


PROJECT LEAD THE WAY

**PLTW**

Igniting imagination and innovation through learning.

**The Chemistry of Life**

# Directions

- To move forward click the arrow. 
- Answer questions included in the presentation to help you review key material.
- Complete work as indicated in your laboratory journal.



# Part I: Chemistry Basics



# Why Chemistry?

- To understand the chemical reactions that occur in the human body, it is essential to have some knowledge of basic chemistry.
- **Biochemistry**, the study of chemical processes in living organisms, is an important foundation for the biomedical sciences.
- So let's learn a bit of chemistry!



# Elements

- All matter is made of **elements**.
- There are 117 known elements, of which 92 occur in nature. The other 25 are produced in laboratories and exist for very short periods of time.
- You can view the periodic table of elements at <http://periodic.lanl.gov/index.shtml>



# Elements in the Human Body

- Four major elements make up 96% of the mass of a human body.
  - Oxygen
  - Carbon
  - Hydrogen
  - Nitrogen



# Elements in the Human Body

Copy this chart in your notebook.

## Major

Oxygen

Carbon

Hydrogen

Nitrogen

## Minor

Calcium

Chlorine

Iron

Phosphorous

Potassium

Sodium

Sulfur

## Trace

Aluminum

Copper

Iodine

Zinc



# Symbols of Elements

- Chemical symbols are often the first letter of the element's name in upper case form. For example, the symbol for carbon is **C**.
- Because several elements begin with the same first letter, for some elements the first and second letters of the name are used. The second letter is in lower case. For example, the symbol for chlorine is **Cl**.
- Sometimes the Latin version of the element's name is used. For example, the symbol for iron is **Fe** from the Latin word *Ferrum*.



# Symbols of Elements

- Using the periodic table, write the correct symbol next to the name of each of the elements in the human body you copied into your notebook.
- Be careful of upper and lower case letters!
- After you have listed the symbols, check your answers with a partner, and go to the next slide.



# Atomic Structure

- Elements are made of **atoms**.
- An atom is the smallest whole particle of an element.
- Atoms have 3 major subatomic particles, and some of these subatomic particles have charges.
  - Protons - positive charge
  - Electrons - negative charge
  - Neutrons - no charge



# Atomic Number

- The number of protons in an atom determines the atom's **atomic number**.
- For example, an element with the atomic number 2 has 2 protons, each with a positive charge.
- The atomic number determines an element's placement on the periodic table.



# Atomic Charges

- The number of protons in an atom is equal to the number of electrons.
- Consequently, the number of positive charges equals the number of negative charges, resulting in a net charge of zero.
- Therefore, atoms do not have a charge and are considered to be neutral.



# Choose One

*Let's practice using atomic numbers to determine atomic structure:*

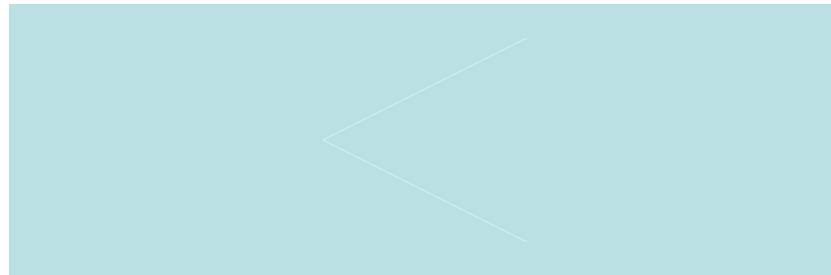
*Oxygen has the atomic number 8. Therefore,*

- Oxygen has 8 protons and 8 electrons.
- Oxygen has 16 protons and 8 electrons.
- Oxygen has 8 protons and 16 electrons.



# Sorry!

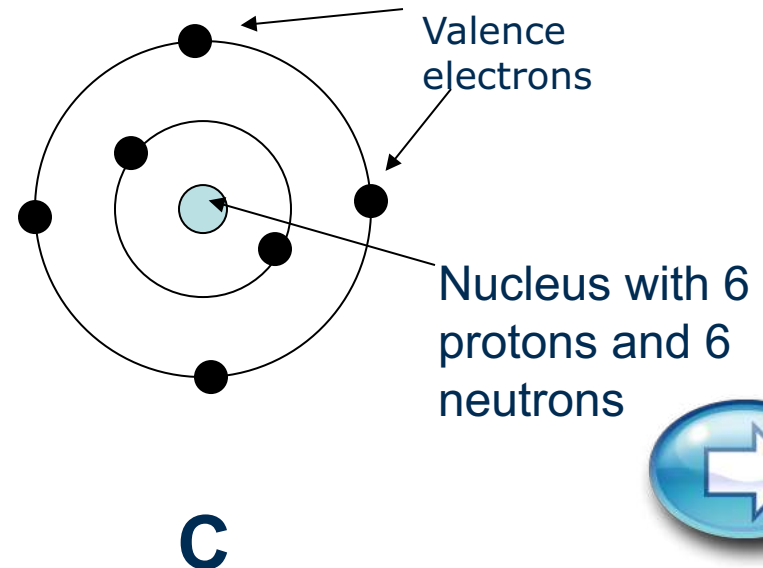
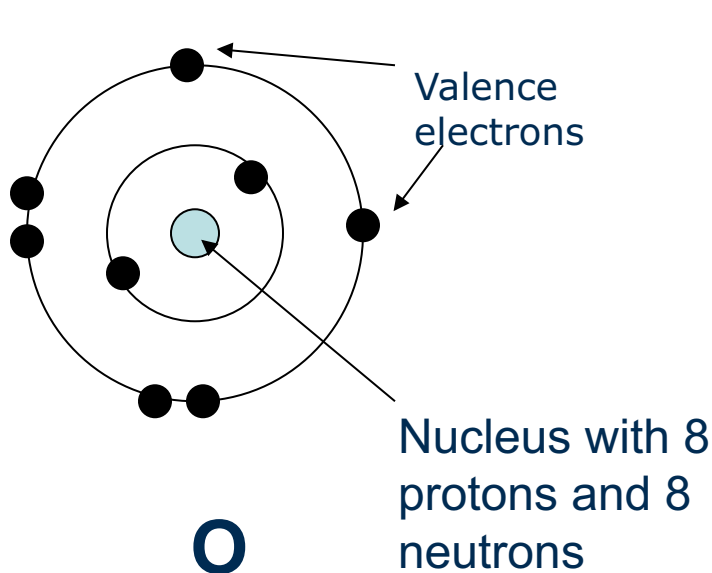
- Go back and review information about atomic number:



# Good Job!

## Now Let's Look At Atomic Structure

- Protons and neutrons are located in the **nucleus**, the center portion of the atom.
- Electrons are moving in **orbits** outside the nucleus.
- The outermost electrons are called **valence electrons**.
- Oxygen has 6 valence electrons and Carbon has 4 valence electrons.



# Valence Electrons

- Valence electrons are very important in chemical reactions.
- An atom strives to have a complete outer shell, consisting of eight valence electrons. An atom gains these electrons and completes this **octet**, or set of eight, by interacting with other atoms.

Note: The exception to this is that hydrogen and helium want 2 electrons in the outer shell.

- Atoms form chemical **bonds** in an attempt to fill their outer shells. If an atom already has a full outer shell, it has no reason to react with another atom.



# Valence Electrons

- Valence electrons can be **transferred** from one atom to the valence shell of another atom, or the valence electrons from two atoms can be **shared**. These interactions form **chemical bonds**.
- When the valence electrons of two atoms are shared, the atoms remain neutral.
- An atom can share each of its valence electrons.



# Chemical Bonds

- Chemical bonds form due to the **force of attraction** between the atoms.
- The stronger the force of attraction, the stronger the bond.
  - Chemical bonds act like glue.
  - Bonds vary in strength from very weak to very strong, just as different glues have varying holding strengths – consider a glue stick compared to super glue.



# Chemical Bonds

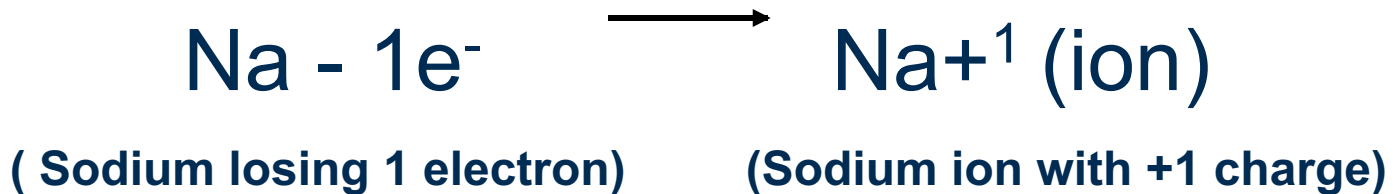
- Two or more atoms can join together to form a new unit. The force holding the atoms together is called a chemical bond.
- When valence **electrons are transferred or shift in location**, an **ionic bond** forms between the atoms. The bond is formed due to the attraction of opposite charges.
- When valence **electrons are shared** between atoms, a **covalent bond** forms between the atoms. The bond is formed due to the physical sharing of the electrons.



# Ionic Bonding

- When atoms transfer electrons, they become **ions** and take on either positive(+) or negative(-) charges.

**Example:**



# Ionic Bonding

- Opposite charges attract and **ionic bonds** can be formed, creating a compound known as a salt.

- **Example**

The opposite charges on sodium and chlorine attract and complete the octet of each molecule, forming an ionic bond.



# Choose One

*An atom of potassium (K) may become a potassium ion ( $K^+$ ) by:*

- Losing one electron



- Gaining one electron

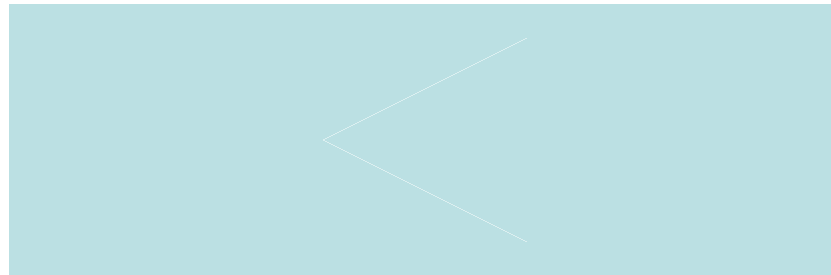


- Losing one proton



# Sorry!

- Go back and review ions and ionic bonding:



Correct!

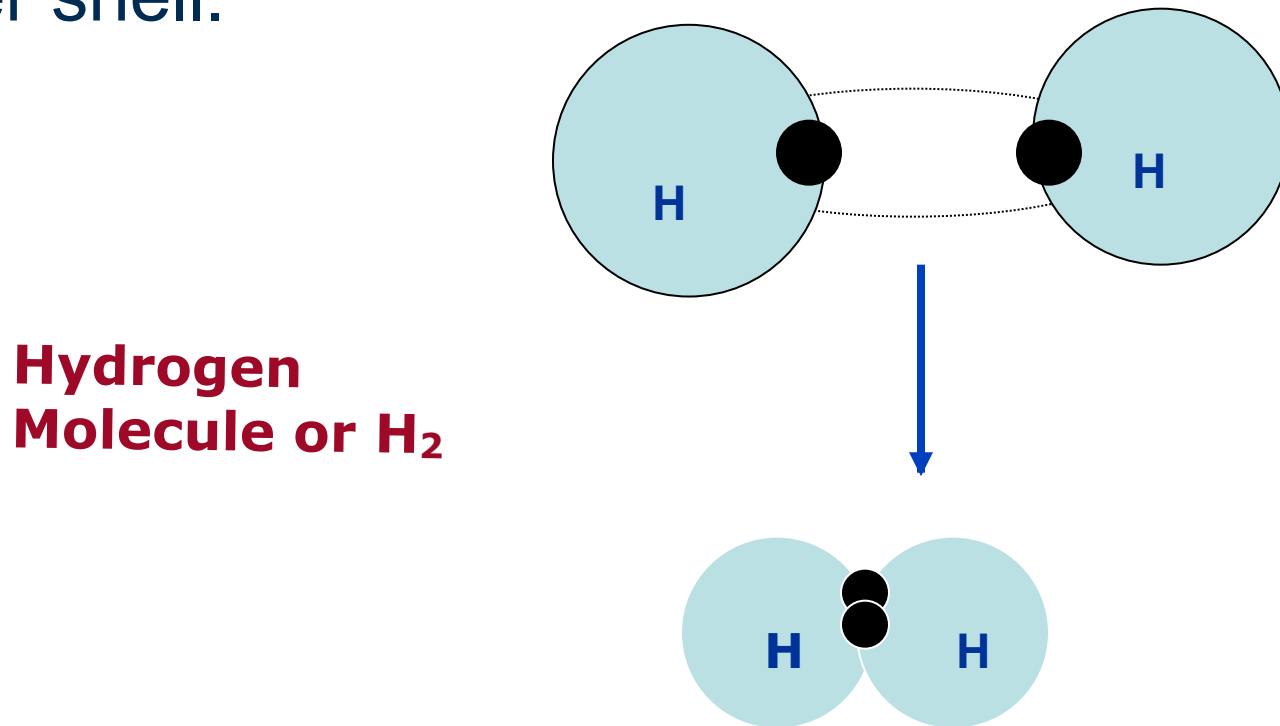
- Continue on to Covalent Bonding



# Covalent Bonds

- Electrons are shared between atoms.

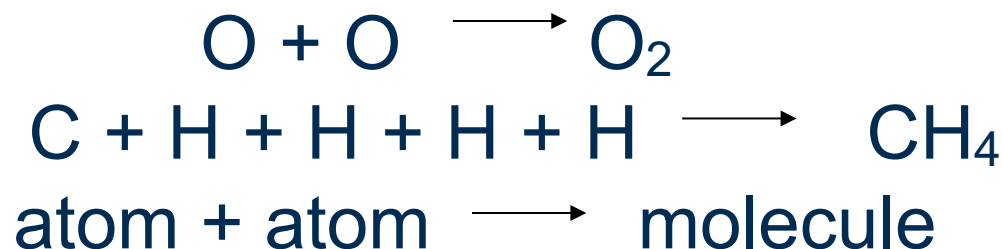
Note: Hydrogen, H, only needs 2 electrons in its outer shell.



# Covalent Bonds

- Covalent bonds form between atoms of the same element or between atoms of different elements.
- **Molecules** are formed when two or more atoms are joined together by covalent bonds.
- These atoms can come from the same or different elements.

**Examples:**



# Covalent Bonds

- If two atoms share a single pair of electrons, a **single bond** is formed.
- If two atoms share two pairs of electrons, a **double bond** is formed.
- Three pairs of electrons can even be shared in a **triple bond**.



# Chemical Reactions

- **Chemical reactions** occur when atoms, molecules, or ions interact. Bonds are either broken or assembled.
- Energy is stored in chemical bonds.
- The energy in these bonds is released when the bonds are broken.
- The large macromolecules consumed in our food are broken down into smaller molecules to release energy for our daily activities.

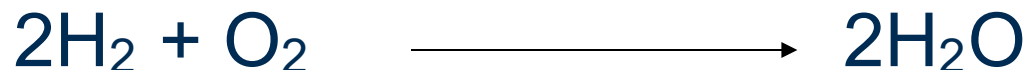


# Chemical Equations

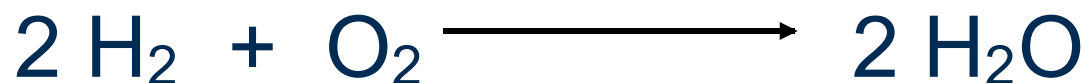
- **Chemical equations** are “chemical sentences” showing what is happening in a reaction.
- **Example:**



What does the equation below mean?



# Answer



2 Hydrogen molecules plus 1 Oxygen molecule react to form 2 molecules of water. The hydrogen and oxygen molecules are the reactants and the water molecules are the products.

Were you correct? If yes, proceed. If not, go back and review or ask for clarification from your teacher.



# Nice Work!



- You now have a basic knowledge of chemistry that you will use in your continued study of the biomedical sciences.
- You will now explore the molecules of life in more detail.



# Return to Step 3 in Activity

Note: Leave this presentation open as you will return to it shortly



# Part II: Macromolecules



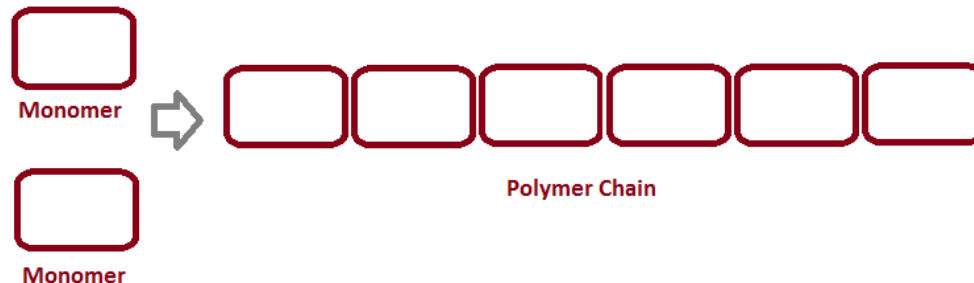
# The Building Blocks of Life

- All life is made up of four main building blocks called **macromolecules**.
- The four types of macromolecules are:
  - Carbohydrates
  - Proteins
  - Lipids
  - Nucleic Acids



# Macromolecules

- Macromolecules are large molecules (the word *macro* means big or large).
- With the exception of lipids, macromolecules are also **polymers**.
  - A polymer is a large molecule made of many smaller repeating sub-units, called **monomers**, linked together.



Monomer: A single unit

Polymer: Chain of multiple monomers



# Return to Step 10 in Activity

Note: Leave this presentation open as you will return to it shortly



# Click on the Puzzle Set that you will be using next:



**Puzzle Set #1 – Carbohydrates**



**Puzzle Set #2 – Proteins**



**Puzzle Set #3 – Lipids**



**Nucleic Acids**

# **Puzzle Set #1 – Carbohydrates**



# Carbohydrates

- Carbohydrates are the primary energy source for the human body.
  - The body can obtain energy from lipids and proteins, but carbs are used first if available
  - Carbs are easily broken down by the body
  - The energy stored in carbs is captured and ultimately transferred to another molecule called adenosine triphosphate (ATP)
    - ATP is the actual energy source for all cell processes including communication, growth, repair, and reproduction



# Carbohydrates

- All carbohydrates are made up of only three elements: **carbon**, **hydrogen**, and **oxygen**.
- All carbs are composed of simple sugars (composed on one monomer) – called ***monosaccharides***.
  - Examples of monosaccharides:
    - Glucose – the primary building block of many complex carbohydrates that are essential for our bodies; common sweetener used in foods
    - Fructose – simple sugar found in many fruits
    - Deoxyribose – the sugar molecule used to form DNA
    - Ribose – the sugar molecule used to form RNA



# Choose One

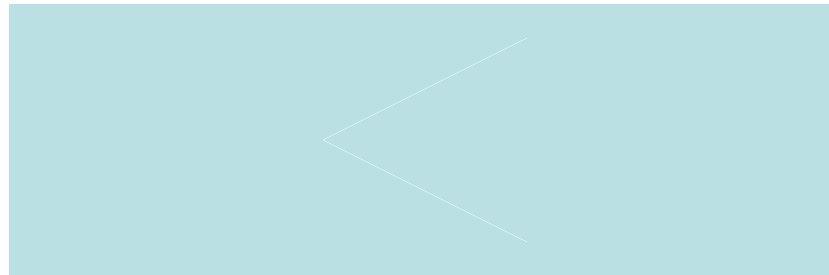
■ *Carbohydrates are mainly used in our bodies for... ?*

- Structural molecules, such as hair and fingernails
- Building genetic material
- Energy storage
- Lipid storage



# Sorry!

- Go back and review  
Carbohydrates:



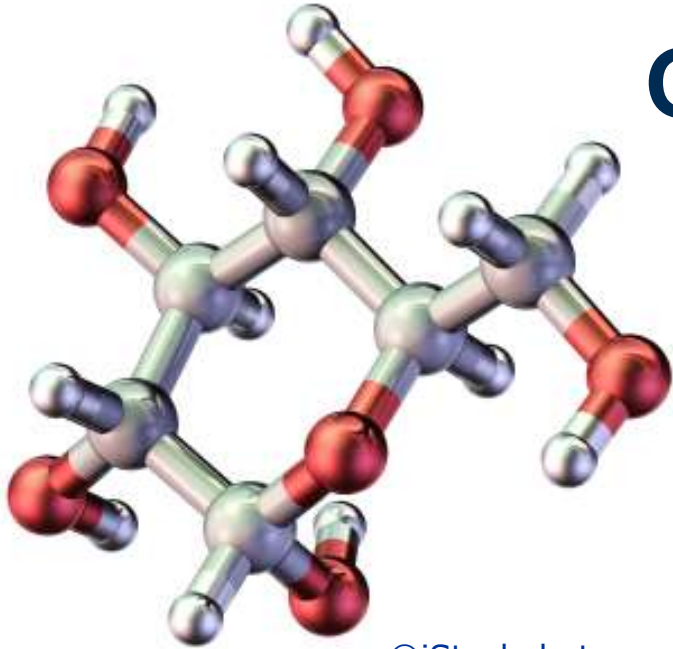
# Correct!

- Continue on to the next slide

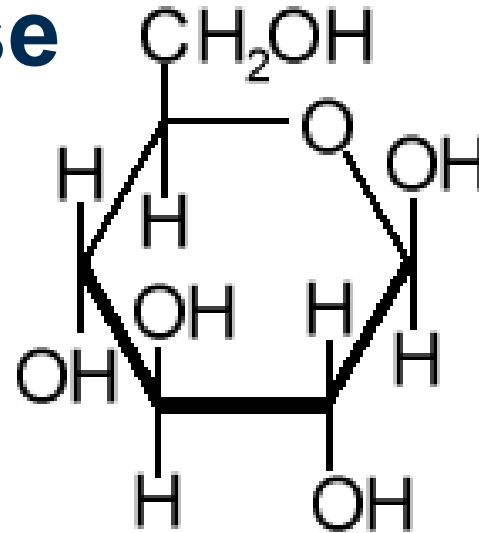


# Monosaccharides

## Glucose



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**Return to Step 15 in Activity**

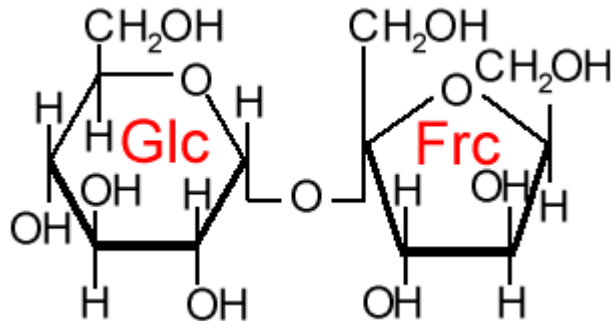
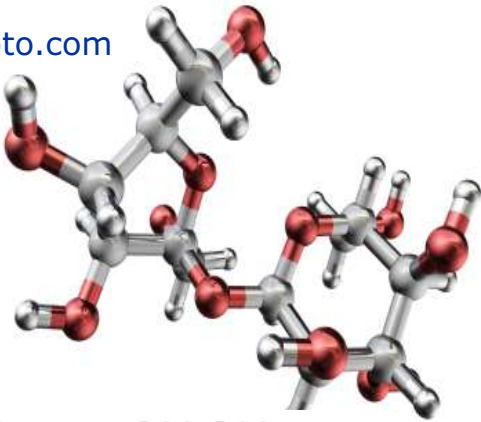
Note: Leave this presentation open as you will return to it shortly



# Disaccharides

- A disaccharide is a carbohydrate created when two monosaccharides are linked together.

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**Sucrose**

## Examples of disaccharides:

- Sucrose – glucose linked to fructose (common table sugar)
- Maltose – two linked glucose molecules (sugar used to make malted candy and milkshakes)
- Lactose – glucose linked to galactose (sugar found in cow's milk)

## Return to Step 17 in Activity

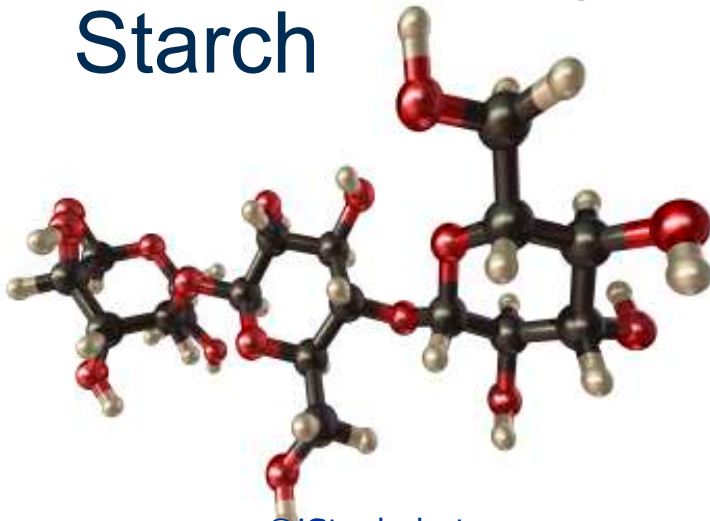


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# Polysaccharides

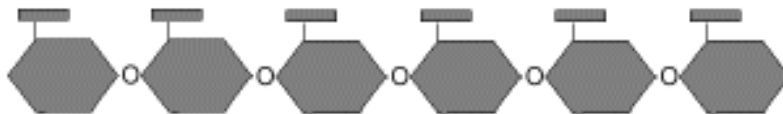
- A polysaccharide is a carbohydrate created when three or more monosaccharides are linked together (polysaccharides can contain hundreds or even thousands of sugar units bonded together).

## Starch



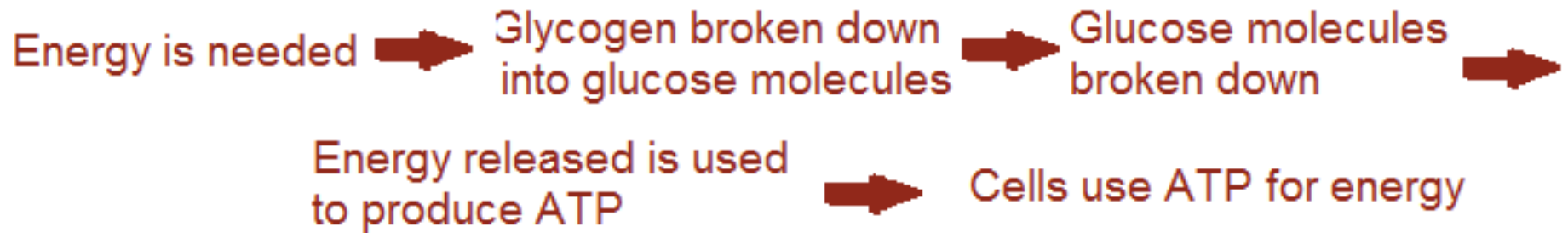
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- These carbohydrates are referred to as complex carbohydrates.
- Complex carbohydrates:
  - Don't taste sweet
  - Are insoluble in water
  - High energy foods that can be harnessed for energy



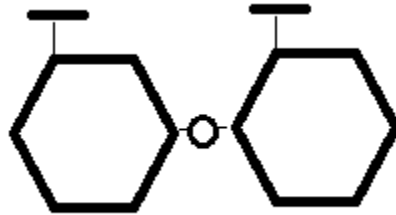
# Polysaccharides

- Animals, including humans, combine multiple glucose molecules obtained from food to form **glycogen**.
- Glycogen is stored in the liver and muscle tissue to use as an energy source for when the body needs it.



# Choose One

- *The molecule shown below is a ... ?*

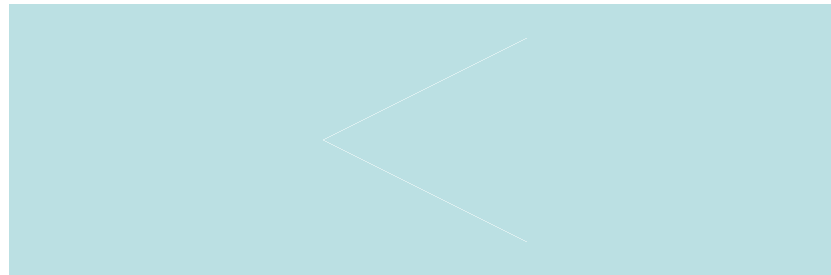


- Disaccharide
- Monosaccharide
- Complex Carbohydrate



# Sorry!

- Go back and review  
Carbohydrates:



# Correct!

- Continue on and return to Step 25 in Activity

Note: Leave this presentation open as you will return to it shortly



# Click on the Puzzle Set that you will be using next:



**Puzzle Set #1 – Carbohydrates**



**Puzzle Set #2 – Proteins**



**Puzzle Set #3 – Lipids**



**Nucleic Acids**

# Puzzle Set #2 – Proteins



# Proteins

- Are large molecules with many different shapes and structures.
- Are the primary structural component of all tissues in humans and all other animals.
- Build, maintain, and repair the tissues in the body.
- Are highly specialized and have specific purposes in the body.
  - Structural components
  - Signal or communication molecules
  - Enzymes
  - Transport molecules
  - Hormones



# Proteins

- All proteins are composed of **amino acids** linked together.
- All amino acids are composed of:
  - Amine group ( $\text{NH}_2$ )
  - Carboxyl group ( $\text{COOH}$ )
  - Variable group (referred to as a R group)

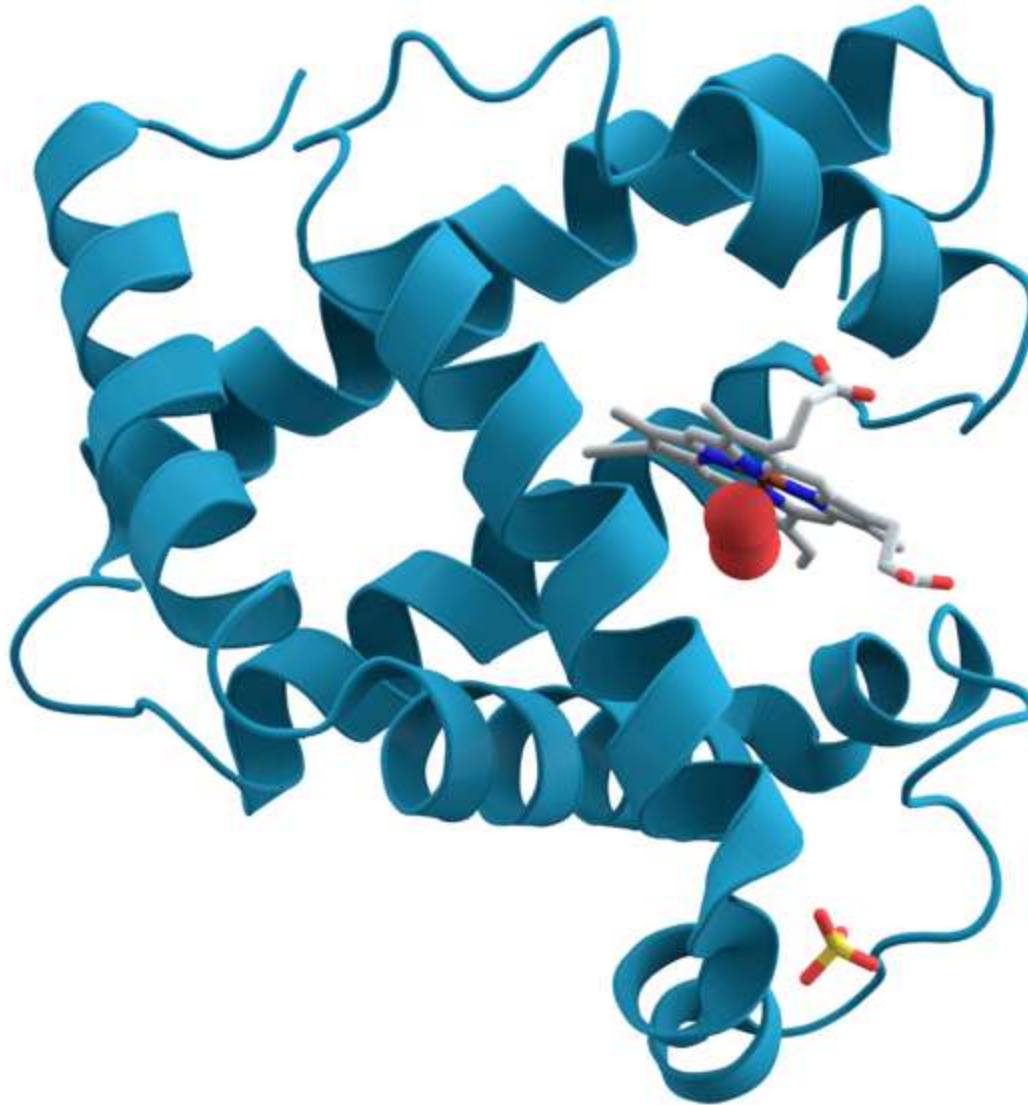


# Proteins

- The bond that holds two amino acids together is called a **peptide bond**.
- Short chains of amino acids, generally containing fewer than 50 amino acids, are referred to as **peptides**.
- Longer chains of amino acids are referred to as **polypeptides**.
- Each protein has its own combination of different amino acids.



# Proteins



# Choose One

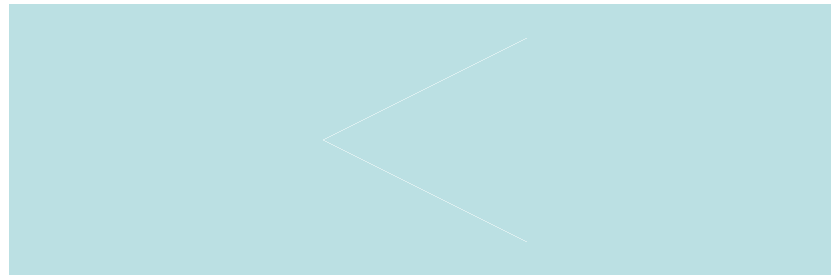
*Proteins are made up of ... ?*

- Fatty acids
- Amino acids
- Carbohydrates



# Sorry!

- Go back and review Proteins:



# Correct!

- Return to Step 31 on the activity document.



# Click on the Puzzle Set that you will be using next:



**Puzzle Set #1 – Carbohydrates**



**Puzzle Set #2 – Proteins**



**Puzzle Set #3 – Lipids**



**Nucleic Acids**

# Puzzle Set #3 – Lipids



# Lipids

- Are made up of **fatty acids** and **glycerol**.
- Are non-polar (no atomic charges or ions) and hydrophobic (do not dissolve in water).
- Are primarily composed of **hydrogen** and **carbon** atoms, along with a few **oxygen** atoms.
- Examples:
  - Triglycerides (commonly referred to as fats and oils)
  - Phospholipids
  - Steroids
  - Fat-soluble vitamins such as A, E, D and K

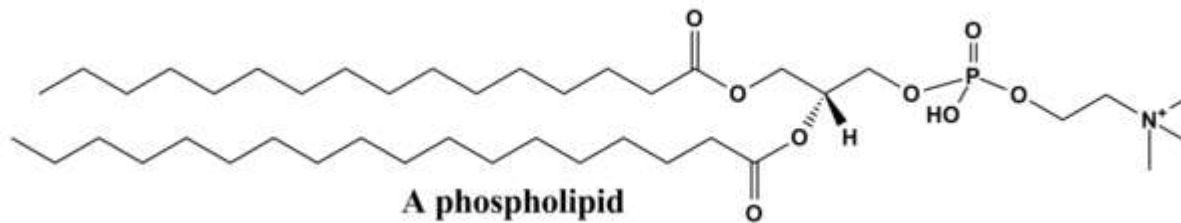
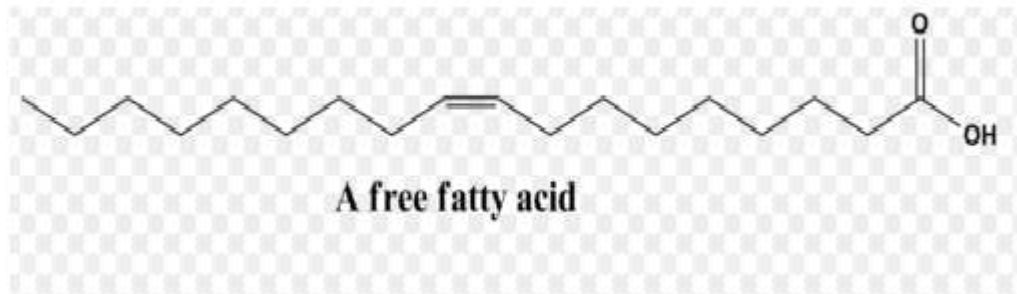
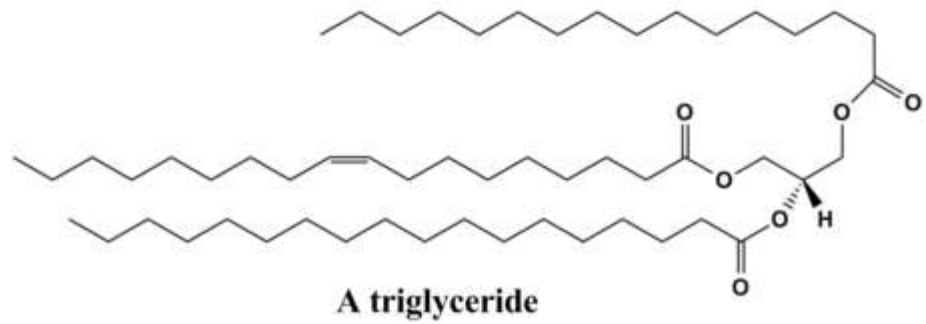
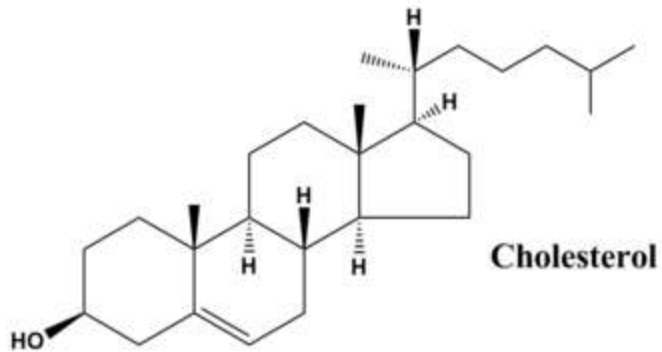


# Lipids

- Lipids have many functions in the body.
  - **Triglycerides**, fats in the food we eat, store large quantities of energy and can be classified as saturated or unsaturated
  - **Phospholipids** are essential for the structure of membranes
  - **Steroid hormones** are responsible for cell communication
  - **Vitamin D** responsible for bone structure



# Lipids



# Choose One

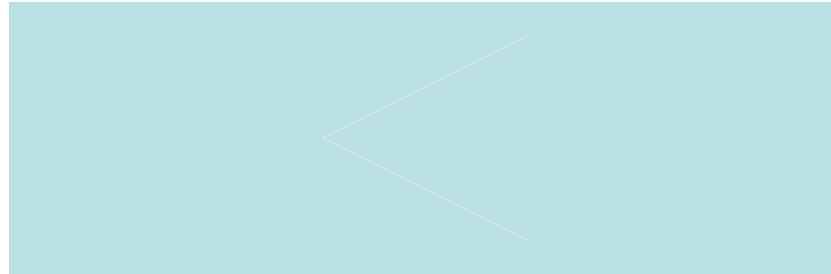
*Which of these is considered to be a lipid?*

- Fatty acids
- Triglycerides
- Steroid hormones
- All of the above



# Sorry!

- Go back and review Lipids:



# Correct!

- Return to Step 45 on the activity document.



# Click on the Puzzle Set that you will be using next:



**Puzzle Set #1 – Carbohydrates**



**Puzzle Set #2 – Proteins**



**Puzzle Set #3 – Lipids**



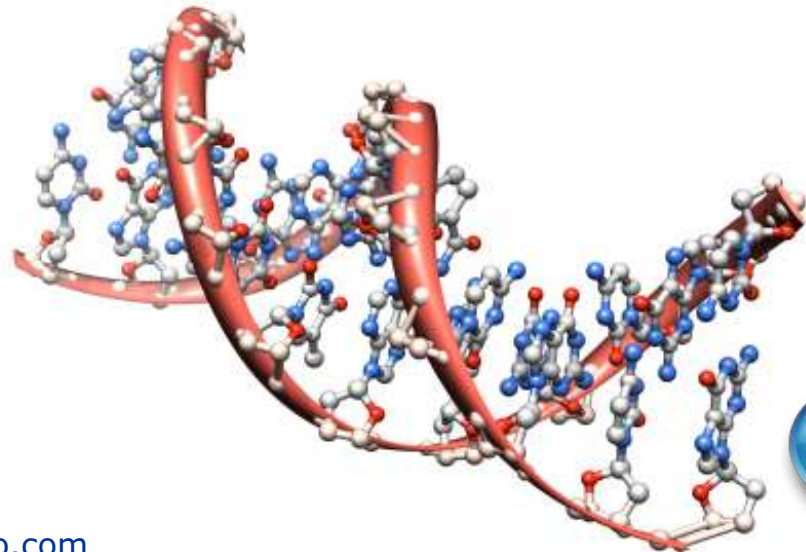
**Nucleic Acids**

# Nucleic Acids



# Nucleic Acids

- Nucleic acids are composed of **carbon, oxygen, hydrogen, nitrogen, and phosphorus** atoms
- Nucleic acids are made up of **nucleotides**.
- Stores and carries genetic information in the form of **DNA** and **RNA**.



# Choose One

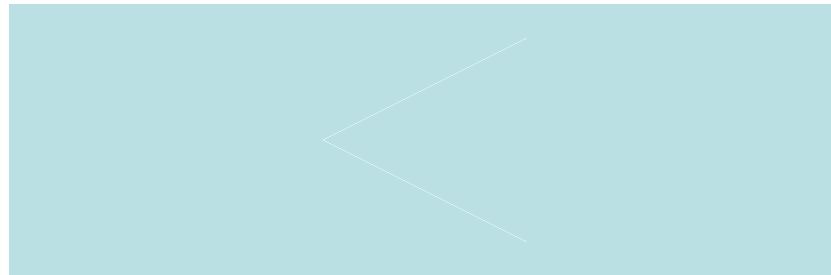
*DNA is a polymer made of ... ?*

- Fatty acids
- Nucleotides
- Ribose sugars
- All of the above



# Sorry!

- Go back and review Nucleic Acids:



# Correct!

- Continue on to the next slide



# Nice Work!



- You're done!! Return to Step 61 in Activity