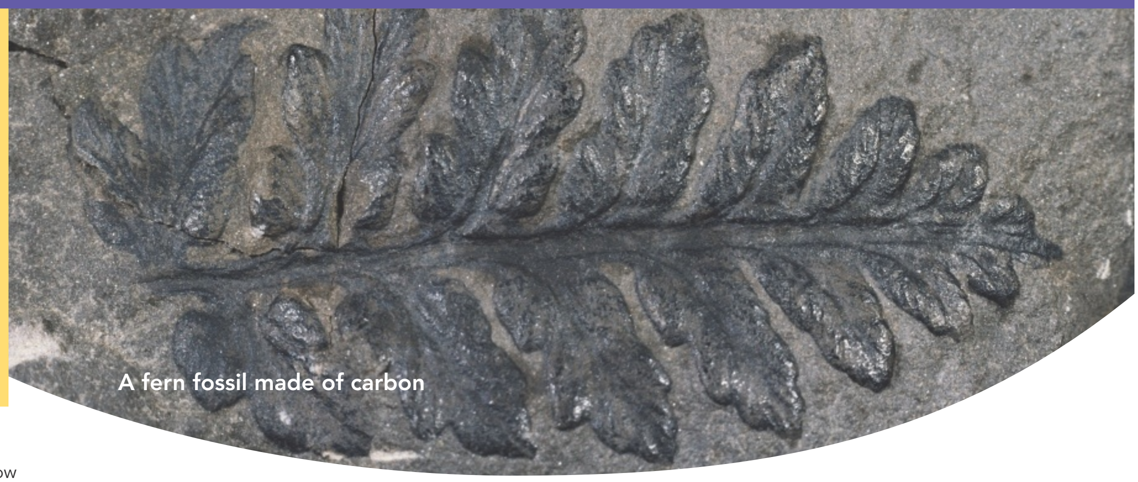
Grade 10 NTI Day #7 Biology

Assignment: Please read the excerpt below as an independent reading assignment. Then read and answer the questions below the excerpt.

LESSON 2.3

Carbon Compounds


A fern fossil made of carbon

KEY QUESTIONS

- *What elements does carbon bond with to make up life's molecules?*
- *What are the functions of each of the four groups of macromolecules?*

HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

VOCABULARY

monomer • polymer
carbohydrate
lipid • nucleotide
nucleic acid • protein
amino acid

READING TOOL

As you read, identify the similarities and differences between the different groups of macromolecules. Take notes in your **Biology Foundations Workbook.**

Chemists once called the compounds in living things "organic," believing they were different from nonliving compounds. Today we understand that living things obey the same chemical principles as nonliving. But the term "organic chemistry" is still around, referring today to the chemistry of carbon.

The Chemistry of Carbon

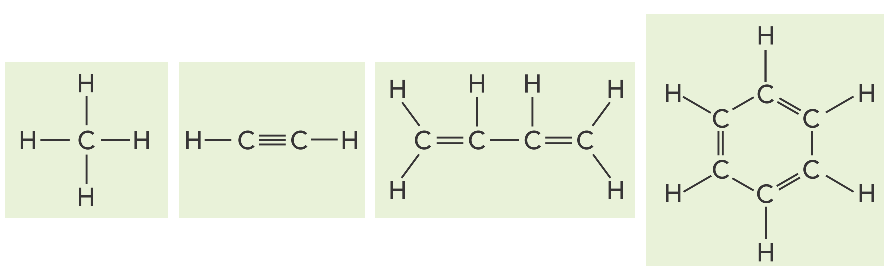
What's the big deal about carbon? Why is it so interesting that it has its own branch of chemistry? There are two reasons for this. First, carbon atoms have four valence electrons, allowing them to form strong covalent bonds with many other elements. ***Carbon can bond with many elements—including hydrogen, oxygen, phosphorus, sulfur, and nitrogen—to form compounds with many different chemical properties***. Living organisms depend upon these compounds.

Even more important, one carbon atom can bond to another, which gives carbon the ability to form chains that are almost unlimited in length. As shown in **Figure 2-12**, these carbon-carbon bonds can be single, double, or triple covalent bonds. Chains of carbon atoms can even close up on themselves to form rings, as shown by the structure of benzene. No other element matches carbon's versatility or the size of molecules that carbon can build.

Figure 2-12

Carbon Structure

Carbon can form single, double, or triple bonds with other atoms. Each line between atoms in a molecular drawing represents one covalent bond.



Methane **Acetylene** **Butadiene** **Benzene**

Macromolecules

The large organic molecules found in living things are known as macromolecules, literally—"giant molecules"—because of their size. Most macromolecules are produced by a process known as polymerization (pah lih mur ih ZAY shun), in which larger compounds are built by joining smaller ones together. The smaller units, or **monomers**, are joined together to form **polymers**. The monomers in a polymer may be identical, like the links on a metal watchband, or different, like the beads in a multicolored necklace. **Figure 2-13** illustrates the process of polymerization.

Four major groups of macromolecules are found in living things: carbohydrates, lipids, nucleic acids, and proteins. As you read about these molecules, compare their structures and functions.

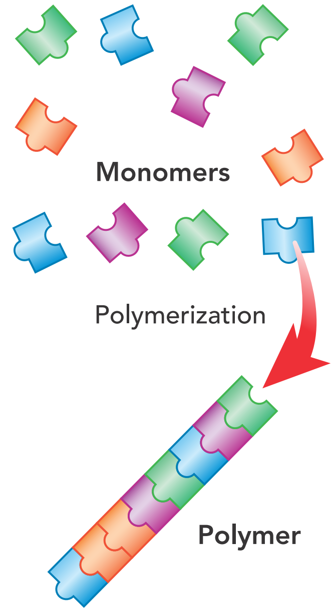


Figure 2-13
Polymerization

When monomers join together, they form polymers.

Carbohydrates

Examples of carbohydrates include sugar, starch, and cellulose. **Carbohydrates** are made up of carbon, hydrogen, and oxygen atoms, usually in a ratio of 1 : 2 : 1. ***Organisms use carbohydrates to store and release energy, as well as for structural support and protection.*** The breakdown of sugars, such as glucose, supplies immediate energy for cell activities. Many organisms store extra sugar as complex carbohydrates known as starches. The monomers in starch polymers are sugar molecules.

BUILD VOCABULARY

Prefixes The prefix *mono-* means one, the prefix *di-* means "two," and the prefix *poly-* means "many."

Simple Sugars Single sugar molecules are also known as monosaccharides (mahn oh SAK uh rydz). Besides glucose, which is shown in **Figure 2-14**, monosaccharides include galactose, which is a component of milk, and fructose, which is found in many fruits. Ordinary table sugar, sucrose, is a disaccharide, a compound made by joining together two simple sugars, fructose and glucose.

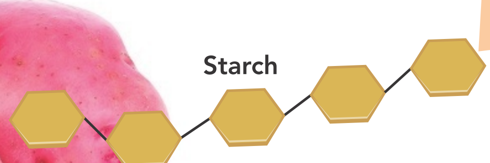
Complex Carbohydrates The macromolecules formed by joining many monosaccharides together are known as polysaccharides. Many animals store excess sugar in a polysaccharide called glycogen. When the level of glucose in your blood runs low, glycogen is broken down into glucose, which is then released into the blood. The glycogen stored in your muscles supplies the energy for muscle contraction and, thus, for movement.

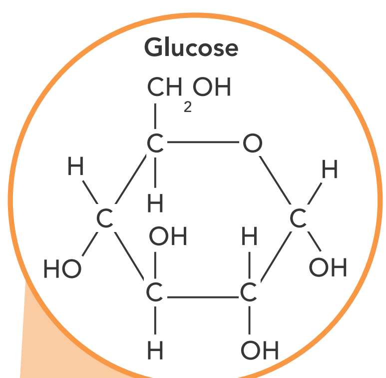
Video

Discover the stinky chemicals in the durian fruit.

Figure 2-14
Carbohydrates

Starches form when sugar molecules join together in a long chain. Potatoes are made up mostly of starches, as are foods like bread and pasta.





CASE STUDY Analyzing Data

Trace Elements

Just four elements—oxygen, carbon, hydrogen, and nitrogen—make up 96 percent of living things. The table shows the percentages of some other elements.

1. **Construct an Explanation** Is the importance of an element in the body related to its percentage of body weight? Cite the evidence in the table to support your explanation.
2. **Evaluate Claims** A student claims that the four types of macromolecules make up all of the important compounds of the human body. Provide evidence and reasoning to support or refute this claim.

Element	Percentage of Body Weight	Uses
Phosphorus	1.0	Formation of bones and teeth
Potassium	0.25	Regulation of nerve function
Sulfur	0.25	Present in two amino acids
Sodium	0.15	Regulation of nerve function, blood levels
Chlorine	0.15	Fluid balance
Magnesium	0.05	Bone and muscle function
Iron	0.006	Carrying oxygen in the blood

Other trace elements include fluorine, copper, zinc, and iodine.

INTERACTIVITY

Explore how dietary fat affects blood cholesterol levels.

Starches and Cellulose Plants use a slightly different polysaccharide, called starch, to store excess sugar. Plants also make an important polysaccharide called cellulose. Tough, flexible cellulose fibers give plants much of their strength and rigidity. Cellulose is the major component of both wood and paper, so you may actually be looking at cellulose if you are reading these words on a printed page.

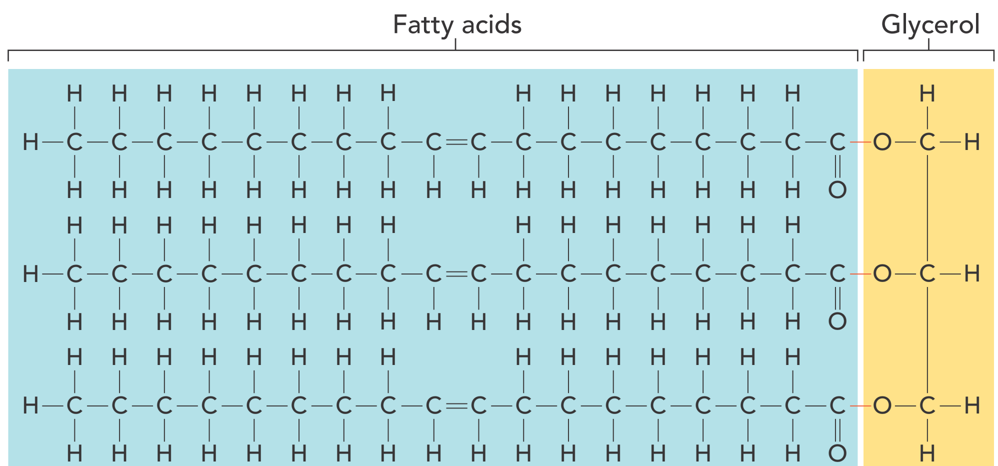
Lipids

Lipids are a large and varied group of macromolecules that are generally not soluble in water. **Lipids** are made mostly from carbon and hydrogen atoms, as shown in **Figure 2-15**. Lipids include the compounds we call fats, oils, and waxes. ***Lipids can be used to store energy, and they form important parts of biological membranes and waterproof coverings***. Many lipids, such as steroid hormones, function as chemical messengers.

Figure 2-15

Lipids

Lipid molecules, like this triglyceride, are built from fatty acids and glycerol. Olive oil, which contains mainly unsaturated fatty acids, is liquid at room temperature.



Many lipids are formed when a glycerol molecule combines with compounds called fatty acids. If each carbon atom in these fatty acid chains is joined to another carbon atom by a single bond, the lipid is said to be saturated because the fatty acids contain the maximum possible number of hydrogen atoms. If there is at least one carbon-carbon double bond in a fatty acid, the fatty acid is said to be unsaturated. Lipids whose fatty acids contain more than one double bond are said to be polyunsaturated. If the terms *saturated* and *polyunsaturated* seem familiar, you have probably seen them on food package labels. Lipids that contain unsaturated fatty acids, such as olive oil, tend to be liquids at room temperature. Other cooking oils, such as corn oil, sesame oil, canola oil, and peanut oil, contain polyunsaturated lipids.

READING CHECK **Compare** How are saturated fats different from unsaturated fats?

INTERACTIVITY

Explore how the body breaks down sugar molecules in order to build other types of macromolecules needed by the body.

Nucleic Acids

As shown in **Figure 2-16**, **nucleotides** are monomers that consist of three components: a 5-carbon sugar, a phosphate group ($-PO_4$), and a nitrogenous base. **Nucleic acids** are polymers assembled from nucleotides. Some nucleotides, including the compound known as adenosine triphosphate (ATP), have important functions in capturing and transferring chemical energy. Individual nucleotides can be joined by covalent bonds to form a polynucleotide, or nucleic acid.

There are two kinds of nucleic acids: ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). As their names indicate, RNA contains the sugar ribose while DNA contains the sugar deoxyribose. The sequence of bases in both DNA and RNA contains information used by the cell to build other molecules such as proteins. ***Nucleic acids store and transmit hereditary, or genetic, information.***

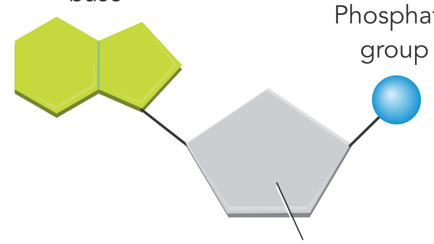


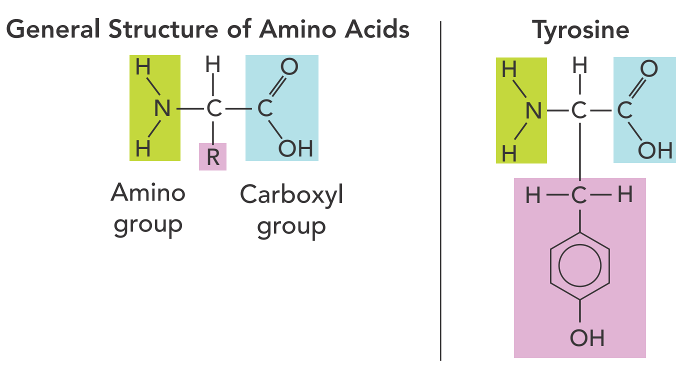
Figure 2-16

A Nucleotide

The monomers that make up a nucleic acid are nucleotides. Each nucleotide has a 5-carbon sugar, a phosphate group, and a nitrogenous base.

Proteins

Proteins are macromolecules containing nitrogen as well as carbon, hydrogen, and oxygen. Proteins are polymers of molecules called amino acids. **Amino acids** are compounds with an amino group ($-NH_2$) on one end and a carboxyl group ($-COOH$) on the other end. In addition to serving as the building blocks of proteins, many amino acids serve other purposes. The amino acid tyrosine, shown in **Figure 2-17**, is used to produce a hormone, or chemical messenger, known as thyroxine. Thyroxine is produced in the thyroid gland from tyrosine and as many as four atoms of iodine.



CASE STUDY

Figure 2-17

Amino Acids

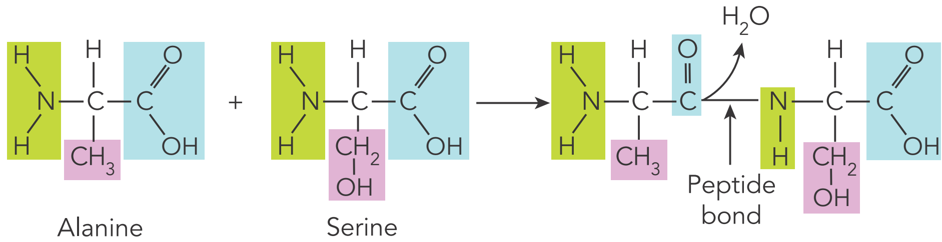
All amino acids have the same basic structure. Only the R group differs among them. Amino acids join together to form proteins or may help form compounds like thyroxine.

Figure 2-18

Peptide Bonding

Peptide bonds are formed between the amino group of one amino acid and the carboxyl group of another amino acid. In this diagram, the amino groups are shaded in green, the carboxyl groups are shaded in blue, and the R-groups are shaded in purple.

Formation of Peptide Bond



Peptide Bonding Covalent bonds called peptide bonds link amino acids together to form a polypeptide. As shown in **Figure 2-18**, the amino group (–NH_2) of one amino acid links to the carboxyl group (–COOH) of another amino acid. When the two groups react, they release a water molecule (H_2O) as the peptide bond forms.

Function A protein is a functional molecule built from one or more polypeptides. Proteins can have a variety of shapes and sizes, and they serve a variety of purposes as well. ***Some proteins function to control the rate of reactions and regulate cell processes. Others form important cellular structures, while still others transport substances into or out of cells or help to fight disease.*** Hair (shown in **Figure 2-19**) and nails are made of protein.

Proteins enable the cells of the body to communicate and interact. Many cells have proteins exposed on their surfaces that act as receptors to certain compounds. When a receptor encounters such a compound, it transmits a chemical signal into the cell, setting off a response. The result may be an increase or decrease in cellular activity, the production of a new protein, or a change in the cell's pattern of growth and development.

For example, thyroxine binds to cells with a specific receptor protein on their surfaces. That binding increases cell activity. In this way, the thyroid gland can send chemical signals throughout the body that control the activities of millions of cells. If thyroxine levels are too low, especially during childhood, development of the brain and nervous system can be affected.

Figure 2-19

Protein

Hair and nails are made of a tough protein called keratin.

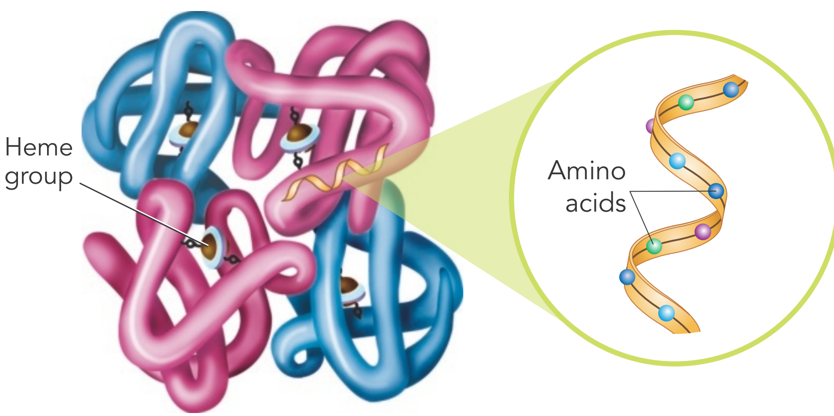
Structure More than 20 different amino acids are found in nature. All amino acids are identical in the regions where they may be joined together by covalent bonds. This uniformity allows any amino acid to be joined to any other amino acid by linking an amino group to a carboxyl group.

Proteins are among the most diverse macromolecules. The reason is that amino acids differ from each other in a side chain called the R-group, which can have a range of different properties. Some R-groups are acidic and some are basic. Some are polar, some are nonpolar, and some even contain large ring structures. Two of the amino acids—methionine and cysteine—contain sulfur in their R-groups.

Levels of Organization Amino acids are assembled into polypeptide chains according to instructions coded in DNA. However, proteins do not take on a linear shape. Instead, the polypeptides bend and twist into three-dimensional shapes.

To help understand these large molecules, scientists describe proteins as having four levels of structure. A protein's primary structure is the sequence of its amino acids. Secondary structure is the folding or coiling of the polypeptide chain. Tertiary structure is the complete three-dimensional arrangement of a polypeptide chain. Proteins with more than one chain are said to have a fourth level of structure, describing the way in which the different polypeptides are arranged with respect to each other. **Figure 2-20** shows the structure of hemoglobin, a protein found in red blood cells that transports oxygen in the bloodstream.

The shape of a protein is maintained by a variety of forces, including ionic and covalent bonds, as well as van der Waals forces and hydrogen bonds. In the next lesson, you will learn why a protein's shape is so important.



INTERACTIVITY

Figure 2-20

Protein Structure

The protein hemoglobin consists of four subunits. The iron-containing heme group in the center of each subunit gives hemoglobin its red color. An oxygen molecule binds tightly to each heme group.

Name ________________________________ Class____________ Date __________

Lesson Quiz

2.3 Carbon Compounds

Directions

For multiple choice questions, write the letter that best answers the question or completes the statement on the line provided. For other question types, follow the directions provided.

For question 1, complete the paragraph with words from the word bank. Write the correct word or phrase on each line. Not all words will be used.

1. Write words or phrases from the word bank to complete the paragraph.

amino acids	carbohydrates	lipids	monomers	nucleic acids	nucleotides	polymers	proteins	sugars

Very long and large organic molecules called __________ are made of small units called ___________. Examples of the small units include sugars, which combine to form ____________; nucleotides, which form __________; and amino acids, which form __________.

_______ **2.** Carbon is a vital part of the phospholipids that make up cell membranes and the carbohydrates that make up cell walls. Which of the following allows carbon to bond with up to four other atoms at a time and form the macromolecules that are essential to life?

a. the six protons in its nucleus
b. the six neutrons in its nucleus
c. the two electrons in its inner shell
d. the four electrons in its outer shell

_______ **3.** The cell walls of a plant consist mostly of cellulose, a carbohydrate, which provides a strong structure. The cell membrane gets its structure primarily from lipids, and embedded proteins allow for material transport.

Which of the following elements would be found in the lowest amounts in both the cell wall and cell membrane?

a. carbon **c.** hydrogen
b. phosphorus **d.** sodium

_______ **4.** Which two types of organic polymers are made from the same type of monomer?

a. starches and cellulose

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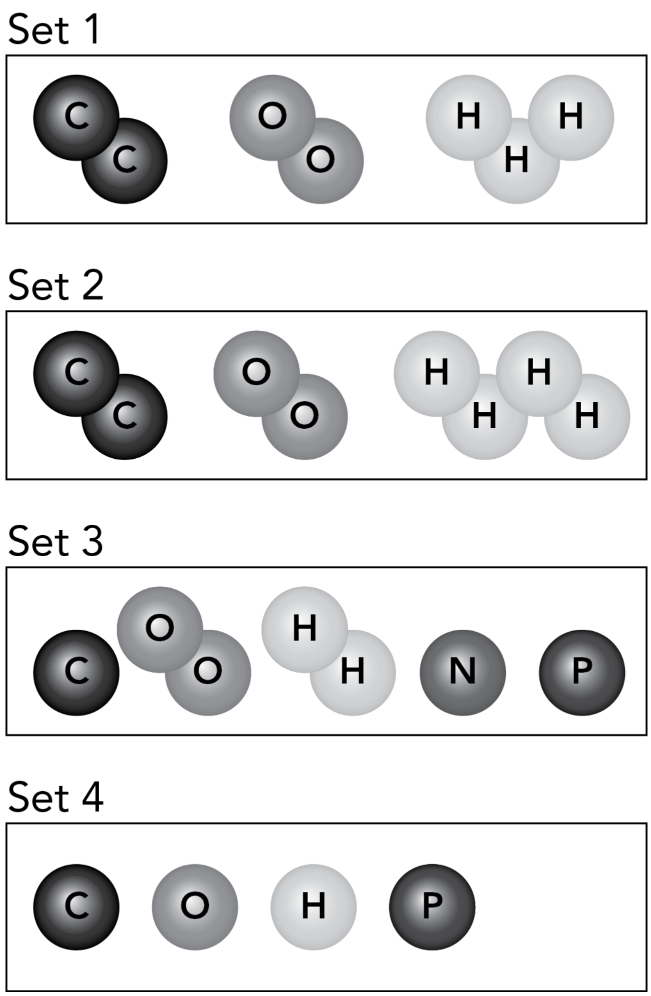
b. DNA and proteins
c. fatty acids and nucleic acids
d. proteins and cellulose

Refer to the following passage and diagram to answer questions 5 and 6.

A store sells a variety of sets for building molecular models. The sets are described by the diagram below. Each circled letter represents a box of 6 model atoms of one element. For example, the circled letter "P" represents a box with 6 model phosphorous atoms.



_______ **5.** Kendra wishes to build a model of a carbohydrate molecule, ideally containing as many monomers a possible. Which set should she choose?

a. Set 1 **c.** Set 3
b. Set 2 **d.** Set 4

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_______ **6.** Which change to one of the kits would make it useful for modeling proteins?

a. Set 1, add a box for phosphorous (P) atoms.
b. Set 2, add a box for sulfur (S) atoms
c. Set 3, replace the box of phosphorous (P) atoms with a box of sulfur (S) atoms
d. Set 4, replace the box of oxygen (O) atoms with a box of nitrogen atoms (N)

_______ **7.** Which of the following is NOT one of the functions of lipids?

a. forming the exoskeletons of insects
b. forming waxy leaf coverings
c. storing energy in fat cells
d. forming cell membranes