Chapter 3
Part 2

The Molecules of Cells

PROTEINS

&

NUCLEIC ACIDS

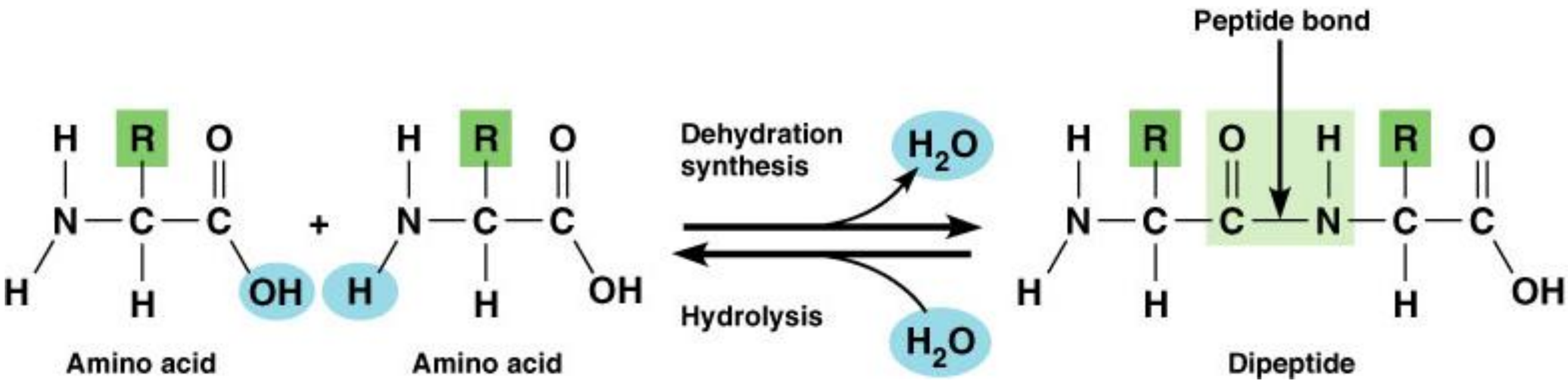
Lecture by Dr. Fernando Prince

3.11 Nucleic Acids are the blueprints of life
Proteins are the machines of life

- We have already learned that the most abundant substance in the body is water.
- Today we learn that the second most abundant substance in the body is protein.
- Proteins have both structural and physiological functions and are amongst the most varied substances in the body.

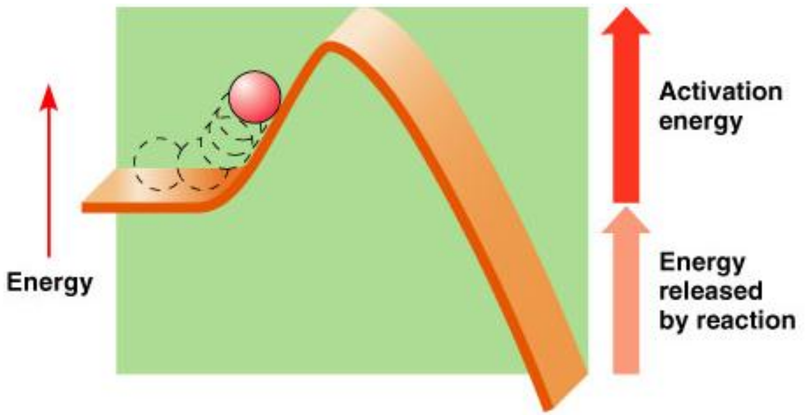
Protein

- Proteins are macromolecules composed of combinations of 20 different types of amino acids bound together by peptide bonds in the order dictated by the genetic code.

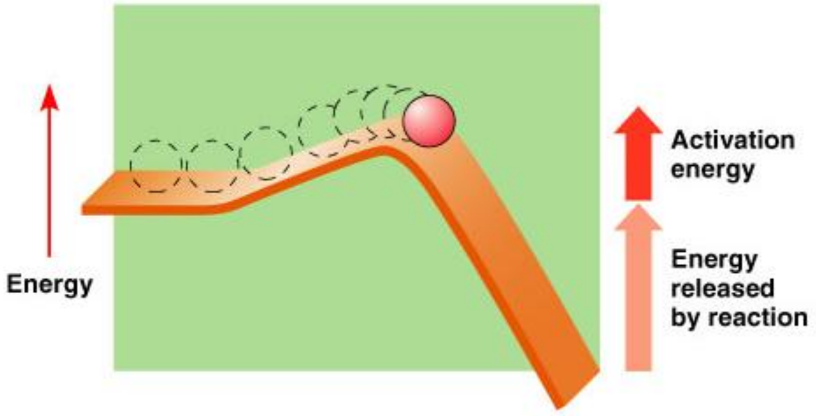


Enzymes are the biological machines that carry out the life's functions

- Most enzymes are globular proteins that act as biological catalysts that is, they speed up reactions by lowering their activation energy.
- Enzymes are chemically specific and are named for the reaction they catalyze and characteristically end in –*ase.*

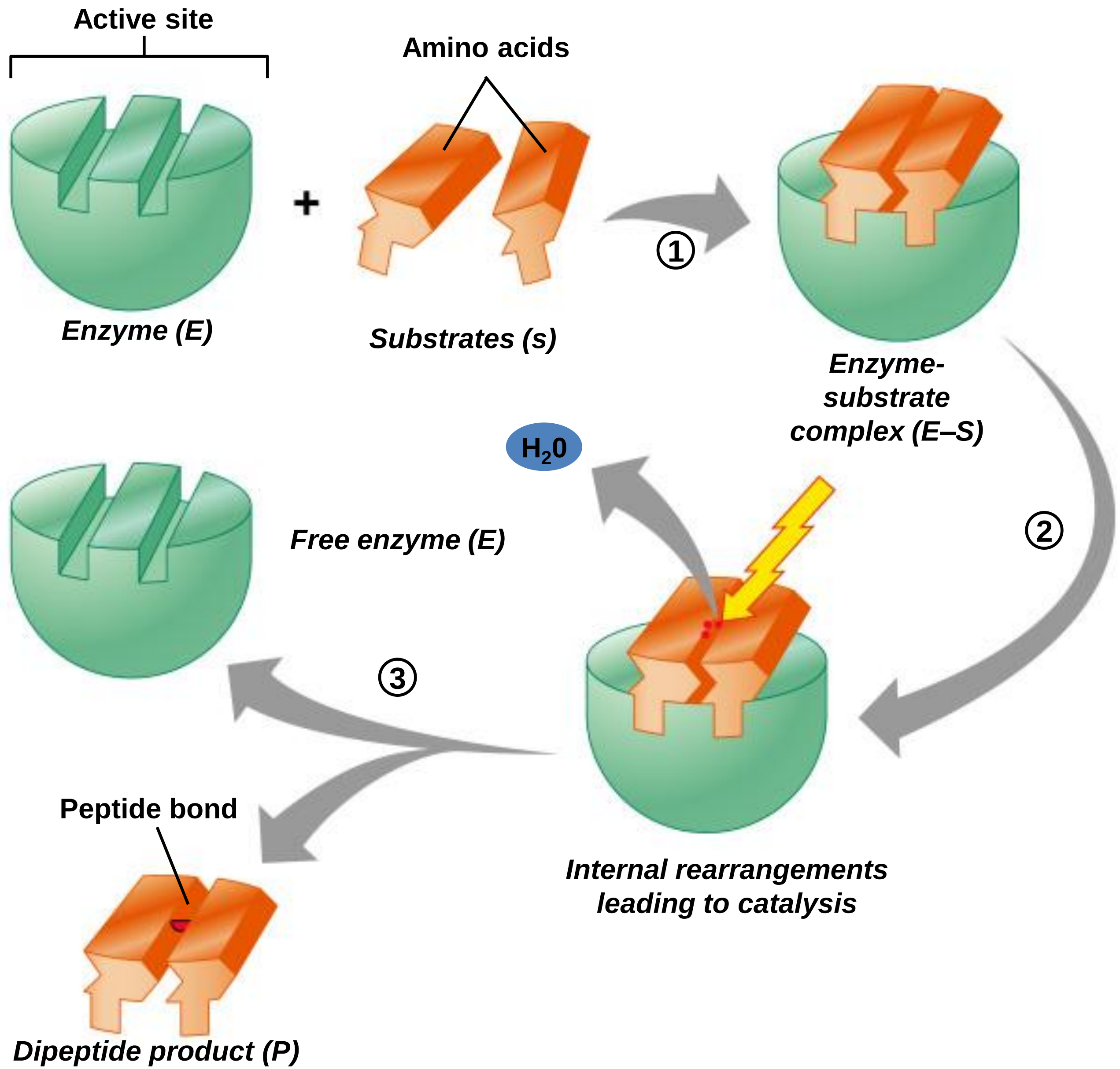


(a) Noncatalyzed reaction



(b) Enzyme-catalyzed reaction

Mechanism of Enzyme Action

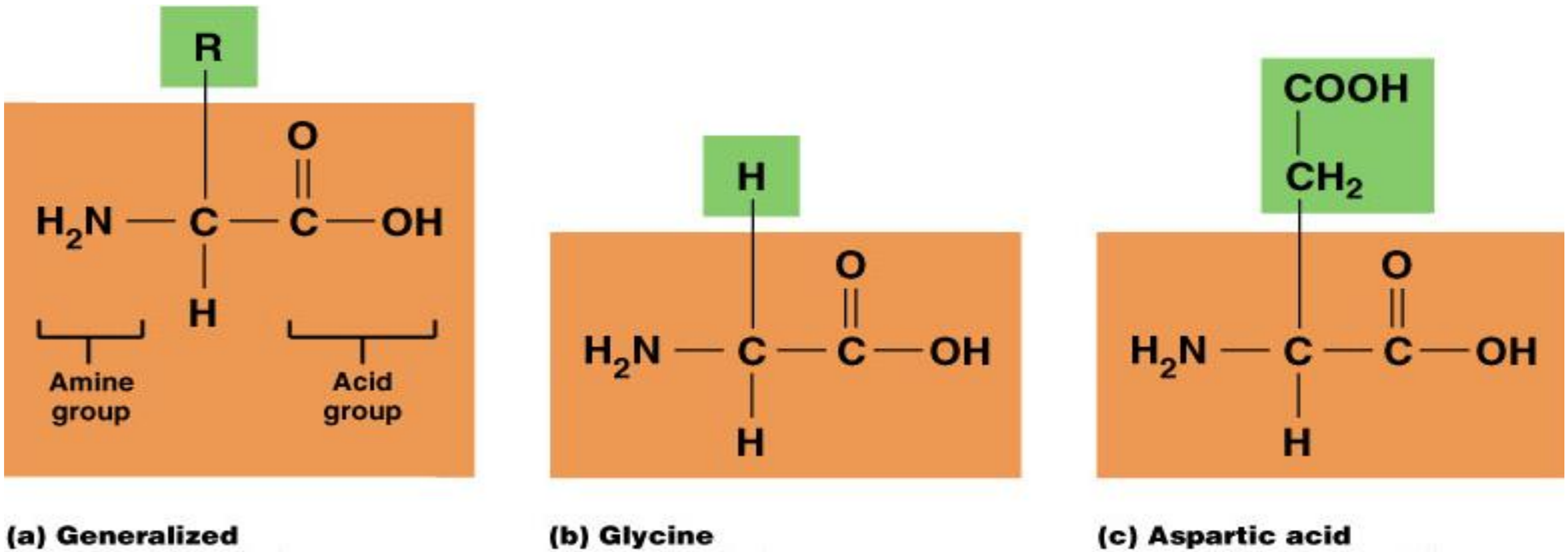


3.11 Proteins are essential to the structures and functions of life

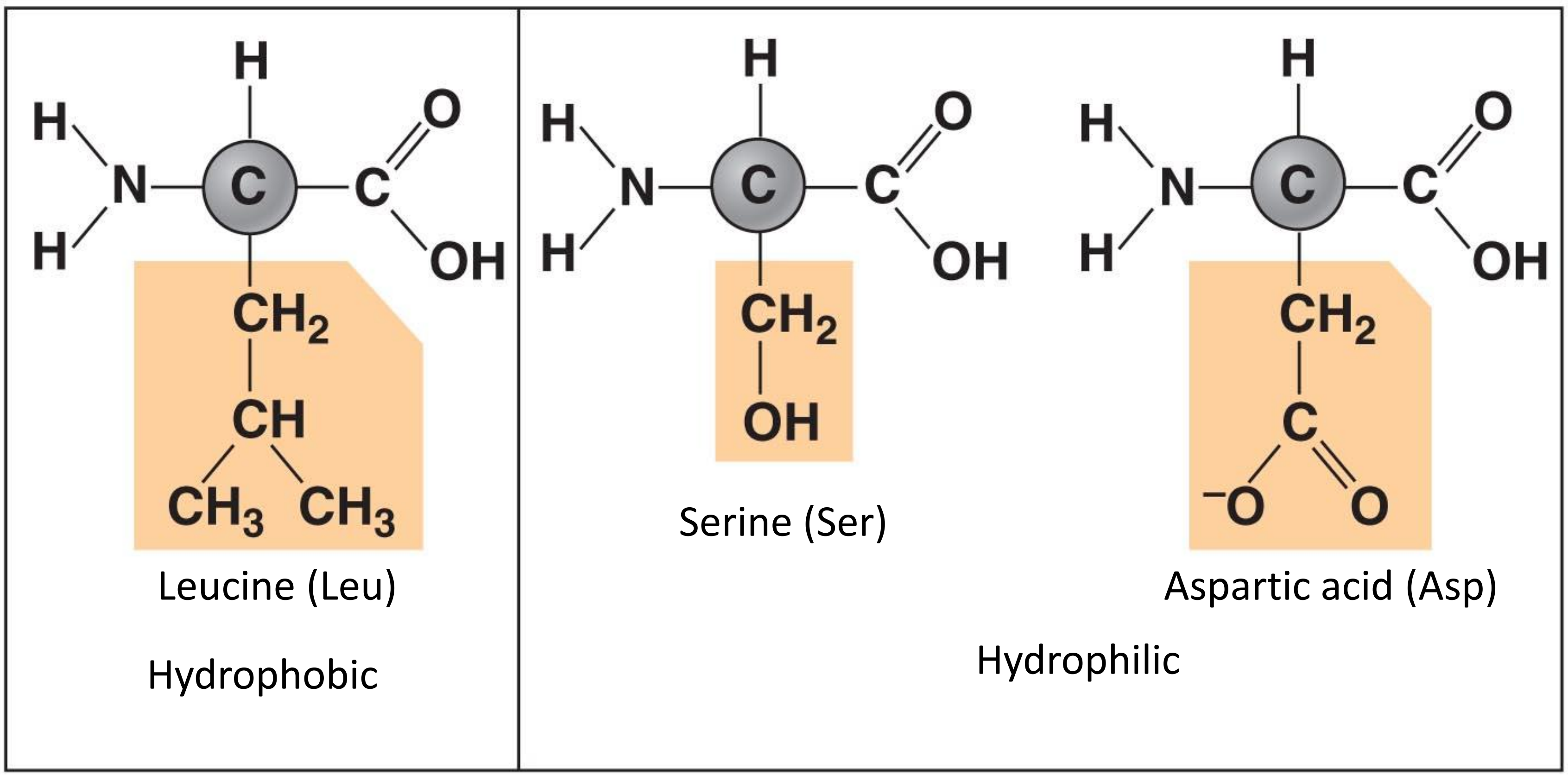
- **Structural** proteins provide associations between body parts (Fibrous)
- **contractile** proteins are found within muscle (Fibrous)
- **Defensive** proteins include antibodies of the immune system (Globular)
- **signal** proteins are best exemplified by the hormones (Globular)
- **Receptor** proteins serve as antenna for outside signals (Globular)
- **transport** proteins carry oxygen (Globular)
- **Enzymes** speed up reactions (Globular)

3.12 The building blocks of proteins

- **Amino acids** are the building blocks of proteins.
- Amino acids have an amino group and a carboxyl group thus the name, amino acid!

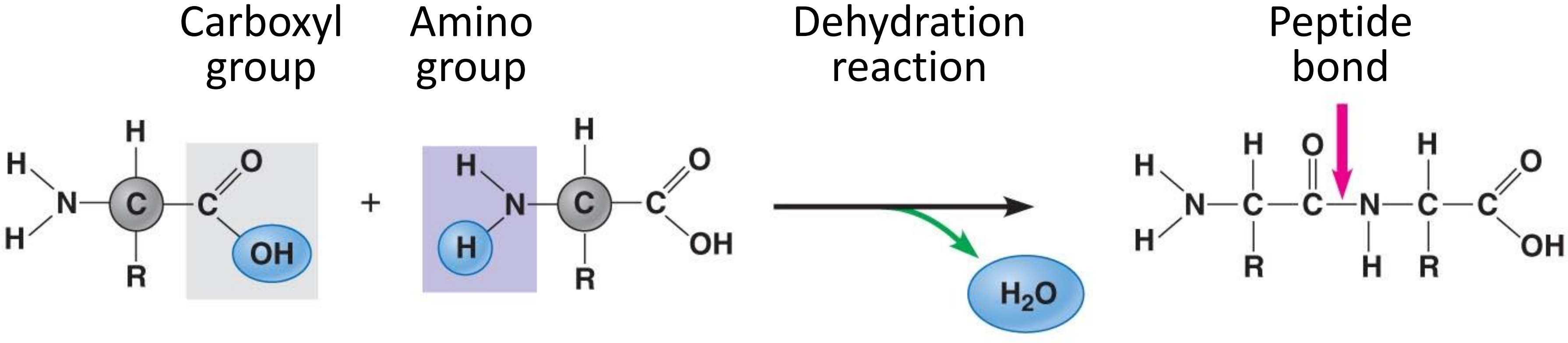


Amino acids are classified as hydrophobic or hydrophilic



3.12 The building blocks of proteins

- Amino acids are the monomer building blocks that make proteins (polymers).
- The covalent bond resulting from **dehydration synthesis** between the carboxyl group of one amino acid and the amino group of a second amino acid is called a **peptide bond.**

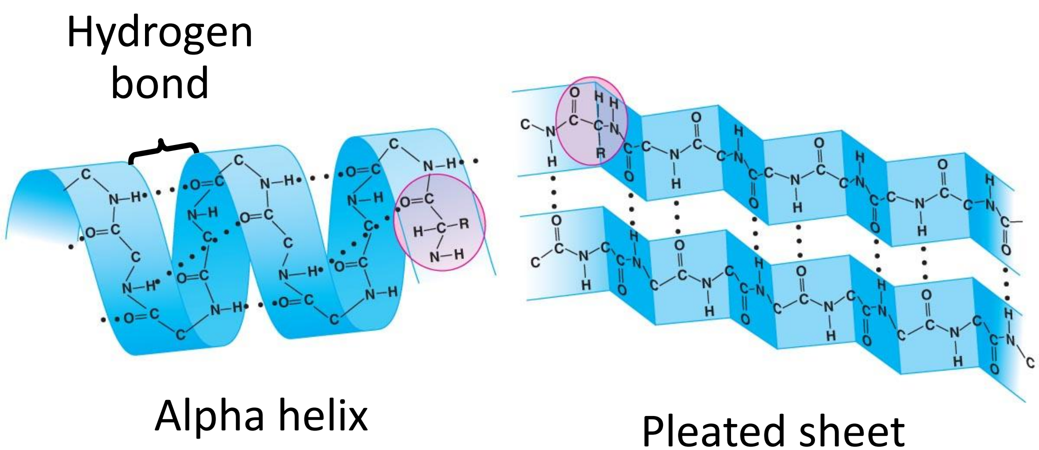


Structural Levels of Proteins

- DNA the dictator!
- The sequence of the amino acids is the **primary structure** of a protein and is dictated by the genetic code found in DNA.

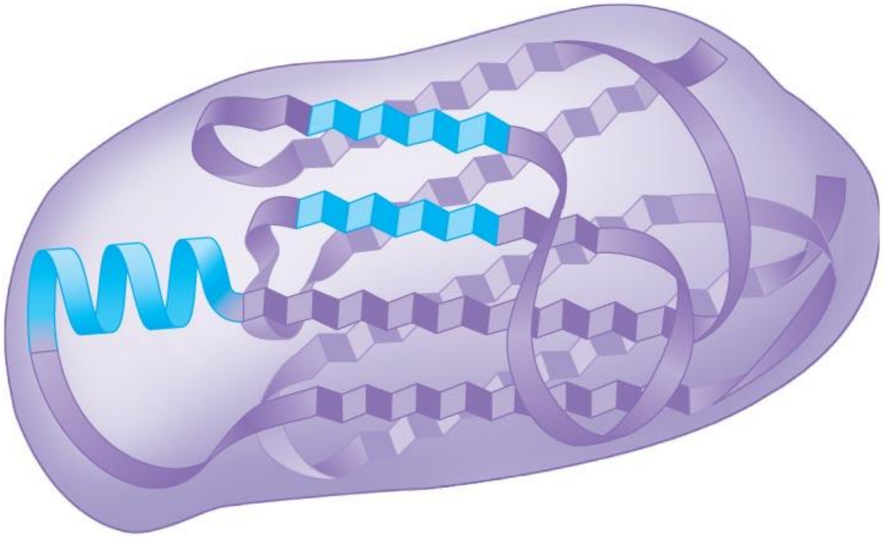
3.14 Hydrogen bonds bend the chain

- As the chain bends and folds due to atraction from the amino acid side chains the **secondary structure** becomes evident.
- There are alpha helixes and beta pleates.



3.14 The 3D structure of the chain from start to finish

- The overall three-dimensional shape of a protein is its **tertiary structure**



3.14 Some functional proteins need more than one chain

- When the functional protein must have more than one polypeptide chain that protein has a **quaternary structure**
  - Hemoglobin is an example of a protein with quaternary structure

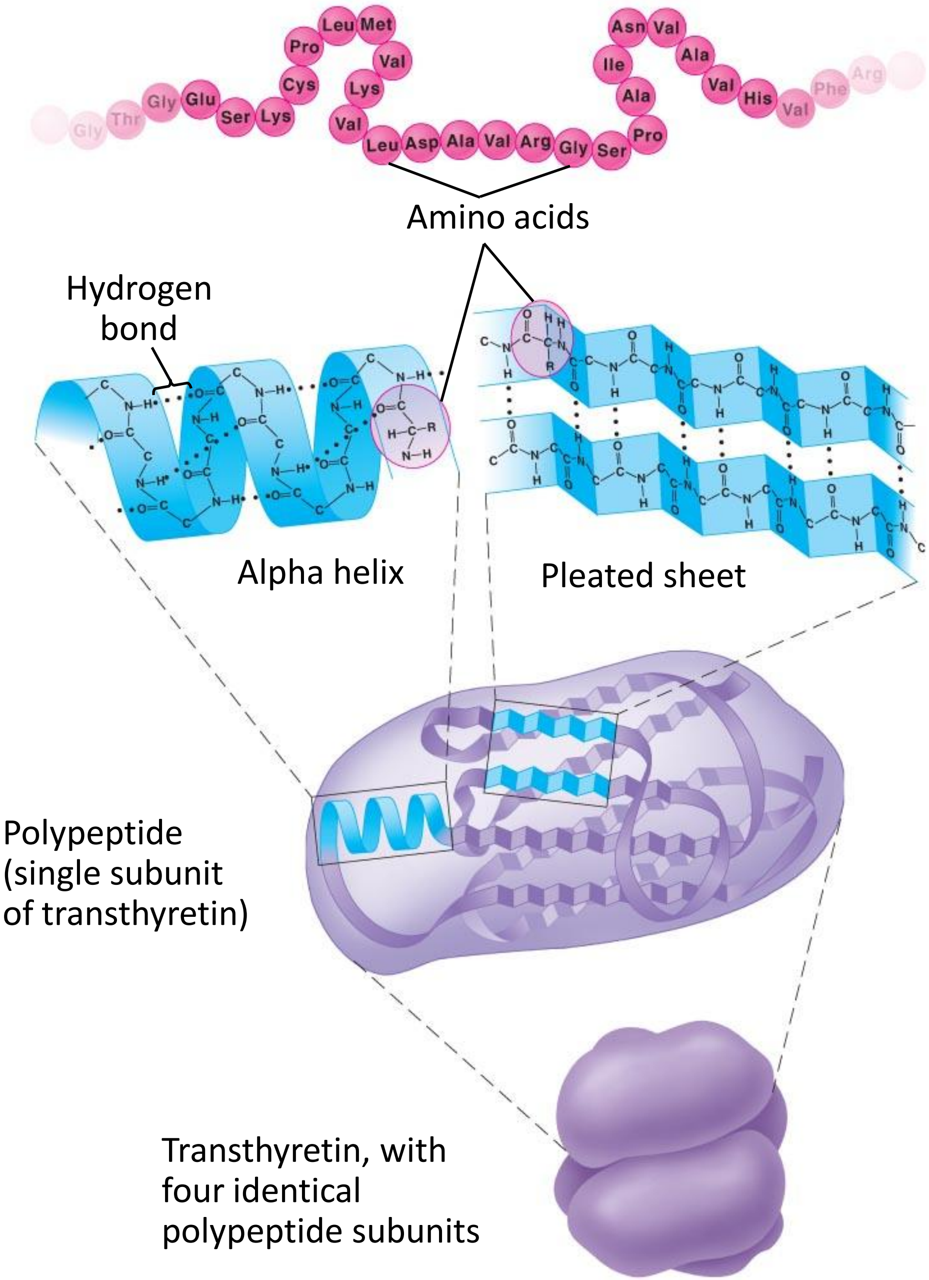
Four Levels of Protein Structure

Primary structure

Secondary structure

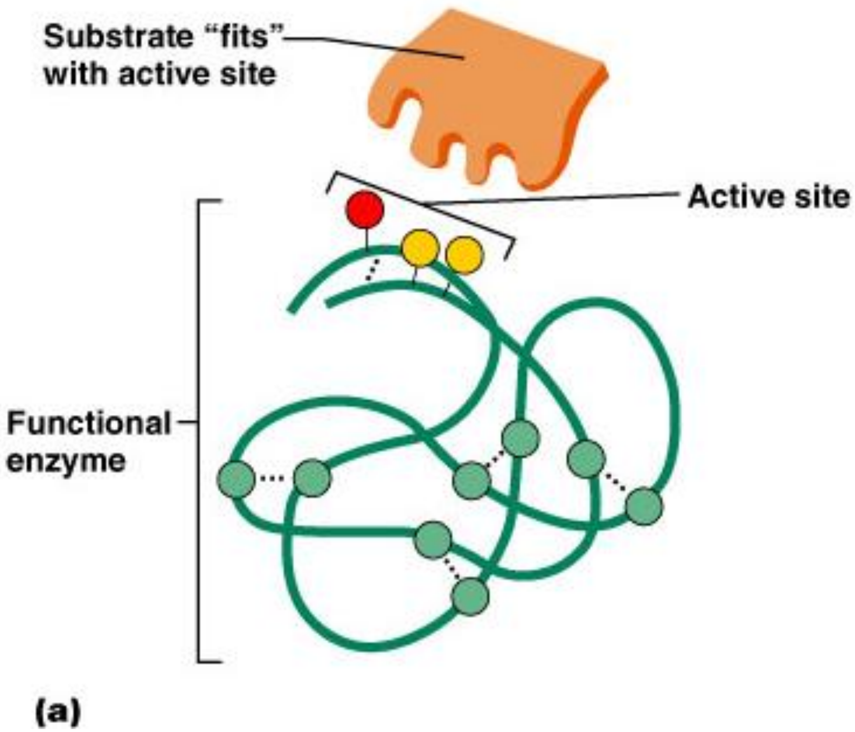
Tertiary structure

Quaternary structure



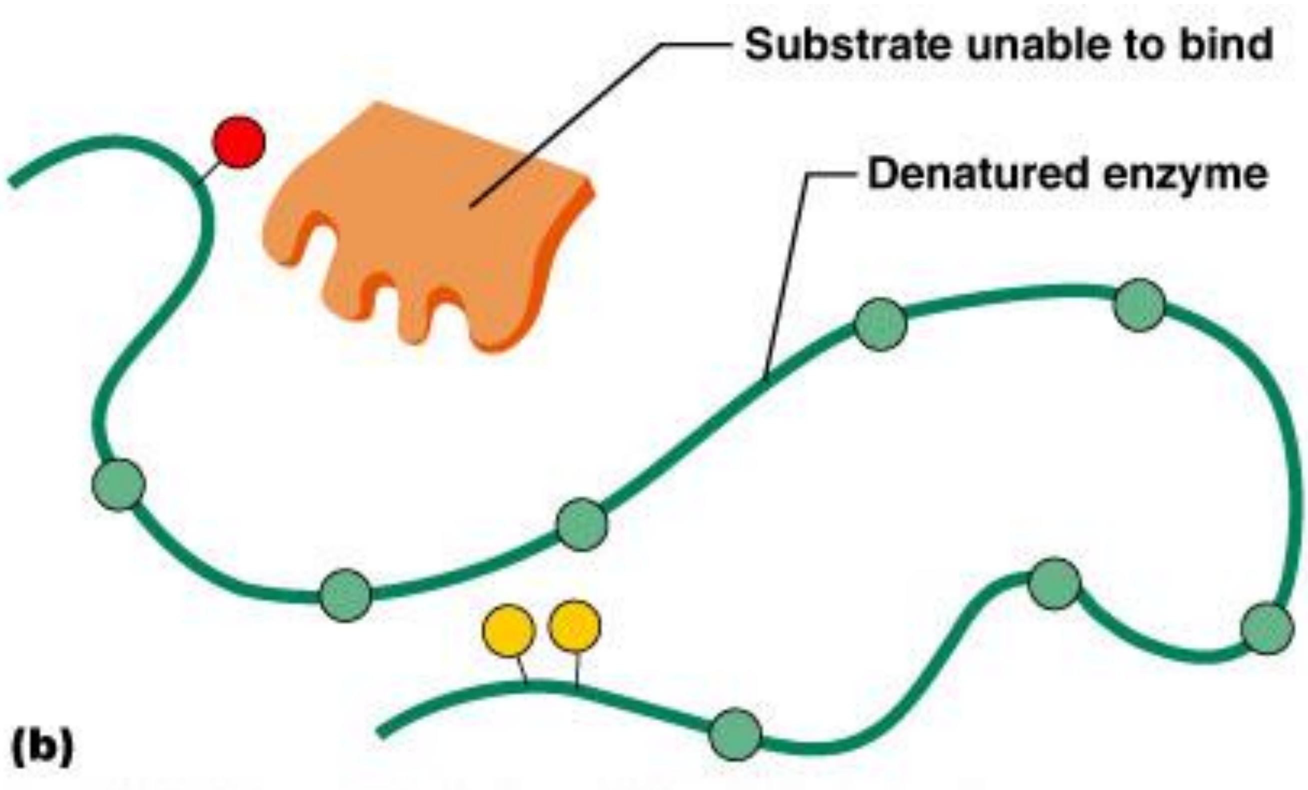
3.13 Function follows form!

– The shape of a protein determines its specific function



3.13 For a protein staying in shape means everything

– **When the shape of a protein is changed permanently it loses its nature, it is Denatured!**



3.15 TALKING ABOUT SCIENCE: Linus Pauling contributed to our understanding of the chemistry of life

- After winning a Nobel Prize in Chemistry, Pauling spent considerable time studying biological molecules
  - He discovered an oxygen attachment to hemoglobin as well as the cause of sickle-cell disease
  - Pauling also discovered the alpha helix and pleated sheet of proteins

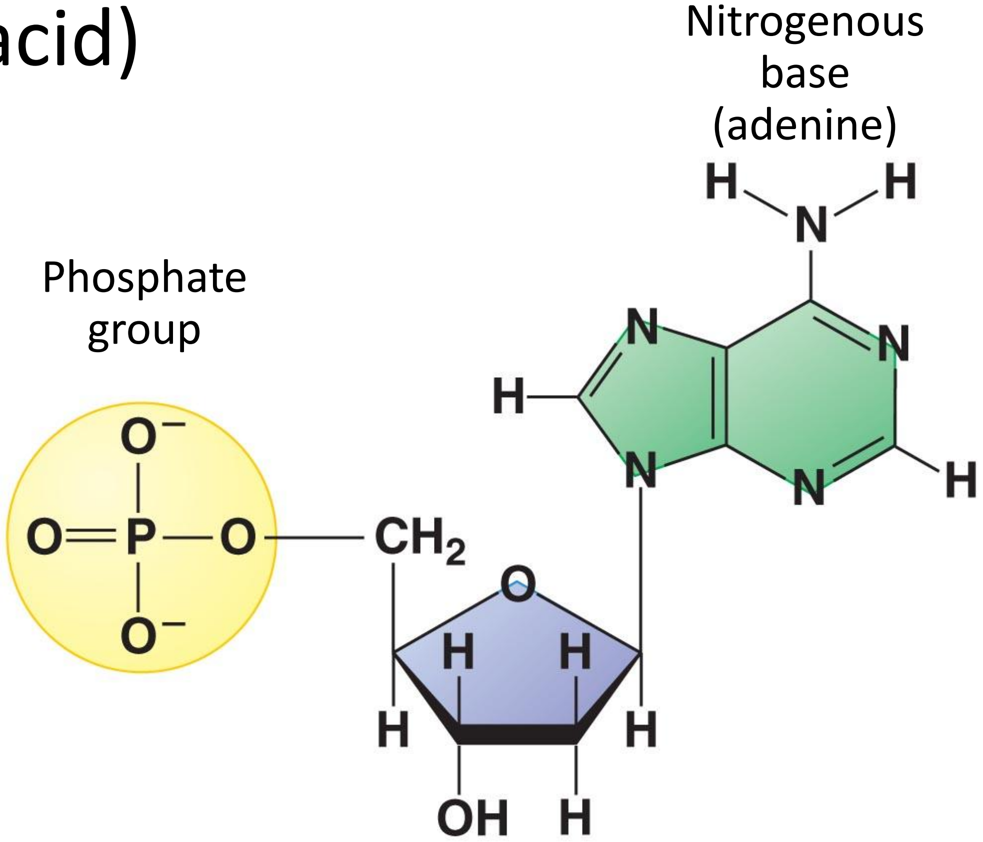
Nucleic Acids

- Composed of C, O, H, N, and P
- Five nitrogen bases contribute to nucleotide structure – adenine (A), guanine (G), cytosine (C), thymine (T), and uracil (U)
- DNA contains thymine (T) but no uracil (U)
- RNA contains uracil (U) but no thymine (T)

3.16 The building blocks of nucleic acids are nucleotides

- **DNA** (deoxyribonucleic acid)
- **RNA** (ribonucleic acid)

The Structure of a **Nucleotide**



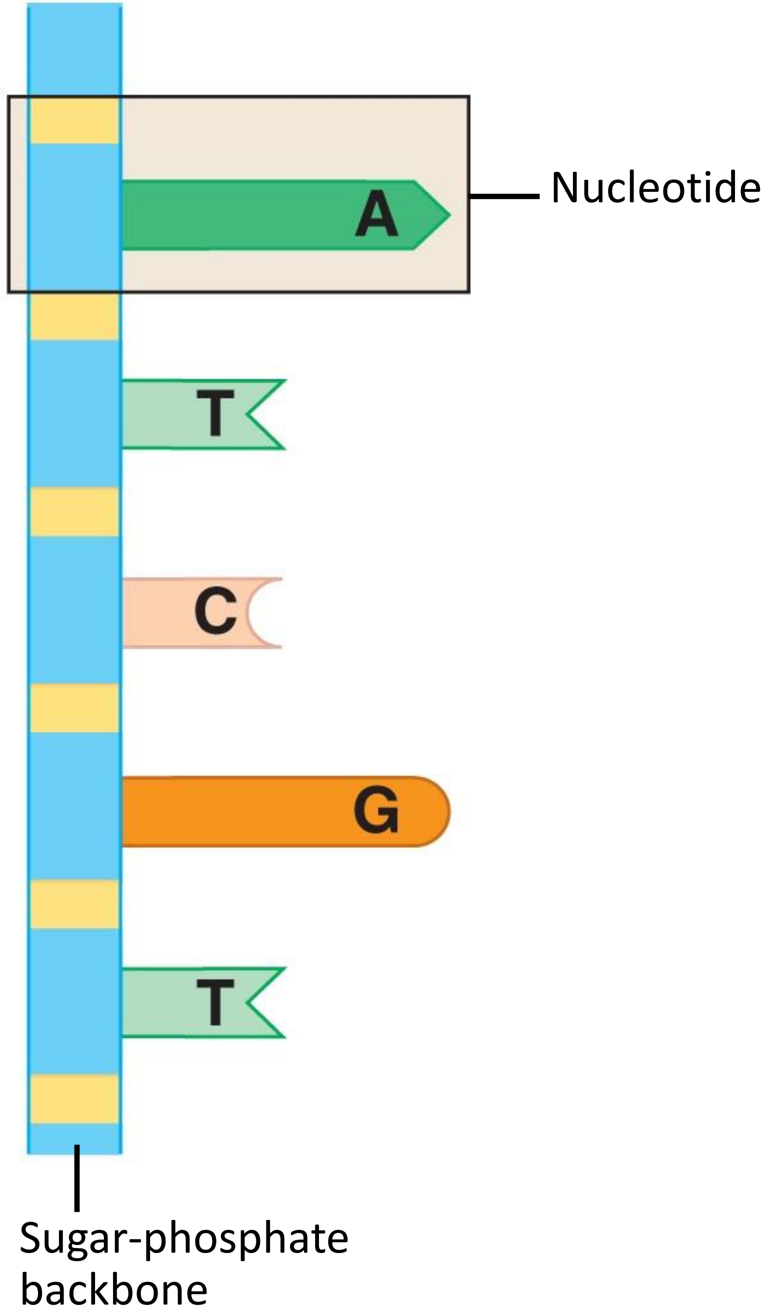
The sugar is a ribose or deoxyribose

3.16 Nucleic acids are information-rich polymers of nucleotides

- A nucleic acid polymer, a polynucleotide, forms from the nucleotide monomers when the phosphate of one nucleotide bonds to the sugar of the next nucleotide
  - The result is a repeating sugar-phosphate backbone with protruding nitrogenous bases

3.16 Nucleic acids are information-rich polymers of nucleotides

- Two polynucleotide strands wrap around each other to form a DNA **double helix**
  - The two strands are associated because particular bases always hydrogen bond to one another
  - A pairs with T, and C pairs with G, producing **base pairs**
- RNA is usually a single polynucleotide strand


Nucleotide
A
T
C
G
T
Sugar-phosphate backbone

Structure of DNA

Double-stranded helical molecule found in the nucleus of the cell and some other organelles

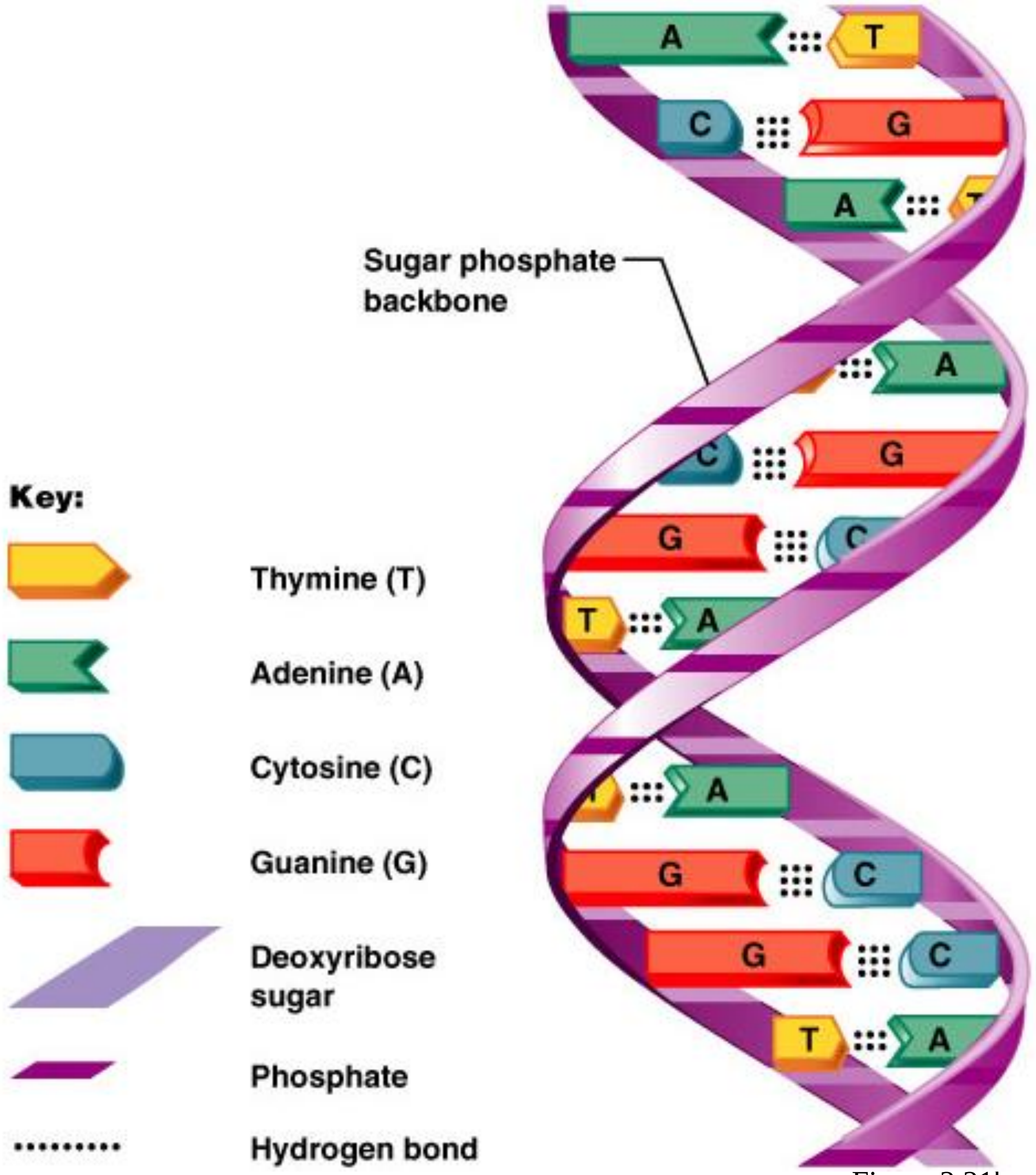
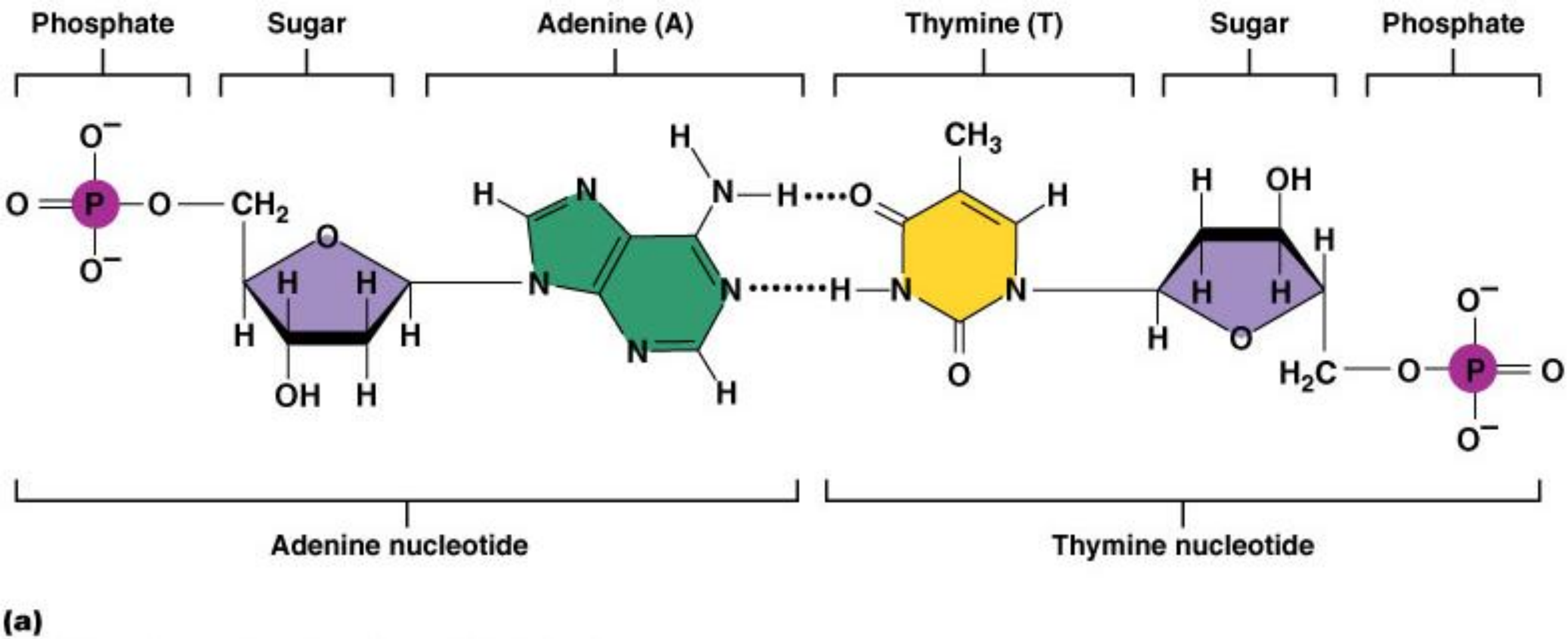


Figure 2.21b



Phosphate
Sugar
Adenine (A)
Thymine (T)
Sugar
Phosphate
Adenine nucleotide
Thymine nucleotide
(a)

Figure 2.21a

3.16 Nucleic acids are information-rich polymers of nucleotides

- A particular nucleotide sequence that can instruct the formation of a polypeptide is called a **gene**
  - Most DNA molecules consist of millions of base pairs and, consequently, many genes
  - These genes, many of which are unique to the species, determine the structure of proteins and, thus, life's structures and functions

3.17 EVOLUTION CONNECTION: Lactose tolerance is a recent event in human evolution

- Mutations are alterations in bases or the sequence of bases in DNA
  - Lactose tolerance is the result of mutations
  - In many people, the gene that dictates lactose utilization is turned off in adulthood
  - Apparently, mutations occurred over time that prevented the gene from turning off
  - This is an excellent example of human evolution

Deoxyribonucleic Acid (DNA)

- Replicates itself before the cell divides, ensuring genetic continuity (during the S phase of the cell cycle)
- Provides all the instructions for protein synthesis

Ribonucleic Acid (RNA)

- Single-stranded molecule found in both the nucleus and the cytoplasm of a cell (smaller than DNA, much smaller)
- Uses the nitrogenous base uracil instead of thymine
- Three types of RNA: messenger RNA, transfer RNA, and ribosomal RNA

Adenosine Triphosphate (ATP)

- Molecule used for energy transport, not used for energy storage!
- Adenine-containing RNA nucleotide with three phosphate groups

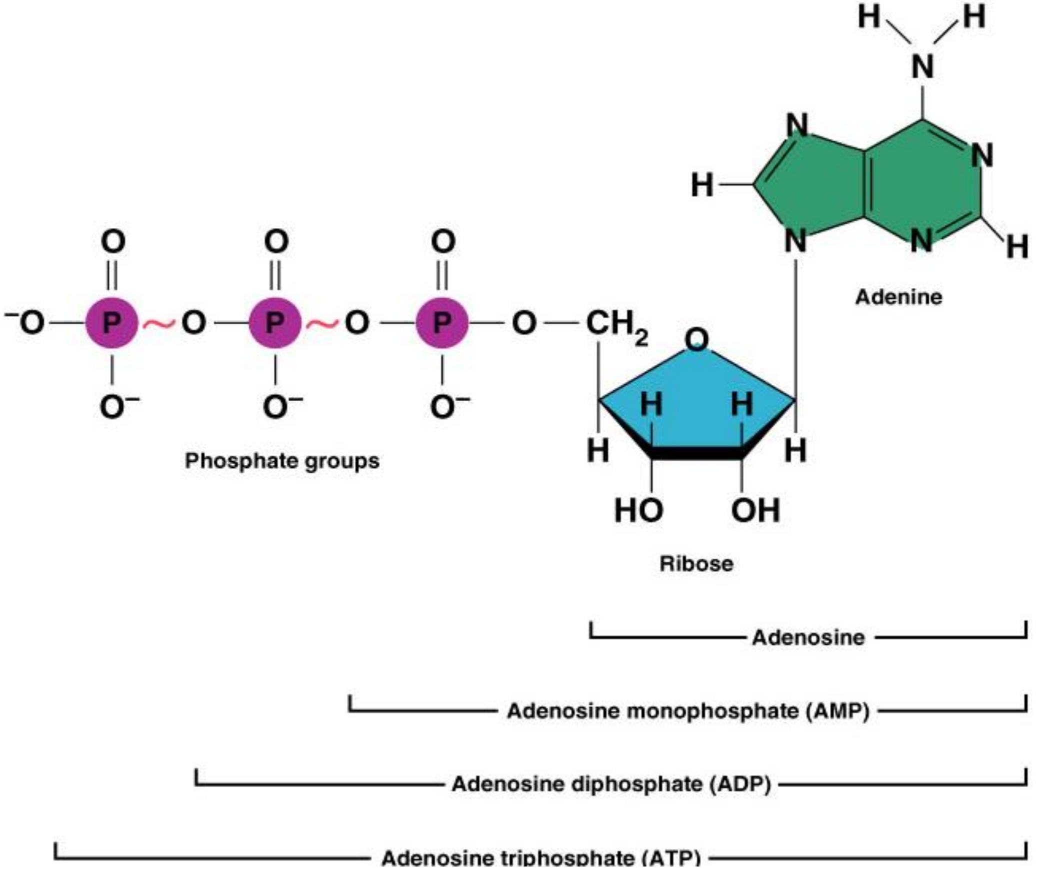
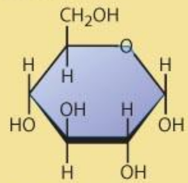
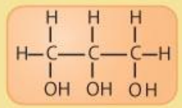
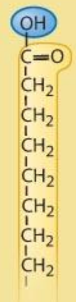
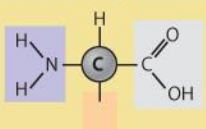
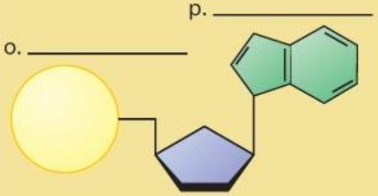


Figure 2.22

Classes of macromolecules and their components	Functions	Examples
Carbohydrates  Monosaccharides	Energy for cell, raw material	a. ______
	b. ______	Starch, glycogen
	Plant cell support	c. ______
Lipids (don't form polymers)  Glycerol  Fatty acid. Components of a fat molecule	Energy storage	d. ______
	e. ______	Phospholipids
	Hormones	f. ______
Proteins g. ______ h. ______  i. ______ Amino acid	j. ______	Lactase
	k. ______	Hair, tendons
	l. ______	Muscles
	Transport	m. ______
	Communication	Signal proteins
	n. ______	Antibodies
	Storage	Egg albumin
	Receive signals	Receptor protein
Nucleic Acids p. ______ o. ______  q. ______ Nucleotide	Heredity	r. ______
	s. ______	DNA and RNA

You should now be able to

1. Discuss the importance of carbon to life's molecular diversity
2. Describe the chemical groups that are important to life
3. Explain how a cell can make a variety of large molecules from a small set of molecules
4. Define monosaccharides, disaccharides, and polysaccharides and explain their functions
5. Define lipids, phospholipids, and steroids and explain their functions

You should now be able to

6. Describe the chemical structure of proteins and their importance to cells
7. Describe the chemical structure of nucleic acids and how they relate to inheritance