The Molecules of Cells

3

Human beings have visited the moon, and space shuttles and a space station regularly orbit the Earth. Some people now hope that our goal in space for the next century will be to send people to Mars. One of the attractions of the red planet is the possibility that life exists there. The Viking missions of the 1970s tested Martian soil for the presence of life, and the results were at best inconclusive. In 1996, researchers reported finding traces of organic matter and possible bacterial fossils in a meteorite that may have come from Mars. Most scientists think there is good reason to expect that if we find life elsewhere—on Mars, or perhaps on Titan, a moon of Saturn, or maybe by listening for radio transmissions from other star systems—the life we find will be based on the chemistry of carbon. On Earth, only carbon seems able to form the variety and complexity of stable compounds that can perform the myriad of activities needed to produce life. This chapter is about carbon and carbon compounds in life.

Organizing Your Knowledge

Exercise 1 (Module 3.1)

Web/CD Activity 3A *Diversity of Carbon-Based Molecules*

The great variety of organic compounds results from the ability of carbon atoms to bond with four other atoms, forming branching chains of different lengths. Several hydrocarbon molecules, consisting only of carbon and hydrogen, are shown in Module 3.1. Practice seeing the versatility of carbon by sketching some hydrocarbon molecules of your own, as suggested below.

1. Sketch a hydrocarbon molecule that is a straight chain, containing five carbon atoms and twelve hydrogen atoms, molecular formula C_5H_{12}:

Question: Why does each carbon bond to four other atoms?

2. Now sketch a shorter hydrocarbon chain, with only four carbon atoms:

Question: What is the molecular formula of the above molecule?

3. Sketch another five-carbon hydrocarbon, but this time include one double bond:

Question: What is the molecular formula of this molecule?

4. Sketch a five-carbon hydrocarbon molecule that is branched (and contains no double bonds):

Question: What is the molecular formula of this molecule? What is the term for its relationship to molecule 1 (in this exercise)?

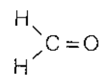
Sketch two five-carbon hydrocarbon molecules in the form of rings, one without double bonds and one with one double bond.

Question: How many hydrogen atoms are in each of these molecules?

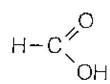
Exercise 2 (Module 3.2)

Web/CD Activity 3B *Functional Groups*

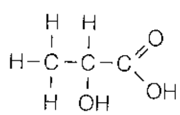
Circle the functional groups that are discussed in this module in the molecules below. Label an example of each of the following: **hydroxyl group, carbonyl group, carboxyl group, amino group**. There are a total of ____ hydroxyl groups, ____ carbonyl groups, ____ carboxyl groups, and ____ amino groups. (The properties of the molecules are described at the right.)



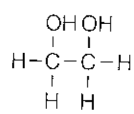
Formaldehyde is the starting point for making many chemicals.



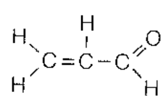
Formic acid gives ant venom its sting.



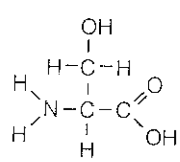
Lactic acid builds up as a waste product in exercising muscles and makes them feel tired.



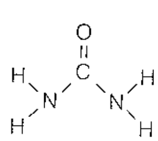
Ethylene glycol is in automobile antifreeze.



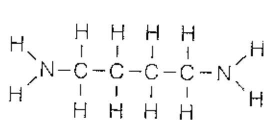
Acrolein is produced when meat is heated; it is the barbecue smell.



Serine is part of many protein molecules.



Urea is a waste product in urine.



Putrescene's name is descriptive; it is produced in rotting flesh.

Exercise 3 (Module 3.3)

Web/CD Activity 3C *Making and Breaking Polymers*

There are four main classes of macromolecules. Most are polymers, assembled from smaller monomers in a process called dehydration synthesis. Hydrolysis breaks the polymers back down to monomers. State whether each of the following relates to dehydration synthesis (D) or hydrolysis (H).

_______________ 1. Connects monomers to form a polymer.

_______________ 2. Produces water as a by-product.

_______________ 3. Breaks up polymers, forming monomers.

_______________ 4. Water is used to break bonds between monomers.

_______________ 5. Joins amino acids to form a protein.

_______________ 6. Glycerol and fatty acids combine this way to form a fat.

_______________ 7. Occurs when polysaccharides are digested to form monosaccharides.

_______________ 8. —H and —OH groups form water.

_______________ 9. Nucleic acid breaks up to form nucleotides.

_______________10. Water breaks up, forming —H and —OH groups on separate monomers.

Exercise 4 (Modules 3.3 - 3.7)

Web/CD Activity 3C *Making and Breaking Polymers*
Web/CD Activity 3D *Models of Glucose*
Web/CD Activity 3E *Carbohydrates*

After reading these modules, review carbohydrates by filling in the blanks in the following story.

Carbohydrates are a class of molecules ranging from the simplest sugars, called 1_________________, to giant molecules called 2_________________, built of many sugars. Carbohydrates are the main fuel molecules for cellular work.

Plants make their own carbohydrates, but humans, like all animals, must obtain them from plants or other animals. Imagine eating a piece of whole-wheat bread spread with strawberry jam. It contains a mixture of carbohydrates, along with other macromolecules like 3_________________ and 4_________________. Much of the carbohydrate in the bread itself is in the form of a polysaccharide called 5_________________, which is simply a chain of 6_________________ monomers. The monomers were linked together in the wheat plant in a process called 7_________________ synthesis. As the glucose units joined, 8_________________ was produced as a by-product. When you swallow a bite of bread, digestive juices in the intestine separate the monomers in the opposite reaction, called 9_________________. In the intestine, this is actually a two-step process.

Secretions from the pancreas first break the starch down to maltose, a type of carbohydrate called a [10]________________, which consists of two glucose monomers. Secretions from the walls of the intestine complete the process, breaking each maltose molecule down to two individual glucose molecules.

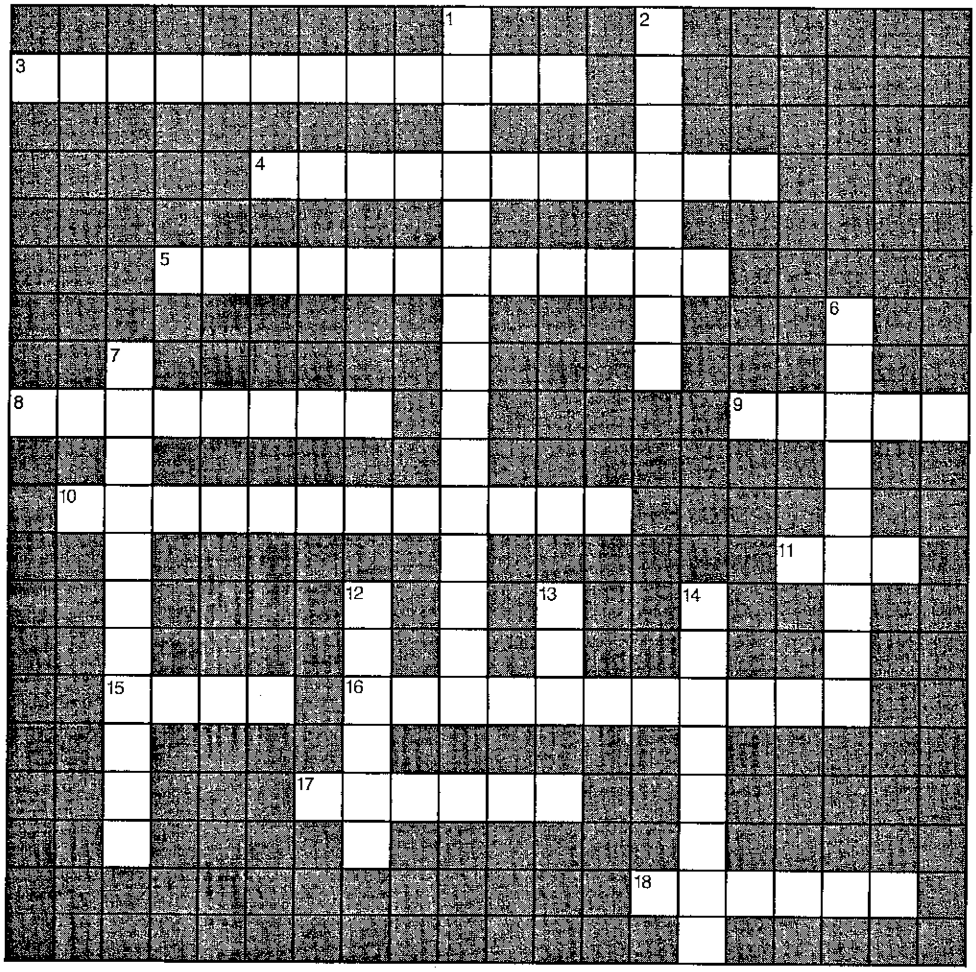
There are other carbohydrates in the bread and jam. Whole-wheat flour contains the tough coats of the wheat seeds. These contain a lot of [11]________________, the fibrous polysaccharide that makes up plant cell walls. Like starch, it is made of glucose monomers, but these monomers are [12]________________ in a different orientation. The human digestive tract is not capable of [13]________________ cellulose, so it passes through the digestive tract unchanged, in the form of [14]________________. Sucrose, a [15]________________ refined from sugar cane or sugar beets, may be used to sweeten the strawberry jam. Each sucrose molecule is hydrolyzed in the small intestine to form one molecule of [16]________________ and one molecule of [17]________________. The jam naturally also contains a small amount of fructose, a [18]________________that is produced by strawberries and is considerably sweeter than sucrose. (If the jam is artificially sweetened, it might contain other molecules whose [19]________________ are similar to natural sugars. These molecules bind to "sweet" [20]________________ on the tongue, producing the sensation of sweetness.)

Once all the carbohydrates have been hydrolyzed to small monosaccharides, they can be absorbed by the body. Glucose and fructose pass through the wall of the intestine and into the bloodstream, which carries them to the liver. Here the fructose is converted to glucose. This process is relatively easy because glucose and fructose are [21]________________, having the same molecular formula, [22]________________, but slightly different structures. Glucose circulates around the body as "blood sugar" and is taken up by the cells for fuel as needed. Extra glucose molecules are taken up by liver and muscle cells and linked together by [23]________________ synthesis to form a polysaccharide called [24]________________. This molecule is similar to [25]________________, except it is more branched. Later the glycogen can be hydrolyzed to release [26]________________ into the blood.

Exercise 5 (Modules 3.8 – 3.10)

Web/CD Activity 3F *Lipids*

Review the structures and functions of lipids by completing the following crossword puzzle.



Across

3. ____ means that hydrogen has been added to unsaturated fats.
4. ____ is a steroid common in cell membranes.
5. A ____ is similar to a fat; found in cell membranes.
8. A fat molecule is composed of ____ and 3 fatty acids.
9. Glycerol and 3 ____ acids make a triglyceride.
10. ____ is another name for "fat."
11. A ____ forms a waterproof coat that keeps a fruit or insect from drying out.
15. Olive and corn ____ are examples of unsaturated fats.
16. Fats with double bonds are said to be ____.
17. ____ is a lipid-containing deposit in a blood vessel.
18. ____ are grouped together because they do not dissolve in water.

Down

1. ____ is when lipid-containing deposits block blood vessels.
2. Female and male sex hormones are examples of ____.
6. Animal fats are said to be ____.
7. Lipids are water-avoiding, or ____ substances.
12. Unsaturated fats contain more ____ bonds than saturated fats.
13. A ____ is a large molecule whose main function is energy storage.
14. ____ steroids are dangerous variants of testosterone.

Exercise 6 (Module 3.11)

Web/CD Activity 3G *Protein Functions*

Everything a cell does involves proteins. Seven classes of proteins are discussed in Module 3.11. Match each of the classes with one of the descriptions below.

________________ 1. Hemoglobin carries oxygen in the blood.

________________ 2. A protein in muscle cells enables them to move.

________________ 3. Antibodies fight disease-causing bacteria.

________________ 4. Collagen gives bone strength and flexibility.

________________ 5. Insulin signals cells to take in and use sugar.

________________ 6. Proteins in seeds provide food for plant embryos.

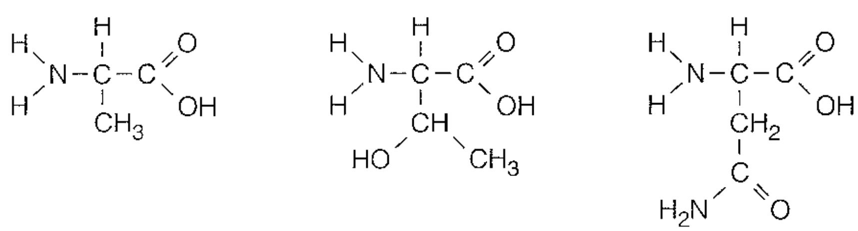
________________ 7. A protein called sucrase promotes the chemical conversion of sucrose into monosaccharides.

Exercise 7 (Modules 3.12 – 3.13)

Web/CD Activity 3H *Protein Structure*

Three amino acids not shown in the modules are diagrammed below.

1. Draw a box around the unique R group of each, and label it **R group**.
2. Draw a red circle around the amino group of each, and label it **amino group**.
3. Draw a blue triangle around the acid group of each, and label it **acid group**.



Alanine — Threonine — Asparagine

4. In the space below, sketch the three amino acids to show how they would join to form a tripeptide. What is this chemical reaction called? How many molecules of water would be formed? Show where the water would come from.

Exercise 8 (Modules 3.14 – 3.18)

Web/CD Activity 3H *Protein Structure*

Identify each of the levels of protein structure in the diagrams. Then choose the descriptions from the list below that go with each of the levels.

1. ____________ Structure →

Descriptions: ____________

2. ____________ Structure →

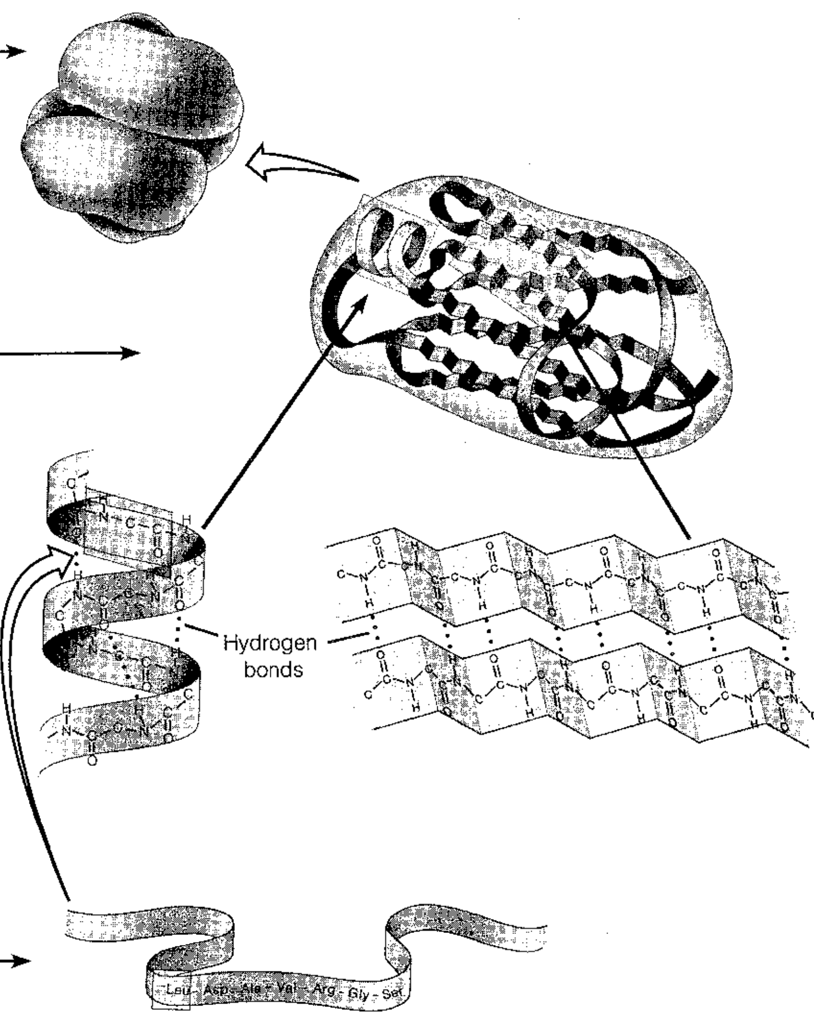
Descriptions: ____________

3. ____________ Structure →

Descriptions: ____________

4. ____________ Structure →

Descriptions: ____________



Choose from these descriptions:

A. Overall three-dimensional shape
B. Amino acid sequence
C. Even a slight change in this can alter tertiary structure.
D. This level occurs in proteins with more than one polypeptide subunit.
E. Coiling and folding produced by hydrogen bonds between —NH and C=O groups
F. Not present in all proteins
G. Level of structure that is held together by peptide bonds
H. Alpha helix and pleated sheet
I. Stabilized by clustering of hydrophobic R groups, hydrogen bonds, and ionic bonds
J. "Globular" or "fibrous" might describe this level of structure.

Exercise 9 (Module 3.20)

Web/CD Activity 3I *Nucleic Acid Functions*
Web/CD Activity 3J *Nucleic Acid Structure*

Nucleic acids are the fourth group of macromolecules discussed in this chapter. Review their structures and functions by matching each of the phrases on the right with a word or phrase from the list on the left. Answers may be used more than once.

A. Phosphate group
B. Deoxyribose
C. A, T, C, G
D. DNA
E. Nucleotide
F. A, U, C, G
G. Double helix
H. Ribose
I. Nitrogenous base
J. RNA

____ 1. Sugar in RNA
____ 2. Overall structure of DNA
____ 3. Short for ribonucleic acid
____ 4. Passed on from parent to offspring
____ 5. Nitrogenous bases of RNA
____ 6. Sugar in DNA
____ 7. Nitrogenous bases of DNA
____ 8. Short for deoxyribonucleic acid
____ 9. DNA works through this intermediary.
____ 10. Nucleotide is sugar, phosphate, and this.
____ 11. Sugar of one nucleotide bonds to this of next nucleotide.
____ 12. Monomer of nucleic acids

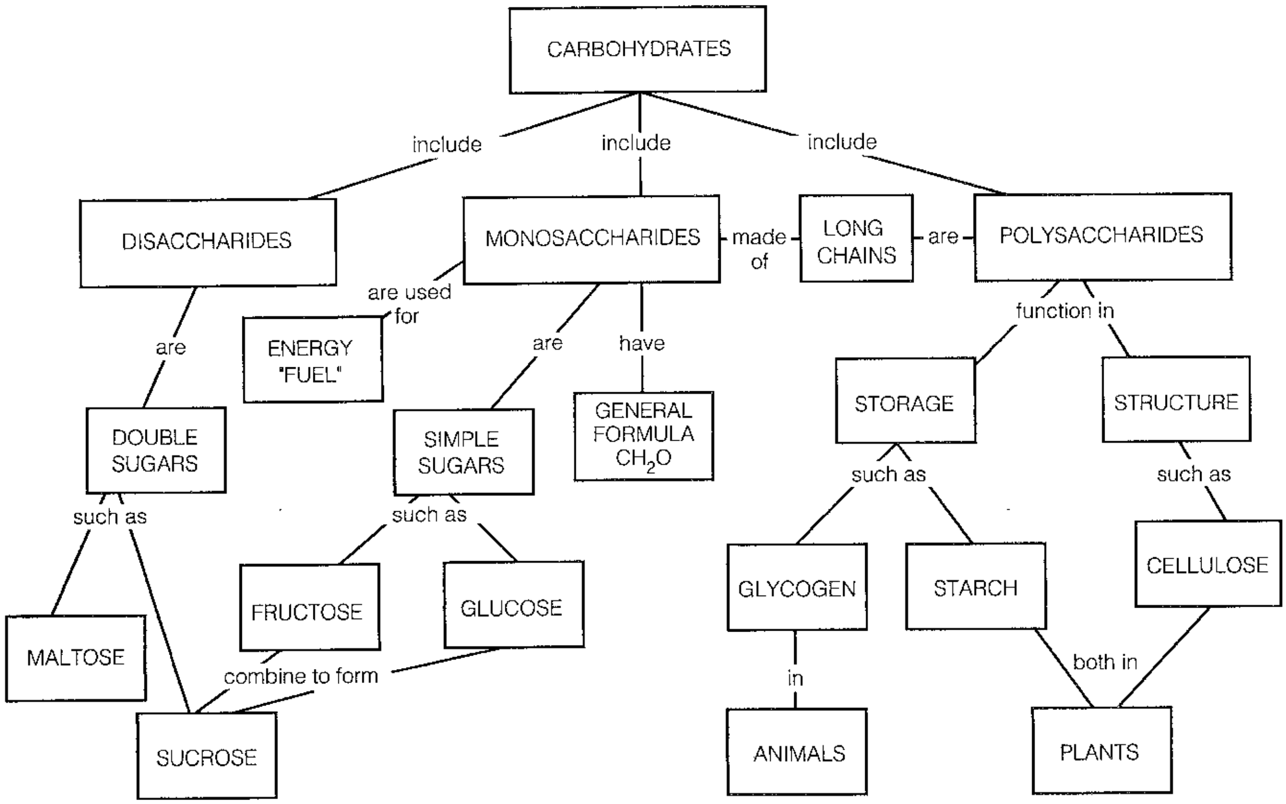
Exercise 10 (Summary)

You may find that making a concept map is a useful way to organize your knowledge. Such a map for the topic of carbohydrates is shown at the top of the next page. A concept map shows how key ideas are connected. Making a concept map can help you learn because it causes you to focus on main concepts and how they are related. It helps you to sort out what is important from unimportant details, and helps you tie your knowledge together into a more meaningful and useful whole.

To make a concept map, you must first decide which ideas are most important. Place the biggest, or most inclusive, concept at the top of the page. Just a word or phrase is enough. Cluster subconcepts around it, and cluster sub-subconcepts around them. Draw lines between the concepts to show how they are connected, and describe these connections next to the lines. Again, use only a word or two.

If the topics or connections are not clear, perhaps they are unimportant, or perhaps you are not clear on how they connect, or perhaps they do not really connect. Remember, clarifying relationships is the purpose of making the map. Generally, maps that are more "branched" are more useful than ones with many long straight "chains" of boxes, but there is no one "correct" map for a particular topic.

Focus on the process of making the map, rather than on the map itself. More learning will take place while you are making the map than when you look at the finished product. You might want to "tune up" your maps by comparing them with maps made by other students. After reviewing the following concept maps, on separate paper, try making your own concept maps for proteins and nucleic acids. Keep them simple at first. Remember, "Practice makes perfect!" Also, keep the concept map idea in mind for upcoming chapters.



Practice working with a concept map by filling in the blanks on this map for lipids.