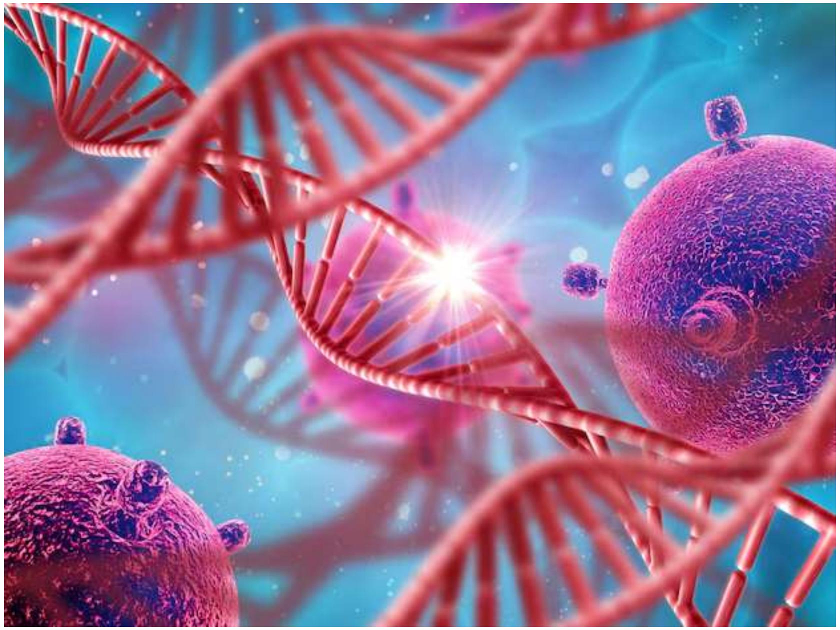
Lecture 5

General Biology & Cytology Course 2301130



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The Structure and Function of Macromolecules

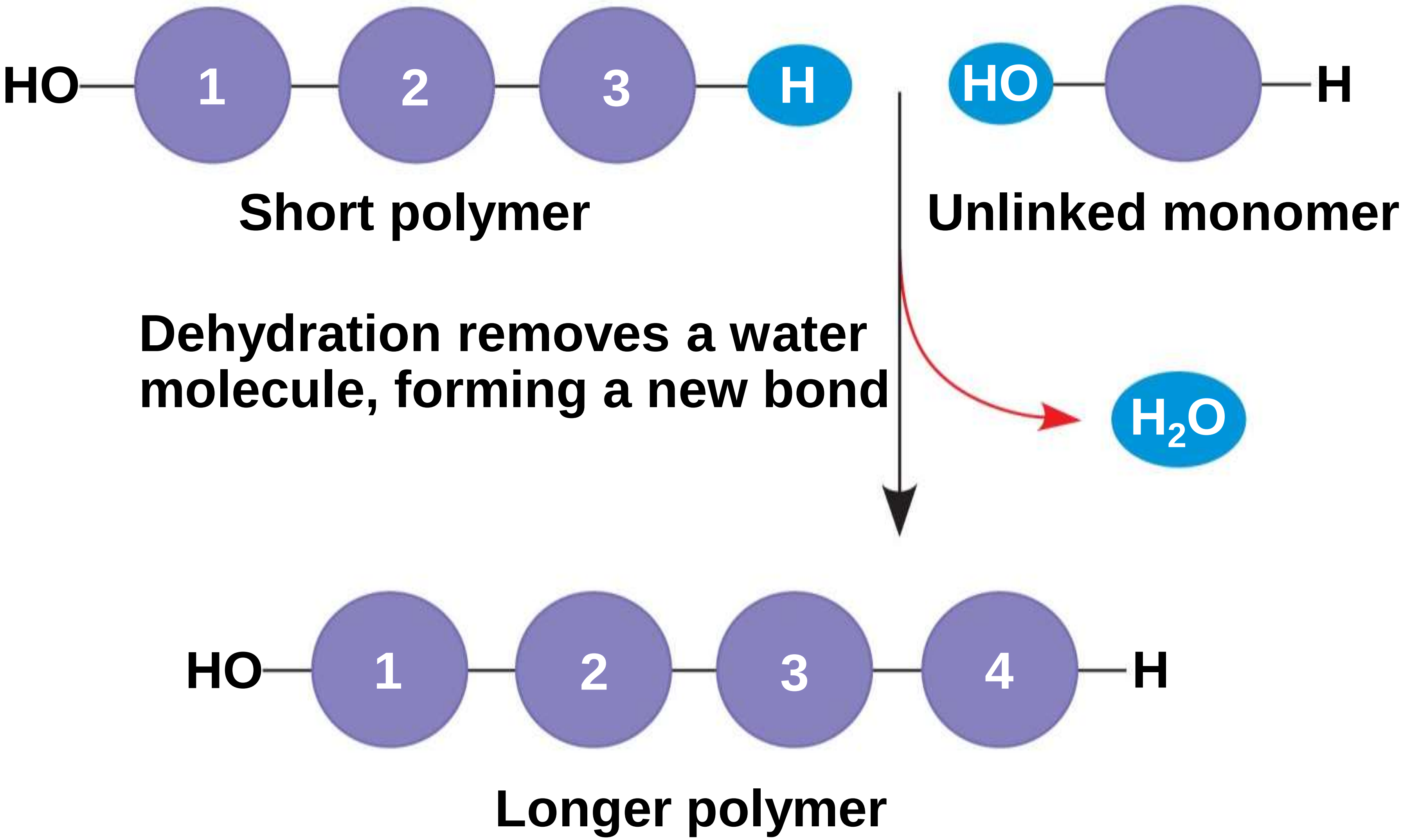
Overview: The Molecules of Life

- All living things are made up of four classes of large biological molecules: carbohydrates, lipids, proteins, and nucleic acids
- Within cells, small organic molecules are joined together to form larger molecules
- **Macromolecules** are large molecules composed of thousands of covalently connected atoms
- Molecular structure and function are inseparable

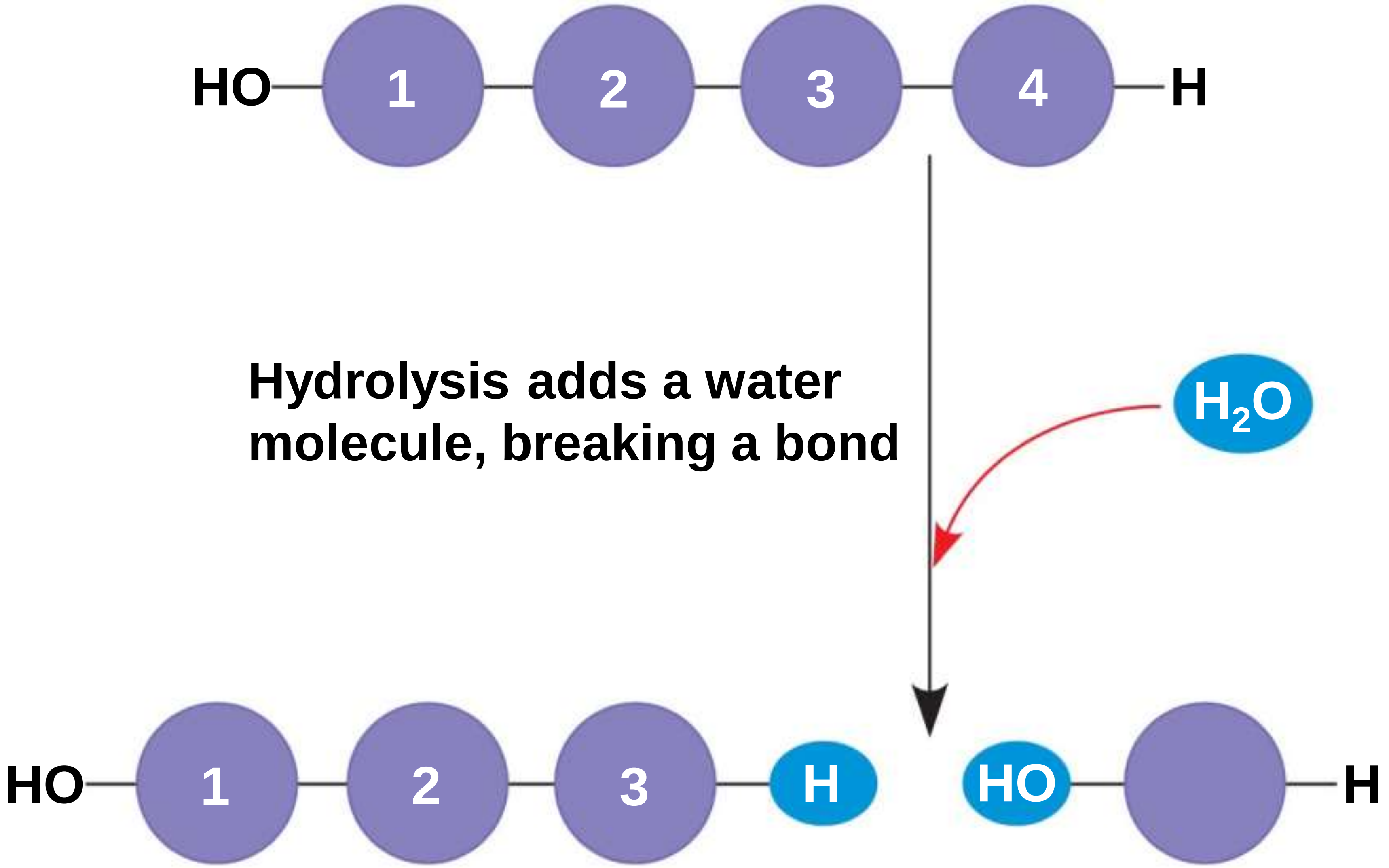
- A **polymer** is a long molecule consisting of many similar building blocks
- These small building-block molecules are called **monomers**
- Three of the four classes of life’s organic molecules are polymers:
  - Carbohydrates
  - Proteins
  - Nucleic acids

The Synthesis and Breakdown of Polymers

- A **condensation reaction** or more specifically a **dehydration reaction** occurs when two monomers bond together through the loss of a water molecule
- **Enzymes** are macromolecules that speed up the dehydration process
- Polymers are disassembled to monomers by **hydrolysis**, a reaction that is essentially the reverse of the dehydration reaction



(a) Dehydration reaction in the synthesis of a polymer



(b) Hydrolysis of a polymer

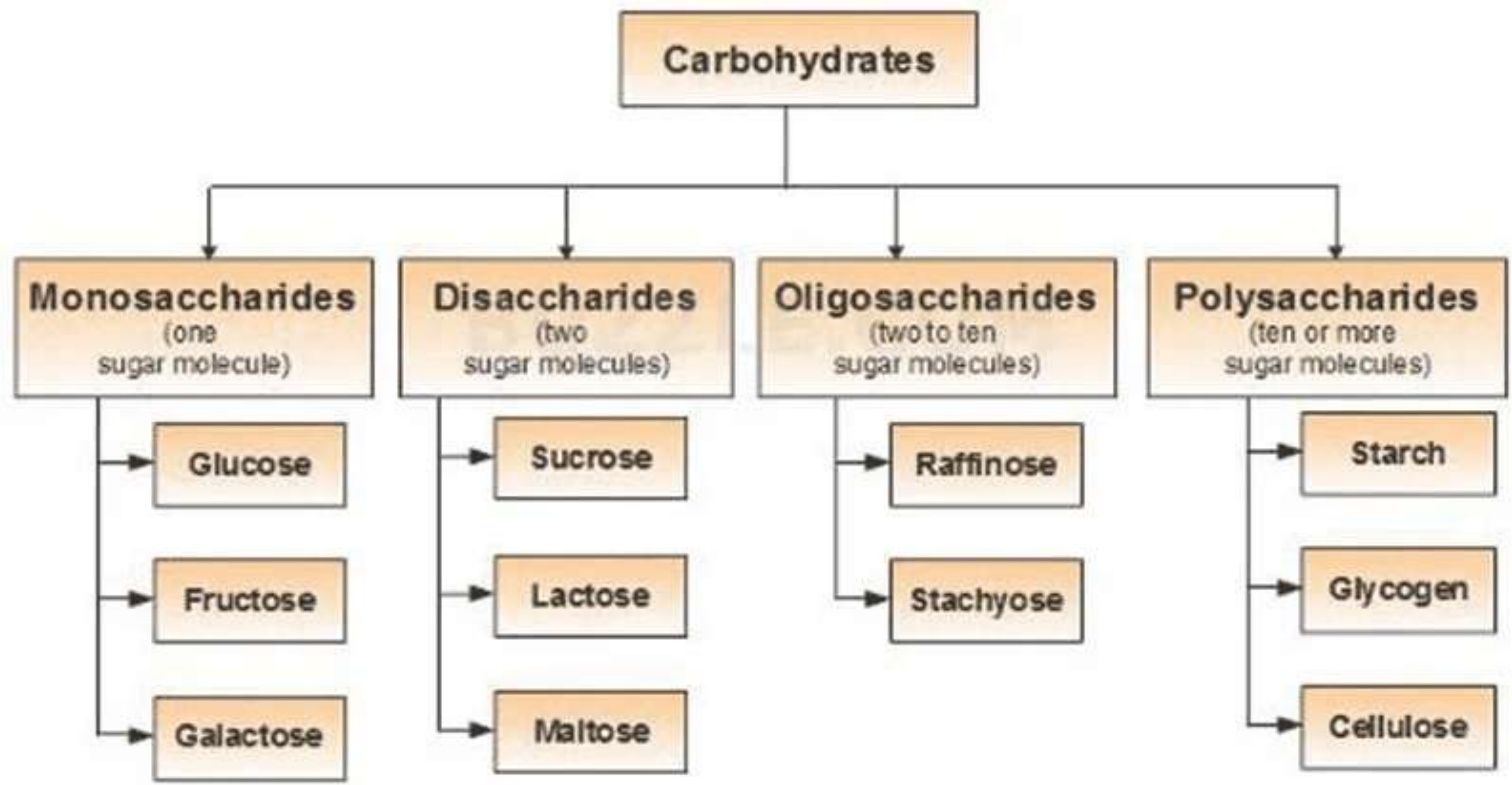
The Diversity of Polymers

- Each cell has thousands of different kinds of macromolecules
- Macromolecules vary among cells of an organism (muscle cells, liver cells, Adipocytes (fat cells), red blood cells), vary more within a species, and vary even more between species.
- An immense variety of polymers can be built from a small set of monomers

Carbohydrates serve as fuel and building material

- **Carbohydrates** include sugars and the polymers of sugars
- The simplest carbohydrates are monosaccharaides, or single sugars.
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks

Carbohydrates classification

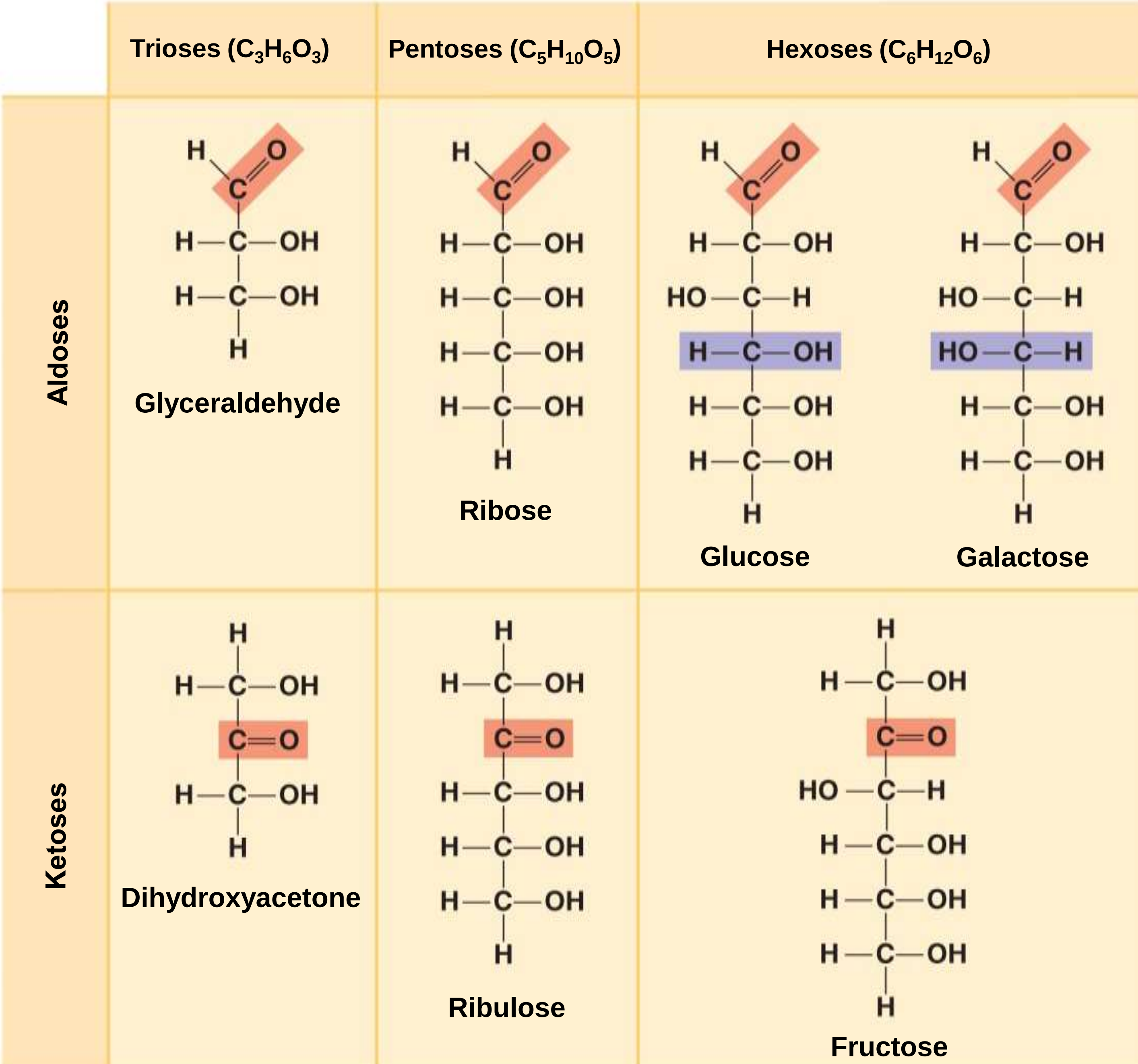


Sugars

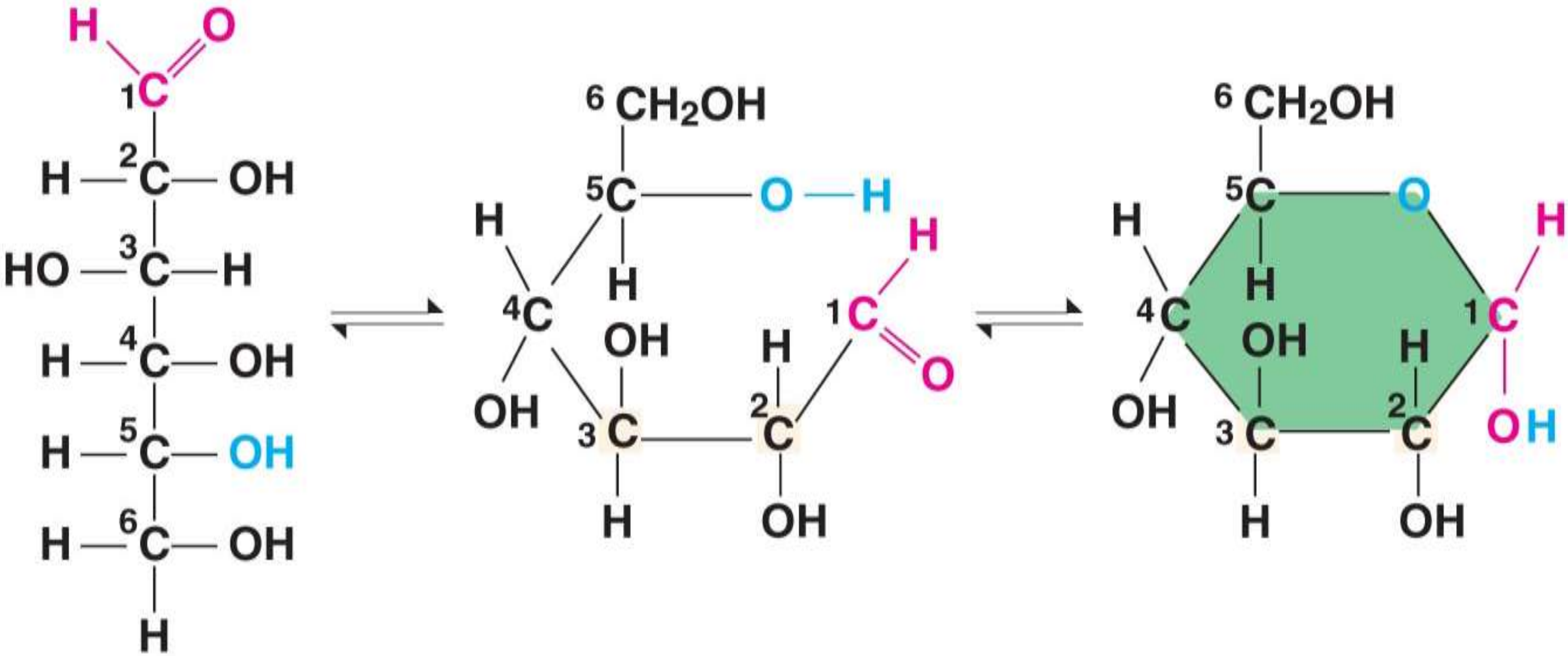
- **Monosaccharides** have molecular formulas that are usually multiples of CH_2O
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Monosaccharides are classified by:

A- The location of the carbonyl group (as aldose or ketose)

B- The number of carbons in the carbon skeleton

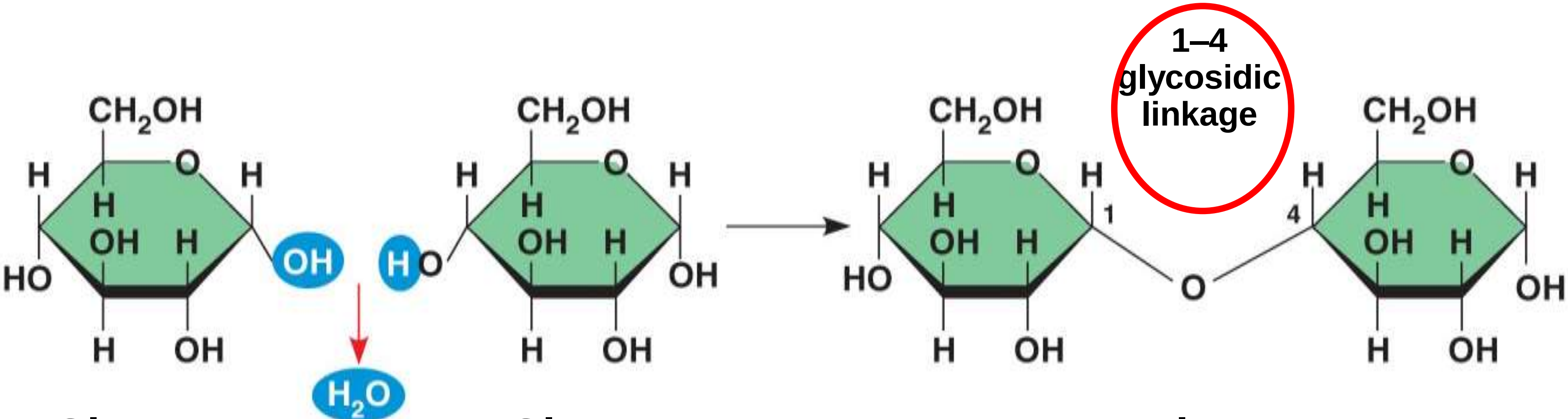

Trioses ($C_3H_6O_3$)
Pentoses ($C_5H_{10}O_5$)
Hexoses ($C_6H_{12}O_6$)
Aldoses
Glyceraldehyde
Ribose
Glucose
Galactose
Ketoses
Dihydroxyacetone
Ribulose
Fructose

- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings
- Monosaccharides serve as a major fuel for cells and as raw material for building molecules



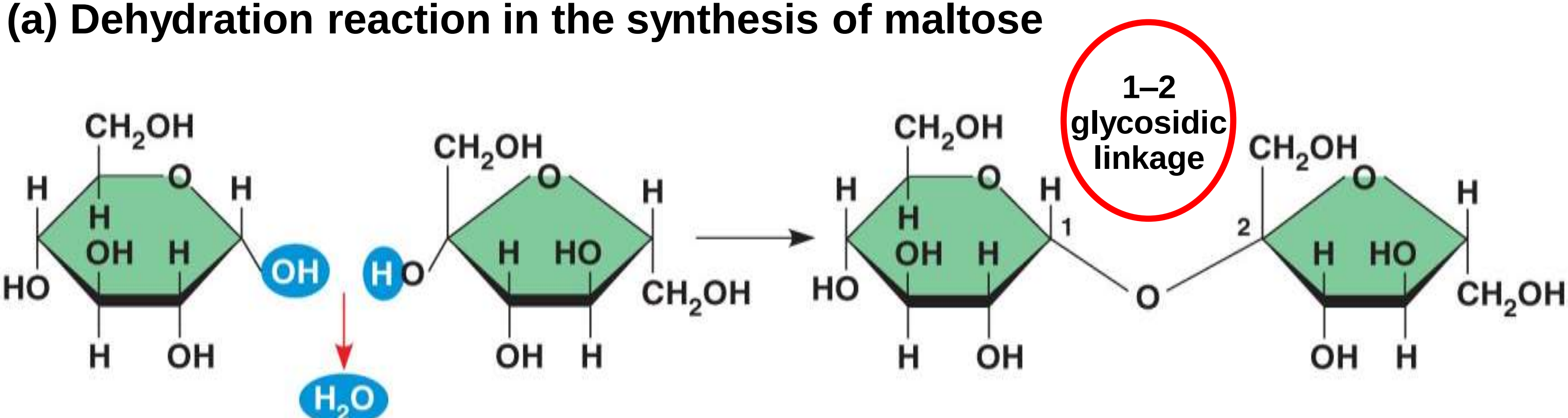
(a) Linear and ring forms

- A **disaccharide** is formed when a dehydration reaction joins two monosaccharides
- This covalent bond is called a **glycosidic linkage**



Glucose Glucose Maltose

(a) Dehydration reaction in the synthesis of maltose



Glucose Fructose Sucrose (table sugar)

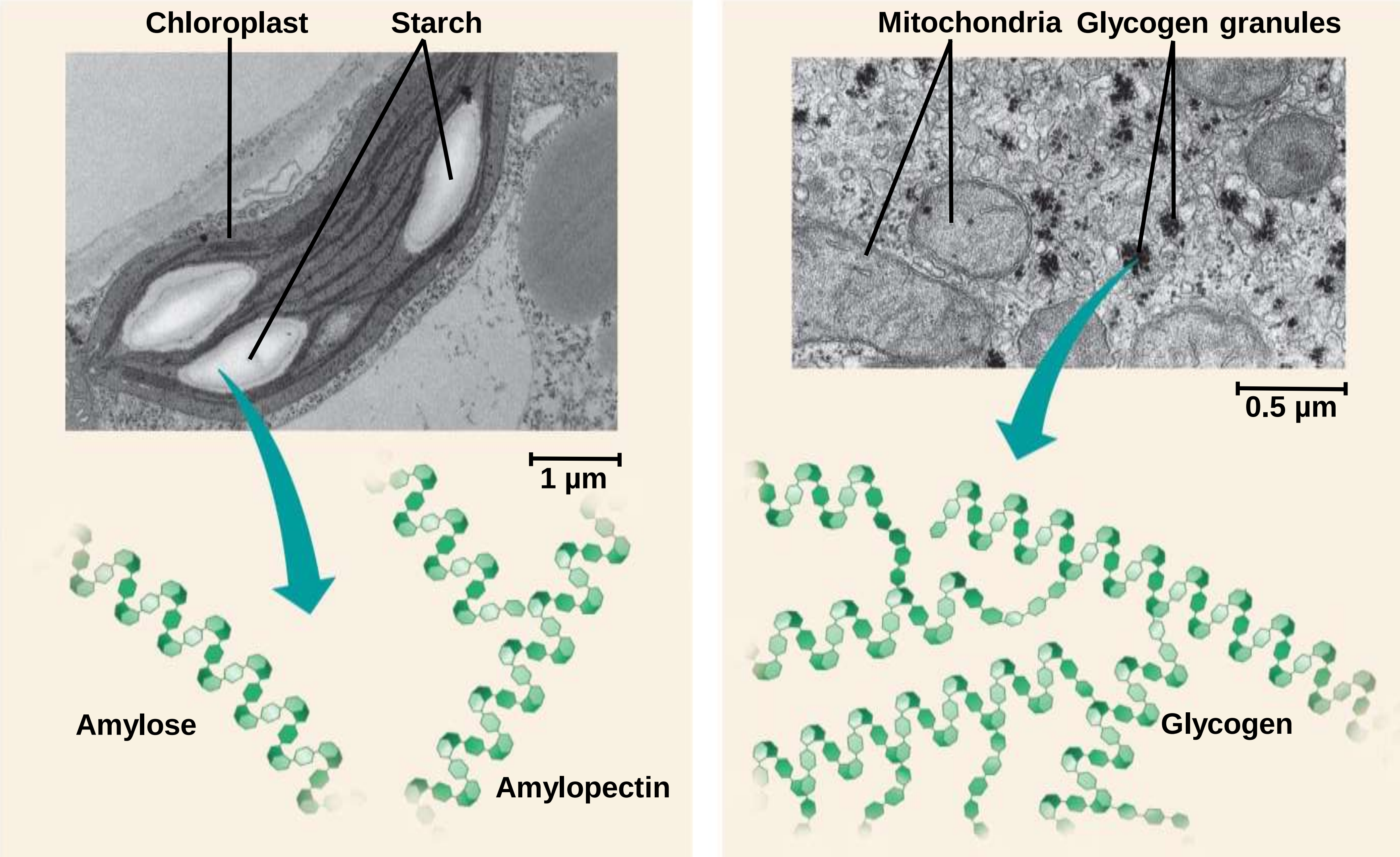
(b) Dehydration reaction in the synthesis of sucrose

Polysaccharides

- **Polysaccharides**, the polymers of sugars, have storage and structural roles
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages

Storage Polysaccharides

- **Starch**, (Energy storage) polysaccharide of plants, consists entirely of glucose monomers.
- Composed mainly of amylopectin and amylose polymers.
- Amylose: a linear chain of glucose, has α 1-4
- Amylopectin: a highly branched chain of glucose, has two glycosidic linkage, α 1-4 and α 1-6
- Plants store surplus starch as granules within chloroplasts and other plastids



(a) Starch: a plant polysaccharide

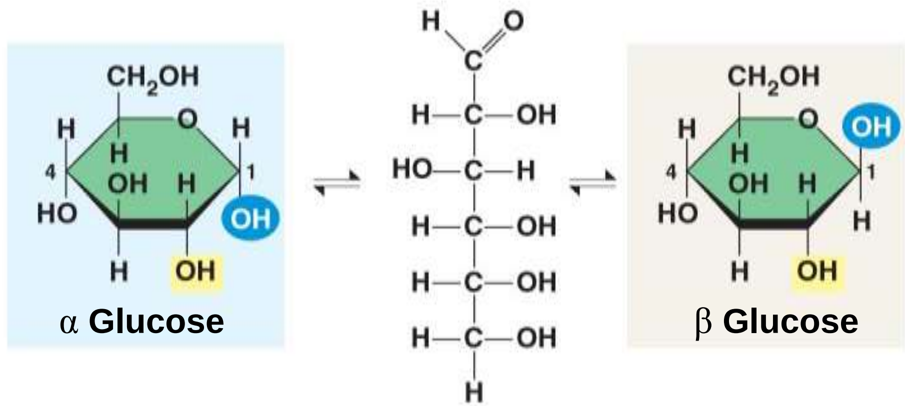
(b) Glycogen: an animal polysaccharide

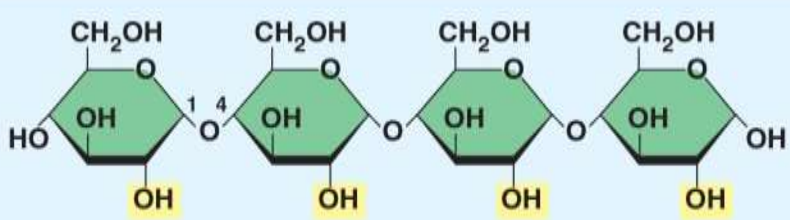
- **Glycogen** is a storage polysaccharide in animals,made of glucose monomers.
- Its highly branched and have similar glycosidic linkage of amylopectin.
- Humans and other vertebrates store glycogen mainly in liver and muscle cells

Structural Polysaccharides

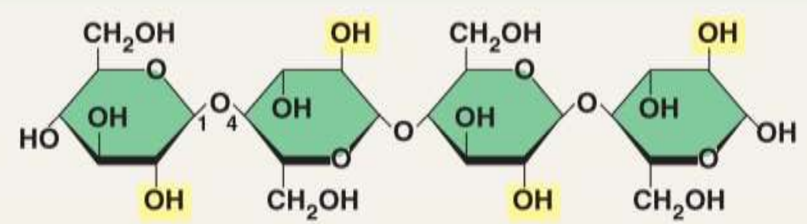
- The polysaccharide **cellulose** is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

(a) α and β glucose ring structures





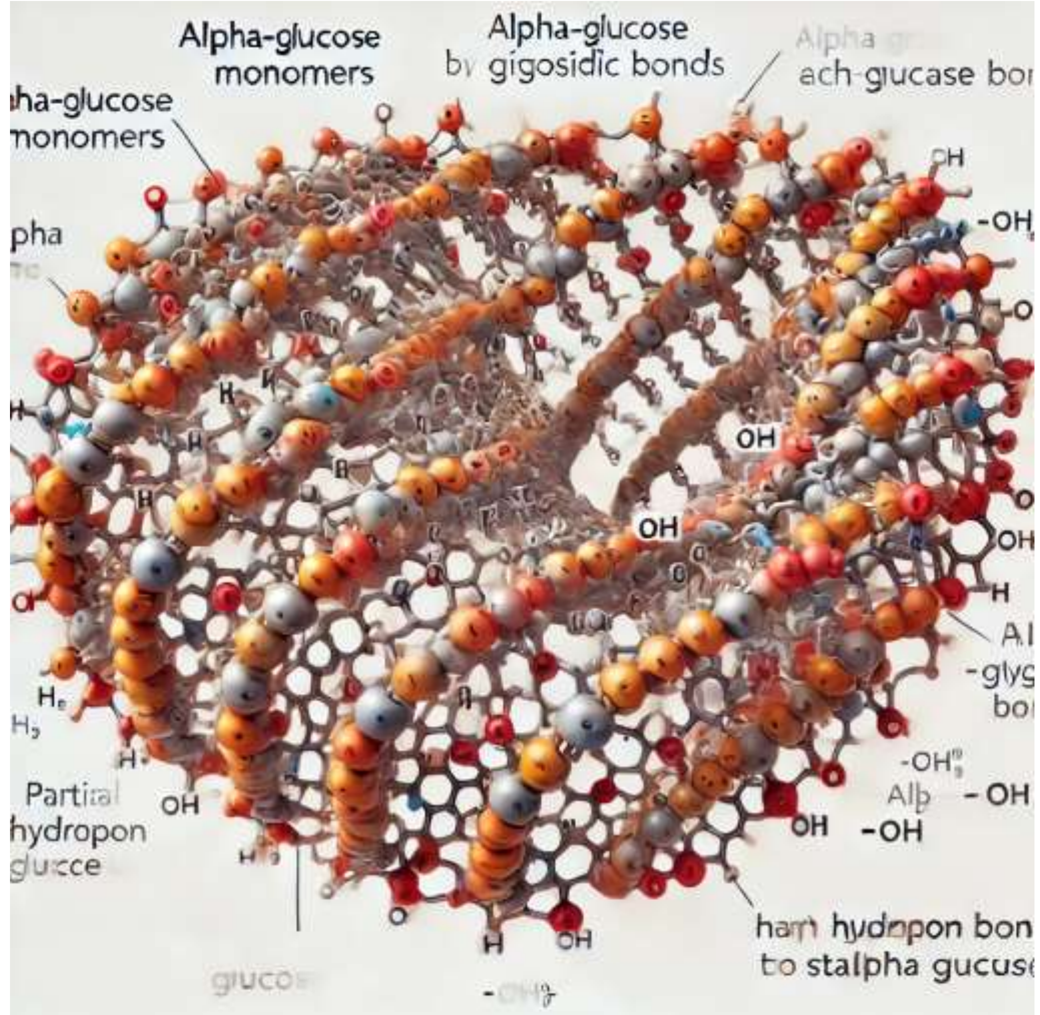
(b) Starch: 1–4 linkage of □ glucose monomers



(b) Cellulose: 1–4 linkage of □ glucose monomers

- Polymers with α glucose are helical
- Polymers with β glucose are straight.
- In straight structures, H atoms on one strand can bond with OH groups on other strands
- Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants

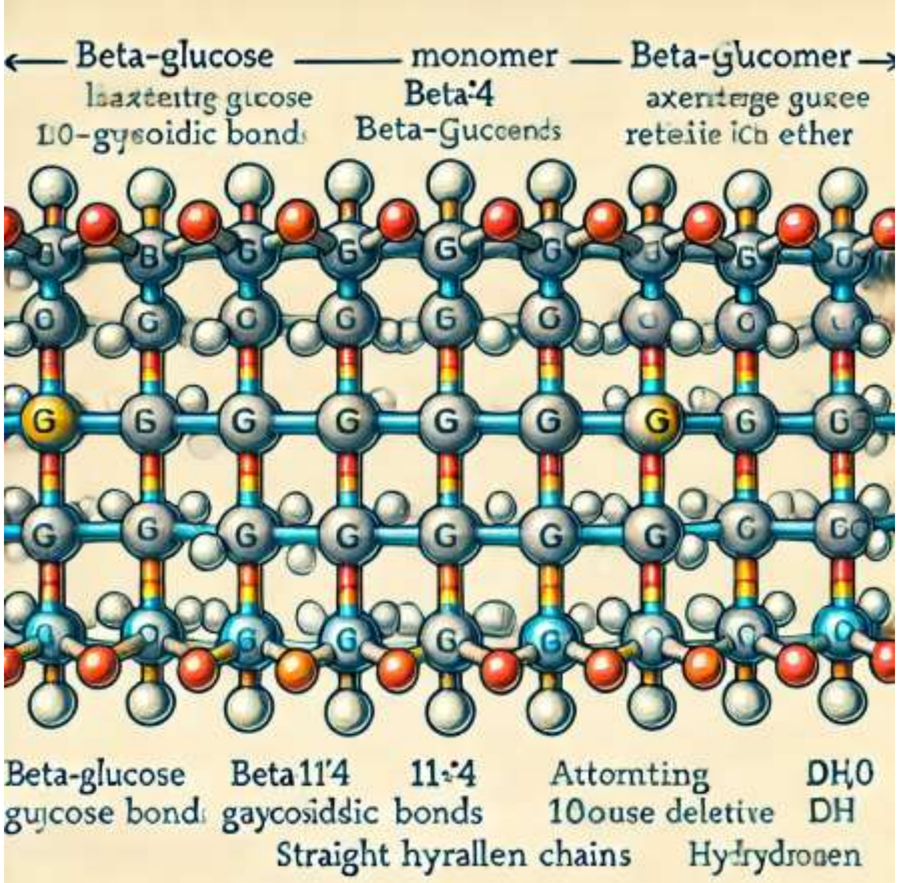
Because of the consistent orientation of the alpha bonds, the glucose units do not form a straight line. Instead, each bond creates a slight angle, causing the chain to twist. Over many glucose units, this twist results in a helical (spiral) shape. This helical formation is stabilized by hydrogen bonds within the chain.

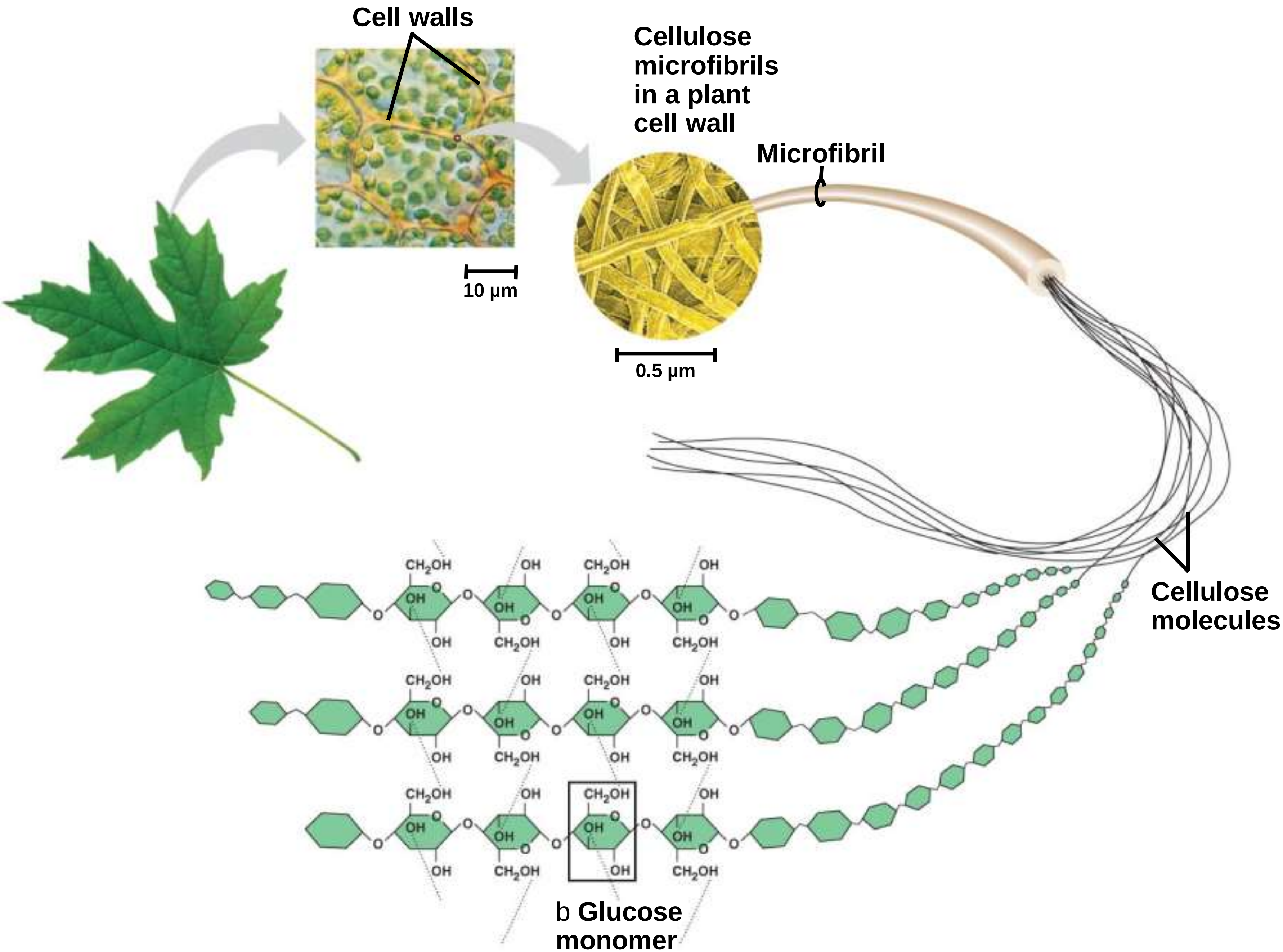


Polymers with α glucose are helical

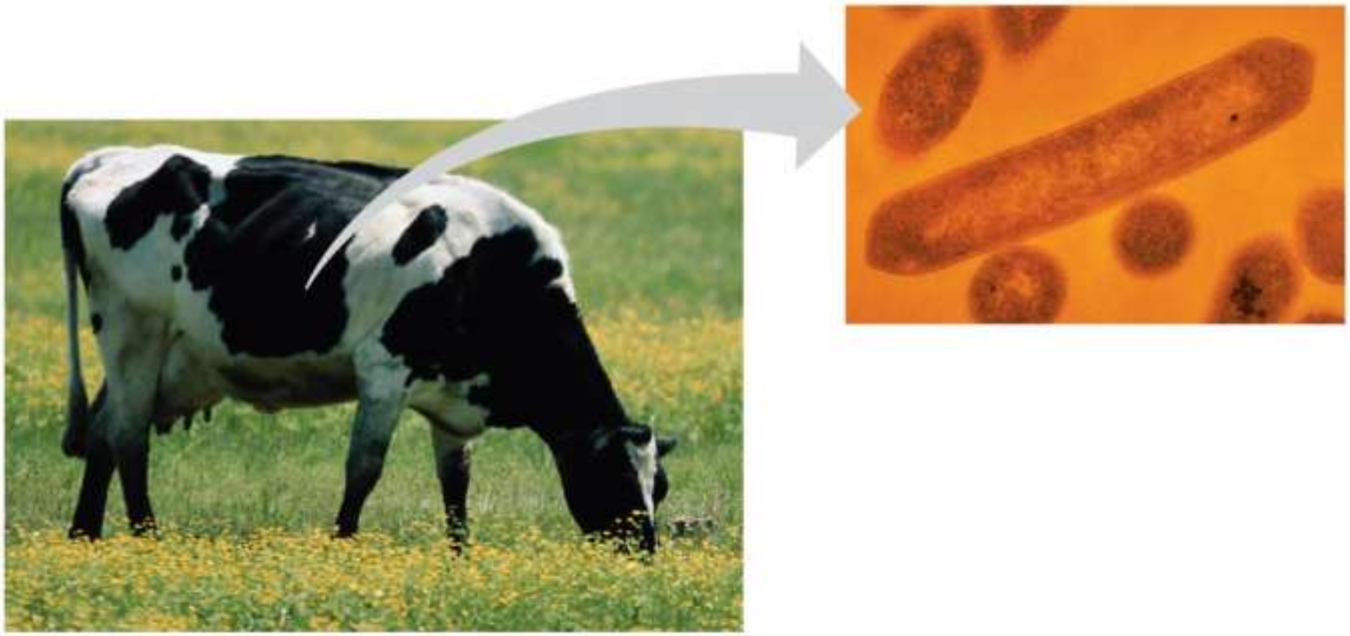
Polymers with β glucose are straight.

- To form stable β(1→4) bonds, each glucose monomer in the chain must flip relative to its neighbor. This alternation creates a straight chain because each successive glucose unit is rotated 180° relative to the previous one, aligning all of the hydroxyl groups optimally for hydrogen bonding.

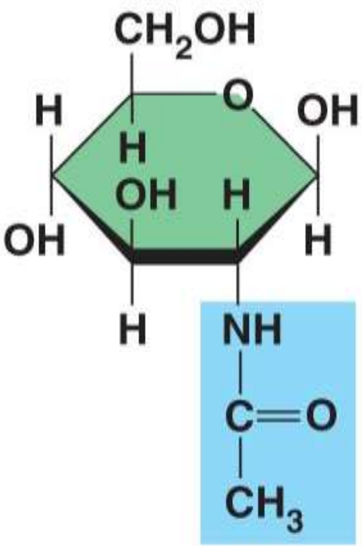



Cell walls
Cellulose microfibrils in a plant cell wall
Microfibril
10 µm
0.5 µm
Cellulose molecules
CH₂OH
OH
O
b Glucose monomer

- Enzymes that digest starch by hydrolyzing α linkages can’t hydrolyze β linkages in cellulose
- Cellulose in human food passes through the digestive tract as insoluble fiber
- Some microbes use enzymes to digest cellulose
- Many herbivores, from cows to termites, have symbiotic relationships with these microbes



- **Chitin**, another structural polysaccharide, is found in the exoskeleton of arthropods or insects.
- Chitin contains nitrogen. The chemical name of chitin biopolymer is poly(Beta-1,4-N-acetyl-d-glucosamine)
- Chitin also provides structural support for the cell walls of many fungi



(a) The structure of the chitin monomer.

(b) Chitin forms the exoskeleton of arthropods.

(c) Chitin is used to make a strong and flexible surgical thread.