Lecture 3

Molecules of Life I: Introduction and Carbohydrates

LIF111

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Buffers

A **buffer** keeps a solution within a consistent range of pH

Most cell and body fluids are buffered because most molecules of life work only within a narrow range of pH

buffer : Set of chemicals that stabilize pH of a solution by alternately donating and accepting ions that contribute to pH

An acid-base conjugate pair of a weak acid and its corresponding base (such as acetic acid and acetate ion) has an important property: it resists changes in the pH of a solution. In other words, it acts as a *buffer*.

The Bicarbonate Buffer System

Carbon dioxide gas becomes a weak acid when it dissolves in the fluid portion of human blood:

$H_2O + CO_2$ (carbon dioxide) → H_2CO_3 (carbonic acid) Catalyzed by carbonic anhydrase

H_2CO_3 (carbonic acid) ↔ $H^+ + HCO_3^-$ (bicarbonate)

Exchange of ions between carbonic acid and bicarbonate keeps blood pH between 7.3 and 7.5 – up to a point

Buffer failure can be catastrophic in a biological system

Example: Too much carbonic acid forms in blood when breathing is impaired suddenly – the resulting decline in blood pH may cause coma

Only living systems can synthesize
carbohydrates, lipids, proteins and nucleic acids

"Molecules of life"

Packets of instantly available energy

Energy stores

Structural material

Metabolic workers

Libraries of hereditary information

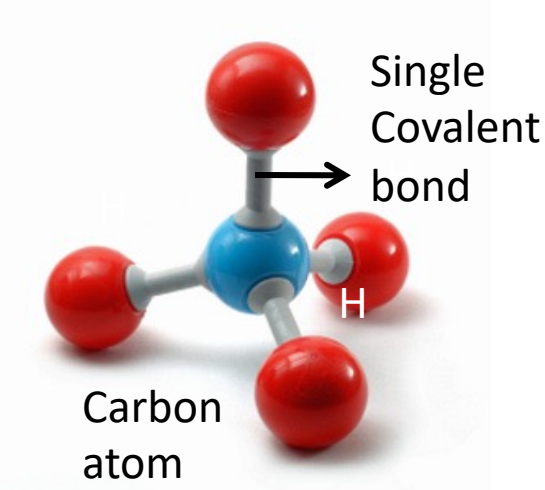
Cell to cell signals


ACALIJAGGAC GAGAGAGAGC

All of these molecules are **organic**

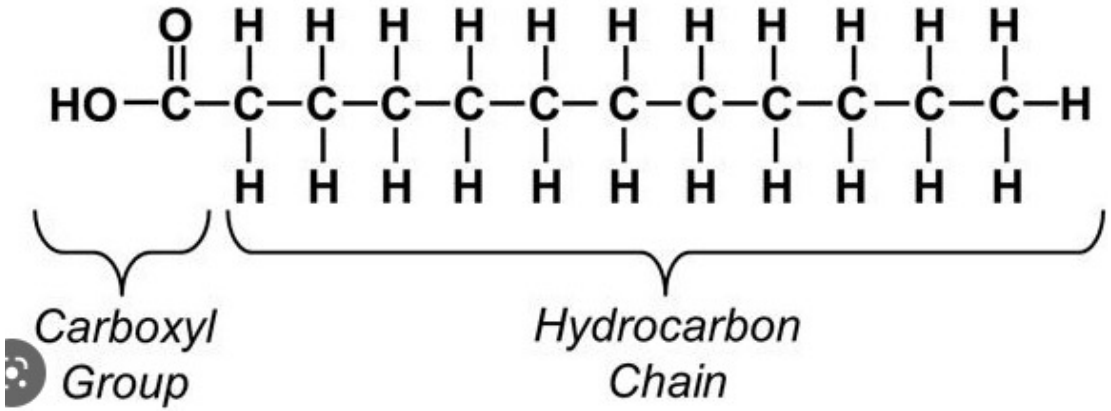
Living things are made of compounds that consists primarily of **carbon**, **oxygen** and **hydrogen** atoms with significant amount of **nitrogen** as well. The other important elements that are present are **phosphorus** and **sulfur**.

Carbon chains or rings form the backbone of molecules of life



EXAMPLES OF BIOMOLECULES

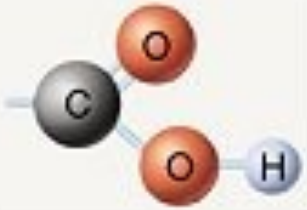
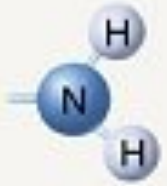
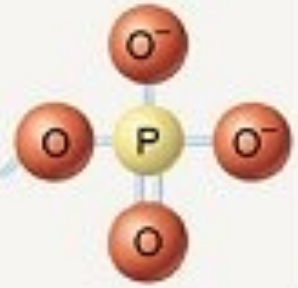
A fatty acid commonly found in coconut oil.

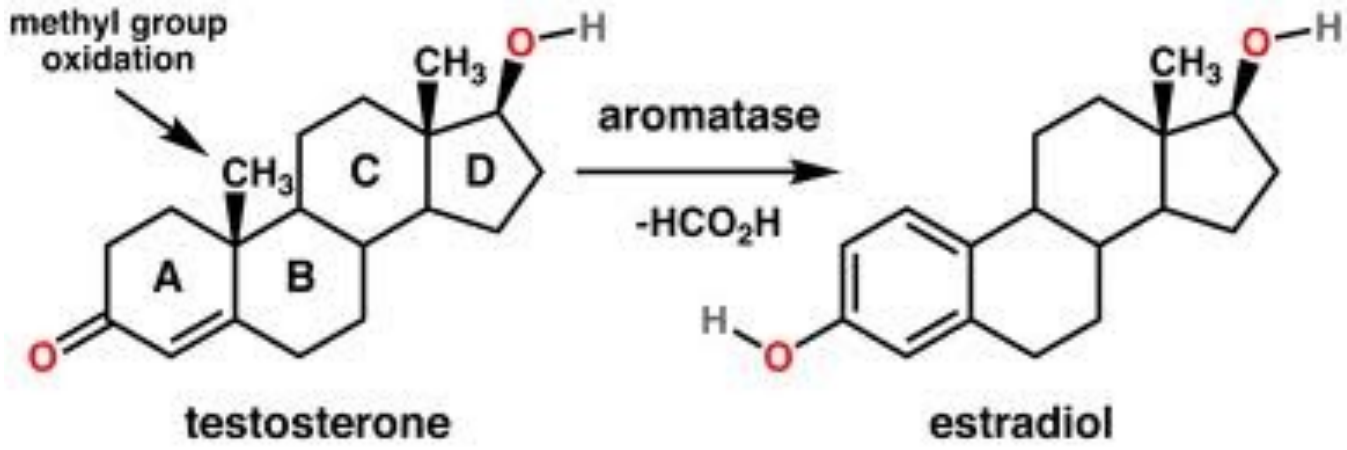


Functional groups

A group of atoms bonded to a carbon of an organic compound.

Imparts a specific chemical property such as polarity or acidity.

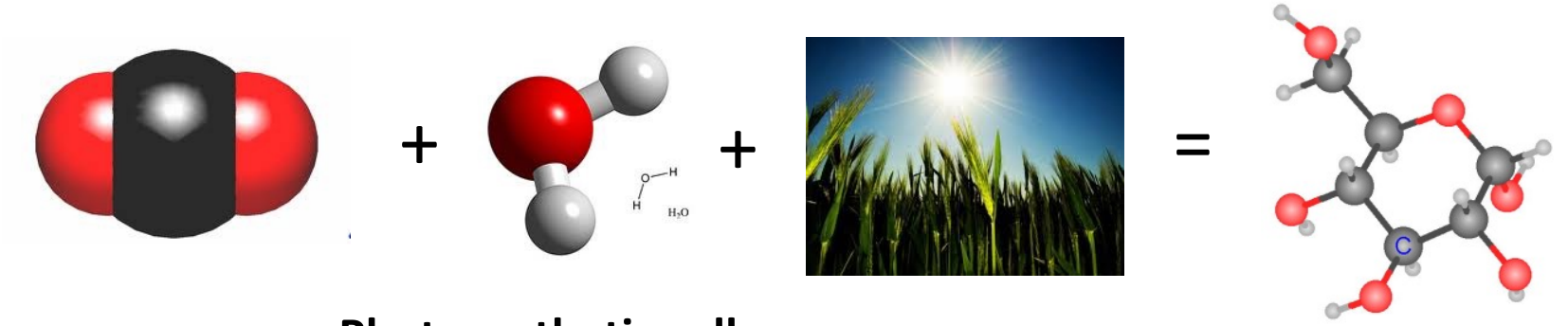
Group	Structural Formula	Ball-and-Stick Model	Found In
Hydroxyl	—OH		Carbohydrates
Carbonyl	C=O		Lipids
Carboxyl	—C(=O)OH		Proteins
Amino	—NH$_2$		Proteins
Phosphate	—O—P(=O)(O$^-$)—O$^-$		DNA, ATP



The adult female wood duck looks very different from the adult male wood duck because of the effect of different hormones e.g. testosterone and estrogen which have the same ring structures but different functional groups.

How do cells build organic compounds?

Carbon from CO_2 Water Sunlight Simple sugars



Photosynthetic cell

Metabolic activities (mediated by enzymes) help cells stay alive, grow, and reproduce

Metabolism: All enzyme-mediated chemical reactions by which cells acquire and use energy as they build and break down organic molecules.

Enzyme: Compound (usually a protein) that speeds a reaction without being changed by it (catalyst).

All the molecules present in living organisms are polymers built from monomeric units such as fatty acids, sugars, amino acids and nucleotides

Major categories of reactions catalyzed by metabolic enzymes

1. **Functional group transfer:** One molecule gives up a functional group which another molecule accepts.

2. **Electron transfer:** One or more electrons stripped from one molecule and donated to another molecule.

3. **Rearrangement:** A juggling of internal bonds converts one type of organic compound into another.

4. **Condensation:** Two molecules combine to form a large molecule through covalent bonding.

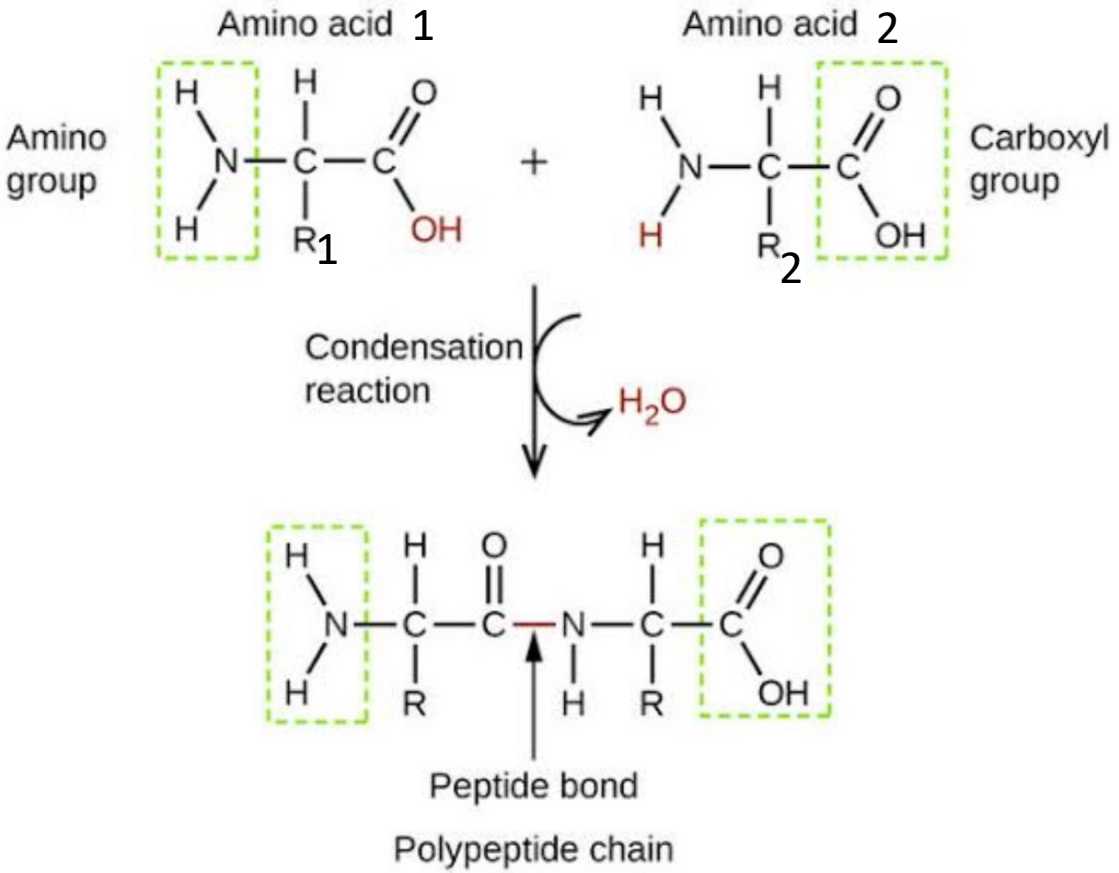
5. **Cleavage/Hydrolysis:** A molecule splits into two smaller ones.

Condensation reactions build **polymers** from **monomers** of simple sugars, fatty acids, amino acids, and nucleotides

Builds a large molecule from smaller ones

Enzyme removes –OH group from one molecule and -H atom from another

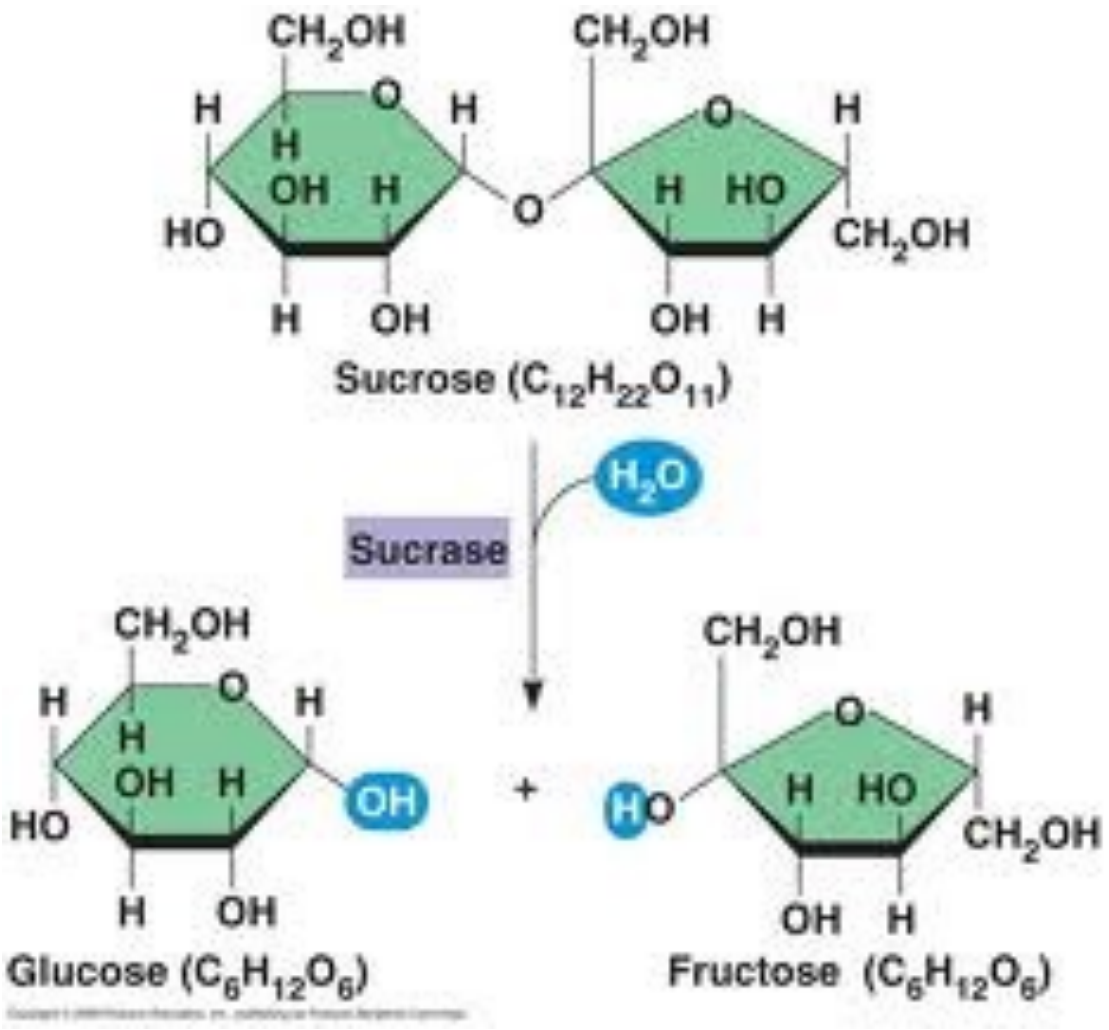
Covalent bond forms between two molecules – water also forms



Hydrolysis reactions release monomers by breaking apart polymers

Splits a large molecule into smaller ones by a water-requiring reaction

Enzyme attaches –OH group and -H atom from water at cleavage site



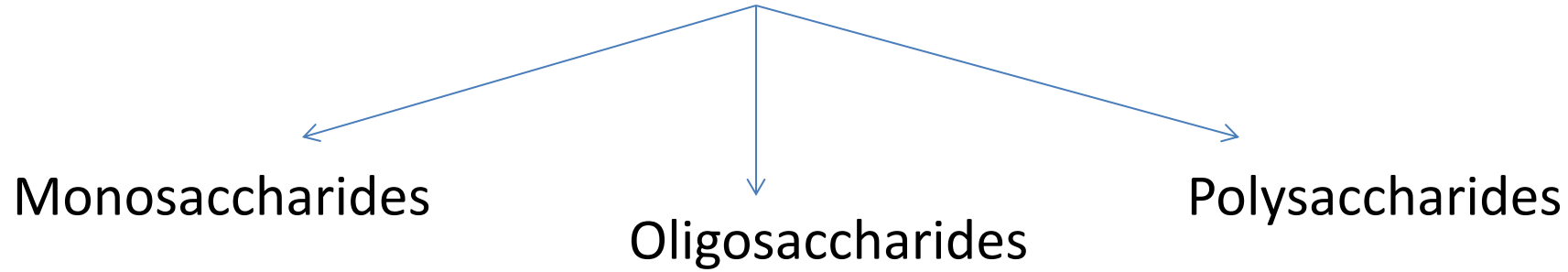
Carbohydrates

Are the most abundant of all biological molecules.

Molecule that consists primarily of carbon, hydrogen, and oxygen atoms in a 1:2:1 ratio which can be written as $(CH_2O)_n$.

Cells use carbohydrates for transportable or **storage forms of energy** and as **structural materials**.

Carbohydrates

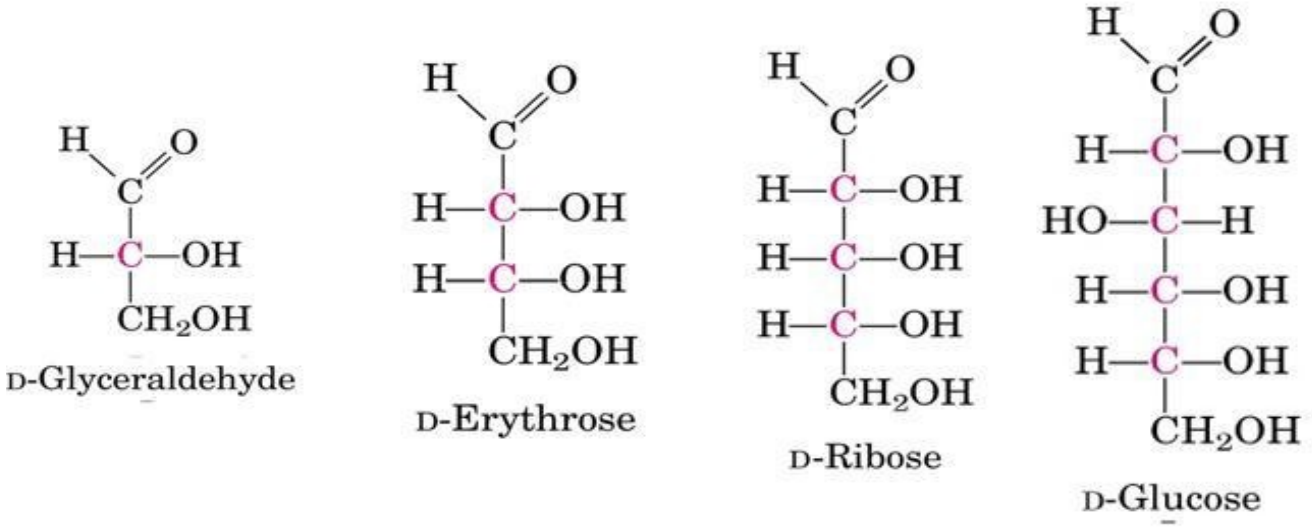


The simple sugars: Monosaccharides

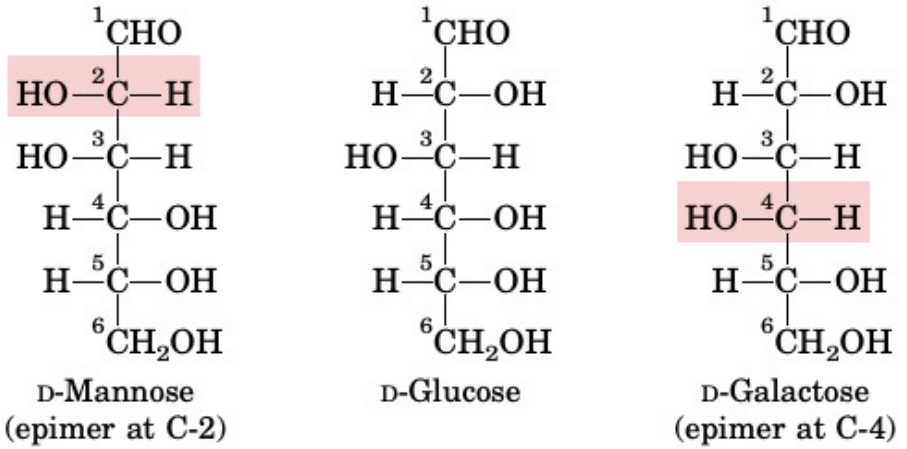
Saccharide = Sugar (Greek) “one monomer of sugar”

SUGARS COME IN DIFFERENT LENGTHS

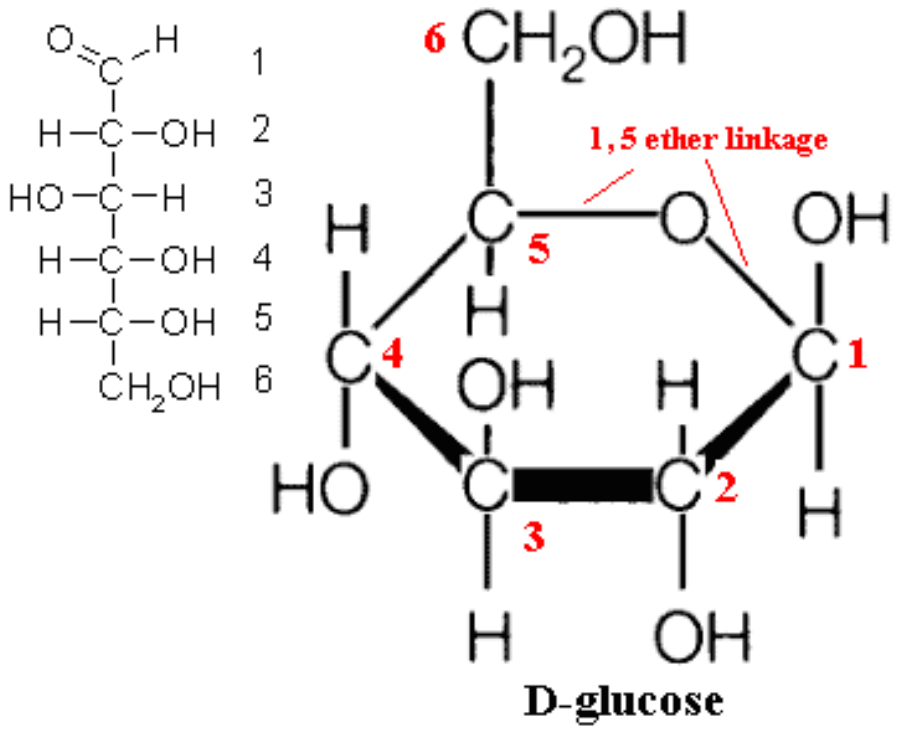
Triose Tetrose Pentose Hexose



Two sugars that differ only in the configuration around one carbon atom are called epimers



The most common types of monosaccharide have a five or six carbon backbone that when dissolved in body fluids tends to form a ring structure.



Glucose is the main energy source for most organisms and is also the precursor for many compounds as well as the building block for larger carbohydrates.

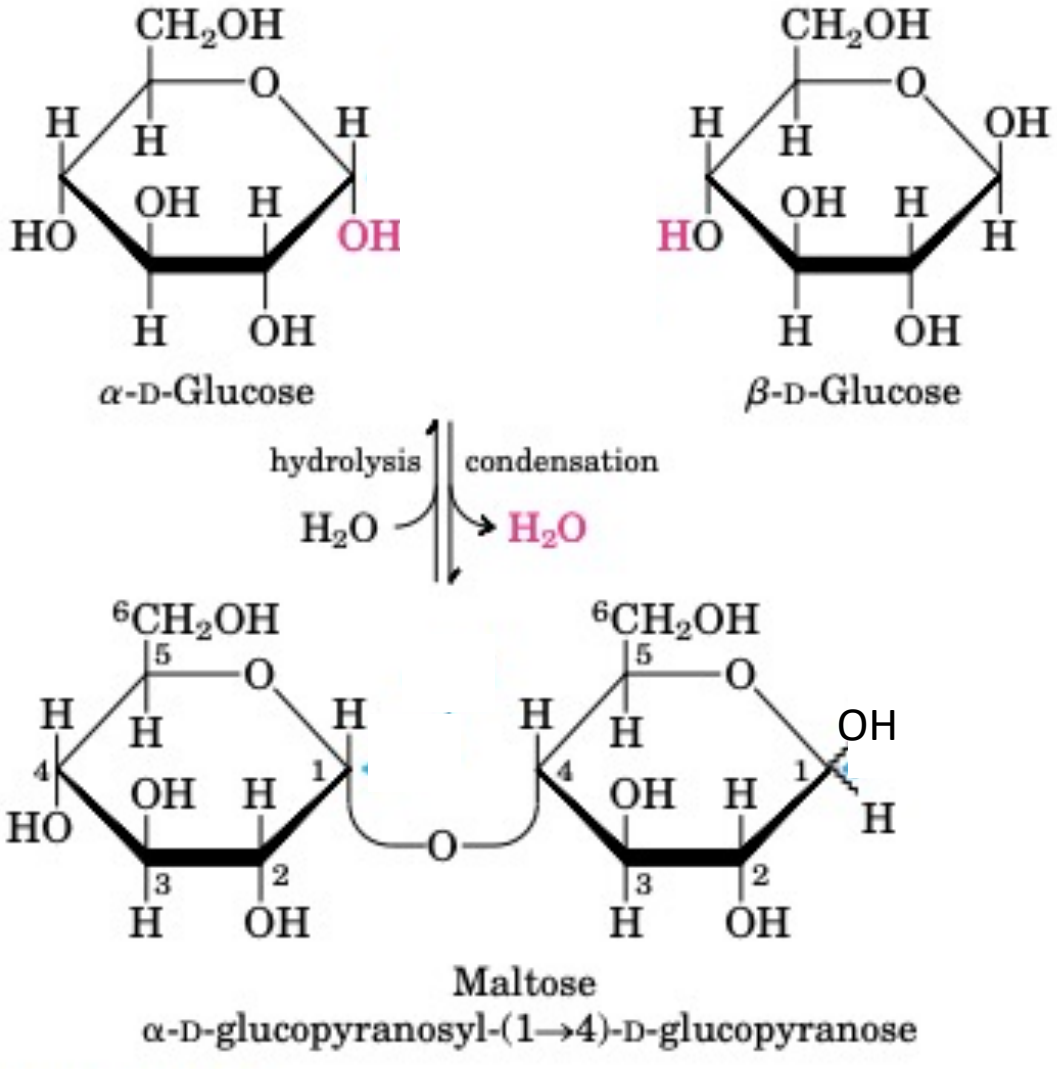
Short-chain carbohydrates: Oligosaccharides

An oligosaccharide is a short chain of coval bonded monosaccharides

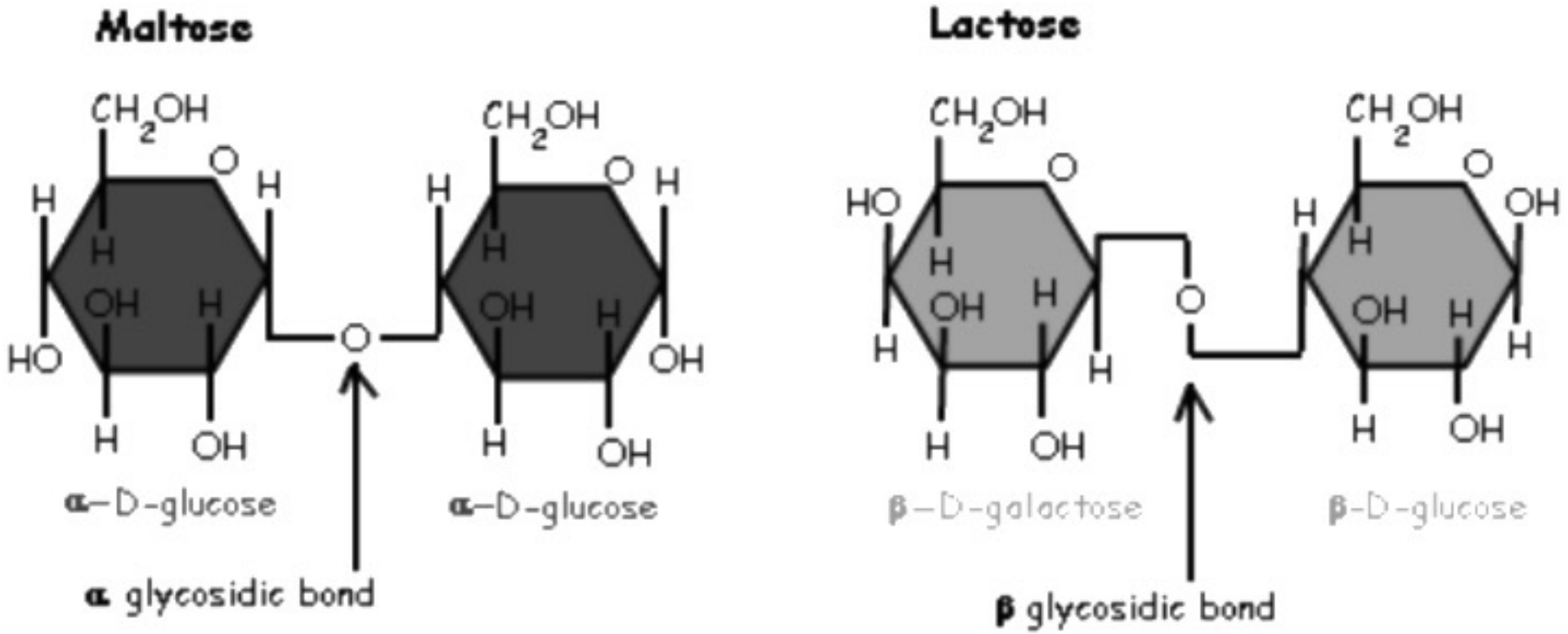
Oligo – means a few

Disaccharides consist of two sugar monomers

Formation of Maltose



Alpha and beta glycosidic bonds



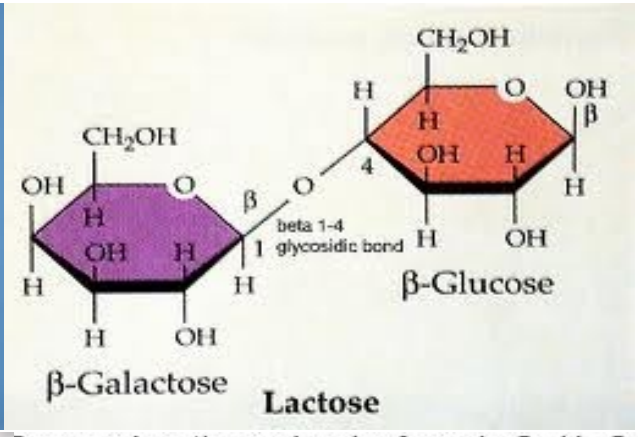
OH of C1 is below the plane of glucose

OH of C1 is above the plane of glucose

Short-chain carbohydrates: Oligosaccharides

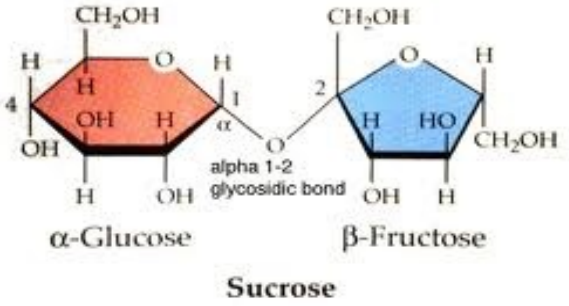
Disaccharides

Lactose
(glucose + galactose)



Sucrose
(glucose + fructose)

Sucrose has the molecular formula $C_{12}H_{22}O_{11}$



Oligosaccharides with three or more sugar units are often attached to lipids or proteins that have important functions in immunity

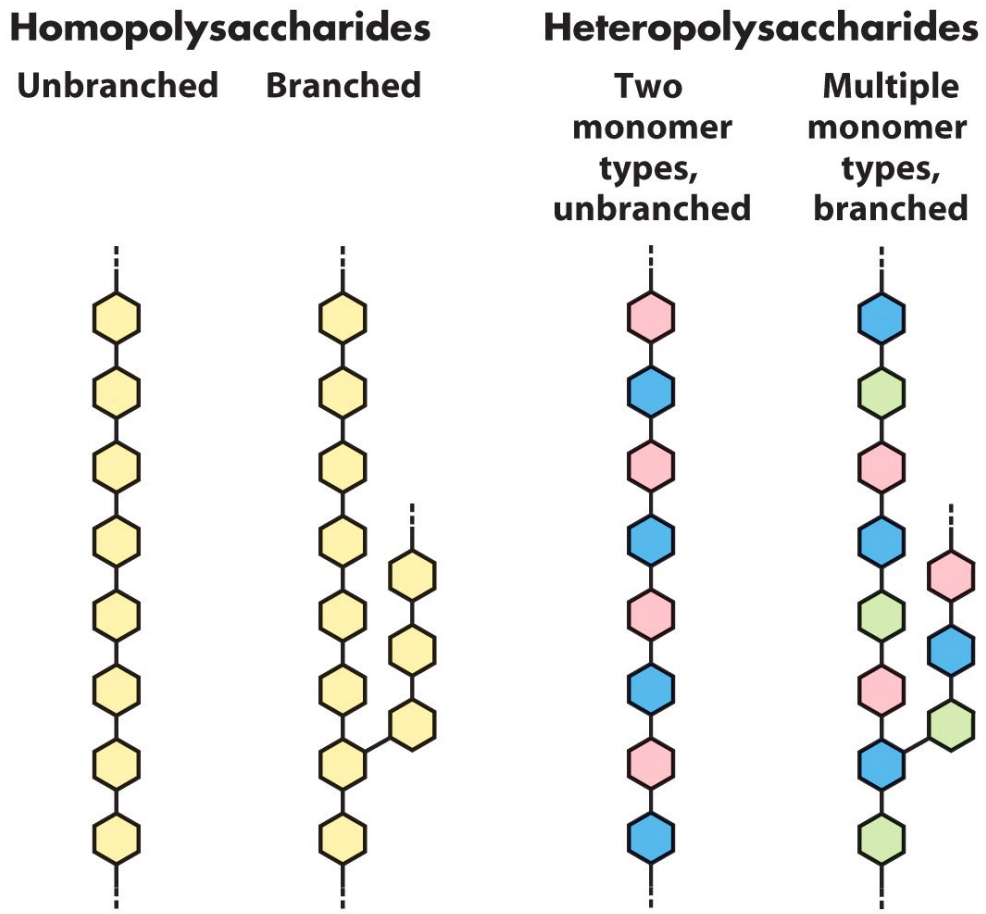
Complex carbohydrates: Polysaccharides

Polysaccharides, are straight or branched chains of many sugar monomers—often hundreds or thousands

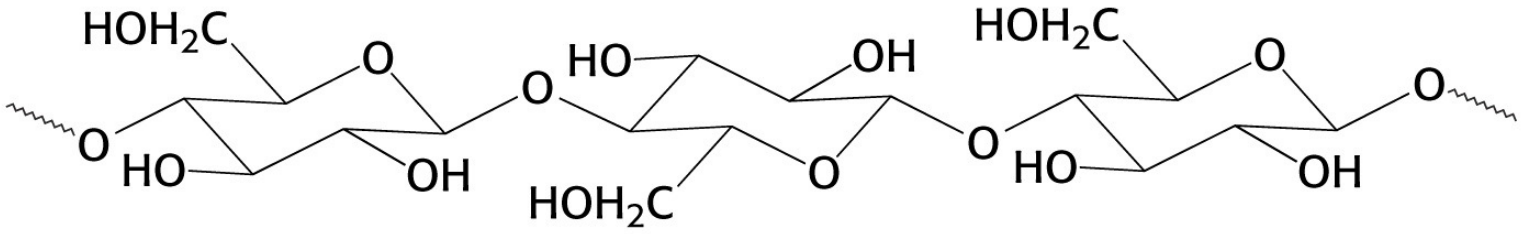
Common polysaccharides: cellulose, glycogen, and starch.

All consist of glucose monomers.

Each has different chemical properties due to different patterns of covalent bonds that link glucose monomers



Cellulose: Structural polysaccharide

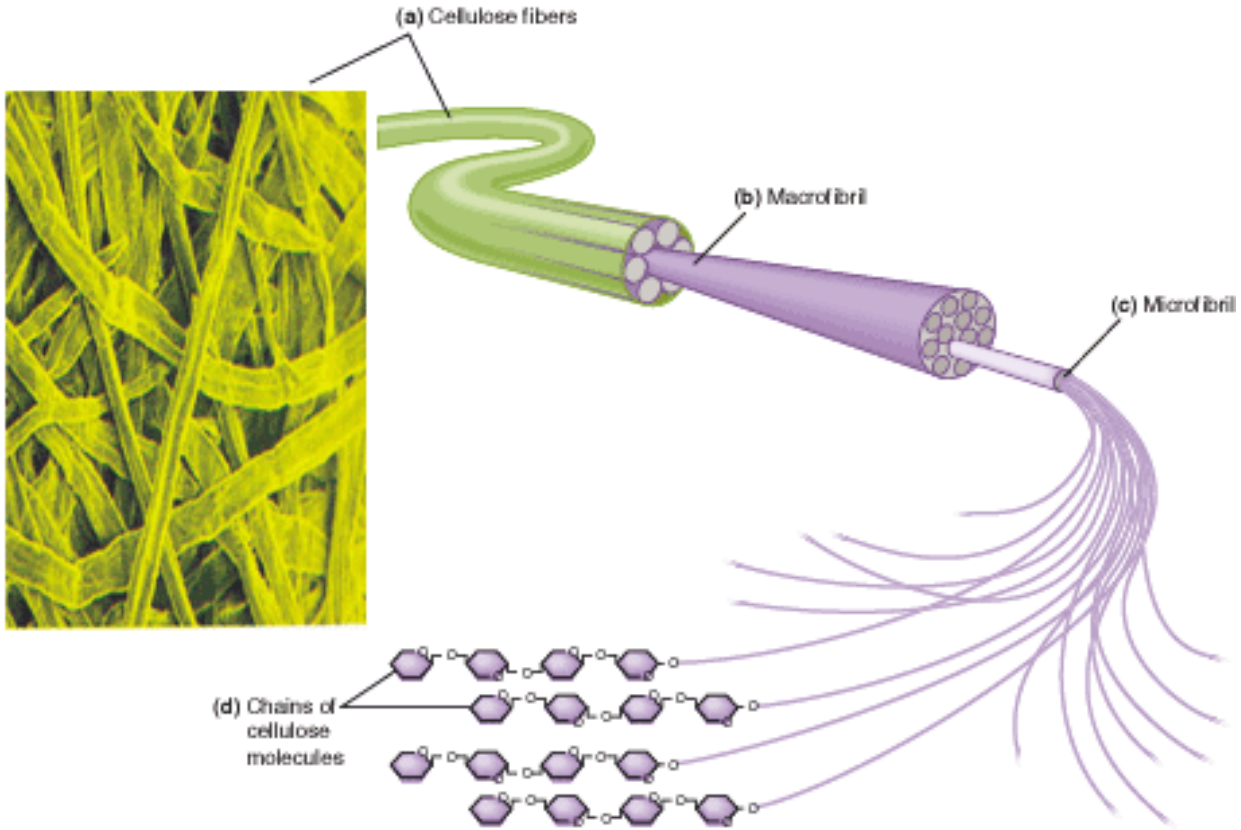


Cellulose
(β-1,4 linkages)

Cellulose is one of the major polysaccharides (STRUCTURAL COMPONENT) found in plants. It is the most abundant organic compound in the bioshpere.

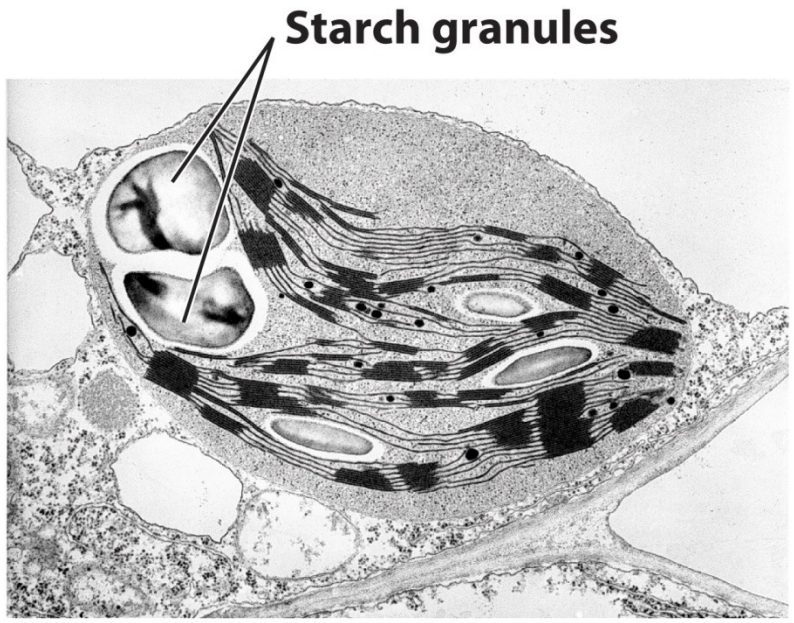
It is an unbranched polymer of glucose joined by β-1, 4 glycosidic linkages. The β configuration allows for very long straight chains.

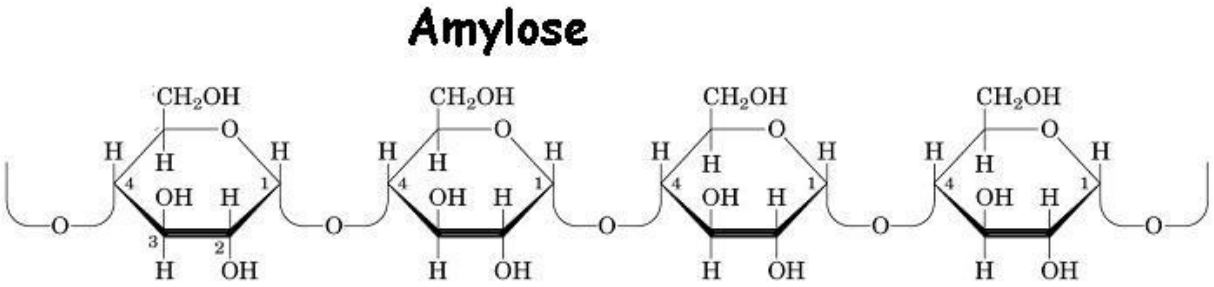
Fibrils are formed by parallel straight chains that interact with one another by hydrogen bonding.



Amylose/Starch: Plant storage polysaccharides

Main energy reserve in plants, which store it in roots, stems, leaves, fruits, and seeds. In amylose, a series of glucose units form a coiled chain

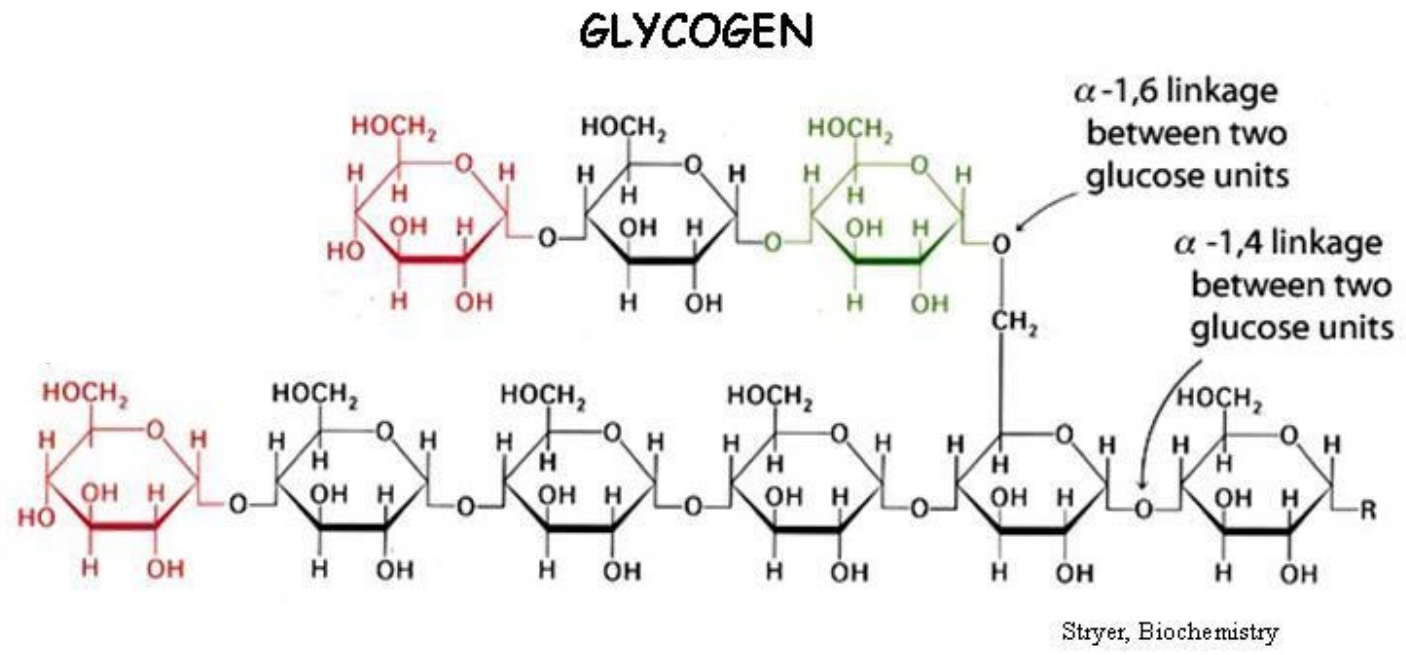




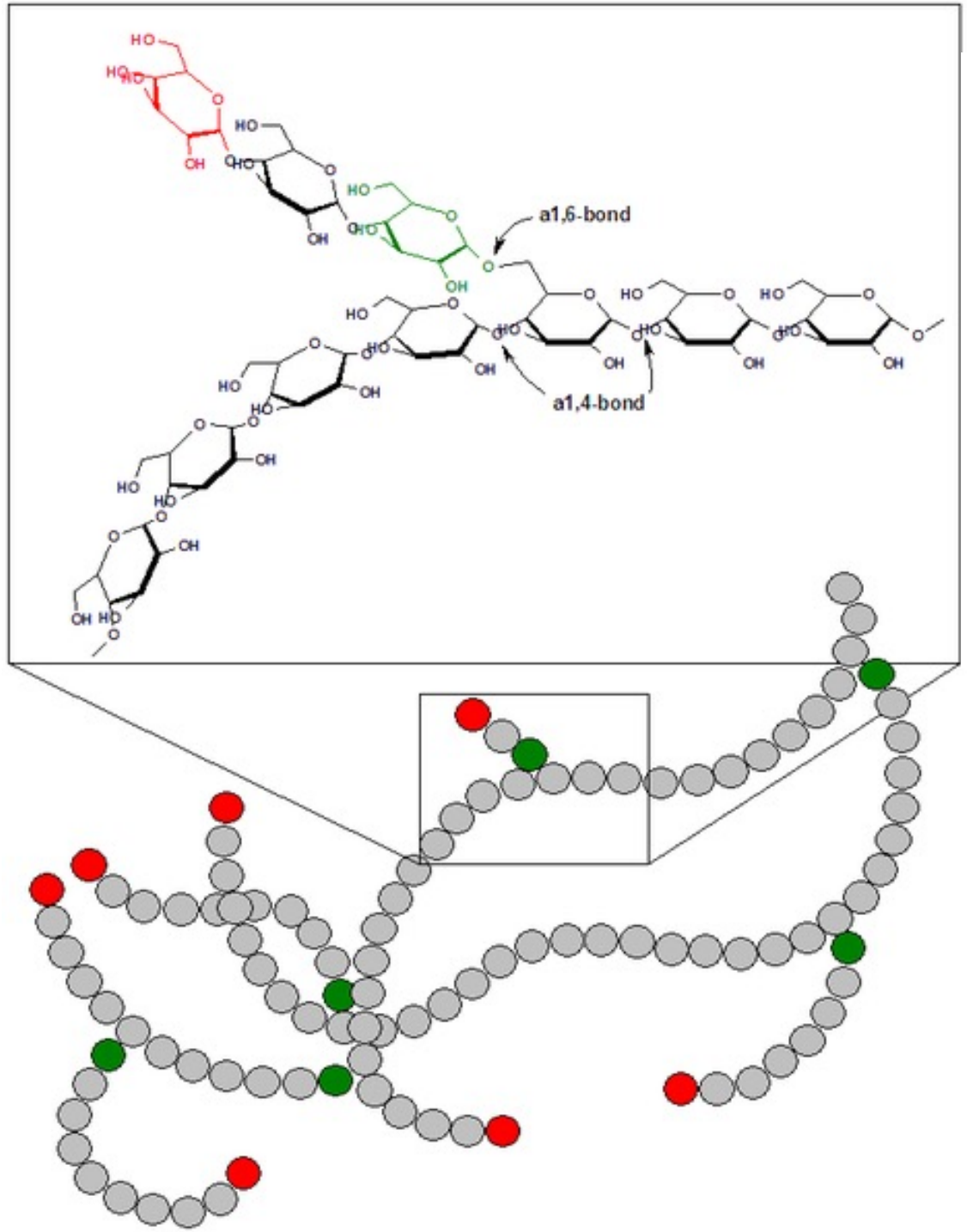
α-Amylose is a linear polymer of α-1,4 linkage where n is in thousands.

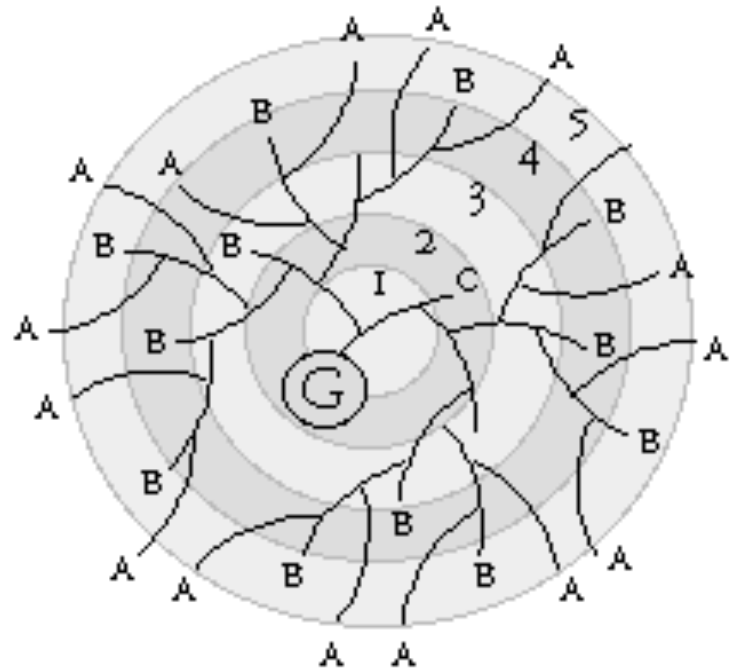
Glycogen: Animal storage polysaccharides

In humans and other animals, glycogen stored in muscles and liver functions as an energy reservoir



Glycogen is a polymer of α 1-4 linkage with α 1-6 branch points.
Glycogen is highly branched with branch points occurring every 8-14 glucose residues.





Due to the α 1-4 linkages glycogen assumes a left-handed helical structure with branch points.

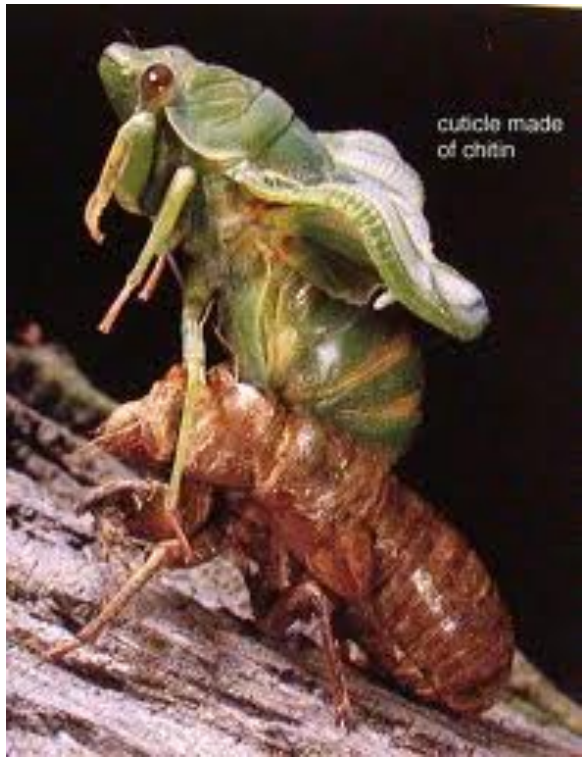
There is a protein at the core of the glycogen structure, **Glycogenin**.

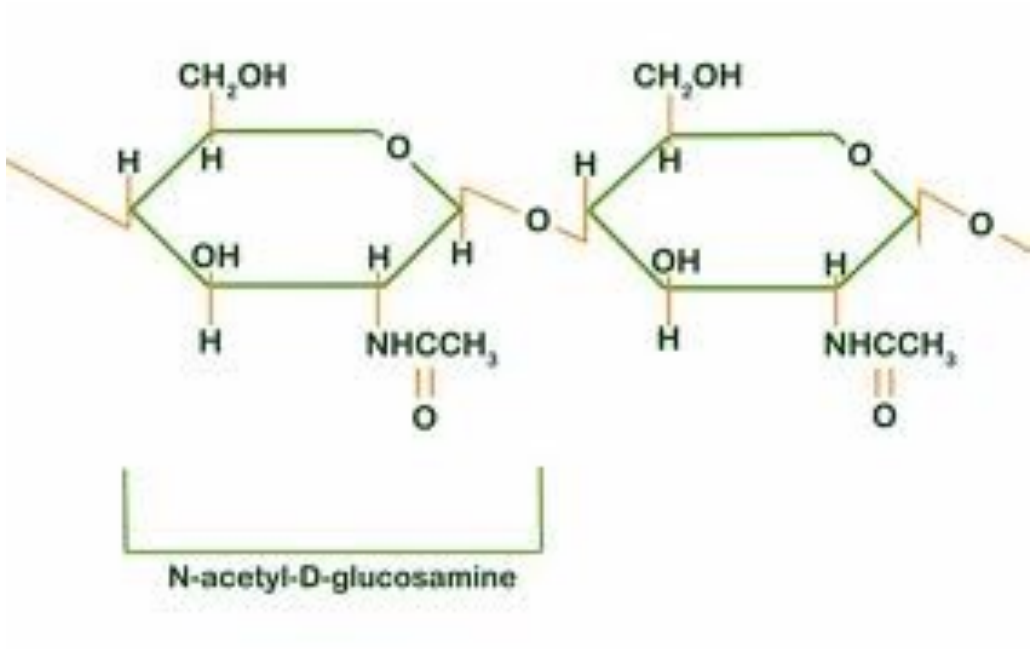
Chitin: Exoskeleton of invertebrates

Monomers are glucose with **nitrogen**-containing carbonyl group

Long, non-branching chains linked by hydrogen bonds.

Strengthens hard parts of many small animals, such as crabs





Questions

1. _____is a simple sugar (a monosaccharide).
    a) Glucose
    b) Sucrose
    c) Ribose
    d) Starch
    e) both a and c
    f) a, b, and c

2. _____ are to proteins as _____are to nucleic acids.
    a) Sugars; lipids
    b) Amino acids; hydrogen bonds
    c) Sugars; proteins
    d) Amino acids; nucleotides

3. Lactose is a monosaccharide. (True or False)