TeachMe

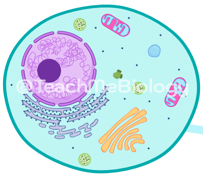
STUDY NOTES

Chapter 2 – Biological Molecules

Carbohydrates

Last update: October 1st 2025

CARBOHYDRATES



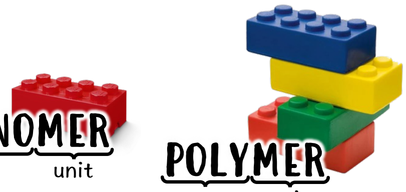
Have you ever wondered what we're really made of? Sure, we're made of cells... but what are *cells* made of?
Over the next few notes we are looking at all the different components of cells one by one

CARBOHYDRATES | **LIPIDS** | **PROTEIN** | **NUCLEIC ACIDS** (Chapter 6) | **WATER**

Macromolecules
literally means giant molecule

Macromolecules are large molecules built from smaller, repeating subunits known as **MONOMERS**. By linking many monomers together, you form a **POLYMER**.

	Monomer	Polymer
Carbohydrates	Monosaccharide	Polysaccharide
Protein	Amino acid	Polypeptide
Nucleic Acids	Nucleotide	Nucleic acid



MONOMER – one unit

POLYMER – many unit

Big Brain Tip!

You can think of a monomer as a single Lego piece, and when you join multiple together you get a large structure (polymer)

Most macromolecules (except lipids) follow this same principle, but each type uses different monomers. You'll get to know their names in the upcoming notes — for now, let's focus on carbohydrates!

CARBOHYDRATES

Simple term: **sugar**

- **MONOSACCHARIDE** – Single Sugar
- **DISACCHARIDE** – Two Sugar
- **POLYSACCHARIDE** – Many Sugar

Just an overview, we learn about each in more detail!

CARBOHYDRATES

Carbon (C)

Hydrogen (H) and **Oxygen** (O) in a ratio of 2:1 — just like water

MONOSACCHARIDES

Page 2

(Sweet taste)

Beta Glucose, Alpha Glucose, Galactose, Fructose — Hexose (6 carbons)

Ribose, Deoxyribose — Pentose (5 carbons)

DISACCHARIDES

Page 4

(Sweet taste)

Alpha glucose – O – Alpha glucose: **Maltose**

Alpha glucose – O – Galactose: **Lactose**

Alpha glucose – O – Fructose: **Sucrose**

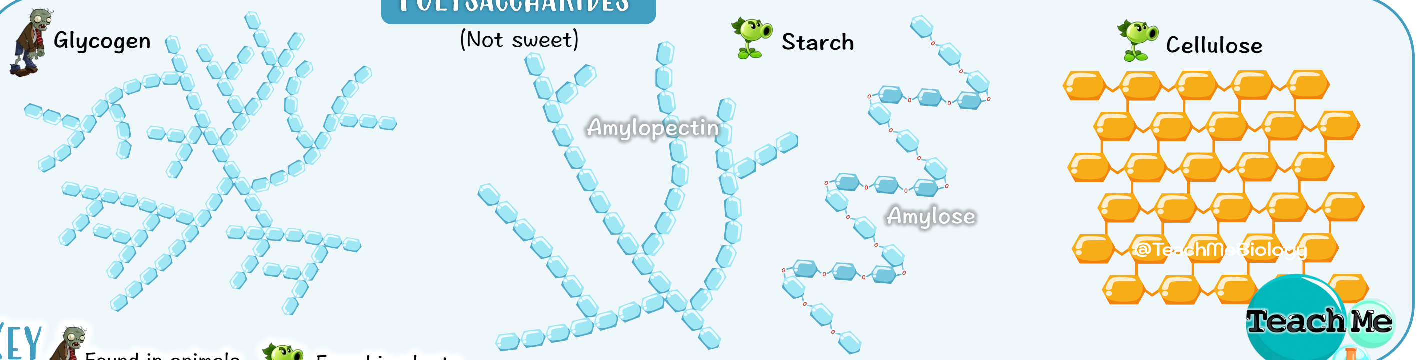
Big Brain Tip!

Carbohydrate names usually end in "ose"

POLYSACCHARIDES

Page 5

(Not sweet)



KEY: Found in animals | Found in plants

MONOSACCHARIDES

Molecules composed of **carbon**, **hydrogen** and **oxygen** with the general formula; $C_nH_{2n}O_n$ or $(CH_2O)_n$

Carbon Hydrate

Molecular Bonds

1 BOND — H — Hydrogen atom

2 BONDS — O — Oxygen atom

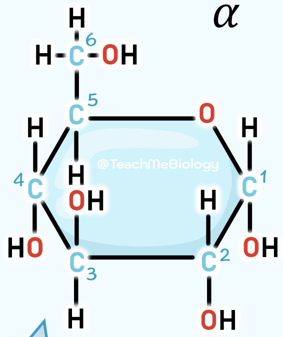
4 BONDS — C — Carbon atom

The Hexose Monosaccharides

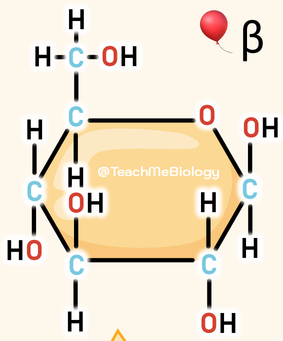
You need to know how to draw it!

Big Brain Tips!
BOHner points up!
Balloons rise up

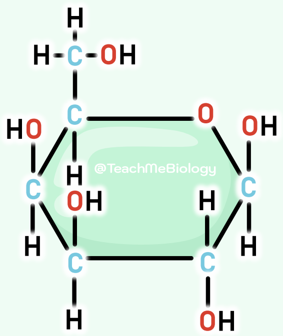
$C_6H_{12}O_6$ — ALPHA GLUCOSE



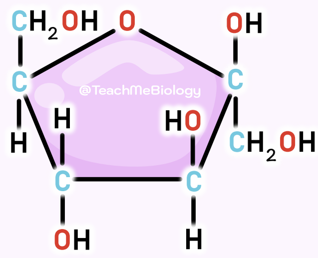
$C_6H_{12}O_6$ — BETA GLUCOSE

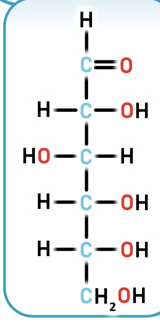


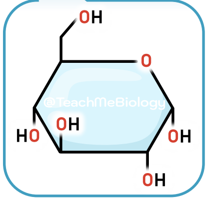
$C_6H_{12}O_6$ — GALACTOSE

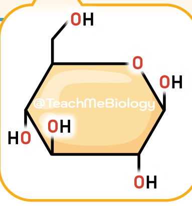


$C_6H_{12}O_6$ — FRUCTOSE









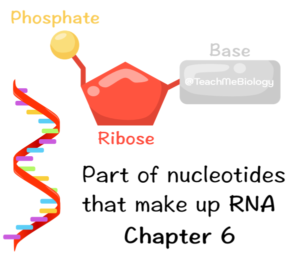
The molecular structure of the monosaccharides can be represented in different ways. You don't need to know how to draw each one, but you should be able to **RECOGNIZE** them in an exam.

Glucose usually exists in a stable ring form, but it can also open into a straight-chain structure — though this open form is less stable.

Alpha and BETA glucose are **isomers**: they have the same formula, but the OH group on carbon 1 is in a different position: in alpha it's down, in beta it's up.

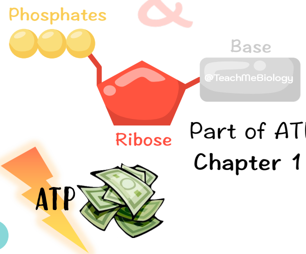
Curious about which kinds of food contain which kind of carbohydrate? See page 8

The Pentose Monosaccharides



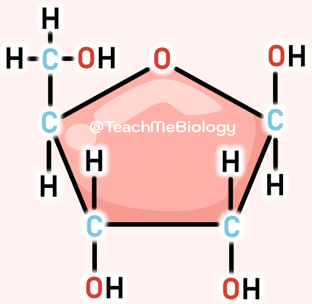
Part of nucleotides that make up RNA
Chapter 6

&

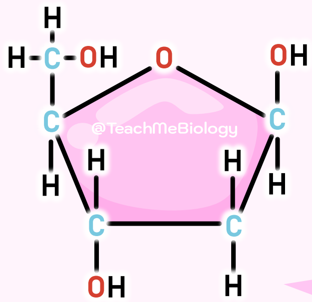


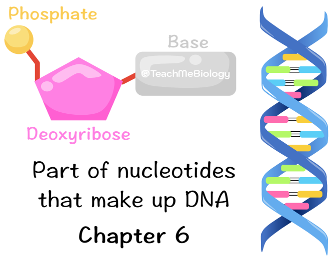
Part of ATP
Chapter 12

$C_5H_{10}O_5$ — RIBOSE



$C_5H_{10}O_4$ — DEOXYRIBOSE





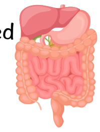
Part of nucleotides that make up DNA
Chapter 6

Deoxy' means missing an oxygen — deoxyribose is ribose with 1 less oxygen atom

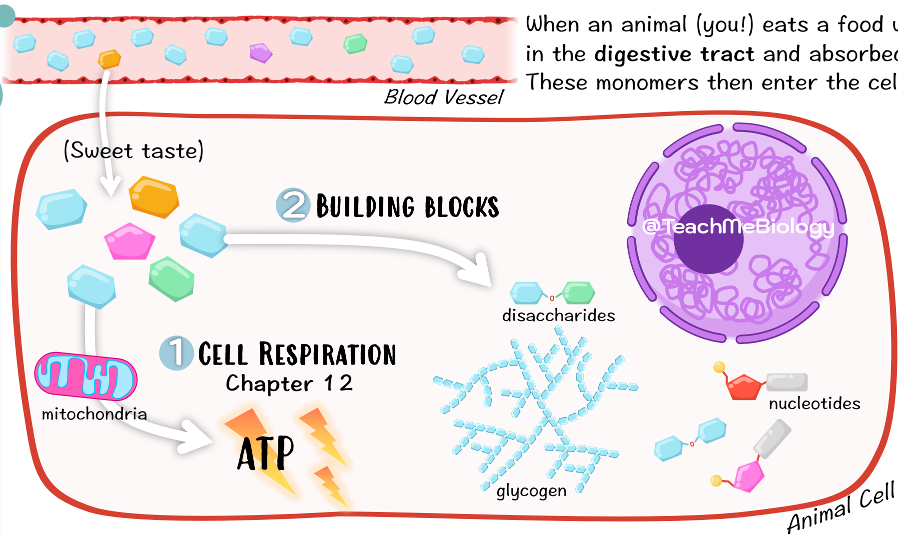
Use of Monosaccharides

Now that we've nailed the structure of monosaccharides, it's time to see them in action! Let's dive into the different uses of monosaccharides:

In Animals



When an animal (you!) eats a food which contains carbohydrates, it gets digested in the **digestive tract** and absorbed as monomers into the blood stream. These monomers then enter the cells of the body to fulfil two main functions:

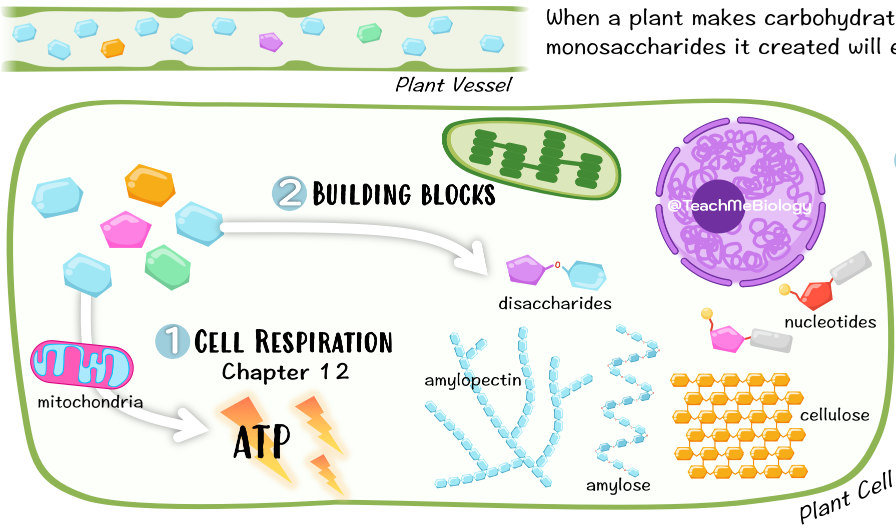


Cell Respiration & **Building blocks**

1. Monosaccharides get used by the mitochondria to generate ATP (energy). You learn about it in more detail in chapter 12.
2. Monosaccharides can be used to build larger molecules, such as **nucleotides** that form DNA and RNA (see page 2). How? See bottom of page
   - They can also join together to form **disaccharides** like maltose or lactose (see page 4), the sugar found in milk.
   - In addition, many glucose molecules can polymerize to form **glycogen** (see page ???), the main storage form of glucose in animals.

In Plants

When a plant makes carbohydrates through photosynthesis (chapter 13), the monosaccharides it created will enter the cells, and fulfil two main functions:



Cell Respiration & **Building blocks**

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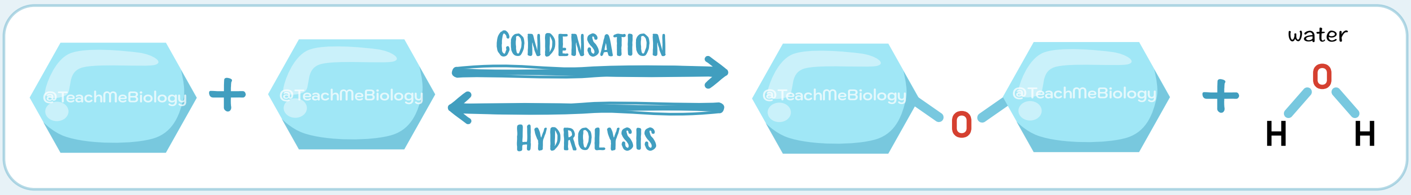
2. Monosaccharides can be used to build larger molecules, such as **nucleotides** that form DNA and RNA (see page 2). How? See bottom of page
   - They can also join together to form **disaccharides** like fructose (see page 4) – the sweet component of table sugar.
   - In addition, many glucose molecules can polymerize to form **amylopectin or amylose** (see page ???), the main storage form of glucose in plants.

How do monomers link together? ... and unlink!

Condensation – Chemical reaction involving the joining together of two molecules by **REMOVAL** of a water molecule.
"Water formation"



Hydrolysis – Chemical reaction by which two molecules are formed through the breaking of a chemical bond by the **ADDITION** of water.
"Water Splitting"

DISACCHARIDES

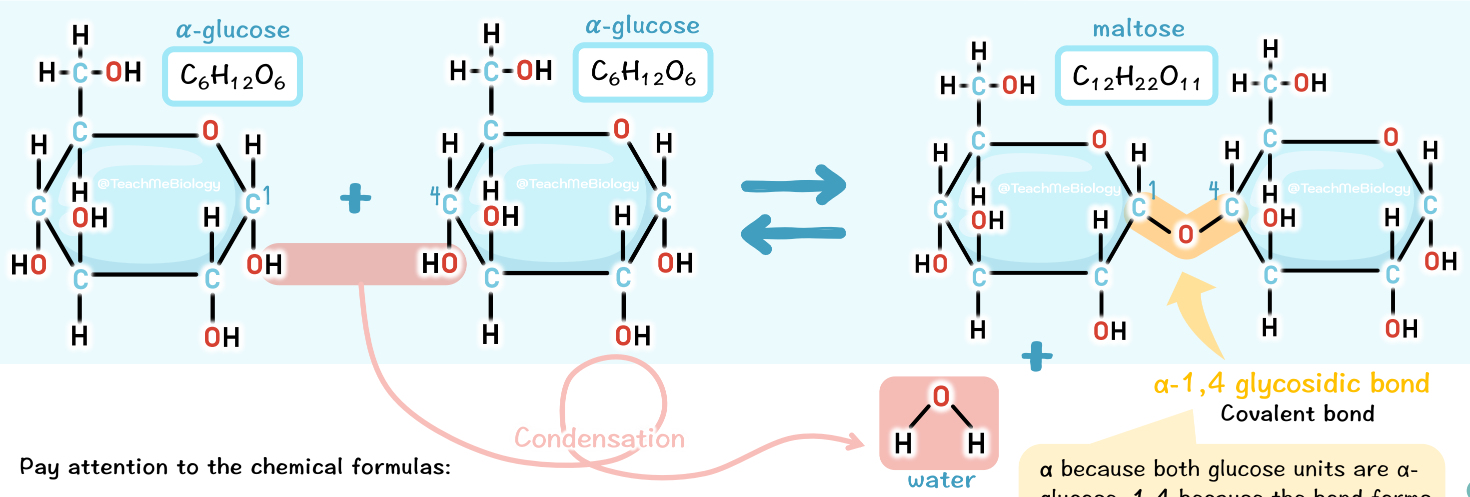
The disaccharides are formed by a CONDENSATION REACTION between two monosaccharides.

MALTOSE FORMATION

You need to know how to draw it!

Maltose formation occurs in both plants and animals.

α-glucose + α-glucose ⇋ maltose + water



α because both glucose units are α-glucose. 1,4 because the bond forms between carbon 1 of the first glucose and carbon 4 of the second glucose.

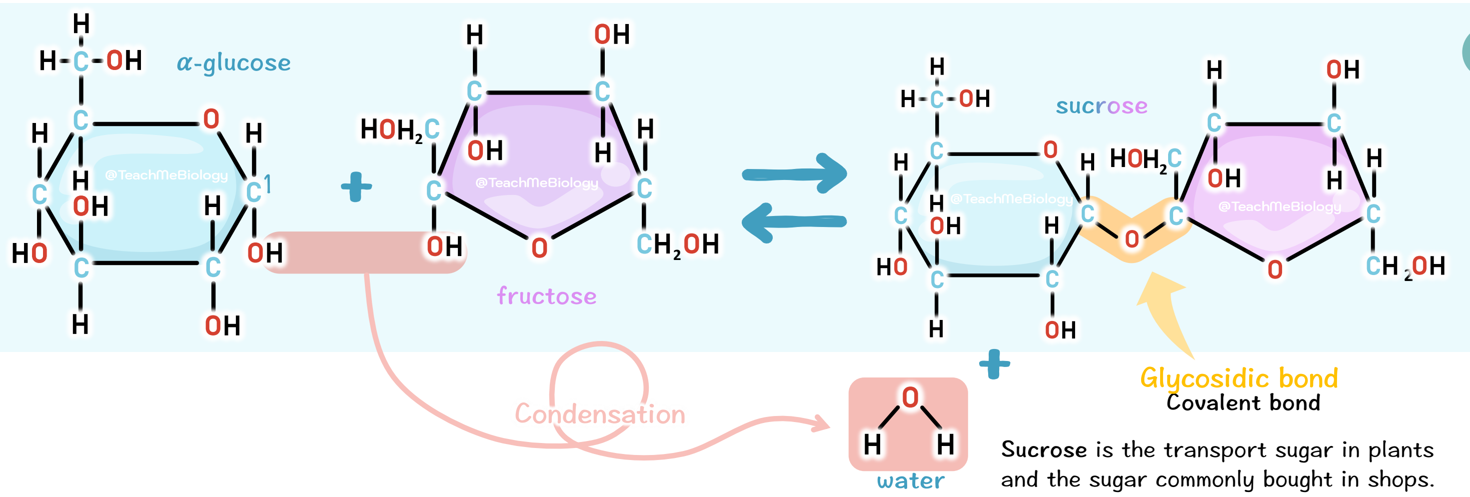
Pay attention to the chemical formulas:

Maltose consists of two glucose units. If you simply doubled the glucose formula ($C_6H_{12}O_6$ × 2), you would expect maltose to be $C_{12}H_{24}O_{12}$.
However, during the condensation reaction a water molecule is lost, giving the actual formula $C_{12}H_{22}O_{11}$.

SUCROSE FORMATION

Sucrose formation occurs only in plants.

α-glucose + fructose ⇋ sucrose + water



Sucrose is the transport sugar in plants and the sugar commonly bought in shops.

LACTOSE FORMATION

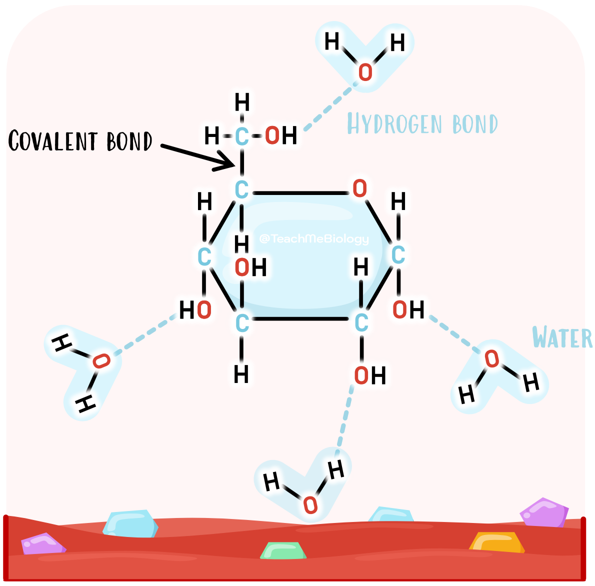
Lactose formation occurs only in animals (only when lactating).

α-glucose + galactose ⇋ lactose + water

POLYSACCHARIDES

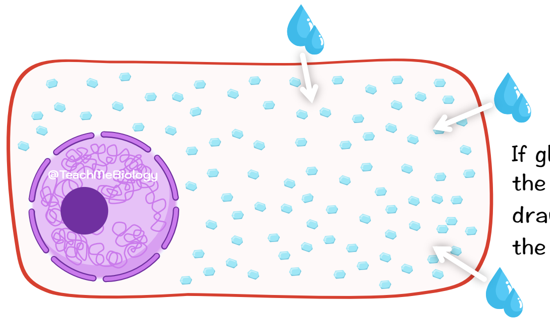
Polysaccharides are formed by REPEATED CONDENSATION REACTIONS between many monosaccharides.

But why? Why should glucose be stored as a polysaccharide?



Glucose is **soluble** in water and hence easily transported via blood and resides in cells.

1.

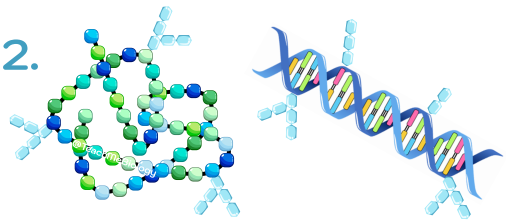


BUT!

If glucose accumulated in the cell, water would get drawn in by OSMOSIS, and the cell would swell.

(Chapter 4)

2.

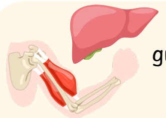


Glucose is very reactive and interferes with normal cell chemistry.

Problem solved: Storage polysaccharides are inert, compact, insoluble and convenient!

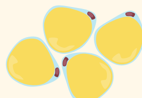
GLYCOGEN – Energy Storage in Animals

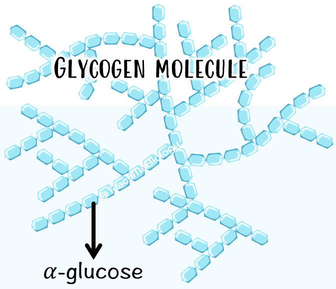
Glycogen is a highly branched polysaccharide made up of α-GLUCOSE. It is a form of energy storage in liver and muscle cells.

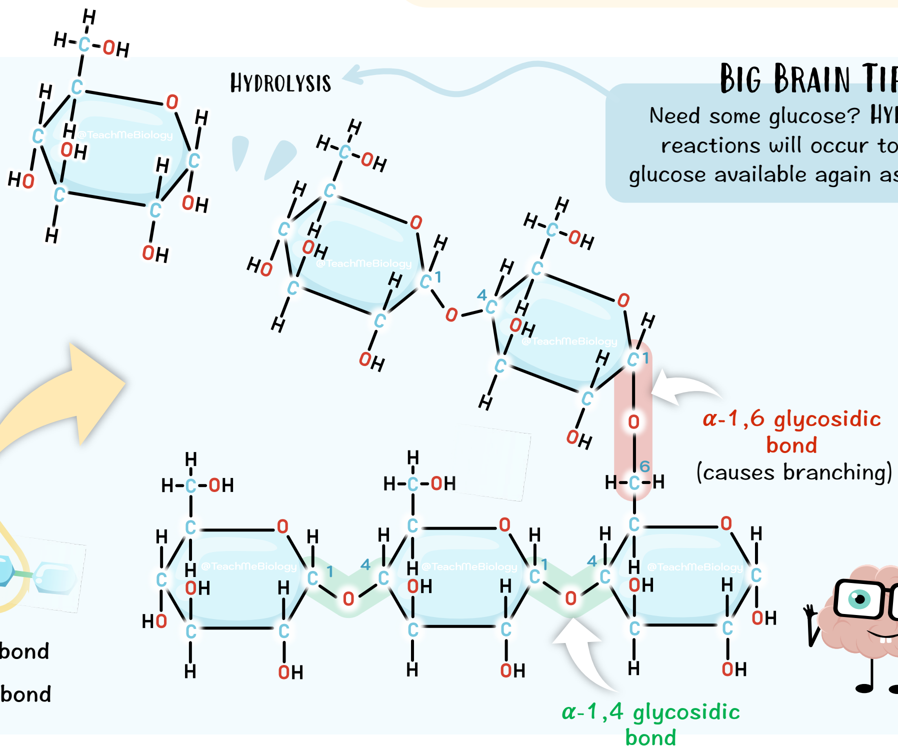


Glycogen molecules clump together to form granules, which are visible in liver and muscle cells where they form an energy reserve.

If glycogen reserves are full, excess glucose will be converted into fats (lipids).



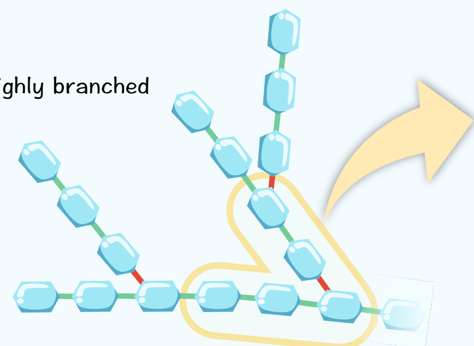




BIG BRAIN TIP!

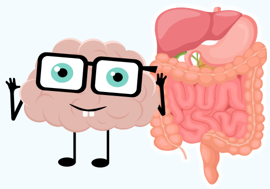
Need some glucose? HYDROLYSIS reactions will occur to make glucose available again as needed.

Highly branched



RED α-1,6 glycosidic bond

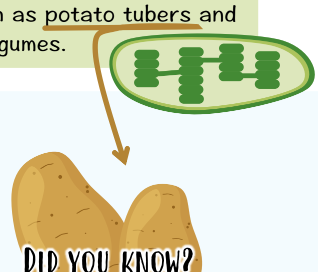
GREEN α-1,4 glycosidic bond

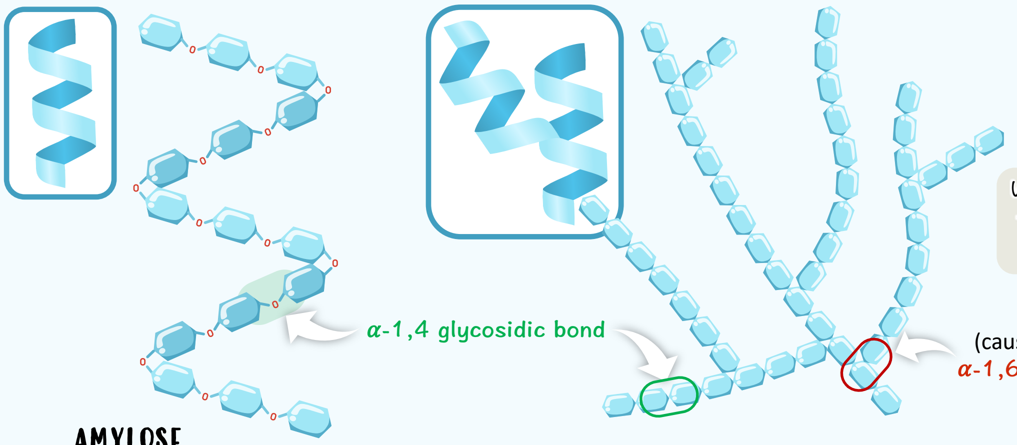


STARCH Energy Storage in Plants

α-glucose is stored as **starch grain** which are made up of two polysaccharides: amylose (unbranched) and amylopectin (branched chains).

Starch grains are commonly found in chloroplasts and in storage organs, such as potato tubers and the seeds of cereals and legumes.





DID YOU KNOW?

We can digest starch because we have the enzyme capable of breaking down **α-1,4 and α-1,6 glycosidic bonds.**

AMYLOSE
Spring-like, helical structure

AMYLOPECTIN 1,4 chains are shorter, leading to shorter individual chains
Less branching than glycogen

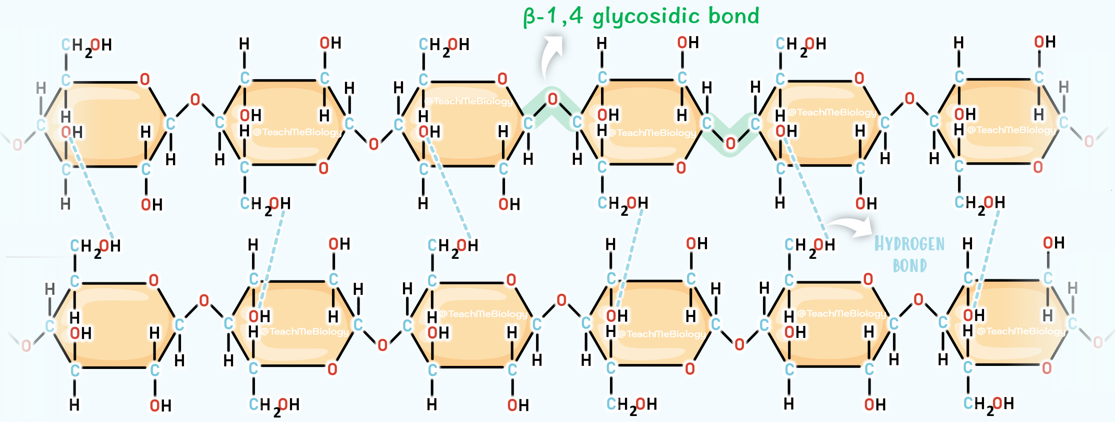
CELLULOSE Structural purposes in Plants

β-glucose is polymerized into cellulose, a structural polysaccharide in plant cell walls. The chains form hydrogen bonds with each other, producing strong microfibrils that give rigidity and support to plant cells.

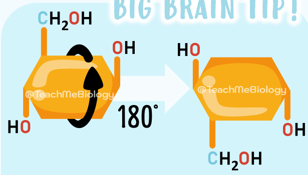
DID YOU KNOW?

We cannot digest cellulose because we don't have the enzyme capable of breaking down **β-1,4 glycosidic bonds.**

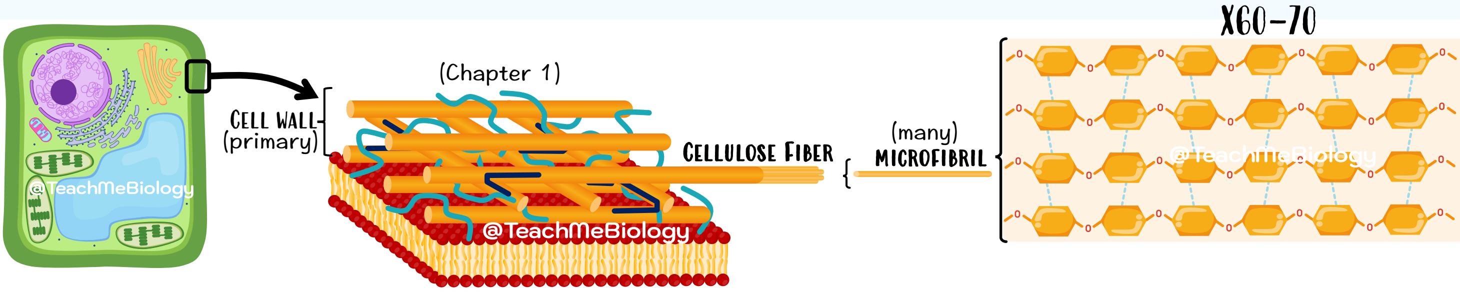
So, it all comes out!



BIG BRAIN TIP!



Alternating beta glucoses in a cellulose chain are flipped 180°



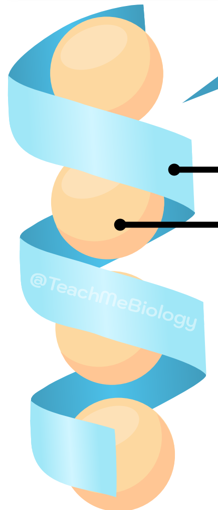
Little Summary – Polysaccharides

Glycogen	Starch		Cellulose
	Amylose	Amylopectin	
Alpha glucose	Alpha glucose	Alpha glucose	Beta glucose
α-1,4 glycosidic bond α-1,6 glycosidic bond	α-1,4 glycosidic bond	α-1,4 glycosidic bond α-1,6 glycosidic bond	β-1,4 glycosidic bond
Animals	Plants	Plants	Plants
Energy storage	Energy storage	Energy storage	Structural purposes

Testing for the presence of carbohydrates

I. The Iodine Test

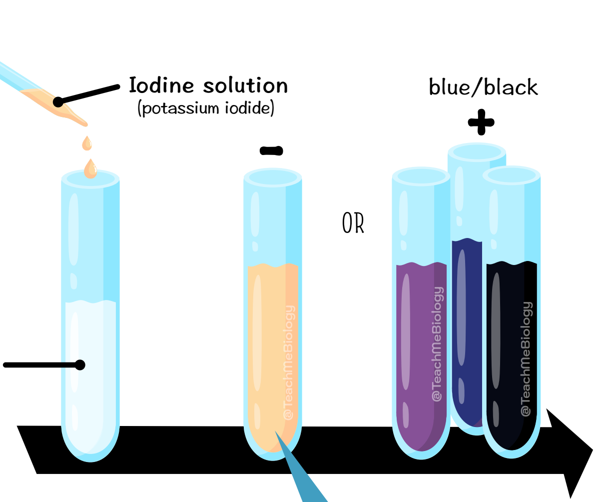
Testing the presence of starch in a sample



When iodine solution is added to starch, the iodine molecules get **trapped in the helix**, producing a characteristic **blue-black** colour.

STARCH Spiral shape (amylose component)

IODINE MOLECULE Fit perfectly in the middle



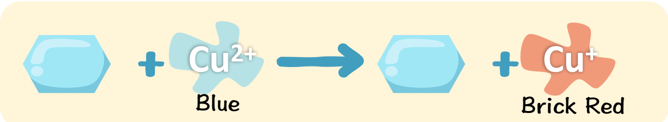
If no starch is present, the iodine solution remains its original **yellow-brown** colour.

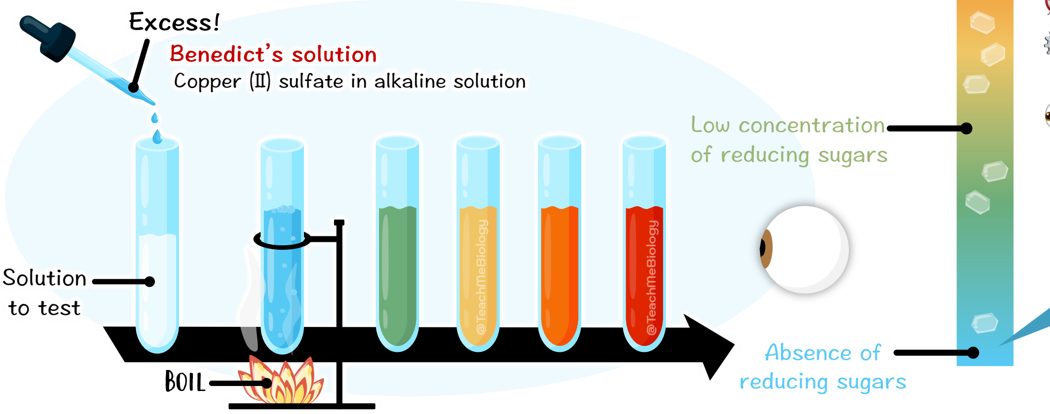
! I cannot stress enough how important it is for you to understand this test! It shows up in Every... Single... exam!

II. The Benedict's Test

Testing the presence of **REDUCING SUGARS**. These include monosaccharides & disaccharides (EXCEPT SUCROSE)

REDUCING SUGARS – Sugars that donate electrons





Doesn't work for sucrose and polysaccharides!

Semi-quantitative test

- Observing color change
- Measuring time for color change
- Using a colorimeter precisely measure the color differences
- Comparing against solutions of known concentration

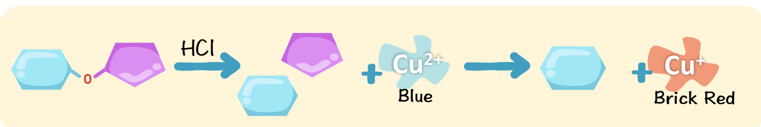
If the solution stays blue, what does it mean?

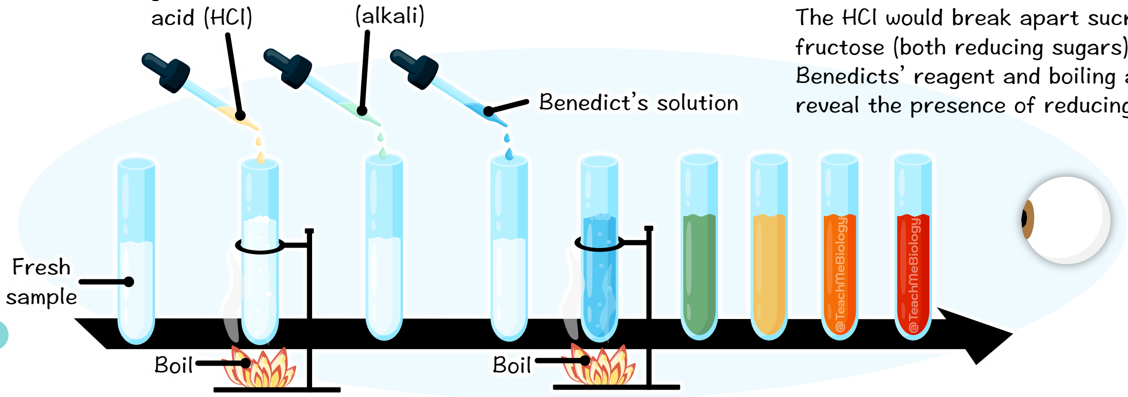
It confirms that there are no reducing sugars. It does not rule out sucrose (non-reducing sugar) or polysaccharides (like starch).

What if sucrose was present in the sample?

STEP 1 The Benedict's test result is negative (blue)

STEP 2

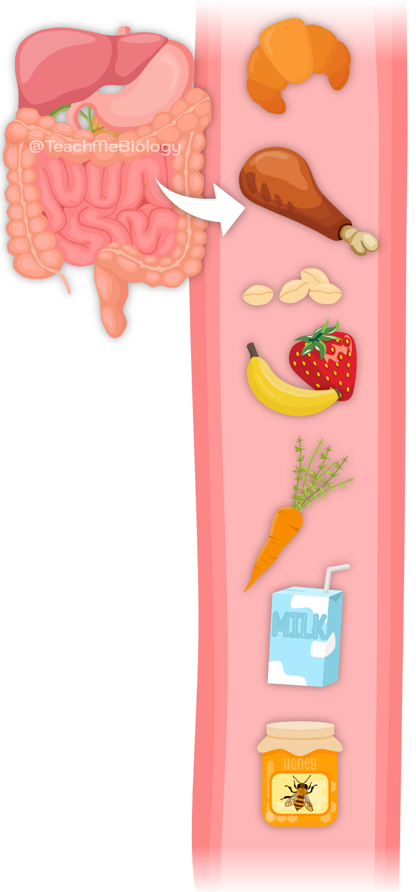




The HCl would break apart sucrose into glucose and fructose (both reducing sugars), then after adding a base, Benedicts' reagent and boiling as normal, the test would reveal the presence of reducing sugars.

Which foods contain which kinds of carbohydrate?

[not part of the syllabus, only for your own curiosity]



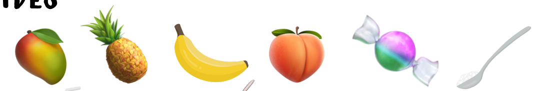
Monosaccharides

Glucose 

Fructose 

Galactose (not found free in foods)

Disaccharides

Sucrose 

Lactose 

Maltose (not found free in foods)

Polysaccharides

Glycogen 

Starch 

Cellulose (fiber)