Temasek Junior College
IP3 Biology
Topic: Biomolecules – Carbohydrates
Notes

Think Cycle
✓ Know

Learning Outcomes

Candidates should be able to:

(a) Describe the structure of carbohydrates, lipids and proteins and state their role in living organisms. [O and A-levels]

(b) Describe the formation and breakage of the following bonds: [A-levels]

- glycosidic bond
- ester bond
- peptide bond

(c) Define the terms with a named example of the primary structure, secondary structure, tertiary structure and quaternary structure and the bonds involved in each level of structure (details of secondary structure not needed). [A-levels]

(d) Explain how the structure of the following biomolecules relate to their roles in living organisms: [A-levels]

- starch
- glycogen
- haemoglobin

Use the knowledge gained in this section in new situations or to solve related problems.

Outline

I. Introduction
II. Structure of carbohydrates
III. Functions of carbohydrates
IV. Tests for carbohydrates

I. INTRODUCTION

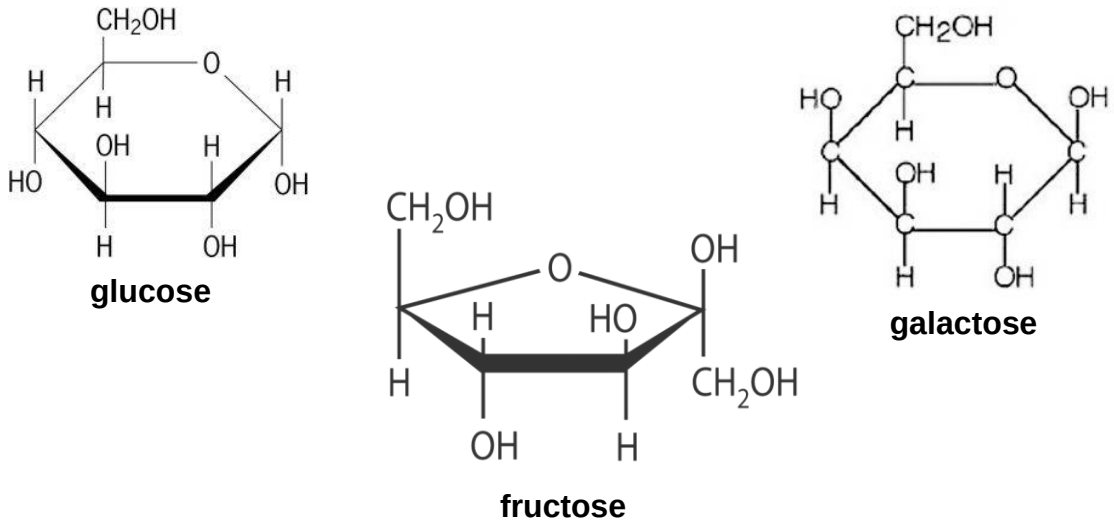
- Carbohydrates are substances that contain the elements <u>carbon, hydrogen and oxygen</u>.
- They have the general formula $C_x(H_2O)_y$, where x and y are variable numbers.

II. STRUCTURE OF CARBOHYDRATES ***LO (a), (b)***

- Carbohydrates are divided into three main classes:
  - Monosaccharides
  - Disaccharides
  - Polysaccharides

1. <u>Monosaccharides</u>

- Defined as a carbohydrate which <u>cannot be hydrolysed to simpler carbohydrate</u>.
- The general formula is $(CH_2O)_n$
- Common examples are glucose, fructose and galactose (hexose sugars)



<u>Fig.1.1 Structure of Monosaccharides</u>

2. Disaccharides

- A disaccharide is formed by a condensation reaction between two monosaccharides – one molecule of water is removed from the pair of monosaccharides (Fig. 1.2 & 1.3).

- Common examples of disaccharides are
  - maltose = glucose + glucose
  - lactose = glucose + galactose
  - sucrose = glucose + fructose

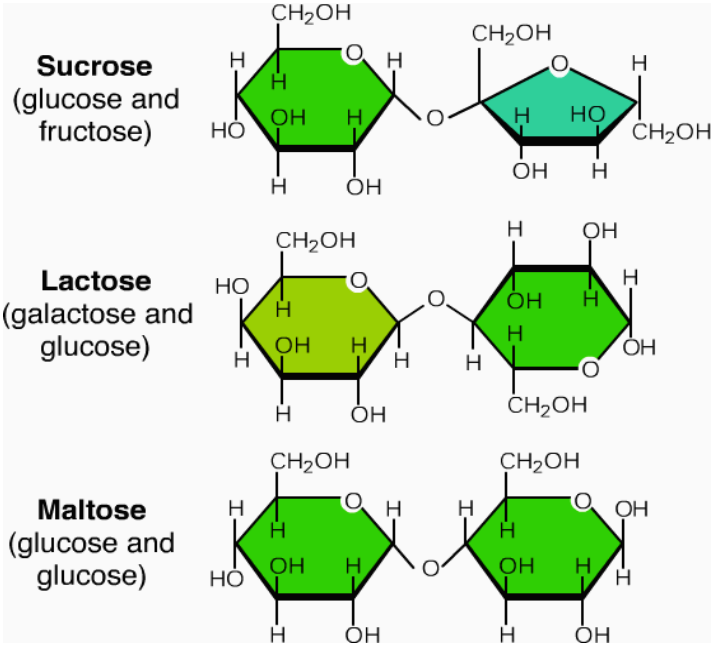


Fig.1.2 Structure of Disaccharides

- The bond formed between the 2 monosaccharides is called the **glycosidic bond**.

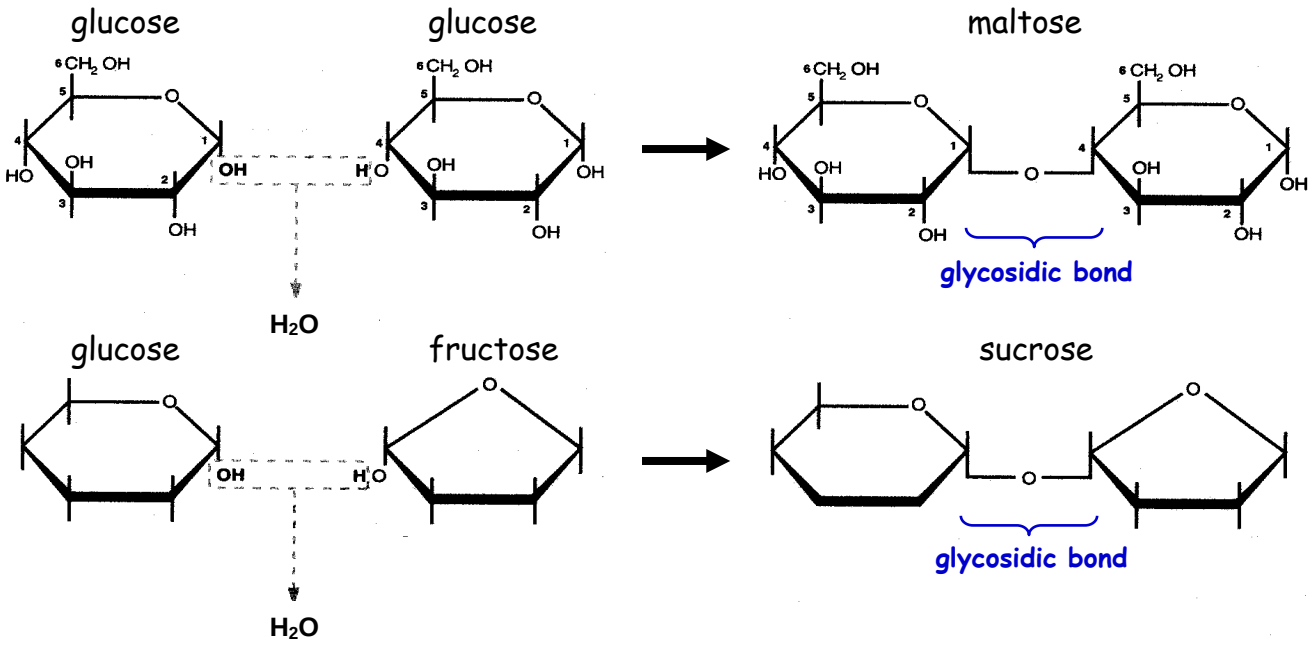


Fig. 1.3 Formation of disaccharides via condensation reaction

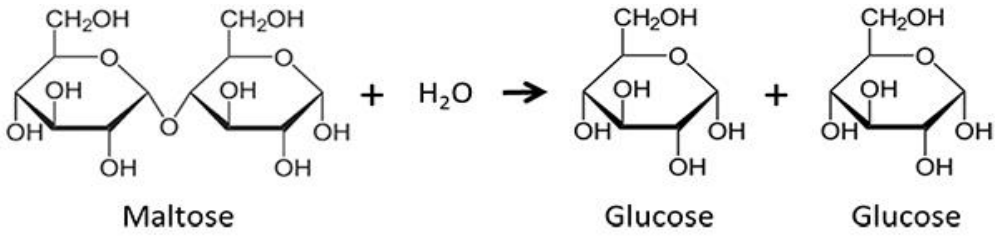


Fig. 1.4 An Example of Hydrolysis of a Disaccharide into two Monosaccharides

3. Polysaccharides *LO (d)*

- Polysaccharides are polymers of monosaccharides.
- Common examples (Fig. 1.5) are
  - Starch (storage polysaccharide in plants)
  - Glycogen (storage polysaccharide in humans)
  - Cellulose (structural polysaccharide in plants)

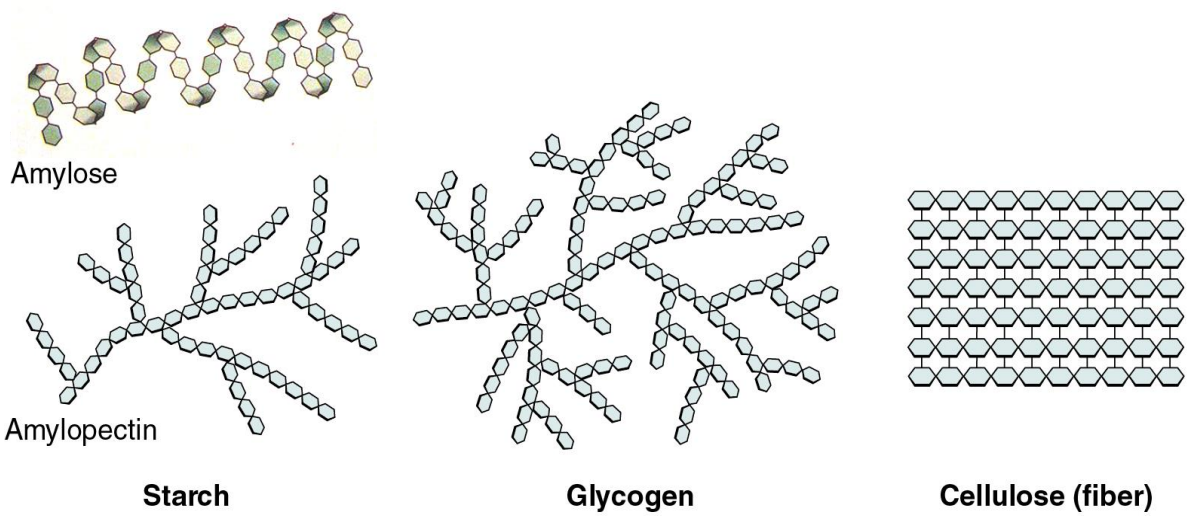


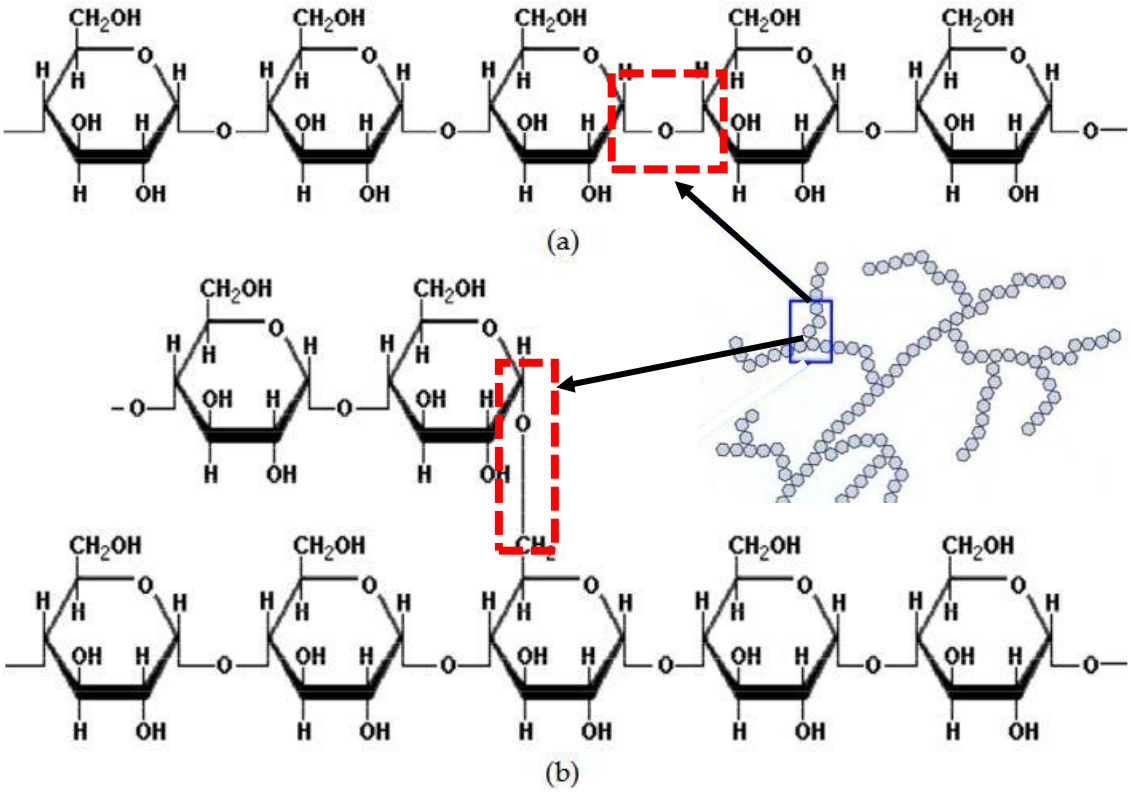
Fig.1.5 Structure of various Polysaccharides

- **Structure of starch**
  - Starch is a polymer of glucose
  - It has two components: amylose and amylopectin (Fig. 1.5).

    1) Amylose
       - It has a straight chain structure with a helical shape (for a more compact structure)
       - Consists of several thousand glucose units joined by glycosidic bonds.

    2) Amylopectin
       - It is also compact but has a highly branched structure.
       - The glucose units within and between the branches are held together by glycosidic bonds (Fig. 1.6)

- It has <u>twice as many glucose units</u> as amylose



<u>Fig. 1.6 Glycosidic bonds in Starch (Amylopectin)</u>

III. FUNCTIONS OF CARBOHYDRATES ***LO (a)***

1. As a <u>source of energy</u>

2. <u>Sucrose</u> is a <u>good transport sugar</u> in phloem of <u>plants</u>.
   - It is very soluble and therefore can be moved in high concentrations
   - Chemically unreactive

3. Polysaccharides such as <u>starch and glycogen are good storage molecules</u>.
   - Large and insoluble (indiffusible through partially permeable membranes)
   - Compact shapes (allow more carbohydrates to be stored in cells)
   - Easily hydrolysed into monosaccharides

4. <u>Cellulose</u> is a <u>good structural polysaccharide</u>.
   - Found in all plant cell wall – a good cell wall material
   - Has good tensile strength.
   - Remains permeable to water and solutes.

5. Monosaccharides are required for <u>synthesis</u> of
   - <u>nucleic acids</u> (deoxyribose is a constituent of DNA, ribose is a constituent of RNA)
   - <u>disaccharides and polysaccharides</u>

IV. TESTS FOR CARBOHYDRATES

The following types of carbohydrates can be detected by using different methods:

1. Reducing sugars
2. Non-reducing sugar
3. Starch

1. Test for Reducing Sugars

- All monosaccharides and some disaccharides (e.g. lactose and maltose) are reducing sugars. However, do note that common table sugar, sucrose, is a **non**-reducing sugar.

- **Principle**:
  - The common test for the presence of reducing sugars is the **Benedict's test**.
  - The test makes use of the ability of these sugars to reduce copper from a valency of 2 to 1.
  - The Benedict's Test involves the use of an alkaline solution of copper(II) sulfate ($CuSO_4$) which is reduced to insoluble copper(I) oxide (Cu_2O) – detected as a brick-red precipitate.
  - Ionic equation:

$$\underset{\text{(blue solution)}}{Cu^{2+}} + e^- \longrightarrow \underset{\text{(brick-red ppt)}}{Cu^+}$$

- **Method**:
  1) To 2 cm^3 of the test sample in a test tube, add an equal volume of Benedict's solution.
  2) Mix well and place the test tube in a boiling water bath for 2 minutes.
  3) Observe any colour change.

- **Observations**:
  - Benedict's test is semi-quantitative, i.e. the greater the amount of reducing sugar, the greater the amount of brick-red precipitate formed.
  - Hence the greater the intensity of red in the final mixture.
  - The colour changes with increasing concentrations of reducing sugar as follows:

No reducing sugar ⟶ *large amounts of reducing sugar*

Blue (solution) → **Green** → **Yellow** → **Brown** → **Red (suspension)**

No precipitate ⟶ *large amounts of precipitate*

2. Test Non-Reducing Sugar (Sucrose)

- If the reducing sugar test turns out negative (remains blue), the non-reducing sugar test can be carried out.

- **Method**:
  1) To 2 cm^3 of the test sample in a test tube, add a few drops of hydrochloric acid.
  2) Heat the mixture for 2 minutes in a hot water bath (this hydrolyses any sucrose present, splitting the molecules to give glucose and fructose)
  3) After two minutes, neutralise the acid by adding sodium hydrogen carbonate until effervescence stops.
  4) Carry out the Benedict's test again.
  5) If there were non-reducing sugars present in the original sample, the test will now turn out to be positive (As the non-reducing sugar has been broken down into reducing sugars, namely glucose and fructose)

3. Test for Starch

- **Method**:
  1) Add a few drops of iodine-potassium iodide solution to the test sample in a test tube or on a white tile.
  2) Observe any colour change.

- **Observations**:
  - The brown (or yellow) solution turns dark blue if starch is present
  - The iodine takes up position in the centre of the amylose helix to form a dark blue starch-iodide complex.
  - The solution remains brown (or yellow) if starch is absent.

End of Carbohydrates Notes