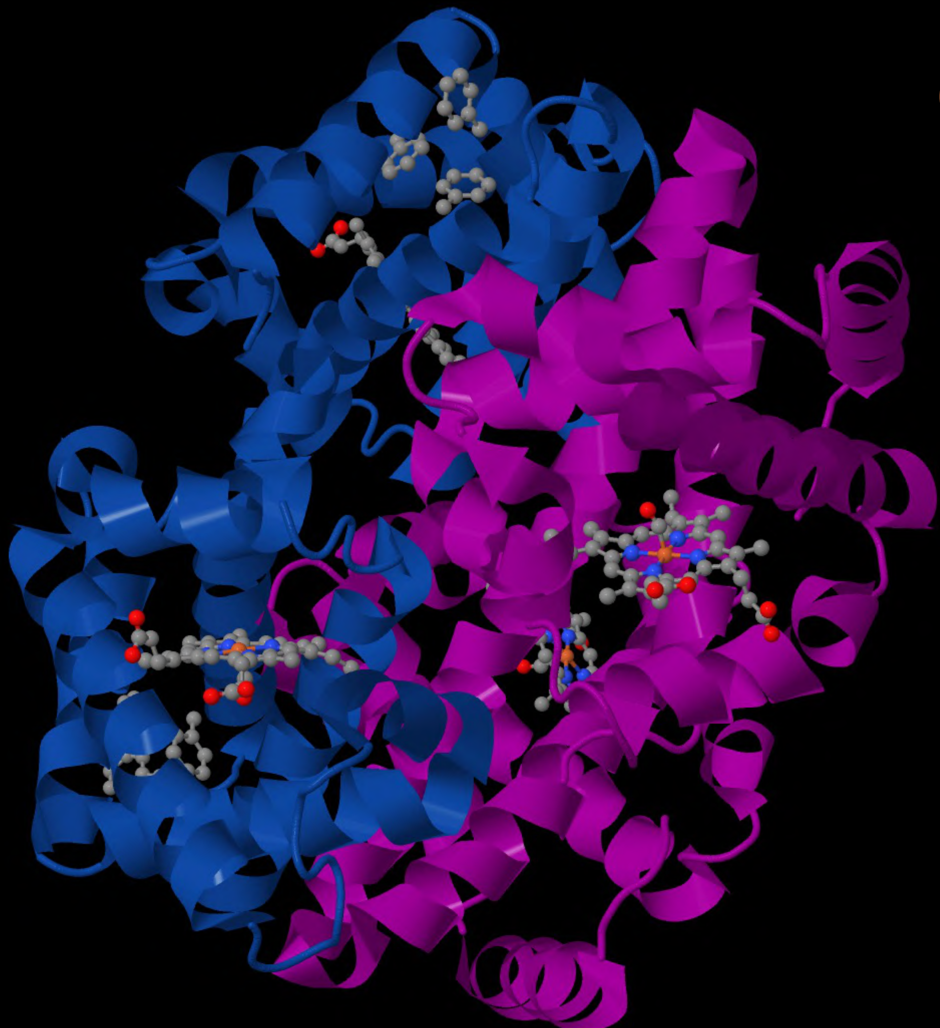
CHEM1200 DISCOVERY IN BIOLOGY



Chemistry of Life

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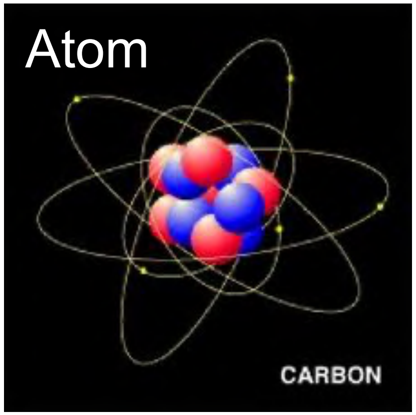
Why study the chemistry of life?

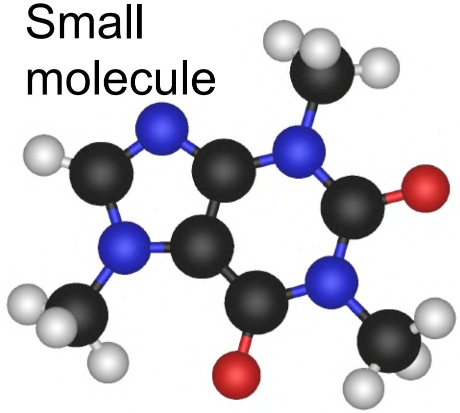
- Our body is made up of many chemicals working together in a highly-controlled manner.
- All the activities in our body are based on chemical reactions.
- Therefore, understanding life should start with understanding chemistry.

From reference:
Russell, Hertz & McMillan(2011). Biology The Dynamic Science. Cengage Learning. 3rd Edition. Chapter 2 and 3.

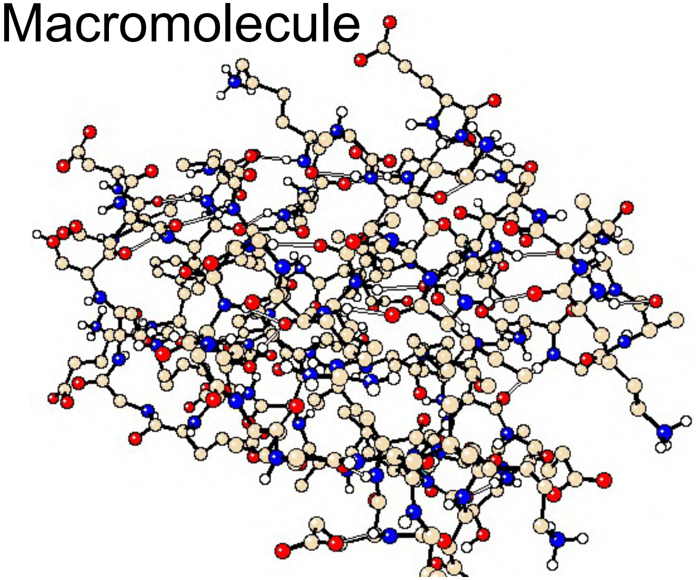
From atom to organism



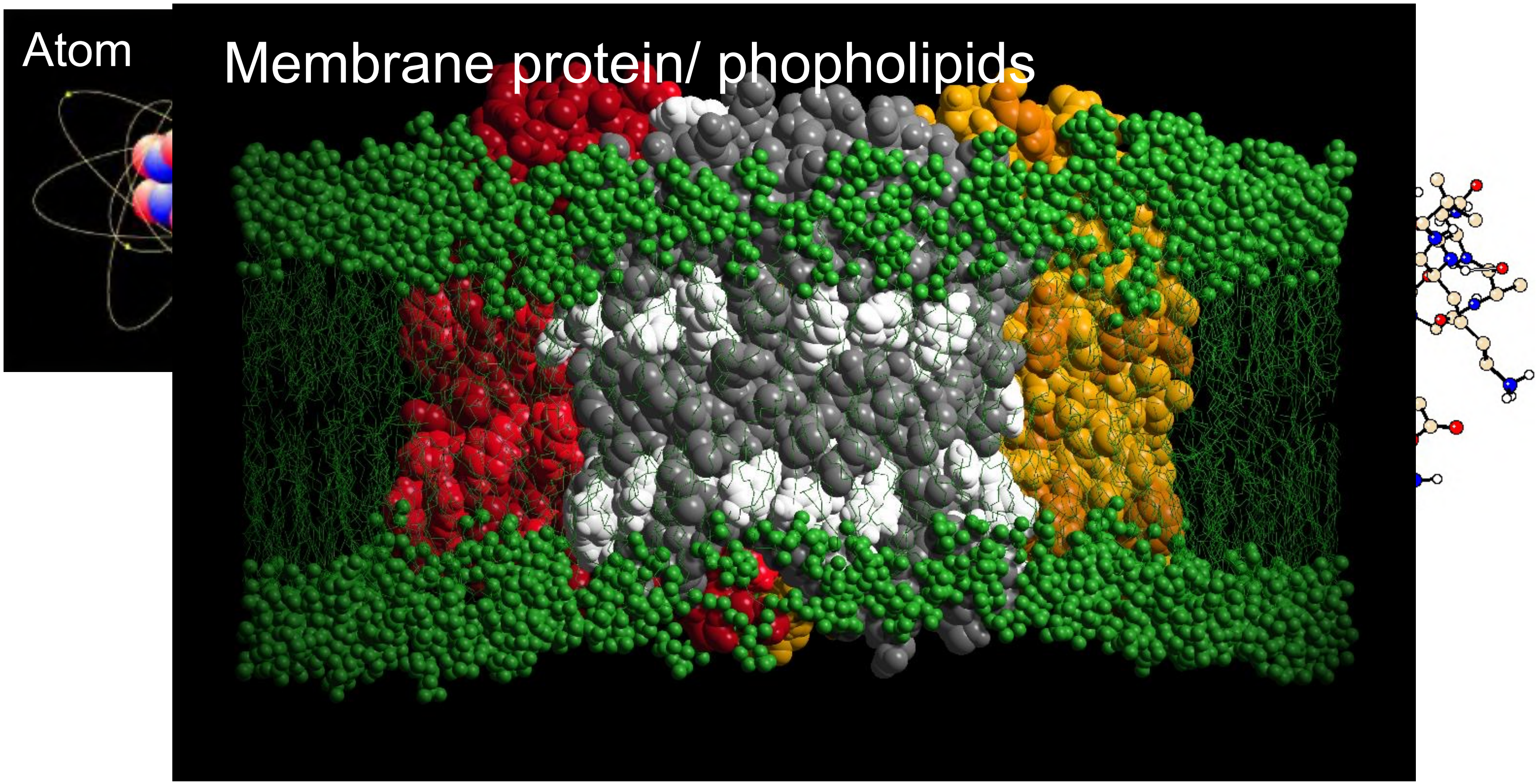
Small molecule



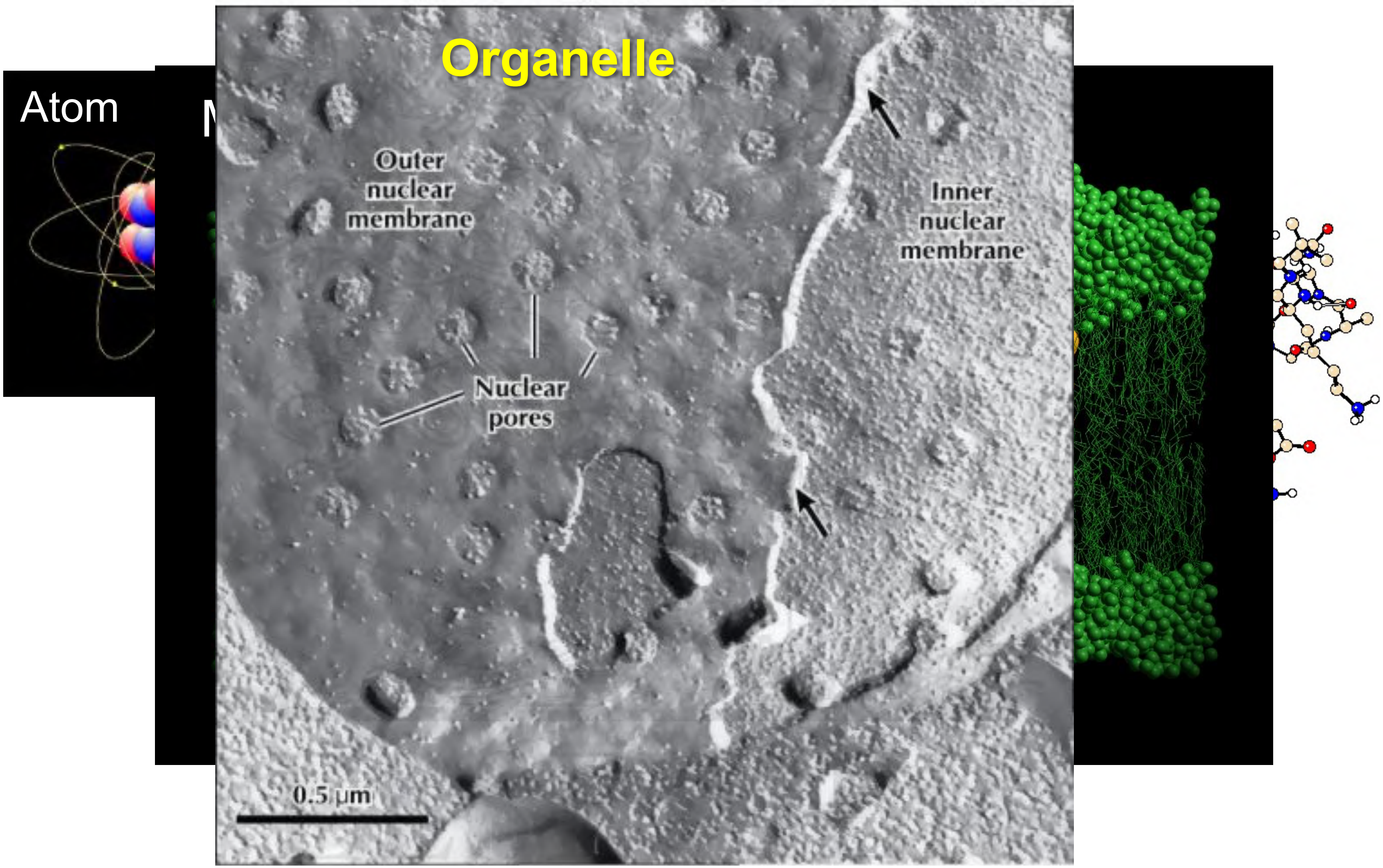
Macromolecule



From atom to organism

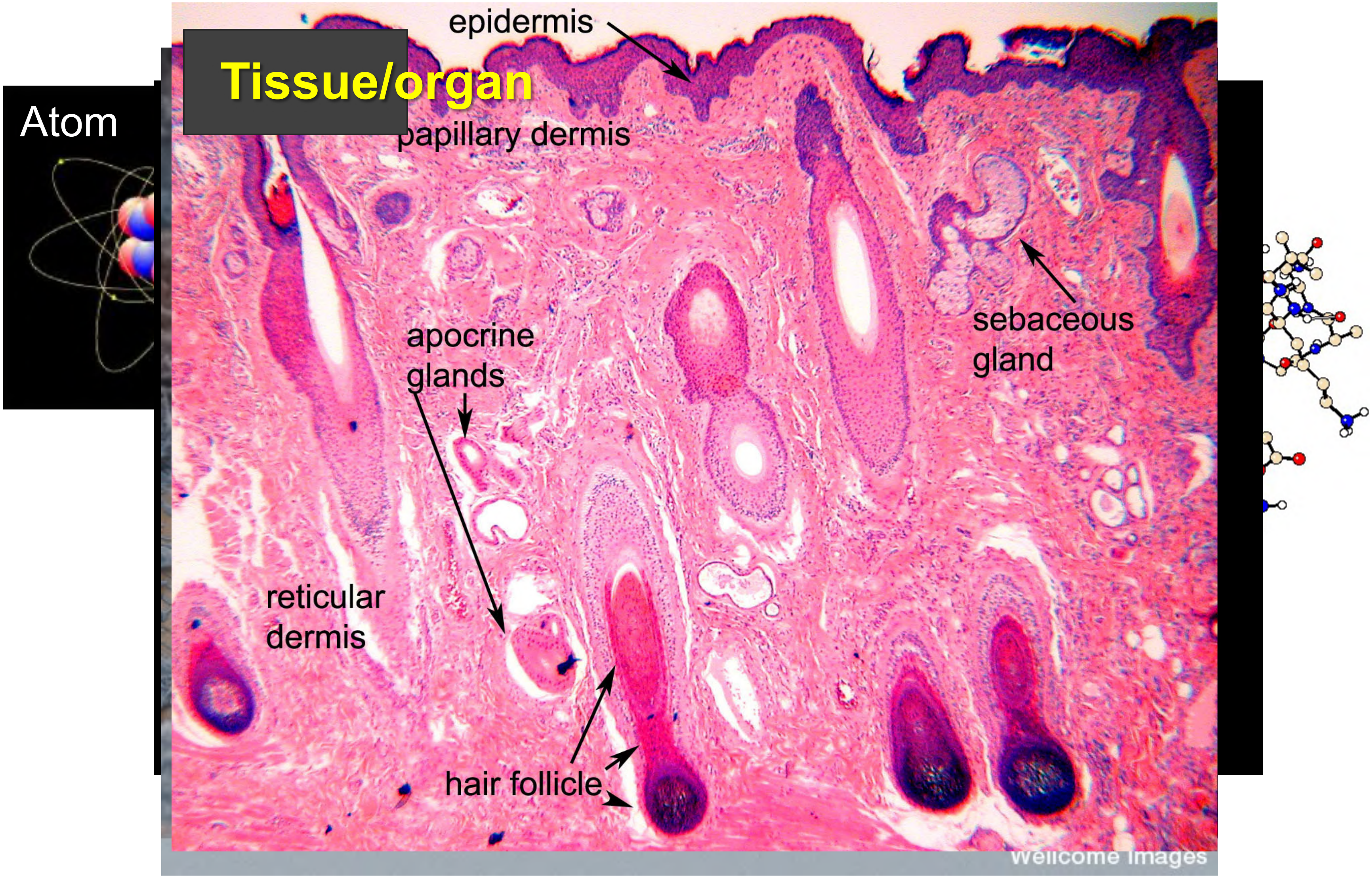


From atom to organism



From atom to organism

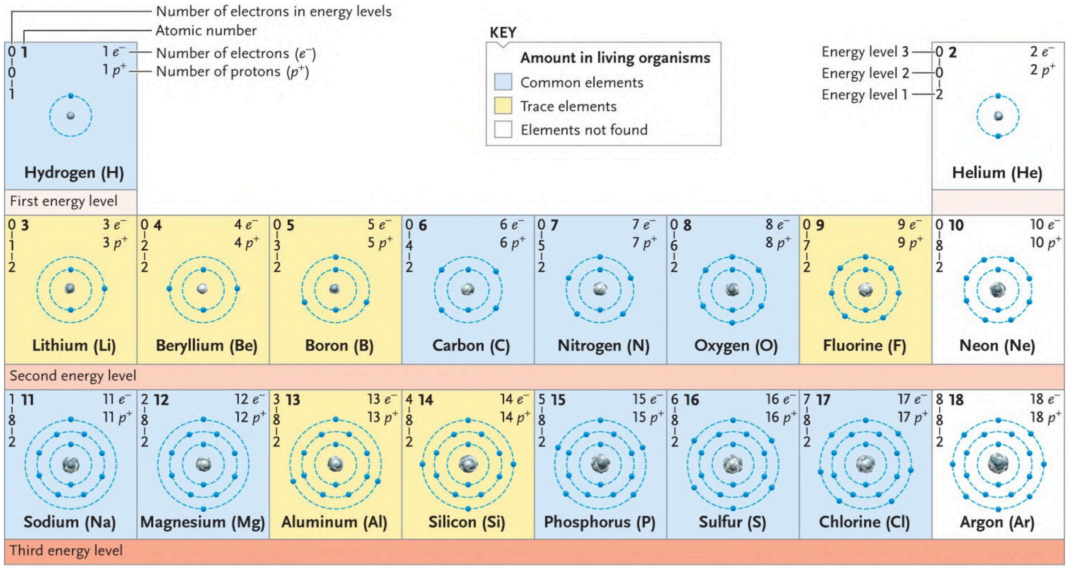
From atom to organism



From atom to organism

The distribution of electrons determines an atom's chemical properties

- Of the three subatomic particles — protons, neutrons, and electrons — only electrons are directly involved in chemical activity.
- Electrons occur in energy levels called **electron shells**.
  - Information about the distribution of electrons is found in the periodic table of the elements.



The distribution of electrons determines an atom's chemical properties

- Atoms with incomplete outer shells tend to react so that both atoms end up with completed outer shells.
- These atoms may react with each other by sharing, donating, or receiving electrons.
- These interactions usually result in atoms staying close together, held by attractions called **chemical bonds**.
- The strongest kind of chemical bond is a **covalent bond** in which two atoms share one or more outer-shell electrons.
- Two or more atoms held together by covalent bonds form a **molecule**.

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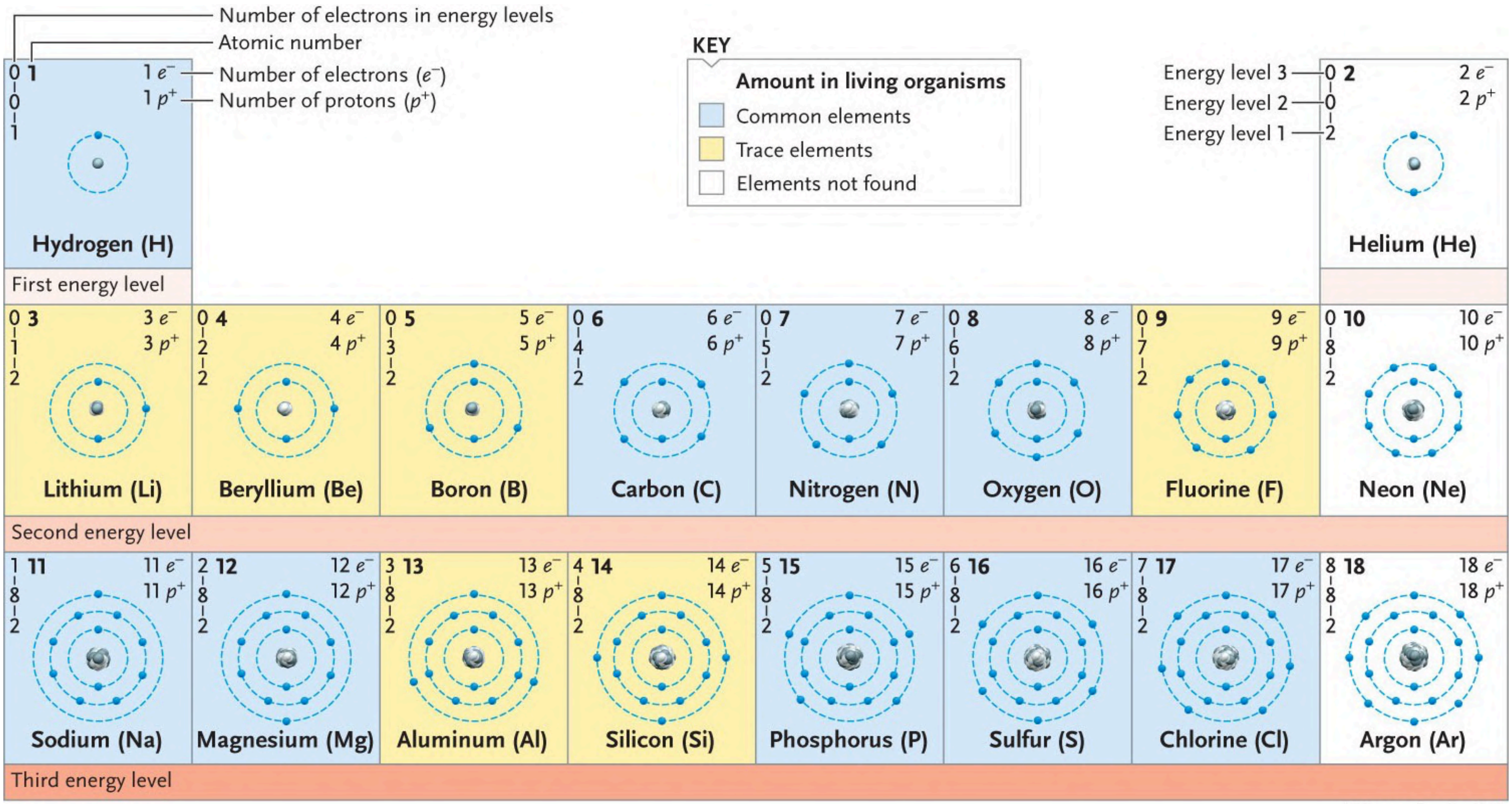

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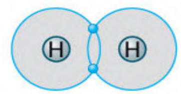
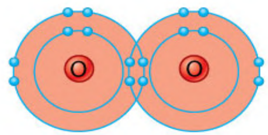
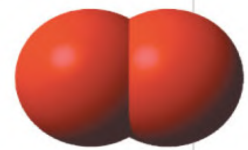
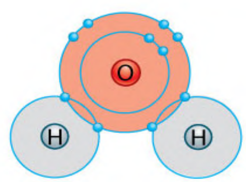
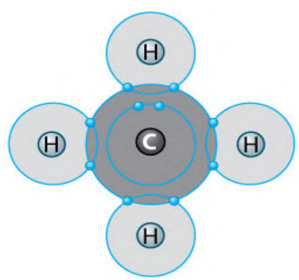
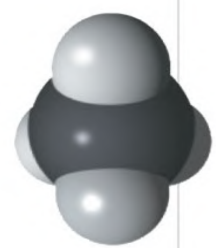
Four ways to represent molecules

TABLE 2.6 ALTERNATIVE WAYS TO REPRESENT FOUR COMMON MOLECULES

Molecular Formula	Electron Distribution Diagram	Structural Formula	Space-Filling Model
H_2 Hydrogen		H—H (Single bond)	
O_2 Oxygen		O=O (Double bond)	
H_2O Water		H–O–H	
CH_4 Methane		H–C(–H)(–H)–H	

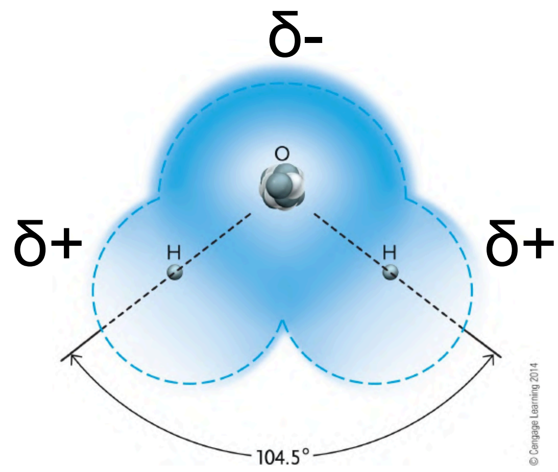
https://www.youtube.com/watch?v=QqjcCvzWwww

Covalent bonds join atoms into molecules through electron sharing

- Atoms in a covalently bonded molecule continually compete for shared electrons.
  - The attraction (pull) for shared electrons is called **electronegativity.**
  - More electronegative atoms pull harder.
- In molecules of only one element, the pull toward each atom is equal, because each atom has the same electronegativity.
  - The bonds formed are called **nonpolar covalent bonds.**

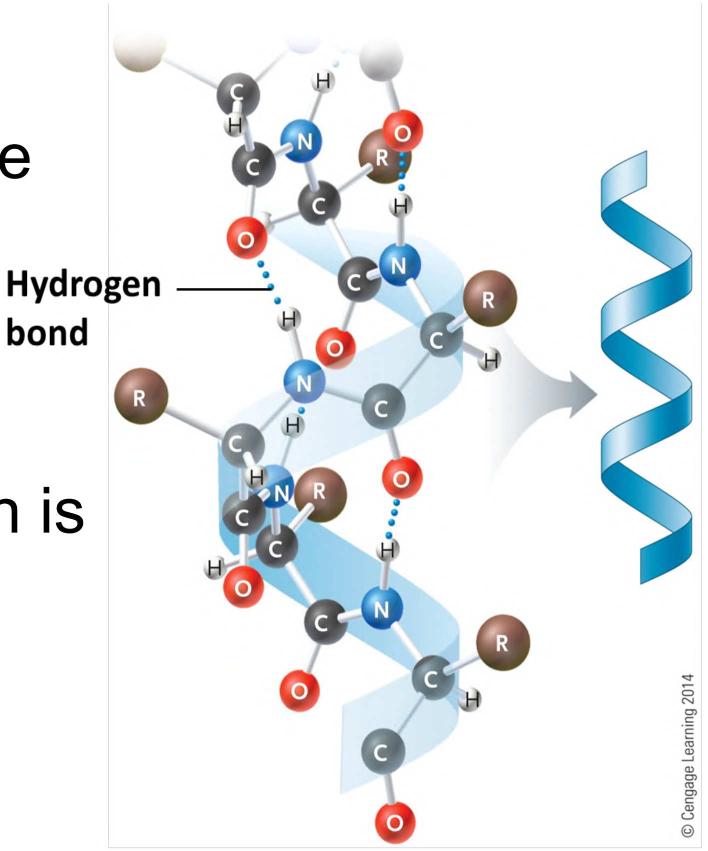
Covalent bonds join atoms into molecules through electron sharing

- Water has atoms with different electronegativities.
  - Oxygen attracts the shared electrons more strongly than hydrogen.
  - So, the shared electrons spend more time near oxygen.
  - The oxygen atom has a slightly negative charge and the hydrogen atoms have a slightly positive charge.
  - The result is a **polar covalent bond.**
  - Water is therefore a **polar molecule**.



Hydrogen bonds are weak bonds important in the chemistry of life

- Most large molecules are held in their three-dimensional functional shape by weak bonds.
- Hydrogen, as part of a polar covalent bond, has a partial positive charge.
- The charged regions on molecules are electrically attracted to oppositely charged regions on neighboring molecules.
- Because the positively charged region is always a hydrogen atom, the bond is called a hydrogen bond.

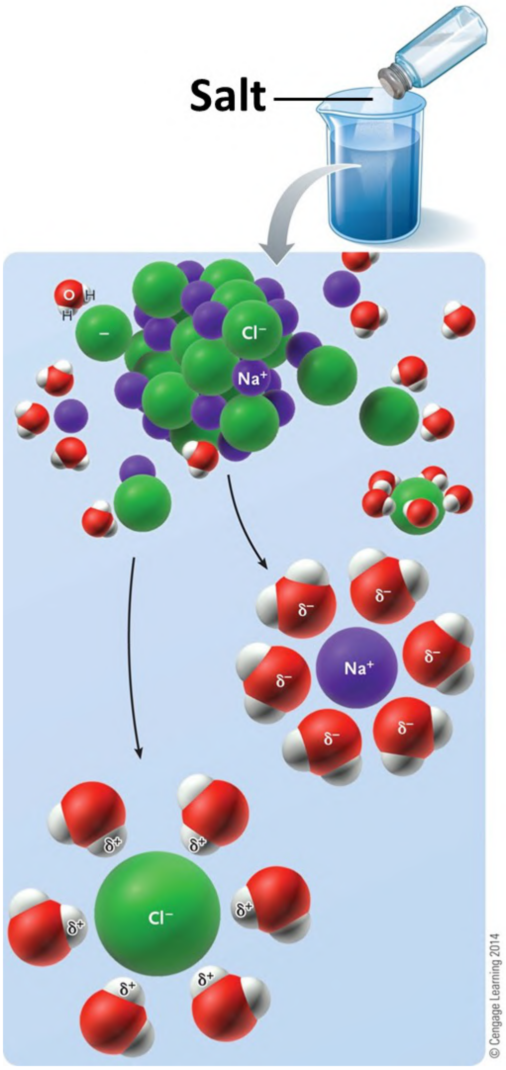


Water's hydrogen bonds moderate temperature

- Because of hydrogen bonding, water has a greater ability to resist temperature change than other liquids.
  - **Heat** is the energy associated with movement of atoms and molecules in matter.
  - **Temperature** measures the intensity of heat.
- Heat is released when hydrogen bonds form.
- Heat must be absorbed to break hydrogen bonds.
- When a substance evaporates, the surface of the liquid that remains behind cools down, in the process of **evaporative cooling**.
- This cooling occurs because the molecules with the greatest energy leave the surface.

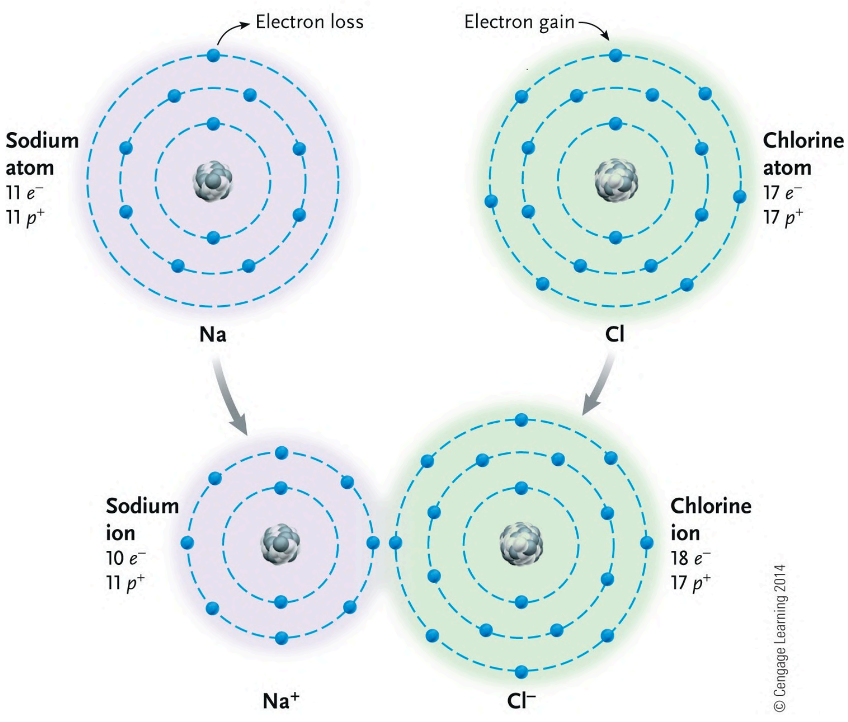
Water is the solvent of life

- Water's versatility as a solvent results from the polarity of its molecules.
- Polar or charged solutes dissolve when water molecules surround them, forming aqueous solutions.
- Table salt is an example of a solute that will go into solution in water.

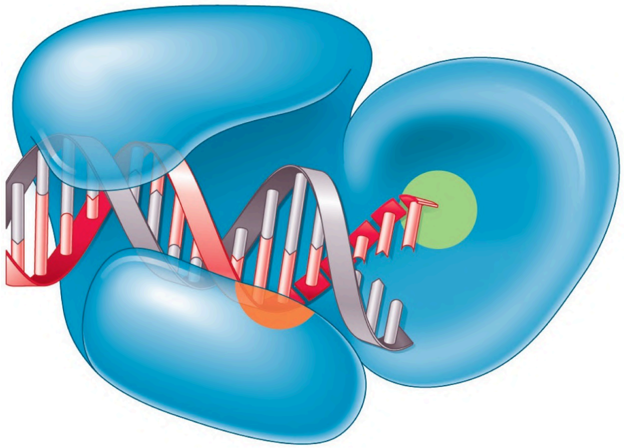


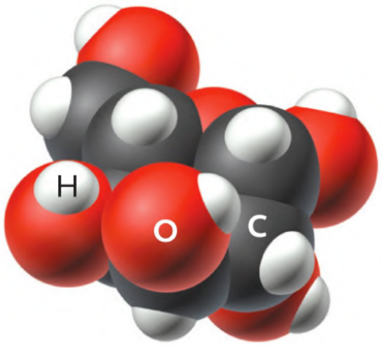
Ionic bonds are attractions between ions of opposite charge

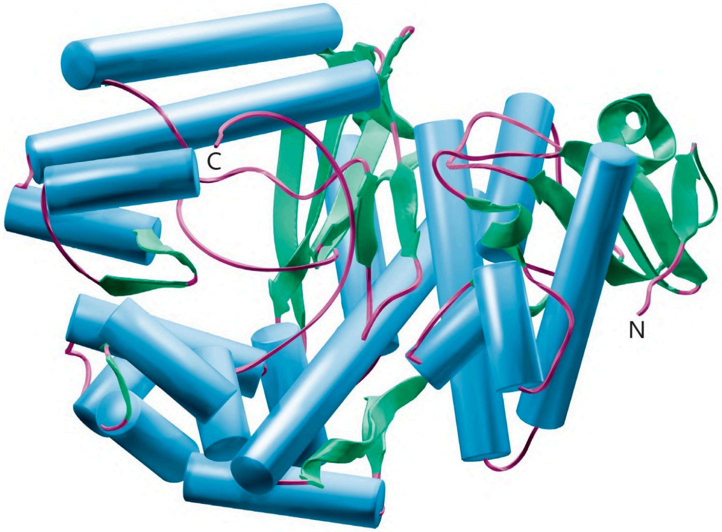
- An **ion** is an atom or molecule with an electrical charge resulting from gain or loss of electrons.
  - When an electron is lost, a positive charge results.
  - When an electron is gained, a negative charge results.
- Two ions with opposite charges attract each other.
  - When the attraction holds the ions together, it is called an **ionic bond**.
  - **Salt** is a synonym for an ionic compound.

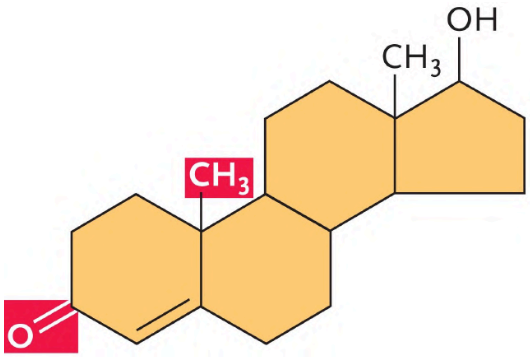


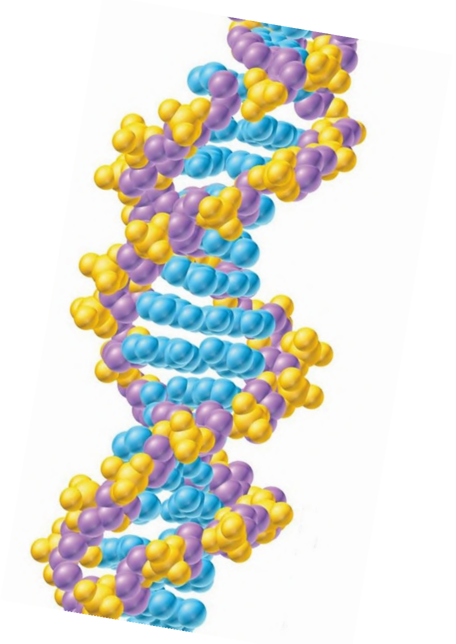
Biochemistry: The molecules of life



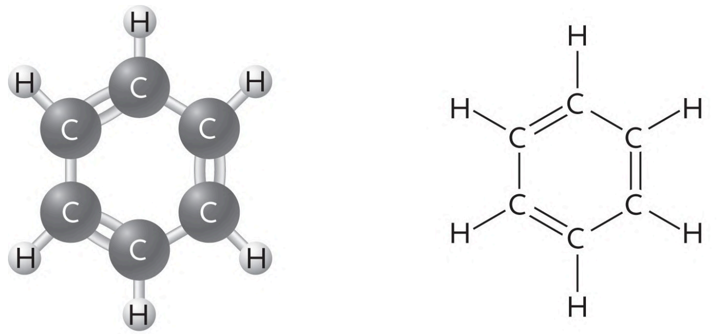








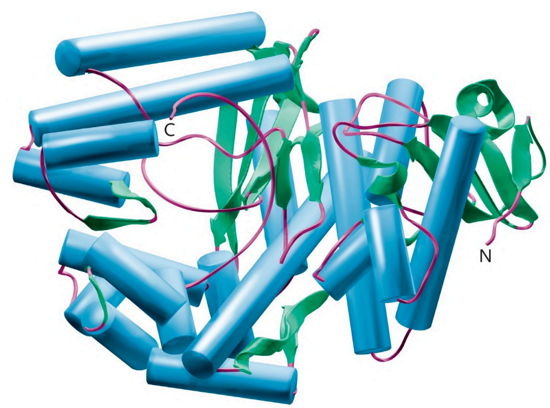
The molecules of life



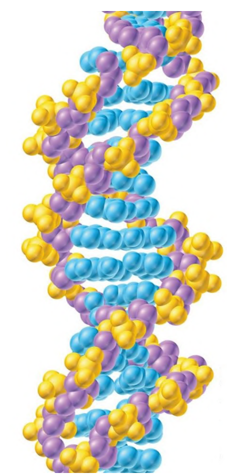
Organic compounds

Carbohydrates

Lipids



Proteins



Nucleic Acids

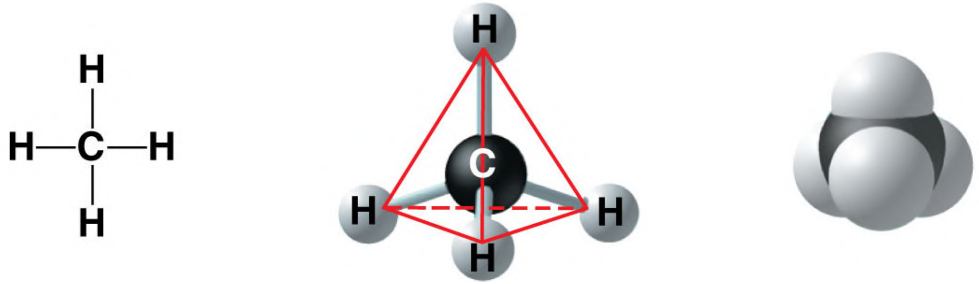
WHAT ARE ORGANIC COMPOUNDS?

Life's molecular diversity is based on the properties of carbon

- Diverse molecules found in cells are composed of **carbon** bonded to
  - other carbons and
  - atoms of other elements.
- Carbon-based molecules are called **organic compounds** (exceptions: CO, CO_2, carbonate, cyanide salts, etc.).

Life's molecular diversity is based on the properties of carbon

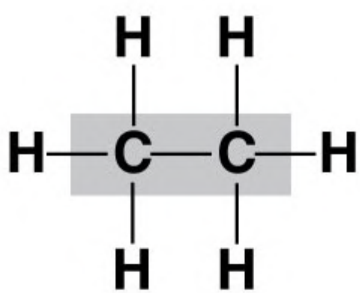
- By sharing electrons, carbon can
  - bond to up to four other atoms and
  - branch in up to four directions.
- Methane (CH_4) is one of the simplest organic compounds.
  - Four covalent bonds link four hydrogen atoms to the carbon atom.
  - Each of the four lines in the formula for methane represents a pair of shared electrons.



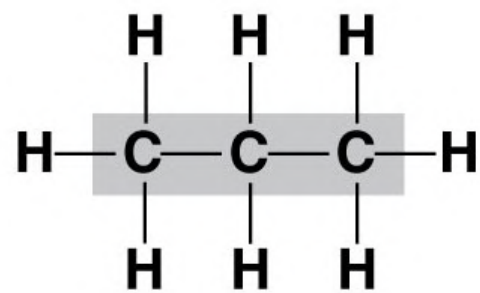
Retrieved from Chapter 3 The Molecules of Cells (P.70) of Campbell Biology: Concepts and Connections, 7th edition. Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

Life’s molecular diversity is based on the properties of carbon

- 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.



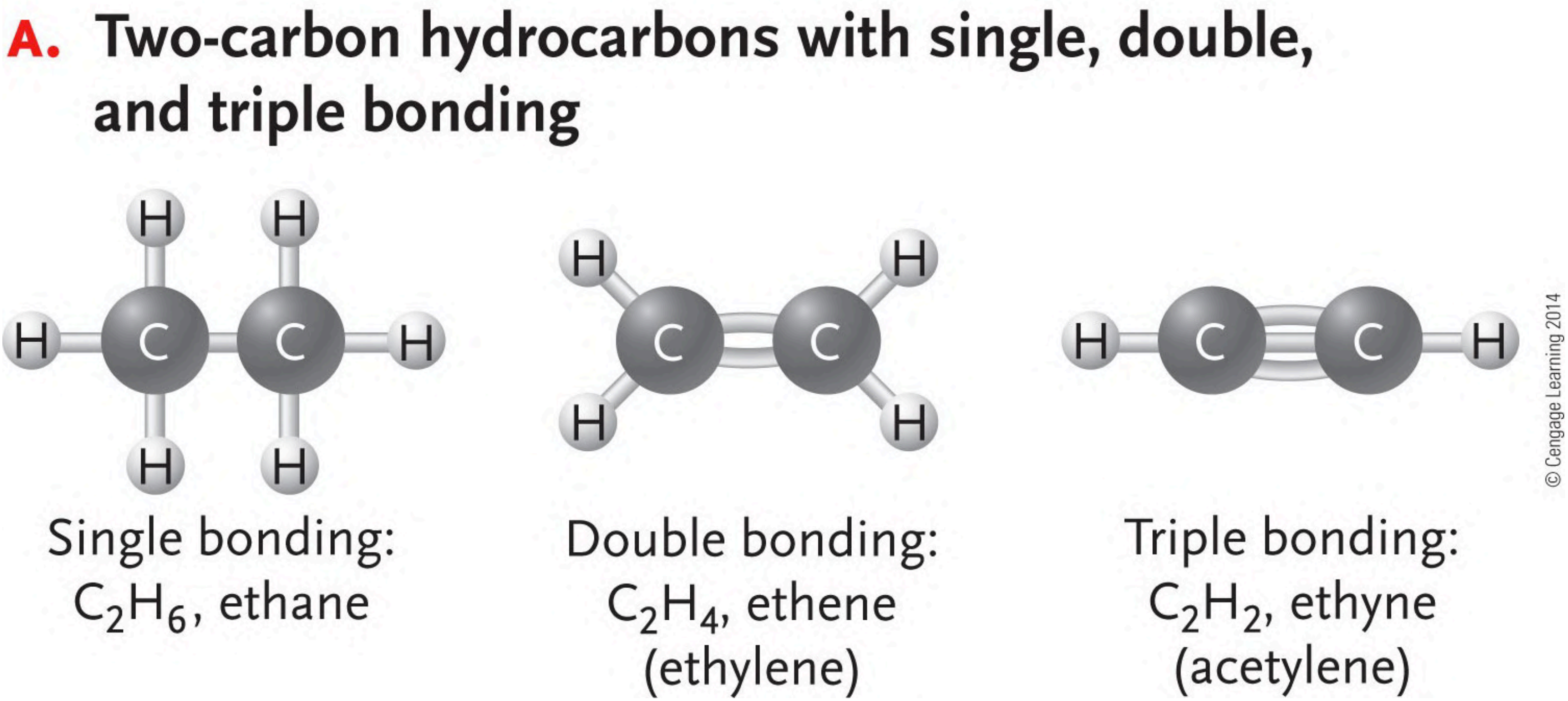
Ethane



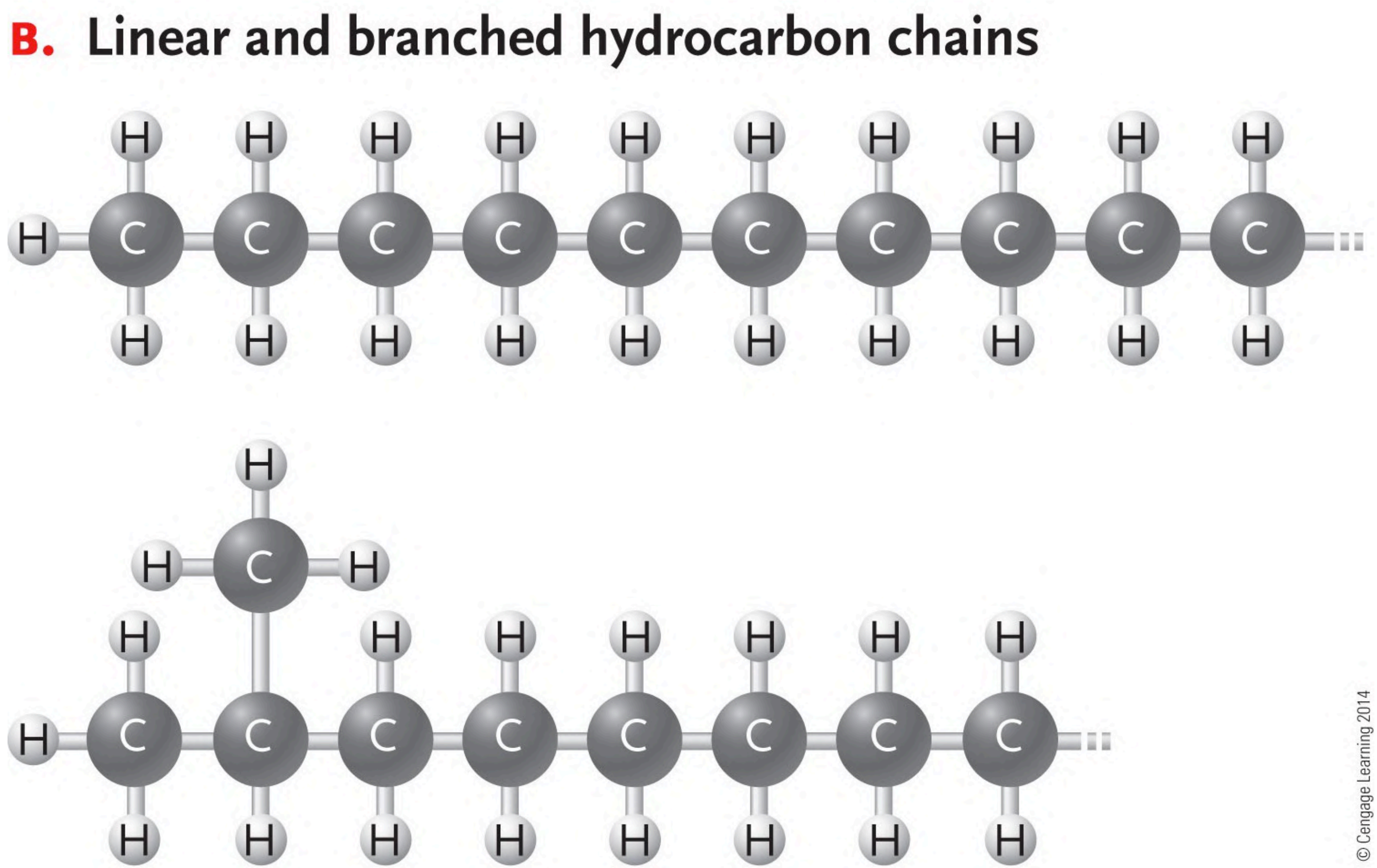
Propane

Retrieved from Chapter 3 The Molecules of Cells (P.70) of Campbell Biology: Concepts and Connections, 7th edition.
Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

Life's molecular diversity is based on the properties of carbon

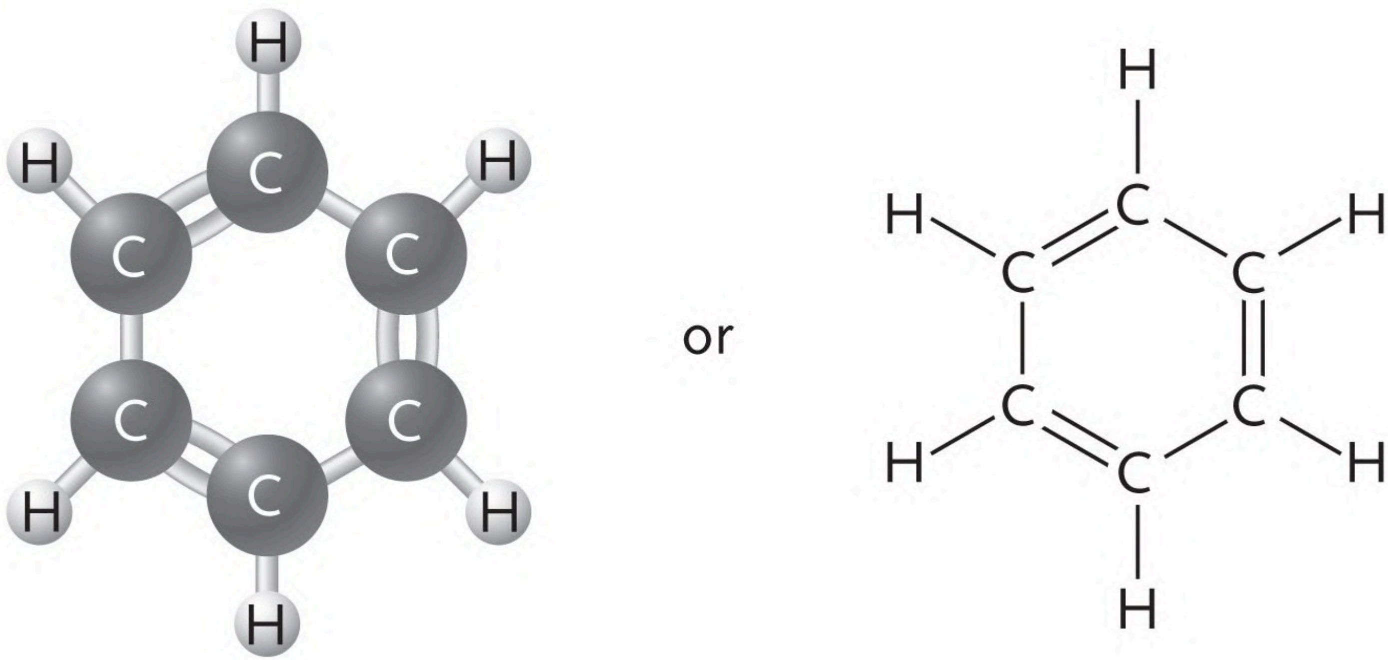


Life's molecular diversity is based on the properties of carbon



Life’s molecular diversity is based on the properties of carbon

c. Hydrocarbon ring, in this case with double bonds



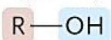
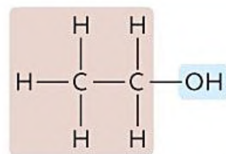
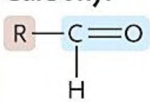
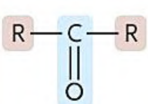
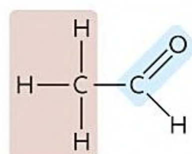
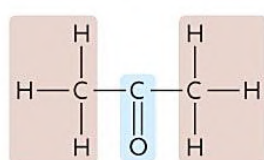
C_6H_6, benzene

A few chemical groups are key to the functioning of biological molecules

- An organic compound has unique properties that depend upon the
  - size and shape of the molecule and
  - groups of atoms (functional groups) attached to it.
- A **functional group** can participate in specific chemical reactions and affects a biological molecule's function in a characteristic way.
- Some of the important functional groups in biological molecules include: hydroxyl, methyl, carbonyl, carboxyl, amino, phosphate, and sulfhydryl groups.

A few chemical groups are key to the functioning of biological molecules

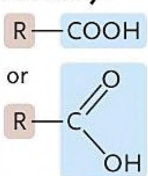
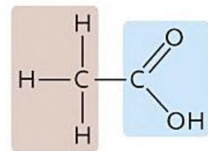
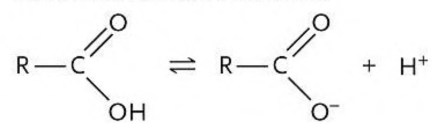
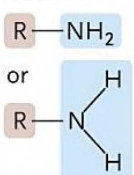
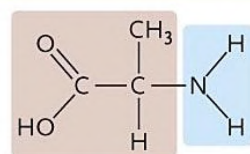
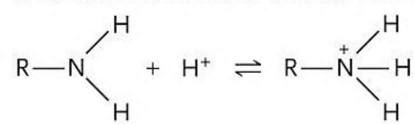
TABLE 3.1 Common Functional Groups of Organic Molecules

Functional Group (boxed in blue)		Major Classes of Molecules and Examples of Them		Properties
Hydroxyl 	An oxygen atom linked to a hydrogen atom. In a molecule, it is linked to an R group on the other side.	**Alcohols**	 Ethyl alcohol (in alcoholic beverages)	Polar; confers polarity on the parts of the molecules that contain them. Hydrogen bonds with water facilitating dissolving of organic molecules. Enables an alcohol to form linkages with other organic molecules through dehydration synthesis reactions (see Figure 3.5A).
Carbonyl  	Oxygen atom linked to an atom by a double bond. In aldehydes, the carbonyl group is linked to a carbon atom at the end of a carbon chain. In ketones, the carbonyl group is linked to a carbon atom in the interior of a carbon chain.	**Aldehydes**	 Acetaldehyde	Reactive parts of aldehydes and ketones, molecules that act as major building blocks of carbohydrates, and that also take part in the reactions supplying energy for cellular activities.
		Ketones	 Acetone (a solvent)	

(Continued)

A few chemical groups are key to the functioning of biological molecules

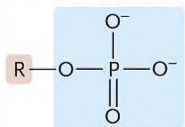
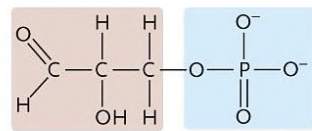
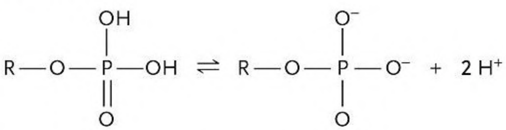
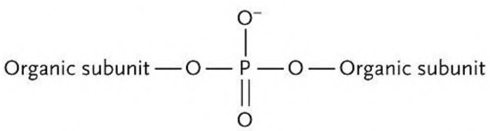
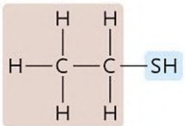
TABLE 3.1 Common Functional Groups of Organic Molecules

Functional Group (boxed in blue)		Major Classes of Molecules and Examples of Them		Properties
Carboxyl 	A carbonyl group and a hydroxyl group combined.	**Carboxylic acids** (a type of organic acid)	 Acetic acid (in vinegar)	Gives organic molecules acidic properties because its —OH group readily releases the hydrogen as a proton (H^+) in aqueous solutions (such as in cells) (see Section 2.5) converting it from a non-ionized to an ionized form: 
Amino 	A nitrogen atom bonded on one side to two hydrogen atoms. In a molecule it is linked to an R group on the other side.	**Amines**	 Alanine (an amino acid)	Readily acts as an organic base by accepting a proton (H^+) in aqueous solutions, converting it from a nonionized to an ionized form: 

(Continued)

A few chemical groups are key to the functioning of biological molecules

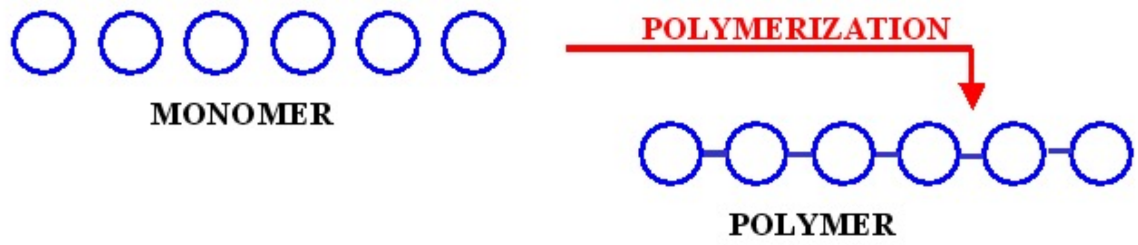
TABLE 3.1 **Common Functional Groups of Organic Molecules *(Continued)***

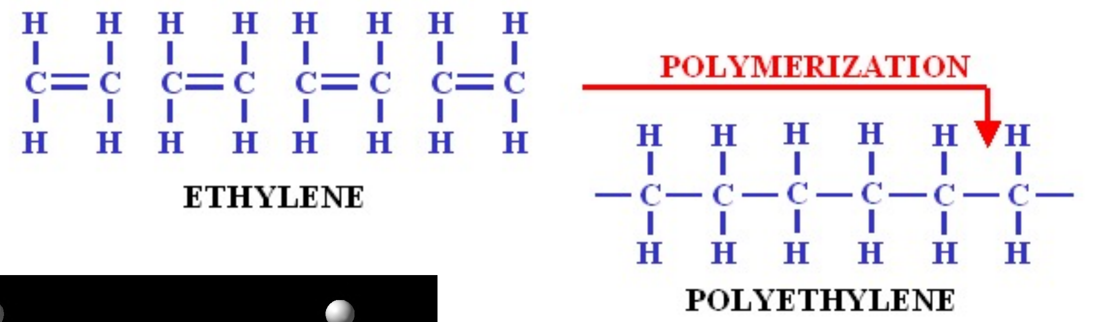
Functional Group (boxed in blue)		Major Classes of Molecules and Examples of Them		Properties
Phosphate  	A central phosphorus bound to four oxygen atoms. In molecules, one of the oxygen atoms links to an R group.	**Organic phosphates**	 Glyceraldehyde-3-phosphate (product of photosynthesis). Nucleotides and nucleic acids are also examples.	Molecules that contain phosphate groups react as weak acids because one or both —OH groups readily release their hydrogens as H^+ in aqueous solutions converting them from a nonionized to an ionized form:  A phosphate group can bridge two organic building blocks to form a larger structure, for example DNA:  Phosphate groups are added to or removed from biological molecules as part of reactions that conserve or release energy, or, for many proteins, to alter activity.
Sulfhydryl R—SH	A sulfur atom linked to a hydrogen atom. In a molecule, the other side is linked to an R group.	**Thiols**	 Mercaptoethanol	Easily converted into a covalent linkage, in which it loses its hydrogen atom as it binds. In many linking reactions, two sulfhydryl groups form a **disulfide linkage** (—S—S—): R—SH + HS—R → R—S—S—R + 2 H^+ + 2 electrons (disulfide linkage)

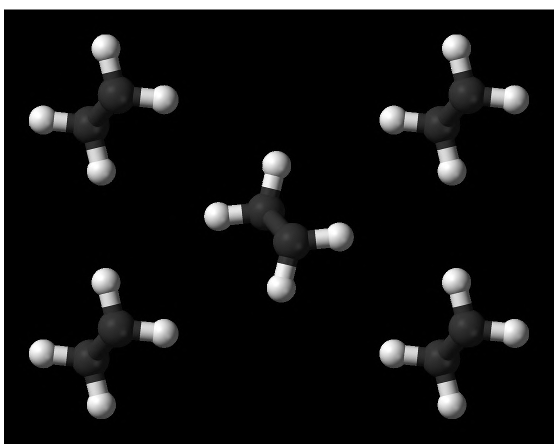
Cells make a huge number of large molecules from a limited set of small molecules

- There are four classes of molecules important to organisms:
  - carbohydrates,
  - proteins,
  - lipids, and
  - nucleic acids.

Monomers and polymers







Cells make a huge number of large molecules from a limited set of small molecules

- The four classes of biological molecules are made from small building blocks
  - 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 of polymers are called **monomers**.

Cells make a huge number of large molecules from a limited set of small molecules

Starting Material(s) $\xrightarrow{\text{Enzyme A}}$ Intermediate 1 $\xrightarrow{\text{Enzyme B}}$ Intermediate 2 • • • • Product

Cells make a huge number of large molecules from a limited set of small molecules

- A cell makes a large number of polymers from a small group of monomers. For example,
  - carbohydrates include polysaccharide composed of a large number of monomeric sugar units
  - proteins are made from only 20 different amino acids
  - DNA is built from just four kinds of nucleotides.
  - Some lipids (e.g. fatty acids and steroids) are synthesized through polymerization of monomeric units
- The monomers used to make polymers are universal.

CARBOHYDRATES

Retrieved from Chapter 3 The Molecules of Cells (P.73) of Campbell Biology: Concepts and Connections, 7th edition. Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

Monosaccharides are the simplest carbohydrates

- **Carbohydrates** range from small sugar molecules (monomers) to large polysaccharides.
- Sugar monomers are **monosaccharides**, such as those found in honey,
  - glucose, and
  - fructose.
- Monosaccharides can be linked together to form more complex sugars called **polysaccharides**.

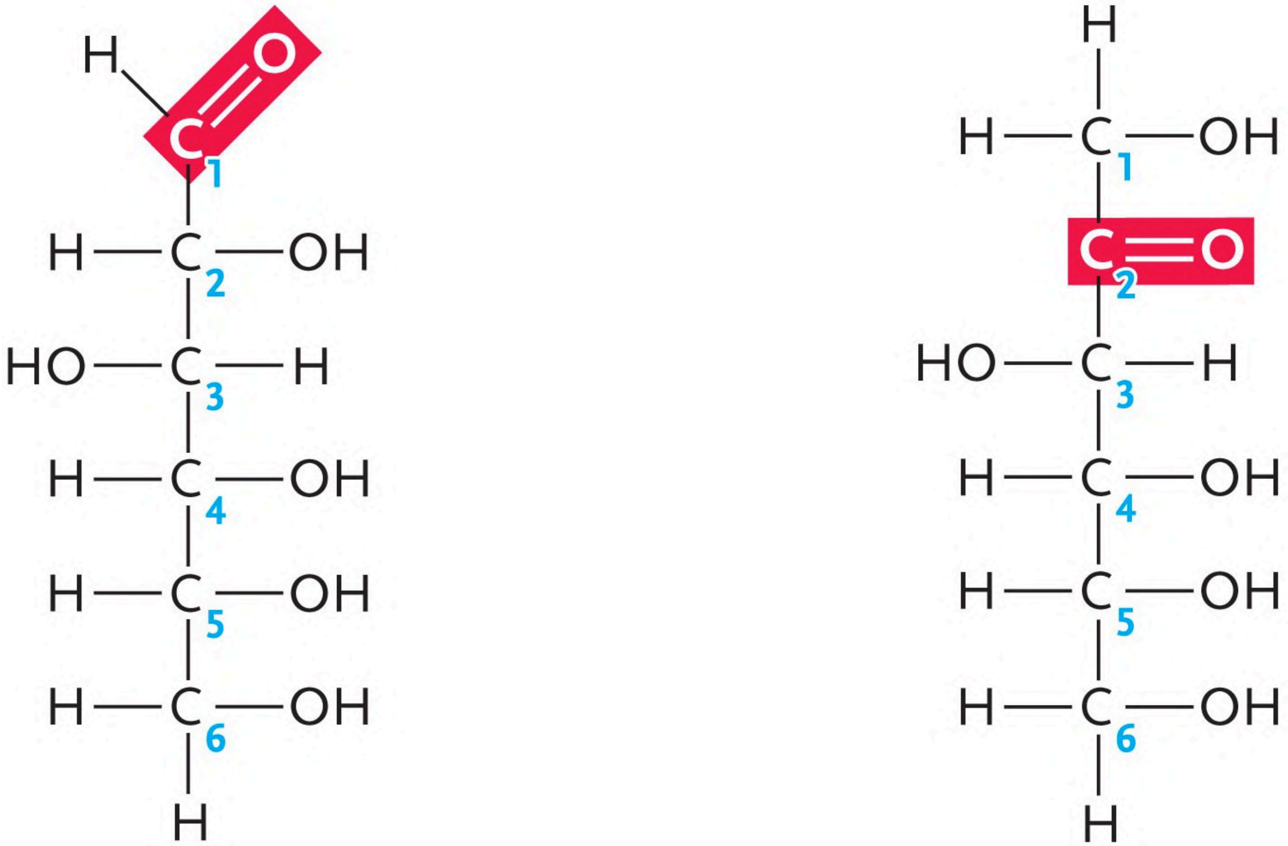
Monosaccharides are the simplest carbohydrates

- The carbon skeletons of monosaccharides vary in length.
  - Glucose and fructose are six carbons long.
  - Others have three to seven carbon atoms.
- Monosaccharides are
  - the main fuels for cellular work and
  - used as raw materials to manufacture other organic molecules.

Monosaccharides: Glucose and Fructose

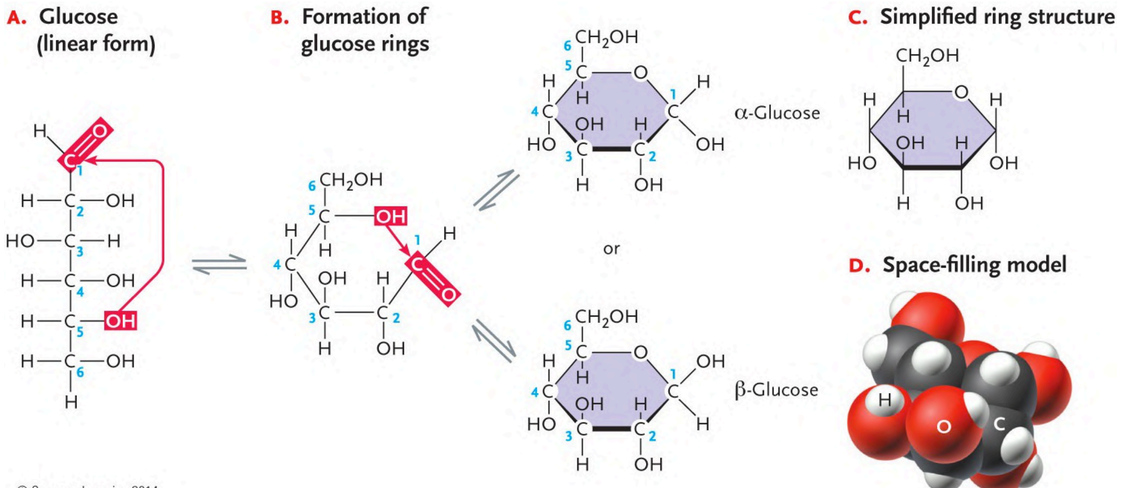
A. Glucose (an aldehyde)

B. Fructose (a ketone)



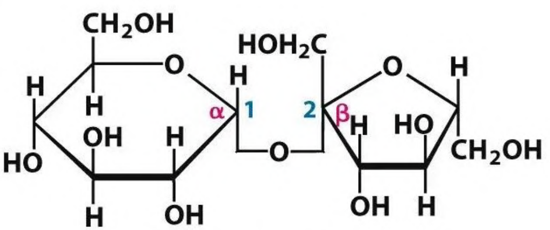
Monosaccharides are the simplest carbohydrates

- Many monosaccharides form rings.
- The ring diagram may be
  - abbreviated by not showing the carbon atoms at the corners of the ring and
  - drawn with different thicknesses for the bonds, to indicate that the ring is a relatively flat structure with attached atoms extending above and below it.

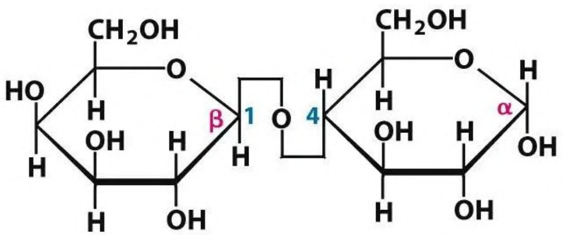


Two monosaccharides are linked to form a disaccharide

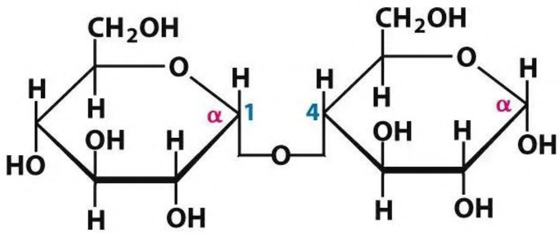
- Two monosaccharides (monomers) can bond together to form a **disaccharide**.
  - glucose + fructose = sucrose
  - glucose + galactose = lactose
  - glucose + glucose = maltose



Sucrose
(α-D-Glucopyranosyl-(1⟶ 2)-β-D-fructofuranose



Lactose
(β-D-Galactopyranosyl-(1⟶ 4)-α-D-glucopyranose



Maltose
(α-D-Glucopyranosyl-(1⟶ 4)-α-D-glucopyranose

Figure 11.11
Biochemistry, Seventh Edition

CONNECTION: What is high-fructose corn syrup, and is it to blame for obesity?

- Sodas or fruit drinks often contain **h**igh-**f**ructose **c**orn **s**yrup (HFCS).
- Fructose tastes sweeter than glucose.
- To make HFCS, glucose atoms are rearranged to make the glucose isomer, fructose.

Retrieved from Chapter 3 The Molecules of Cells (P.74) of Campbell Biology: Concepts and Connections, 7th edition. Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

CONNECTION: What is high-fructose corn syrup, and is it to blame for obesity?

- High-fructose corn syrup (HFCS) is
  - used to sweeten many beverages and
  - may be associated with **weight gain and diabetes**.
- Good health is promoted by
  - a diverse diet of proteins, fats, vitamins, minerals, and complex carbohydrates and
  - exercise.

Polysaccharides are long chains of sugar units

- **Polysaccharides** are
  - macromolecules and
  - polymers composed of many monosaccharides.
- Polysaccharides may function as
  - storage molecules or
  - structural compounds.

Polysaccharides are long chains of sugar units

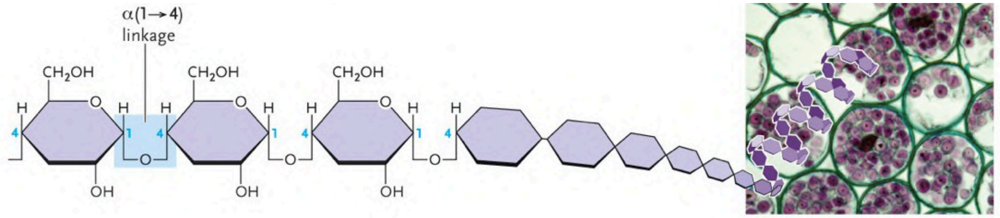
- **Starch** is
  - a polysaccharide,
  - composed of glucose monomers, and
  - used by plants for energy storage.
- **Glycogen** is
  - a polysaccharide,
  - composed of glucose monomers, and
  - used by animals for energy storage.

Polysaccharides are long chains of sugar units

- **Cellulose**
  - is a polymer of glucose and
  - forms plant cell walls.
- **Chitin** is
  - a polysaccharide and
  - used by insects and crustaceans to build an exoskeleton.

A. Amylose, a plant starch

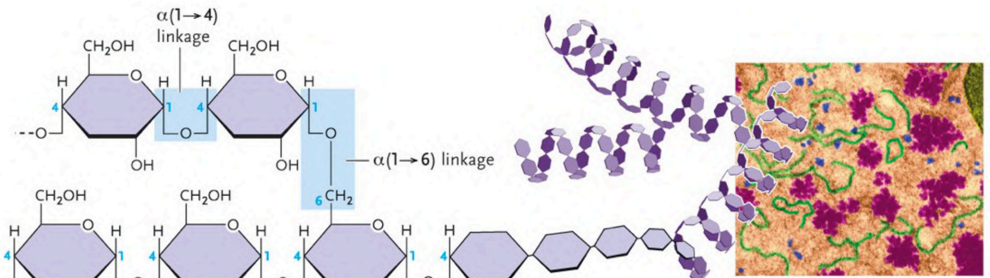
Amylose, formed from α-glucose units joined end to end in α(1→4) linkages. The coiled structures are induced by the bond angles in the α-linkages.



Amylose grains (purple) in plant root tissue

B. Glycogen, found in animal tissues

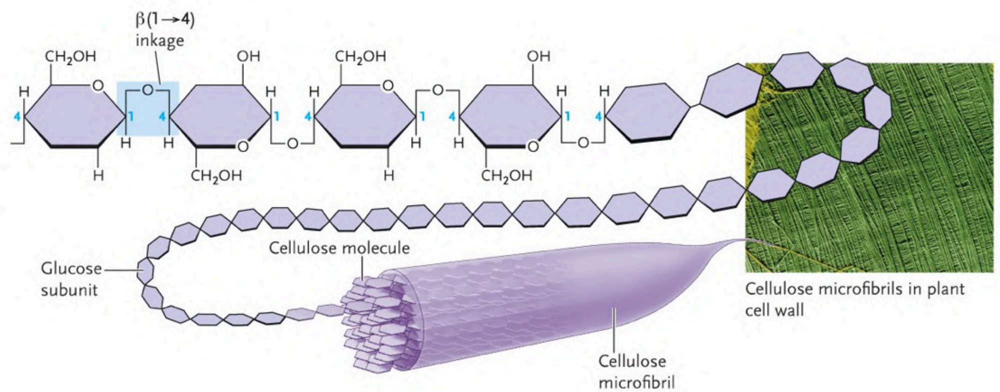
Glycogen, formed from glucose units joined in chains by α(1→4) linkages; side branches are linked to the chains by α(1→6) linkages (boxed in blue).



Glycogen particles (magenta) in liver cell

C. Cellulose, the primary fiber in plant cell walls

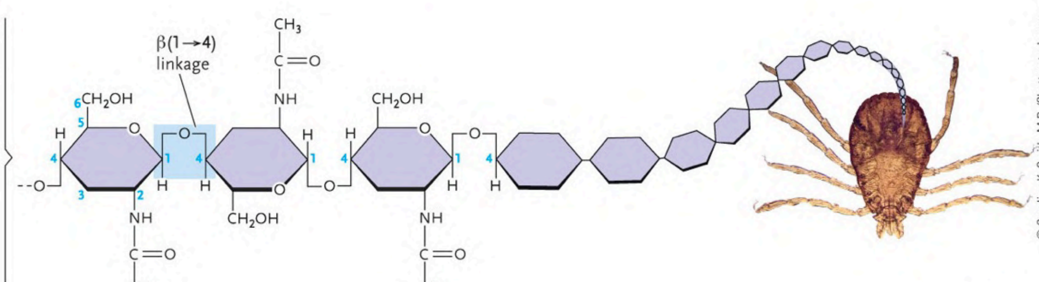
Cellulose, formed from glucose units joined end to end by β(1→4) linkages. Hundreds to thousands of cellulose chains line up side by side, in an arrangement reinforced by hydrogen bonds between the chains, to form cellulose microfibrils in plant cells.



Cellulose microfibrils in plant cell wall

D. Chitin, a reinforcing fiber in the external skeleton of arthropods and the cell walls of some fungi

Chitin, formed from β(1→4) linkages joining glucose units modified by the addition of nitrogen-containing groups. The external body armor of the tick is reinforced by chitin fibers.



Polysaccharides are long chains of sugar units

- Polysaccharides are usually **hydrophilic** (water-loving).
- Bath towels are
  - often made of cotton, which is mostly cellulose, and
  - water absorbent.

LIPIDS

Fats are lipids that are mostly energy-storage molecules

- **Lipids**
  - are water insoluble (**hydrophobic**, or “water-fearing”) compounds,
  - are important in long-term energy storage,
  - contain twice as much energy as a polysaccharide, and
  - consist mainly of carbon and hydrogen atoms linked by nonpolar covalent bonds.

Fats are lipids that are mostly energy-storage molecules

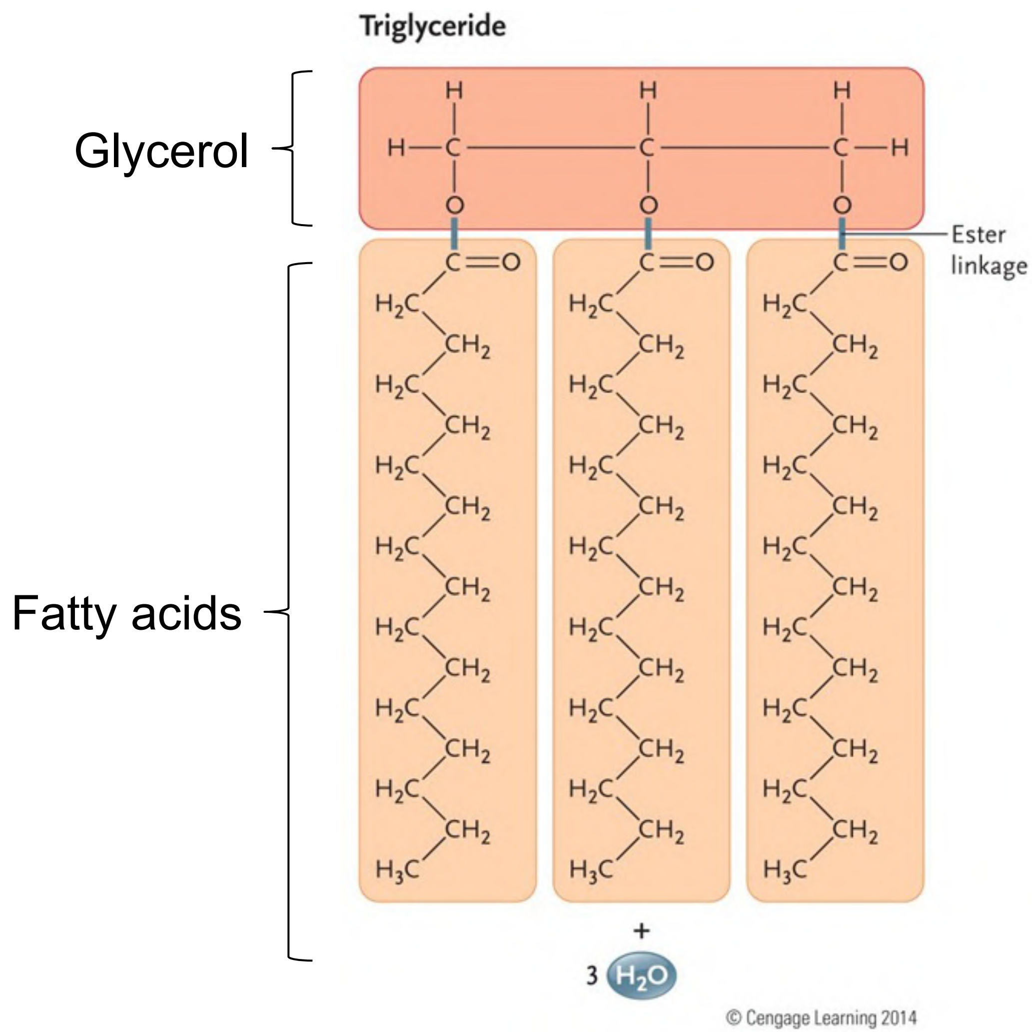
- Lipids differ from polysaccharides, proteins, and nucleic acids in that they are
  - **NOT** huge molecules
- Lipids vary a great deal in
  - structure and
  - function.

Fats are lipids that are mostly energy-storage molecules

- We will consider three types of lipids:
  - fats,
  - phospholipids, and
  - steroids.
- A **fat** is a large lipid made from two kinds of smaller molecules,
  - glycerol and
  - fatty acids.

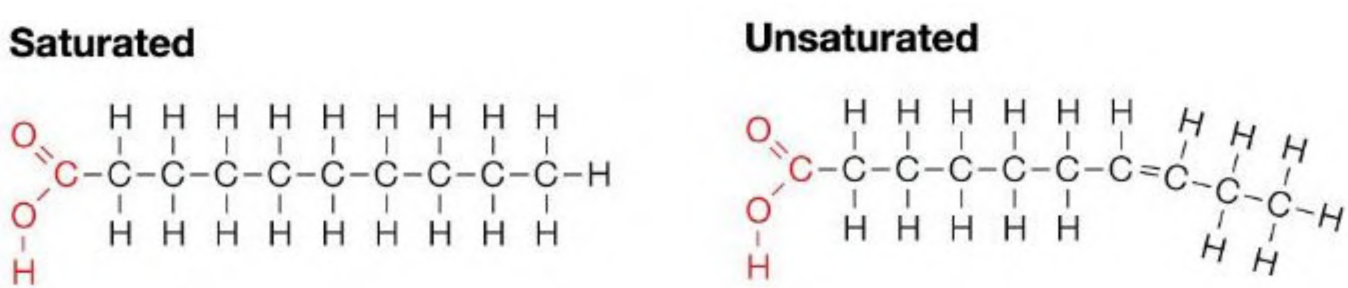
Triacylglyceride

- Fat is formed by dehydration reaction
- One glycerol is linked to three fatty acids.
- Fats are often called triglycerides because of their structure.



Fats are lipids that are mostly energy-storage molecules

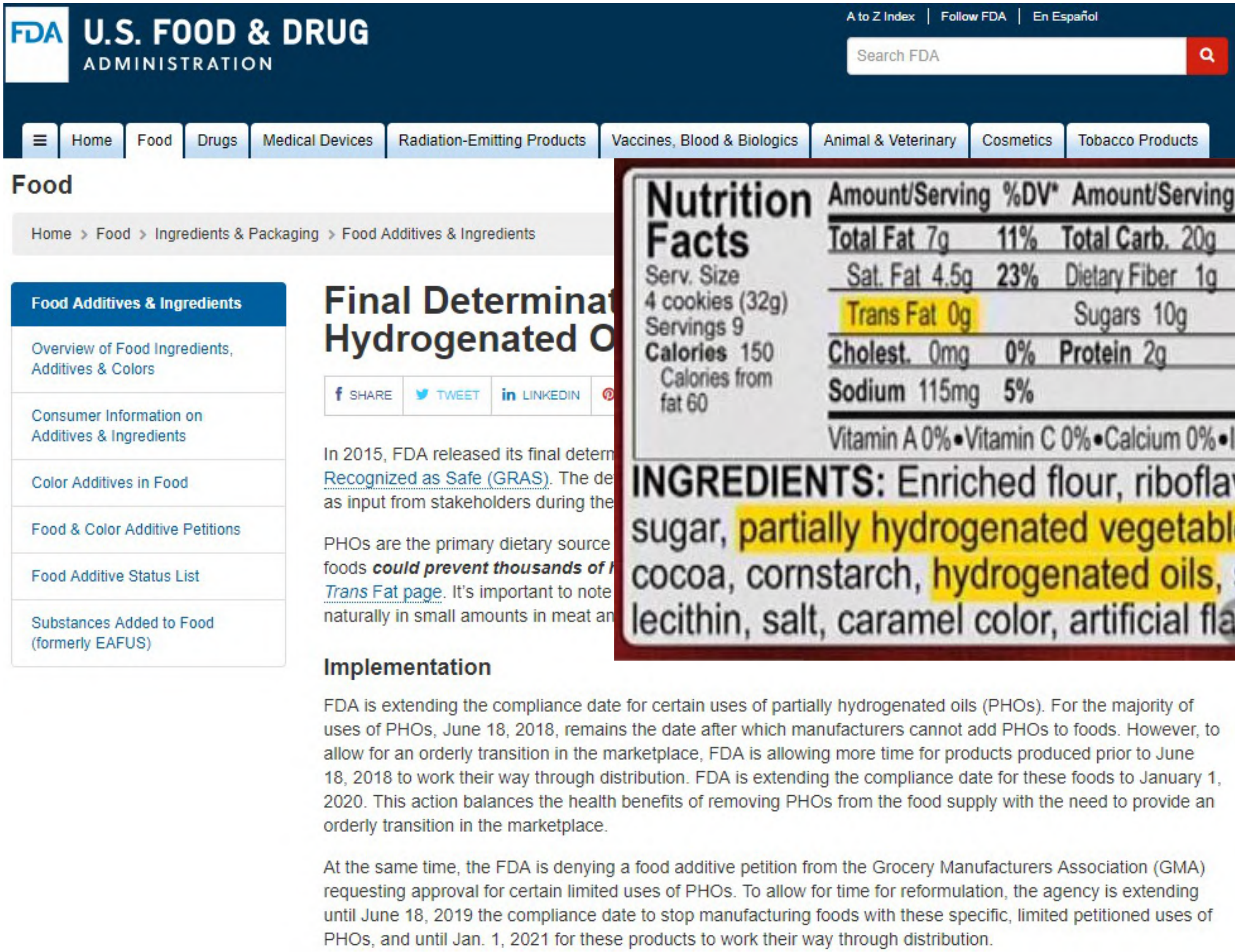
- Some fatty acids contain one or more double bonds, forming **unsaturated fatty acids** that
  - have one fewer hydrogen atom on each carbon of the double bond,
  - cause kinks or bends in the carbon chain, and
  - prevent them from packing together tightly and solidifying at room temperature.
- Fats with the maximum number of hydrogens are called **saturated fatty acids**.



Fats are lipids that are mostly energy-storage molecules

- Unsaturated fats include corn and olive oils.
- Most **animal fats** are saturated fats.
- Hydrogenated vegetable oils are unsaturated fats that have been converted to saturated fats by adding hydrogen.
- This hydrogenation creates **trans fats** associated with health risks.

Trans fats in cooking oil



FDA U.S. FOOD & DRUG ADMINISTRATION

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Food Additives & Ingredients

- Overview of Food Ingredients, Additives & Colors
- Consumer Information on Additives & Ingredients
- Color Additives in Food
- Food & Color Additive Petitions
- Food Additive Status List
- Substances Added to Food (formerly EAFUS)

Final Determinat
Hydrogenated O

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In 2015, FDA released its final determ
Recognized as Safe (GRAS). The de
as input from stakeholders during the

PHOs are the primary dietary source
foods ***could prevent thousands of h***
Trans Fat page. It's important to note
naturally in small amounts in meat an

Implementation

FDA is extending the compliance date for certain uses of partially hydrogenated oils (PHOs). For the majority of uses of PHOs, June 18, 2018, remains the date after which manufacturers cannot add PHOs to foods. However, to allow for an orderly transition in the marketplace, FDA is allowing more time for products produced prior to June 18, 2018 to work their way through distribution. FDA is extending the compliance date for these foods to January 1, 2020. This action balances the health benefits of removing PHOs from the food supply with the need to provide an orderly transition in the marketplace.

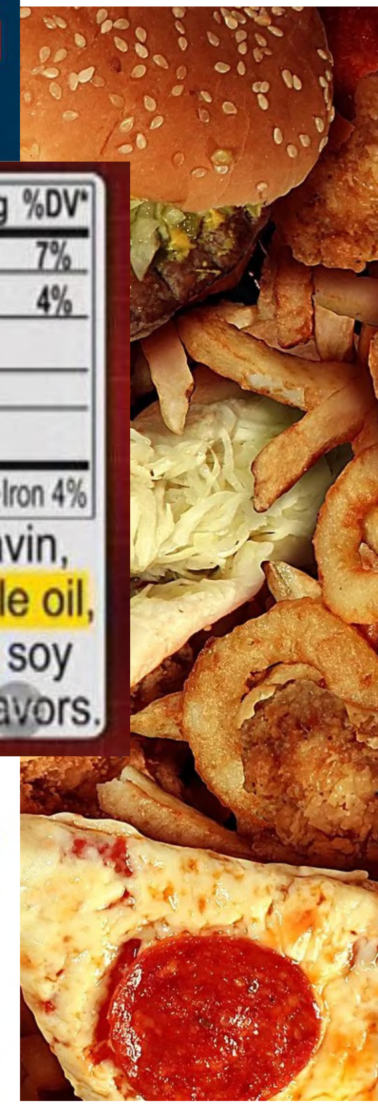
At the same time, the FDA is denying a food additive petition from the Grocery Manufacturers Association (GMA) requesting approval for certain limited uses of PHOs. To allow for time for reformulation, the agency is extending until June 18, 2019 the compliance date to stop manufacturing foods with these specific, limited petitioned uses of PHOs, and until Jan. 1, 2021 for these products to work their way through distribution.

Nutrition Facts
Serv. Size 4 cookies (32g)
Servings 9
Calories 150
Calories from fat 60

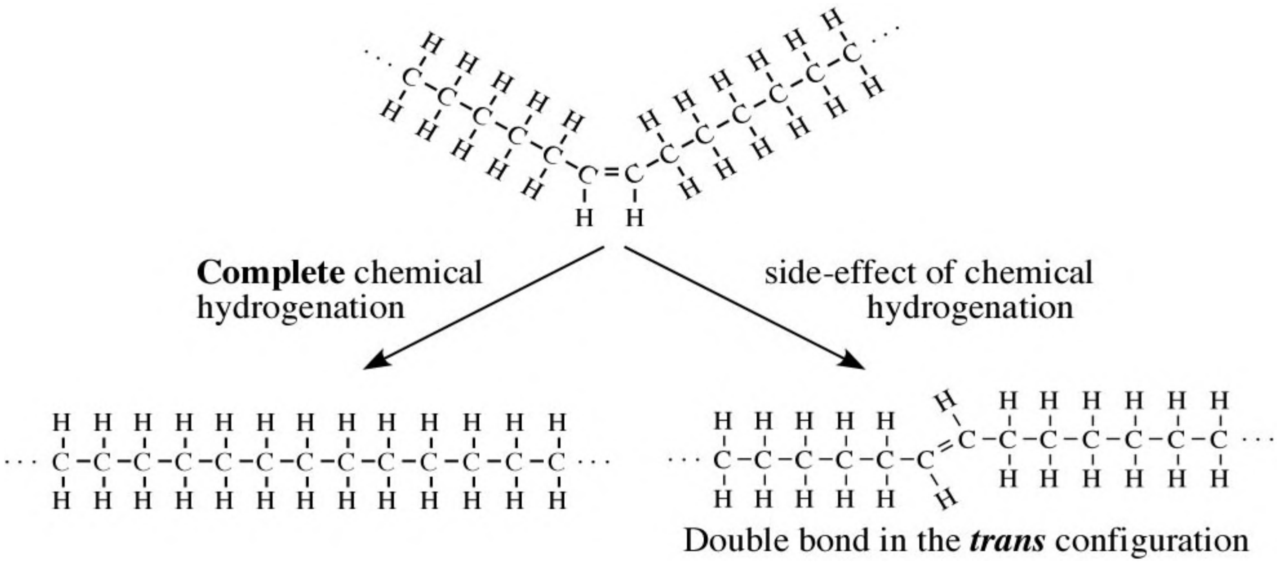
Amount/Serving	%DV*	Amount/Serving	%DV*
Total Fat 7g	11%	**Total Carb.** 20g	7%
Sat. Fat 4.5g	23%	Dietary Fiber 1g	4%
Trans Fat 0g		Sugars 10g	
Cholest. 0mg	0%	**Protein** 2g	
Sodium 115mg	5%		

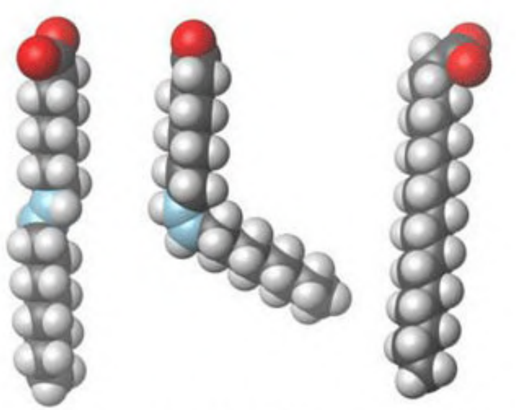
Vitamin A 0% • Vitamin C 0% • Calcium 0% • Iron 4%

INGREDIENTS: Enriched flour, riboflavin, sugar, partially hydrogenated vegetable oil, cocoa, cornstarch, hydrogenated oils, soy lecithin, salt, caramel color, artificial flavors.



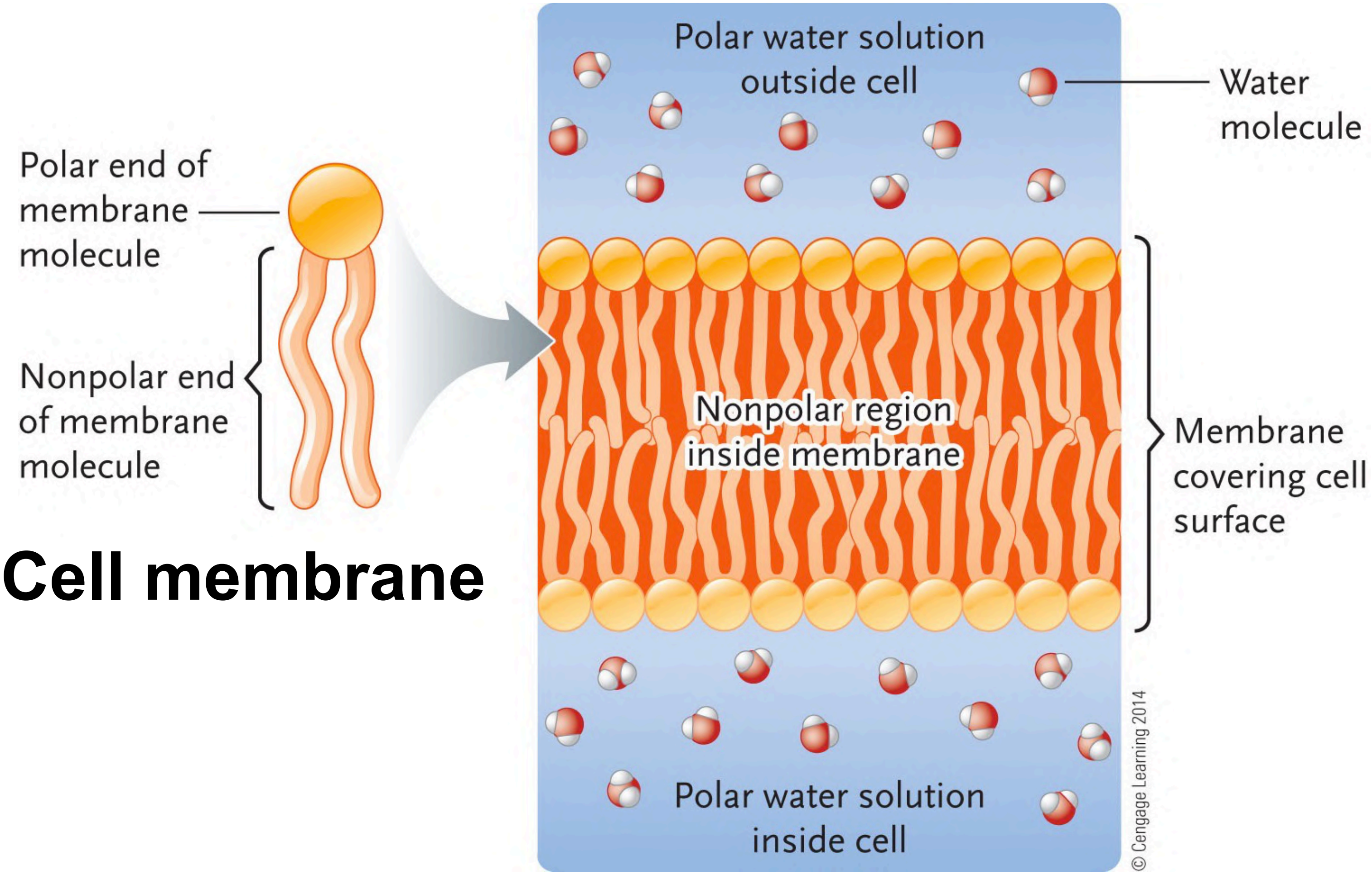
Making of trans-fat





Trans Fat Unsaturated Fat Saturated Fat

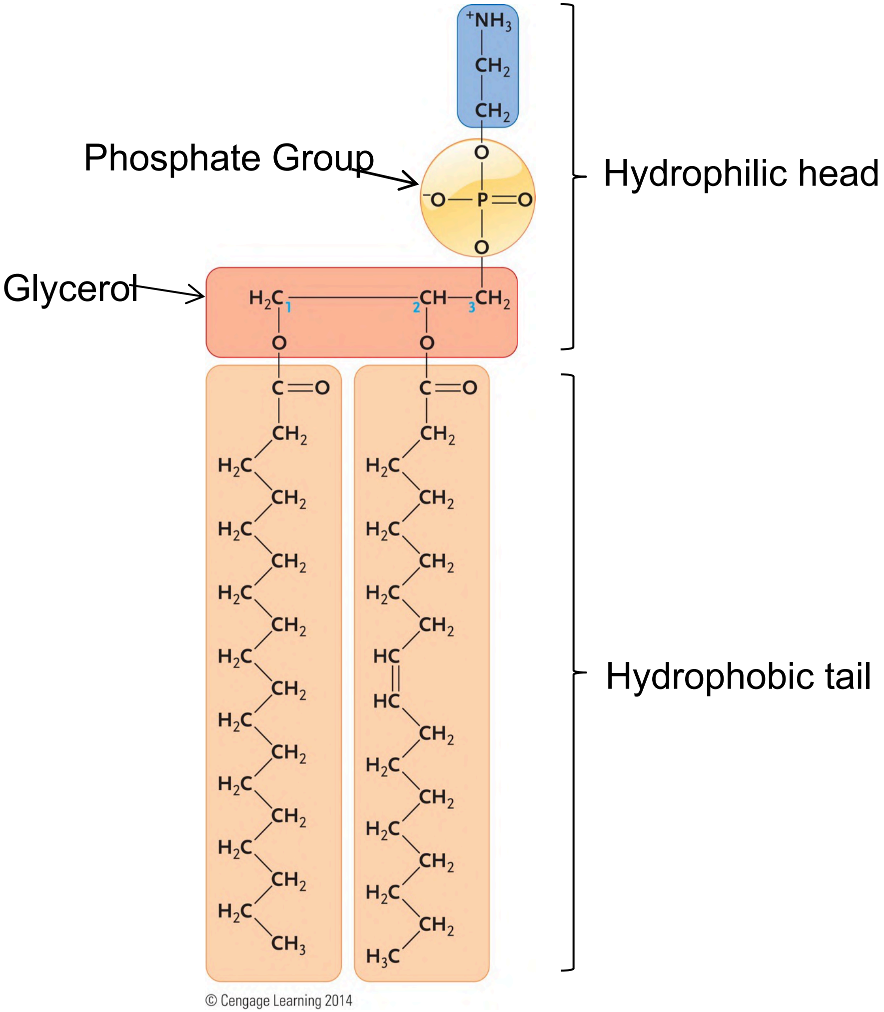
Phospholipids and steroids are important lipids with a variety of functions



Cell membrane

Phospholipids and steroids are important lipids with a variety of functions

- **Phospholipids** are a major component of all cells.
- Phospholipids are structurally similar to fats.
  - Fats contain three fatty acids attached to glycerol.
  - Phospholipids contain two fatty acids attached to glycerol.



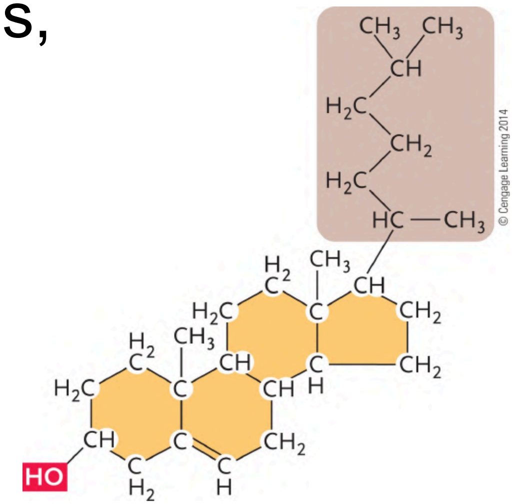
Phosphologipids and steroids are important lipids with a variety of functions

- Phospholipids 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.

Phosphopipids and steroids are important lipids with a variety of functions

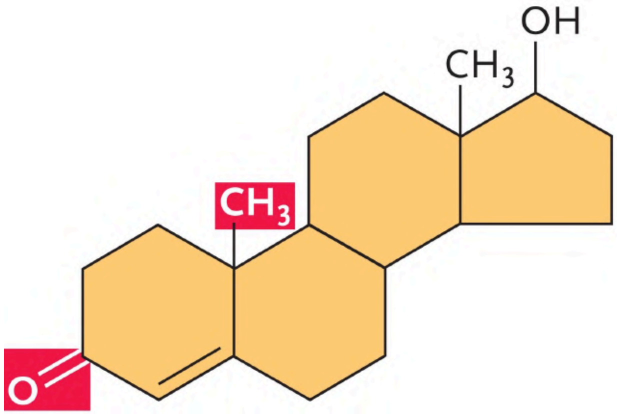
- **Steroids** are lipids in which the carbon skeleton contains four fused rings.
- **Cholesterol** is a
  - common component in animal cell membranes and
  - starting material for making steroids,

    including sex hormones.



CONNECTION: Anabolic steroids pose health risks

- **Anabolic steroids**
  - are synthetic variants of testosterone,
  - can cause a buildup of muscle and bone mass, and
  - are often prescribed to treat general anemia and some diseases that destroy body muscle.



Testosterone

PROTEINS

Enzyme: Lactase (*E. coli*)
http://www.rcsb.org/pdb/explore/explore.do?structureId=3VDB
http://www.rcsb.org/pdb/explore/jmol.do?structureId=3VDB&bionumber=1

DNA binding protein: Myc/Max
http://www.rcsb.org/pdb/explore/explore.do?structureId=1NKP

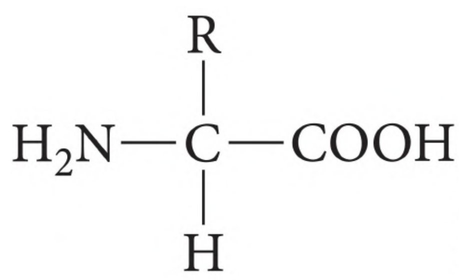
Proteins are made from amino acids linked by peptide bonds

- **Proteins** are
  - involved in nearly every dynamic function in your body and
  - very diverse, with tens of thousands of different proteins, each with a specific structure and function, in the human body.
- Proteins are composed of differing arrangements of a common set of just 20 amino acid monomers.

Proteins are made from amino acids linked by peptide bonds

- **Amino acids** have
  - an amino group and
  - a carboxyl group (which makes it an acid).
- Also bonded to the central carbon is
  - a hydrogen atom and
  - a chemical group symbolized by “R”, which determines the specific properties of each of the 20 amino acids used to make proteins.

Amino group

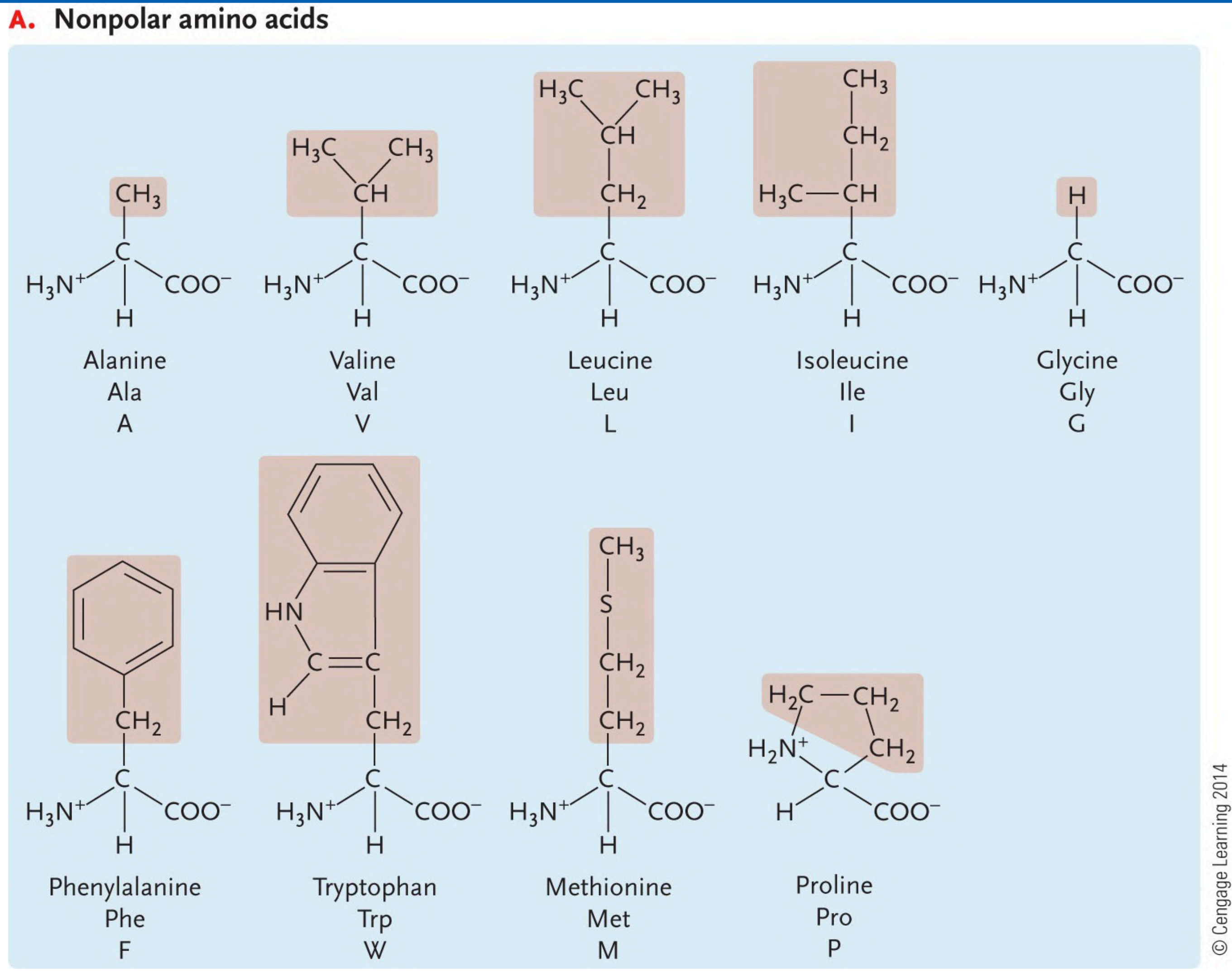


Carboxyl group

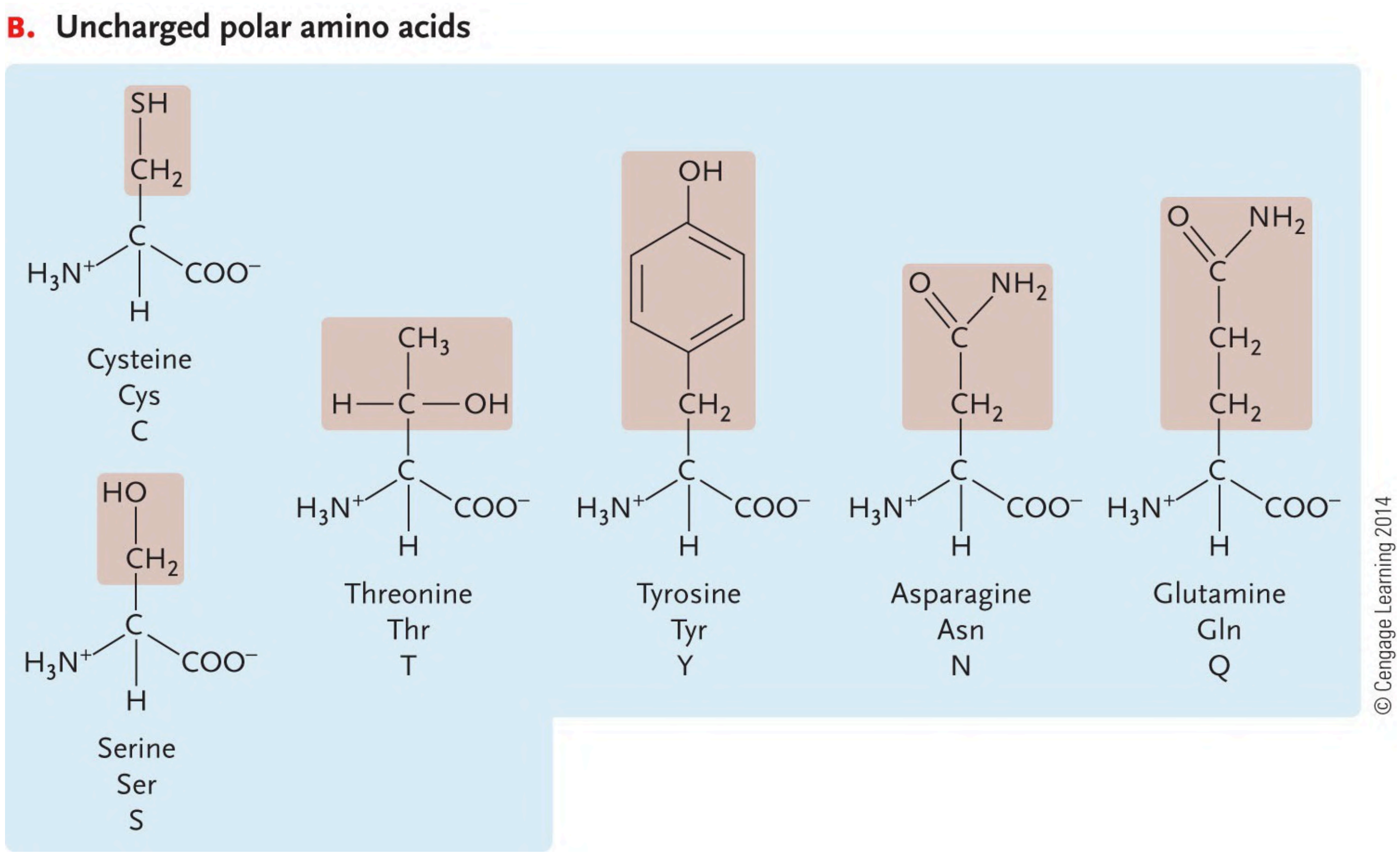
Proteins are made from amino acids linked by peptide bonds

- Amino acids are classified as either
  - hydrophobic or
  - hydrophilic.

Different types of amino acids

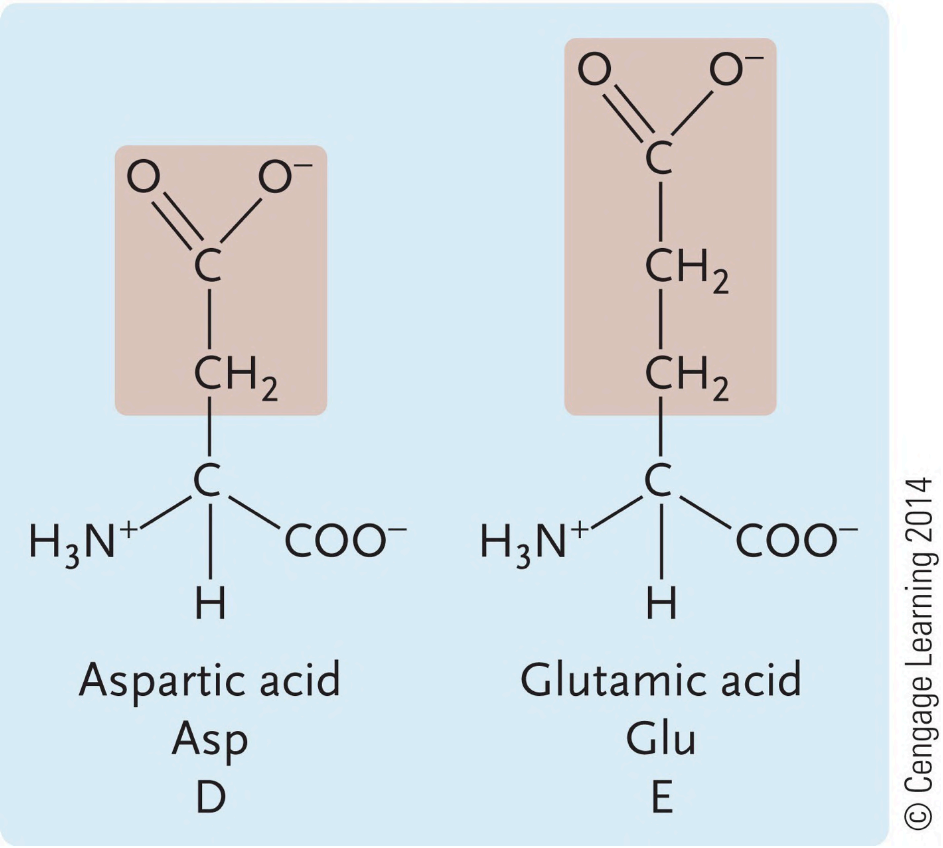


Different types of amino acids

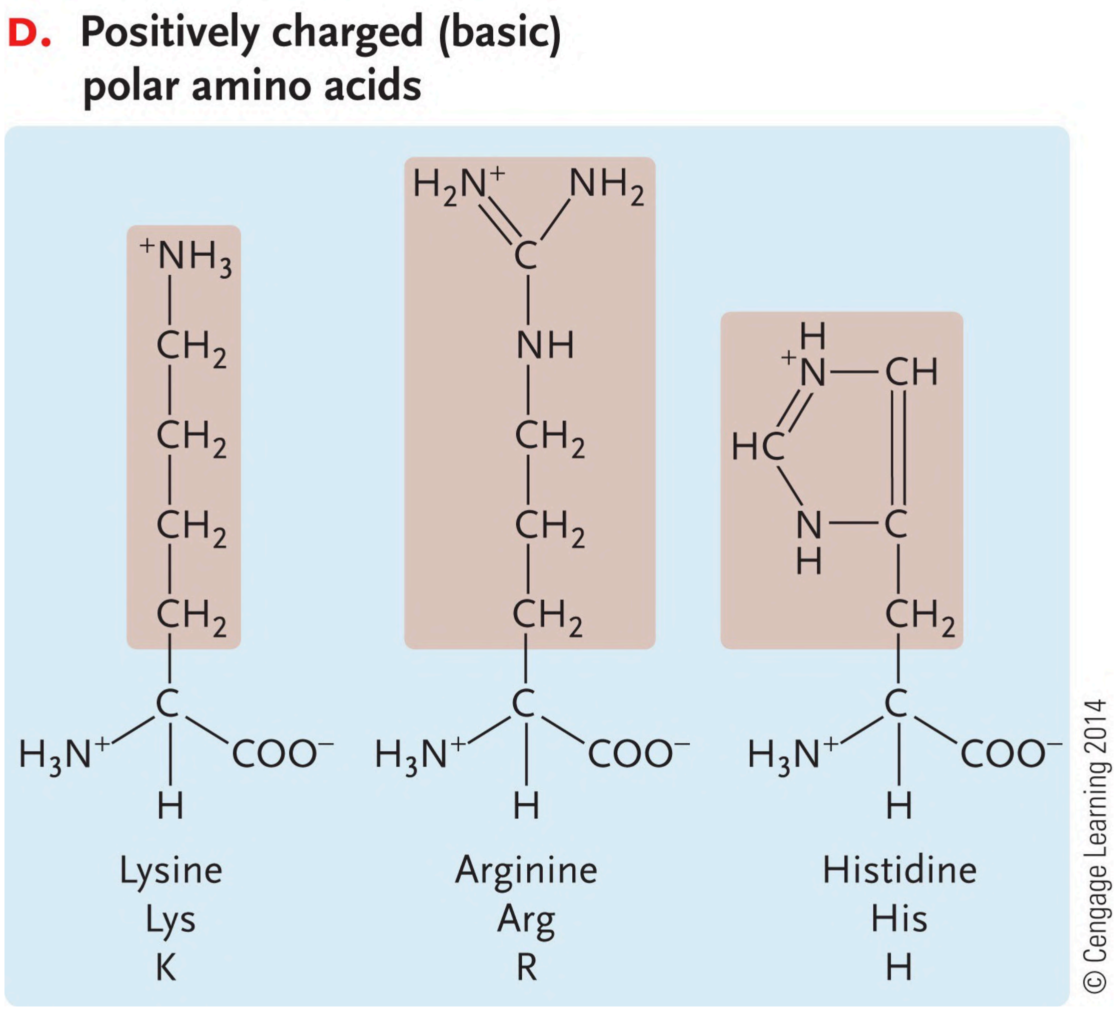


Different types of amino acids

C. Negatively charged (acidic) polar amino acids



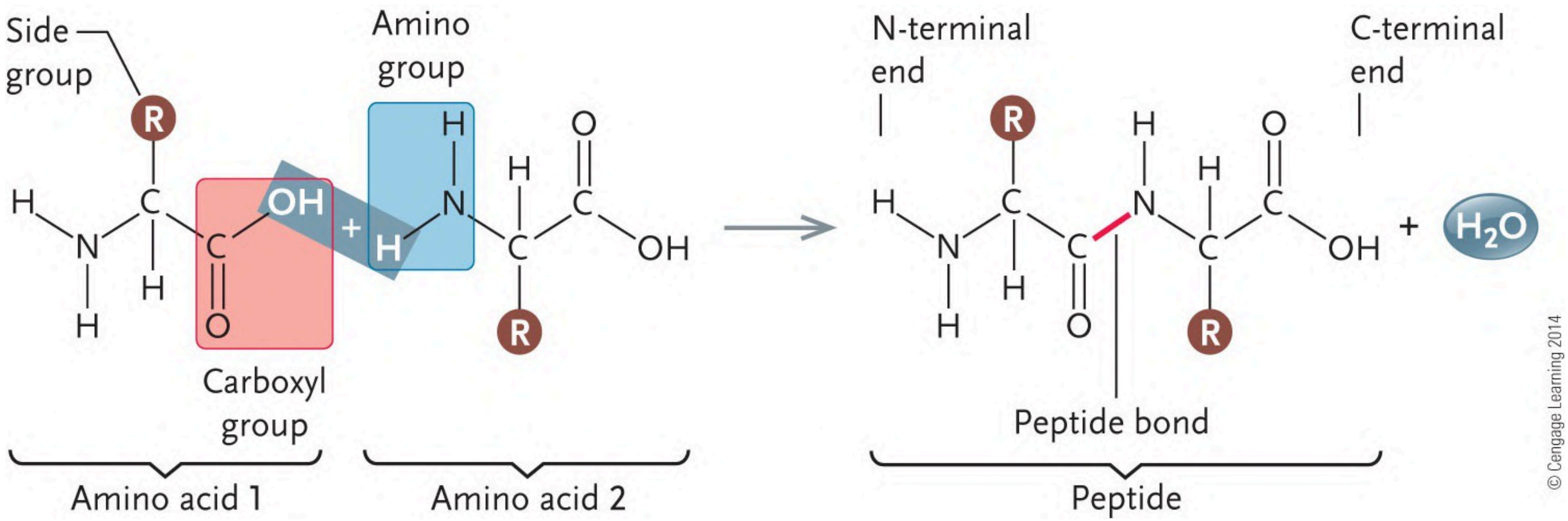
Different types of amino acids



Proteins are made from amino acids linked by peptide bonds

- Amino acid monomers are linked together
  - in a dehydration reaction,
  - joining carboxyl group of one amino acid to the amino group of the next amino acid, and
  - creating a **peptide bond.**
- Additional amino acids can be added by the same process to create a chain of amino acids called a **polypeptide**.

Proteins are made from amino acids linked by peptide bonds



A protein’s specific shape determines its function

- Enzymes are important proteins that
  - serve as metabolic catalysts and
  - regulate the chemical reactions within cells.

A protein's specific shape determines its function

- Other proteins also serve important functions:
  - **Structural** proteins provide associations between body parts.
  - **Contractile** proteins are found within muscle.
  - **Defensive** proteins include antibodies of the immune system.
  - **Signal** proteins are best exemplified by hormones and other chemical messengers.
  - **Receptor** proteins transmit signals into cells.
  - **Transport** proteins carry oxygen.
  - **Storage** proteins serve as a source of amino acids for developing embryos.

A protein’s specific shape determines its function

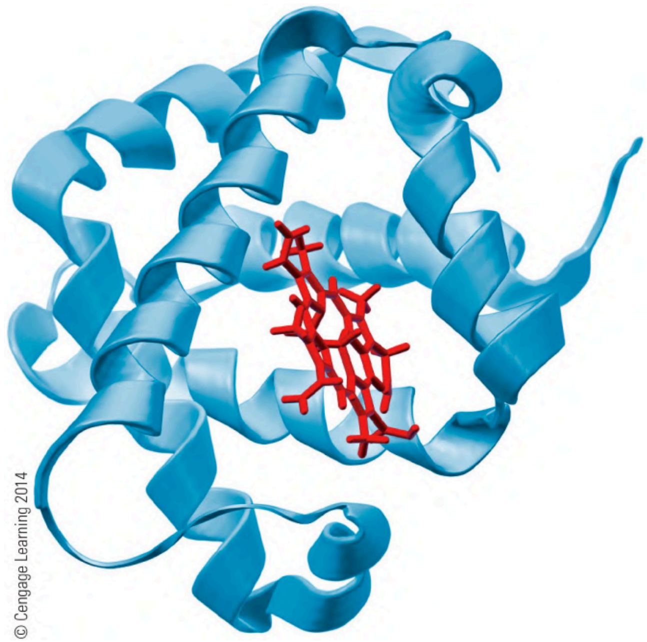
>MYC [Macaca nemestrina] 161aa

SGSPSAGGHSKPPHSPLVLKRCHVSTHQHNYXXPPST
RKDYPAAKRVKLDSVRVLRQISNNRKCTSPRSSDTEEN
DKRRTHNVLERQRRNELKRSFFALRDQIPELENNEKAP
KVVILKKATAYILSVQAEEQKLISEKDLLRKRREQLKHKL
EQLRNSCA

https://www.youtube.com/watch?v=yZ2aY5lxEGE

A protein’s specific shape determines its function

- 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**.



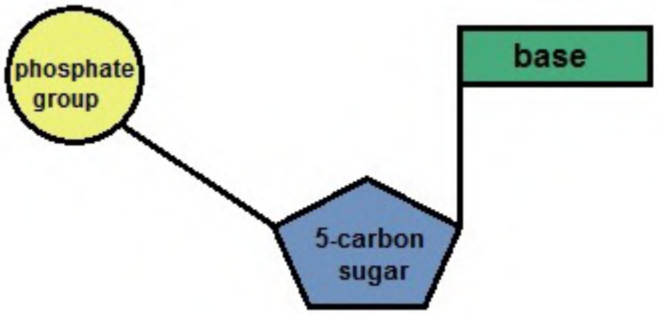
A protein's specific shape determines its function

- Altering a protein's shape may change its function or renders it non-functional.
  - Some proteins are regulated by conformational change
  - Prions are misfolded proteins
- In the process of **denaturation,** a polypeptide chain
  - unravels,
  - loses its shape, and
  - loses its function.
- Proteins can be denatured by changes in salt concentration, pH, or by high heat.

NUCLEIC ACIDS

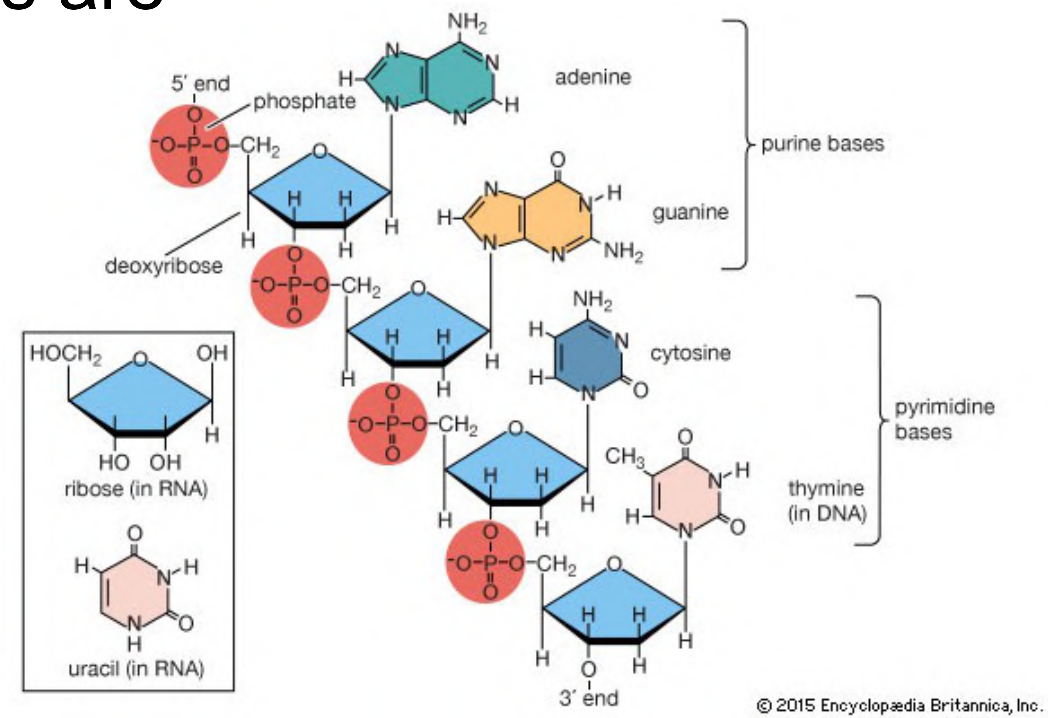
Nucleic acids are polymers of nucleotides

- **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, and
  - a nitrogenous base.



Nucleic acids are polymers of nucleotides

- 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).

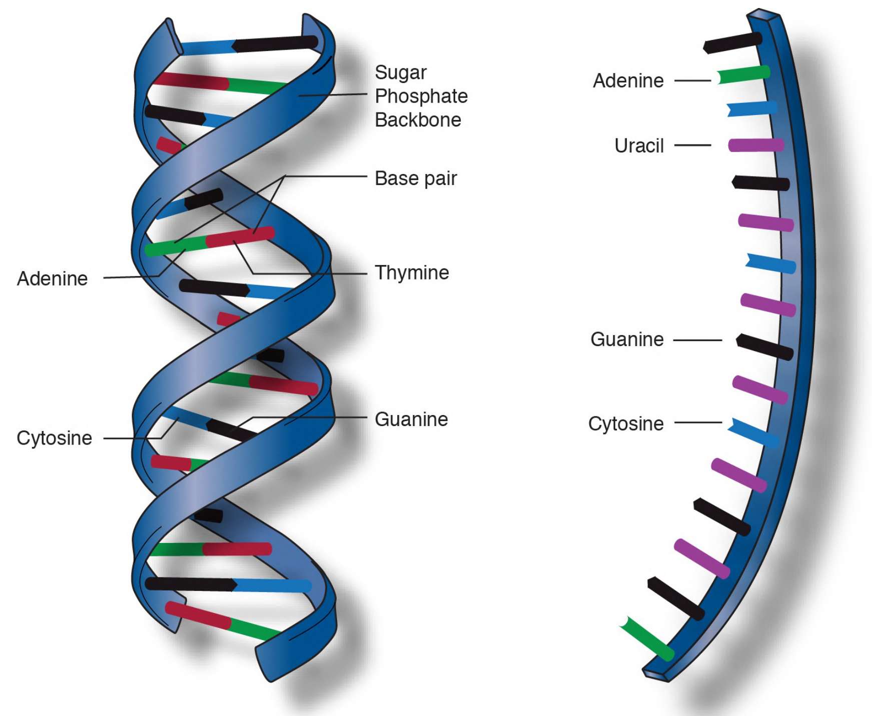
Retrieved from Chapter 3 The Molecules of Cells (P.82) of Campbell Biology: Concepts and Connections, 7th edition.
Jane B. Reece, Martha R. Taylor, Eric J. Simon, Jean L. Dickey.

Nucleic acids are polymers of nucleotides

- 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,
  - by dehydration reactions, and
  - by producing a repeating sugar-phosphate backbone with protruding nitrogenous bases.

Nucleic acids are polymers of nucleotides

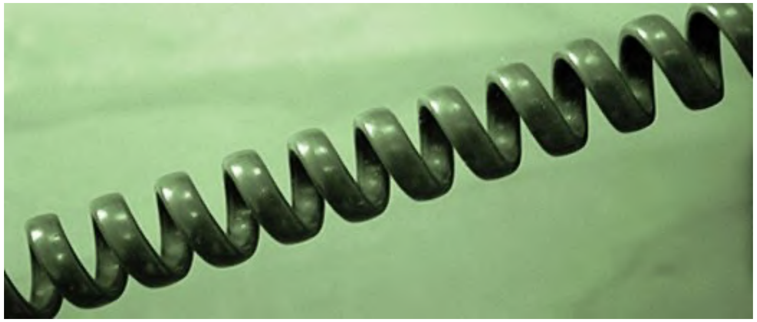
- Two polynucleotide strands wrap around each other to form a DNA **double helix**.
  - The two strands are associated as particular bases always hydrogen bond to one another.
  - **A** pairs with **T**,
  - **C** pairs with **G**,
  - producing **base pairs**.
- RNA is usually a single polynucleotide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

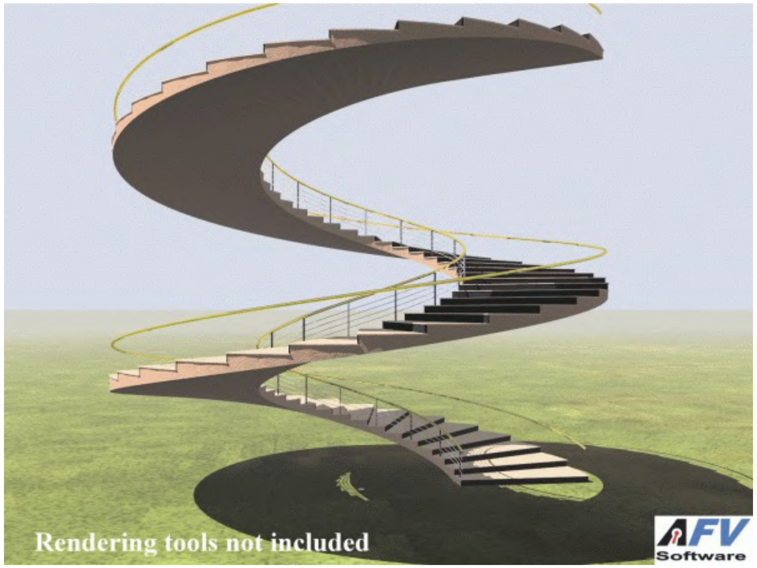


Deoxyribonucleic acid (DNA)

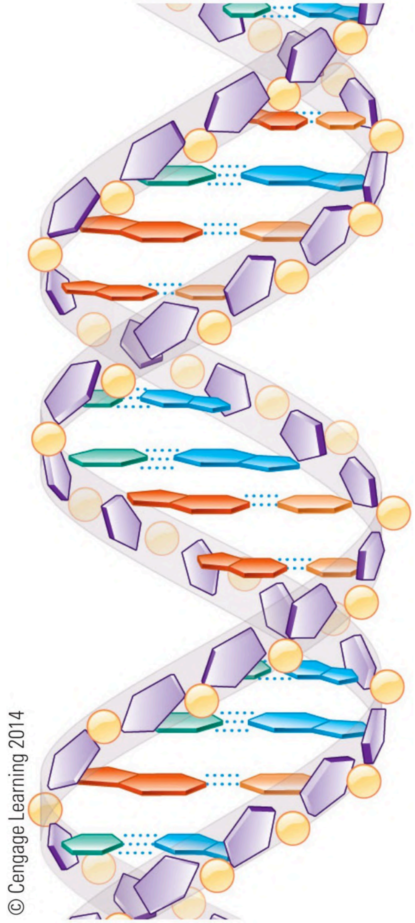
Ribonucleic acid (RNA)

Single-helix





Double-helix

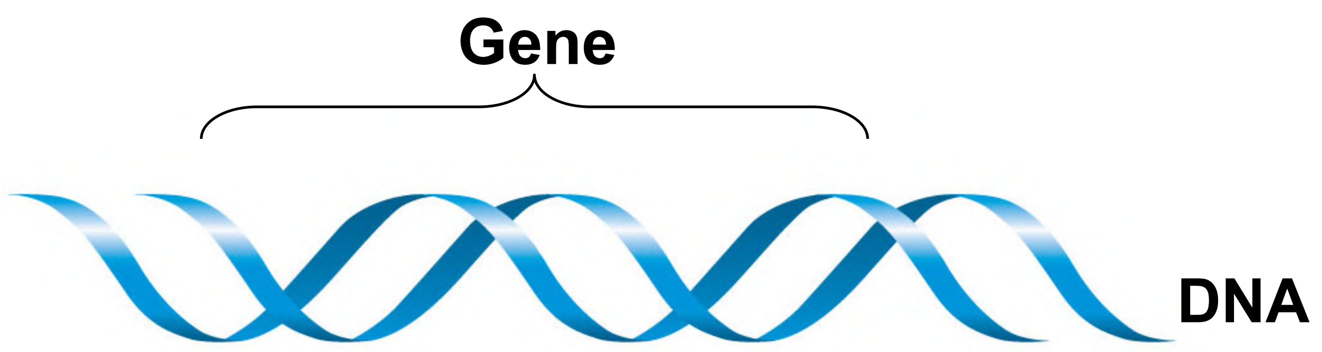


DNA and RNA are the two types of nucleic acids

- The amino acid sequence of a polypeptide is programmed by a discrete unit of inheritance known as a **gene**.
- Genes consist of DNA (deoxyribonucleic acid), a type of nucleic acid.
- DNA is inherited from an organism's parents.
- DNA provides directions for its own replication.
- DNA programs a cell's activities by directing the synthesis of proteins.

DNA and RNA are the two types of nucleic acids

- DNA does not build proteins directly.
- DNA works through an intermediary, **ribonucleic acid (RNA)**.
  - DNA is transcribed into RNA.
  - RNA is translated into proteins.



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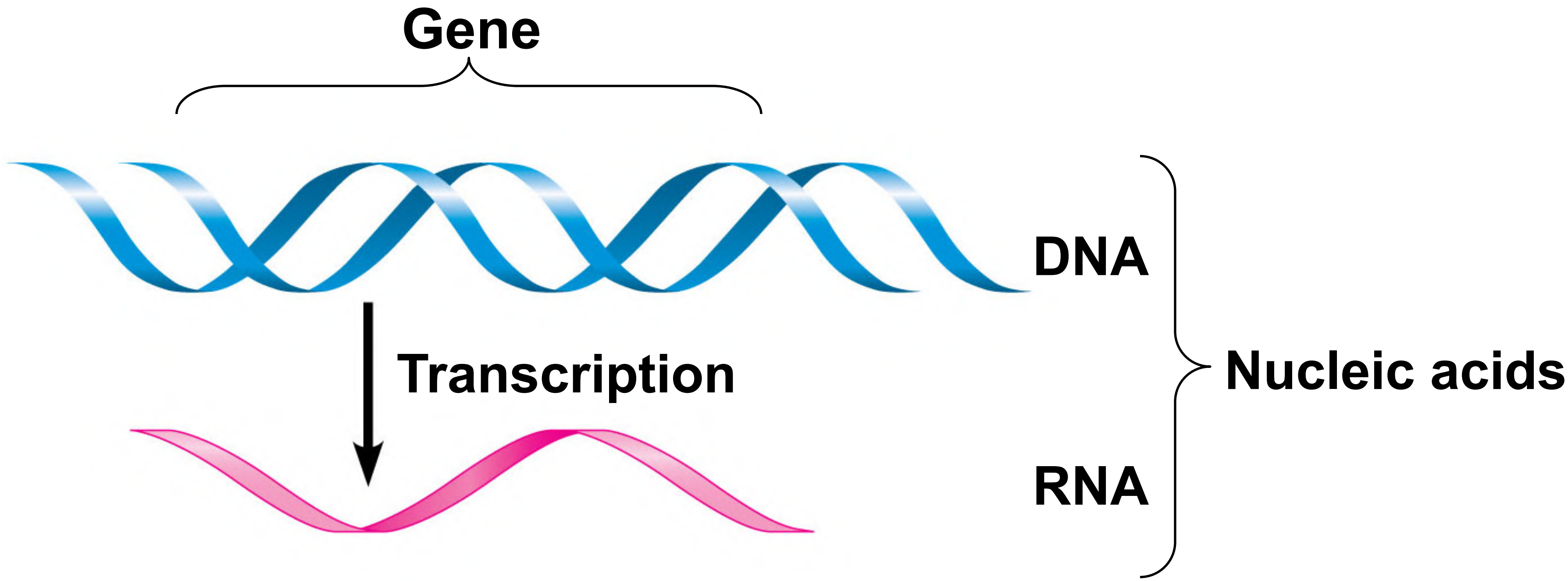

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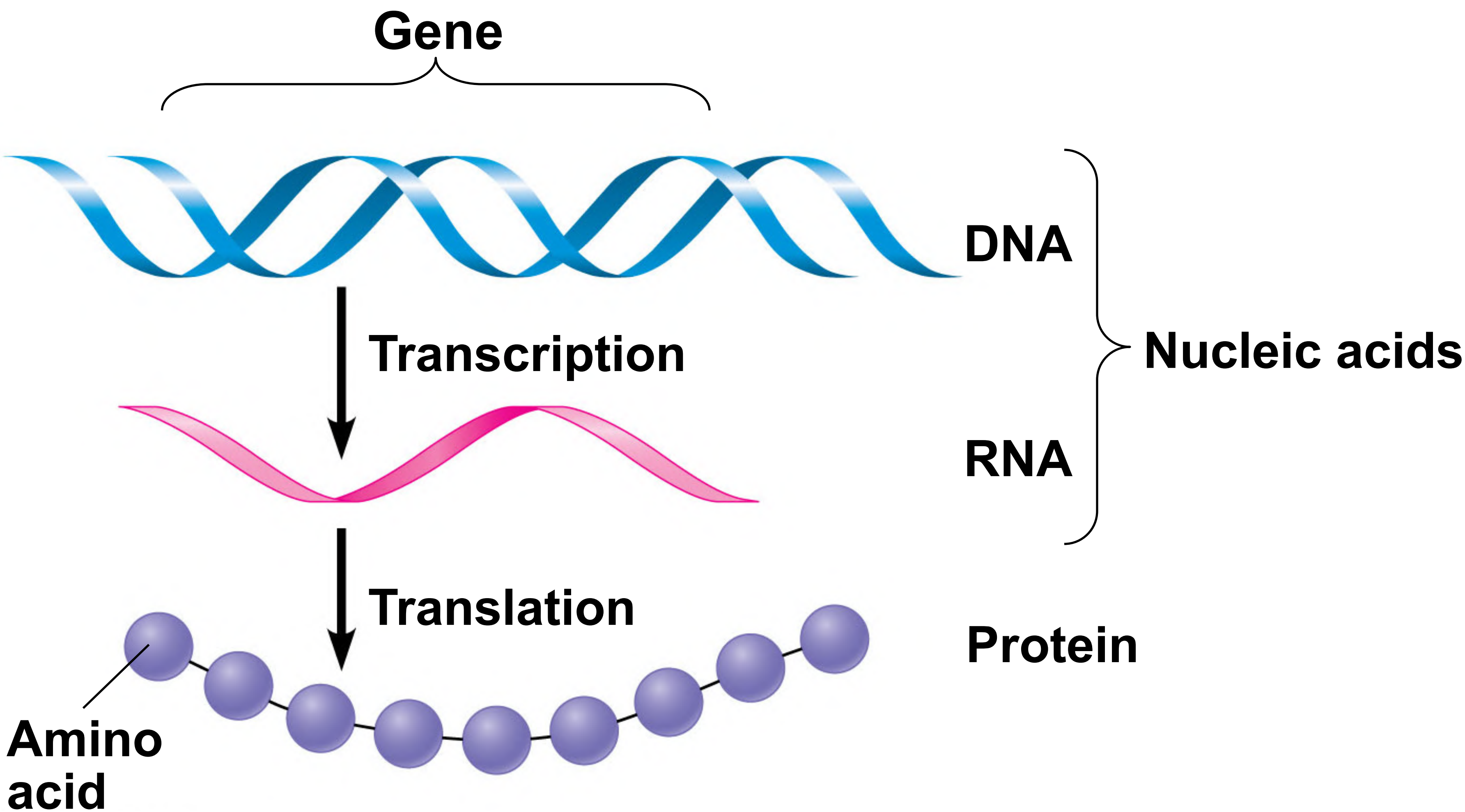

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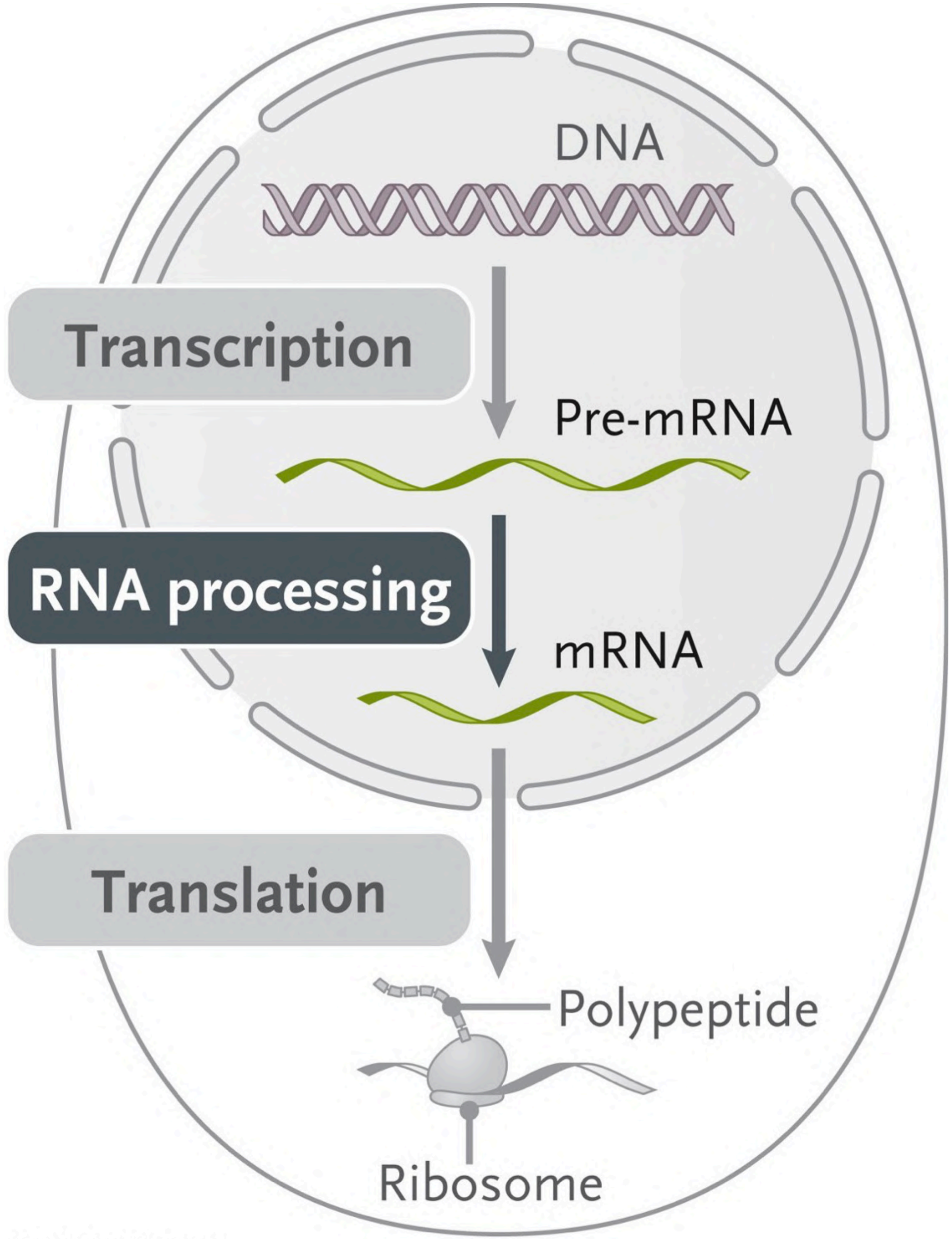
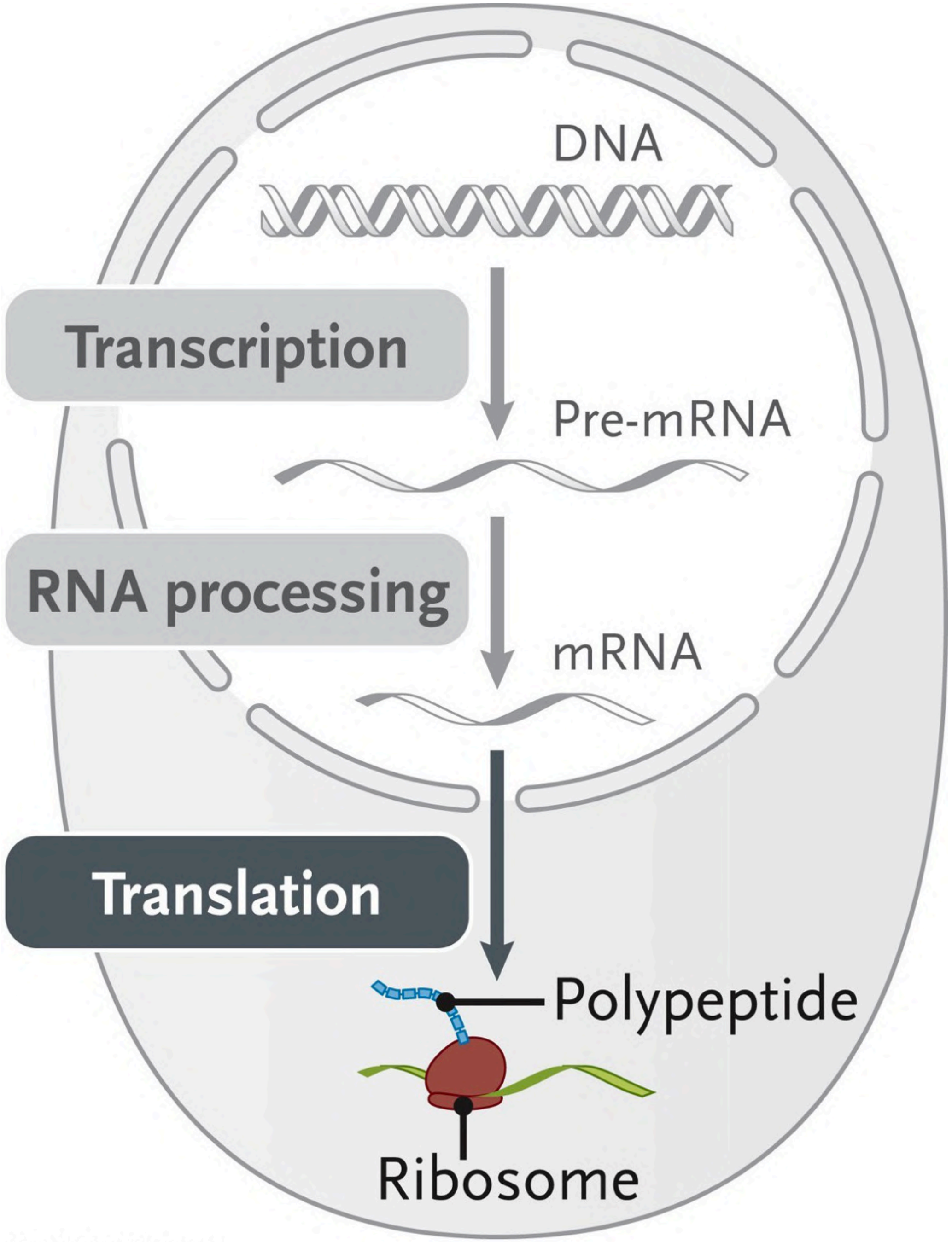

DNA
Transcription
Pre-mRNA
RNA processing
mRNA
Translation
Polypeptide
Ribosome


DNA
Transcription
Pre-mRNA
RNA processing
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Polypeptide
Ribosome

You should now be able to

1. Describe the importance of carbon to life’s molecular diversity.
2. Describe the chemical groups that are important to life.
3. Explain how a cell can make a variety of large molecules from a small set of molecules.
4. Define monosaccharides, disaccharides, and polysaccharides and explain their functions.
5. Define lipids, phospholipids, and steroids and explain their functions.

You should now be able to

6. Describe the chemical structure of proteins and their importance to cells.

7. Describe the chemical structure of nucleic acids and how they relate to inheritance.