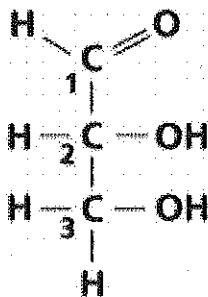


# Carbohydrates

## 1. Monosaccharides

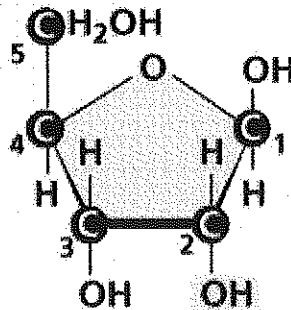
Figure 8. The chain (left) and ring (center and right) method of representing carbohydrates. Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.

### Three-carbon sugar

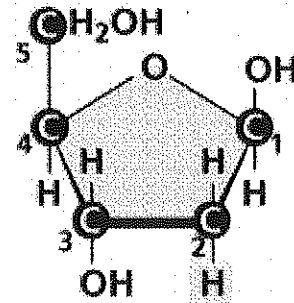


Glyceraldehyde

### Five-carbon sugars

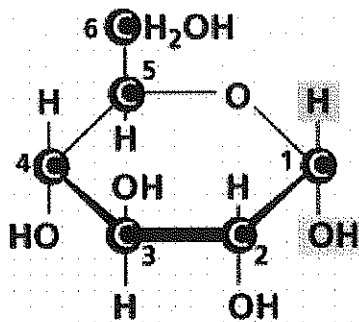


Ribose



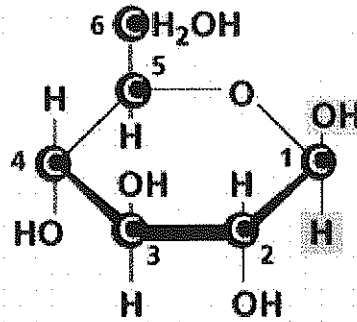
Deoxyribose

Figure 9. Models of glucose and fructose. Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.

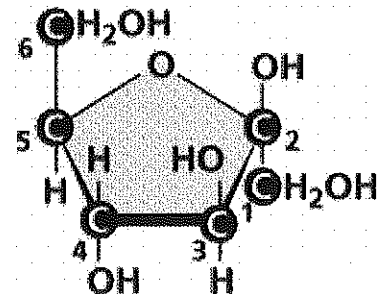
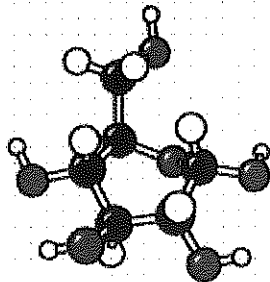


(c)  $\alpha$ -Glucose

or

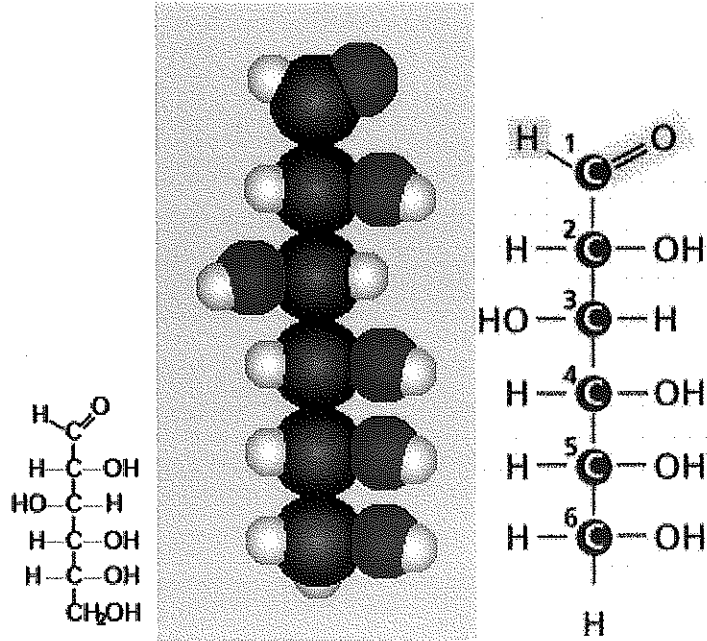


(d)  $\beta$ -Glucose



Fructose

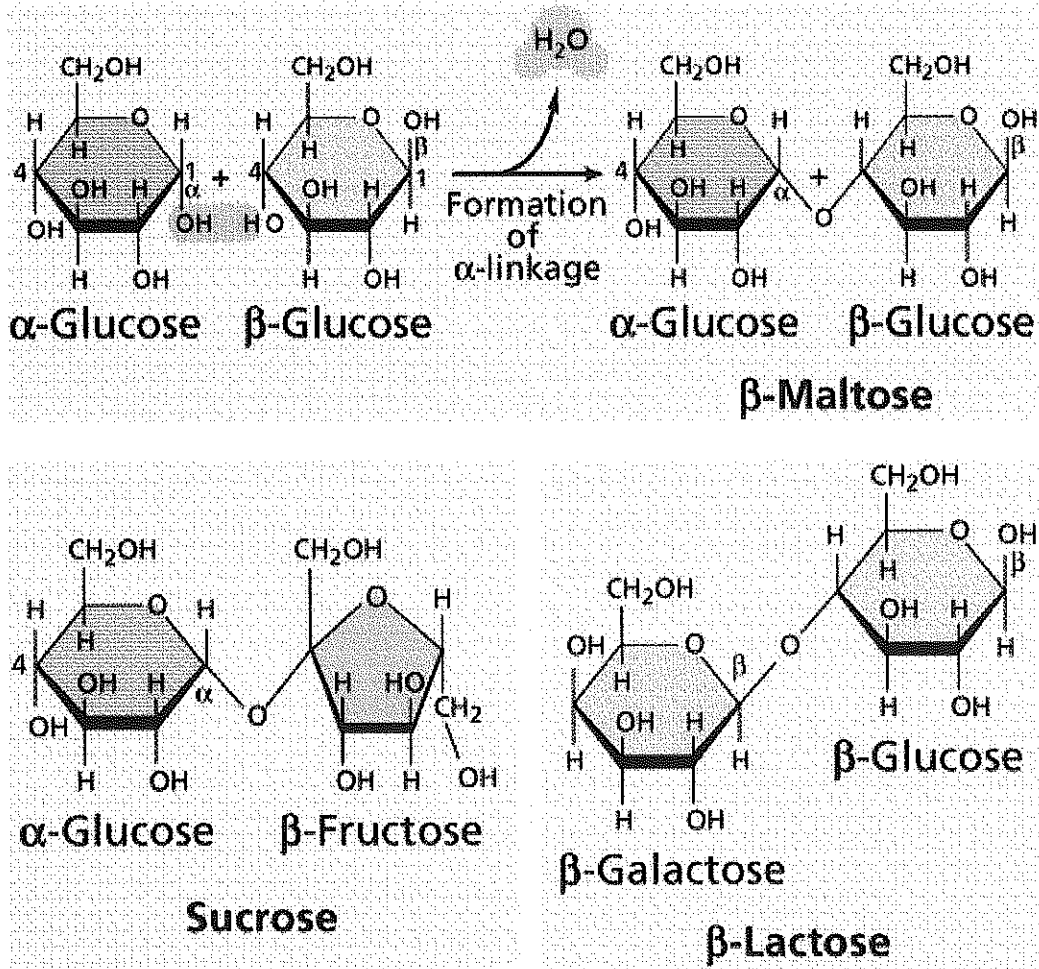
Figure 10. D-Glucose in various views (stick and space-filling) from the web. Right image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



**NOTES:**

# Disaccharides

Figure 11. Formation of a disaccharide (top) by condensation and structure of two common disaccharides. Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.

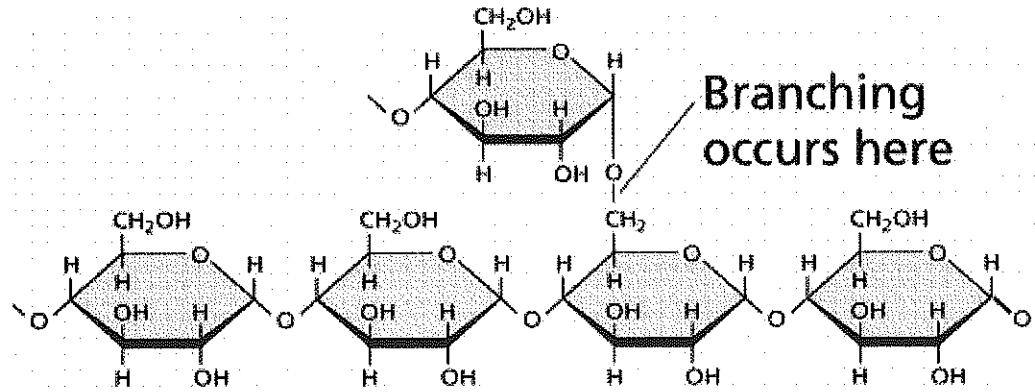


**NOTES:**

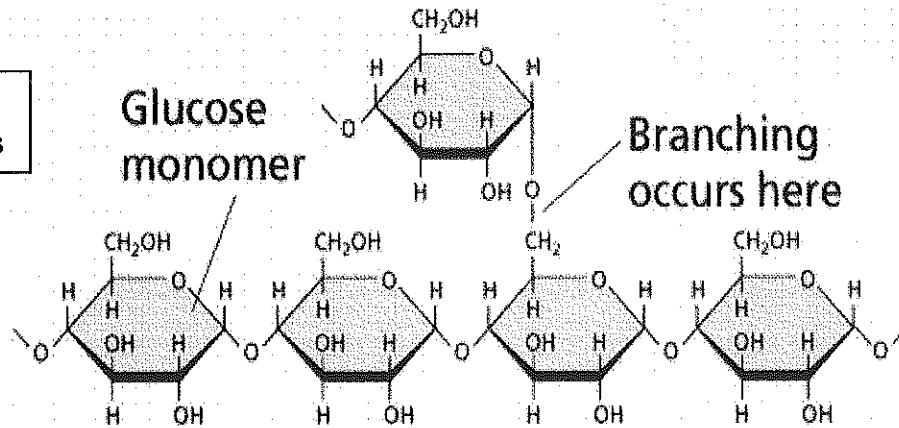
# Polysaccharides

Figure 12. Images of starch (top), glycogen (middle), and cellulose (bottom). Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.

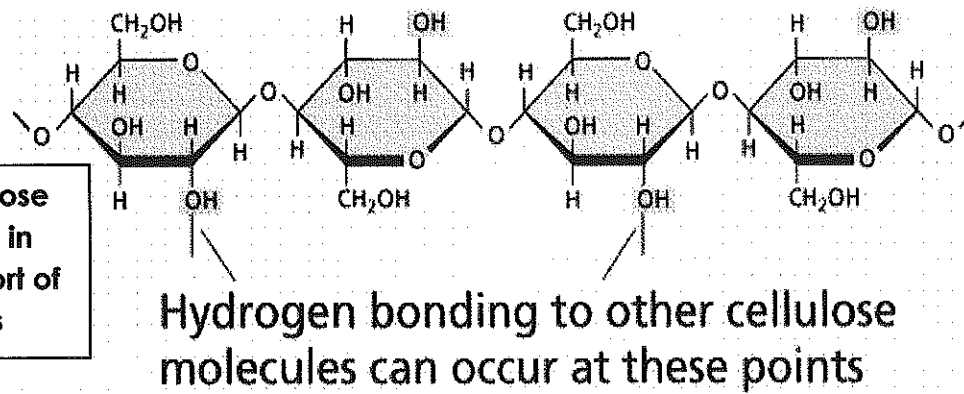
Starch  
found in  
plants



Glycogen  
in humans

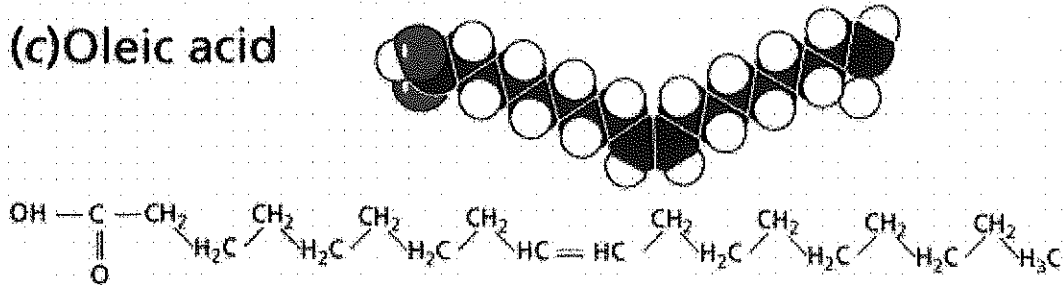


Cellulose  
found in  
support of  
plants





(c) Oleic acid



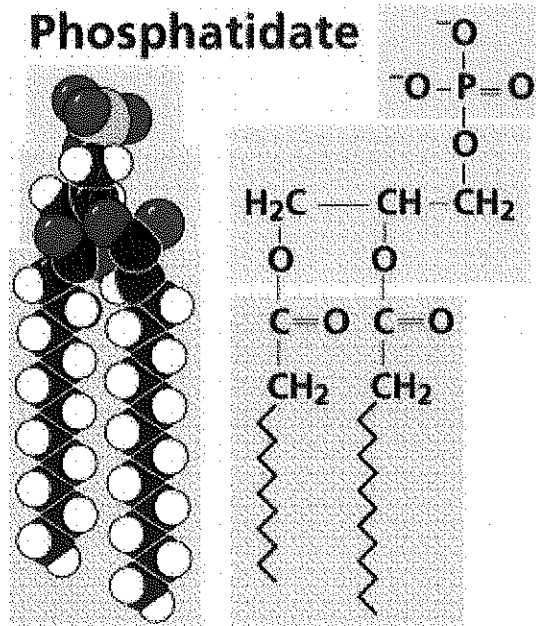
Fats and oils function in long-term energy storage. Animals convert excess sugars (beyond their glycogen storage capacities) into fats. Most plants store excess sugars as starch, although some seeds and fruits have energy stored as oils (e.g. corn oil, peanut oil, palm oil, canola oil, and sunflower oil). Fats yield 9.3 Kcal/gm, while carbohydrates yield 3.79 Kcal/gm. Fats thus store six times as much energy as glycogen.

Diets are attempts to reduce the amount of fats present in specialized cells known as adipose cells that accumulate in certain areas of the human body. By restricting the intakes of carbohydrates and fats, the body is forced to draw on its own stores to make up the energy debt. The body responds to this by lowering its metabolic rate, often resulting in a drop of "energy level." Successful diets usually involve three things: decreasing the amounts of carbohydrates and fats; exercise; and behavior modification.

Another use of fats is as insulators and cushions. The human body naturally accumulates some fats in the "posterior" area. Subdermal ("under the skin") fat plays a role in insulation.

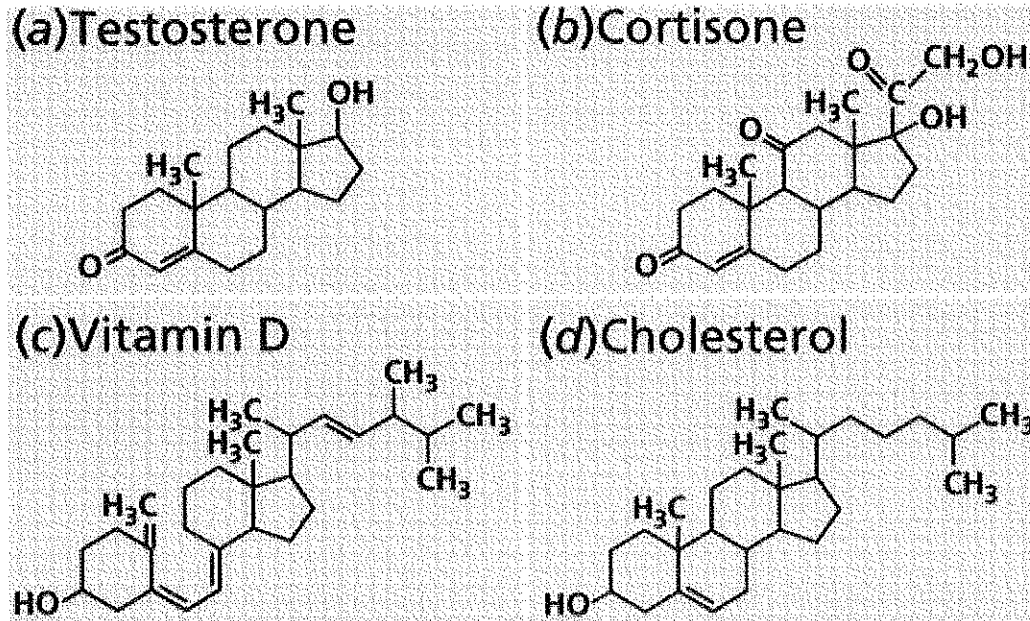
**Phospholipids** and glycolipids are important structural components of cell membranes. Phospholipids, shown in Figure 16, are modified so that a phosphate group (PO<sub>4</sub><sup>-</sup>) is added to one of the fatty acids. The addition of this group makes a polar "head" and two nonpolar "tails". Waxes are an important structural component for many organisms, such as the cuticle, a waxy layer covering the leaves and stems of many land plants; and protective coverings on skin and fur of animals.

Figure 16. Structure of a phospholipid, space-filling model (left) and chain model (right). Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



**Cholesterol and steroids:** Most mention of these two types of lipids in the news is usually negative. Cholesterol, illustrated in Figure 17, has many biological uses, it occurs in cell membranes, and its forms the sheath of some types of nerve cells. However, excess cholesterol in the blood has been linked to atherosclerosis, hardening of the arteries. Recent studies suggest a link between arterial plaque deposits of cholesterol, antibodies to the pneumonia-causing form of *Chlamydia*, and heart attacks. The plaque increases blood pressure, much the way blockages in plumbing cause burst pipes in old houses.

Figure 17. Structure of four steroids. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



3. Proteins are very important in biological systems as control and structural elements. Control functions of proteins are carried out by enzymes and proteinaceous hormones. Enzymes are chemicals that act as organic catalysts (a catalyst is a chemical that promotes but is not changed by a chemical reaction). Click [here](#) for an illustrated page about enzymes. Structural proteins function in the cell membrane, muscle tissue, etc.

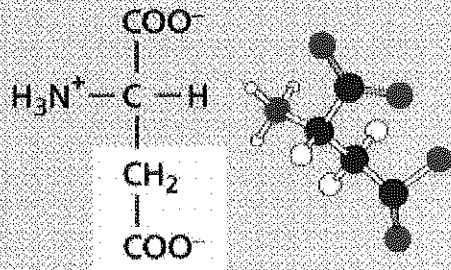
The building block of any protein is the amino acid, which has an amino end ( $\text{NH}_2$ ) and a carboxyl end ( $\text{COOH}$ ). The structure of a generalized amino acid as well as the specific structures of the 20 biological amino acids are shown in Figure 18 and 19 respectively. The R indicates the variable component (R-group) of each amino acid. Alanine and Valine, for example, are both nonpolar amino acids, but they differ, as do all amino acids, by the composition of their R-groups. All living things (and even viruses) use various combinations of the same twenty amino acids. A very powerful bit of evidence for the phylogenetic connection of all living things.

Figure 18. Structure of an amino acid. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.

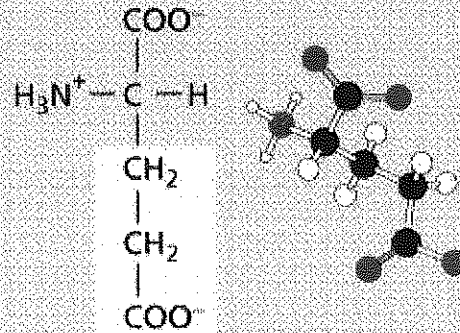


**A. Amino acids with electrically charged side chains: Negative**

**Aspartic acid (Asp)**

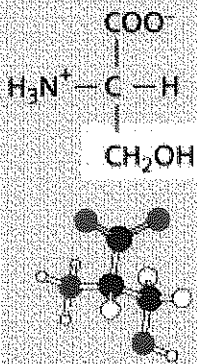


**Glutamic acid (Glu)**

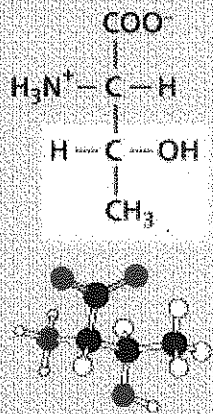


**B. Amino acids with polar but uncharged side chains**

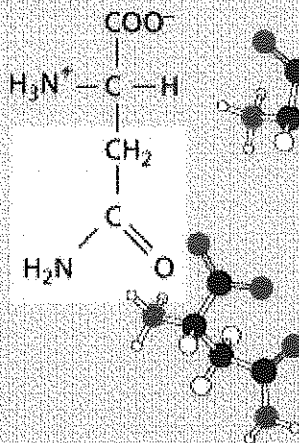
**Serine (Ser)**



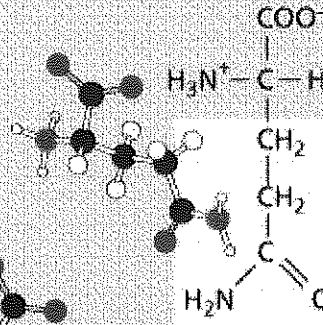
**Threonine (Thr)**



**Asparagine (Asn)**

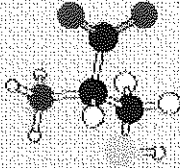
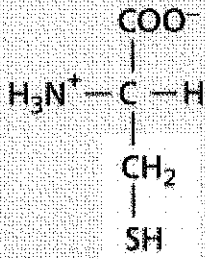


**Glutamine (Gln)**

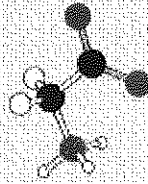
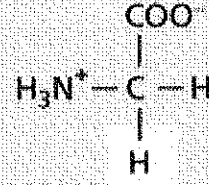


### C. Special cases

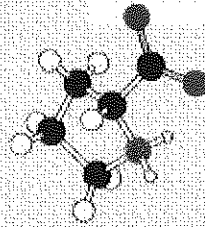
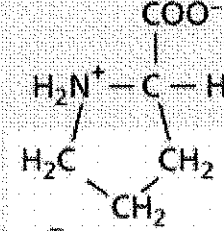
Cysteine (Cys)



Glycine (Gly)

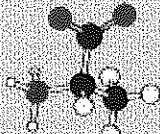
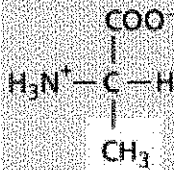


Proline (Pro)

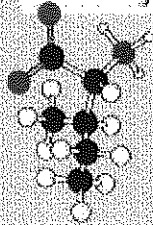
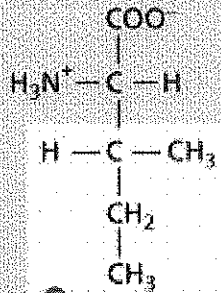


### D. Amino acids with hydrophobic side chains

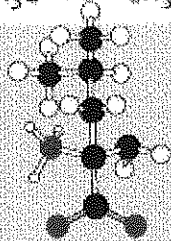
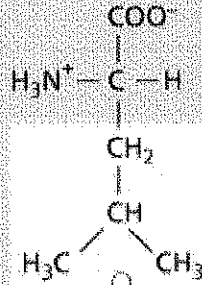
Alanine (Ala)



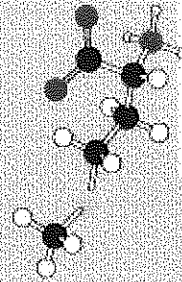
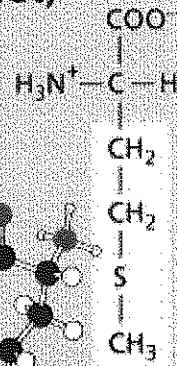
Isoleucine (Ile)



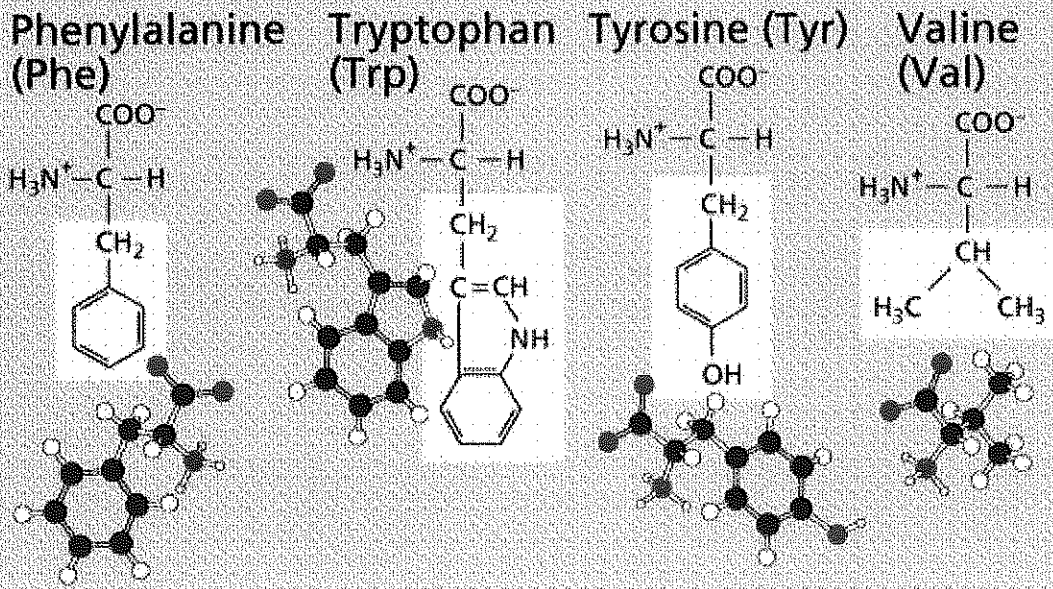
Leucine (Leu)



Methionine (Met)

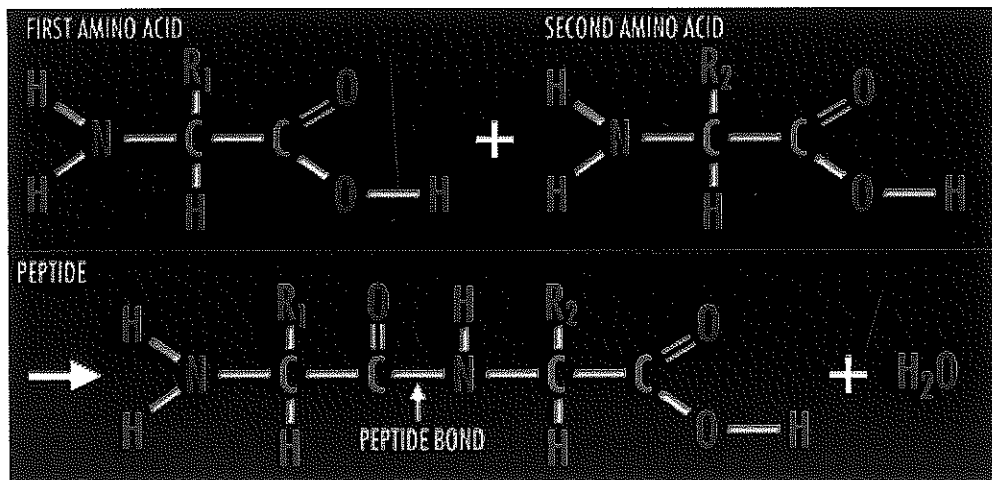


## D. Amino acids with hydrophobic side chains (continued)



Amino acids are linked together by joining the amino end of one molecule to the carboxyl end of another. Removal of water allows formation of a type of covalent bond known as a peptide bond. This process is illustrated in Figure 20.

Figure 20. Formation of a peptide bond between two amino acids by the condensation (dehydration) of the amino end of one amino acid and the acid end of the other amino acid. The above image is from <http://zebu.uoregon.edu/internet/images/peptide.gif>.

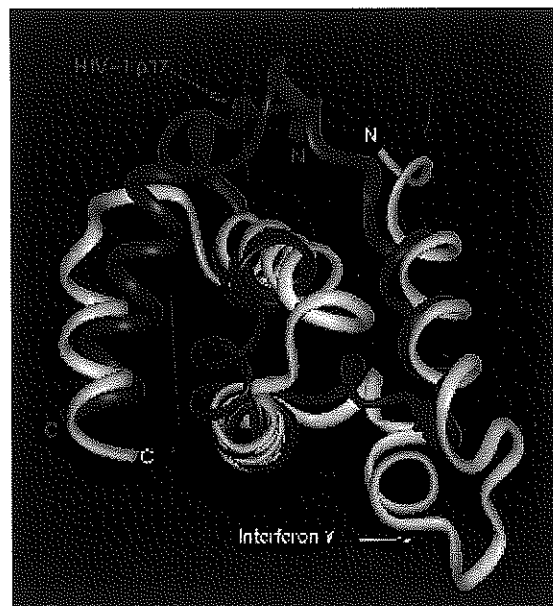


Amino acids are linked together into a polypeptide, the primary structure in the organization of proteins. The primary structure of a protein is the sequence of amino acids, which is directly related to the sequence of information in the RNA molecule,

which in turn is a copy of the information in the DNA molecule. Changes in the primary structure can alter the proper functioning of the protein. Protein function is usually tied to their three-dimensional structure. The primary structure is the sequence of amino acids in a polypeptide..

The secondary structure is the tendency of the polypeptide to coil or pleat due to H-bonding between R-groups. The tertiary structure is controlled by bonding (or in some cases repulsion) between R-groups. Tertiary structure of an HIV protein and its similarity to gamma interferon are shown in Figure 22. Many proteins, such as hemoglobin, are formed from one or more polypeptides. Such structure is termed quaternary structure. Structural proteins, such as collagen, have regular repeated primary structures. Like the structural carbohydrates, the components determine the final shape and ultimately function. Collagens have a variety of functions in living things, such as the tendons, hide, and corneas of a cow. Keratin is another structural protein. It is found in fingernails, feathers, hair, and rhinoceros horns. Microtubules, important in cell division and structures of flagella and cilia (among other things), are composed of globular structural proteins.

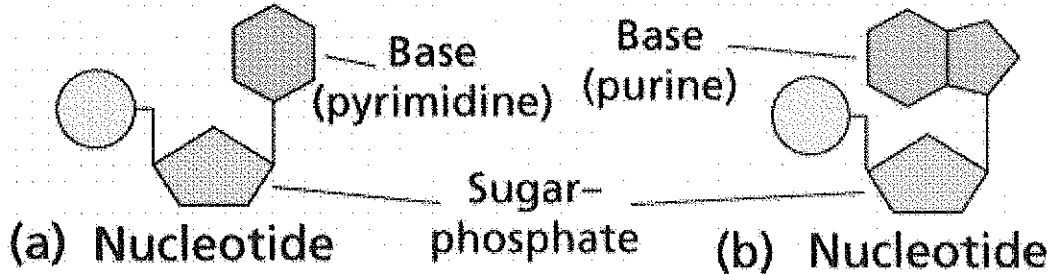
Figure 21. HIV p17 protein and similarities of its structure to gamma interferon. Image is from <http://nmra.ocms.ox.ac.uk/public/pdb/p17/p17.html>.



4. Nucleic acids are polymers composed of monomer units known as nucleotides. There are a very few different types of nucleotides. The main functions of nucleotides are information storage (DNA), protein synthesis (RNA), and energy transfers (ATP and NAD). Nucleotides, shown in Figure 22, consist of a sugar, a nitrogenous base, and a phosphate. The sugars are either ribose or deoxyribose. They differ by the lack of one oxygen in deoxyribose. Both are pentoses usually in a ring form. There are five

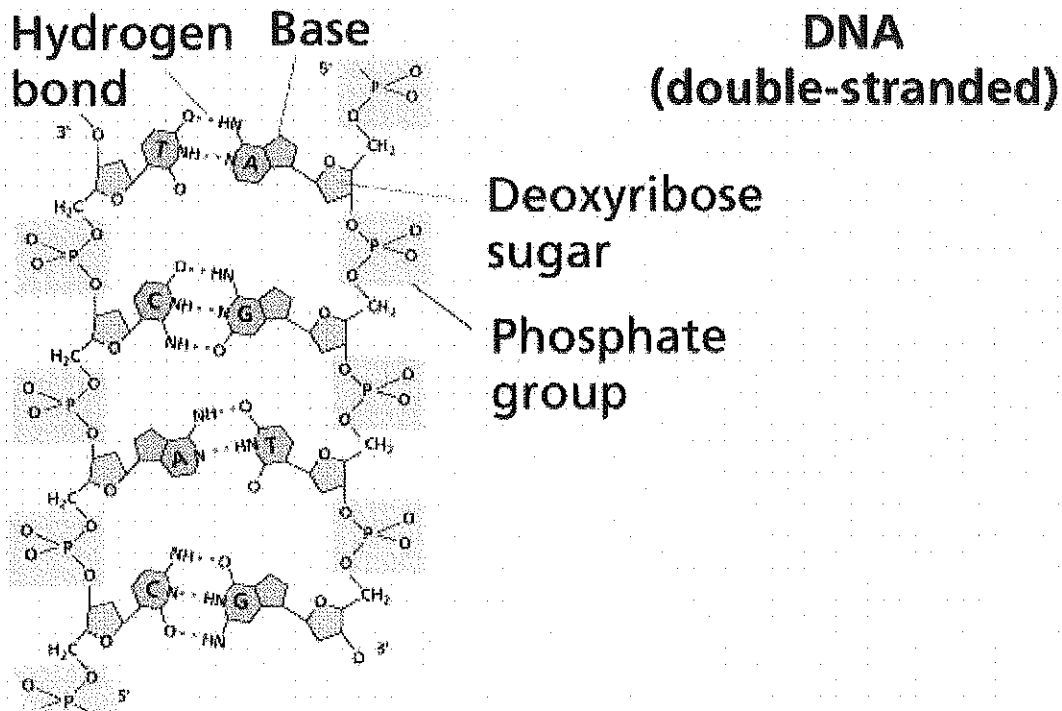
nitrogenous bases. Purines (Adenine and Guanine) are double-ring structures, while pyrimidines (Cytosine, Thymine and Uracil) are single-ringed.

Figure 22. Structure of two types of nucleotide. Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



Deoxyribonucleic acid (better known as DNA) is the physical carrier of inheritance for 99% of living organisms. The bases in DNA are C, G, A and T, as shown in Figure 23. We will learn more about the DNA structure and function later in the course (click [here](#) for a quick look [actually take all the time you want!] ;)).

Figure 23. Structure of a segment of a DNA double helix. Image from Purves et al., *Life: The Science of Biology*, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



DNA functions in information storage. The English alphabet has 26 letters that can be variously combined to form over 50,000 words. DNA has four letters (C, G, A, and T, the nitrogenous bases) that code for twenty words (the twenty amino acids found in all living things) that can make an infinite variety of sentences (polypeptides). Changes in the sequences of these bases information can alter the meaning of a sentence.

For example take the sentence: **I saw Elvis**. This implies certain knowledge (that I've been out in the sun too long without a hat, etc.).

If we alter the sentence by inverting the middle word, we get: **I was Elvis** (thank you, thank you very much). Now we have greatly altered the information.

A third alteration will change the meaning: **I was Levis**. Clearly the original sentence's meaning is now greatly changed.

Changes in DNA information will be translated into changes in the primary structure of a polypeptide, and from there to the secondary and tertiary structures. A mutation is any change in the DNA base sequence. Most mutations are harmful, few are neutral, and a very few are beneficial and contribute the organism's reproductive success. Mutations are the wellspring of variation, variation is central to Darwin and Wallace's theory of evolution by natural selection.

Ribonucleic acid (RNA), shown in Figure 24 was discovered after DNA. DNA, with exceptions in chloroplasts and mitochondria, is restricted to the nucleus (in eukaryotes, the nucleoid region in prokaryotes). RNA occurs in the nucleus as well as in the cytoplasm (also remember that it occurs as part of the ribosomes that line the rough endoplasmic reticulum). There are three types of RNA:

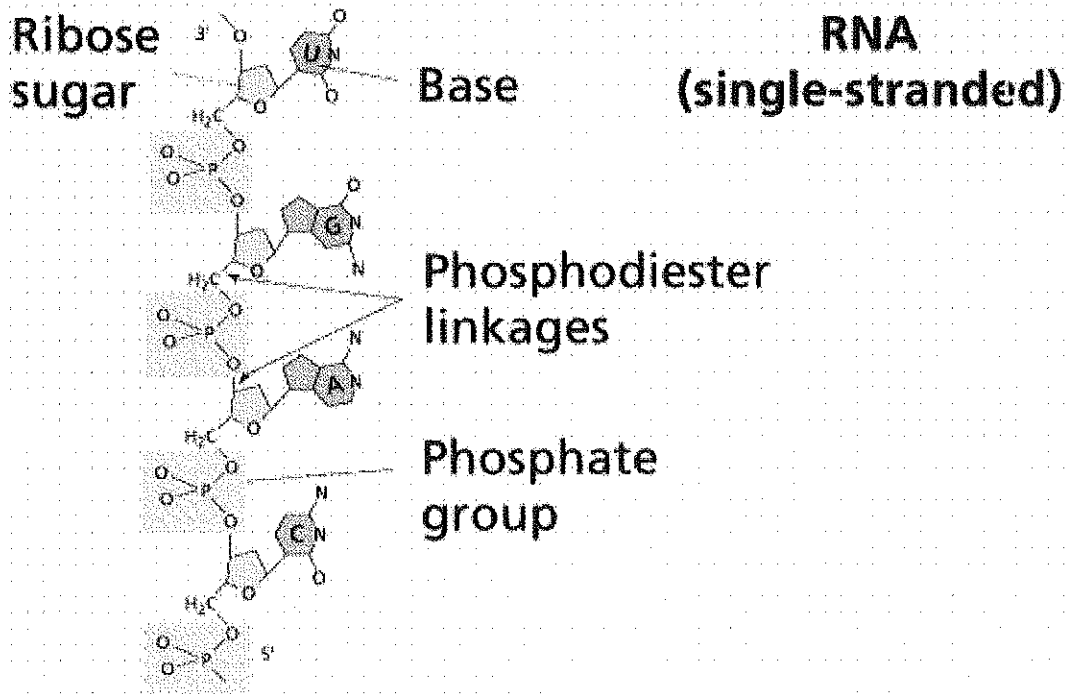
Messenger RNA (mRNA) is the blueprint for construction of a protein.

Ribosomal RNA (rRNA) is the construction site where the protein is made.

Transfer RNA (tRNA) is the truck delivering the proper amino acid to the site at the right time.

Details of RNA and its role in protein synthesis are available by clicking here.

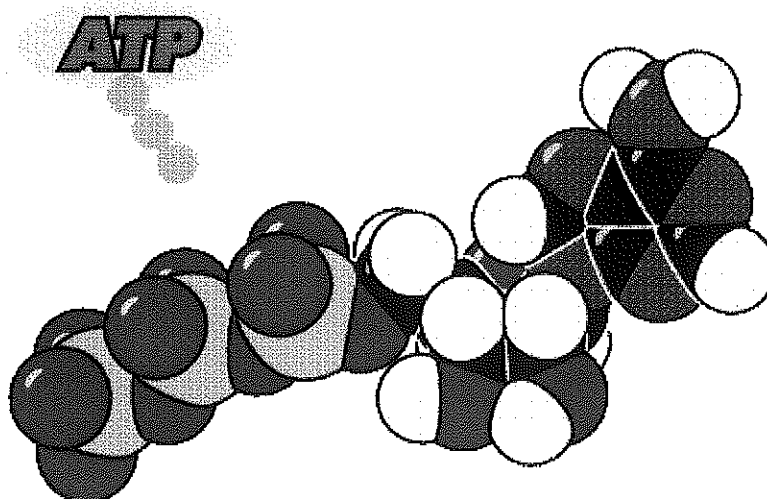
Figure 24. Structure of the RNA molecule. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



Adenosine triphosphate, better known as ATP (Figure 25), the energy currency or coin of the cell, transfers energy from chemical bonds to endergonic (energy absorbing) reactions within the cell. Structurally, ATP consists of the adenine nucleotide (ribose sugar, adenine base, and phosphate group,  $\text{PO}_4^{-2}$ ) plus two other phosphate groups.

Energy is stored in the covalent bonds between phosphates, with the greatest amount of energy (approximately 7 kcal/mole) in the bond between the second and third phosphate groups. This covalent bond is known as a pyrophosphate bond.

Figure 25. A cartoon and space-filling view of ATP. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates ([www.sinauer.com](http://www.sinauer.com)) and WH Freeman ([www.whfreeman.com](http://www.whfreeman.com)), used with permission.



## Learning Objectives | [Back to Top](#)

- Dissolved substances are called solutes; a fluid in which one or more substances can dissolve is called a solvent. Describe several solutions that you use everyday in terms of what is the solvent and what is the solute.
- Define acid and base and be able to cite an example of each.
- The concentration of free hydrogen ions in solutions is measured by the pH scale..
- Nearly all large biological molecules have their organization influenced by interactions with water. Describe this interaction as it exists with carbohydrate molecules.
- Be able to list the three most abundant elements in living things.
- Each carbon atom can form as many as four covalent bonds with other carbon atoms as well as with other elements. Be able to explain why this is so.
- Be able to list the four main groups of organic molecules and their functions in living things.
- Enzymes are a special class of proteins that speed up chemical reactions in cells. What about the structure of proteins allows for the reaction specificity that occurs with most enzymes.
- Condensation reactions result in the formation of covalent bonds between small molecules to form larger organic molecules. Be able to describe a condensation reaction in words.
- Be able to describe what occurs during a hydrolysis reaction.
- Be able to define carbohydrates and list their functions.
- The simplest carbohydrates are sugar monomers, the monosaccharides. Be able to give examples and their functions.
- A polysaccharide is a straight or branched chain of hundreds or thousands of sugar monomers, of the same or different kinds. Be able to give common examples and their functions.
- Be able to define lipids and to list their functions.

- Distinguish between a saturated fat and an unsaturated fat. Why is such a distinction a life and death matter for many people?
- A phospholipid has two fatty acid tails attached to a glycerol backbone. What is the importance of these molecules.
- Define steroids and describe their chemical structure. Be able to discuss the importance of the steroids known as cholesterol and hormones.
- Be able to describe proteins and cite their general functions.
- Be prepared to make a sketch and name the three parts of every amino acid.
- Describe the complex structure of a protein through its primary, secondary, tertiary, and quaternary structure. How does this relate to the three-dimensional structure of proteins?
- Describe the three parts of every nucleotide..
- Be able to give the general functions of DNA and RNA molecules.