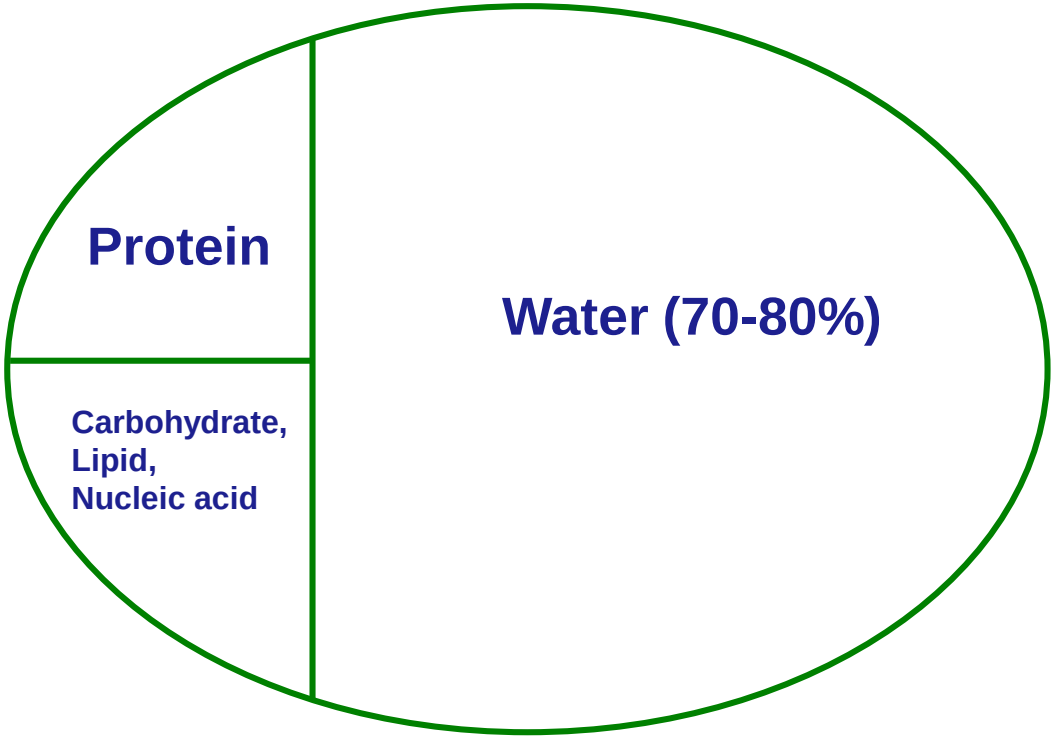
2.2 Cell Construction

- Elemental composition of typical bacterial cell
  - C 50%, O 20%, N 14%, H 8%, P 3%, S 1%, and others (K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, vitamin)

- Molecular building blocks
  - Lipids
  - Carbohydrates
  - Proteins
  - Nucleic acid
    - DNA (deoxyribonucleic acid)
    - RNA (ribonucleic acid)

Molecular Components of Cells

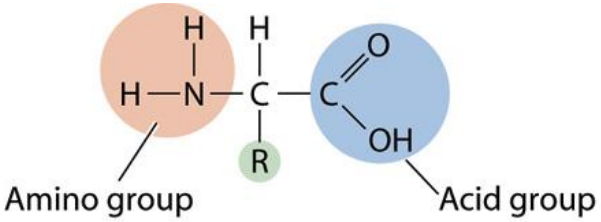


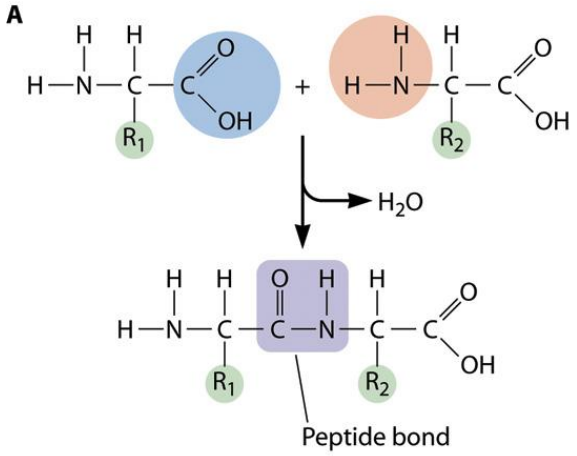
Subunits of Biological Molecules

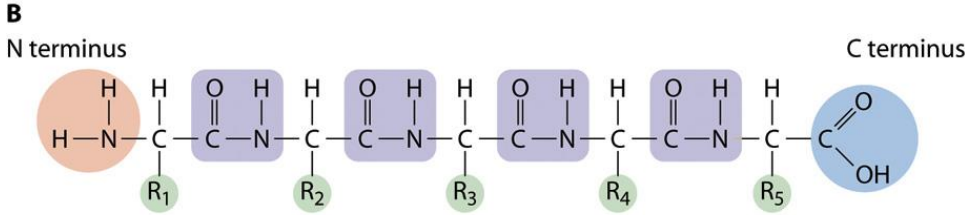
Class of Molecule	Examples	Smallest Repeating Unit
Lipid	Fats, oils	Glycerol, fatty acid
Carbohydrate	Sugars, starch, cellulose	Simple sugars
Nucleic acid	DNA, RNA	Nucleotide
Proteins	Enzymes	Amino acids

Amino Acids and Primary Structure

- Amino acids
  - Amino group
  - Carboxyl group
  - R group; 20 Side chains
- Peptide bond
  - Between NH_2 and COOH
- Polypeptide
  - A chain of amino acids
  - N terminus and C terminus



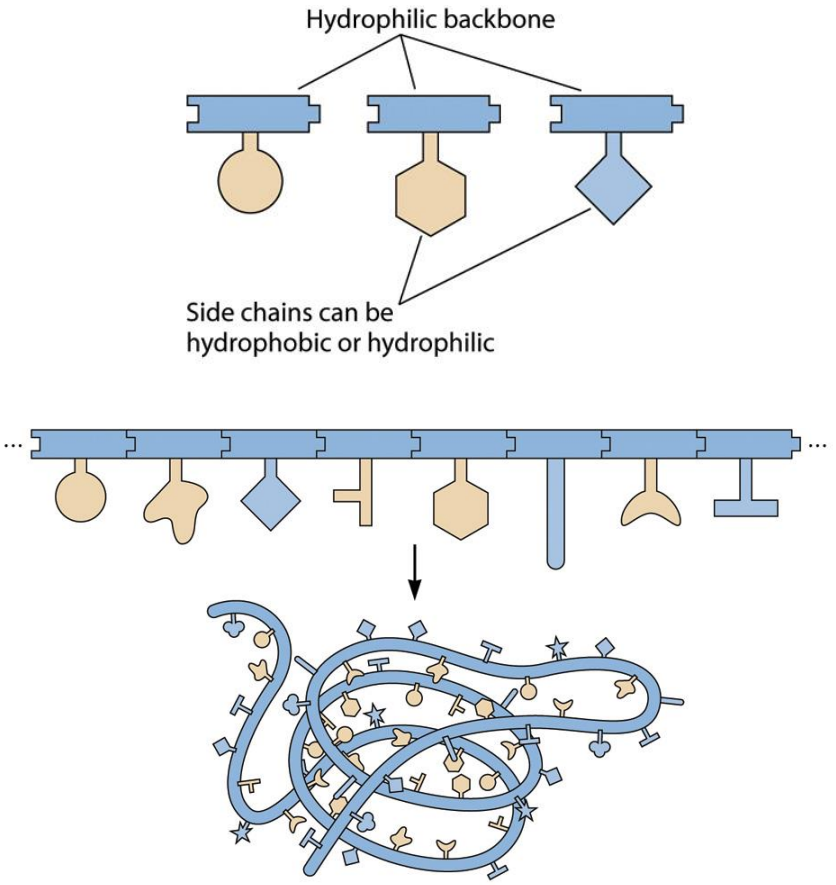




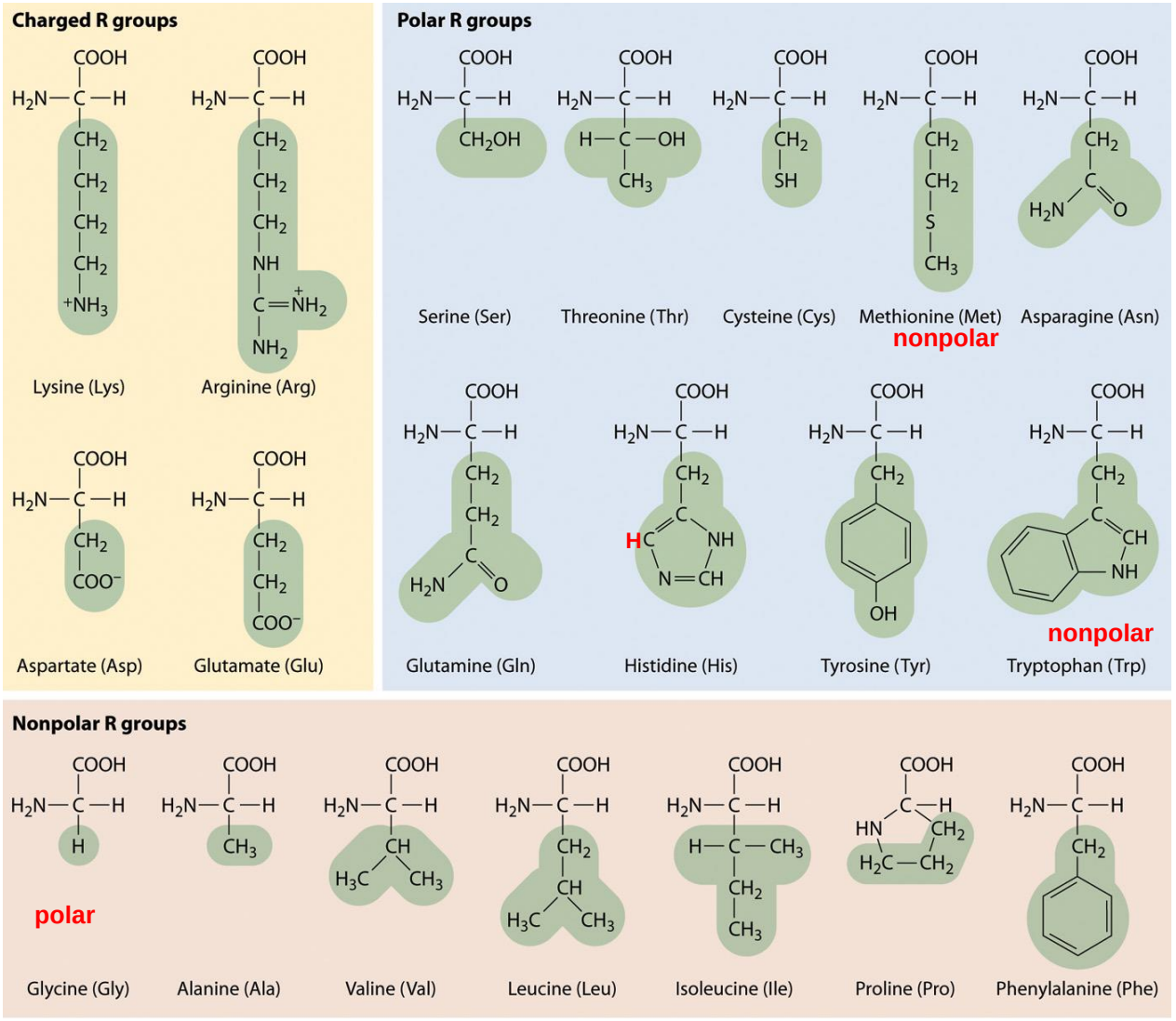
Proteins

- 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



Amino Acids


Charged R groups
Lysine (Lys)
Arginine (Arg)
Aspartate (Asp)
Glutamate (Glu)
Polar R groups
Serine (Ser)
Threonine (Thr)
Cysteine (Cys)
Methionine (Met)
nonpolar
Asparagine (Asn)
Glutamine (Gln)
Histidine (His)
Tyrosine (Tyr)
Tryptophan (Trp)
nonpolar
Nonpolar R groups
polar
Glycine (Gly)
Alanine (Ala)
Valine (Val)
Leucine (Leu)
Isoleucine (Ile)
Proline (Pro)
Phenylalanine (Phe)

Biological Function of Proteins

- Structural proteins
- Catalytic proteins
- Transport proteins
- Regulatory proteins
- Protective proteins

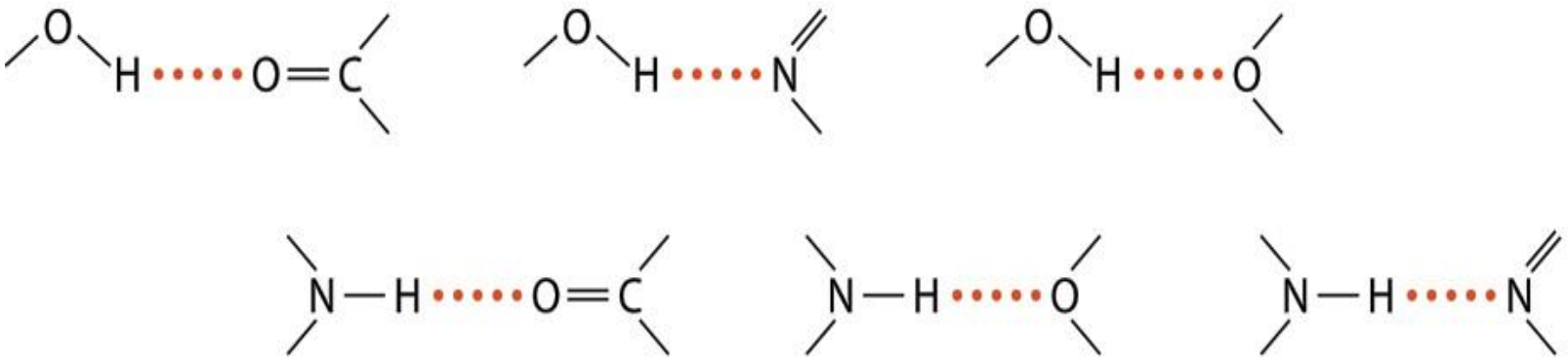
Primary and Secondary Structure

- Primary structure
  - Linear arrangement (sequence) of amino acids
- Secondary structure
  - Core elements of protein architecture
  - Local folding of polypeptide chain
    - α helix, β sheet : 60% of the polypeptide chain
    - Random coils and U-shaped turn

Three Dimensional Structure of Protein

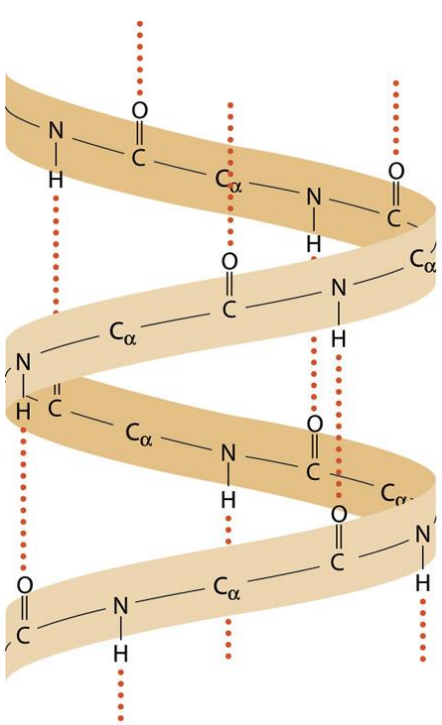
- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure
  - only proteins with multiple polypeptides

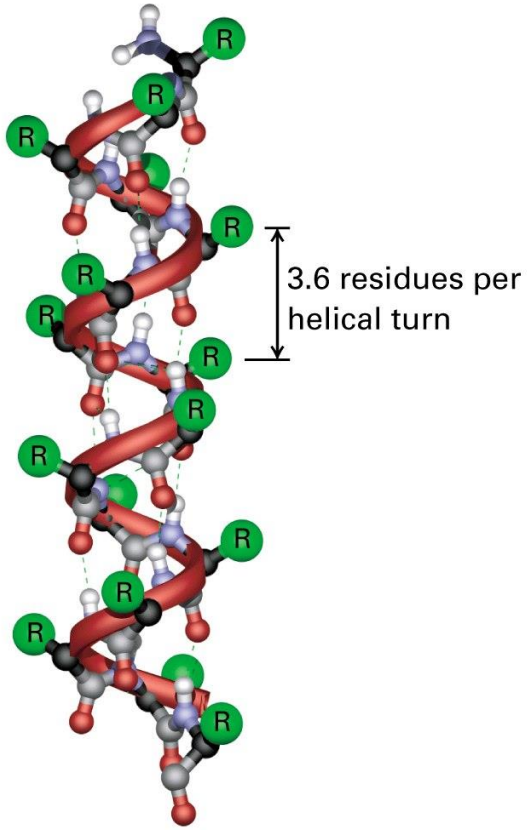
Common Hydrogen Bonds in Biological Systems



α-Helix

- Hydrogen bond between O (C=O, n) and H (NH, n+4)
- Directionality on the helix : The same orientation of H bond donor
- Side chains point outward : Determine hydrophobic or hydrophilic quality





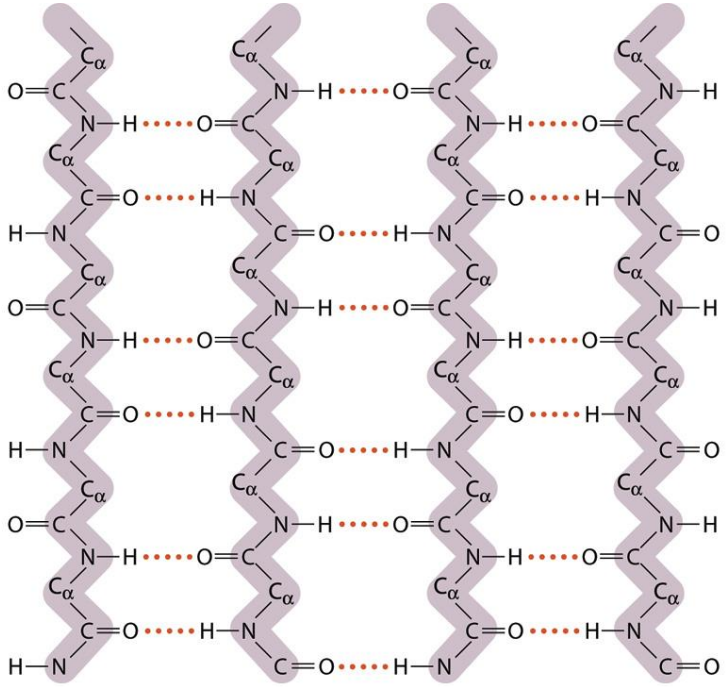
β-Sheet

- Hydrogen bonding between β strands → β sheet,

  pleated sheet

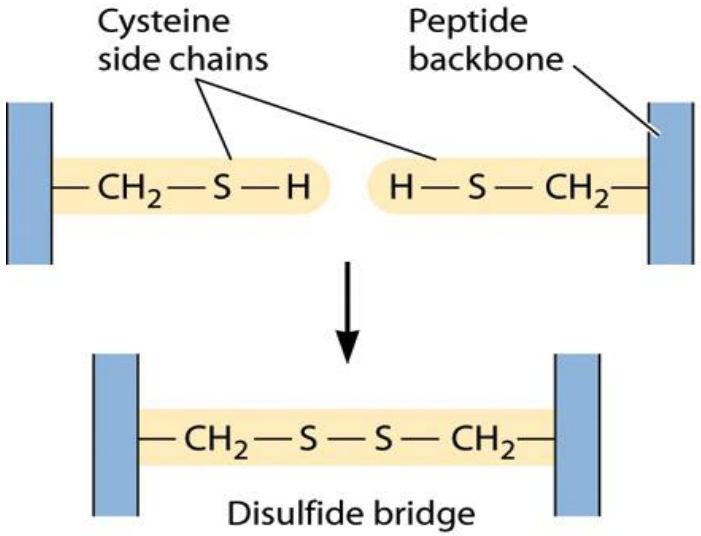
- Usually not flat,

  but twisted



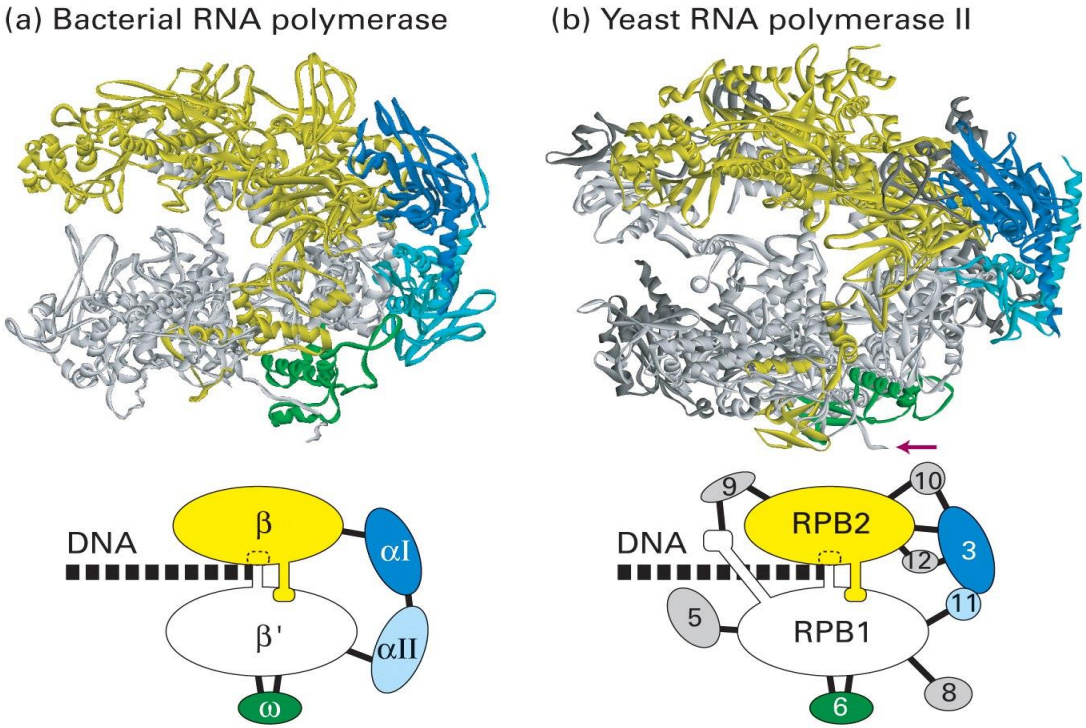
Tertiary Structure

- Overall folding of a polypeptide chain
- Stabilization
  - weak interaction
    - Hydrophobic interaction between nonpolar side chains
    - Hydrogen bond between polar side chains and peptide bonds
  - Disulfide bond formation



Quaternary Structure

- Association of multiple polypeptide chains
  - Lambda repressor : dimer
  - *E. coli* RNA polymerase : Five polypeptide chains



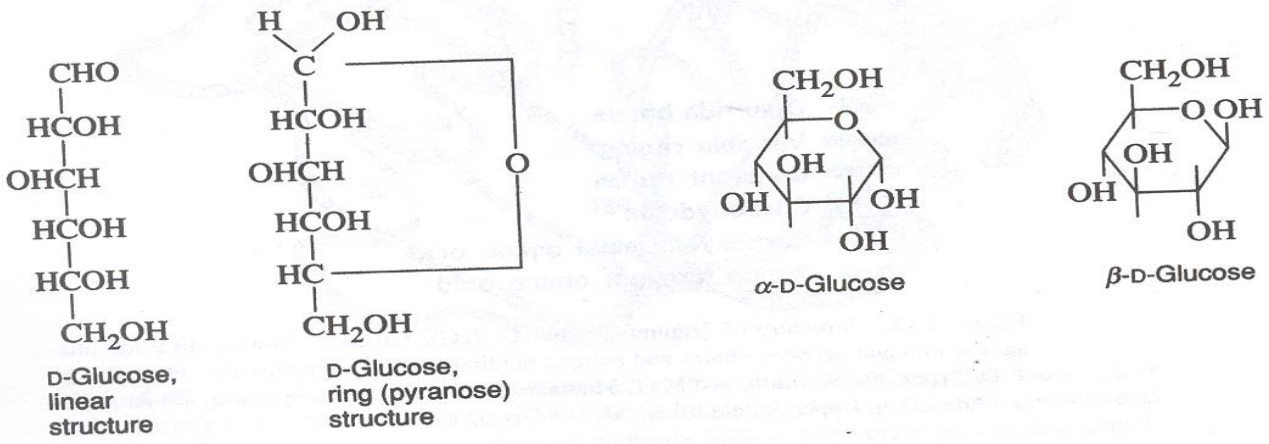
2.2.3 Carbohydrates: Mono- and Polysaccharides

- 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)

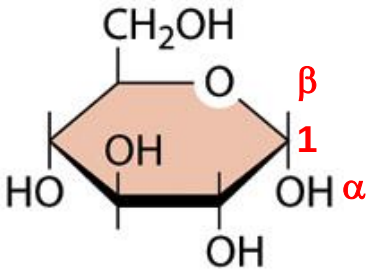
Linear and Ring Structure

- p 34 (glucose 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.

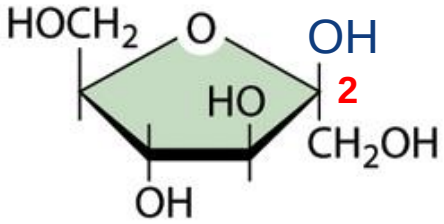


Mono- and Disaccharides

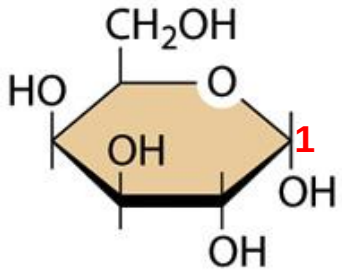
A. Simple sugars



Glucose (α form)

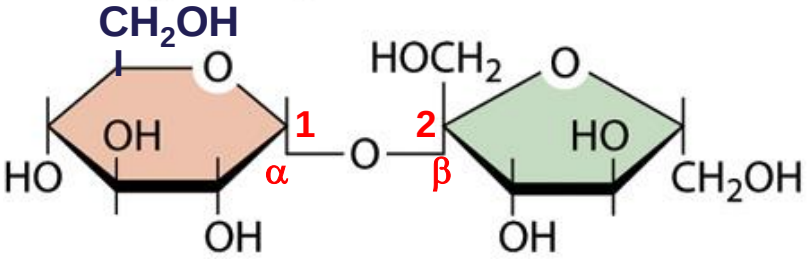


Fructose (β form)

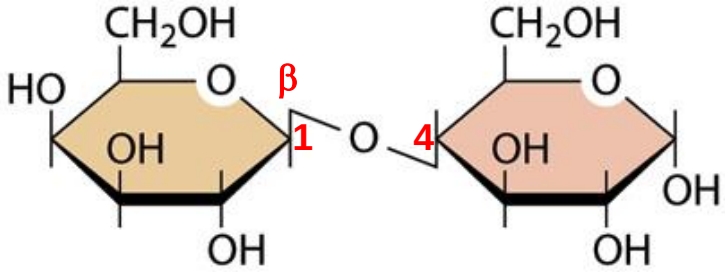


Galactose (α form)

B. Complex sugars



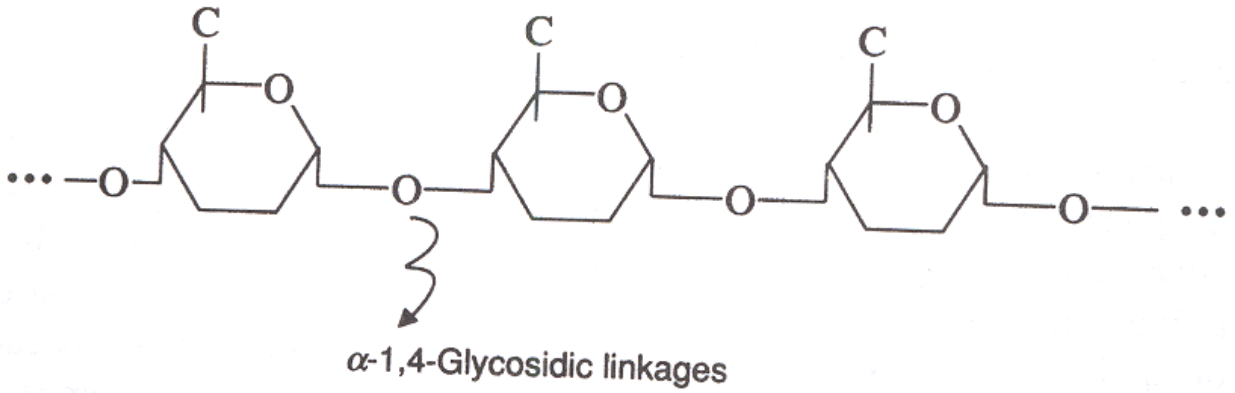
Sucrose (table sugar)
Glucose + fructose



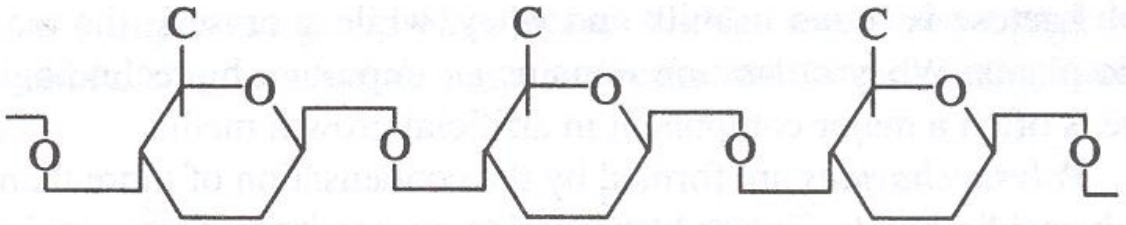
Lactose (milk sugar)
Galactose + glucose

Polysaccharides

- Amylose (α-1,4-Glycosidic linkage)

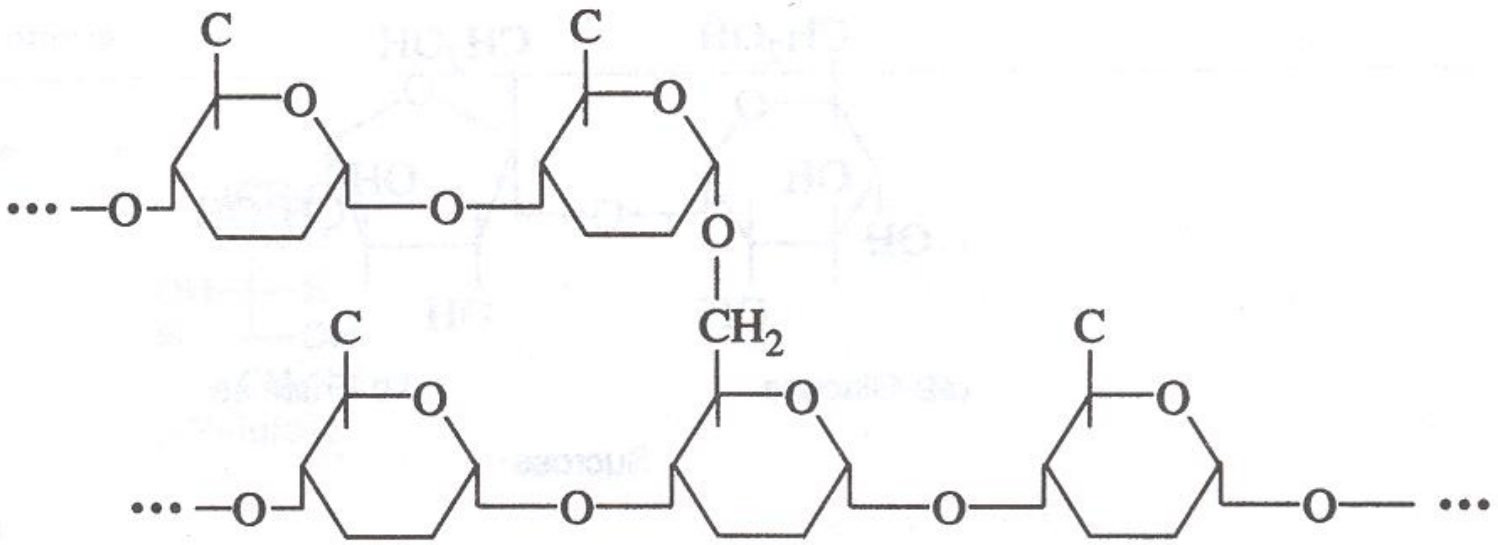


- Cellulose (β-1,4-Glycosidic linkage)



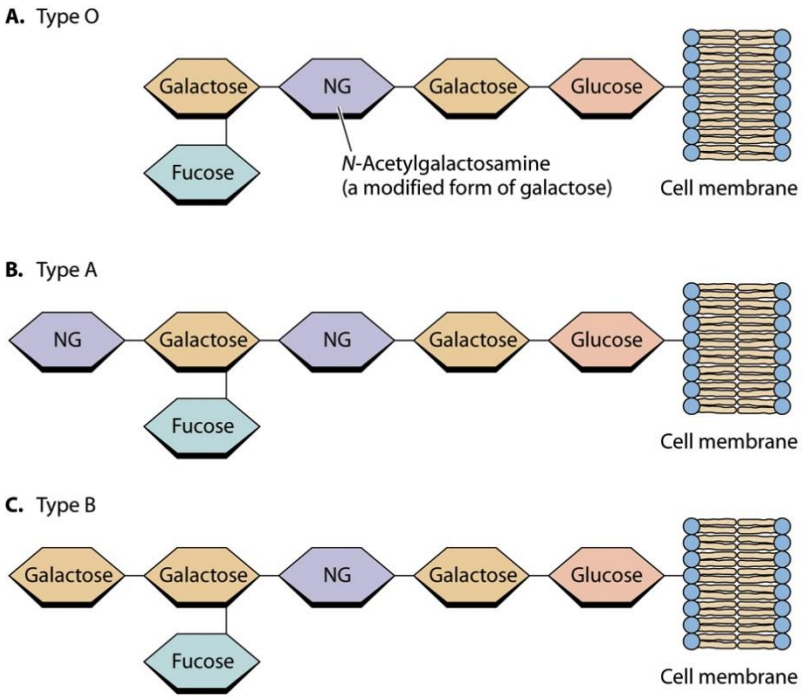
Polysaccharides

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



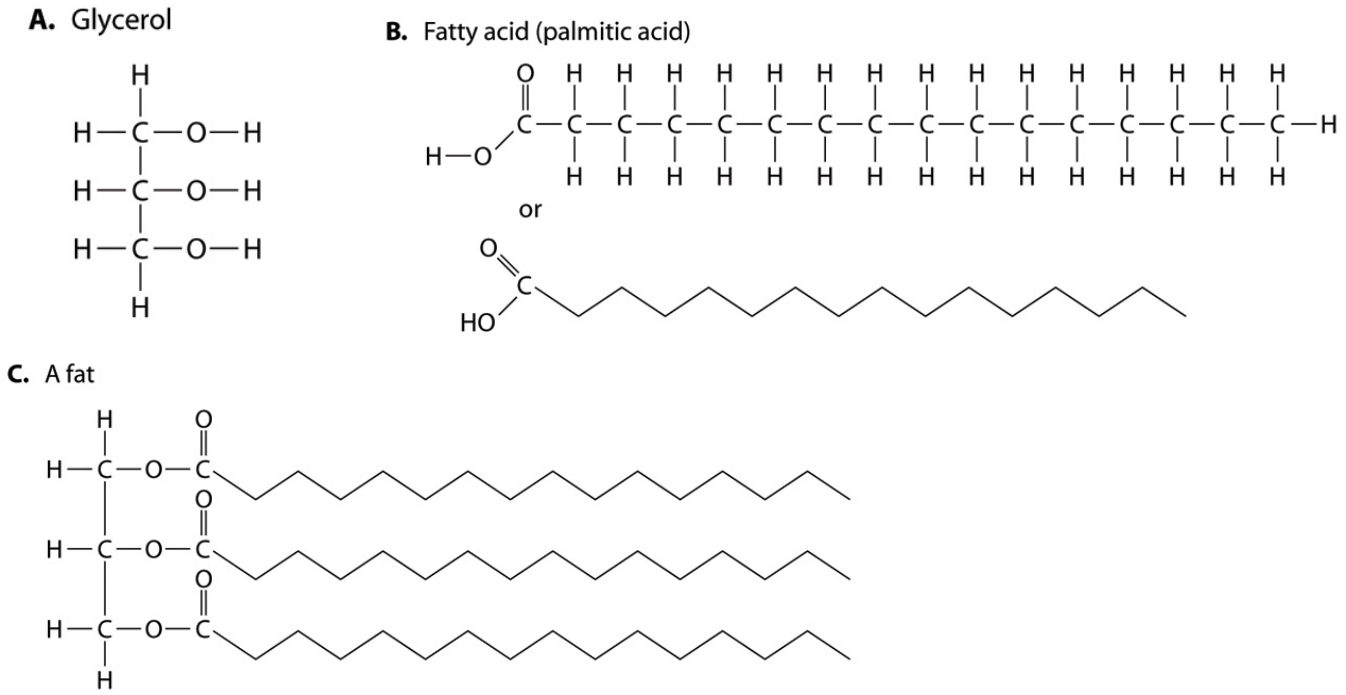
Roles of Carbohydrates

- 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



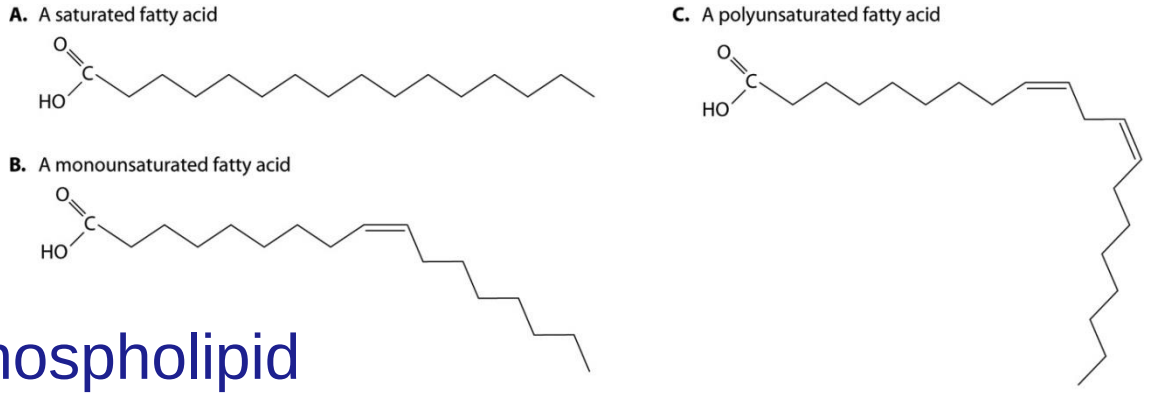
2.2.4. Lipids, Fats, and Steroids

- Hydrophobic fats, oils, and cholesterol etc.
- High energy C-H, C-C bonds → good energy storage
- Fats : glycerol + fatty acids (Table 2.6 example of fatty acid)

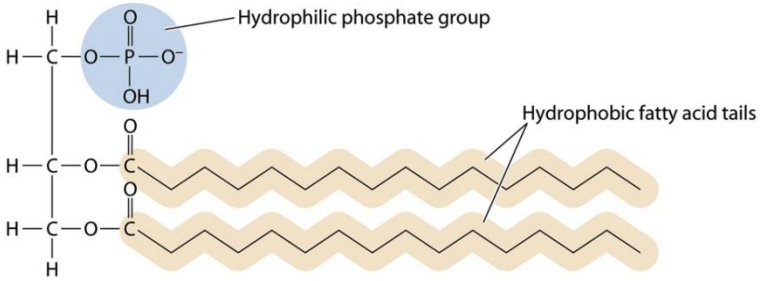


Lipid

- Fatty acid
  - Saturated: tight packing →solid at room temperature
  - Unsaturated: more double bonds → liquid

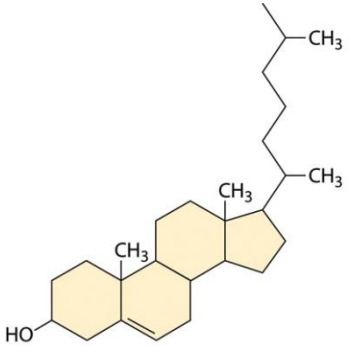


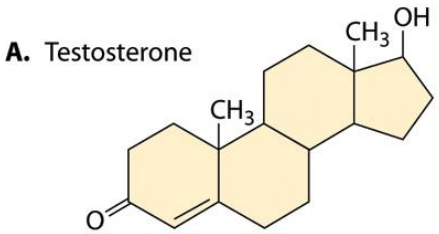
- Phospholipid
  - Glycerol backbone
  - two fatty acids (hydrophobic)+ phosphate (hydrophilic)

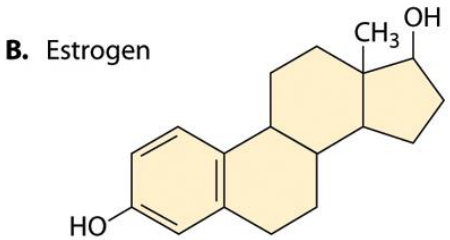


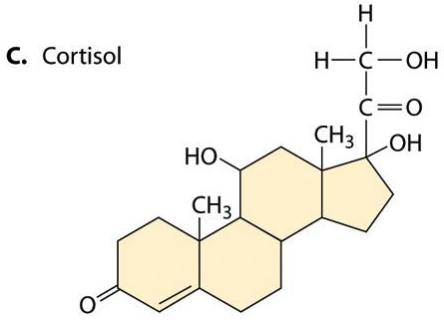
Steroids

- Cyclic hydrocarbon compounds
- Cholesterol (well-known steroid)
  - Component of animal cell membranes
    - Increase membrane fluidity
  - Starting material for steroid hormones and bile synthesis





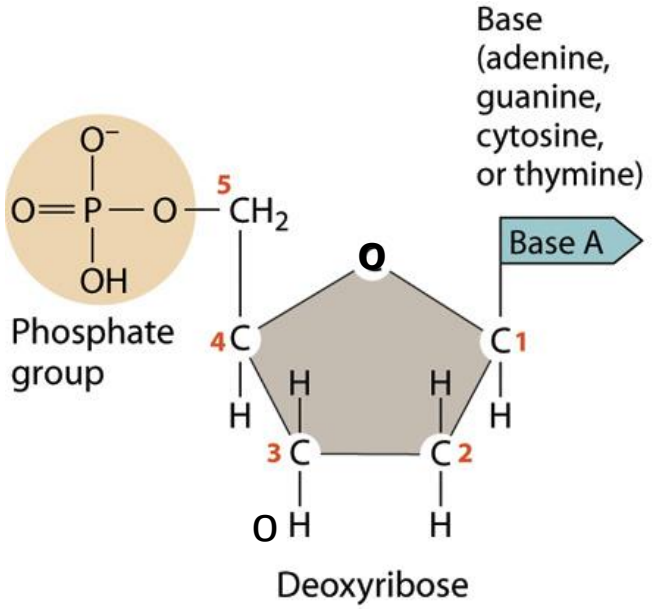




Steroid hormones

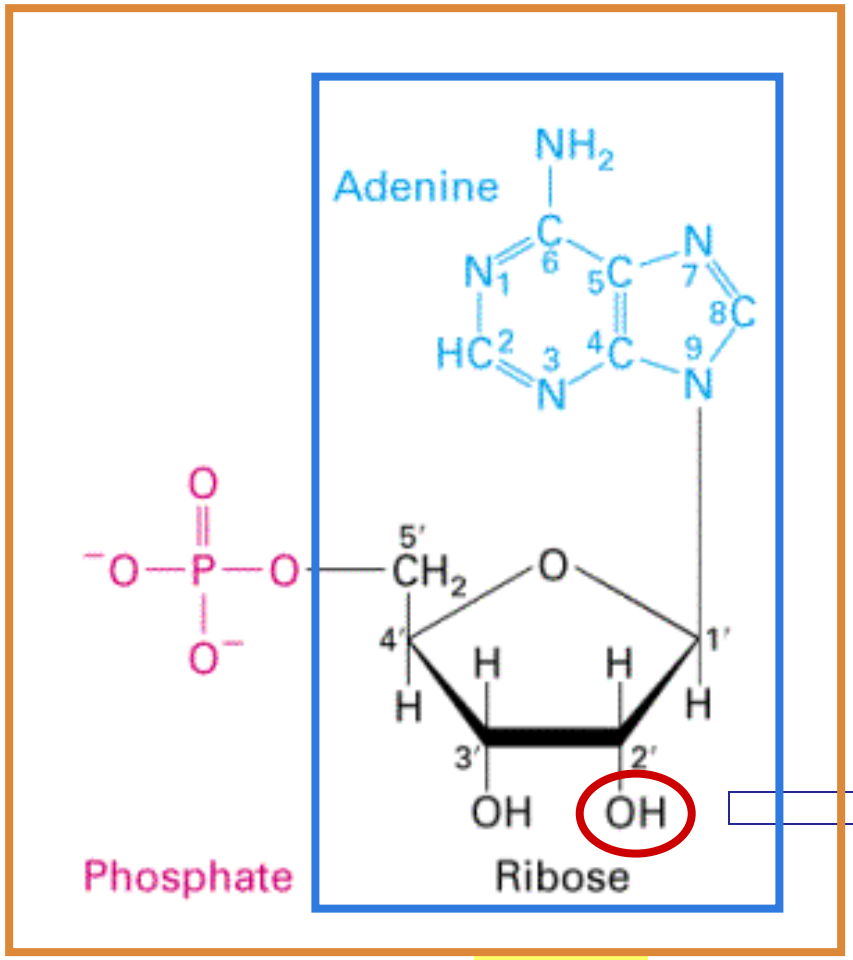
2.2.5. Nucleic Acids, RNA, and DNA

- Nucleotides
  - Building blocks of nucleic acids
  - (deoxy)ribose + phosphate group + base
  - Bases: adenine (A), guanine (G), cytosine (C), thymine (T)



- Terminology
  - Base
  - Nucleoside : sugar + base
  - Nucleotide : sugar + base + phosphate

Nucleotides



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

Purine

Pyrimidine

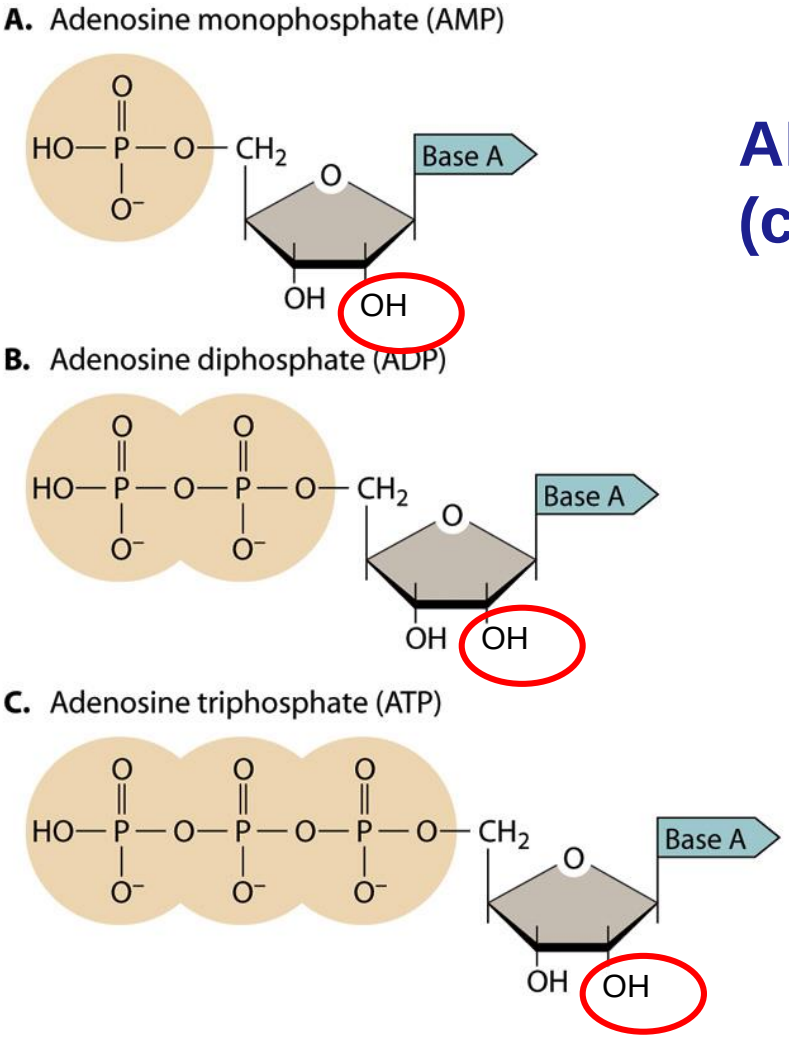
H

2’-Deoxyribose

RNA

DNA

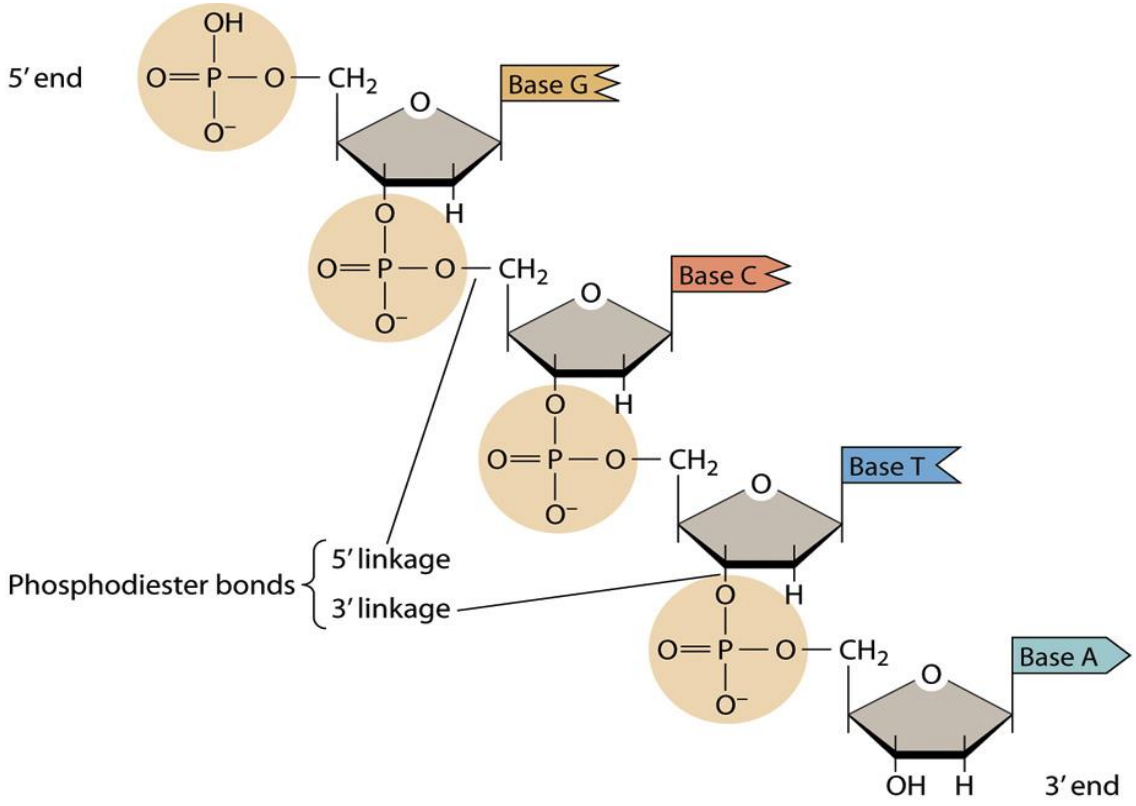
AMP, ADP, ATP



AMP = Adenylate (cf. dAMP)

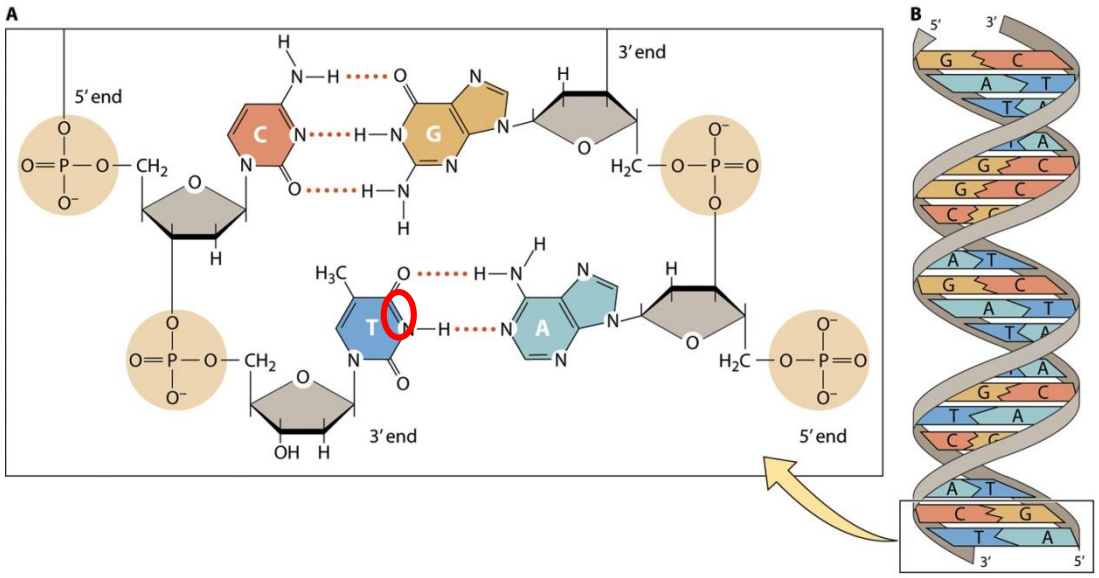
Nucleotide Chains

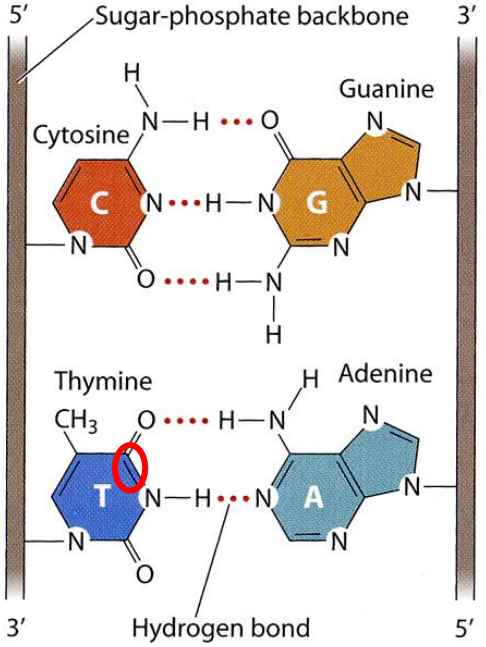
- Linkage of 5’ carbon to 3’ carbon through phosphodiester bond

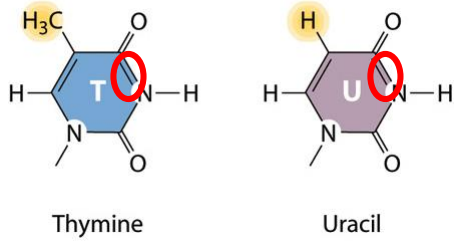


Nucleotide Chains

- Fig. 2.15 Structure of Bases
- Base pairing
  - C≡G, T=A : hydrogen bonding
  - Complementary base pairs
  - Antipararallel strand in DNA molecule

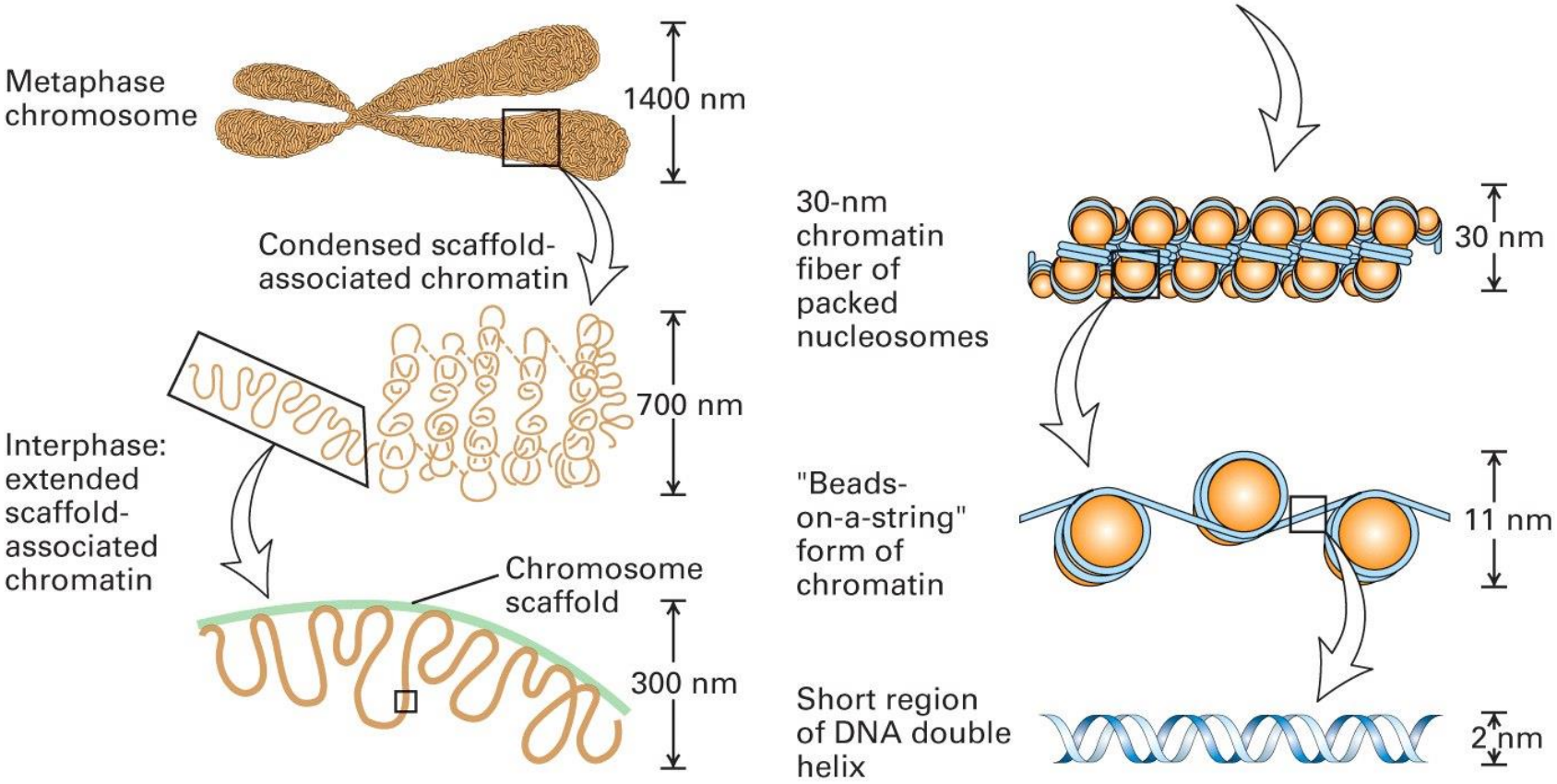






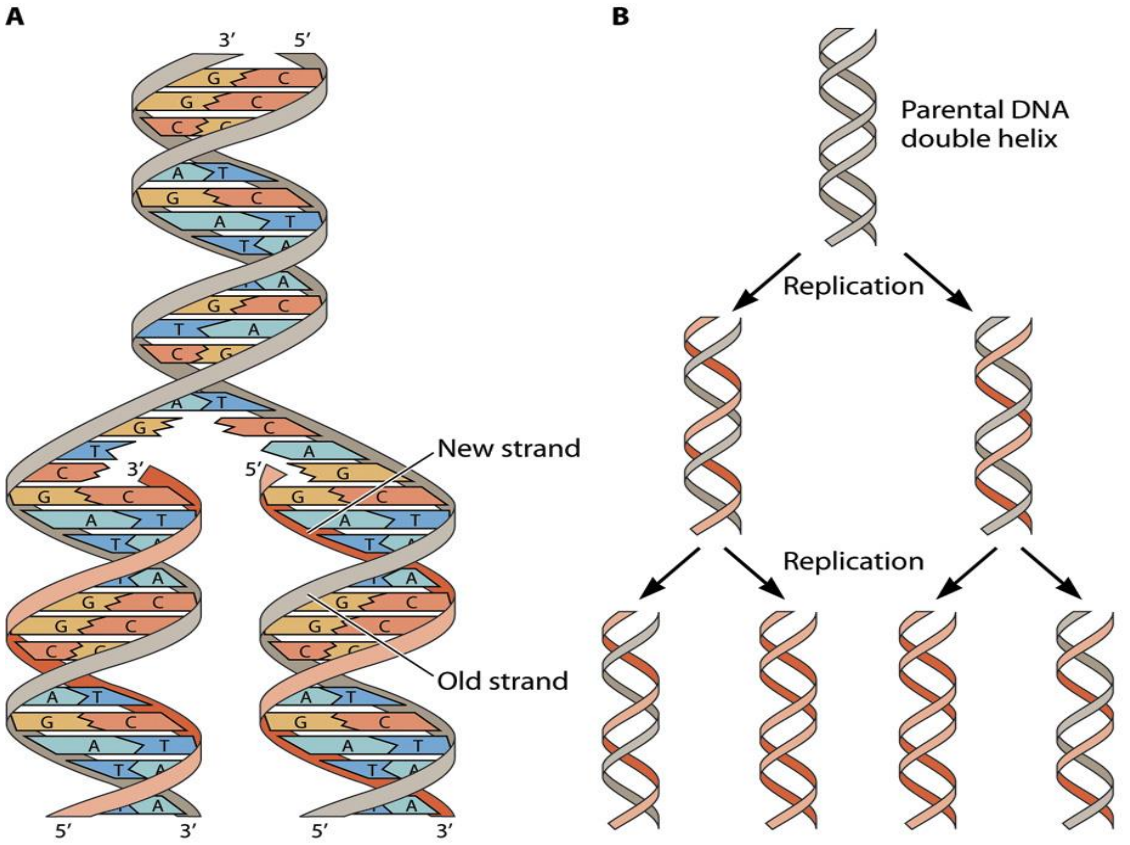
Chromosome

- Tightly packed complex of DNA and histone proteins

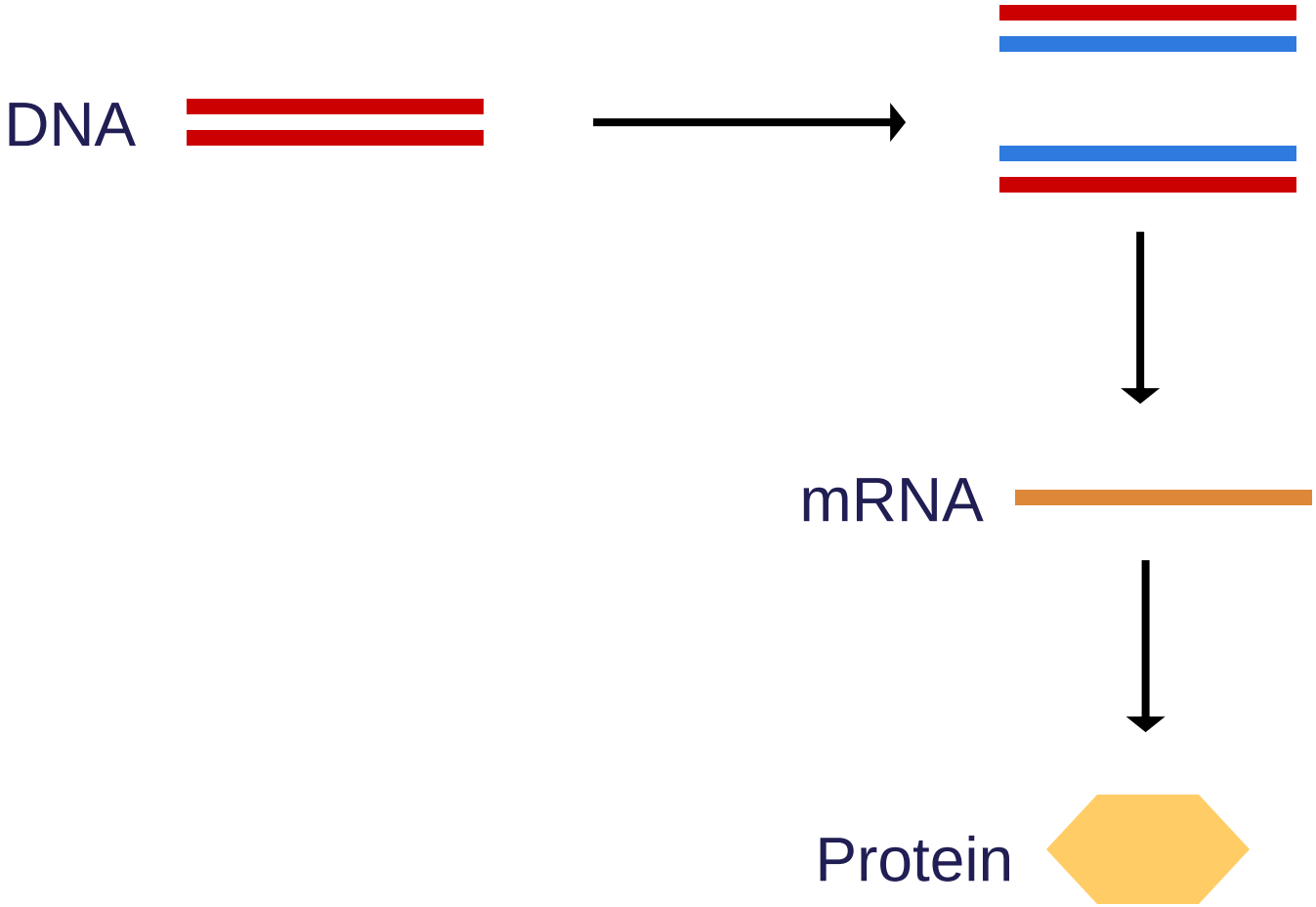


DNA Replication

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



Expression of Genetic Information



2.3 Cell Nutrients

- Macronutrient
  - Necessary in concentrations > 10^{-4} M
  - C, N, O, H, S, P, Mg^{2+} , K^{2+}
- Micronutrient
  - Necessary in concentrations < 10^{-4} M
  - Trace elements such as Mo^{2+} , Zn^{2+} , Cu^{2+} , Mn^{2+} , Ca^{2+} , Na^{+}

2.3.2. Macronutrients

- Carbon
- Microorganisms are classified in two categories on the basis of their carbon source.
  - Heterotroph --- organic compounds as a carbon source
  - Autotroph --- CO_2 as a carbon source
  - Mixotroph --- grows under both autotrophic and heterotrophic conditions
  - Chemoautotroph --- CO_2 as a carbon source, energy from inorganic compounds such as H_2, CO, NH_3, NO_2^-, Fe^{2+} , H_2S, S, $S_2O_3^{2-}$
  - Photoautotroph --- CO_2 as a carbon source, energy from light

Carbon sources

- Common carbon sources in the laboratory fermentation
  - Glucose, sucrose, fructose
- Common carbon sources in industrial fermentation
  - Molasses (sucrose), starch (glucose, dextrin), corn syrup, waste sulfite liquor (glucose)
- In aerobic condition
  - 50% carbon → cell material, 50% carbon → energy
- In anaerobic condition
  - Small fraction of C → cell material, Large fraction of C → product

Nitrogen Sources

- Inorganic Nitrogen Sources
  - Ammonia
  - Ammonium salts (NH_4Cl, $(NH_4)_2SO_4$, NH_4NO_3)
- Organic Nitrogen Sources
  - Yeast extract, peptone --- amino acids
- Nitrogen Sources in Industrial Fermentation
  - Table 2.8

2.3.3. Micronutrients

- Most widely needed trace elements
  - Fe, Zn, Mn
- Trace elements needed under specific growth conditions
  - Cu, Co, Mo, Ca, Na, Cl, Ni, Se, Cu
- Rarely needed trace elements
  - B, Al, Si, Cr, V, Sn, Be, F, Ti, Ga, Ge, Br, Zr, W, Li