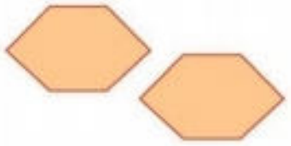
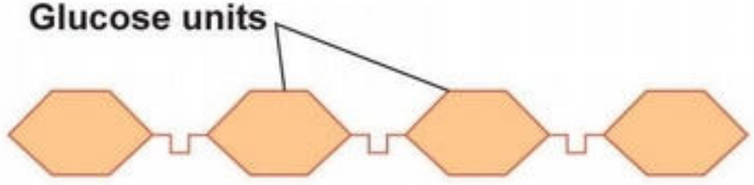
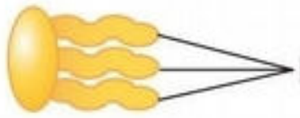
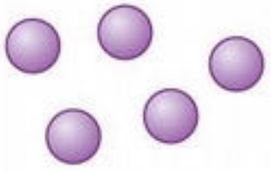
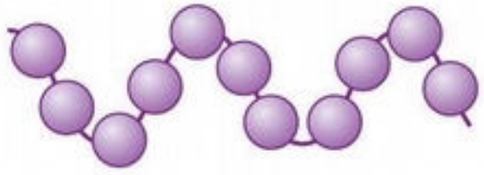
Unit 1

BIOMOLECULES

Dr Sairindhri Tripathy

Structural Differences Between Carbohydrates, Lipids, and Proteins

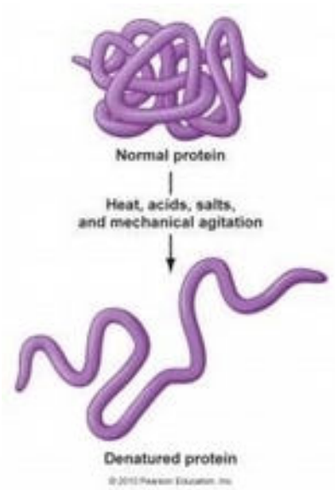
Macronutrients	Chains of	Example
Carbohydrates	Glucose 	Glucose units 
Lipids	Fatty acids 	Triglyceride 
Proteins	Amino acids 	Amino acids 

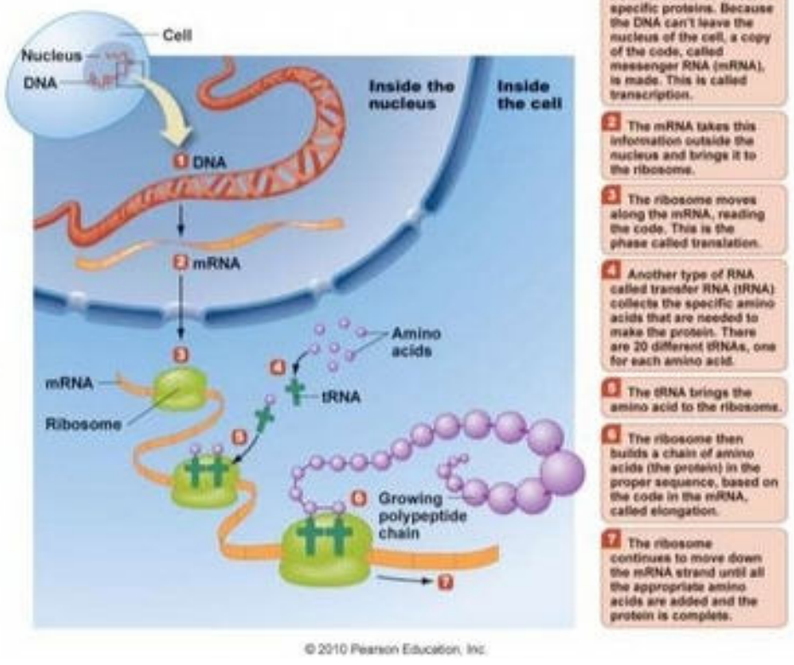
PROTEINS

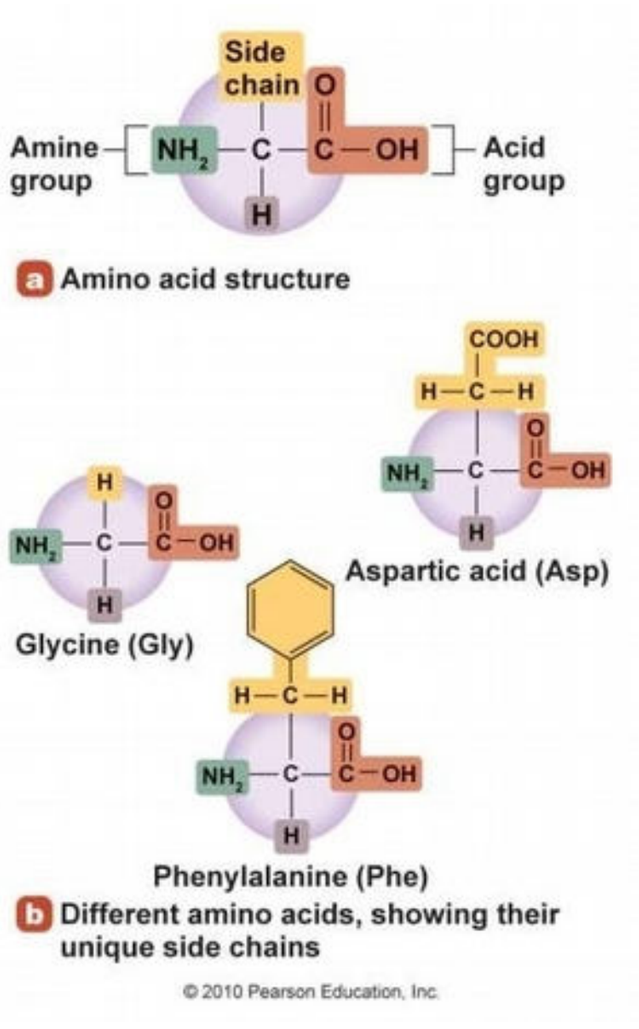
Introduction

- Proteins are the most abundant biological macromolecules, occurring in all cells and all parts of cells. Proteins also occur in great variety; thousands of different kinds, ranging in size from relatively small peptides to huge polymers with molecular weights in the millions, may be found in a single cell.

Proteins and Amino Acids







What Are Proteins?

- Large molecules
- Made up of chains of amino acids
- Are found in every cell in the body
- Are involved in most of the body's functions and life processes
- The sequence of amino acids is determined by DNA

Structure of Proteins

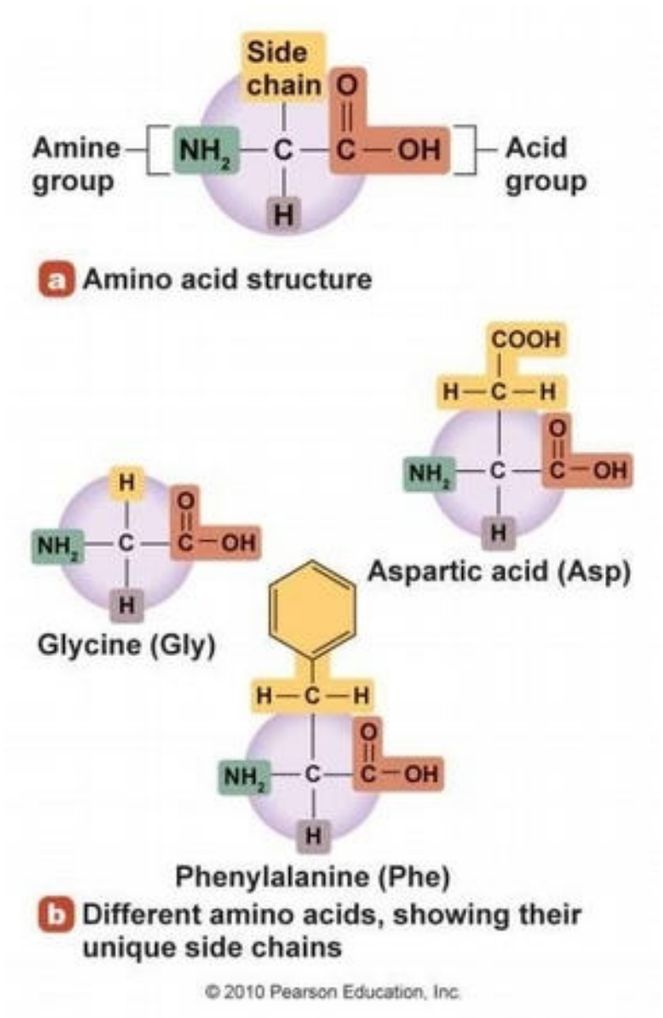
Made up of chains of amino acids; classified by number of amino acids in a chain

- Peptides: fewer than 50 amino acids
  - Dipeptides: 2 amino acids
  - Tripeptides: 3 amino acids
  - Polypeptides: more than 10 amino acids
- Proteins: more than 50 amino acids
  - Typically 100 to 10,000 amino acids linked together

Chains are synthesizes based on specific bodily DNA

Amino acids are composed of carbon, hydrogen, oxygen, and nitrogen

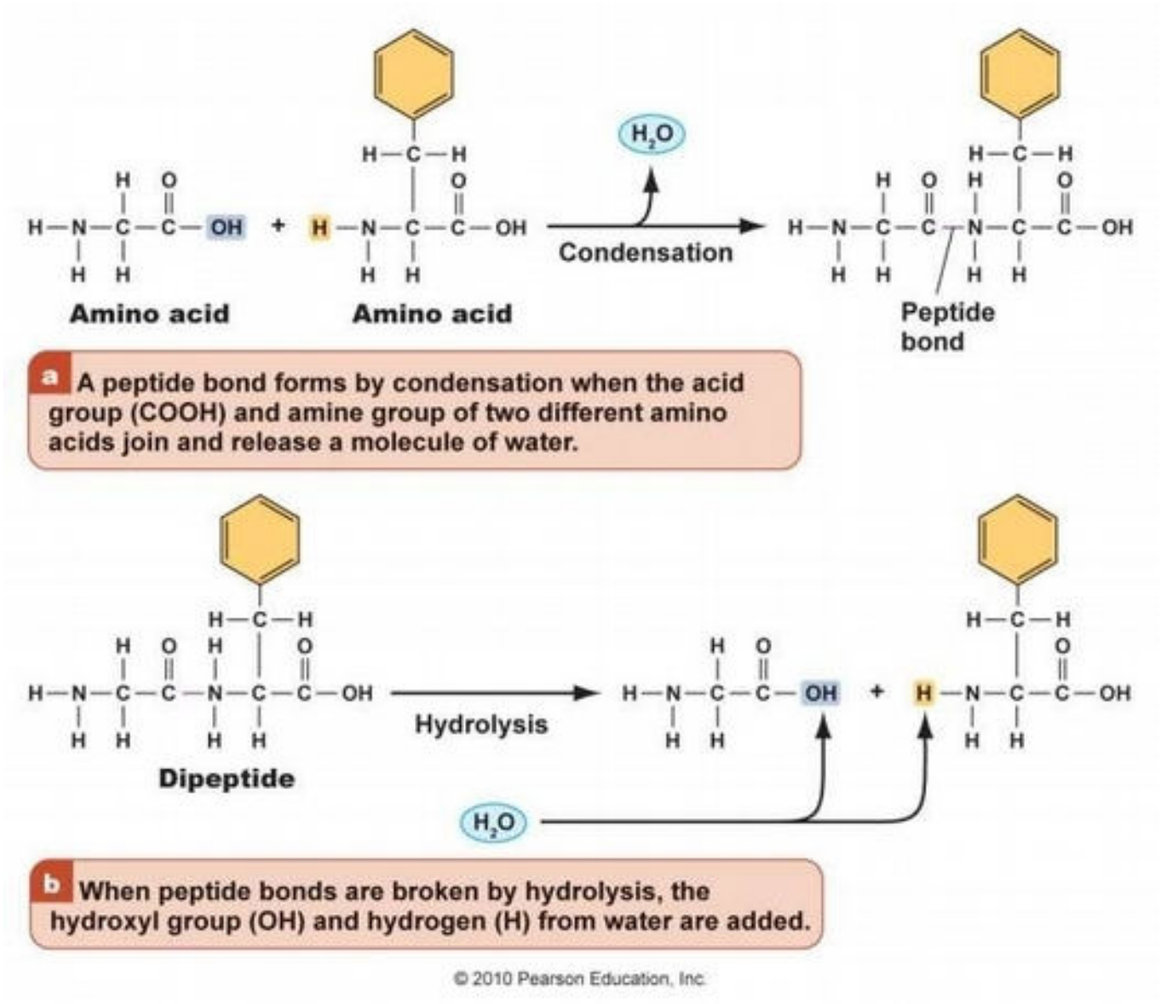
The Anatomy of an Amino Acid



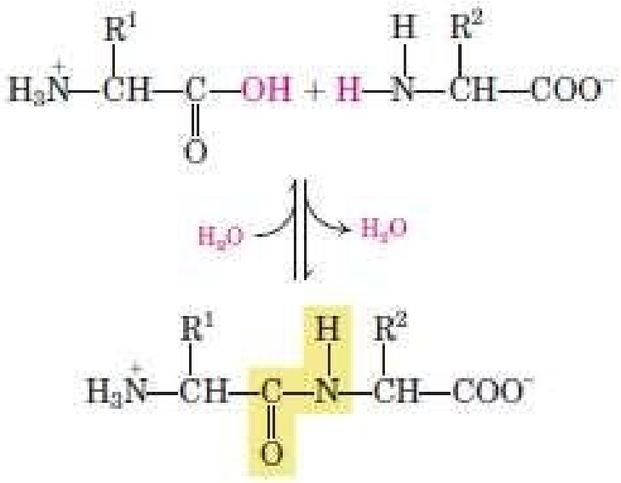
Peptide Bonds Link Amino Acids

- Form when the acid group (COOH) of one amino acid joins with the amine group (NH_2) of a second amino acid
- Formed through condensation
- Broken through hydrolysis

Condensation and Hydrolytic Reactions to form a dipeptide



- Two amino acid molecules can be covalently joined through a substituted amide linkage, termed a **peptide bond, to yield a dipeptide.** **Such a linkage is formed by** removal of the elements of water (dehydration) from the α-carboxyl group of one amino acid and the α–amino group of another



- Three amino acids can be joined by two peptide bonds to form a tripeptide; similarly, amino acids can be linked to form tetrapeptides, pentapeptides, and so forth.
- When a few amino acids are joined in this fashion, the structure is called an **oligopeptide.**
- **When many** amino acids are joined, the product is called a **polypeptide.**
- Proteins may have thousands of amino acid residues. Although the terms “protein” and “polypeptide” are sometimes used interchangeably, molecules referred to as polypeptides generally have molecular weights below 10,000, and those called proteins have higher molecular weights.

Essential, Nonessential, and Conditional

- Essential – must be consumed in the diet
- Nonessential – can be synthesized in the body
- Conditionally essential – cannot be synthesized due to illness or lack of necessary precursors
  - Premature infants lack sufficient enzymes needed to create arginine

Table 6.1

The Mighty Twenty

Essential Amino Acids	Nonessential Amino Acids
Histidine (His)[a]	Alanine (Ala)
Isoleucine (Ile)	Arginine (Arg)[b]
Leucine (Leu)	Asparagine (Asn)
Lysine (Lys)	Aspartic acid (Asp)
Methionine (Met)	Cysteine (Cys)[b]
Phenylalanine (Phe)	Glutamic acid (Glu)
Threonine (Thr)	Glutamine (Gln)[b]
Tryptophan (Trp)	Glycine (Gly)[b]
Valine (Val)	Proline (Pro)[b]
	Serine (Ser)
	Tyrosine (Tyr)[b]

[a] Histidine was once thought to be essential only for infants. It is now known that small amounts are also needed for adults.

[b] These amino acids can be "conditionally essential" if there are either inadequate precursors or inadequate enzymes available to create these in the body.

Carbohydrates

- Carbohydrates are the major components of most plants.
- Plants make carbohydrates on their own through photosynthesis.
- Separated into two categories
  - Simple
  - Complex

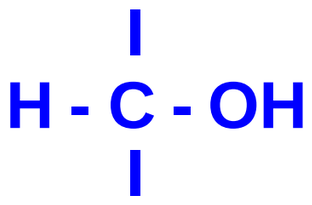
Functions of Carbohydrates

- Main source of energy
- Spare protein from being burned so it can be used to build and repair
- Dietary fiber can help lower blood cholesterol
- Part of connective tissues, some hormones and enzymes and genetic material.

Characteristics of Carbohydrates

- Consist of carbon, hydrogen, & oxygen
- Energy containing molecules
- Some provide structure
- Basic building block is a monosaccharide $(CH_2O)_n$; n = 3,5,6
- Two monosaccharides form a disaccharide

Carbohydrates (glycans) have the following basic composition:

$(CH_2O)_n$ or 

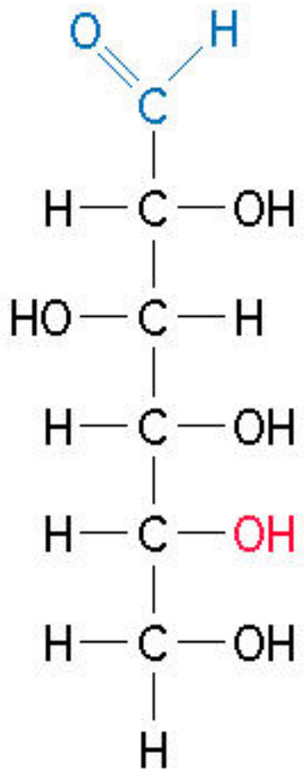
Monosaccharides - simple sugars with multiple OH groups. Based on number of carbons (3, 4, 5, 6), a monosaccharide is a triose, tetrose, pentose or hexose.

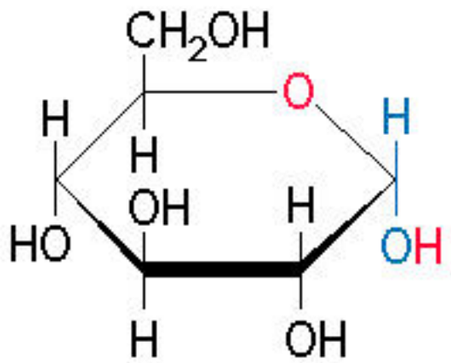
Disaccharides - 2 monosaccharides covalently linked.

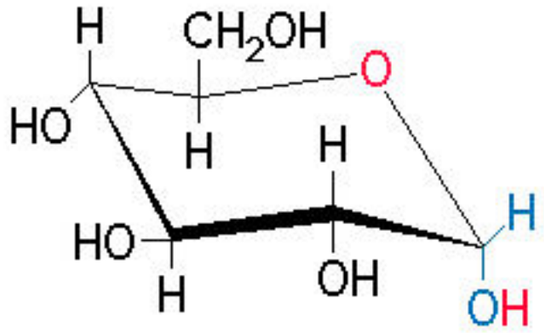
Oligosaccharides - a few monosaccharides covalently linked.

Polysaccharides - polymers consisting of chains of monosaccharide or disaccharide units.

Different Forms of Glucose

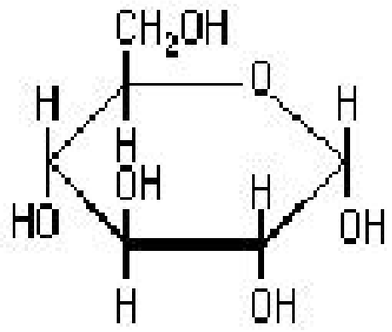




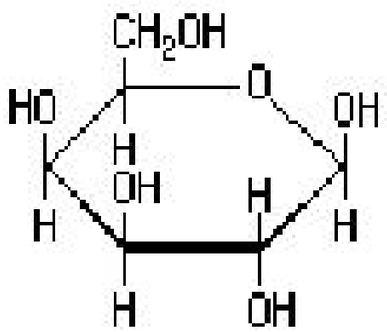


Three Monosaccharides

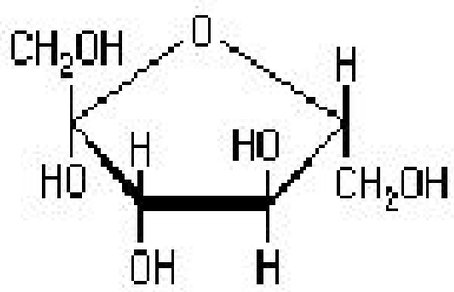
$C_6H_{12}O_6$



Glucose

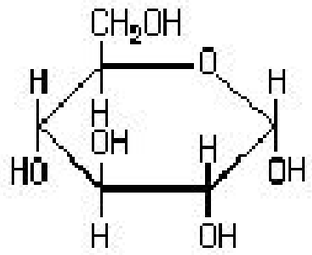


Galactose



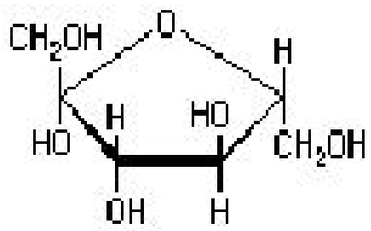
Fructose

Dehydration Synthesis of a Disaccharide



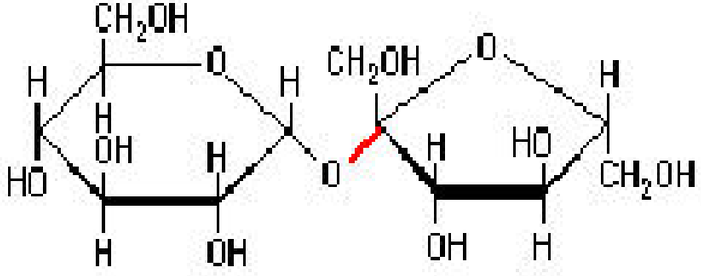
Glucose

+



Fructose

→

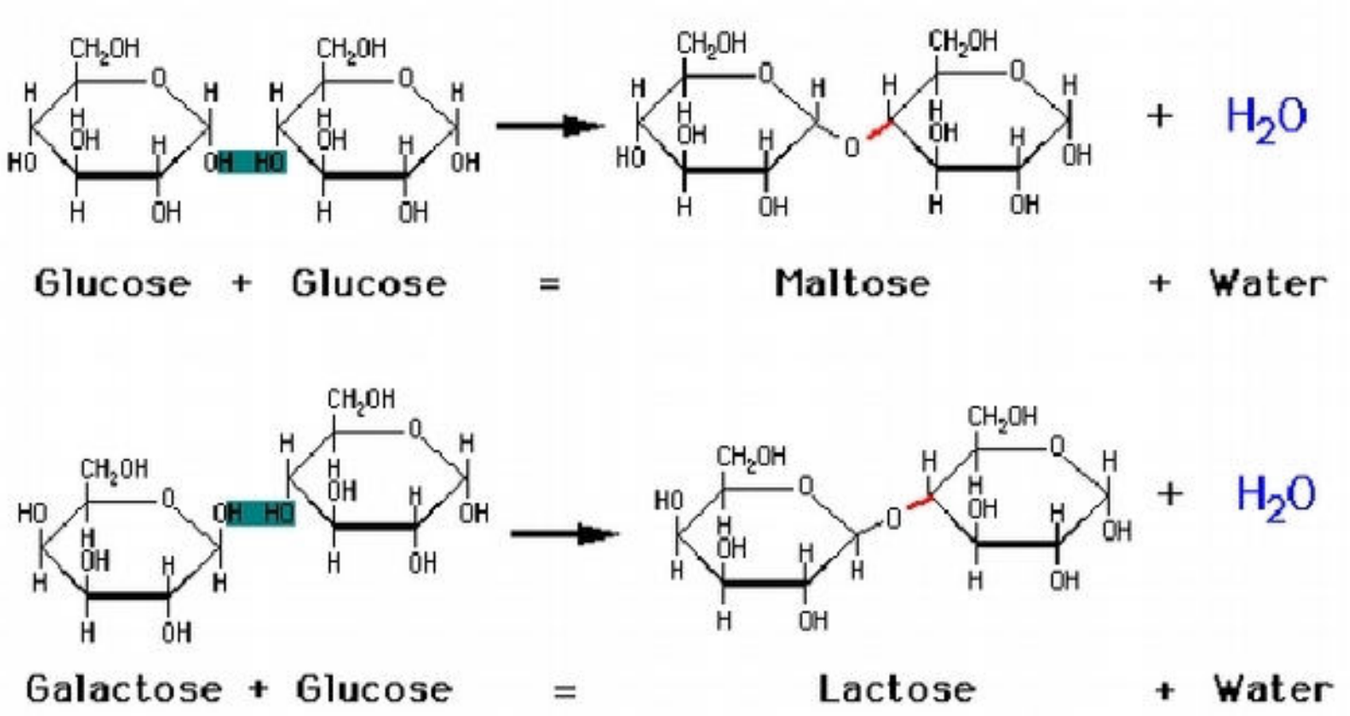


Sucrose

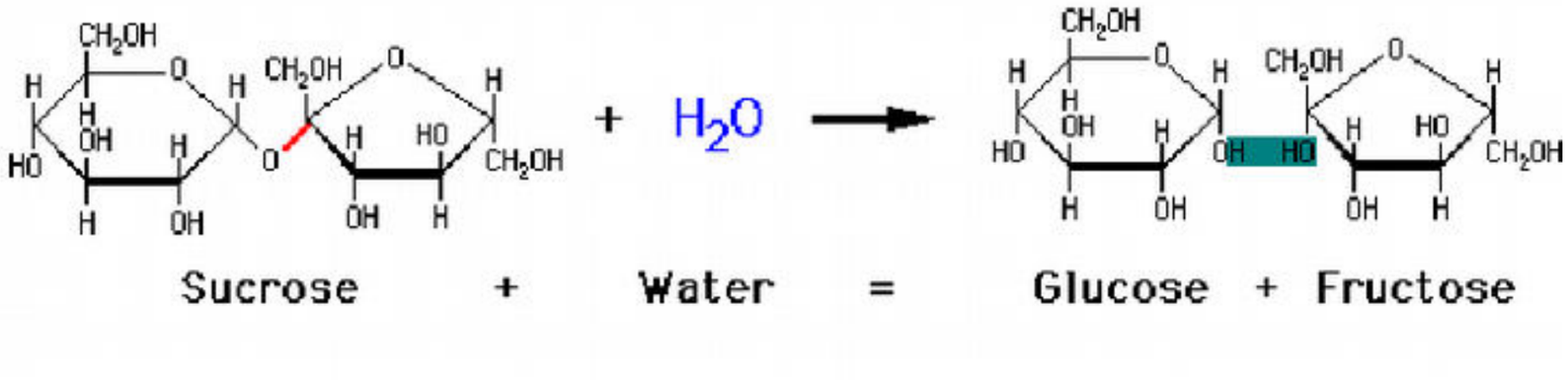
+ H_2O

Water

Formation of Disaccharides



Hydrolysis of a Disaccharide



LIPIDS AND FATS

"Biological molecules that are insoluble in aqueous solutions and soluble in organic solvents, have some relation to fatty acids as esters, and have potentiality of utilization by living organisms are classified as lipids."

They perform four major physiological functions:

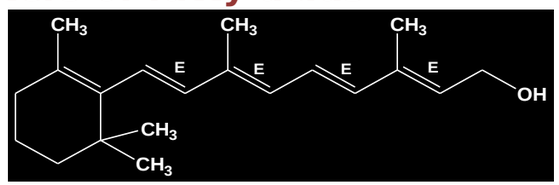
1. **Serve as structural components of biological membranes**
2. **Provide energy reserves, predominantly in the form of triacylglycerols**
3. **Both lipids and lipid derivatives serve as vitamins and hormones**
4. **Lipophilic bile acids aid in lipid solubilization**

Classification

Bloor's Classification

A. Simple lipid - ester of fatty acids with various alcohols

1. Natural fats and oils (triglycerides)
2. Waxes
   (a) True waxes: cetyl alcohol esters of fatty acids
   (b) Cholesterol esters
   (c) Vitamin A esters
   (d) Vitamin D esters



B. Compound lipid - esters of fatty acids with alcohol plus other groups

1. Phospholipids and spingomyelin: contains phosphoric acid and often a nitrogenous base
2. Spingolipids (also include glycolipids and cerebrosides): contains aminoalcohol spingosine, carbohydrate, N-base; glycolipids contains no phosphate
3. Sulfolipids : contains sulfate group
4. Lipoproteins : lipids attached to plasma/other proteins
5. Lipopolysaccharides: lipids attached to polysaccharides

Classification cont.

C. Derived lipids – hydrolytic products of A & B with lipid characters
   1. Saturated & unsaturated fatty acids
   2. Monoglycerides and diglycerides
   3. Alcohols (carotenoid ring, e.g., vitamin A, certain carotenoids)

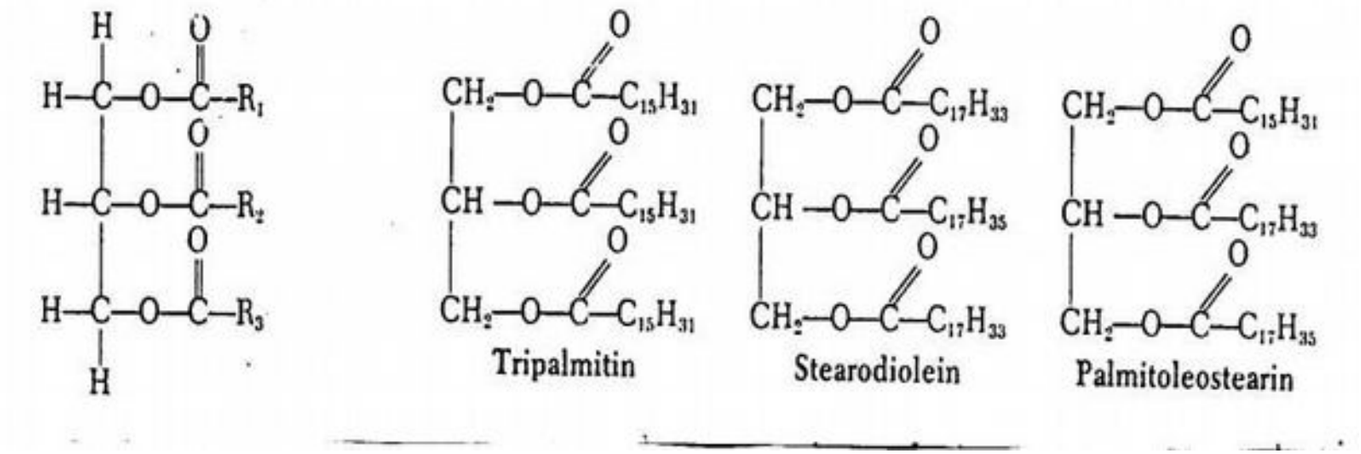
D. Miscellaneous lipids

1. Aliphatic hydrocarbons: found in liver fat and certain hydrocarbon found in beeswax and plant waxes
2. Carotenoids
3. Squalene : found in shark and mammalian liver and in human sebam; an important intermediate in biosynthesis of cholesterol
4. Vitamin E and K

Nomenclature and Structure

Fats and oils:

- Vegetable oils are triglycerides that are liquid at room temp due to their higher unsaturated or shorter-chain fatty acids
- Triglycerides are most abundant natural lipids



- Natural fats have D-configuration
- Usually R_1 and R_3 are saturated and R_2 is unsaturated
- Natural fats are mixture of two or more simple triglycerides

Fatty acids

“ A fatty acid may be defined as an acid that occurs in a natural triglyceride and is a mono carboxylic acid ranging in chain length From four carbon to 24 carbon atoms and including , with exceptions, only the even-numbered members of the series ”

Some Natural Fatty Acids

Some naturally occurring fatty acids

Common name	No. of C atoms	Structure	Melting point (°C)
Saturated fatty acids			
Myristic	14	$H_3C(CH_2)_{12}COOH$	54
Palmitic	16	$H_3C(CH_2)_{14}COOH$	63
Stearic	18	$H_3C(CH_2)_{16}COOH$	70
Unsaturated fatty acids			
Palmitoleic	16	$H_3C(CH_2)_5CH{=}^{cis}CH(CH_2)_7COOH$	−0.5
Oleic	18	$H_3C(CH_2)_7CH{=}^{cis}CH(CH_2)_7COOH$	13
Linoleic	18	$H_3C(CH_2)_4CH{=}^{cis}CHCH_2CH{=}^{cis}CH(CH_2)_7COOH$	−5
Linolenic	18	$H_3CCH_2(CH{=}^{cis}CHCH_2)_2CH{=}^{cis}CH(CH_2)_7COOH$	−10
Arachidonic	20	$H_3C(CH_2)_4(CH{=}^{cis}CHCH_2)_3CH{=}^{cis}CH(CH_2)_3COOH$	−50

Hydroxy acids : ricinoleic acid and dihydroxy stearic acid (castor oil) cerebronic acid ($C_{23}H_{46}[OH]COOH$, 2 – hydroxy tetracosanoic acid) (cerebroside of animal tissues)

Cyclic acids: Hydnocarpic and chaunmoogric acids (chaulmoogra oil, used in treatment of leprosy)

Linoleic acid, linolenic acid and arachidonic acid are essential fatty acids

Fatty acids (FA)

A. Carboxylic acids

Name	Number of carbons Number of double bonds Position of double bonds	
Formic acid	1 : 0	Not contained in lipids
Acetic acid	2 : 0	
Propionic acid	3 : 0	
Butyric acid	4 : 0	
Valerianic acid	5 : 0	
Caproic acid	6 : 0	$HOOC-CH_2-CH_2-CH_2-CH_2-CH_3$ Caproic acid
Caprylic acid	8 : 0	
Capric acid	10 : 0	
Lauric acid	12 : 0	
Myristic acid	14 : 0	
Palmitic acid	16 : 0	
Stearic acid	18 : 0	
Oleic acid	18 : 1; 9	
Linoleic acid	18 : 2; 9,12	
Linolenic acid	18 : 3; 9,12,15	
Arachidic acid	20 : 0	
Arachidonic acid	20 : 4; 5,8,11,14	
Behenic acid	22 : 0	
Erucic acid	22 : 1; 13	
Lignoceric acid	24 : 0	
Nervonic acid	24 : 1; 15	

Essential in human nutrition

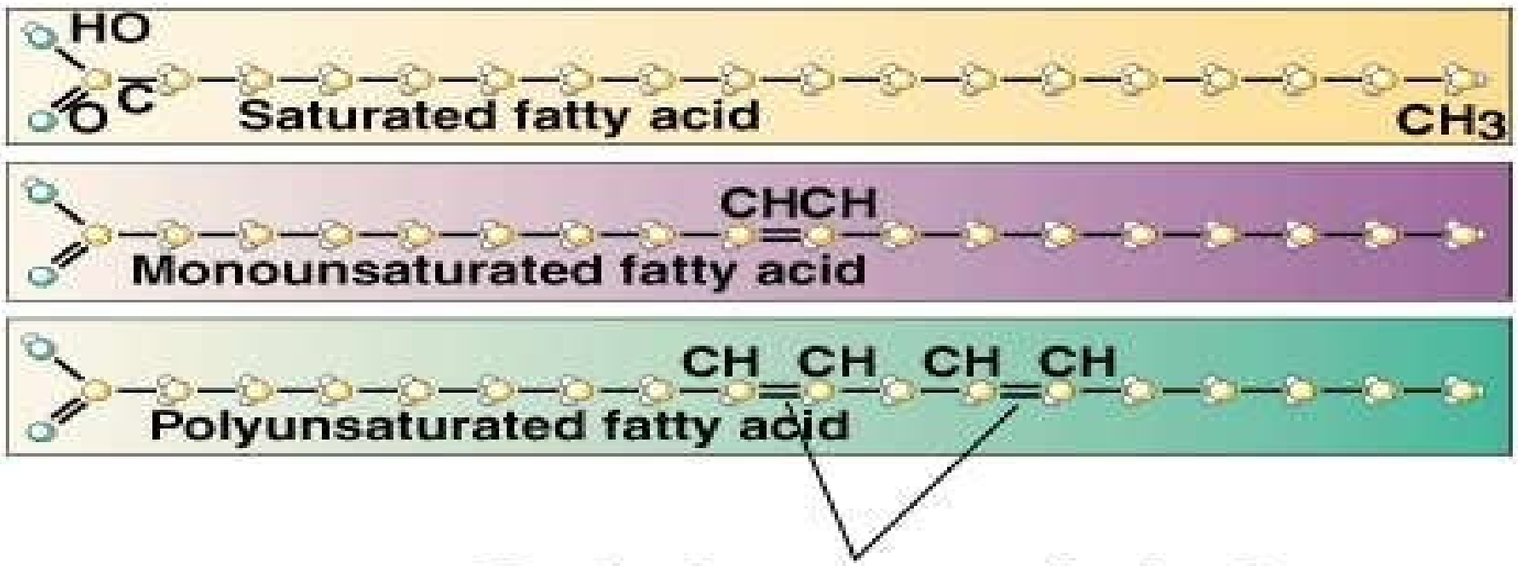
A Closer View of Fats

A. Chain Length (number of carbons linked together)

- **Shorter = more soluble in water**

B. Saturated vs. Unsaturated (number of hydrogens the chain is holding)

- **Maximum = saturated**
- **Unsaturated = one or more is missing**
- **Point of unsaturation = site where hydrogen is missing**

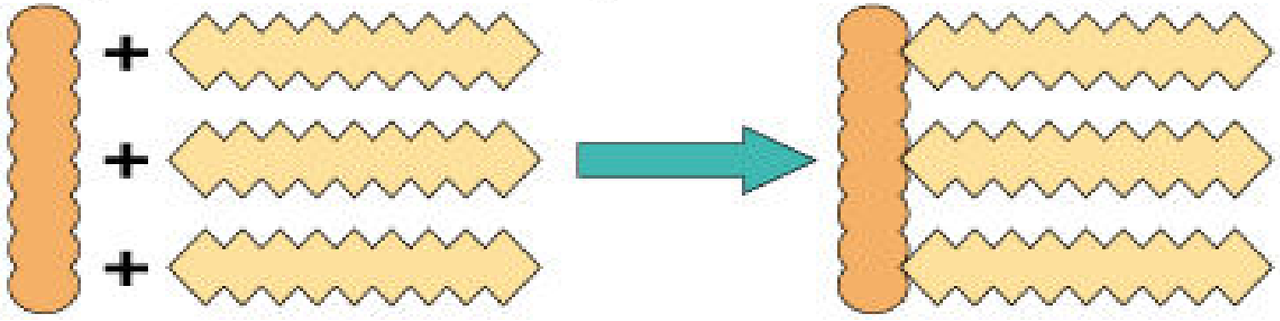


Two hydrogens are missing from each of these carbon-carbon links, making the fatty acid polyunsaturated. With fewer hydrogens to attach to, these carbons are doubly bonded to each other. Monosaturated fatty acids have only one carbon-carbon bond.

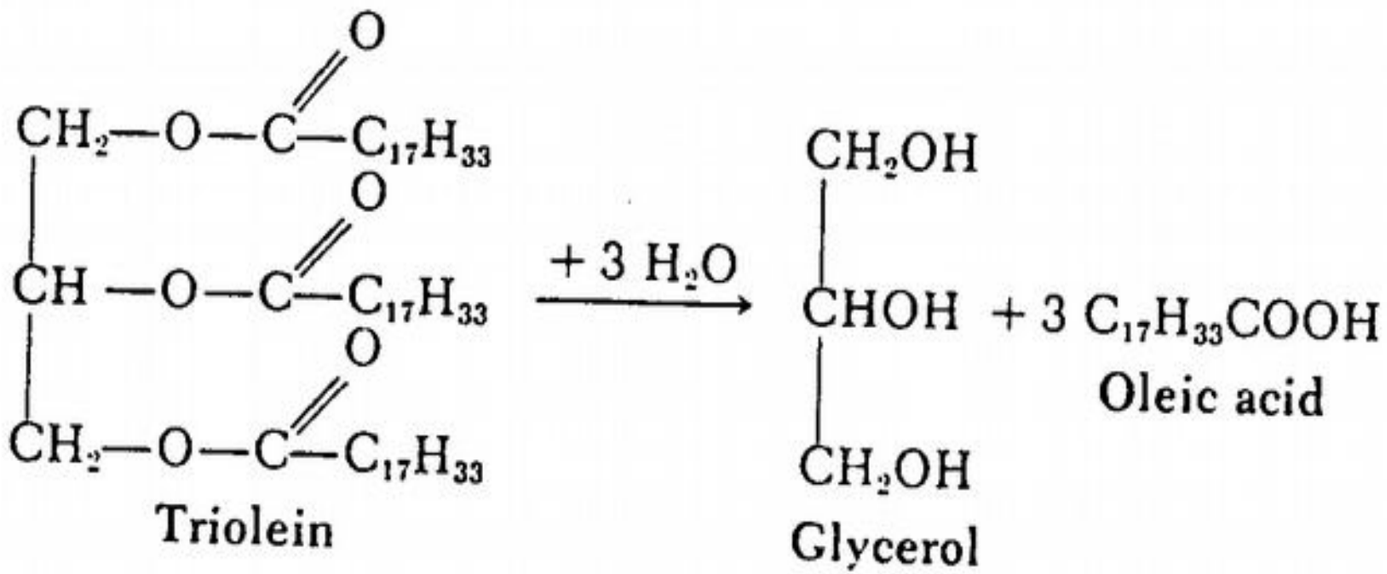
TRIGLYCERIDES

- **Triglycerides: the major class of dietary lipids, including fats & oils**
  - **Made up of 3 units known as fatty acids and 1 unit called glycerol (backbone)**
  - **Comprise about 95% of lipids in food and the human body**

Glycerol + 3 fatty acids = Triglyceride



Hydrolysis



If Alkali is used (saponification):

Triolein + 3NaOH ⟶ Glycerol + $3C_{17}H_{33}COO^-Na^+$ (Sodium oleate, soap)

NUCLEIC ACIDS

- Nucleotides have a variety of roles in cellular metabolism.
- They are the energy currency in metabolic transactions, the essential chemical links in the response of cells to hormones and other extracellular stimuli, and the structural components of an array of enzyme cofactors and metabolic intermediates. And, last but certainly not least, they are the constituents of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), the molecular repositories of genetic information. The structure of every protein, and ultimately of every biomolecule and cellular component, is a product of information programmed into the nucleotide sequence of a cell’s nucleic acids. The ability to store and transmit genetic information from one generation to the next is a fundamental condition for life.

- The amino acid sequence of every protein in a cell, and the nucleotide sequence of every RNA, is specified by a nucleotide sequence in the cell's DNA. A segment of a DNA molecule that contains the information required for the synthesis of a functional biological product, whether protein or RNA, is referred to as a **gene. A cell typically has many** thousands of genes, and DNA molecules, not surprisingly, tend to be very large. The storage and transmission of biological information are the only known functions of DNA.

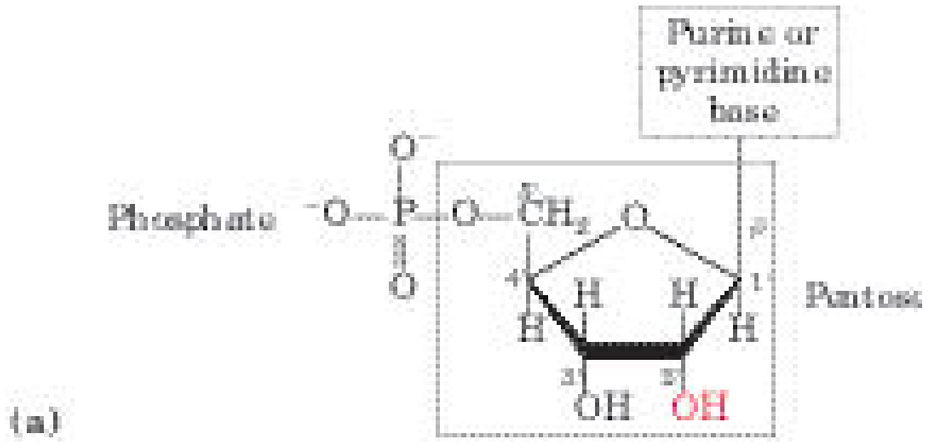
- RNAs have a broader range of functions, and several classes are found in cells. **Ribosomal RNAs (rRNAs) are components of ribosomes, the complexes** that carry out the synthesis of proteins. **Messenger RNAs (mRNAs) are intermediaries, carrying genetic** information from one or a few genes to a ribosome, where the corresponding proteins can be synthesized.

- **Transfer RNAs (tRNAs) are adapter molecules that** faithfully translate the information in mRNA into a specific sequence of amino acids.

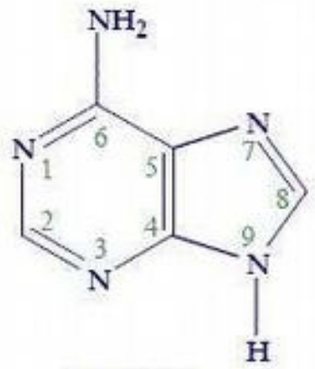
Nucleotides and Nucleic Acids Have Characteristic Bases and Pentoses

- **Nucleotides have three characteristic components:**
- (1) a nitrogenous (nitrogen-containing) base, (2) a pentose, and (3) a phosphate. The molecule without the phosphate group is called a **nucleoside.**
- **The** nitrogenous bases are derivatives of two parent compounds, **pyrimidine and purine. The bases and pentoses** of the common nucleotides are heterocyclic compounds.
- The carbon and nitrogen atoms in the parent structures are conventionally numbered to facilitate the naming and identification of the many derivative compounds.

- Both DNA and RNA contain two major purine bases, **adenine (A) and guanine (G), and two major pyrimidines.**
- In both DNA and RNA one of the pyrimidines is **cytosine (C), but the second major pyrimidine is not**the same in both: it is **thymine (T) in DNA and uracil** (U) in RNA. Only rarely does thymine occur in RNA or uracil in DNA.



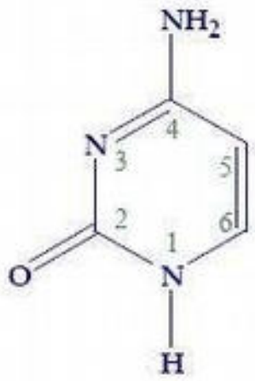
PURINES



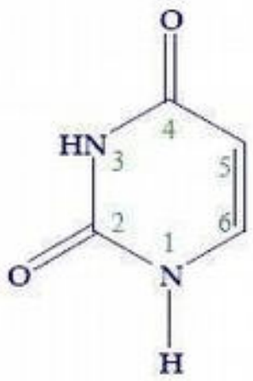
Adenine

Guanine

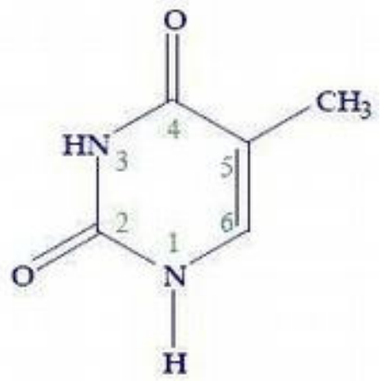
PYRIMIDINES



Cytosine



Uracile



Thymine

DNA STRUCTURE