INTRODUCTION

Biological molecules

Introduction

Macromolecules

Large molecules made up of smaller molecules

- **4 main classes of biological molecules:**

Carbohydrates

Proteins

Biomolecules made up of C, H, O and sometimes S and P

Lipids

Nucleic acids

DNA and RNA

Introduction

Are all Macromolecules polymers?

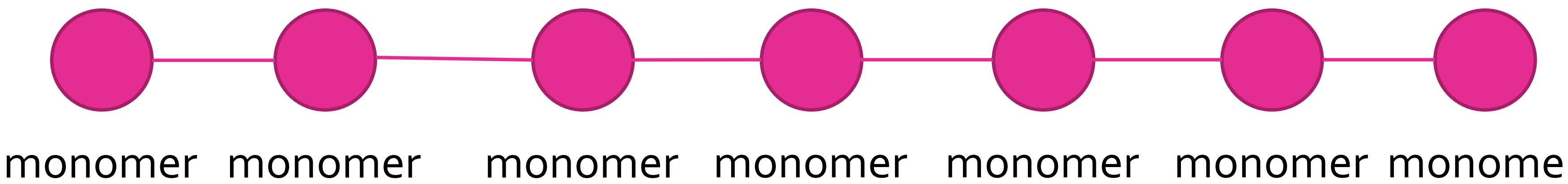
NO!!!

Carbohydrates	can be a polymer (polysaccharide)
Proteins	polymer
Nucleic acids	polymer
Lipids	Not polymer

What are polymers?

long molecules made up of **many repeating** monomers which can be similar or identical

Introduction



Monomers linked by covalent bonds

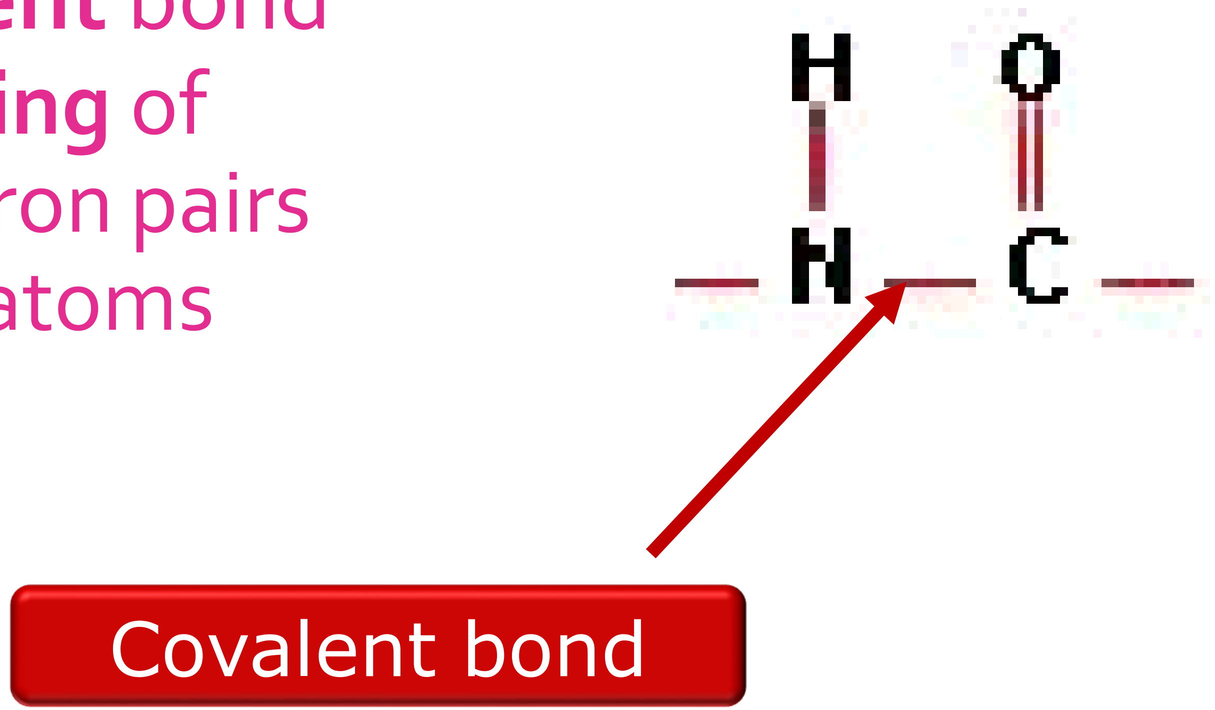
What are polymers?

long molecules made up of **many repeating** <u>monomers</u> which can be <u>similar or identical</u>

Chemical Bonds / Interactions

Covalent bond

- **Sharing** of electron pairs by 2 atoms



Other important bonds / interactions required for subsequent topics

- Hydrogen bond
- Ionic bond
- Hydrophobic interactions

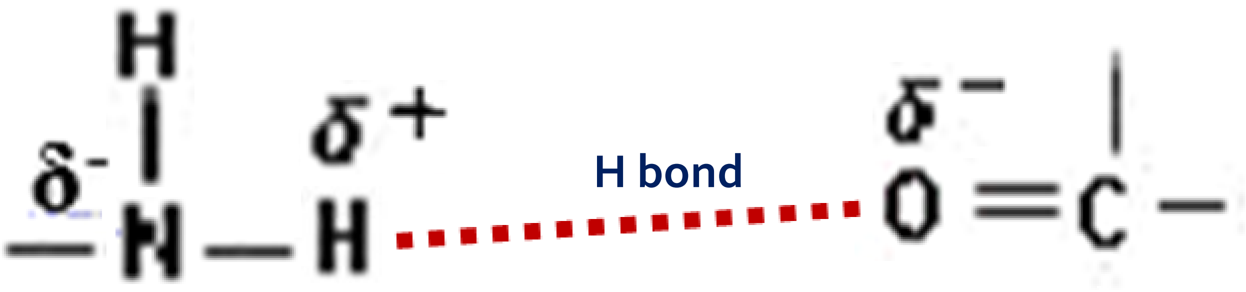
Chemical Bonds / Interactions

Hydrogen bond

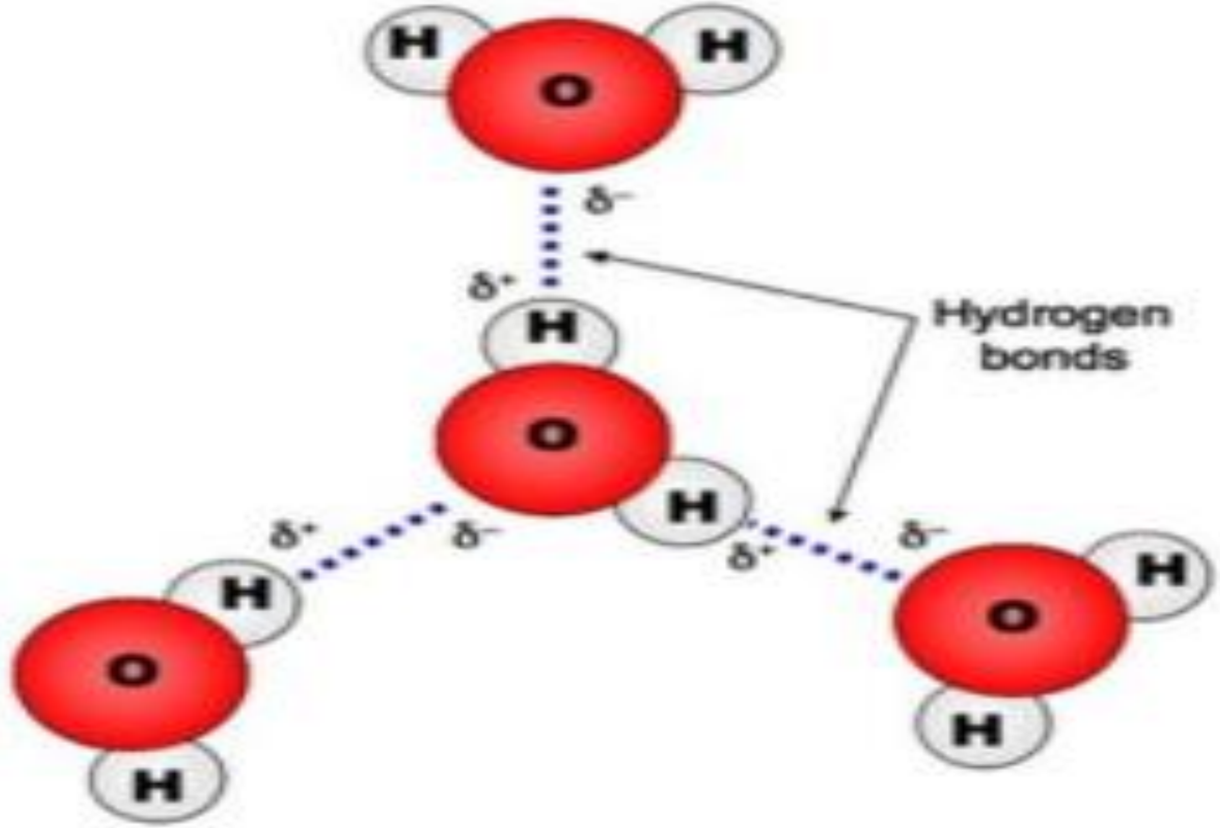
- Attraction between the hydrogen atom bonded to an electronegative atom with another electronegative atom

Why is there an attraction?

Electronegativity: tendency of an atom to attract a shared pair of electrons towards itself



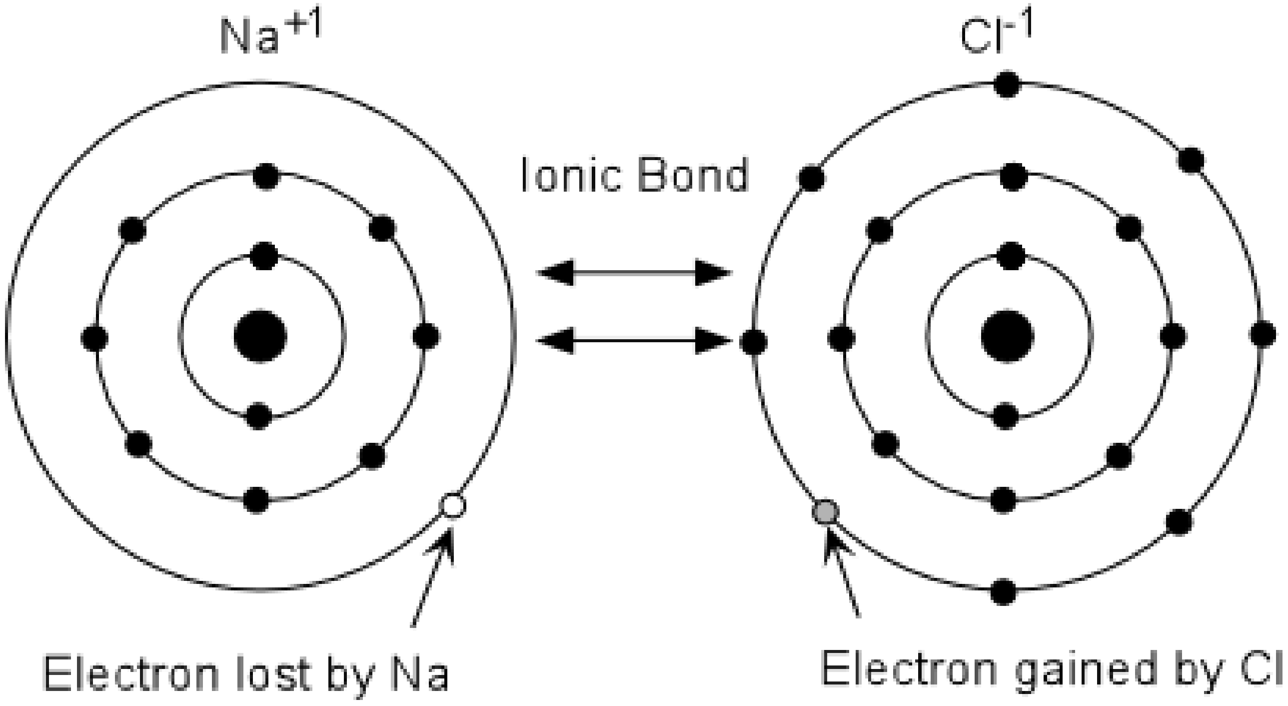
Hydrogen bond



Chemical Bonds / Interactions

Ionic bond

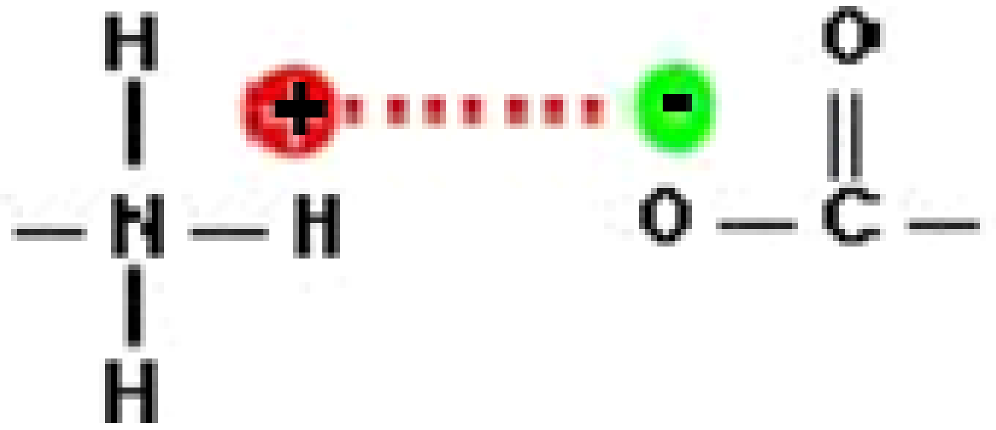
- Attraction between **oppositely charged** ions.



Chemical Bonds / Interactions

Ionic bond

- Attraction between **oppositely charged** ions.



Chemical Bonds / Interactions

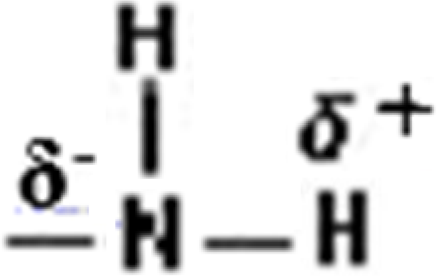
Hydrophobic interactions

- Interaction between **non-polar** molecules due to tendency of **non-polar** molecules to interact with each other in **polar** solvent (usually water)

What do polar and non-polar mean?

Polar

when atoms in the molecule **do not share electrons equally** in a covalent bond



other eg:

O – H

S – H

Non-polar

when atoms in the molecule **share electrons equally** in a covalent bond

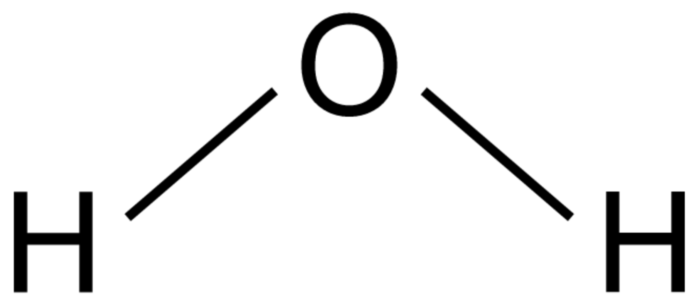
C – C

C – H

Important!!!

DO NOT call ions polar or non-polar. They are CHARGED.

Is this polar, non-polar or charged?



Water

Polar!

Is this polar, non-polar or charged?

Cancels out!

More electronegative

More electronegative

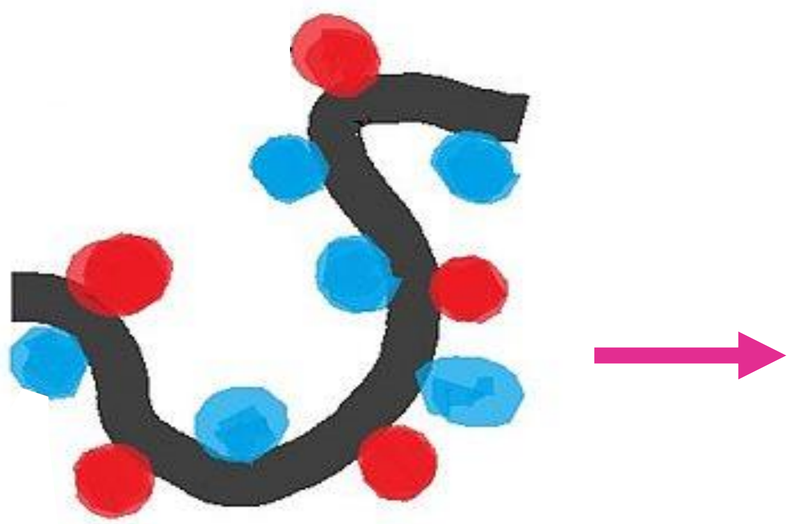
Carbon dioxide

Non-polar!

Chemical Bonds / Interactions

Hydrophobic interactions

- Interaction between **non-polar** molecules due to tendency of **non-polar** molecules to interact with each other in **polar** solvent (usually water)



Isolated Protein

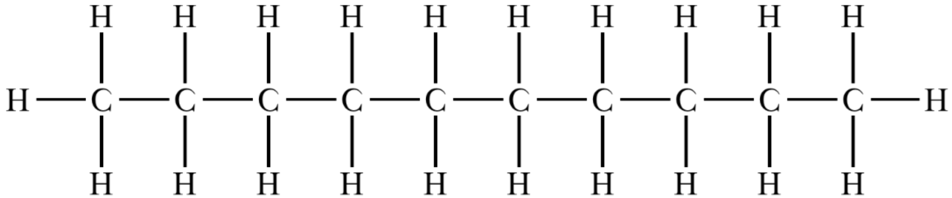
Hydrophilic versus hydrophobic

- Hydrophilic
  - Water ‘loving’
  - Polar molecules
  - Ionic/Charged molecules

- Hydrophobic
  - “water-fearing”
  - Non-polar molecules

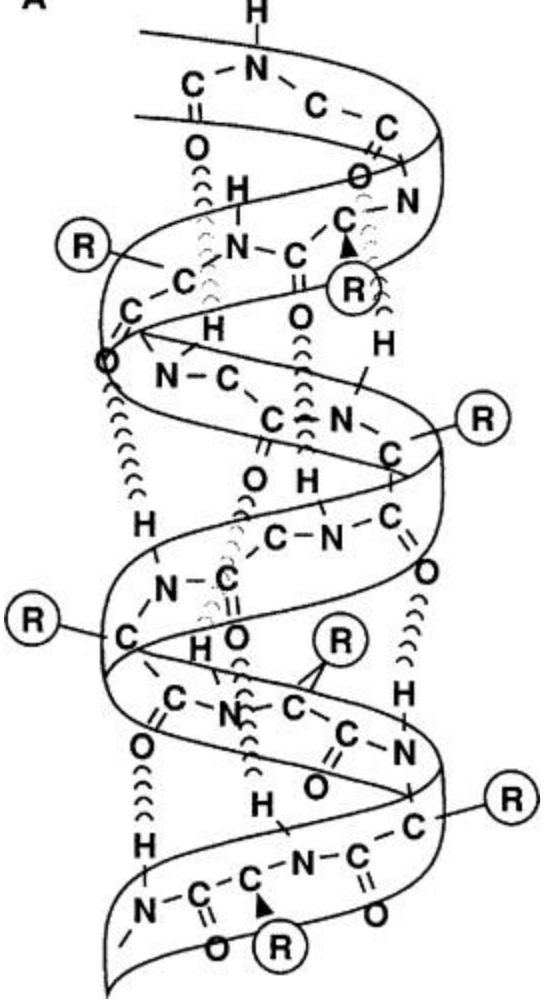
O – H
S – H
N – H

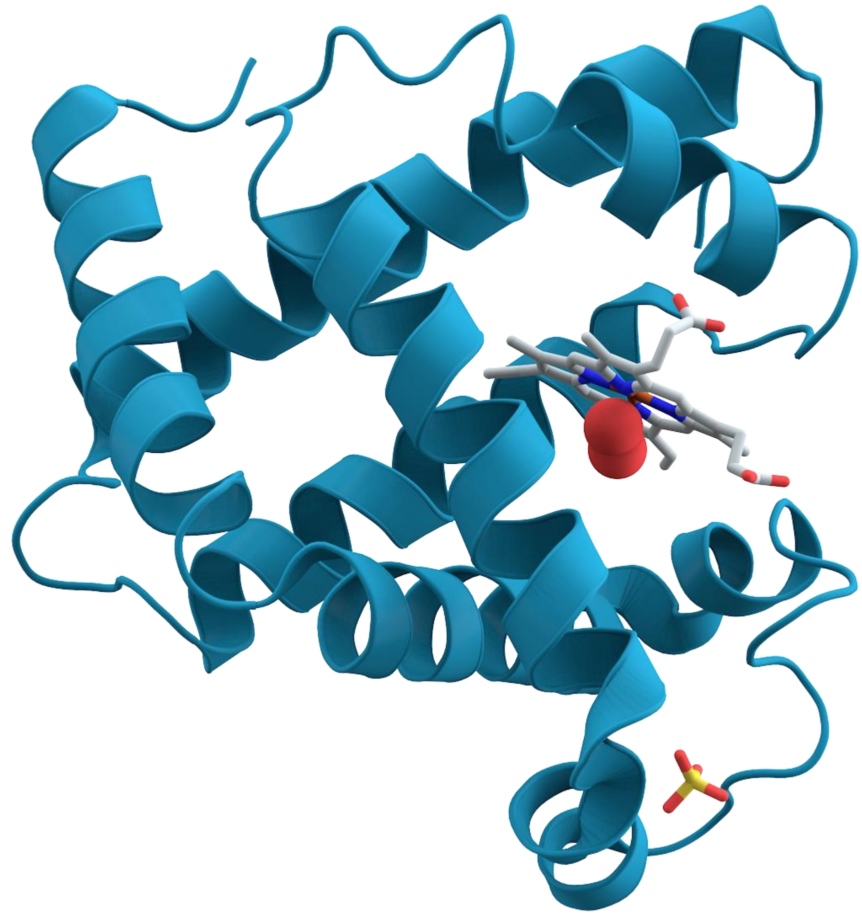
} Polar



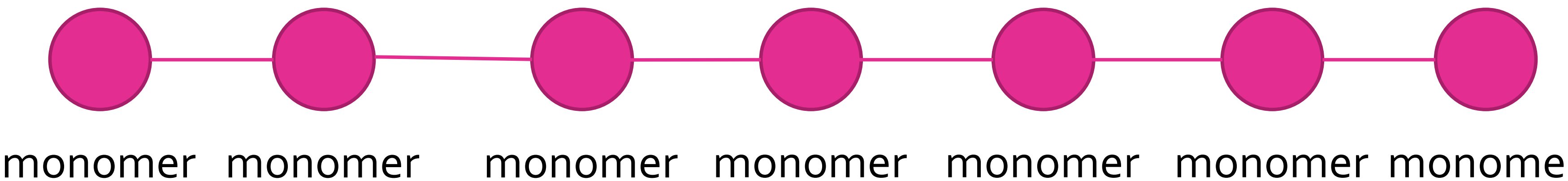
Identify the covalent, ionic, hydrogen bonds and hydrophobic interactions

A





Polymers

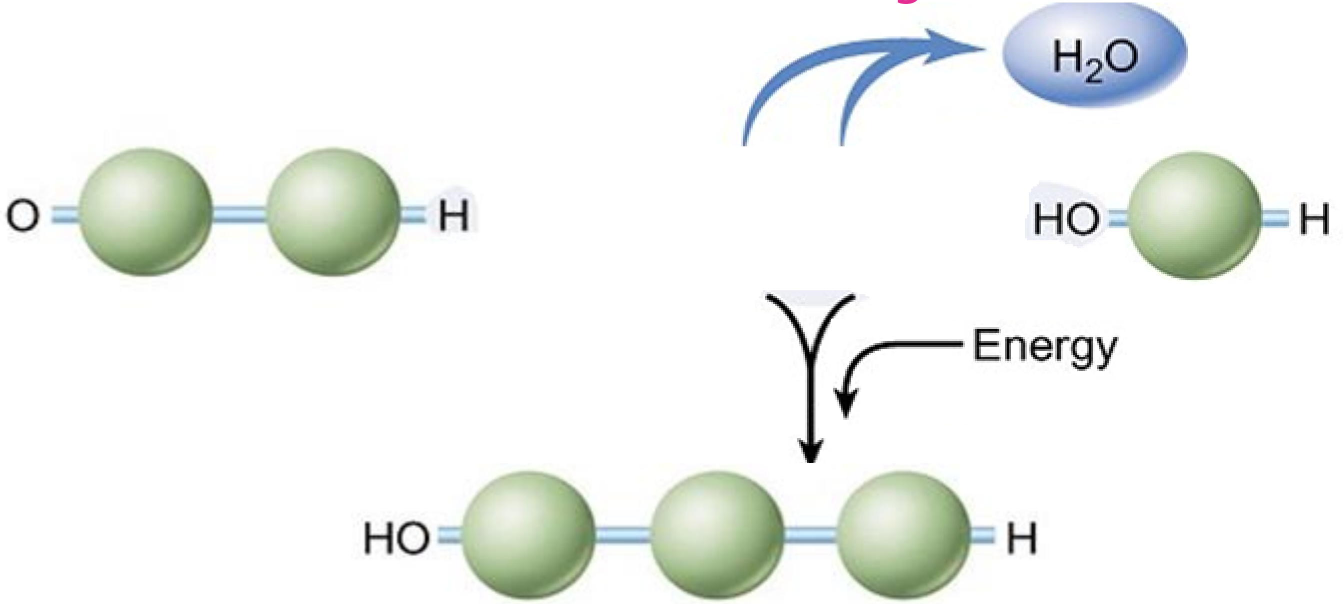


Monomers linked by **covalent bonds**

Through what **reaction?**

Reaction between monomers

- **Condensation** reaction
- Two molecules **combine** to form a larger molecule

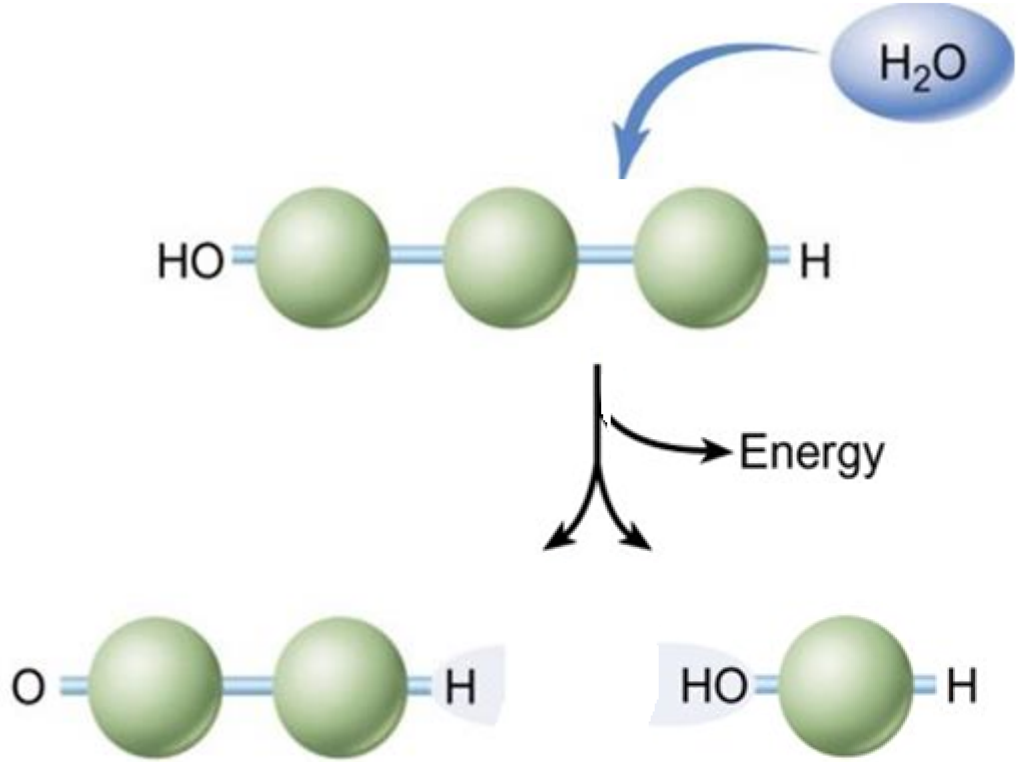


- **Loss** of a small molecule (commonly water)

Condensation – to synthesise a polymer

To disassemble a polymer to monomers..

- **Hydrolysis** reaction
- Cleavage of chemical bonds by the **addition of water**



BIOMOLECULES

Carbohydrates

LEARNING OBJECTIVES

1(e)(i) Describe the structure and properties of **α-glucose** and **β-glucose** (in carbohydrates)

1(f)(i) **Describe the formation and breakage of a** glycosidic bond.

1(g)(i) Describe the structures and properties of **starch** (including amylose and amylopectin), **cellulose** and explain how these are related to their roles in living organisms.

Carbohydrates – why study them?

https://youtu.be/sG82Fna4-AQ

Introduction: Carbohydrates

- made up of the elements **carbon, hydrogen and oxygen**
- general formula $C_x(H_2O)_y$

How do we classify carbohydrates?

Carbohydrate Classification

- Carbohydrates
  - **Mono**saccharides
    - Single sugar
  - **Di**saccharides
    - Two monosaccharides joined
      - Double sugar
      - Condensation rxn
  - **Poly**saccharides
    - Many monosaccharides joined
      - Condensation rxns

One Sugar

Monosaccharides

- cannot be hydrolysed to simpler carbohydrates
- general formula $(CH_2O)_n$ where n = 3 – 9

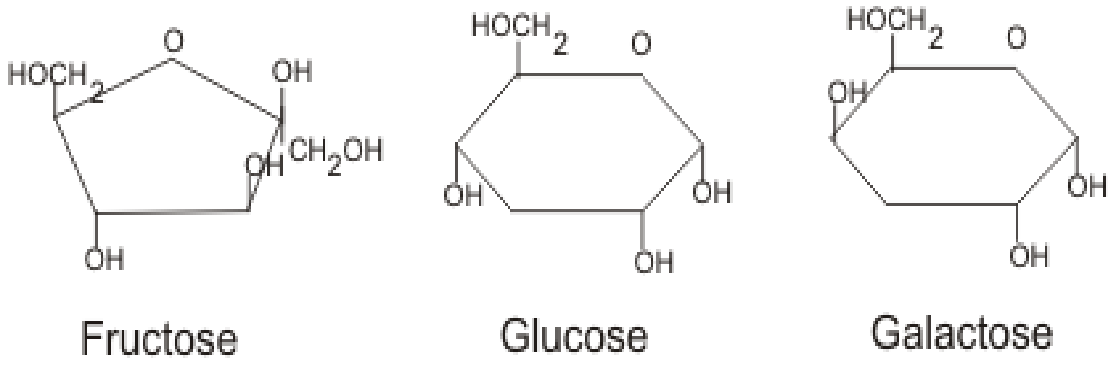
Carbon atoms in $(CH_2O)_n$	General terms	Common examples
3	triose	glyceraldehye
4	tetrose	
5	pentose	ribose ; ribulose
6	hexose	glucose
7	heptose	

One Sugar

Monosaccharides

- Show **isomerism**

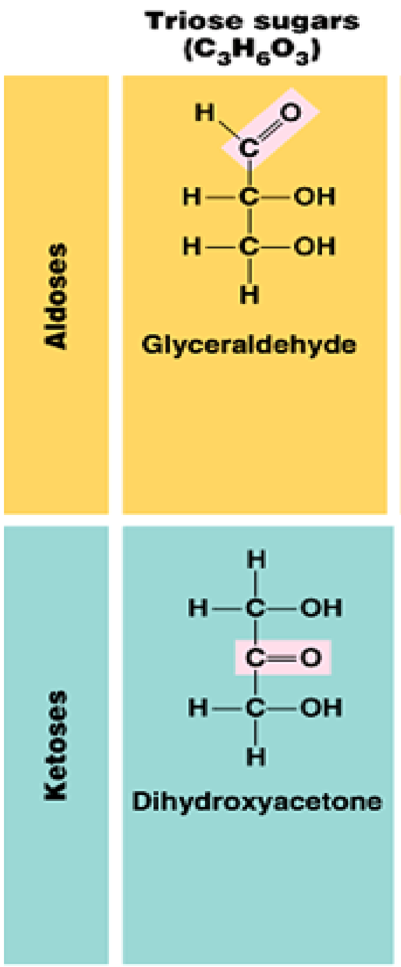
Formula for hexose: $C_6H_{12}O_6$



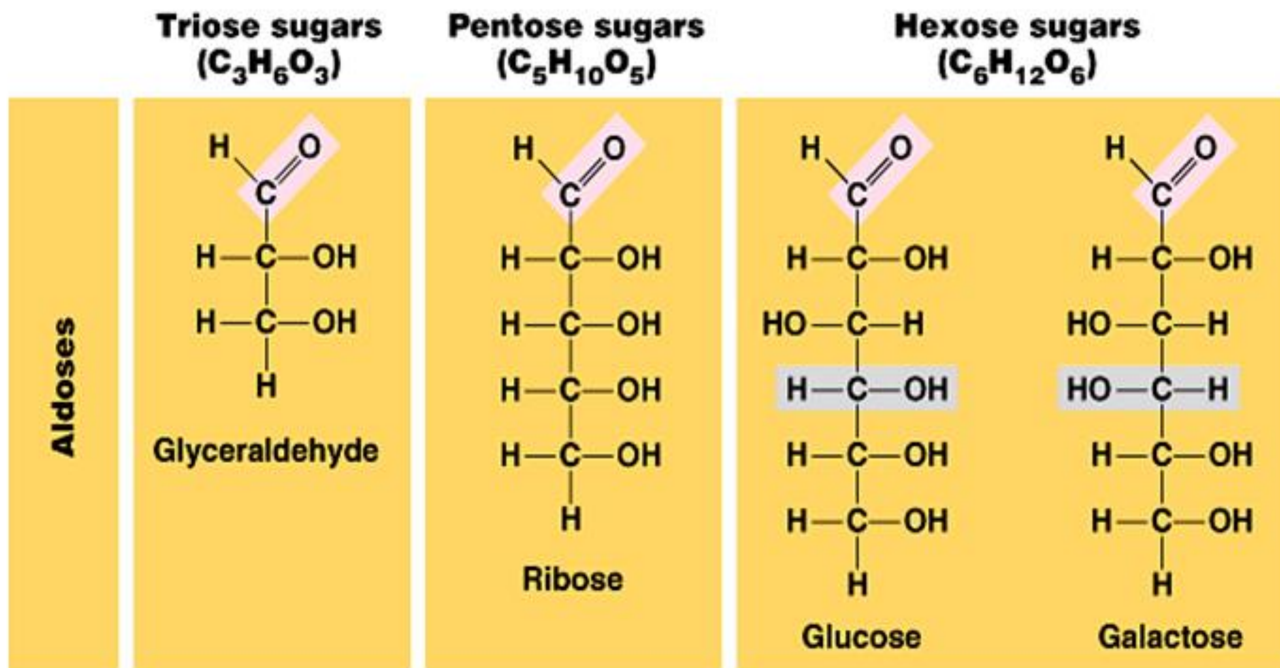
Same molecular formula,
different structural arrangements

Classification of Monosaccharides

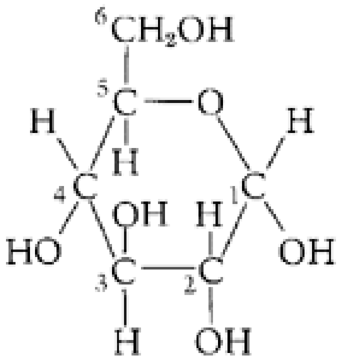
1) Aldose or Ketoses



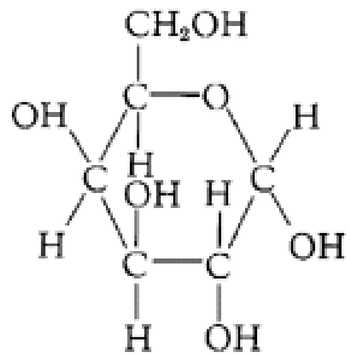
2) Length of C skeleton



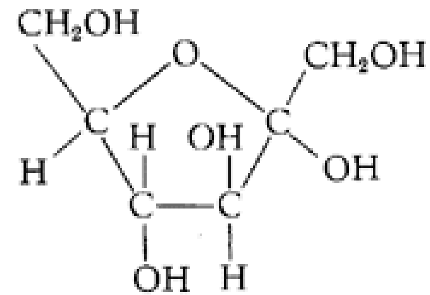
3) Spatial arrangement around asymmetric carbons (eg. glucose and galactose)



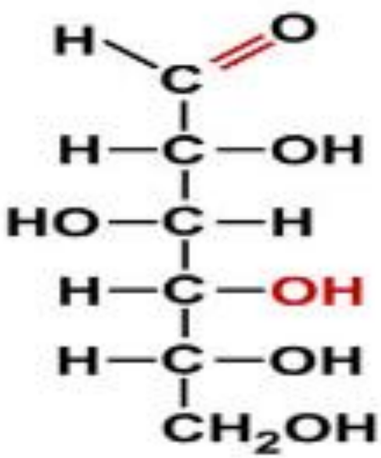
GLUCOSE



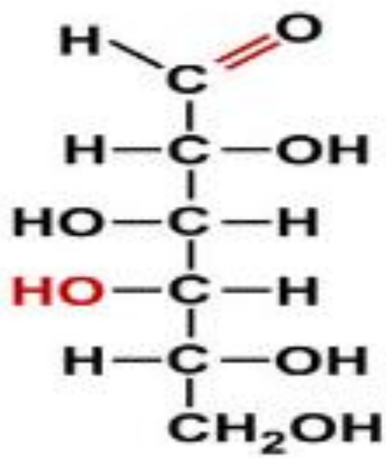
GALACTOSE



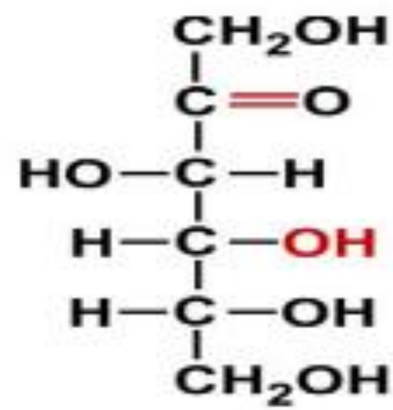
FRUCTOSE



Glucose



Galactose

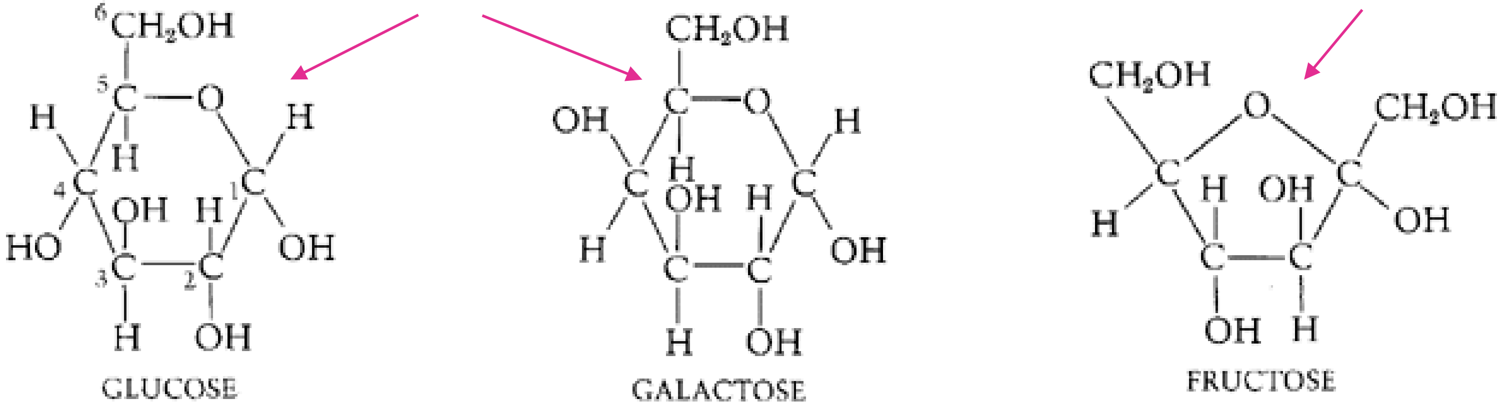


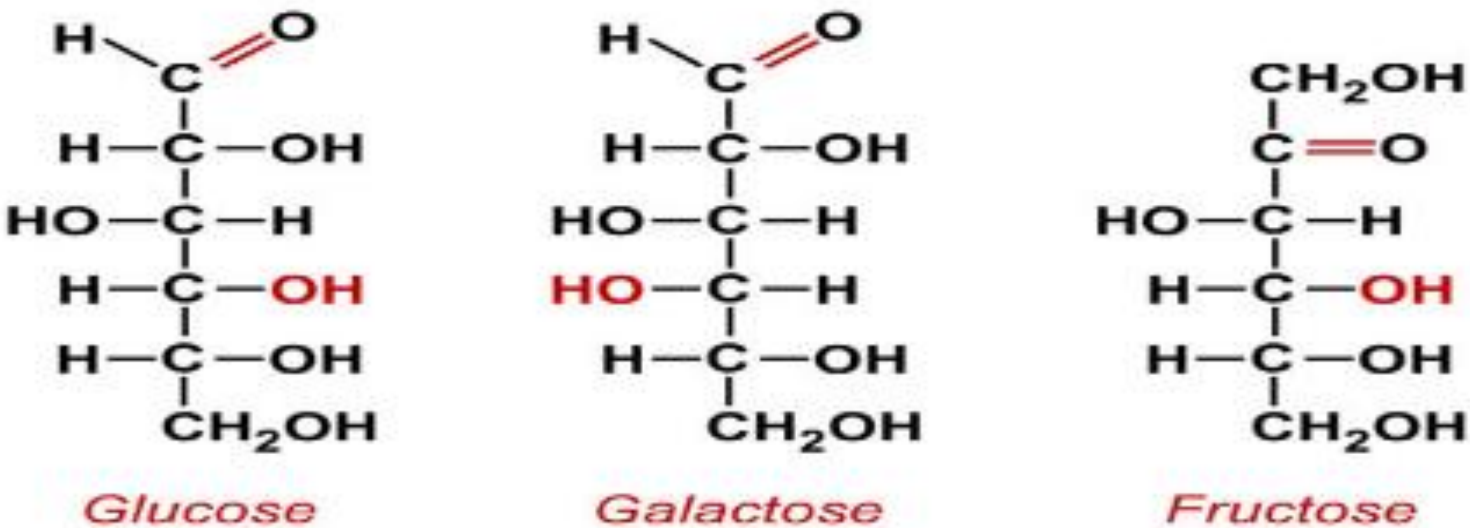
Fructose

Ring form is thermodynamically more stable

pyranose ring

furanose ring





What is sugar?

Carbohydrates

- **Mono**saccharides
  - Single sugar
- **Di**saccharides
  - Two monosaccharides joined
    - Double sugar
    - Condensation rxn
- **Poly**saccharides
  - Many monosaccharides joined
    - Condensation rxns

Find the sugar in your food

Ingredients: Whole Grain Rolled Oats, **Sugar**, **Barley Malt Extract**, Salt, **Sugar**, Whole Wheat Flakes, Canola Oil, **Molasses**, Bleached Wheat Flour, **Malted Barley Flour**, Niacin, Reduced Iron, Thiamine Mononitrate, Riboflavin, Folic Acid, Soy Lecithin, Sodium Bicarbonate, Nonfat Dry Milk, Caramel Color, **Corn Syrup,** Rice, **Sugar**, **Barley Malt Extract**, Salt, **Sugar**, **Chocolate Liquor**, Cocoa Butter, Soy Lecithin, Salt, Vanilla, **Sugar, Corn Syrup Solids, Sugar, Corn Syrup**, Modified Cornstarch, Gelatin, Artificial Flavors), Wheat Flour, **Sugar**, Whole Wheat Flour, Partially Hydrogenated Soybean And Cottonseed Oil, **Honey Powder**, Baking Soda, Salt, Annatto [Color], Caramel Color, **High Fructose Corn Syrup**, Glycerin, Palm Oil.

60 DIFFERENT NAMES FOR SUGAR

Agave Nectar
Barbados Sugar
Barley Malt
Beet Sugar
Blackstrap Molasses
Brown Rice Syrup
Brown Sugar
Buttered Sugar
Buttered Syrup
Cane Juice Crystals
Cane Juice
Cane Sugar
Caramel
Carob Syrup
Caster Sugar
Coconut Sugar
Corn Sweetener
Corn Syrup
Corn Syrup Solids
Crystal Line Fructose
Date Sugar
Demara Sugar
Dextran
Diastatic Malt
Diatase

Ethyl Maltol
Evaporated Cane Juice
Fructose
Fruit Juice Concentrate
Galactose
Golden Sugar
Golden Syrup
Grape Sugar
High Fructose Corn Syrup
Honey
Invert Sugar
Icing Sugar
Lactose
Malt Syrup
Maltodextrin
Maltose
Maple Syrup
Molasses Syrup
Muscovado Sugar
Organic Raw Sugar
Oat Syrup
Panela
Panocha
Confectioner's Sugar
Rice Bran Syrup

Rice Syrup
Sorghum
Sorghum Syrup
Sucrose
Sugar
Syrup
Treacle
Tapioca Syrup
Turbinado Sugar
Yellow Sugar

Honey

From Wikipedia, the free encyclopedia

For other uses, see Honey (disambiguation).

Honey is a sweet, viscous food substance produced by bees and some related insects.[1] Bees produce honey from the sugary secretions of plants (floral nectar) or from secretions of other insects (such as honeydew), by regurgitation, enzymatic activity, and water evaporation. Bees store honey in wax structures called honeycombs.[1][2] The variety of honey produced by honey bees (the genus *Apis*) is the best-known, due to its worldwide commercial production and human consumption.[3] Honey is collected from wild bee colonies, or from hives of domesticated bees, a practice known as beekeeping.

Honey gets its sweetness from the monosaccharides fructose and glucose, and has about the same relative sweetness as sucrose (granulated sugar).[4][5] It has attractive chemical properties for baking and a distinctive flavor when used as a sweetener.[4] Most microorganisms do not grow in honey, so sealed honey does not spoil, even after thousands of years.[6][7]

Honey provides 46 calories in a serving of one tablespoon (15 ml).[8] Although generally safe,[9] honey may potentially have adverse effects or interactions upon excessive consumption, existing disease conditions, or use of prescription drugs.[10]

Honey use and production have a long and varied history as an ancient activity. Cave paintings in Cuevas de la Araña, Spain, depict humans foraging for honey at least 8,000 years ago.[11][12]

Contents [hide]

LEARNING OBJECTIVES

1(e)(i) Describe the structure and properties of α-glucose and β-glucose (in carbohydrates)

1(f)(i) Describe the formation and breakage of a glycosidic bond.

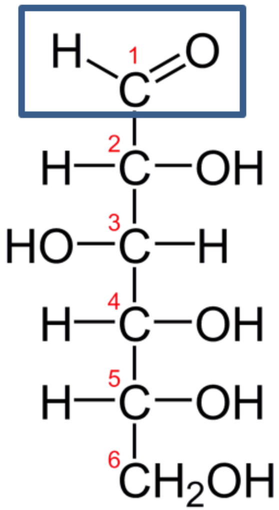
1(g)(i) Describe the structures and properties of starch (including amylose and amylopectin), cellulose and explain how these are related to their roles in living organisms.

MOST COMMON MONOSACCHARIDE

Glucose

Structure of Glucose

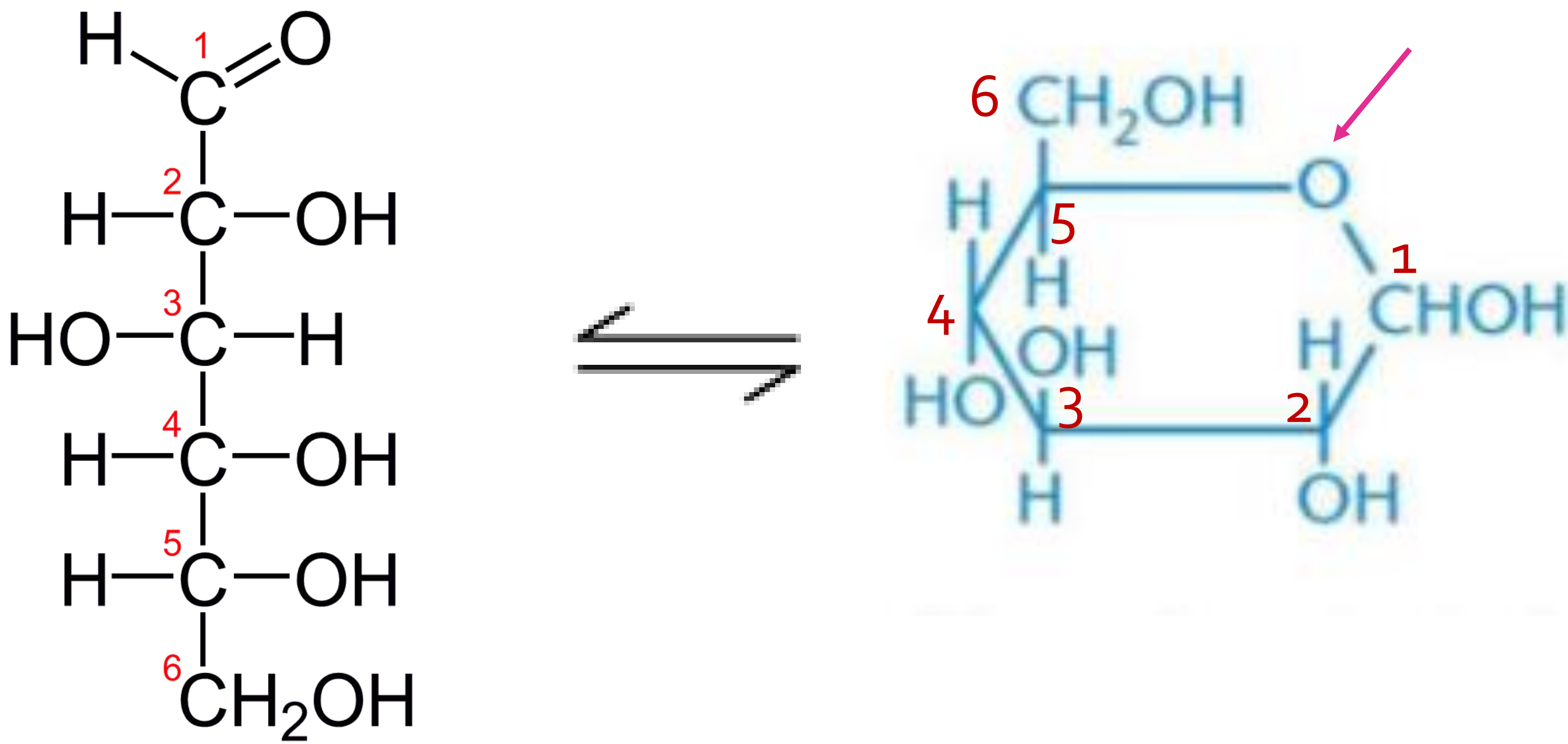
- Monosaccharide; formula: $C_6H_{12}O_6$
- 6 carbon atoms => hexose sugar
- five OH groups arranged in <u>specific</u> way along 6-carbon backbone



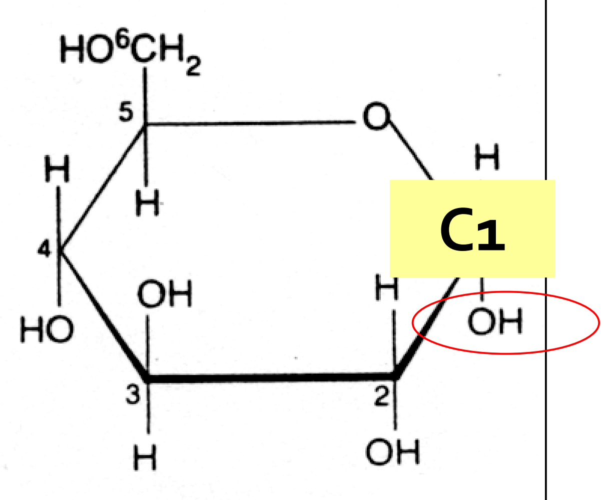
Aldehyde functional group

- Aldose sugar
- Open chain form thermodynamically unstable; isomerises to form cyclic forms of glucose:
  - ➢ **α**-isomer (called α- glucose)
  - ➢ **β**-isomer (called β- glucose)

Linear and ring forms of glucose



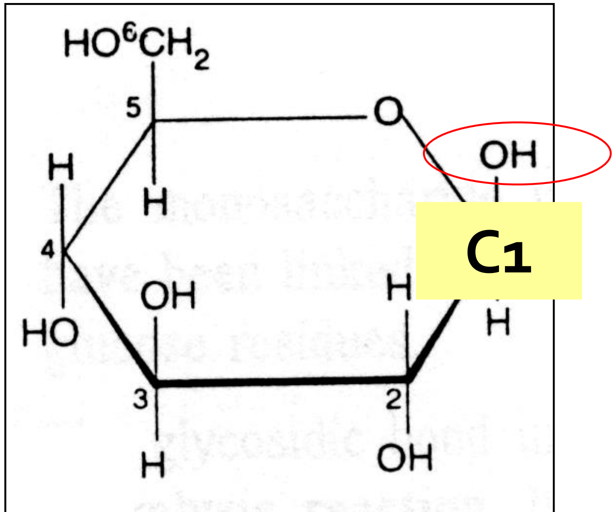
α-isomer



α–glucose

-OH group on **carbon 1** is **below** the plane of the ring

β-isomer



β–glucose

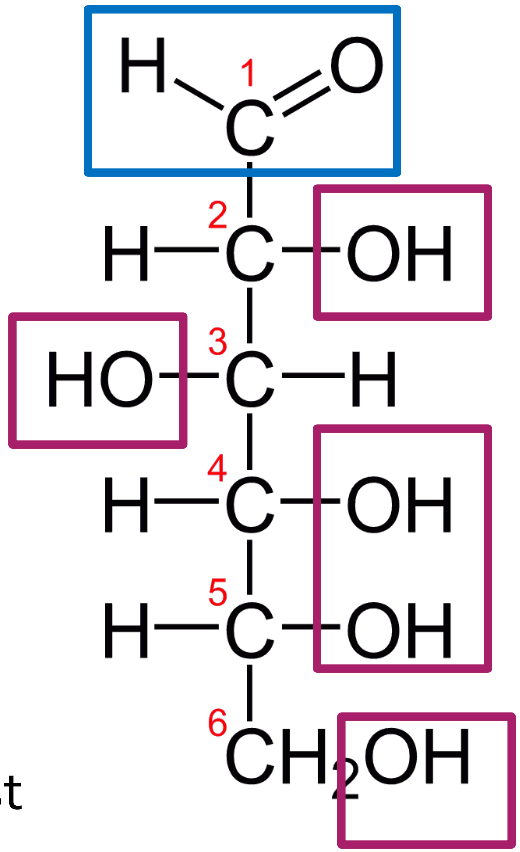
-OH group on **carbon 1** is **above** the plane of the ring

NOTE: -OH group is the same as hydroxyl group

Properties of α-glucose and β-glucose

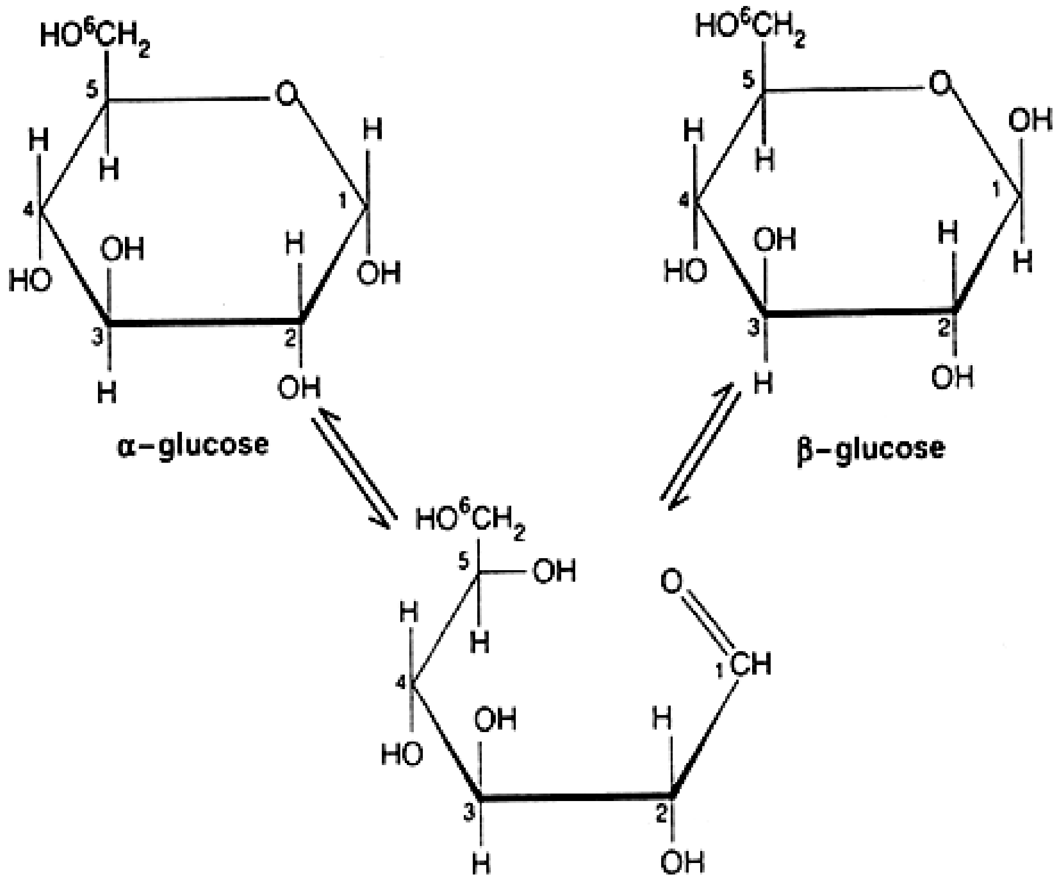
- Glucose is colourless
- **Soluble** in water due to many polar hydroxyl (–OH) groups
- Slightly soluble in organic solvents
- Glucose is a **reducing sugar** due to presence of a free aldehyde group (which reduces the Cu^{2+} in Benedict's solution to Cu^{+})

  → forms a brick red precipitate in Benedict's test



For general knowledge

- The α- and β-isomers of glucose are <u>inter-convertible in aqueous solution</u>.



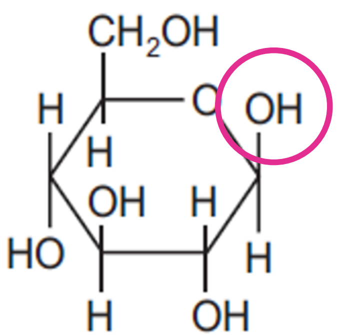
- It is possible to have an equilibrium between both linear and ring forms in solution.
- For both forms, if there is the presence of a *free* aldehyde or ketone group, the monosaccharide is a <u>reducing sugar</u>.

Tutorial 2: MCQ 2

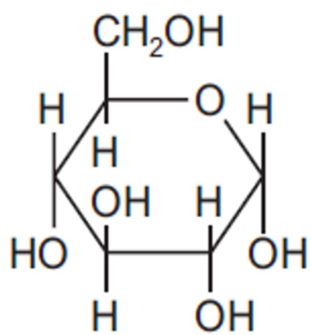
The diagrams show four monosaccharides with the formula $C_6H_{12}O_6$.

Which diagram shows α-glucose?

A



B



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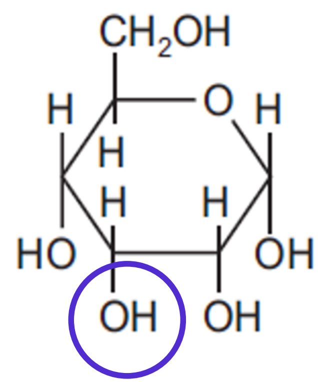

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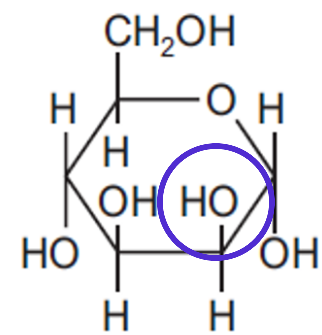


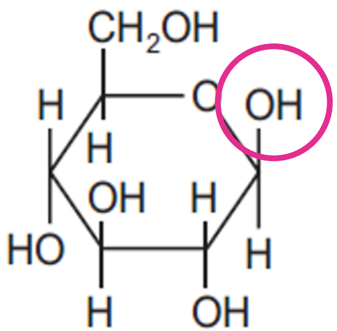
B-glucose

-OH groups at the plane differ from α-glucose

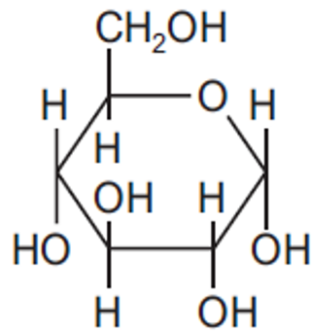
Tutorial 2: MCQ 2

What is the term that describe these 4 monosaccharides having same formula but different structural arrangements? ISOMERISM

A



B



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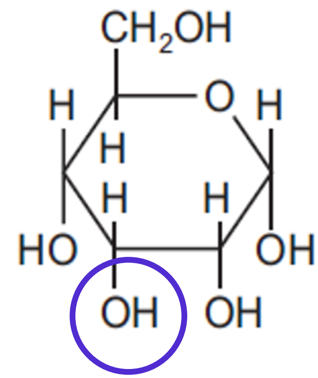
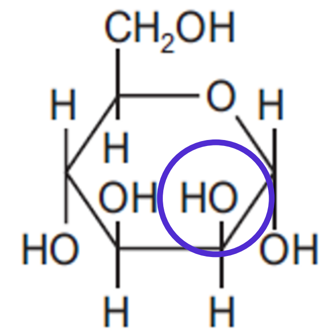


D



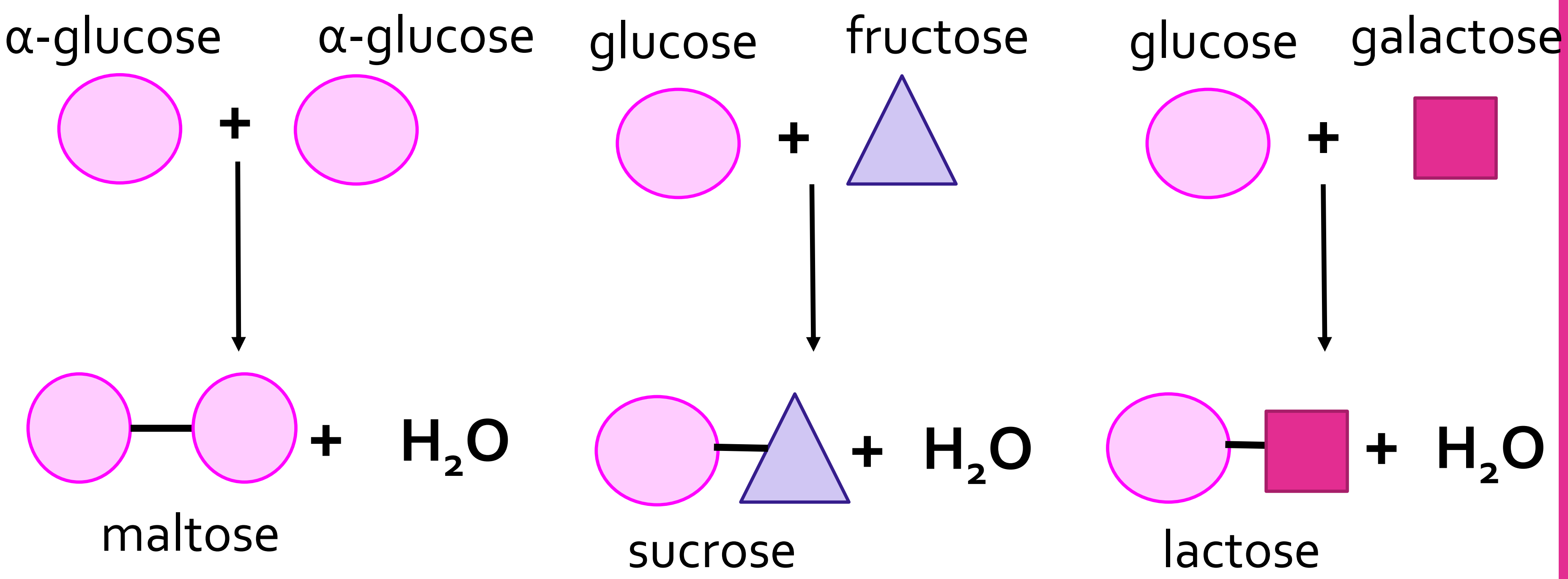
B-glucose

-OH groups at the plane differ from α-glucose

Two Sugar

Disaccharides

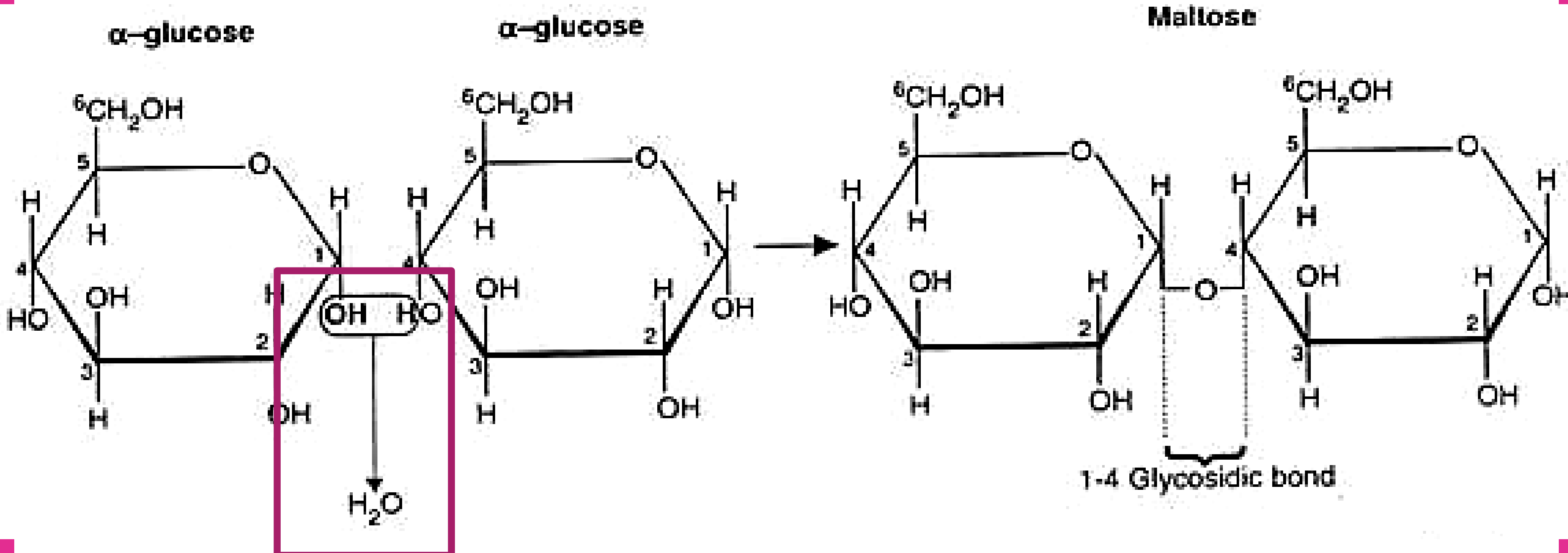
- Formed by **condensation reaction** between **two** monosaccharides
- with release of one water molecule



bond formed: glycosidic bond

Maltose formation

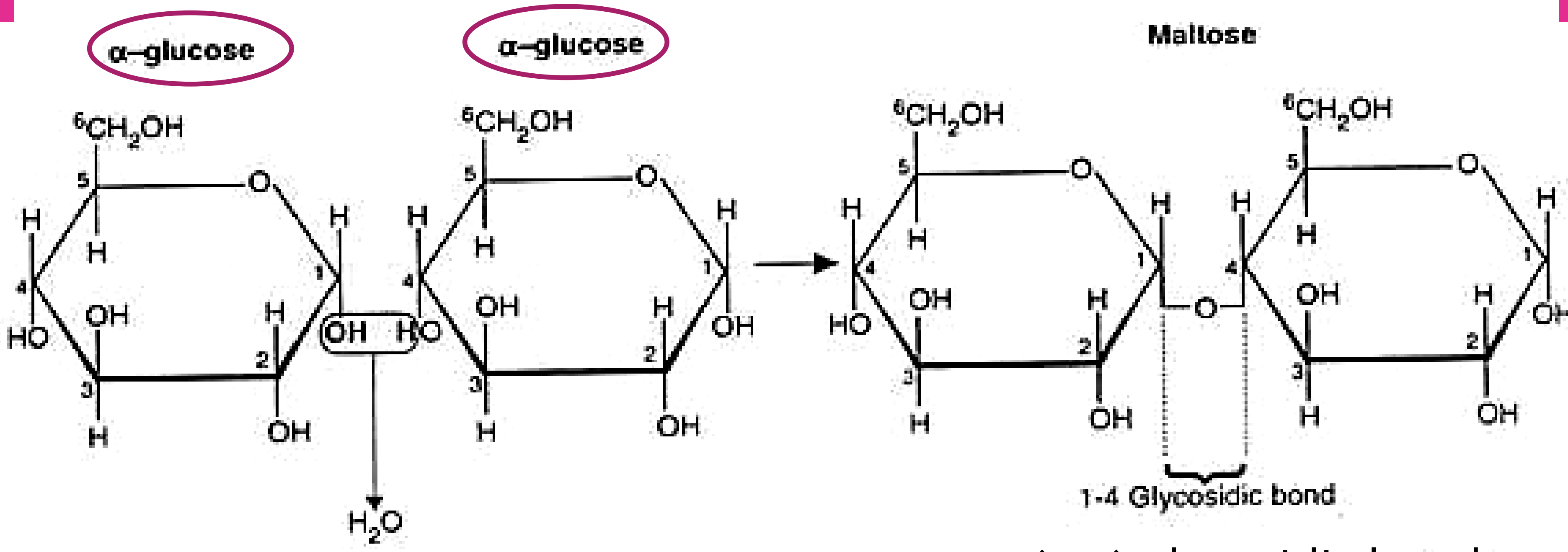
- **Glucose + Glucose → <u>Maltose</u>** <u>+ Water</u>



Condensation rxn
release of 1 water molecule per glycosidic bond formed

Maltose formation

- **Glucose + Glucose → Maltose + Water**



α (1,4) glycosidic bond

Two Sugar

Disaccharides

- Condensation reactions are catalysed by specific enzymes in living cells and require energy for the reaction to proceed

How can glycosidic bonds be broken?

- By a **hydrolysis reaction**
- Involves **addition of one water molecule**
- Hydrolysis of disaccharides into monosaccharides:
  - Chemical method
  - Enzymatic method

Hydrolysis of disaccharides

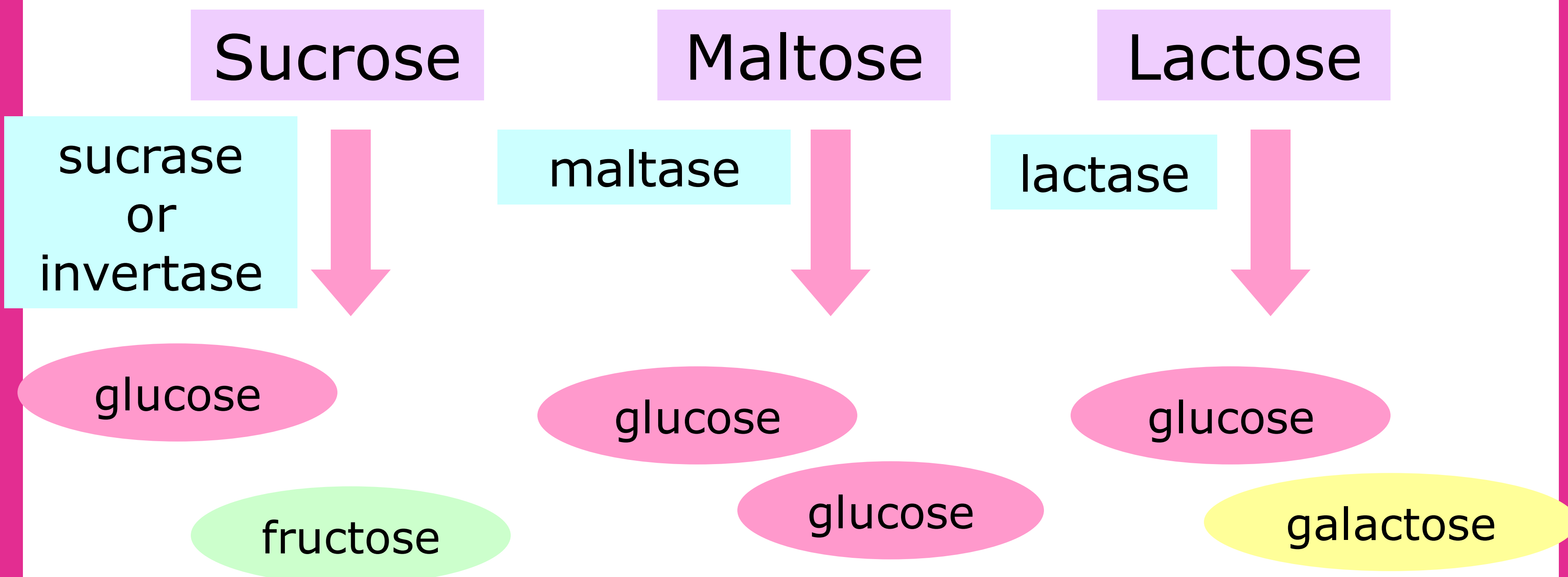
- **Chemical Method**

→Incubating the disaccharide with a dilute acid at 100°C.

Hydrolysis of disaccharides

- **Enymatic Method**

→Incubating the disaccharide with an enzyme at room temperature.



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Tutorial 2: Class Activity (page 2)

Class Activity:

Three monosaccharides condensed together to form a trisaccharide. How many glycosidic bonds does a trisaccharide have?

Ans: **two**

Draw the condensation reaction of 2 α-glucose to self-check if you are able to understand and apply the concept of LO1(h)(i) ie the formation of glycosidic bonds. Note: Draw a disaccharide consisting of 2 β–glucose for a challenge.

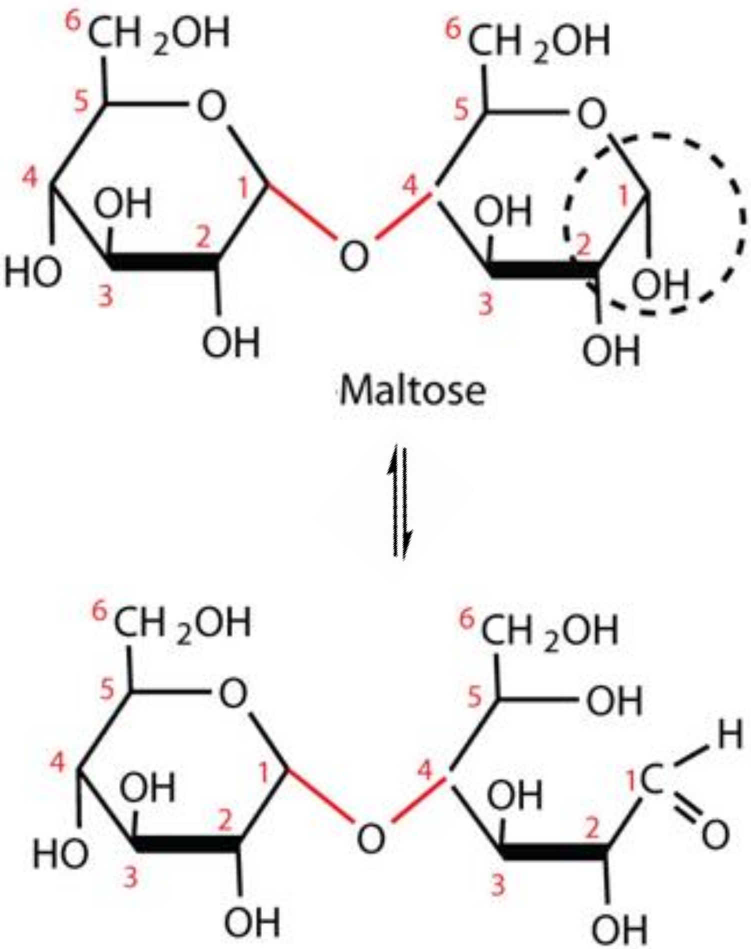
Ans:

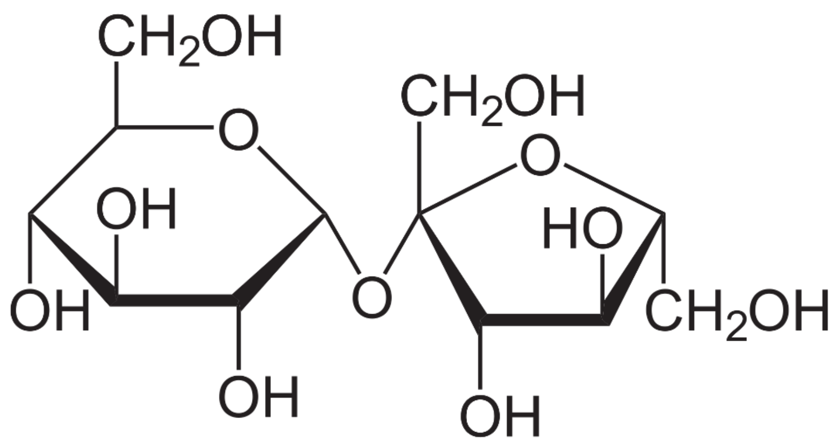
Reducing sugars

- All monosaccarides
- For dissacharides => lactose and maltose
- Sucrose is not a reducing sugar

General knowledge

- Many disaccharides, like lactose and maltose have a reducing form, as one of the two sugar units may have an open-chain with an aldehyde group.
- However, in sucrose, the aldehyde and ketone groups are linked together (no free aldehyde group), hence sucrose is a non-reducing disaccharide (negative result in Benedict's test).





sucrose

Video - Benedict's Test

https://youtu.be/MRAVhZA_77Q

How to test for reducing sugars' presence?

Benedict's test

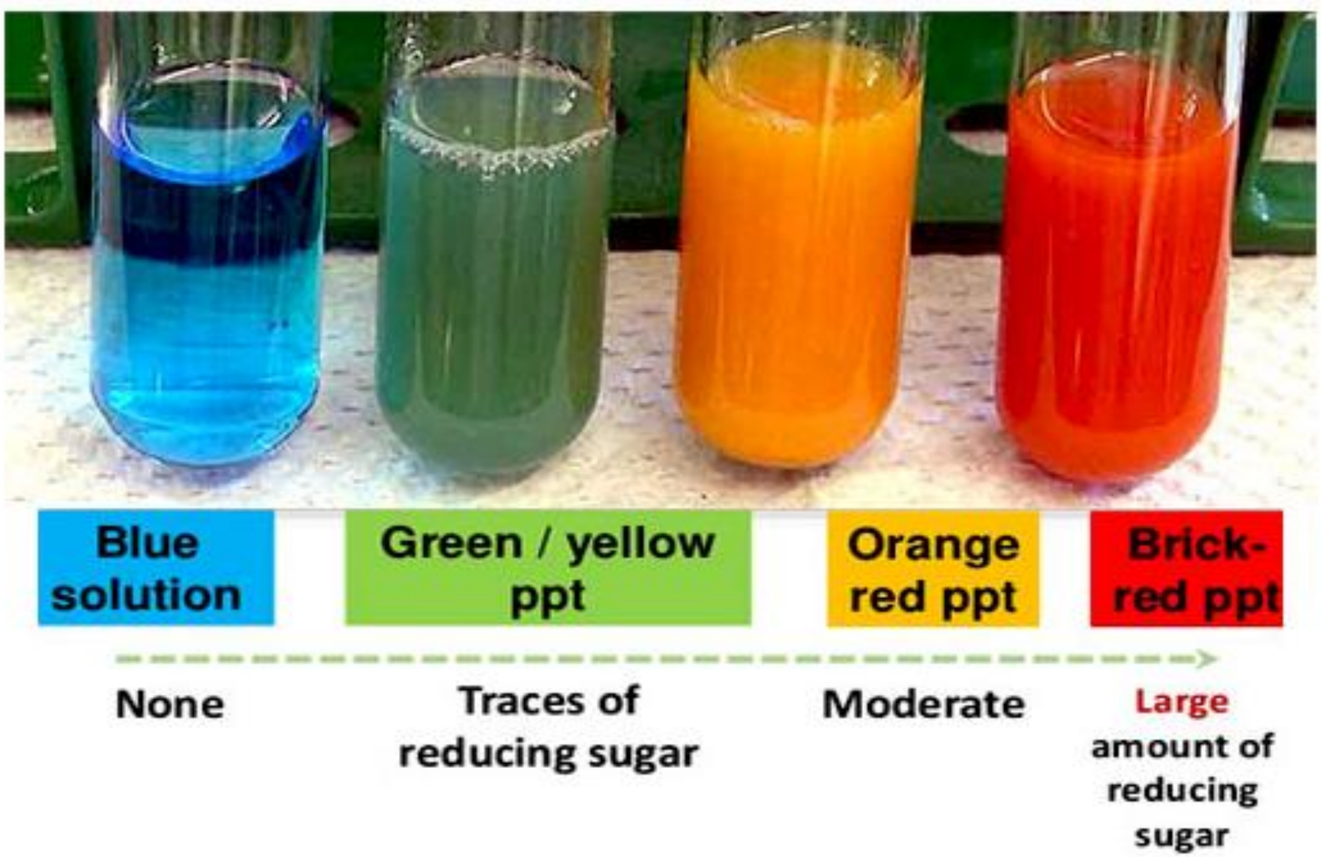
- *Basis of test:*
  - Benedict's solution contains copper (II) sulphate.
  - Reducing sugars (having a *free* aldehyde or ketone group) reduce soluble blue copper sulphate containing Cu^{2+} to insoluble red - brown copper oxide containing copper (I), which is seen as a precipitate.

- *Observation:*
  - Initial blue coloration of the mixture turns green, then yellowish and may finally form a brick red precipitate.

blue → green → yellow → brick red precipitate

Larger quantity of reducing sugar

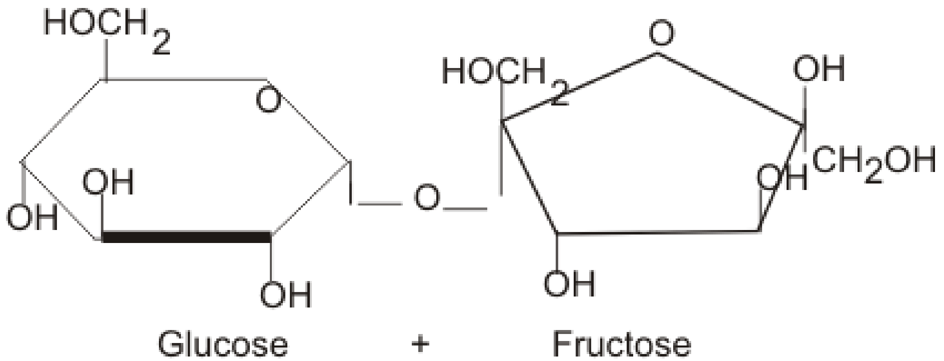
Reducing sugars



Disaccharides: non-reducing sugars

- Sucrose

→ Non-reducing sugar



Sucrose

How to test for the presence of non-reducing sugars?

Disaccharides

Reducing sugars

Maltose

Lactose

1. Benedict's test

Non-reducing sugars

Sucrose

1. **Hydrolyse** sucrose to glucose & fructose (reducing sugars)

Using dilute hydrochloric acid

2. Carry out **Benedict's test**

Tutorial 2: MCQ 1

The equation shows a reversible reaction.

$$\text{sucrose} + \text{water} \underset{2}{\overset{1}{\rightleftharpoons}} \text{glucose} + \text{fructose}$$

Disaccharide

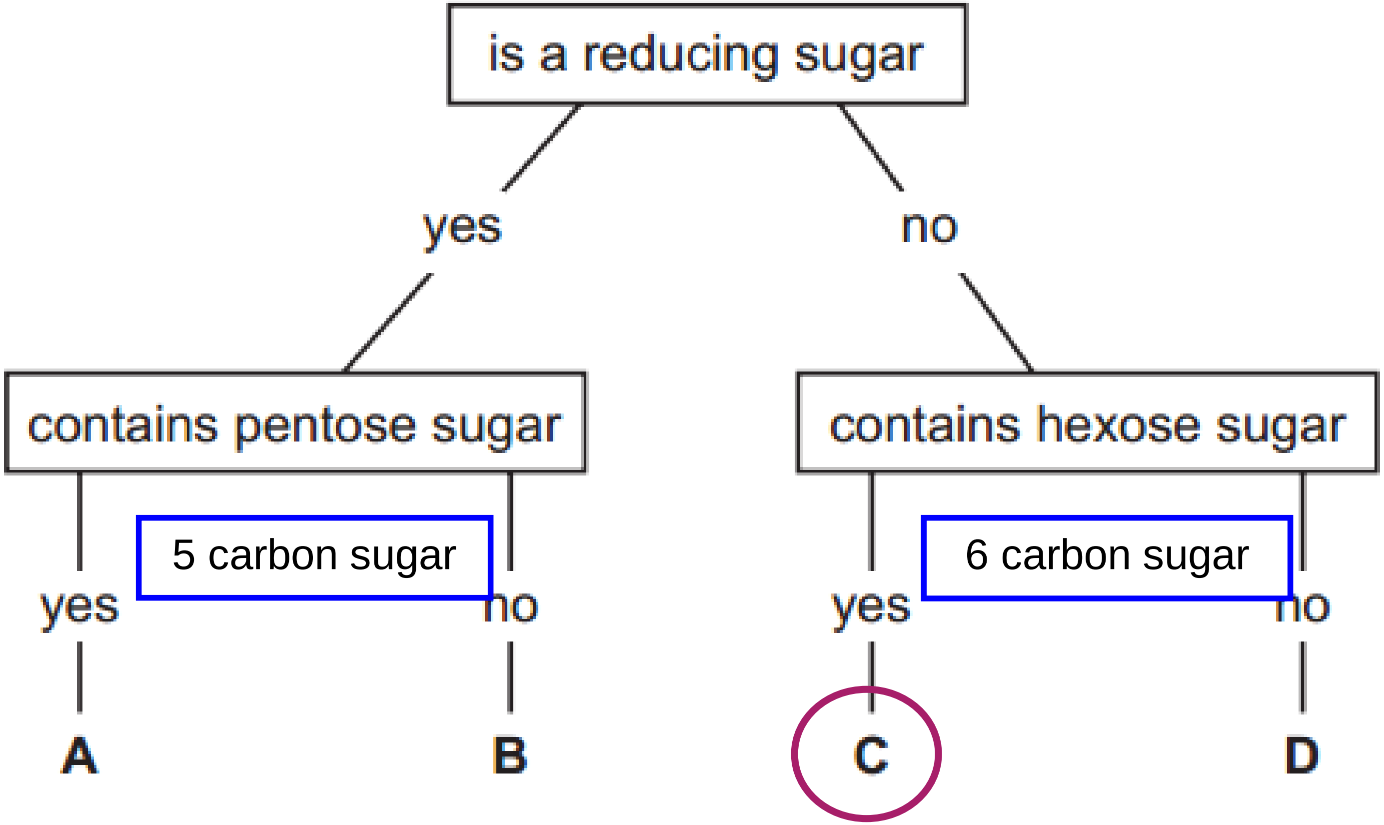
Monosaccharides

In this reaction, what enzyme catalyses reaction 1 and what types of reaction occur at **1** and **2**?

	enzyme	reaction at 1	reaction at 2
A	sucrase	condensation	hydrolysis
B	sucrase	hydrolysis	condensation
C	sucrose	condensation	hydrolysis
D	sucrose	hydrolysis	condensation

Tutorial 2: MCQ 3

- Which molecule in the key is sucrose?

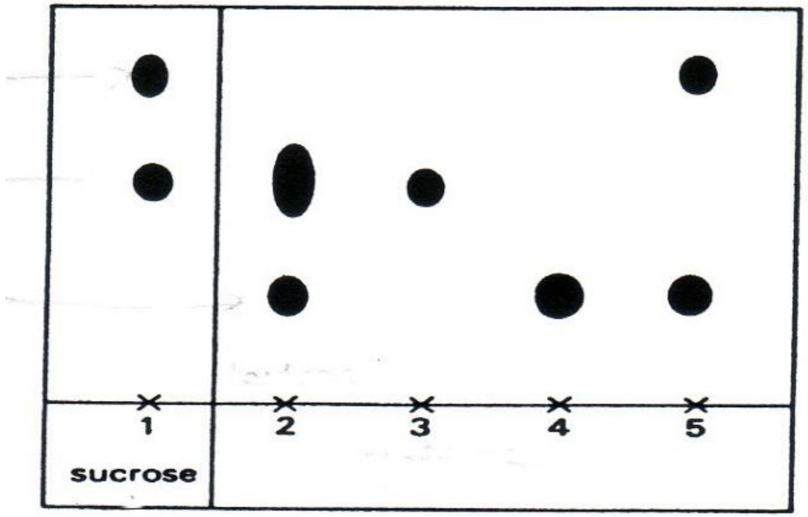


Tutorial 2: MCQ 6

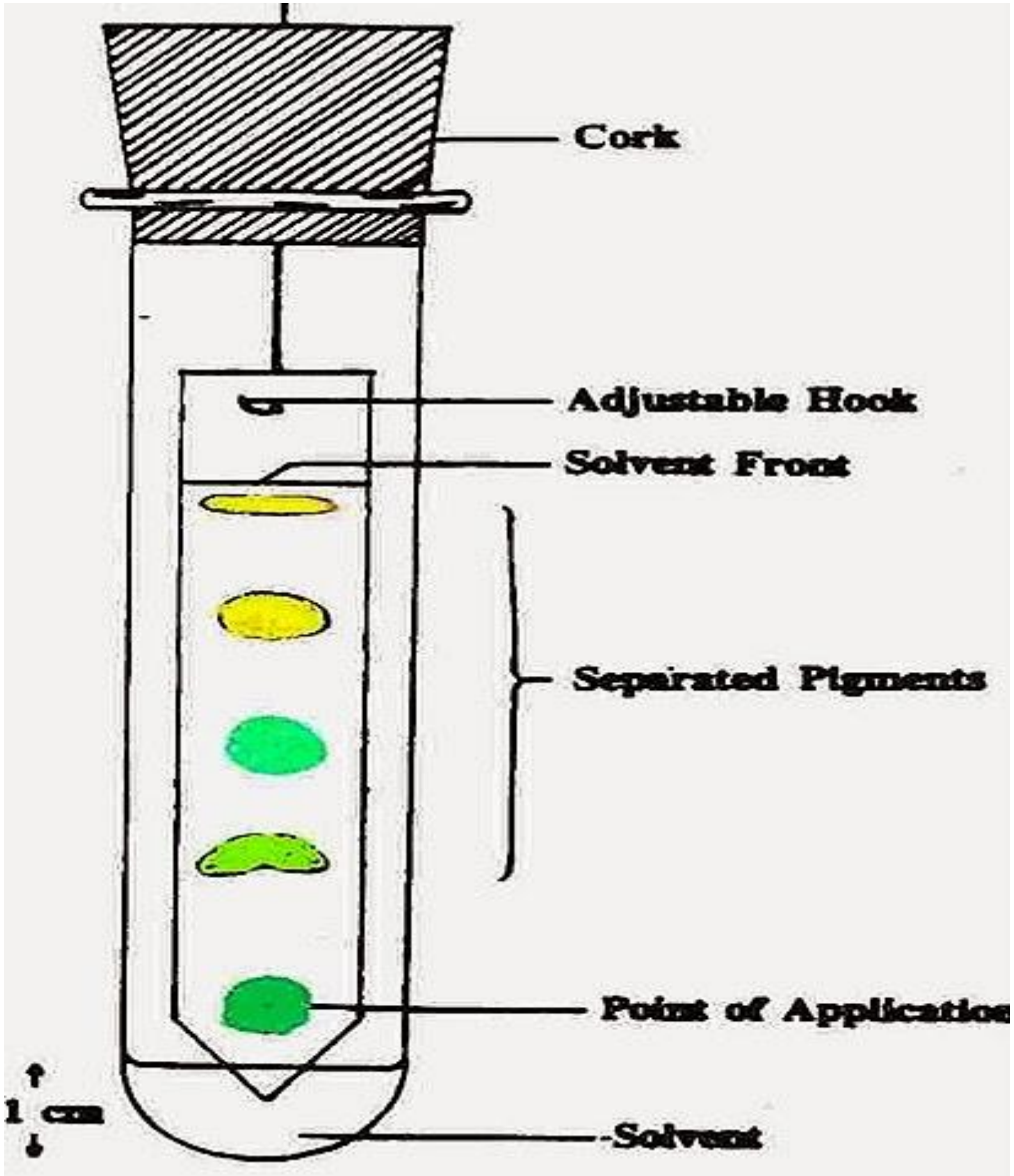
Five disaccharides were each hydrolysed with dilute acid, and the purified products were separated by one-dimensional chromatography.

The final chromatogram is shown in the diagram below.

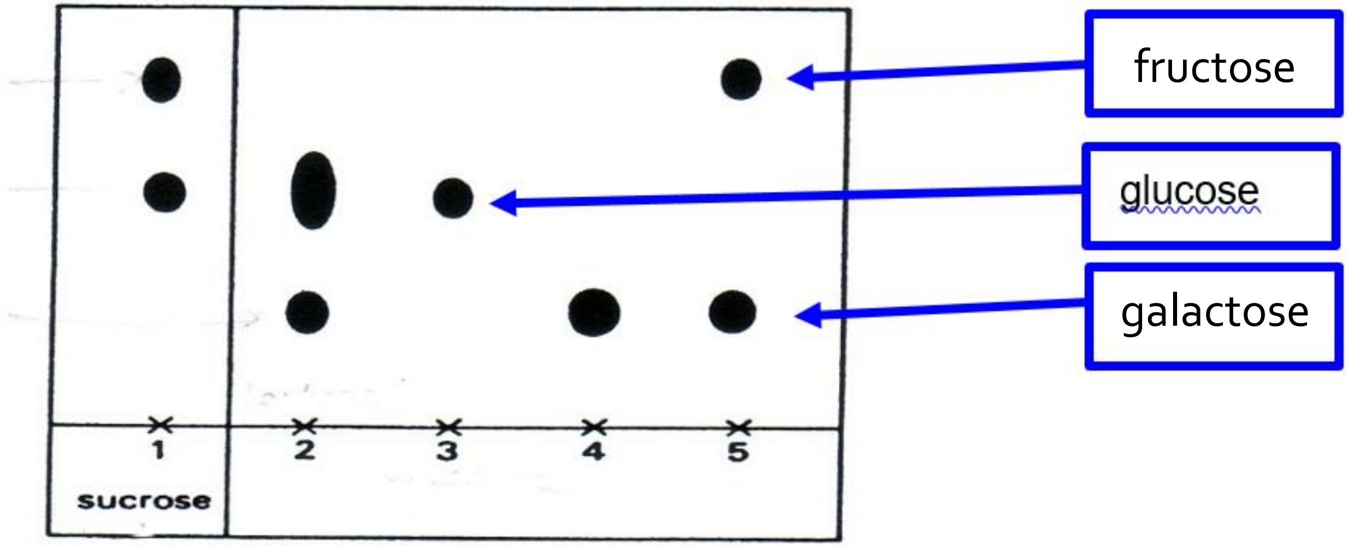
If spot 1 represents the products obtained from the hydrolysis of sucrose, which one of the following indicates the results obtained from the hydrolysis of lactose and maltose?



	Lactose	Maltose
A	2	3
B	2	4
C	5	2
D	5	3


Cork
Adjustable Hook
Solvent Front
Separated Pigments
Point of Application
1 cm
Solvent

Tutorial 2: MCQ 6



If spot 1 represents the products obtained from the hydrolysis of sucrose, which one of the following indicates the results obtained from the hydrolysis of lactose and maltose ?

	Lactose	Maltose
A	2	3
B	2	4
C	5	2
D	5	3

How did you arrive at the answer?

- **Sucrose is a disaccharide formed by the condensation of glucose and fructose with the use of one molecule of water.**
- **Lactose is a disaccharide formed by the condensation of glucose and galactose.**
- **Hence, lactose on hydrolysis should have two spots on the chromatography with one spot at the same position as that of sucrose on chromatography.**
- **Maltose is a disaccharide formed by the condensation of glucose and glucose.**
- **=> Only one spot on the chromatography, at the same position of one of the two spots for sucrose.**

Carbohydrate Classification

- Carbohydrates
  - **Mono**saccharides
    - Single sugar
  - **Di**saccharides
    - Two monosaccharides joined
      - Double sugar
      - Condensation rxn
  - **Poly**saccharides
    - Many monosaccharides joined
      - Condensation rxns

Learning Objectives

1(e)(i) Describe the structure and properties of α-glucose and β-glucose (in carbohydrates)

1(f)(i) Describe the formation and breakage of a glycosidic bond.

1(g)(i) Describe the structures and properties of starch (including amylose and amylopectin), and cellulose and explain how these are related to their roles in living organisms.

Polysaccharides

Based on their functions, polysaccharides can be divided into 2 groups

Storage

Hydrolysed (when needed) to **provide sugar** for cells

starch (plants)

glycogen (animals)

Structural

Building material for **protection**

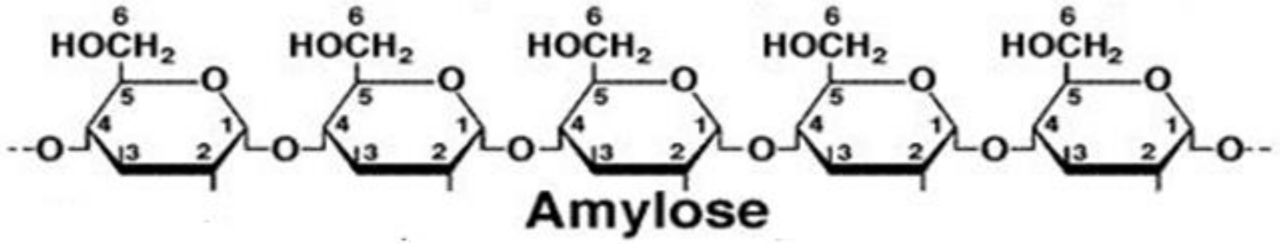
cellulose (plants)

Video – Starch

https://youtu.be/UaF8vKEgoro

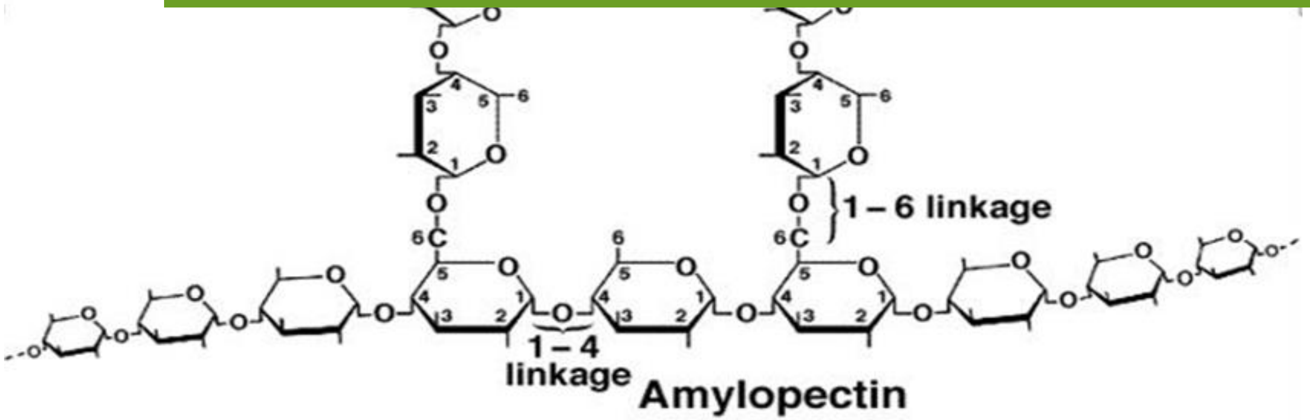
Polysaccharides: Starch

- 2 components: amylose and amylopectin.
- Both made up of α-glucose molecules.



unbranched

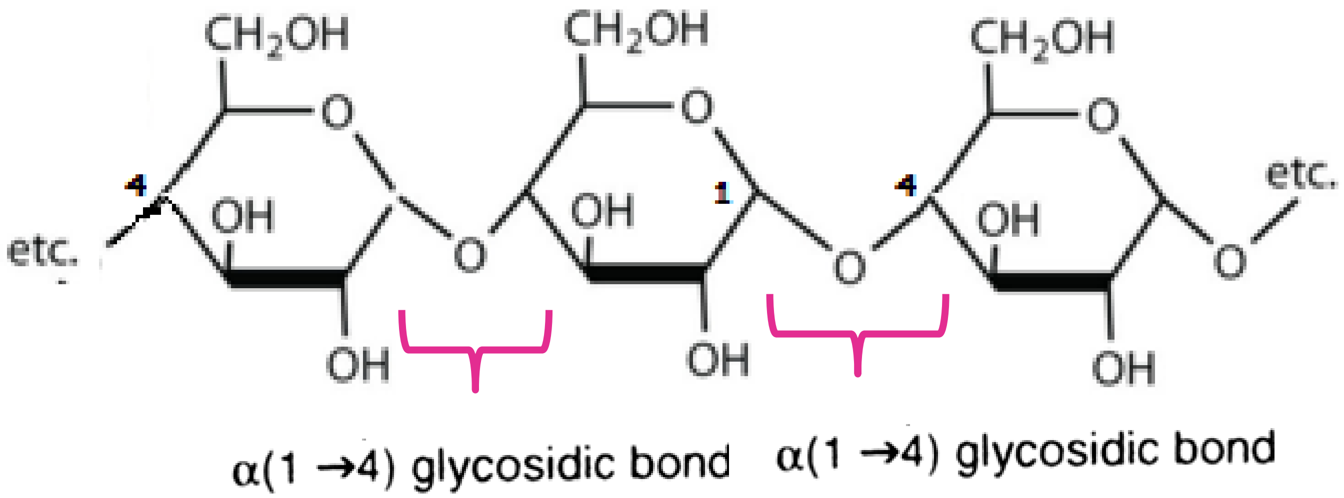
Difference between amylose and amylopectin?



branched

Amylose

- Unbranched
- α-glucose residues linked by α(1→4) glycosidic bonds

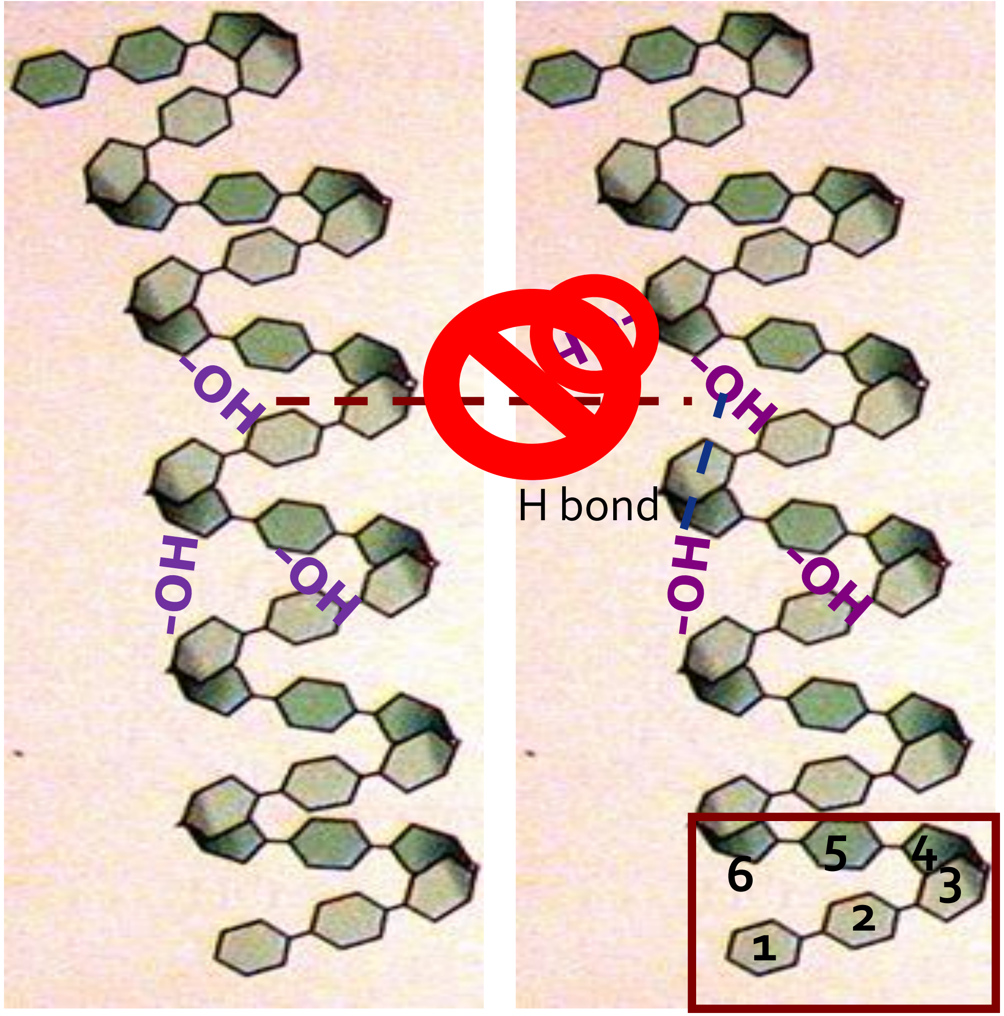


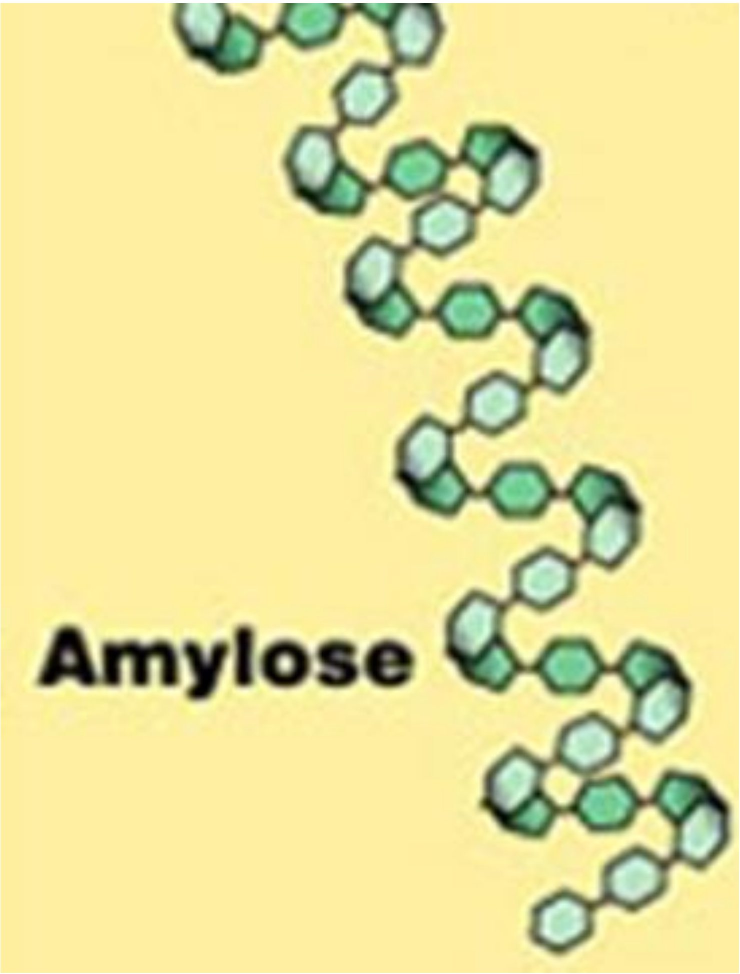
-C-O-C-

Amylose

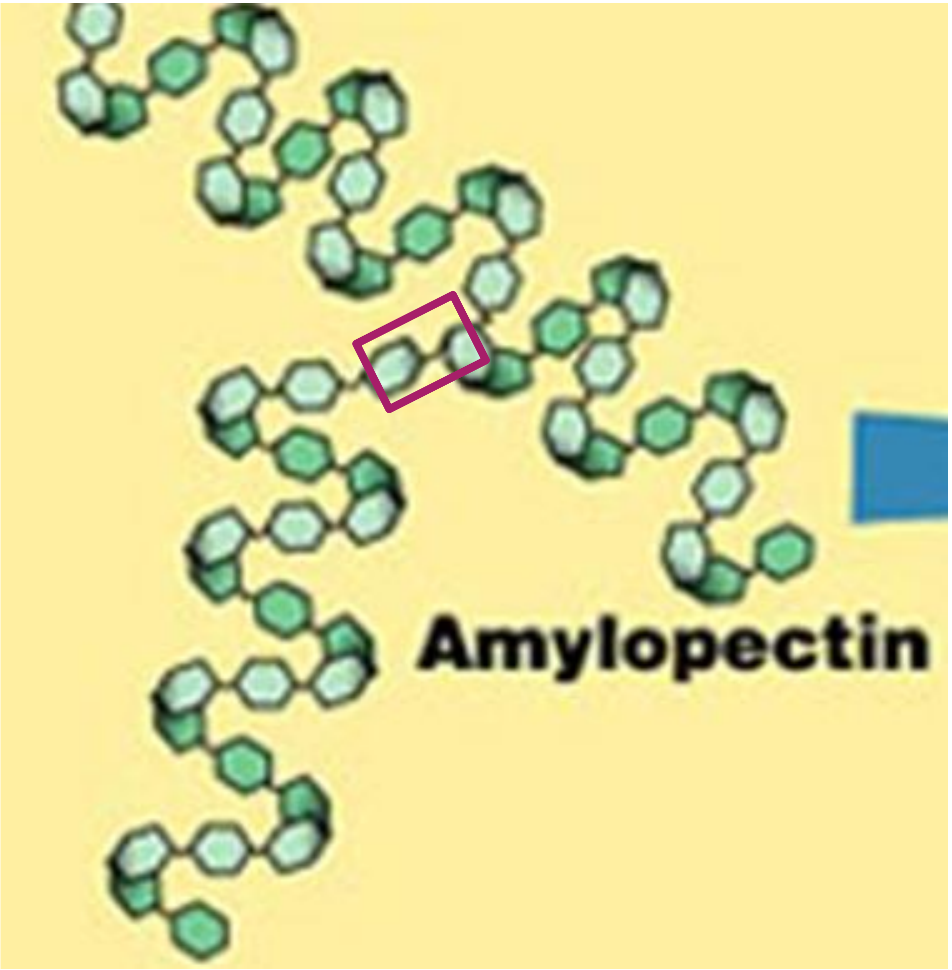
- Each amylose chain coiled into a <u>helix</u>
- 6 glucose residues for every complete turn of helix
- helical shape held together by **hydrogen bonds** formed between –OH groups
- hydroxyl groups of glucose residues <u>project into **interior** of the helix</u>

→ **<u>no cross-linking of amylose chains</u>**



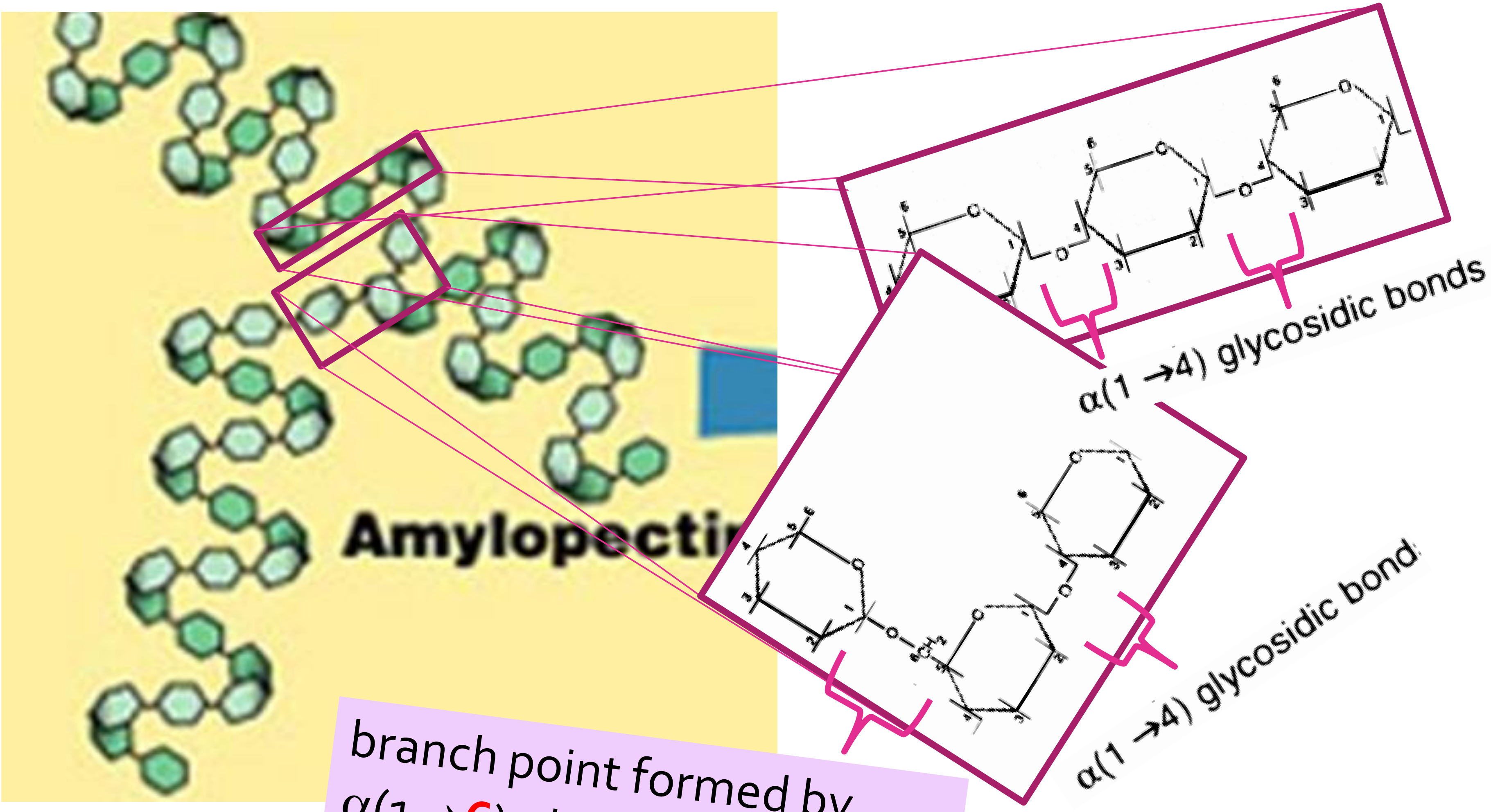


unbranched



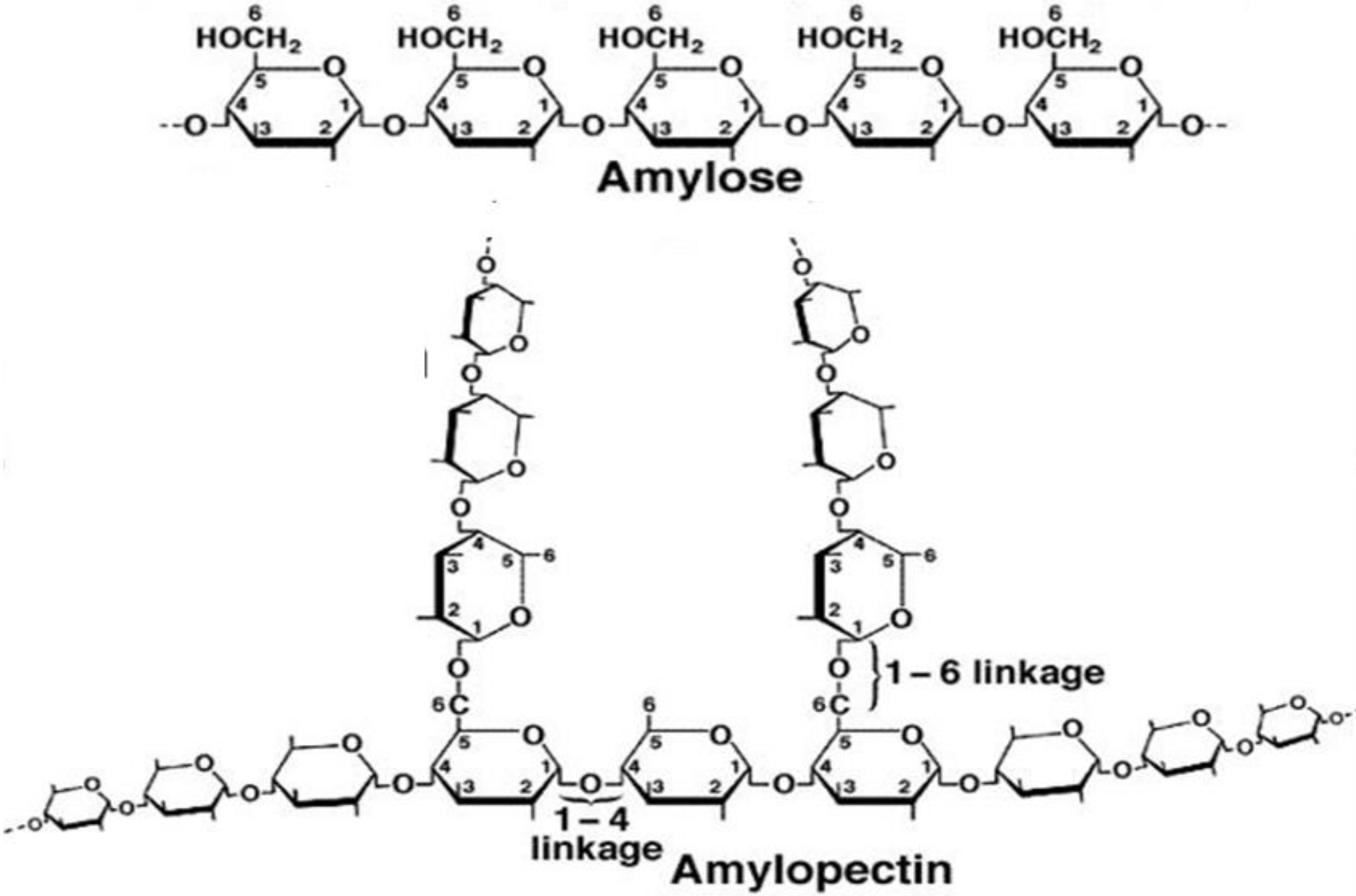
branched

Amylopectin



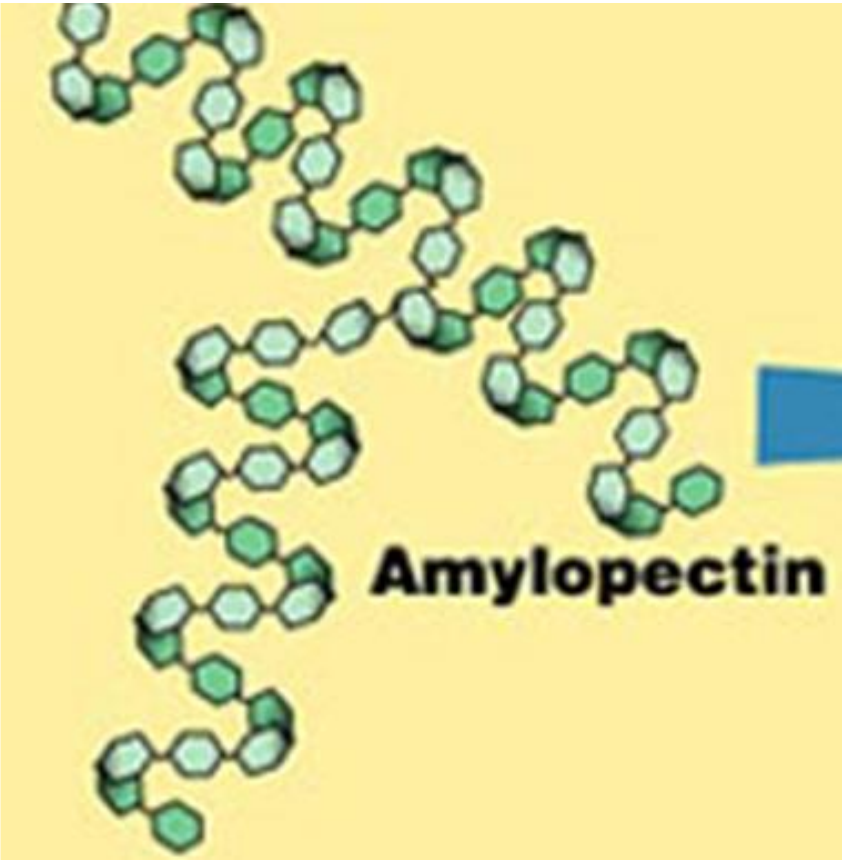
branch point formed by
α(1→6) glycosidic bond

Amylopectin



Amylopectin

- Like amylose, amylopectin is coiled into a helix and there is **no cross-linking** between amylopectin chains.



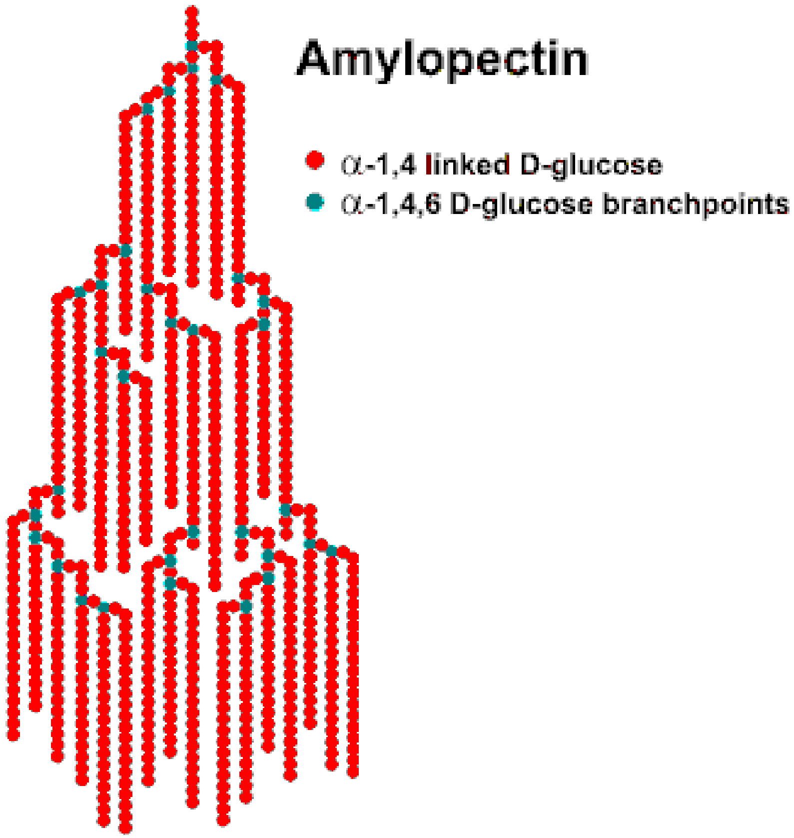
Pictures not in notes

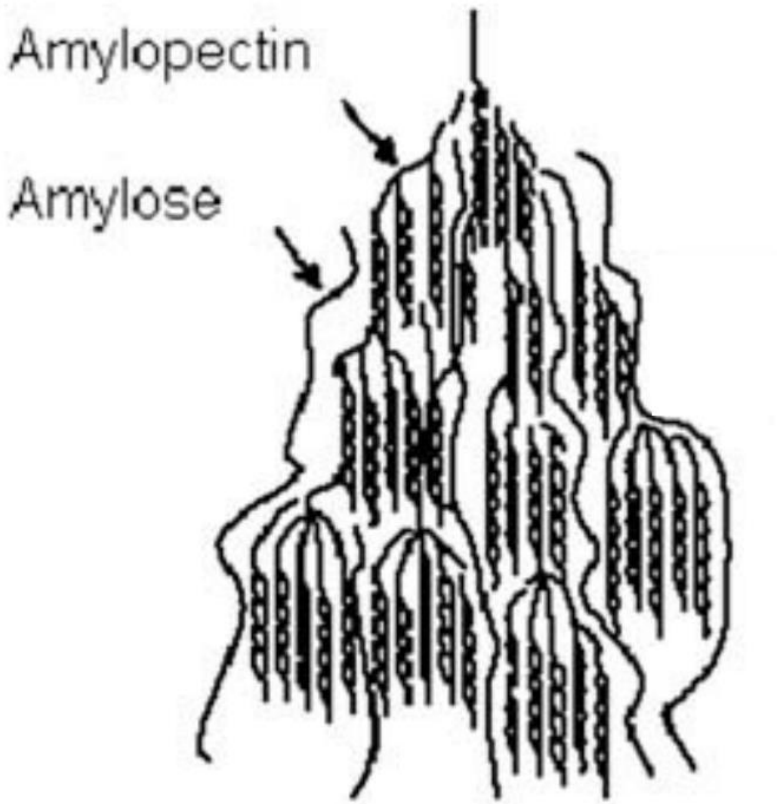
Starch = Amylose + Amylopectin

<u>*For General Knowledge*</u>

The two components of starch fit together to form a complex three-dimensional structure in which the amylose helices are entangled in the branches of amylopectin molecules.

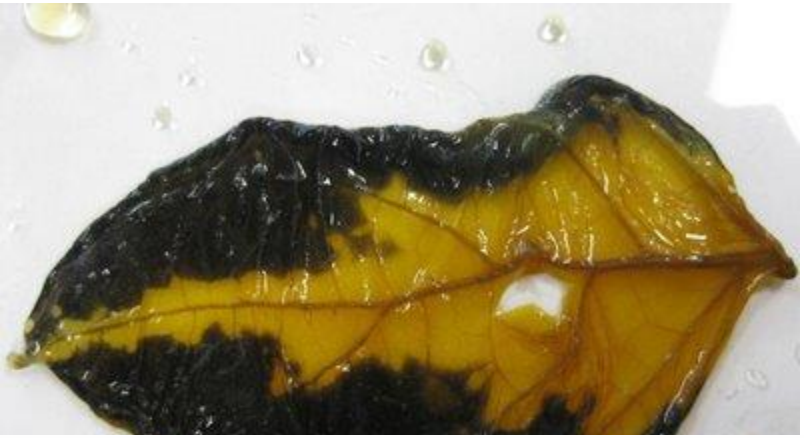
<u>Note</u> : many OH groups are protected within the helix and rendered less reactive.

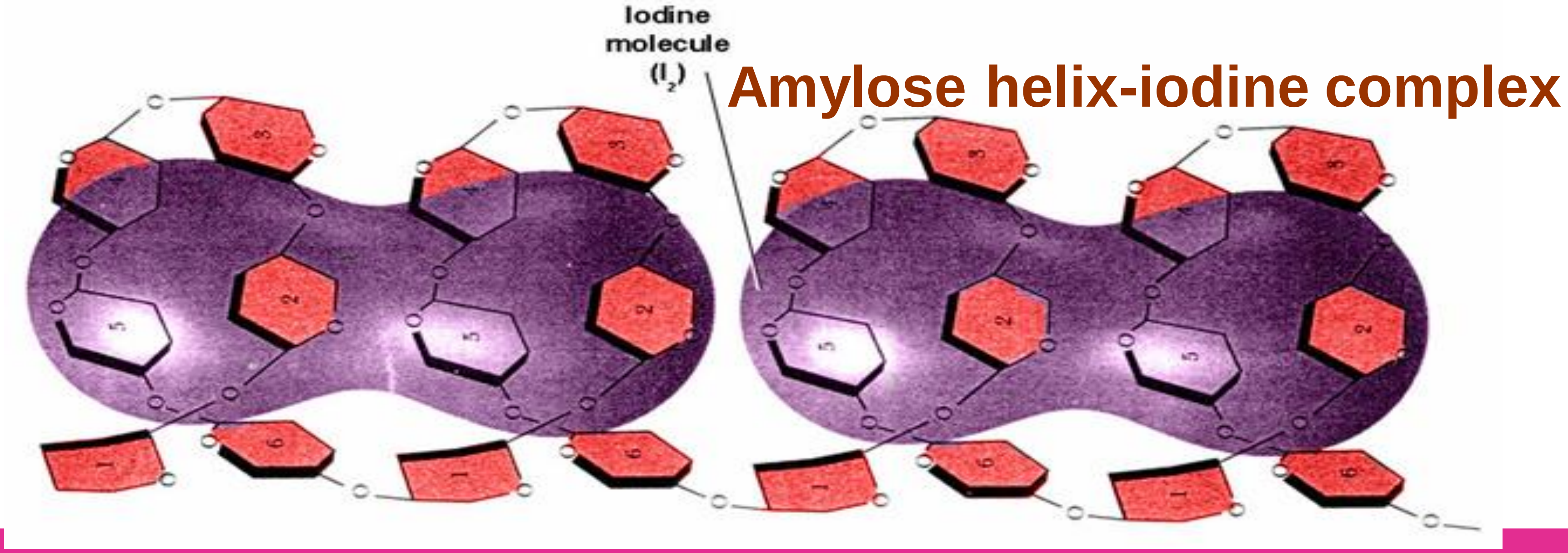




Testing for presence of starch

- *Iodine/potassium iodide test*





HOW TO HYDROLYSE STARCH INTO MONOSACCHARIDES?

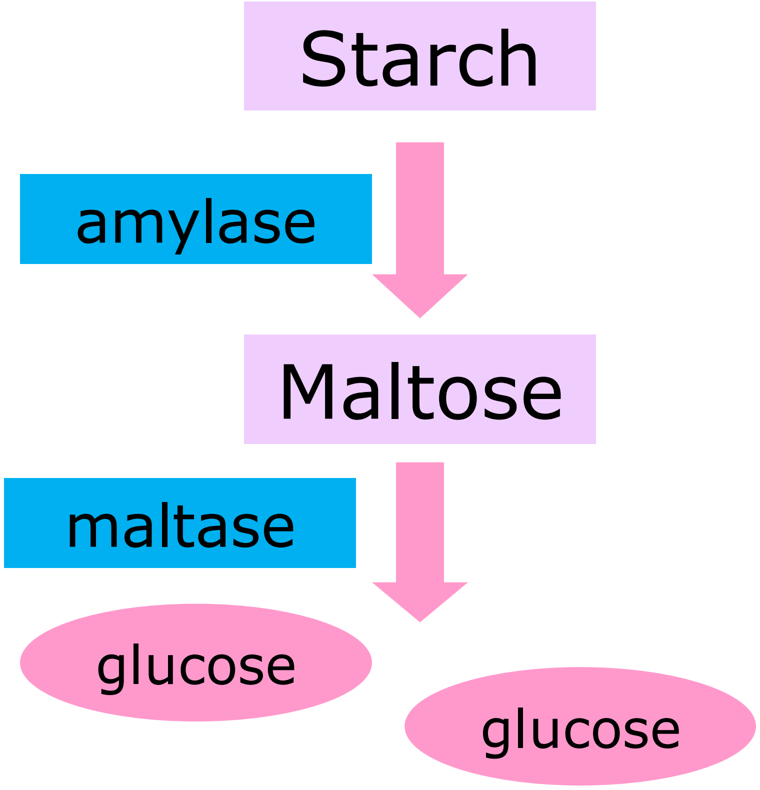
1. Chemical method
2. Enzymatic method

Hydrolysing starch: **Chemical** method

- Incubating starch with a dilute acid at 100°C.

Hydrolysing starch: **Enzymatic** method

- Incubating starch with **enzymes** at room temperature.



Polysaccharides

Based on their functions, polysaccharides can be divided into 2 groups

Storage

Hydrolysed (when needed) to **provide sugar** for cells

starch (plants)

Structural

Building material for **protection**

cellulose (plants)

Extra handout

Reading time

What makes starch a good storage molecule?

- Relate **structure** to **function**
- Framework:
  - **S**tructure
  - **P**roperty
  - **F**unction

Test yourself

A 2% solution of starch (amylose) and a 2% solution of amylase were mixed together and incubated at 25°C. After one hour, samples of the solution were tested with two reagents.

Which result would be expected?

	reagent added to samples	
	Benedict's solution and heated	Iodine in potassium iodide solution
A	Brown	brick-red
B	Blue	blue-black
C	blue-black	blue
D	brick red	brown

Tutorial 2: MCQ 5

Which statement describes how the molecular structure of starch is suited to its function?

A	Amylose has a branched structure and amylopectin is coiled to give a compact molecule for transport.
B	In the breakdown of amylose and amylopectin, many condensation reactions release stored energy.
C	The helical structure of amylose and amylopectin gives starch high tensile strength.
D	The amylose-amylopectin complex is insoluble and does not affect the water potential of the cell.

Polysaccharides

Based on their functions, polysaccharides can be divided into 2 groups

Storage

Hydrolysed (when needed) to **provide sugar** for cells

starch (plants)

Structural

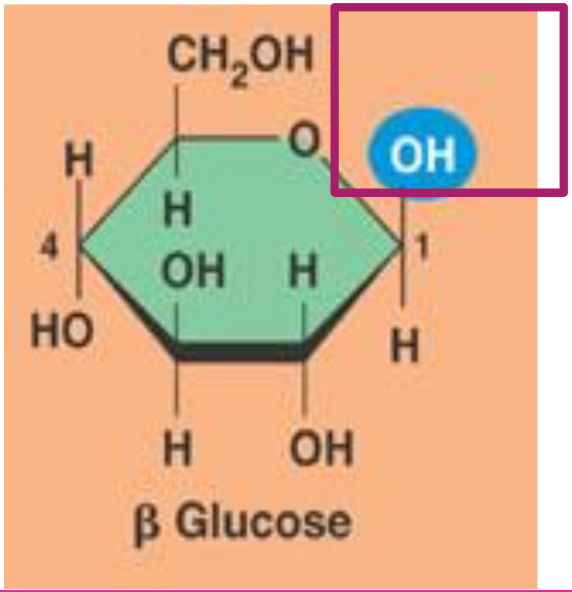
Building material for **protection**

cellulose (plants)

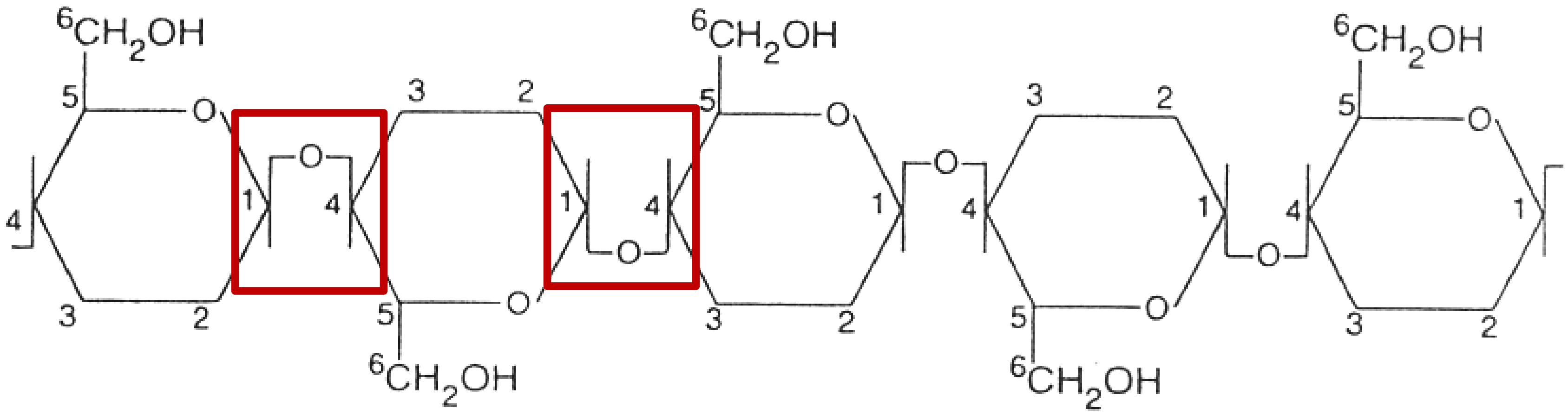
Polysaccharides: Cellulose

between what monomers?

- unbranched polymer
- linked by β(1→4) glycosidic bonds between β-glucose molecules
- Condensation reaction catalysed by enzyme e.g cellulose synthase



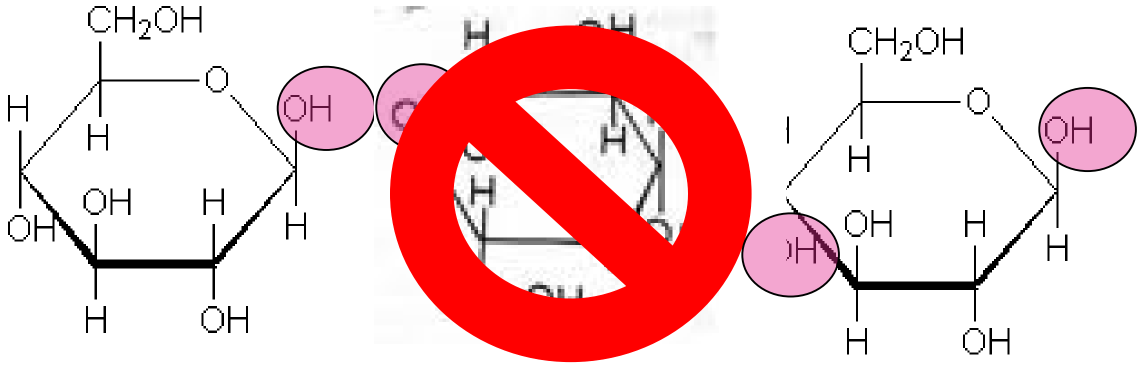
Polysaccharides: Cellulose

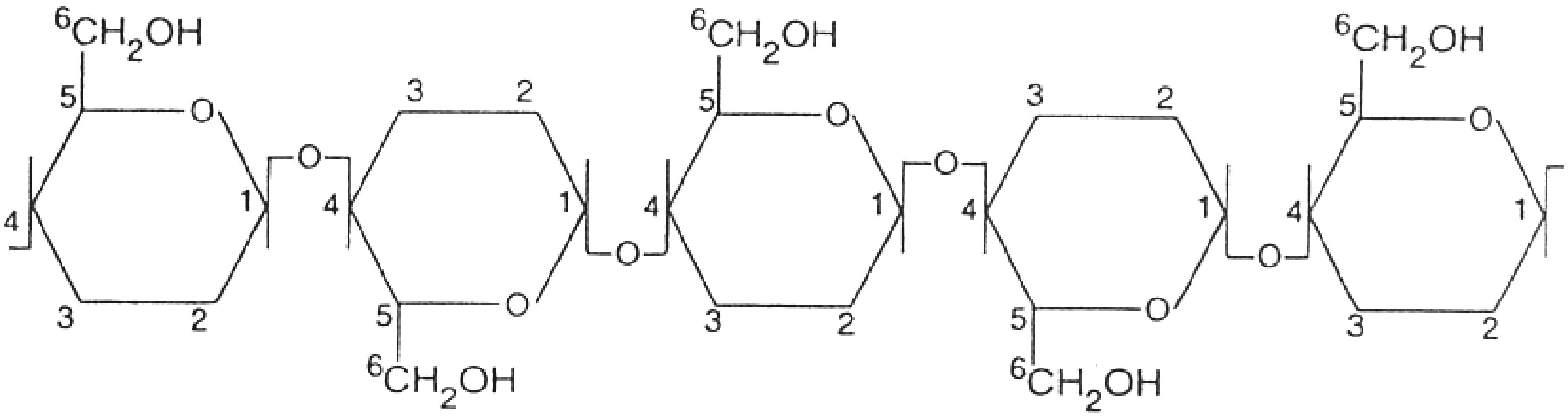


What do you notice about the glycosidic linkages compared to starch & glycogen?

- adjacent units oriented 180° to each other,
- i.e. every other glucose monomer is upside down with respect to the others.

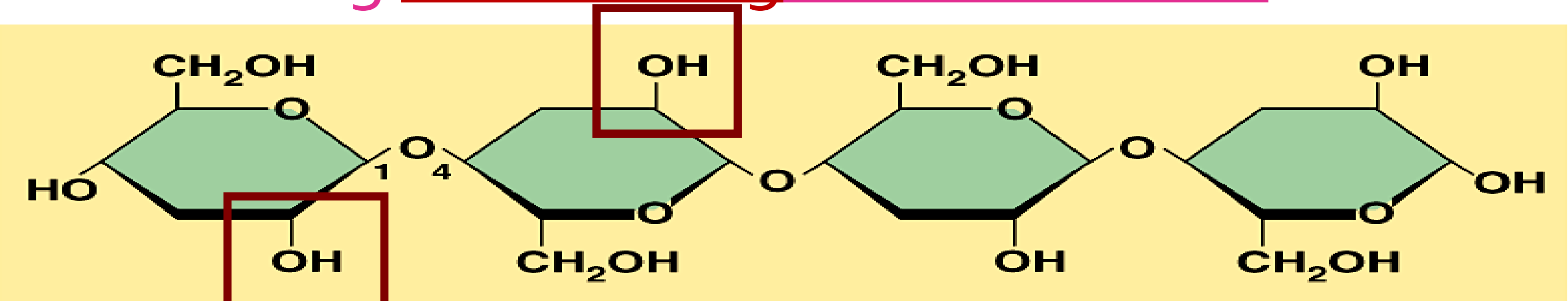
Polysaccharides: Cellulose



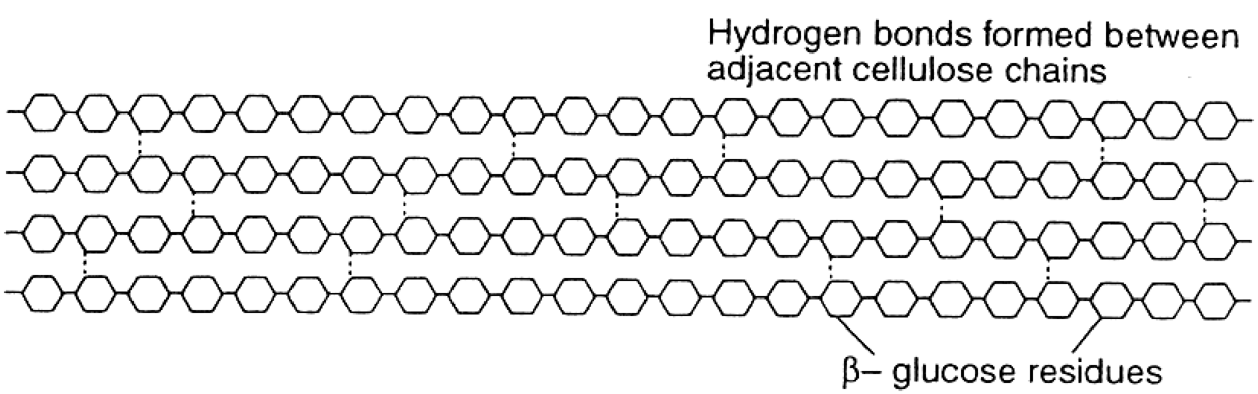


Polysaccharides: Cellulose

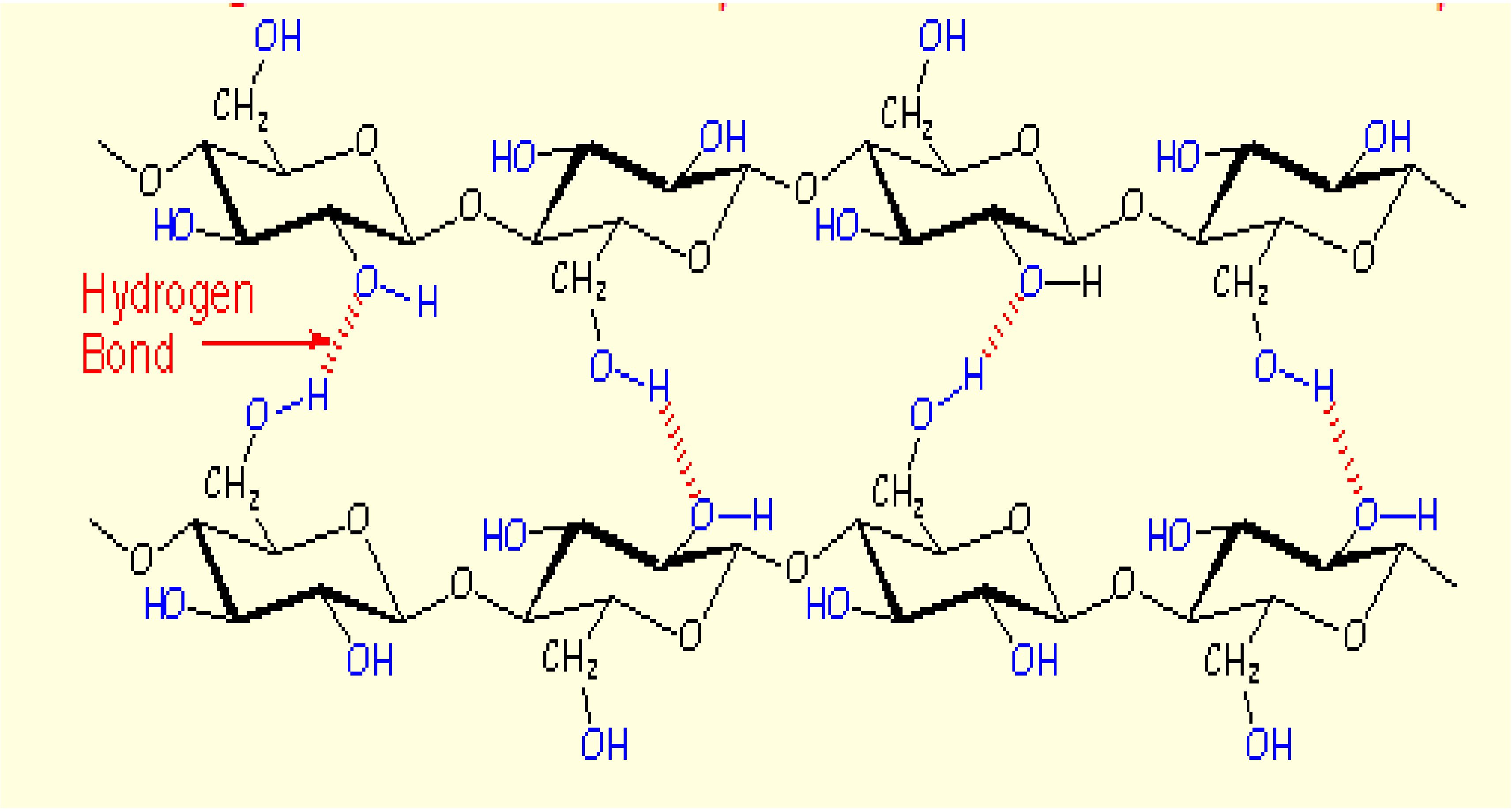
- hydroxyl groups (at carbon atom 2) project outwards
- form hydrogen bonds with neighbouring chains lying parallel to it,
- establishing cross-linking between chains.

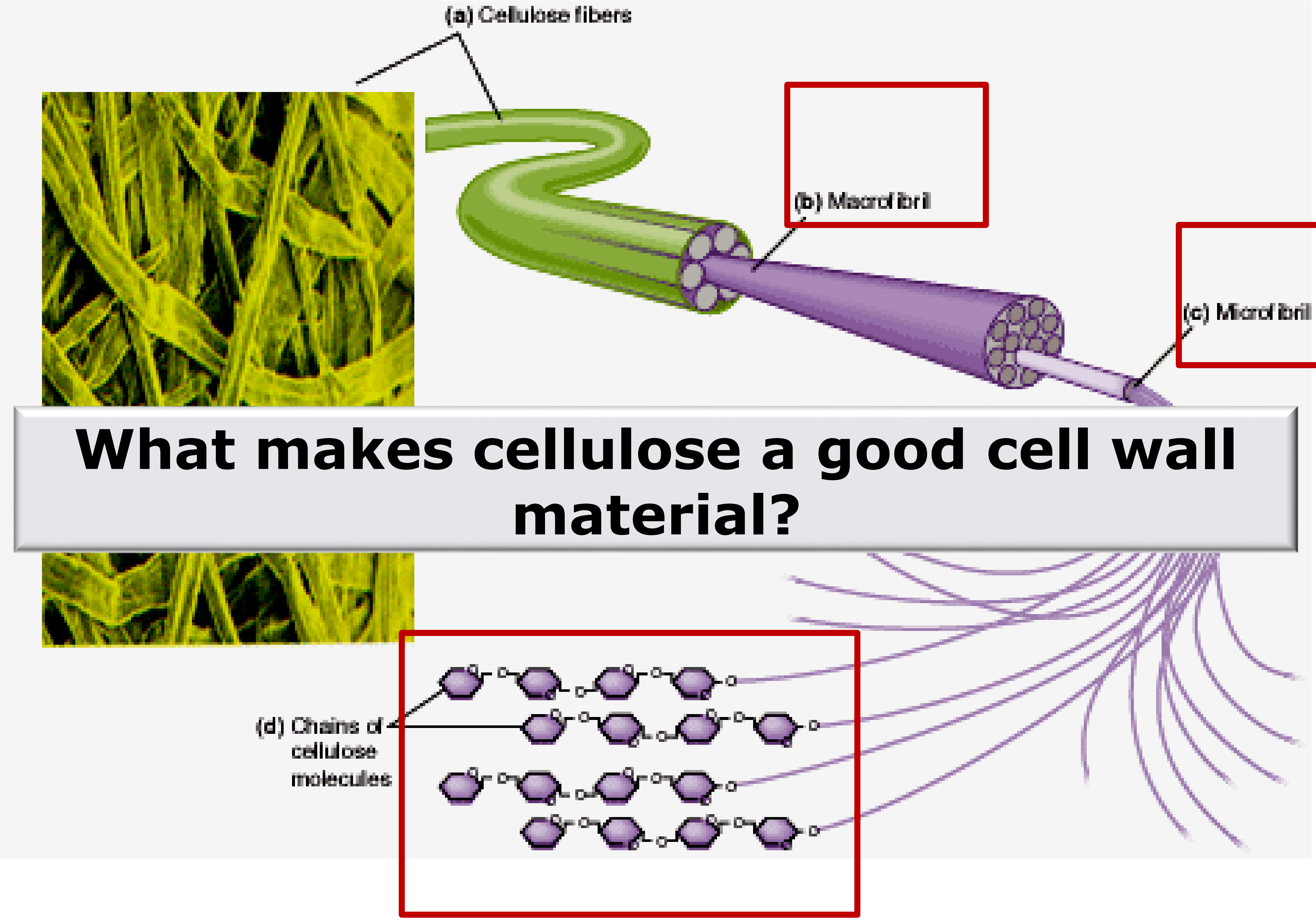


(c) Cellulose: 1—4 linkage of β glucose monomers



Cellulose – cross-linking between 2 molecules





What makes cellulose a good cell wall material?

Reading Time

What makes cellulose a good cell wall material?

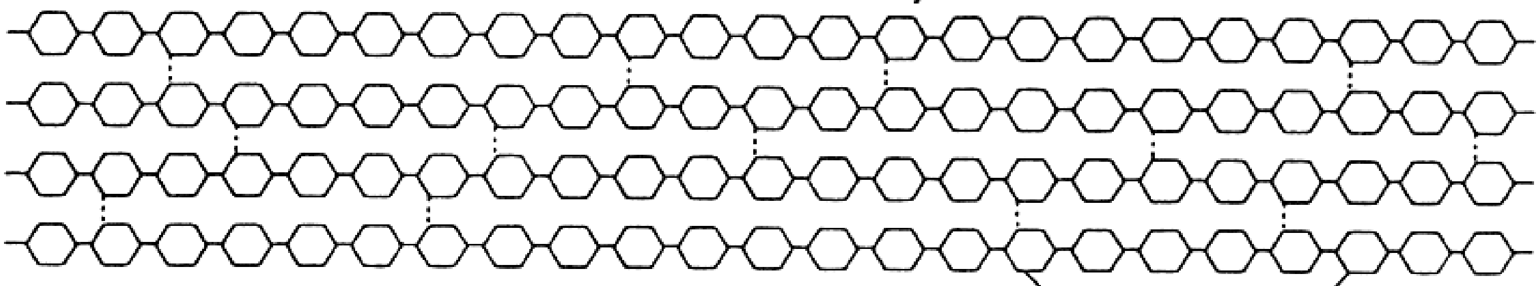
- Relate **structure** to **function**
- Framework:
  - **S**tructure
  - **P**roperty
  - **F**unction

Good cell wall material:

1. Great tensile strength

What structural feature contributes to this?

- cross-linking of chains



What is the advantage of having high tensile strength?

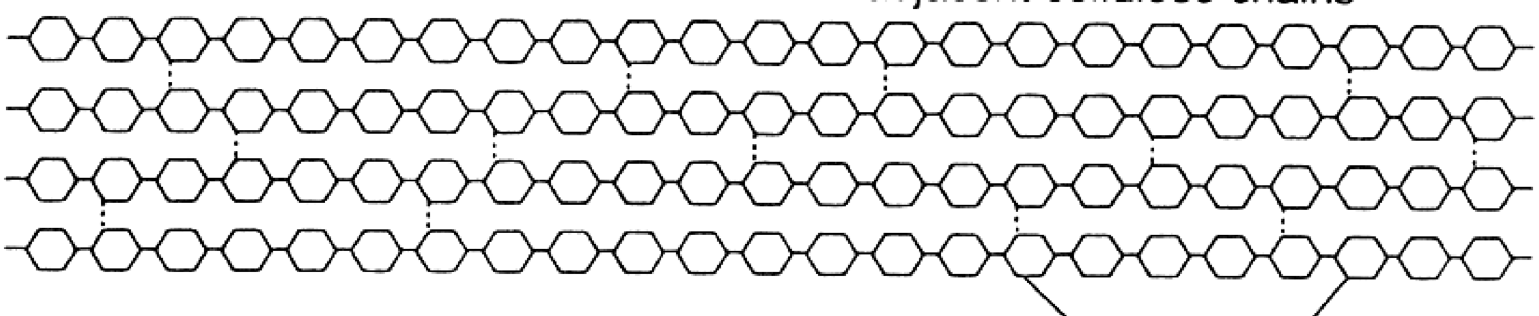
- prevents plant cells from bursting when placed in solutions of higher water potential.

Good cell wall material:

2. Insoluble in water

What structural feature contributes to this?

- Long chains of β-glucose molecules **and** cross-linkages resulting in high molecular weight and crystalline structure



How does this relate to its function?

Good cell wall material:

Pg 82

3. Large intermolecular spaces between macrofibrils

- Allows the passage of water and solute molecules.

Tutorial 2: Carbohydrates (MCQ 4)

Which statements about amylopectin and cellulose are correct?

1. Both contain 1-4 glycosidic bonds
2. Amylopectin contains β-glucose while cellulose contains α-glucose
3. Both have cross linkages.
4. Both are branched molecules.

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

LEARNING OBJECTIVES

- 1(e)(i) Describe the structure and properties of α-glucose and β-glucose (in carbohydrates)
- 1(f)(i) Describe the formation and breakage of a glycosidic bond.
- 1(g)(i) Describe the structures and properties of starch (including amylose and amylopectin), cellulose and explain how these are related to their roles in living organisms.

Next topic....

- Molecules in **cells**
- 4 main classes:

Carbohydrates

Proteins

Lipids

Nucleic acids