Introduction

Despite the complexity of life on Earth, the most important large molecules found in all living things (biomolecules) can be classified into only four main categories: carbohydrates, lipids, proteins and nucleic acids. Three of these four classes of biomolecules – carbohydrates, proteins and nucleic acids – are considered macromolecules because they form long, chain-like molecules called polymers. Polymers are composed of repeating units of smaller molecules referred to as monomers. These monomer units are linked together by covalent bonds. Lipids are a diverse group of hydrophobic molecules that interact with each other through “hydrophobic interactions” rather than covalent bonds, and are not considered true polymers. Generally, lipid molecules are not large enough to be considered macromolecules.

Since all of these biomolecules interact in an aqueous environment, we have included water in the collection.

You will explore the structure of water and the four biomolecules featured in the collection. Each station has an 8.5 x 11 individual workstation mat and models of the molecules. Some of the chemical structures of the molecules are drawn on the mats. Although you do not need to memorize these structures, you will need to be able to interpret the structures to complete the worksheet.

- Some of the structures use chemical shorthand – if there is a bend in the “stick” structure that is not labeled (see circled region in figure at right), it is a carbon atom.

- Although many of these molecules contain hydrogen atoms, these atoms are not always drawn in the chemical structure on the information sheets (see example below). To determine if a hydrogen is present (but not drawn), keep in mind that carbon forms four covalent bonds.

- Please note that a single monomer or building block is highlighted in green in each of the polymers or larger structures featured in the Molecules of Life Collection©.
Use the information on the corresponding 8.5 x 11 workstation mats to complete the questions below.

**Water**

Life happens in water. The amount of water in the human body ranges from 50%-75% depending on a number of factors including gender and age.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>1. Examine a water molecule. What is the empirical formula for water?</td>
<td></td>
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<tr>
<td>2. What colors represent each of the atoms present in the water molecule model?</td>
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<tr>
<td>3. Water molecules are polar molecules. Polarity refers to the partial positive charge (+) and partial negative charge (-) that a molecule has when electrons are unequally shared between two or more atoms. Molecules that have these partial charges are referred to as polar molecules. Predict which part of the water molecule has the partial positive charge and which part has the partial negative charge.</td>
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<tr>
<td>4. Examine the model of the crystal structure formed when water freezes. Which atoms interact with each other in this structure?</td>
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<tr>
<td>5. What type of bonds form between the water molecules?</td>
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<tr>
<td>6. Propose an explanation for why solid water (ice) is less dense than liquid water.</td>
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Complex Carbohydrates

Carbohydrates are a class of biomolecules that include simple sugars (monosaccharides), double sugars (disaccharides) and complex carbohydrates (polysaccharides). They are energy-rich molecules that provide fuel for the body. Monosaccharides are the monomers from which complex carbohydrates are built. Two monosaccharides covalently bond to form a disaccharide. Carbohydrate macromolecules composed of many monomeric units linked together form polymers called polysaccharides.

1. Identify the name of the monomer featured in the Molecules of Life Collection®.
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2. Examine the example monomer (monosaccharide) of a carbohydrate. What atoms compose this monomer and what are their corresponding colors?
_____________________________________________________________________________

3. What is the ratio of these atoms to each other? Keep in mind that the hydrogens are not shown in the 3D model and they are not drawn on the carbons in the stick structure.
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4. How is this monomer produced?
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_____________________________________________________________________________

5. Which linear polymers are composed of these monomers?
_____________________________________________________________________________

6. In what form is glucose stored in a human?
_____________________________________________________________________________

7. Which of the complex carbohydrates is used to store glucose in plants?
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8. How many carbons make up the ring structure of the carbohydrate monomer?
_____________________________________________

9. Using the carbon numbering system shown at right and the structural formula for the disaccharide on the large placemat and/or individual workstation mat, which carbons are involved when one monomer links to a second monomer?
_____________________________________________
_____________________________________________

10. What molecule is given off when two monosaccharides (monomeric units) covalently bind to form a disaccharide?
_____________________________________________

11. Compare and contrast the physical structures of starch, cellulose and glycogen. Make note of where the sixth carbon of the glucose - highlighted with a purple dot - is located. Based on your observations, explain why these structures are different even though all of them are composed of glucose monomers.
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Lipids

Lipids are a heterogeneous group of hydrophobic biomolecules that resemble one another more in their solubility properties than in their chemical structures. They include fatty acids, triglycerides, steroids, glycolipids and phospholipids.

1. Examine the phospholipid molecule model in the Molecules of Life Collection® and identify the different types of atoms found in the molecule and their associated colors.

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2. Explain the chemical property exhibited by the tails of the phospholipid model.

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3. Explain how the chemical property of the head is different from that of the tails.

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4. Compare the phospholipid monomer with the structure on the workstation mat. What causes the kink in the tail?

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5. What important cellular structure is formed by these molecules?

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6. Describe the orientation of the phospholipid molecules as they spontaneously assemble into a lipid bilayer in an aqueous environment.

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7. Why aren’t phospholipids considered to be true polymers?

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8. Simulate the diffusion of water through the lipid bilayer by dropping one of the water molecule models into the membrane model. Did the water diffuse through the membrane? What properties of water and phospholipids may explain what you have observed?

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Proteins

Proteins are an important class of biomolecules fundamental to almost all of the dynamic functions in living organisms. The structural sophistication of these macromolecules determines the vast array of functions performed by this group which include structural support, transport of substances, protection against disease, response to stimuli, movement, and metabolism.

1. Identify the monomeric unit of a protein.

_____________________________________________________________________________

2. Twenty common amino acids, each with a distinct shape and chemical property, comprise the proteins in the body. Examine the structure of the amino acid model included in the Molecules of Life©. Which atoms compose this monomer and what are their associated colors?

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3. Identify the specific monomer featured in the collection.

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4. What is the specific protein polymer featured in the collection?

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5. How does the length of this protein compare to the height of the phospholipid bilayer?

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6. Detach the magnet-docked portion of the protein by placing your thumb under the green monomer and gently lifting up. Examine the inside of the protein. What is the function of this protein?

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7. What occurs at the pink water molecule position?

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8. Describe how the water molecules orient themselves as they are being transported into the cell.
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9. Approximately how many amino acid monomers compose this protein?
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10. Examine the polypeptide structure drawn on the workstation mat. How are the monomers linked together to form the polypeptide? What substance is given off when monomers are linked together?
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_____________________________________________________________________________
_____________________________________________________________________________
Nucleic Acids

Nucleic acids are macromolecules responsible for storing and transmitting the code that enables living organisms to reproduce their complex components from one generation to the next.

1. Identify the atoms and their associated colors found in the nucleic acid monomer model in the Molecules of Life Collection©.

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_____________________________________________________________________________

2. What is the monomeric unit of a nucleic acid?

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3. What are the three constituent parts of this monomer?

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4. Identify the four different types of monomers of DNA.

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5. Which part of the monomer differs among the different types?

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6. Identify the specific monomer model featured in the collection.

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7. There are two families of nitrogenous bases. The pyrimidines have one six-membered ring of carbon and nitrogen atoms while the purines are larger with a six-membered ring fused to a five-membered ring. Identify the type of nitrogenous base depicted in the monomer model. How can you tell?

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_____________________________________________________________________________
8. Examine the DNA model included in the Molecules of Life®. Focus on the end of the molecule with the green highlighted monomer. Using the model and the workstation mat, determine which nitrogenous base pairs with the green highlighted monomer. What type of nitrogenous base is found in this monomer? How can you tell?

_____________________________________________________________________________

9. Now, examine the end of the DNA model without the green highlighted monomer. Identify the nitrogen bases forming this base pair. How many hydrogen bonds bind these bases together?

_____________________________________________________________________________

10. Examine the chemical structures drawn on the Molecules of Life® workstation mat. What type of bond holds the complementary base pairs together?

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11. Which parts of the monomer comprise the sides of the double helix?

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12. Compare and describe the orientation of the phosphate group on each side of a base pair in the DNA molecule.

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13. Two complementary strands of DNA wrap around each other to form a double helix. Observe the DNA model. In which direction does the helix turn?

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14. How many base pairs are found in one turn of the helix?

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15. Propose a purpose of the major groove found in the DNA model.

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