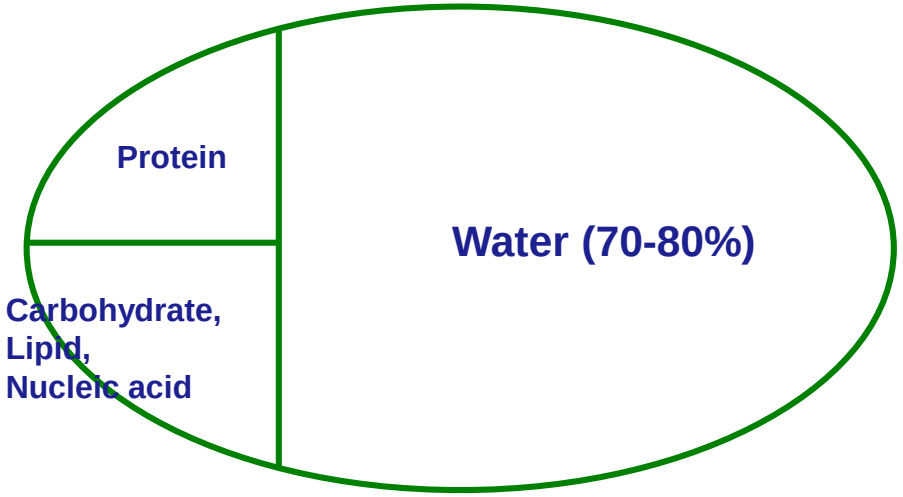
Chapter 3

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

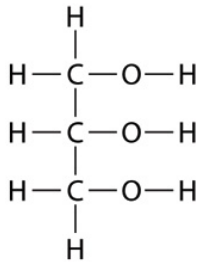
Subunits of Biological Molecules

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

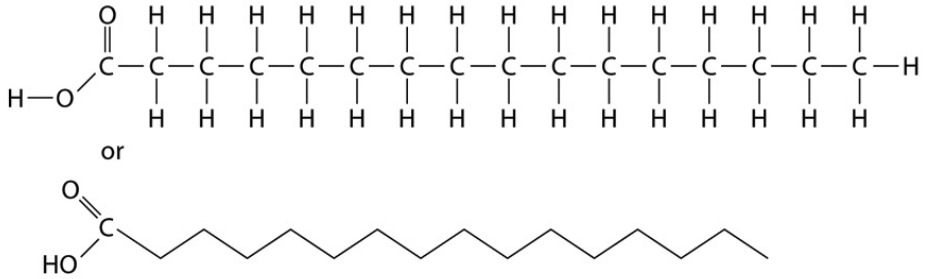
Lipids

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

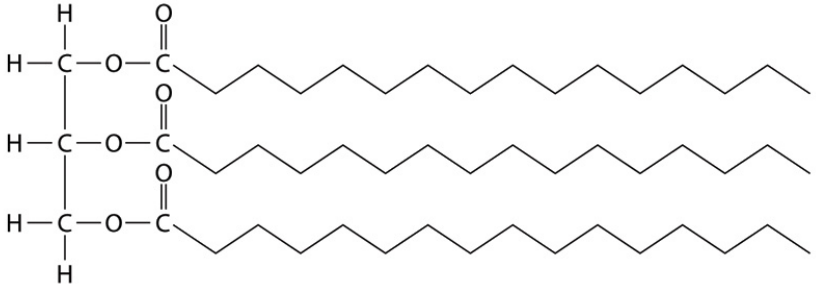
A. Glycerol



B. Fatty acid (palmitic acid)



C. A fat

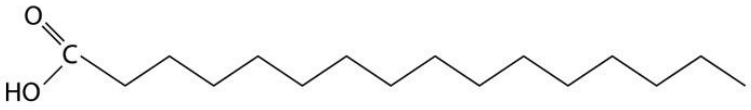


Triglyceride

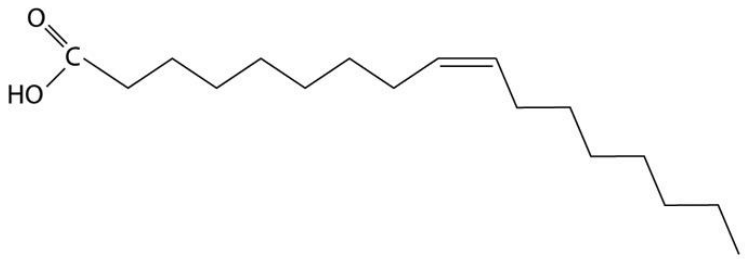
Lipids

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

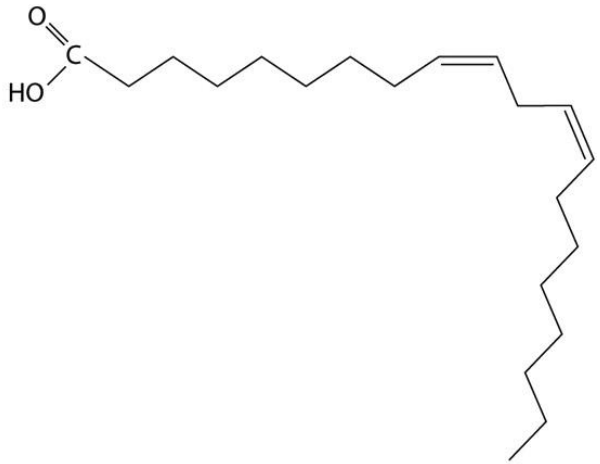
A. A saturated fatty acid



B. A monounsaturated fatty acid

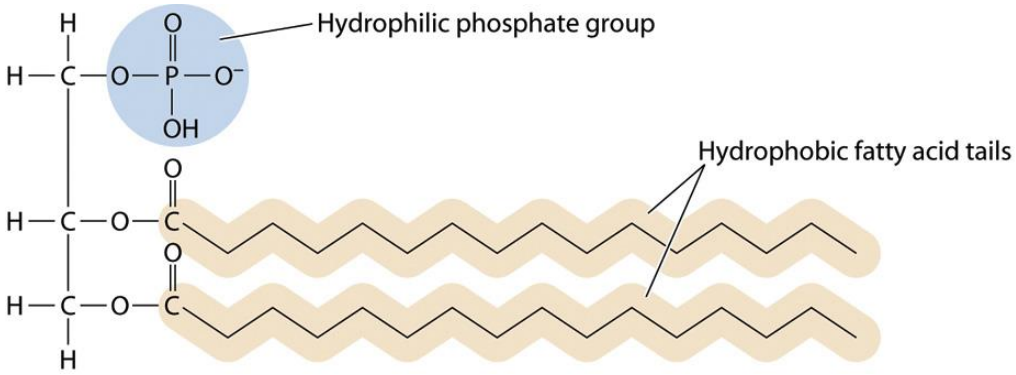


C. A polyunsaturated fatty acid



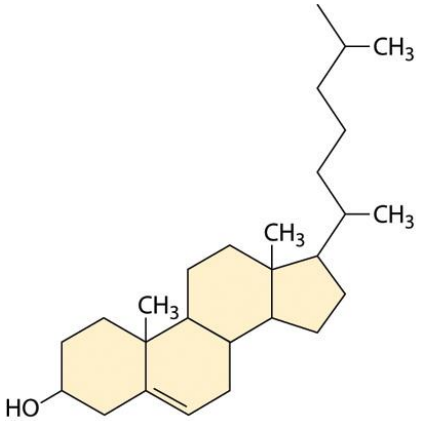
Lipids

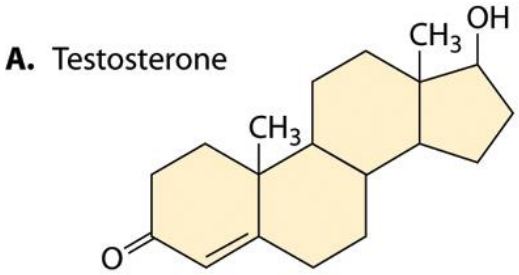
- Phospholipid
  - Major component of cellular membrane
  - Glycerol backbone
  - two fatty acids (hydrophobic)+ phosphate (hydrophilic)

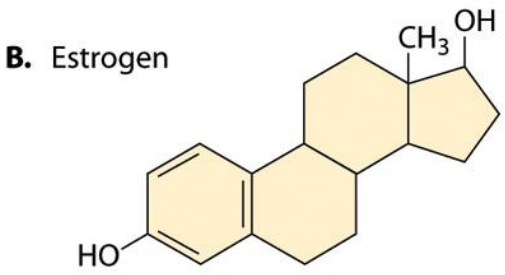


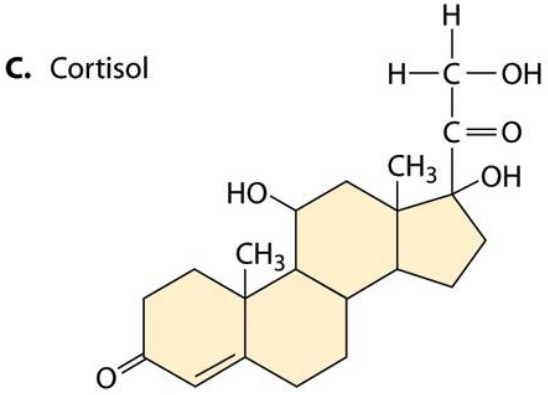
Lipids

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









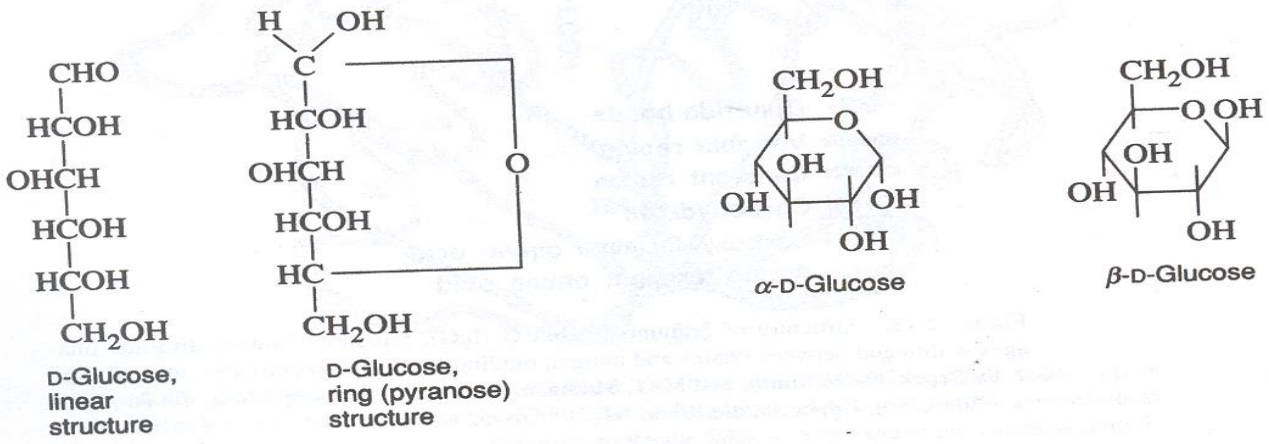
Carbohydrates

- 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)

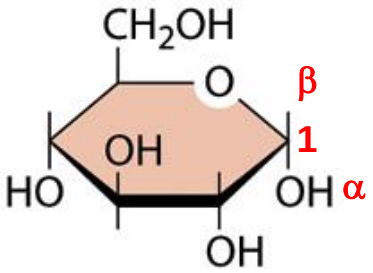
Linear and Ring Structure

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

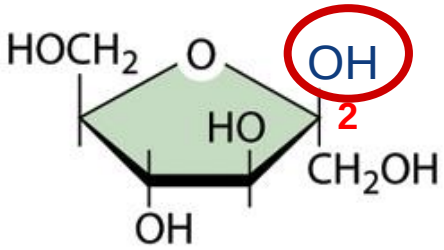


Mono- and Disaccharides

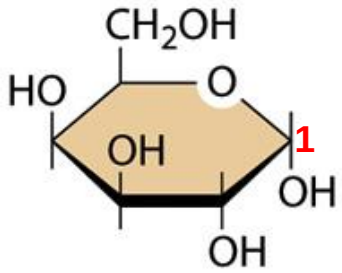
A. Simple sugars



Glucose (α form)

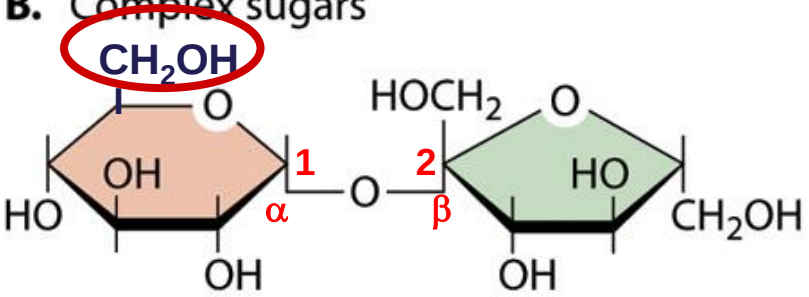


Fructose (β form)

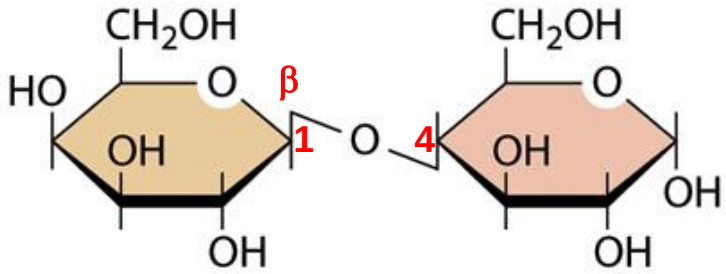


Galactose (α form)

B. Complex sugars



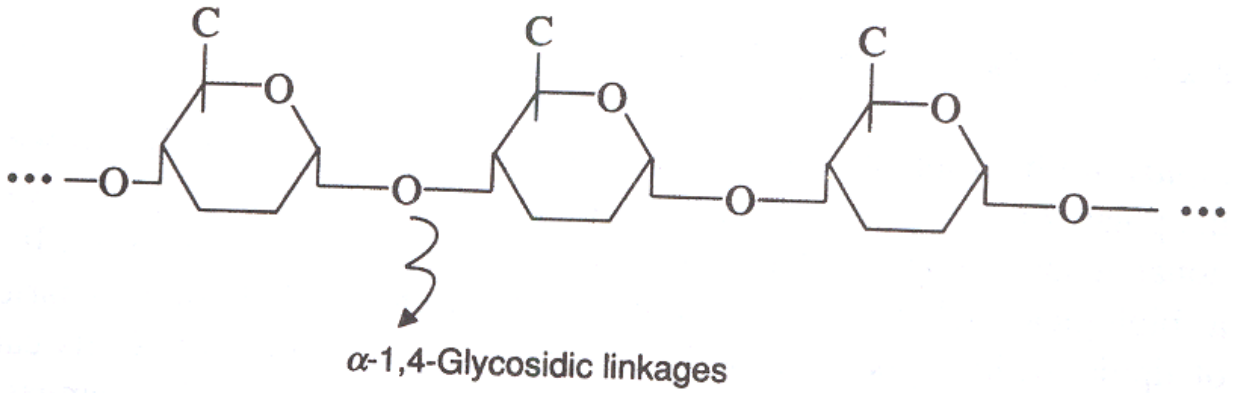
Sucrose (table sugar)
Glucose + fructose



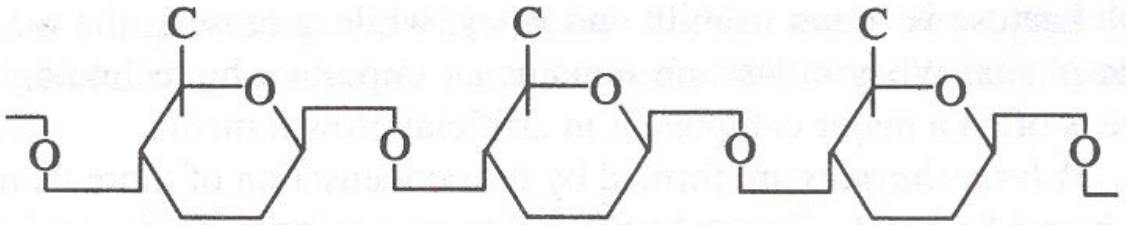
Lactose (milk sugar)
Galactose + glucose

Polysaccharides

- Amylose (α-1,4-Glycosidic linkage)

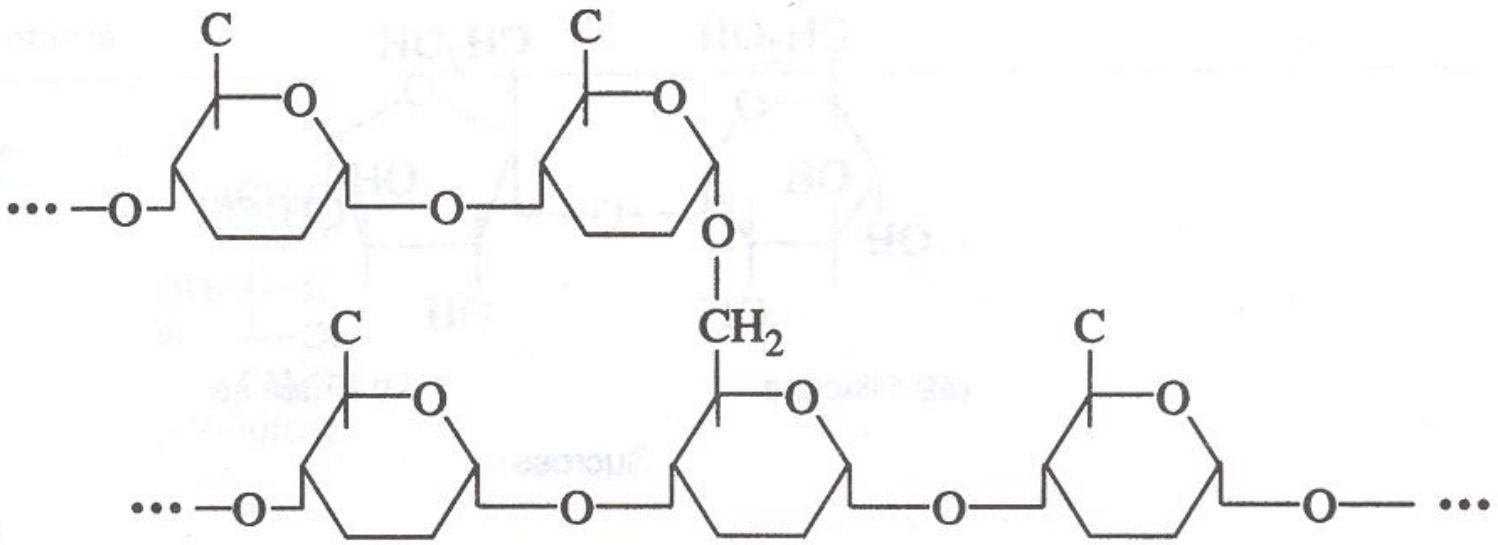


- Cellulose (β-1,4-Glycosidic linkage)



Polysaccharides

- Amylopectin (branched chain, α-1,6-Glycosidic linkage)



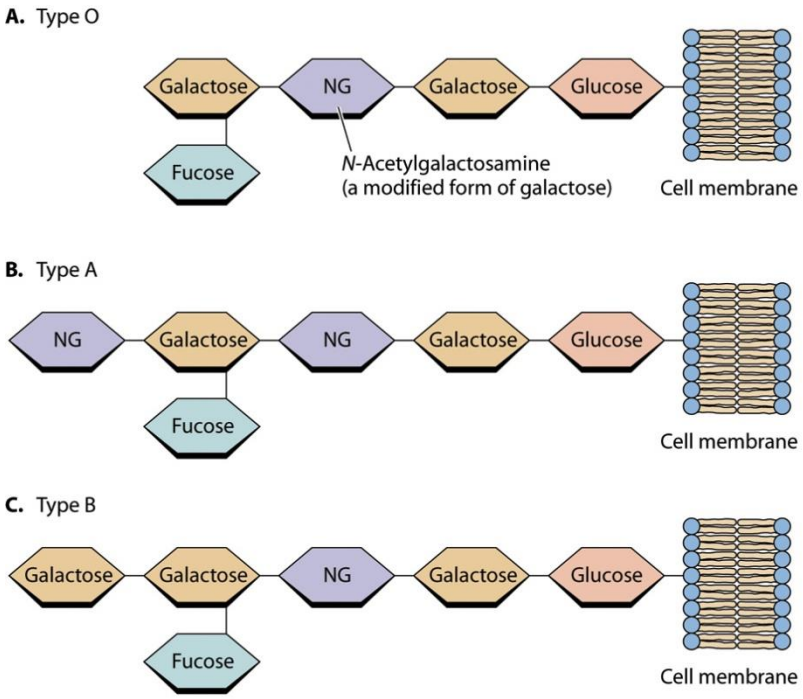
Roles of Carbohydrates I

- 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

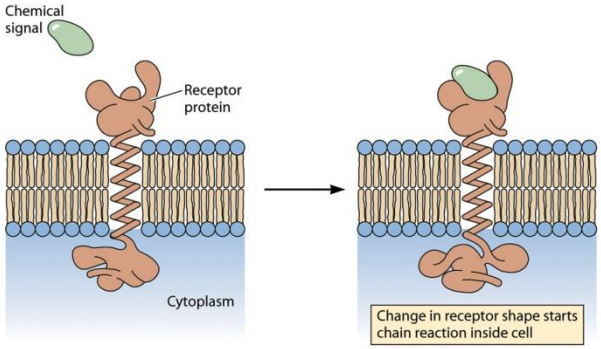
Roles of Carbohydrates II

- 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



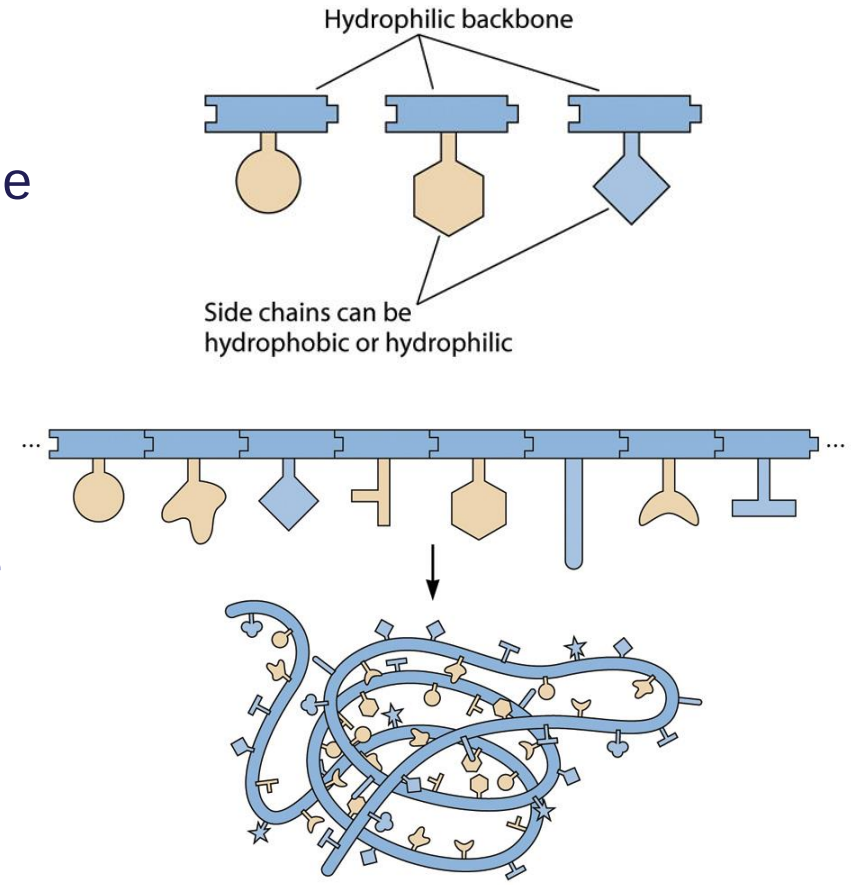
Proteins

- 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



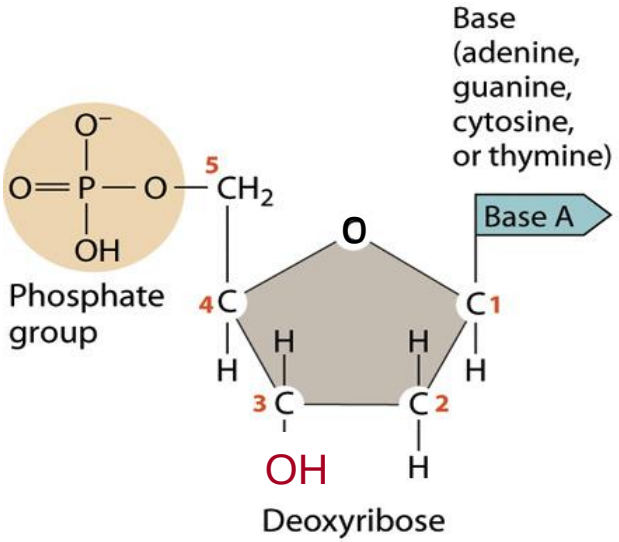
Proteins

- 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

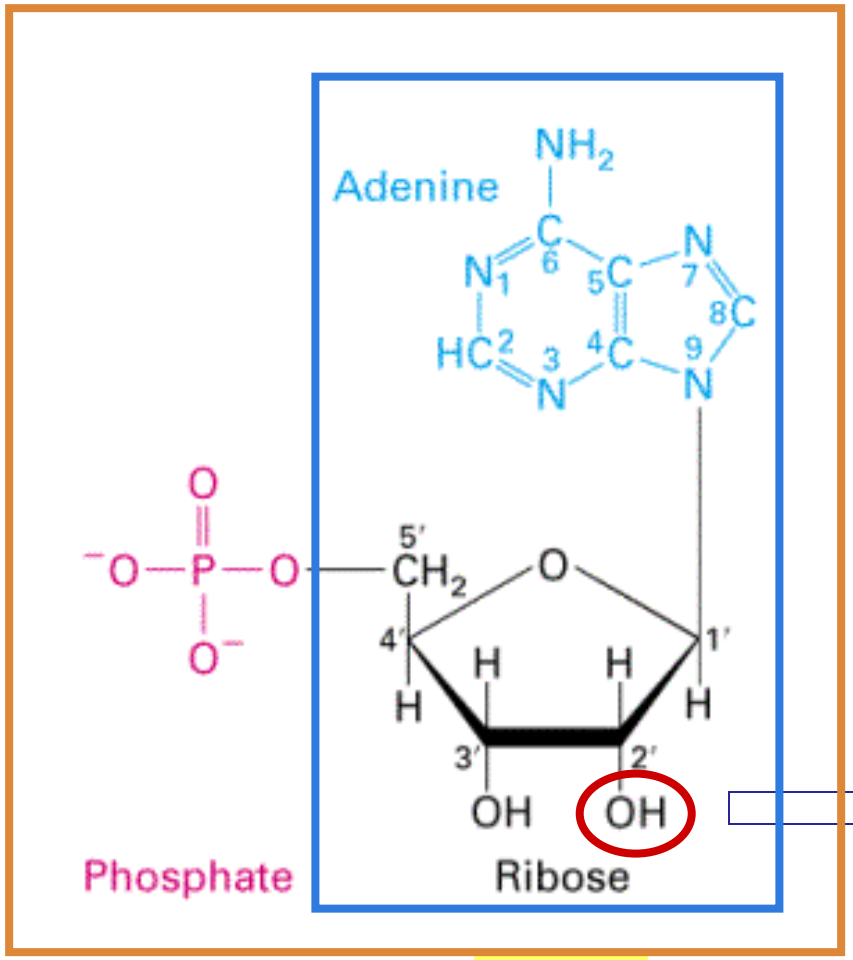


Nucleic acids

- 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

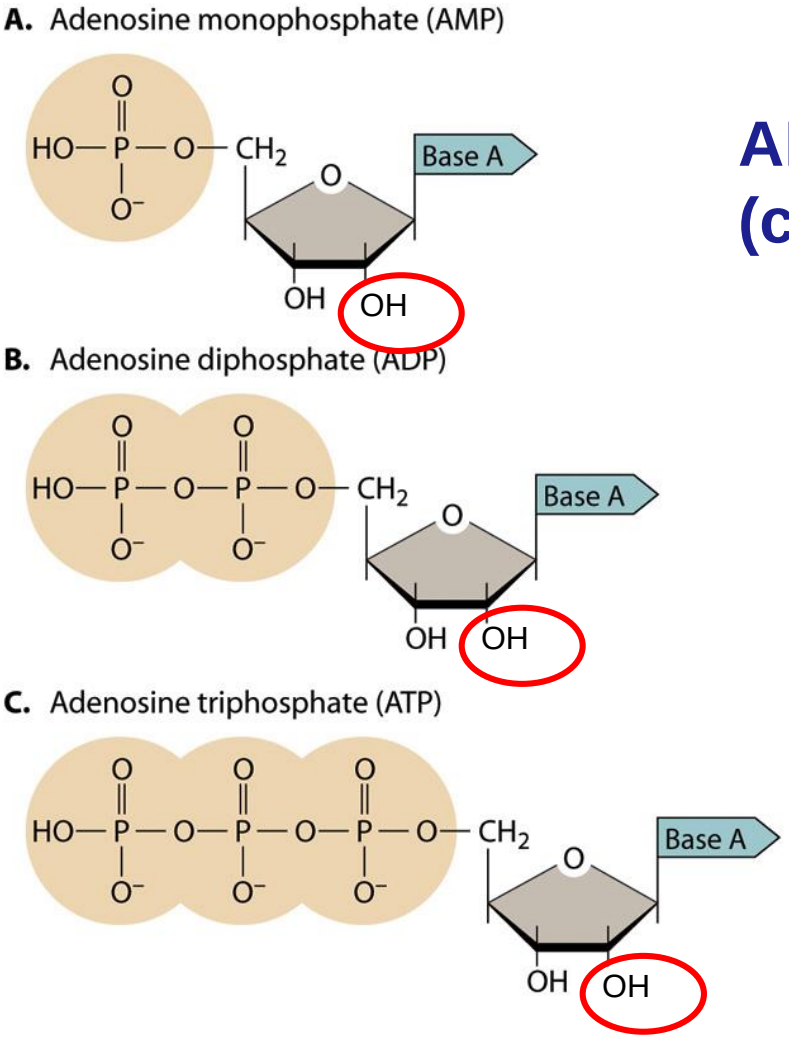
Pyrimidine

H

RNA

DNA

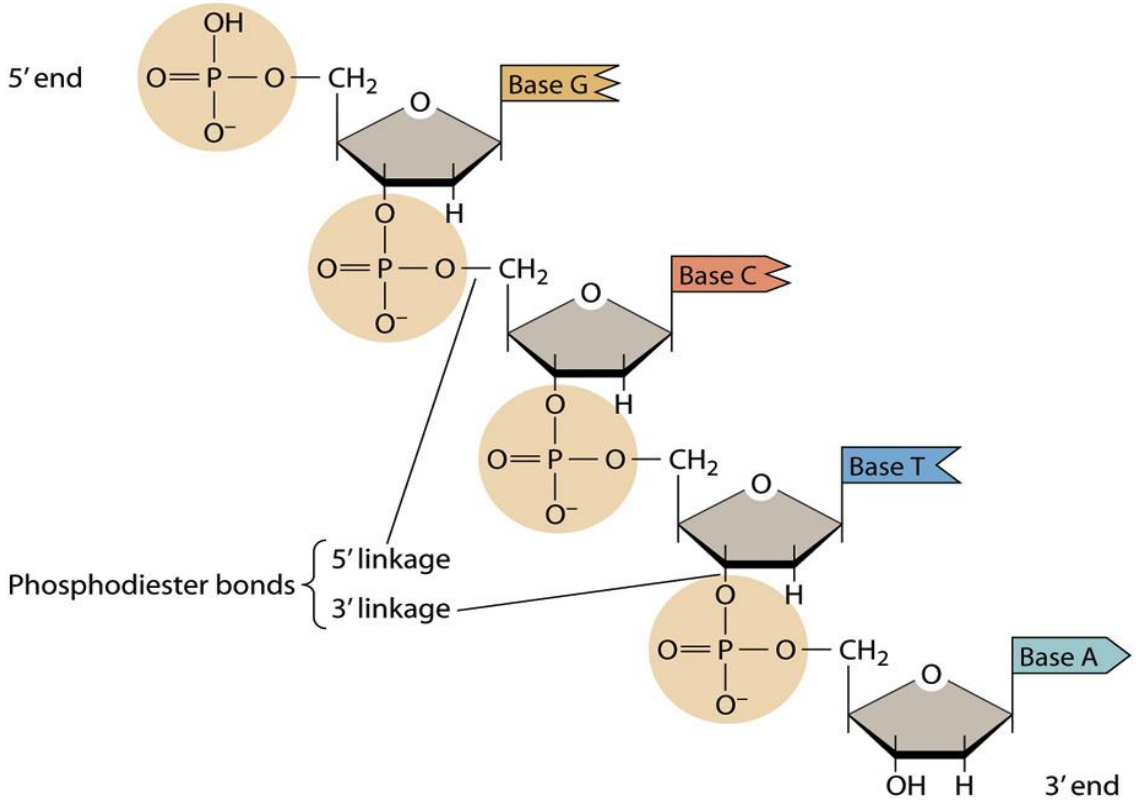
AMP, ADP, ATP



AMP = Adenylate (cf. dAMP)

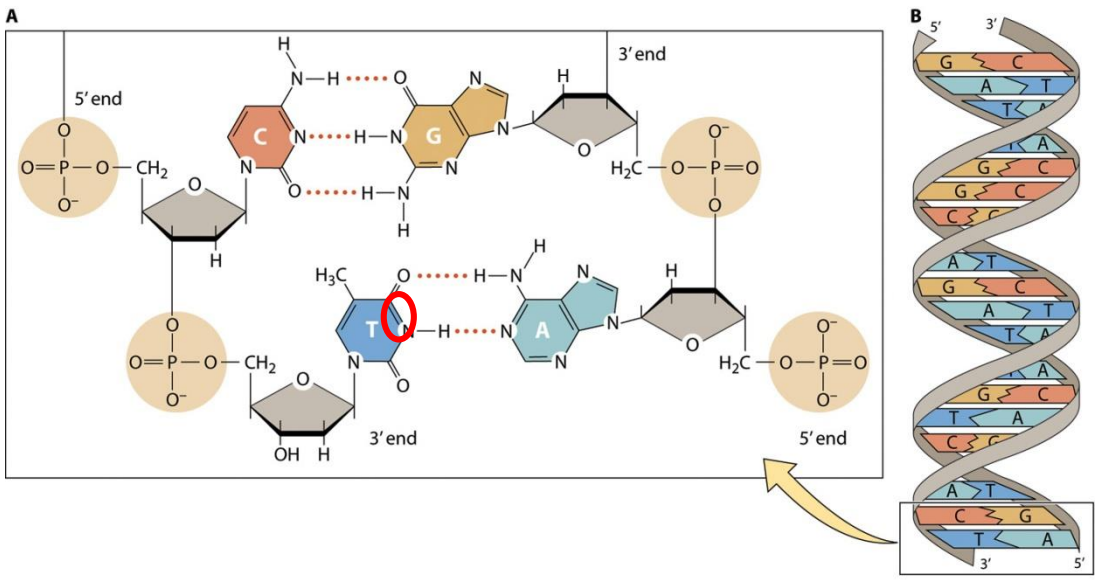
Nucleotide Chains

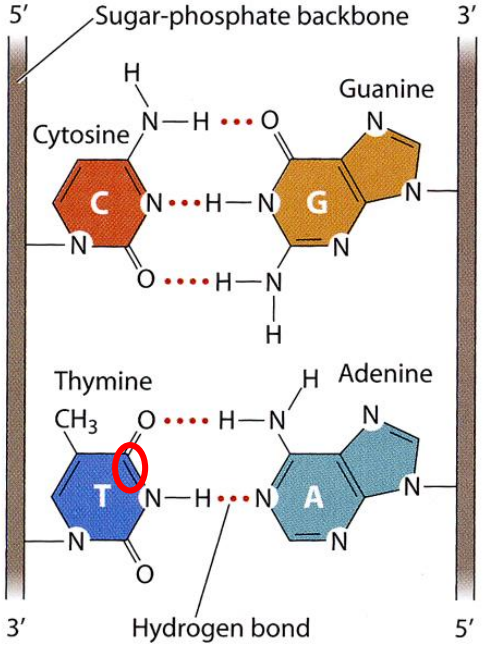
- Linkage of 5’ carbon to 3’ carbon through phosphodiester bond

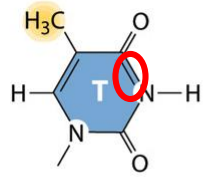


Nucleotide Chains

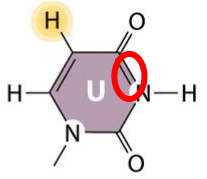
- Base pairing
  - C≡G, T=A : hydrogen bonding
  - Complementary base pairs
  - Antiparallel strand in DNA molecule







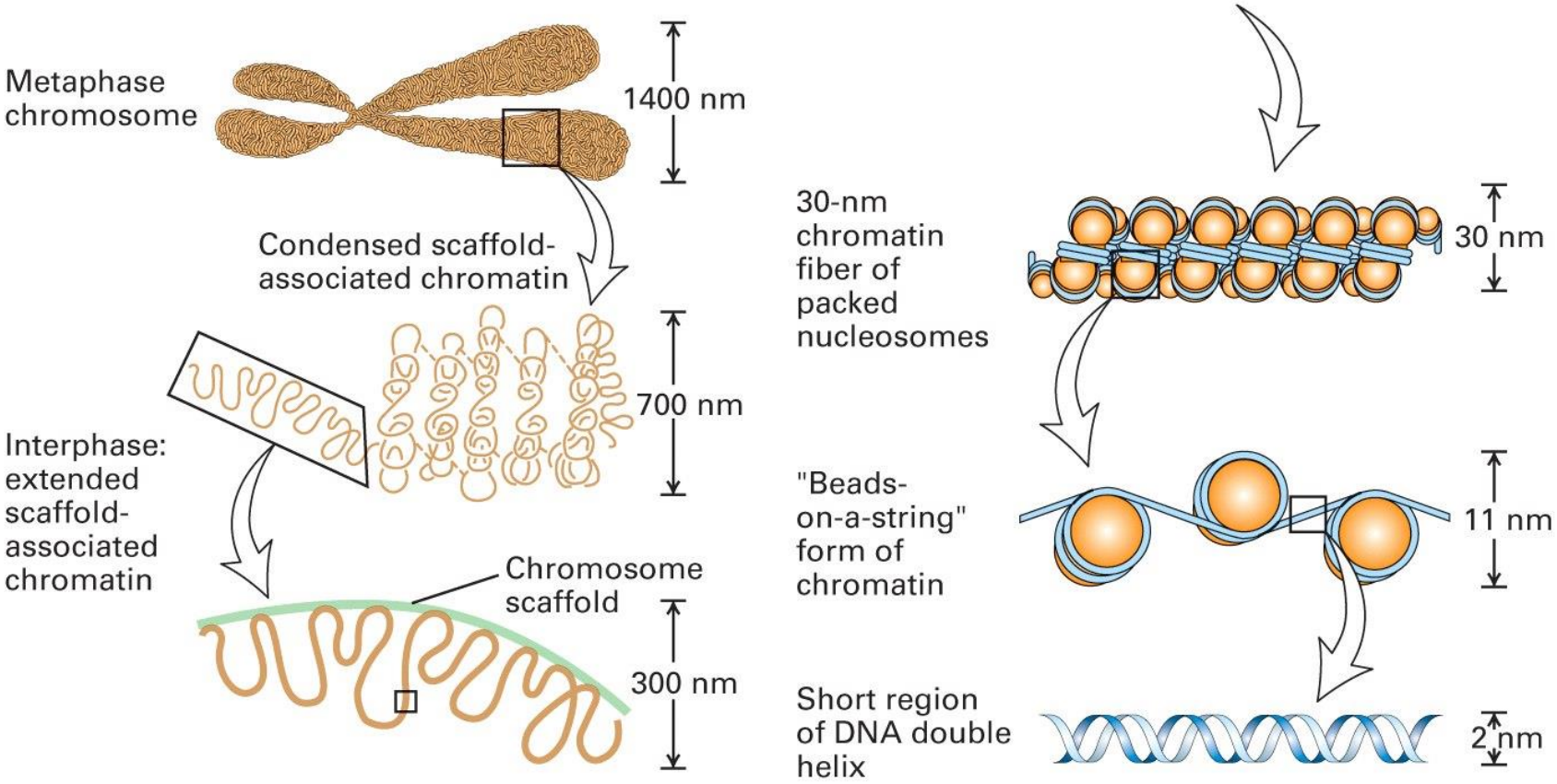
Thymine



Uracil

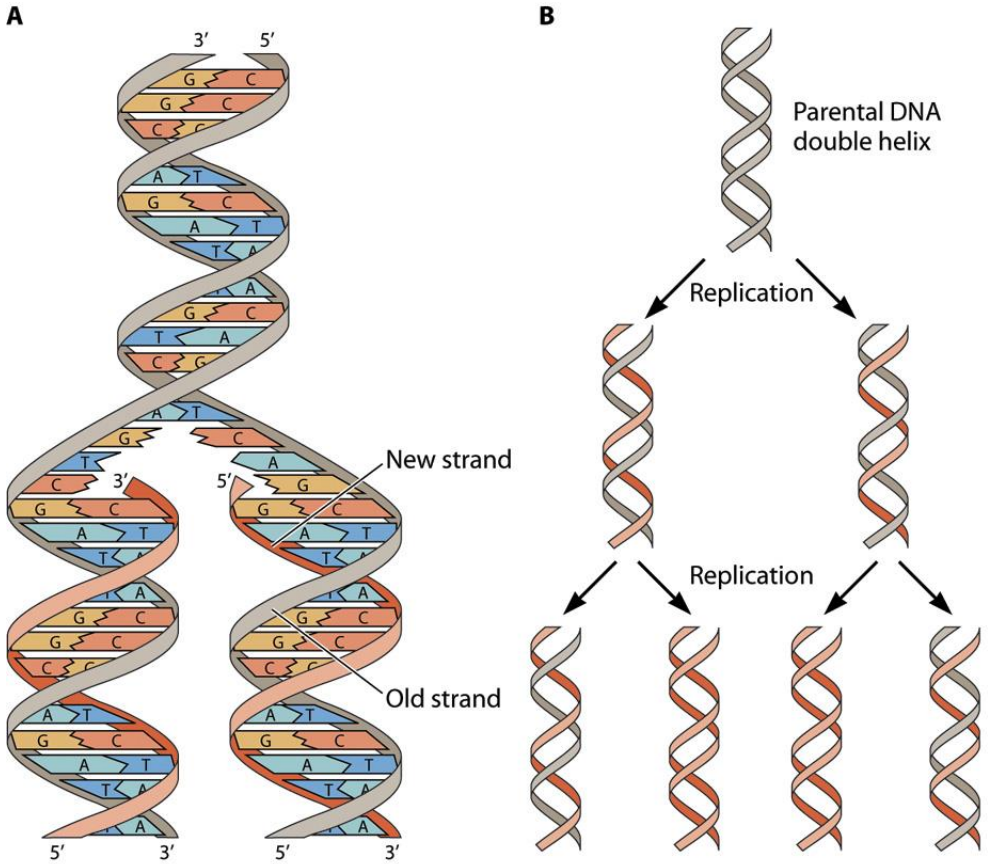
Chromosome

- 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