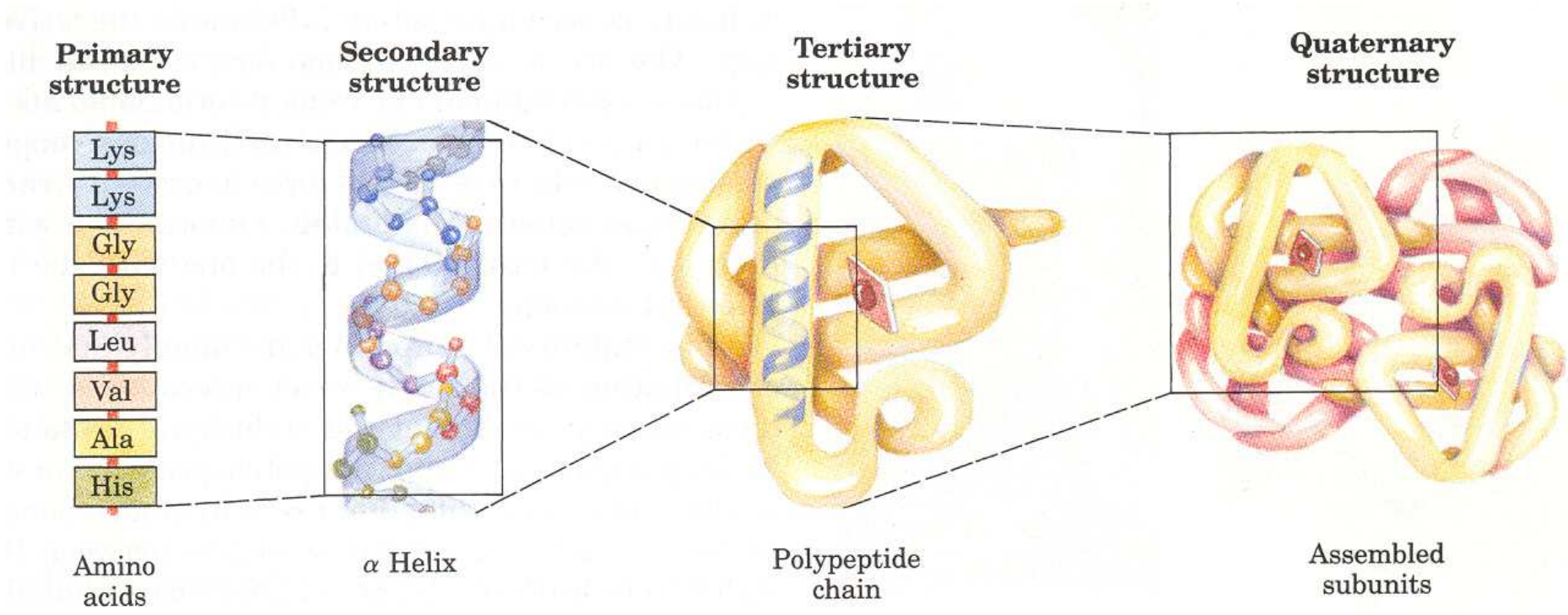
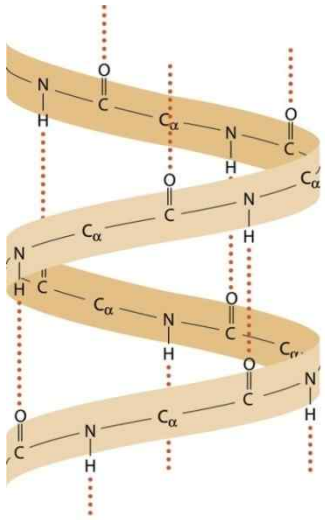
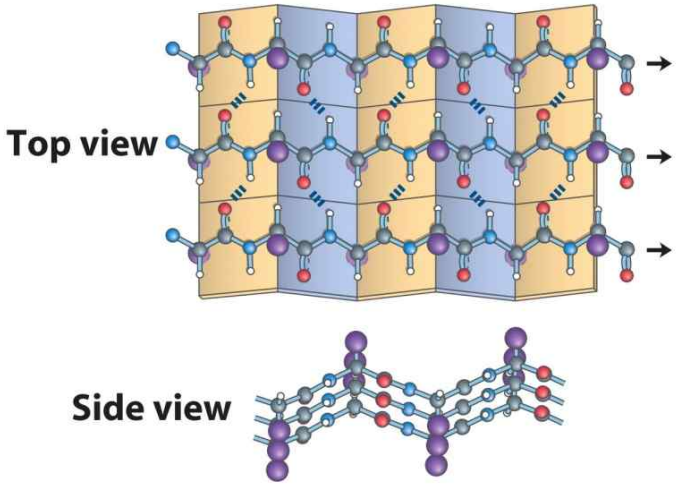
Structural hierarchy of protein



Primary and Secondary Structure

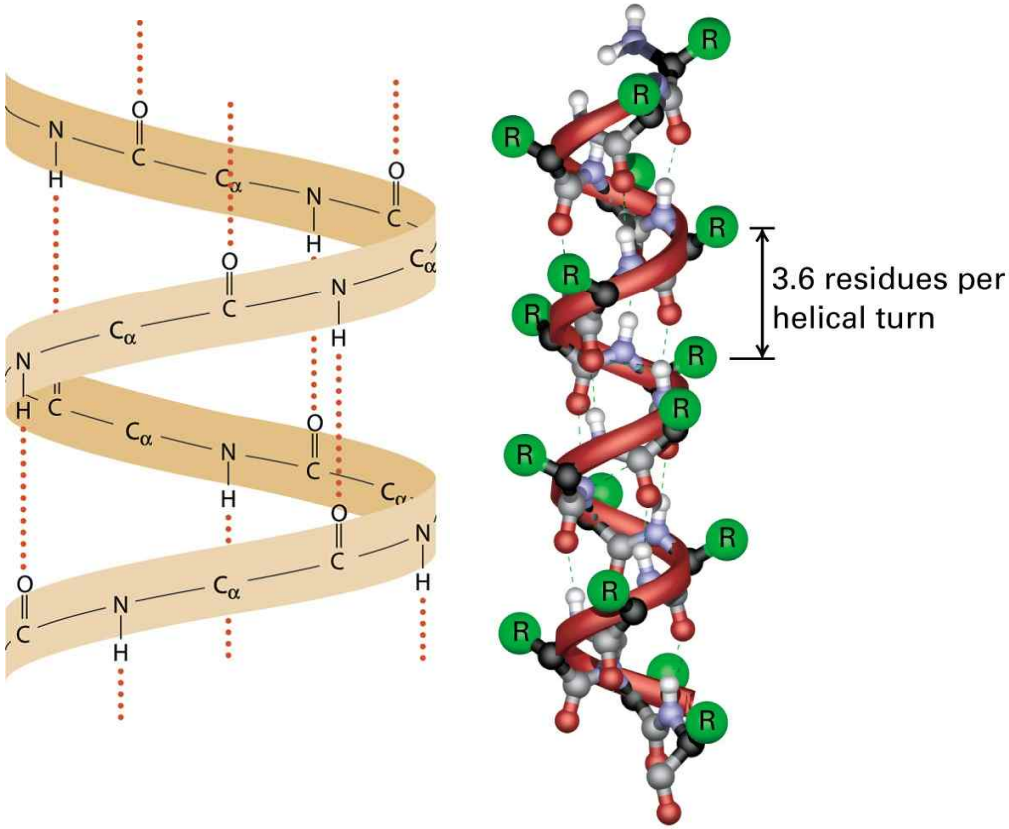
- **Primary structure**
  - Linear arrangement (sequence) of amino acids
- **Secondary structure**
  - Local folding of polypeptide chain
    - α helix, β sheet : 60% of the polypeptide chain
    - Random coils and U-shaped turn



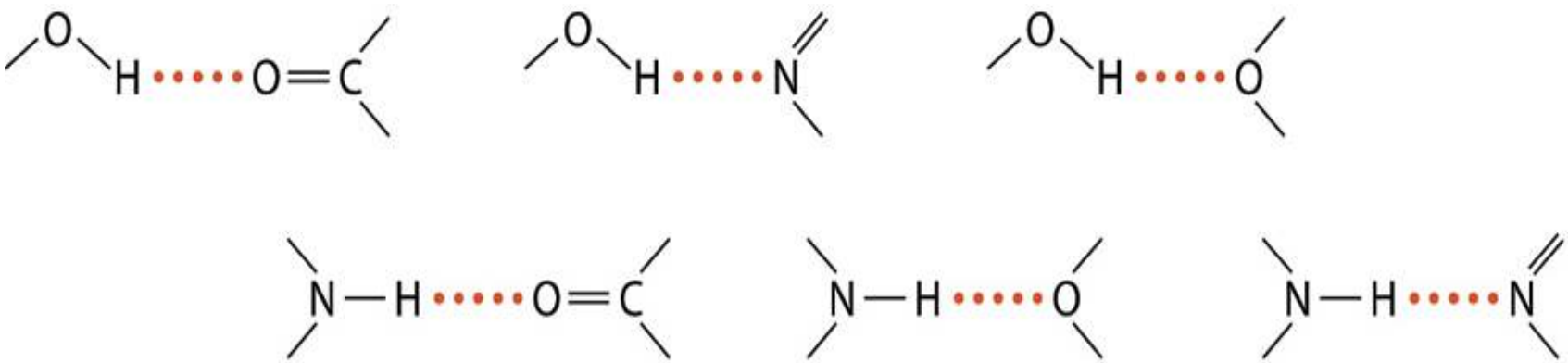


α-Helix

- Hydrogen bond between O (C=O, n) and H (NH, n+4)
- Side chains point outward
- α-keratins (hair)



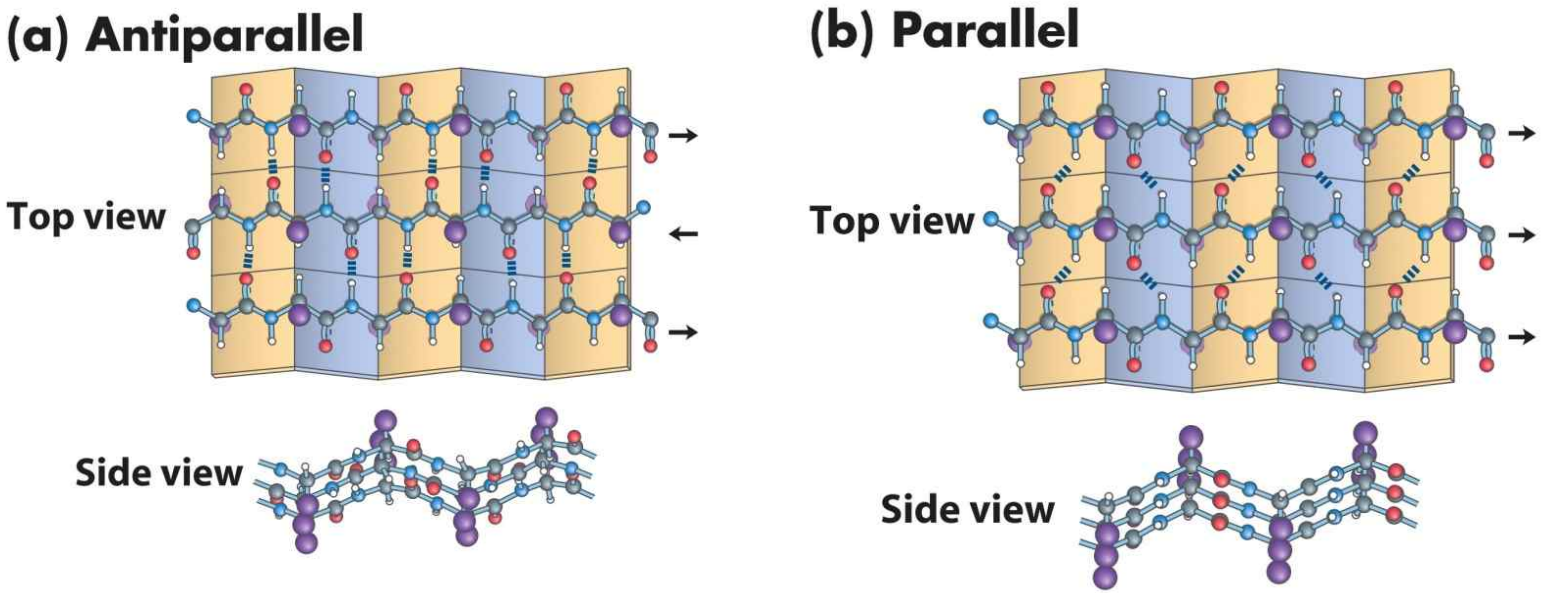
Common Hydrogen Bonds in Biological Systems



β sheet

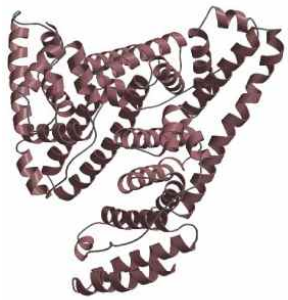
- **β sheet**
  - Zigzag polypeptide backbone
  - Hydrogen bonding between adjacent β strands
  - Parallel or antiparallel

- **Amino acids for specific β sheet structure**
  - β-keratins (silk fibroin, spider web) : rich in small amino acids (Gly, Ala)



Protein conformation is stabilized largely by weak interactions

- **Conformation**
  - Spatial arrangement of atoms in a protein



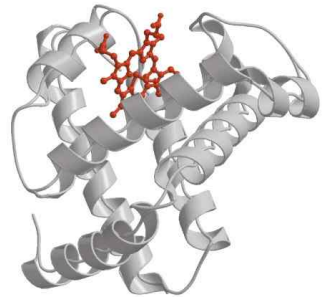
Protein conformation

- **Noncovalent interactions determining protein conformation**
  - hydrogen bonding within protein
  - Hydrophobic interaction
  - Ionic interactions within protein

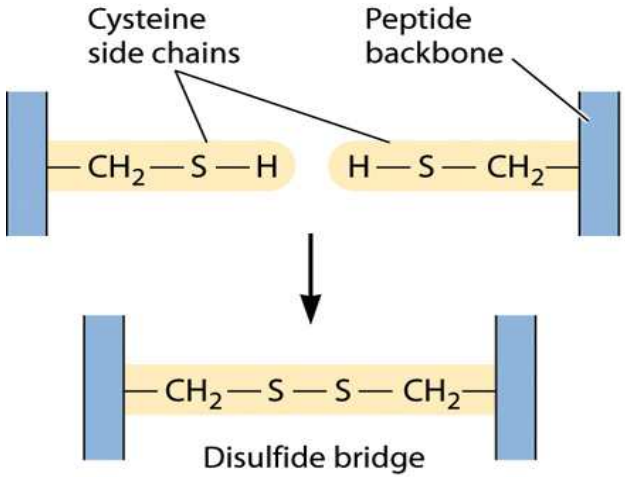
- **Covalent bond determining protein conformation**
  - Disulfide bonds : uncommon

Tertiary Structure

- **Overall 3D arrangement of a polypeptide chain**

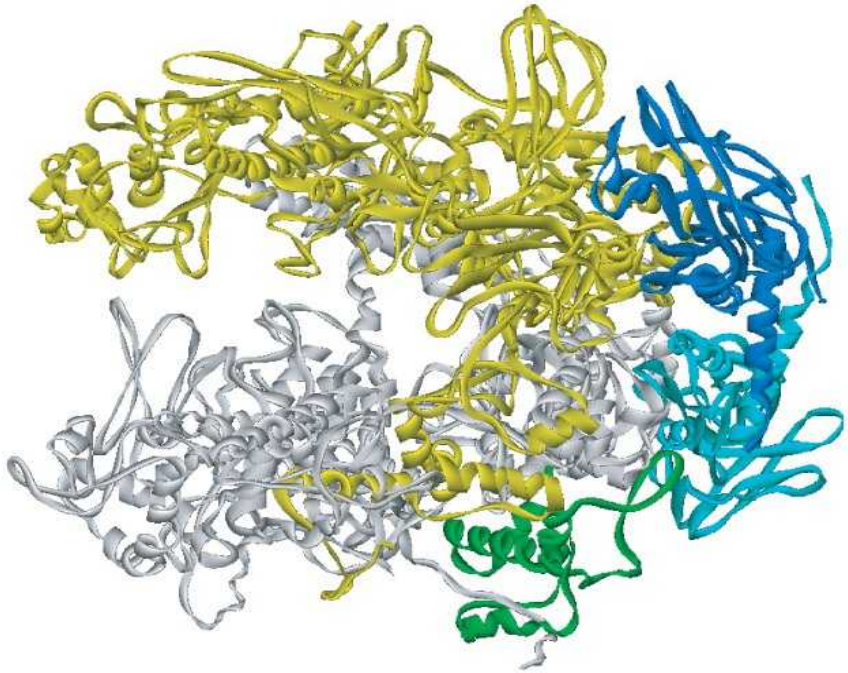


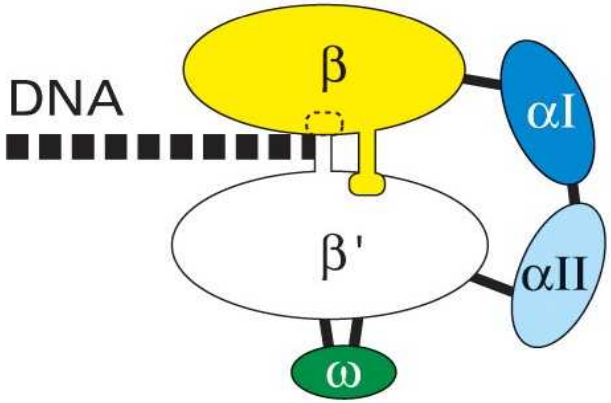
- **Stabilization**
  - weak interaction
    - Hydrophobic interaction between nonpolar side chains
    - Hydrogen bond between polar side chains and peptide bonds
  - Disulfide bond formation



Quaternary Structure

- Arrangement of protein subunits
- *E. coli* RNA polymerase : Five polypeptide chains





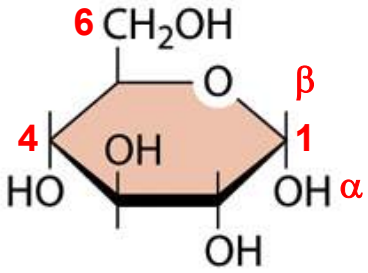
Bacterial RNA polymerase

Carbohydrates: Mono- and Polysaccharides

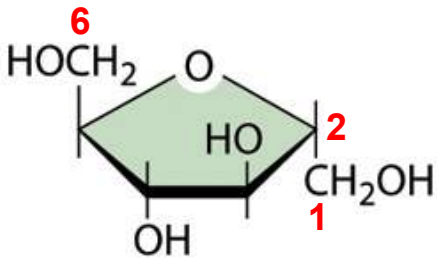
- $(CH_2O)_n$, C : H : O = 1 : 2 : 1
- **Monosaccharide ; Simple sugars**
- **Disaccharide**
  - sucrose (glucose + fructose)
  - lactose (galactose + glucose)
- **Polysaccharide**
  - pectin, starch, cellulose --- from glucose
  - agar

Mono- and Disaccharides

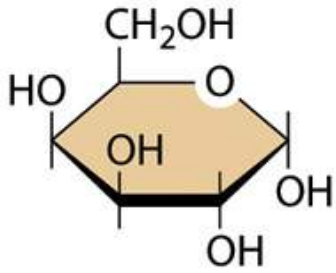
A. Simple sugars



Glucose (α form)

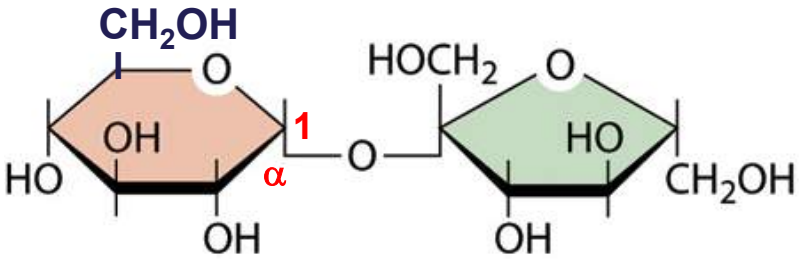


Fructose

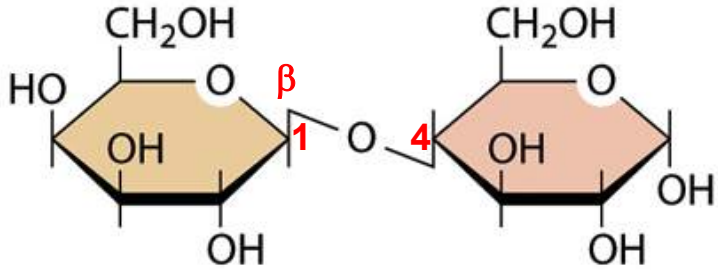


Galactose

B. Complex sugars



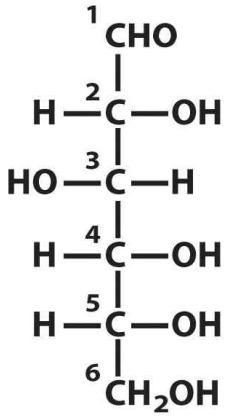
Sucrose (table sugar)
Glucose + fructose



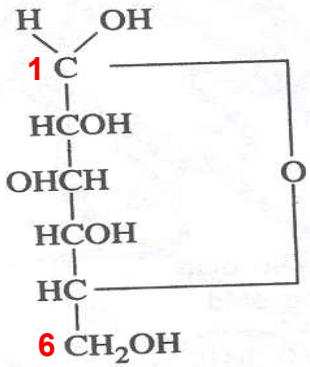
Lactose (milk sugar)
Galactose + glucose

Linear and Ring Structure

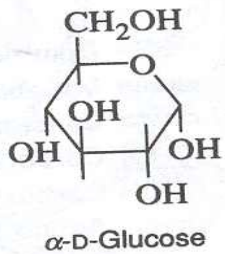
- Monosaccharide may be present in the form of a linear or ring structure
- In solution, it is in the form of a ring structure
- Numbering C from the C nearest the carbonyl group



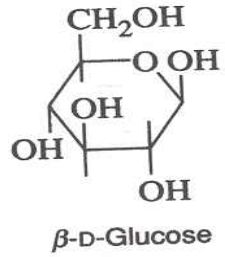
D-Glucose



D-Glucose, ring (pyranose) structure



α-D-Glucose

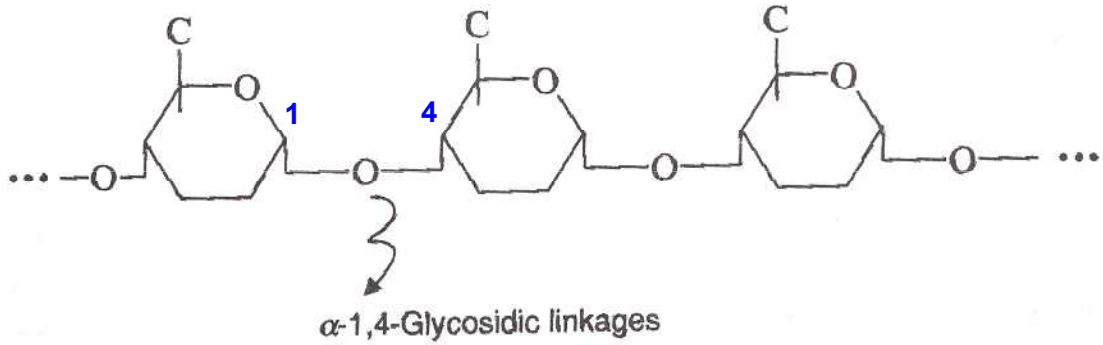


β-D-Glucose

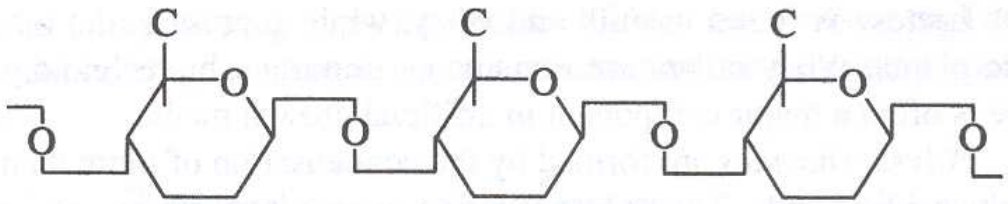
No L-glucose exists

Polysaccharides

- Starch: amylose + amylopectin
- Amylose (α-1,4-Glycosidic linkage)

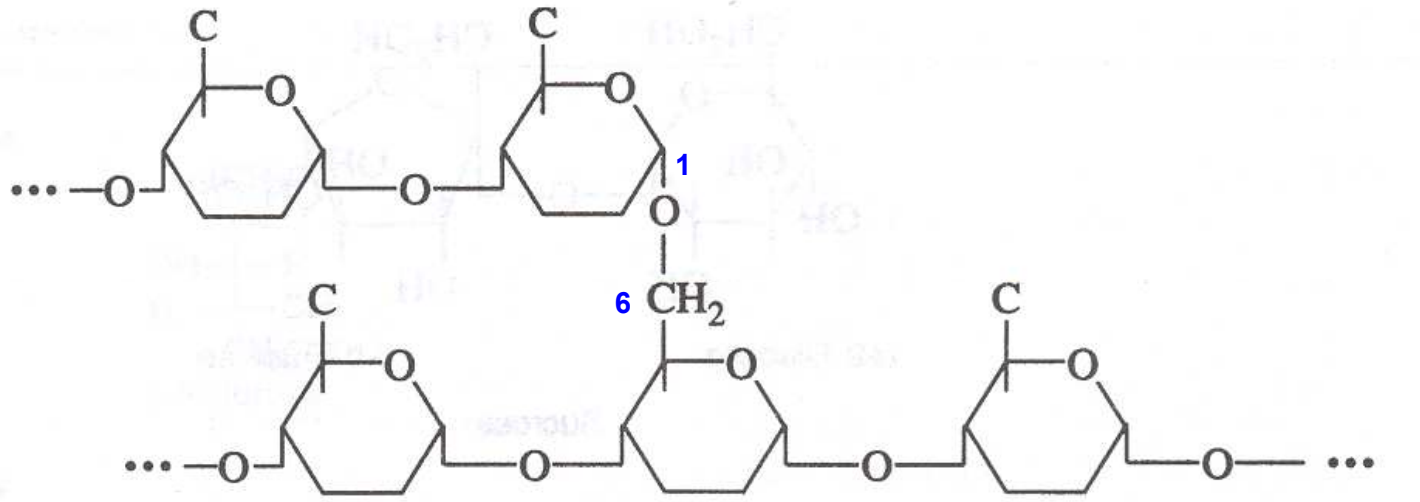


- Cellulose (β-1,4-Glycosidic linkage)



Polysaccharides

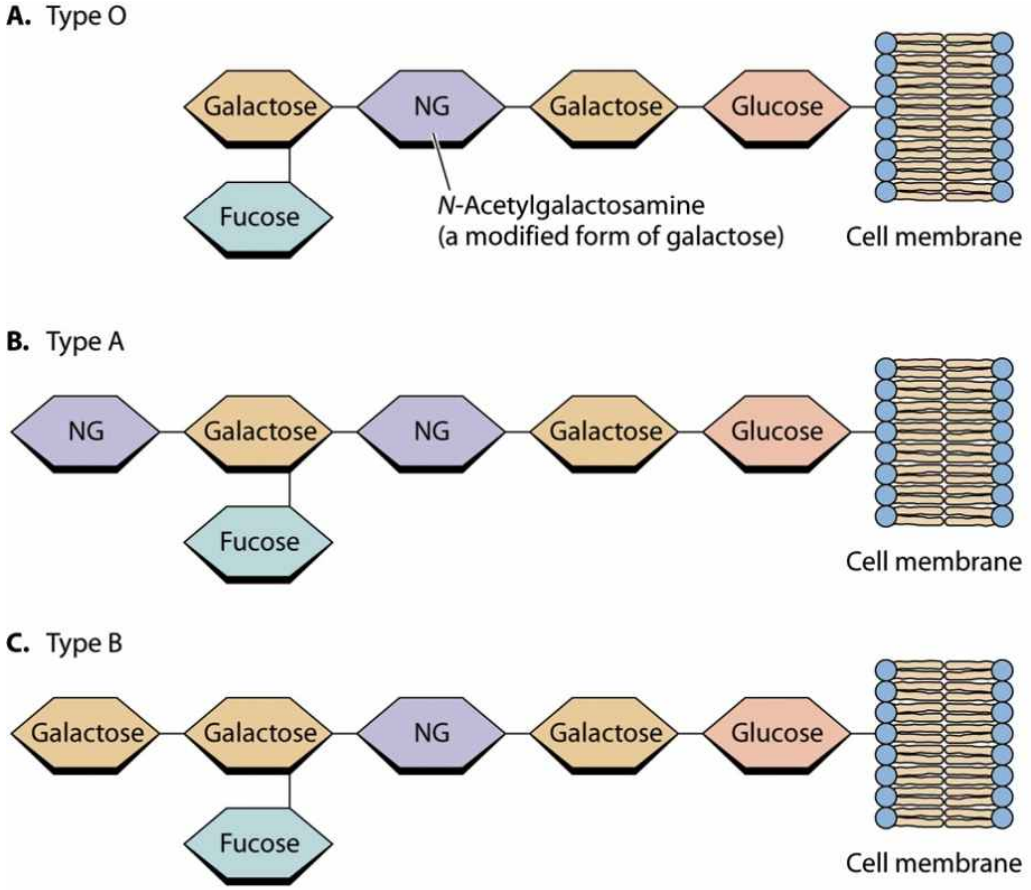
- **Amylopectin (branched chain, α-1,6-Glycosidic linkage)**

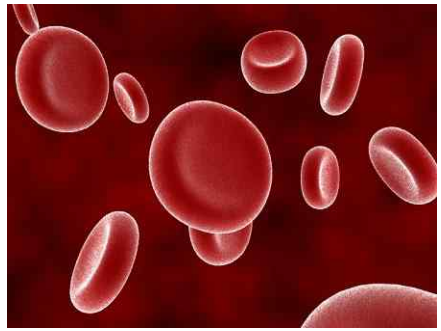


- **Glycogen**
  - the main storage polysaccharide of animal cells
  - similar structure to that of amylopectin

Roles of Carbohydrates

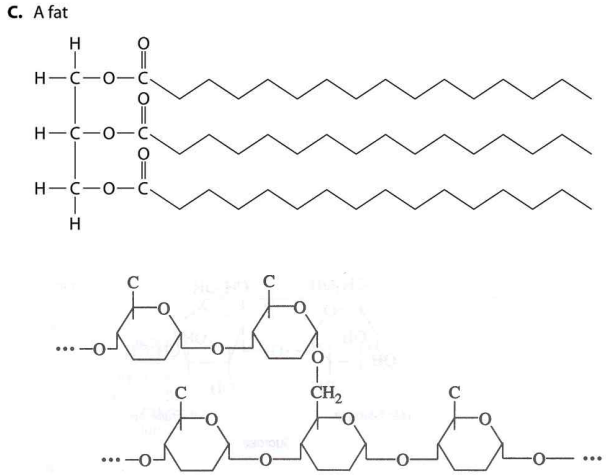
- Molecular recognition
  - Often found connected to other molecules on the outsides of cells --- cellular recognition, cell signaling, cell adhesion
  - e.g. blood typing : sugar chains in the membrane of RBC





Lipids

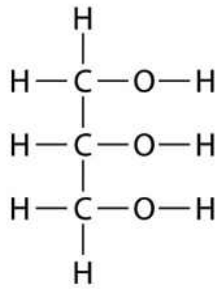
- **Characteristics**
  - Water insolubility
  - Diverse structures
- **Functions**
  - Energy storage
    - Fatty acid derivatives (fat)
  - Components of biological membrane
    - Glycerophospholipids, sphingolipids, cholesterol
  - Signals
    - Hormones (steroids, Vitamin D_3 (hormone precursor))
  - Enzyme cofactors
    - Vitamin K
  - Pigment
    - Vitamin A



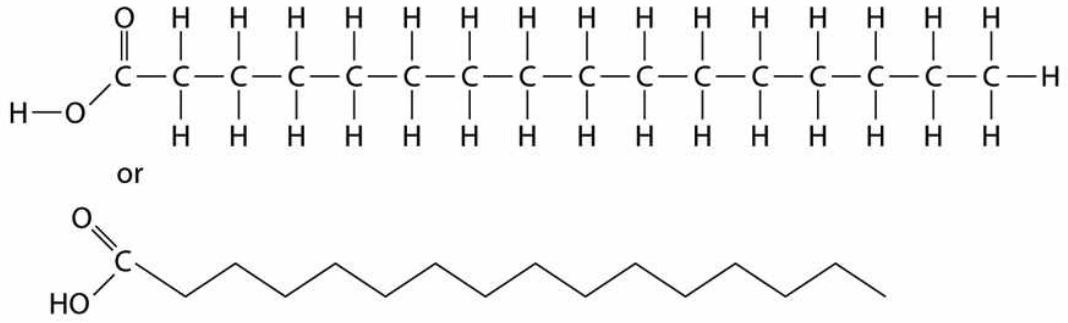
Fat

- Triacylglycerol
- glycerol + fatty acid (Ester linkage of glycerol with 3 fatty acids)
- High energy C-H, C-C bonds → good energy storage

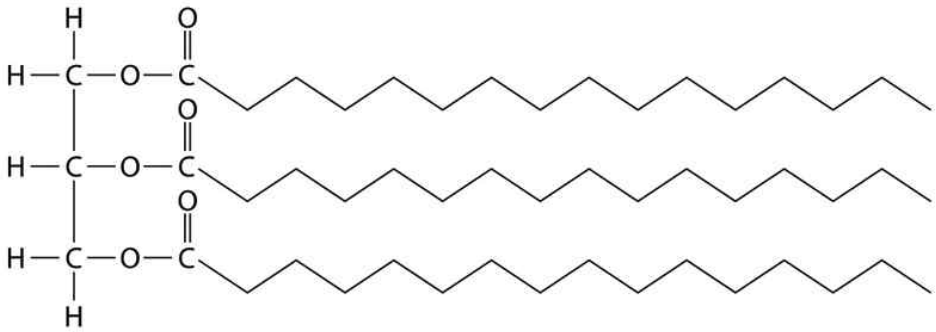
A. Glycerol



B. Fatty acid (palmitic acid)

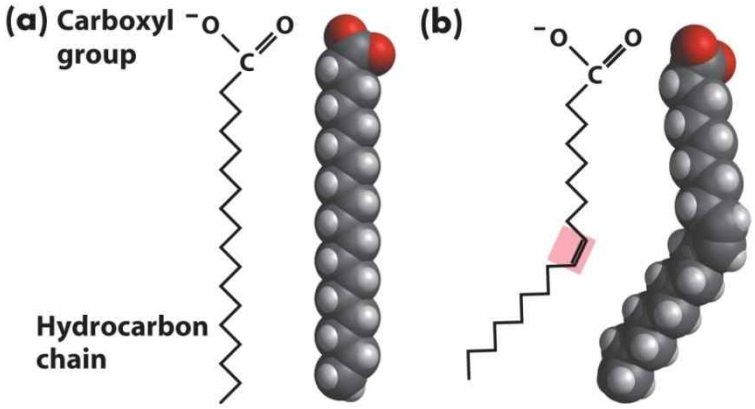


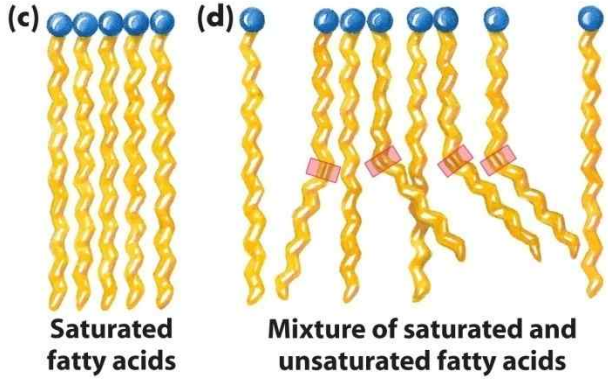
C. A fat



Physical Properties of Fatty Acids

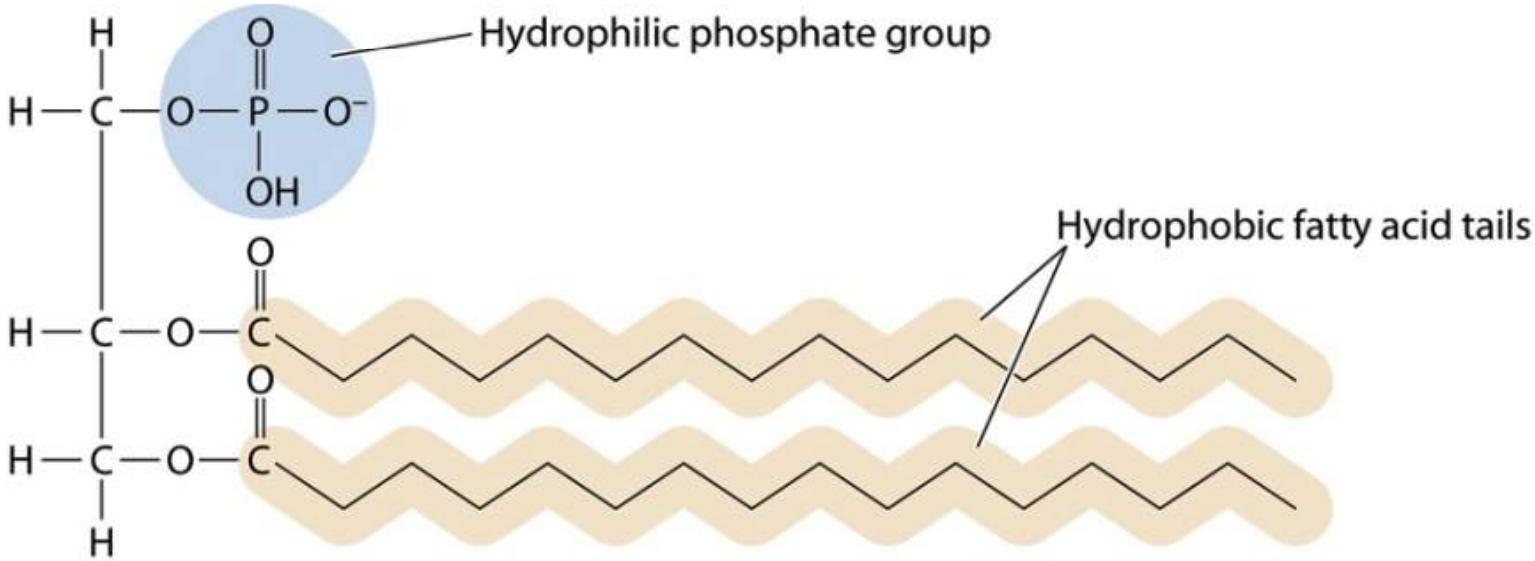
- **Water solubility**
  - Longer chain → lower solubility
- **Melting point**
  - Depending on the degrees of packing
    - Length and degree of unsaturation
  - Saturated fatty acid (a, c)
    - Tight packing → high melting point
    - Solid at room temperature
  - Unsaturated fatty acid (b)
    - more double bonds → liquid at room temperature





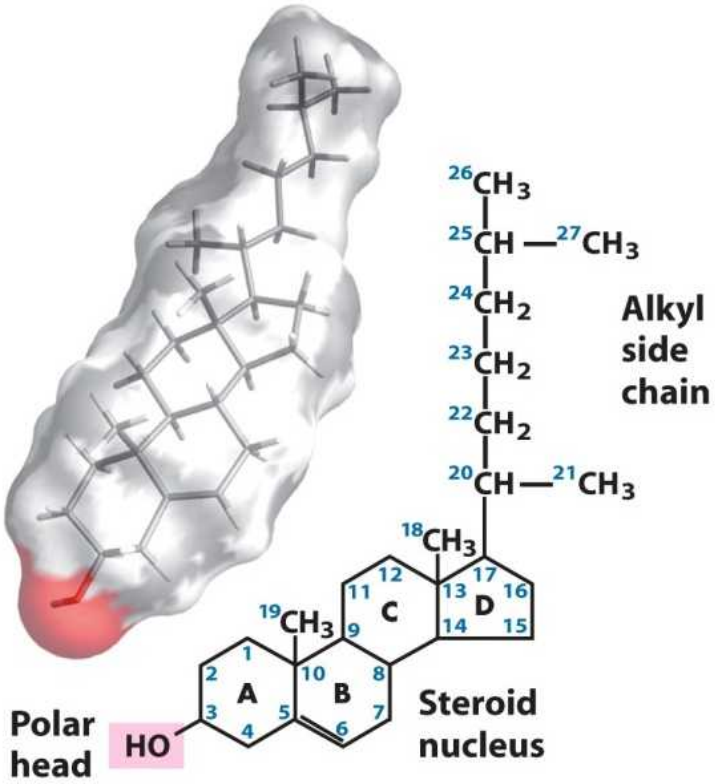
Phospholipid

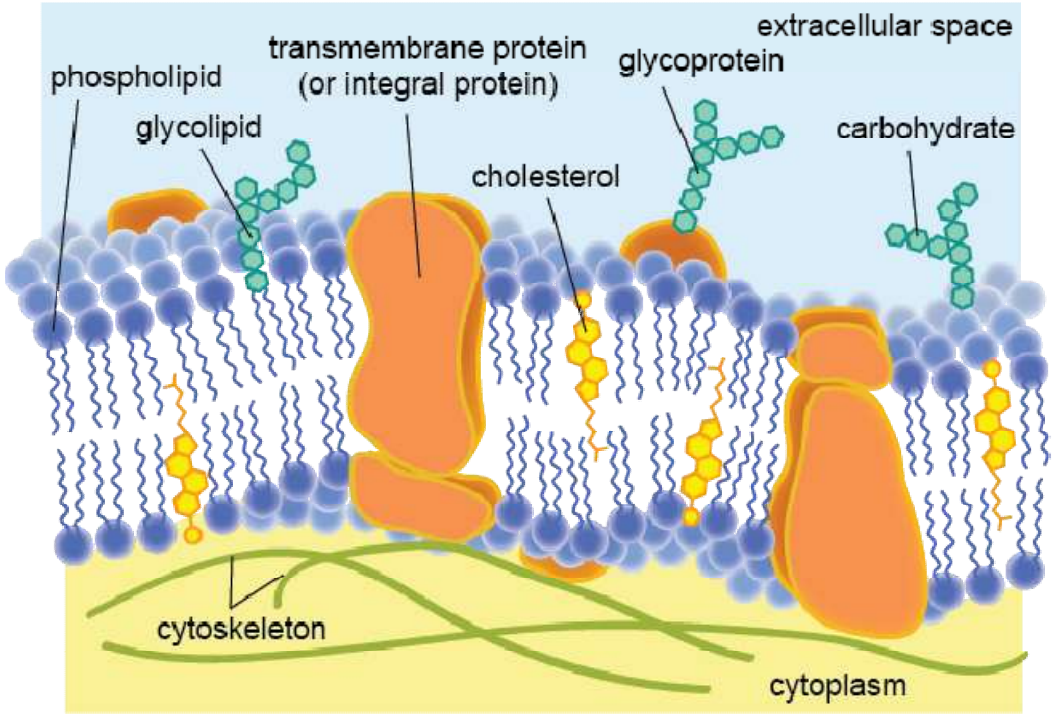
- Glycerol backbone
- two fatty acids (hydrophobic) + phosphate (hydrophilic)



Cholesterol

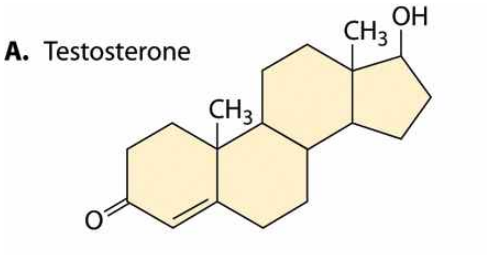
- Component of animal cell membranes : increase membrane fluidity
- Starting material for steroid hormones and bile

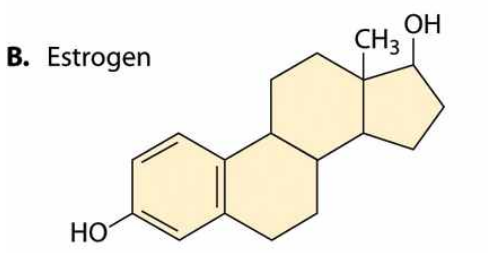


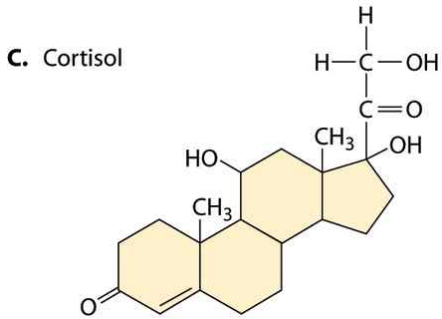


Steroids

- **Derivatives of sterols**
  - Lacking alkyl chain on ring D of cholesterol
  - More polar that cholesterol
- **Working mechanism**
  - Moving through blood stream
  - Bind to receptors in nucleus and activate gene expression and thus metabolism
  - Very high affinity to the receptor
    - Working at less than nanomolar



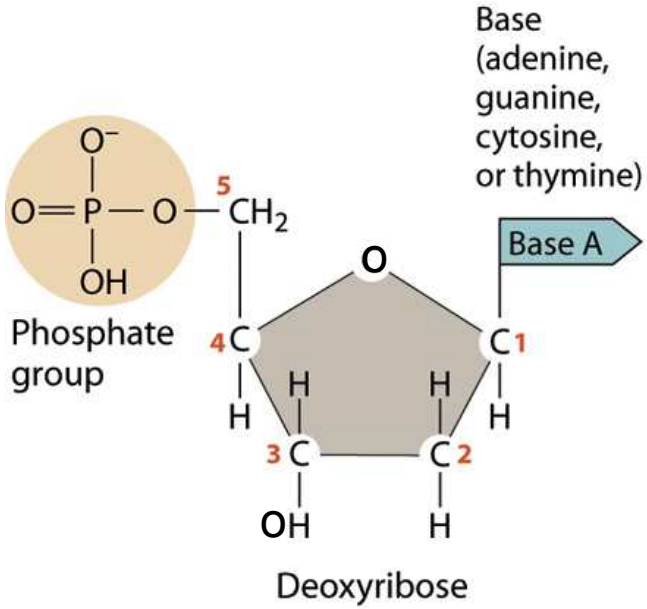




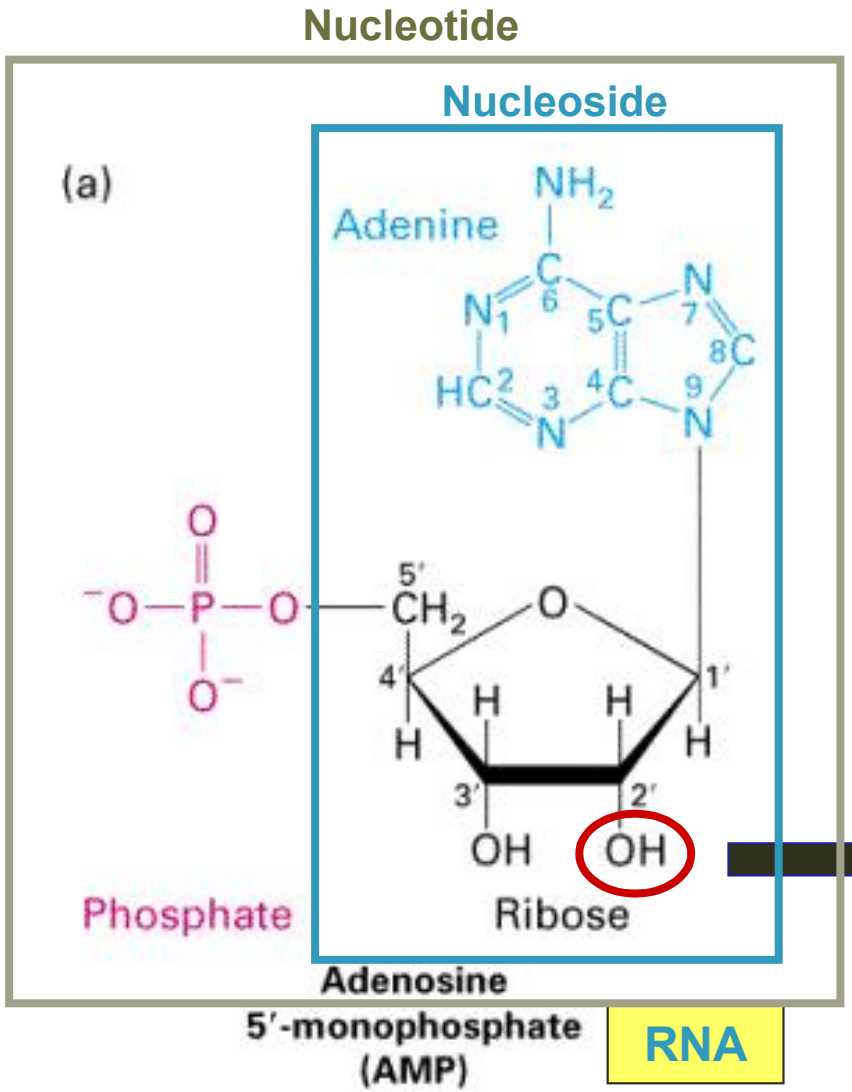
Nucleic Acids, RNA, and DNA

- **Nucleotides**
  - Building blocks of nucleic acids (DNA or RNA)
  - (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

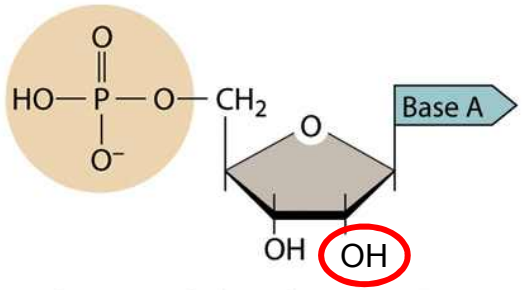
2’-Deoxyribose

RNA

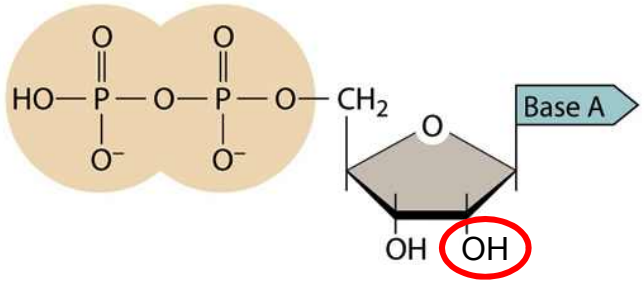
DNA

AMP, ADP, ATP

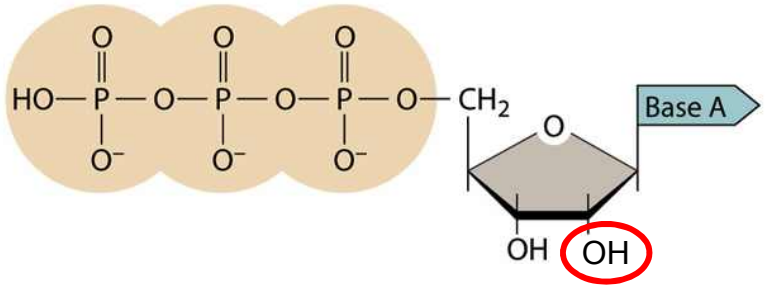
A. Adenosine monophosphate (AMP)



B. Adenosine diphosphate (ADP)



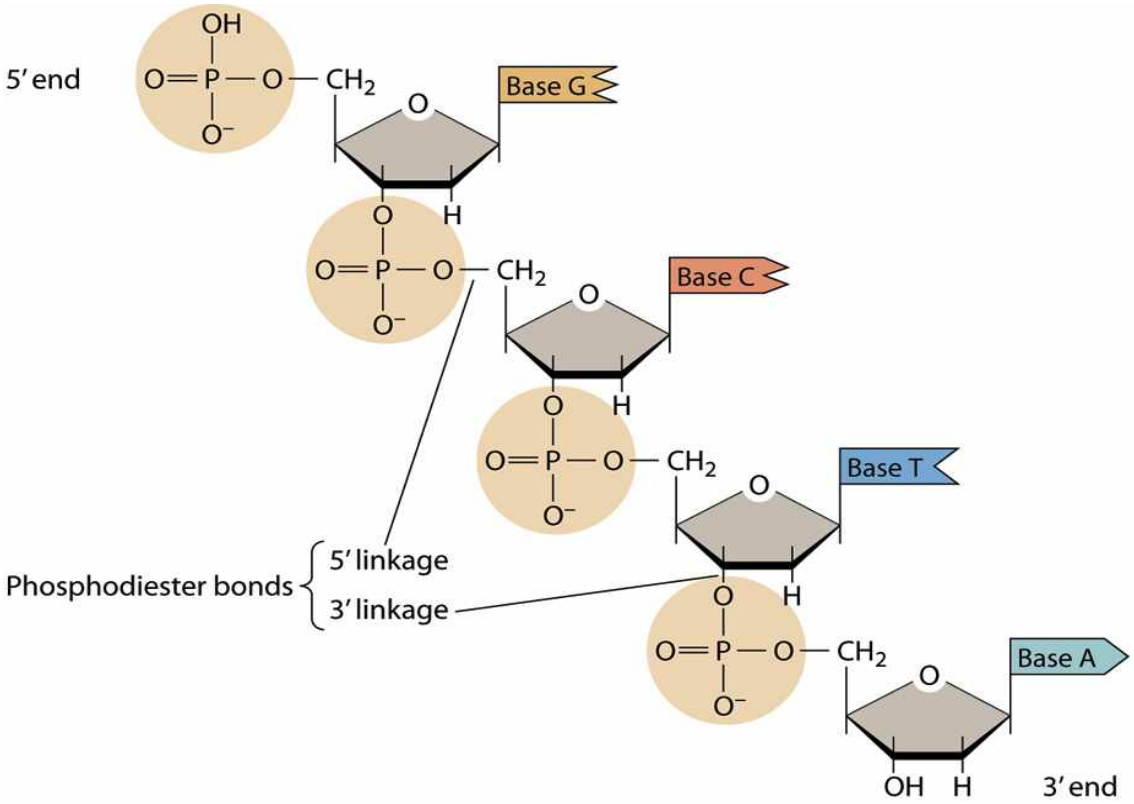
C. Adenosine triphosphate (ATP)



AMP = Adenylate
(cf. dAMP)

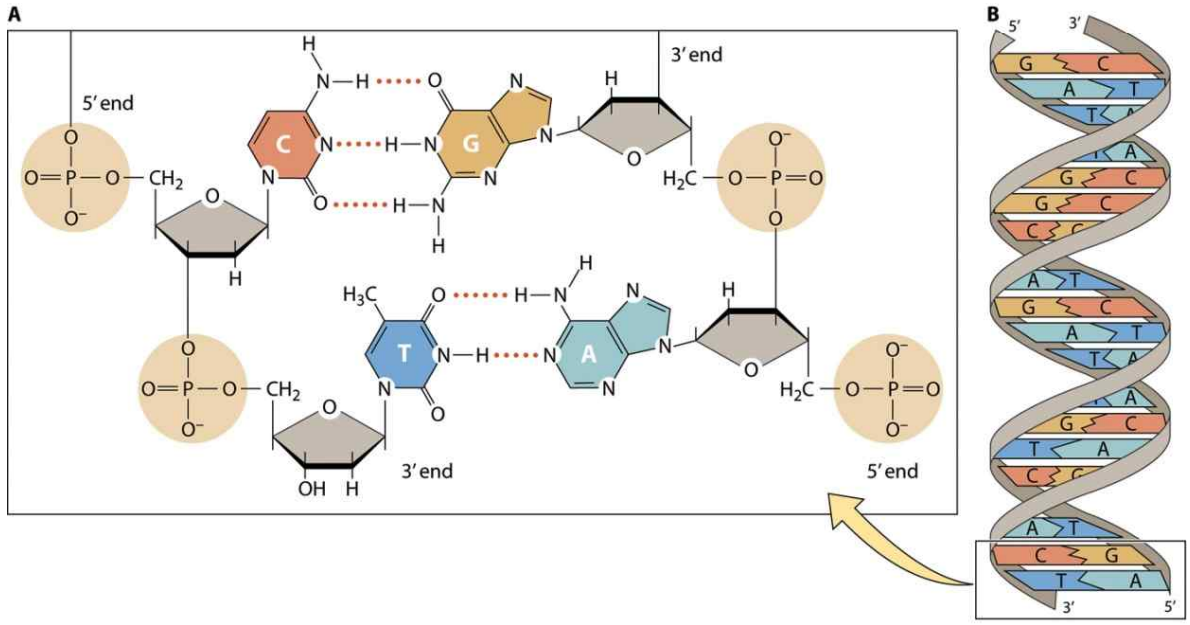
Nucleotide Chains

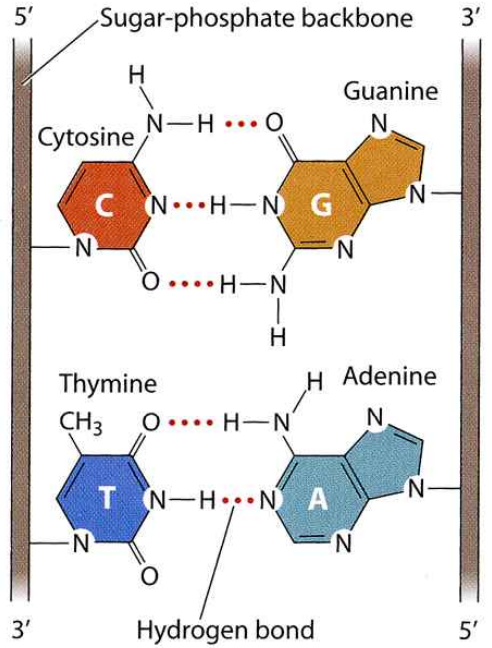
- e.g., DNA
- Linkage of 5’ carbon to 3’ carbon through phosphodiester bond

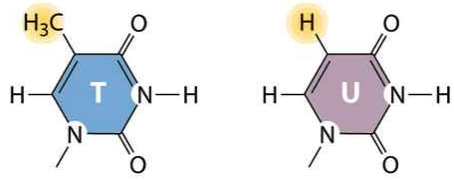


Nucleotide Chains

- **e.g., DNA double strand**
- **Base pairing**
  - C=G, T=A : hydrogen bonding
  - Complementary base pairs
  - Antiparallel strand in DNA molecule

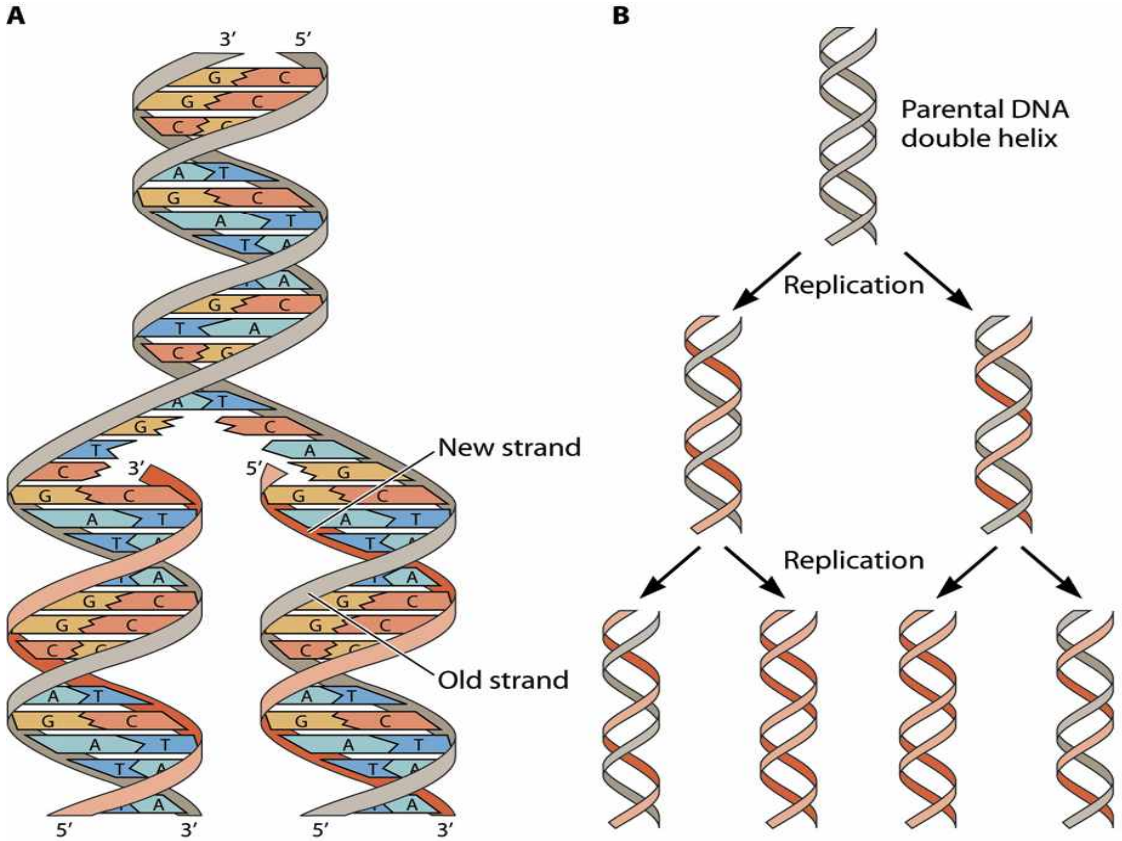




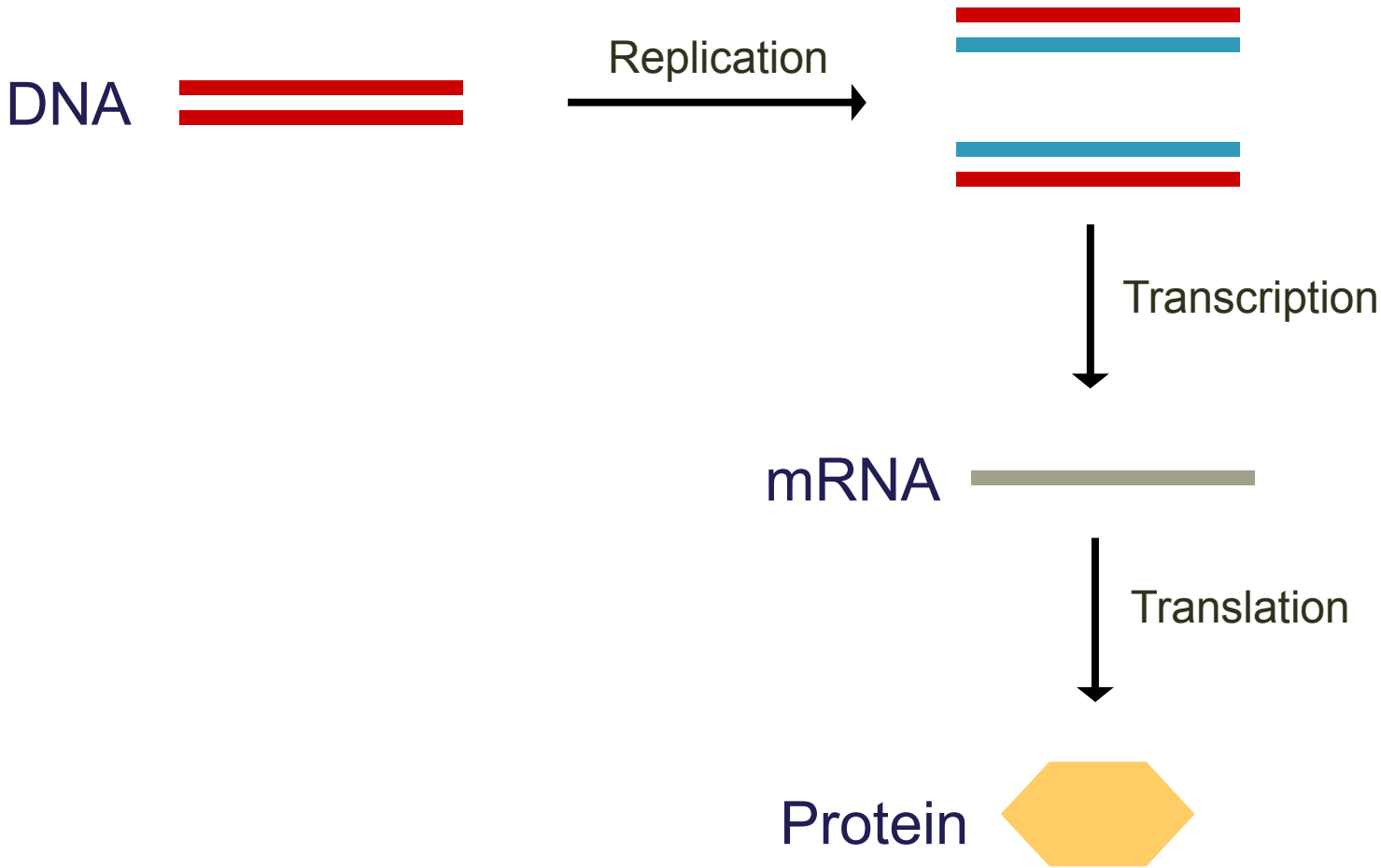


DNA Replication

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



Expression of Genetic Information



Cell Nutrients

TABLE 2.9 The Eight Macronutrient Elements and Some Physiological Functions and Growth Requirements

Element	Physiological function	Required concentration (mol l^{-1})
Carbon	Constituent of organic cellular material. Often the energy source.	$>10^{-2}$
Nitrogen	Constituent of proteins, nucleic acids, and coenzymes.	10^{-3}
Hydrogen	Organic cellular material and water.	—
Oxygen	Organic cellular material and water. Required for aerobic respiration.	—
Sulfur	Constituent of proteins and certain coenzymes	10^{-4}
Phosphorus	Constituent of nucleic acids, phospholipids, nucleotides, and certain coenzymes	10^{-4} to 10^{-3}
Potassium	Principal inorganic cation in the cell and cofactor for some enzymes.	10^{-4} to 10^{-3}
Magnesium	Cofactor for many enzymes and chlorophylls (photosynthetic microbes) and present in cell walls and membranes.	10^{-4} to 10^{-3}

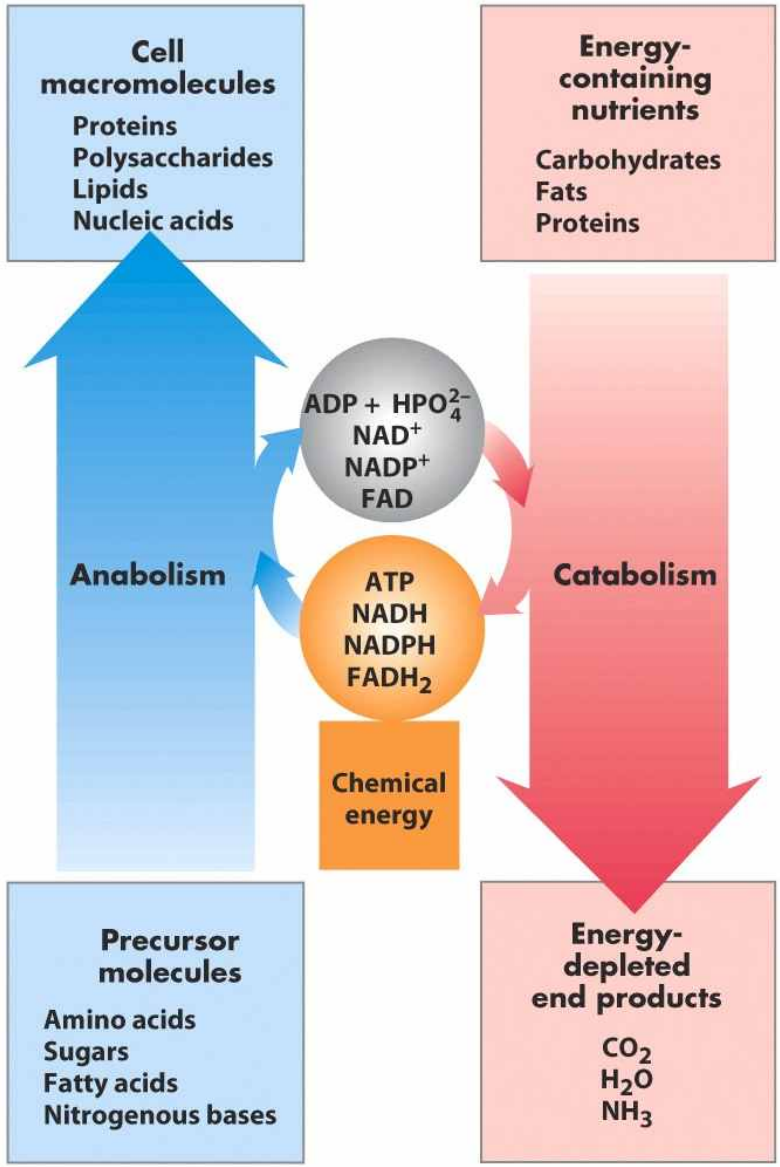
With permission, from G. M. Dunn in *Comprehensive Biotechnology,* M. Moo-Young, ed., Vol. I, Elsevier Science, 1985.

Growth media

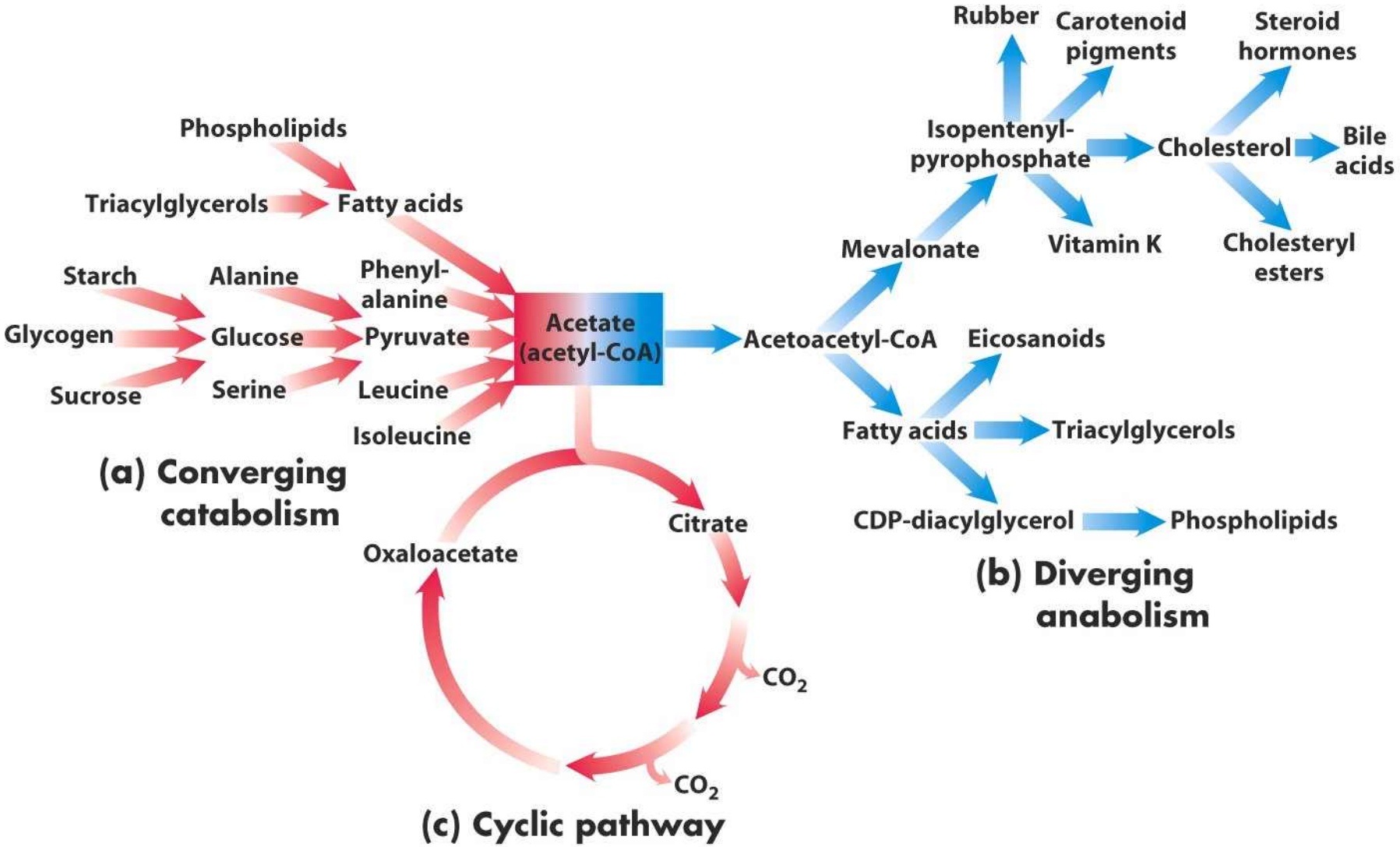
TABLE 2.10 Compositions of Typical Defined and Complex Media

Defined medium		
Constituent	Purpose	Concn (g/liter)
Group A		
Glucose	C, energy	30
KH_2PO_4	K, P	1.5
$MgSO_4 \cdot 7H_2O$	Mg, S	0.6
$CaCl_2$	Ca	0.05
$Fe_2(SO_4)_3$	Fe	15×10^{-4}
$ZnSO_4 \cdot 7H_2O$	Zn	6×10^{-4}
$CuSO_4 \cdot 5H_2O$	Cu	6×10^{-4}
$MnSO_4 \cdot H_2O$	Mn	6×10^{-4}
Group B		
$(NH_4)_2HPO_4$	N	6
$(NH_4)H_2PO_4$	N	5
Group C		
$C_6H_5Na_3O_7 \cdot 2H_2O$	Chelator	4
Group D		
Na_2HPO_4	Buffer	20
KH_2PO_4	Buffer	10
Complex medium used in a penicillin fermentation		
Glucose or molasses (by continuous feed)		10% of total
Corn steep liquor		1–5% of total
Phenylacetic acid (by continuous feed)		0.5–0.8% of total
Lard oil (or vegetable oil) antifoam by continuous addition		0.5% of total
pH to 6.5 to 7.5 by acid or alkali addition		

Metabolism


Cell macromolecules
Proteins
Polysaccharides
Lipids
Nucleic acids
Energy-containing nutrients
Carbohydrates
Fats
Proteins
ADP + HPO_4^{2-}
NAD^+
$NADP^+$
FAD
Anabolism
ATP
NADH
NADPH
$FADH_2$
Catabolism
Chemical energy
Precursor molecules
Amino acids
Sugars
Fatty acids
Nitrogenous bases
Energy-depleted end products
CO_2
H_2O
NH_3

Metabolism


Phospholipids
Triacylglycerols
Fatty acids
Starch
Alanine
Phenyl-alanine
Glycogen
Glucose
Pyruvate
Sucrose
Serine
Leucine
Isoleucine
Acetate (acetyl-CoA)
(a) Converging catabolism
Acetoacetyl-CoA
Mevalonate
Isopentenyl-pyrophosphate
Rubber
Carotenoid pigments
Steroid hormones
Cholesterol
Bile acids
Vitamin K
Cholesteryl esters
Eicosanoids
Fatty acids
Triacylglycerols
CDP-diacylglycerol
Phospholipids
(b) Diverging anabolism
Citrate
Oxaloacetate
CO_2
CO_2
(c) Cyclic pathway

Bioenergetics