Chapter 4 – Nutrients

4.1 The Need for Food

Importance of food:

<table>
<tr><th>Importance</th><th>Explanation</th></tr>
<tr><td>1. Provides energy</td><td>• Photosynthesis (green plants)
▪ Use light energy from Sun
▪ Convert raw materials → food (carbohydrates)
• Food: contain chemical energy
→ animals get stored energy
1) consume green plants
2) consume organisms that feed on green plants</td></tr>
<tr><td>2. Provides raw materials
→ make new protoplasm</td><td>Carry out processes:
1) Grow
2) Reproduce
3) Repair worn-out parts</td></tr>
<tr><td>3. Stay healthy</td><td>Examples
<table>
<tr><th>Nutrient</th><th>Distribution</th><th>Function</th></tr>
<tr><td>1) Vitamin C</td><td>Limes</td><td>Prevents gum bleeding & teeth fall out</td></tr>
<tr><td>2) Calcium</td><td>Milk</td><td>Keep bones & teeth strong</td></tr>
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Nutrients
1) **Carbohydrates**
2) **Fats**
3) **Proteins**

4.2 Water

Functions of water in animals

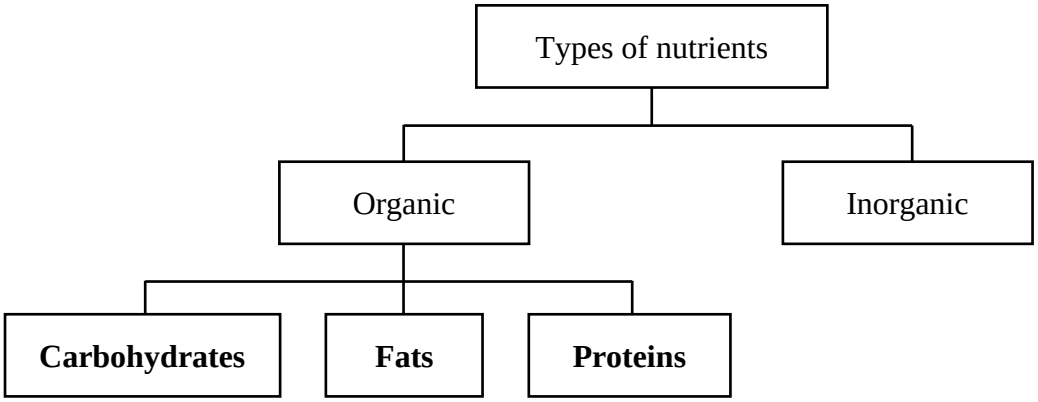
Function	Explanation
1. **Solvent** – chemical reactions	Digestion: hydrolysis of carbo, fats, proteins
2. **Main component** – protoplasm & body fluids	(a) digestive juices (b) blood (c) lubricant found in joints
3. Regulate body **temperature**	Produce sweat to cool body down
4. **Transport** dissolved substances within body	Digested products: small intestine → other parts Waste products → removal

Functions of water in plants

Function	Explanation
1. **Photosynthesis**	
2. Keep plant cells **turgid** & upright	
3. **Transport** mineral salts	Roots → xylem → leaves
4. **Transport** food substances	Leaves → phloem → rest of plant

Amount of water needed

Factor	Explanation
1. **Activeness**	Need more water 1) Play sports 2) Carry out physical labour
2. **Healthiness**	Diseases (diabetes) → pass more urine
3. **Environmental conditions**	• Hot & dry climates: more water • Live for long time: adapted → less water



Summary of nutrients – organic molecules

Nutrient	Elements	Composition	Examples	Test	Function
Carbohydrates	1. C 2. H 3. O H:O = 2:1	1. Monosaccharide ($C_6H_{12}O_6$)	1) Glucose 2) Fructose 3) Galactose	Benedict's test Iodine test	1. Substrate for respiration, provide energy for cell activities 2. Form supporting structures 3. Converted into organic compounds (a) cellulose (d) nucleic acids (b) amino acids (e) lubricants (c) fats (f) nectar 4. Form nucleic acids 5. Synthesise lubricants 6. Synthesise nectar
		2. Disaccharide ($C_{12}H_{22}O_{11}$)	1) Maltose 2) Sucrose 3) Lactose		
		3. Polysaccharide ($C_mH_{2n}O_n$)	1) Starch 2) Cellulose 3) Glycogen		
Fats	1. C 2. H 3. O H:O > 2:1	1. Glycerol 2. Fatty acids	Tristearin (beef fat)	Ethanol emulsion test	1. Source and store energy 2. Prevent excessive heat loss (insulating) 3. Solvent for fat-soluble vitamins 4. Essential part of protoplasm 5. Reduce water loss from skin surface (form hydrophobic layer – prevent water from evaporating)
Proteins	1. C 2. H 3. O 4. N 5. S	Amino acids 1. Amino group (-NH2) 2. Acidic group (-COOH) 3. Side chain (R)	Millions	Biuret test	1. Synthesise new protoplasm (growth & repair worn-out body cells) 2. Synthesise enzymes & hormones 3. Form antibodies

Tests

Benedict's test	**Iodine test**	**Ethanol emulsion test**	**Biuret test**
Reducing sugars	Starch	Fats	Proteins
Benedict's solution	Iodine solution	Ethanol + water	Biuret solution
1. Place food sample into test tube 2. Add Benedict's solution 3. Shake mixture, boil in water bath	Add few drops of iodine solution to substance	Liquid food 1. Place in test tube 2. Add $2cm^3$ ethanol 3. Shake mixture thoroughly 4. Add water, shake	1. Add sodium hydroxide solution (NaOH) 2. Add copper(II) sulfate ($CuSO_4$) drop by drop, shake after every drop

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<td></td>
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<td>Solid food
1. Grind, place in test tube
2. Add 2cm^3 ethanol
3. Shake thoroughly, allow solid particles settle
4. Decant ethanol (pour off top layer) into test tube of 2cm^3 water</td>
<td>OR

Add equal volume of biuret solution to test tube</td>
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<tr>
<td>Colour change in solution
<table>
<tr><th>Colour</th><th>Amount</th></tr>
<tr><td>Blue mixture</td><td>No</td></tr>
<tr><td>Green mixture</td><td>Traces</td></tr>
<tr><td>Yellow / orange mixture</td><td>Moderate</td></tr>
<tr><td>Brick-red precipitate</td><td>Large</td></tr>
</table></td>
<td>Colour change of iodine solution
<table>
<tr><th>Starch</th><th>Colour</th></tr>
<tr><td>Present (+ve)</td><td>Blue-black</td></tr>
<tr><td>Absent (-ve)</td><td>Brown</td></tr>
</table></td>
<td>Change in mixture
<table>
<tr><th>Fats</th><th>Result</th></tr>
<tr><td>Present (+ve)</td><td>Cloudy white emulsion</td></tr>
<tr><td>Absent (-ve)</td><td>Clear solution</td></tr>
</table></td>
<td>Colour change
<table>
<tr><th>Proteins</th><th>Colour</th></tr>
<tr><td>Present (+ve)</td><td>Violet</td></tr>
<tr><td>Absent (-ve)</td><td>Blue</td></tr>
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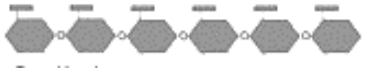
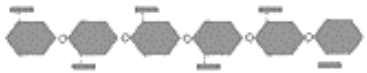
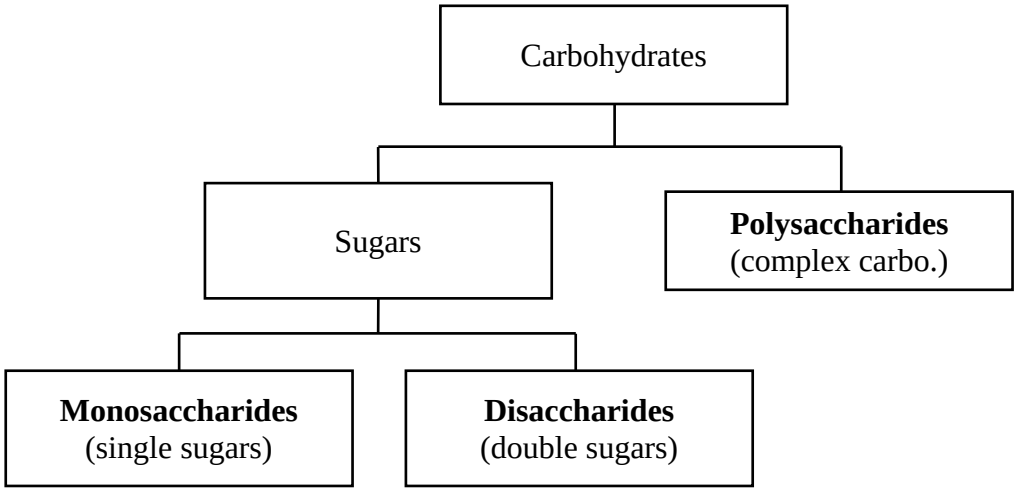
4.3 Carbohydrates

Structures

Starch	
Cellulose	
Glycogen	



Classification	Characteristics			
	Examples	Structure	Role	Occurrence
Monosaccharides	1. **Glucose**		• × further digested into smaller molecules • Pass thru cell membrane → absorbed into cell	Plant-based products, all animals
	2. **Fructose**			Fruit, vegetables, honey
	3. **Galactose**			Milk, some fruit and vegetables
Disaccharides	1. **Maltose**	Glucose + glucose		Grains, malt
	2. **Sucrose**	Glucose + fructose		Root vegetables (carrot)
	3. **Lactose**	Glucose + galactose		Milk
Polysaccharides	1. **Starch**	Glucose molecules joined together	• Storage form of carbo. in plants • Digested → glucose (provide energy for cellular activities)	Storage organs of plants (potato tubers, tapioca)
	2. **Cellulose**	Glucose molecules joined together (different bonds)	• Protects plants cells from bursting / damage • Cannot be digested in human intestines • Serve as dietary fibres (prevent constipation)	Cell wall of plants
	3. **Glycogen**	Glucose molecules joined together (branched molecule)	• Storage form of carbo. in mammals • Digested → glucose (provide energy for cellular activities)	Stored in liver & muscles of mammals

Benedict's test

- Reducing sugars
  1. glucose
  2. fructose
  3. galactose
  4. maltose
  5. lactose
- Cannot identify what type of reducing sugar present

Condensation

Chemical reaction in which 2 simple molecules are joined together to form a larger molecule with the removal of 1 water molecule

$C_6H_{12}O_6$ + $C_6H_{12}O_6$ ⟶ $C_{12}H_{22}O_{11}$ + H_2O

monosaccharide — disaccharide — water

Hydrolysis

Chemical reaction in which 1 water molecule is needed to break up a complex molecule into smaller molecules

$C_{12}H_{22}O_{11}$ + H_2O ⟶ $C_6H_{12}O_6$ + $C_6H_{12}O_6$

disaccharide — water — monosaccharide

Stores of glucose

Store glucose in form of:

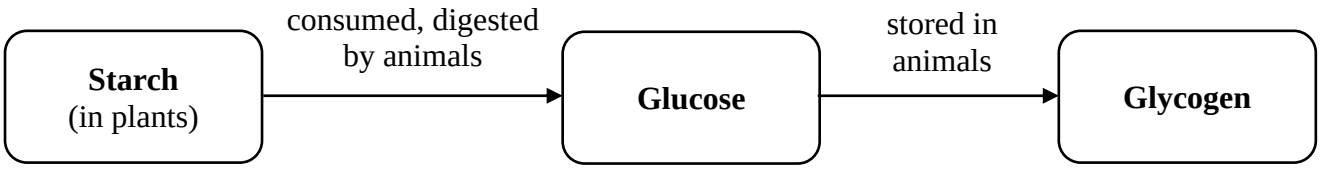
Animals	Plants
Glycogen	**Starch**

Animals: × make & store starch in bodies

- Get carbohydrates from plants in form of starch
- Glycogen: stored mainly in liver and muscles

Suitable as storage materials

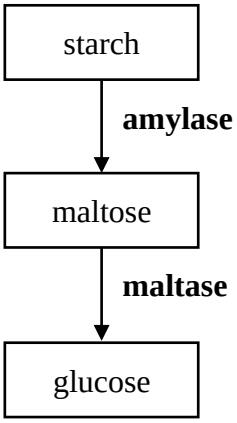
Properties	Explanation
1. **Insoluble** in water	× change water potential in cells
2. **Large** molecules	× diffuse through cell membranes, will not be lost from cell
3. Easily **hydrolysed** → glucose	when needed (tissue respiration)
4. Molecules have **compact shapes**	Occupy less space than all individual glucose molecules that make up a glycogen / starch molecule



Complete hydrolysis of starch

Alimentary canal: starch hydrolysed and digested

Process	Hydrolysis
Starch → Maltose	• Bonds within polysaccharide are broken, release glucose molecules • Digestion: starch $\xrightarrow{\text{amylase}}$ maltose • Amylase digests starch → maltose, does not hydrolyse maltose → glucose
Maltose → Glucose	Hydrolysis: maltose $\xrightarrow{\text{maltase}}$ glucose

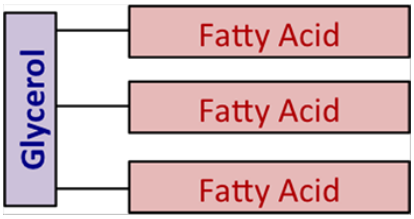


4.4 Fats

What fats are

Fat molecule: made up of

1. **fatty acids**
2. **glycerol**



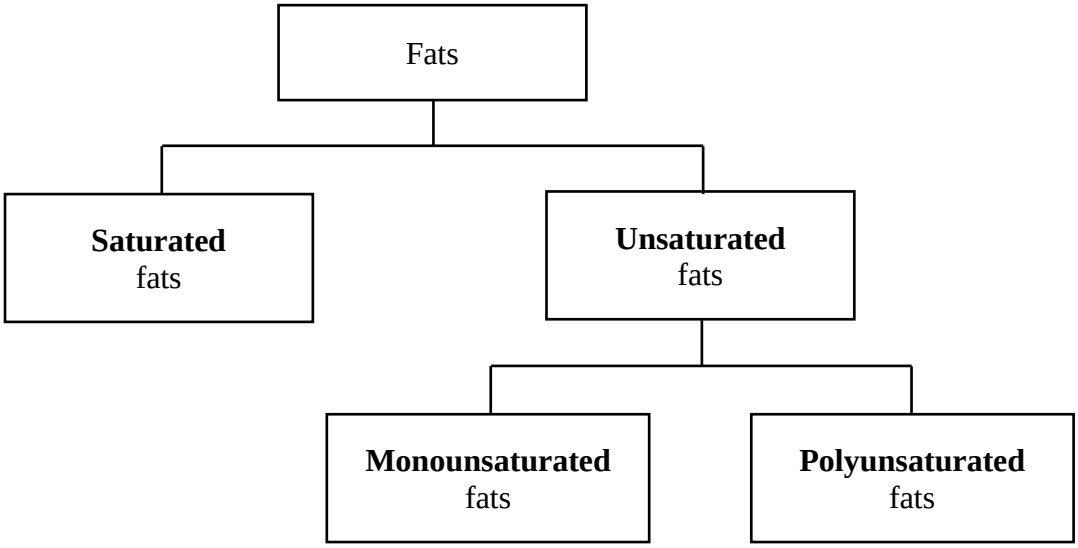
Sources of fats

Rich in fats	Less fats
1. Butter 2. Cheese 3. Fatty meat 4. Olives 5. Nuts 6. Peas 7. Beans 8. Seeds of castor oil & palm oil	1. Meat of most fishes 2. 'White meats' 3. Some fishes 1) herring 2) salmon

Hydrolysis of tristearin (a type of fats)

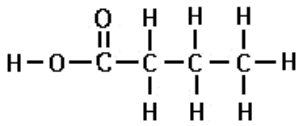
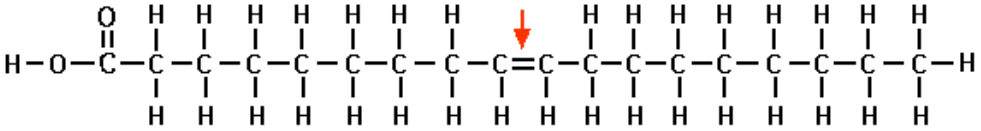
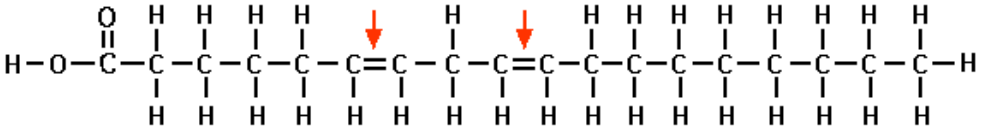
$$\text{Tristearin} + \text{Water} \xrightarrow{\text{lipase}} \text{Glycerol} + \text{Stearic acid}$$

Types of fats



Types of fats	Characteristics			
	State at r.t.	Bond	Fatty acid chain	Cholesterol
Saturated	solid	only C – H	straight	Present together with cholesterol (excess cholesterol – coronary heart disease, gallstone)
Monounsaturated	liquid	only 1 C = C	bent	
Polyunsaturated		> 1 C = C	bent in > 1 place	↓ cholesterol level in blood

Structures

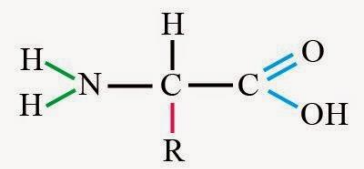
Saturated fats: 
Monounsaturated fats: 
Polyunsaturated fats: 

4.5 Proteins

Amino acids – building blocks of proteins

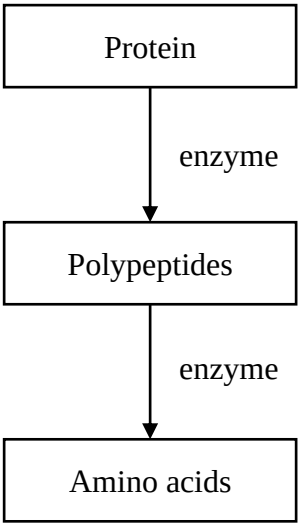
Amino acid

- consists:
  1. amino group (– NH_2)
  2. acidic group (– COOH)
  3. side chain (denoted by *R*) – may contain:
     1) sulfur
     2) acidic groups
     3) amino groups
     4) hydroxyl groups (– OH)
- Examples:
  1) methionine
  2) valine



Formation of protein

- Different R groups → different amino acids
- Different combination of amino acids → different protein molecules
- Protein molecules → linked up by peptide bond, amino acid form polypeptide
- Polypeptide $\xrightarrow{\text{more extensive, coil up}}$ protein



Hydrolysis of proteins

Animal × directly absorb protein molecules

- too large to pass through cell surface membrane
- Broken down by enzymes during digestion
- Digestion: a series of hydrolytic reactions

Source of proteins

Animal foods	Plant foods
1. Milk 2. Eggs 3. Seafood 4. Meat (chicken, lean beef)	1. Soya beans 2. Buts 3. Grains 4. Vegetables (French beans)

Protein deficiency

- 50 ~ 100g of proteins a day
- **kwashiorkor**: disease caused by protein deficiency
    1. swollen stomachs
    2. skins crack and become scaly

Typical questions

Multiple choice questions

1. In the human body, large molecules are synthesised from small molecules.
   Which row is correct for the small molecules required for synthesis of glycogen, lipids and proteins?
   (N2013/P1/Q5)

	glycogen	lipids	proteins
A	amino acids	glucose	glycerol and fatty acids
B	glycerol and amino acids	fatty acids	glucose
C	glycerol and fatty acids	glycerol and amino acids	fatty acids
D	glucose	glycerol and fatty acids	amino acids

2. Three properties of water are listed.
   ① Water cools a surface from which it evaporates.
   ② Water is used as a solvent for many chemicals.
   ③ Water is involved in many metabolic reactions.
   Which of these properties make water suitable to use in a blood transport system?
   (N2014/P1/Q4 / N2018/P1/Q7)

   A 1 and 2
   B 1 and 3
   C 2 only
   D 3 only

3. Which conversion does not take place in the body of a human? (N2015/P1/Q4)
   A amino acids into polypeptides
   B glucose into starch
   C glycerol and fatty acids into fats
   D glycogen into glucose

4. Which row shows features of carbohydrates, fats and proteins? (N2017/P1/Q5)

	carbohydrates	fats	proteins
A	active site present on some types	no active site present	active site present on some types
B	contain the elements carbon, hydrogen and oxygen only	contain the elements carbon, hydrogen and oxygen only	contain the elements carbon, hydrogen, oxygen and nitrogen
C	formed from two different types of molecules	formed from many molecules of the same type	formed from many molecules of the same type
D	give a positive result with the ethanol emulsion test	give a positive result with Benedict's test	give a positive result with biuret test

*active site: region of an enzyme where substrate molecules bind and undergo chemical reaction

Structured questions

1. A volume of 2cm^3 of Benedict's solution is dropped into a solution of ground-up food in a test tube. The test tube is then placed in a beaker of boiling water for five minutes. The contents remain blue in colour. Next, another test tube of the same food solution is boiled with dilute hydrochloric acid. Sodium hydrogen carbonate is then used to neutralise the excess acid. The Benedict's test is repeated on the new test tube. A brick-red precipitate is formed.

   (a) Explain the changes that occurred in the second test tube during the Benedict's test. [2]

   Blue copper(II) ions in Benedict's solution were reduced to brick-red precipitate of copper(I) by the reducing sugar present.

   (b) (i) What was the purpose of adding the dilute hydrochloric acid? [1]

   Break down the sugar in the food solution into reducing sugar.

   (ii) Name the type of reaction involved in (b)(i). [1]

   Neutralisation reaction

   (iii) What do the results of the second test show? [1]

   A brick-red precipitate is formed, hence there is large amount of reducing sugar.

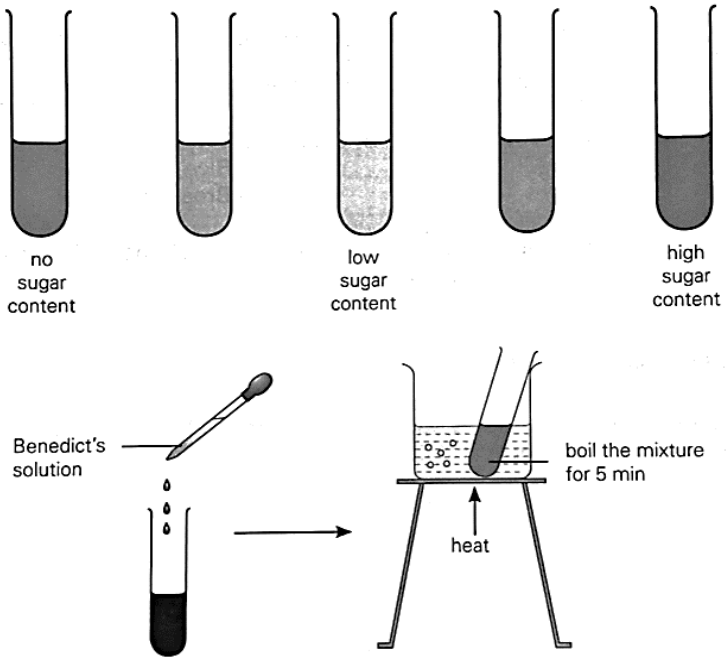
   (c) Name one possible sugar present in the food and the reducing sugar(s) that was / were formed in the second test tube. [2]

   Starch, glucose

   (d) Why did the food have to be ground up and added to water before the tests were carried out? [2]

   This is to increase the surface area, which increases the rate of reaction with the Benedict's solution. It is also easier for the reaction to take place when sugar in the food dissolves in water.

2. An indicative test for the presence of sugar in the urine and the onset of diabetes is the Benedict's test. When Benedict's solution and sugar are heated together, the solution changes colour.



(a) Suggest the colours of the solutions in the leftmost and rightmost test tubes. [2]

Leftmost: blue
Rightmost: brick-red

(b) What is the precipitate that contributes to the colour in the rightmost test tube? [1]

Copper(I) ion

(c) What is a reducing sugar? Give one example of it. [2]

Reducing sugar is a sugar that can act as a reducing agent, example: glucose.

(d) What difference would be observed if an unknown solution were heated before adding Benedict's solution instead of heating both together as shown in the diagram above? Give a reason for this difference. [3]

The difference is that the redox reaction would not be completed in the first case since not enough heat would remain to ensure the reaction to proceed. The reason is that the reaction is organic in nature and depends on sufficient heat to react completely. Therefore, heating the reactant together will be the best option.

(e) Which group of sugars, monosaccharides or disaccharides, is the Benedict's test most likely testing for? What are the exceptions for the other group of sugars? [2]

Monosaccharides.
Maltose, lactose

3. Three tests are carried out to find out if carbohydrates, proteins and fats are present in four kinds of food. The results of the test are shown below.

Food	Benedict's test	Biuret test	Emulsion test
A	Blue solution	Purple solution	Milky white emulsion
B	Orange-red precipitate	Blue solution	Colourless solution
C	Blue solution	Blue solution	Colourless solution
D	Orange precipitate	Blue solution	Milky white emulsion

(a) Which of the following could foods A, B, C and D be?

(i) Beef [1] A
(ii) Rice [1] C
(iii) Apple [1] B
(iv) Breakfast cereal [1] D

(b) All four kinds of food were tested using iodine test. Which food will show an orange-brown colour in the solution? [1]

A (does not contain starch)

4. Refined carbohydrates such as table sugar and flour are highly processed carbohydrates that have much of their nutrients and fibers removed.
   (a) Give one reason why carbohydrates are refined. [1]

   Easier digestion in human body.

   (b) State two examples of food that contain refined carbohydrates. [2]

   White bread, pasta

   (c) Eating food made with refined carbohydrates can leave you feeling hungry more quickly. Give a reason why. [1]

   The human body digests them quickly.

   (d) Explain why you should eat less of food that are made with refined carbohydrates. [2]

   Refined carbohydrates do not contain the nutrients that our body requires.
   As refined carbohydrates are digested quickly, we tend to eat more, resulting in high sugar level in the blood.

   (e) Grains such as barley and oats are also refined. Explain why refined grains are less nutritious than unrefined grains. [2]

   The covering of the grains are rich in nutrients and fiber, refining these grains remove their covering and make them less nutritions.

5. Runners are advised to consume plenty of carbohydrates such as potatoes and pasta days before a marathon. This is called ‘carbo loading’.
   (a) Explain why ‘carbo loading’ is necessary and why it is done several days before a marathon. [4]

   Most of carbohydrates are stored as glycogen in the muscles and liver. Glycogen can be easily broken down for use during prolonged intensive activities.

   (b) Many fruits are high in carbohydrates. However, it is not advisable to eat fruits just before a marathon. Explain why and give an example of fruit that can be consumed before marathon. [4]

   Fruits contain high level of fiber. Too much of fiber may cause stomach problems during a marathon. Hence, it is not advisable to consume fruits before a marathon.
   Banana is an example of a fruit that can be eaten before a marathon as it is high in carbohydrates and low in fiber.

6. Compare the chemical structures of carbohydrates and fats. [3]

   Carbohydrates and fats both are organic molecules made up of the elements carbon, hydrogen and oxygen. In carbohydrates, hydrogen and oxygen atoms are in the ratio 2:1; in fats, oxygen is much less in proportion to hydrogen.

7. Using examples, explain the difference between a condensation and a hydrolysis reaction. [3]

During condensation of glucose molecules, it forms maltose, many simple molecules are chemically joined to form a complex molecule. During hydrolysis of lactose, it forms glucose and galactose, a complex molecule is chemically broken down to form simple molecules.
During condensation, a molecule of water is released whereas a molecule of water is taken in during hydrolysis.

8. The mixtures in the table below were tested with Benedict's solution and iodine solution. Each mixture was created and kept at room temperature for 10 minutes before testing.

Mixture		**Colour of mixture after testing with Benedict's solution**	**Colour of mixture after testing with iodine solution**
W	Saliva + water	blue	brown
X	Starch + water	blue	blue-black
Y	Saliva + starch + water	brick-red precipitate	brown
Z	Saliva (boiled then cooled) + starch + water	blue	blue-black

(a) Write down your observations for mixture Y and Z in the table. [1]

(b) Explain your observations for mixture Z when it was tested with Benedict's solution and iodine solution. [2]

Amylase in the saliva has been denatured upon boiling. Starch is not hydrolysed into reducing sugars and therefore mixture Z remains blue when tested with Benedict's solution and blue-black when tested with iodine solution.

9. Give an account of why water is essential to both plant and animal life. [6]

Key component of many fluids in the body
- In animals, water is a key component of protoplasm of cells, tissue fluids, digestive secretions and blood. [1]

As a solvent and hence transport medium in the body
- In both plant and animal cells, it acts as a solvent to transport dissolved substances. In animals, water helps transport digested products from the small intestines to other parts of the body [1]
- ; and waste products from the cells to be removed. [1]

To help maintain body temperature
- Water is important in maintaining body temperature of animals as it is a component of sweat. As water in sweat evaporates from the skin surface, it takes away latent heat of vapourisation, cooling the body. [1]

Role of water in plant life
- In plant cells, water is an essential raw material for photosynthesis. [1]
- It is also needed to keep plant cells turgid for structural support. [1]
- Finally, water is important in transporting dissolved mineral salts from the soil to the leaves. [1]