starch: amylose and amylopectin.

Amylose is a linear polysaccharide made up of glucose monomers that are linked together through alpha-1,4-glycosidic bonds (refer to **Figure 6** in the previous section (/study/app/bio/sid-422-cid-755105/book/chemical-bonding-andpolymerisation-id-44681/)). It has a coiled structure and is typically composed of between 300 and 3000 glucose units.

Amylopectin, on the other hand, is a highly branched polysaccharide made up of glucose units linked together through alpha-1,4-glycosidic bonds, with occasional alpha-1,6-glycosidic bonds that create branches in the molecule. This branching structure allows amylopectin to form a more complex three-dimensional structure,

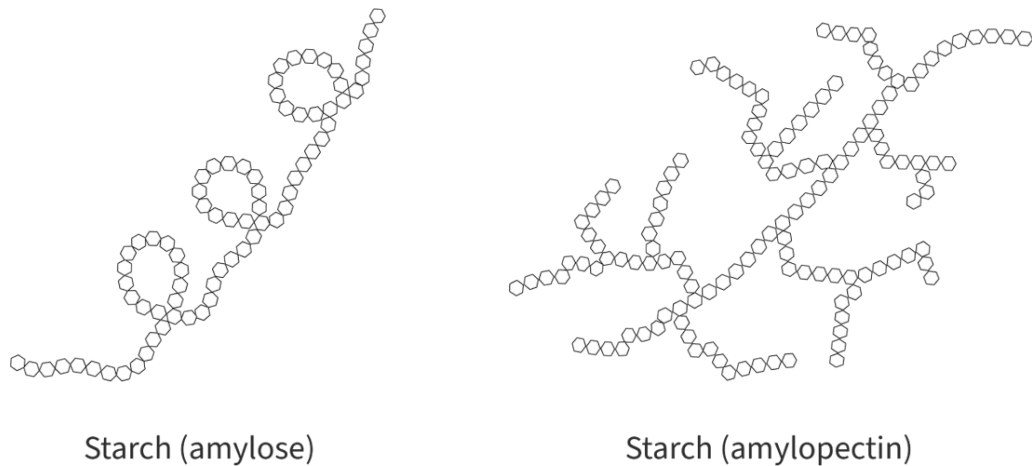


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allowing for more efficient storage of glucose (**Figure 4**). Amylopectin is the major component of starch, making up about 80–85% of the starch molecules in plants. The relative amounts of amylose and amylopectin in starch vary depending on the plant species and tissue. Some plants, such as potatoes, have a relatively high proportion of amylose in their starch, whereas others, such as corn, have more amylopectin.



A starch molecule contains hundreds of glucose molecules in either occasionally branched chains (amylopectin) or unbranched chains (amylose).

Figure 4. Amylose and amylopectin.

More information for figure 4

The diagram depicts two structures described as starch molecules: amylose and amylopectin. The left structure, labeled "Starch (amylose)," shows a linear chain of connected hexagon shapes representing glucose units, with a slight helical pattern. The right structure, labeled "Starch (amylopectin)," shows a more complex, branched arrangement of hexagons, indicating the presence of branching in the glucose chain. Below the structures, the text reads: "A starch molecule contains hundreds of glucose molecules in either occasionally branched chains (amylopectin) or unbranched chains (amylose)."

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Starch is the main energy storage molecule in plants, and it is stored in specialised plant structures such as seeds and roots. Starch is compact in structure due to its coiling and branching during polymerisation, which allows for efficient storage in a



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small space. These polysaccharides are also relatively insoluble due to their large molecular size, which helps to maintain osmotic balance within an organism. When the plant is in need of glucose, starch can be broken down through hydrolysis to release the needed glucose molecules. Glucose can then be used as a source of energy by the plant to carry out various cellular processes such as growth and photosynthesis.

Glycogen

In animals, glycogen is the primary storage form of glucose. Glycogen is a branched polymer of glucose molecules that form a highly compact, coiled structure in cells. The linear chains of glucose molecules in glycogen are linked together through both alpha-1,4-glycosidic bonds, forming a backbone, and frequent alpha-1,6-glycosidic bonds that occur about every 8–12 glucose units. The coiled structure of glycogen is due to the branching pattern of the molecule, which allows for efficient storage and mobilisation of glucose when energy is needed. Like starch, glycogen is relatively insoluble due to its large molecular size, helping maintain osmotic balance within an organism.

Glycogen is stored mainly in the liver and muscle cells of animals. The liver stores glycogen primarily to maintain blood glucose levels, as the liver can break down glycogen and release glucose into the bloodstream when blood glucose levels drop. Muscle cells, on the other hand, store glycogen primarily to provide energy for muscle contraction during exercise. When energy is needed, glycogen can be quickly mobilised and broken down into glucose molecules, which can then be used by the body for energy through cellular respiration. This process is particularly important during times of fasting or physical activity when the body needs to maintain its energy levels.

Creativity, activity, service

Strand: Service

Learning outcomes: Show commitment to, and perseverance in,
CAS experiences



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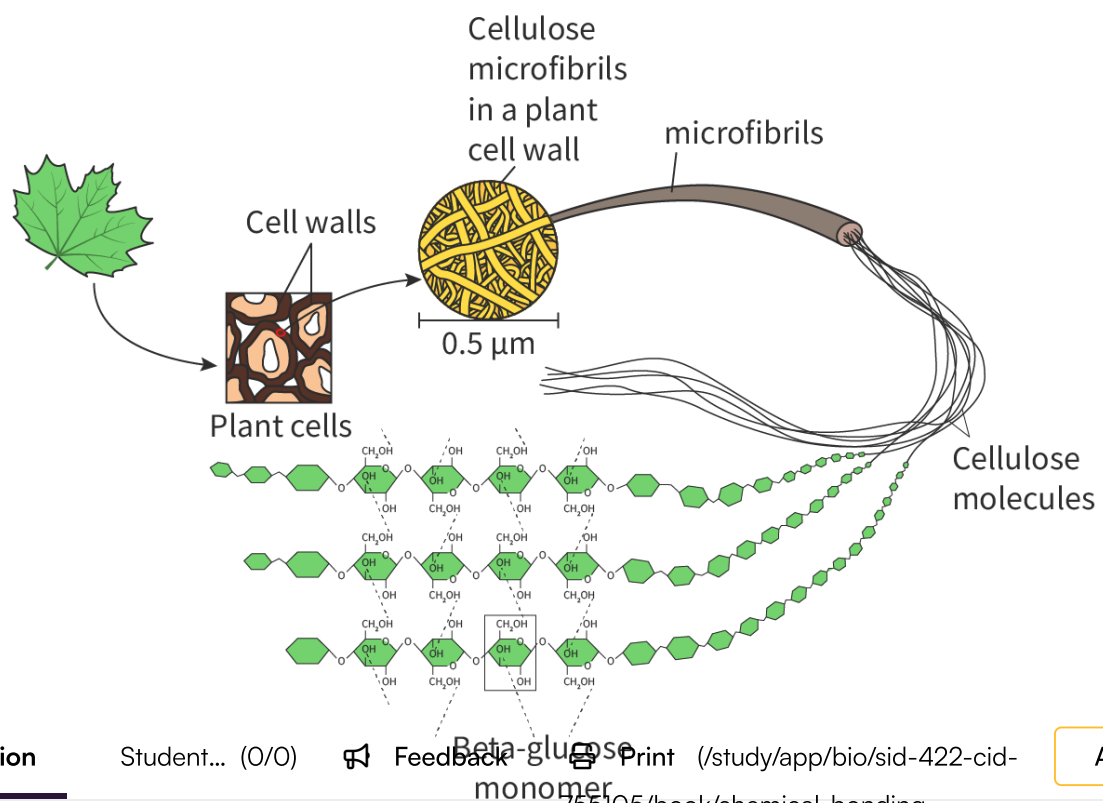


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Collaborate with a local group or organisation to create and maintain a community garden. This can be an excellent opportunity to learn about the nutritional benefits of various types of fruits and vegetables, especially those that are high in carbohydrates and healthy fats. Through this project, you can also develop important skills such as teamwork, leadership and communication, while making a positive impact in your community.

Polysaccharides as structural compounds: cellulose

Cellulose is a complex polysaccharide that is composed of beta-glucose molecules and is an essential component of the plant's cell wall. Unlike starch and glycogen, which are branched, cellulose forms a straight chain because the beta-glucose molecules alternate in orientation. This unique structure allows the cellulose molecules to form long, unbranched chains that can be grouped into bundles called microfibrils (**Figure 5**). The microfibrils are held together by hydrogen bonding that occurs between adjacent cellulose molecules.



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Figure 5. Cellulose molecules are linear chains of glucose molecules that form hydrogen bonds with other cellulose molecules forming a microfibril. These microfibrils give tensile



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strength to the cell wall.

More information for figure 5

The diagram illustrates the structure and arrangement of cellulose in plant cell walls. Starting from the left, a green leaf is depicted, representing the source of cellulose. Moving right, a section labeled "Plant cells" shows a close-up of cell walls, which are made up of tightly packed cellulose fibers. An enlarged circular segment labeled "Cellulose microfibrils in a plant cell wall" shows a dense bundle of yellow fibers, indicating the arrangement of cellulose microfibrils within the cell wall, with a measurement marker showing 0.5 μm . Extending from these are long, curved lines labeled "microfibrils," depicting how these are structured within the cell wall. Below, there are details of the molecular level, showing chains of repeating green shapes labeled "Beta-glucose monomer." These chains are linked by bonds illustrated as lines. The chains are depicted coming together to form the cellulose molecules, labeled at the right. Chemical structures are included within the green shapes, representing the composition of the monomers.

[Generated by AI]

The strong and rigid structure of cellulose is due to the way in which the chains are cross-linked. Hydrogen bonds between the chains create a strong and stable lattice structure, which gives cellulose a lot of tensile strength. This tensile strength is critical for its function in plants, where it forms an essential component of the cell wall.

The cell wall of plants is made up of cellulose, along with other polysaccharides, proteins and lipids. The cellulose in the cell wall gives the plant cells a rigid and sturdy structure, which is essential for maintaining the shape and integrity of the plant. Without the cellulose in the cell wall, plant cells would be unable to withstand the forces of osmosis and would collapse under their own weight.

Overall, the unique structure of cellulose, with its straight chains and cross-linked microfibrils, gives it exceptional tensile strength and rigidity. This makes it an essential component of the cell wall in plants, where it provides critical support and protection to the cells.



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Role of glycoproteins in cell—cell recognition

Glycoproteins are proteins that have one or more carbohydrates attached to them. These carbohydrates can be attached to specific amino acid residues within the protein, or they can form branched or linear chains that extend from the protein surface. There is more about amino acids and the structure of proteins in subtopic B1.2 (</study/app/bio/sid-422-cid-755105/book/big-picture-id-43531/>). Glycoproteins are found in many cellular structures, including the extracellular matrix, cell membranes and secreted proteins.

Glycoproteins play important roles in cell signalling and communication. The following are some of the roles of glycoproteins.

1. **Cell–cell recognition:** Glycoproteins play a role in cell–cell recognition as they act as markers on the surface of cells, allowing them to identify each other and interact appropriately. For example, immune cells recognise and attack foreign cells that display different glycoproteins on their surface, such as viruses or bacteria.
2. **Receptors:** Glycoproteins can act as receptors on the surface of cells, allowing them to receive signals from other cells or molecules in the environment. For example, insulin binds to a glycoprotein receptor on the surface of cells in the body, triggering a cascade of events that leads to glucose uptake by the cell.
3. **Ligands:** Other glycoproteins can act as ligands. Glycoproteins bind to specific receptors on other cells to initiate signalling pathways.
4. **Structural support:** Glycoproteins also contribute to the structural integrity of cells and tissues. They can form part of the extracellular matrix, providing support for the cell.

ABO blood groups

The ABO blood group system is based on the presence of specific glycoproteins on the surface of red blood cells. These glycoproteins are called A and B antigens.

Individuals can have one, both or neither of these antigens on their red blood cells.

The presence or absence of these antigens determines an individual's blood type.



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For example, individuals with the A antigen have type A blood, whereas individuals with the B antigen have type B blood. Individuals with both A and B antigens have type AB blood, whereas individuals with neither antigen have type O blood.

A summary of blood types and their corresponding glycoproteins is given in **Figure 6**.


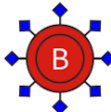
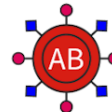

ABO blood groups	Blood group A	Blood group B	Blood group AB	Blood group O
RBC type				

Figure 6. ABO blood groups have different glycoproteins on the surface of red blood cells.

More information for figure 6

This diagram depicts the different ABO blood groups, showcasing the glycoproteins on the surface of red blood cells (RBCs). The diagram includes four blood groups: A, B, AB, and O. Each group is represented with a labeled circular RBC.

- Blood Group A: The RBC is labeled 'A' and has round glycoproteins poised around its edge.
- Blood Group B: The RBC is labeled 'B' and has diamond-shaped glycoproteins arranged similarly.
- Blood Group AB: The RBC is labeled 'AB' and includes both round and diamond-shaped glycoproteins distributed around it.
- Blood Group O: The RBC is labeled 'O' and lacks any surface glycoproteins.

[Generated by AI]

The compatibility of blood types is based on recognition and interaction of specific glycoproteins on the surface of red blood cells. When incompatible blood types are mixed, the immune system can recognise the other glycoproteins as foreign molecules and attack. This leads to the clumping of red blood cells, which may lead



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to organ failure and death. Therefore, it is important to match blood types carefully before blood transfusions. Type O blood is often used as a universal donor, whereas type AB blood is usually considered as the universal recipient as it has both A and B antigens.

Watch **Video 1** to learn about the inheritance of the different blood groups.

Why do blood types matter? - Natalie S. Hodge



Video 1. Why blood types matter and how they are inherited.

Try the activity below to carry out a simulation to test for the presence of carbohydrates.



Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills — Being curious about the natural world
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity



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Testing for carbohydrates



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The Benedict's test can detect simple sugars such as glucose, fructose, galactose, maltose and lactose. In this [online simulation](https://web.archive.org/web/20210208014828/http://www.olabs.edu.in/?sub=79&brch=17&sim=205&cnt=4) (<https://web.archive.org/web/20210208014828/http://www.olabs.edu.in/?sub=79&brch=17&sim=205&cnt=4>), you will test for the presence of glucose in banana extract.

Instructions

1. Drop Benedict's solution into the test tube containing banana extract: pick up the dropper and drag it above the test tube, click on the dropper to dispense Benedict's solution. The Help button will give you instructions.
2. Place the test tube into the water bath: pick up the test tube and hover it over the water bath, click to release it into the water bath.
3. Turn on the hot plate by clicking the switch.
4. Observe the colour of the solution in the test tube. If simple sugars are present in the sample solution, the colour of the solution will change from blue to green, yellow, orange or red. The intensity of the colour change will depend on the concentration of simple sugars present in the sample.
5. Click the Information button at the end for the result.

5 section questions ✓

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Properties and functions of lipids

B1.1.8: Hydrophobic properties of lipids B1.1.9: Formation of triglycerides and phospholipids

B1.1.10: Saturated, monounsaturated and polyunsaturated fatty acids B1.1.11: Triglycerides in adipose tissues



Learning outcomes

By the end of this section you should be able to:



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- Describe lipids such as fats, oils, waxes and steroids as hydrophobic substances in living organisms that dissolve in non-polar solvents.
- Explain the difference between saturated, monounsaturated and polyunsaturated fatty acids.
- Recognise that triglycerides and phospholipids are types of lipids that form by condensation reactions and triglycerides are suited to long-term energy storage.
- Recall that triglycerides are used as thermal insulators to body temperature and habitat.

Have you ever wondered why some substances dissolve in water, while others do not? Have you ever noticed how some oils and fats are solid at room temperature, while others are liquid? The answers lie in the form and function of lipids. Lipids are a diverse group of organic molecules that play many important roles in energy storage, insulation and cell membrane structure. In this section, you will explore the form and function of lipids.

Hydrophobic properties of lipids

Lipids are a diverse group of non-polar molecules that are characterised by their low solubility in water. Due to their hydrophobic nature, lipids ‘repel’ water and are typically insoluble in aqueous solutions. In contrast, if you place lipids in non-polar solvents they have the ability to dissolve. This is because non-polar solvents have a similar polarity to the lipid molecules, allowing them to dissolve.

Triglycerides are a type of lipid that can be both consumed in food and synthesised by the liver. They are also commonly found in foods such as butter, lard and ghee. These fats are typically solid at room temperature, whereas oils such as olive oil and canola oil are liquid.

Another type of lipid is wax. Waxes are completely water insoluble and have a high melting point, which is why they are generally solid at room temperature. Wax can be found naturally on the surface of leaves, where it forms a waterproof layer reducing rate of transpiration (see sections B3.1.7–10 (/study/app/bio/sid-422-cid-755105/book/gas-exchange-in-leaves-id-44440/), B3.2.7–10 (/study/app/bio/sid-422-



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cid-755105/book/transport-in-plants-id-44452/), B3.2.17–18 (/study/app/bio/sid-422-cid-755105/book/phloem-and-xylem-hl-id-44454/) and D4.2.3 (/study/app/bio/sid-422-cid-755105/book/stability-of-ecosystems-id-44455/)).

Steroids are also another type of lipid, composed of four carbon rings that are fused together (see section B1.1.12–13 (/study/app/bio/sid-422-cid-755105/book/phospholipid-bilayer-id-44683/)).

Formation of triglycerides and phospholipids by condensation reactions

One common type of lipid is triglycerides, which are formed by condensation of one glycerol molecule and three fatty acid molecules. Each time a fatty acid molecule joins the glycerol molecule, a water molecule is released. The bond that forms between the glycerol and fatty acid is called an ester bond. When three fatty acids join to a glycerol molecule, a triglyceride (**Figure 1**) is formed.

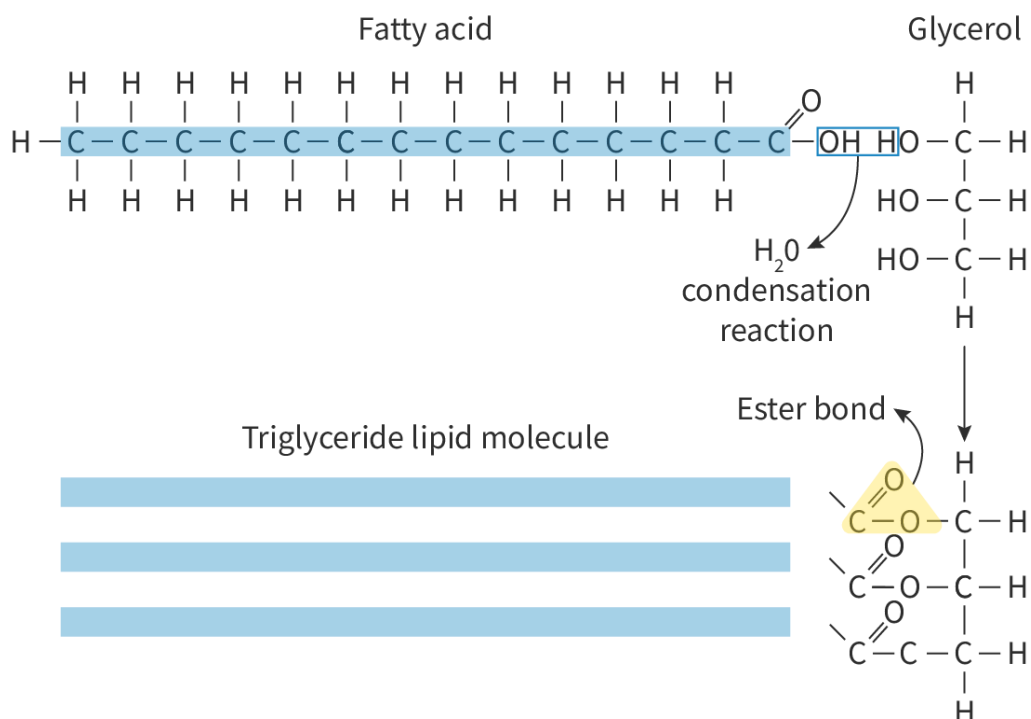


Figure 1. Fatty acids can bind to glycerol through a condensation polymerisation reaction. Three fatty acids join to glycerol, a triglyceride is formed and three water molecules are released.

More information for figure 1

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The diagram illustrates the chemical structure and reaction involved in the formation of a triglyceride molecule. At the top left, a long carbon chain represents a fatty acid, with hydrogen atoms attached on either side. On the right side is a glycerol molecule depicted as three carbon atoms, each bonded to OH groups and hydrogen atoms. The diagram highlights a condensation reaction where water (H_2O) is released as three fatty acid chains attach to the glycerol molecule, forming ester bonds. This reaction results in a triglyceride molecule shown below, represented by three parallel lines. An arrow points to the formation of the ester bond, and annotations like "Fatty acid," "Glycerol," "Condensation reaction," and "Ester bond" provide additional context.

[Generated by AI]

Phospholipids are another important type of lipid that also form by condensation. A phospholipid consists of a glycerol molecule modified with a phosphate group and two fatty acids (**Figure 2**). Like triglycerides, when the two fatty acids join to the modified glycerol phosphate molecule, an ester bond is made and water is released. See subtopic B2.1 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43205/) for more about phospholipids and their unique structure.

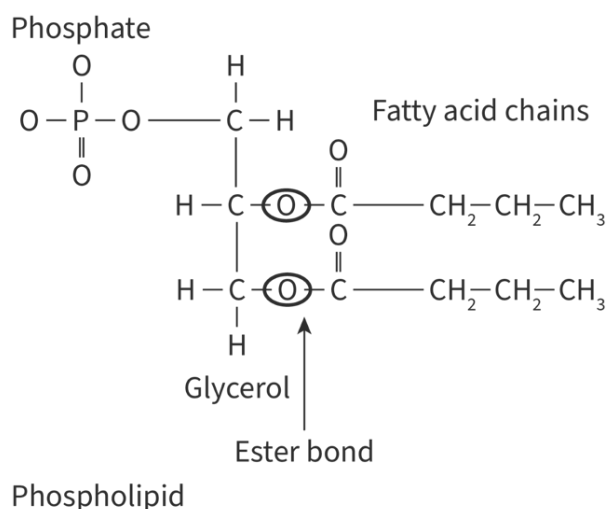


Figure 2. Phospholipid structure.

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The diagram illustrates the structure of a phospholipid, a type of lipid molecule. It consists of a glycerol backbone, shown in the center, with an ester bond attaching a phosphate group and two fatty acid chains. At the top, the phosphate group is labeled "Phosphate," consisting of phosphorus (P) and oxygen (O) atoms. Below the glycerol, two fatty acid chains extend to the right, labeled "Fatty acid chains." The glycerol structure shows its bonding to both the phosphate group and the fatty acids. The diagram labels include "Phosphate," "Glycerol," "Ester bond," and "Fatty acid chains." The configuration displays how the components are chemically structured and connected in the phospholipid.

[Generated by AI]

Difference between saturated, monounsaturated and polyunsaturated fatty acids

Fatty acids can be classified as saturated, monounsaturated or polyunsaturated based on the number of double bonds in their hydrocarbon chain. Hydrocarbon chains are long, linear chains of carbon and hydrogen atoms that make up the backbone of fatty acid molecules (**Figure 3**). They are called 'hydrocarbon' chains because they consist primarily of carbon and hydrogen, which are two of the most common elements in organic compounds.

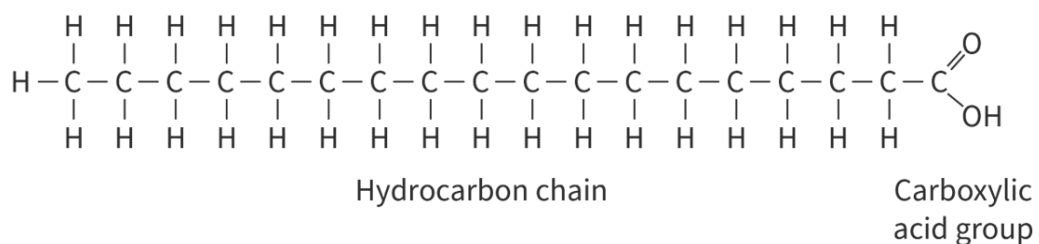


Figure 3. The hydrocarbon chain is an essential feature of fatty acids.

More information for figure 3

The image is a diagram of a hydrocarbon chain, which is a key component of fatty acids. The diagram shows a linear arrangement of carbon (C) and hydrogen (H) atoms, with each carbon atom being bonded to two hydrogen atoms and linked to adjacent carbon atoms. The chain extends horizontally and is labeled "Hydrocarbon chain" below the carbon and hydrogen atoms. The diagram also includes a



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carboxylic acid group at one end, marked by a carbon atom double-bonded to an oxygen atom (O), and single-bonded to a hydroxyl group (OH). This structure is essential in defining the properties and characteristics of fatty acids. The text annotations in the diagram help identify the hydrocarbon chain and the carboxylic acid group, highlighting the molecular structure of a typical fatty acid.

[Generated by AI]

The hydrocarbon chain of a fatty acid can vary in length, ranging from 4 to 36 carbons long. The carbon atoms in the chain are bonded together by single covalent bonds, and each carbon atom is also bonded to a hydrogen atom. The arrangement and number of these bonds determine the structure and properties of the fatty acid. The more double bonds there are, the lower the melting point.

- Saturated fatty acids have a straight, linear shape because there are no double bonds between the carbon atoms. Each carbon atom in the hydrocarbon chain is bound to 4 atoms. This allows the fatty acids to pack tightly together, forming a solid at room temperature. In contrast, unsaturated fatty acids have one or more double bonds, which introduce kinks or bends in the fatty acid chain. These kinks prevent the fatty acid molecules from packing closely together, resulting in a liquid at room temperature. Meats such as beef, pork and poultry, full-fat dairy products such as whole milk, cheese, butter and cream, eggs and tropical oils such as coconut and palm oil are all high in saturated fat (**Figure 4**). Because they are typically solid at room temperature, they are sometimes called 'solid fats'.



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Figure 4. These foods are high in saturated fat.

Credit: AlexPro9500, Getty Images (<https://www.gettyimages.com/detail/photo/sources-of-saturated-fats-royalty-free-image/504641264>)

- Unsaturated fatty acids can either be monounsaturated or polyunsaturated (**Figure 5**).
 - Monounsaturated fats: These fats have one double bond in their hydrocarbon chain, which causes a kink or bend in the chain. This kink makes it difficult for the molecules to pack together tightly, resulting in a liquid state at room temperature. Examples of monounsaturated fats include oleic acid, which is found in olive oil, and palmitoleic acid, which is found in macadamia nuts.
 - Polyunsaturated fats: These fats have two or more double bonds in their hydrocarbon chain, causing multiple kinks or bends in the chain (**Figure 6**). This structure makes it even more difficult for the molecules to pack together, resulting in a liquid state at room temperature. Examples of polyunsaturated fats include linoleic acid, which is found in vegetable oils like soybean oil, and alpha-linolenic acid, which is found in fatty fish like salmon.



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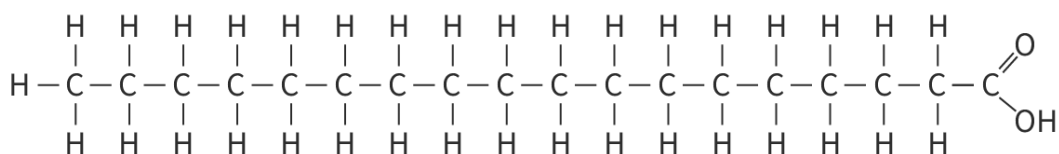
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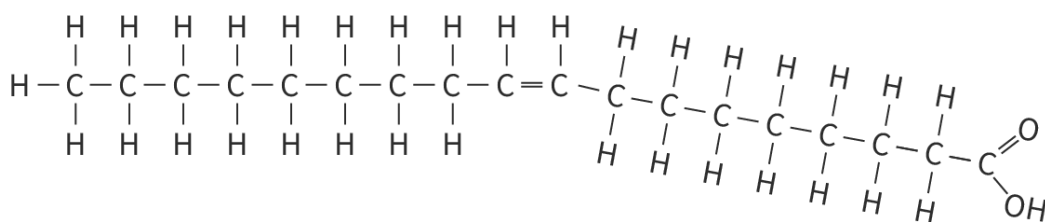
Figure 5. Foods that contain unsaturated fat.

Credit: a_namenko, Getty Images (<https://www.gettyimages.com/detail/photo/selection-of-healthy-unsaturated-fats-omega-3-royalty-free-image/1126186457>)

Saturated fatty acid (stearic acid)



Monounsaturated fatty acid (oleic acid)



Polyunsaturated fatty acid
(linolenic acid – an omega-3 fatty acid)

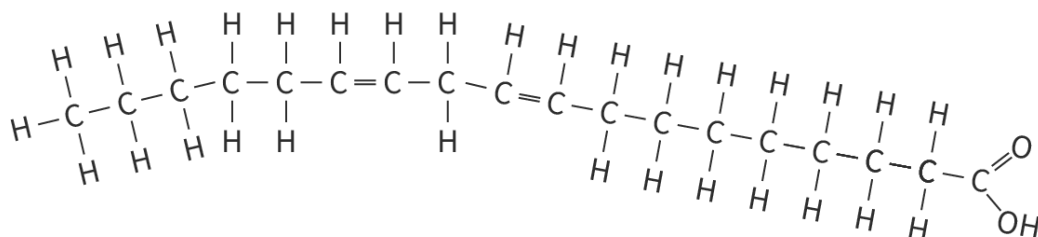


Figure 6. Examples of types of fatty acids.



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More information for figure 6

The image shows chemical structures of three types of fatty acids. The first diagram is labeled "Saturated fatty acid (stearic acid)". It represents a linear chain where all carbon atoms (C) are single-bonded and fully saturated with hydrogen atoms (H). It ends with a carboxyl group (COOH).

The second diagram is labeled "Monounsaturated fatty acid (oleic acid)". This chain includes a single double bond between two carbon atoms, resulting in a kink in the chain. Like the first, it ends with a carboxyl group.

The third diagram is labeled "Polyunsaturated fatty acid (linolenic acid - an omega-3 fatty acid)". This shows a chain with multiple double bonds, creating several kinks along the structure. It also ends with a carboxyl group.

Each chemical diagram presents hydrogen atoms bonded to carbon, with lines representing chemical bonds — single lines for single bonds and double lines for double bonds. These structures illustrate the differences in saturation and molecular configuration among the types of fatty acids.

[Generated by AI]

Watch **Video 1** to see examples of fatty acids and the foods that contain them.

Saturated vs. Unsaturated Fats - Bite Sci-zed



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Video 1. Examples of fatty acids and their sources in the food you eat.



International Mindedness

Consider traditional foods from various countries or regions around the world, learning about the cultural and historical significance of these foods, as well as understanding the role they play in the local diet. Additionally, you could identify the sources of carbohydrates and lipids in these dishes and compare them with those found in your own diet. This will allow you to appreciate the diversity of food cultures and traditions around the world and understand the various factors that influence food choices and dietary habits.

Degree of unsaturation of fatty acids

Unsaturated fatty acids (with double bonds) are liquid at room temperature, runny (less viscous) and have lower melting points when compared with, for example, saturated fatty acids which have no double bonds. The more double bonds that are present in the unsaturated fatty acid, the lower its melting point. This is because the double bonds disrupt the regular packing of the fatty acid molecules, making it easier for them to break apart and transition from a solid to a liquid state. As a result, oils that contain more unsaturated fatty acids have a lower melting point and are liquid at room temperature.

Saturated fatty acids have a higher melting point because their linear shape allows them to pack closely together, making it harder for them to break apart and transition from a solid to a liquid state. This is why fats, such as butter, lard and ghee are solid at room temperature, viscous and require more energy to melt.

Cis and trans are terms used to describe the arrangement of atoms around the double bonds in unsaturated fatty acids (**Figure 7**).



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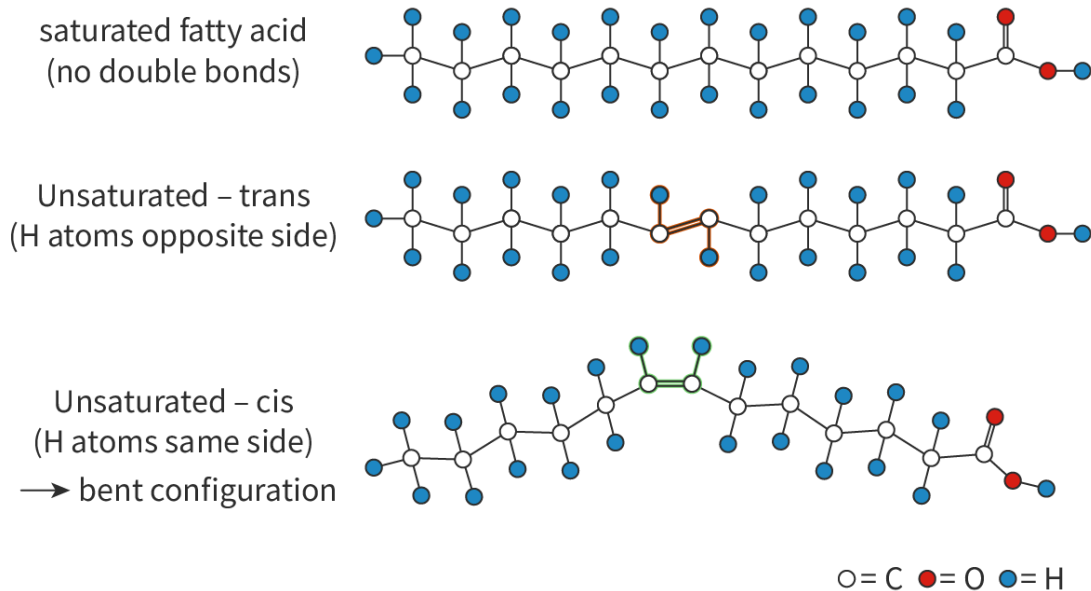



Figure 7. Types of fatty acid configurations.

 More information for figure 7

The diagram illustrates three types of fatty acid configurations. At the top, it shows a saturated fatty acid with no double bonds, characterized by a straight chain of blue and white circles representing Hydrogen (H) and Carbon (C) atoms, respectively. Below it, an unsaturated trans fatty acid is depicted, where the H atoms are on opposite sides of a double bond, represented by orange lines, creating a more linear structure. The lowest structure shows an unsaturated cis fatty acid, where H atoms are on the same side of a double bond, represented by green lines, causing a bend or kink in the structure. The bottom section of the diagram has a legend identifying the circles: white for Carbon (C), red for Oxygen (O), and blue for Hydrogen (H).

[Generated by AI]

In cis unsaturated fatty acids, the hydrogen atoms attached to the carbon atoms around the double bond are located on the same side of the molecule. This creates a bend or a kink in the molecule, which causes the molecule to have a less linear structure. In contrast, in trans unsaturated fatty acids (commonly termed ‘trans fats’), the hydrogen atoms attached to the carbon atoms around the double bond are located on opposite sides of the molecule. This creates a more linear structure



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and results in a molecule that is less flexible and more rigid than a cis fatty acid. In addition, while cis unsaturated fatty acids occur naturally, trans fats are not found in nature and have to be made industrially.

Watch **Video 2** to learn about the differences between saturated and unsaturated fatty acids.

Unsaturated vs Saturated vs Trans Fats, Animation



Video 2. Review of unsaturated versus saturated fats.

Energy storage in plants and endotherms

All living organisms require lipids for their physiological processes. Plants store fats or oils as a source of energy in many of their seeds, primarily as unsaturated fatty acids. The energy from the stored fat is used by the germinating seedling to grow and establish itself until it is capable of photosynthesis.

Endotherms are animals that rely on metabolic reactions to generate heat to maintain a constant internal body temperature. To generate heat, endotherms require a constant supply of energy in the form of food. Fat is a particularly important source of energy for endothermic animals, as it is stored in adipocytes as liquid droplets and can be broken down into ATP, which is used to power cellular processes.



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Triglycerides in adipose tissue for energy and thermal insulation

In addition to their role as an energy reserve, triglycerides also serve as effective thermal insulators in many organisms, helping to regulate body temperature and protect against the cold. A prime example of this is the blubber found in whales which is primarily composed of adipose tissues containing large amounts of triglycerides. The blubber layer serves as a highly effective insulator, keeping the whale warm even in the cold temperatures of the ocean. In fact, the bowhead whale has a blubber layer that is 43–50 cm thick, allowing it to survive in the cold Alaskan waters (**Figure 8**). This layer of blubber not only helps to insulate the whale from the cold, but also serves as an energy reserve allowing the whale to survive long periods without food.

Section

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Feedback



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Figure 8. The bowhead whale (*Balaena mysticetus*) can survive the cold temperatures of the Alaskan waters due to the thickness of its blubber.

Credit: flyingrussian, [Getty Images \(https://www.gettyimages.com/detail/photo/bowhead-whales-balaena-mysticetus-swimming-in-the-royalty-free-image/1410514715\)](https://www.gettyimages.com/detail/photo/bowhead-whales-balaena-mysticetus-swimming-in-the-royalty-free-image/1410514715)



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Theory of Knowledge

How can the choice of language create misinformation/deception within knowledge?

The question of how we can know whether language is intended to deceive or manipulate us is a complex and challenging one, particularly in an era of widespread misinformation and 'fake news'. One example of this is the claim that 'No food is healthy. Not even kale'

(https://www.washingtonpost.com/lifestyle/food/no-food-is-healthy-not-even-kale/2016/01/15/4a5c2d24-ba52-11e5-829c-26ffb874a18d_story.html), which was made in an article published in *The Washington Post*.

This statement, which appears to contradict the widely held belief that kale is a healthy food, raises important questions about the role of language in shaping our understanding of the world and the ways in which it can be used to manipulate our beliefs and behaviours. To critically evaluate claims such as this one, we must engage in careful analysis of the language used and the evidence presented, as well as consider the biases and motivations of those making the claim. By doing so, we can work towards a more informed understanding of the role of language in shaping our knowledge and beliefs.

Try this data analysis activity to find out about the fatty acid composition of different foods.



Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Experimenting with new strategies for learning
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity



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Use the information provided in **Table 1** to answer the questions given below the table.



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SFA = saturated fatty acids

PUFA = polyunsaturated fatty acids

MUFA = monounsaturated fatty acids.

Table 1. Percentage fatty acid composition in different types of

Data source: Figures from [USDA National Nutrient Database \(https://data.nal.usda.gov/se](https://data.nal.usda.gov/se)
 in the [public domain \(https://creativecommons.org/publicdomain/zer](https://creativecommons.org/publicdomain/zer)

Fatty acids	SFA	Short and medium chains (≤ 10 carbons)	Long chains (> 10 carbons)	Total MUFA	Total PUFA
Whole milk	1.87	0.32	1.58	0.81	0.00
Cheddar cheese	21.09	2.46	17.68	9.39	0.00
Yogurt	2.10	0.30	1.66	0.89	0.00
Butter	51.37	8.96	42.41	21.02	3.00
Sirloin steak (grilled)	3.75	0.01	3.74	3.96	0.00
Shoulder steak (grilled)	8.66	0.00	8.66	9.46	1.00
Chicken (roast)	1.81	0.00	1.81	2.50	1.00
Palm oil	49.30	0.00	49.30	37.00	9.00
Coconut oil	86.50	14.10	72.40	5.80	1.00

1. Which source has the greatest amount of saturated fatty acids, SFA?
2. Which two sources of fatty acids have similar total SFA?
3. What is the percentage difference in total polyunsaturated fatty acids, PUFA, between palm oil and coconut oil?
4. Compare the fatty acid composition of butter with that of palm oil.



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Be prepared to discuss your answers with your class and teacher.

5 section questions ▾

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Phospholipid bilayer

B1.1.12: Formation of phospholipid bilayers B1.1.13: Movement of steroids through the phospholipid bilayer



Learning outcomes

By the end of this section you should be able to:

- Describe the formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions.
- Define the term 'amphipathic'.
- Summarise the ability of non-polar steroids (e.g. oestradiol and testosterone) to pass through the phospholipid bilayer.
- Identify compounds as steroids from molecular diagrams.

Phospholipids are a crucial component of every cell on Earth, playing a vital role in forming the cell membrane that encloses and protects the cell (see subtopic B2.1 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43205/)). In this section, you will learn about how these phospholipid bilayers form and learn more about how important molecules, such as steroids, can pass through the bilayer.



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Phospholipid bilayers form as a consequence of the hydrophobic and hydrophilic regions

The cell membrane is an essential structure that surrounds and protects the contents of cells. These membranes are primarily composed of a bilayer of phospholipid molecules arranged in a specific orientation. A phospholipid consists of a negatively charged phosphate head that readily interacts with water molecules; hence the head of the phospholipid is considered to be hydrophilic ('water-loving'). On the other hand, the hydrocarbon tails consist of long non-polar fatty acid chains that repel water molecules; therefore, the tails are hydrophobic. As a portion of the phospholipid is hydrophilic and another region is hydrophobic, phospholipids are considered to be amphipathic molecules (**Figure 1**). The term amphipathic refers to any molecule that has both hydrophobic and hydrophilic properties.

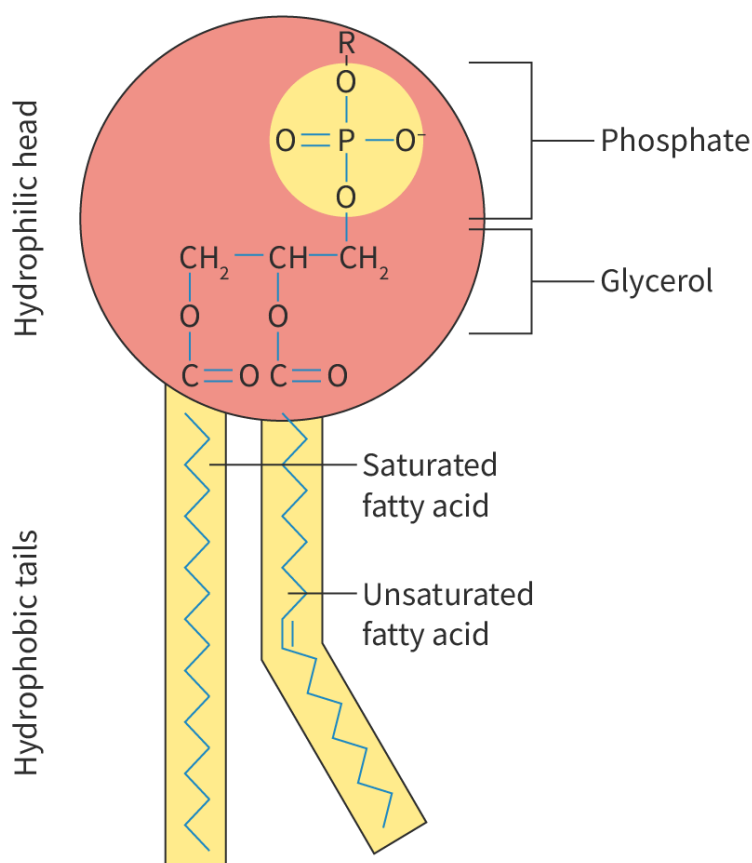


Figure 1. A phospholipid consists of a hydrophilic head, which has a negatively charged phosphate group, and two hydrophobic fatty acid tails.

More information for figure 1



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The diagram illustrates the structure of a phospholipid molecule. It consists of two main parts: a hydrophilic head and two hydrophobic tails. The head is depicted as a circular region labeled as 'Hydrophilic head,' and contains a negatively charged phosphate group and glycerol. The chemical structure of the phosphate group is shown with the labels 'R,' 'O,' and 'P' with respective chemical bonds. The tails extend downward from the head and are labeled as 'Hydrophobic tails.' One tail is identified as a saturated fatty acid with straight lines, while the other is labeled as an unsaturated fatty acid, depicted with a kinked appearance. This structural depiction highlights the amphipathic nature of phospholipids, having both water-attracting and water-repelling properties.

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The phospholipid bilayer is made up of a double layer of phospholipids that are oriented in a special way. As phospholipids are amphipathic, when placed in an aqueous (water) environment, the hydrophilic heads will face the aqueous solution while the hydrophobic tails orient themselves towards each other as they are more attracted to each other than to the water molecules. Consequently, phospholipids can spontaneously form a phospholipid bilayer when placed in water. You can see how phospholipids orient themselves into a bilayer in **Figure 2**.



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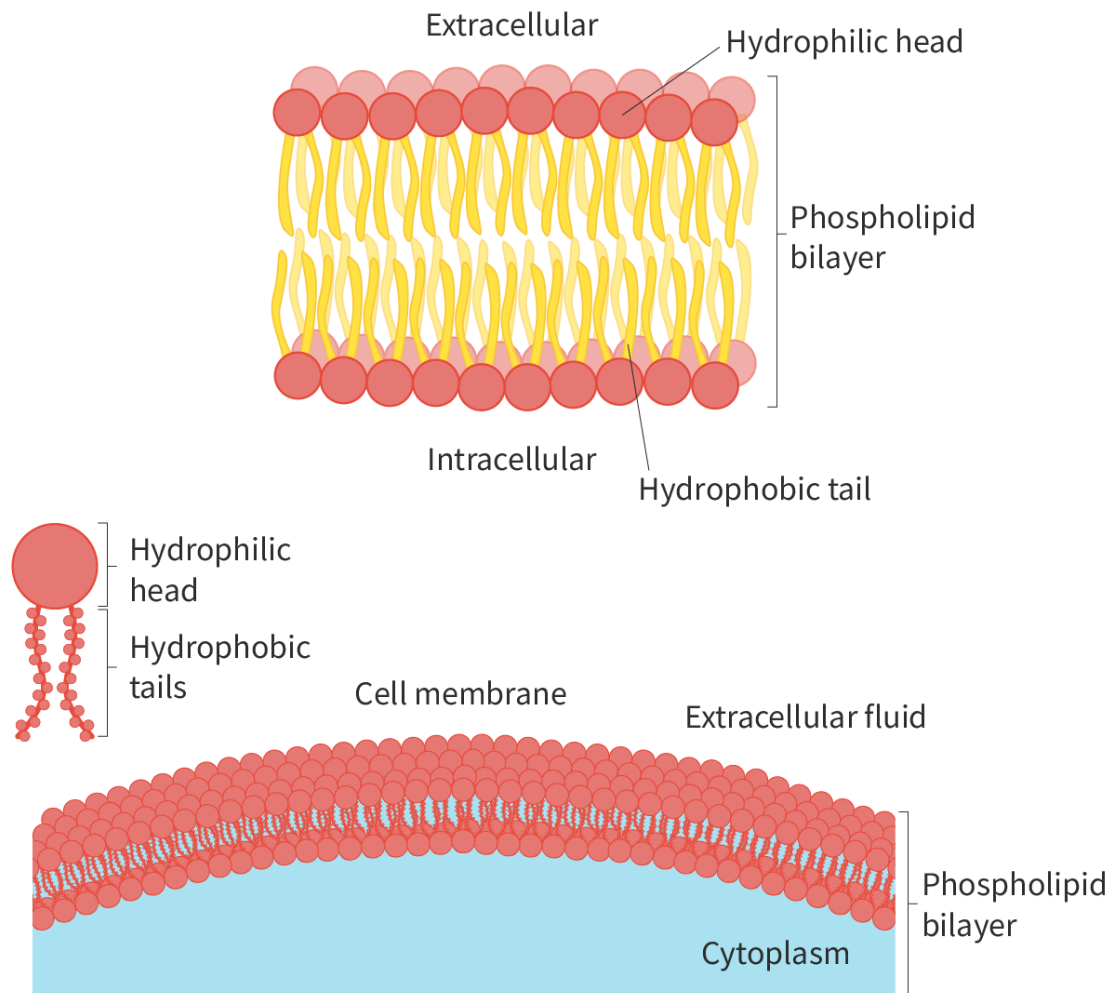


Figure 2. Phospholipids orient themselves so that the hydrophobic tails stay away from an aqueous environment while the hydrophilic heads interact with the aqueous extracellular matrix or cytoplasm. By doing so, phospholipids orient themselves into a bilayer.

More information for figure 2

The image is a detailed diagram illustrating the structure of a phospholipid bilayer. At the top, there is a cross-section of the bilayer with labels indicating the extracellular and intracellular regions. The diagram shows the hydrophilic heads of the phospholipids oriented towards the extracellular and intracellular spaces, while the hydrophobic tails face inward, away from the water on either side. Below the main diagram, there's an enlarged view of a single phospholipid detailing the hydrophilic head and hydrophobic tails. The lower part of the image displays a section of a cell membrane, showing how the bilayer is situated between an extracellular fluid and the cytoplasm. Labels on the image include "Hydrophilic head," "Hydrophobic tail," "Phospholipid bilayer," "Extracellular," "Intracellular," "Cell membrane," "Extracellular fluid," and "Cytoplasm."

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Non-polar steroids have the ability to pass through the phospholipid bilayer

Steroids are a group of naturally occurring hormones that play a vital role in regulating a wide range of physiological functions in the body. Steroid molecules are organic compounds that are composed of four carbon-based rings as the basic structure but the difference in functional groups is vast allowing steroids to have a diverse array of functions (**Figure 3**).

Steroids such as cholesterol are an important component of the phospholipid bilayer providing it with both stability and flexibility (see subtopic B2.1 (</study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43205/>)). Other steroids play an important role in signalling. For example, the steroids oestradiol and testosterone play key roles in the development of female and male reproductive development, respectively. As steroids are hydrophobic molecules, they are capable of passing through the phospholipid bilayer of cells. This allows these cells to have a faster response to the presence of these steroids allowing the signal to occur more efficiently.

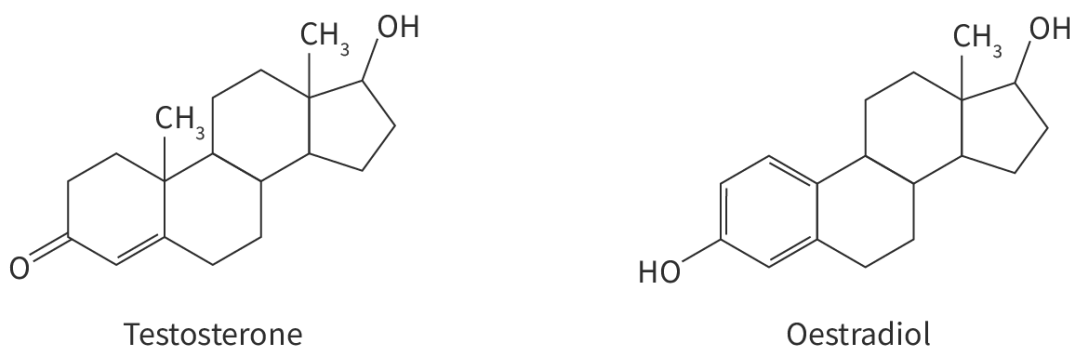


Figure 3. Molecular structure of the steroids testosterone and oestradiol. Steroids have three 6-carbon rings and one 5-carbon ring.

More information for figure 3

The image shows the chemical structures of two steroids: testosterone and oestradiol. The structure of testosterone is on the left, featuring three hexagonal rings and one pentagonal ring. It has identifiable functional groups, including a hydroxyl group (OH) attached to the pentagon and a methyl group (CH₃) extending from one of the hexagons. Oestradiol is depicted on the right with a similar structure of three



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hexagonal rings and one pentagonal ring, but it includes a hydroxyl group on both sides of its structure—
positioned differently from testosterone. These structures demonstrate the steroidal backbone
characteristic of these molecules.

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Try this activity to find out more about different types of steroids found in the body.



Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills — Using search engines and libraries effectively
- **Time required to complete activity:** 45 minutes
- **Activity type:** Group activity

In this section, you were introduced to steroids. Now it's time for you to learn more about the many different types. Each group will research the role of one steroid and share what they learned with their class in the form of an oral presentation.

Success criteria:

- Clearly explaining the steroid's chemical structure and fundamental properties.
- Providing precise and current information on the steroid's effects on the body.
- Describing the steroid's natural production in the body or synthetic creation in a laboratory.
- Discussing the steroid's therapeutic uses, including its mechanism of action and administration methods.
- Examining the potential side effects and risks associated with using this steroid if applicable.

Possible steroids to research:



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- progesterone
- cortisol
- aldosterone
- vitamin D
- cholesterol.

5 section questions ▾

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Summary and key terms

- Carbon atoms can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements.
- International scientific conventions are based on international agreement, such as the SI metric unit prefixes 'kilo', 'centi', 'milli', 'micro' and 'nano'.
- Macromolecules are produced by condensation reactions that link monomers to form a polymer. Polymers can be digested into monomers by hydrolysis reactions that split water molecules to provide the $-H$ and $-OH$ groups necessary to produce monomers.
- Glucose is a stable polar monosaccharide (hexose) that is soluble in blood plasma and can be oxidised in cellular respiration.
- Polysaccharides, such as starch and glycogen, are energy storage compounds that are compact and insoluble due to their large molecular size and coiling and branching during polymerisation.
- Cellulose is a structural polysaccharide in plants with straight chains that can be grouped in bundles and cross-linked with hydrogen bonds.
- Glycoproteins play a role in cell–cell recognition, such as ABO antigens.
- Lipids are substances in living organisms that dissolve in non-polar solvents and include fats, oils, waxes and steroids.



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- Triglycerides in adipose tissues are used for long-term energy storage and thermal insulation.
- Phospholipid bilayers are formed as a consequence of the hydrophobic and hydrophilic regions of phospholipids, which allow hydrophobic steroids to pass through them, such as oestradiol and testosterone.

⬇️ Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. Carbohydrates and lipids are both types of _____, which are large molecules made up of smaller subunits.
2. Monosaccharides can join together by a type of covalent bond called a _____.
3. _____ are composed of three fatty acids and a glycerol molecule.
4. _____ are amphipathic molecules.
5. Macromolecules can be formed through a process called _____, which involves the removal of water molecules to form a larger molecule.
6. _____ involves the addition of water molecules to break apart a larger molecule into its smaller subunits.
7. Animals store energy in the form of _____.
8. _____ is an important structural component of plant cell walls.

Triglycerides

Hydrolysis

Phospholipids

Cellulose

macromolecules

condensation

glycosidic bond

glycogen

✓ Check



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Interactive 1. Carbohydrates and Lipids.

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Checklist

What you should know

After studying this subtopic you should be able to:

- Describe the nature of a covalent bond and that a carbon atom can form up to four single bonds or a combination of single and double bonds with other carbon atoms or atoms of other non-metallic elements.
- Explain how macromolecules, such as polysaccharides, are formed by condensation reactions that link monomers to form a polymer.
- Explain that water molecules are split to provide the —H and —OH groups that are incorporated to produce monomers in a hydrolysis reaction.
- Recognise monosaccharides (pentoses and hexoses) and know the properties of glucose (glucose is soluble, stable and can be oxidised).
- Outline the role of polysaccharides as energy storage compounds (i.e. glycogen, starch) and as structural components (i.e. cellulose).
- Explain the role of glycoproteins in cell—cell recognition (e.g. ABO antigens).
- Describe lipids such as fats, oils, waxes and steroids as hydrophobic substances in living organisms that dissolve in non-polar solvents.
- Explain the difference between saturated, monounsaturated and polyunsaturated fatty acids.
- Recognise that triglycerides and phospholipids are types of lipids that form by condensation reactions and triglycerides are suited to long-term energy storage.



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- Recall that triglycerides are used as thermal insulators to body temperature and habitat.
- Describe the formation of phospholipid bilayers as a consequence of the hydrophobic and hydrophilic regions.
- Define the term 'amphipathic'.
- Summarise the ability of non-polar steroids (e.g. oestradiol and testosterone) to pass through the phospholipid bilayer.
- Identify compounds as steroids from molecular diagrams.

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Investigation

Section	Student... (0/0)	Feedback	Print (/study/app/bio/sid-422-cid-755105/book/investigation-id-44753/print/)	Assign
Section	Student... (0/0)	Feedback	Print (/study/app/bio/sid-422-cid-755105/book/summary-and-key-terms-id-44687/print/)	Assign

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills – Experimenting with new strategies for learning
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity and classroom discussion

Your task

Trans fats are a type of unsaturated fat that is industrially produced and used in the food industry. They have been found to have many health risks. You can read this article (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3551118/>) to learn more.

Figure 1 shows data obtained from the U.S. Department of Agriculture Economic Service in which the mean amount of trans fats per serving in grams (g) was monitored for different food products over the years 2005–2010. Use **Figure 1** to answer the following questions.



Student
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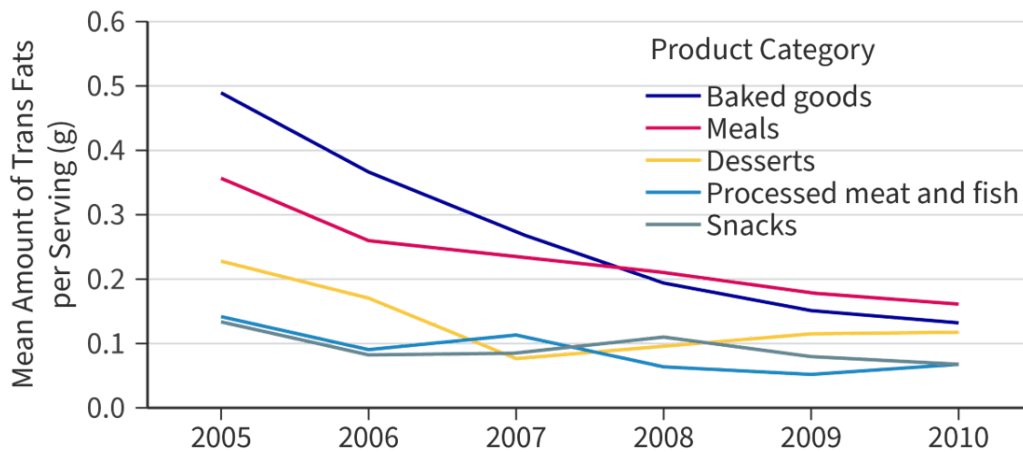


Figure 1. Mean trans fats per serving of different food products, 2005–2010.

Data source: Figures from [USDA Economic Service \(https://www.ers.usda.gov/\)](https://www.ers.usda.gov/) are in the [public domain \(https://creativecommons.org/publicdomain/zero/1.0/\)](https://creativecommons.org/publicdomain/zero/1.0/)

More information for figure 1

The line graph illustrates the mean amount of trans fats per serving in grams for various food categories from 2005 to 2010. The X-axis represents the years, ranging from 2005 to 2010, and the Y-axis indicates the mean amount of trans fats per serving in grams, ranging from 0 to 0.6 grams. Five categories are shown with distinct lines: Baked goods (blue), Meals (red), Desserts (yellow), Processed meat and fish (light blue), and Snacks (gray).

Over the years, all categories show a general decline in trans fat levels. Baked goods initially have the highest level of trans fats, starting above 0.5 grams in 2005, decreasing to below 0.2 grams by 2010. Meals follow a similar trend, starting around 0.3 grams and decreasing slightly more sharply, aligning close to the baked goods by 2010. Desserts start between 0.2 and 0.3 grams, dropping under 0.1 grams in 2010. Processed meat and fish, as well as Snacks, begin with less than 0.1 grams and decrease slightly over time, maintaining a consistently lower level compared to other categories throughout the period.

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Section

Student... (0/0)

Feedback

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Assign

1. Which product category had the greatest mean amount of trans fats per serving in 2005?

2. Which product category had the greatest mean amount of trans fats per serving in 2008?

3. Which product had the least difference in trans fats between 2005 and 2010?



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4. Describe the overall trend in the data.
5. Suggest reasons for this overall trend.
6. This data provides information for various food product categories. Suggest two ways to expand the data set.

Once you have answered the questions, be prepared to discuss your answers with your class and teacher.

B1. Form and function: Molecules / B1.1 Carbohydrates and lipids

Reflection

Section

Student... (0/0)



Feedback



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Assign



Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.



Reflection

Now that you've completed this subtopic, let's come back to the guiding question introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43530/).

- In what ways do variations in form allow diversity of function in carbohydrates and lipids?
- How do carbohydrates and lipids compare as energy storage compounds?



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With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

Section

Student... (0/0)



Feedback



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Assign

You can use the following questions to guide you:

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of-lipids-id-44588/print/)

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

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Submit

Rate subtopic B1.1 Carbohydrates and lipids

Help us improve the content and user experience.



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