



# Macromolecules

Chapter 5, Campbell



# Macromolecules

- Composed of long chains of smaller molecules
- Macromolecules are formed through the process of polymerization.
- **Polymerization** = large compounds are built by joining smaller ones together
- Small units (monomers) form larger units (polymers)
- There are four groups of organic compounds found in living things...



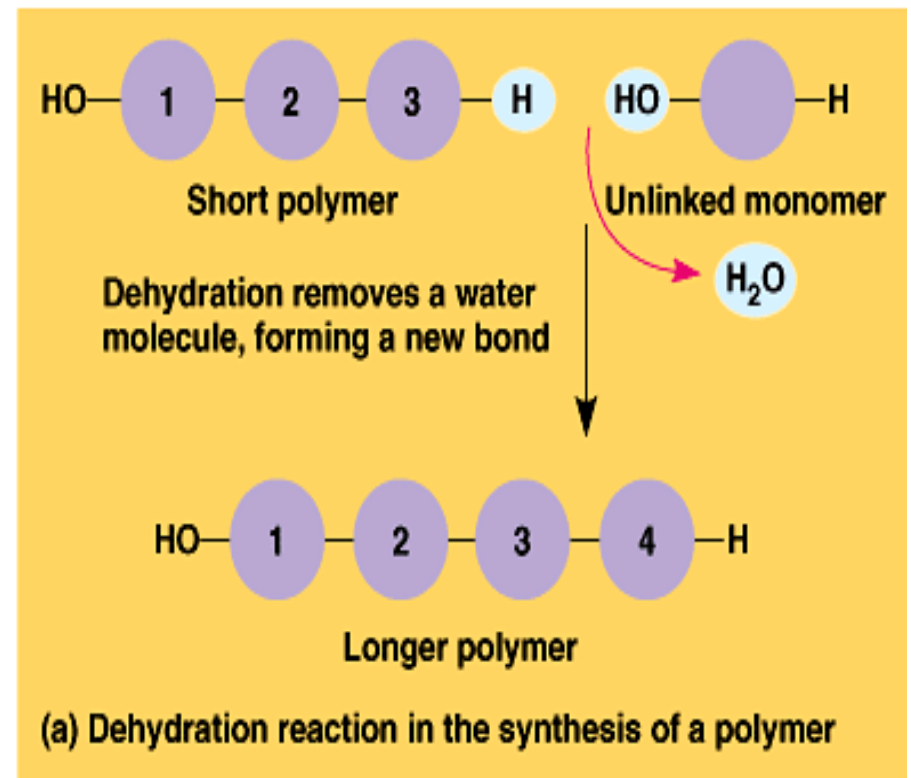
# Macromolecules

- There are four groups of organic compounds found in living things:

1. Carbohydrates
2. Proteins
3. Nucleic Acids
4. Lipids

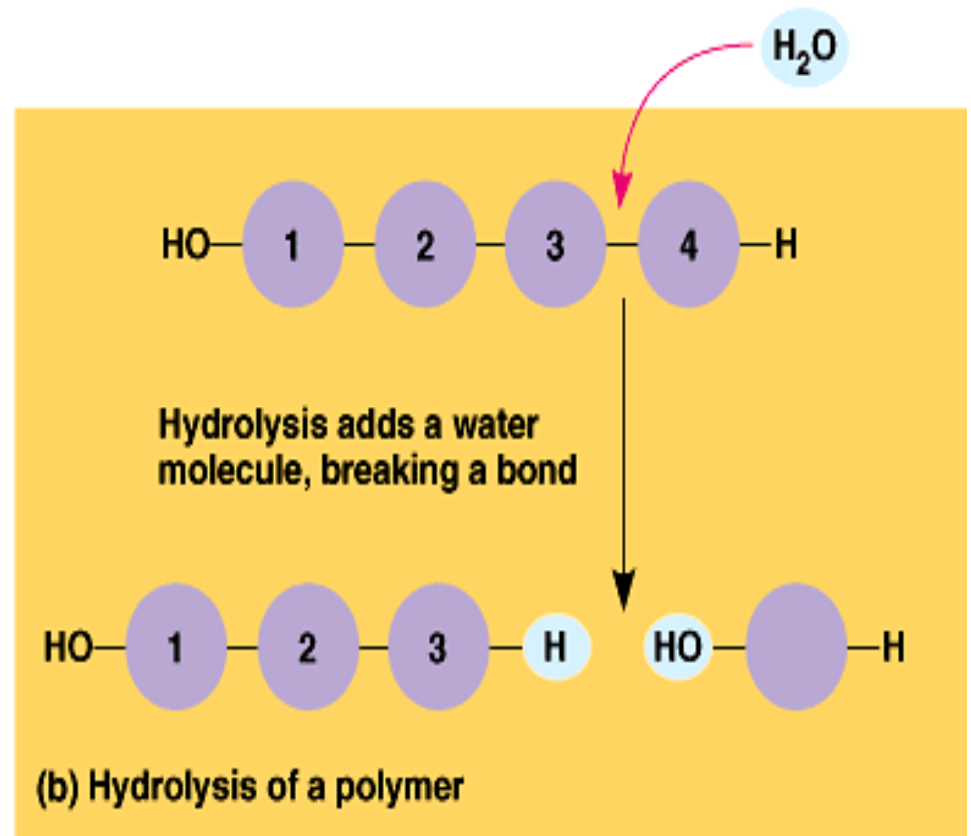
# Dehydration Synthesis

- “AKA” condensation reaction
- *Dehydrate* = lose water
- *Synthesis* = to join or make
- Monomers are combined
- $H_2O$  released



# Hydrolysis

- Form of digestion
- *Hydrate* = to water
- *ysis* = process of
- With the breaking of bonds, water molecules are added to each smaller molecule



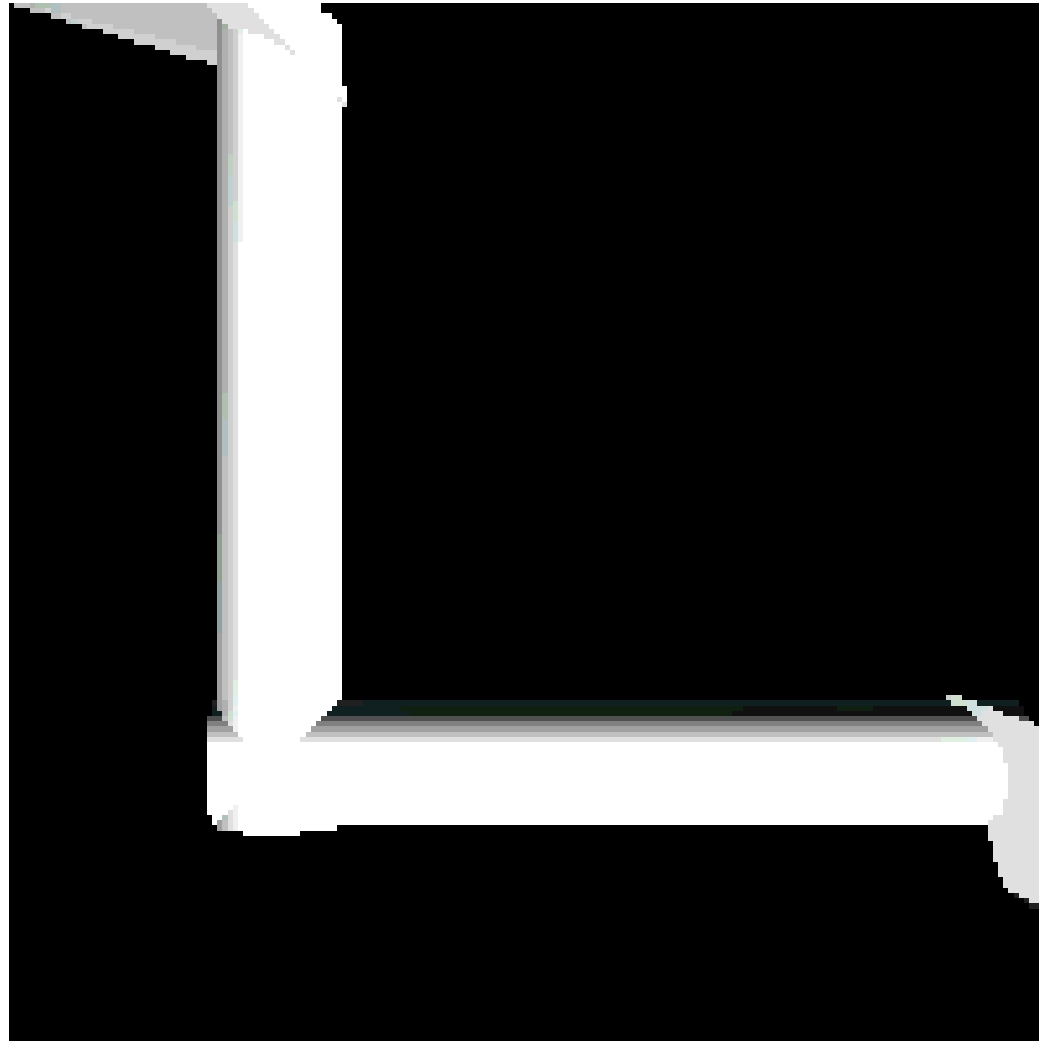


# 1. Carbohydrates

- “AKA” sugars or carbs
- Chemical compounds that contain carbon, hydrogen, and oxygen .
- The three elements exist in a *1:2:1* ratio  
Empirical vs molecular formula
- Organisms use carbohydrates as a primary source of fuel (energy) .
- Plants use carbohydrates for structural support .

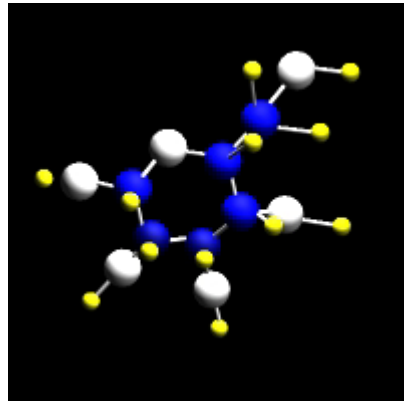


# 1. Carbohydrates



# Monosaccharide

- **Monosaccharide** = simple sugars
- Small in size & easily diffuse into and out of the cell
- There are three monosaccharides;
  1. *Glucose*
  2. *Fructose*
  3. *Galactose*
- Products of the following chemical reactions:
  - Photosynthesis
  - Digestion
  - Conversion of fats & proteins
- Organism uses:
  - Fuel for respiration
  - Building larger sugars
- Monosaccharides link together forming two – sugar







# Disaccharide

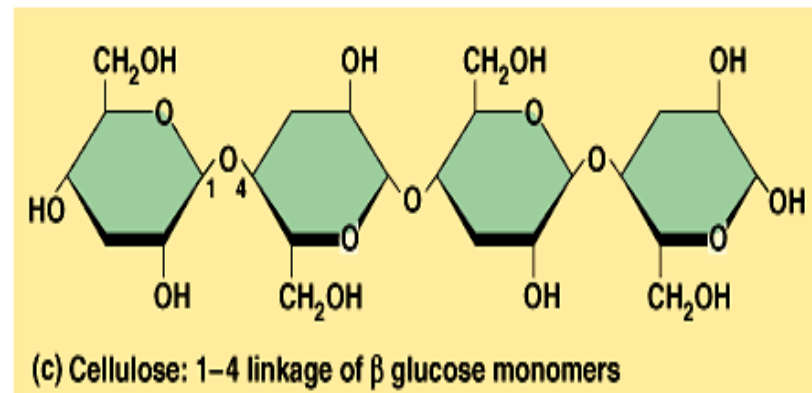
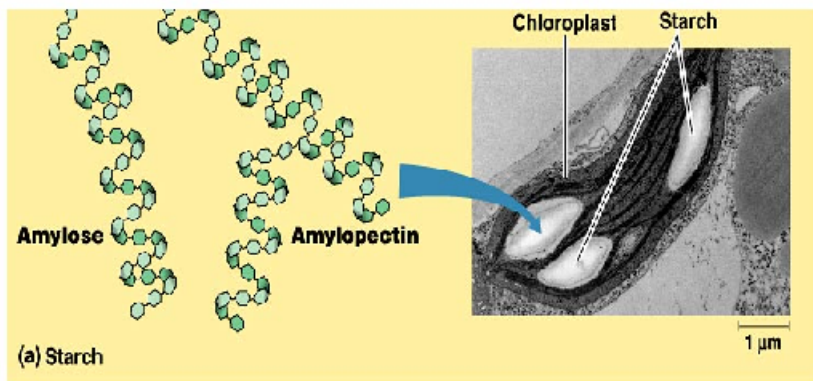
- **Disaccharide** = a sugar made from the combination of two monosaccharides
- Disaccharides are water-soluble, but cannot diffuse into or out of the cell
- There are three disaccharides in your home:
  1. **Sucrose** = Glucose + Fructose (table sugar)
  2. **Lactose** = Glucose + Galactose (milk sugar)
  3. **Maltose** = Glucose + Glucose (cereal)



# Polysaccharide

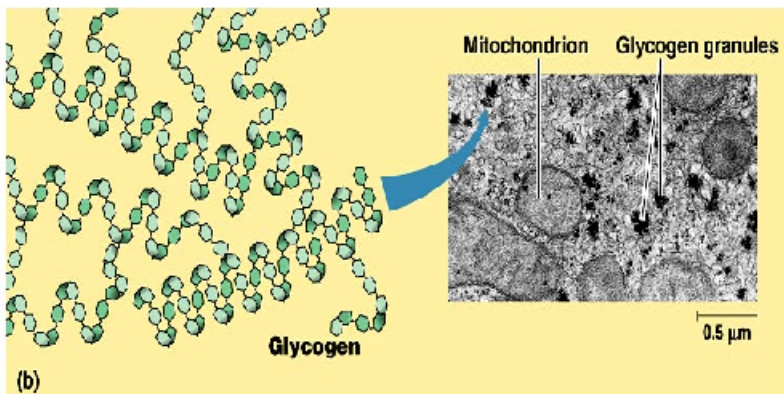
- **Polysaccharides** = “giant” sugar made from the combination of 3 or more monosaccharides
- “AKA” starches
- Large insoluble molecules that cannot diffuse into or out of a cell
- Used for long – term energy storage or structural support purposes
- Major bio – starches include
  - Glycogen
  - Amylose
  - Cellulose

# Plant Starch



- Amylose = surplus glucose storage in chloroplasts
- Cellulose = structural glucose that forms the cell wall in plant cells

# Animal Starch



- **Glycogen** = storage starch for an organisms supply of glucose
- Glycogen is highly branched, many strands
- Animals store glycogen a one – day supply of glycogen in the liver and muscles
- **Chitin** = starch that forms the exoskeleton of arthropods and insects
- Chitin also forms the cell walls of various fungi



## 2. Proteins

- Organic polymers that contain carbon, hydrogen, oxygen and nitrogen
- Formed from the bonding of monomer building blocks called ***amino acids***
- Used in the protective skin and muscle tissue of animals
- Also used as enzyme catalysts in both plants and animals

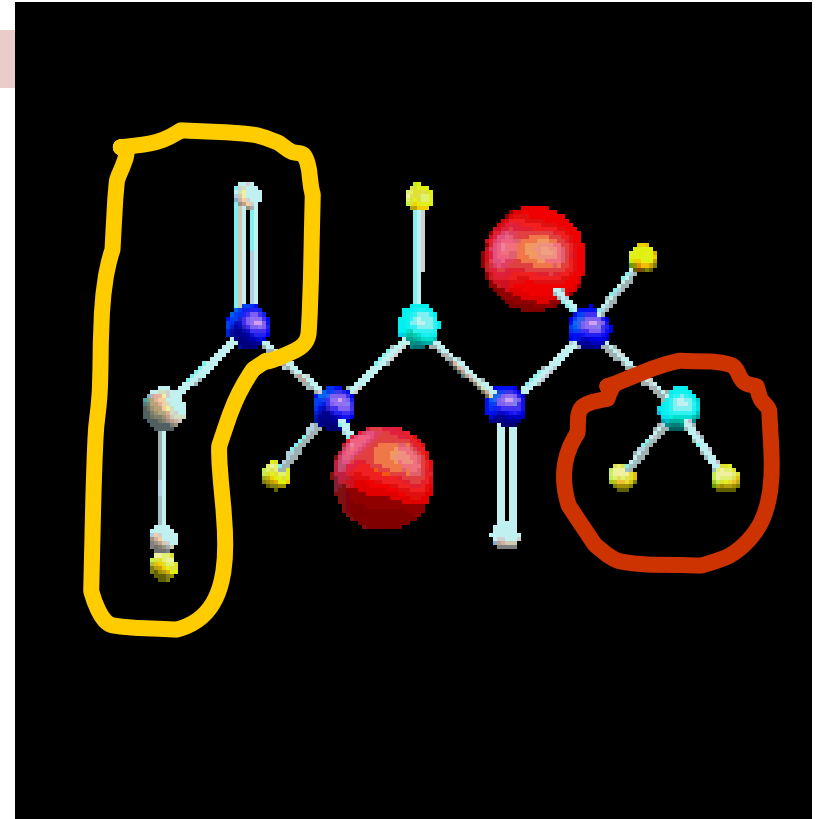


# Amino Acids

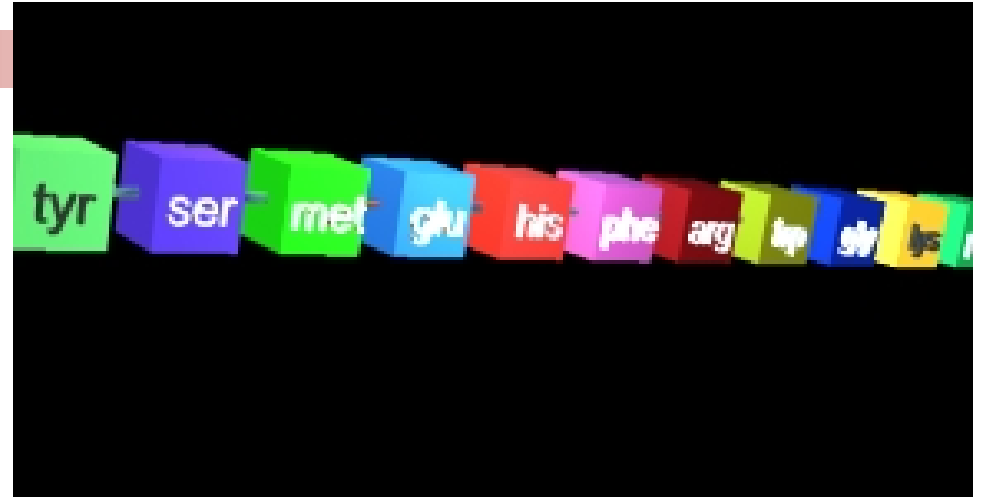
- Building blocks for proteins
- Small molecules that can easily diffuse into and out of the cell
- Integral to the formation and copying of DNA
- 20 different amino acids are divided into two categories
  1. Essential = must be ingested (9)
  2. Non-Essential = can be produced in the body

# Structure of Amino Acids

- Amino acids are built like a sandwich
- One slice of bread must be an amine group
- The other slice must be a **carboxyl group**
- In this image the large red structures represent the R group of the Amino acid. The R group represents an organic variable.
- This organic molecule is different in each of the 20 amino acids and determines their behavior.



# Peptides

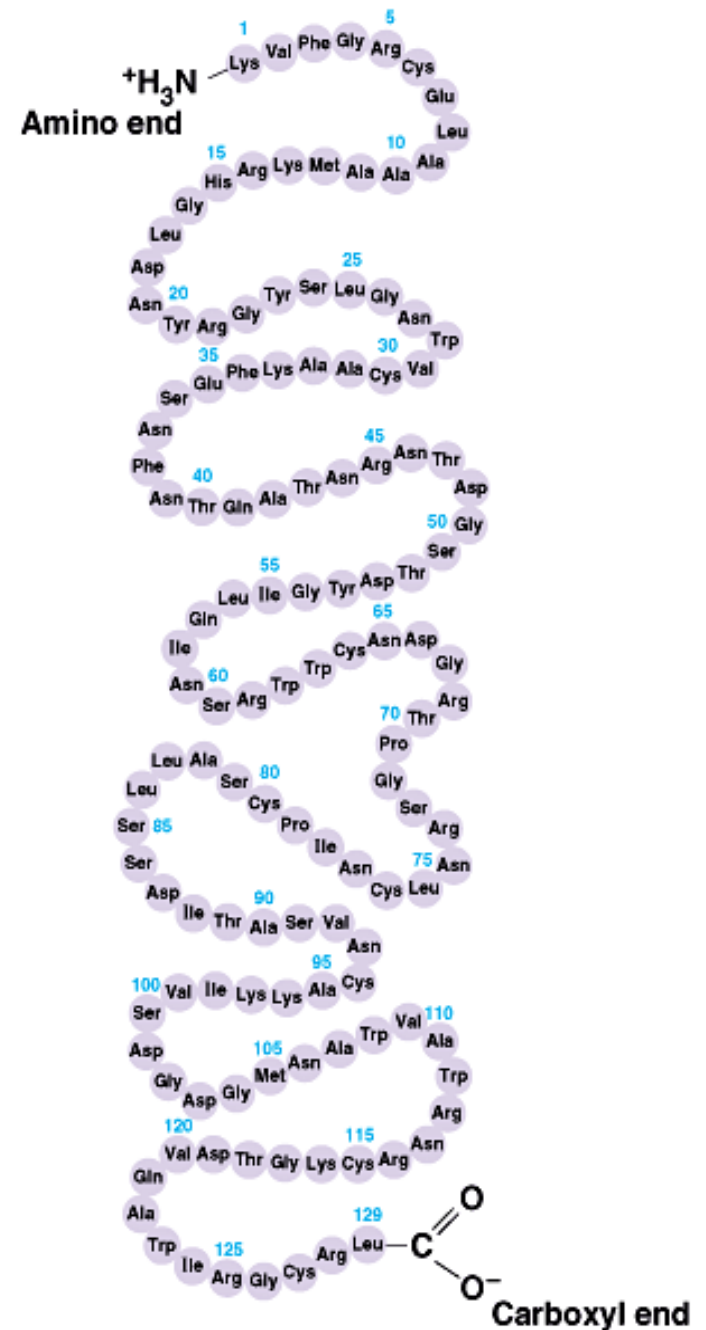


- During the dehydration synthesis of two monomers, a *peptide bond* forms
- **Peptide bond** is a covalent bond that links amino acids together to create proteins.
- **Polypeptide** = bonding together of numerous amino acids
- Proteins are composed of polypeptides in various bond structures



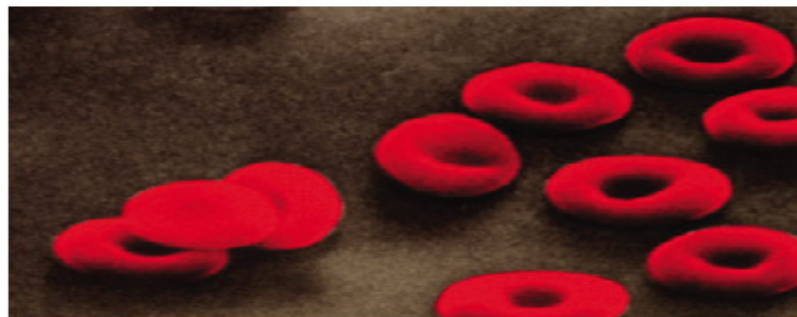
# Primary Structure

- Unique sequence of amino acids
- Single polypeptide chain of amino acids
- Mistakes in sequence and structure will result in a failure to complete function
- Primary structure is determined through genetic inheritance



# Primary Structure & Function

- A mistake in the reading sequence of amino acids in a polypeptide results in the change in shape of the human RBC
- Sickle cell anemia



Val His Leu Thr Pro Glu Glu . . .  
1 2 3 4 5 6 7

(a) Normal red blood cells and the primary structure of normal hemoglobin

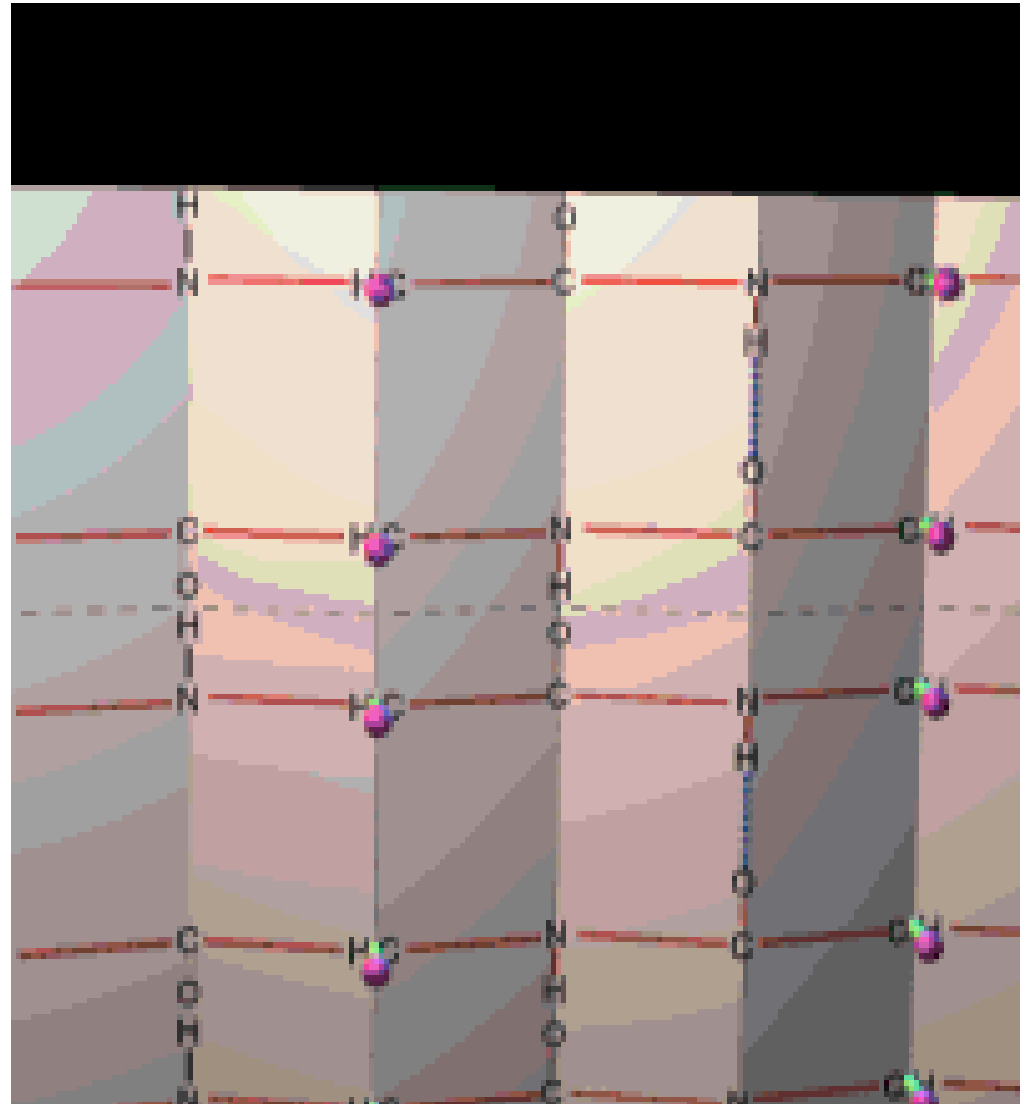


Val His Leu Thr Pro Val Glu . . .  
1 2 3 4 5 6 7

(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

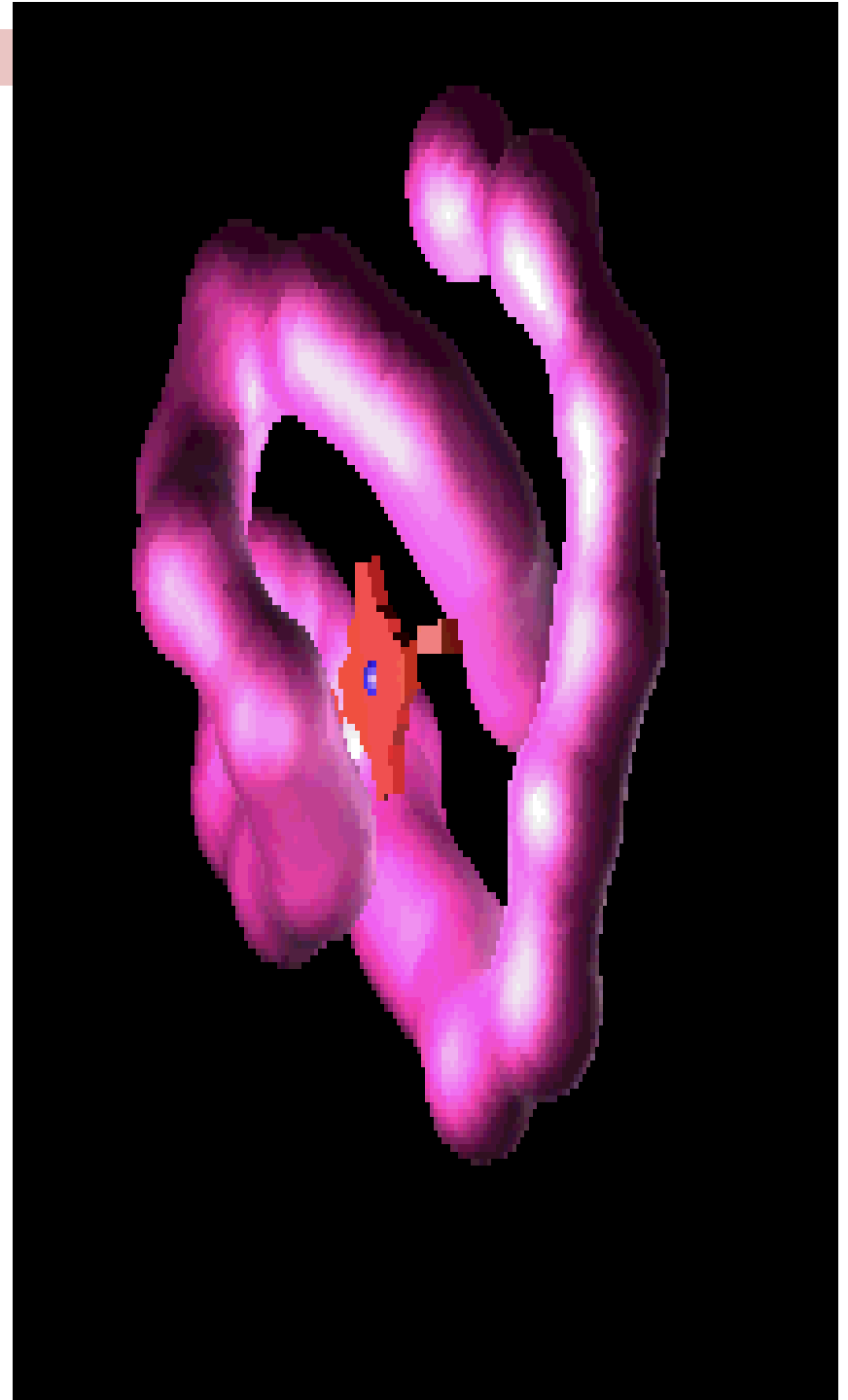
# Secondary Structure

- Results from hydrogen bond inserted between peptide bonds at regular intervals along the amino acid sequence
- This alternation of bonding forms a coil or helix shape or a pleated sheet (folded paper)



# Tertiary Structure

- Determined by interactions among functional groups of amino acids along the peptide bond chain
- Functional group interactions produce hydrophobic regions and van der Waals interactions



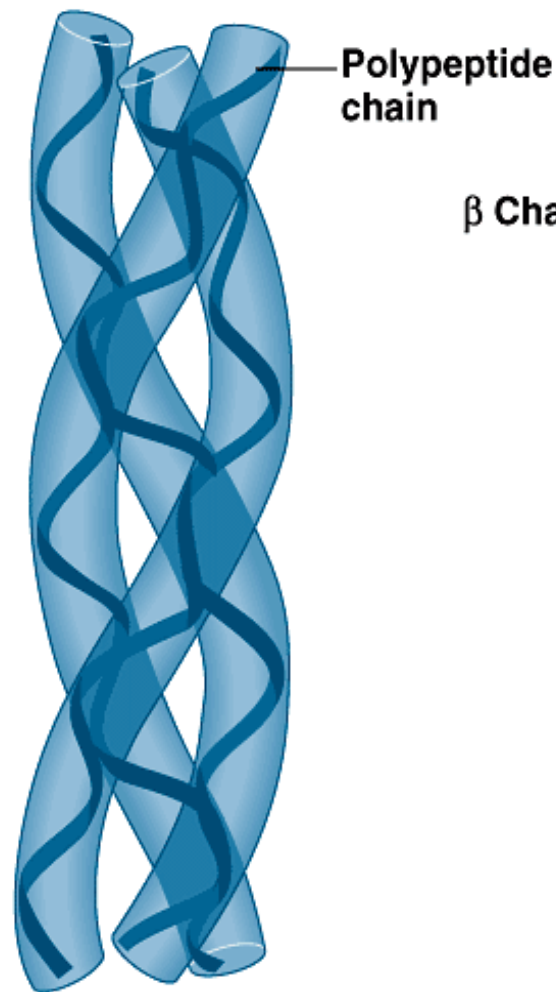


# Quaternary Structure

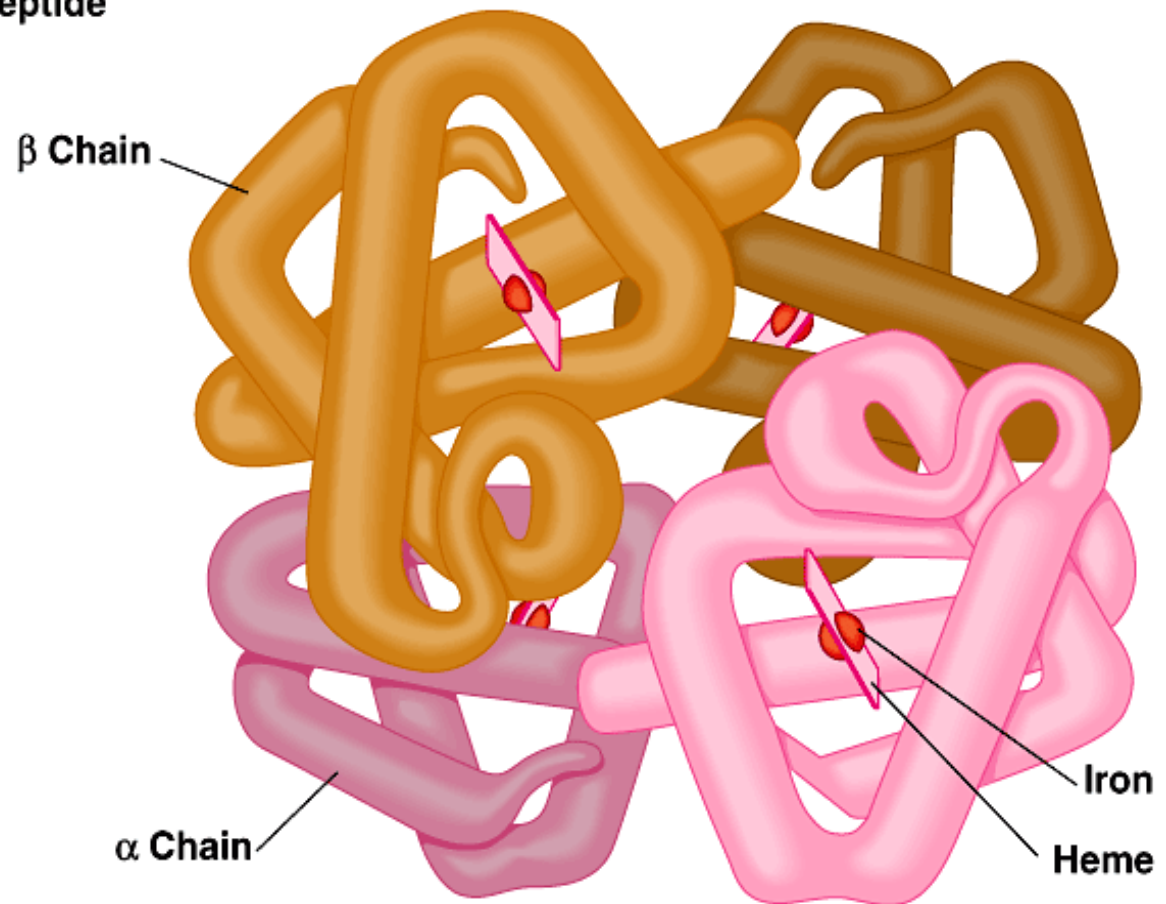
- Results from the bonding or combination of two or more polypeptide chains
- Amino acids form a super coil of bond between the various chains
- Structure of these proteins similar to braided rope and is very strong



# Quaternary Structure

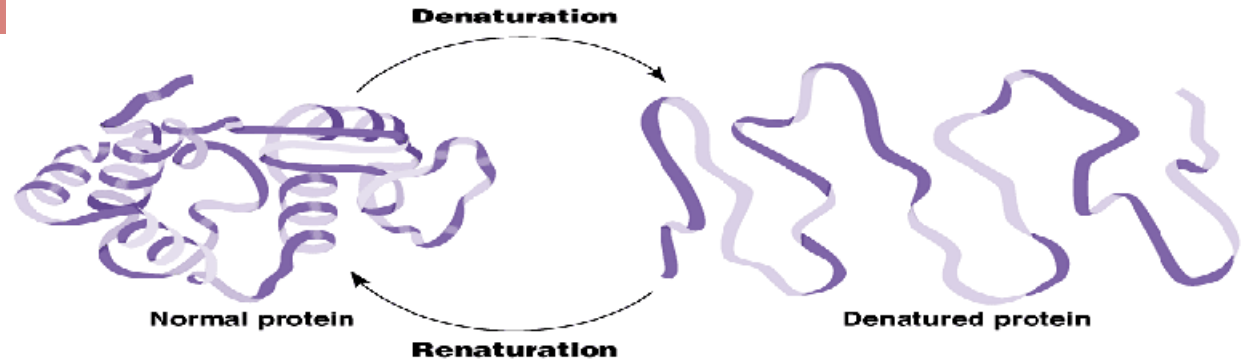


(a) Collagen



(b) Hemoglobin

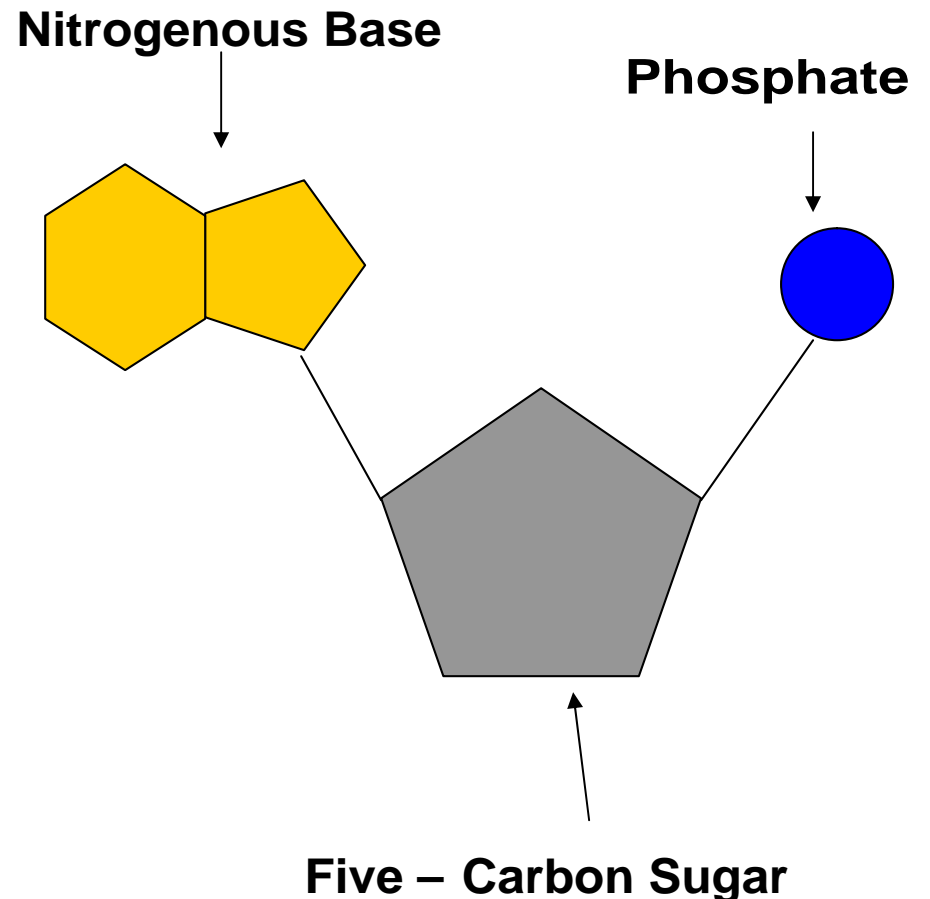
# Denaturing



- Any change in shape, structure, & function of a protein
- The protein is now biologically inactive
- The protein is said to be “denatured”
- Causes of Denaturing:
  - Alteration of pH
  - Changes in solute concentration
  - Changes in environmental conditions
  - Temperature changes
- Some proteins may renature, other cannot

# 3. Nucleic Acids

- Macromolecule monomer containing H, O, N, C, and P
- **Nucleotides** = 5-carbon sugar combined with a phosphate group and nitrogenous base
- Nucleic acids store and transmit genetic info
  1. Ribonucleic Acid (RNA)
  2. Deoxyribonucleic Acid (DNA)





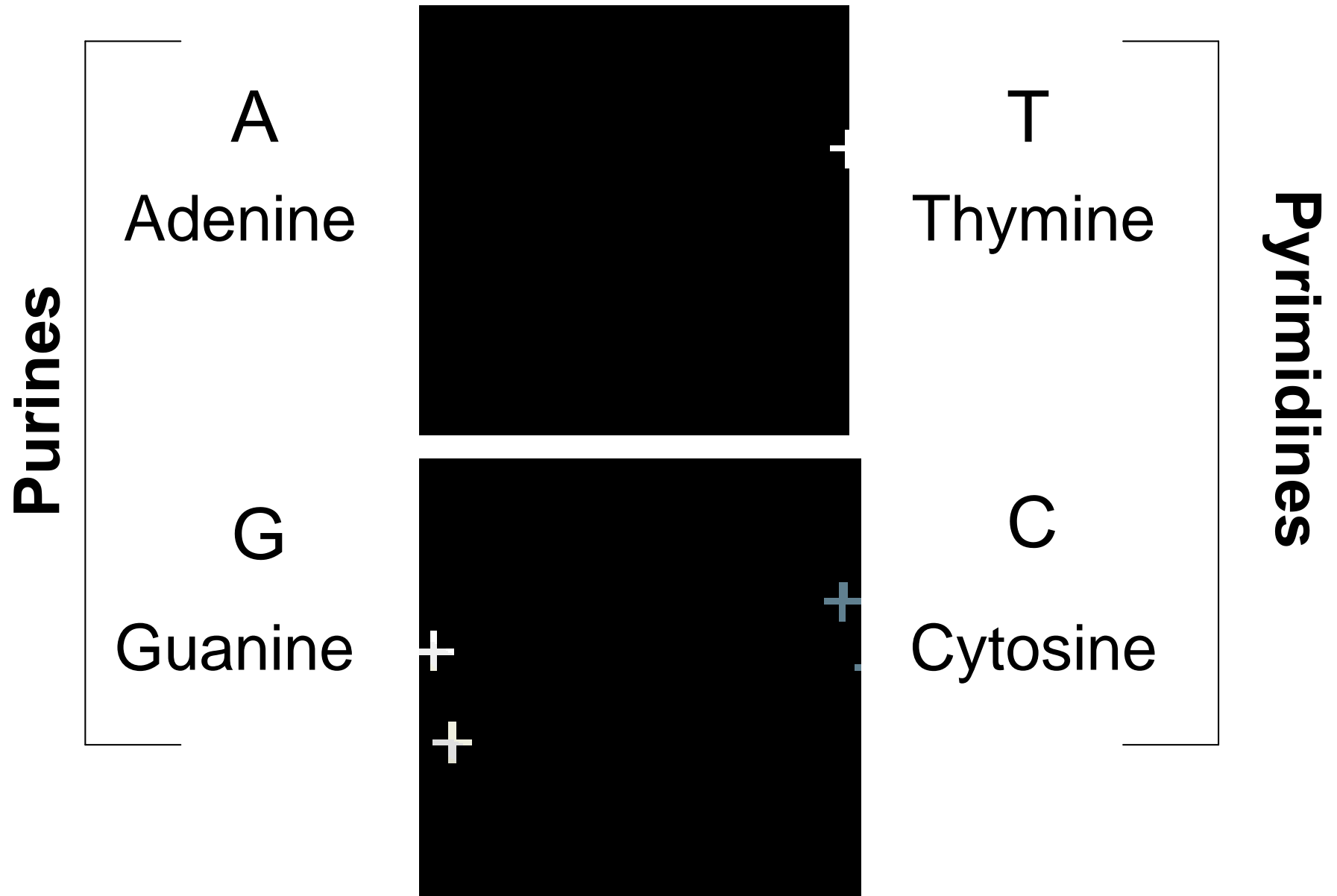


# Nucleic Acid Bonding

- DNA is composed of four nitrogenous bases
- The bases are represented by a letter
  - 1) Adenine (A)
  - 2) Guanine (G)
  - 3) Cytosine (C)
  - 4) Thymine (T)
- The four bases are divided into two classifications based on their chemical structure
  - 1) **Purines** = have two rings of carbon (A & G)
  - 2) **Pyrimidines** = have only one carbon ring (T & C)

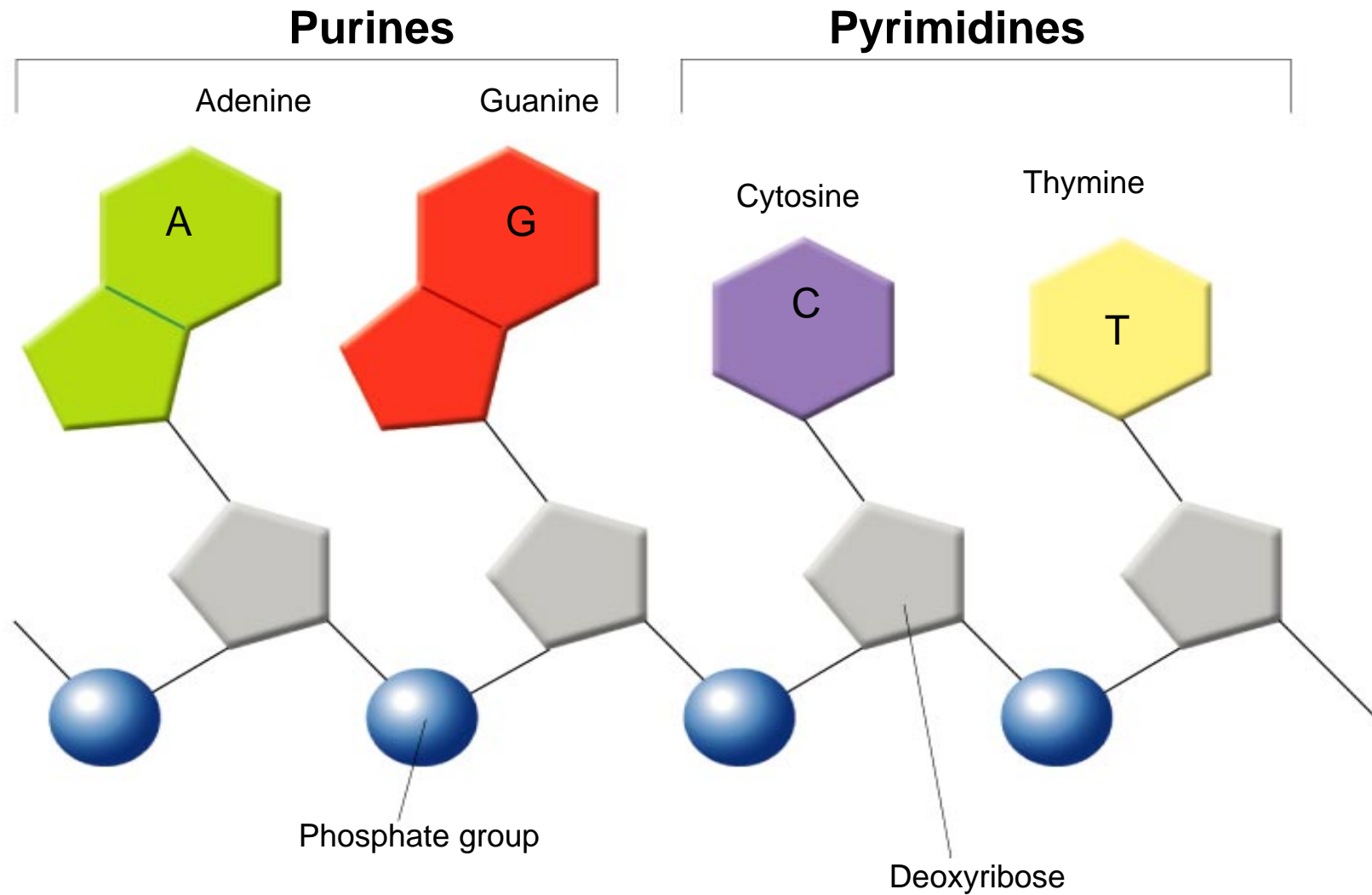


# Classification of Nucleotides

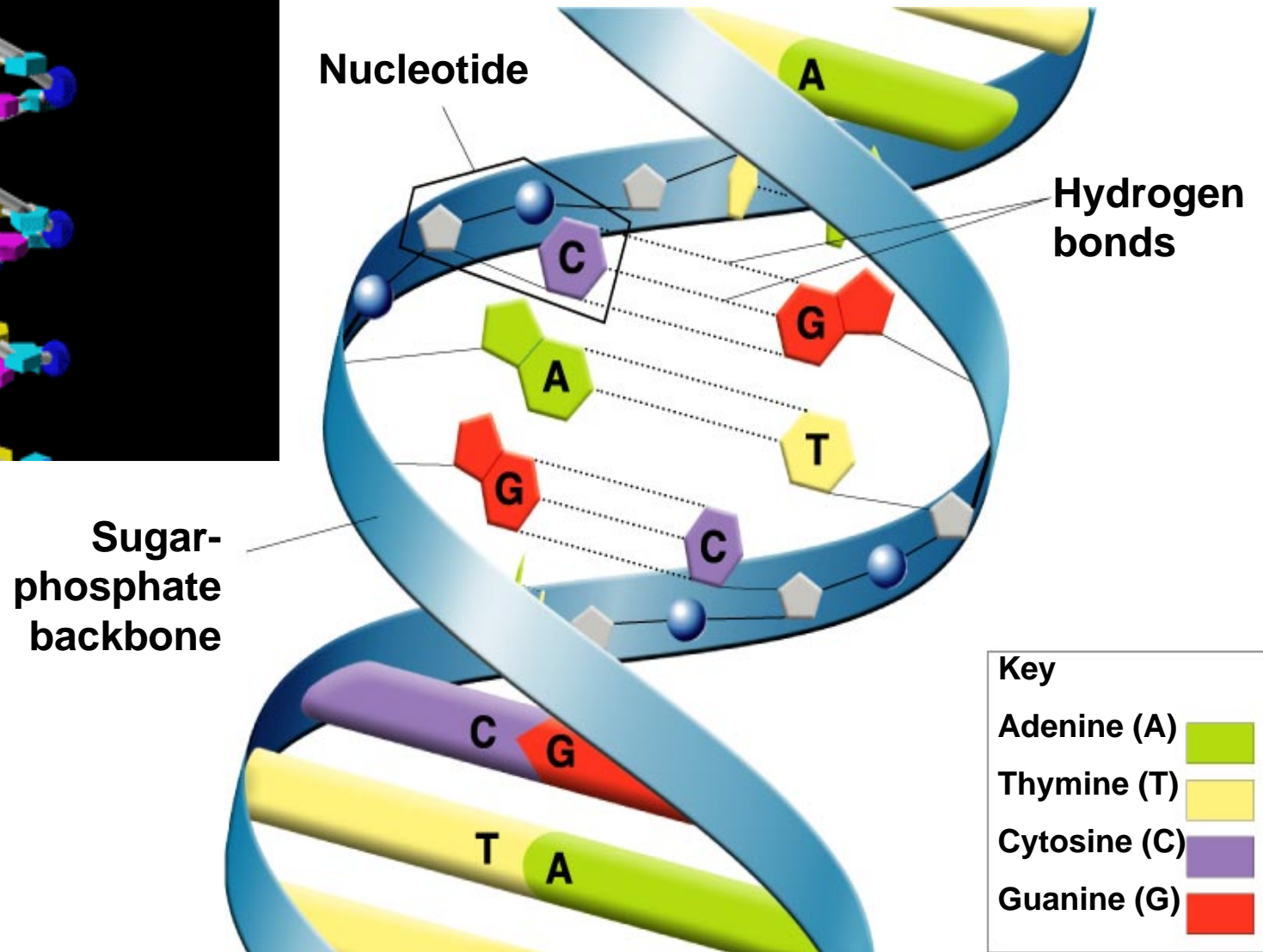
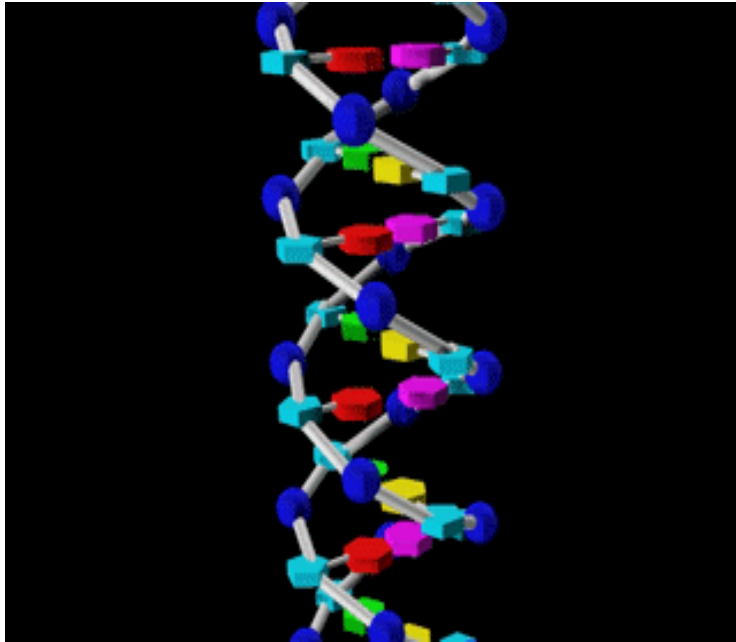




# Classification of Nucleotides



# Double Helix & Base Pairing



DNA

A with T  
G with C

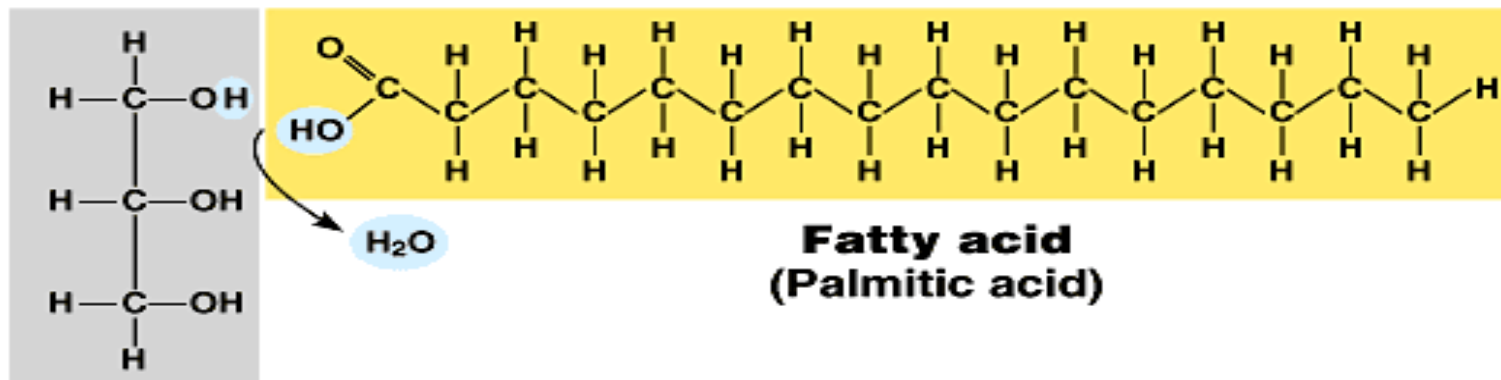
## 4. Lipids

- “AKA” fats
- Chemical compounds that contain carbon, hydrogen, and oxygen
- Hydrogen and Oxygen could exist in a *many:1* ratio
- Are the macromolecule exception in that they are not polymers
- Lipids are formed from smaller molecules through dehydration reactions
- Any fat is constructed from two sub – units
  - Glycerol
  - Fatty acids



# Fat Structure

- Glycerol consists of a 3- carbon skeleton with a hydroxyl group attached
- Fatty acid consists of a carboxyl group attached to a long carbon skeleton, often 16 to 18 carbons long
- Joined through dehydration synthesis



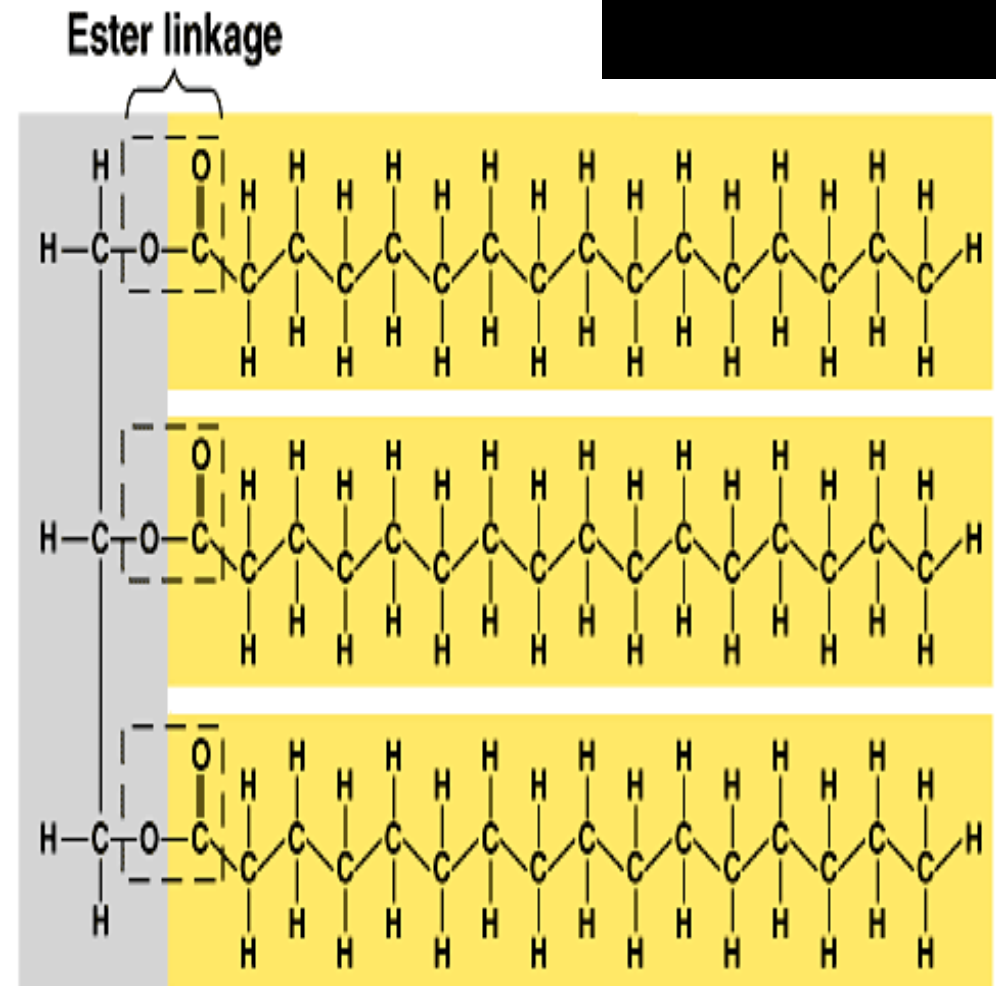
**Glycerol**

**Fatty acid  
(Palmitic acid)**

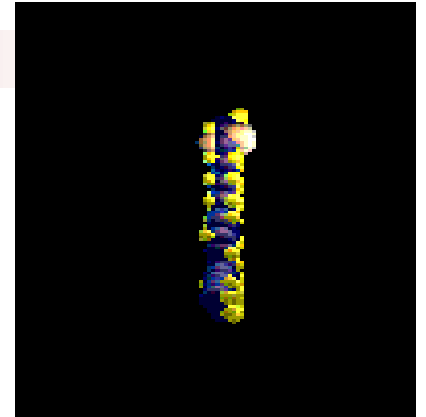
**(a) Dehydration synthesis**

# Triglycerides

- Complex lipid
- “AKA”  
triacylglycerol
- Formed by the linkage of three fatty acid tails (*tri*) to a glycerol head

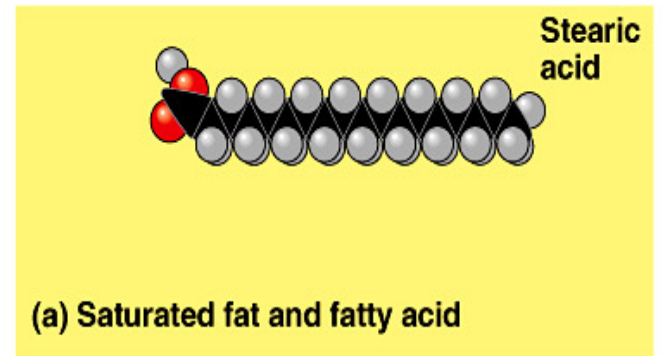


(b) Fat molecule (triacylglycerol)



# Saturated Fats

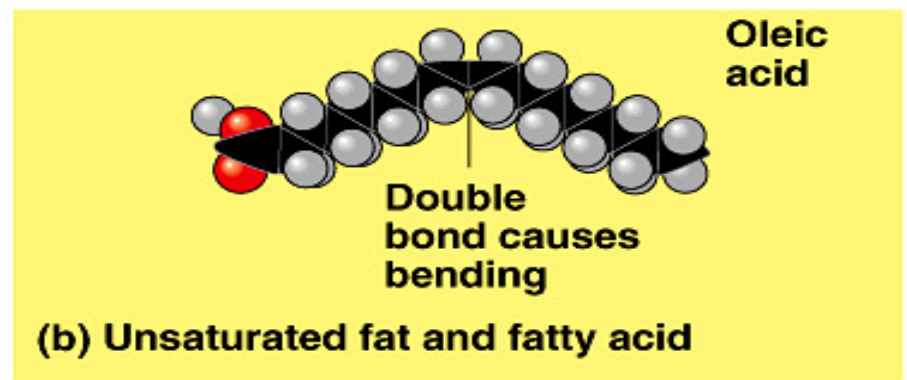
- Solid at room temp.
- Found in animal products
- The hydrocarbon tail of this lipid has carbon atoms **saturated** with hydrogen at each bond site
- Contains no double or triple bonds between carbon atoms





# Unsaturated Fats

- Liquids at room temp.
- Found in plant & fish oils & legumes
- The carbons are **not saturated** with hydrogen bonds
- May contain one or more double or triple bonds between carbon atoms





# Fat Functions

## ■ Animals:

- ☐ Energy storage
- ☐ Waterproof coverings
- ☐ Insulation
- ☐ Cushioning of organs
- ☐ Cell membranes

## ■ Plants:

- ☐ Oils for seed dispersion
- ☐ Cell membranes

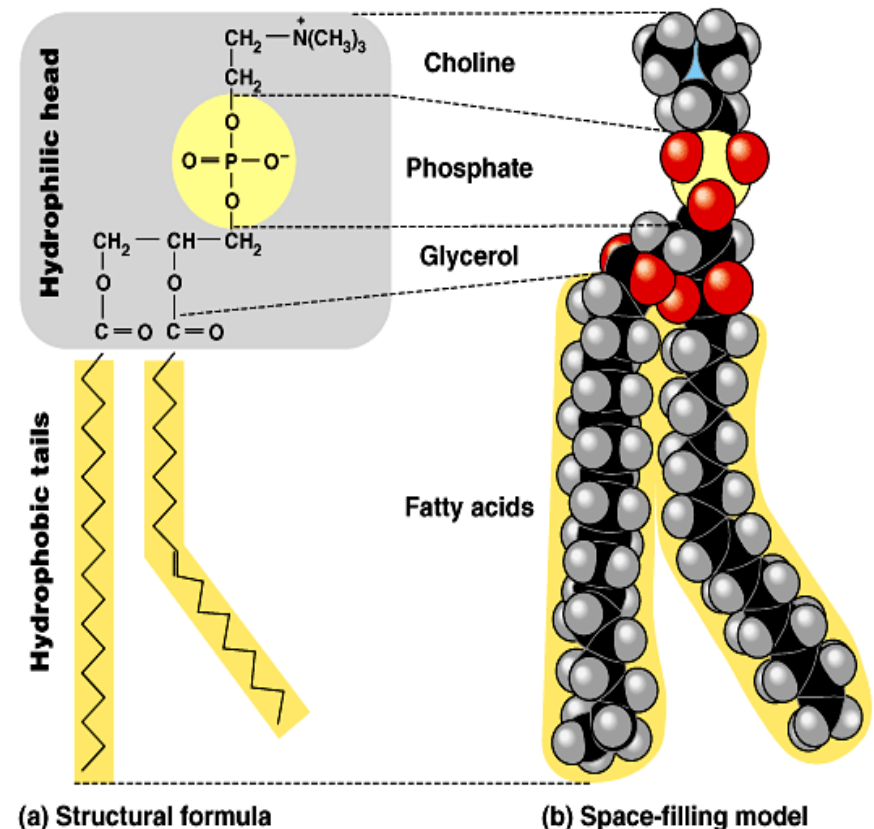
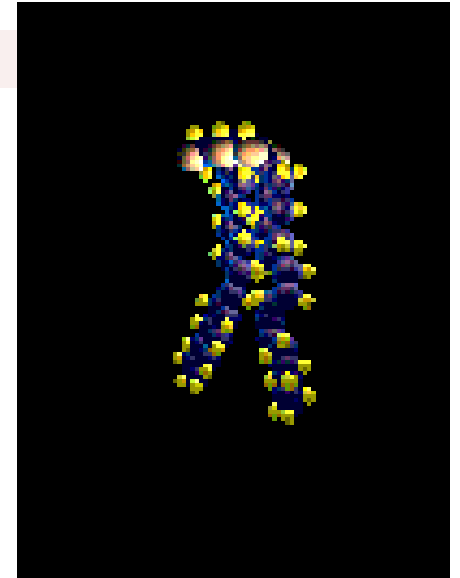


# Phospholipids

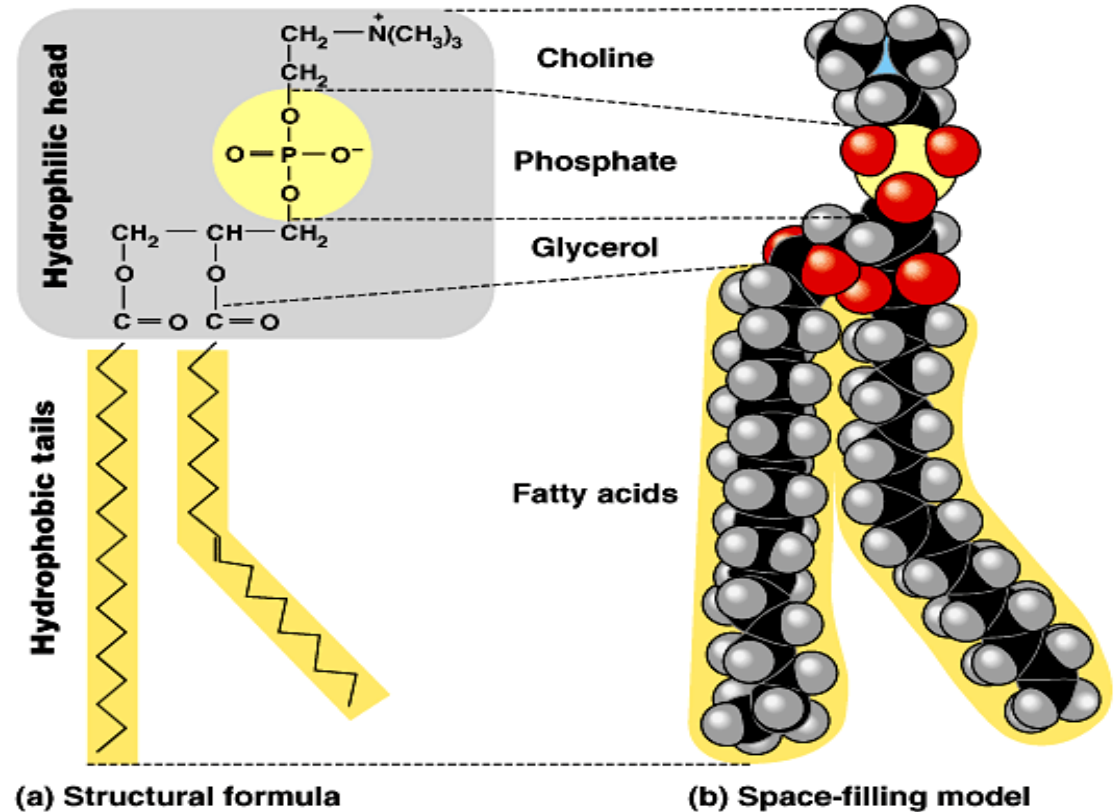
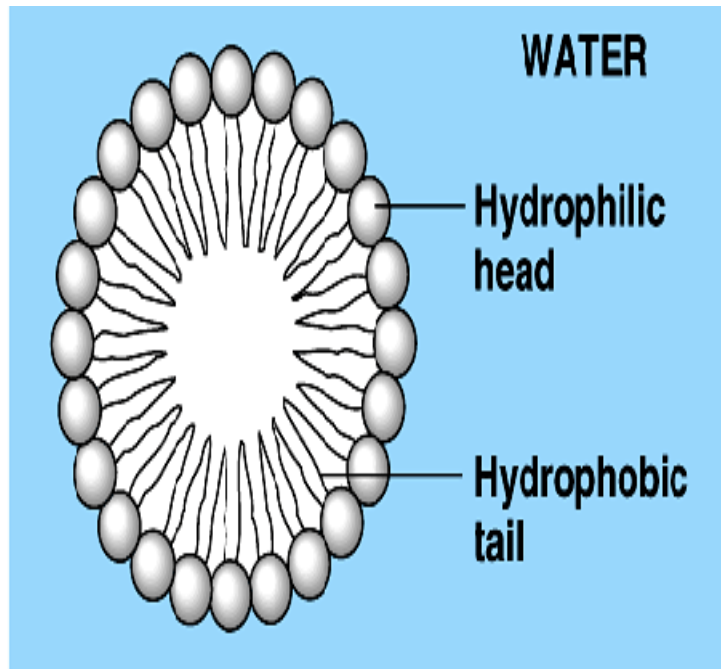
- Phospholipids = major components of cell membranes of various organisms
- Phospholipids have two fatty acids attached to glycerol & a phosphate group at the third position
- The phosphate group carries a negative charge giving the molecule polarity
- Phospholipids interaction with water determine what can and cannot pass the cell membrane

# Phospholipid Structure

- The fatty acid tail is hydrophobic (repels  $\text{H}_2\text{O}$ )
- Phosphate head group is hydrophilic (loves  $\text{H}_2\text{O}$ )
- As phospholipids are added to water, they self-assemble with the hydrophobic tails pointing toward the center and the hydrophilic heads on the outside



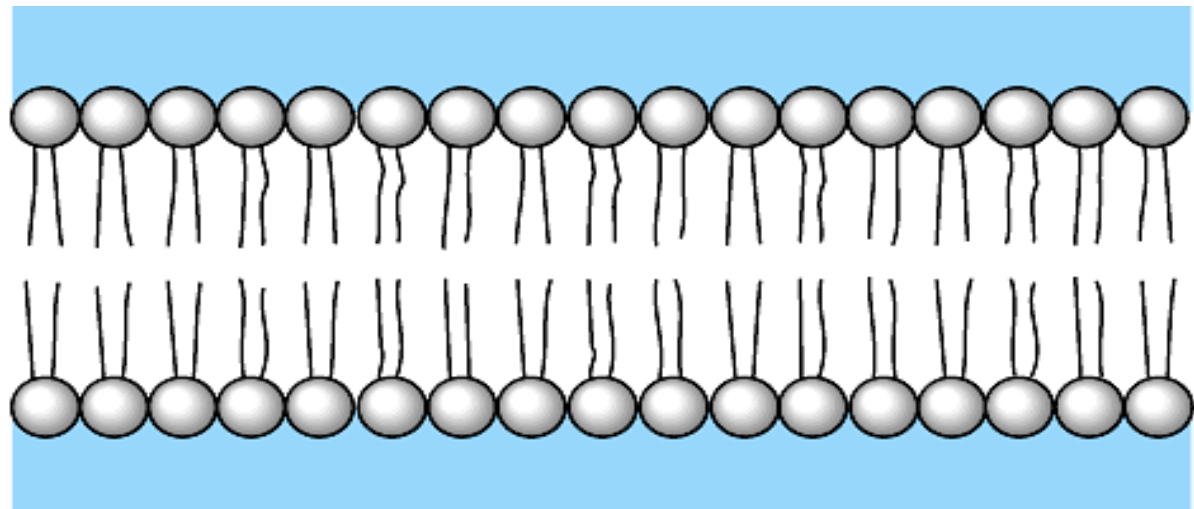
# Phospholipid Structure



# Bilayers

- At the surface of a cell phospholipids are arranged as a bilayer
- The arrangement of heads & tails creates a bilayer between the cell and its external environment

**(b) Phospholipid bilayer**



# Steroids

- Fat-based molecule composed of four fused carbon rings and a functional group
- Chemical basis of many animal hormones
- Human hormones include:
  - Cholesterol = nerve cell function
  - Testosterone = male sexual hormone
  - Estrogen & Progesterone = female sexual hormones

