## **Ch 3 Carbon and the Molecular Diversity of Life**

# **Overview: Carbon Compounds and Life**

## Aside from water, living organisms consist mostly of carbon-based compounds

## Carbon is unparalleled in its ability to form large, complex, and diverse molecules

## A compound containing carbon is said to be an **organic** **compound**

## Critically important molecules of all living things fall into four main classes

### Carbohydrates

### Lipids

### Proteins

### Nucleic acids

## The first three of these can form huge molecules called **macromolecules**

## **Concept 1.1: Carbon atoms can form diverse molecules by bonding to four other atoms**

# **The Formation of Bonds with Carbon**

## With four **valence** electrons, carbon can form four covalent bonds with a variety of atoms

### This ability makes large, complex molecules possible

## In molecules with multiple carbons, each carbon bonded to four other atoms has a tetrahedral shape

## However, when two carbon atoms are joined by a double bond, the atoms joined to the carbons are in the same plane as the carbons

## Figure 3.2

## The electron configuration of carbon gives it covalent compatibility with many different elements

## The valences of carbon and its most frequent partners (hydrogen, oxygen, and nitrogen) are the “building code” that governs the architecture of living molecules

# **Molecular Diversity Arising from Variation in Carbon Skeletons**

## Carbon chains form the skeletons of most organic molecules

## Carbon chains vary in length and shape

## Figure 3.4

## **Hydrocarbons** are organic molecules consisting of only carbon and hydrogen

## Many organic molecules, such as fats, have hydrocarbon components

## Hydrocarbons can undergo reactions that release a large amount of energy

# **The Chemical Groups Most Important to Life**

## **Functional groups** are the components of organic molecules that are most commonly involved in chemical reactions

## The number and arrangement of functional groups give each molecule its unique properties

## Figure 3.5

# **ATP: An Important Source of Energy for Cellular Processes**

## One organic phosphate molecule, **adenosine triphosphate** (**ATP**), is the primary energy-transferring molecule in the cell

## ATP consists of an organic molecule called adenosine attached to a string of three phosphate groups

# **Concept 3.2: Macromolecules are polymers, built from monomers**

## A **polymer** is a long molecule consisting of many similar building blocks

## These small building-block molecules are called **monomers**

## Some molecules that serve as monomers also have other functions of their own

# **The Synthesis and Breakdown of Polymers**

## Cells make and break down polymers by the same process

## A **dehydration reaction** occurs when two monomers bond together through the loss of a water molecule

## Polymers are disassembled to monomers by **hydrolysis**, a reaction that is essentially the reverse of the dehydration reaction

## These processes are facilitated by **enzymes**, which speed up chemical reactions

## **Figure 3.6**

# **Concept 3.3: Carbohydrates serve as fuel and building material**

## **Carbohydrates** include sugars and the polymers of sugars

## The simplest carbohydrates are monosaccharides, or simple sugars

## Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks

# **Sugars**

## Monosaccharides have molecular formulas that are usually multiples of CH2O

## Glucose (C6H12O6) is the most common monosaccharide

## Monosaccharides serve as a major fuel for cells and as raw material for building molecules

## **Figure 3.7**

## A **disaccharide** is formed when a dehydration reaction joins two monosaccharides

## This covalent bond is called a **glycosidic linkage**

# ***Storage Polysaccharides***

## **Starch**, a storage polysaccharide of plants, consists entirely of glucose monomers

### Plants store surplus starch as granules

## **Glycogen** is a storage polysaccharide in animals

### Humans and other vertebrates store glycogen mainly in liver and muscle cells

# ***Structural Polysaccharides***

## The polysaccharide **cellulose** is a major component of the tough wall of plant cells

### In straight structures (cellulose), H atoms on one strand can form hydrogen bonds with OH groups on other strands

### Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants

# **Concept 3.4: Lipids are a diverse group of hydrophobic molecules**

## **Lipids** do not form true polymers

## Lipids are hydrophobic because they consist mostly of hydrocarbons, which form nonpolar covalent bonds

## The most biologically important lipids are fats, phospholipids, and steroids

# **Fats**

## **Fats** are constructed from two types of smaller molecules: glycerol and fatty acids

## Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon

## A **fatty acid** consists of a carboxyl group attached to a long carbon skeleton

## Held together by an Ester Linkage

## **Figure 3.12**

### Fats separate from water because water molecules hydrogen-bond to each other and exclude the fats

### In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a **triacylglycerol**, or triglyceride

### **Figure 3.12b**

## Fatty acids vary in length (number of carbons) and in the number and locations of double bonds

## **Saturated fatty acids** have the maximum number of hydrogen atoms possible and no double bonds

## **Unsaturated fatty acids** have one or more double bonds

# **Fat Functions**

## The major function of fats is energy storage

## Insulation

## Protection of Organs

## Waterproof covering (Phospholipids)

## Hormones (Steroids)

# **Phospholipids**

## In a **phospholipid**, two fatty acids and a phosphate group are attached to glycerol

## The two fatty acid tails are hydrophobic, but the phosphate group and its attachments form a hydrophilic head

## Phospholipids are major constituents of cell membranes

## **Figure 3.14cd**

# **Steroids**

## **Steroids** are lipids characterized by a carbon skeleton consisting of **four fused rings**

## Different steroids are distinguished by the specific chemical group attached. Below is **Cholesterol**

# **Concept 3.5: Proteins include a diversity of structures, resulting in a wide range of functions**

## Proteins account for more than 50% of the dry mass of most cells

## Protein functions include

### defense,

### storage,

### transport,

### cellular communication,

### movement, and

### structural support

**Structure of a Protein**

## A **protein** is a biologically functional molecule that consists of one or more polypeptides

# **Protein Structure and Function**

## A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape

## The sequence of amino acids, determined genetically, leads to a protein’s three-dimensional structure

## A protein’s structure determines its function

# **4 Levels of Protein Structure**

## The primary structure of a protein is its unique sequence of amino acids

## Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain

## Tertiary structure is determined by interactions among various side chains (R groups)

## Quaternary structure results from interactions between multiple polypeptide chains

## **Figure 3.21**

# ***What Determines Protein Structure?***

## In addition to primary structure, physical and chemical conditions can affect structure

## Alterations in pH, salt concentration, temperature, or other environmental factors can cause a protein to unravel

## This loss of a protein’s native structure is called **denaturation**

## A denatured protein is biologically inactive

## **Figure 3.23-3**

# ***Protein Folding in the Cell***

## It is hard to predict a protein’s structure from its primary structure

## Most proteins probably go through several intermediate structures on their way to their final, stable shape

## Scientists use **X-ray crystallography** to determine 3-D protein structure based on diffractions of an X-ray beam by atoms of the crystalized molecule

# **Concept 3.6: Nucleic acids store, transmit, and help express hereditary information**

## The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a **gene**

## Genes are made of DNA, a **nucleic acid** made of monomers called nucleotides

# **The Roles of Nucleic Acids**

## There are two types of nucleic acids

### **Deoxyribonucleic acid (DNA)**

### **Ribonucleic acid (RNA)**

## DNA provides directions for its own replication

## DNA directs synthesis of messenger RNA (mRNA) and, through mRNA, controls protein synthesis

## **Figure 3.25-3**

# **The Components of Nucleic Acids**

## Nucleic acids are polymers called **polynucleotides**

## Each polynucleotide is made of monomers called **nucleotides**

## Each nucleotide consists of a nitrogenous base, a pentose sugar, and one or more phosphate groups

## The portion of a nucleotide without the phosphate group is called a nucleoside

## Figure 3.26a

# **The Structures of DNA and RNA Molecules**

## RNA molecules usually exist as single polypeptide chains

## DNA molecules have two polynucleotides spiraling around an imaginary axis, forming a?

## In the DNA double helix, the two backbones run in opposite 5′→ 3′ directions from each other, an arrangement referred to as **antiparallel**

## One DNA molecule includes many genes (hereditary information

## **Figure 3.26**