3 Biological Molecules

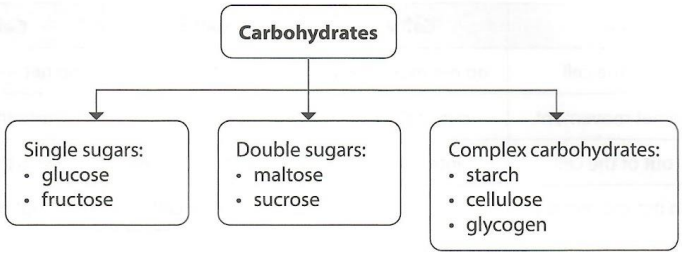
Study Station ▸▸

A Carbohydrates

Learning Outcomes

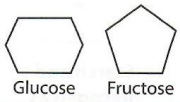
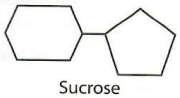
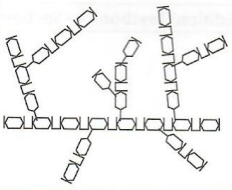
- State the main role of carbohydrates as an immediate source of energy in living organisms.
- State that large molecules are synthesised from smaller basic units, e.g., cellulose, glycogen and starch are formed from glucose.

1. Carbohydrates are classified into three groups.

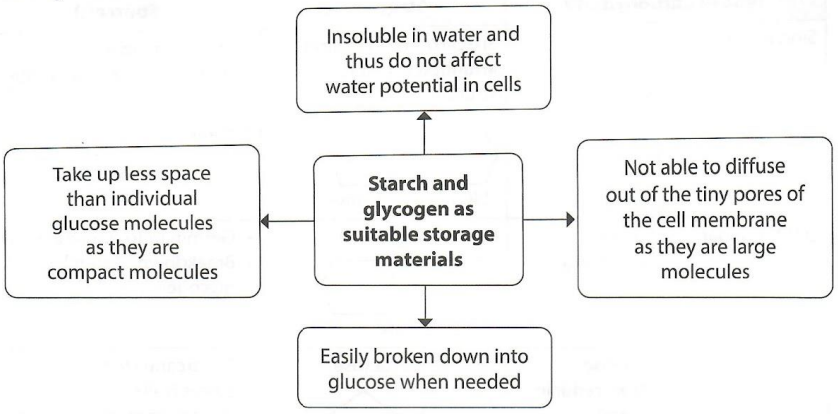


2. **Single sugars** are the basic units of carbohydrates. They can pass through cell membranes easily.
   - Glucose and fructose are common single sugars. They have the same chemical formula but their atoms are arranged differently, giving them different properties.
3. **Double sugars** are made up of two single sugars joined together.
   - A double sugar can be split into two single sugars with the action of an enzyme. When mixed with the enzyme maltase, maltose splits to form two glucose molecules.
4. A **complex carbohydrate** is made up of many single sugar molecules joined together to make a larger molecule.
   - **Starch** is the storage form of carbohydrates in plants.
   - **Cellulose** is found in plant cell walls which protect plants from bursting and damage. Our intestines cannot digest cellulose. It serves as dietary fibre to prevent constipation.
   - **Glycogen** is the storage form of carbohydrates in animals.

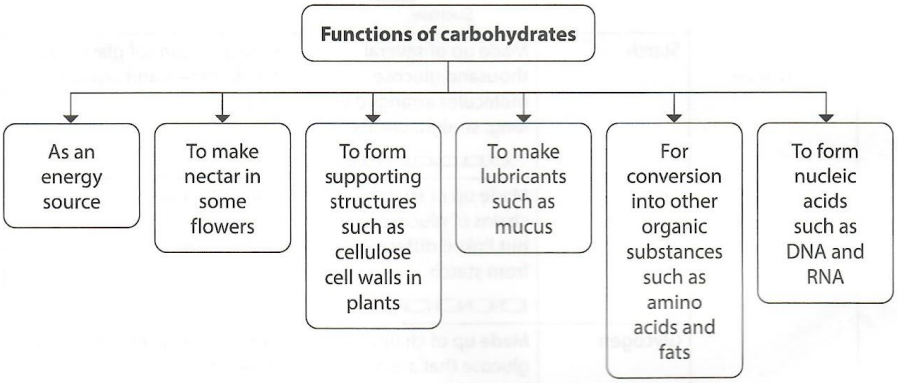
5. The table below describes the structure and sources of carbohydrates.

Type of Carbohydrate		Structure	Source(s)
Single sugar	Glucose	Six-carbon compound arranged in a ring structure  Glucose Fructose	• Leaves of plants • Animals (in small quantities)
	Fructose		• Fruits and vegetables • Honey
Double sugar	Maltose (Reducing sugar)	Glucose + Glucose  Maltose	• Germinating grains e.g. malt • Breakdown of starch or glycogen in animals
	Sucrose (Non-reducing sugar)	Glucose + Fructose  Sucrose	• Sugarcane stems • Sweet fruits • Storage roots e.g. carrots
Complex carbohydrate	Starch	Made up of several thousand glucose molecules arranged in long, straight chains 	Storage organs of plants like potato tubers and tapioca roots
	Cellulose	Made up of straight chains of glucose but linked differently from starch 	Cell walls of plants
	Glycogen	Made up of chains of glucose that are highly branched 	Stored in the liver and muscles of animals

6. The diagram below shows the characteristics of starch and glycogen that make them suitable storage materials.



7. The diagram below shows the important functions of carbohydrates in animals and plants.



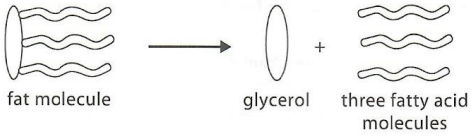
Link Discover Biology (3rd Edition) Textbook — Section 3.1

B Fats

Learning Outcomes

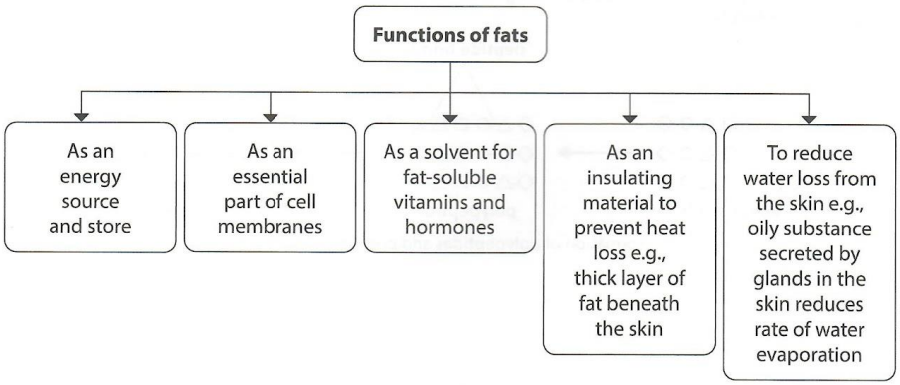
- State the main role of fats for insulation and long-term storage of energy in living organisms.
- State that large fat molecules are synthesised from smaller basic units such as glycerol and fatty acids.

1. **Fats** are a type of lipid.
2. Each fat molecule is made from a glycerol and three fatty acid molecules.



Breakdown of fats

3. Fats are insoluble in water but soluble in organic solvents such as ethanol.
4. Fats can be found in both animal and plant foods.
   - Animal sources include fish, such as herring and salmon, fatty red meat and dairy products, such as butter and cheese.
   - Plant sources include olives, nuts, peas, beans and seeds of castor and palm.
5. The diagram below shows the important functions of fats in animals and plants.



6. Fats have a higher energy value compared to carbohydrates and function as a long-term store of energy especially in animals.

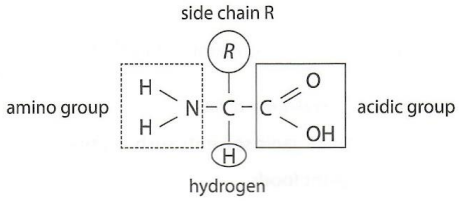
Link Discover Biology (3rd Edition) Textbook — Section 3.2

C Proteins

Learning Outcomes

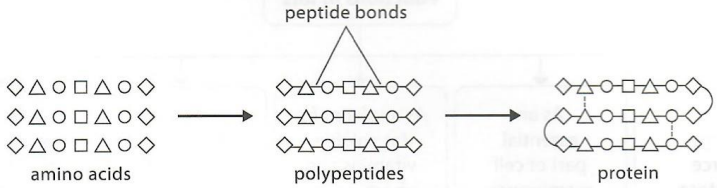
- State the main role of proteins for growth and repair in cells in living organisms.
- State that large molecules are synthesised from smaller basic units, e.g. proteins and polypeptides are formed from amino acids.

1. **Proteins** are composed of compounds known as amino acids.
2. Each amino acid is made up of an amino group (**-NH_2**), an acidic group (**-COOH**) and a side chain (***R***). The side chain, *R*, can sometimes contain sulfur. There are 20 naturally occurring amino acids, each differing in their *R* groups.



General formula for an amino acid

3. Amino acids are combined in a reaction to form strong **peptide bonds**.
4. Many amino acids are combined to form a **polypeptide**.
5. One or more polypeptide chains fold together to form a complex three-dimensional protein molecule.



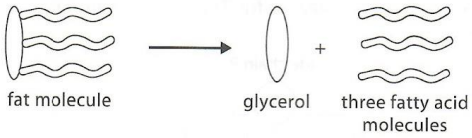
Formation of polypeptides and protein molecules

B Fats

Learning Outcomes

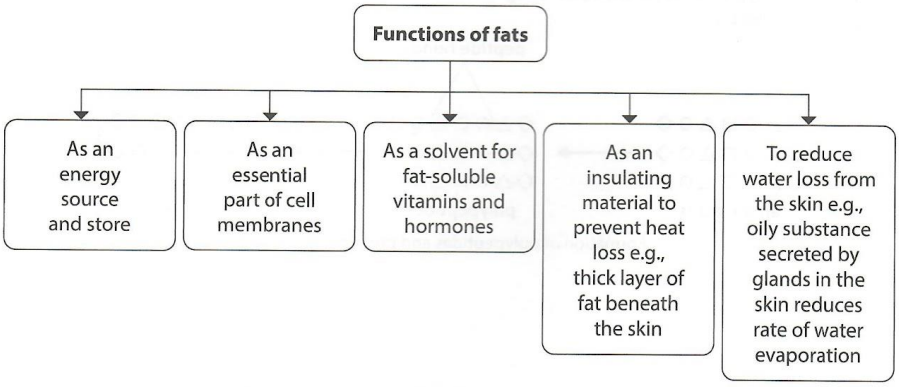
- State the main role of fats for insulation and long-term storage of energy in living organisms.
- State that large fat molecules are synthesised from smaller basic units such as glycerol and fatty acids.

1. **Fats** are a type of lipid.
2. Each fat molecule is made from a glycerol and three fatty acid molecules.



Breakdown of fats

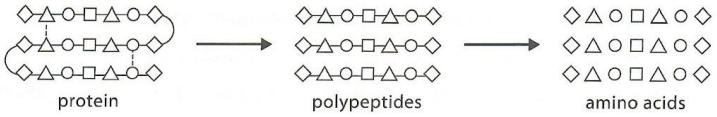
3. Fats are insoluble in water but soluble in organic solvents such as ethanol.
4. Fats can be found in both animal and plant foods.
   - Animal sources include fish, such as herring and salmon, fatty red meat and dairy products, such as butter and cheese.
   - Plant sources include olives, nuts, peas, beans and seeds of castor and palm.
5. The diagram below shows the important functions of fats in animals and plants.



6. Fats have a higher energy value compared to carbohydrates and function as a long-term store of energy especially in animals.

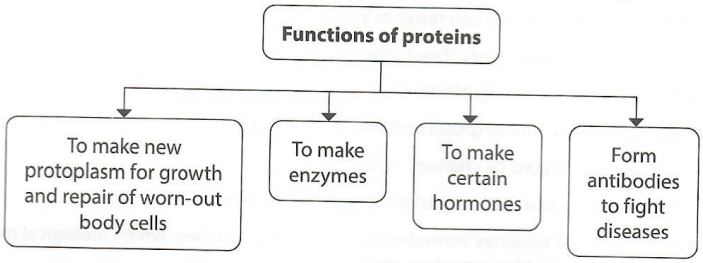
Link Discover Biology (3rd Edition) Textbook — Section 3.2

6. Proteins can be partially broken down to polypeptides and completely broken down to amino acids.



Breaking down of protein molecules

7. The three-dimensional structure of proteins is affected by exposure to high temperatures or extreme changes in pH. The protein loses its shape and function and is said to be denatured.
8. Proteins can be found in both animal and plant foods.
   - Animal sources include milk, eggs, seafood, chicken and lean meat.
   - Plant sources include soya beans, nuts, grains and vegetables.
9. The diagram below shows the important functions of proteins in animals and plants.

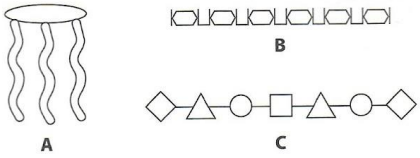


10. Insufficient intake of proteins in a child's diet, or protein deficiency, may lead to a disease called kwashiorkor. The symptoms include scaly, cracked skin and a pot-belly appearance.
11. Carbohydrates, fats and proteins are too large to pass through the cell surface membranes and thus, must be broken down by enzymes during digestion before they can be absorbed by the body.

Link Discover Biology (3rd Edition) Textbook — Section 3.3

Checkpoint 3.1

1. Which of the following statements about complex carbohydrates is **false**?
   - **A** Complex carbohydrates are made up of long chains of glucose molecules.
   - **B** Sucrose is a complex carbohydrate made up of one glucose and one fructose molecule joined together.
   - **C** Animals store complex carbohydrates in the form of glycogen in the liver and muscles.
   - **D** Cellulose is an important complex carbohydrate that makes up the cell wall of plants.
2. Which of the following statements about fats is **true**?
   - **A** Fats consist of glycogen and fatty acids.
   - **B** Fats can function as long-term energy storage.
   - **C** Fats are water-soluble.
   - **D** An insufficient intake of fats can result in kwashiorkor.
3. Which of the following statements about proteins is **false**?
   - **A** Amino acids are the building blocks of protein.
   - **B** Amino acids have an amino group and an acidic group.
   - **C** Proteins are not affected by changes in pH.
   - **D** High temperatures can cause a protein to lose its function.
4. Tennis players often eat bananas immediately before long matches. Which biological molecule in bananas is most important for providing energy?
   - **A** Fats
   - **B** Polypeptide
   - **C** Protein
   - **D** Carbohydrates
5. Three types of biological molecules are shown below.



   (a) Identify the small units that make up each molecule.

   (b) Explain why these large molecules need to be broken down into their small units in the body.

Tip

The basic units of large biological molecules have been asked in examination questions. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2020 Paper 1 Q22 or N GCE N(A) Level Science (Biology) Sep/Oct 2018 Paper 5 Q4.

D Food Tests

Learning Outcome

- Describe and carry out tests for the presence of reducing sugars, starch, fats, and proteins.

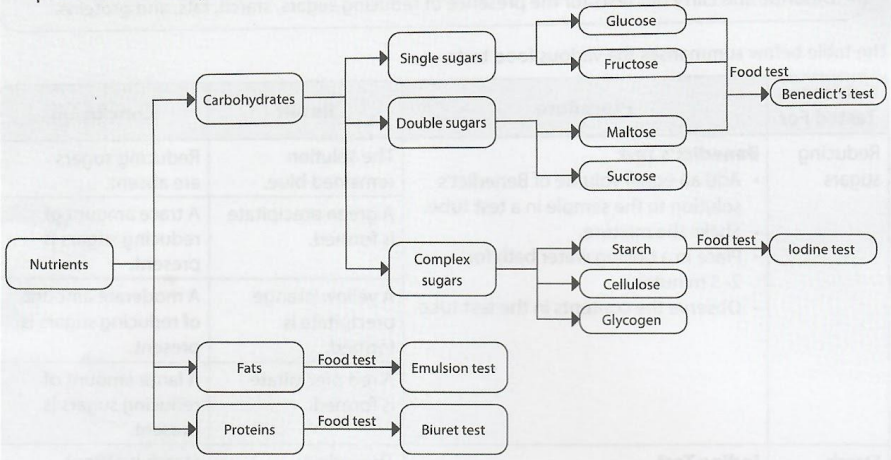
The table below summarises the various food tests.

Substance Tested For	Procedure	Result	Conclusion
Reducing sugars	**Benedict's Test** • Add an equal volume of Benedict's solution to the sample in a test tube. • Shake the mixture. • Place in a boiling water bath for 2–3 minutes. • Observe the contents in the test tube.	The solution remained blue.	Reducing sugars are absent.
		A green precipitate is formed.	A trace amount of reducing sugars is present.
		A yellow/orange precipitate is formed.	A moderate amount of reducing sugars is present.
		A red precipitate is formed.	A large amount of reducing sugars is present.
Starch	**Iodine Test** Add a few drops of iodine solution to the sample.	The iodine remained brown.	Starch is absent.
		The iodine turned from brown to blue-black.	Starch is present.
Fats	**Emulsion Test** • For a liquid sample: – Add 2 cm^3 of ethanol to a drop of the sample in a test tube. – Shake the mixture. – Add 2 cm^3 of water and shake the mixture. • For a solid sample: – Crush the sample into small pieces and place the pieces in a test tube. – Add 2 cm^3 of ethanol. – Shake the mixture. – Let solid particles settle. – Decant ethanol into another test tube with 2 cm^3 of water.	The mixture remained clear.	Fats are absent.
		A white emulsion is formed.	Fats are present.
Proteins	**Biuret Test** • Add 2 cm^3 of Biuret solution (made of sodium hydroxide and copper(II) sulfate) to 2 cm^3 of the sample. • Shake the mixture. • Let the mixture stand for five minutes.	The mixture remained blue.	Proteins are absent.
		The mixture turned from blue to violet.	Proteins are present.

Link Discover Biology (3rd Edition) Textbook — Sections 3.1–3.3

Tip

In answering questions on nutrients, take note of the food tests that identify the nutrients present in the samples.



Worked Example 3.1

The table below shows the results of various food tests. Which types of food should a person consume immediately before going to the gym for a weight-lifting regime?

Food Item	Test	Result
1	Benedict's test	Brick-red precipitate formed
2	Biuret test	Blue solution turned violet
3	Ethanol emulsion test	White emulsion formed
4	Iodine test	Iodine turned from brown to blue-black

A 2 only

B 1 and 2 only

C 1, 2 and 3 only

D 1, 2, 3 and 4

Solution

Option **B** is the correct answer.

Explanation

- The brick-red precipitate in Benedict's test indicates the presence of reducing sugars which can provide the energy needed immediately before a weight-lifting session.
- The violet colour in Biuret's test indicates the presence of proteins which are needed to support muscle growth.
- Starch and fats are storage forms of energy which are not immediately needed before a gym session.

Checkpoint 3.2

1. A food sample produced a white emulsion when ethanol and water were added to it. A brick-red precipitate was formed when Benedict's solution was added to it. What classes of food are present in the food sample?

   A Fats and starch

   B Reducing sugars and starch

   C Fats and reducing sugars

   D Reducing sugars and proteins

2. Food tests were carried out on four different food samples. The results below show the final colour change after the respective tests.

Food Sample	Food Test			
	Benedict's	Biuret	Iodine	Ethanol
A	Blue	Blue	Blue-black	Clear
B	Blue	Violet	Brown	Clear
C	Blue	Blue	Brown	White emulsion
D	Red	Blue	Brown	Clear

   (a) Identify the classes of food present in samples **A**, **B** and **C**.

   (b) Name the type of biological molecule present in sample **D**.

Tip

Questions requiring students to identify biological molecules from food test results have appeared in the examinations. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2019 Paper 4 Q24 or N GCE N(A) Level Science (Biology) Sep/Oct 2018 Paper 5 Q5.

Common Error

✗ Benedict's test gives positive results for single sugars only.

✓ Benedict's test gives positive results for reducing sugars only.

Explanation

Reducing sugars include all single sugars and the double sugars lactose and maltose. Benedict's test will not show a positive result for sucrose and all complex carbohydrates.

Test Station ▸▸

1. Which of the following rows correctly identifies the basic units of glycogen, starch, proteins and fats?

	Glycogen	Starch	Proteins	Fats
A	Fatty acids and glycerol	Amino acids	Glucose	Amino acids
B	Amino acids	Glucose	Amino acids	Fatty acids and glycerol
C	Glucose	Glucose	Amino acids	Fatty acids and glycerol
D	Glucose	Amino acids	Glucose	Amino acids and glycerol

2. Ripe bananas taste best as they are sweet. Various food tests were carried out on some bananas. Using the results of food tests shown below, which one of the following is most likely the result for ripe bananas?

	Benedict's Test	Iodine Test	Biuret Test
A	Green precipitate formed	Turned from brown to blue-black	Remained blue
B	Red precipitate formed	Turned from brown to blue-black	Remained blue
C	Green precipitate formed	Remained brown	Turned from blue to violet
D	Red precipitate formed	Remained brown	Turned from blue to violet

3. Four different samples containing fructose, sucrose, lactose and starch were completely broken down and then analysed using paper chromatography. Paper chromatography is an analytical method used to separate substances into their individual components.

   The results are shown in Figure 3.1.

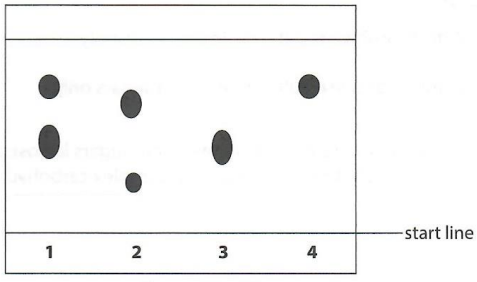


Figure 3.1

(a) Explain which of these samples is/are double sugars. [2]

(b) Explain which of these samples is/are potentially starch. [2]

(c) Identify another class of carbohydrate that will give the same chromatography result as in (b). [1]

4. Seals live in the cold waters of the north and south poles. They have a thick layer of blubber under their skin as shown in Figure 3.2.

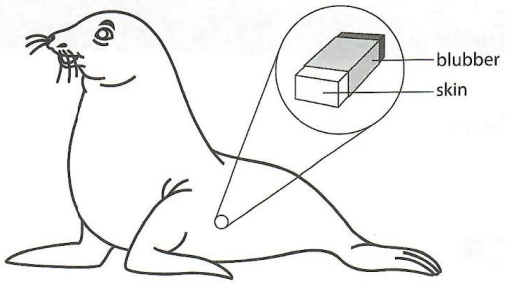


Figure 3.2

(a) State what biological molecule a seal's blubber is made of. [1]

(b) State the characteristic of (a) that allows seals to live in cold climates. [1]

(c) Name a test and the corresponding observation to confirm your answer in (a). [2]

(d) People living in cold climates consume seals' blubber for food. State the small molecules produced when blubber is broken down in the body. [2]

5. Amy wants to test for the presence of proteins in two food samples.

(a) What test would Amy have to conduct? [1]

(b) The two food samples were banana and milk. What would Amy's observations of the food test conducted be and what conclusion could she make? [4]

(c) Nicole, Amy's classmate, decided to add iodine to a small portion of each food sample. In which sample would she observe a blue-black colour? [1]