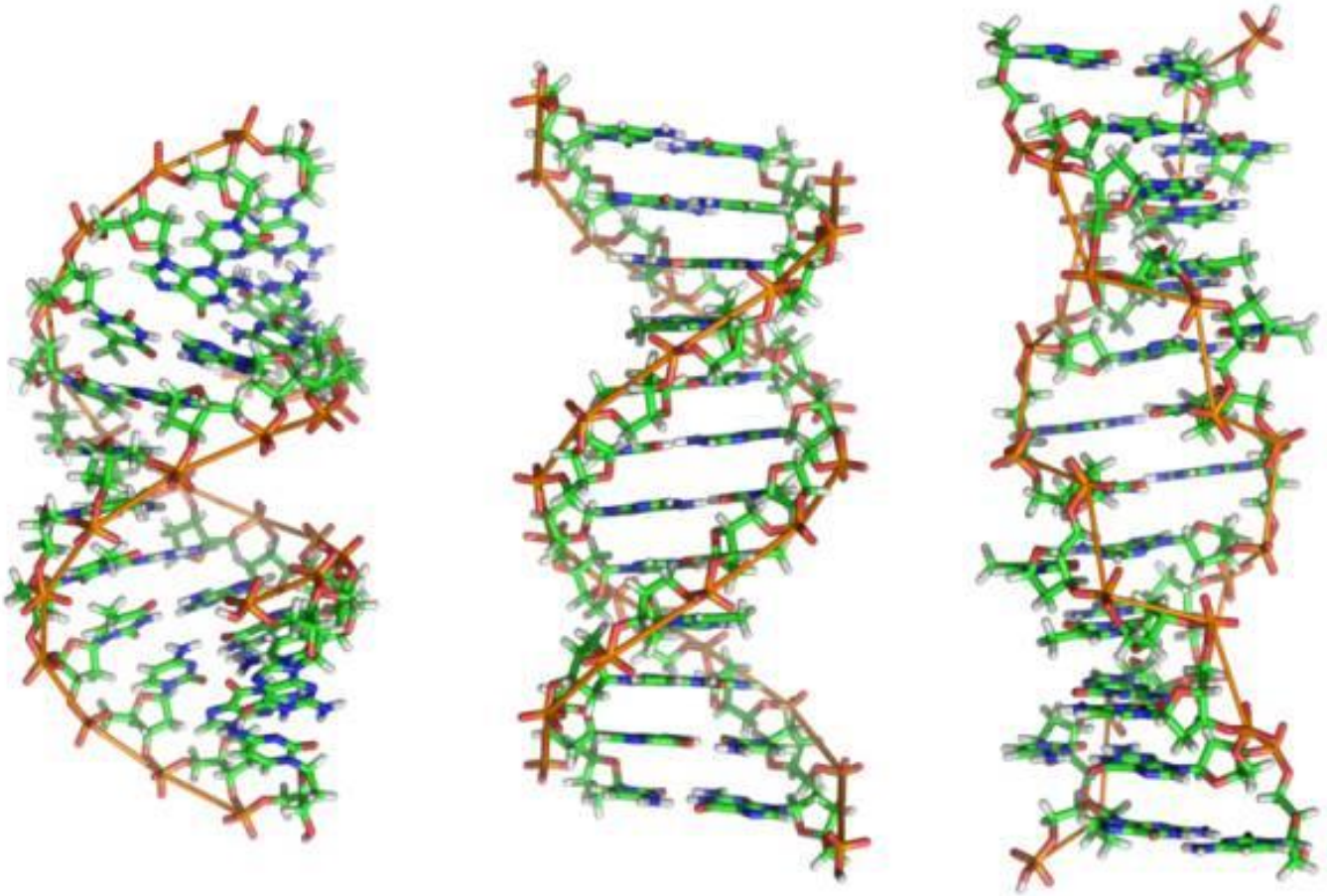
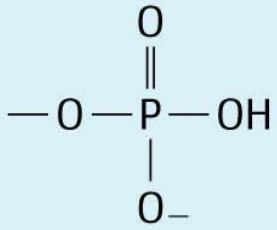
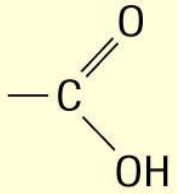
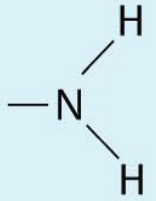
Biomolecules (생체분자)



Biomolecules:
What cells are made of Organic Molecules

- **Carbohydrates**
- **Lipids**
- **Amino acids and proteins**
- **Nucleotides**

Common Functional Groups in Biomolecules

Functional group	Chemical formula	Structure	Chemical property
Hydroxyl	—OH	—O—H	Polar
Sulfhydryl	—SH	—S—H	Polar
Phosphate	$—HPO_4^-$		Polar
Carboxyl	—COOH		Acid
Amino	$—NH_2$		Base

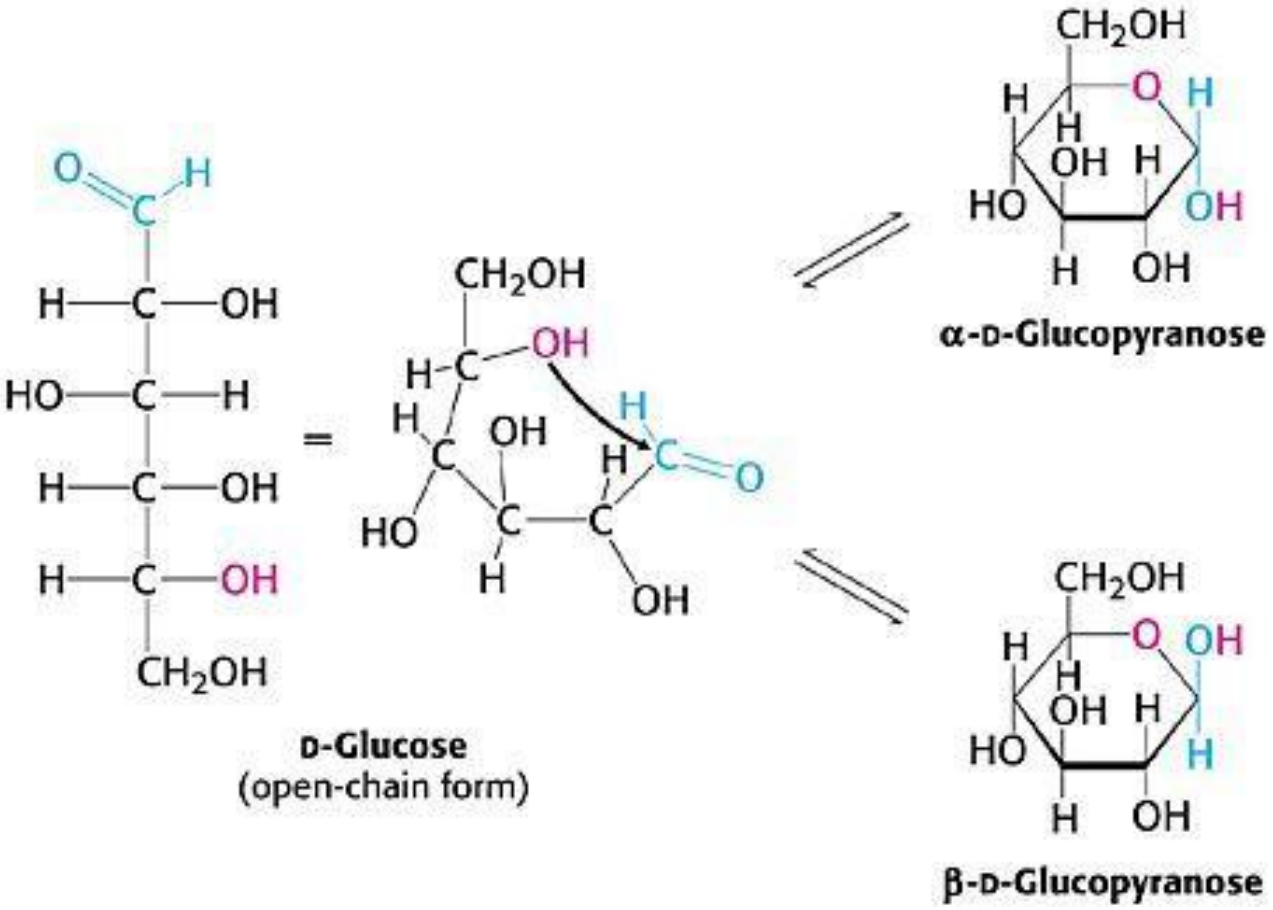
Carbohydrate

- organic compound
- empirical formula $C_n(H_2O)_n$; that is,
- consists only of carbon, hydrogen, and oxygen, with a hydrogen:oxygen atom ratio of 2:1 (as in water).

(e.g., glucose is $C_6H_{12}O_6$)

- However, there are exceptions to this. One common example would be deoxyribose, a component of DNA, empirical formula $C_5H_{10}O_4$.

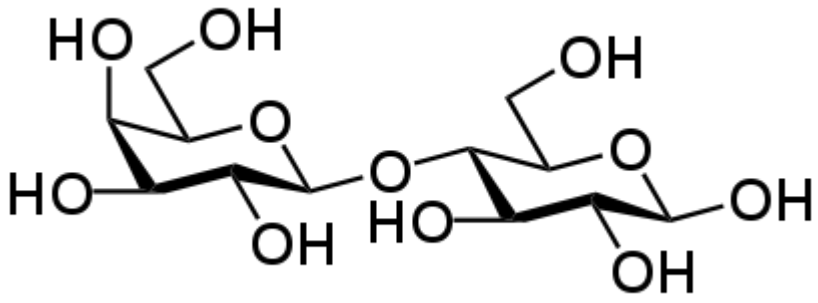
Monosaccharides



Glucose (포도당)

Disaccharides

- 2 monosaccharides linked together
- Ex)
  - sucrose (a common plant disaccharide is composed of the monosaccharides glucose and fructose)
  - lactose (or milk sugar; a disaccharide composed of glucose and the monosaccharide galactose)

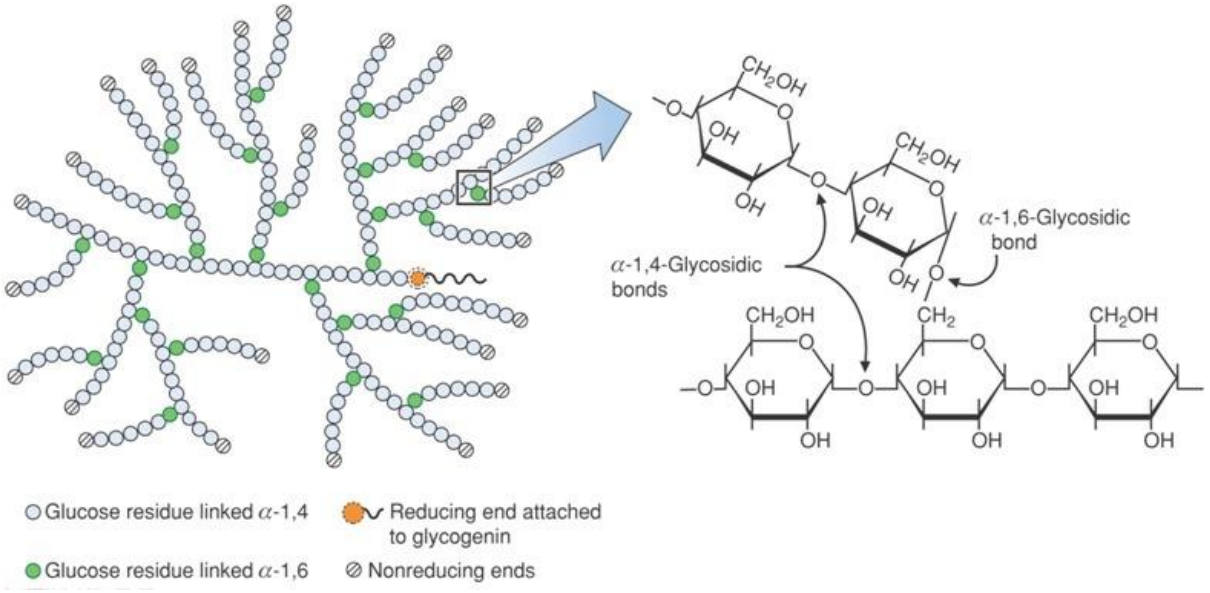


Lactose is a disaccharide found in milk. It consists of a molecule of D-galactose and a molecule of D-glucose

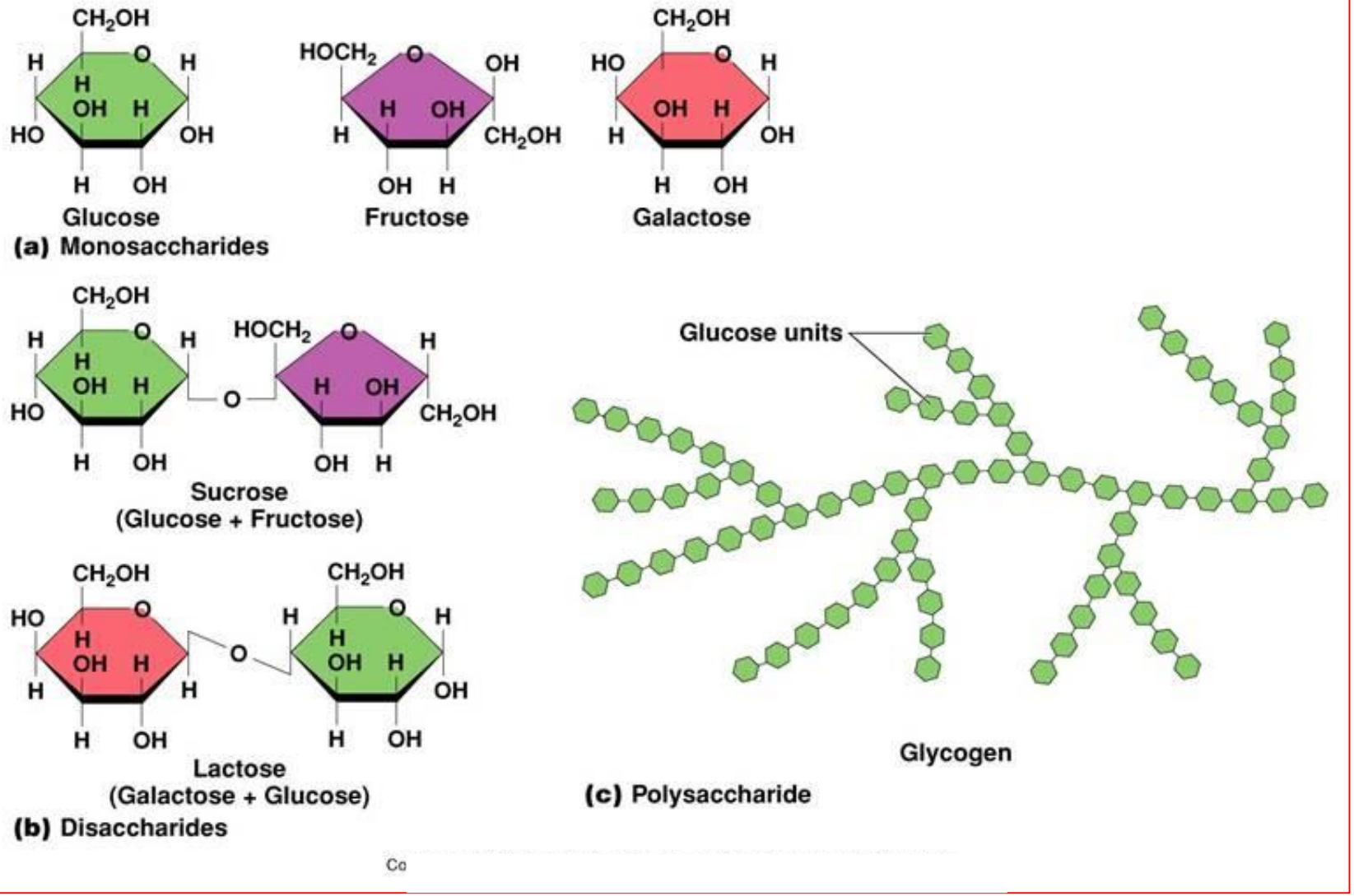
Polysaccharides

Glycogen

- Storage form of glucose
- α-1,4-glycosidic bonds, with α-1,6-branches every 8 to 10 residues: rapid degradation and synthesis



Examples of Carbohydrates



Lipids (지방)

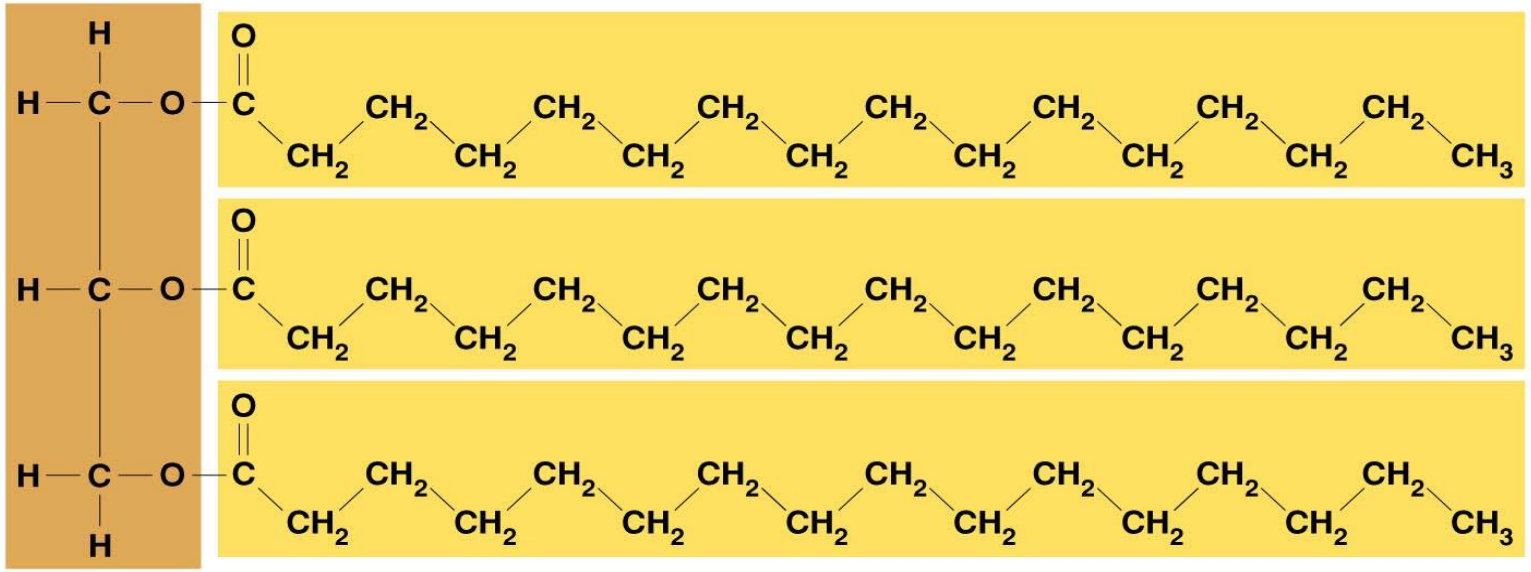
- about 40% of the dry mass of a typical cell
- composed largely of carbon & hydrogen
- generally insoluble in water = hydrophobic
- non-polar covalent bonds
- involved mainly with long-term energy storage;
- other functions are as structural components

  - as in the case of phospholipids that are the major building block in cell membranes
  - "messengers" (hormones) that play roles in communications within and between cells

Lipids (지방)

Subclasses include:

- triglycerides - one glycerol molecule + 3 fatty acids (e.g., stearic acid in the diagram below).
- Fatty acids typically consist of chains of 16 or 18 carbons (plus lots of hydrogens).



(d) Triglyceride

Lipids (지방)

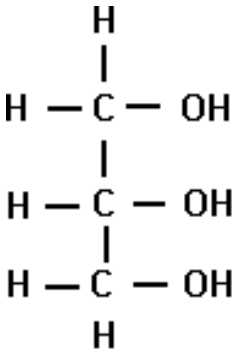
Subclasses include:

- triglycerides - one glycerol molecule + 3 fatty acids (e.g., stearic acid in the diagram below).
- Fatty acids typically consist of chains of 16 or 18 carbons (plus lots of hydrogens).

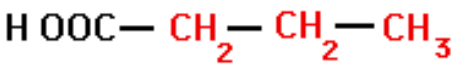
- phospholipids - a phosphate group (-PO4) substitutes for one fatty acid & these lipids are an important component of cell membranes

- steroids - include testosterone, estrogen, & cholesterol

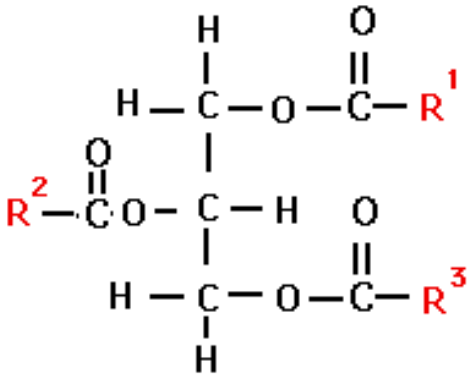
Lipids (지방)



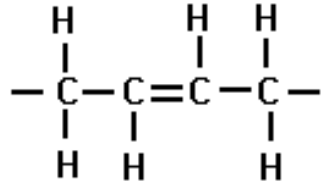
Glycerol



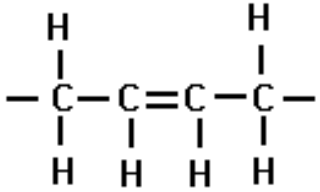
Saturated Fatty Acid (Butyric acid)



Triglyceride



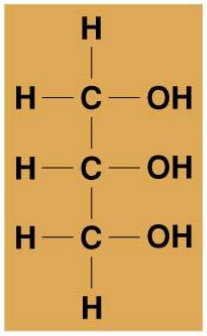
Trans double bond



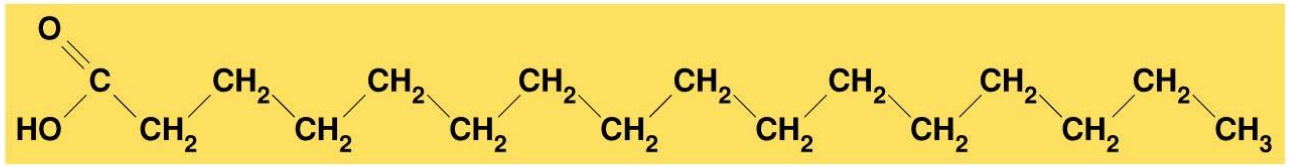
Cis double bond

Unsaturated

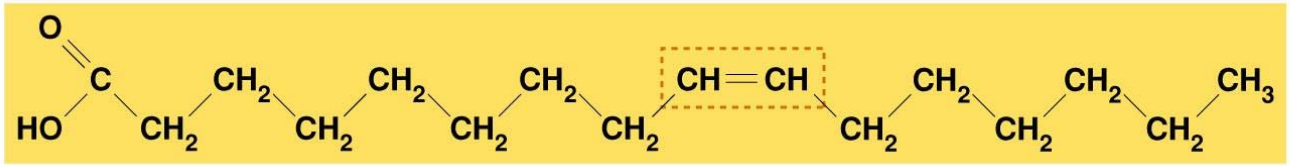
Chemical Structures



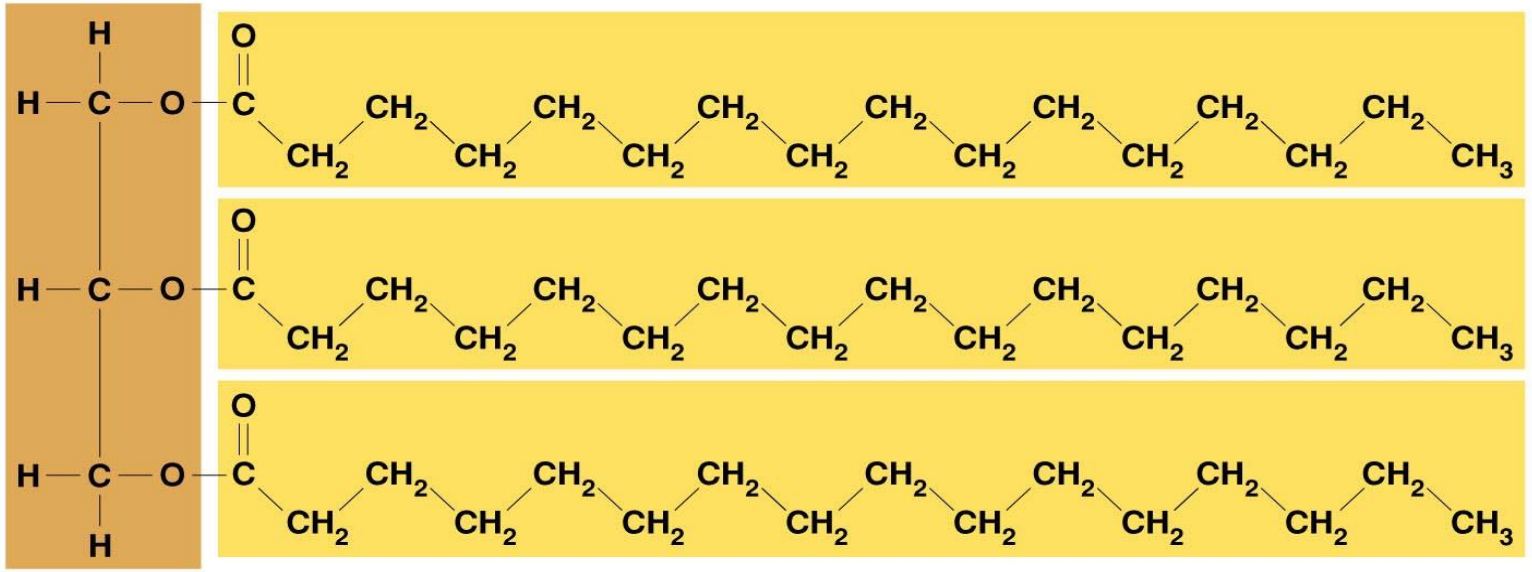
(a) Glycerol



(b) Saturated fatty acid



(c) Unsaturated fatty acid

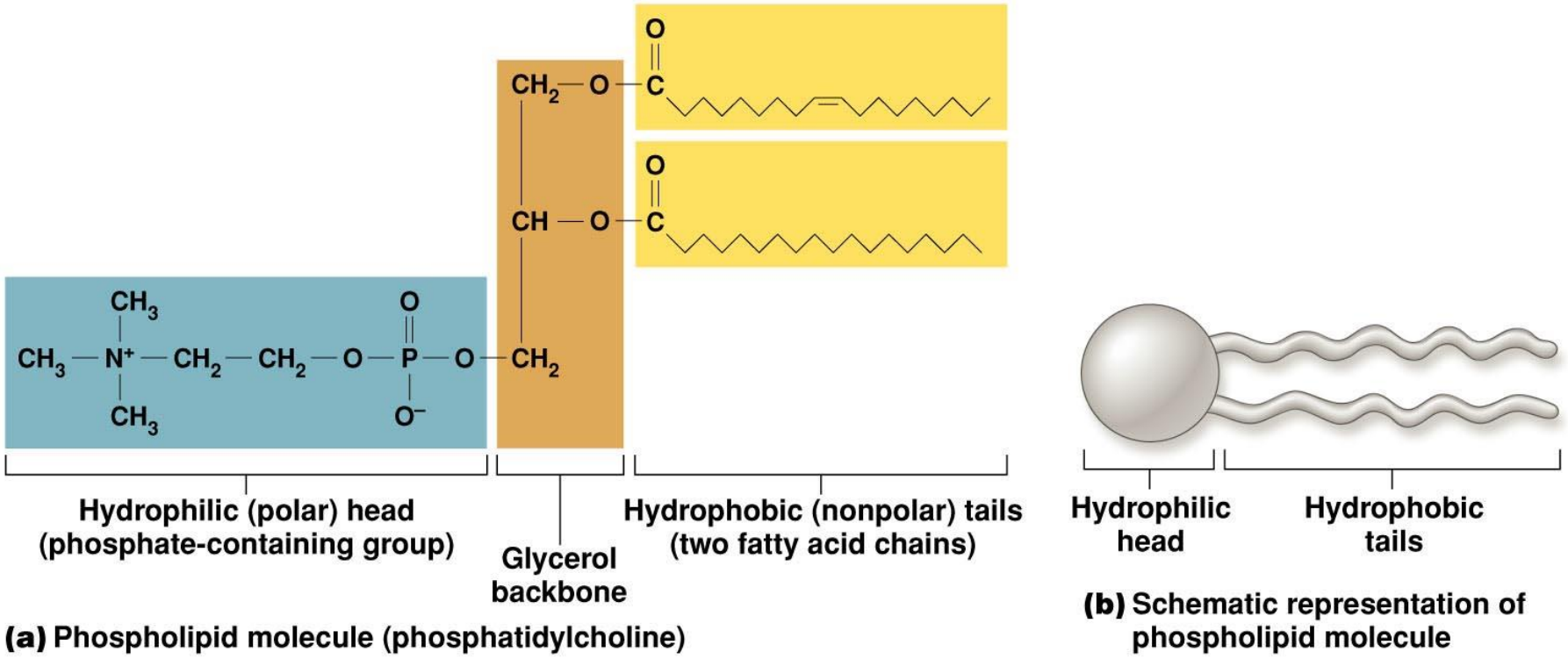


(d) Triglyceride

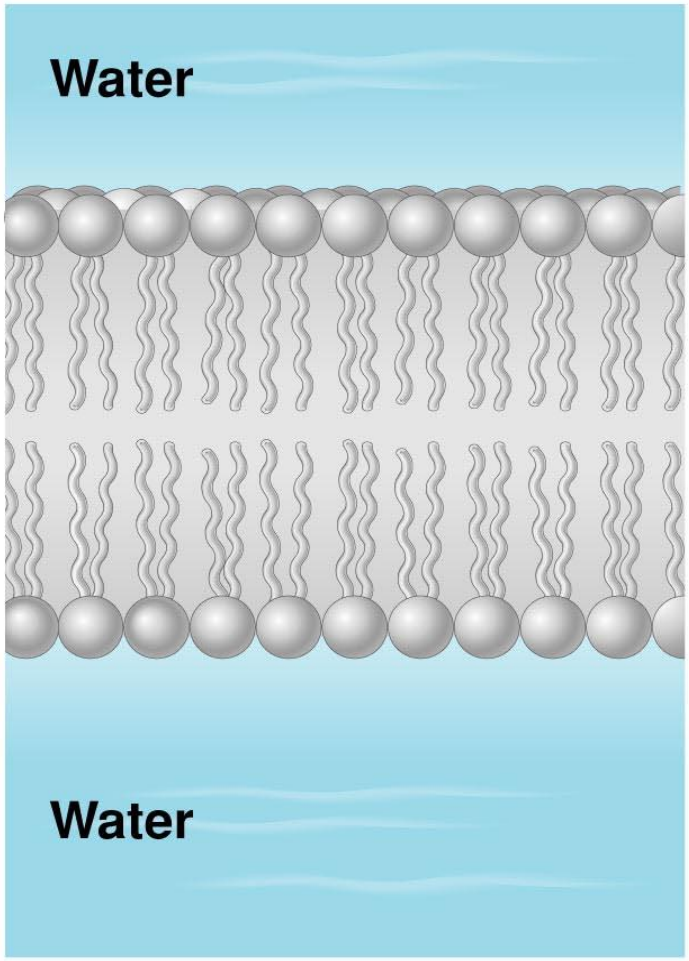
Phospholipids

Phospholipids are amphipathic molecules

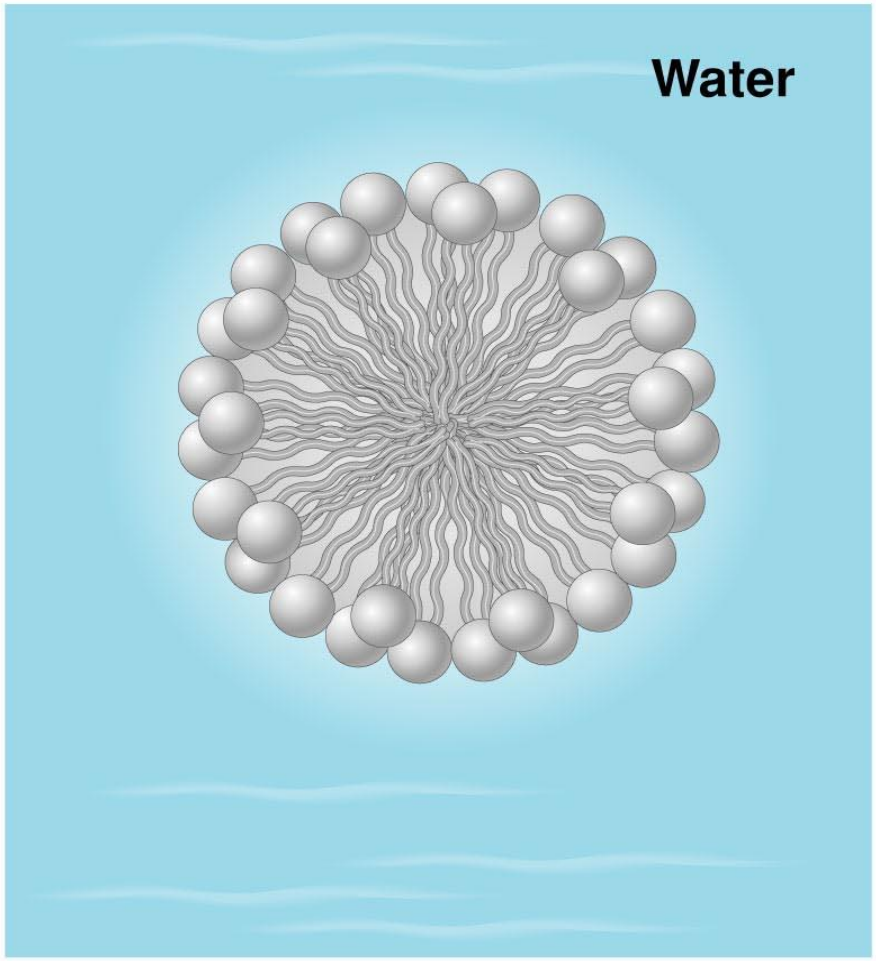
Structures formed by phospholipids in an aqueous environment



Phospholipids



(a) Phospholipid bilayer



(b) Micelle

Proteins (단백질)

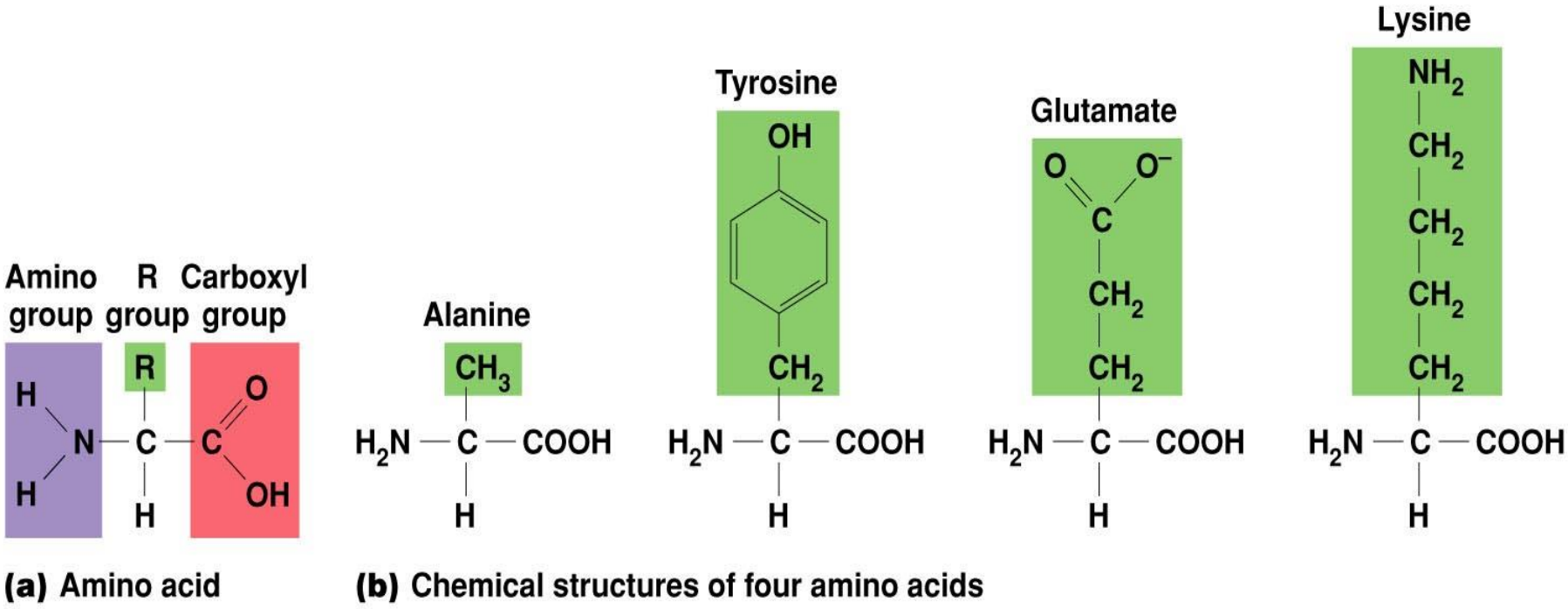
- about 50 - 60% of the dry mass of a typical cell
- subunit is the amino acid & amino acids are linked by peptide bonds
- 2 functional categories = structural (proteins part of the structure of a cell like those in the cell membrane) & enzymes

Important!!

Enzymes are *catalysts*. Enzymes bind temporarily to one or more of the reactants of the reaction they catalyze. In doing so, they lower the amount of activation energy needed and thus speed up the reaction

Polymer of amino acids

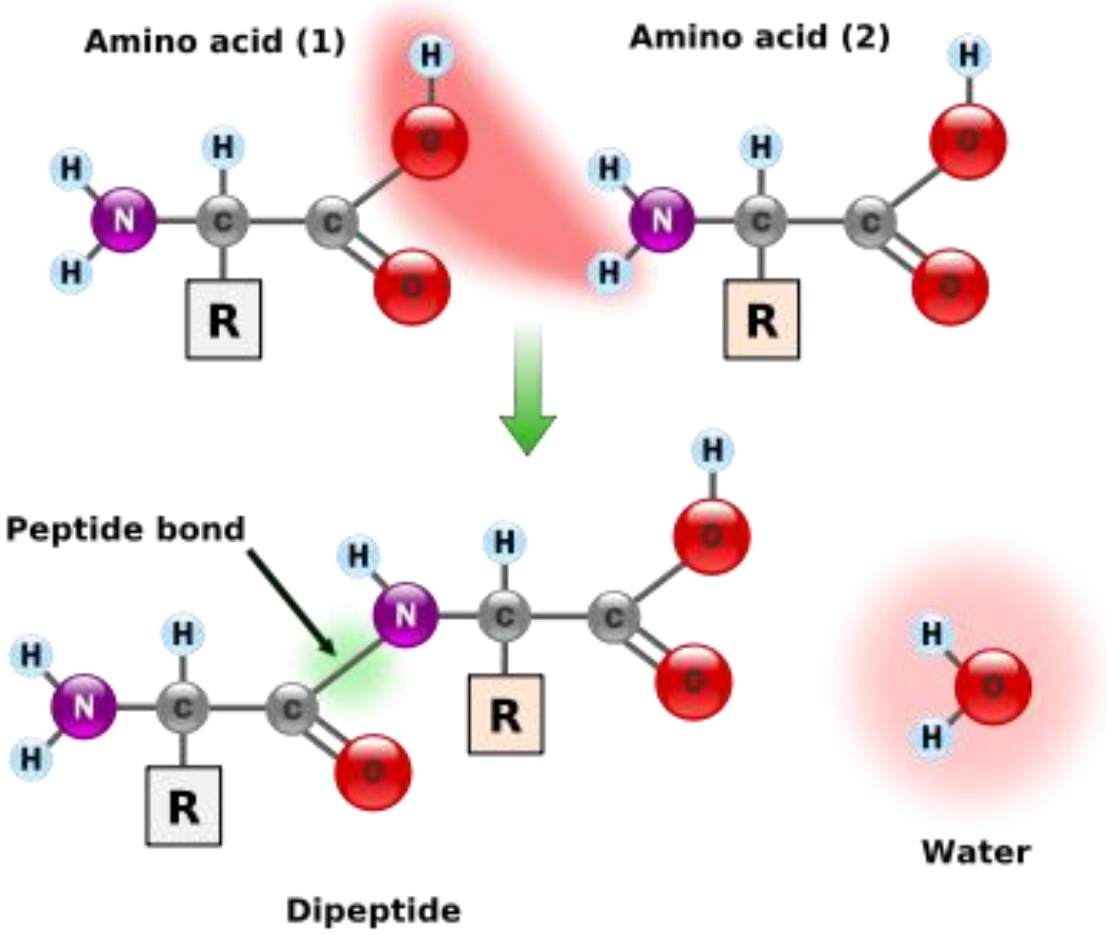
There are 20 common amino acids. Amino acids share a common structure except for one chemical group (R, side chain) attached to the central carbon atom.



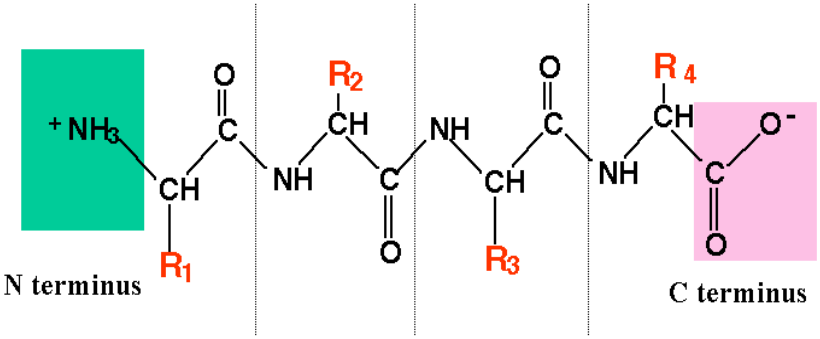
Polymers of Amino Acids

- **Peptide bond**

Covalent bond between carboxyl group of one amino acid and amino group of another amino acid

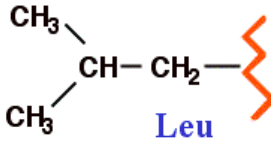
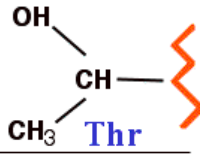
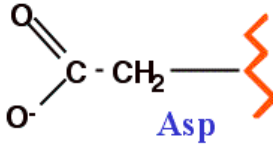
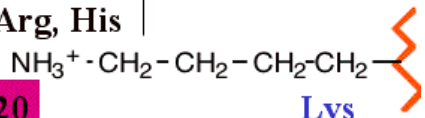


Peptide = chain of amino acids



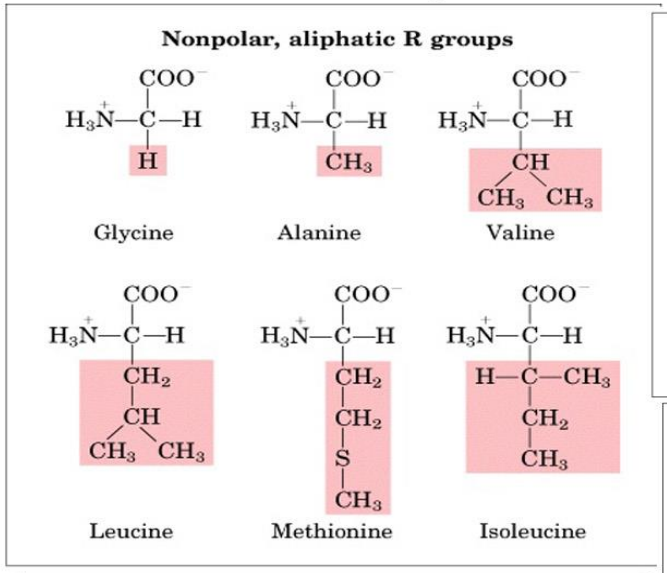
polypeptide chain

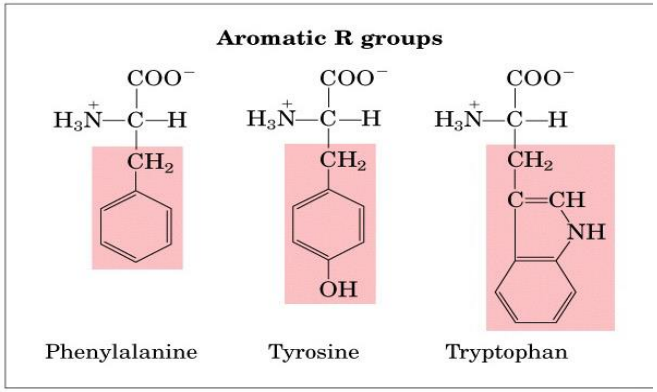
Amino acids groups

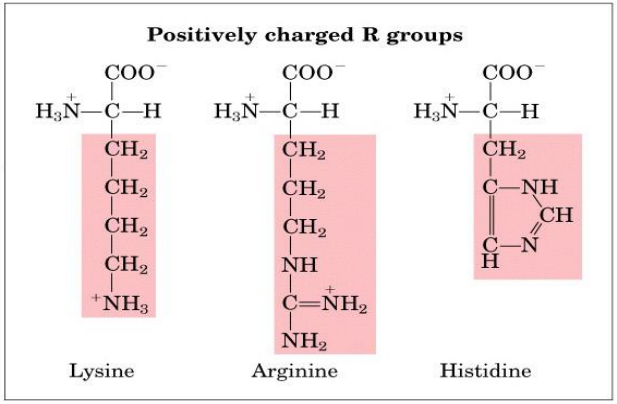
Group	Characteristics	Names	Example (-Rx)
non-polar	hydrophobic	Ala, Val, Leu, Ile, Pro, Phe Trp, Met	 Leu
polar	hydrophilic (non-charged)	Gly , Ser, Thr, Cys, Tyr, Asn Gln	 Thr
acidic	negatively charged	Asp, Glu	 Asp
basic	positively charged	Lys, Arg, His	 Lys

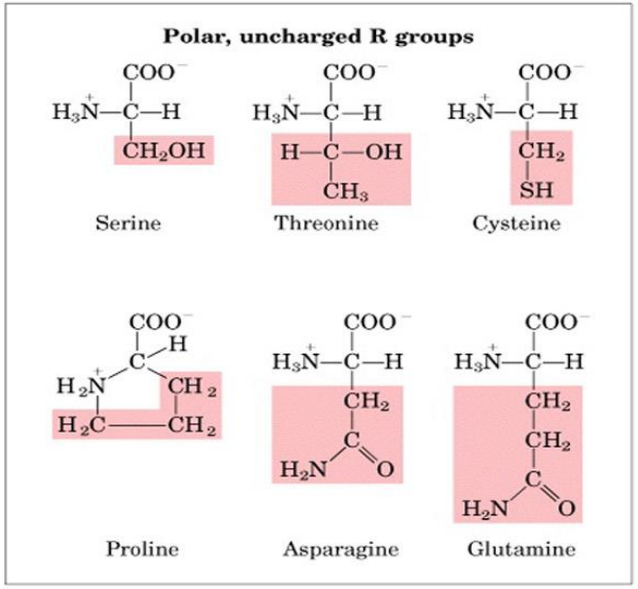
Total = 20

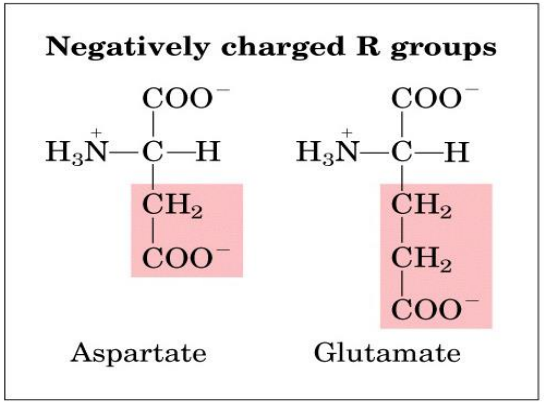
Twenty standard Amino Acids



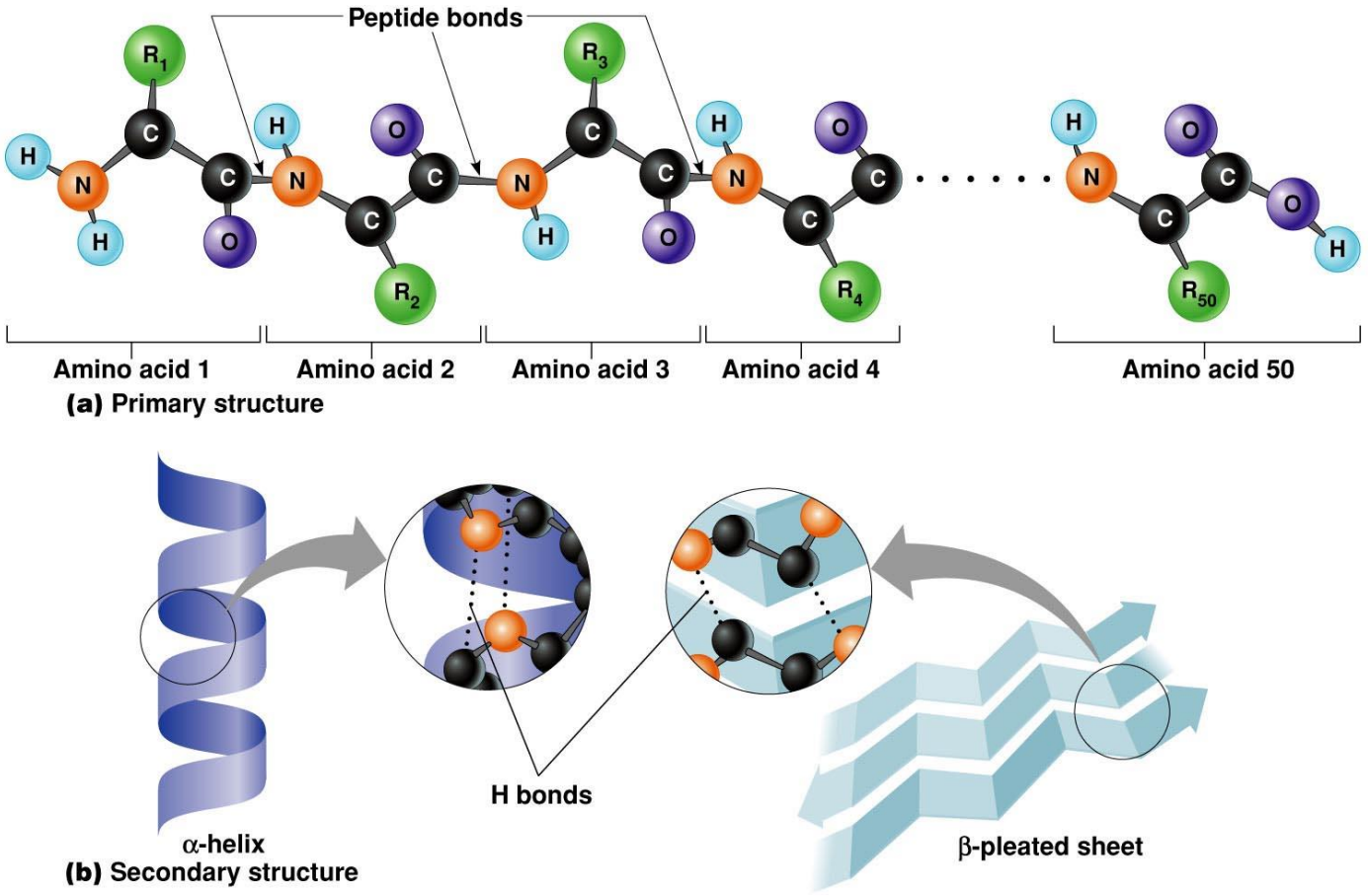


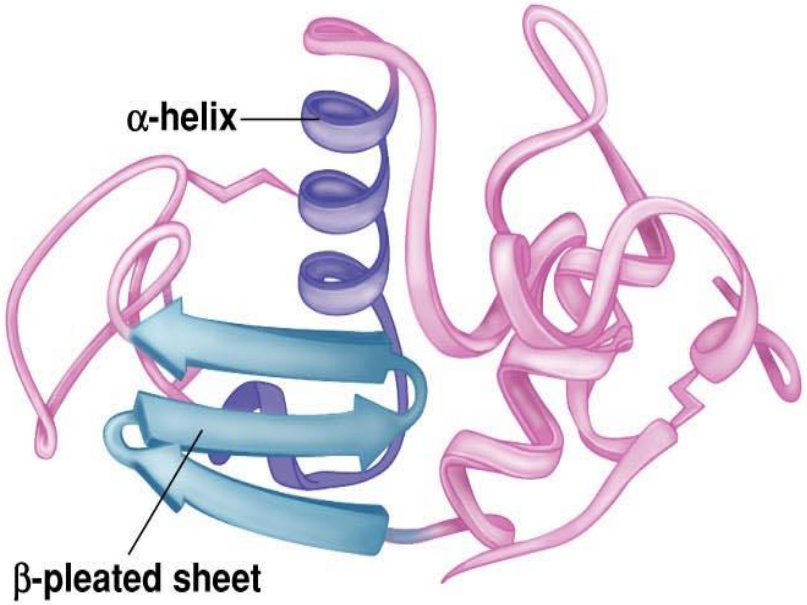




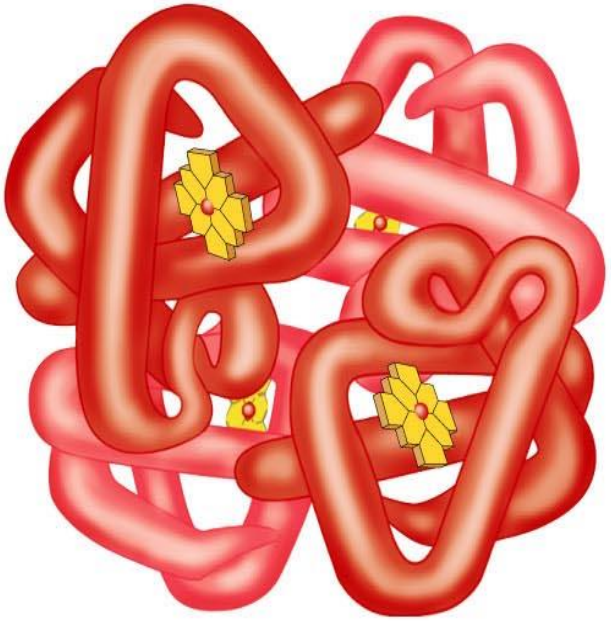


- **Peptides**
  - **Generally 2–50 amino acids**
- **Proteins**
  - **Greater than 50 amino acids**





(c) Tertiary structure



(d) Quaternary structure

Tertiary Protein Structure: Formation of bends and loops in polypeptide chain due to interactions between R groups

Interactions Causing Tertiary Structure

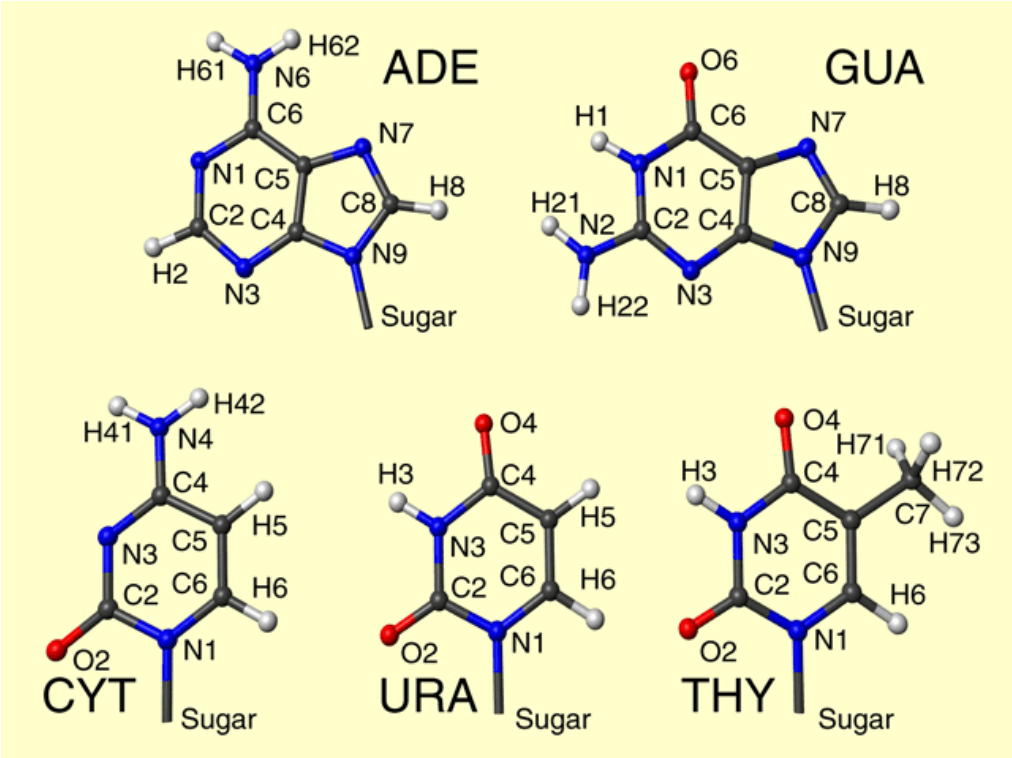
- **Ionic bonds**
- **van der Waals forces**
- **Hydrogen bonds**
- **Covalent bonds (disulfide bridge)**

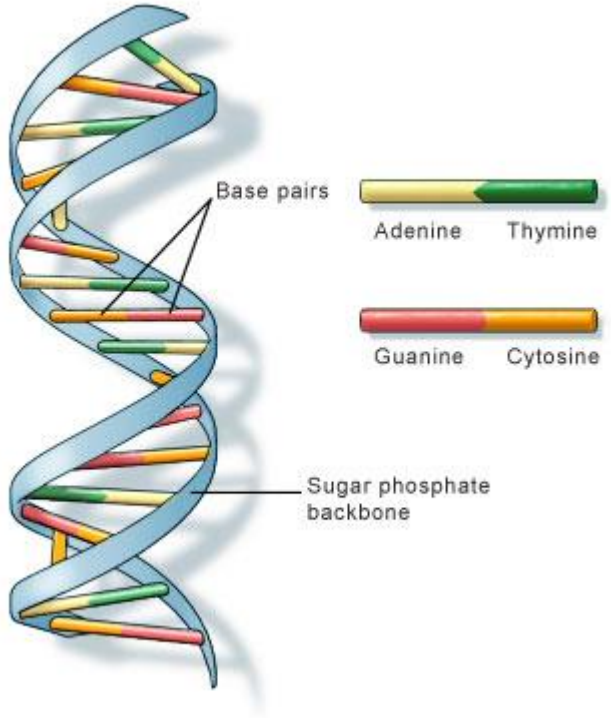
Quaternary Protein Structure: Formation of proteins with more than one polypeptide chain

Protein types

Type	Function	Examples
Structural	Give shape and structure to cell or organelles	Actin Tubulin
Enzymes	Catalyse biological reactions	Trypsin Adenylate cyclase
Receptors	Bind to other molecules and transmit signal	Glutamate R. Steroid R.
Other functional proteins	Have specific functions	Antibodies Nuclear factors Neuropeptides

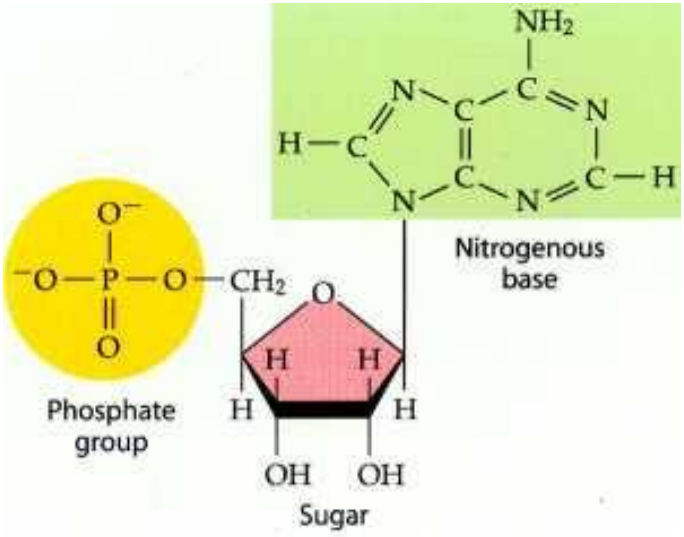
Nucleic Acids

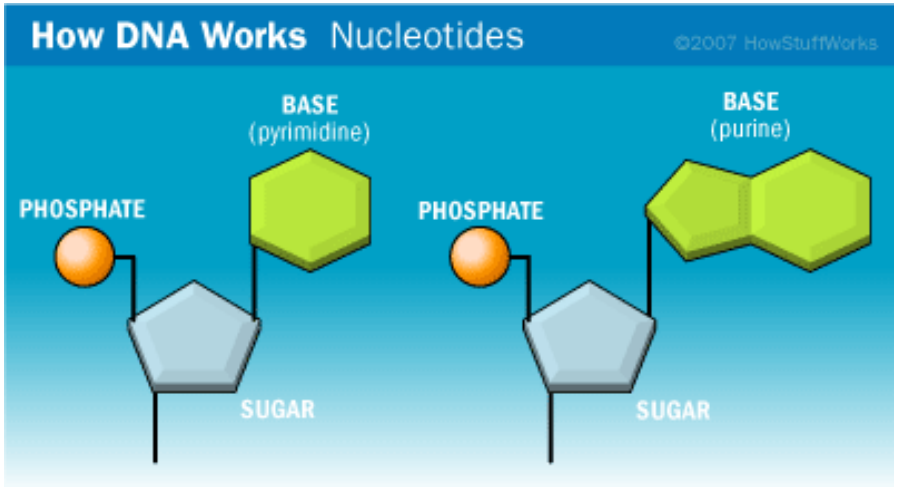




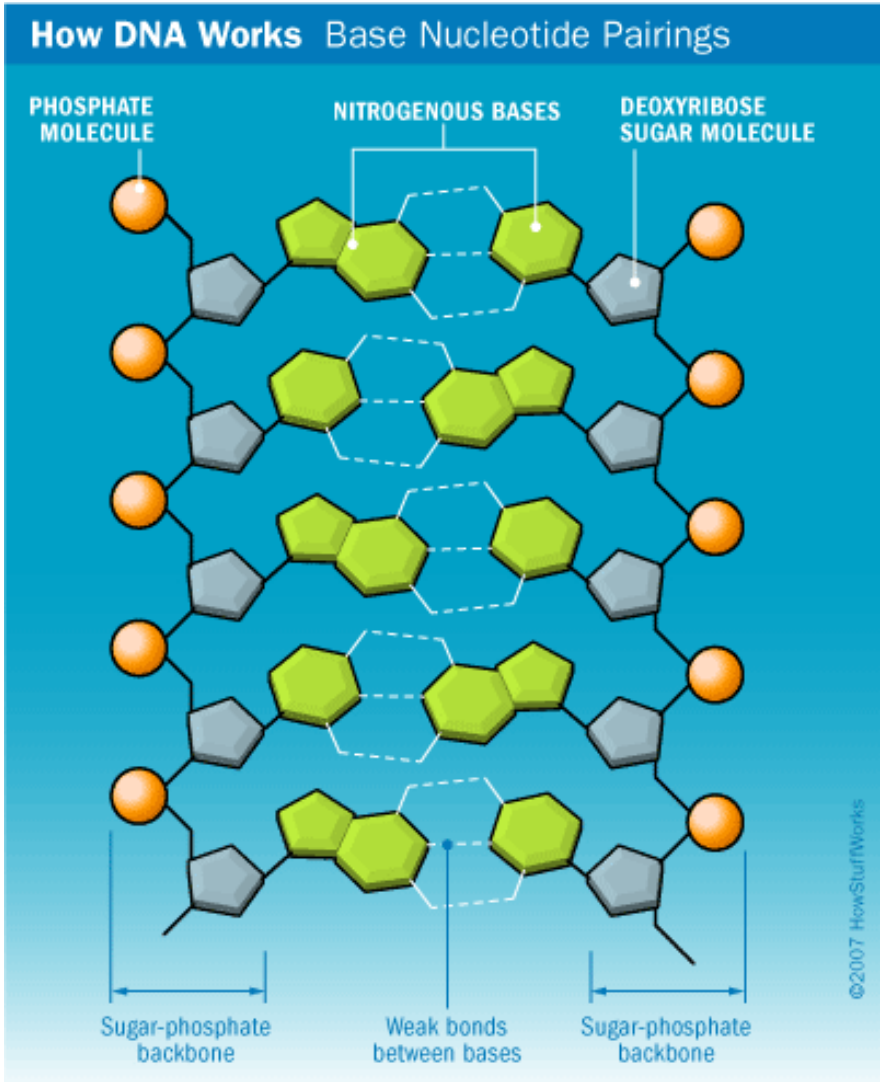
Nucleic Acids

- Nucleic acids, which are relatively strong acids found in the nuclei of cells, were first isolated in 1869.
- The nucleic acids are polymers with molecular weights as high as 100,000,000 grams per mole.
- They can be broken down, or digested, to form monomers known as **nucleotides**.
- Each nucleotide contains three units: a sugar, an amine, and a phosphate, as shown in the figure below.





- 핵산
  - 5탄당 D-ribose, phosphate, nitrogenous base(A, G, C, T, U)
  - 말단은 3'-수산기, 5'-인산기 상태로 존재
  - 인산기의 (-)전하→높은 극성
  - 디에스텔인산 결합 : 하나의 뉴클레오타이드 ribose 5'탄소 수산기+다른 뉴클레오타이드 3'탄소 수산기

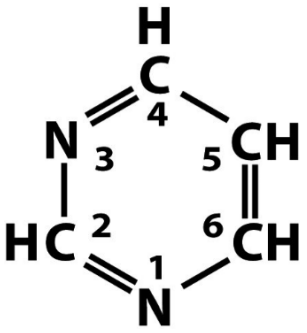


Nucleotide Structure

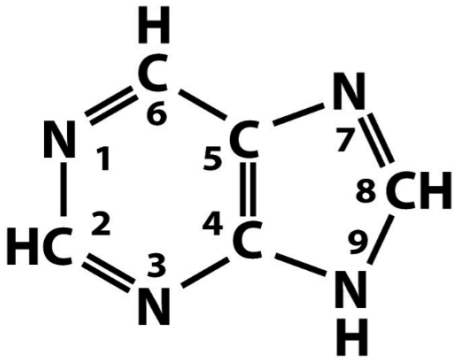
There are two classes of nitrogen bases called **purines** (double-ringed structures) and **pyrimidines** (single-ringed structures).

The four bases in DNA's alphabet are:

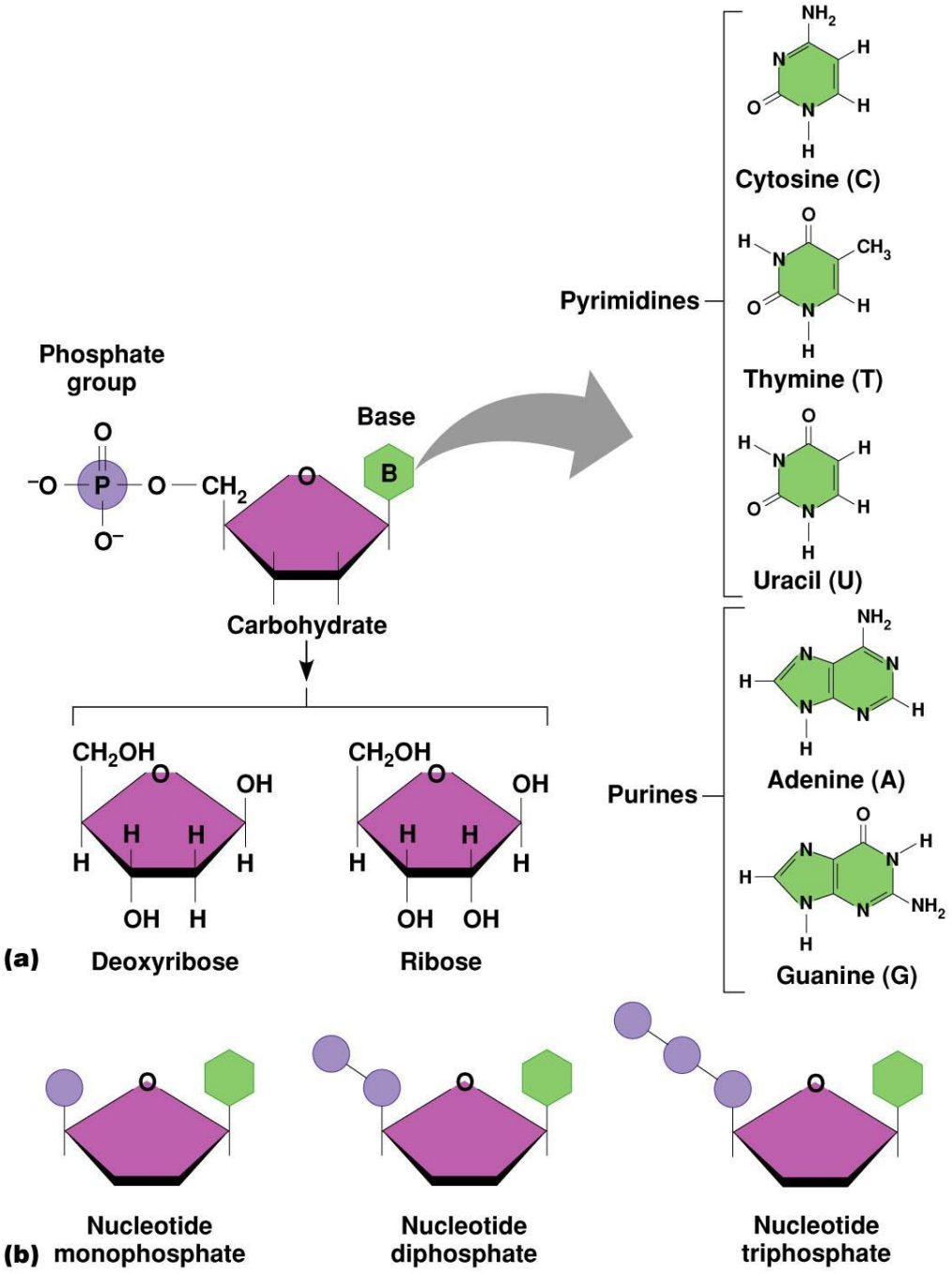
- **adenine (A)** - a purine
- **cytosine(C)** - a pyrimidine
- **guanine (G)** - a purine
- **thymine (T)** - a pyrimidine



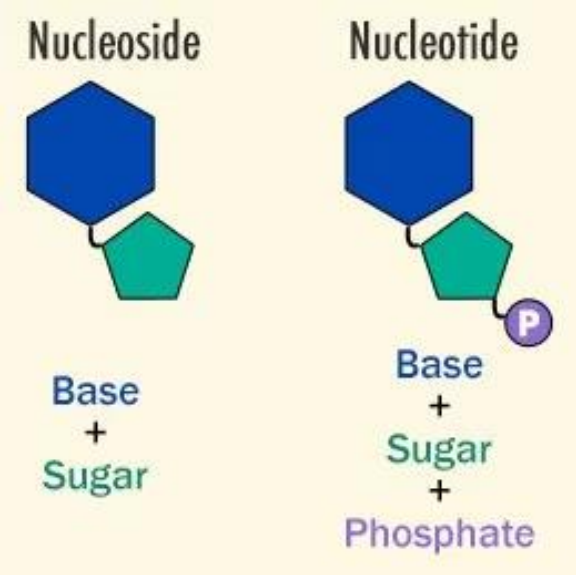
Pyrimidine



Purine

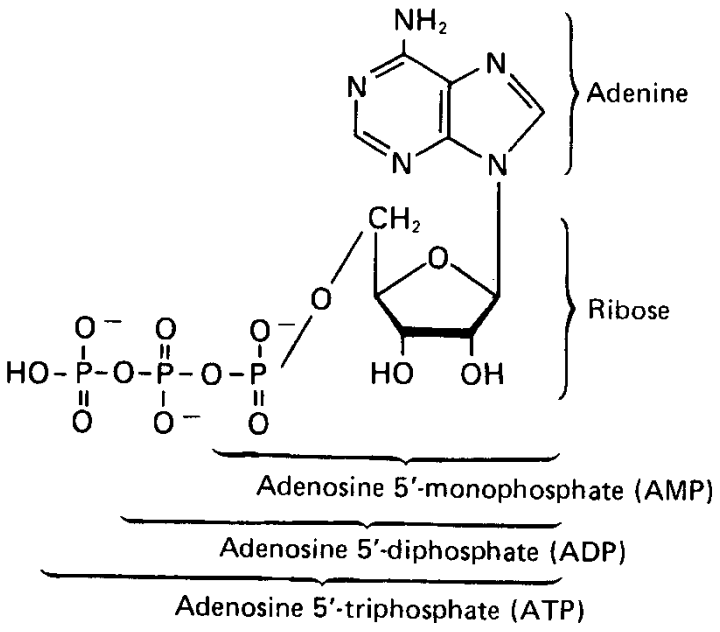

Phosphate group
Base
Carbohydrate
Pyrimidines
Cytosine (C)
Thymine (T)
Uracil (U)
Purines
Adenine (A)
Guanine (G)
(a)
Deoxyribose
Ribose
(b)
Nucleotide monophosphate
Nucleotide diphosphate
Nucleotide triphosphate

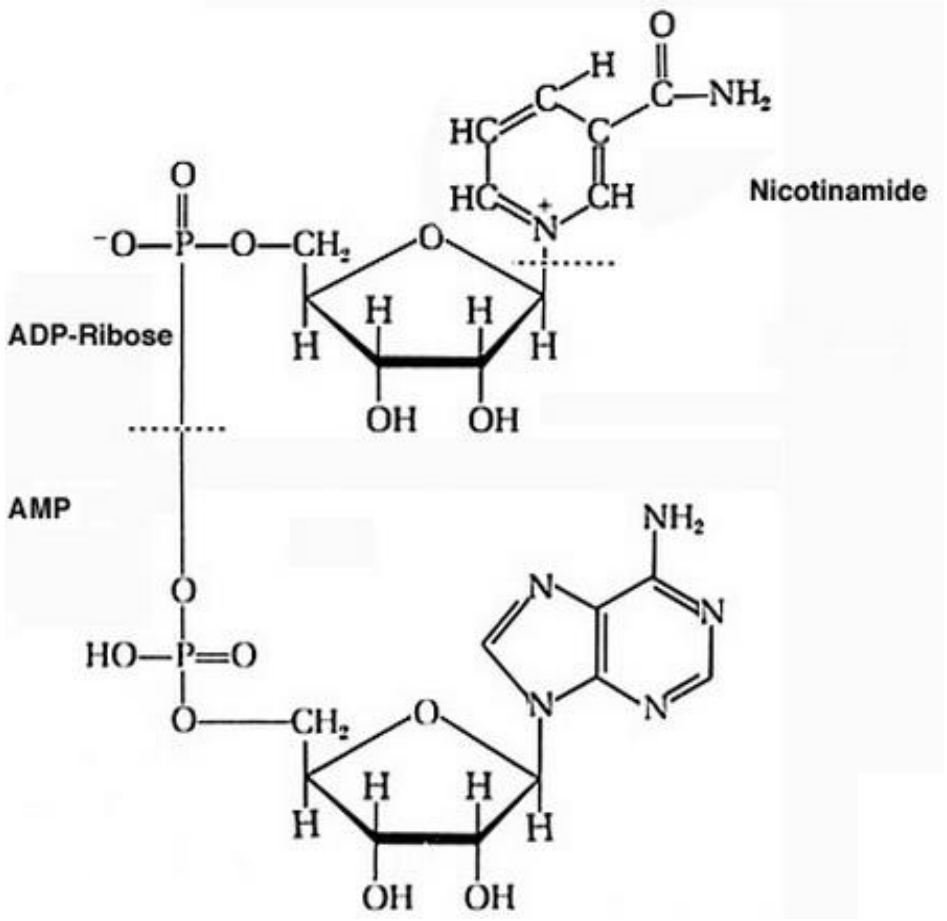
nucleoSide = base + Sugar.
nucleoTide = base + sugar + phosphate



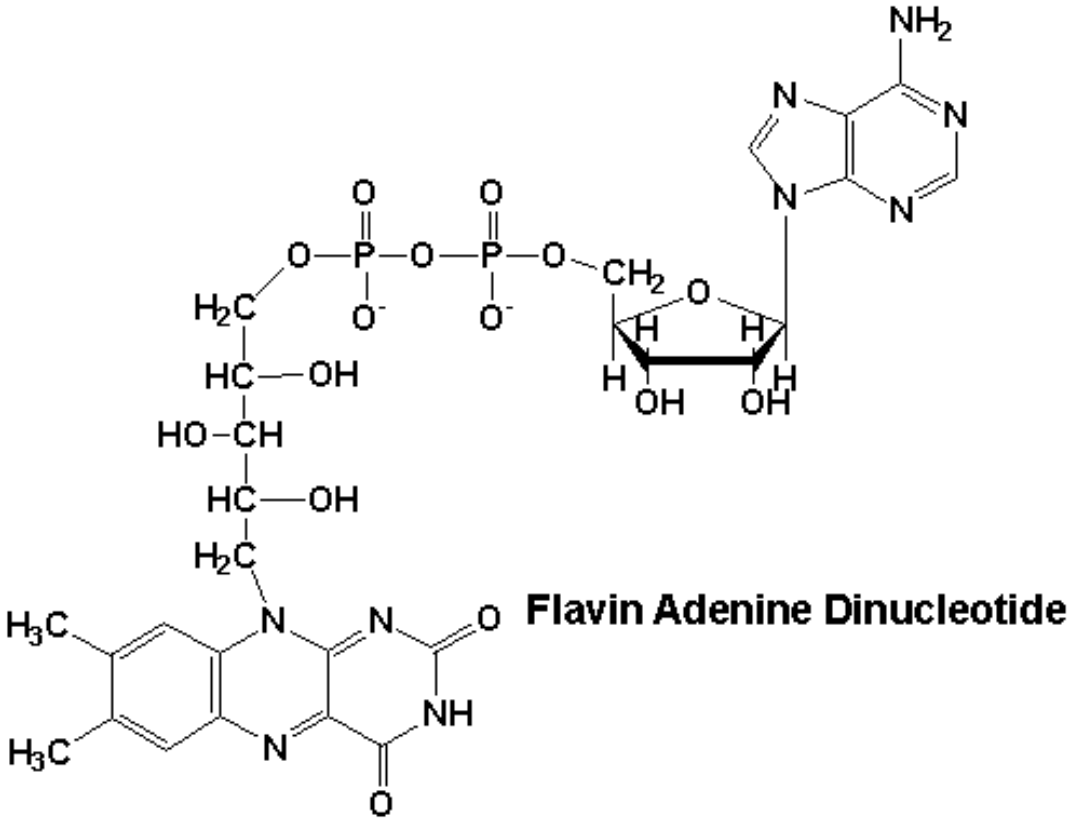
Energy-Transferring Nucleotides

- **Adenosine di(tri)phosphate ADP/ATP**
  - **Adenine + ribose + 2 or 3 phosphates**
  - **Adenine + ribose = adenosine**
- **Nicotinamide adenine dinucleotide (NAD)**
- **Flavin adenine dinucleotide (FAD)**





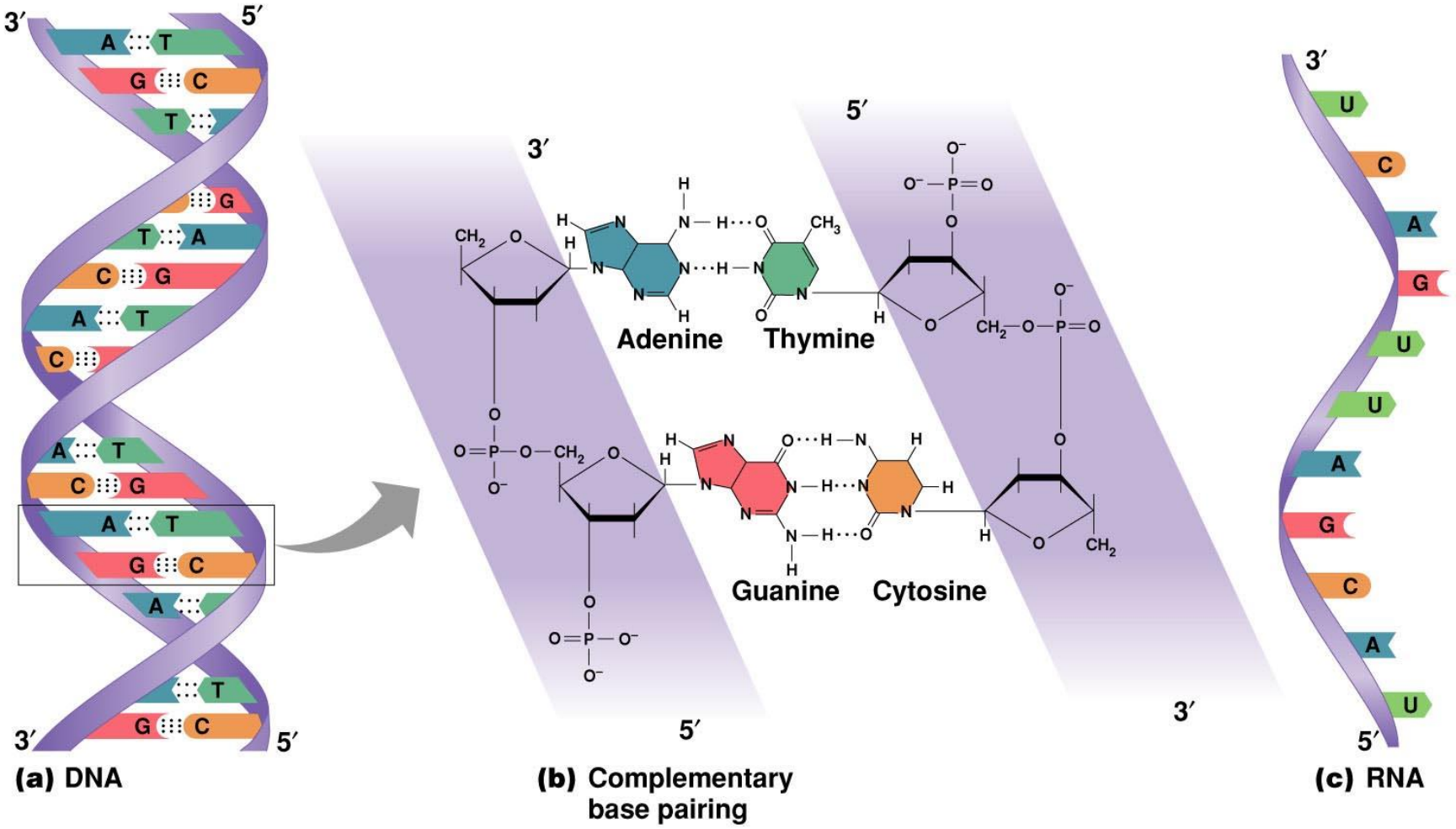
The Structure of NAD. Nicotinamide Adenine Dinucleotide is composed of two nucleotide molecules: Adenosine monophosphate (adenine plus ribose-phosphate) and nicotinamide ribotide (nicotinamide plus ribose-phosphate).



Flavin Adenine Dinucleotide (FAD)

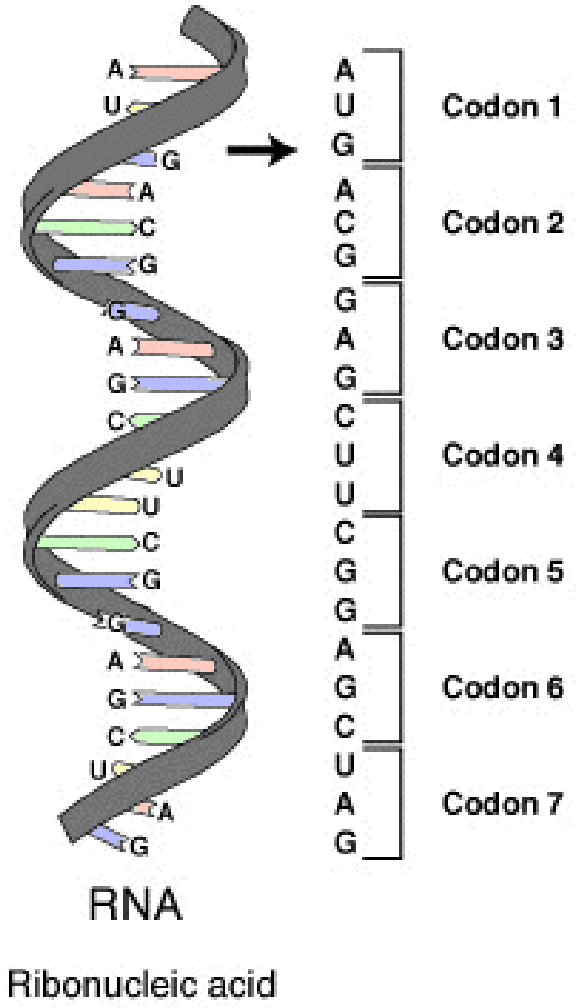
Nucleic Acids Store and Express Genetic Code

Nucleic acids = polymers of nucleotides



DNA: The Double Helix

Deoxyribonucleic Acid



- **DNA: Stores genetic code**
- **RNA: Needed for expression of genetic code**

DNA

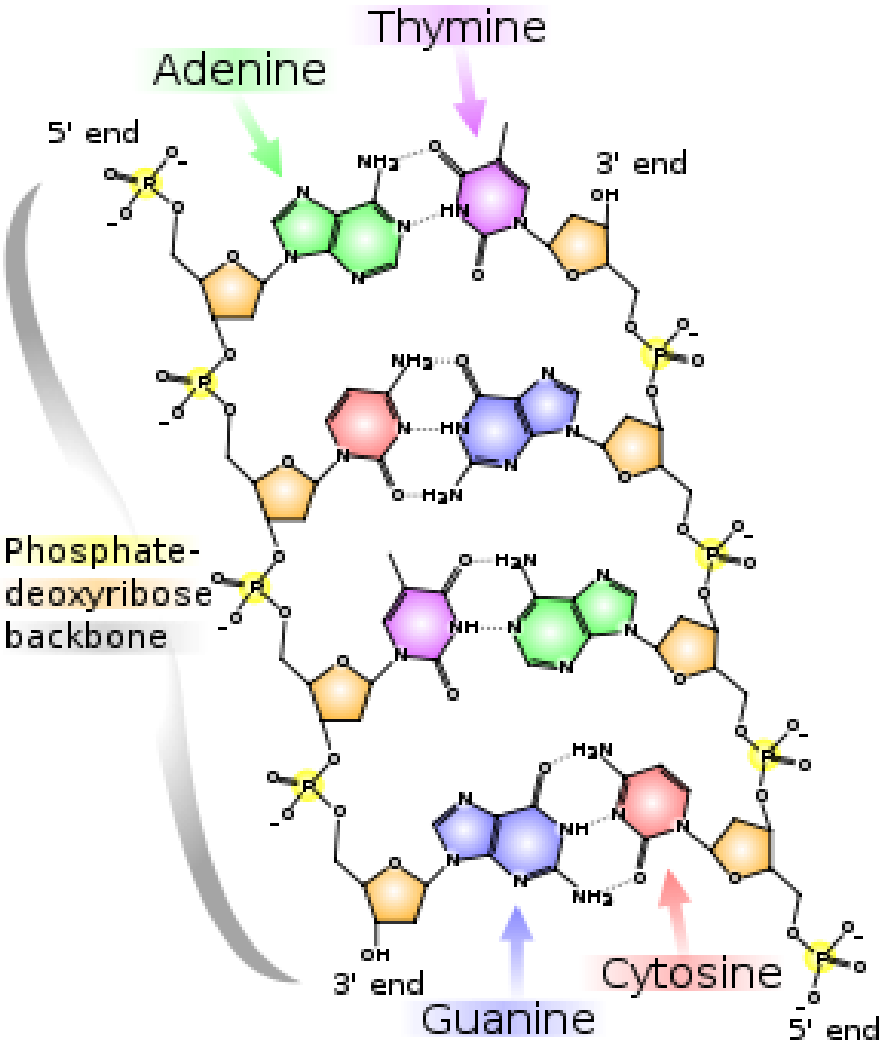
- **Carbohydrate = deoxyribose**
- **Bases :**
  - **Purines**
    - **Adenine (A)**
    - **Guanine (G)**
  - **Pyrimidines**
    - **Cytosine (C)**
    - **Thymine (T)**
- **Double-stranded**
- **Helix**

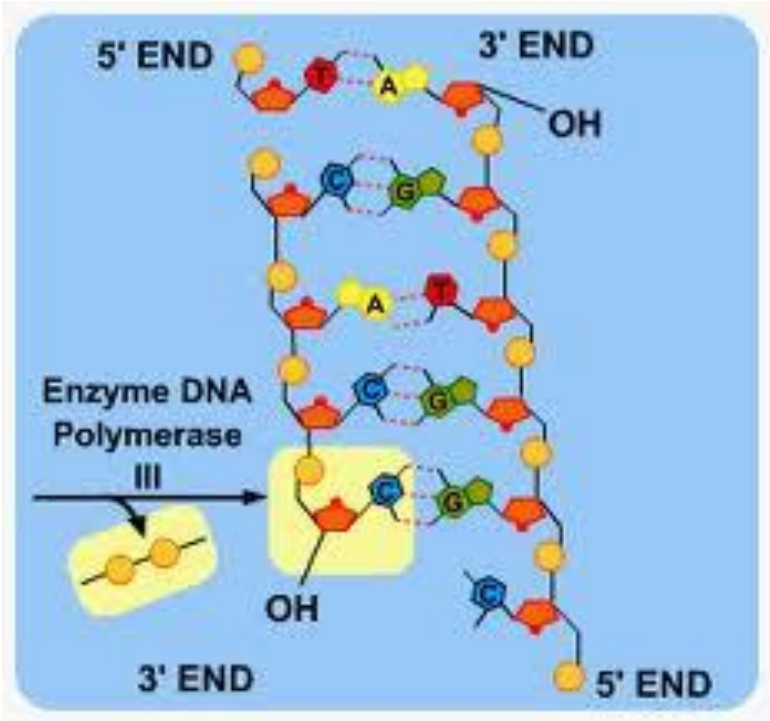
Law of Complementary Base Pairing

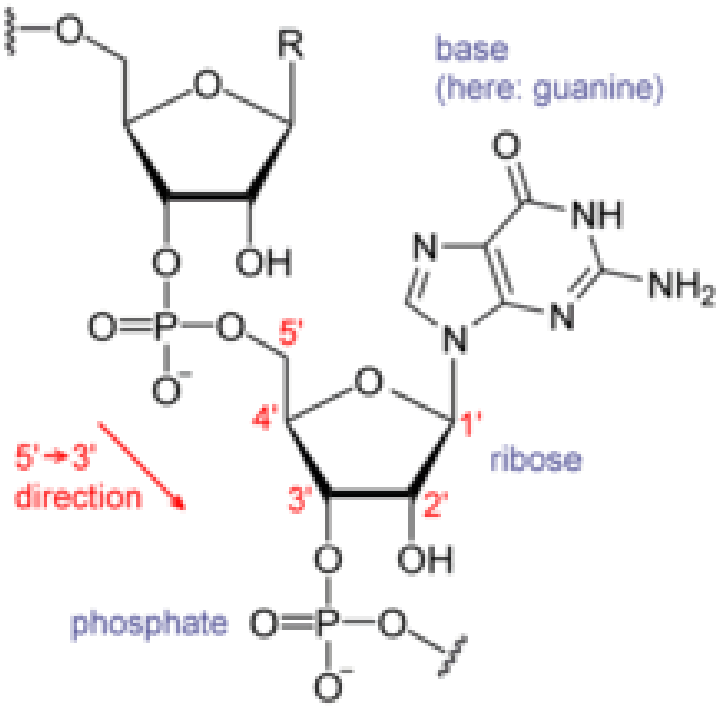
- **A-T (A-U)**
- **C-G**

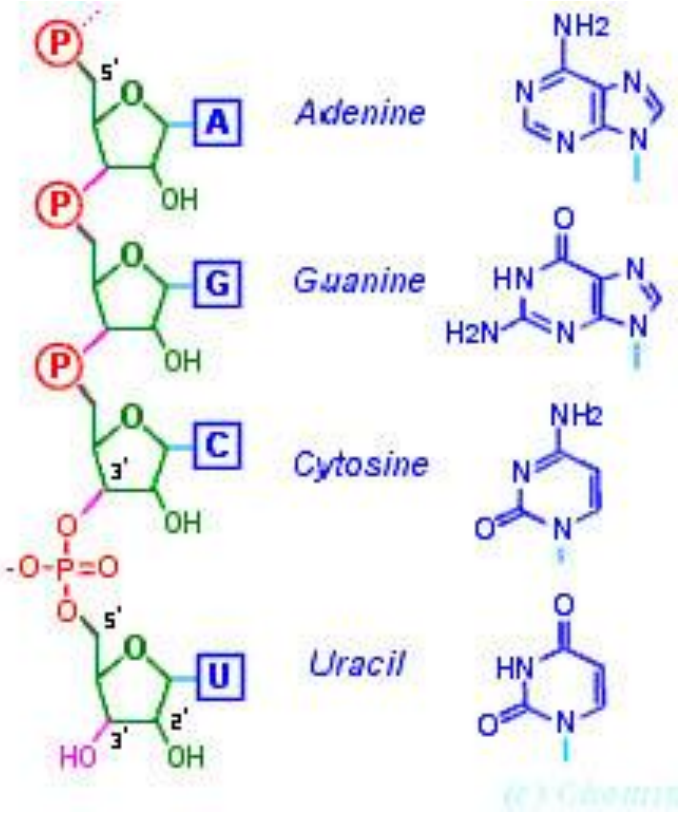
RNA

- **Sugar = Ribose**
- **Bases**
  - **Purines**
    - **Adenine (A)**
    - **Guanine (G)**
  - **Pyrimidines**
    - **Cytosine (C)**
    - **Uracil (U)**


Thymine
Adenine
5' end
3' end
Phosphate-
deoxyribose
backbone
3' end
Guanine
Cytosine
5' end


5' END
3' END
OH
Enzyme DNA
Polymerase
III
OH
3' END
5' END


base
(here: guanine)
ribose
phosphate
5'→3'
direction
5'
4'
1'
3'
2'
OH
NH
NH2
R


A
Adenine
G
Guanine
C
Cytosine
U
Uracil
NH2
HN
H2N
OH
HO

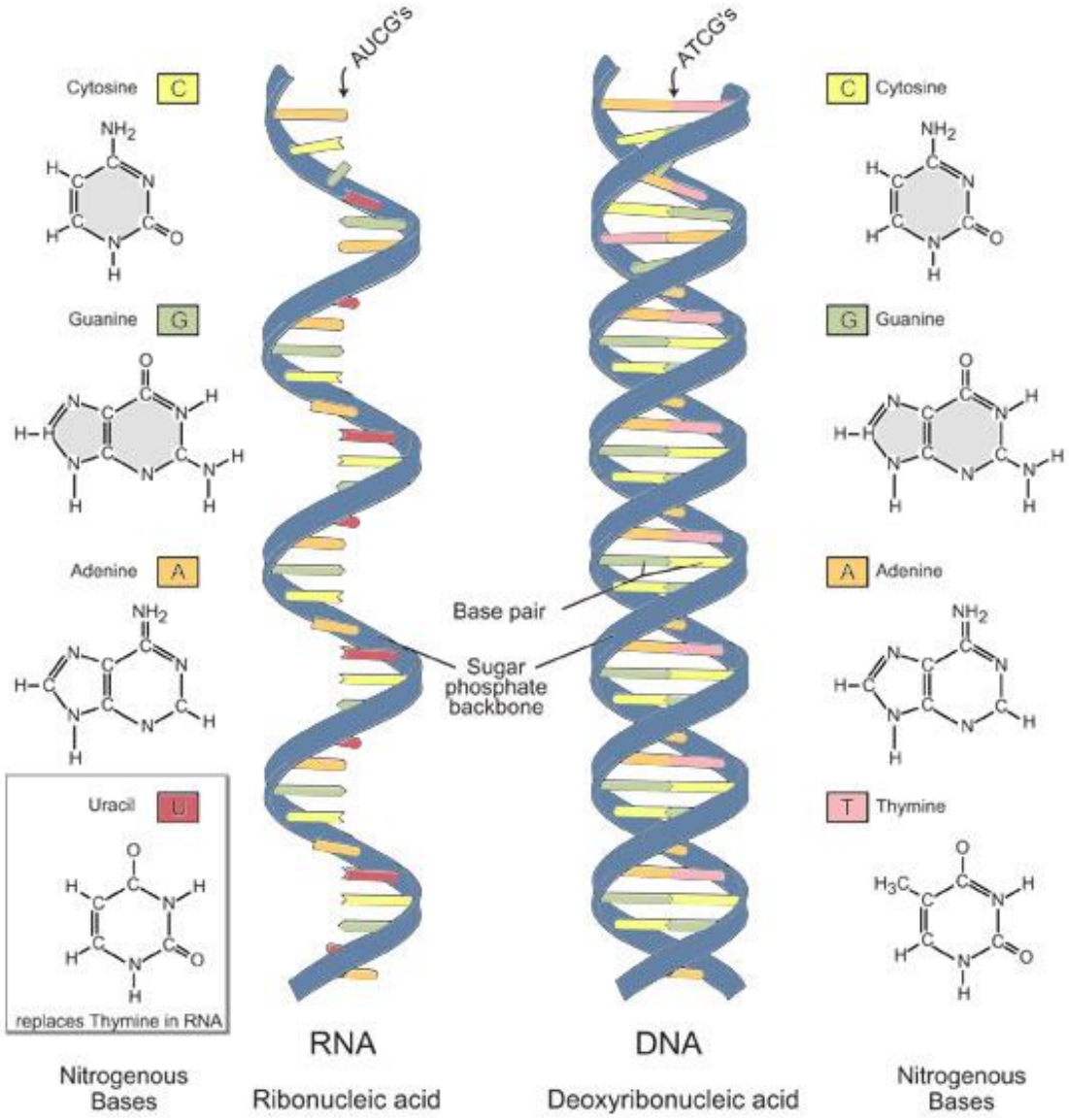
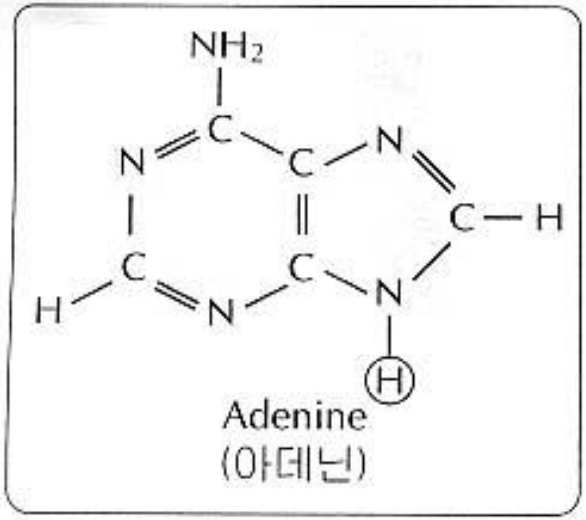
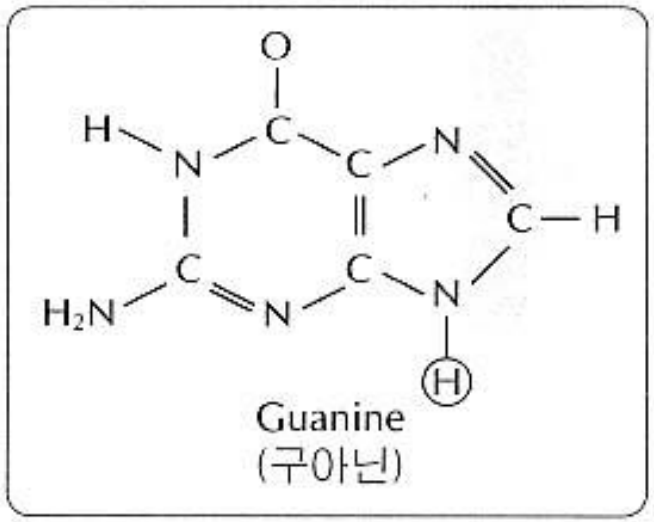
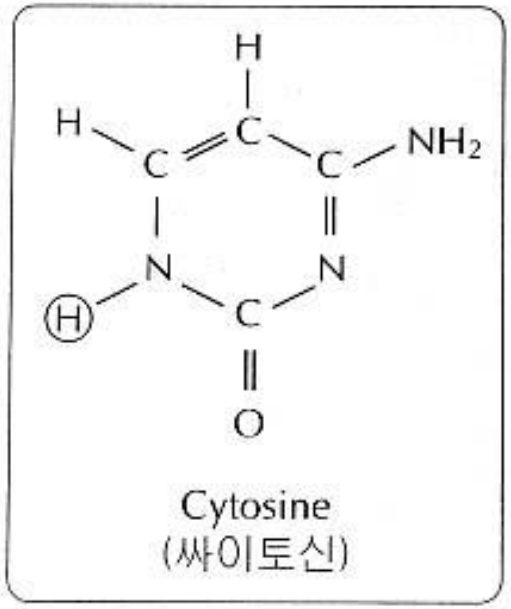
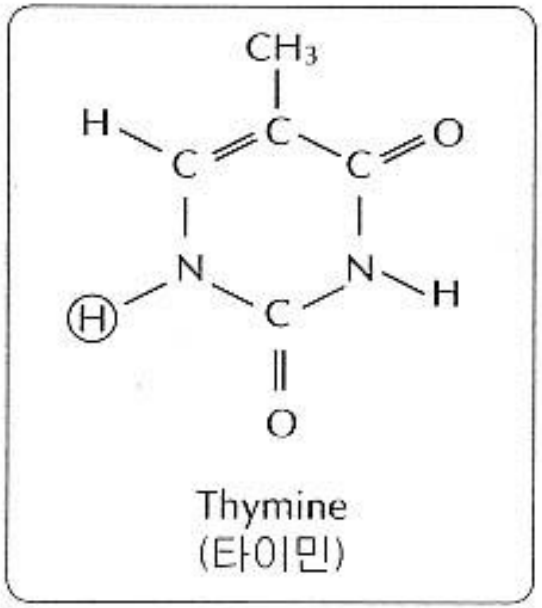


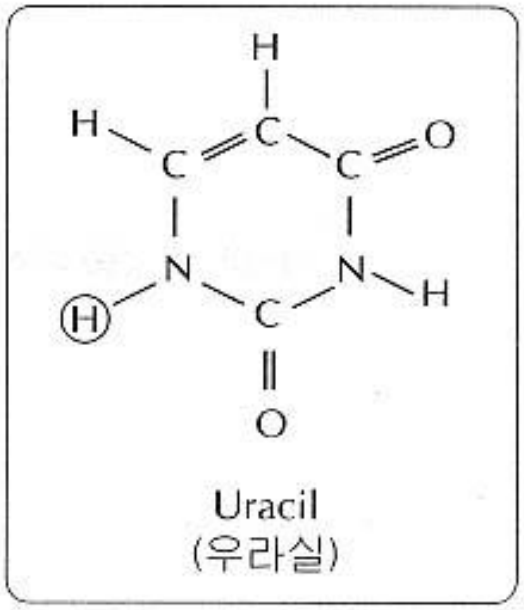
Image adapted from: National Human Genome Research Institute. Talking Glossary of Genetic Terms. Available at: www.genome.gov/Pages/Hyperion//DIR/VIP/Glossary/Illustration/rna.shtml.









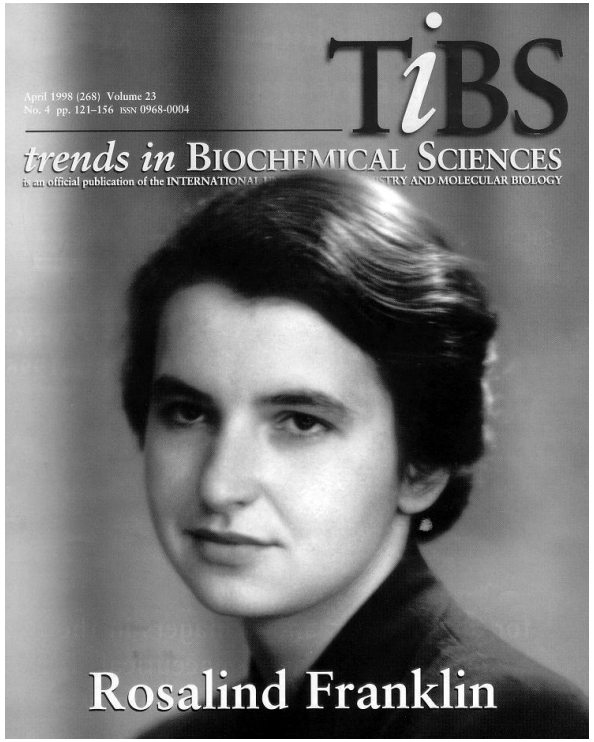


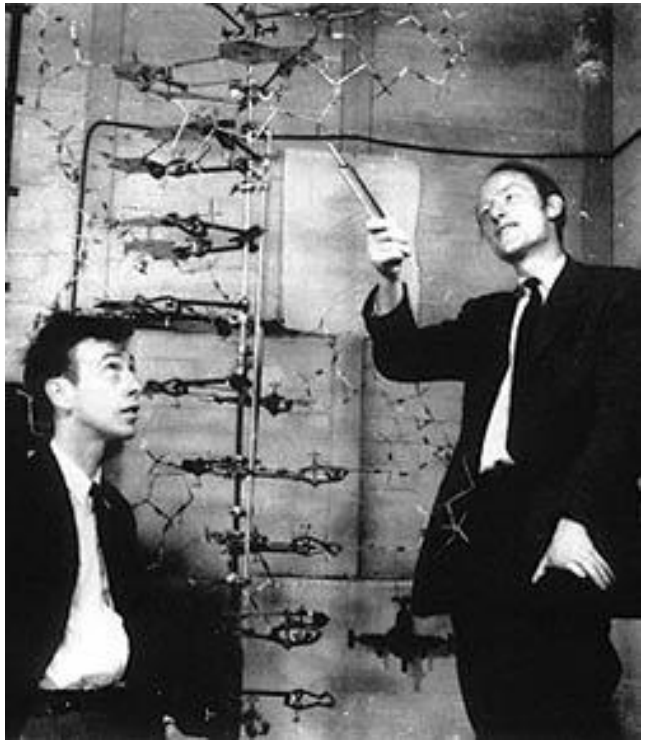
핵산 염기의 종류

핵산을 형성하는 염기들의 화학구조
(단, Ⓗ에 해당하는 수소는 라이보즈 또는 디옥시라이보즈와 결합시 탈락된다.)

특징	DNA	RNA
당	디옥시라이보즈	라이보즈
N-base	A, G, C, T	A, G, C, U
뉴클레오타이드의 수	〈 45,000,000	100 ~ 50,000
분자의 형태	이중나선	사슬의 수소결합에 따라 변화
기능	유전 정보의 저장	유전 정보에 따른 단백질 합성

RNA와 DNA의 비교





Watason, Crick, Wilkins

지구와 초승달이 뜨는 상황