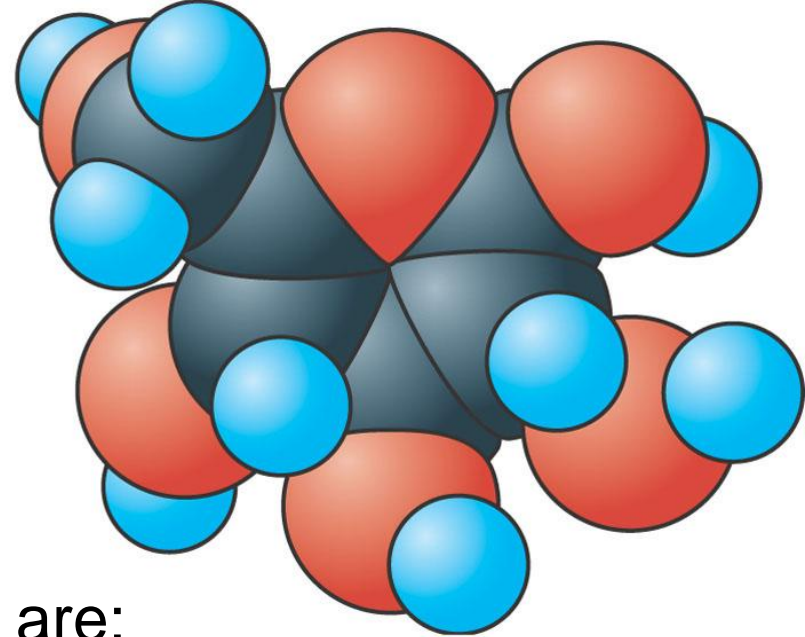


Lecture 3

Macromolecules



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Some of the roles of macromolecules are:

- Energy storage
- Structural support
- Catalysis
- Transport
- Protection and defense
- Regulation of metabolic activities
- Maintenance of homeostasis
- Means for movement, growth, and development
- Heredity

Cells cannot live by sugar and water alone - they need to put the chemical "building blocks" C, O, H, and N (and others) together to make useful molecules for food and energy that allow them to perform the functions of life.

Cells join together small organic molecules (monomers; building blocks) to form large molecules (polymers) or Macromolecules

Types of Macromolecules

Carbohydrates

Lipids

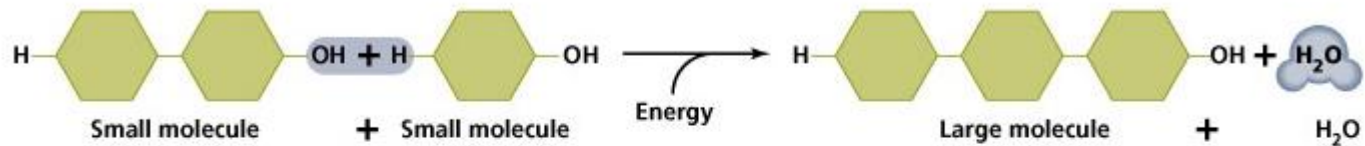
Proteins

Nucleic Acids

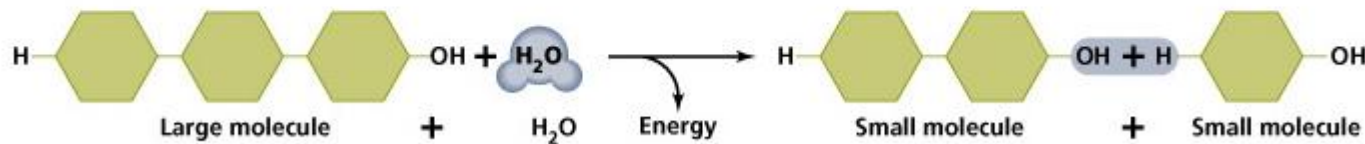
Chemical reactions assemble monomers into polymers and break polymers back down into monomers:

Dehydration reactions remove water from molecules to join monomers into polymers

Hydrolysis reactions break down polymers back down to monomers - bonds are broken by the addition of water



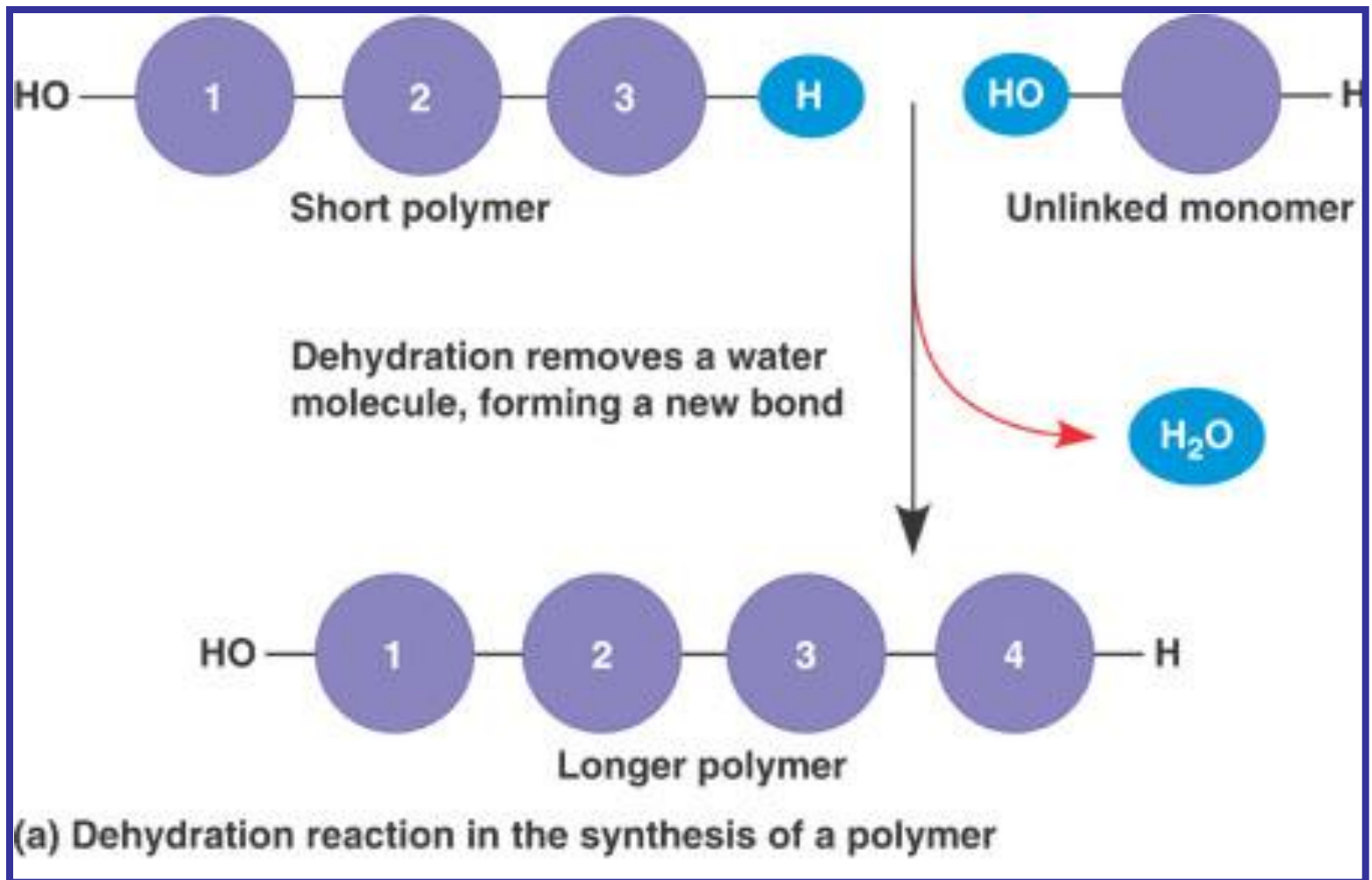
(a) Dehydration synthesis



(b) Hydrolysis

Dehydration (Polymer) Synthesis

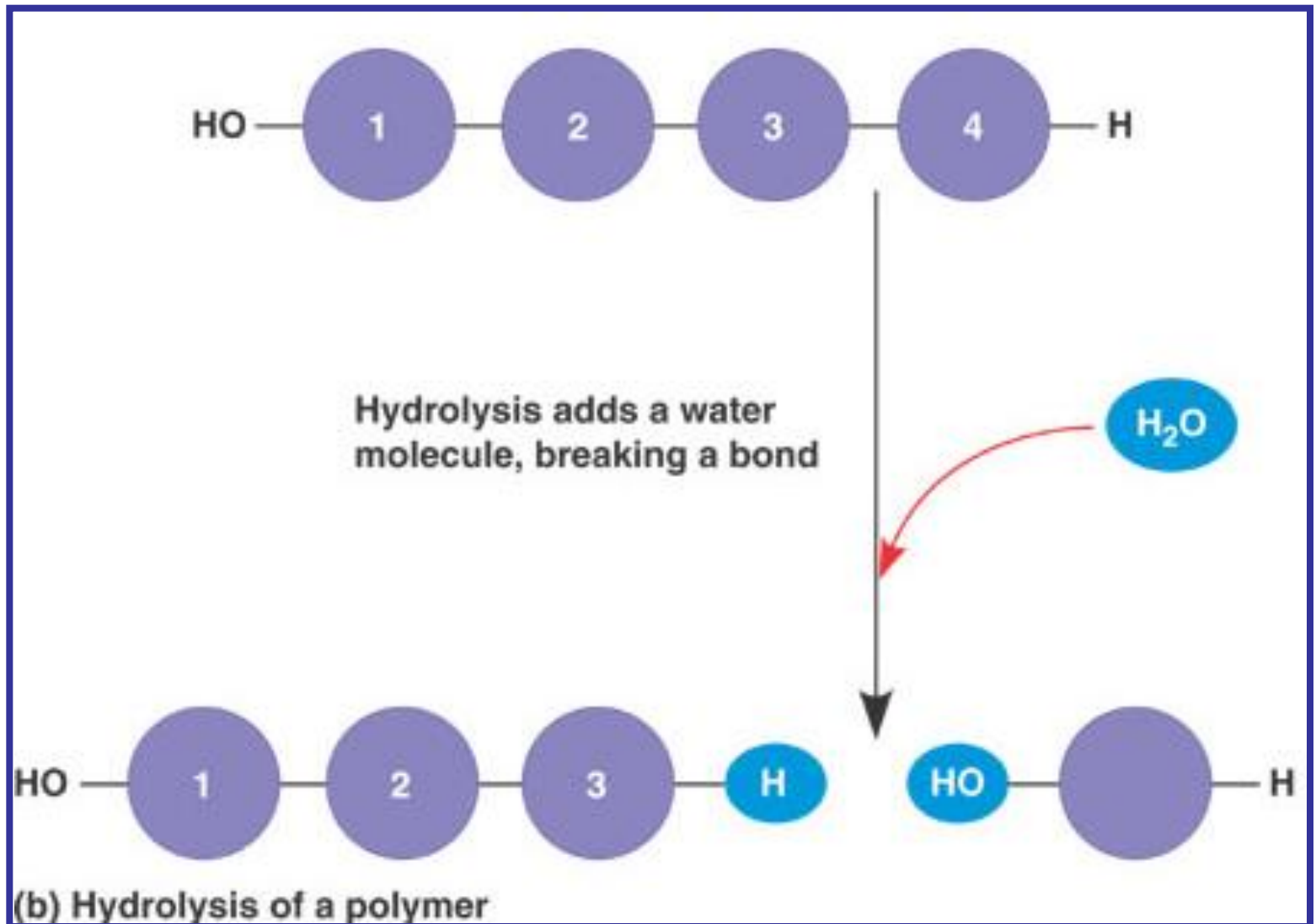
Energy +



- A.K.A., condensation reaction, dehydration reaction

Hydrolysis—Polymer Breakdown

- Enzymes are employed in biological systems to effect most hydrolysis reactions



+ Energy

Polymers, Monomers, and Lipids

category of biomolecules	monomer	polymer
carbohydrates	monosaccharides	polysaccharide
proteins	amino acids	polypeptides
RNA & DNA	nucleotides	polynucleic acids

- ❑ Lipid monomers are less persistent than the above monomers
- ❑ Consequently, lipids are less-readily described using the same polymeric terms. Lipids don't really have polymers.

Carbohydrates

Basic Formula: $(CH_2O)_n$

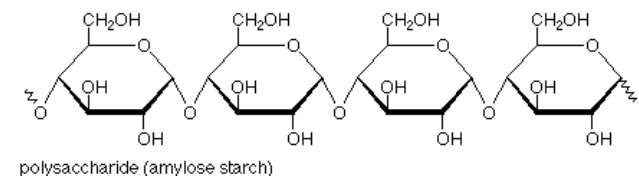
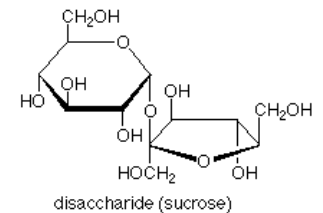
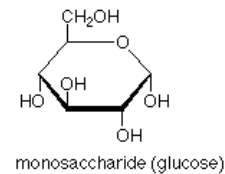
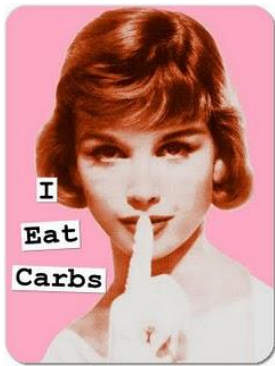
Carbohydrates are carbon molecules with hydrogen and hydroxyl groups.

- They act as energy storage and transport molecules.
- They also serve as structural components.



There are four major categories of carbohydrates:

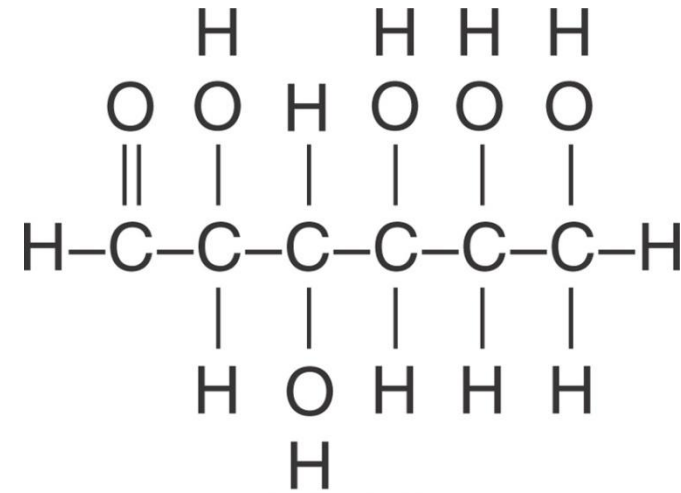
- Monosaccharides
- Disaccharides, which consist of two monosaccharides
- Oligosaccharides, which consist of between 3 and 20 monosaccharides
- Polysaccharides, which are composed of hundreds to thousands of monosaccharides



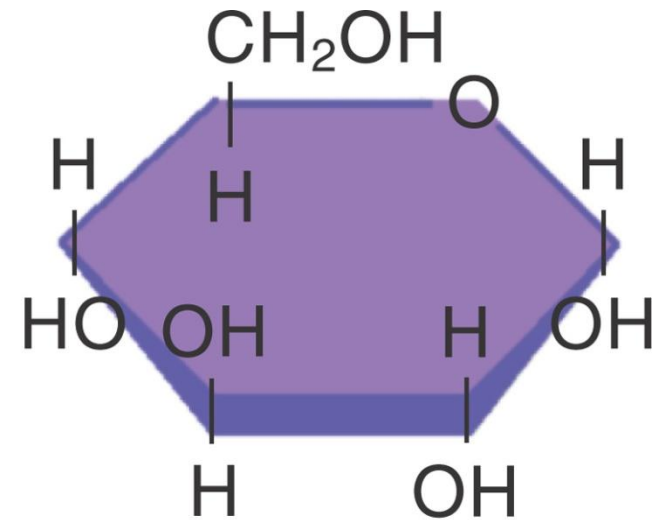
Monosaccharides

Monosaccharides are simple, single sugars

- All living cells contain glucose ($C_6H_{12}O_6$).
- Green plants produce monosaccharides; other organisms acquire glucose, or the energy to make it, from plants.
- Cells break down glucose to release energy, with the final products being carbon dioxide and water.
- Glucose exists as a straight chain and a ring.
- The ring form is predominant (>99%).
- There are two forms of the ring: α -glucose and β -glucose.
- The two forms exist in equilibrium when dissolved in water.

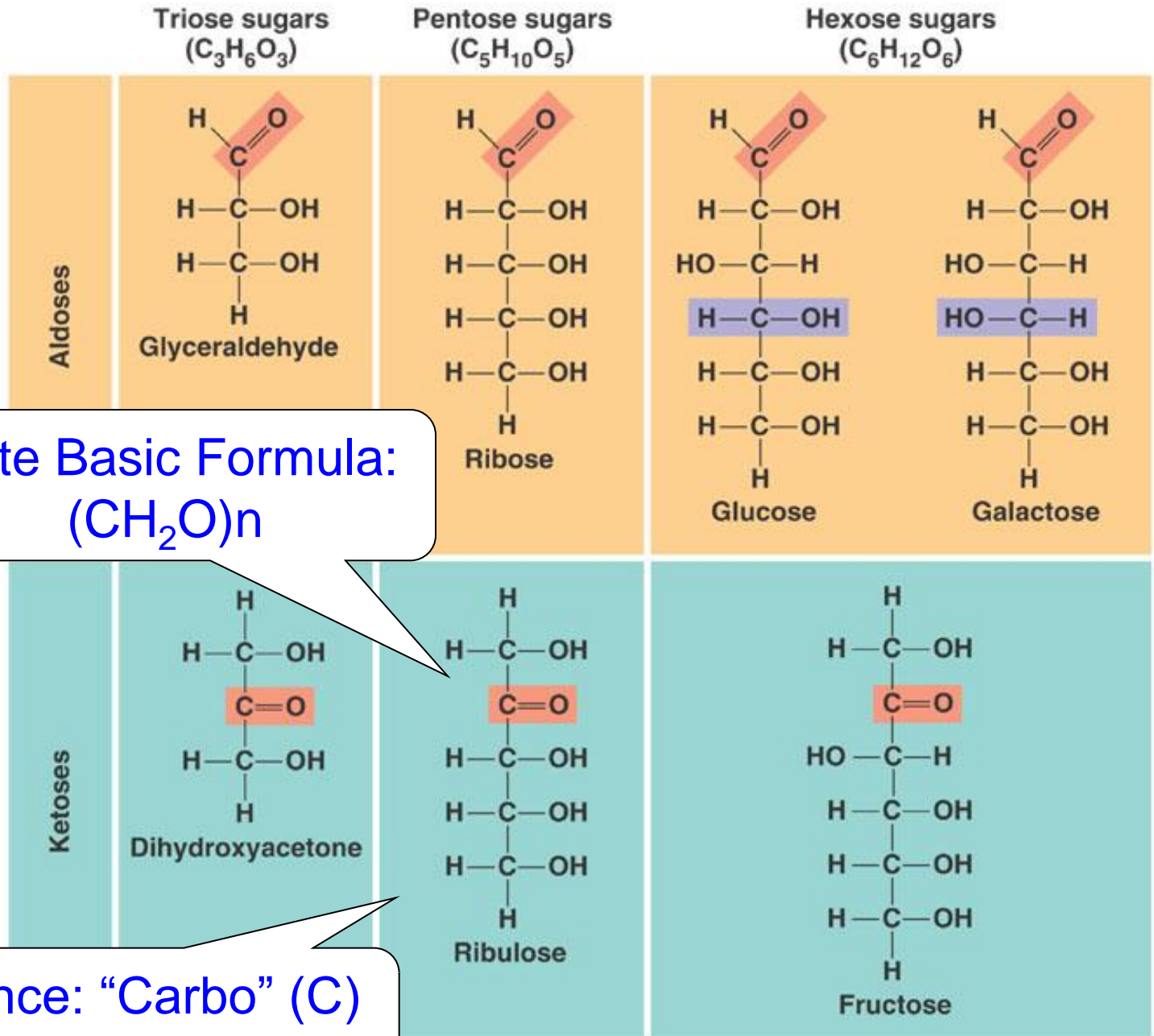


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Some Monosaccharides



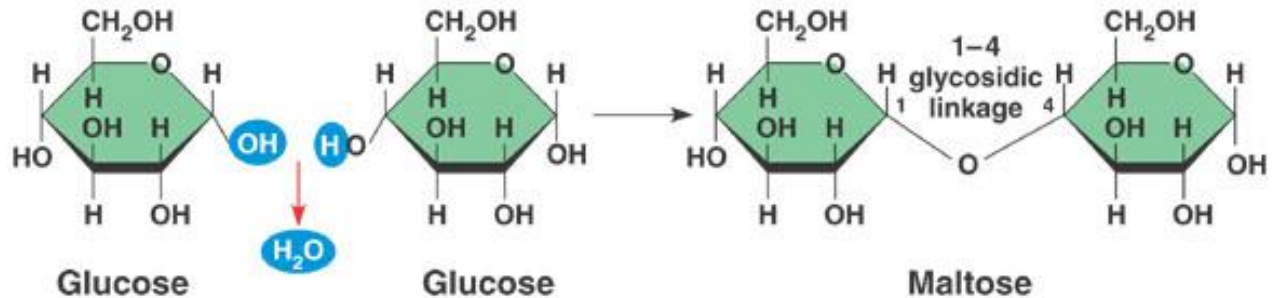
Note Basic Formula:
 $(CH_2O)_n$

Hence: "Carbo" (C)
"Hydrate" (H_2O)

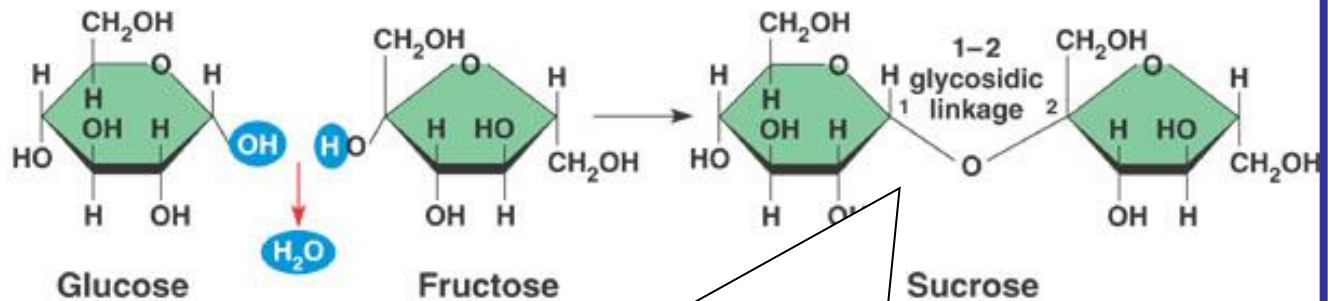
Disaccharide Synthesis

Energy +

(a) Dehydration reaction in the synthesis of maltose



(b) Dehydration reaction in the synthesis of sucrose



monosaccharides become disaccharides and polysaccharides through dehydration synthesis and are bound together by Glycosidic linkages

Sucrose

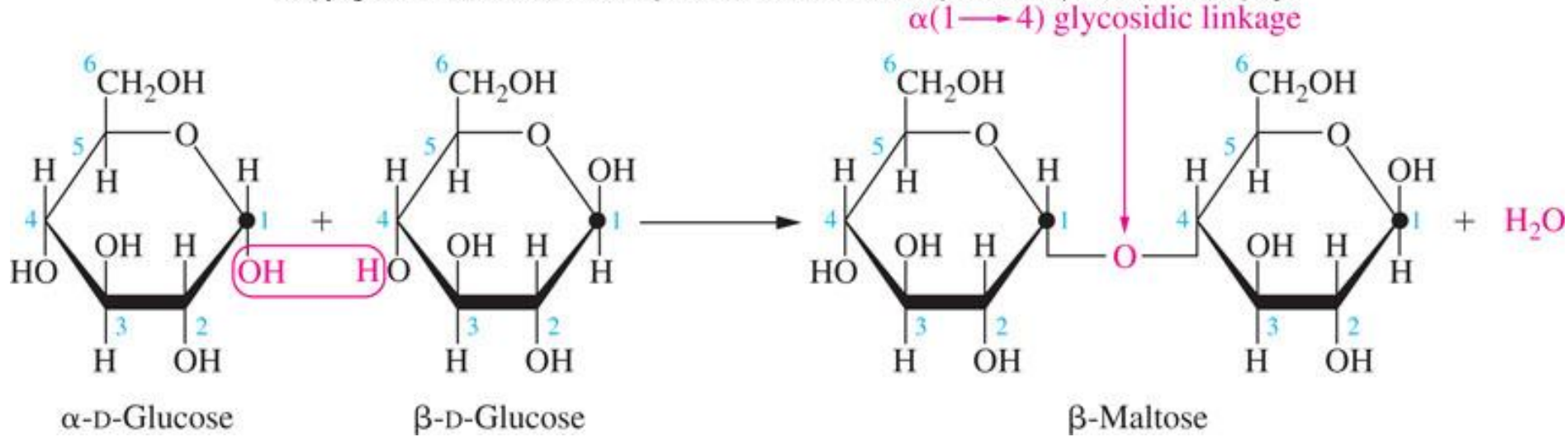
- Sucrose is formed by linking two monosaccharides (a glucose and a fructose)
- Important plant carbohydrate
 - Water soluble
 - Easily transported in plant circulatory system
- Cannot be synthesized by animals
- Sucrose called:
 - Table sugar
 - Cane sugar
 - Beet sugar



Linked to tooth decay, obesity, heart disease, depressed immune system, and type 2 diabetes

Formation of Maltose

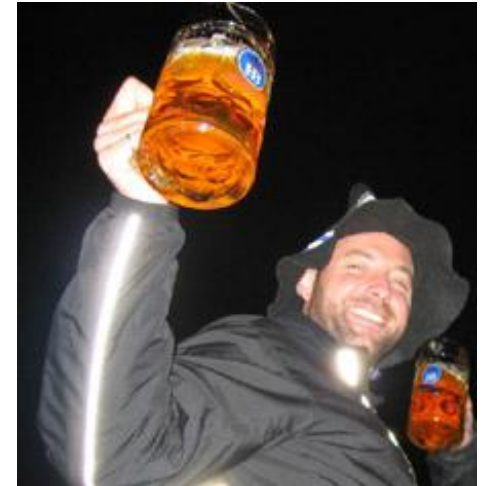
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Important to make beer

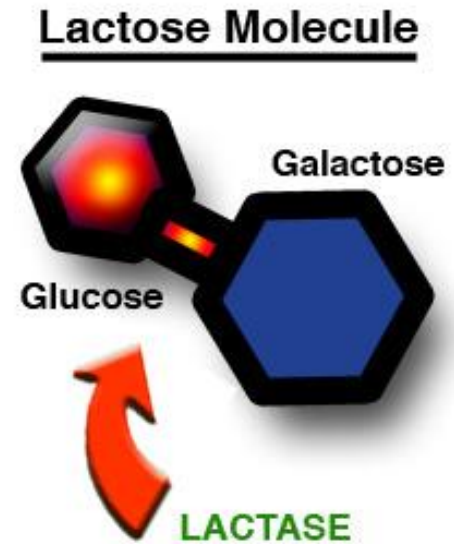


+

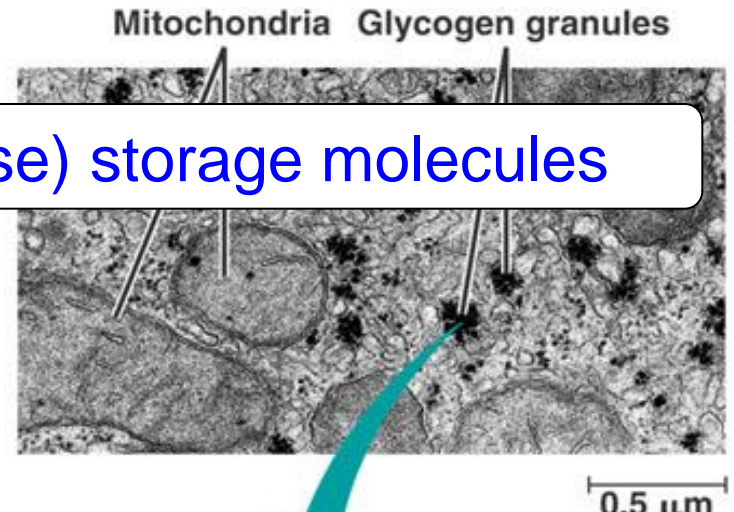
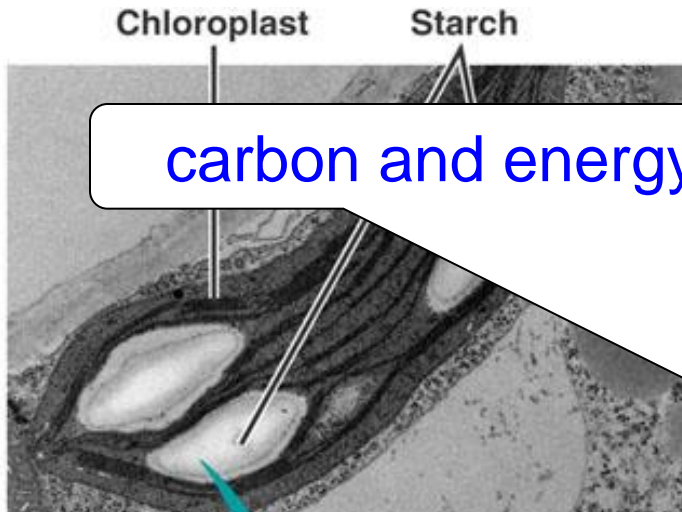


Galactosemia & Lactose Intolerance

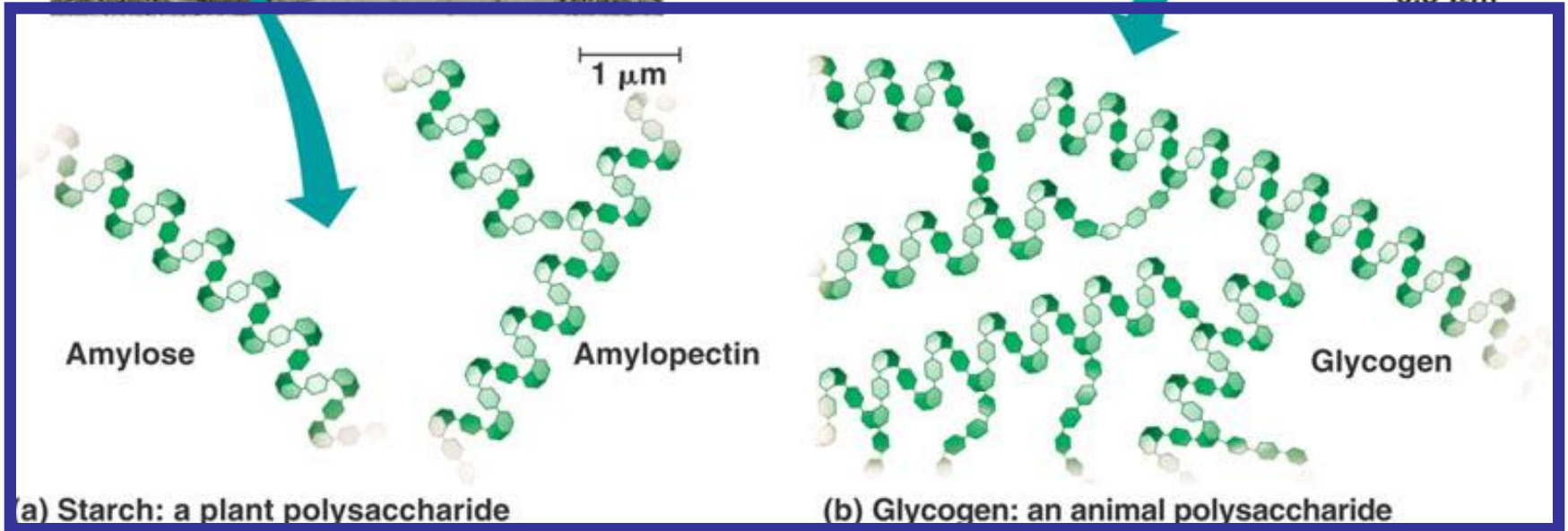
- **Lactose intolerance** involves individuals who lack the enzyme lactase and are unable to digest lactose (break it into glucose and galactose). 75% of the world population is lactose intolerant.
- In order for galactose to be used as an energy source, it must be converted to a phosphorylated glucose molecule. When enzymes necessary for this conversion are absent, the genetic disease **Galactosemia** results (i.e. Inability to use galactose).



Starches



carbon and energy (glucose) storage molecules

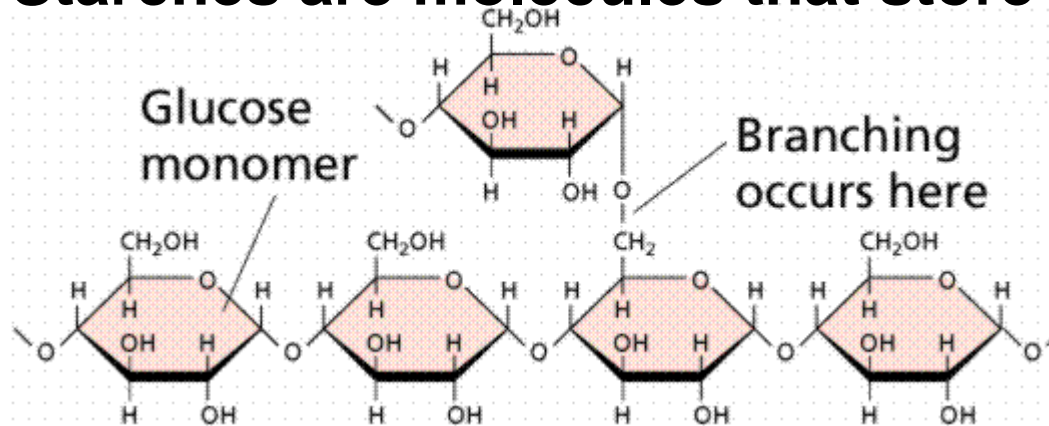


more branching

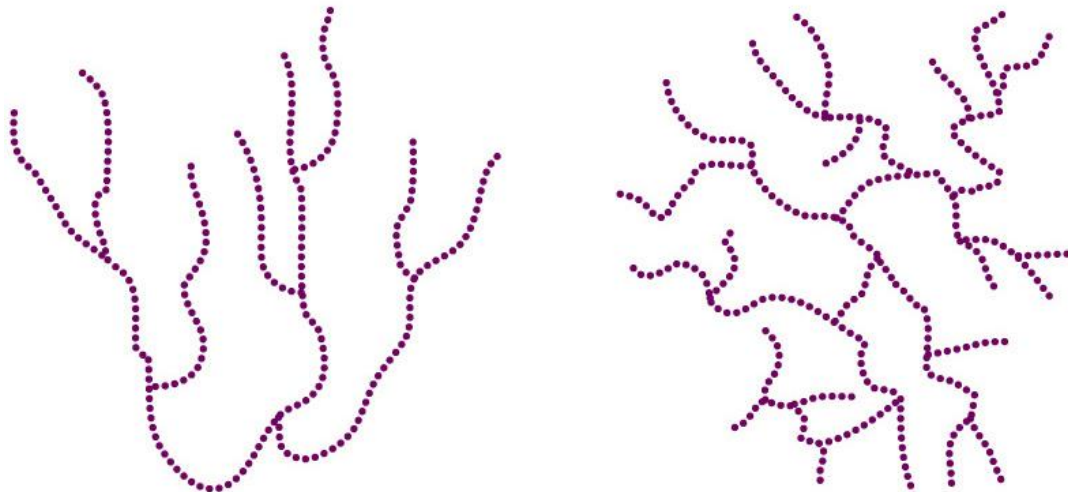
Starch/Glycogen

Starches vary by amount of branching.

- Plant starch, consists of amylose (not branched) and amylopectin, which is slightly branched.
- Animal starch, called glycogen, is highly branched.
- Starches are molecules that store glucose.



Each polymer molecule has essentially the same effect as one monomer molecule on the osmotic pressure of a solution.

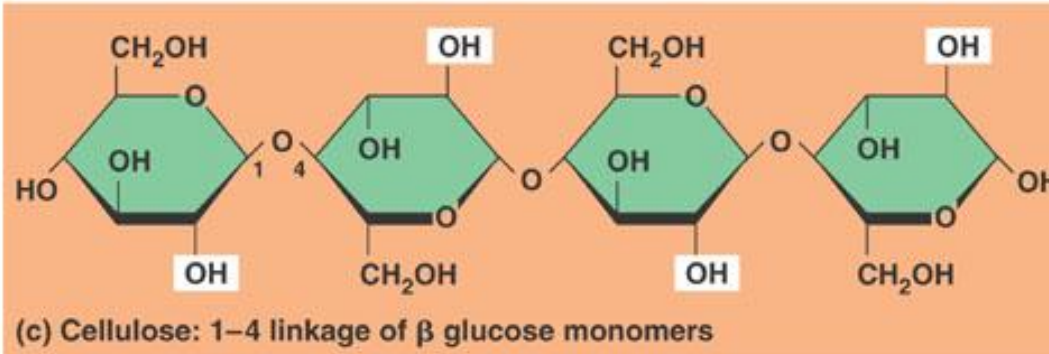
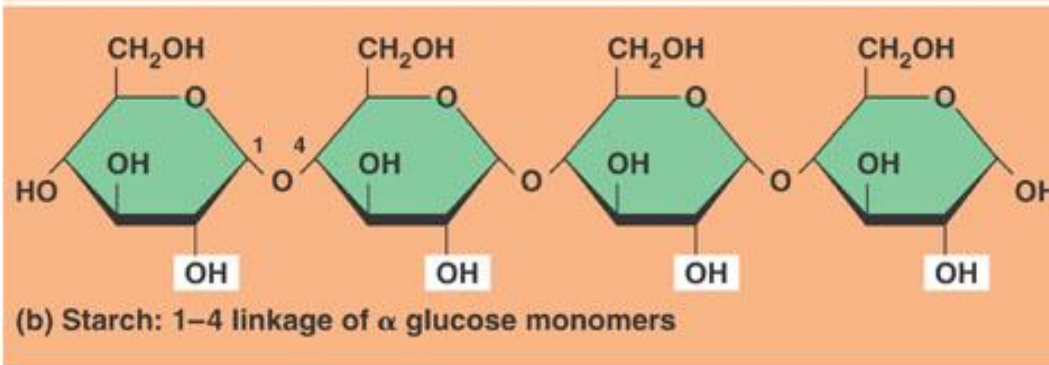
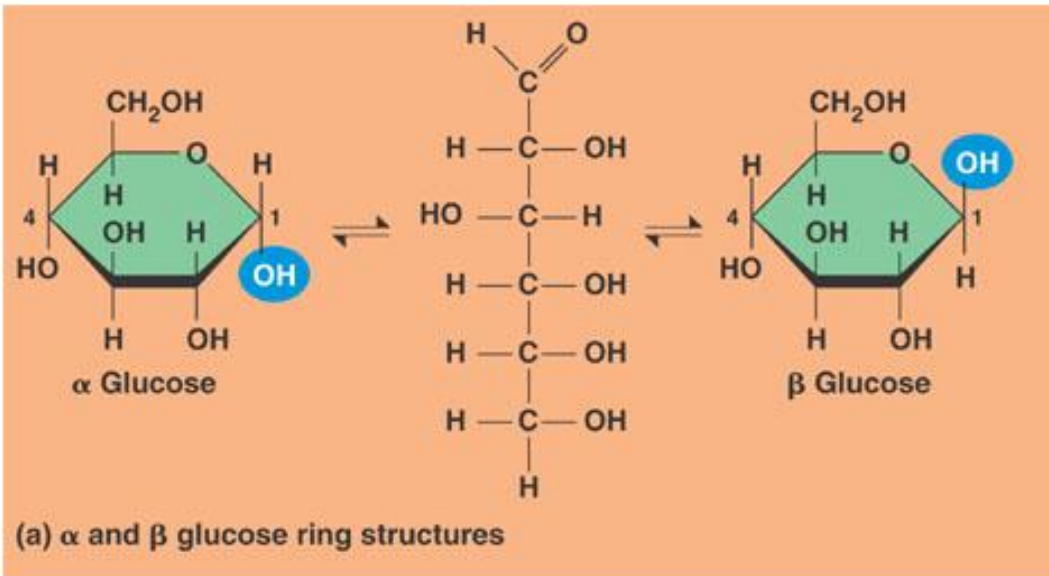


Amylopectin
(in plants)

Glycogen
(in animals)

Combining many glucose molecules into just one reduces the osmotic effect, allowing storage of lots of energy, without disturbing the water content of a cell too much.

Cellulose



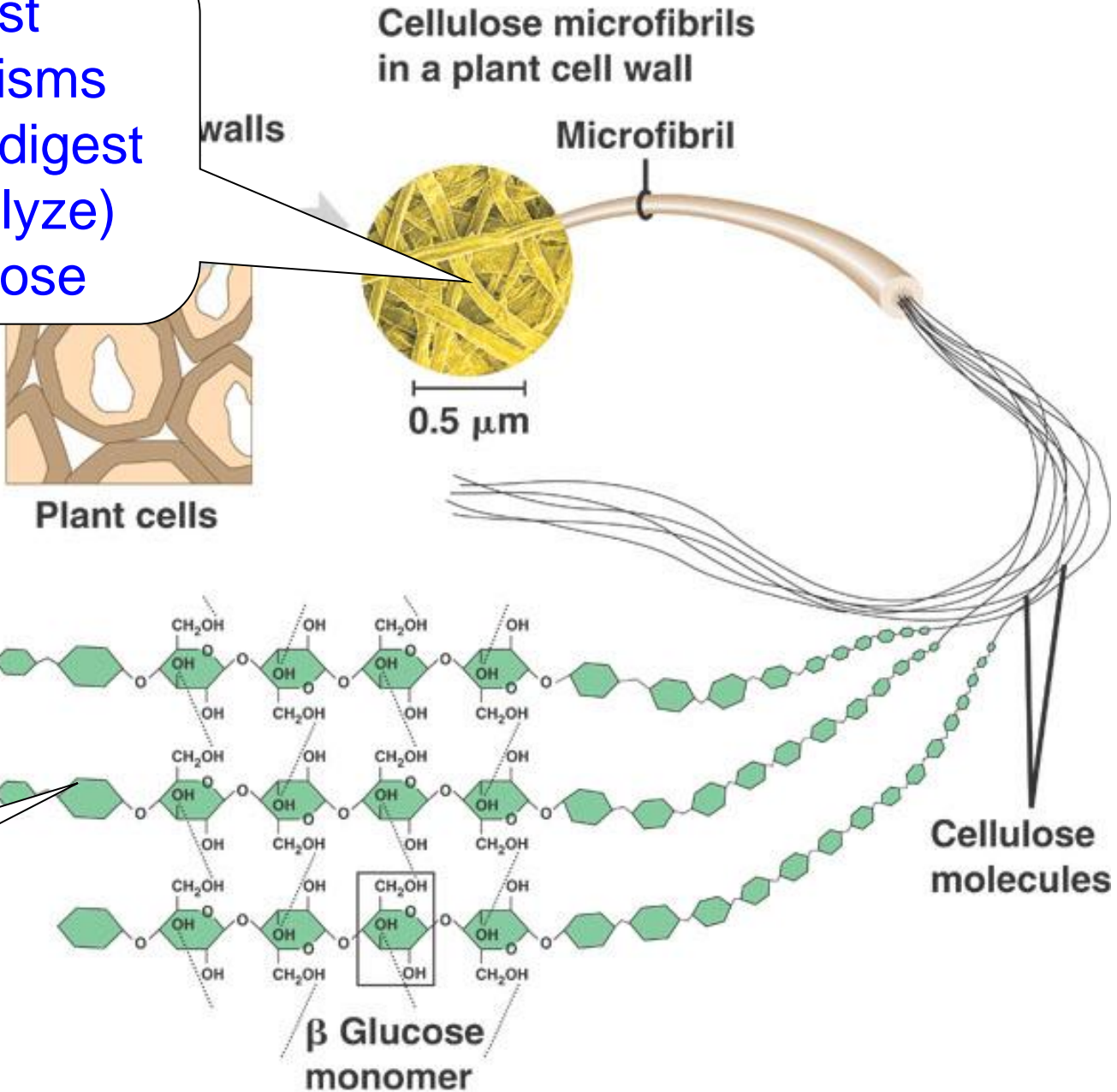
Starch can be readily degraded by the action of chemicals or enzymes, making it a good storage medium.

Cellulose is much more stable chemically than starch and more difficult to hydrolyze chemically and enzymatically. This quality makes it an excellent structural material.

Cellulose

Most organisms cannot digest (hydrolyze) cellulose

Cellulose is a Structural polysaccharide



Cellulose

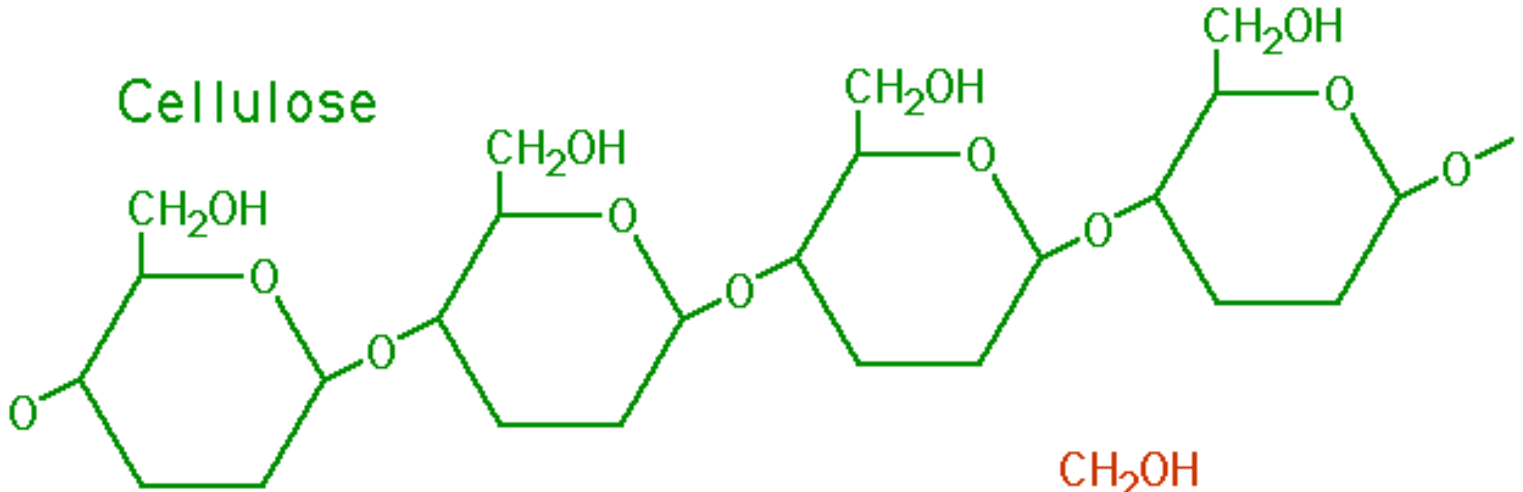
Organisms that can digest cellulose include the microorganisms living in the gastrointestinal tract of many organisms typified especially by cows and termites and many fungi (i.e., the things that “eat” the wood of fallen trees)



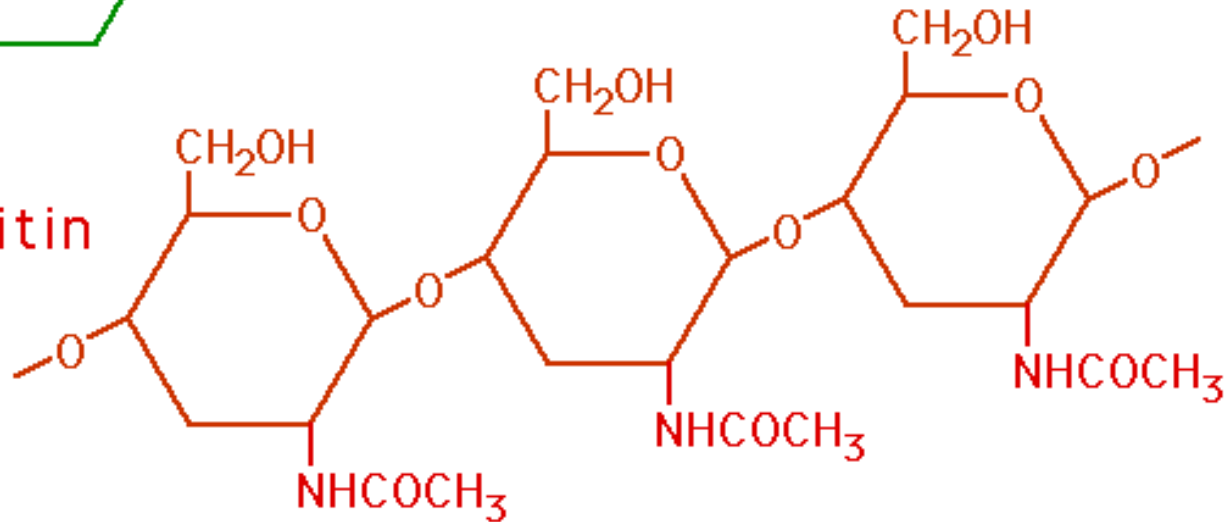
Chitin is another example of a structural carbohydrate. Chitin is found in the exoskeletons of insects, spiders, and crustaceans. Chitin is also found in the cell walls of fungi.

Chi
via

Cellulose



Chitin



Chitin



CH₃



The structure of the chitin monomer

Lipids: Water-Insoluble Molecules.

- *Life is cellular; the differences between what is outside and inside a cell define life.*
- *Biological molecules called lipids maintain these differences.*
- Lipids are diverse biological molecules that share a common chemical property: They are insoluble in water.
- This insolubility results from the many nonpolar covalent bonds of hydrogen and carbon in lipids.
- Lipids aggregate away from water, which is polar, and attract to each other via weak, but additive, van der Waals forces.

Lipids



The roles for lipids in organisms include energy storage (fats and oils), cell membranes (phospholipids), capture of light energy (carotenoids), chemical messengers, hormones and vitamins (steroids and modified fatty acids), thermal insulation, electrical insulation of nerves, and water repellency (waxes and oils).

Various Lipids

Fat

Fatty acid

Palmitic acid

Triacylglycerol

Triglyceride

Saturated fatty acid

Unsaturated fatty acid

Monounsaturated fatty acid

“Trans fatty acid”

Polyunsaturated fatty acid

Arachidonic acid

Linoleic acid

Oil

Phospholipid

Phosphatidylcholine

Steroid

Cholesterol

Steroid hormone

Sex hormone

Testosterone

Estrogen

Waxes

Omega-3-fatty acids

Omega-6-fatty acids

Free fatty acids

“Butter”

“Margarine”

Oil

Flax seed oil

“Toasted Sesame oil”

Bile salts

“Vegetable shortening”

“Hydrogenated vegetable shortening”

“Partially hydrogenated veg. short.”

Lipids do not share a common core structure

What is common to lipids is their hydrophobicity

NOT TRUE POLYMERS

Saturated & Unsaturated F.A.

❑ Fat

Fully saturated

Solid at room temp.

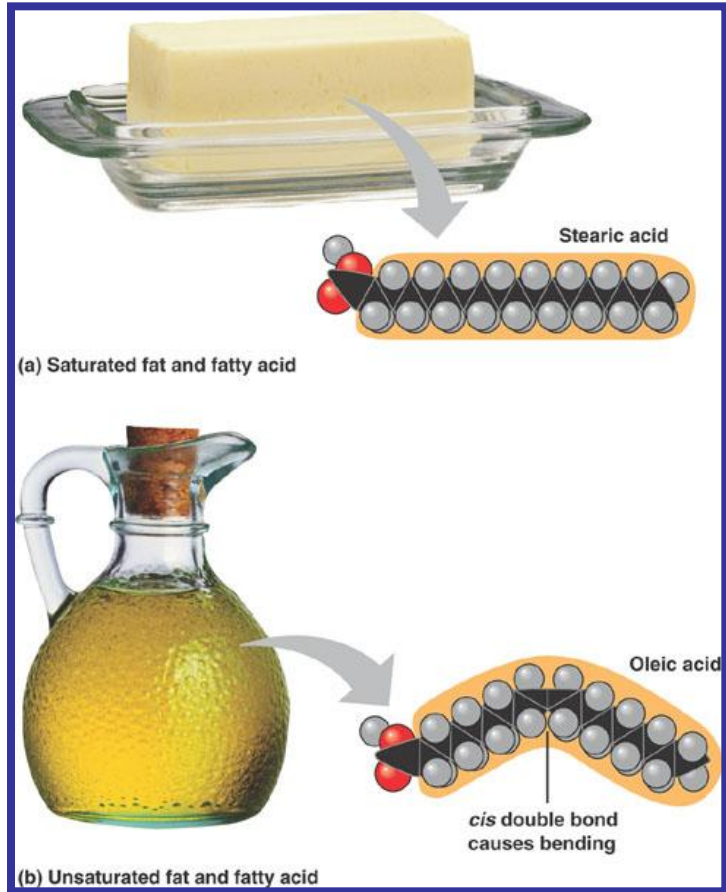
> high-temp. stability

❑ Oil

Unsaturated

Liquid at room temp.

> low-temp. fluidity



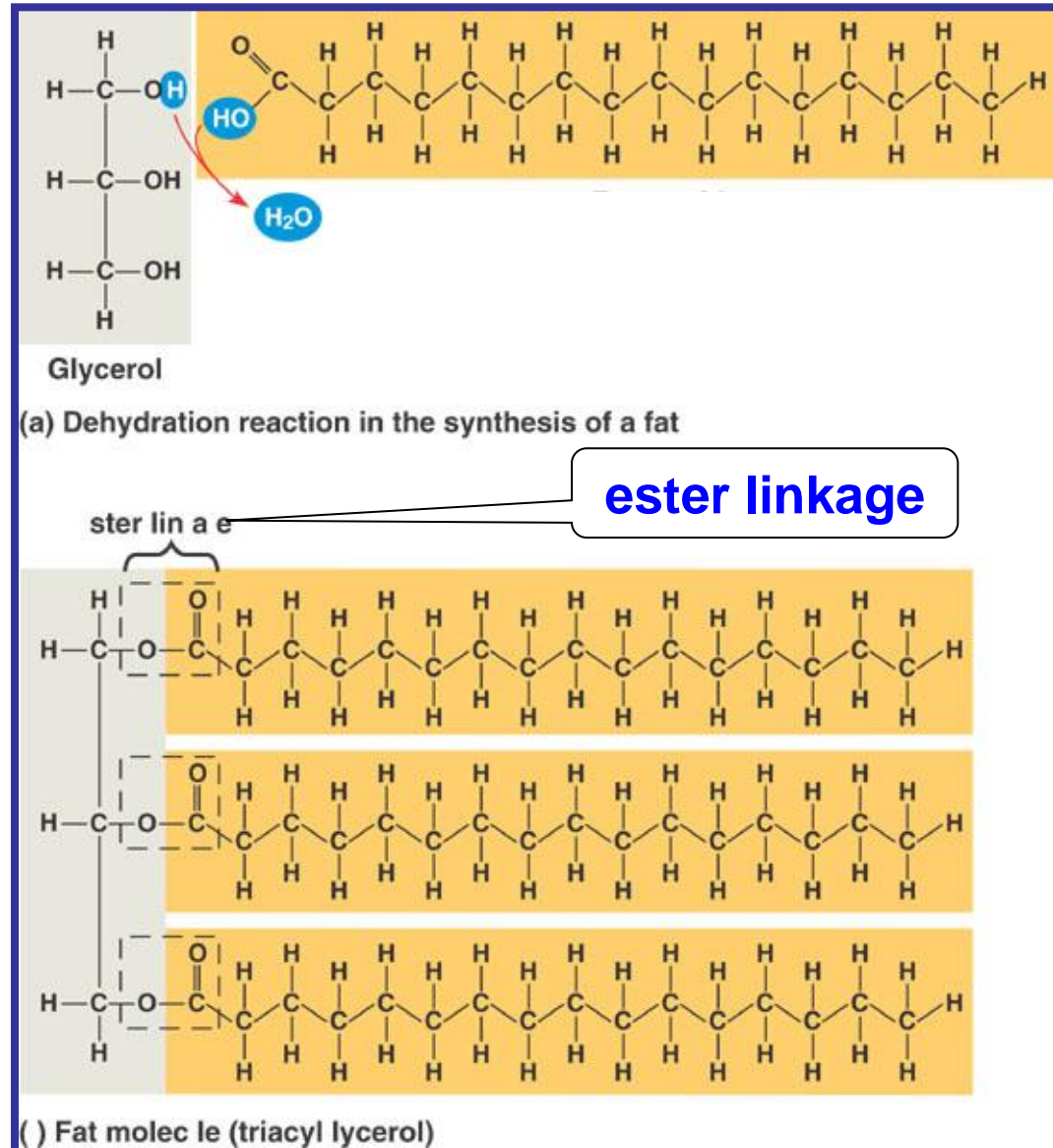
Triglycerides, or fats

Most abundant lipids and most concentrated source of energy

The building blocks of triglycerides are glycerol (the same for each fat molecule) and fatty acids (different for each fat, they determine its chemical nature)

Types of fatty acids—saturated fatty acid (all available bonds are filled) and unsaturated fatty acid (has one or more double bonds)

Triglycerides are formed by a dehydration synthesis



Triacylglycerols, -ides

Fats possess more energy per molecule and less hydration compared with carbohydrates, resulting in fats possessing much more energy stored per unit mass or volume

Saturated

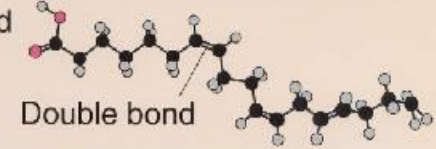
Unsaturated

(a) Fatty acids.

Saturated fatty acid

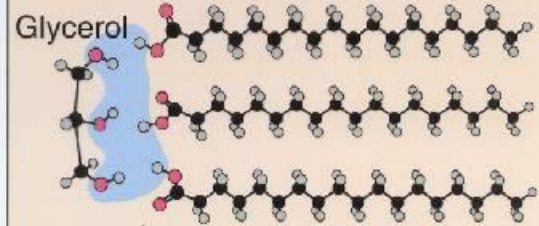


Unsaturated fatty acid



Reactions of fatty acids with glycerol give neutral fat, triglyceride.

Glycerol



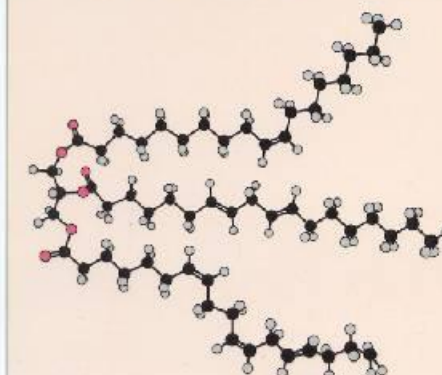
Dehydration synthesis



Tightly packed saturated fatty acids give solid fat.



Bacon fat



Loosely packed unsaturated fatty acids give a liquid fat (an oil).



Corn oil

Neutral Fats (Triglycerides or Triacylglycerols)

Nutrition Facts			
Serving size: 1/4 Recipe (188g)			
Servings Per Recipe 4			
Amount Per Serving			
Calories 199		Cal. from Fat 45	
% Daily Value*			
Total Fat 5g			8%
Saturated Fat 1g			4%
Cholesterol 0mg			0%
Sodium 245mg			10%
Total Carbohydrate 31g			10%
Dietary Fiber 8g			35%
Sugars 0g			
Protein 10g			
Vitamin A 75%	Vitamin C		40%
Calcium 10%	Iron		20%

* Percent Daily Values is based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Total Fat = 5 grams

Saturated Fat = 1 gram

What is the rest of the fat?

Unsaturated

Monounsaturated

Polyunsaturated

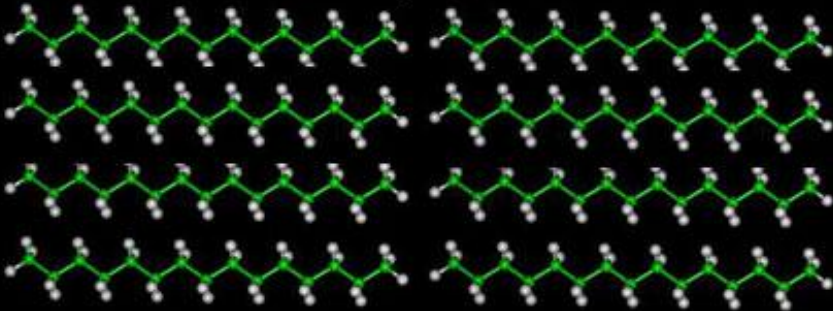
Hydrogenated

Cis and Trans fats

Neutral Fats (Triglycerides / Triacylglycerols)

Saturated Fats Align Solid

Tight Fit



As Hard As Butter

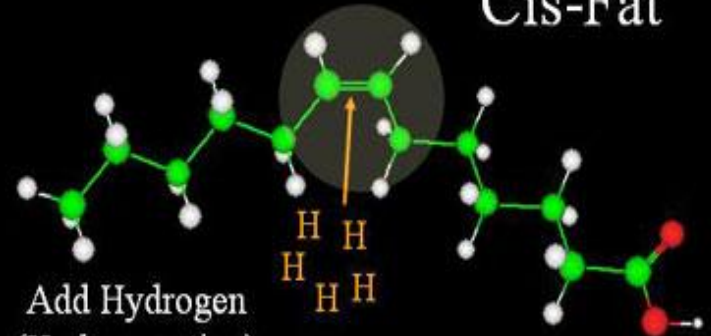
Polyunsaturated Fats Are Fluid

Loose Fit

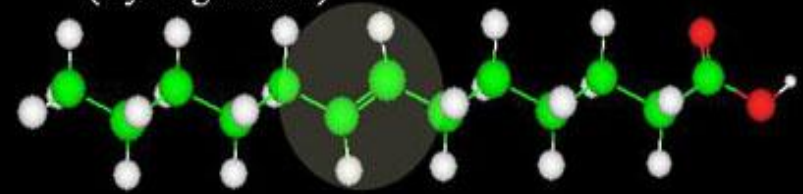


Liquid Oil

Cis-Fat



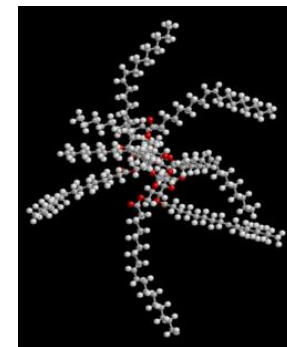
Add Hydrogen
(Hydrogenation)



Straight and Solid

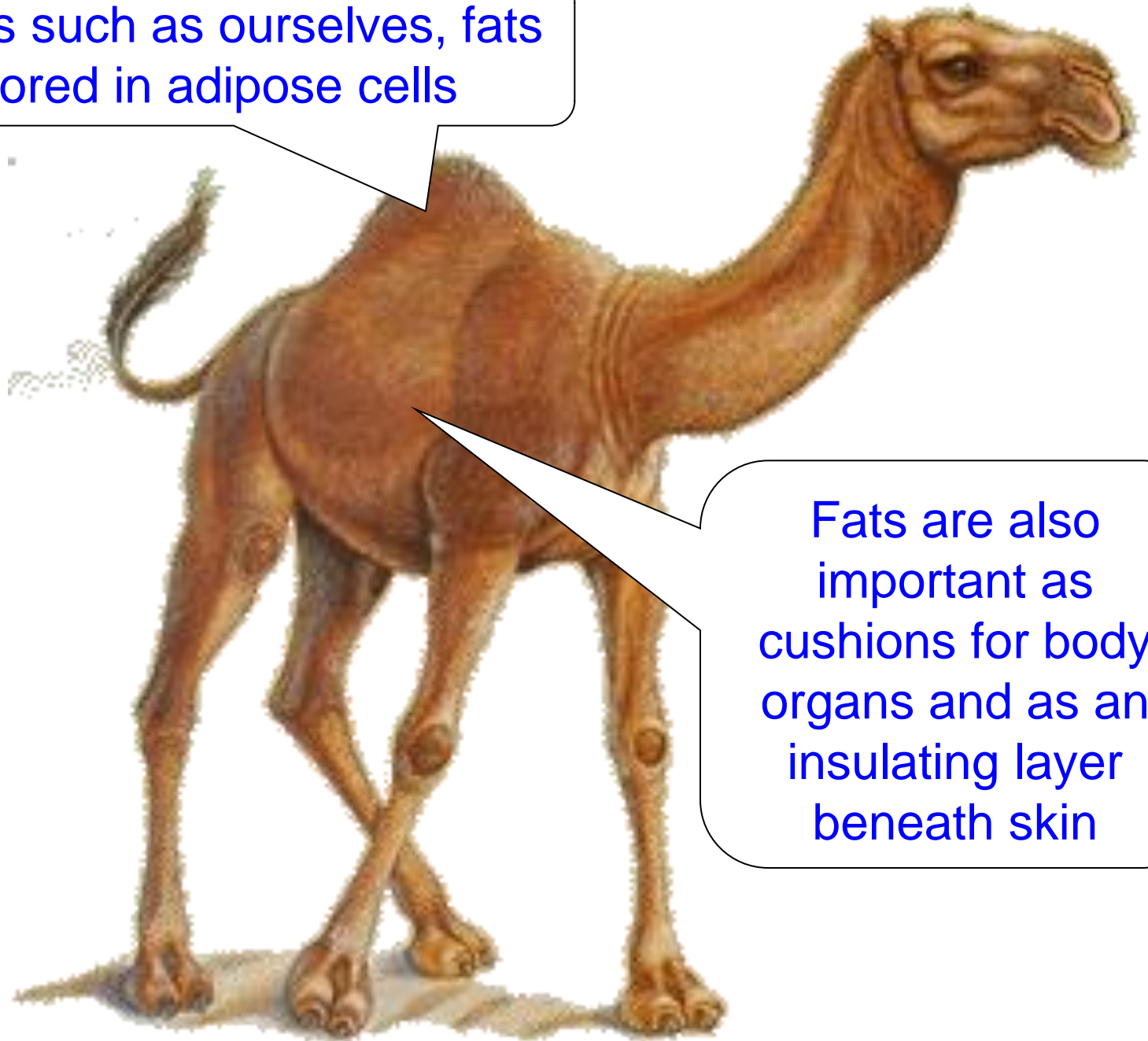
Trans-Fat

OLESTRA



In animals such as ourselves, fats are stored in adipose cells

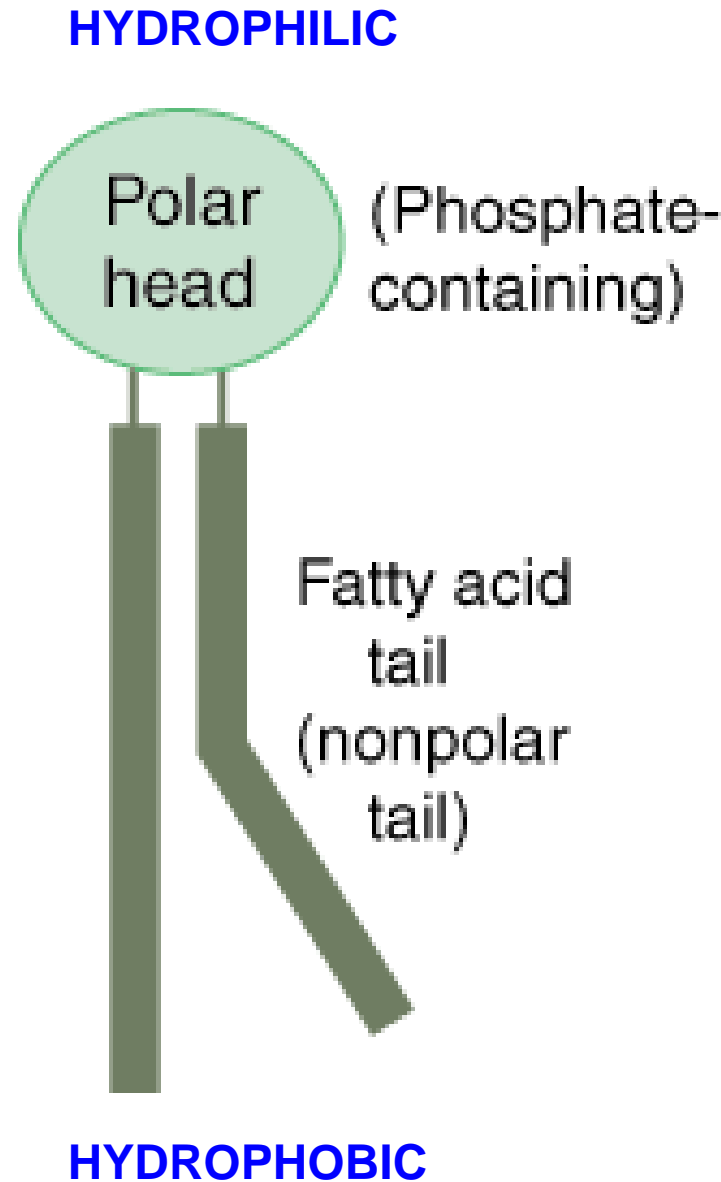
Fat Functions



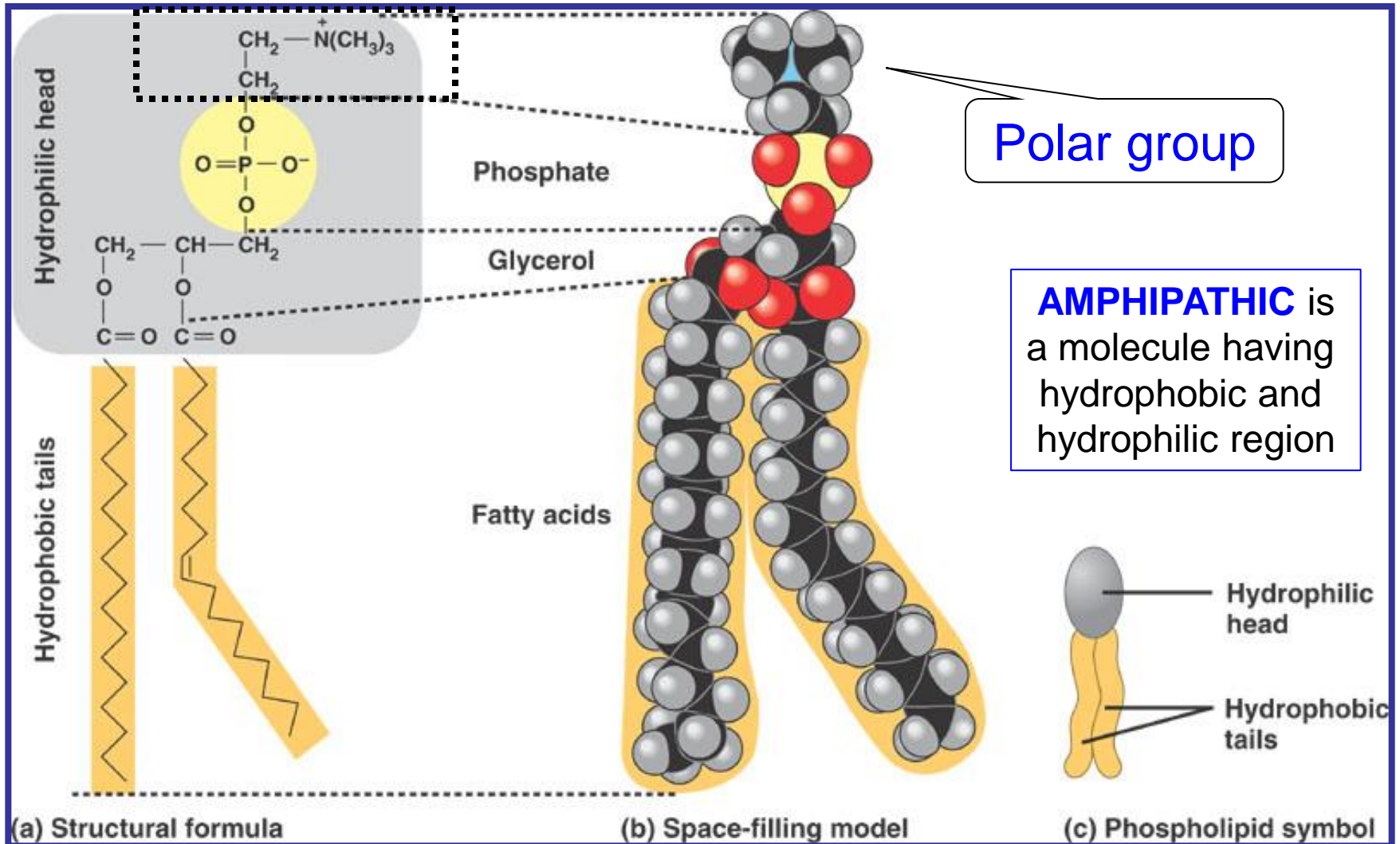
Fats are also important as cushions for body organs and as an insulating layer beneath skin

Phospholipids

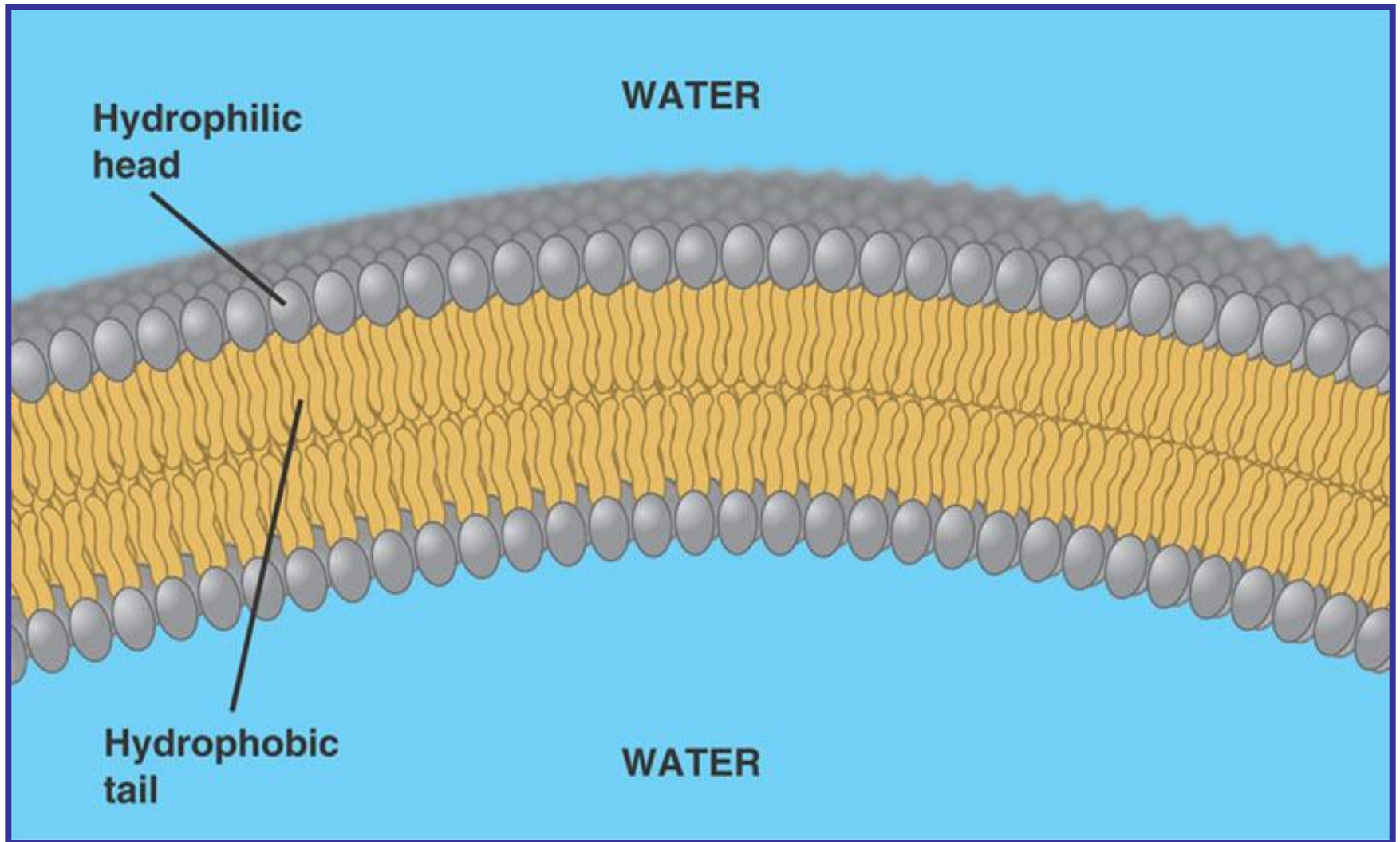
- Fat compounds similar to triglyceride
- One end of the phospholipid is water-soluble (hydrophilic); the other end is fat-soluble (hydrophobic)
- Phospholipids can join two different chemical environments
- Phospholipids may form double layers called bilayers that make up cell membranes



Phospholipids



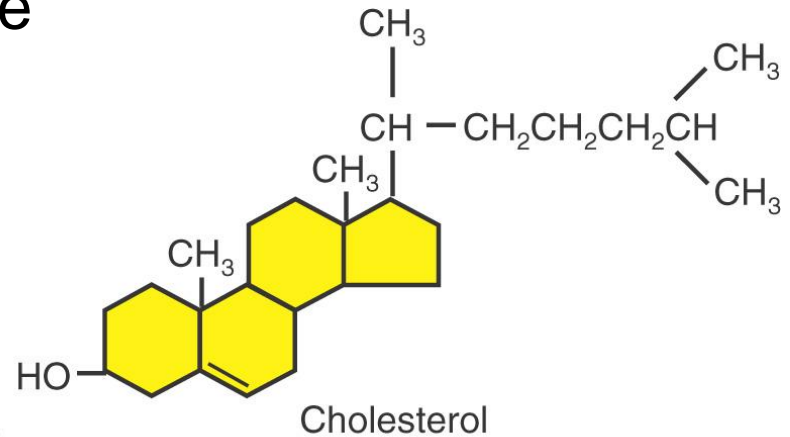
Phospholipid Bilayer



The hydrophobic and hydrophilic ends are essential for making biological membrane

Steroids

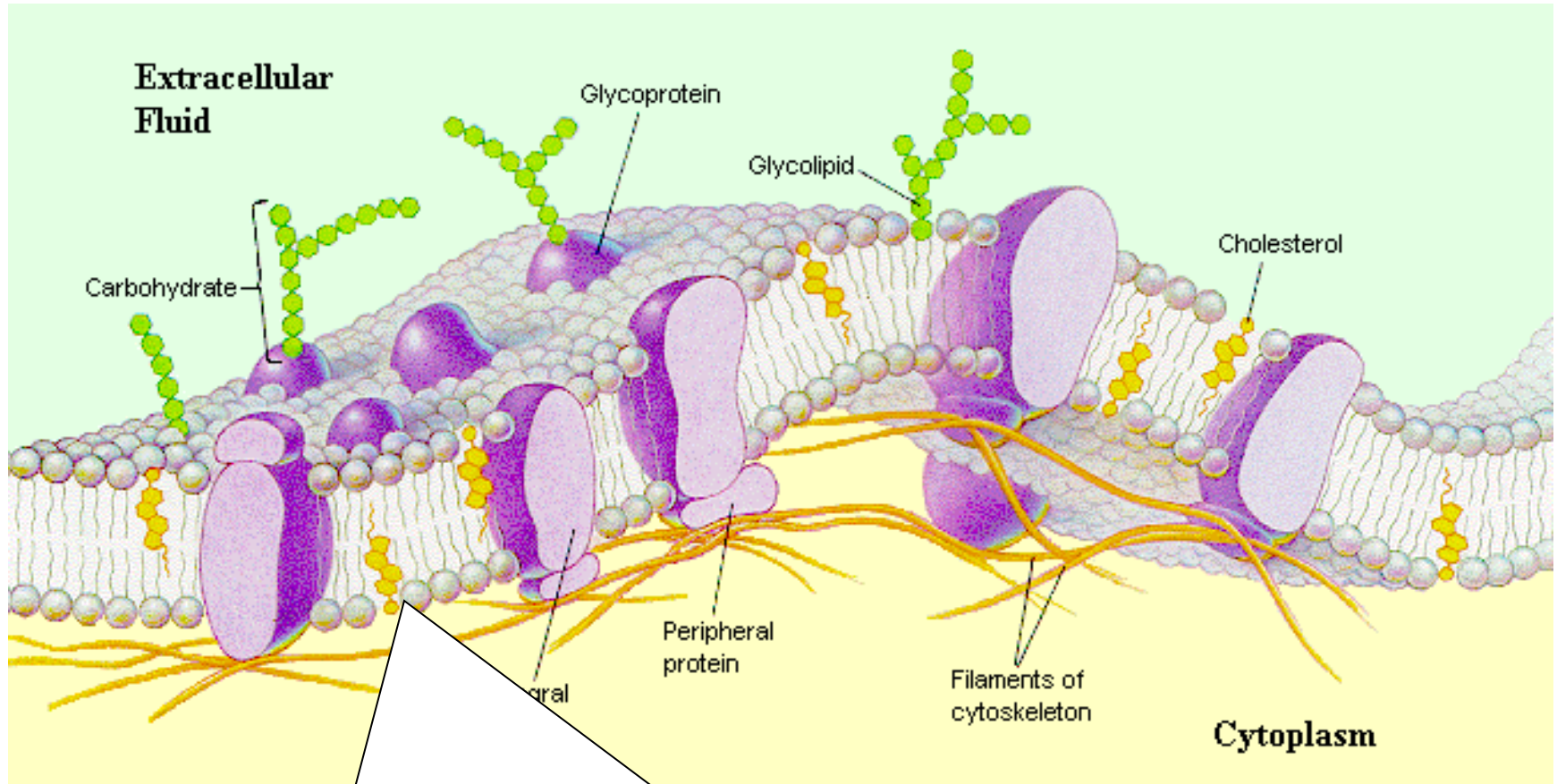
- Recognize common 4-ring structure
- Involved in many structural and functional roles
- Steroids are signaling molecules.
- Steroids are organic compounds with a series of fused rings.
- Cholesterol is an example. It is a common part of animal cell membranes.
- Cholesterol is absorbed from food and synthesized in the liver.
- In addition to being a membrane constituent, it also is an initial substrate for synthesis of the hormones testosterone and estrogen.



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Cholesterol



Cholesterol is a membrane temperature fluidity buffer

Finally,

Some lipids are vitamins

Vitamins are small organic molecules essential to health.

- Vitamin A, for example, is made from β -carotene. It is important for normal development, maintenance of cells, and night vision.
- Vitamin D is important for absorption of calcium in the intestines.
- Vitamin E is an antioxidant. It protects membranes.
- Vitamin K is a component required for normal blood clotting.



Wax coatings repel water

Waxes are highly nonpolar molecules. They protect our hair, birds' feathers, and insects' eggs from both the damaging effects of excess water, and the damaging effects of water loss.

Waxes are saturated long fatty acids bonded to long fatty alcohols via an ester linkage.

