Chapter 8: The Structure of DNA, RNA and Proteins

This chapter will explore the structure of nucleic acids and proteins.

DNA Structure

DNA is composed of several different subunits. The backbone of the molecule is made of a sugar called deoxyribose. The deoxyribose is held together by phosphate groups. Deoxyribose also forms bonds with the four bases, adenine (A), cytosine (C), thymine (T) and guanine (G). Figures 8.1-8.6 depict how the subunits are assembled in a DNA molecule. In these figures, black represents adenine, white thymine, dark gray guanine, and light gray cytosine.

Figure 8.1: Rasmol Image of DNA Double Helix Segment

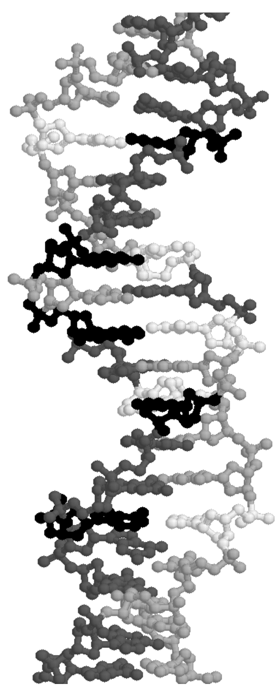


Figure 8.2: Closer View of DNA

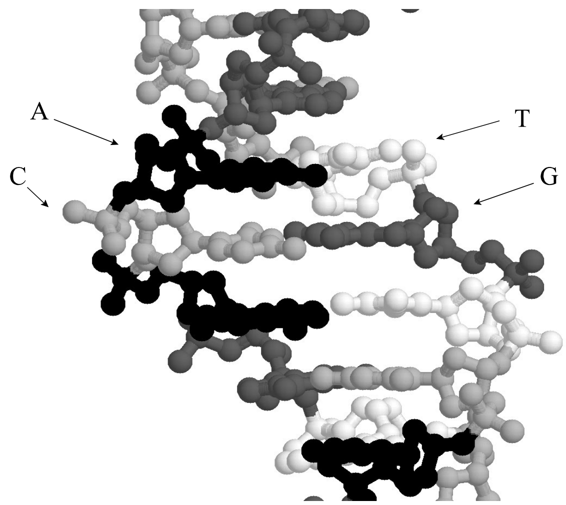


Figure 8.3: Conceptual DNA Model

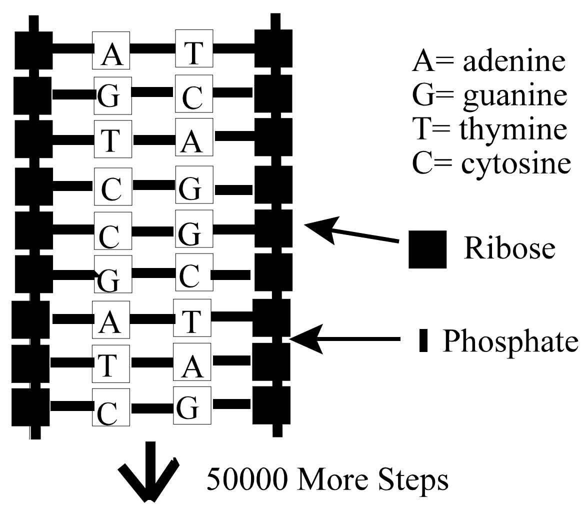
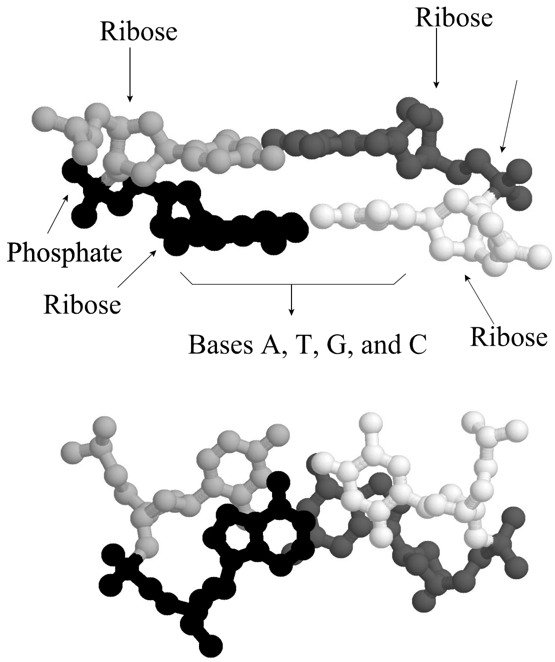


Figure 8.4: Top and Side view of Two Steps



Chapter 3 describes how this structure stores information. The order of the four bases (A, T, C and G) read three at a time per table 3.2 determine the amino acid sequence in the final protein.

RNA Structure

RNA is very similar to DNA, but it normally does not form the characteristic double helix (twisted ladder). RNA is a mixture of single stranded and double stranded segments (figure 8.7). The 3-D structure is often stabilized by complementary base pairing in short regions (boxes in figure 8.7). RNA uses the base uracil in place of thymine. It also uses ribose instead of deoxyribose (figure 8.6).

Figure 8.5: Detailed DNA Structure

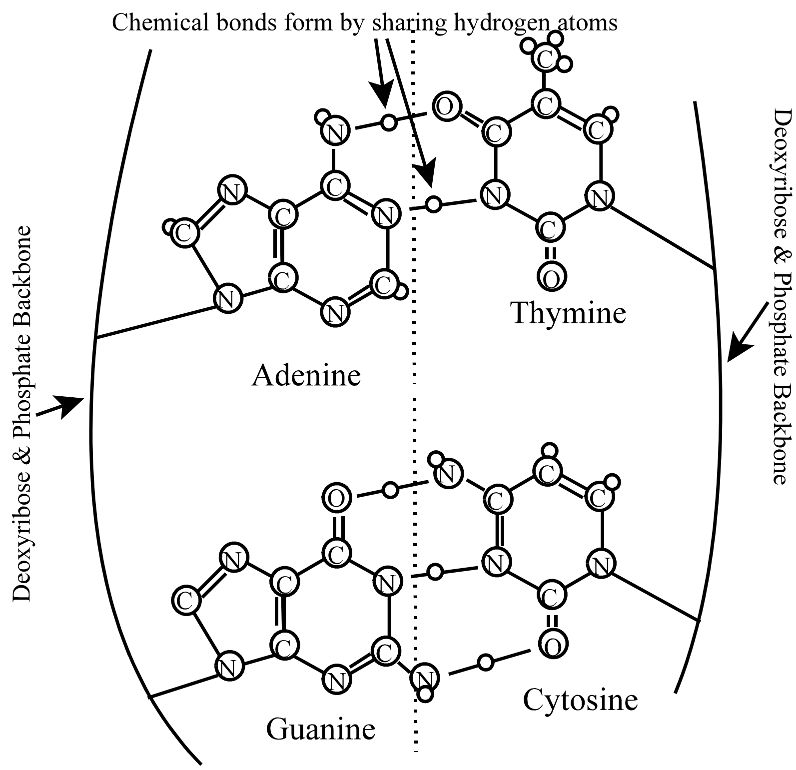
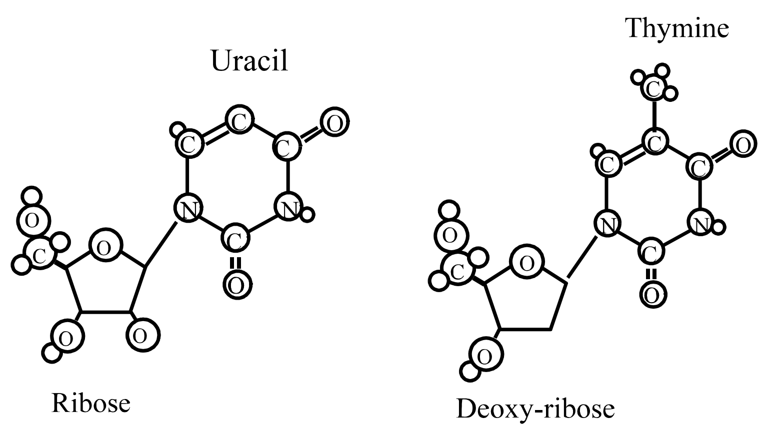


Figure 8.6: Ribose, Deoxyribose, Uracil and Thymine

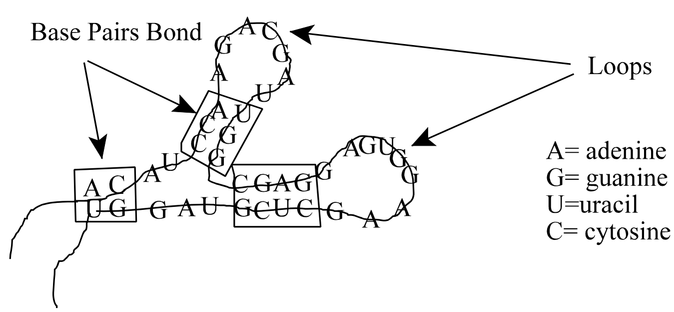


Because RNA is a single strand, it does not form the characteristic helix found in DNA, but it can still fold up on itself, creating a complex 3-D structure. Figure 8.7, shows how base pair bonds can stabilize such a structure.

This 3-D structure is extremely important, because it conveys to RNA some of the properties found in proteins. RNA can regulate chemical reactions just like proteins. This is why RNA has taken center stage in most origin of life theories. RNA can store information and it can regulate chemical reactions. Nevertheless, the initial optimism for self replicating RNA molecules has largely been replaced by doubt. The reasons for the doubt will be discussed in the next two chapters.

Figure 8.7: RNA Structure Stabilized by Base Pair Bonds

RNA Curls up On Itself Form Double and Single Stranded Regions



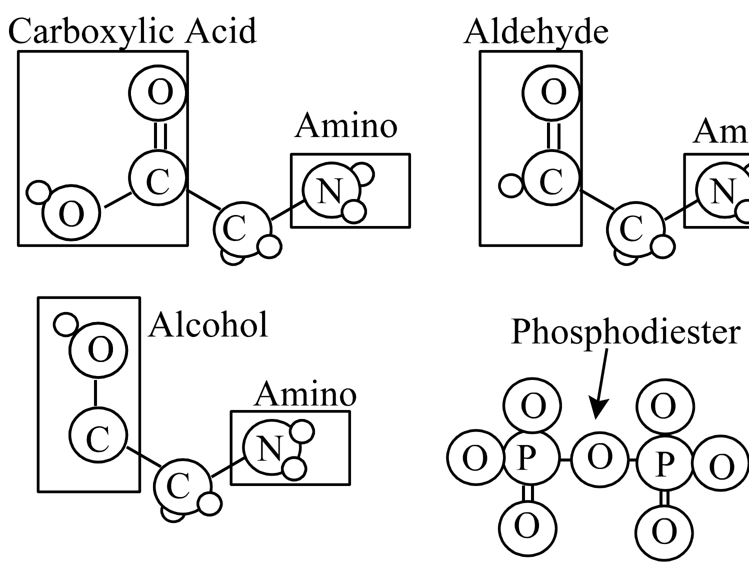
Proteins

Proteins are created at ribosomes. The information in messenger RNA specifies the amino acid sequence. Proteins are the most versatile molecules in biology. Chapter 3 discussed some of the functions that they serve in life.

Organic Chemistry Functional Groups

Organic chemistry is the study of how chemicals containing mostly carbon interact. Many chemicals used by life are organic. Because organic chemicals are very large, the structures of many are overwhelming. Fortunately, the chemicals can only interact with each other in a very limited set of reactions. These reactions are controlled by functional groups. The functional groups relevant to the origin of life are shown in figure 8.8. The functional groups in figure 8.8 are the atoms found inside the boxes. The carboxylic acid and amino groups are found in all amino acids. P = phosphorous, O = oxygen, N = nitrogen, C = carbon, and unlabeled small spheres = hydrogen.

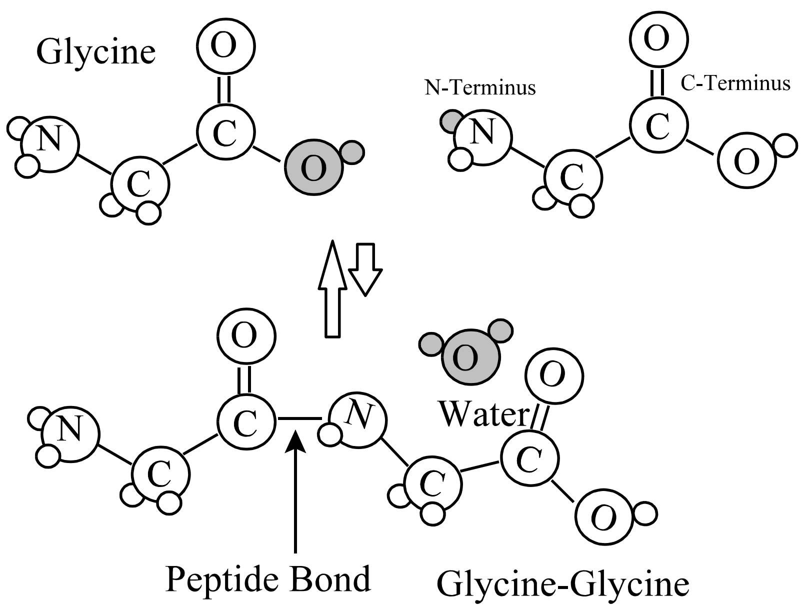
Figure 8.8: Functional Groups



Structure of Amino Acids

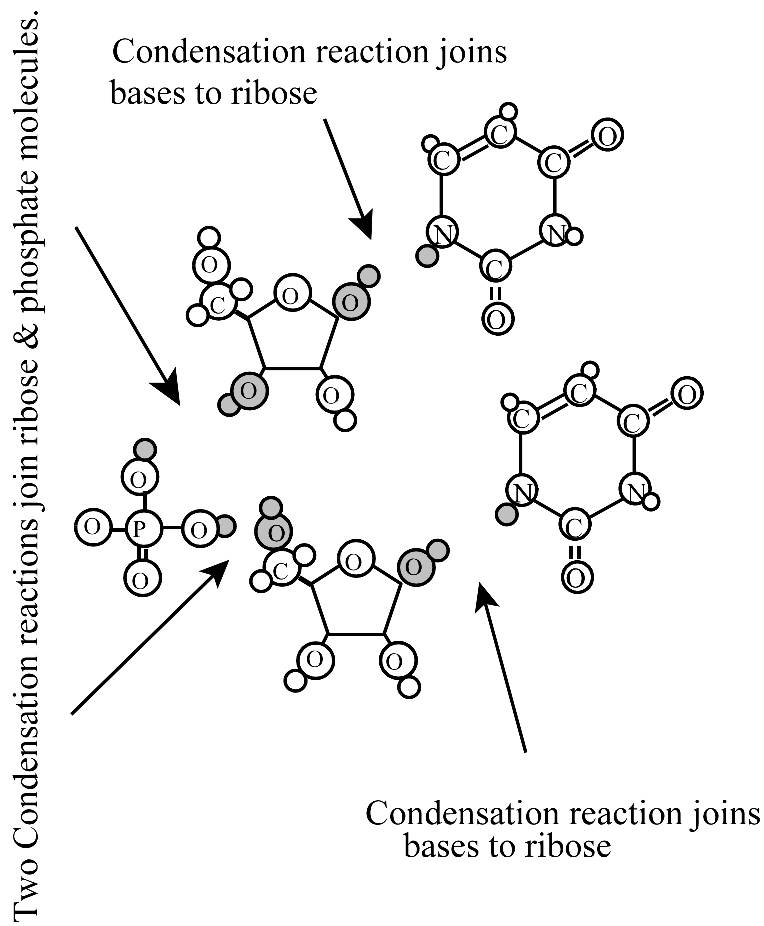
Amino acids are composed of 5 elements - carbon, oxygen, nitrogen, hydrogen and sulfur. It is their chemical structure that permits them to form long chains. These long chains fold up into complex three dimensional patterns forming proteins. Each amino acid can be broken down into three critical parts: the side chain or side group, the N-terminus (amino group) and the C-terminus (carboxylic acid). The N-terminus of one amino acid can attack the C-terminus of another. Under the right conditions, this attack will form a link between the amino acids. This link is called an amide bond or a peptide bond. Figure 8.9 illustrates the key structural components using the amino acid glycine.

Figure 8.9: Glycine and the Peptide Bond



Notice that after the peptide bond forms, and the two glycines are linked by a peptide bond, one C-terminus and one N-terminus still exist. This allows the chain to continue growing. A short chain of amino acids is called a peptide. A peptide may or may not contain information. The dark atoms in figure 8.9 are the atoms that leave forming water when the two glycine molecules join. Because this reaction creates water, it is called a condensation reaction. Condensation reactions do not occur readily in water and are particularly problematic for RNA and DNA prebiotic synthesis.

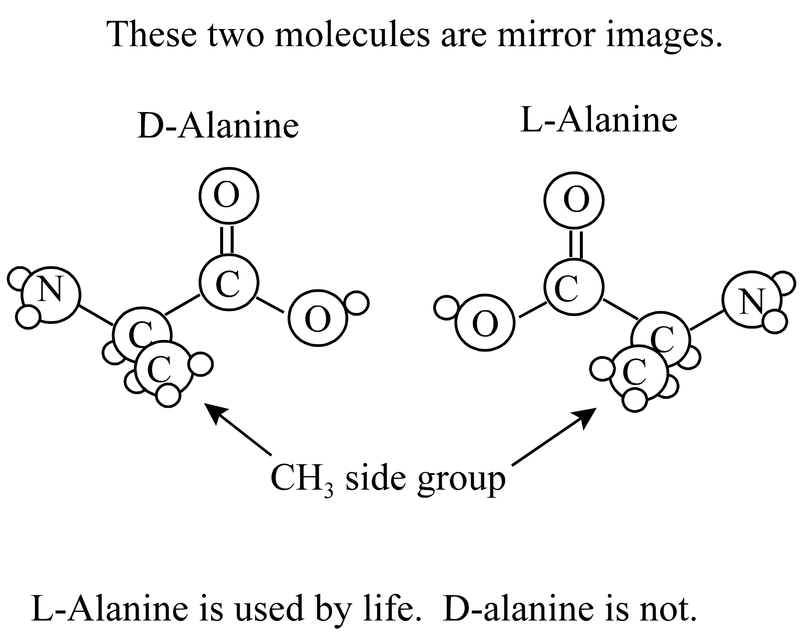
Figure 8.10: RNA and DNA Requires Many Condensation Reactions



A protein is a chain of many amino acids (typically more than 100 amino acids). Proteins have a specific function. Therefore, proteins contain useful information (knowledge). This information is specified by the order of amino acids in the chain. The 20 amino acids used by life differ only in their side chains.

Every amino acid except glycine has two forms, L and D. One form is the mirror image of the other. These forms are called isomers. The L and D isomer of the amino acid alanine is shown in figure 8.11.

Figure 8.11: L and D Isomers of Alanine



The L and D isomers can form peptide bonds. But the location of the side group is located in the wrong position when the L isomer is replaced with the D. This of course may influence protein function. One of life's greatest mysteries is why did life chose to only use the L-amino acids? Nineteen of the amino acids used by life are shown in figures 8.12-8.17. Glycine is shown in figure 8.9.

Figure 8.12: Hydrophobic Amino Acids (Do Not Like Water)

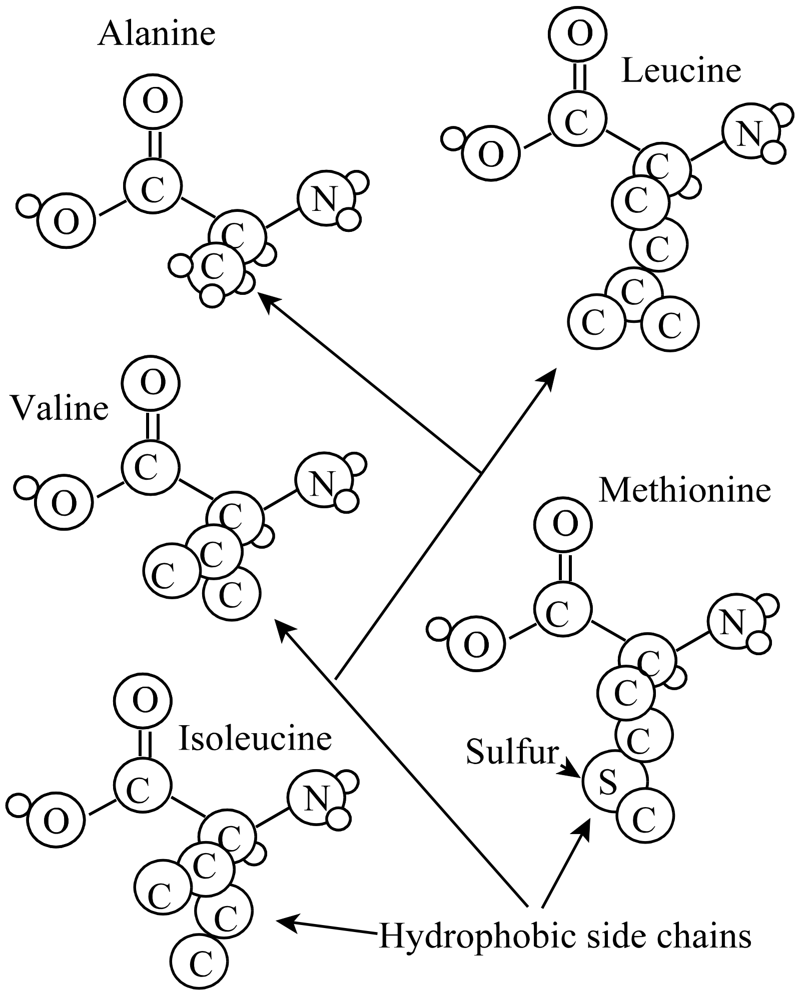


Figure 8.13: Basic Amino Acids

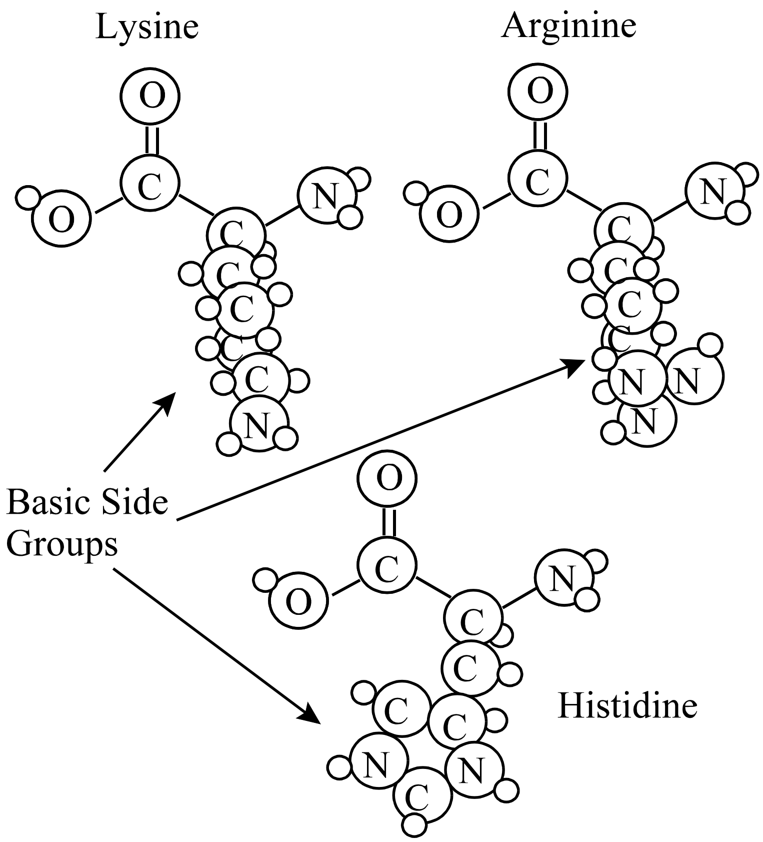


Figure 8.14: Polar Uncharged Amino Acids

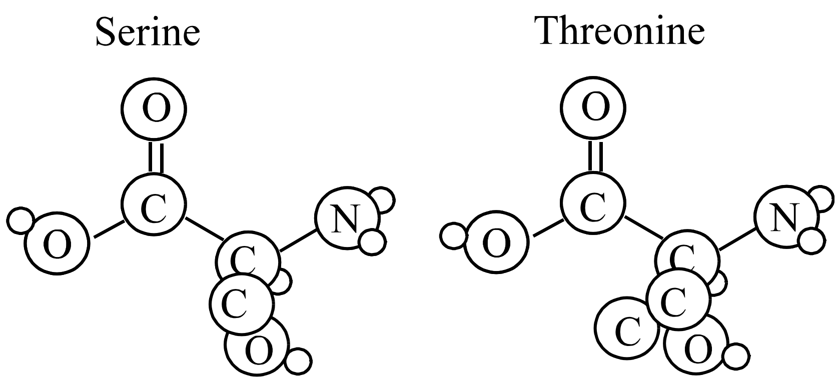


Figure 8.15: Two Unique Amino Acids

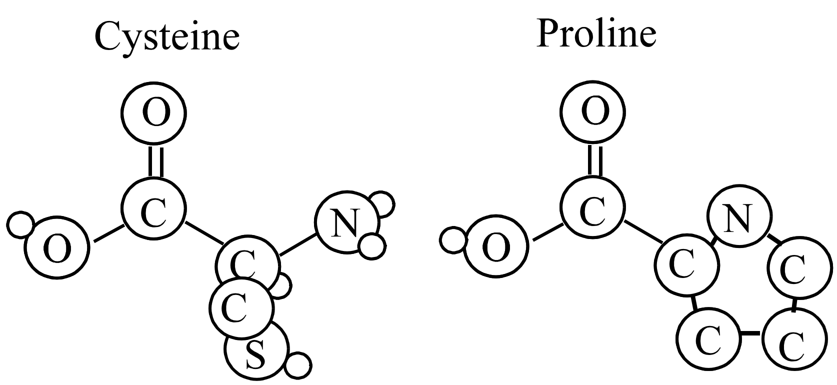


Figure 8.16: Bulky Amino Acids

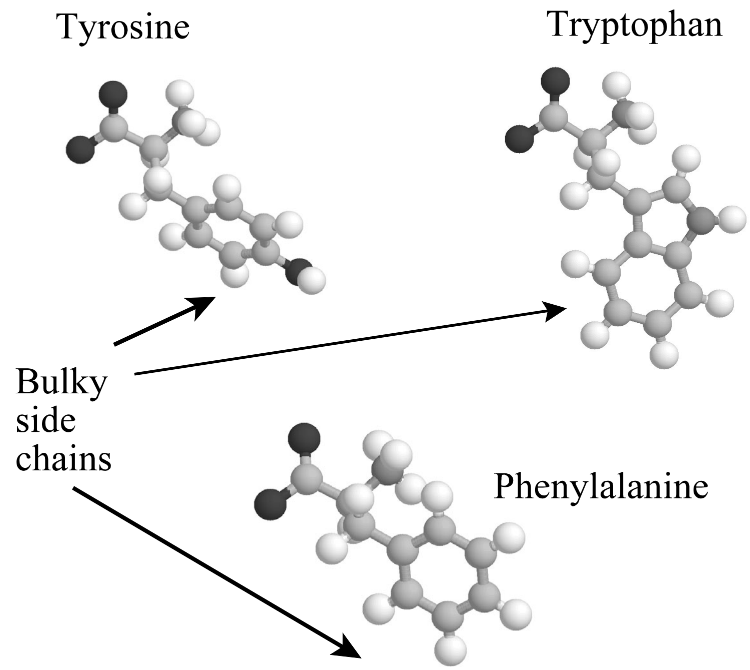
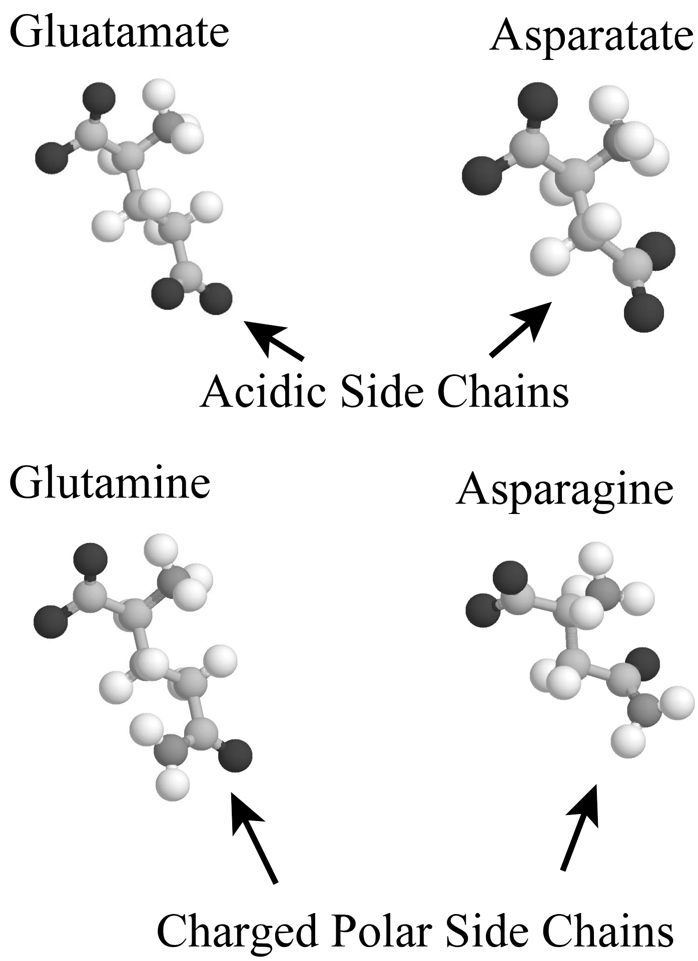


Figure 8.16 was generated using Rasmol. This is a free molecular viewer that allows users to view the 3-D structure of complex molecules. In this view, oxygen is black, hydrogen is white, carbon is gray, and nitrogen is a slightly darker gray. Rasmol was also used to generate the DNA images at the beginning of this chapter.

Figure 8.17: More Rasmol Images of Amino Acids



http://www.theory-of-evolution.net