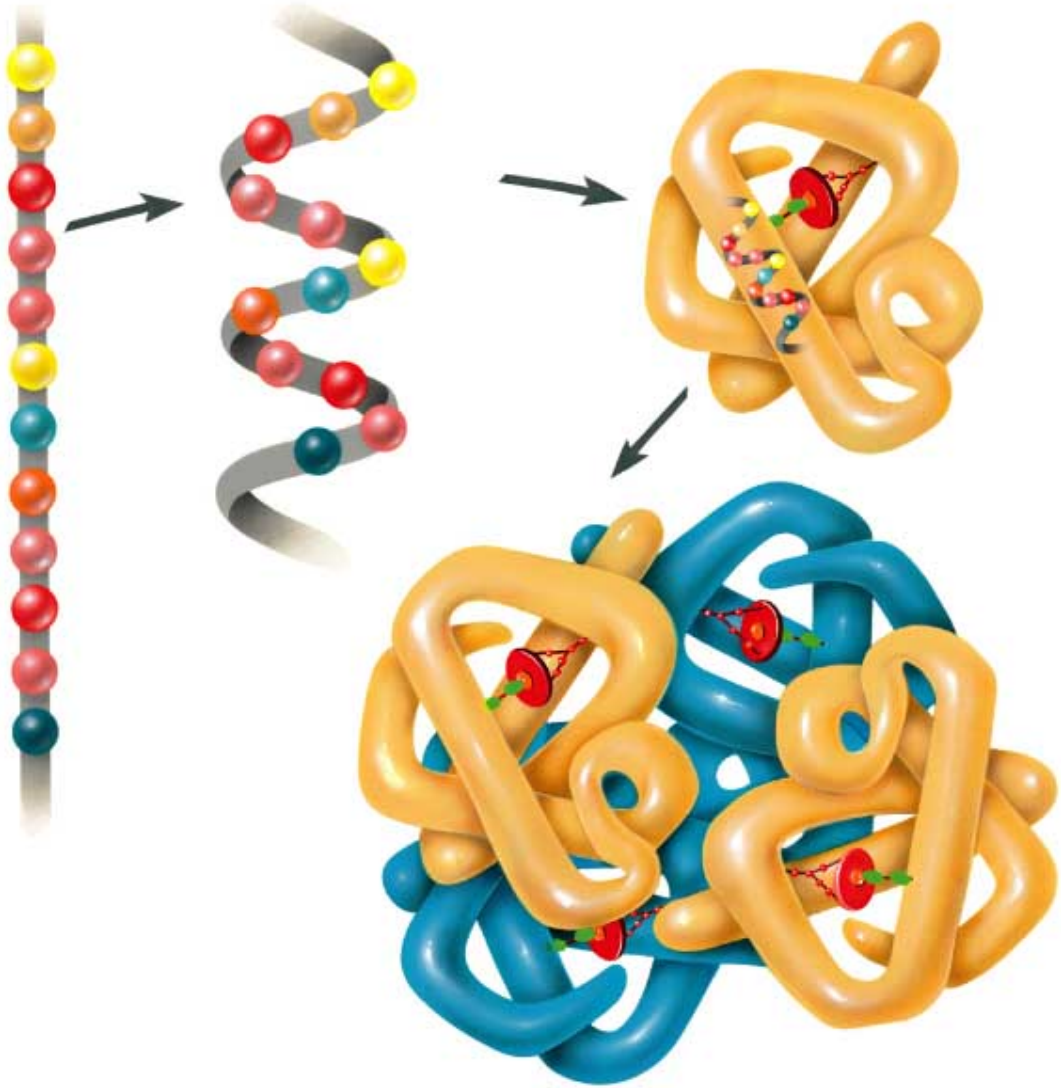
Chapter 3: Biological Molecules



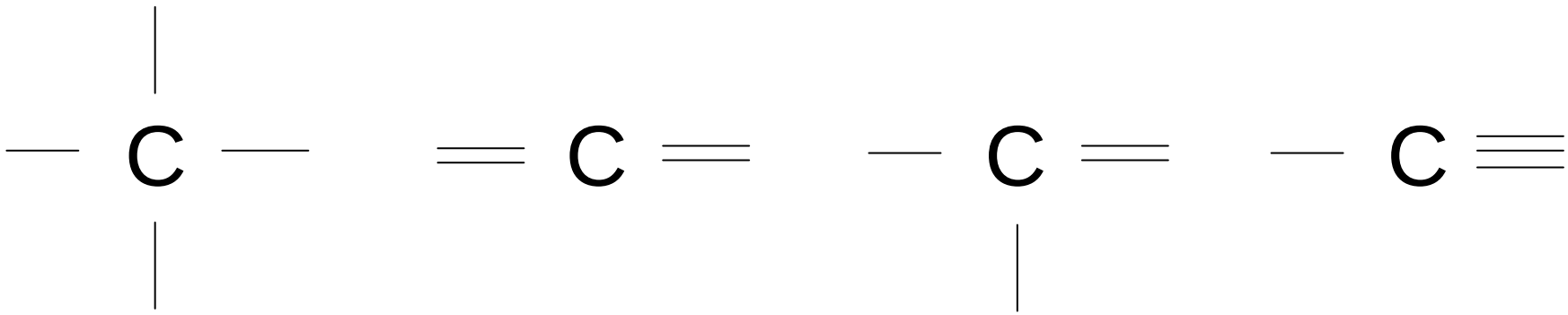
Nearly all biological molecules can be grouped into one of four general categories (Table 3.2):

Category	General Function
1) Carbohydrates	• Energy source • Structural material
2) Lipids	• Energy storage • Structural material
3) Proteins	• Structural material • Catalyze cell processes
4) Nucleic Acids	• Store genetic material • Transfer genetic material

Why is Carbon so Important in Biological Molecules?

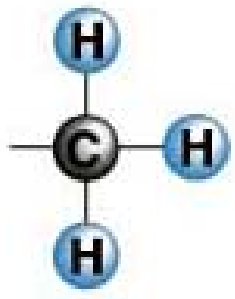
Answer: Carbon is versatile

- Can form many covalent bonds resulting in molecules with complex structures (chains, rings, branching)



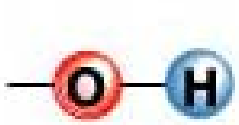
  - Organic: Molecules with a carbon skeleton
  - Inorganic: Molecules without a carbon skeleton
- Functional Groups: Determine characteristics of molecules

Functional Groups (Table 3.1)



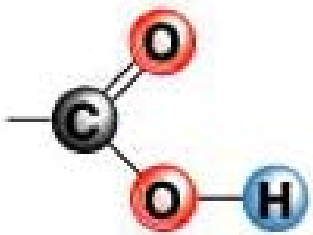
A) Methyl Group

- Non-polar (hydrophobic)
- Lipids



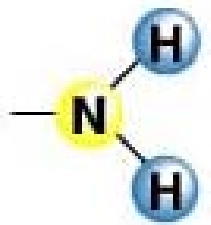
B) Hydroxyl Group

- Polar (hydrophilic)
- Carbohydrates



C) Carboxyl Group

- Acidic (H^+ dissociates)
- Fatty acids / amino acids



D) Amino Group

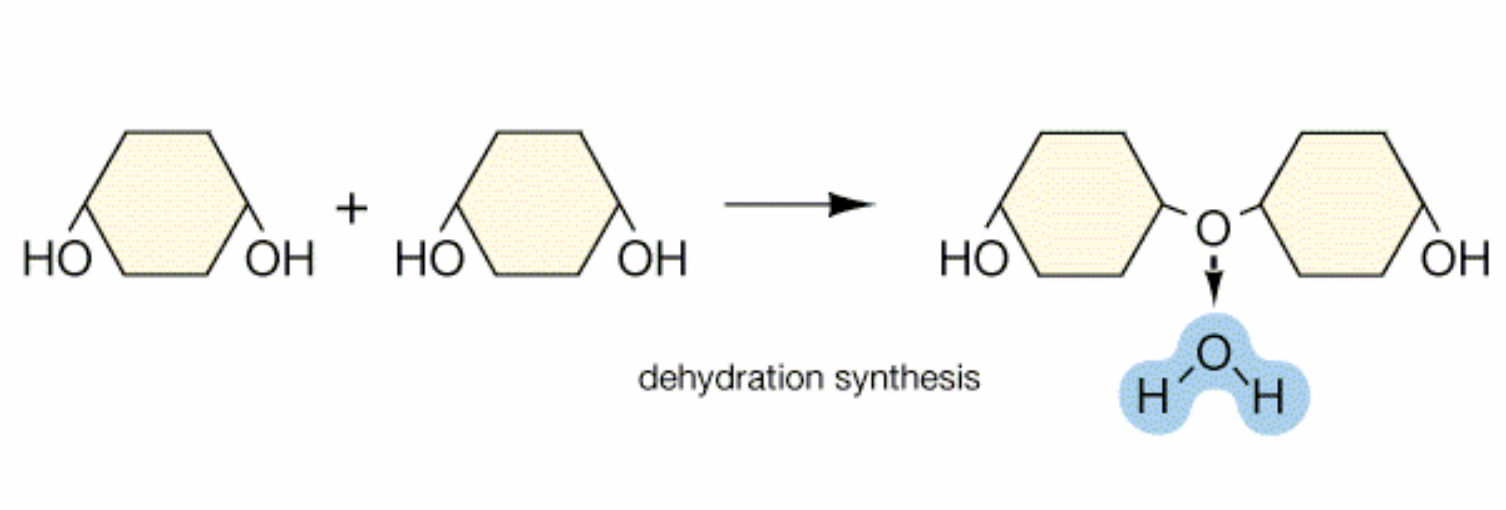
- Basic (H^+ bonds)
- Amino acids / Nucleic acids

How are Organic Molecules Synthesized?

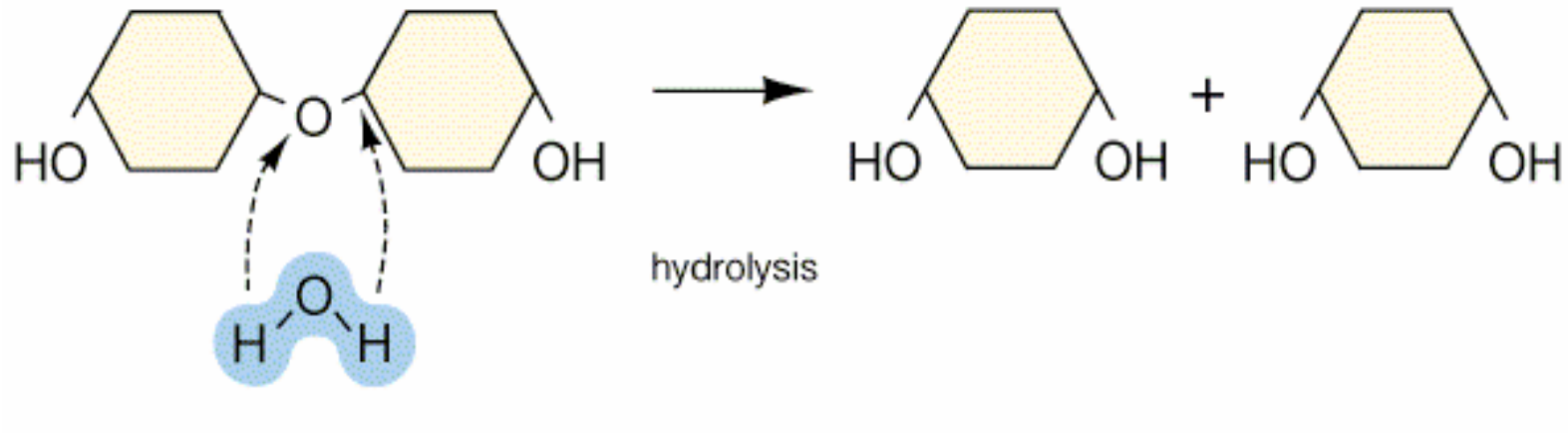
Answer: They are synthesized by a modular approach

- Sub-units are added one to another
  - Single sub-unit = monomer ("one part")
  - Long chains of monomers = polymer ("many parts")
- Biological molecules subtract or add water as they are joined together or broken apart

Dehydration Synthesis: To form by removing water



Hydrolysis: To break apart with water



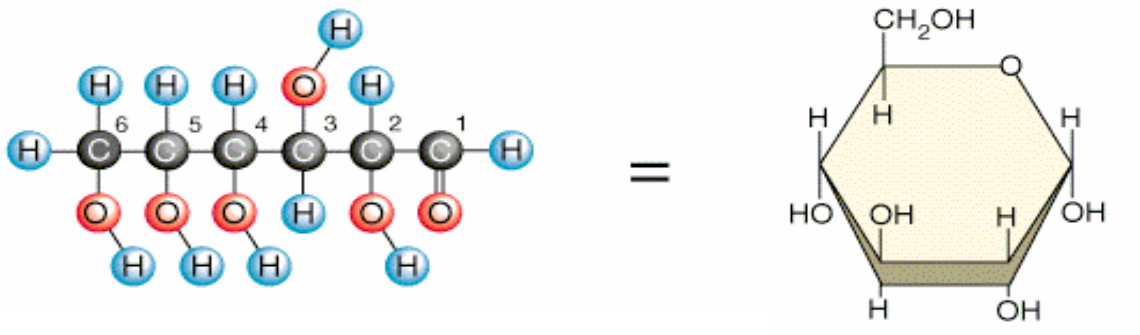
What Are Carbohydrates?

- Molecules composed of carbon, hydrogen, and oxygen (1:2:1)
- Composed of water-soluble sugar molecules:
  - Monosaccharide = Single sugar (*e.g.* glucose)
  - Disaccharide = Two sugars (*e.g.* sucrose)
  - Polysaccharide = Many sugars (*e.g.* starch / glycogen)
- Important as:
  1) Energy source for most organisms
  2) Structural support (plants / insects)

Carbohydrates - Monosaccharides:

- Backbone of 3 - 7 carbons = $(CH_2O)_n$
- Fold up into rings in solution:

(*e.g.* glucose)



Monosaccharide Types:

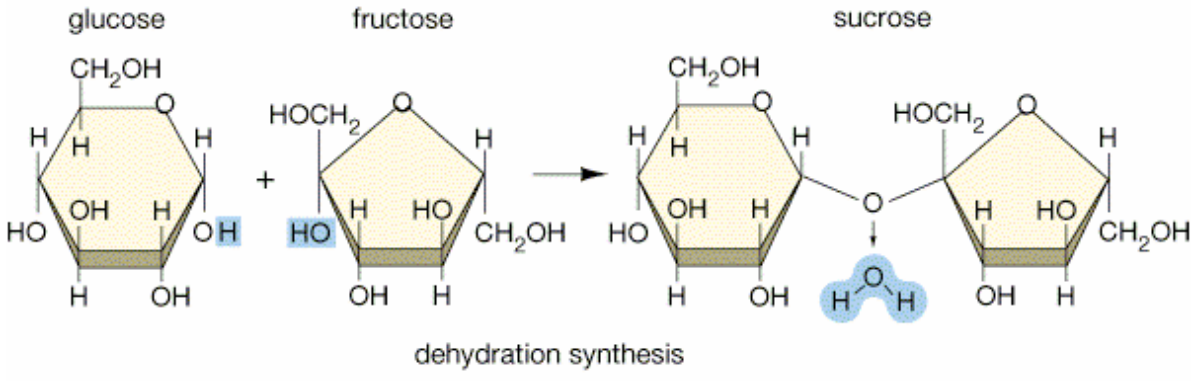
1) 6-C Backbone ($C_6H_{12}O_6$)
   - Glucose (most common)
   - Fructose (corn sugar)
   - Galactose (milk sugar)

2) 5-C Backbone ($C_5H_{10}O_5$)
   - Ribose / Deoxyribose

RNA DNA

Carbohydrates - Disaccharides:

- Two sugar molecules linked (dehydration synthesis):



(Figure 3.1)

- Short-term energy storage

Disaccharide Types:

1) Sucrose = Glucose + Fructose
2) Lactose = Glucose + Galactose
3) Maltose = Glucose + Glucose

Carbohydrates - Polysaccharides:

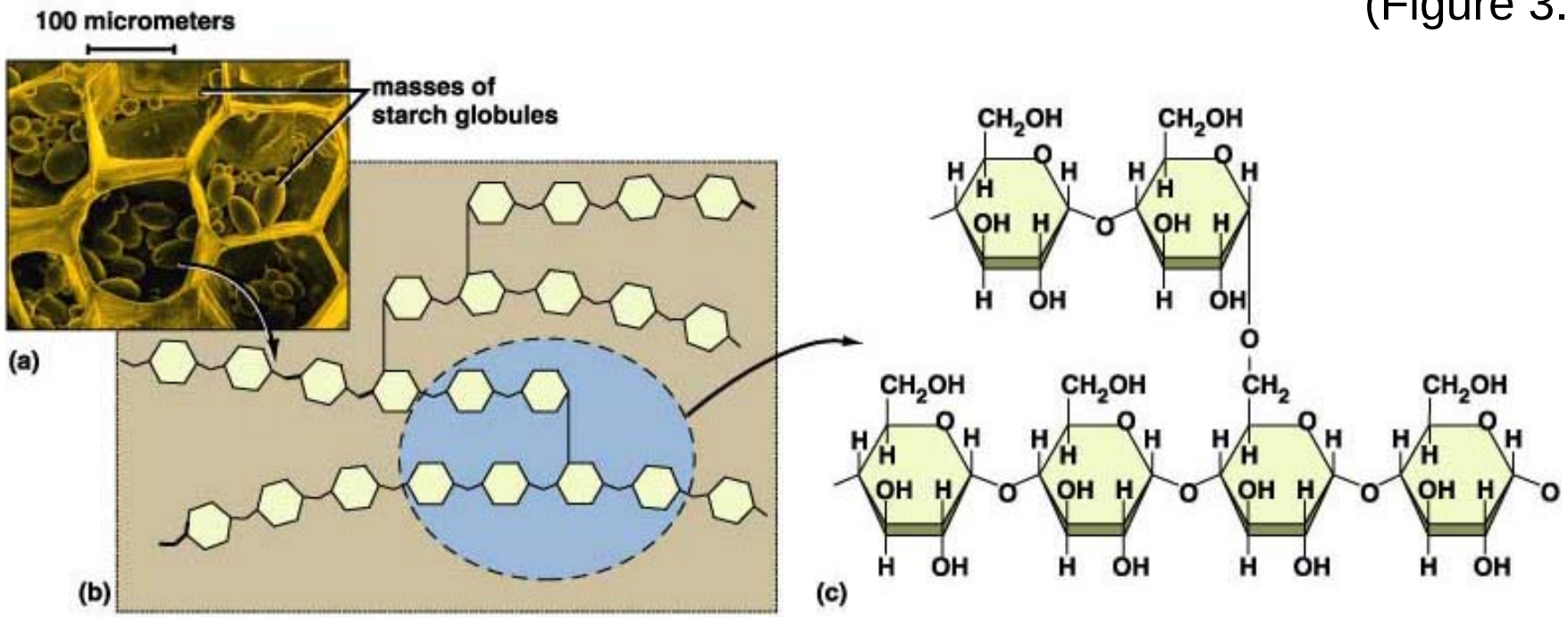
- Multiple sugar molecules linked together

1) Long term energy storage:

A) Starch (1000 - 500,000 glucose molecules)

- Found in roots and seeds (plants)

(Figure 3.2)



Carbohydrates - Polysaccharides:

- Multiple sugar molecules linked together

1) Long term energy storage:

A) Starch (1000 - 500,000 glucose molecules)

- Found in roots and seeds (plants)

B) Glycogen (1000 - 100,000 glucose molecules - many branches)

- Found in skeletal muscle and liver (animals)

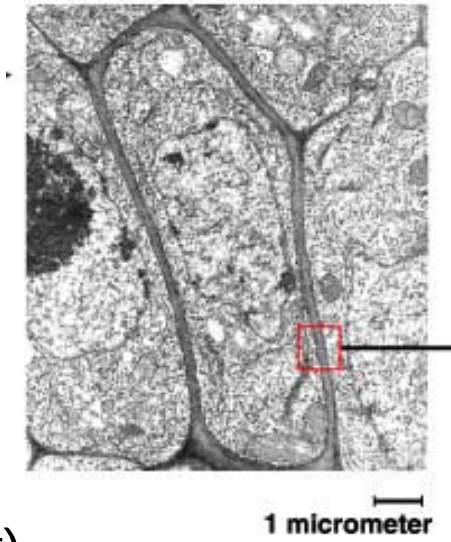
Carbohydrates - Polysaccharides:

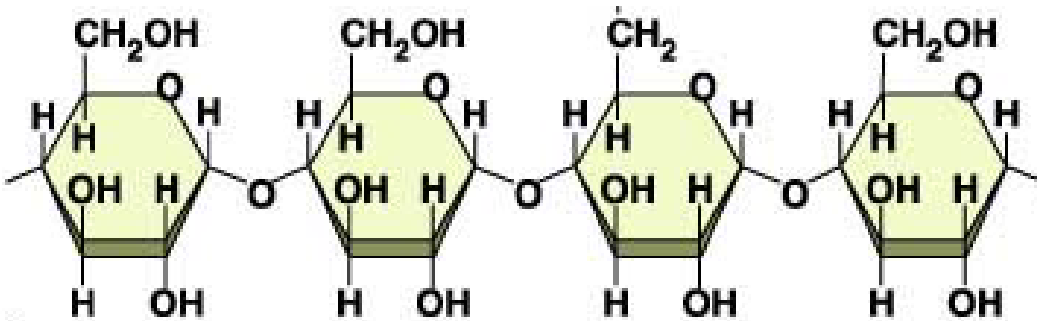
- Multiple sugar molecules linked together

2) Structural Material:

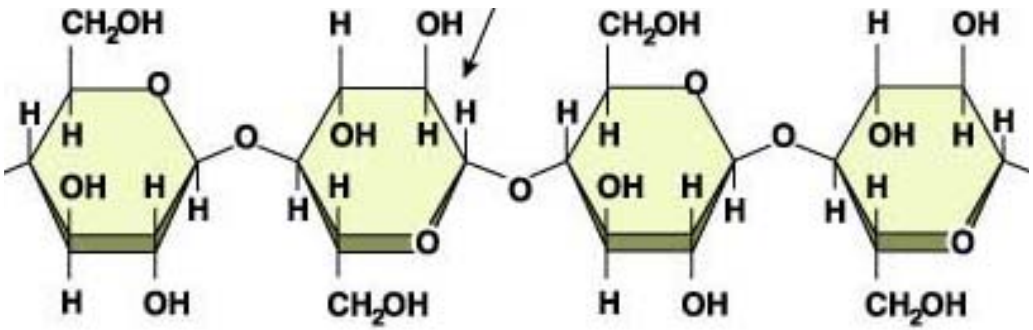
A) Cellulose (Plants - composes cell wall)

- Not digestible by most animals (fiber in diet)





Starch
(Digestible)



Cellulose
(Indigestible)

Carbohydrates - Polysaccharides:

- Multiple sugar molecules linked together

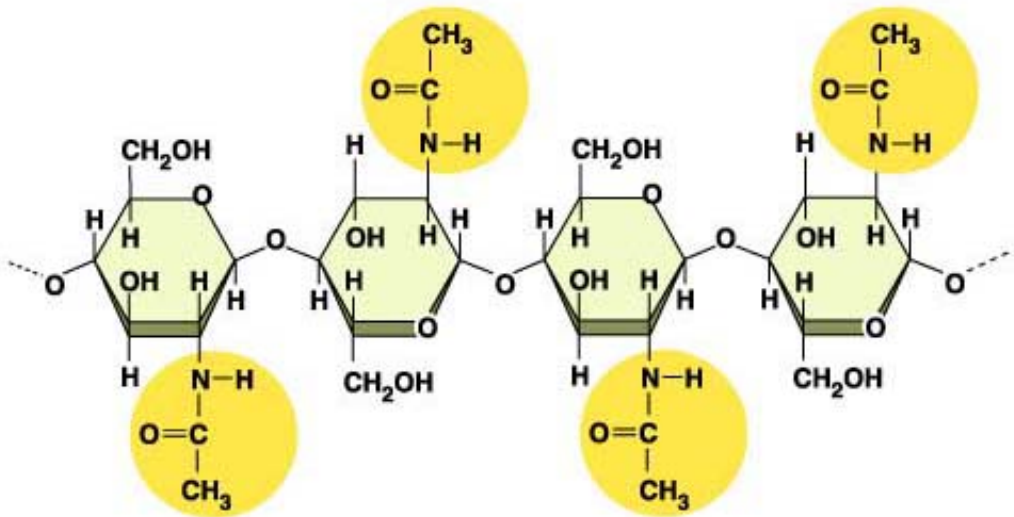
2) Structural Material:

A) Cellulose (Plants - composes cell wall)

- Not digestible by most animals (fiber in diet)

B) Chitin (Exoskeleton - insects / crabs / spiders)

- Nitrogen functional groups attached to glucose sub-units



(Figure3.4)

What Are Lipids?

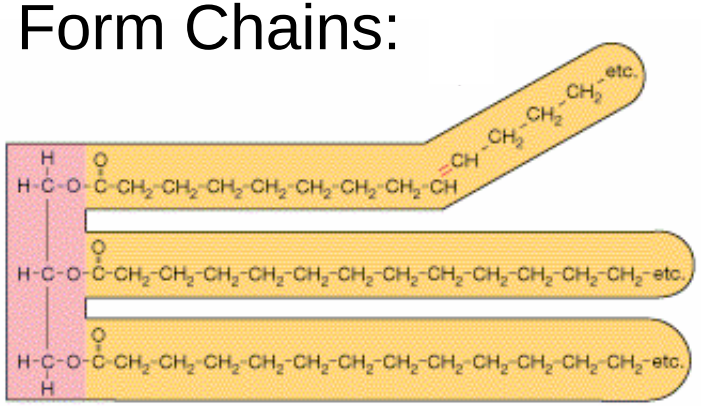
- Molecules composed almost entirely of carbon and hydrogen with non-polar carbon-carbon bonds (Hydrophobic)

Types of Lipids:

1) Oils & Fats:

- Composed of carbon, hydrogen, and oxygen

Form Chains:



3 fatty acid sub-units (CH_2 w/ COOH)

&

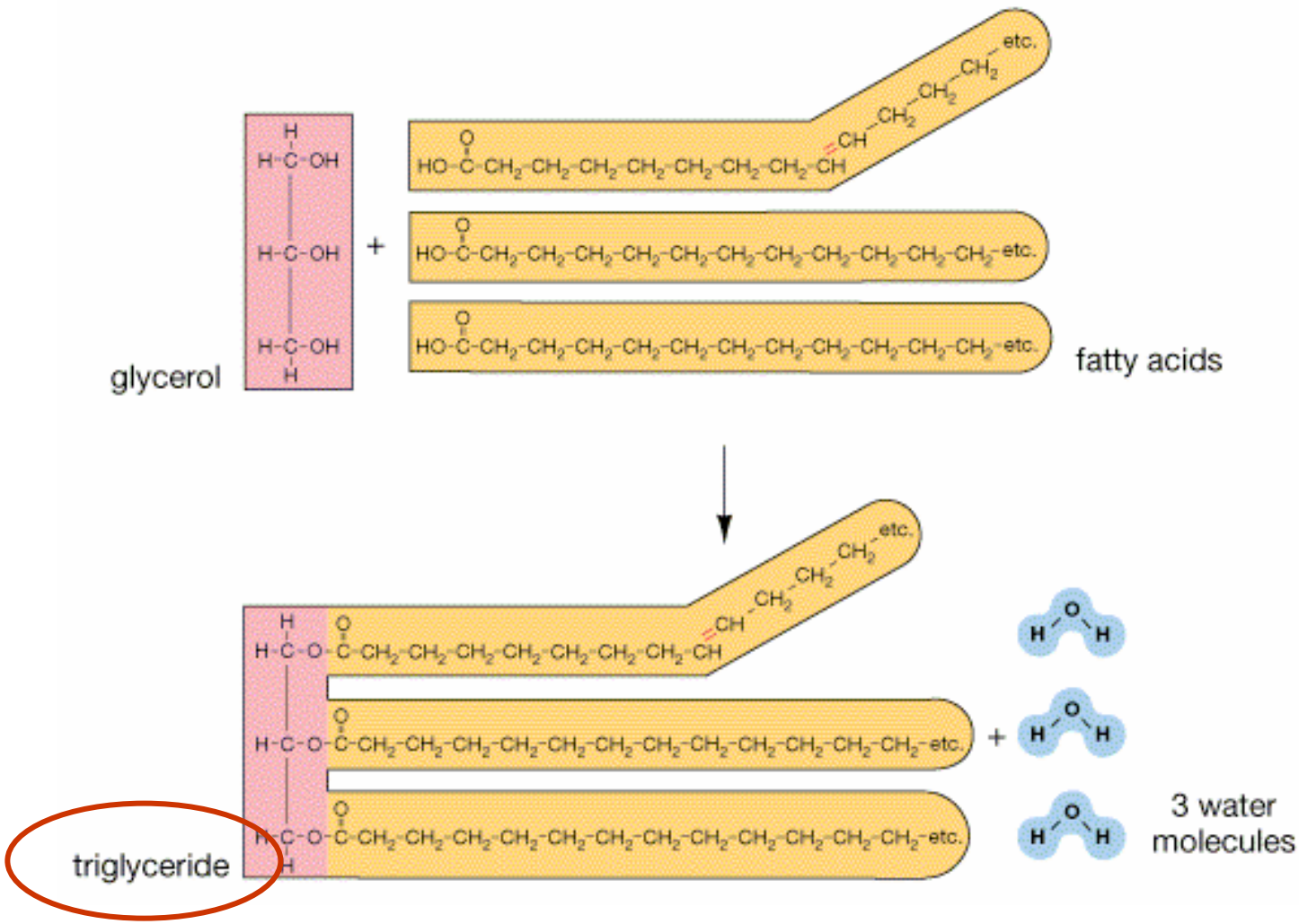
Glycerol

Function: Energy Storage

Fats / Oils = 9.3 Calories / gram

Fat & Oil Formation:

- Dehydration synthesis of 3 fatty acids and a glycerol

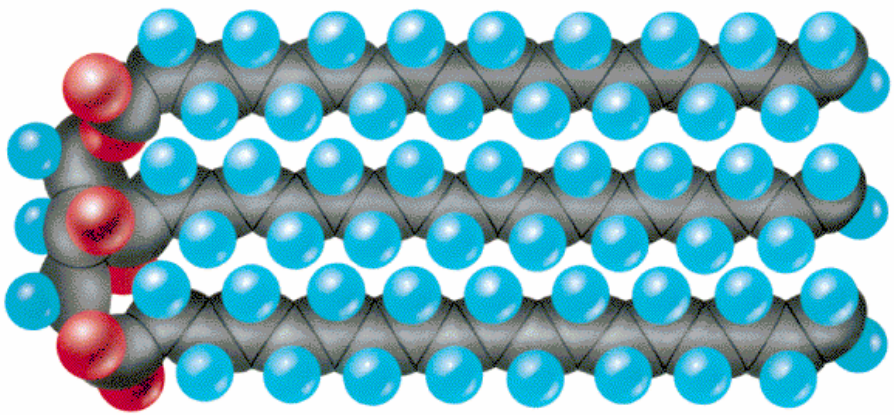


Why are fats solid at room temperature and oils liquid at room temperature?

Answer: Variation in Fatty Acid Structure

Saturated Fatty Acids:

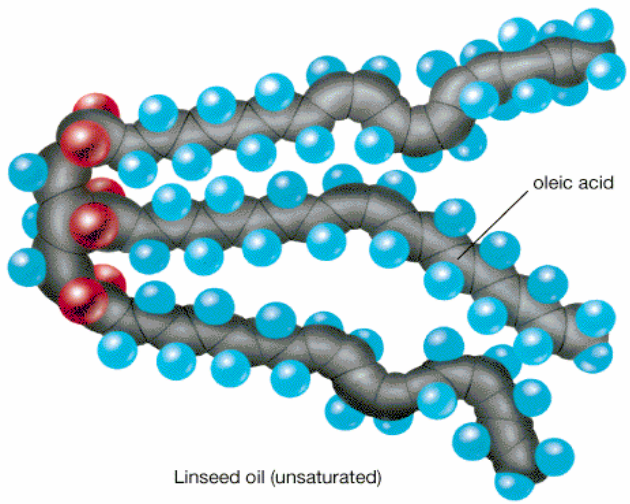
- Carbon chains have single bonds
  - Saturated with hydrogen
  - Form straight chains



Beef fat (saturated)

Unsaturated Fatty Acids:

- Double bonds present in C chains
  - Not saturated with hydrogen
  - Form kinked chains



Linseed oil (unsaturated)

What Are Lipids?

- Molecules composed almost entirely of carbon and hydrogen with non-polar carbon-carbon bonds (Hydrophobic)

Types of Lipids:

1) Oils & Fats
2) Waxes:
   - Similar in structure of saturated fats (solid at room temp.)

Functions:

1) Form waterproof outer covering

2) Structural material

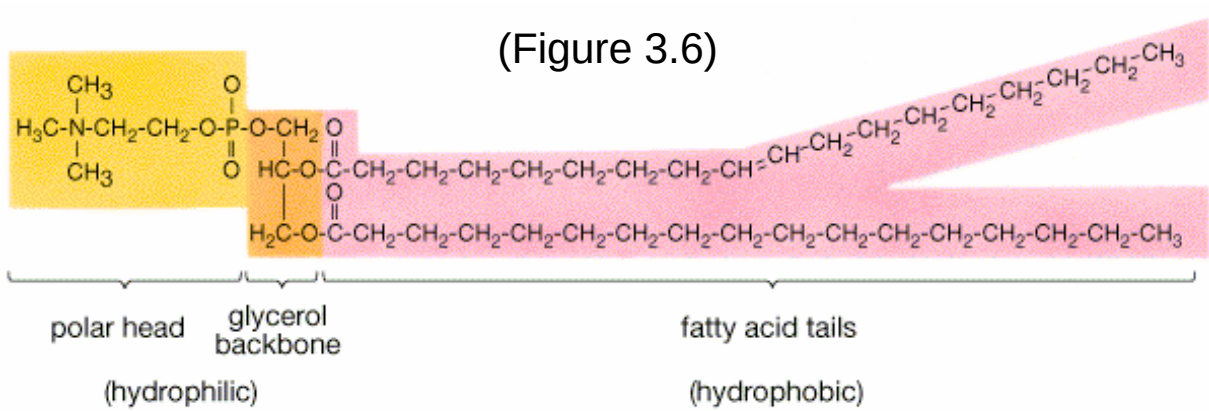
What Are Lipids?

- Molecules composed almost entirely of carbon and hydrogen with non-polar carbon-carbon bonds (Hydrophobic)

Types of Lipids:

1) Oils & Fats
2) Waxes:
3) Phospholipids:

(Figure 3.6)



- Similar in structure to fats / oils except 1 of 3 fatty acids replaced by phosphate group
  - Found in plasma membrane of cells

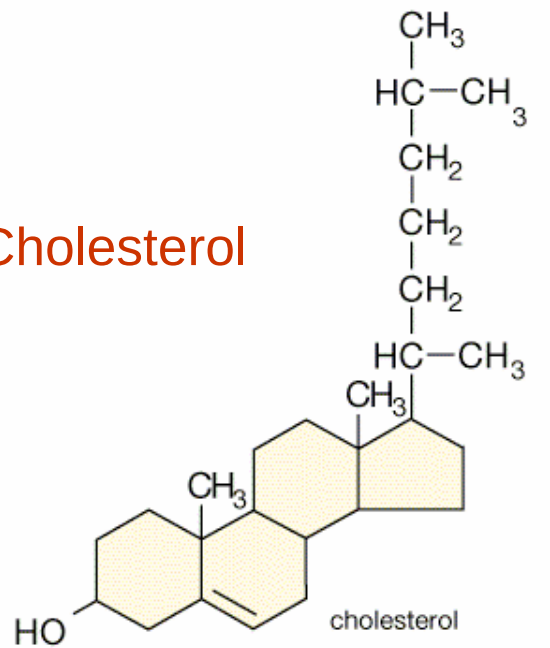
What Are Lipids?

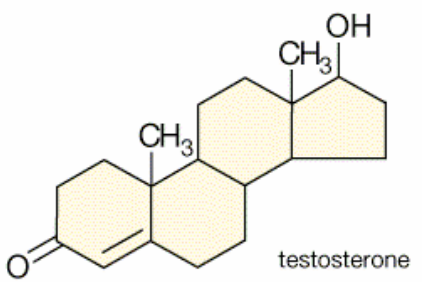
- Molecules composed almost entirely of carbon and hydrogen with non-polar carbon-carbon bonds (Hydrophobic)

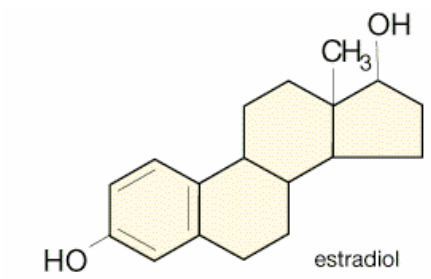
Types of Lipids:

1) Oils & Fats
2) Waxes:
3) Phospholipids:
4) Steroids:
   - 4 rings of carbon with functional groups attached

Cholesterol







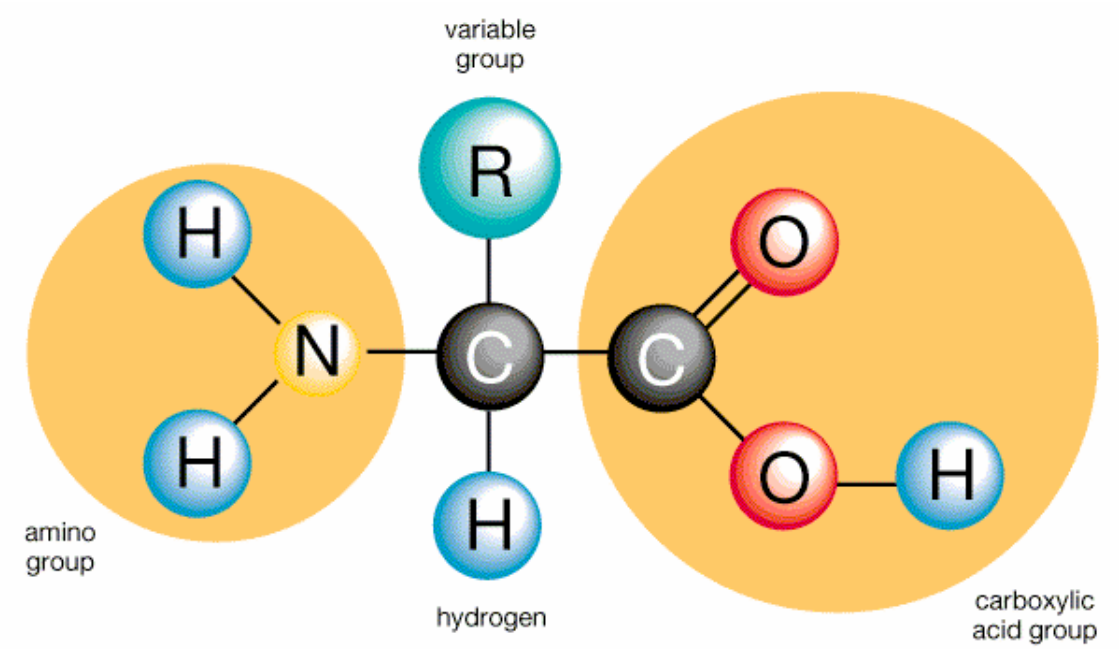
Hormones

What Are Proteins?

- Molecules composed of 1 or more chains of amino acids

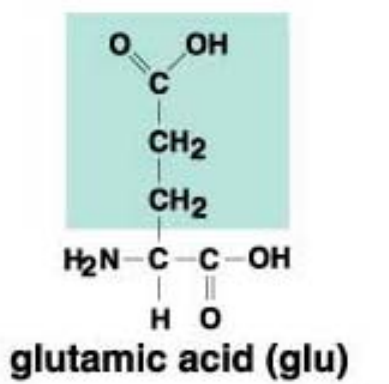
Amino Acids:

- A central carbon with four bonds:
  1) An amine group (-NH2)
  2) A carboxyl group (COOH)
  3) A hydrogen
  4) A variable group (R)

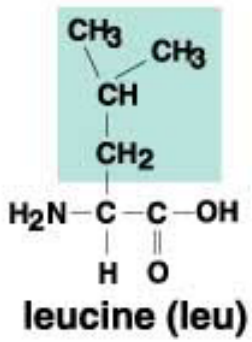


Amino Acids:

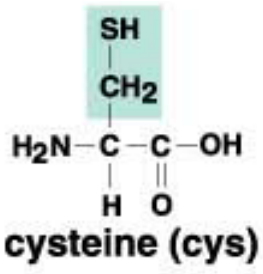
- 20 unique amino acids
- Amino acid characteristics depend on variable (R) groups



Hydrophilic

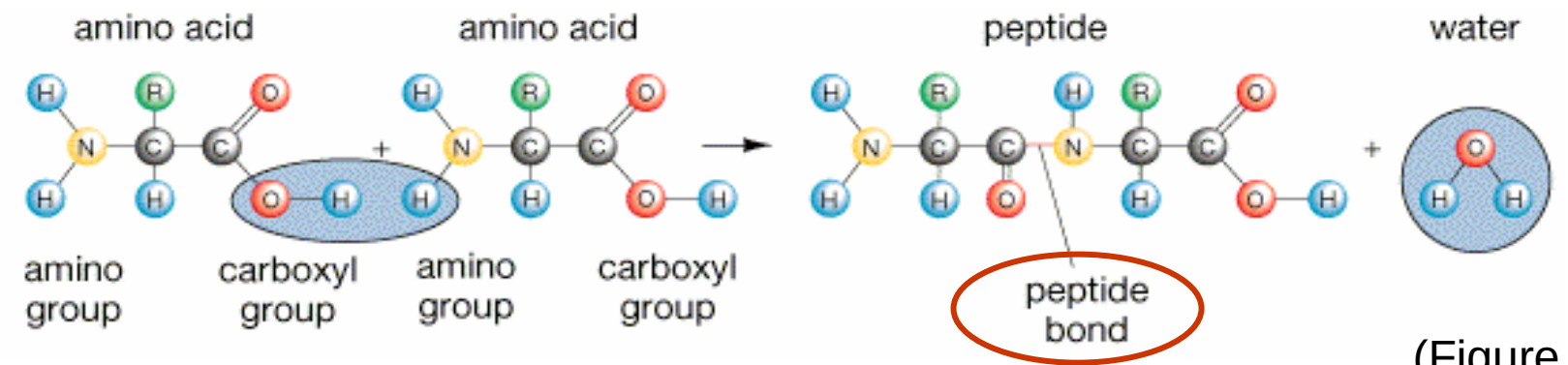


Hydrophobic



Disulfide Bonds

- Amino acids attached via dehydration synthesis:



(Figure 3.10)

Protein Structure Dictates Protein Function!

Levels of Protein Structure:

1) Primary

Sequence of amino acids

2) Secondary

Hydrogen bonds between AAs

Helix
Pleated Sheet

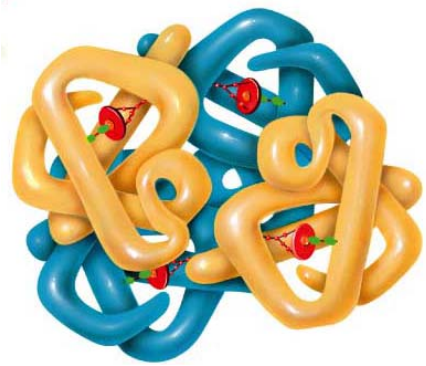
3) Tertiary

Disulfide bonds between AAs

Hydrophilic / phobic interactions between AAs

4) Quaternary

Hydrogen bonds between peptide chains (2 or more)

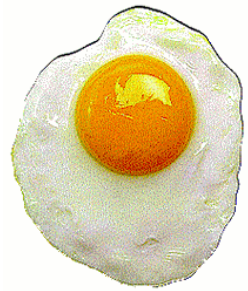


(Hemoglobin)

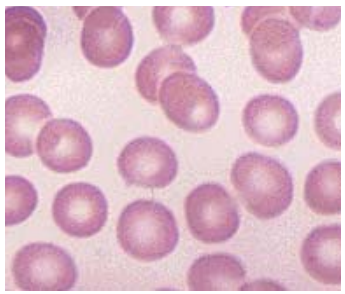
Functions of Proteins (Table 3.3):

1) Catalyze Chemical Reactions (e.g. amylase)

2) Structure (e.g. keratin)

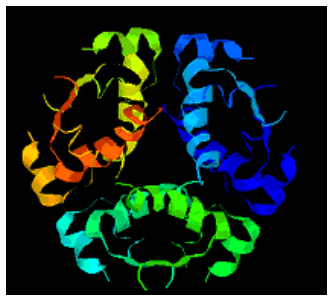


3) Energy Storage (e.g. albumin)

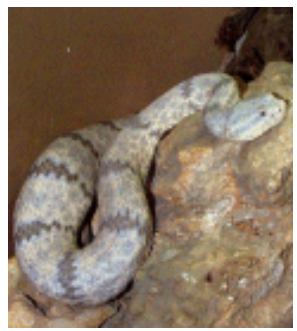


4) Transport (e.g. hemoglobin)

5) Movement (e.g. muscle fibers)

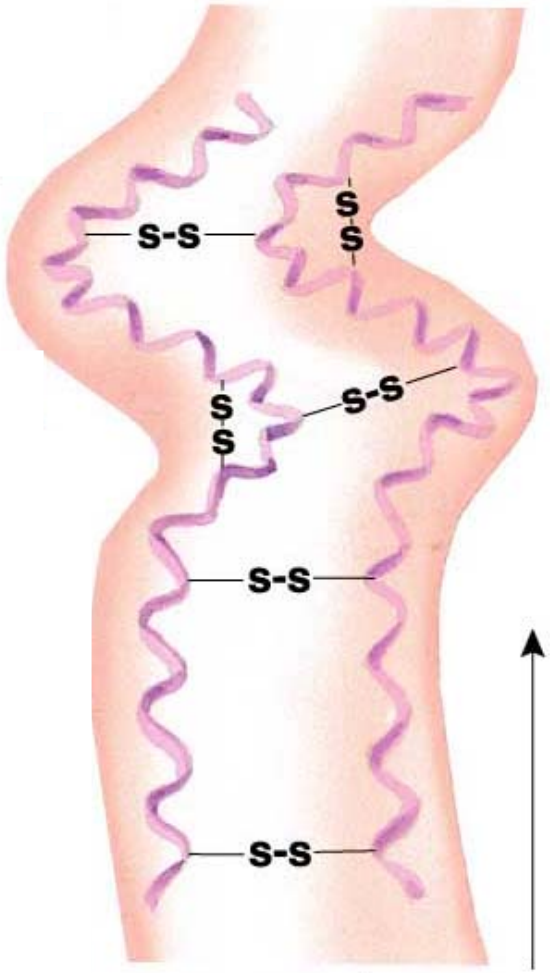


6) Hormones (e.g. insulin)

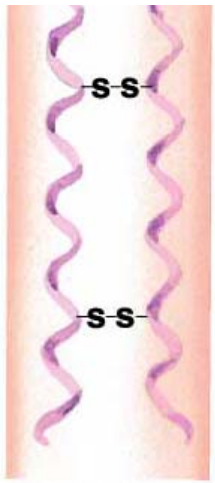


7) Poisons (e.g. venom)

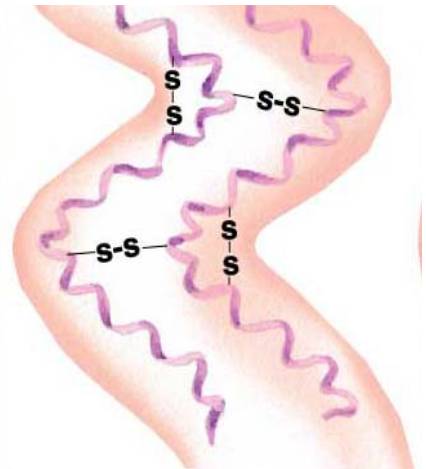
The Story Behind Hair...



permanent wave
growing out straight



straight hair

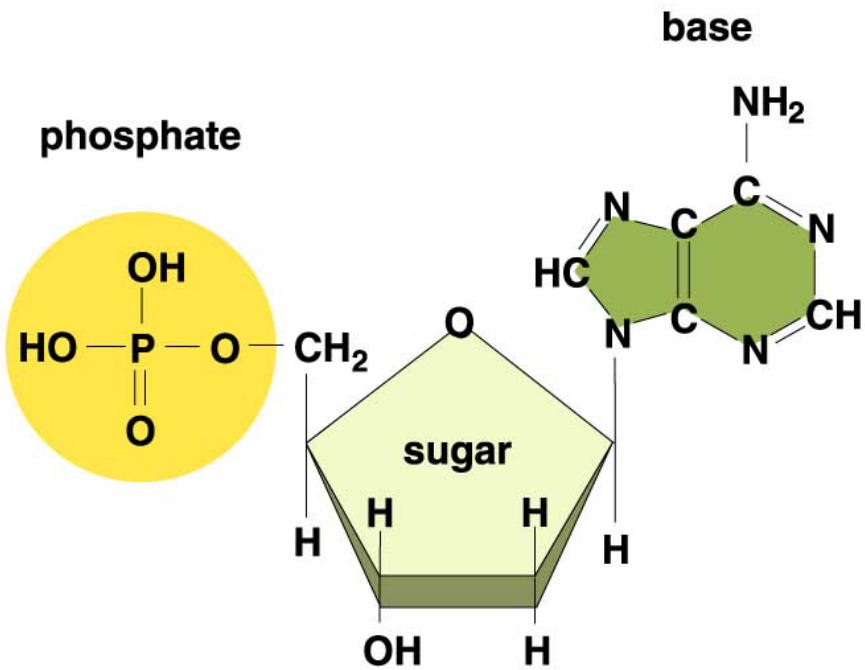


naturally
curly hair

What Are Nucleic Acids?

- Molecules composed of nucleotides:

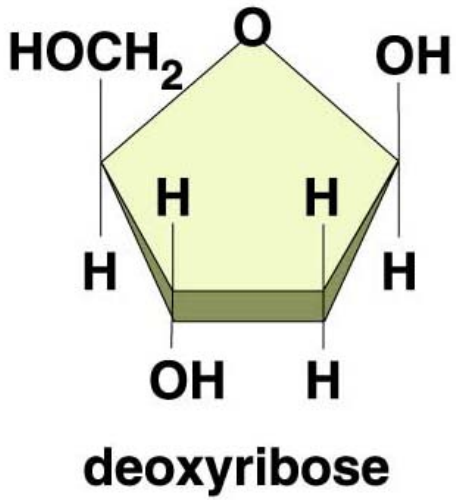
1) 5-carbon sugar
2) Phosphate group
3) Nitrogen-containing base (Variable)



Nucleic Acid Types (based on sugar in nucleotide):

1) Deoxyribonucleic Acid (DNA)

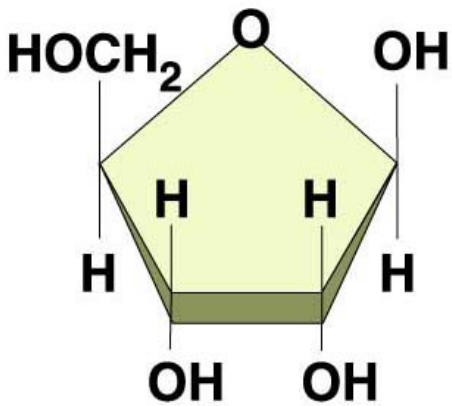
- Sequence of nucleotides housing the genetic code for an organism



deoxyribose

2) Ribonucleic Acid (RNA)

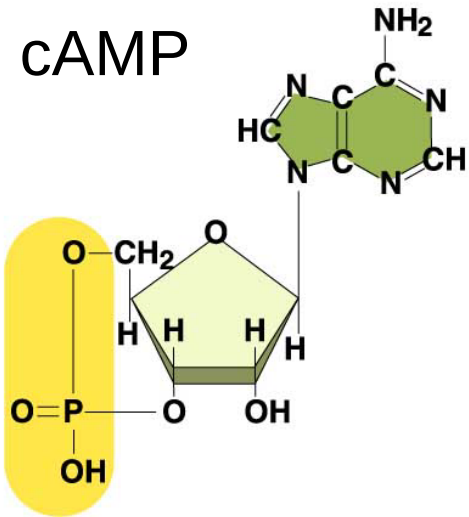
- A copy of the genetic code which directs the synthesis of proteins



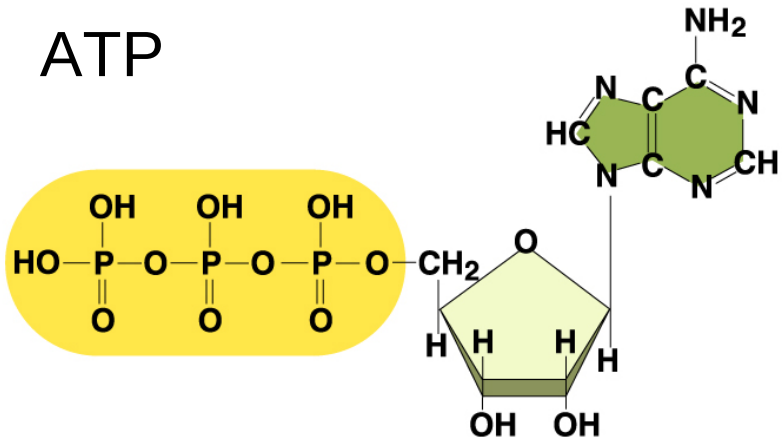
ribose

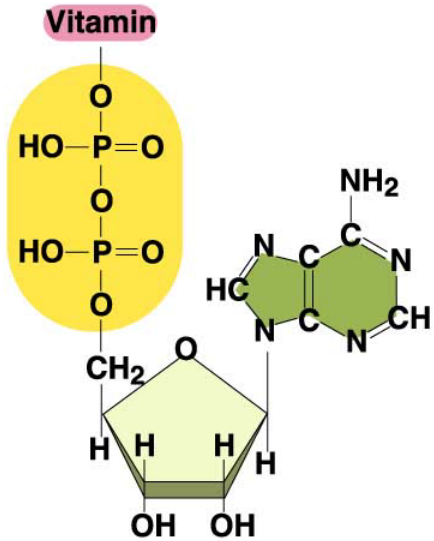
Other Functions of Nucleotides:

cAMP



ATP





Cyclic Nucleotides

- Intracellular messengers

Nucleotides with Extra Phosphate Groups

- Energy transfer molecules

Coenzymes

- Assist enzyme action