INTRODUCTION TO ORGANIC COMPOUNDS

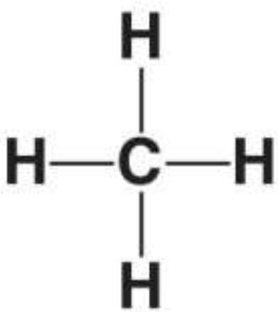
3.1 I can explain why carbon is unparalleled in its ability to form large, diverse molecules.

- Diverse molecules found in cells are composed of carbon bonded to other elements
  - Carbon-based molecules are called **organic compounds**
  - By sharing electrons, carbon can bond to four other atoms
  - By doing so, it can branch in up to four directions

3.1 I can explain why carbon is unparalleled in its ability to form large, diverse molecules.

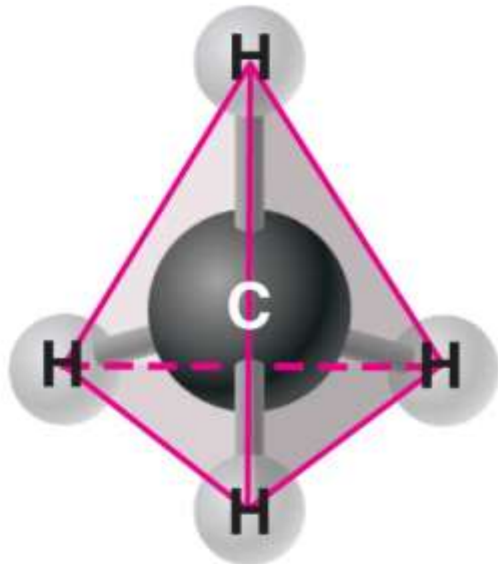
- Methane (CH_4) is one of the simplest organic compounds
  - Four covalent bonds link four hydrogen atoms to the carbon atom
  - Each of the four lines in the formula for methane represents a pair of shared electrons

Structural formula



Methane

Ball-and-stick model



Space-filling model

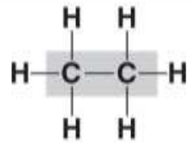
The four single bonds of carbon point to the corners of a tetrahedron.

3.1 I can define organic compounds, hydrocarbons, and carbon skeletons.

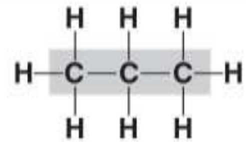
- Methane and other compounds composed of only carbon and hydrogen are called **hydrocarbons**
  - Carbon, with attached hydrogens, can bond together in chains of various lengths

3.1 I can define organic compounds, hydrocarbons, and carbon skeletons.

- A chain of carbon atoms is called a **carbon skeleton**
  - Carbon skeletons can be branched or unbranched
  - Therefore, different compounds with the same molecular formula can be produced
    - These structures are called **isomers**

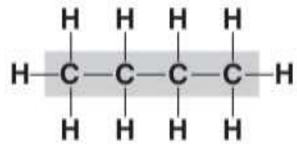


Ethane

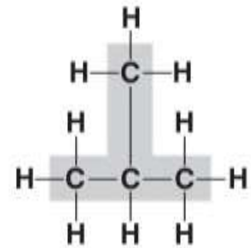


Propane

Length. Carbon skeletons vary in length.

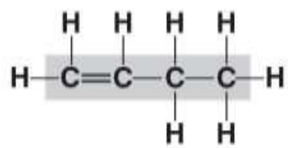


Butane

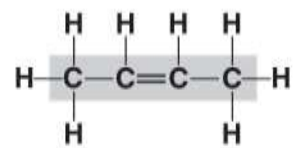


Isobutane

Branching. Skeletons may be unbranched or branched.

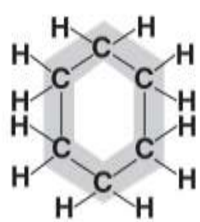


1-Butene

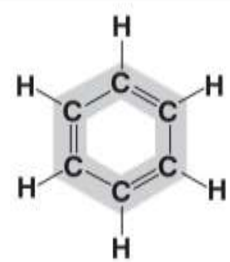


2-Butene

Double bonds. Skeletons may have double bonds, which can vary in location.



Cyclohexane



Benzene

Rings. Skeletons may be arranged in rings.

3.3 I can list the four main classes of macromolecules.

- There are four classes of biological molecules
  - Carbohydrates
  - Proteins
  - Lipids
  - Nucleic acids

3.3 I can explain the relationship between monomers and polymers

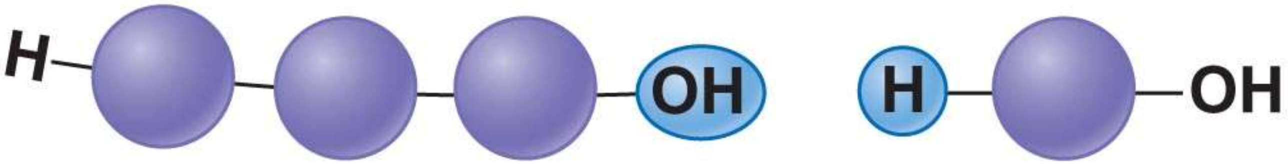
- The four classes of biological molecules contain very large molecules
  - They are often called **macromolecules** because of their large size
  - They are also called **polymers** because they are made from identical building blocks strung together
  - The building blocks are called **monomers**

3.3 I can explain the relationship between monomers and polymers

- A cell makes a large number of polymers from a small group of monomers
  – Proteins are made from only 20 different amino acids, and DNA is built from just four kinds of nucleotides
- The monomers used to make polymers are universal

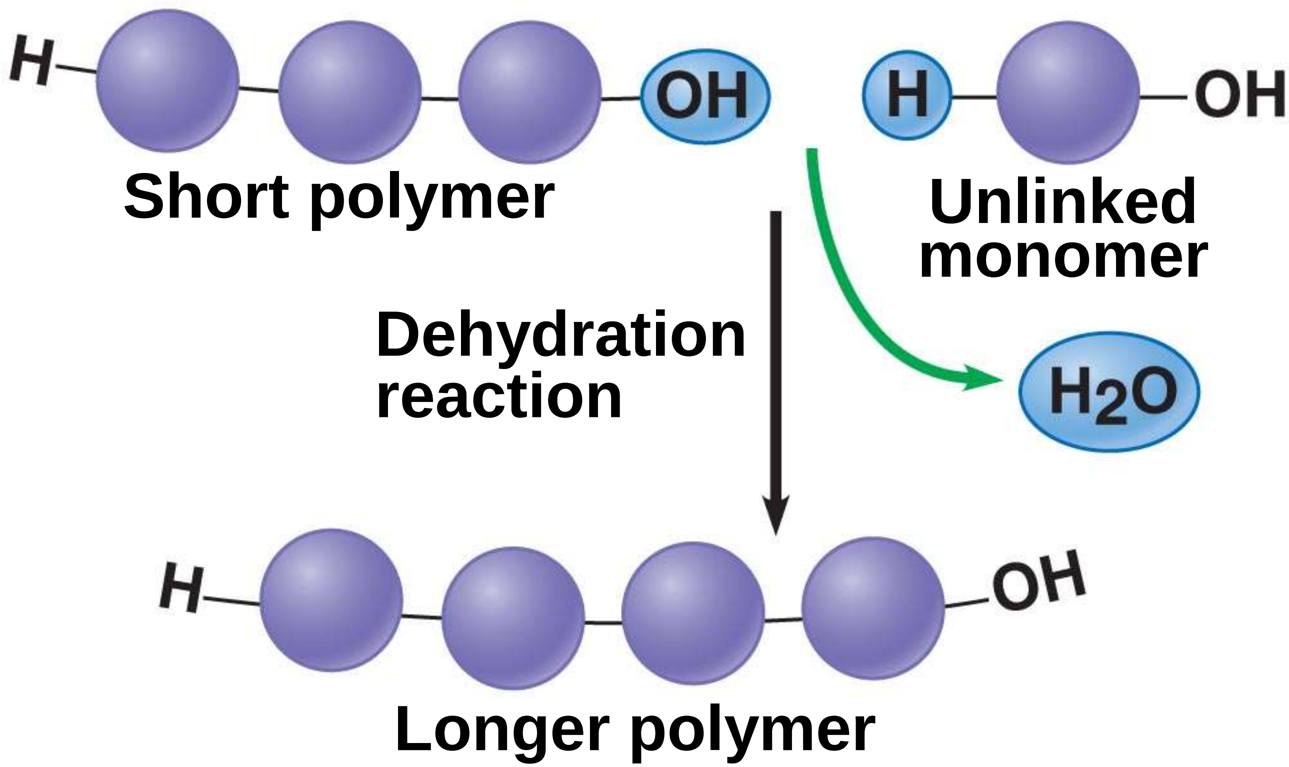
3.3 I can compare the processes of dehydration synthesis and hydrolysis.

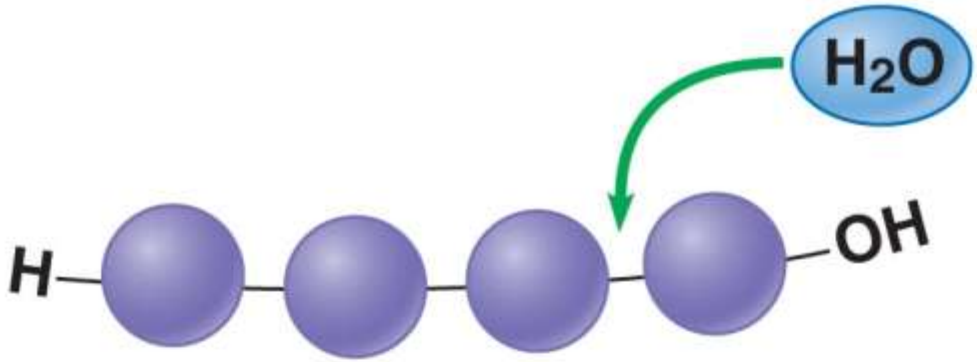
- Monomers are linked together to form polymers through **dehydration reactions**, which remove water
- Polymers are broken apart by **hydrolysis**, the addition of water
- All biological reactions of this sort are mediated by **enzymes**, which speed up chemical reactions in cells



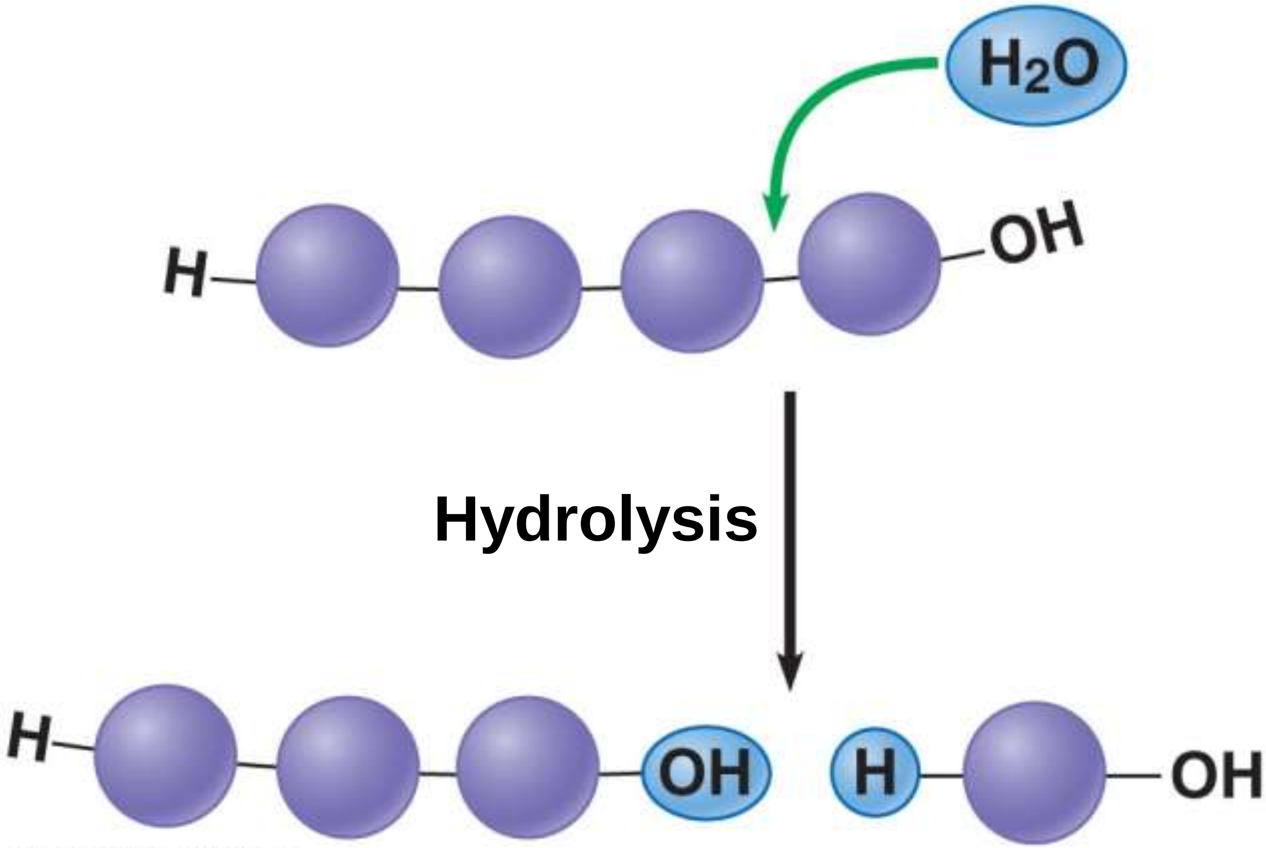
Short polymer

Unlinked monomer


H
OH
H
OH
Short polymer
Unlinked
monomer
Dehydration
reaction
H2O
H
OH
Longer polymer



H_2O
H
OH


H₂O
H
OH
Hydrolysis
H
OH
H
OH

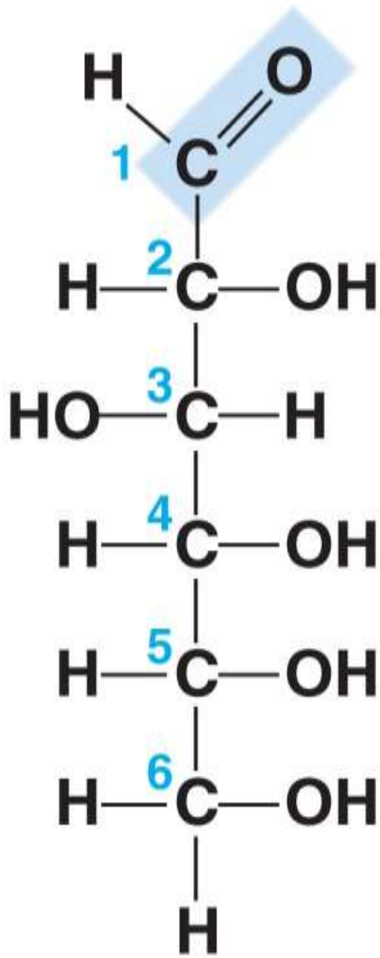
CARBOHYDRATES

3.4 I can describe the structures, functions, properties, and types of carbohydrate molecules.

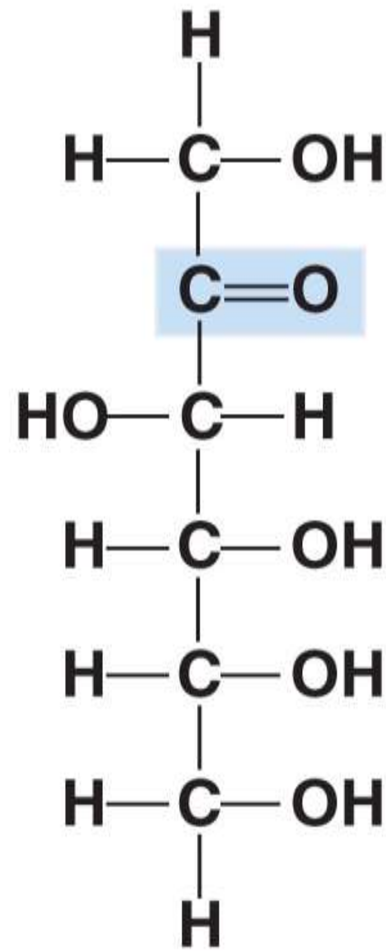
- Carbohydrates range from small sugar molecules (monomers) to large polysaccharides
  - Sugar monomers are **monosaccharides**, such as glucose and fructose
  - These can be hooked together to form the polysaccharides

3.4 I can describe the structures, functions, properties, and types of carbohydrate molecules.

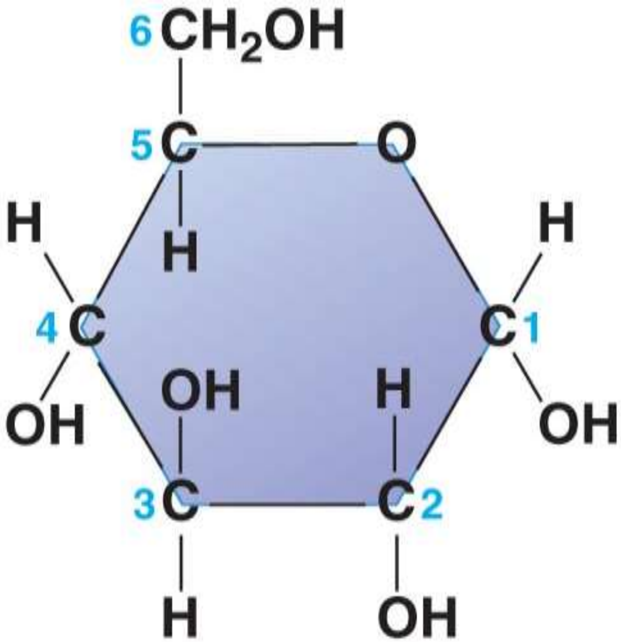
- Monosaccharides are the main fuels for cellular work
  - Monosaccharides are also used as raw materials to manufacture other organic molecules



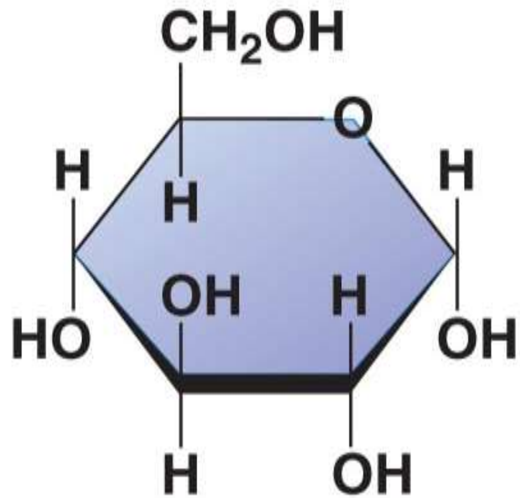
Glucose
(an aldose)



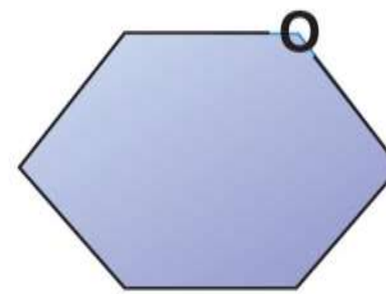
Fructose
(a ketose)



Structural formula



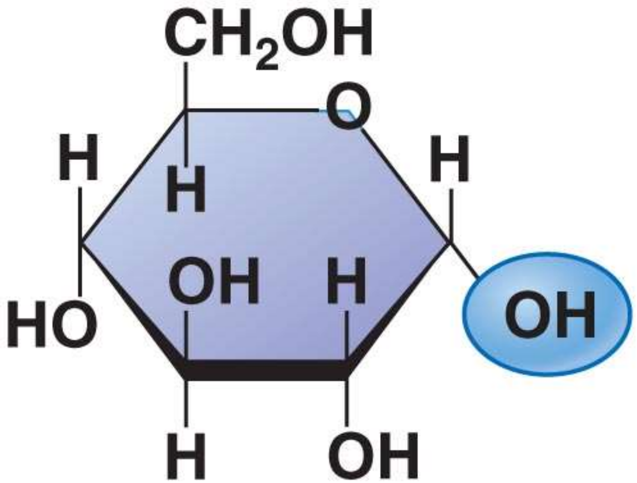
Abbreviated structure



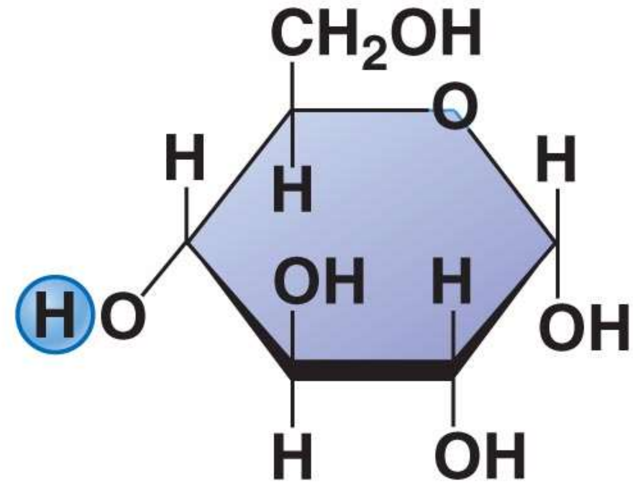
Simplified structure

3.5 I can describe the structures, functions, properties, and types of carbohydrate molecules.

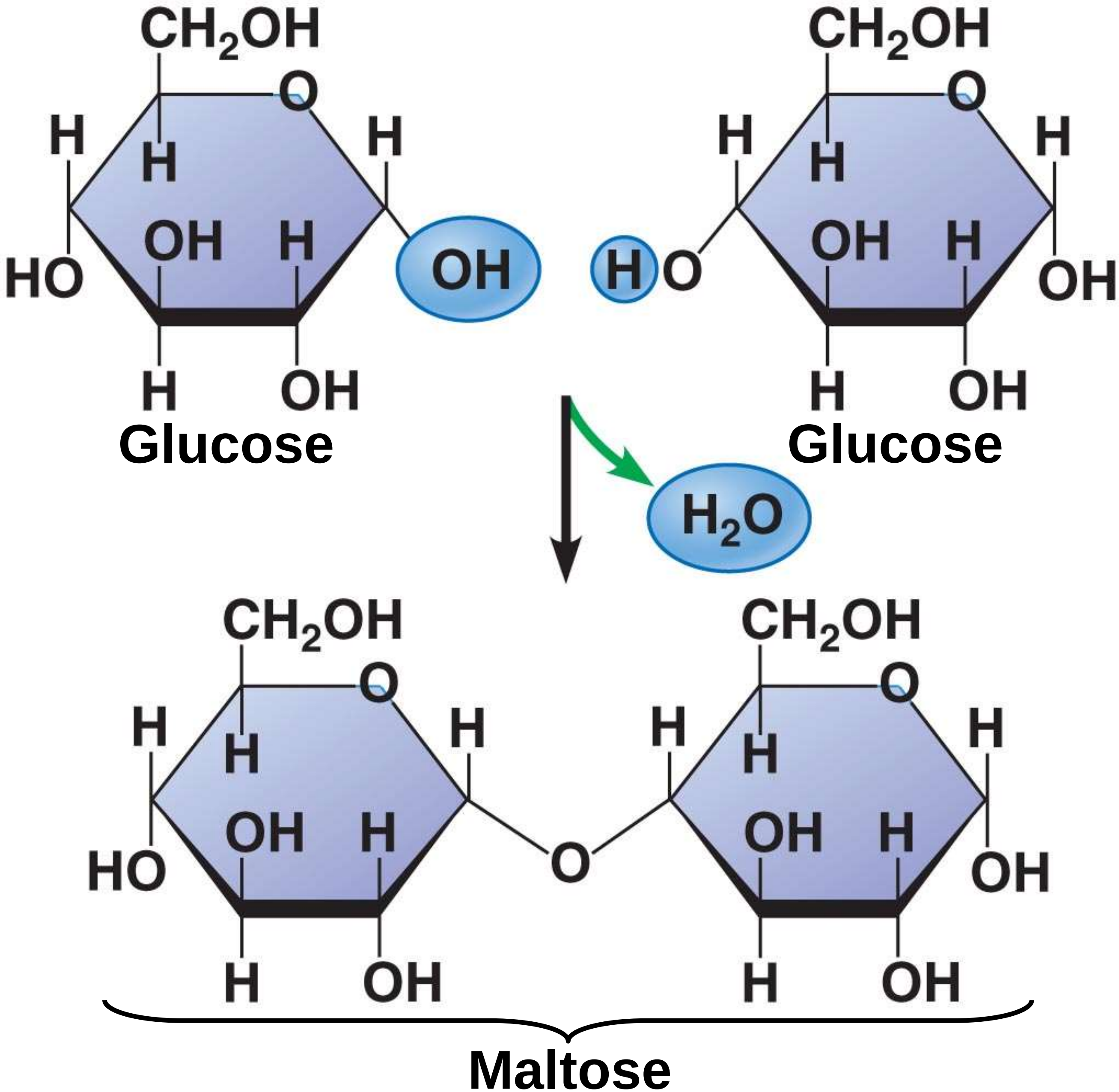
- Two monosaccharides (monomers) can bond to form a **disaccharide** in a dehydration reaction
  - An example is a glucose monomer bonding to a fructose monomer to form sucrose, a common disaccharide



Glucose



Glucose

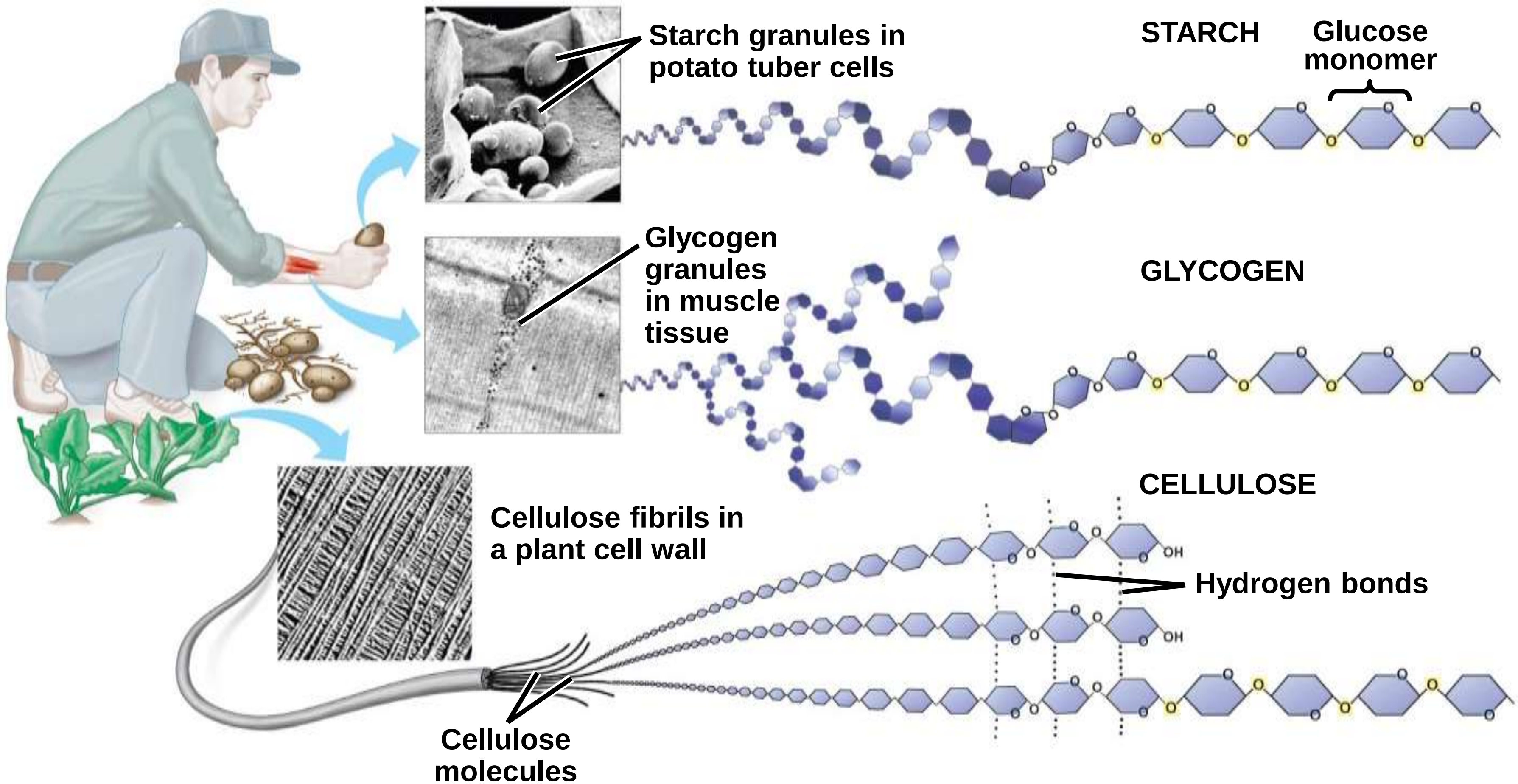

CH2OH
O
H
OH
HO
Glucose
H2O
Maltose

3.7 I can describe the structures, functions, properties, and types of carbohydrate molecules.

- **Polysaccharides** are polymers of monosaccharides
  - They can function in the cell as a storage molecule or as a structural compound

3.7 I can describe the structures, functions, properties, and types of carbohydrate molecules.

- **Starch** is a storage polysaccharide composed of glucose monomers and found in plants
- **Glycogen** is a storage polysaccharide composed of glucose, which is hydrolyzed by animals when glucose is needed
- **Cellulose** is a polymer of glucose that forms plant cell walls
- **Chitin** is a polysaccharide used by insects and crustaceans to build an exoskeleton

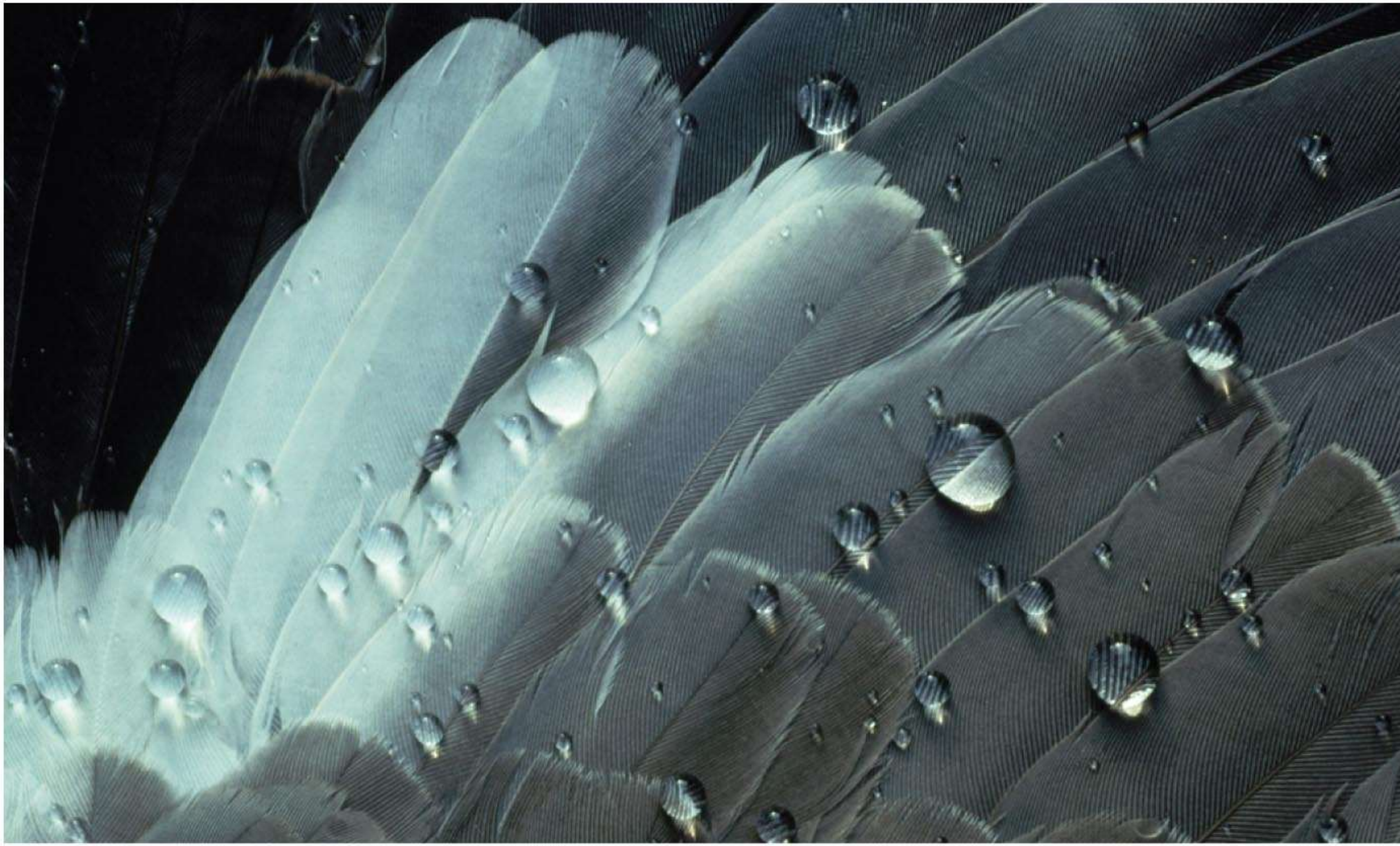


Starch granules in potato tuber cells
STARCH
Glucose monomer
Glycogen granules in muscle tissue
GLYCOGEN
CELLULOSE
Cellulose fibrils in a plant cell wall
Hydrogen bonds
Cellulose molecules

LIPIDS

3.8 I can describe the structures, functions, properties, and types of lipid molecules.

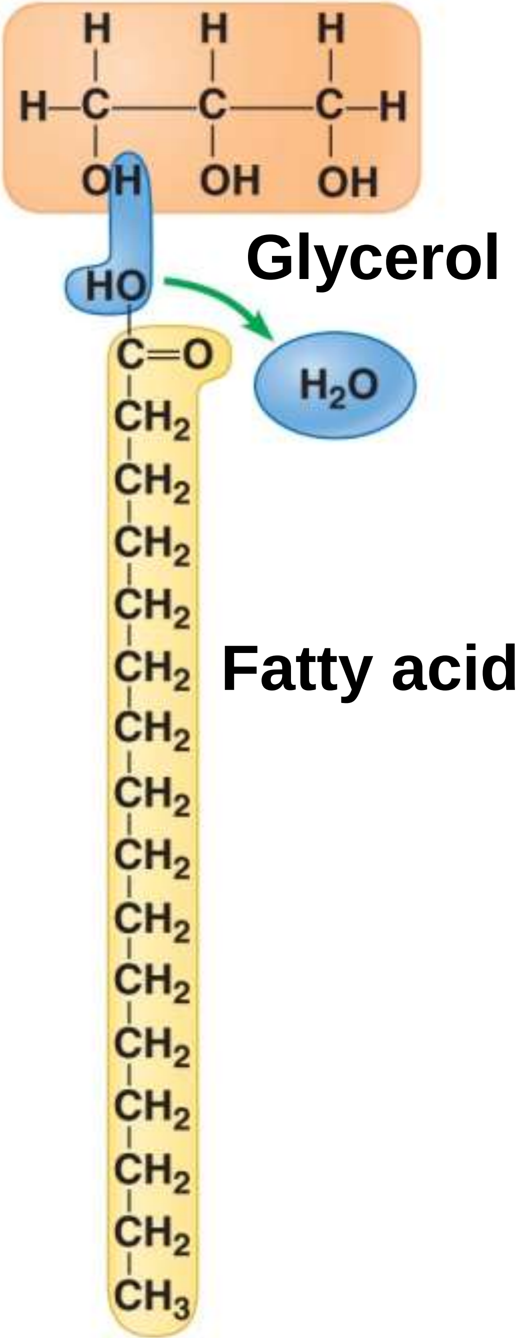
- **Lipids** are water insoluble (**hydrophobic**, or water fearing) compounds that are important in energy storage
  - They contain twice as much energy as a polysaccharide
- **Fats** are lipids made from glycerol and fatty acids



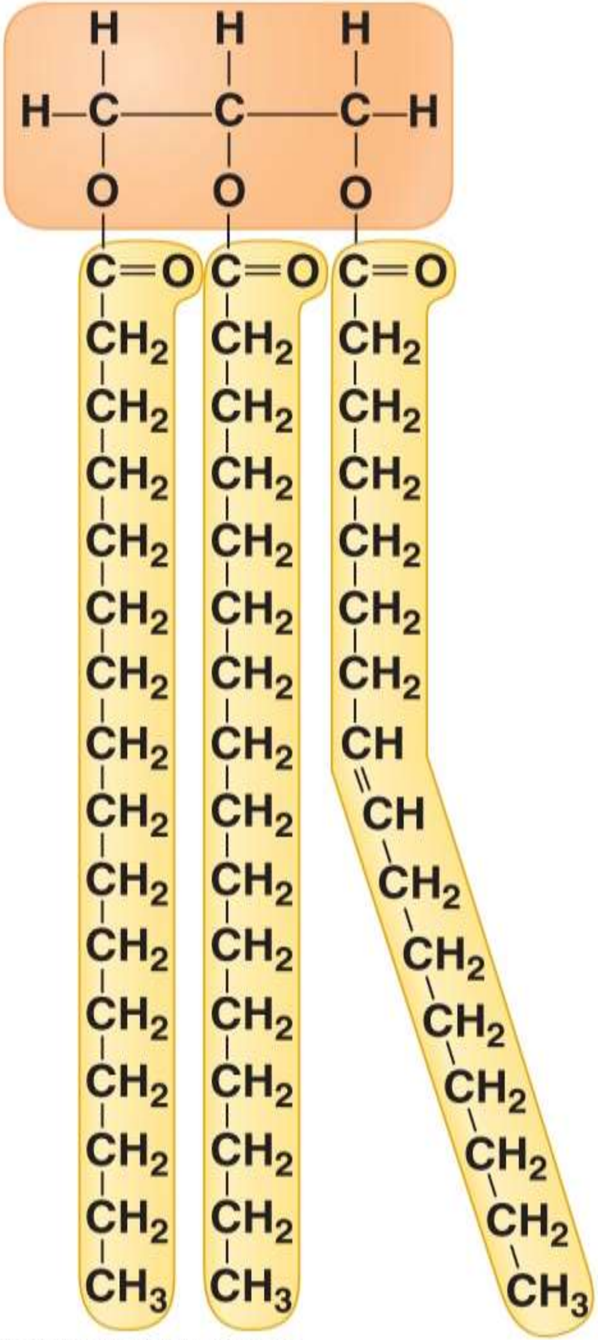
3.8 I can describe the structures, functions, properties, and types of lipid molecules.

- Fatty acids link to glycerol by a dehydration reaction
  - A fat contains one glycerol linked to three fatty acids
  - Fats are often called triglycerides because of their structure

PLAY Animation: Fats



Glycerol
H_2O
Fatty acid

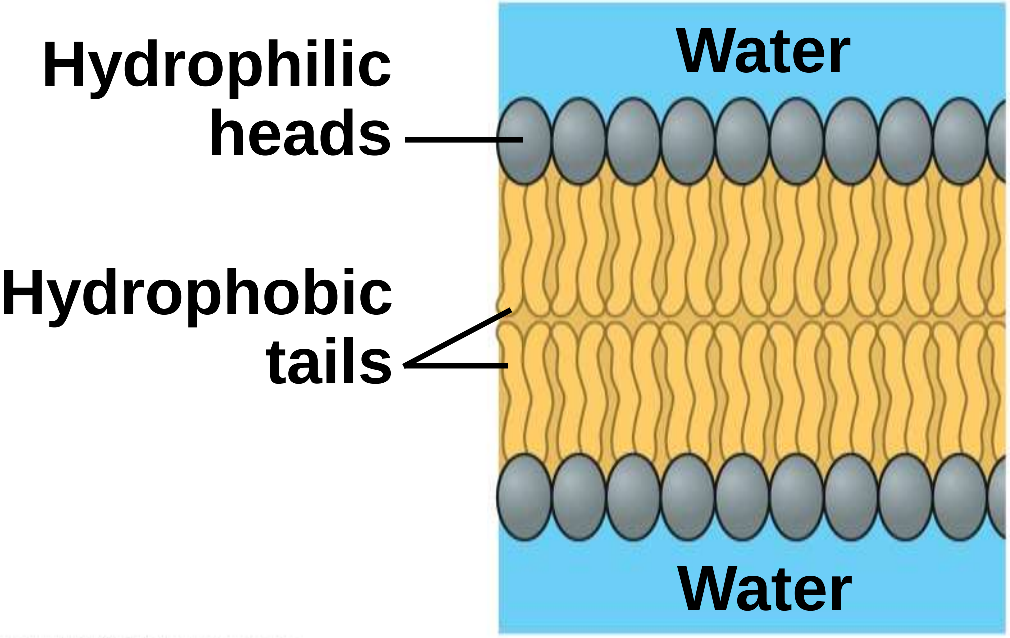


3.8 I can describe the structures, functions, properties, and types of lipid molecules.

- Some fatty acids contain double bonds
  - This causes kinks or bends in the carbon chain because the maximum number of hydrogen atoms cannot bond to the carbons at the double bond
  - These compounds are called **unsaturated fats** because they have fewer than the maximum number of hydrogens
    - Fats with the maximum number of hydrogens are called **saturated fats**

3.9 I can describe the structures, functions, properties, and types of lipids molecules.

- **Phospholipids** are structurally similar to fats and are an important component of all cells
  - For example, they are a major part of cell membranes, in which they cluster into a bilayer of phospholipids
  - The hydrophilic heads are in contact with the water of the environment and the internal part of the cell
  - The hydrophobic tails band in the center of the bilayer


Hydrophilic heads
Hydrophobic tails
Water
Water

3.9 I can describe the structures, functions, properties, and types of lipid molecules.

- **Steroids** are lipids composed of fused ring structures
  - **Cholesterol** is an example of a steroid that plays a significant role in the structure of the cell membrane
  - In addition, cholesterol is the compound from which we synthesize sex hormones

PROTEINS

3.11 I can describe the structures, functions, properties, and types of protein molecules.

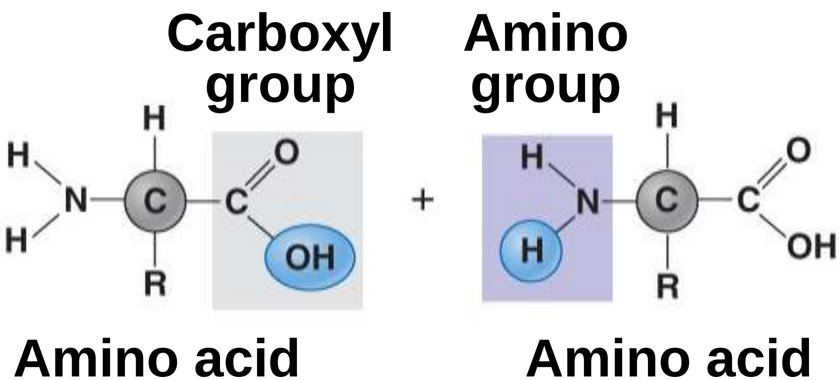
- A **protein** is a polymer built from various combinations of 20 amino acid monomers
  - Proteins have unique structures that are directly related to their functions
  - **Enzymes**, proteins that serve as metabolic catalysts, regulate the chemical reactions within cells

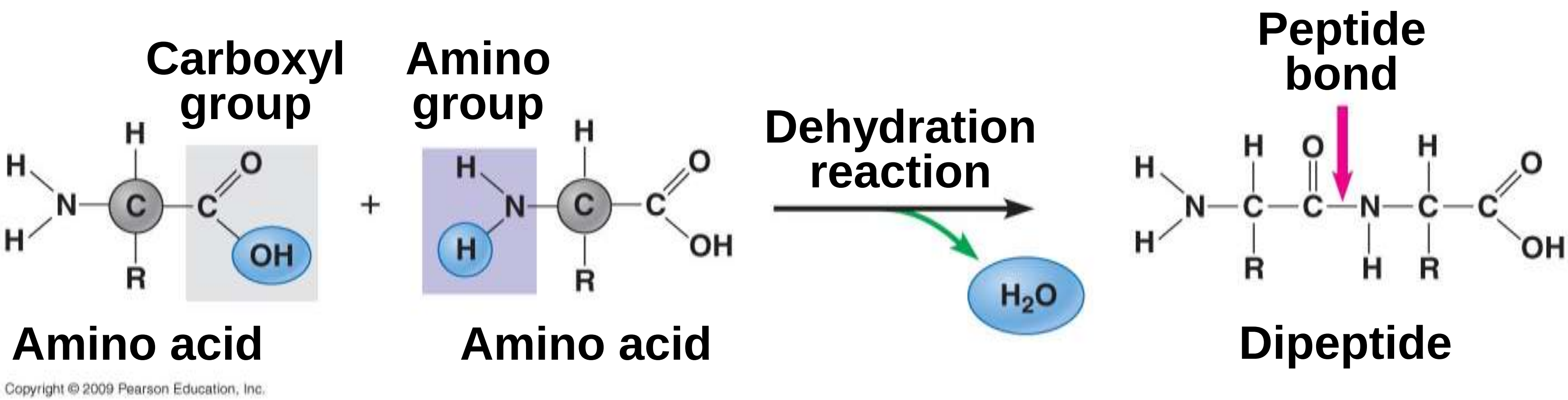
3.11 I can describe the structures, functions, properties, and types of protein molecules.

- **Structural** proteins provide associations between body parts and **contractile** proteins are found within muscle
- **Defensive** proteins include antibodies of the immune system, and **signal** proteins are best exemplified by the hormones
- **Receptor** proteins serve as antenna for outside signals, and **transport** proteins carry oxygen

3.12 I can describe the structures, functions, properties, and types of protein molecules.

- Amino acid monomers are linked together to form polymeric proteins
  - This is accomplished by an enzyme-mediated dehydration reaction
  - This links the carboxyl group of one amino acid to the amino group of the next amino acid
    - The covalent linkage resulting is called a **peptide bond**


Carboxyl group
Amino group
H
H
N
C
C
O
OH
H
R
+
H
N
H
C
H
C
O
OH
R
Amino acid
Amino acid


Carboxyl group
Amino group
Dehydration reaction
Peptide bond
H
N
C
O
OH
R
+
H_2O
Amino acid
Amino acid
Dipeptide
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3.13 I can describe the structures, functions, properties, and types of protein molecules.

- A polypeptide chain contains hundreds or thousands of amino acids linked by peptide bonds
  - The amino acid sequence causes the polypeptide to assume a particular shape
  - The shape of a protein determines its specific function

3.13 I can describe the structures, functions, properties, and types of protein molecules.

- If for some reason a protein's shape is altered, it can no longer function
  - **Denaturation** will cause polypeptide chains to unravel and lose their shape and, thus, their function
  - Proteins can be denatured by changes in salt concentration and pH

3.14 I can describe the structures, functions, properties, and types of protein molecules.

- A protein can have four levels of structure
  - Primary structure
  - Secondary structure
  - Tertiary structure
  - Quaternary structure

3.14 I can describe the structures, functions, properties, and types of protein molecules.

- The **primary structure** of a protein is its unique amino acid sequence
  - The correct amino acid sequence is determined by the cell's genetic information
  - The slightest change in this sequence affects the protein's ability to function

3.14 I can describe the structures, functions, properties, and types of protein molecules.

- Protein **secondary structure** results from coiling or folding of the polypeptide
  - Coiling results in a helical structure called an alpha helix
  - Folding may lead to a structure called a pleated sheet
    - Coiling and folding result from hydrogen bonding between certain areas of the polypeptide chain

3.14 I can describe the structures, functions, properties, and types of protein molecules.

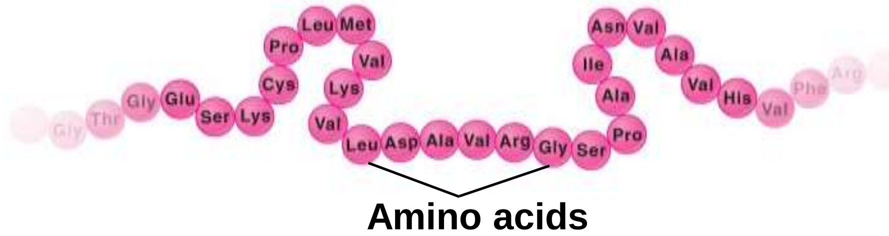
- The overall three-dimensional shape of a protein is called its **tertiary structure**
  - Tertiary structure generally results from interactions between the R groups of the various amino acids
  - Disulfide bridges are covalent bonds that further strengthen the protein's shape

3.14 I can describe the structures, functions, properties, and types of protein molecules.

- Two or more polypeptide chains (subunits) associate providing **quaternary structure**
  - Collagen is an example of a protein with quaternary structure
  - Its triple helix gives great strength to connective tissue, bone, tendons, and ligaments

Four Levels of Protein Structure

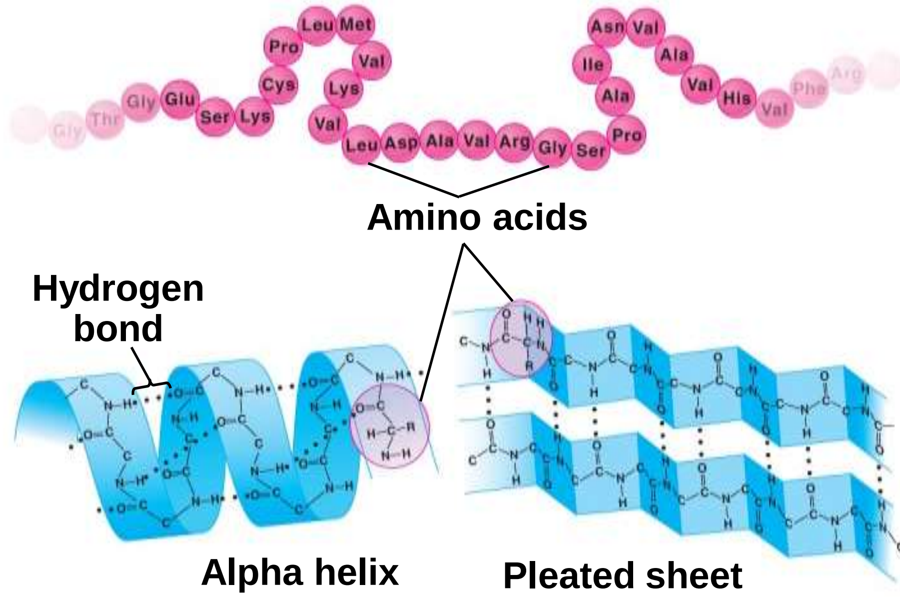
Primary structure



Four Levels of Protein Structure

Primary structure

Secondary structure

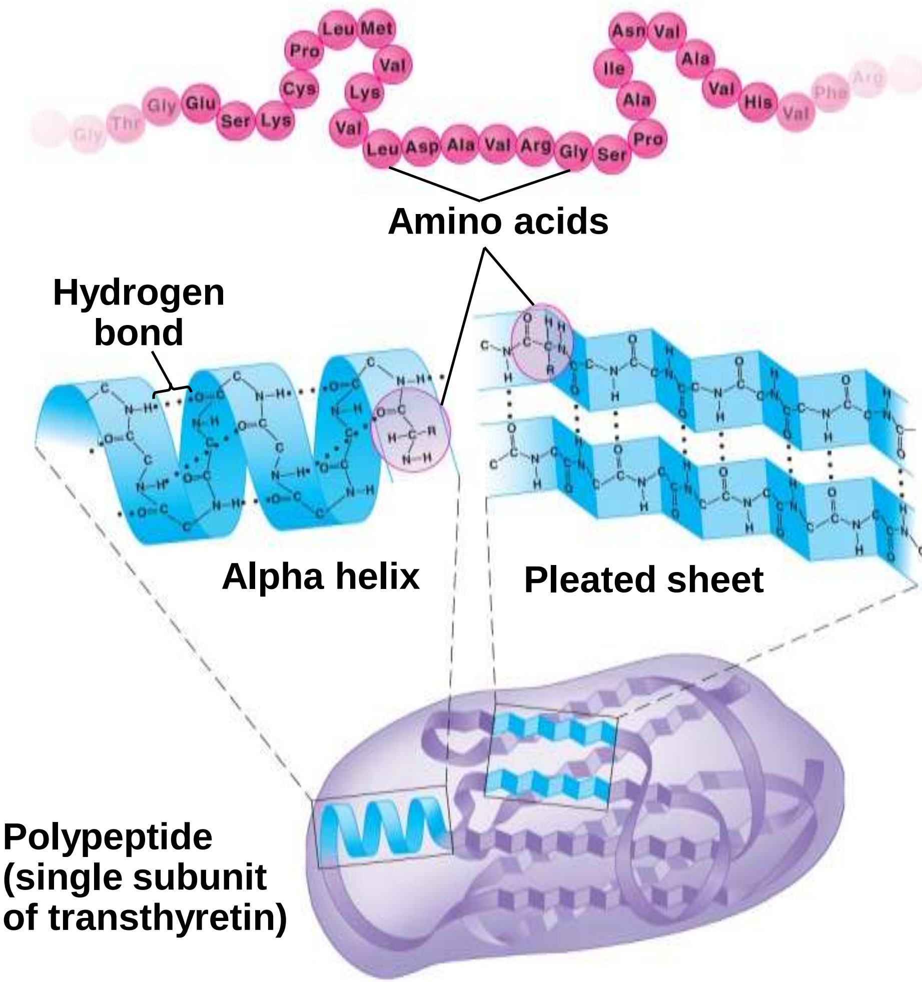


Four Levels of Protein Structure

Primary structure

Secondary structure

Tertiary structure



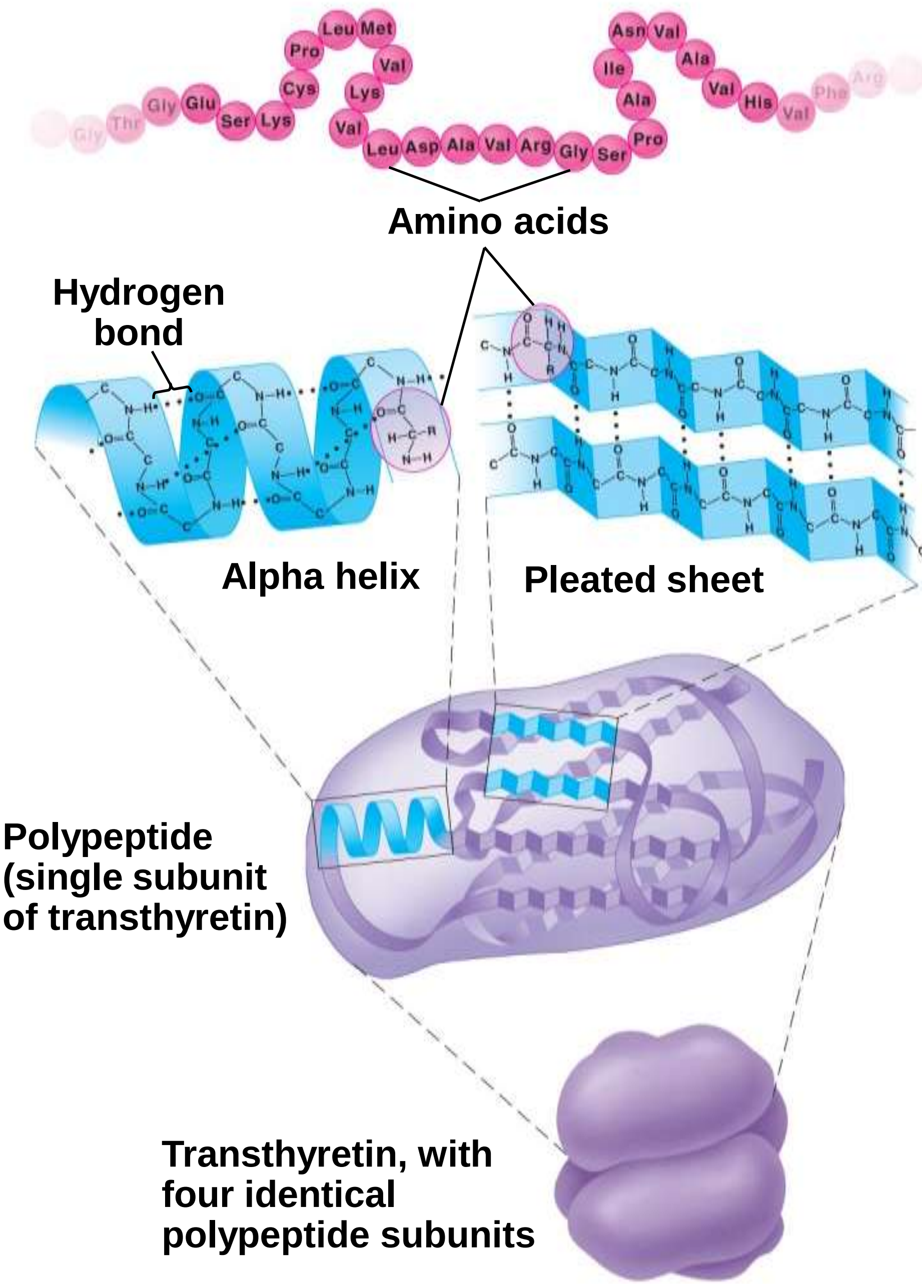
Four Levels of Protein Structure

Primary structure

Secondary structure

Tertiary structure

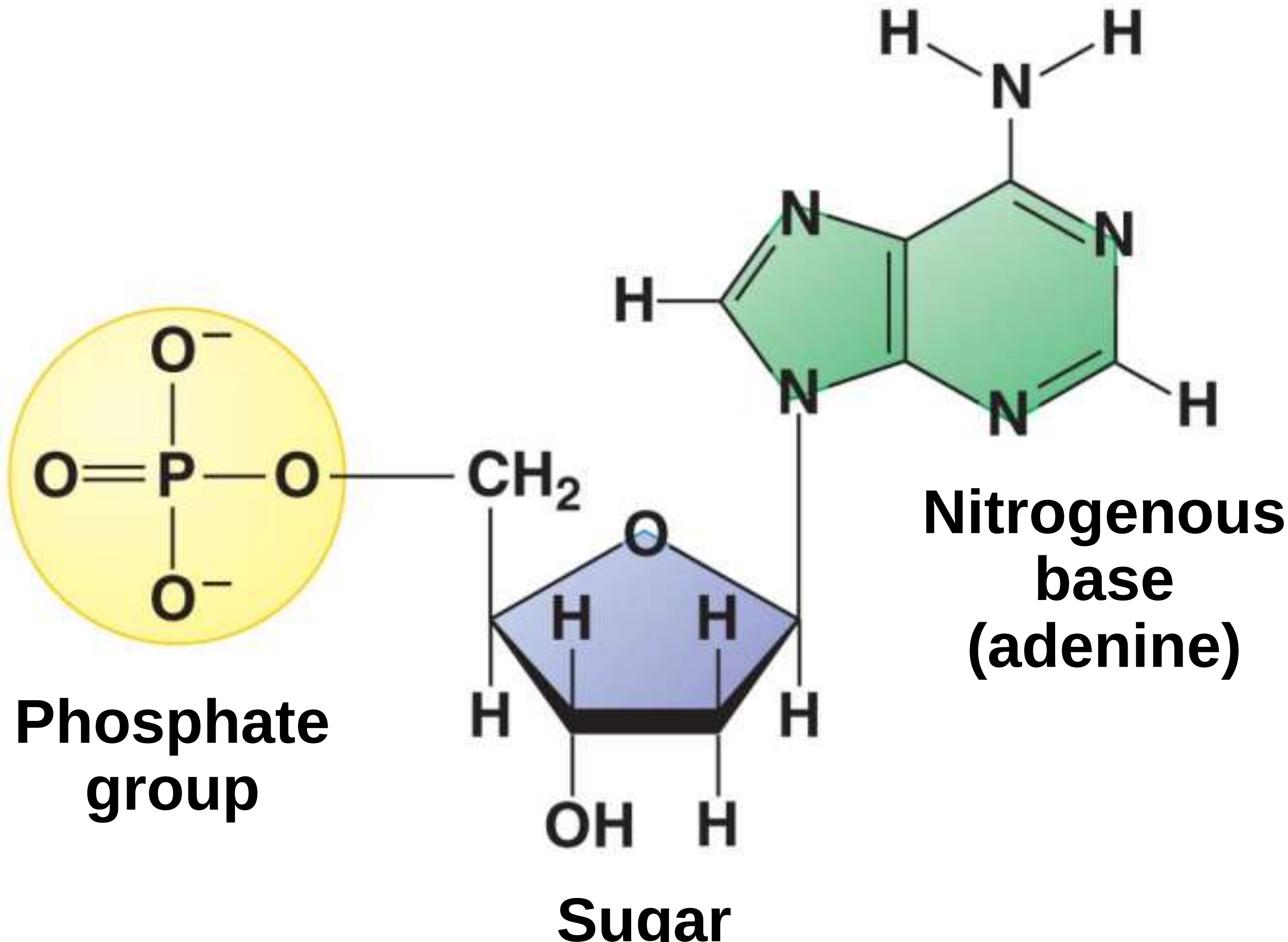
Quaternary structure



NUCLEIC ACIDS

3.16 I can compare the structures and functions of DNA and RNA.

- **DNA (deoxyribonucleic acid)** and **RNA (ribonucleic acid)** are composed of monomers called **nucleotides**
  - Nucleotides have three parts
    - A five-carbon sugar called ribose in RNA and deoxyribose in DNA
    - A phosphate group
    - A nitrogenous base

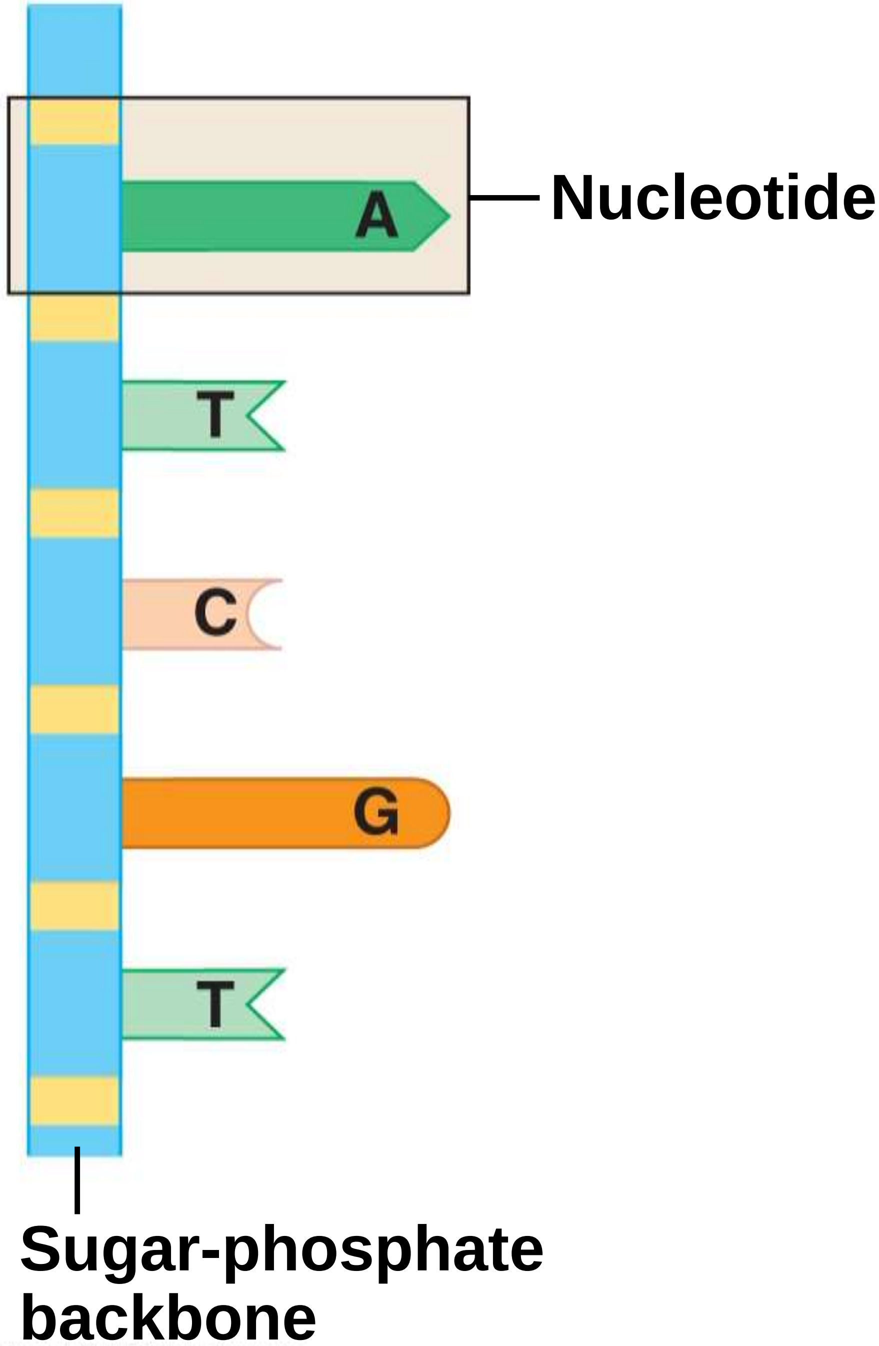

Phosphate
group
Sugar
Nitrogenous
base
(adenine)

3.16 I can compare the structures and functions of DNA and RNA.

- DNA nitrogenous bases are adenine (A), thymine (T), cytosine (C), and guanine (G)
  - RNA also has A, C, and G, but instead of T, it has uracil (U)

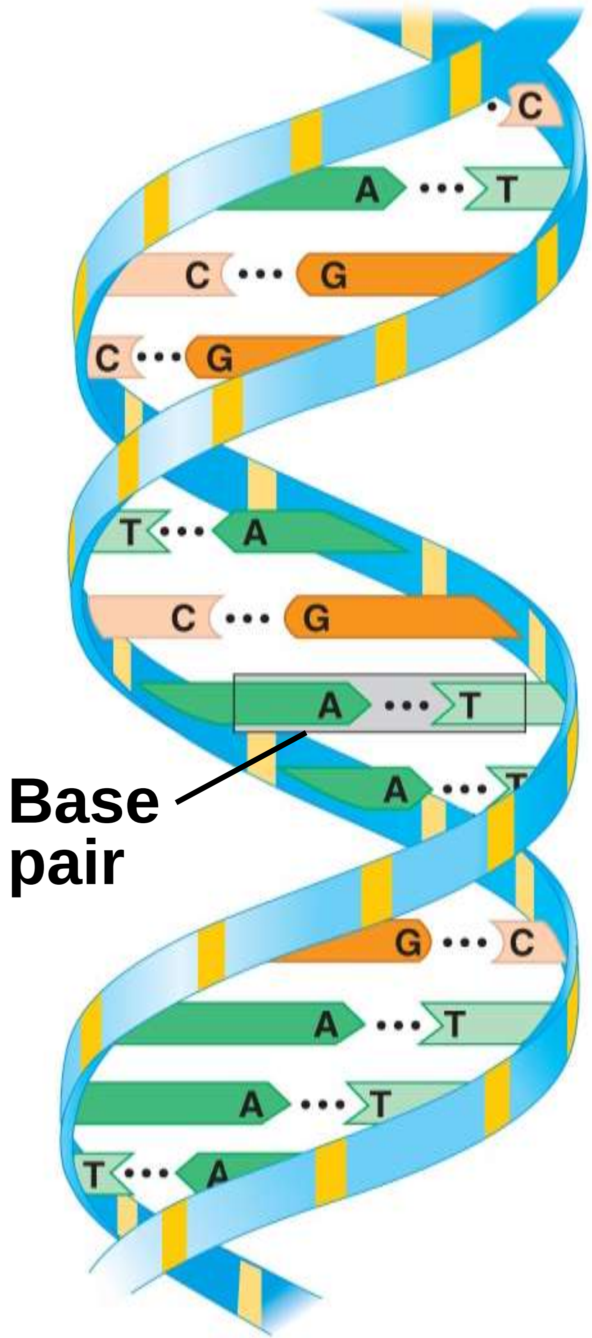
3.16 I can compare the structures and functions of DNA and RNA.

- A nucleic acid polymer, a polynucleotide, forms from the nucleotide monomers when the phosphate of one nucleotide bonds to the sugar of the next nucleotide
  - The result is a repeating sugar-phosphate backbone with protruding nitrogenous bases


A
Nucleotide
T
C
G
T
Sugar-phosphate
backbone

3.16 I can compare the structures and functions of DNA and RNA.

- Two polynucleotide strands wrap around each other to form a DNA **double helix**
  - The two strands are associated because particular bases always hydrogen bond to one another
  - A pairs with T, and C pairs with G, producing **base pairs**
- RNA is usually a single polynucleotide strand


C
A
T
C
G
C
G
T
A
C
G
A
T
A
Base pair
G
C
A
T
A
T
T
A

3.16 I can compare the structures and functions of DNA and RNA.

- A particular nucleotide sequence that can instruct the formation of a polypeptide is called a **gene**
  - Most DNA molecules consist of millions of base pairs and, consequently, many genes
  - These genes, many of which are unique to the species, determine the structure of proteins and, thus, life’s structures and functions