SBI4U-C

Lesson 2

Structure and Function of Biomolecules

Introduction

In this lesson, you will learn about the four main classes of biological molecules: carbohydrates, lipids, proteins, and nucleic acids. You will also explore applications such as testing for biological molecules in foods.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (Hours)	
Introduction to Biological Molecules	½
A Closer Look at the Macromolecules of Life	1½
Activity: Viewing Important Biological Molecules	1
Testing for Biological Molecules in Food	½
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- construct and draw three-dimensional molecular models of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids
- conduct biological tests to identify biochemical compounds found in various food samples
- describe the structure of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids, and explain their function within cells
- identify common functional groups within biological molecules (for example, hydroxyl, carbonyl, carboxyl, amino, and phosphate groups), and explain how they contribute to the function of each molecule

Introduction to Biological Molecules

In order to understand the “how” and “why” of biochemical reactions, you need to consider the structure and composition of the biological molecules involved in the reactions. This section will help you to understand why the presence of carbon atoms and reactive areas known as functional groups, along with the size of biological molecules, contribute to their biochemical reactions in living things.

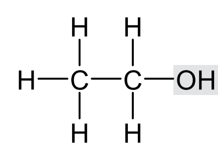
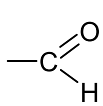
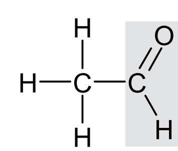
Carbon-based Biological Molecules

Virtually all of the chemicals of life are carbon-based. Compounds that contain carbon and hydrogen, along with other elements such as nitrogen, are called organic compounds. The compounds that are made up almost entirely of carbon and hydrogen are called hydrocarbons (for example, fossil fuels).

Carbon is a key element found in living cells. Because it contains four valence electrons, the carbon atom has the ability to bond with other carbon atoms in several ways to form molecules with numerous configurations, from straight to branched chains, to rings. Hydrocarbons contain carbon and hydrogen, and some contain elements such as oxygen, sulphur, and phosphorus in reactive clusters called functional groups. Functional groups possess certain chemical properties that they pass on to the molecules.

Functional Groups

The functional groups are summarized in Figure 2.1, which follows.

Functional group	Formula	Name of compound	Structural example
Hydroxyl	—OH	Alcohols	 Ethanol
Carbonyl		Aldehydes	 Acetaldehyde (ethanal)

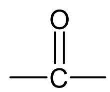
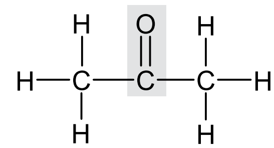
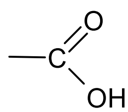
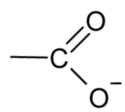
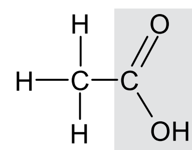
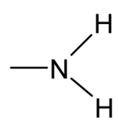
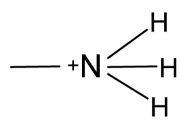
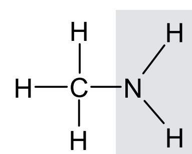
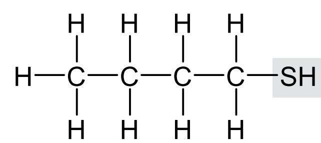
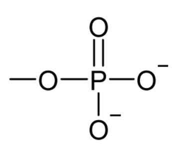
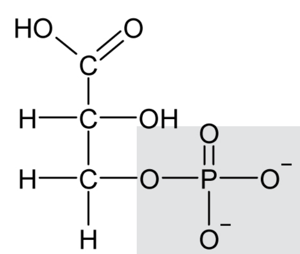
Functional group	Formula	Name of compound	Structural example
		Ketones	 Acetone
Carboxyl	 	Carboxylic acids	 Acetic acid
Amino	 	Amines	 Methylamine
Sulfhydril	—SH	Thiols	 Butanethiol
Phosphate		Organic phosphates	 3-phosphoglyceric acid

Figure 2.1: The functional groups of organic compounds

These functional groups are hydrophilic (attracted to water), and therefore increase the solubility of the molecules that contain these functional groups. The functional groups also have specific roles in cell metabolism. For example, the sulfhydril group found in proteins allows amino acids to join together, which increases the stability of the proteins. The phosphate group is present in adenosine triphosphate (ATP) and is readily removed during cell metabolism, which makes energy available to the cell.

Biological Molecules are Macromolecules

Macromolecules are large molecules. They are made up of smaller repeating units called monomers. Biochemical reactions usually involve using building blocks known as monomers to make larger macromolecules, or breaking down macromolecules to form the monomers.

In order to join monomers to form macromolecules, water must be removed. As you've already learned, this reaction is called a condensation reaction. It is also sometimes called a dehydration synthesis reaction (because the molecule becomes "dehydrated") and an anabolic (building-up) reaction, since larger units are formed from smaller units.

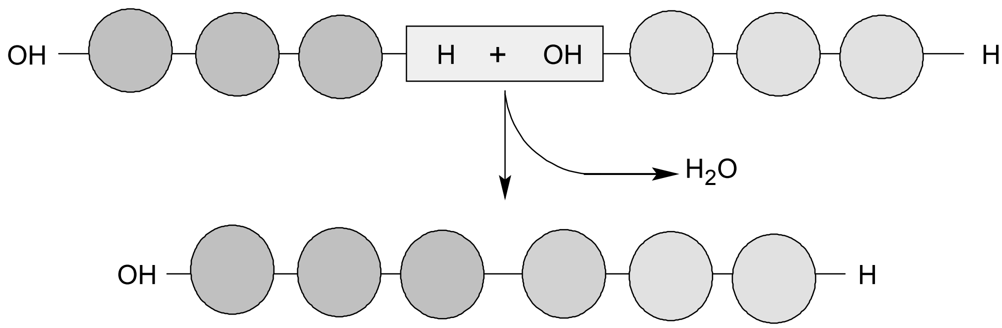


Figure 2.2: In dehydration synthesis (condensation) reactions, water is removed to join smaller macromolecules together, forming larger polymers.

In order to break down macromolecules into smaller units, a catabolic reaction called hydrolysis must occur. In this reaction, water is used to break down the macromolecule into its smaller monomer units.

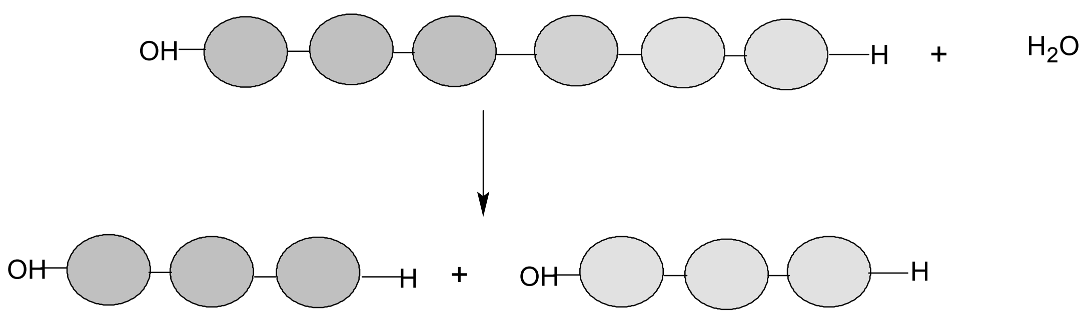


Figure 2.3: A hydrolysis reaction is the reverse of a dehydration synthesis reaction.

These reactions take place with the help of enzymes, which are protein catalysts that speed up chemical reactions. The role of enzymes will be discussed in more detail in a later lesson. There are four macromolecules of life:

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic acids

In the next section, you will learn about each type of macromolecule in greater detail.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

11. What feature shared by all functional groups affects their solubility? Suggested answer

12. What kind of chemical reaction is required to join monomers together to form macromolecules? Suggested answer

A Closer Look at the Macromolecules of Life

You have just learned that the four macromolecules of life are carbohydrates, lipids, proteins, and nucleic acids. They are formed using dehydration synthesis reactions and are broken apart using hydrolysis reactions. In the next part of this lesson, you will learn the details of the structure and functions of each of these important macromolecules.

Carbohydrates

Carbohydrates are used as building materials for energy, and for cell identification and communication. Carbohydrates contain carbon, hydrogen, and oxygen in a 1:2:1 ratio. Figure 2.4 on the next page provides a simple road map to follow, as you work through this section.

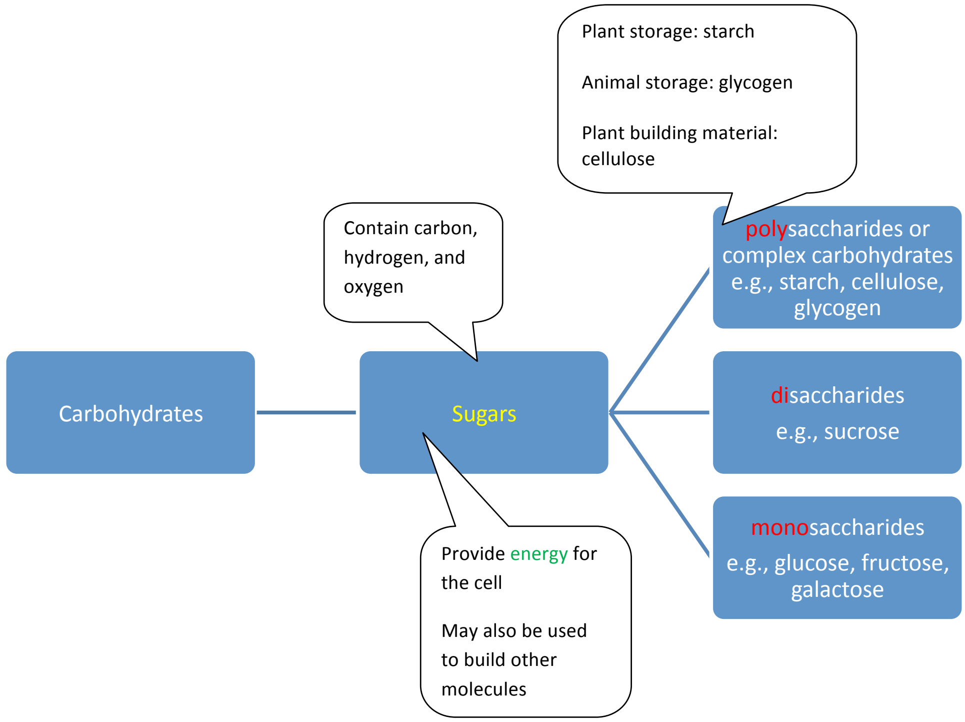


Figure 2.4: Carbohydrates

Carbohydrates are classified into three groups:

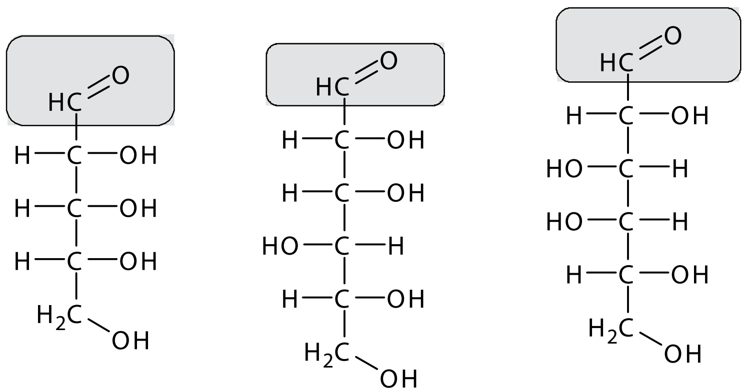
1. Monosaccharides
2. Oligosaccharides
3. Polysaccharides

Monosaccharides

Monosaccharides ("mono-" means "one," and "saccharide" means "sugar") are simple chains that can form rings when they dissolve in water. These sugars are distinguished from one another by the carbonyl group they possess. All monosaccharides contain one subunit of carbohydrate. There are two types of monosaccharide: aldoses and ketoses.

Aldoses

All carbons have *hydroxyl* groups attached, with the exception of a *carbonyl* group found on a *terminal* carbon (see Figure 2.5).

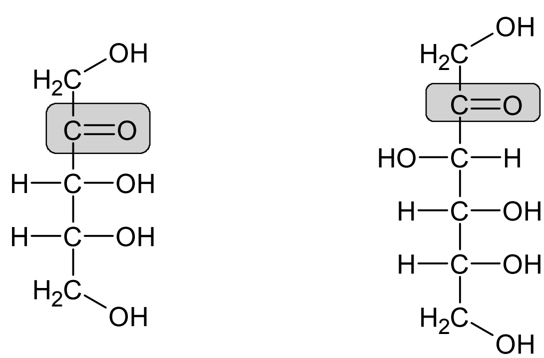


Ribose Glucose Galactose

Figure 2.5: Aldoses contain a terminal carbonyl functional group (shown in the shaded boxes).

Ketoses

All carbons have *hydroxyl* groups attached, with the exception of a *carbonyl* group found on a *central* carbon (see Figure 2.6).



Ribulose Fructose

Figure 2.6: Ketoses contain a carbonyl group in place of a hydroxyl group at one point in the carbon chain (shown in the shaded boxes).

When dissolved in water, sugars with five or more carbons form ring structures. When dry, they form linear structures. Glucose is an example of a monosaccharide that can exist as a chain, when dry, and as a ring, when it is dissolved in water (aqueous form).

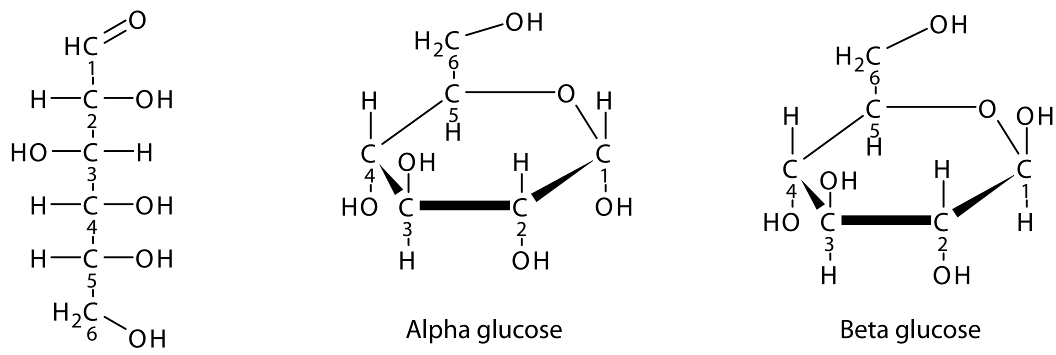


Figure 2.7: Forms of the simple monosaccharide, glucose. The carbons are numbered to the right of the oxygen atom in ring form, and from the carbonyl group in chain form.

Looking at alpha and beta glucose, it may be difficult to tell the difference between the two forms, since they are almost identical. The subtle difference between the two molecules is the position of the hydroxyl group on carbon atom 1 (labelled in Figure 2.7). The hydroxyl group is in the "down" position on alpha glucose, but in the "up" position on beta glucose. Molecules that contain the same atoms, but in a different "order" or arrangement, are called isomers.

The most important monosaccharides are isomers of each other: glucose, galactose, and fructose. They all have the same molecular formula: $C_6H_{12}O_6$.

Oligosaccharides

Oligosaccharides ("oligo-" means "few") contain two or three simple sugars, attached to one another by covalent bonds, called glycosidic linkages. Glycosidic linkages are formed from dehydration synthesis reactions. These reactions form disaccharides such as lactose, maltose, and sucrose.

The word equations for the formation of these disaccharides are summarized below:

Glucose + glucose → maltose + water

Glucose + fructose → sucrose + water

Glucose + galactose → lactose + water

Figure 2.8 on the next page shows the glucose + glucose → maltose dehydration synthesis reaction in more detail:

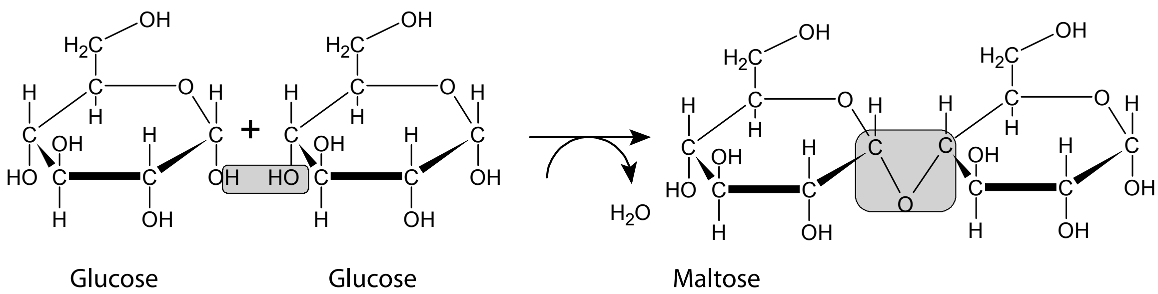


Figure 2.8: Maltose is formed by dehydration synthesis (removal of water). The grey box surrounding the H, OH in the reactants shows where the atoms are removed to produce the water molecule. The resulting maltose contains a glycosidic linkage between carbon number 1 of one molecule and carbon atom number 4 of the adjacent molecule (the grey box in the products). For this reason, it is called an alpha glycosidic 1-4 linkage.

Polysaccharides (Complex Carbohydrates)

Polysaccharides are polymers composed of several hundred to several thousand monosaccharide subunits, held together by glycosidic linkages. These molecules are very important in our diet and provide much of nature's building material. There are four types of polysaccharides: starch, glycogen, cellulose, and chitin.

Starch

Starch is composed of amylose (with α1-4 links) and amylopectin (with α1-6 links). It is the primary energy storage molecule for plants. Root vegetables, such as carrots and potatoes, have an abundance of starch, which humans can digest for energy.

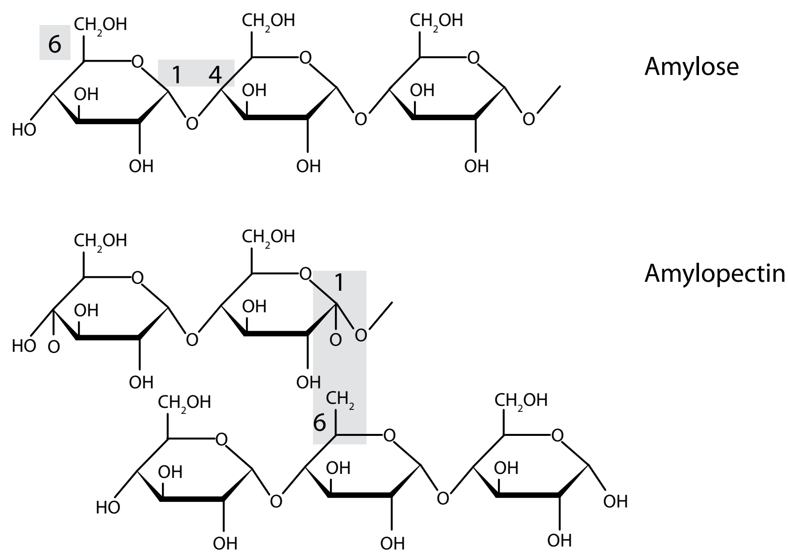


Figure 2.9: Starch is a polysaccharide combining the unbranched amylose (top) with the branched amylopectin (bottom). The carbons 1, 4, and 6 are numbered in the first two glucoses of amylose as a reference. Amylose is linked together using the 1 and 4 carbons. Note the linkage across two monosaccharides (from the 1 carbon to the 6 carbon), which creates a branch in the amylopectin.

Glycogen

Like starch, glycogen is composed of α1-4 links, and α1-6 links where it branches, but glycogen is more branched than starch. It is the main energy storage molecule for animals. Glycogen regulates blood glucose levels. As glucose increases, the liver and muscles convert excess glucose to glycogen. Enzymes in the liver and muscles can also break glycogen molecules apart, when glucose is required. For example, adrenalin stimulates the breakdown of chemical bonds in a glycogen chain for quick energy, such as that needed for an animal's "flight or fight" reaction when it is confronted with danger.

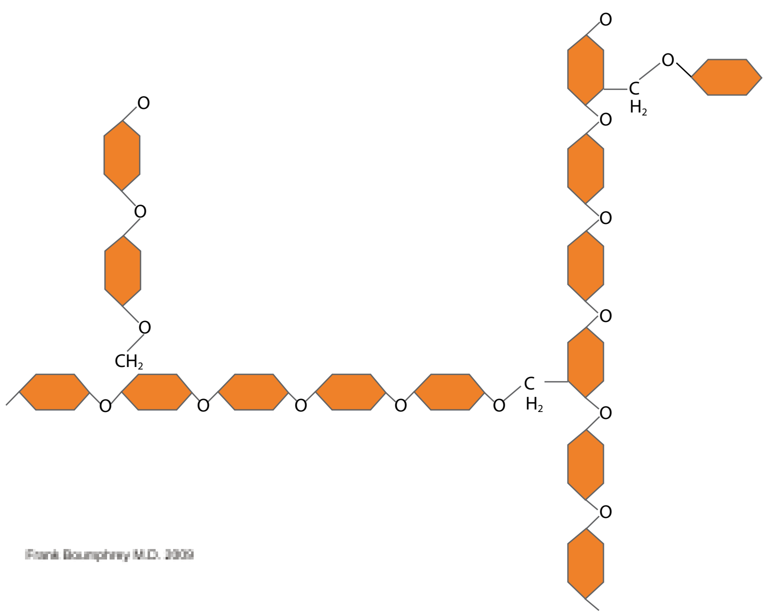


Figure 2.10: The polysaccharide glycogen is the storage form of glucose in animals. It is a long molecule with many branches. In humans, it is typically stored in the liver and muscles.

Cellulose

Cellulose is composed of β1-4 links. Every other glucose subunit becomes inverted to accommodate this link. Unlike starch and glycogen, it is not coiled or branched. This allows cellulose to form long chains that are tough, making it an ideal building material for plants. For example, it is used in plant cell walls, to make them rigid and firm.

Humans cannot digest cellulose. However, it is a form of fibre, which is an important part of our daily diet, as it aids in regular egestion (bowel movements). Humans also use cellulose to make paper and fabrics. Cellulose is the tough "thread" that plants use to make them rigid, and that humans began to use long ago as a manufacturing material.

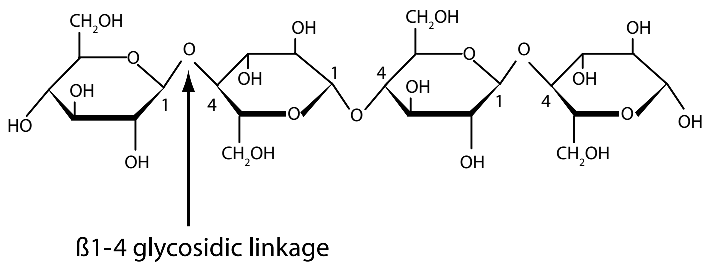


Figure 2.11: Cellulose is a polysaccharide composed of β1-4 links. Notice that every glucose molecule is upside down, in relation to its neighbours.

Chitin

Chitin is a cellulose-like polymer of N-acetylglucosamine. The monomer is a glucose molecule with a nitrogen-containing group attached at the second carbon position. Chitin is used by insects and crustaceans (for example, shrimp, lobster, and crabs) to form their hard exoskeletons. Since chitin is such a strong material, we use it to manufacture items such as surgical thread.

Lipids

Lipids (fats) are a group of organic molecules that dissolve in oils, but not in water. They are very efficient energy-storage molecules that yield about twice the amount of chemical energy per gram than carbohydrates or proteins. Lipids serve as physical and thermal insulation for the body, are key components in cell membranes, and act as raw materials for the synthesis of hormones. Figure 2.12 on the next page provides you with a simple road map to follow, as you consider this section.

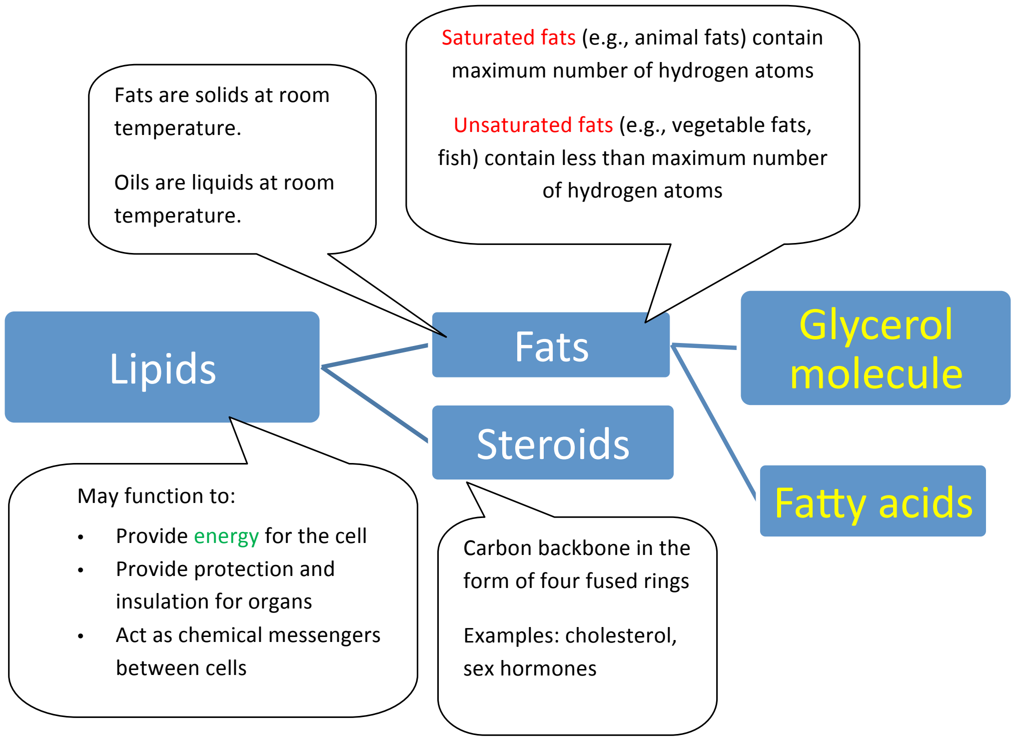


Figure 2.12: Lipids

Lipids are mostly made up of hydrogen, carbon, and oxygen. Generally, they do not dissolve in water, but dissolve in non-polar substances. Some lipids form chains, while the others form rings. There are four families of lipids:

1. Fats
2. Phospholipids
3. Steroids
4. Waxes

Fats

Fats are the most common form of energy storage and insulation in plants and animals. They consist of one glycerol molecule and a maximum of three fatty-acid chains. Each fatty-acid chain has a terminal carboxylic acid, and contains between 16 and 18 carbons (Figure 2.13).

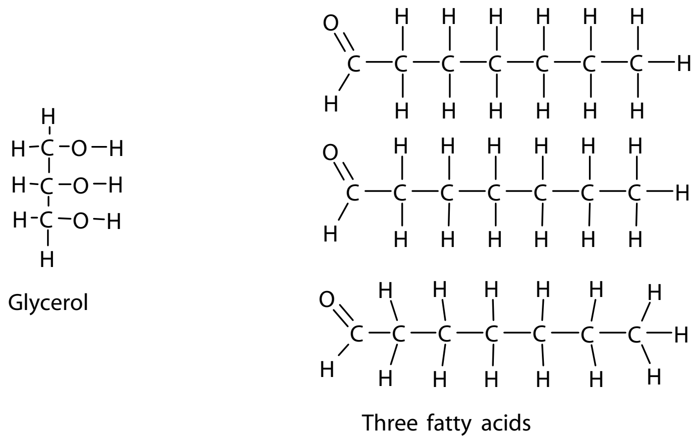


Figure 2.13: Triglycerides are composed of a glycerol molecule and three fatty acids.

A dehydration synthesis reaction creates the ester linkages that attach the fatty acids to the glycerol (Figure 2.14). This process is called esterification. If the fat is made up of three fatty-acid chains, it is called a triglyceride.

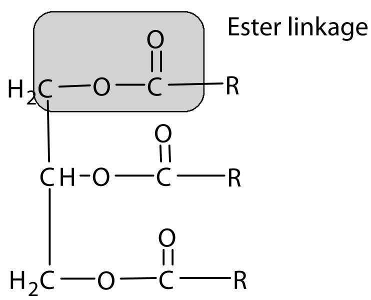


Figure 2.14: Triglycerides are formed by dehydration synthesis (condensation) reactions. Water is produced, and the molecule contains ester linkages.

Fatty acids may be either saturated or unsaturated. Saturated fatty acids have no double bonds between their carbon atoms and are saturated with hydrogen atoms. These acids are solids at room temperature. Examples include lard and butter. Unsaturated fatty acids have one or many double bonds between carbons, so they are not saturated with hydrogen. They are liquids at room temperature. Examples include corn oil and olive oil.

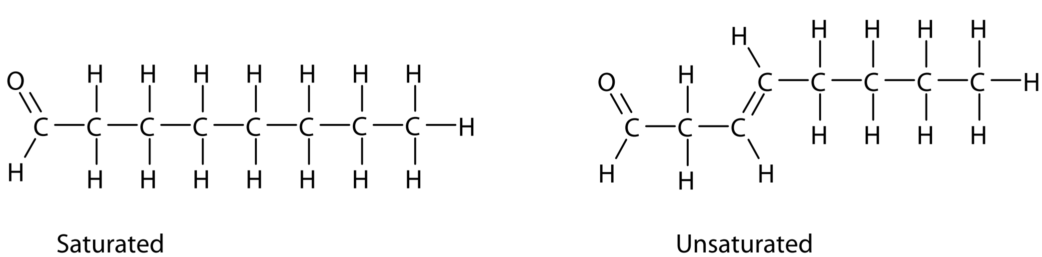


Figure 2.15: Fatty acids can be saturated (all single C–C bonds) or unsaturated (at least one double or triple C–C bond).

Phospholipids

Phospholipids make up the cell membranes of an animal cell. They consist of a hydrophilic head and a hydrophobic two-stranded tail. They are composed of one glycerol, two fatty acids, and a highly polar phosphate group. The phospholipid bilayer in cells is virtually impermeable to macromolecules, relatively impermeable to charged ions, and quite permeable to small, lipid-soluble molecules.

Steroids

Sterols are compact hydrophobic molecules containing four fused hydrocarbon rings. Sterols are a subgroup of steroids. Types of sterols include cholesterol and many other important hormones. Cholesterol is an important component of cell membranes because it affects the membrane's fluidity and acts as a messenger in cell communication during development. It can also be converted into vitamin D. Other steroid compounds, such as sex hormones, control the development of sex traits and gametes (egg and sperm cells).

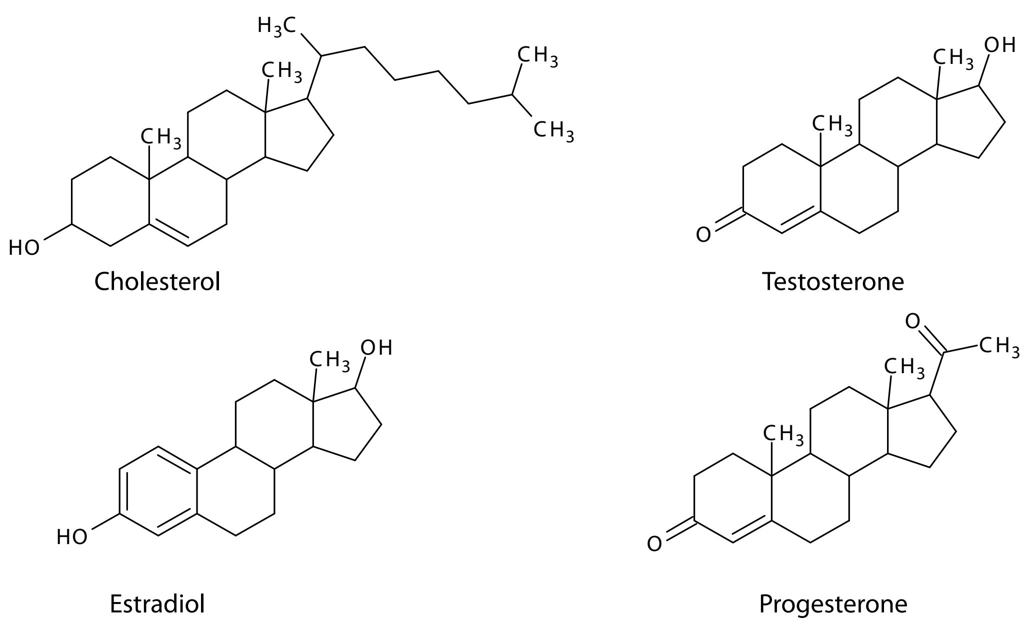


Figure 2.16: Steroid molecules are derivatives of the molecule cholesterol. Cholesterol is found in cell membranes to provide support. Too much cholesterol in your diet can lead to clogged arteries and cardiovascular disease.

Waxes

Waxes are hydrophobic molecules that contain long-chain fatty acids linked to alcohols or carbon rings. Waxes often form waterproof coatings, such as beeswax, paraffin, and the cuticle on plants' leaves. Waxes are used to manufacture items such as fuel, candles, and furniture polish.

Proteins

Proteins are involved in almost everything cells do. They can be enzymes, immunoglobulin, hemoglobin, keratin, fibrin, and so on. Proteins are made up of many amino acids. Figure 2.17, which follows, provides you with a simple road map to follow, as you consider this section.

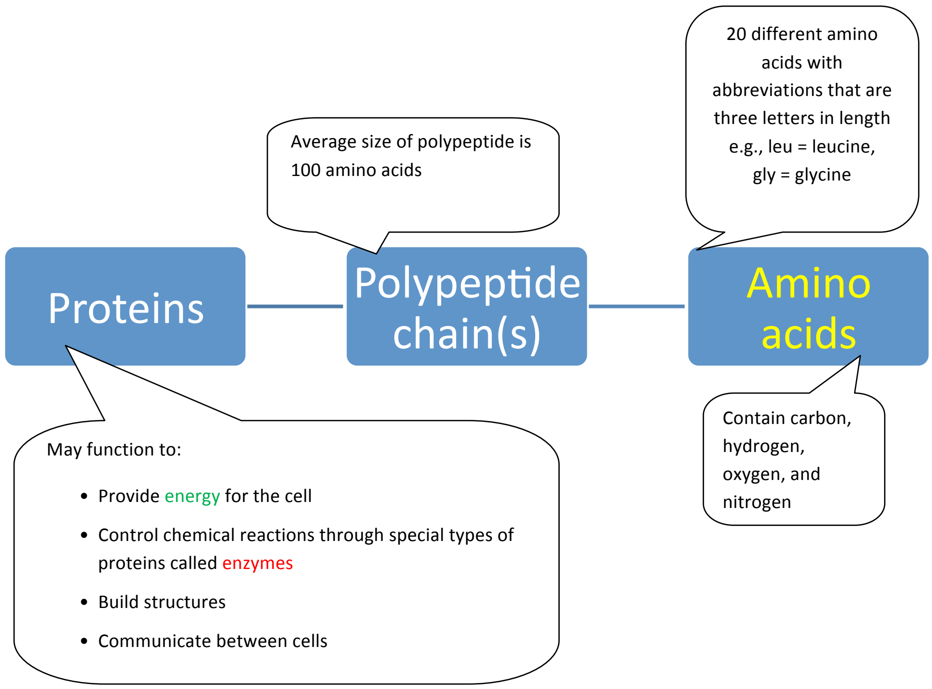


Figure 2.17: Proteins

Amino Acids

Amino acids contain three distinct parts:

- An amino group (NH_2)
- A carboxylic acid group (COOH)
- A radical group (denoted by the letter "R")

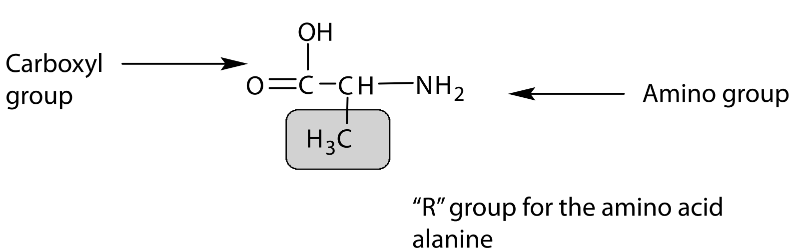


Figure 2.18: Amino acids contain a carboxylic acid group, an amino group, and a unique "R" group.

The 20 amino acids vary in the "R" groups they contain. These side chains can make the amino acid polar (hydrophilic), non-polar (hydrophobic), or charged (acidic/basic).

Eight of the amino acids are essential, meaning that we must obtain these from our diet, while manufacturing the other 12 in our cells.

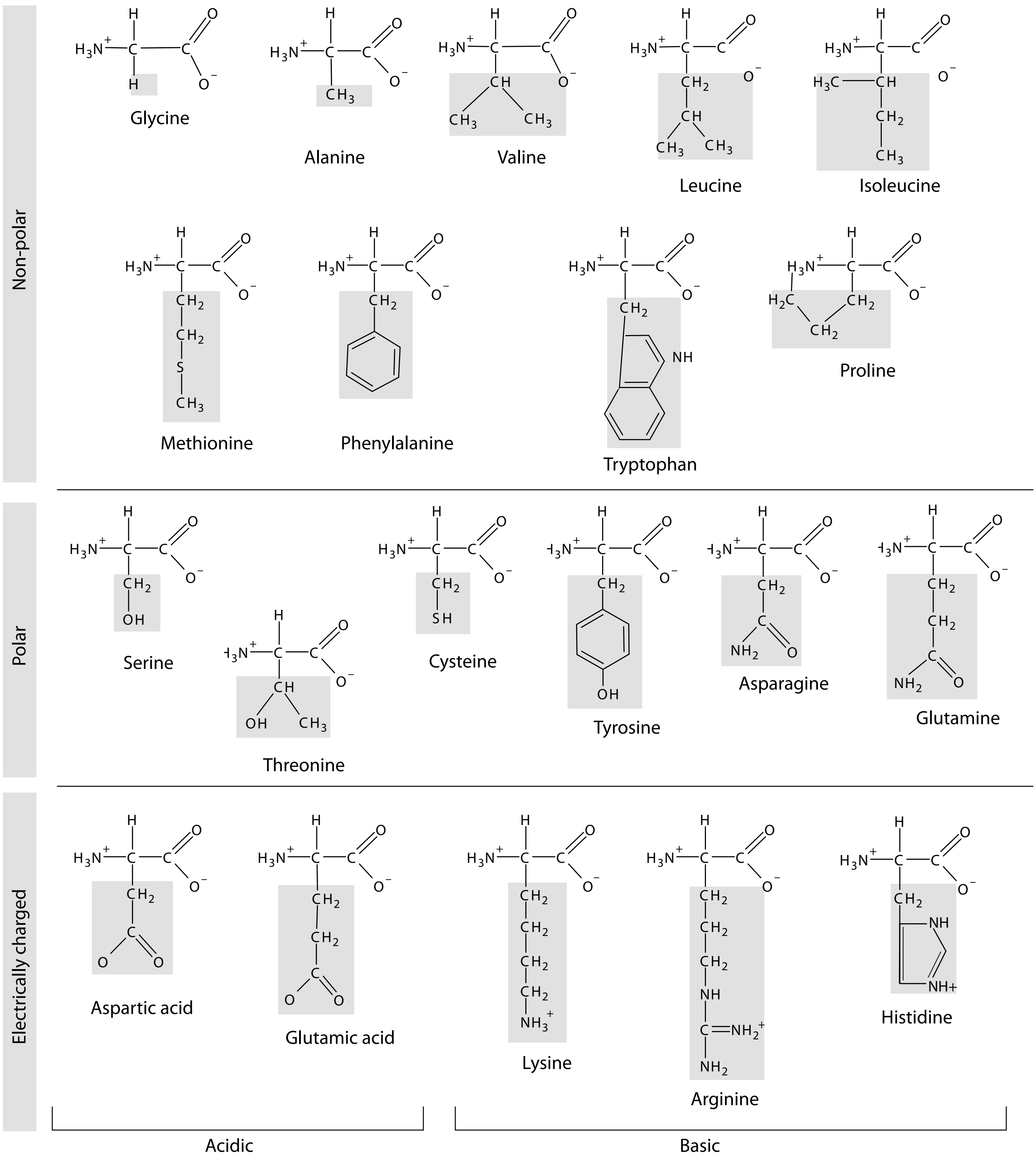


Figure 2.19: There are 20 amino acids, 8 of which are essential. The radical, or "R" group, for each amino acid is highlighted.

Amino acids are the monomers that make up proteins. The bonds that hold amino acids together are called peptide bonds. Peptide bonds are formed by a dehydration synthesis reaction, as shown in Figure 2.20.

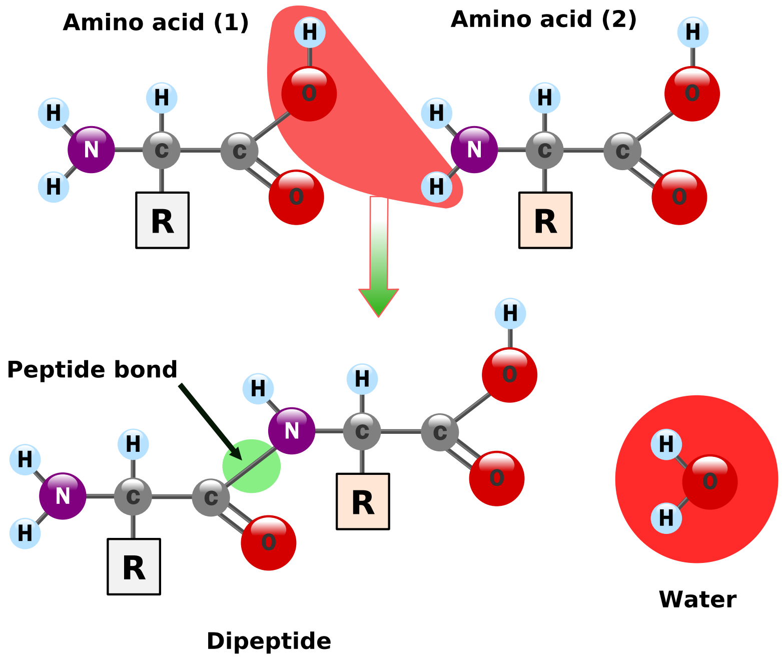


Figure 2.20: The formation of a polypeptide bond between two amino acids releases a water molecule. Chains of amino acids can be created with peptide bonds between each amino acid "link" in the chain.

Example of a Formation of a Peptide Bond

Figure 2.21 shows how two amino acids can be joined together. Note that the carboxyl and amino functional groups are involved in the formation of the peptide bond and contribute atoms for the water molecule. The carboxyl group from the serine gives up OH and the amino group from glycine contributes H.

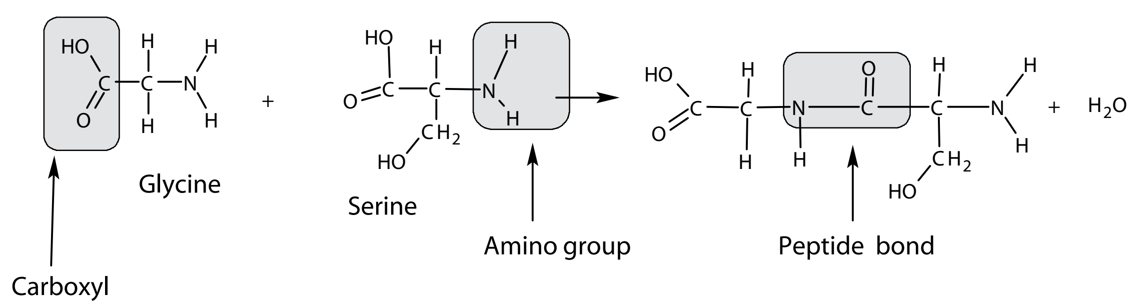


Figure 2.21: The formation of a peptide bond between two amino acids, glycine and serine.

Protein Structure

Once proteins are formed, they fold up into compact shapes. Although the shape of each protein is generally globular (like rolled-up balls), these shapes are still very specific, enabling them to carry out their specialized functions within the cells.

The final shape of a protein is also called its conformation. The conformation is the result of the amino acid sequence it contains and the interactions among those amino acids. There are four stages of protein structure possible. These are shown in Figure 2.22, which follows.

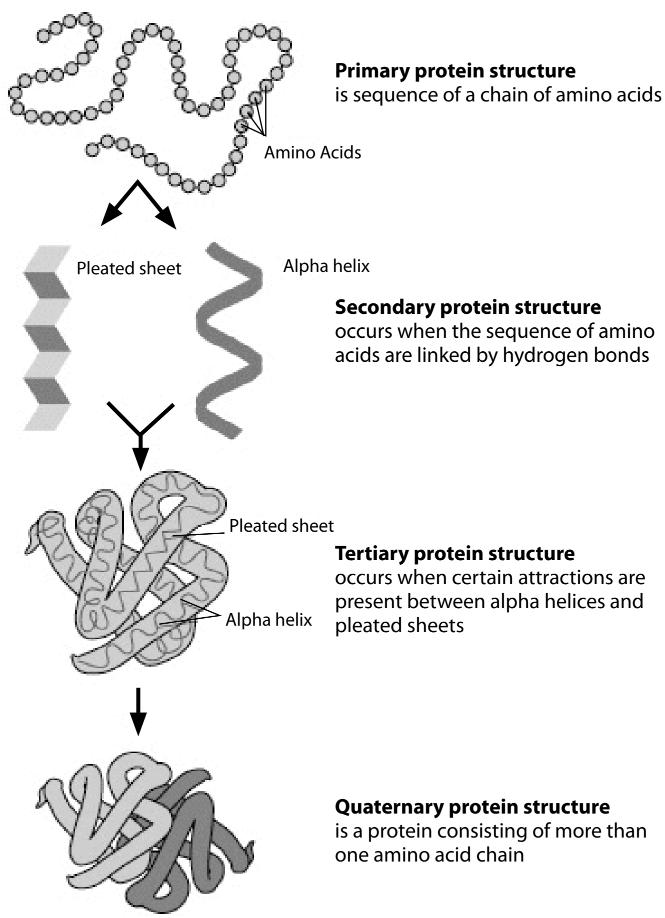


Figure 2.22: The four possible levels of protein organization, as the polypeptide chain twists and folds into its final conformation

Primary (1°) structure: When proteins are first assembled, they are said to be in their primary (1°) structure. This is a simple chain of amino acids joined together by peptide bonds, or a "polypeptide chain," as it is commonly called. The sequence of amino acids is determined by the nucleotide (DNA) sequence of a particular gene. With 20 different amino acids, there are endless possibilities for the primary structure. For instance, in a protein containing X number of amino acids, the number of possibilities is 20^x.

Secondary (2º) structure: As the amino acid assembly process creates the primary structure, the protein chain begins folding and coiling as it grows. This is called its secondary (2º) structure. Secondary structures are formed by hydrogen bonds between the oxygen atoms of a carboxyl group and the hydrogen atoms of an amino group. There are two types of secondary structures:

- **α helix:** A tight coil produced by hydrogen bonds occurring at every fourth peptide bond. This bonding is repeated along the entire length of the polypeptide to form a twisted "rope."
- **β pleated sheets:** Hydrogen bonds formed between parallel stretches of a polypeptide to form sheets

Tertiary (3º) structure: The polypeptide chain undergoes additional folding, due to side-chain ("R"-group) interactions. The most common are covalent bonds between sulphur atoms, called disulphide bridges. These bridges help to form the globular structure called the tertiary (3º) structure. All proteins eventually settle into their tertiary structure. Imagine folding a piece of paper in shapes or rolling coils of string into a ball. That is what happens to the peptides during the formation of their tertiary structure.

Quaternary (4º) structure: In some cases, two or more polypeptides join together to make a functional protein. In this case, the final structure depends on how the two or more polypeptides fold together. This is called the quaternary (4º) structure. It occurs when two or more folded polypeptide chains come together, such as those in collagen and hemoglobin.

Nucleic Acids

Nucleic acids are found in DNA (deoxyribonucleic acid), RNA (ribonucleic acid), ATP (adenosine triphosphate), and nucleotide coenzymes (NAD^+, $NADP^+$, and FAD). DNA and RNA are called nucleotide polymers. Nucleotides consist of a nitrogenous base, a five-carbon sugar, and a phosphate group. The phosphate and ribose groups are joined together by a phosphodiester linkage. You will learn more about this important linkage in later lessons.

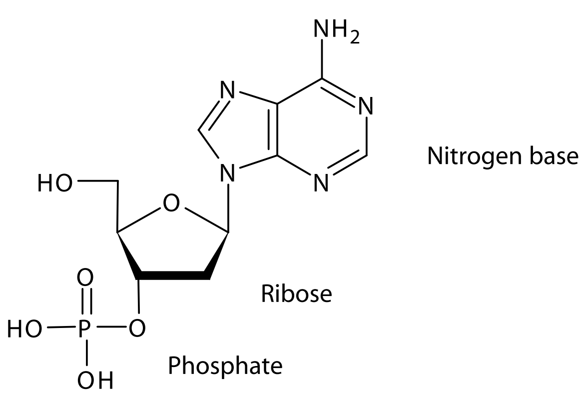


Figure 2.23: Nucleic acids are composed of nucleotides, which are made up of a sugar, a phosphate, and a nitrogen base.

There are five nitrogenous bases:

1. Adenine (A)
2. Guanine (G)
3. Cytosine (C)
4. Thymine (T)
5. Uracil (U)

These are amongst the most famous molecules in biology because they are the alphabet of life. You will learn more about this in a later unit. The structures of each base are shown in Figure 2.24 below.

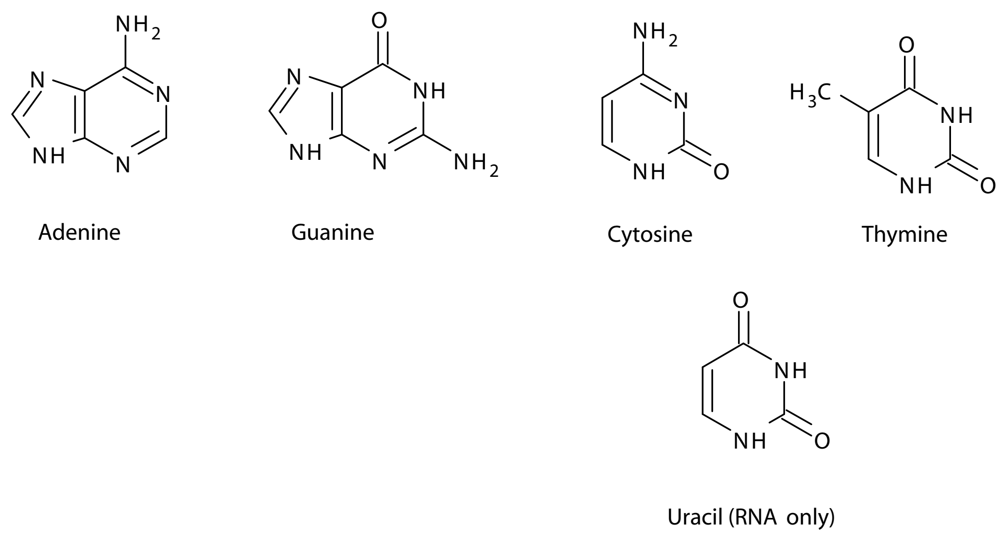


Figure 2.24: The five nitrogenous bases. Uracil occurs only in RNA.

Adenine and guanine are called purines. They have a double-ring structure. Cytosine, thymine, and uracil are called pyrimidines and have a single-ring structure.

Nucleic acids will be discussed in further detail in a later unit, when you learn more about DNA, the main hereditary molecule.

Support Questions

13. Fill in the blanks in the following paragraph. You can print this out or answer elsewhere.

Carbohydrates are the most common organic materials on earth. They contain carbon, hydrogen, and oxygen in a ____________________ ratio. When two or three monosaccharides join together, they are called ____________________. The bond that links them together is called a(n) ____________________ linkage. When only two sugars bond together, they are called a ____________________. When several hundred to several thousand sugars link together, they are called ____________________. These substances are important, either for energy storage, such as starch and ____________________, or for structural support, such as ____________________.

Suggested answer

14. Fill in the blanks in the following paragraph. You can print this out or answer elsewhere.

Lipids are a large group of hydrophobic molecules composed of carbon, hydrogen, and oxygen. They are divided into four families: fats, phospholipids, steroids, and waxes. Fats are the most common ____________________ molecules in living things. The most common fats in plants and animals are the ____________________. These contain ____________________ fatty acids and ____________________ molecule of glycerol. Fatty acids are long hydrocarbon chains with a single ____________________ group at one end. Fatty acids can either be saturated, if all of the carbons have ____________________ single bonds, or unsaturated, if they have one or more carbon-carbon double bonds. When glycerol reacts with a fatty acid, a(n) ____________________ linkage is formed, along with the production of ____________________. The membranes of cells are composed of phospholipids, molecules in which one of the fatty acids has been replaced by a(n) ____________________ group, which is ____________________ polar and therefore very ____________________, with respect to water. The sterols contain four fused hydrocarbon rings and several different functional groups. One of the most well-known sterols is ____________________, which is important in cell membrane structure, but has been linked to clogged arteries and cardiovascular disease. Waxes contain long-chain fatty acids linked to alcohols or carbon rings. They make good waterproof coatings. An example in plants would be the ____________________, which forms a water-resistant coating on the surface of leaves.

Suggested answer

15. Fill in the blanks in the following paragraph. You can print this out or answer elsewhere.

____________________ are the most diverse biological molecules. Proteins are polymers of amino acids. Amino acids contain a central carbon, to which a(n) ____________________ group, a(n) ____________________ group, and a variable group of atoms called a(n) ____________________ group (which is symbolized by the letter "R") are attached. There are ____________________ different "R" groups. The final shape or ____________________ of the protein is determined by the sequence of the amino acids it contains. The bonds that hold the amino acids together are called ____________________ bonds. These bonds are formed by a ____________________ ____________________ reaction between the amino group of one amino acid and the carboxyl group of another amino acid.

Suggested answer

16. Complete the reactions for the following. Draw the structural formula for both the reactants and products. Label the reactants, products, functional groups, and linkages present.

a) Glycerol + three fatty acids

b) Glucose + glucose →

c) Glycine + alanine →

Suggested answer

Activity: Viewing Important Biological Molecules

One of the best ways to understand macromolecules is to see and manipulate them, using models. You can view examples of each of the four macromolecules listed below using a 3D molecular viewer available on the ILC website.

Carbohydrates

Fats

Proteins

Nucleic acids

Support Question

17. Draw a ball-and-stick model of one of the macromolecules you have just viewed. Include all of the carbon, oxygen, and nitrogen atoms in the molecule. If there are too many hydrogen atoms to draw, you can indicate their position with a line indicating the bond. A good drawing is one that helps you to understand the molecule's structure.

Suggested answer

Testing for Biological Molecules in Food

Most of the compounds present in your cells either originate in, or are made from the food you eat. Therefore, you should be able to confirm the presence of many of these compounds in typical foods. Although you will not actually complete this investigation physically, you will learn about how nutritional scientists can test foods to determine what nutrients are present.

What types of compounds are present in foods? How can you find out? Biologists, chemists, and nutritional scientists have developed several chemical tests to detect the presence of three of the main macromolecules found in food: carbohydrates, lipids, and proteins.

Carbohydrates

There are two tests that test for carbohydrates (sugars): the Benedict's reagent tests for simple sugars and the Iodine test (using Lugol's solution) for polysaccharides, such as starch.

Benedict's reagent is a light blue reagent which, when added to a substance containing simple sugar, changes colour according to the table below, if simple sugars are present.

Table 2.1: Sample data from a test using Benedict's reagent

Colour of Benedict's reagent	Sugar concentration (%)
Blue	None
Light green	0.5–1.0
Green to yellow	1.0–1.5
Orange	1.5–2.0
Red to red brown	> 2.0

The iodine that you can use to clean your wounds also can be used to test for the polysaccharide, starch. The iodine solution turns from light brown to a deep purple-black, if starch is present. Try putting a drop of iodine on a soda cracker at home, and you will see this reaction (do not eat the cracker afterwards). Most labs use a form of iodine solution called Lugol's solution to perform the test.

Lipid Testing

A common method to test for the presence of lipids in food is the Sudan IV lipid test. This indicator tests for lipids present in food and turns from a pink to a red colour, if lipids are present.

Proteins

A common method of testing for the presence of proteins in food is Biuret's protein test. Biuret's reagent tests for proteins. If proteins are present in the solution, Biuret's reagent changes from light blue to a deep purple.

Support Question

18. The following table shows the results submitted by a technician for a nutrient analysis report. Help the technician to interpret her results by stating what nutrients are present in each one.

Unknown sample	Benedict's reagent	Iodine (Lugol's solution)	Sudan IV indicator	Biuret's reagent
A	blue	black	pink	violet
B	orange	black	red	blue
C	blue	light brown	pink	blue

Suggested answer

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

Total: 17 marks

5. For each of the following four macromolecules, list their

- **i)** monomer(s).
- **ii)** functional groups.
- **iii)** linkage type.
- **iv)** primary function.

Macromolecules:

- **a)** Carbohydrates
- **b)** Proteins
- **c)** Lipids
- **d)** Nucleic acids

(Total 8 marks: ½ mark for each correct answer)

6. Show how a peptide bond forms between the two amino acids, glycine and valine. Draw the structural formulas for the reactants and the product. Label the functional groups and linkages present. **(5 marks)**

Glycine + valine → ?

7. Chocolate milk has been a choice for many athletes, as it is a good source of protein, carbohydrates, and lipids. Suppose you were to conduct nutrient testing on a sample of chocolate milk. Describe

- **a)** the tests you would perform and the reagents you would use. **(2 marks)**
- **b)** the results you would expect to find. **(2 marks)**

Now go on to Lesson 3. Send your answers to the Key Questions to the ILC when you have completed Unit 1 (Lessons 1 to 4).