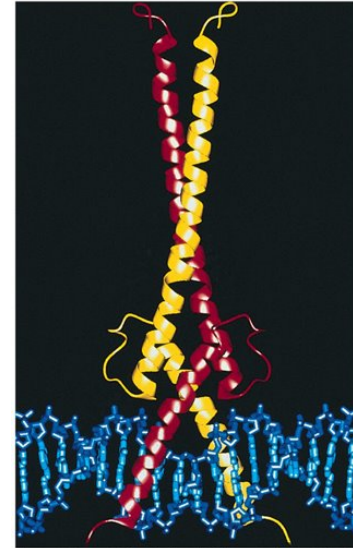


Introduction to macromolecules

Read:
Section 2.5-2.8
Four types of biological molecules

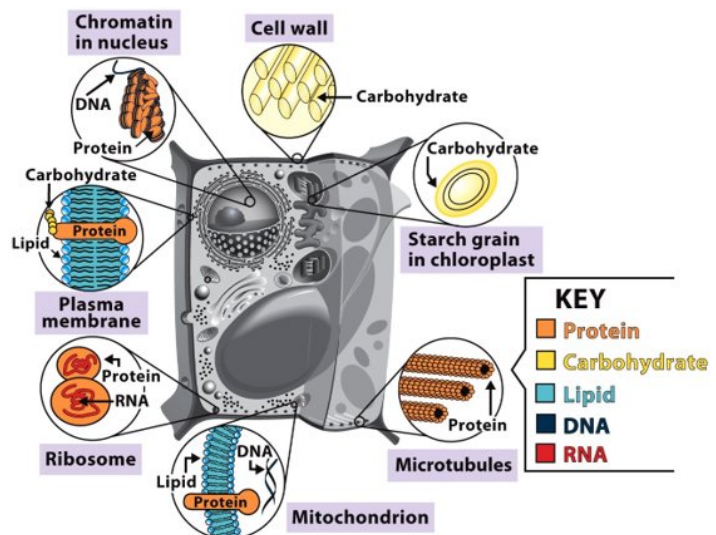


Chapter 2 Opener Cell and Molecular Biology, 4/e (© 2005 John Wiley & Sons)

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Functional classification of biological molecules

- **Large molecules can be made of polymers**
- **Polymer:** poly-aggregation of small molecules (monomers)
- **Macromolecules:** large structural and functional molecules in cells.
- **Include four major categories:** proteins, nucleic acids, polysaccharides and lipids.

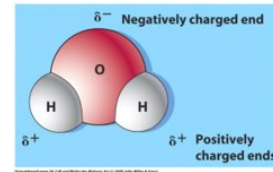


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Lipids are polar hydrophobic molecules

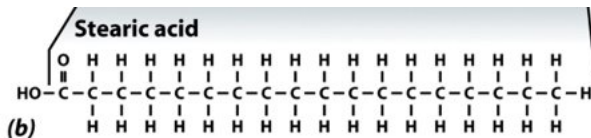
a. Small, diverse organic molecules that are insoluble in H₂O but soluble in nonpolar organic liquids.

- Polar = different parts of the molecule have net negative or positive charge



Water is a polar molecule

b. Hydrophobic ("water fearing") or contain significant hydrophobic regions.



Can have hydrophilic parts (eg this carboxylate moiety). If a molecule has both hydrophilic and hydrophobic parts, it's called amphipathic.

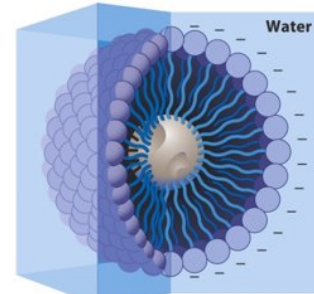


Figure 3-28 Cell and Molecular Biology, 4/e (© 2005 John Wiley & Sons)

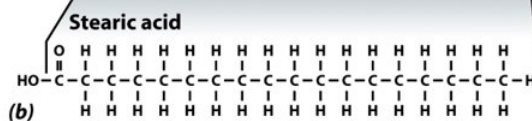
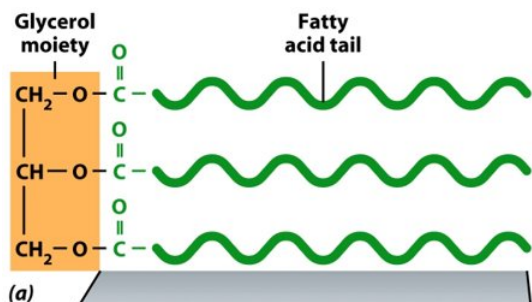
A micelle. Hydrophilic heads are towards the outside and interact with water.

Hydrophobic tails point inwards and interact with each other.

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Fats are made of glycerol and linked by three ester bonds to three fatty acids (FAs)

- FAs are unbranched hydrocarbons with one carboxyl group; they are amphipathic.
- **Saturated** FAs lack C=C double bonds and are solid at room temperature.
- **Unsaturated** FAs have one or more C=C double bonds and are liquid at room temperature.



Stearic acid is an 18 C saturated fatty acid

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Lipids have diverse roles within cells

a. Source of energy in the diet and serve to store energy in the body.

- e.g. fats and oils

b. Some hormones (chemical messengers) are lipids.

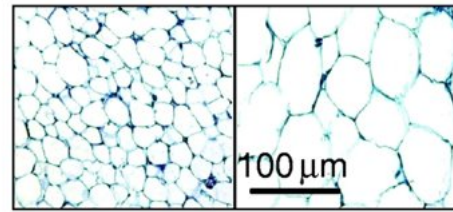
- e.g. steroids and prostaglandins.

c. Many vitamins are lipids.

- e.g. vitamins A, D, E

d. The basic structural elements of biological membranes.

- e.g. phospholipids



adipocytes

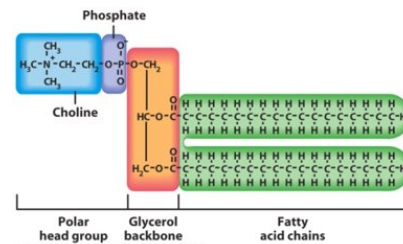
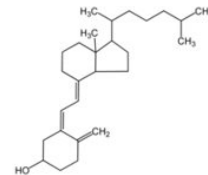
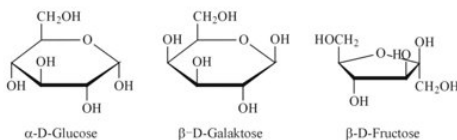


Figure 2.22 Cell and Molecular Biology, 4th ed. (© 2005 John Wiley & Sons)

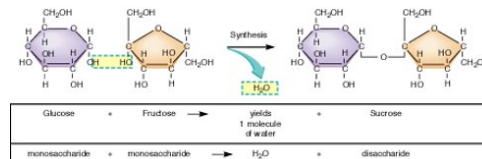
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Carbohydrates

- **Carbohydrates** include simple sugars and sugar polymers.
- Carbohydrates are made of carbon, oxygen & hydrogen
- Carbohydrate monomers are called monosaccharides
- Monosaccharides are generally some combination of CXH_2XOH (eg glucose = $C_6H_{12}O_6$)



Some example monosaccharides...



Monosaccharides can be linked by dehydration reactions by the loss of a hydroxyl from the a carbon of one monomer and a hydrogen from another carbon of the co-joining monomer (one oxygen & two hydrogens are lost to water!)

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Oligosaccharides (oligo = 'a few') are small chains of monosaccharides.

- Often many different types of monosaccharides in the chain with different branching combinations.
- Can be added onto lipids to make glycolipids and proteins to make glycoproteins
- Can play a role in cell recognition (e.g. ABO blood type)

Antigen	Structure	Minimal determinant structure
H		Fuc- α 1 $\rightarrow$ 2-Gal- β 1-R
B		Gal- α 1 $\rightarrow$ 3-Gal- β 1-R Fuc- α 1 $\rightarrow$ 2 ^A
A		GalNAc- α 1 $\rightarrow$ 3-Gal- β 1-R Fuc- α 1 $\rightarrow$ 2 ^A

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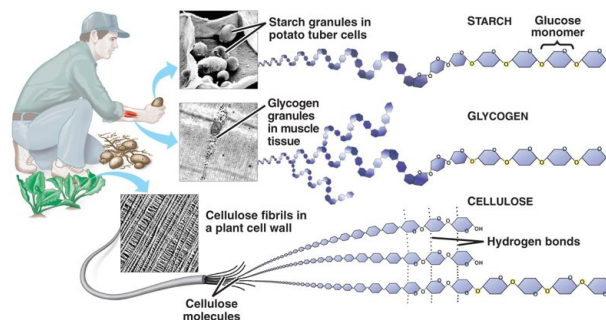
Polysaccharides are long polymers of sugars

1. Can serve as a energy source

- starch in plants is made from linear alpha(1,4) linked glucose
- glycogen in muscles is made from branched alpha(1,4)&(1,6) glucose

2. Can serve structural roles

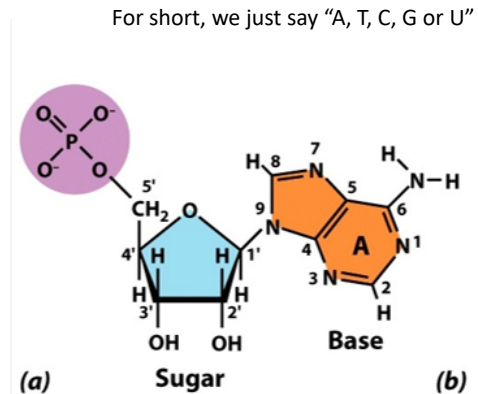
- cellulose in plant cell walls is made from beta(1,4) linked glucose
- chitin is a more complex polysaccharide; main component of insect exoskeleton



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Nucleic acids are polymers of nucleotides that store and transmit genetic information.

- Each nucleotide consists of three parts:
 - A five-carbon sugar
 - A phosphate group
 - A nitrogenous base
 - Bases are either **purines** or **pyrimidines**.
 - The purines are **adenine** and **guanine** in both DNA and RNA.
 - The pyrimidines are **cytosine** and **uracil** in RNA; uracil is replaced by **thymine** in DNA.



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Nucleotides are involved in 3 major cellular functions

1. Nucleotides are monomeric units from which DNA and RNA are made (i.e. the molecules that encode the blueprints to life)

2. Regulatory molecules

- Second messengers in cell signaling (eg. cAMP)
- GTP can serve as a switch to activate some proteins

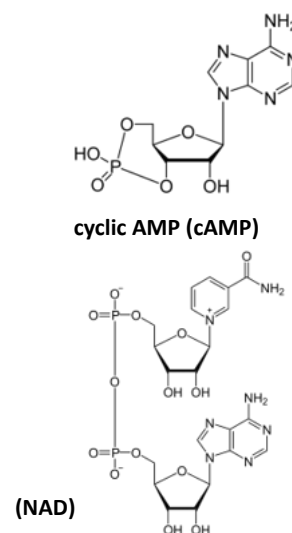
3. Agents of energy transfer for metabolism

Cleaving of phosphate groups releases energy (ATP)

Co-enzymes in energy transfer reactions (NAD)

NAD = nicotinamide adenine dinucleotide

Co-enzymes are non-protein compounds needed for enzyme action



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Nucleic Acids vary based on their bases

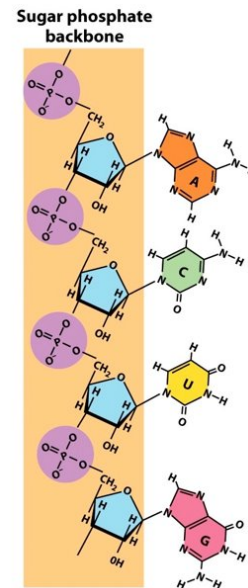
- **Deoxyribonucleic acid (DNA)** holds the genetic information in all cellular organisms and some viruses.

- Four bases:
• A, C, T, G

- **Ribonucleic acid (RNA)** encodes the message of DNA and is the genetic material in some viruses.

- Four bases:
• A, C, G, U

- Nucleotides are connected by 3'-5' phosphodiester bonds between the phosphate of one nucleotide and the 5' carbon of the next.

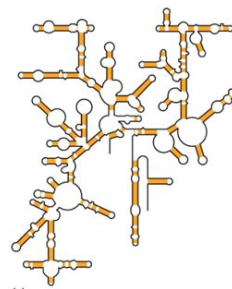


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DNA and RNA structure and function are very different



- DNA is an antiparallel double stranded helix (usually)
- held together by hydrogen bonding between bases ('rungs' of the ladder)
- A pairs with T, G pairs with C

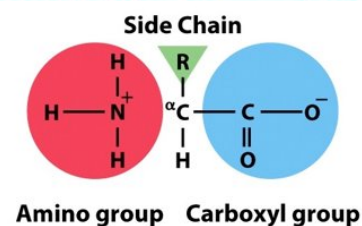


- RNA is single stranded (usually)
- Can fold back on itself to form complex 3D structures (e.g. ribosomes)
- Some RNAs have catalytic activity (**ribozymes**)

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Proteins are polymers of amino acids

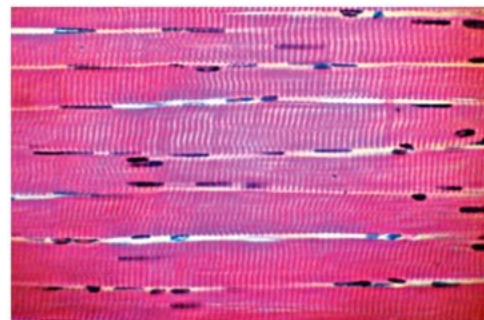
- a diverse group of macromolecules
- They exhibit a high degree of specificity.
- They have a variety of cellular functions.
- Amino acids have an α carbon, an amine group, a carboxyl group, and a variable R group.
- Amino acids are linked together by **peptide bonds** into a **polypeptide chain** to make a protein.



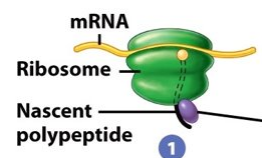
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General examples of proteins and their functions

- Enzymes – protein catalyst – lock and key concept
- Structural element – tubulin
- Contractile elements – myosin especially in muscle cells
- Control of gene transcription
 - Transcription factors
 - Ribosomes
- Transport proteins – material across membranes – glucose transporters
- Carriers – hemoglobin
- Hormones – eg. insulin
- Antibodies – defense against invaders



Contractile elements in muscle cells

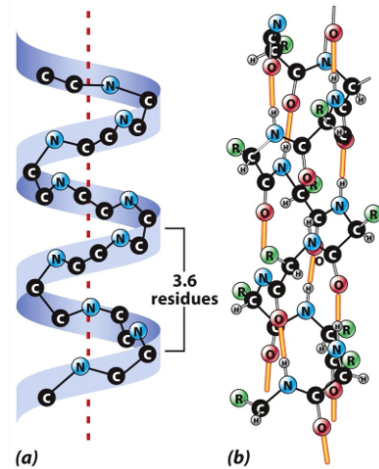


Ribosomes are important proteins in the synthesis of proteins

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The structure of proteins: primary and secondary structure

- *Primary structure*, the sequence of amino acids in the polymer, is critical to the protein function.
- *Secondary structure* refers to the **conformation** of adjacent amino acids into α -helix, β -sheet, hinges, turns, loops, or finger-like extensions.



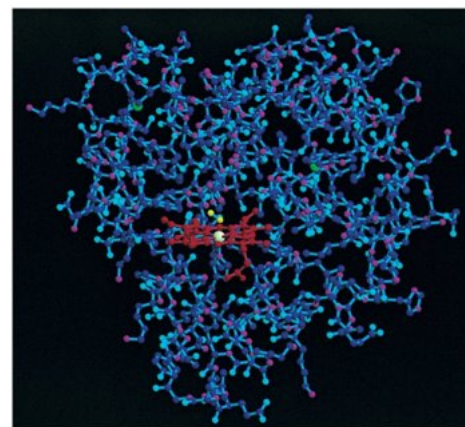
a) 360 degree turn of the helix = 3.6 amino acid residues

b) H bonds between the carbonyl group and the imine group (H-N) hold the helix together

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The structure of proteins: tertiary structure

- *Tertiary structure* is the conformation of the entire polymer.
 - It is stabilized by noncovalent bonds.
 - Eg. Van der Waals' bonds, salt bridges
- **Myoglobin: The First Globular Proteins Whose Tertiary Structure Was Determined**
 - Stores oxygen in muscle cells.
 - Has a heme prosthetic group that binds O₂.
 - Structure derived using X-ray crystallography (explained later!)

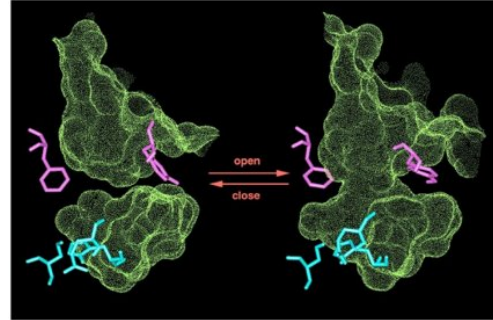


3-D structure of myoglobin.
Heme group is located in red in the center of the protein.

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Conformational changes and quaternary structure

- **Dynamic Changes within Proteins**
 - May occur with protein activity.
 - **Conformational changes** are non-random movements triggered by the binding of a specific molecule.
- **Quaternary structure** refers to proteins composed of **subunits**.
 - It refers to the manner in which subunits interact.
 - Homodimer = 2 similar proteins
 - Heterodimer = 2 different proteins



Dynamic movements of acetylcholinesterase, a protein found in the central nervous system.
 L = closed, catalytic site blocked by aromatic ring.
 R = open, catalytic site open and allows acetylcholine molecules to enter

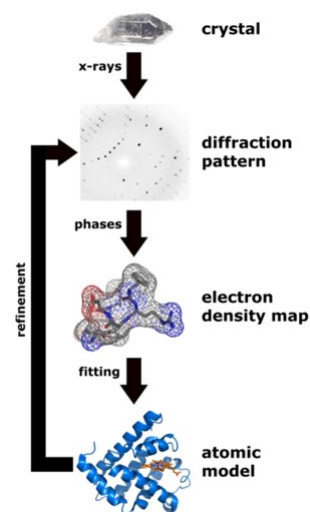
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Protein structure determines its function!

- Subtle changes in a protein's structure can have a huge impact on its ability to perform its function within the cell
- Cells routinely modify protein structures to regulate activities
- The structure is based upon the chemistry of the amino acids, the order of the amino acids are determined by the gene that encodes the protein
- Mutations can be (but are not always) damaging to the protein's function

Tertiary and quaternary structures can be determined using a variety of methods, but two methods are used most widely:

X-ray crystallography
 Nuclear magnetic resonance



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Cells are complex!

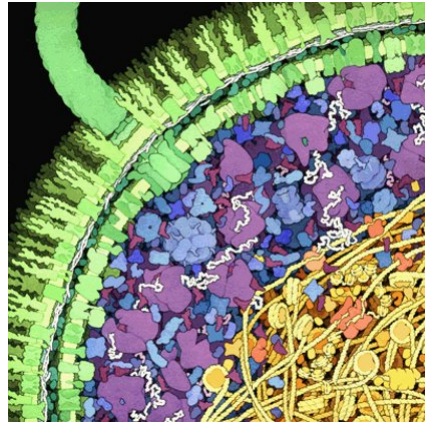


Diagram of
an *E. coli* cell to scale!

© David
S. Goodsell 1999.

1. Proteins (and other macromolecules) are dynamic!
2. The inside of a cell is a very, very packed place!

Watch... 'Protein packing': <https://www.youtube.com/watch?v=uHeTQLNFTgU>

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What you should know about macromolecules:

- The 4 macromolecules
- Multiple functions of each macromolecule
- Distinguishing characteristics of each macromolecule
- The monomers of each polymer
- The factors that determine protein structure

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