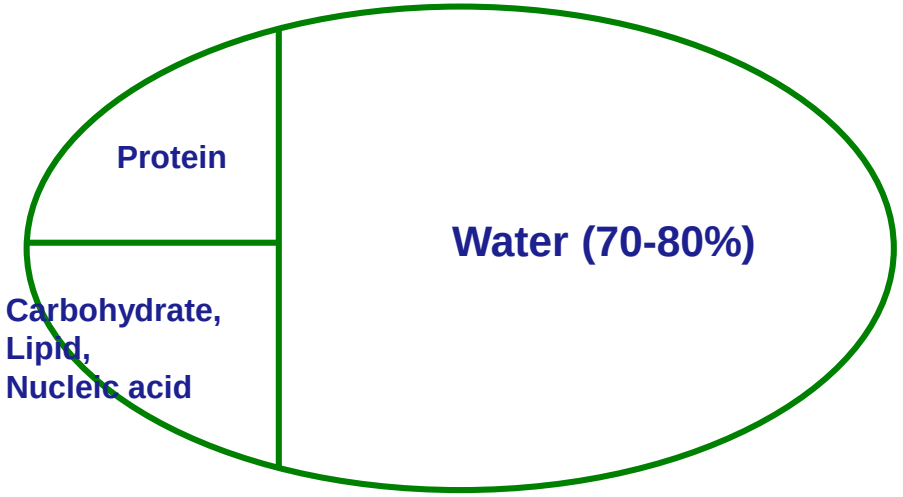
Chapter 3

# Molecular Components of Cells

# Molecular Components of Cells

- Chemical composition
  - C, H, O, N and small amount of other elements
- Molecular building blocks
  - Lipids
  - Carbohydrates
  - Proteins
  - Nucleic acids
    - DNA
    - RNA



# Atoms, Ions, and Molecules

- Atoms
  - Biologically important atoms

    ---- C, H, O, N, S, P, Na, K, Ca, Cl

- Ions
  - Biological importance: electrical impulse, ion balance
    - Ca2+, Na+, K+, Cl-

- Molecules
  - Generated from chemical bonding of atoms

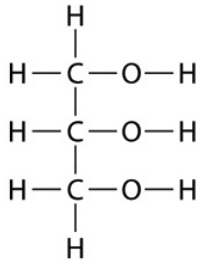
# Subunits of Biological Molecules

| Class of Molecules | Examples | Repeating Unit |
|---|---|---|
| Lipid | Fats, oils | Glycerol, fatty acid |
| Carbohydrate | Sugars, starch, cellulose | Simple sugars |
| Nucleic acid | DNA, RNA | Nucleotide |
| Proteins | Enzymes | Amino acids |

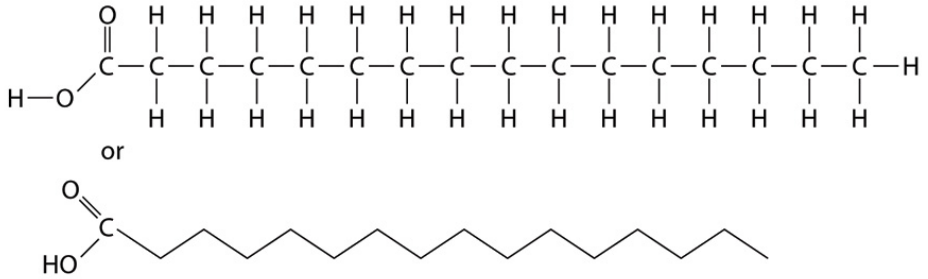
# Lipids

- Hydrophobic fats, oils, and cholesterol etc.
- High energy C-H, C-C bonds → good energy storage
- Fats : glycerol + fatty acids

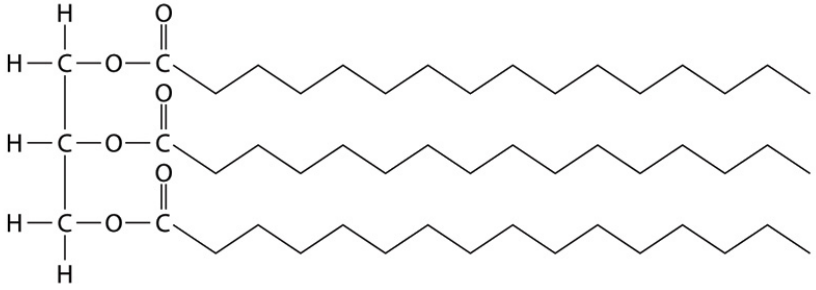
**A.** Glycerol



**B.** Fatty acid (palmitic acid)




**C.** A fat

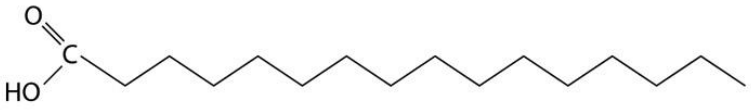


Triglyceride

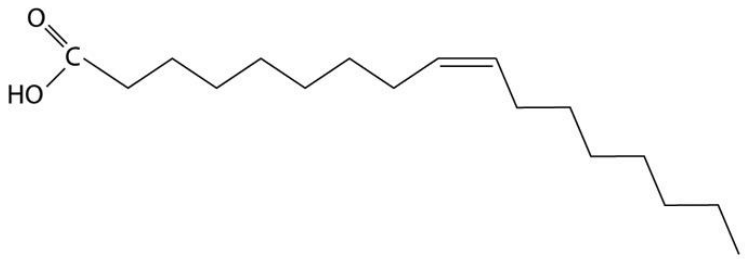
# Lipids

- Fatty acid
  - Saturated: tight packing → solid at room temperature
  - Unsaturated: more than one cis-double bond → liquid

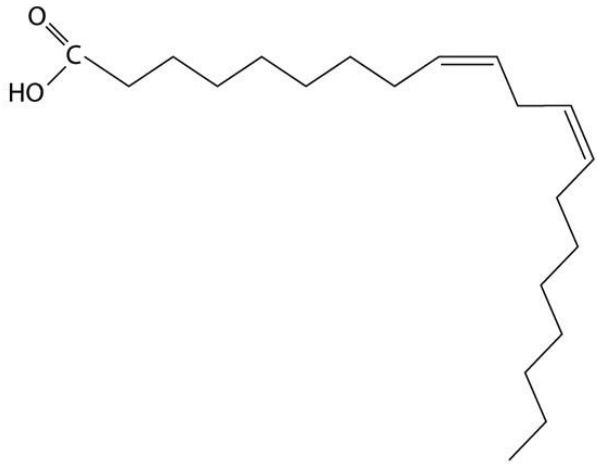
**A.** A saturated fatty acid




**B.** A monounsaturated fatty acid

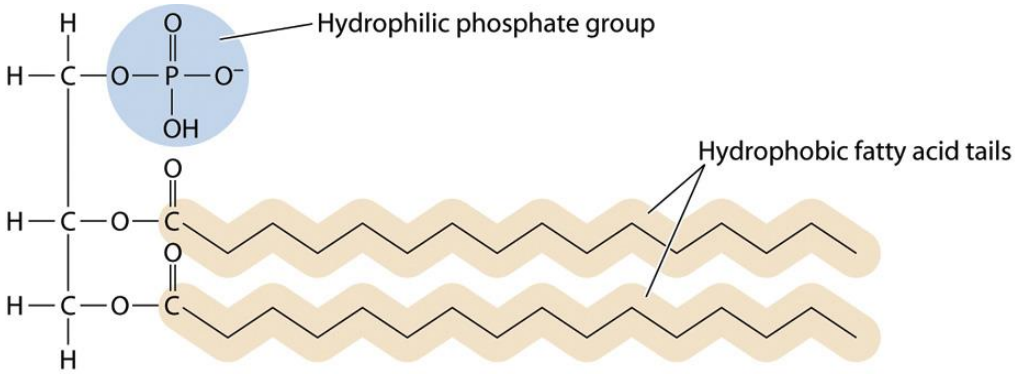



**C.** A polyunsaturated fatty acid



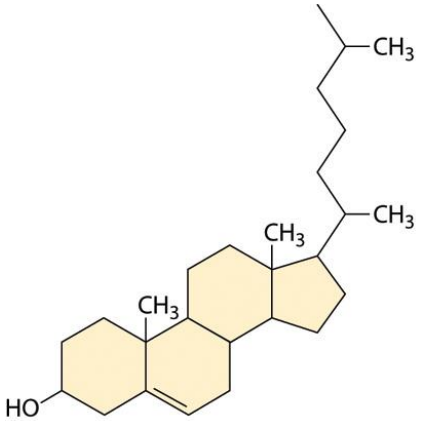
# Lipids

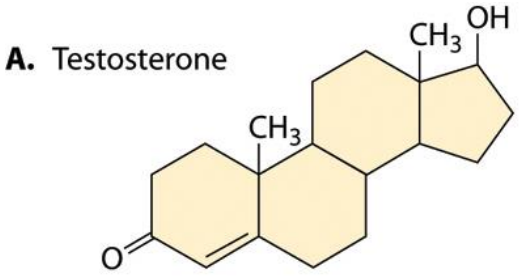
- Phospholipid
  - Major component of cellular membrane
  - Glycerol backbone
  - two fatty acids (hydrophobic)+ phosphate (hydrophilic)

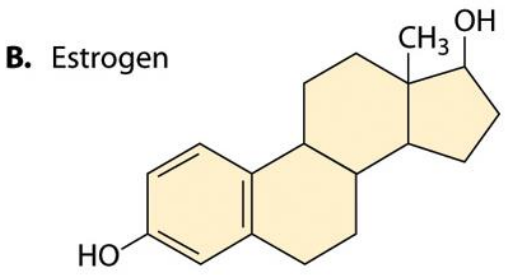


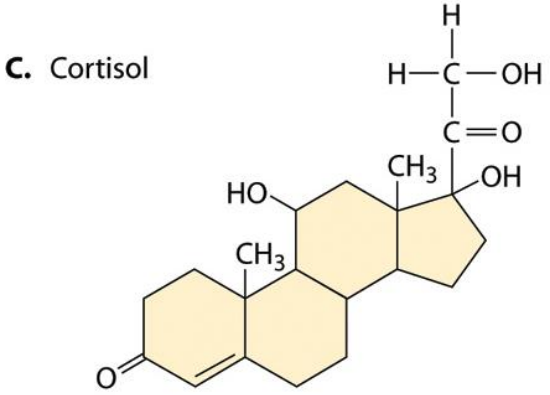
# Lipids

- Sterols
  - Cyclic hydrocarbon compounds
  - Cholesterol
    - Component of animal cell membranes
      - decrease membrane fluidity
    - Starting material for steroid hormones and bile synthesis



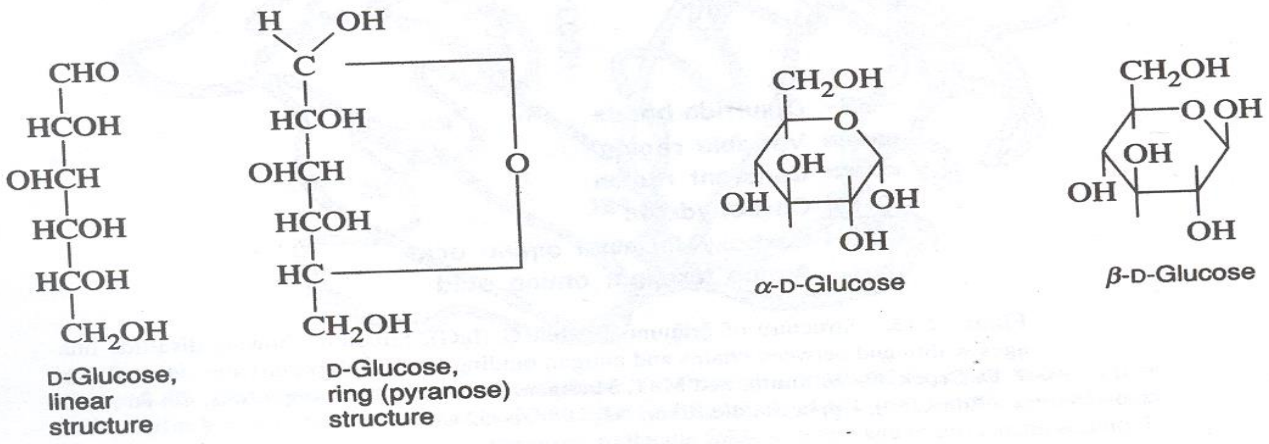
# Carbohydrates

- C : H : O = 1 : 2 : 1
- Simple sugars (monosaccharide)

- Disaccharide
  - sucrose (glucose + fructose)
  - lactose (galactose + glucose)
- Polysaccharide
  - pectin, starch, cellulose --- from glucose
  - agar, carrageenan (thickener for ice cream)

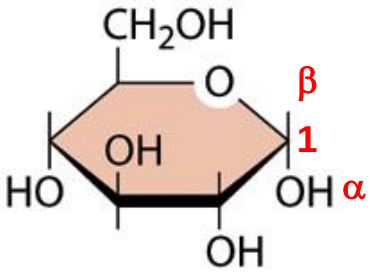
# Linear and Ring Structure

- Monosaccharide may be present in the form of a linear or ring structure.
- In solution, it is in the form of a ring structure.

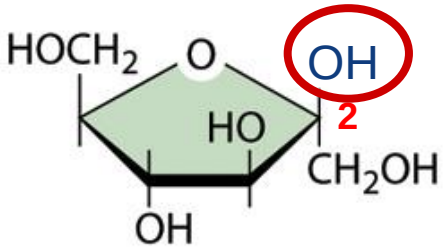


# Mono- and Disaccharides

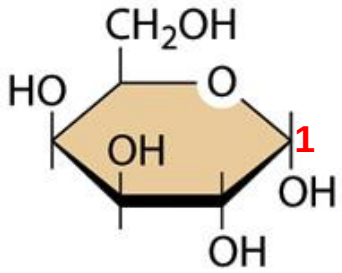
**A.** Simple sugars




Glucose (α form)

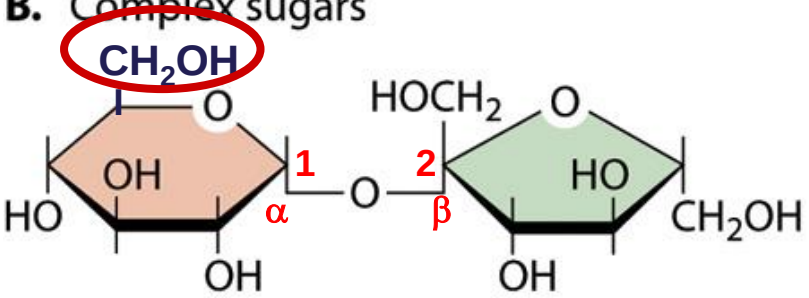



Fructose (β form)

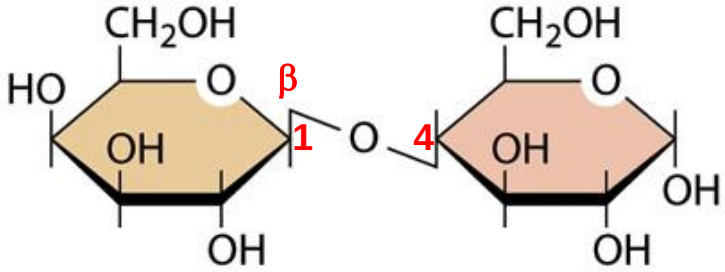



Galactose (α form)

**B.** Complex sugars



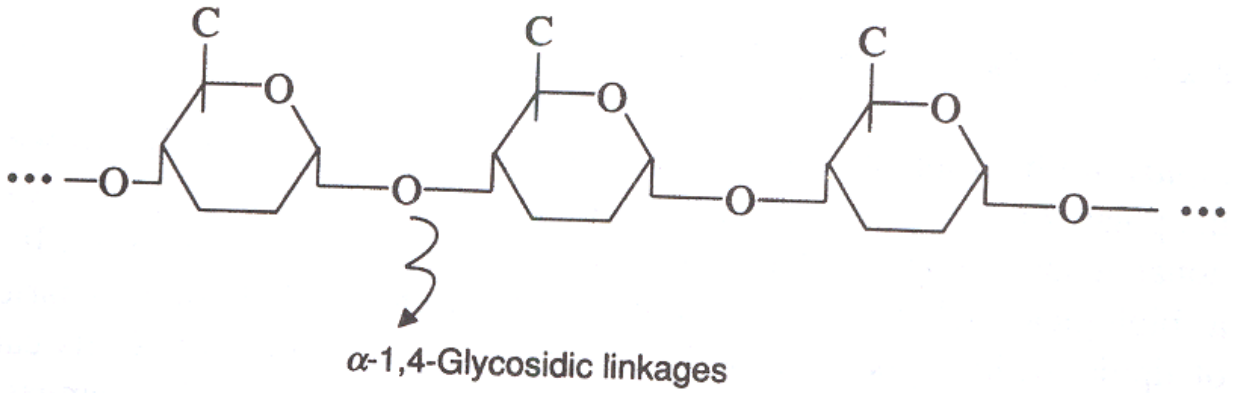

Sucrose (table sugar)
Glucose + fructose



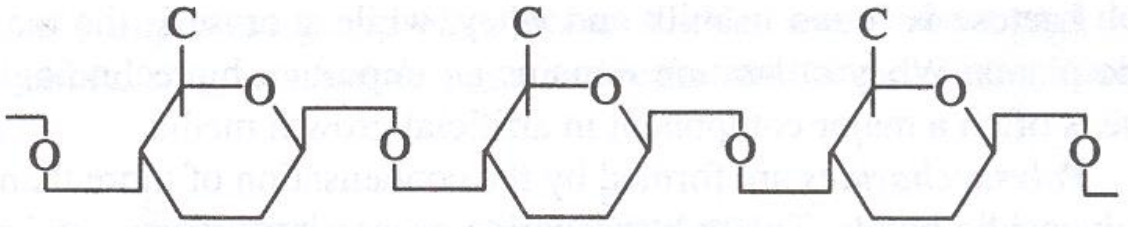

Lactose (milk sugar)
Galactose + glucose

# Polysaccharides

- Amylose ($\alpha$-1,4-Glycosidic linkage)

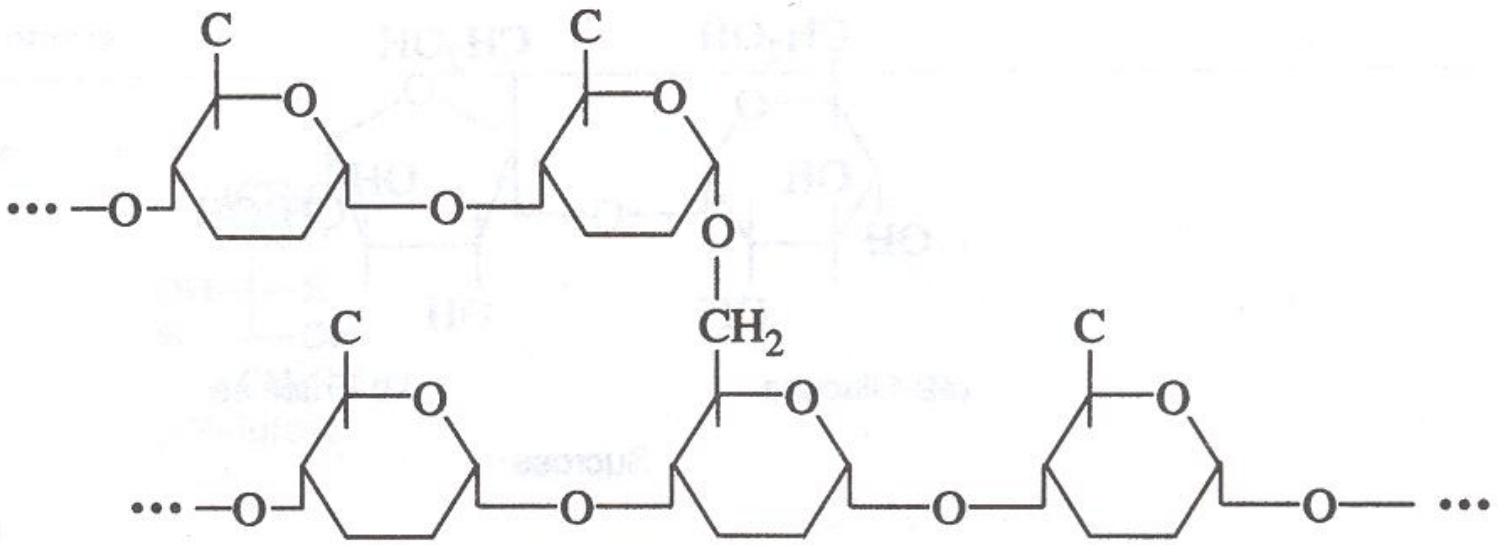



- Cellulose ($\beta$-1,4-Glycosidic linkage)



# Polysaccharides

- Amylopectin (branched chain, $\alpha$-1,6-Glycosidic linkage)



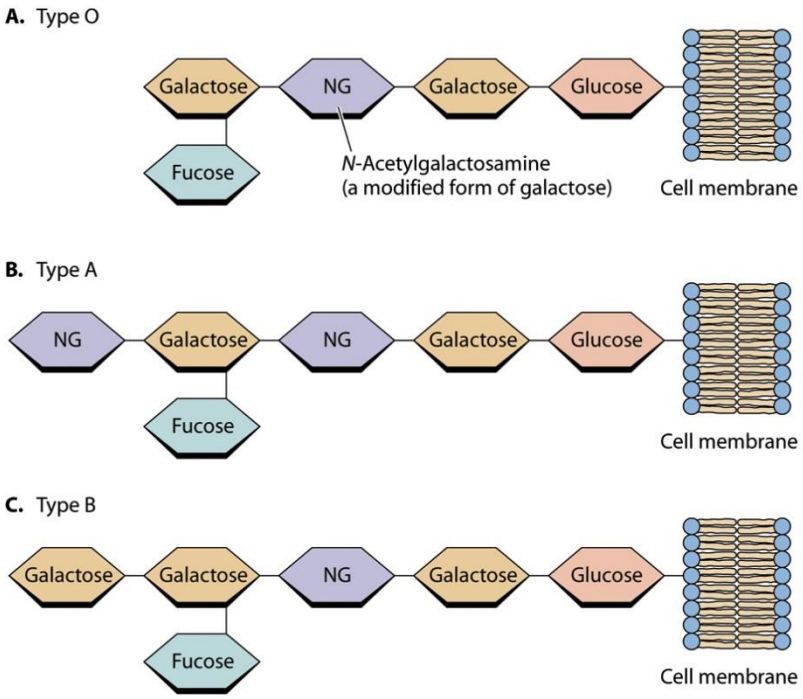
# Roles of Carbohydrates I

- Carbohydrates in energy metabolism
  - Plant
    - Glucose synthesis by photosynthesis

      $6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$
    - Starch for energy storage
    - cellulose for structural compound
  - Animals
    - Intake glucose from food
    - Glycogen for energy storage

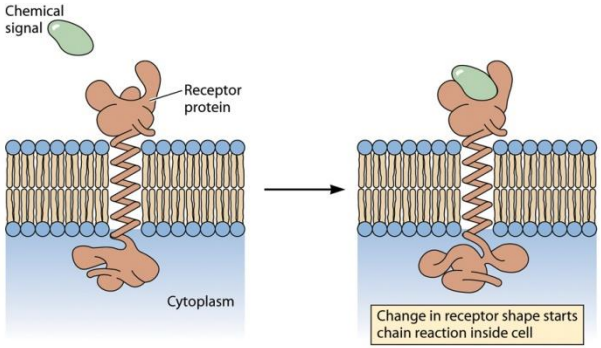
# Roles of Carbohydrates II

- Carbohydrates in molecular recognition
  - Often found connected to other molecules on the outsides of cells --- cellular recognition, cell signaling, cell adhesion
  - e.g. blood typing : sugar chains in the membrane of RBC



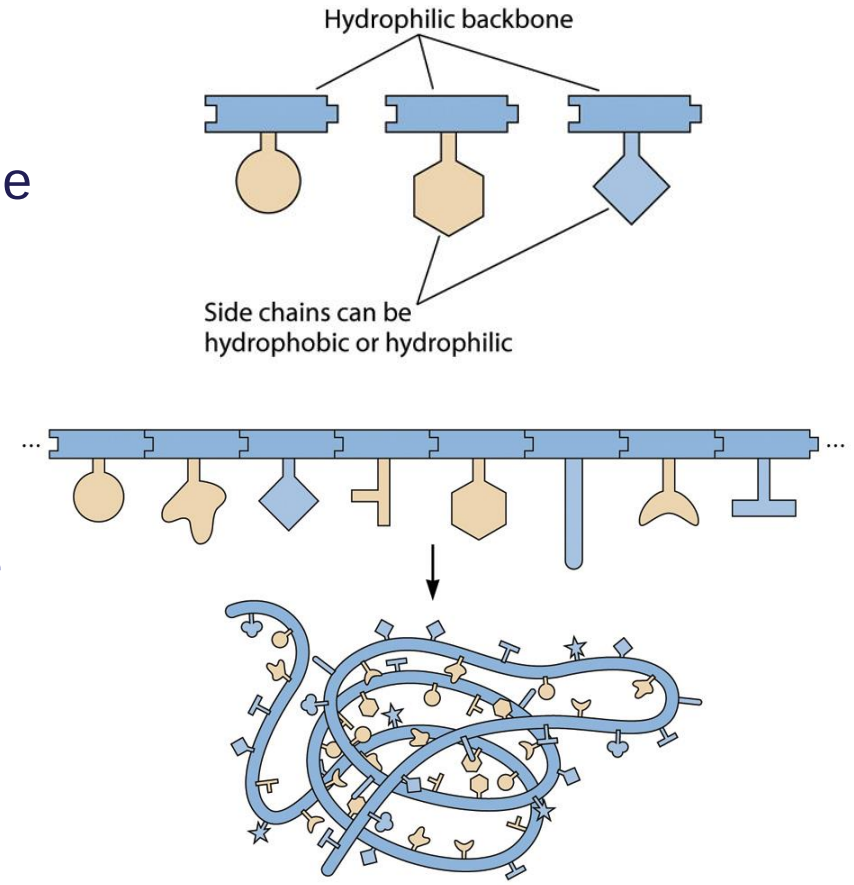
# Proteins

- Roles of proteins
  - Most of the cellular functions
    - Enzymes : chemical reactions
    - Receptors : signal transduction
    - Antibody : recognition of foreign molecules and trigger immune responses
    - Transporters : e.g. hemoglobin for oxygen
    - Structural proteins : keratin (hair and nails), actin and myosin (muscle)
  - Diversity of organism
    - Due to the organization of proteins within an organism
      ---- particularly structural proteins and those that synthesize additional structural body components



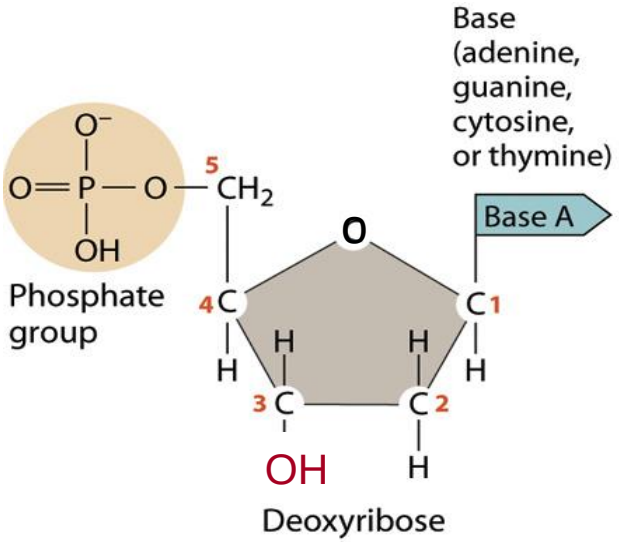
# Proteins

- Amino acids
  - Building blocks of proteins
  - Hydrophilic backbone + 20 side chains
- Polypeptide
  - Amino acid chains linked by peptide bond
- Three-dimensional structure
  - Determines protein function
  - Determined by amino acid sequence

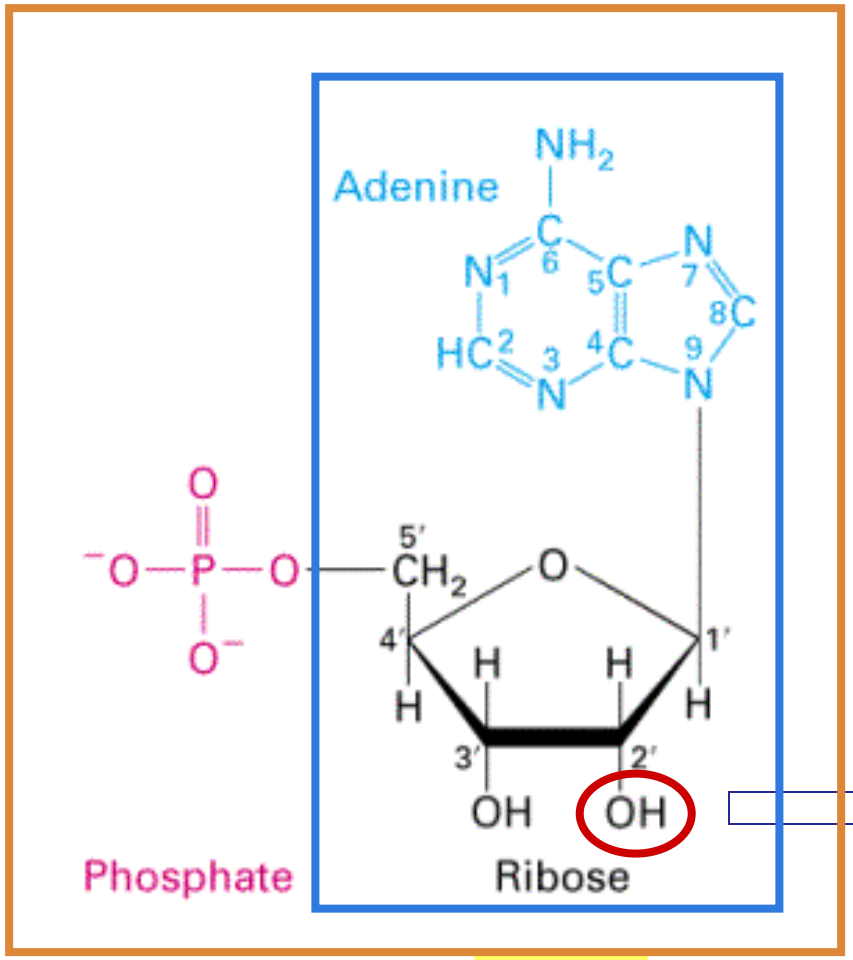


# Nucleic acids

- Nucleotides
  - Building blocks of nucleic acids
  - (deoxy)ribose + phosphate group + 4 bases
  - Bases: adenine (A), guanine (G), cytosine (C), thymine (T)
- Terminology
  - Base
  - Nucleoside : sugar + base
  - Nucleotide : sugar + base
    + phosphate



# Primary Structure : Nucleotides




| Base | Nucleoside | Nucleotide |
|---|---|---|
| Adenine | Adenosine | Adenylate |
| Guanine | Guanosine | Guanylate |
| Cytosine | Cytidine | Cytidylate |
| Thymine (D) | Thymidine | Thymidylate |
| Uracil (R) | Uridine | Uridylate |

**Purine**

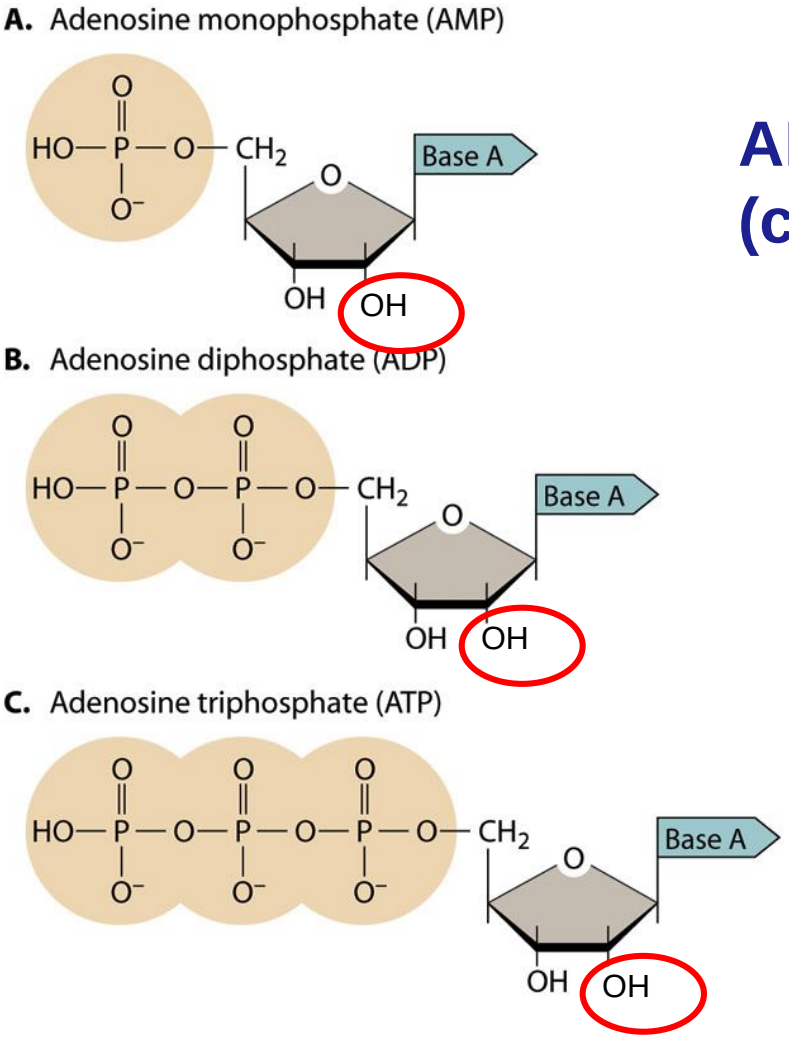
**Pyrimidine**

RNA

H

DNA

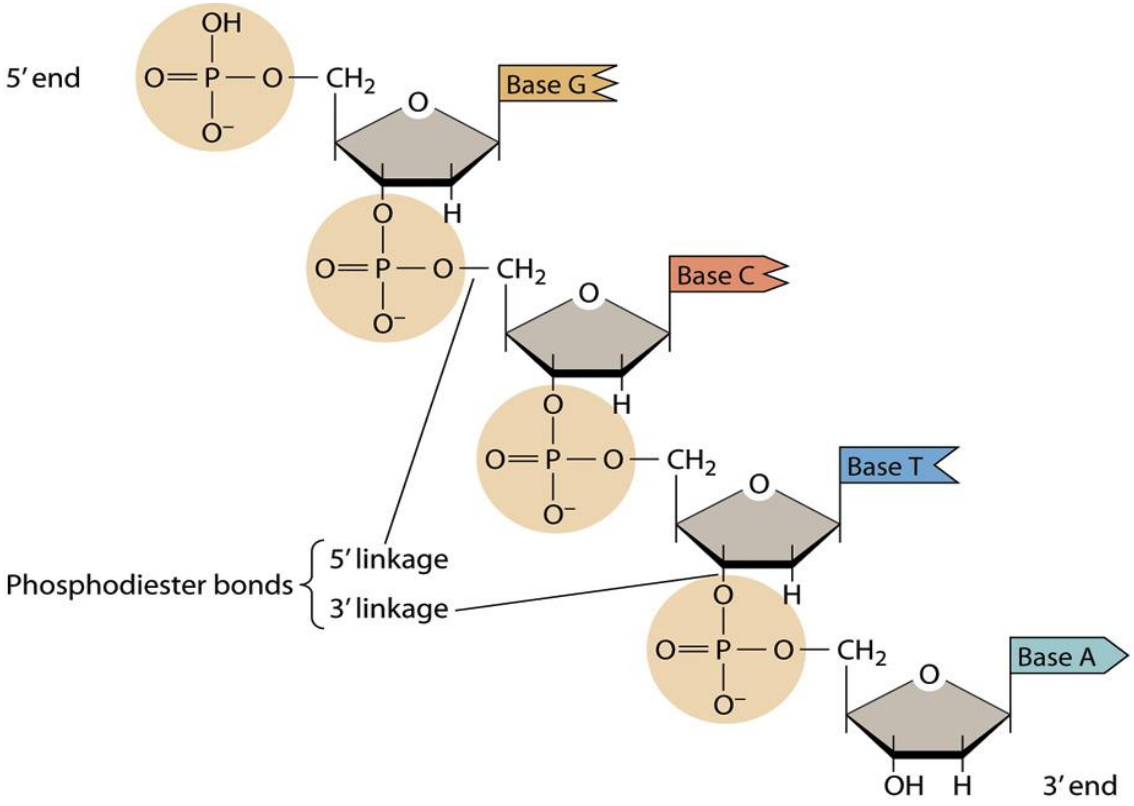
# AMP, ADP, ATP




**AMP = Adenylate (cf. dAMP)**

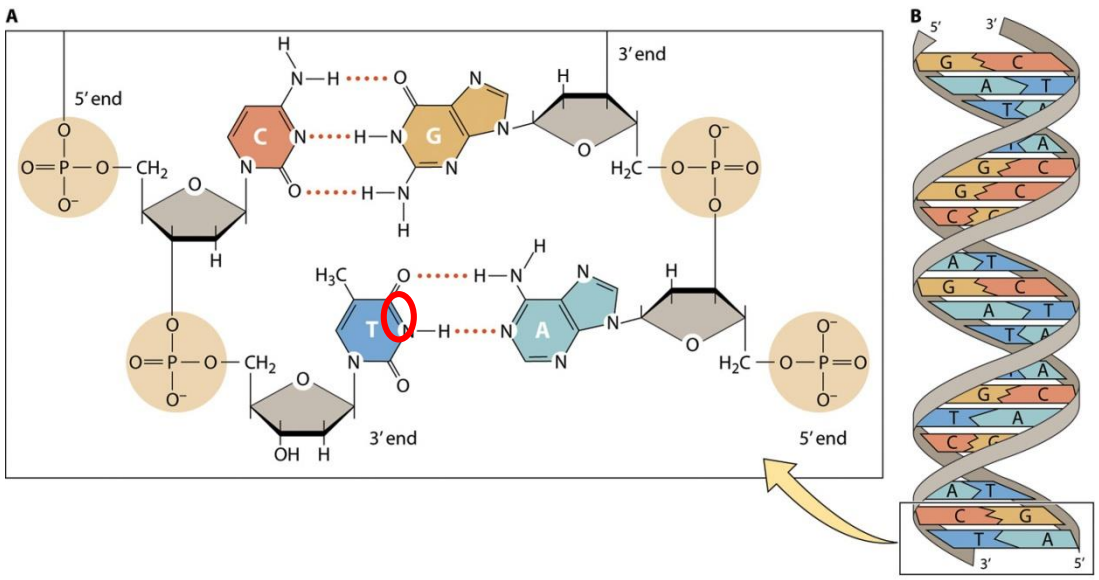
# Nucleotide Chains

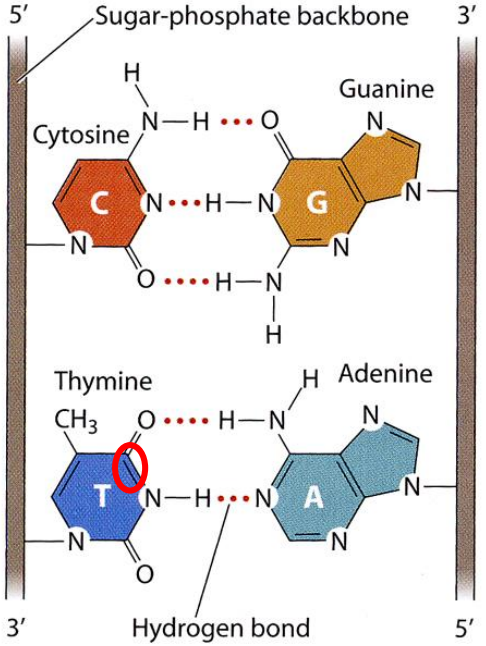
- Linkage of 5’ carbon to 3’ carbon through phosphodiester bond

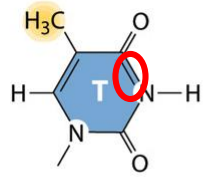


# Nucleotide Chains

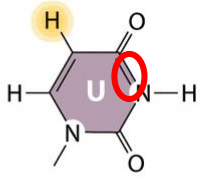
- Base pairing
  - C≡G, T=A : hydrogen bonding
  - Complementary base pairs
  - Antiparallel strand in DNA molecule



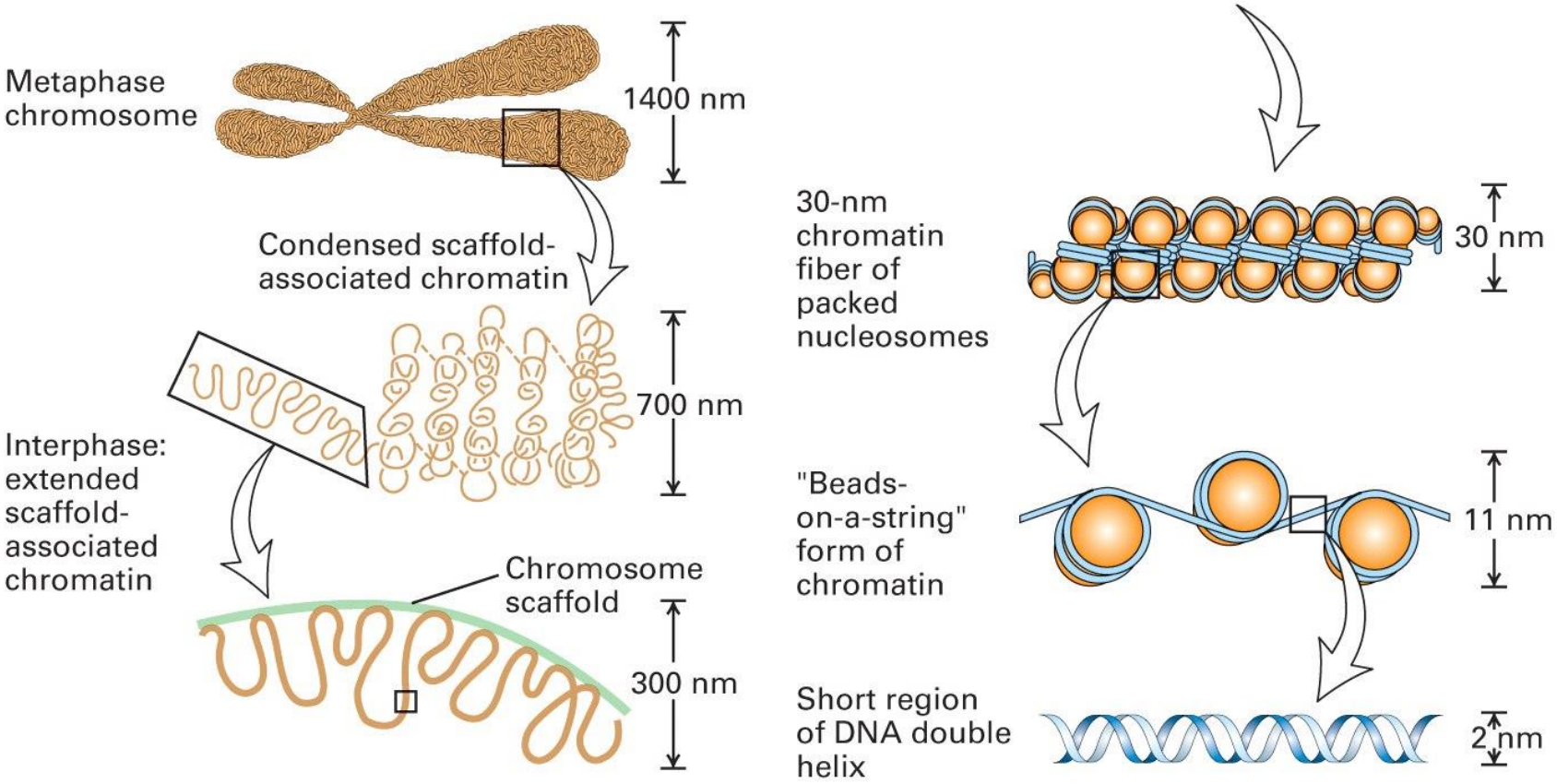
Thymine



Uracil

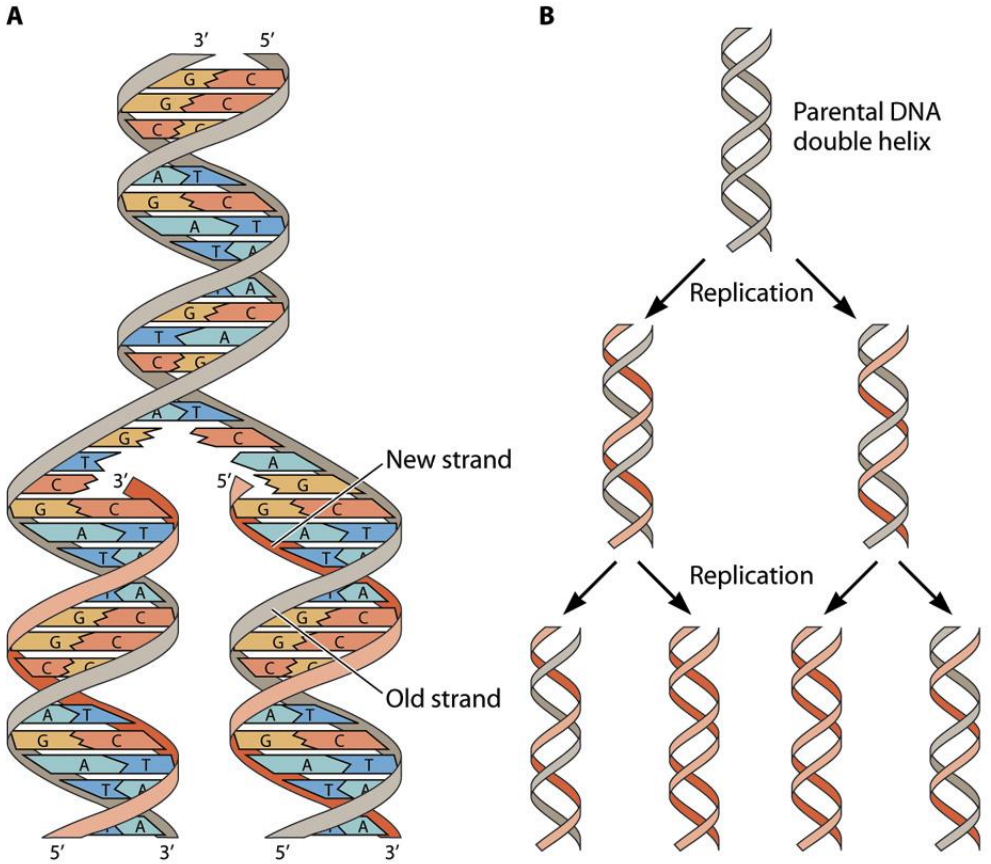
# Chromosome

- Tightly packed complex of DNA and histone proteins



# DNA Replication

- Synthesis of a complementary strand using the other strand as a template
- DNA polymerase



# Expression of Genetic Information