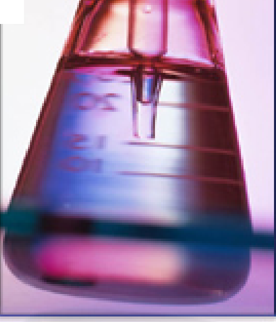
Human Anatomy & Physiology

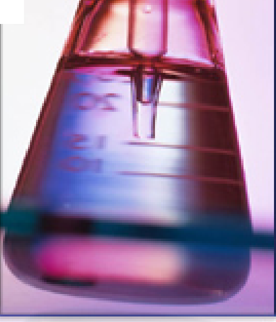
Chapter 2 (emphasis on pages 47-58)

Chemical Basis Of Life



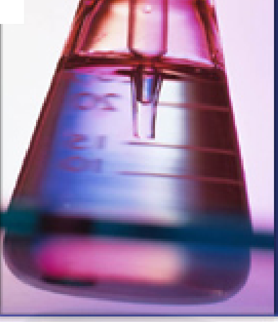
Matter

- The "stuff" of the universe
- Anything that has mass and occupies space
- Mass vs. Weight (amount of matter vs. force)
- States of Matter
  - Solid – has definite shape and volume
  - Liquid – has definite volume, changeable shape
  - Gas – has changeable shape and volume

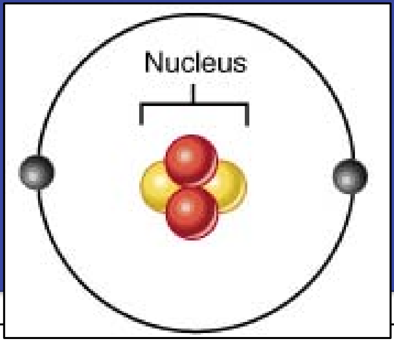


Composition of Matter

- Elements – unique substances that cannot be broken down into simpler substances by ordinary chemical means
- Each element is composed of Atoms
- Physical and Chemical properties of an element’s atoms give the element its unique properties
- Atomic symbol – one- or two-letter chemical shorthand for each element

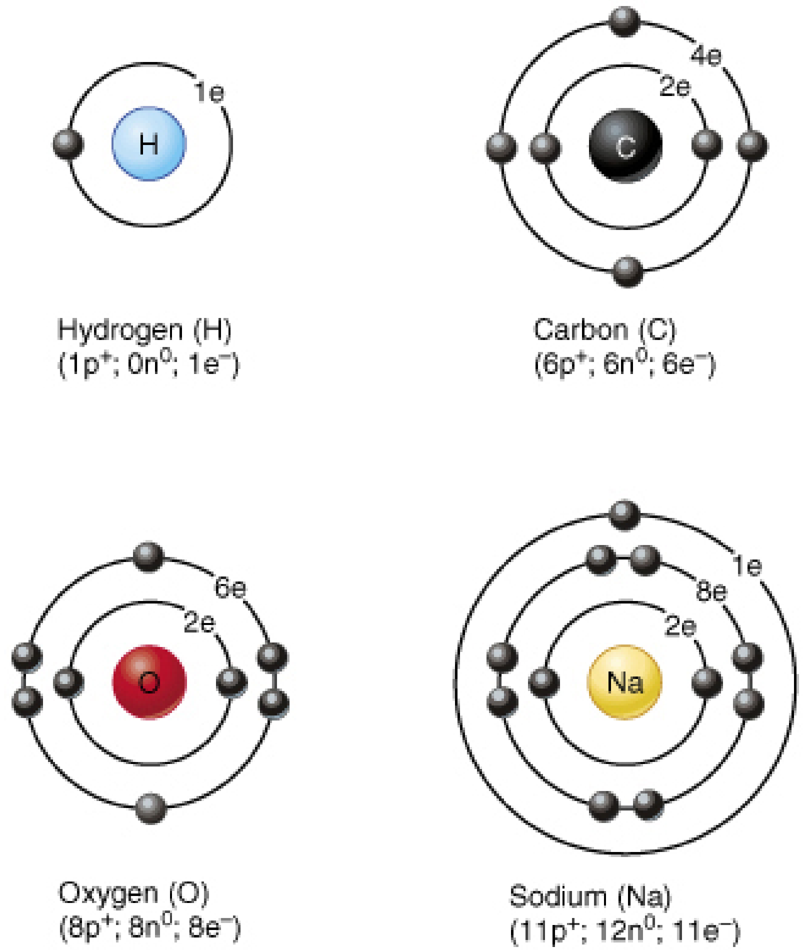


Atomic Structure

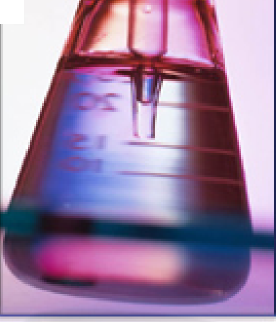


- The Nucleus consists of Neutrons and Protons
  - Neutrons – have no charge (*Neutral*) and a mass of one atomic mass unit (amu)
  - Protons – have a *Positive* charge and a mass of one amu
- Electrons have a negative charge and 1/2000 the mass of a proton (0 amu)
  - Electrons – are located in regions (*Orbitals*) around the nucleus

Atomic Structure: Examples of Different Elements



(b) Chemically active elements (valence shell incomplete)



Examples of Elements

H Hydrogen
Atomic Number: 1
Atomic Mass: 1.00797

C Carbon
Atomic Number: 6
Atomic Mass: 12.01

O Oxygen
Atomic Number: 8
Atomic Mass: 16

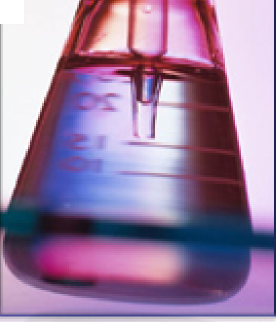
N Nitrogen
Atomic Number: 7
Atomic Mass: 14.01

Ca Calcium
Atomic Number: 20
Atomic Mass: 40.08

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 30.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (97.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (208.98)	85 At (209.99)	86 Rn (222.02)
87 Fr (223.02)	88 Ra (226.03)	89 Ac (227.03)	104 Rf (261.11)	105 Ha (262.11)	106 Sg (263.12)												

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237.05)	94 Pu (244.06)	95 Am (243.06)	96 Cm (247.07)	97 Bk (247.07)	98 Cf (251.08)	99 Es (252.08)	100 Fm (257.10)	101 Md (258.10)	102 No (259.10)	103 Lr (262.11)



Major Elements of the Human Body

- Oxygen (O) – major component of organic and inorganic molecules; as a gas, needed for the production of *ATP*
- Carbon (C) – component of all organic molecules – *carbohydrates, lipids, proteins, and nucleic acids*
- Hydrogen (H) – component of all organic molecules; as an ion, it influences *pH* (degree of acidity or alkalinity) of body fluids
- Nitrogen (N) – component of *proteins* and *nucleic acids*

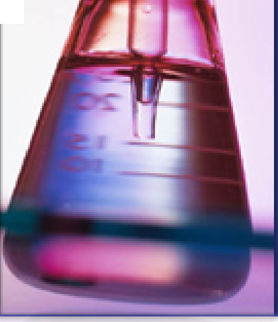
Lesser and Trace Elements of the Human Body

- Other Elements

  Calcium (Ca), Phosphorus (P), Potassium (K), Sulfur (S), Sodium (Na), Chlorine (Cl), Magnesium (Mg), Iodine (I), and Iron (Fe)

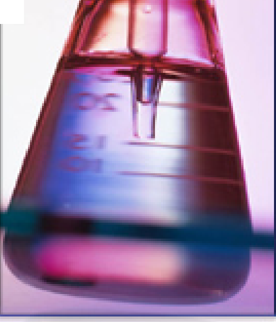
- Trace Elements

  Required in minute amounts, many are found as parts of enzymes: Selenium (Se), Zinc (Zn), Copper (Cu)



Chemical Composition of the Human Body

- Oxygen or O – 65%
- Carbon or C – 18.5%
- Hydrogen or H – 9.5%
- Nitrogen or N – 3.2%
- Calcium or Ca – 1.5%
- Phosphorous or P – 1.0%



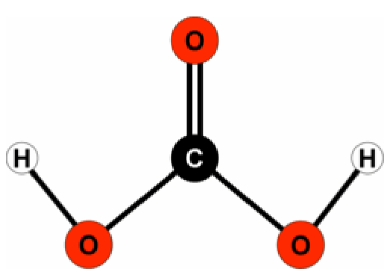
Chemical Constituents of Cells

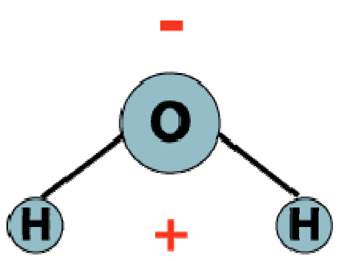
- Inorganic Molecules do not contain carbon and hydrogen together, do have other important roles (water, salts, and many acids and bases)

- Organic Molecules contain carbon covalently bonded to other atoms, determine structure and function

Chemical Constituents of Cells

- Common Inorganic Compounds:
  - Oxygen
  - Water
  - Carbon Dioxide (CO_2)
  - In Blood: $CO_2 + H_2 + O_2 \longrightarrow H_2CO_3$
  - In Lungs: $H_2CO_3 \longrightarrow H_2O + CO_2$





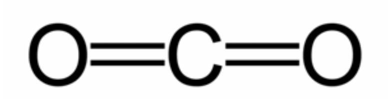
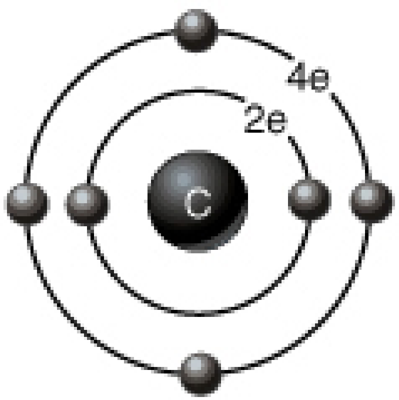


TABLE 2.6 Inorganic Substances Common in Cells

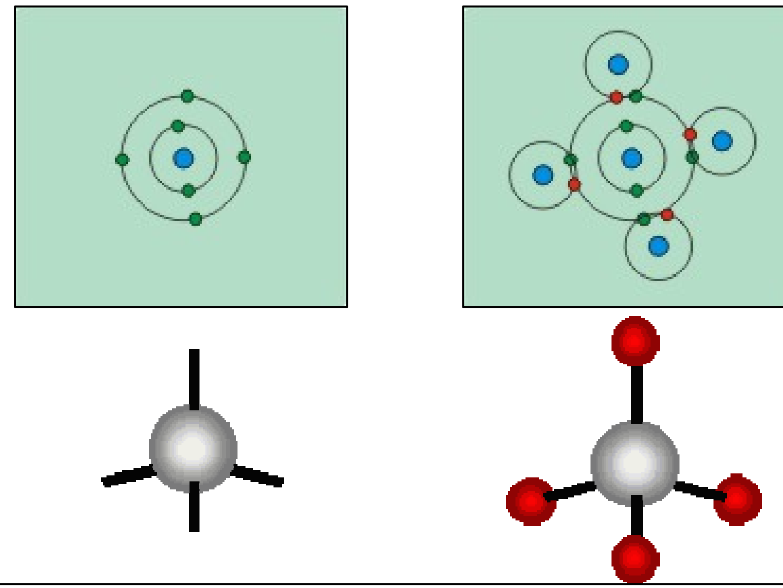
Substance	Symbol or Formula	Functions
I. Inorganic Molecules		
Water	H_2O	Major component of body fluids (chapter 21, p. 808); medium in which most biochemical reactions occur; transports various chemical substances (chapter 14, p. 523); helps regulate body temperature (chapter 6, p. 170)
Oxygen	O_2	Used in release of energy from glucose molecules (chapter 4, p. 111)
Carbon dioxide	CO_2	Waste product that results from metabolism (chapter 4, p. 111); reacts with water to form carbonic acid (chapter 19, p. 762)
II. Inorganic Ions		
Bicarbonate ions	HCO_3^-	Help maintain acid-base balance (chapter 21, p. 819)
Calcium ions	Ca^{+2}	Necessary for bone development (chapter 7, p. 190); muscle contraction (chapter 9, p. 284) and blood clotting (chapter 14, fig. 14.19)
Carbonate ions	CO_3^{-2}	Component of bone tissue (chapter 7, p. 194)
Chloride ions	Cl^-	Help maintain water balance (chapter 21, p. 810)
Hydrogen ions	H^+	pH of the internal environment (chapters 19, p. 754, and 21, p. 817)
Magnesium ions	Mg^{+2}	Component of bone tissue (chapter 7, p. 194); required for certain metabolic processes (chapter 18, p. 715)
Phosphate ions	PO_4^{-3}	Required for synthesis of ATP, nucleic acids, and other vital substances (chapter 4, p. 108); component of bone tissue (chapter 7, p. 194); help maintain polarization of cell membranes (chapter 10, p. 350)
Potassium ions	K^+	Required for polarization of cell membranes (chapter 10, p. 350)
Sodium ions	Na^+	Required for polarization of cell membranes (chapter 10, p. 350); help maintain water balance (chapter 21, p. 810)
Sulfate ions	SO_4^{-2}	Help maintain polarization of cell membranes (chapter 10, p. 350) and acid-base balance (chapter 21, p. 817)

Carbon – "living" chemistry depends on C

What makes Carbon so special?



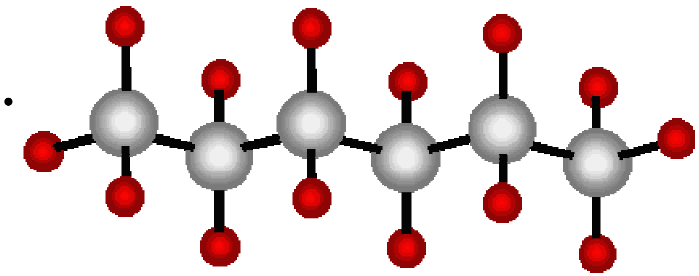
Carbon (C)
(6p$^+$; 6n^0; 6e$^-$)



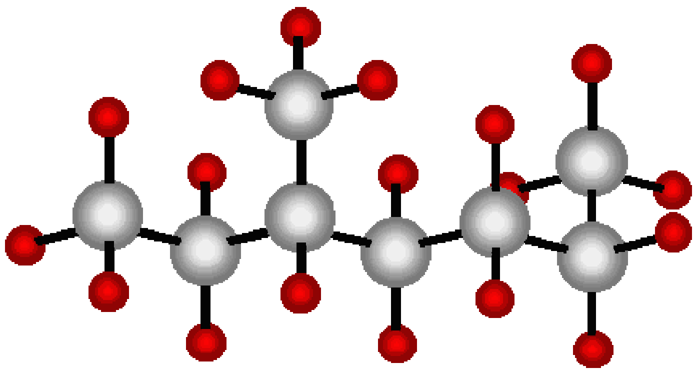
Carbon (C) has 4 electrons in its outer shell. Because 8 electrons are needed to fill its valence shell, it can form strong, stable covalent bonds with 4 other atoms (usually H, O, N, S, P, or another C).

Carbon can bind to itself, which allows the formation of different carbon-based molecules with unique structures

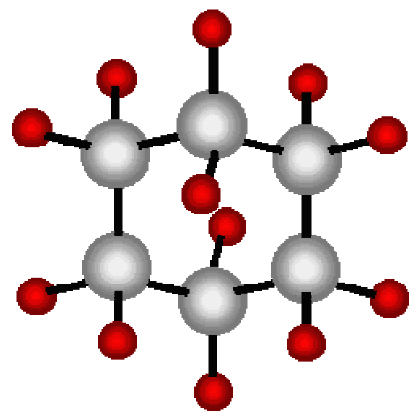
Carbon atoms can form...



long chains,



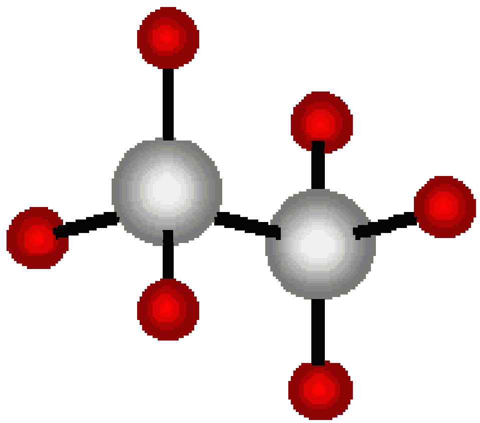
branches,



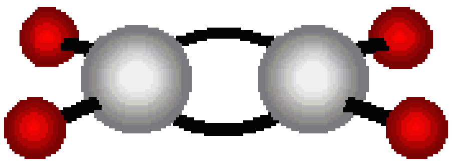
and ring structures.

Carbon Bonds

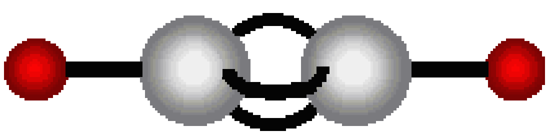
Adjacent carbon atoms can also form Double and Triple bonds.



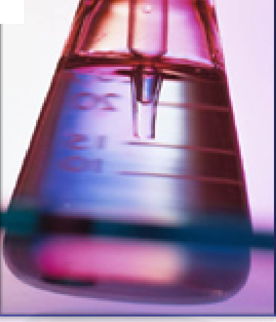
carbon-carbon single bond



carbon-carbon double bond



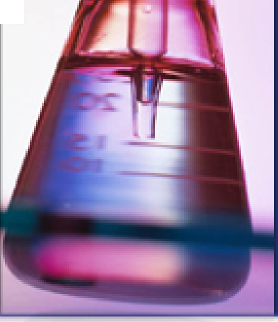
carbon-carbon triple bond



Organic Molecules – Monomers and Polymers

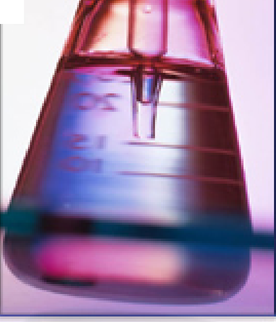
Class	Monomer (subunit)	Polymer
Carbohydrates	Sugar	Polysaccharides
Lipids	Fatty Acids	Lipids, Phospholipids
Proteins	Amino Acids	Proteins
Nucleic Acids	Nucleotides	(DNA, RNA)

Subunits		Large Molecules
Sugars	→	Polysaccharides
Fatty Acids	→	Fats/Lipids/Membranes
Amino Acids	→	Proteins
Nucleotides	→	Nucleic Acids



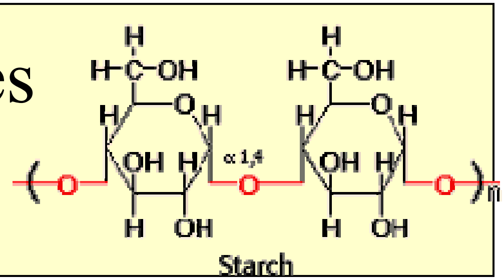
Chemical Constituents of Cells

- Common Organic Substances:
  - Carbohydrates – monosaccharides, disaccharides, & polysaccharides
  - Lipids – saturated & unsaturated fats
  - Proteins – enzymes, antibodies, structural protein (e.g. collagen)
  - Nucleic Acids - nucleotides & polynucleotides

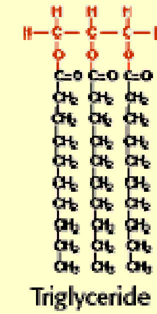


Organic Molecules – Four Classes

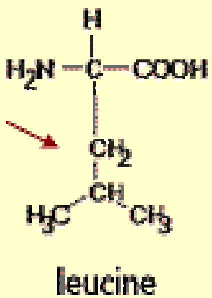
Carbohydrates



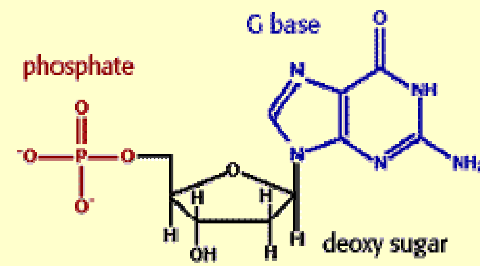
Lipids



Proteins



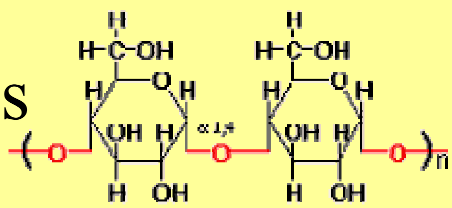
Nucleic Acids



The chemical properties of the different classes depend on the presence of specific functional groups. The larger molecules in each class are formed by joining one or more subunit molecules together.

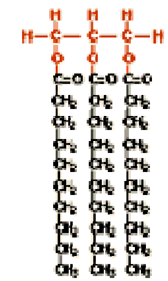
Organic Molecules – Four Classes

Carbohydrates



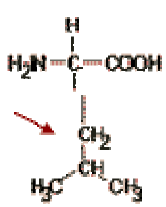
Starch

Lipids



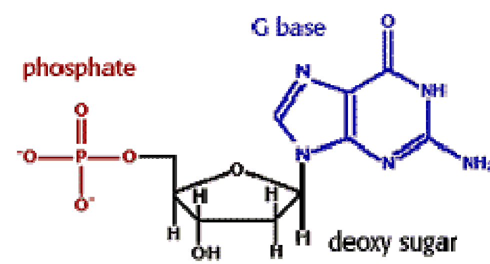
Triglyceride

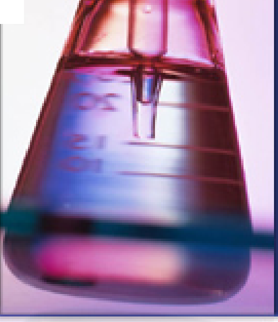
Proteins



leucine

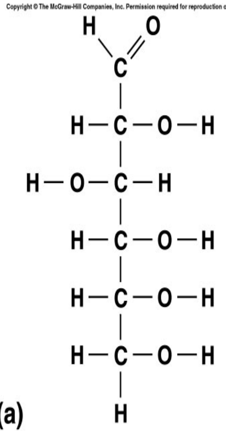
Nucleic Acids



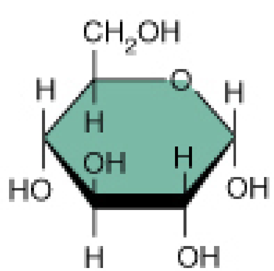


Carbohydrates

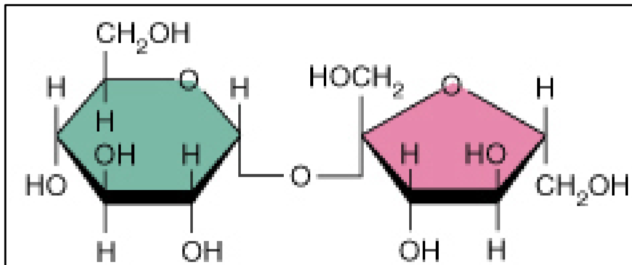
- Contain carbon, hydrogen, and oxygen, generally the hydrogen to carbon ratio is 2:1 (same as water) carbohydrate – “hydrated carbon”
- Classified as:
  - Monosaccharide – “one sugar”- exist as straight chains or rings
  - Disaccharide – “two sugars”
  - Polysaccharide – “ many sugars”



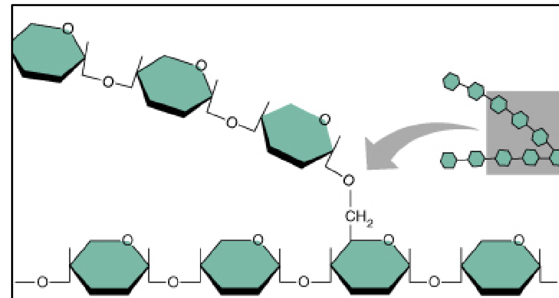
(a)



Glucose



Sucrose

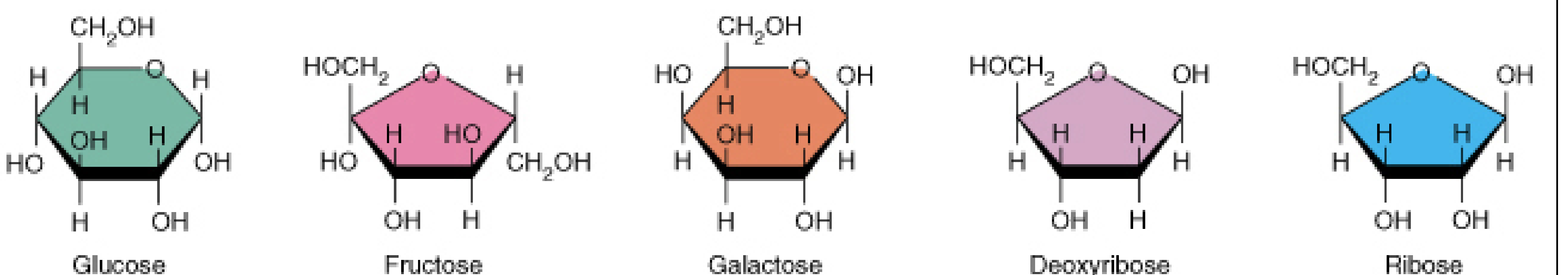


Glycogen

Carbohydrates

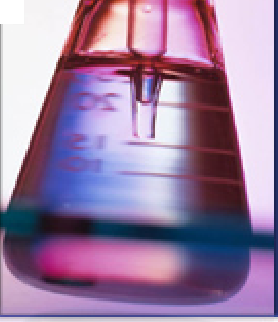
Monosaccharides - simple sugars, single chain or single ring structures

Most important in the body are the pentose and hexose sugars



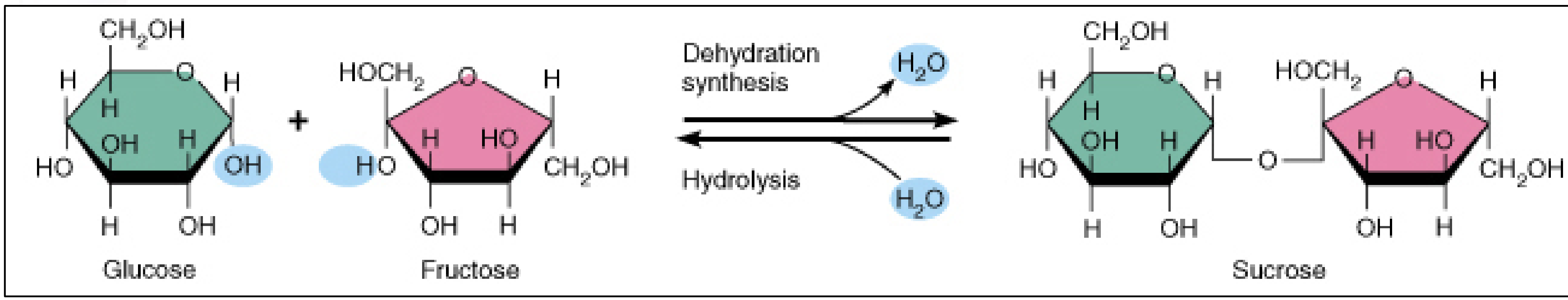
(a) **Monosaccharides**

Glucose, fructose, and galactose are **isomers**, they have the same formula ($C_6H_{12}O_6$), but the atoms are arranged differently

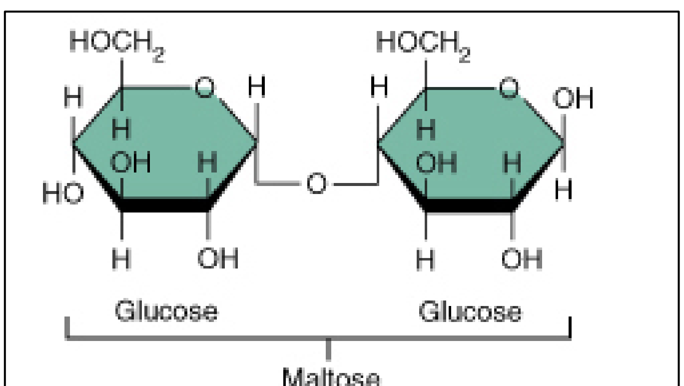


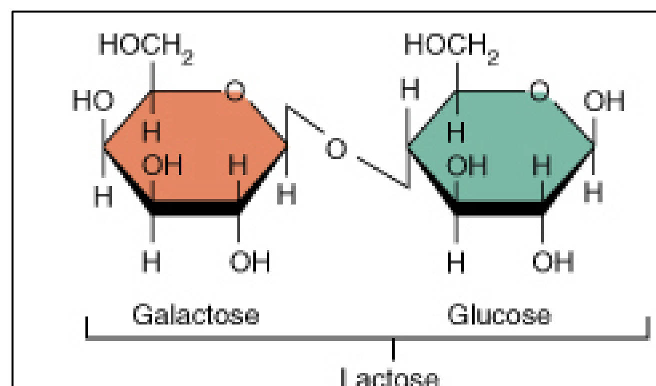
Carbohydrates

Disaccharides - double sugars – two monosaccharides joined by *dehydration synthesis* (loss of water molecule)



Must be broken down by *hydrolysis* to simple sugar units for absorption from digestive tract into blood stream

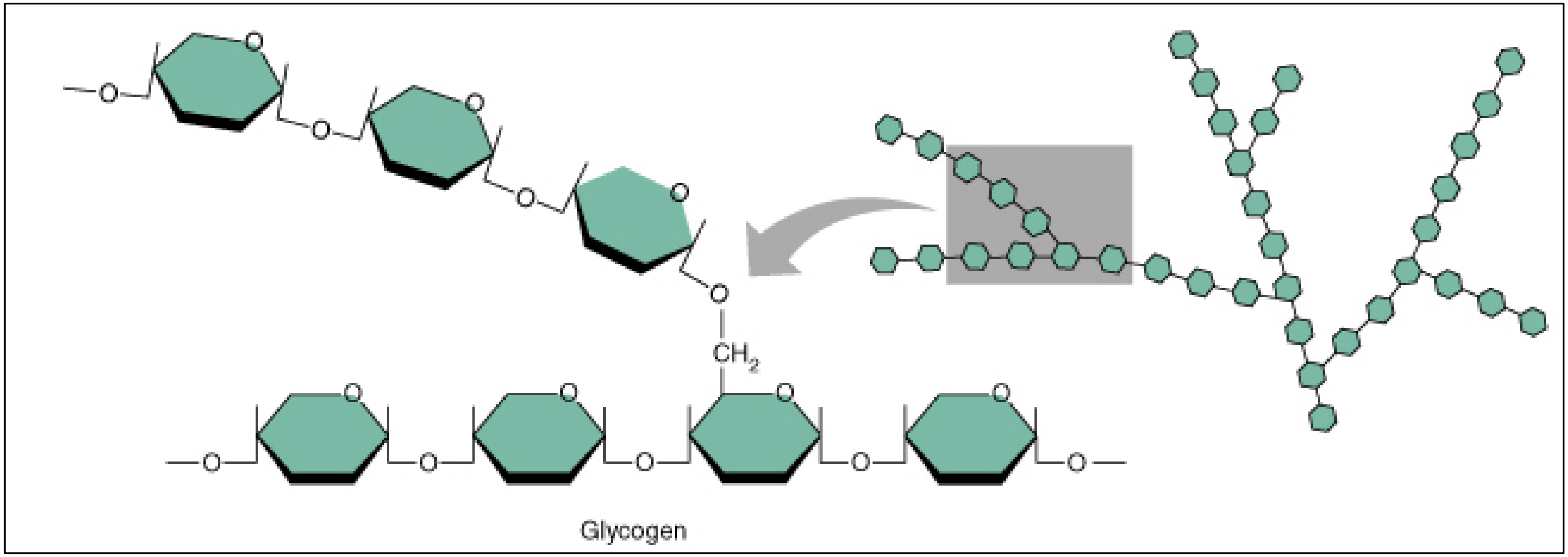




Carbohydrates

Polysaccharides - polymers of simple sugars

(Polymer – long, chain-like molecule)



Carbohydrates – Types of Polysaccharides

Starch - straight chain of glucose molecules, few side branches. Energy storage for plant cells.

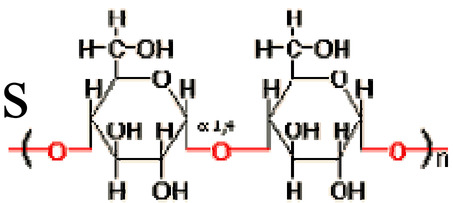
Glycogen - highly branched polymer of glucose, storage carbohydrate of animals.

Cellulose - chain of glucose molecules, structural carbohydrate, primary constituent of plant cell walls.

Chitin - polymer of glucose with amino acids attached, primary constituent of exoskeleton

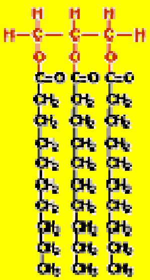
Organic Molecules – Four Classes

Carbohydrates



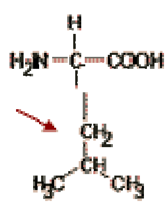
Starch

Lipids



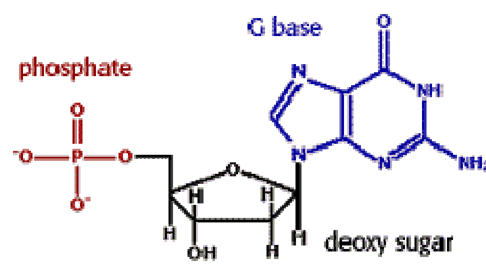
Triglyceride

Proteins



leucine

Nucleic Acids

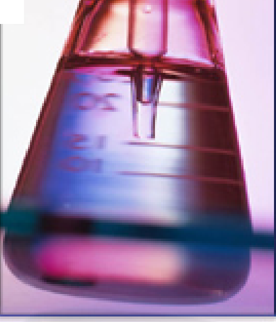


Lipids

- Four Types of Lipids
  - Neutral Fats or Triglycerides
  - Phospholipids
  - Steroids
  - Other Lipoid substances – eicosanoids, lipoproteins

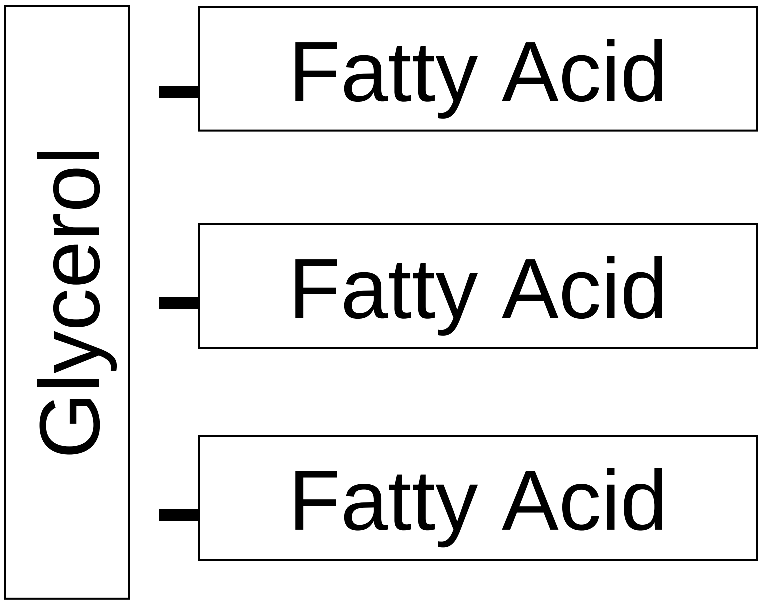
Lipids

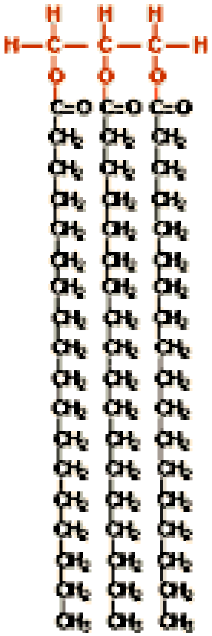
- Lipids are insoluble in water but are soluble in other lipids and in organic solvents (alcohol, ether) or detergents
- Most of the structure of lipids is non-polar, formed almost exclusively of carbon and hydrogen atoms.
- Contain C, H, and O, but the proportion of oxygen in lipids is less than in carbohydrates



Neutral Fats (Triglycerides or Triacylglyycerols)

Glycerol and 3 fatty acids. (Fats & oils)

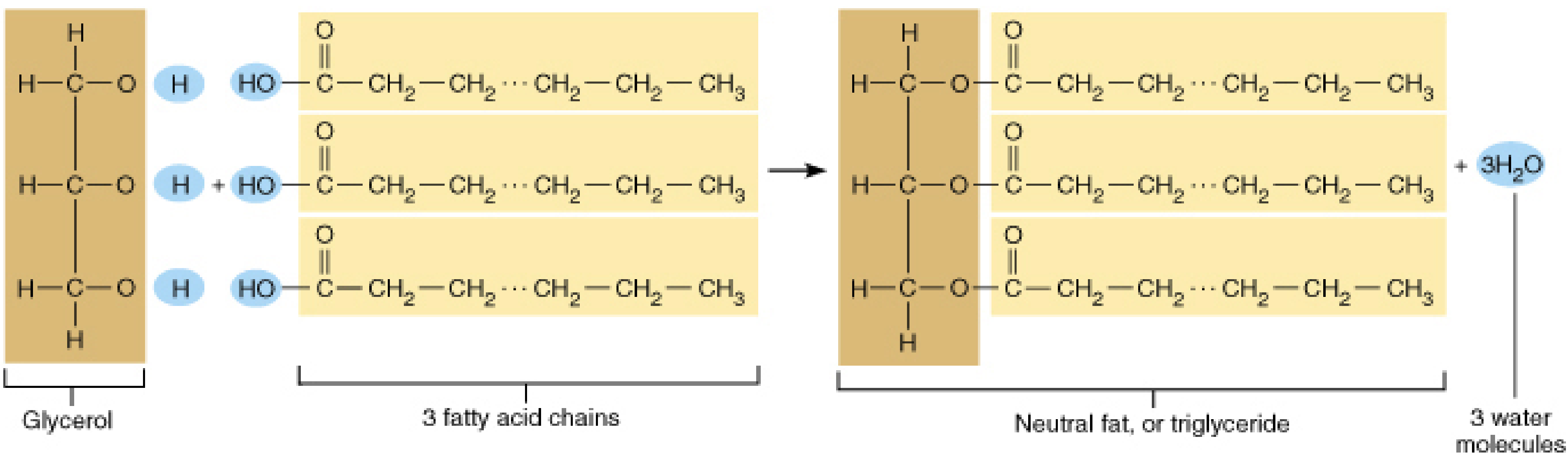




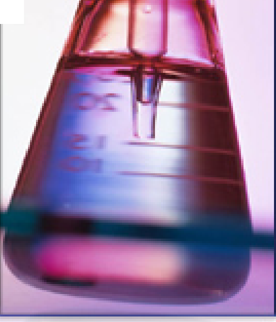
Neutral Fats (Triglycerides or Triacylglyycerols)

Commonly known as *fats* when solid or *oils* when liquid

Composed of three fatty acids (hydrocarbon chains) bonded to a glycerol (sugar alcohol) molecule



(a) Formation of a triglyceride



Neutral Fats (Triglycerides or Triacylglyycerols)

Nutrition Facts

Serving size: 1/4 Recipe (188g)
Servings Per Recipe 4

Amount Per Serving	
Calories 199 Cal. from Fat 45	
	% Daily Value*
Total Fat 5g	**8%**
Saturated Fat 1g	**4%**
Cholesterol 0mg	**0%**
Sodium 245mg	**10%**
Total Carbohydrate 31g	**10%**
Dietary Fiber 8g	**35%**
Sugars 0g	
Protein 10g	

Vitamin A	75%	Vitamin C	40%
Calcium	10%	Iron	20%

* Percent Daily Values is based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Total Fat = 5 grams

Saturated Fat = 1 gram

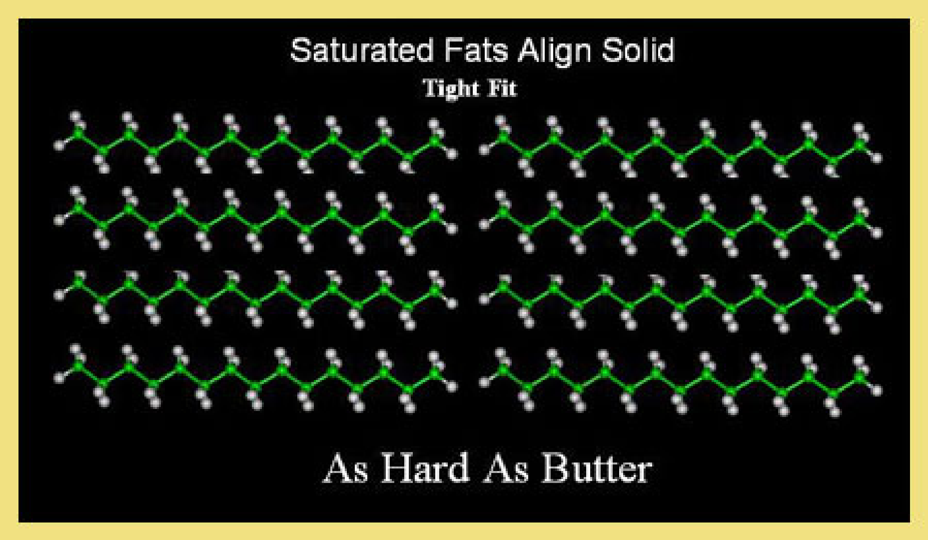
What is the rest of the fat?

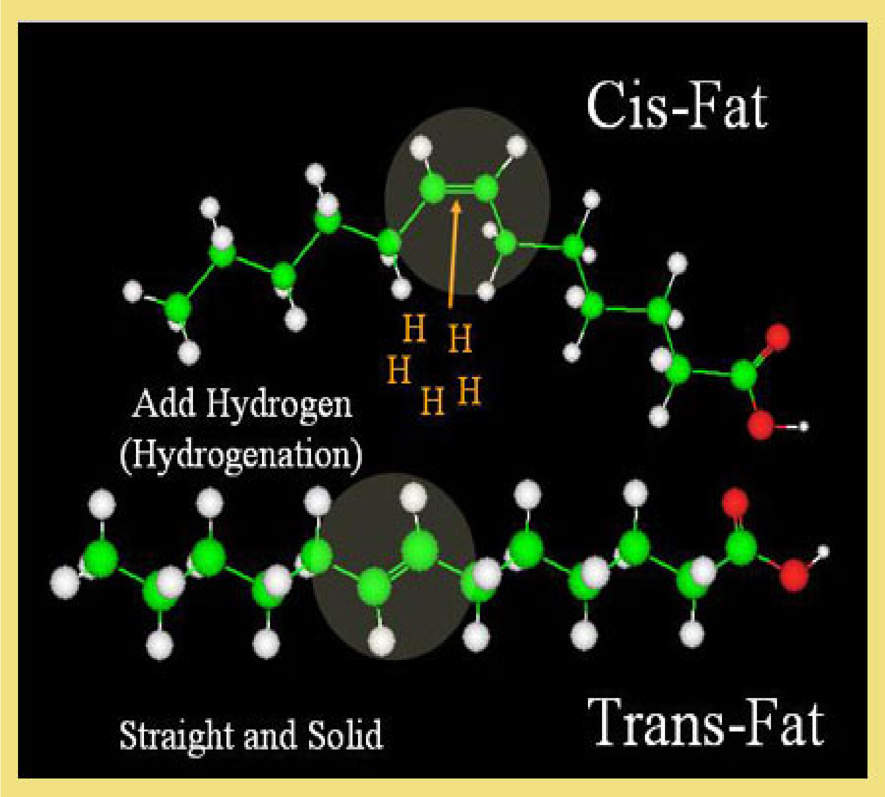
Unsaturated
- Monounsaturated
- Polyunsaturated

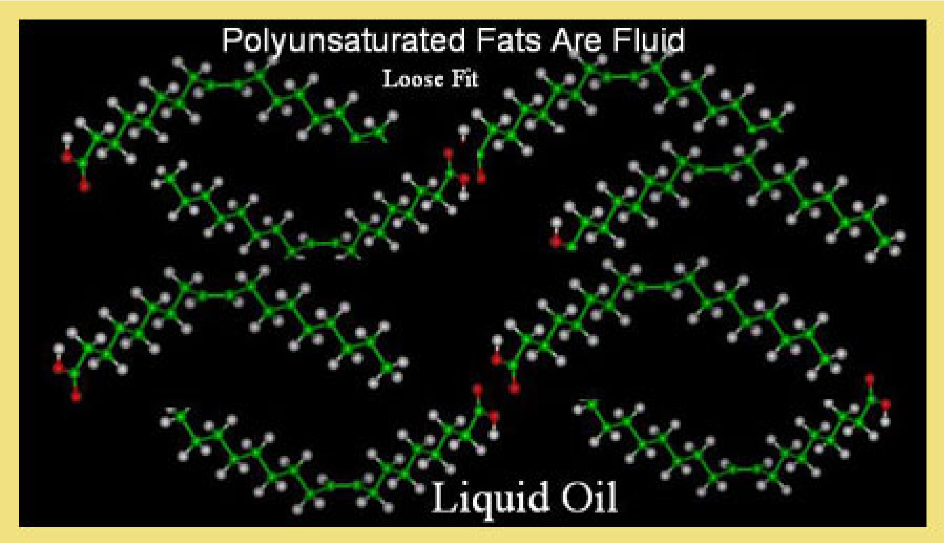
Hydrogenated

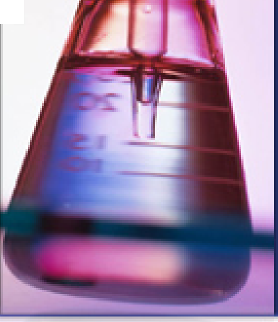
Cis and Trans fats

Neutral Fats (Triglycerides or Triacylglyycerols)



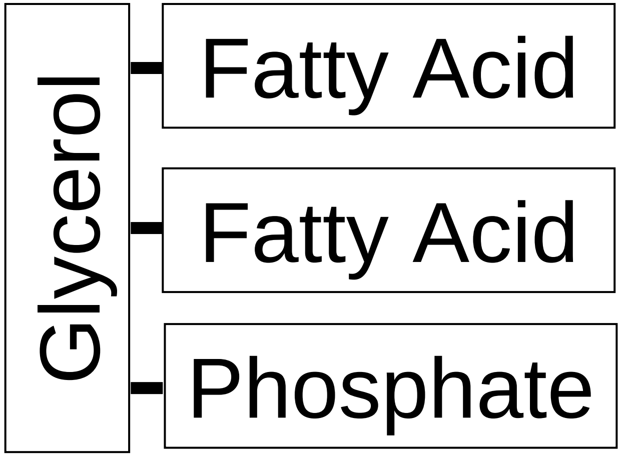


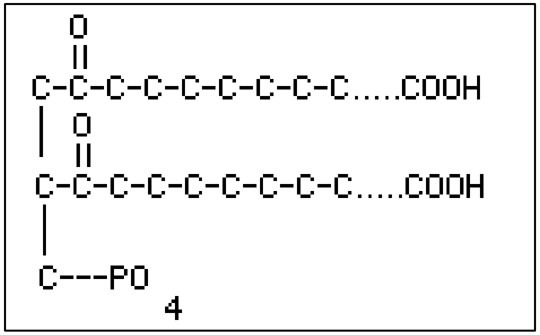


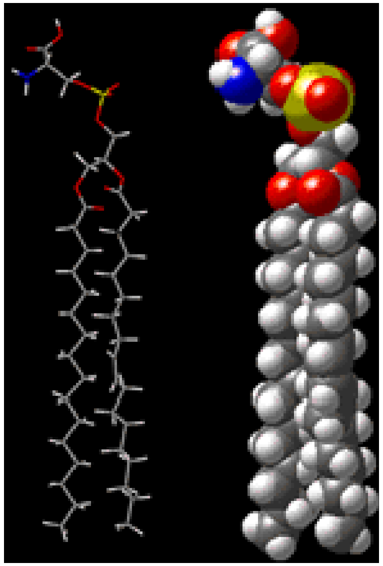


Lipids – Phospholipids

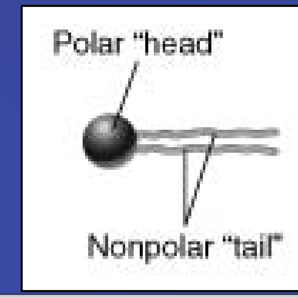
Glycerol, 2 fatty acids, 1 phosphate (Cell Membranes)



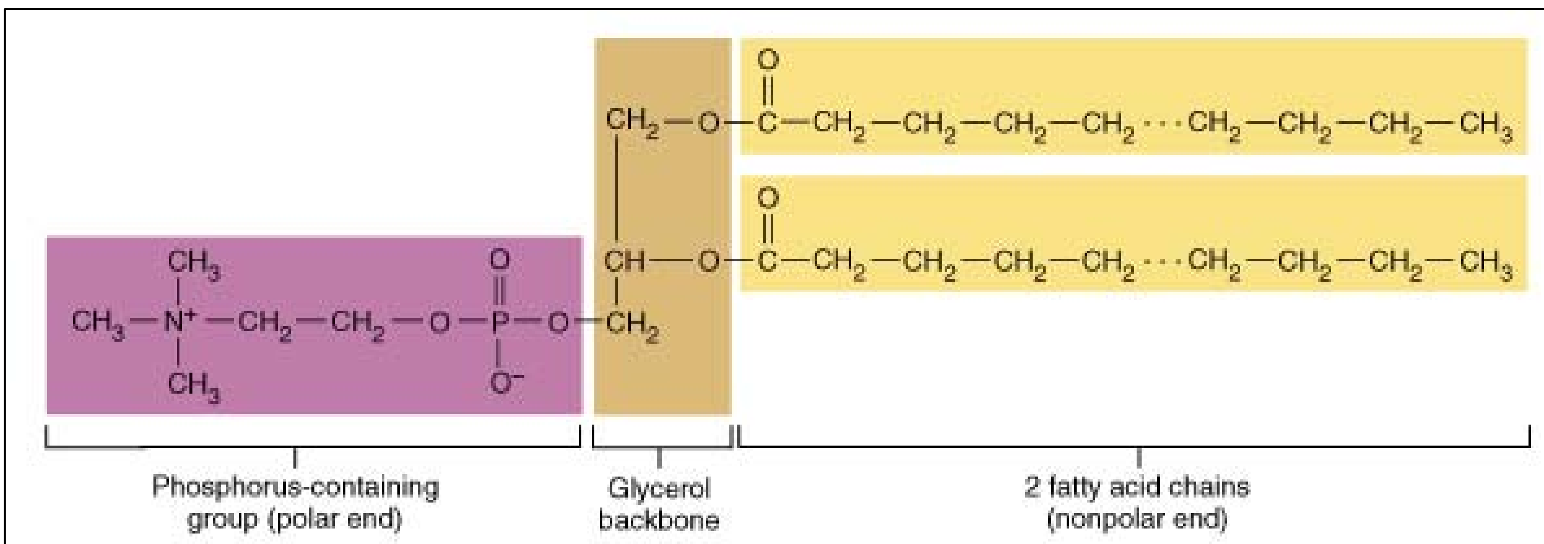




Phospholipids

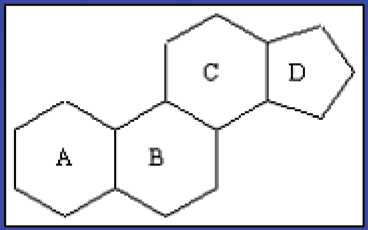


Phospholipids – modified triglycerides with two fatty acid groups and a phosphorus group- main component of cell membranes



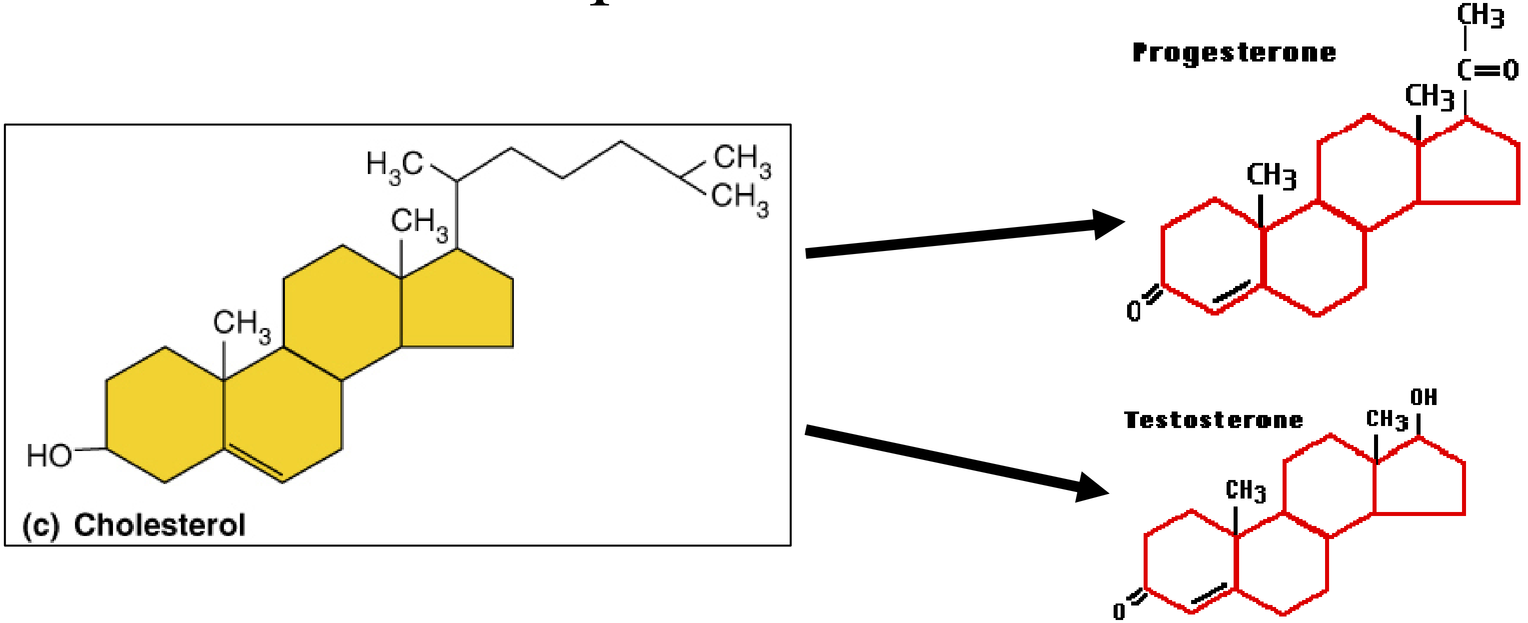
(b) Phospholipid molecule (phosphatidyl choline)

Steroids



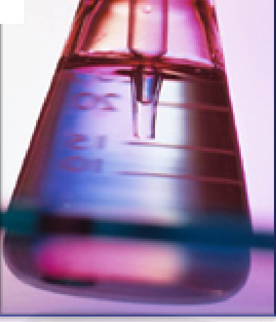
Steroids are fat-soluble with a tetracyclic (four fused carbon rings) base structure.

Cholesterol is a constituent of the animal cell membrane and a precursor of other steroids.



Representative Lipids Found in the Body

- Neutral fats – found in subcutaneous tissue and around organs
- Phospholipids – chief component of cell membranes
- Steroids – cholesterol, bile salts, vitamin D, sex hormones, and adrenal cortical hormones
- Fat-soluble vitamins – vitamins A, E, and K
- Lipoproteins (HDL, LDL) – combinations of fat and protein that transport fatty acids and cholesterol in the bloodstream

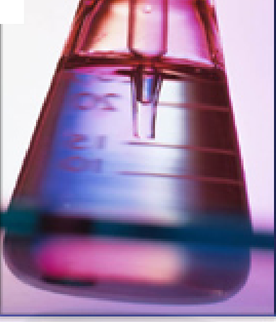


Importance of Lipids

Long- term Energy storage -
highest caloric values per weight

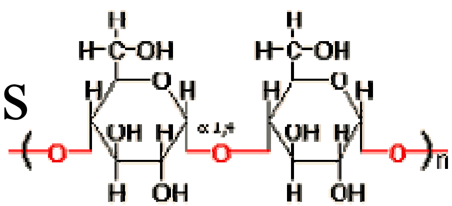
Chemical messengers –
steroid hormones (testosterone & estrogen)

Cell membranes –
phospholipids, cholesterol



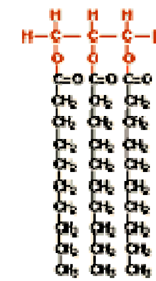
Organic Molecules – Four Classes

Carbohydrates



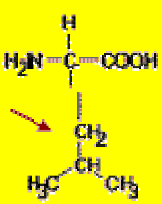
Starch

Lipids



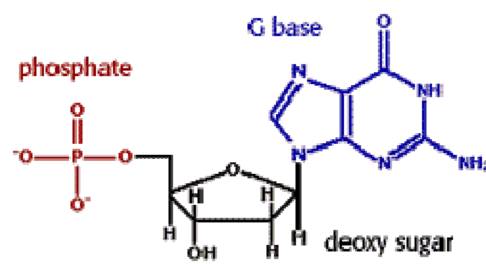
Triglyceride

Proteins



leucine

Nucleic Acids



Proteins

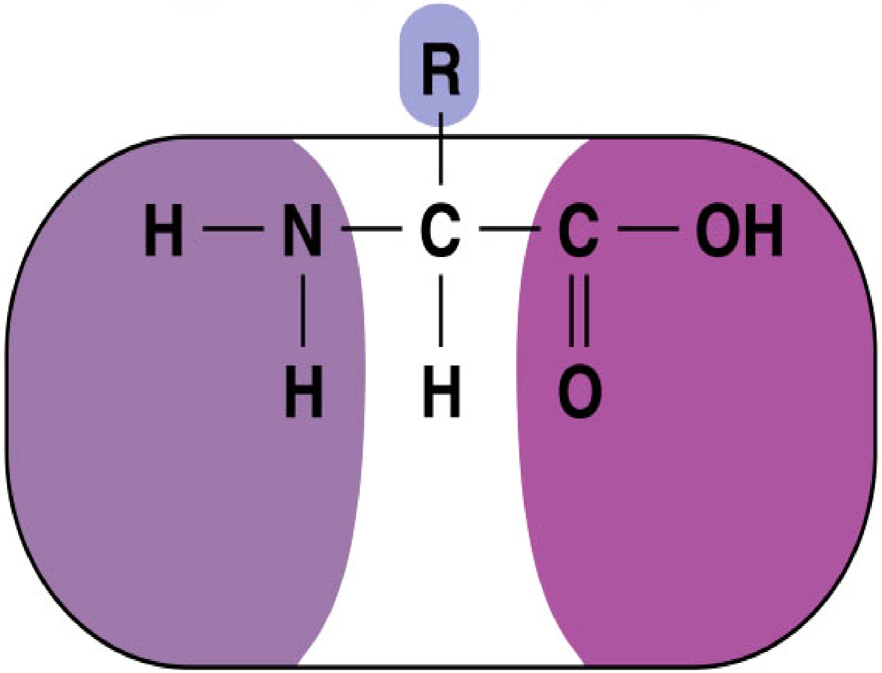
Protein is the basic structural material of the body – 10 to 30% of cell mass

Many other vital functions – enzymes, hemoglobin, contractile proteins, collagen, even proteins that help and protect other proteins

Most are macromolecules, large (100 to 10,000 a.a.), complex molecules composed of combinations of 20 types of amino acids bound together with peptide bonds

Proteins

- structural material
- energy source
- hormones
- receptors
- enzymes
- antibodies
- building blocks are amino acids

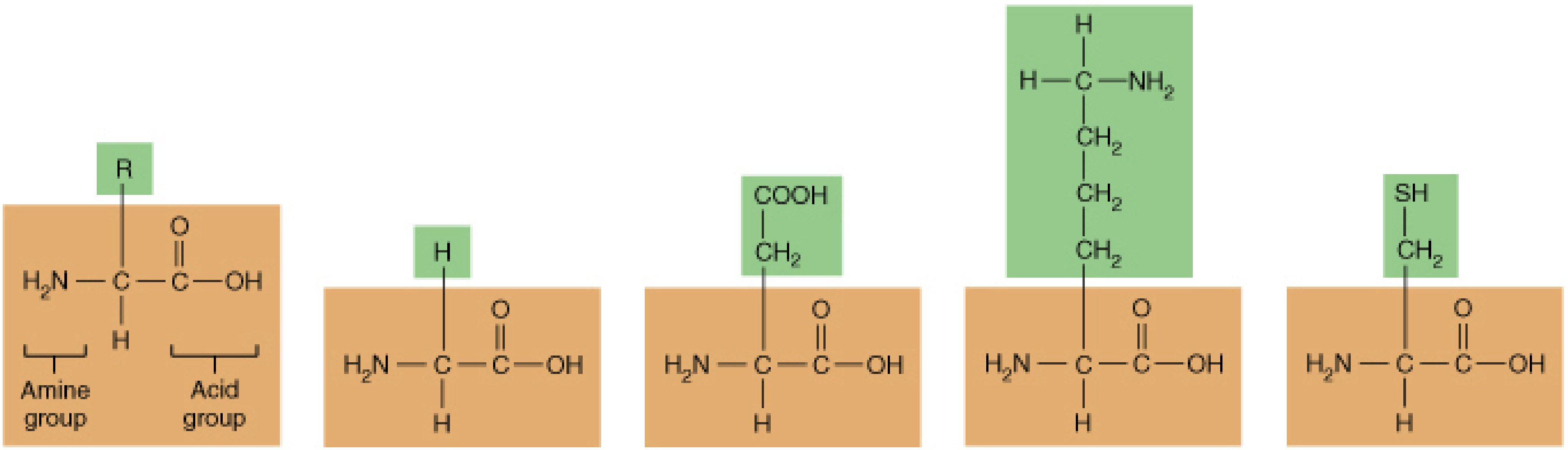


(a) General structure of an amino acid

Note: amino acids held together with peptide bonds

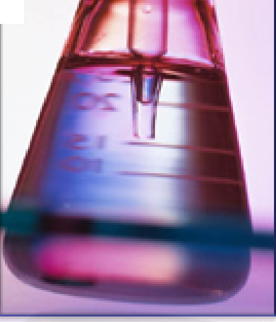
Proteins : Amino Acids

20 types of building blocks for protein molecules
Each amino acid contains an amine group, a carboxyl group (COOH), and a functional (R) group



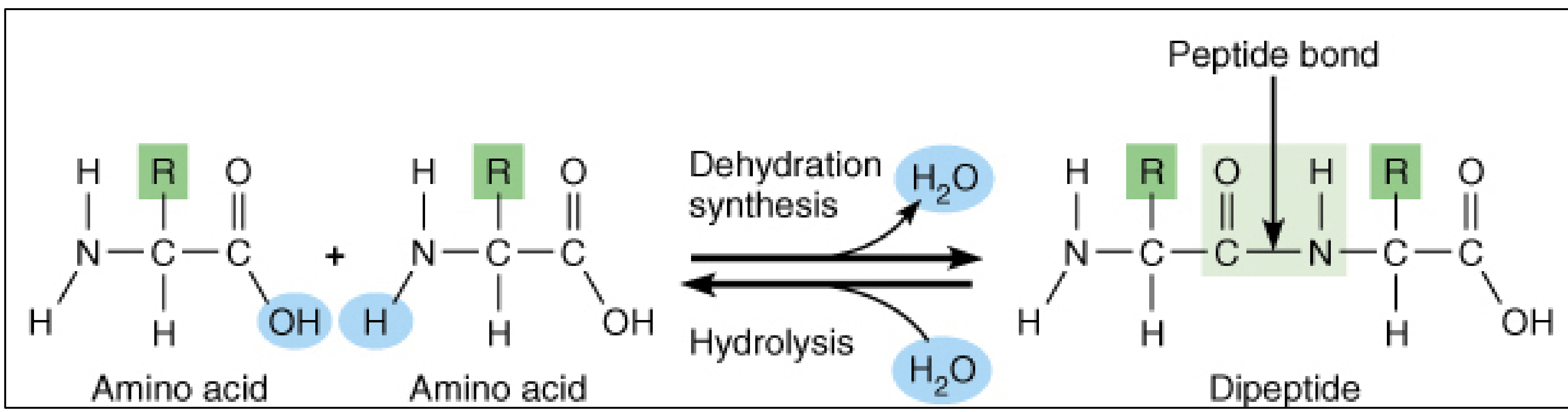
(a) Generalized structure of all amino acids
(b) Glycine (the simplest amino acid)
(c) Aspartic acid (an acidic amino acid)
(d) Lysine (a basic amino acid)
(e) Cysteine (a sulfur-containing amino acid)

Differences in the R group make each amino acid chemically unique



Proteins : Amino Acids and Peptide Bonds

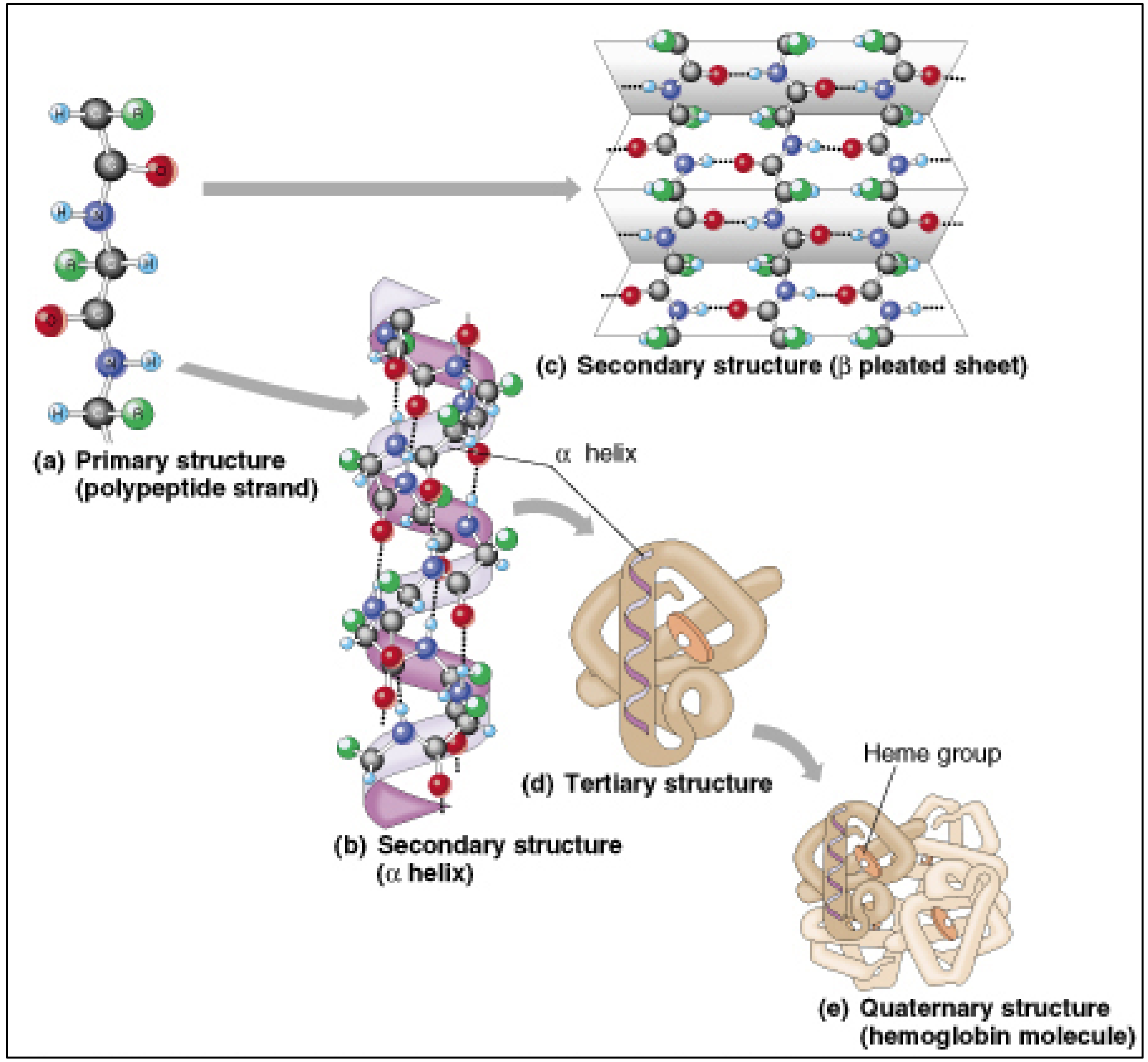
Proteins are polymers – polypeptides – of amino acids held together by *Peptide* bonds with the amine end of one amino acid linked to the carboxyl end of the next



The order or *sequence* of the amino acids determine the function of the protein

Structural Levels of Proteins

- Primary
- Secondary
- Tertiary
- Quaternary



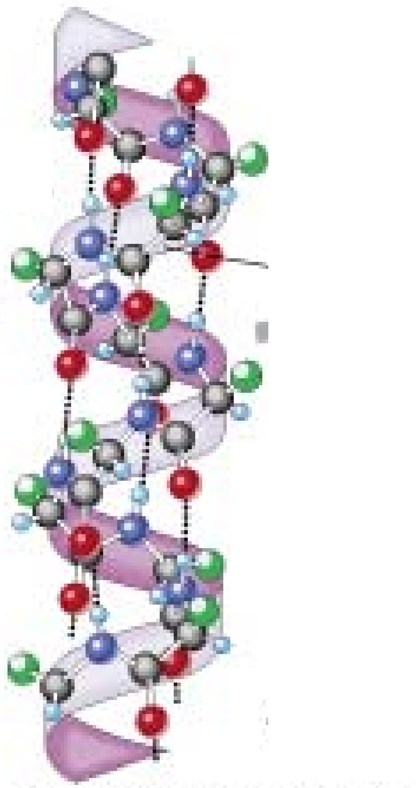
Structural Levels of Proteins

Primary – linear sequence of amino acids composing the polypeptide chain (strand of amino acid “beads”)

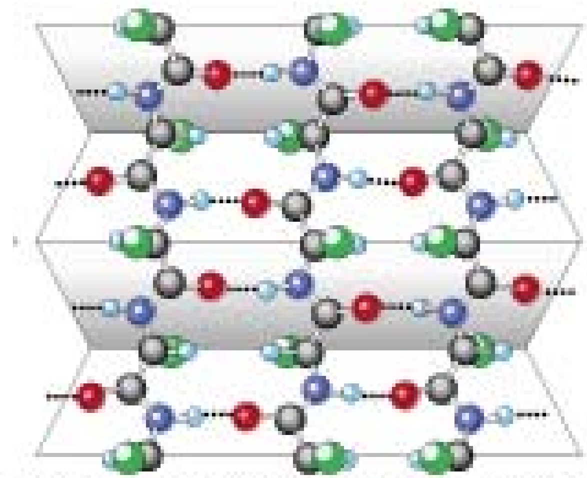
(a) Primary structure (polypeptide strand)

Structural Levels of Proteins

Secondary – alpha helix or beta pleated sheets



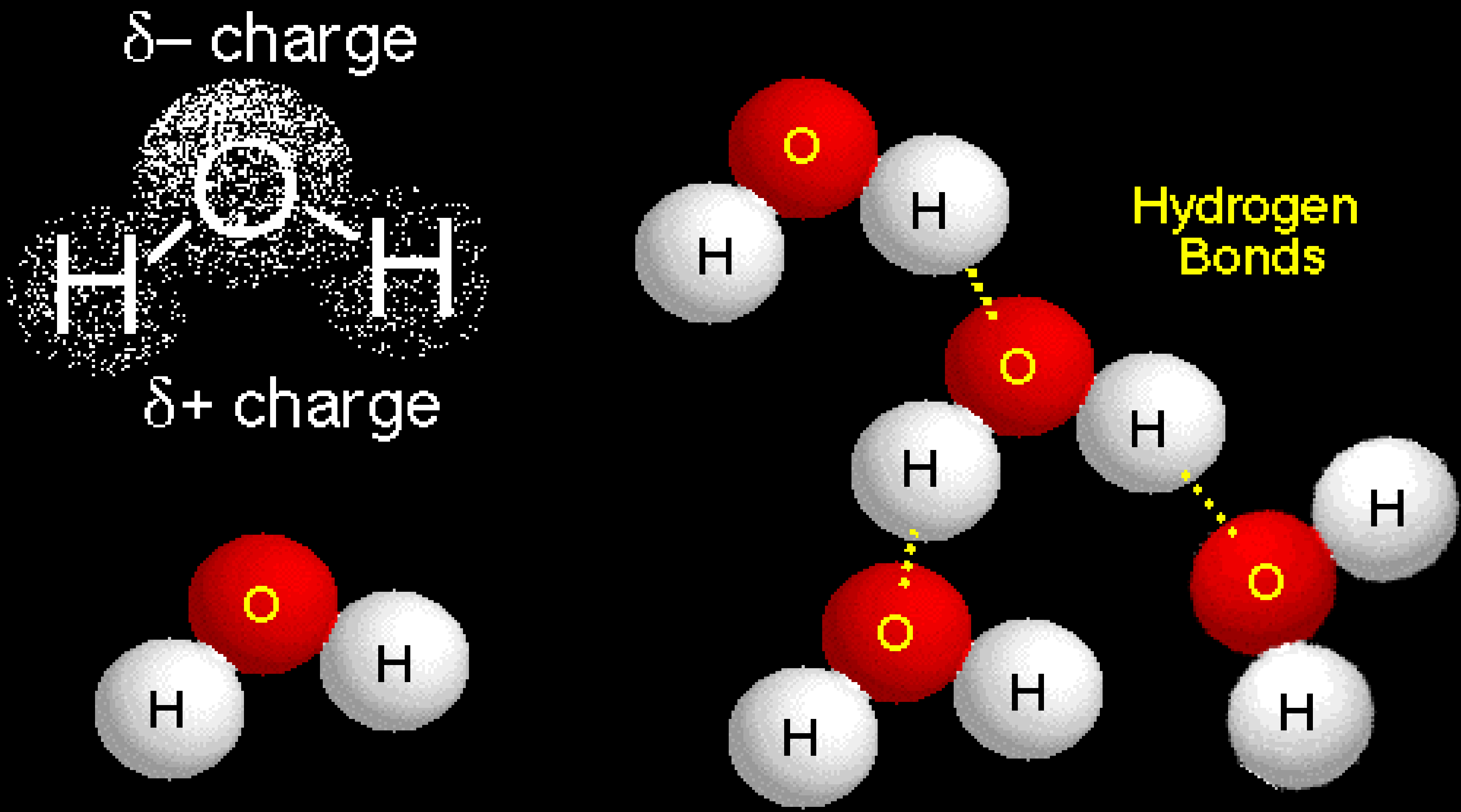
(b) Secondary structure (α helix)



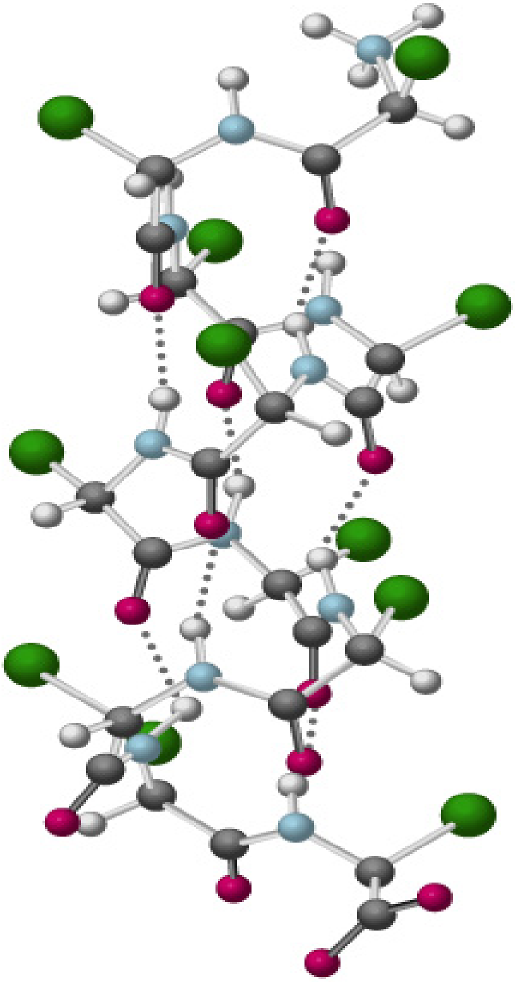
(c) Secondary structure (β pleated sheet)

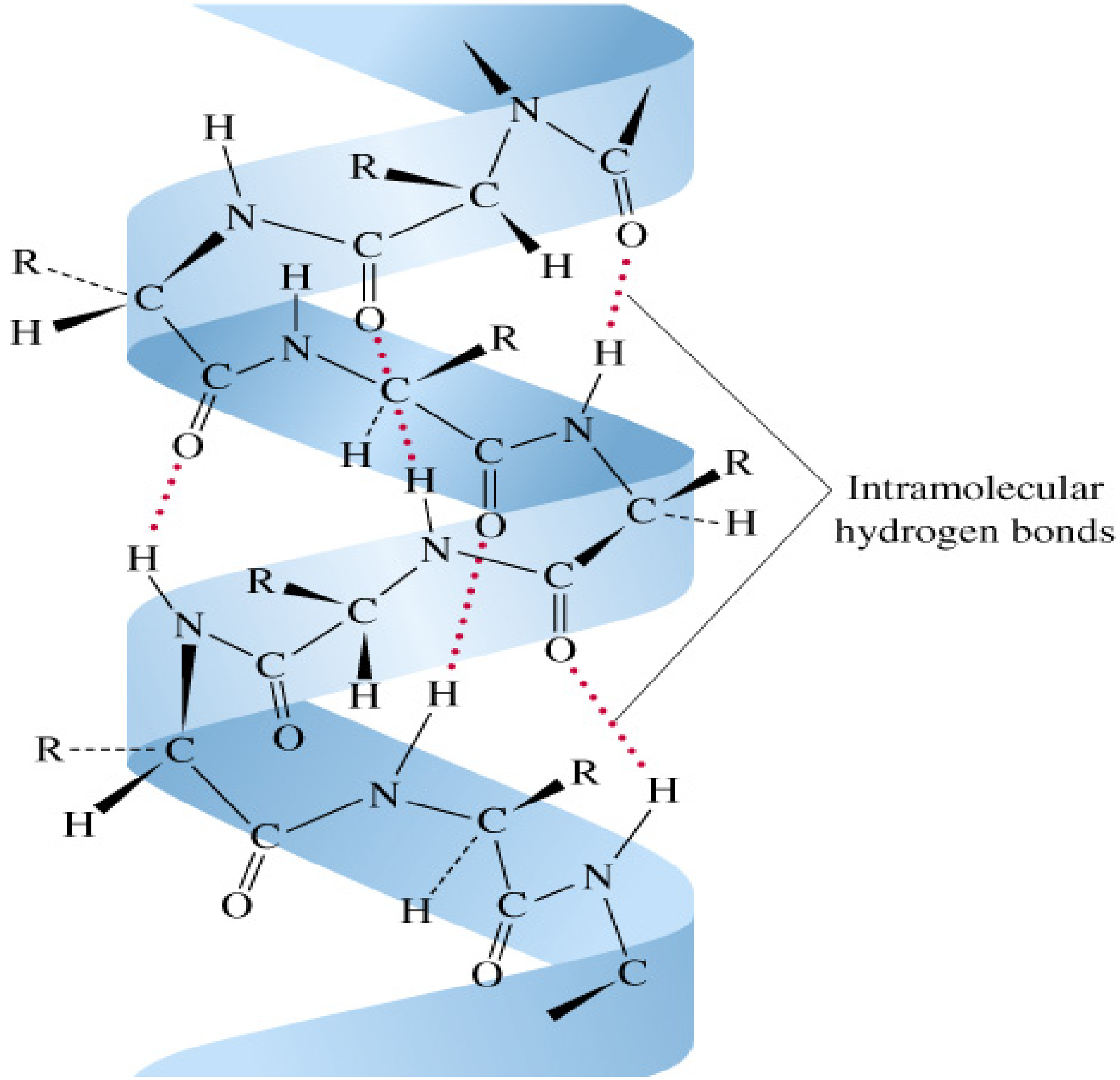
Both stabilized by hydrogen bonds

Hydrogen Bonds in Water



Hydrogen Bonds in Protein



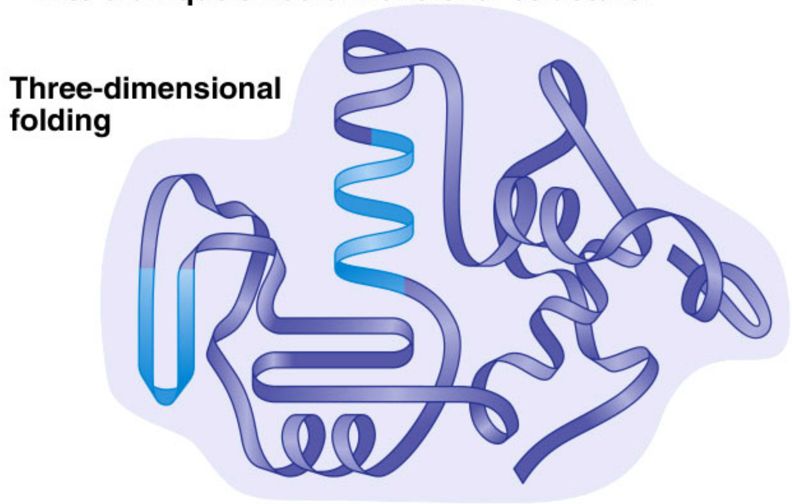


(b)

Tertiary

- Hydrogen bonding as well as covalent bonding between atoms in different parts of a polypeptide cause a tertiary structure. It is the tertiary structure that gives a protein its shape and thus determines its function

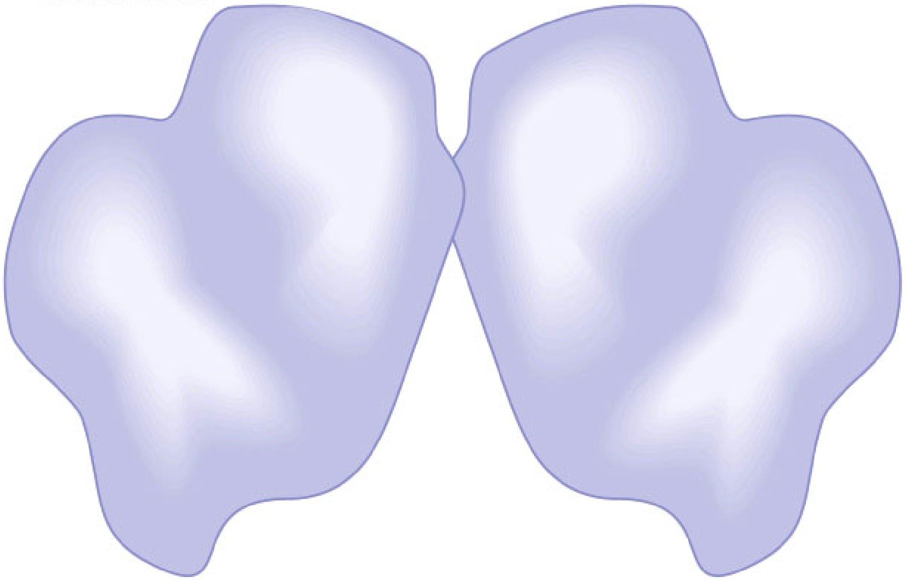
(c) Tertiary structure— The pleated and coiled polypeptide chain of a protein molecule folds into a unique three-dimensional structure.



Quaternary

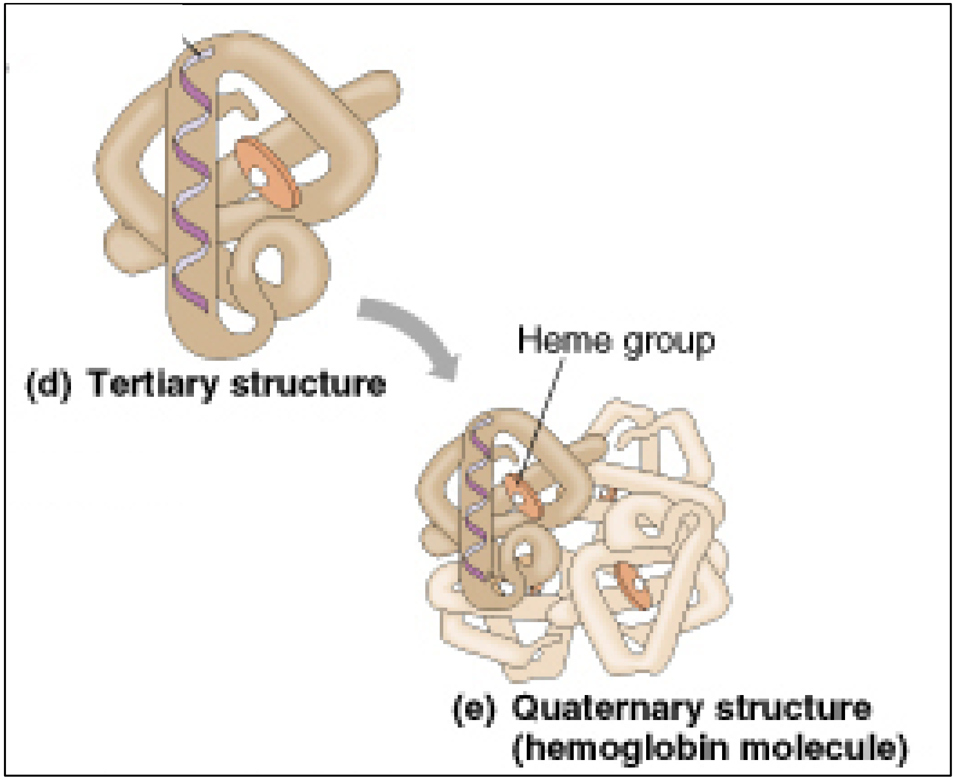
- Although some proteins are just polypeptide chains, others have several polypeptide chains and are connected in a fourth level (quarternary).

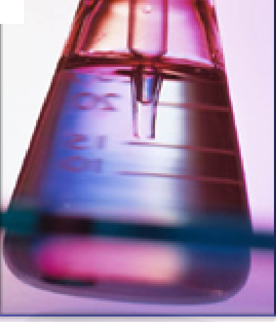
(d) Quaternary structure—Two or more polypeptide chains may be connected to form a single protein molecule.



Structural Levels of Proteins

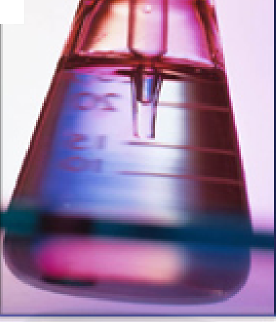
Quaternary – polypeptide chains linked together in a specific manner





Fibrous and Globular Proteins

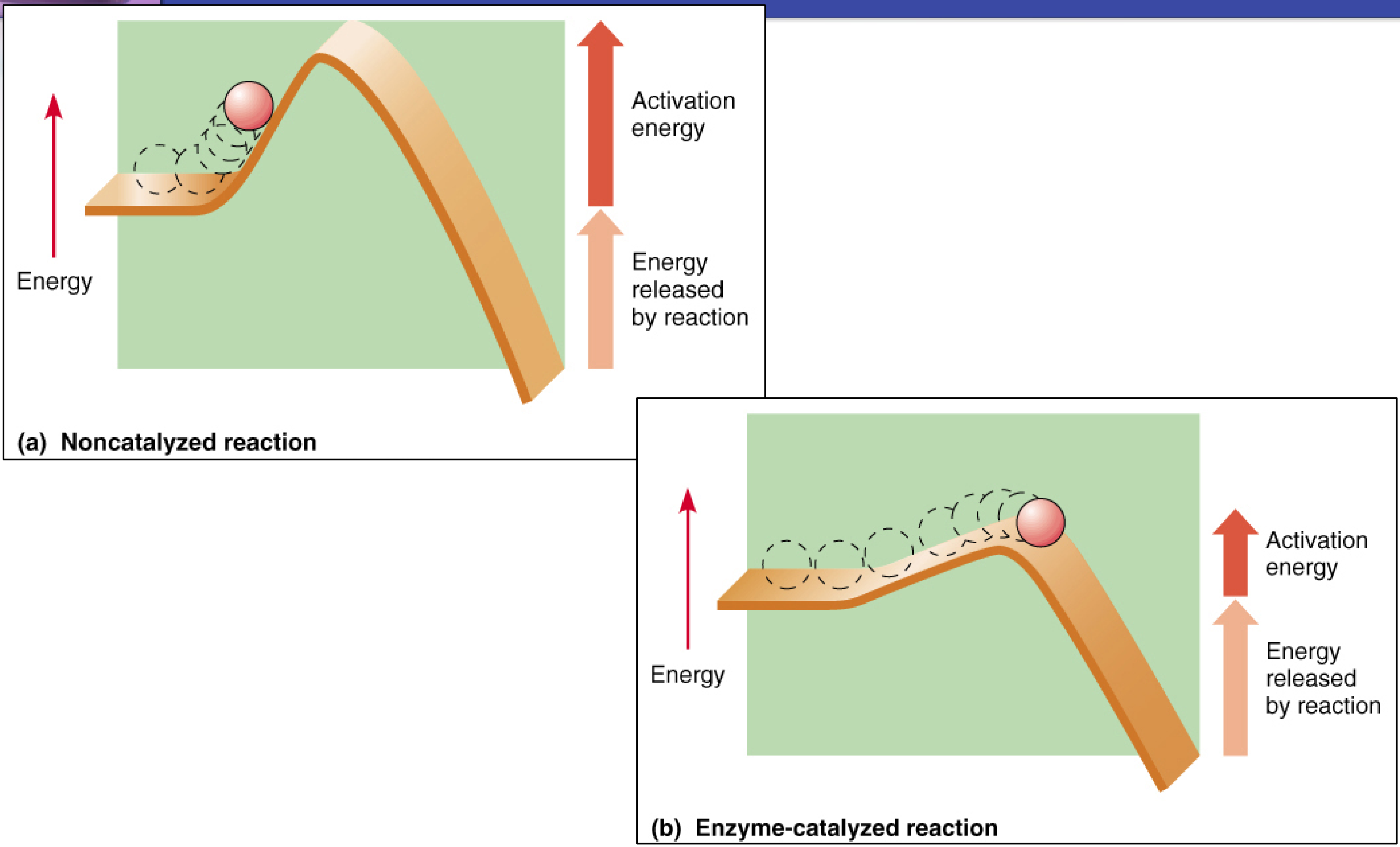
- Fibrous proteins (structural proteins)
  - Extended and strandlike proteins
  - Insoluble in water and very stable
  - Examples: keratin, elastin, collagen, and contractile fibers (actin and myosin)
- Globular proteins (functional proteins)
  - Compact, spherical proteins
  - Insoluble in water and chemically active
  - Examples: antibodies, hormones, and enzymes



Characteristics of Enzymes

- Most are globular proteins that act as biological catalysts
- Enzymes are chemically specific
- Frequently named for the type of reaction they catalyze
- Enzyme names usually end in *–ase* (e.g., amylase, protease, nuclease, triose phosphate isomerase, hexokinase)
- Lower activation energy

Characteristics of Enzymes

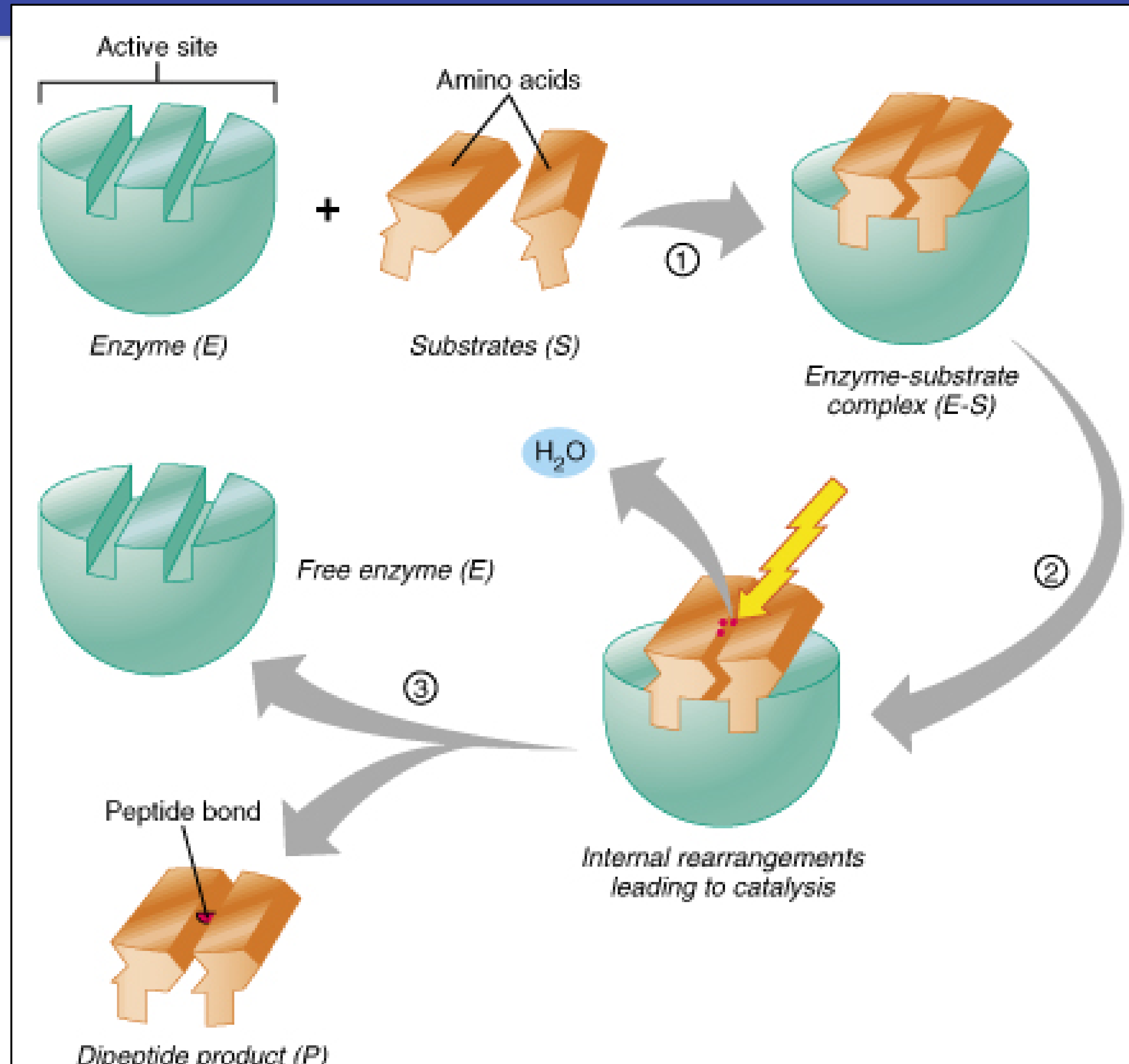


(a) Noncatalyzed reaction

(b) Enzyme-catalyzed reaction

Mechanism of Enzyme Action

- Enzyme binds substrate(s) at active site
- Product is formed at a lower activation energy
- Product is released

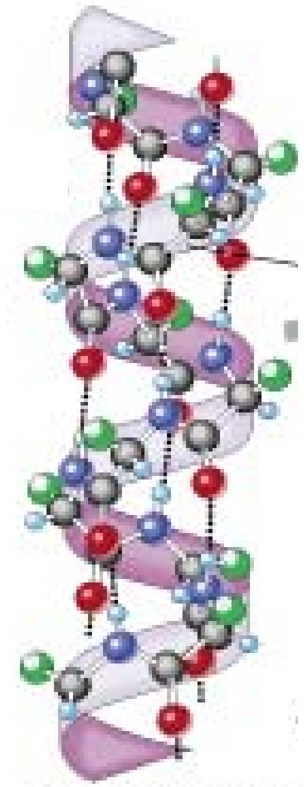


Protein Denaturation

The activity of a protein depends on its three-dimensional structure.

Intramolecular bonds, especially hydrogen bonds, maintain the structure.

Hydrogen bonds may break when the pH drops or the temperature rises above normal

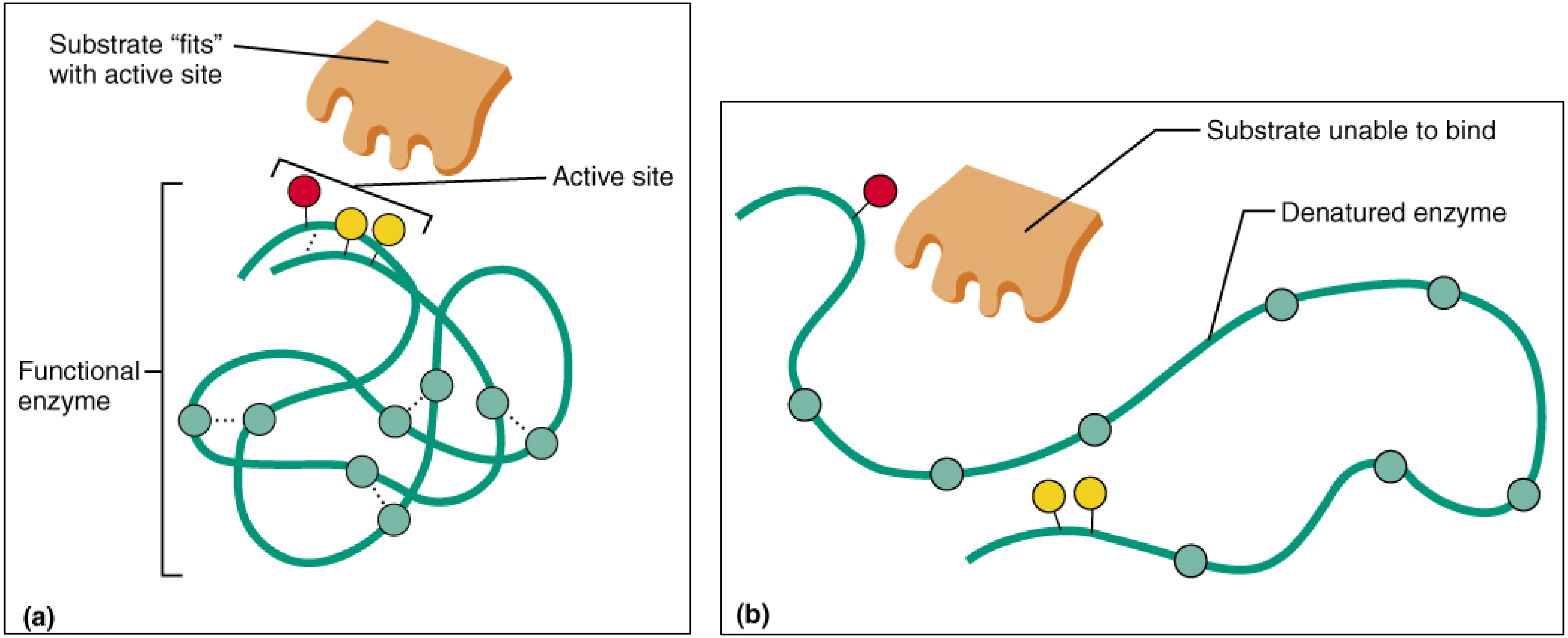


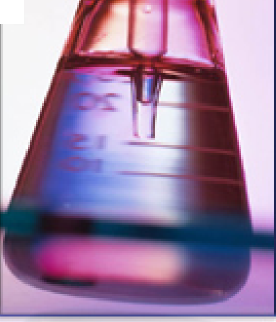
(b) Secondary structure (α helix)

Protein Denaturation

A protein is *denatured* when it unfolds and loses its three-dimensional shape (conformation)

Depending upon the severity of the change, Denaturation may be irreversible





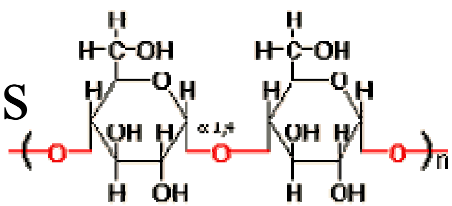
Molecular Chaperones (Chaperonins)

- Help other proteins to achieve their functional three-dimensional shape
- Maintain folding integrity
- Assist in translocation of proteins across membranes
- Promote the breakdown of damaged or denatured proteins

heat shock proteins (hsp), stress proteins

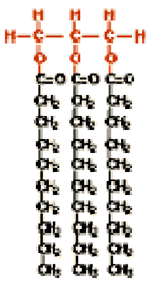
Organic Molecules – Four Classes

Carbohydrates



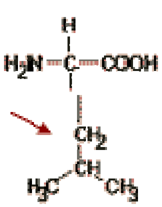
Starch

Lipids



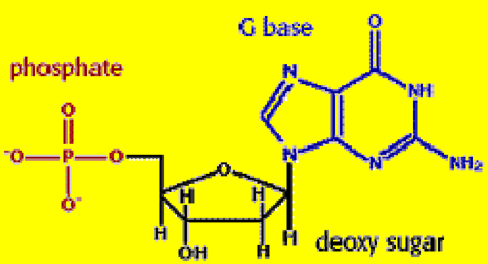
Triglyceride

Proteins

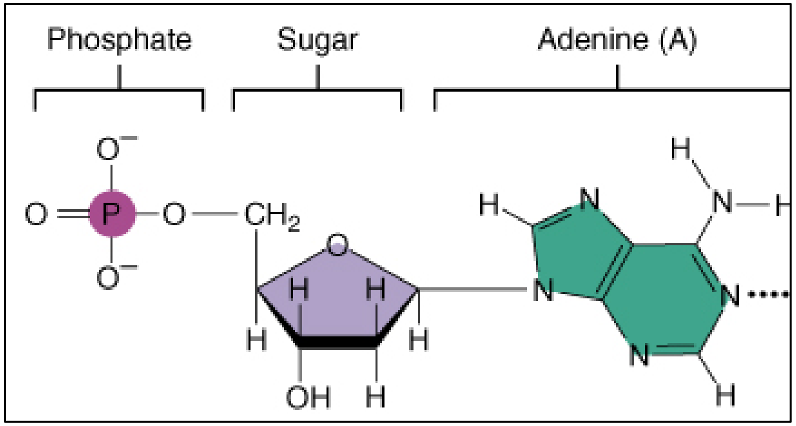


leucine

Nucleic Acids



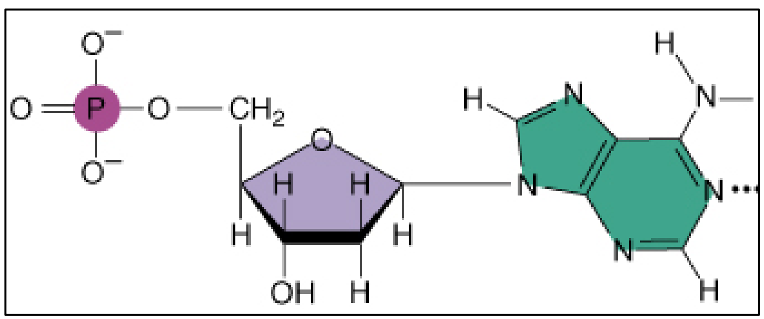
Nucleic Acids – polymers of Nucleotides



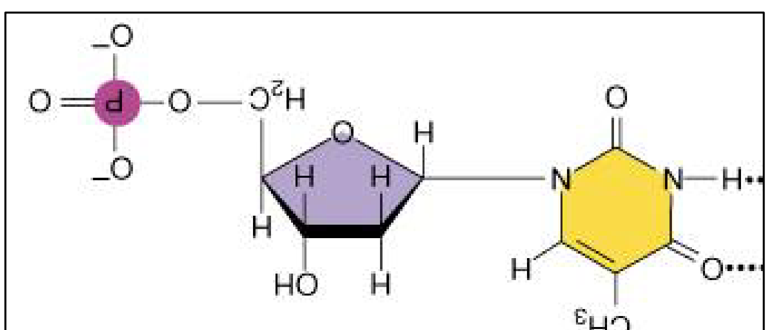
- Composed of carbon, oxygen, hydrogen, nitrogen, and phosphorus
- Nucleotides are composed of N-containing base, a pentose sugar, and a phosphate group
- Five nitrogen bases – adenine (A), guanine (G), cytosine (C), thymine (T), and uracil (U)
- Two major classes – DNA and RNA

Nucleic Acids – polymers of Nucleotides

- Nucleotides are composed of N-containing base, a pentose sugar, and a phosphate group
- Five nitrogen bases – adenine (A), guanine (G), cytosine (C), thymine (T), and uracil (U)

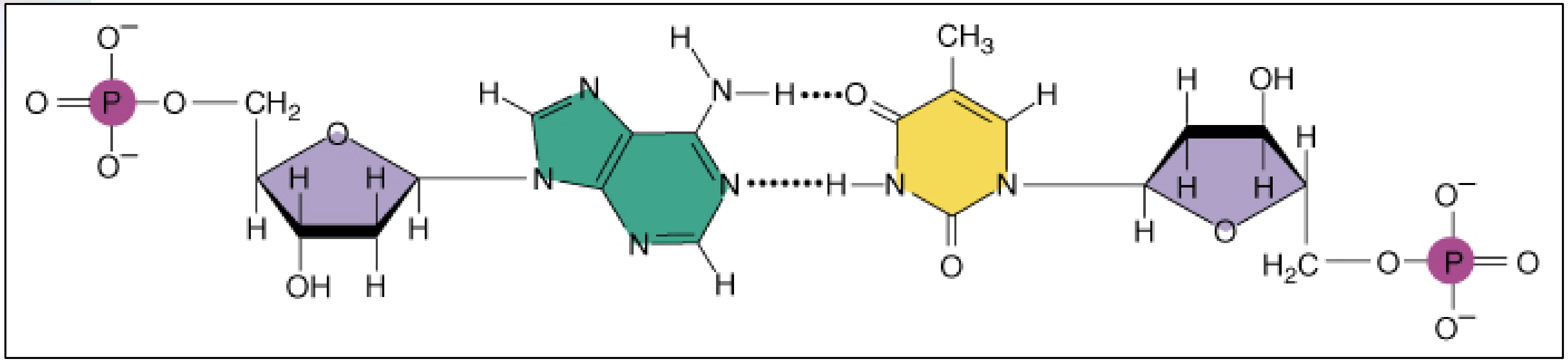


Adenine and Guanine
Purines – 2-ring structure



Cytosine, Thymine, Uracil
Pyrimidines – 1-ring structure

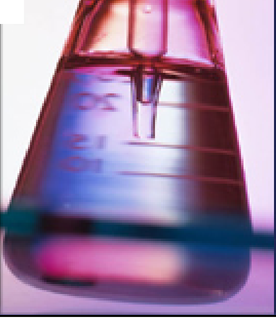
Structure of DNA



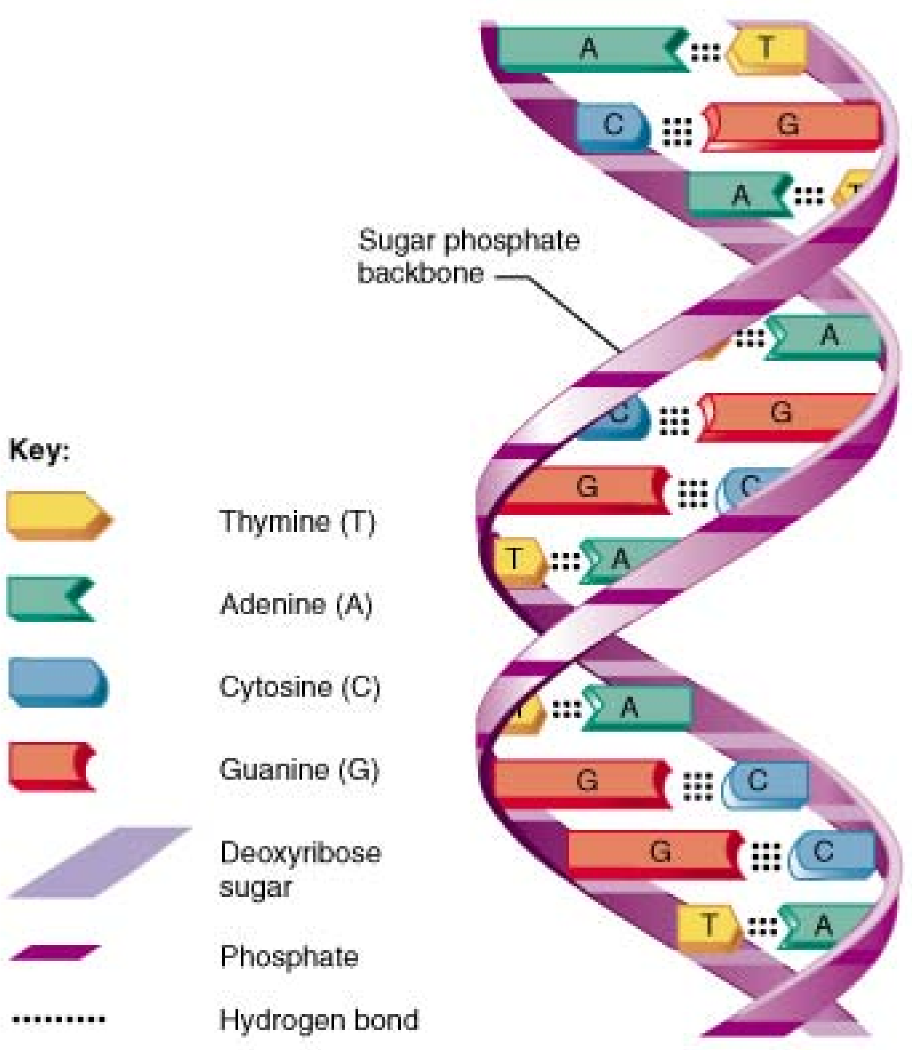
Nucleotides are linked by hydrogen bonds between their complementary bases

A always bonds to T

G always bonds to C



Structure of DNA

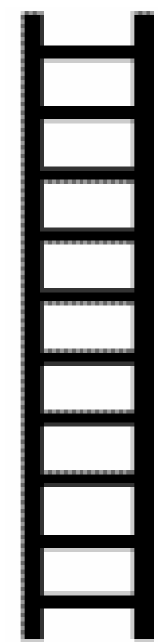


A coiled, double-stranded polymer of nucleotides

The molecule is referred
To as a double helix

Alternating sugar and phosphate?

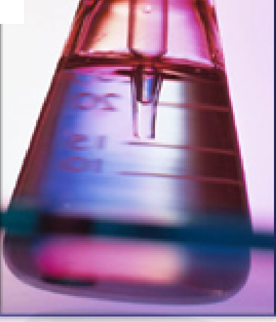
Joined bases?



Deoxyribonucleic Acid (DNA)

- Double-stranded helical molecule found in the nucleus of the cell (also in mitochondria)
- Replicates itself before the cell divides, ensuring genetic continuity - it is the genetic material inherited form parents – it is the genetic code
- Provides instructions for protein synthesis

DNA → RNA → Protein Synthesis → Proteins and Enzymes → Structure and Metabolism

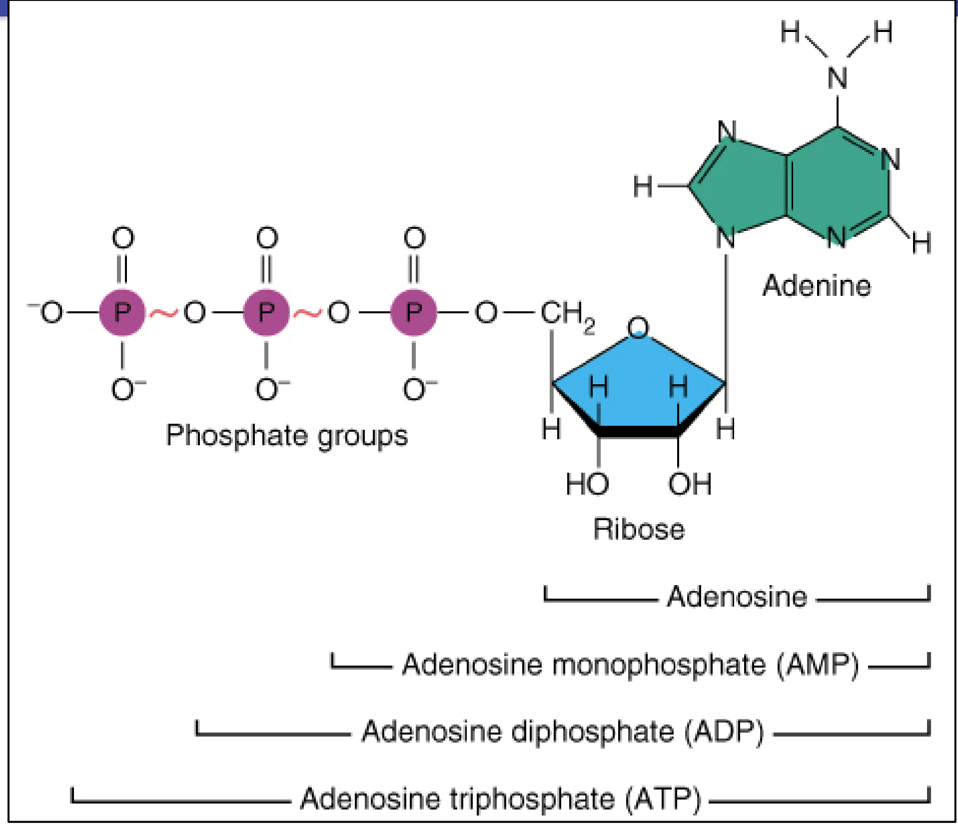


Ribonucleic Acid (RNA)

- Single-stranded molecule found in both the nucleus and the cytoplasm of a cell
- Sugar is Ribose instead of Deoxyribose
- Uses the nitrogenous base Uracil instead of Thymine
- Three varieties of RNA: messenger RNA, transfer RNA, and ribosomal RNA

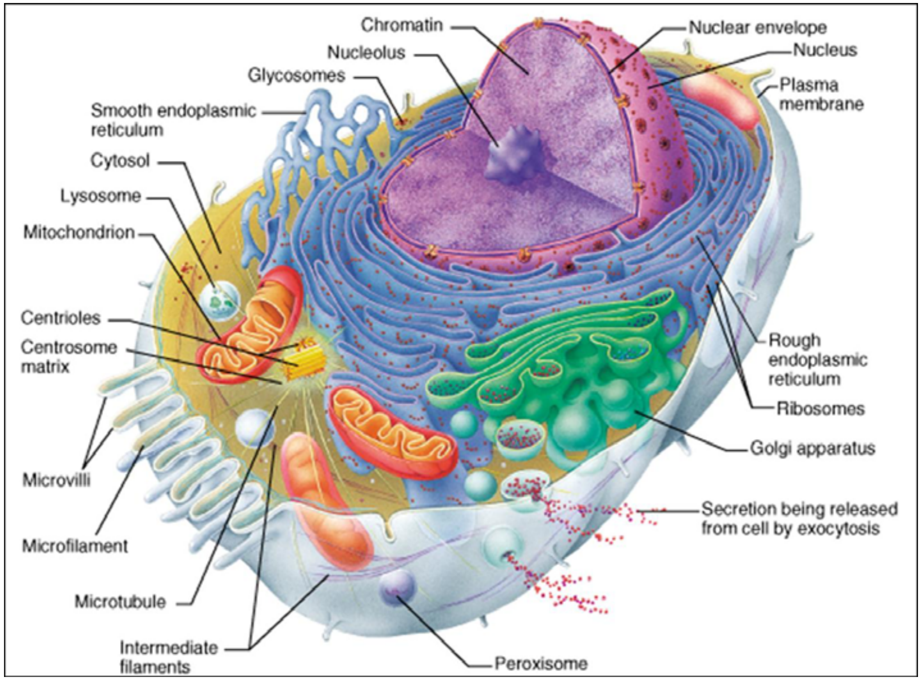
Adenosine Triphosphate (ATP)

- Adenine-containing RNA nucleoside with three phosphate groups
- Source of immediately usable energy for the cell



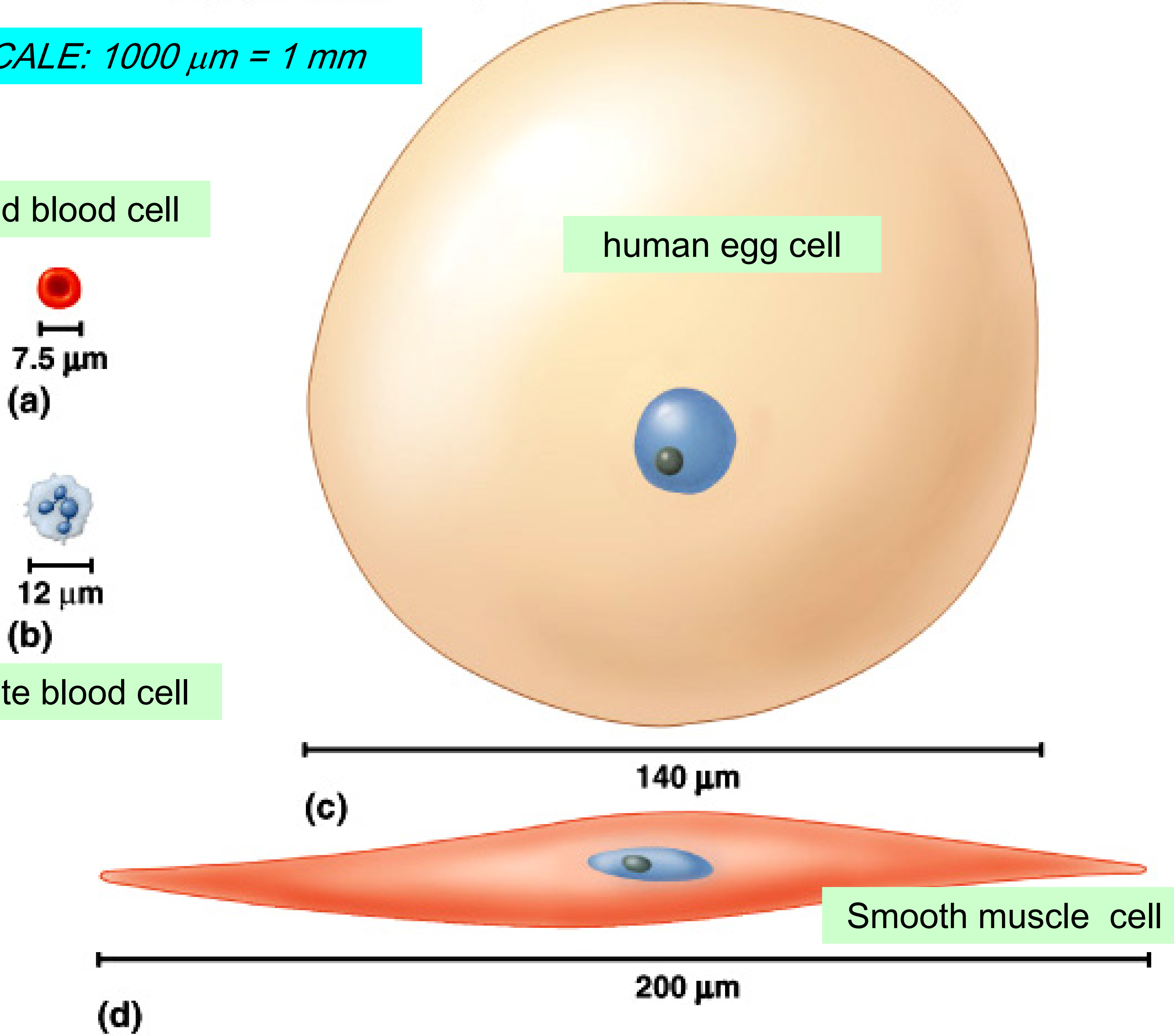
Although glucose is the main cellular fuel, the chemical energy contained in its bonds is not directly used, but the energy released during glucose catabolism is coupled to the synthesis of ATP.

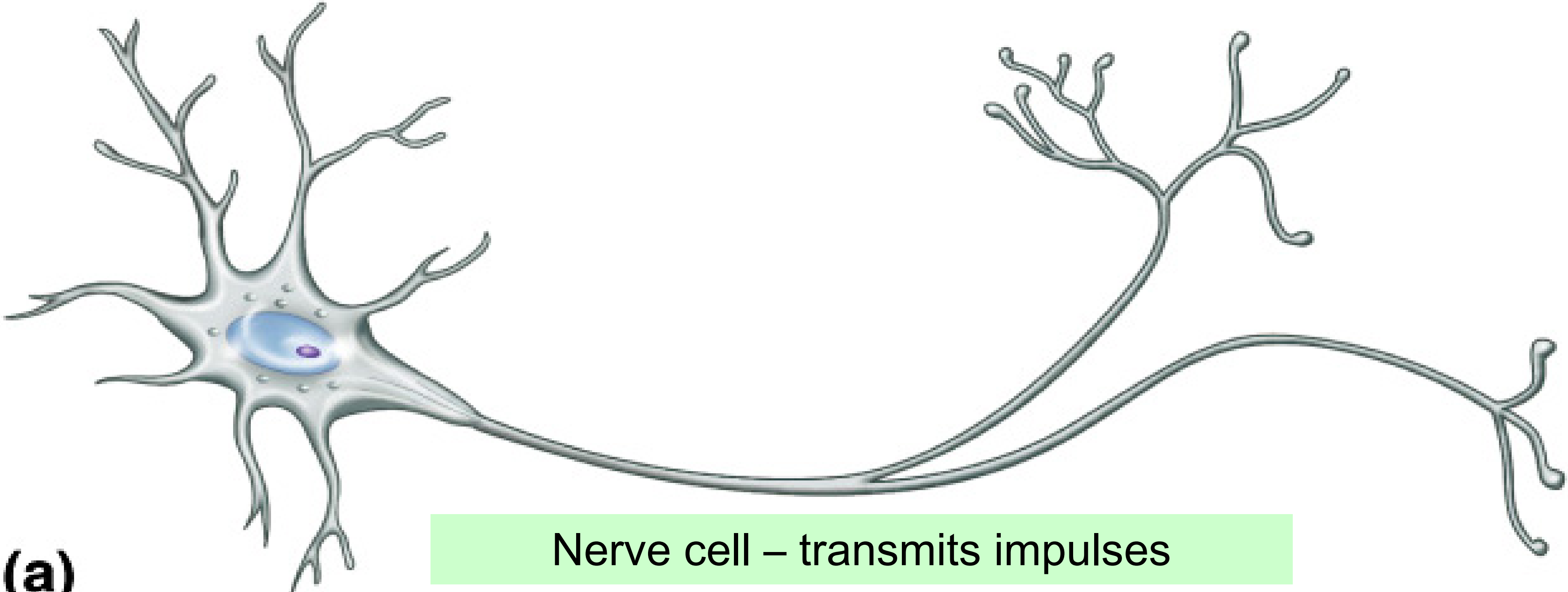
From Molecules to Cells



- From nonliving chemicals to an organized ensemble that possesses the characteristics of life.
- Fundamental unit of life is the cell.
- Humans are multicellular organisms
- An adult human is composed of about 75 trillion cells.

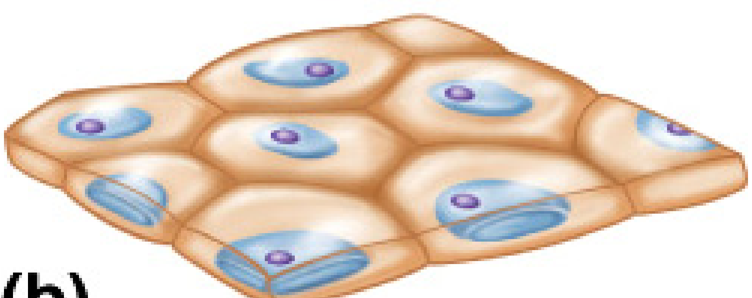
SCALE: 1000 μm = 1 mm





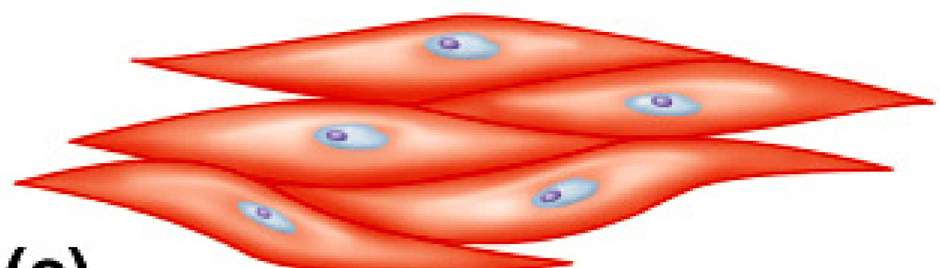
(a)

Nerve cell – transmits impulses



(b)

Epithelial cells – form protective layers



(c)

Muscle cells - contraction