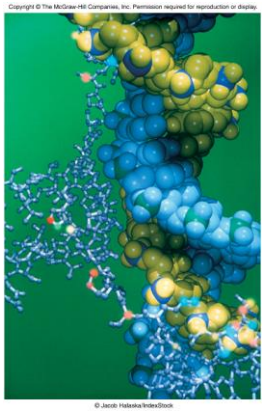
The Chemical Building Blocks of Life

Chapter 3



Biological Molecules

Biological molecules consist primarily of
- -carbon bonded to carbon, or
- -carbon bonded to other molecules.

Carbon can form up to 4 covalent bonds.

Carbon may be bonded to **functional groups** with specific properties.

*satisfies this first criterion

Organic Compounds

Carbon (**C**)

principle bonds → (**C**)

principle bonds → (**H**) hydrogen

secondary bonds

(**O**) oxygen

(**N**) nitrogen

(**P**) phosphorus

(**S**) sulfur

organic compound e.g. **CH_4** methane

inorganic compound e.g. **CO_2** carbon dioxide

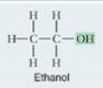
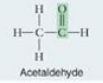
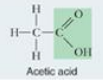
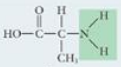
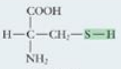
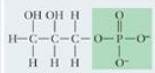
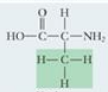
Classes of Organic Compounds

1) carbohydrates
   - energy
   - structure

2) lipids
   - energy
   - structure
   - hormones
   - vitamin D

3) amino acids/proteins
   - energy
   - structure
   - enzymes

4) nucleotides/nucleic acids
   - deoxyribonucleic acid (DNA)
   - ribonucleic acid (RNA)

Functional Group	Structural Formula	Example	Found In
Hydroxyl	—OH	 Ethanol	carbohydrates, proteins, nucleic acids, lipids
Carbonyl		 Acetaldehyde	carbohydrates, nucleic acids
Carboxyl		 Acetic acid	proteins, lipids
Amino		 Alanine	proteins, nucleic acids
Sulfhydryl	—S—H	 Cysteine	proteins
Phosphate		 Glycerol phosphate	nucleic acids
Methyl		 Alanine	proteins

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Biological Molecules

Isomers are molecules with the same chemical formula.

-structural isomers

-stereoisomers

Chiral molecules are mirror-images of each other.

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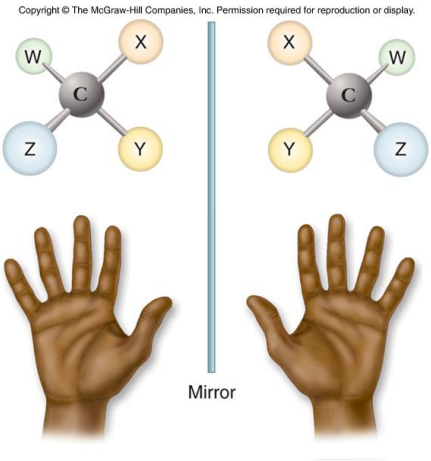
Biological Molecules



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Biological Molecules

Biological molecules are typically large molecules constructed from smaller subunits.

Monomer: single subunit

(mono = 1; -mer = unit)

Polymer: many units

(poly = many)

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Biological Molecules

dehydration synthesis: formation of large molecules by the removal of water

-monomers are joined to form polymers

hydrolysis: breakdown of large molecules by the addition of water

-polymers are broken down to monomers

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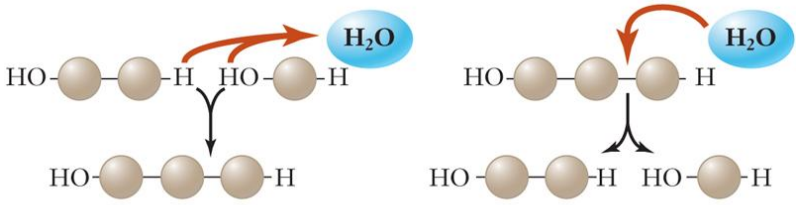
Biological Molecules



a. Dehydration synthesis

b. Hydrolysis

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Carbohydrates

Molecules with a 1:2:1 ratio of carbon, hydrogen, oxygen

-empirical formula: $(CH_2O)_n$

-examples: sugars, starch, glucose

C – H covalent bonds hold much energy

Carbohydrates are good energy storage molecules.

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Carbohydrates

Glucose

-a **monosaccharide** – single sugar

-contains 6 carbons

-very important in energy storage

-fructose is a structural isomer of glucose

-galactose is a stereoisomer of glucose

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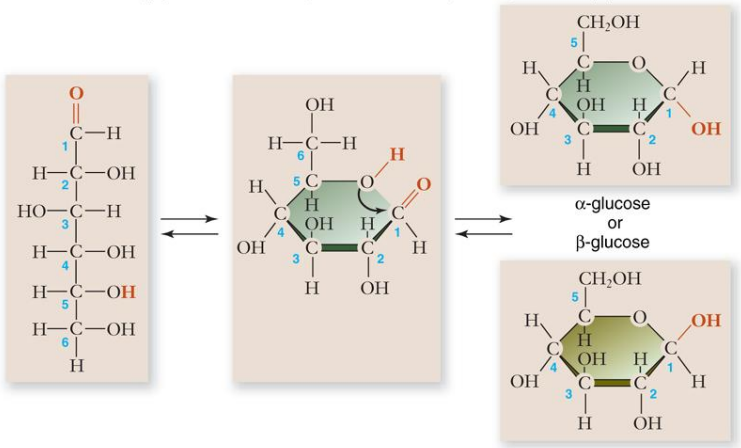
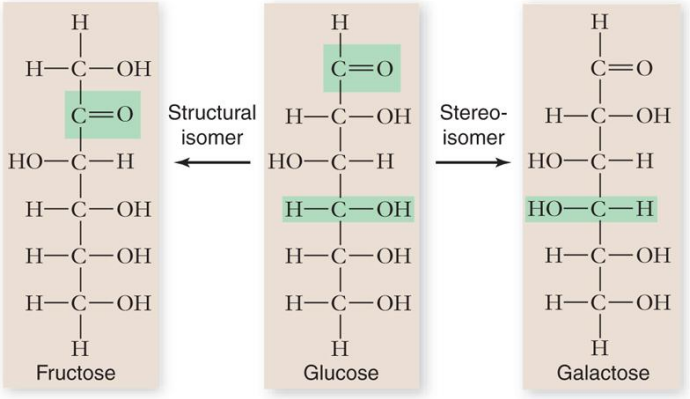
Carbohydrates



Carbohydrates



Carbohydrates

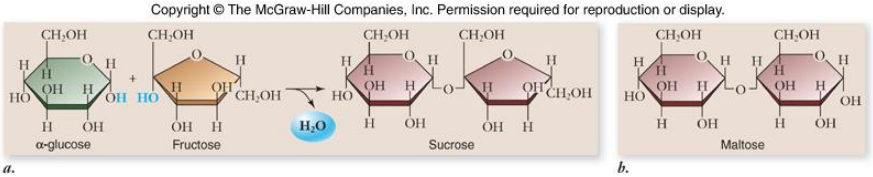
Disaccharides

-2 monosaccharides linked together by dehydration synthesis

-used for sugar transport or energy storage

-examples: sucrose, lactose, maltose

Carbohydrates



a. *b.*

Carbohydrates

Polysaccharides

-long chains of sugars

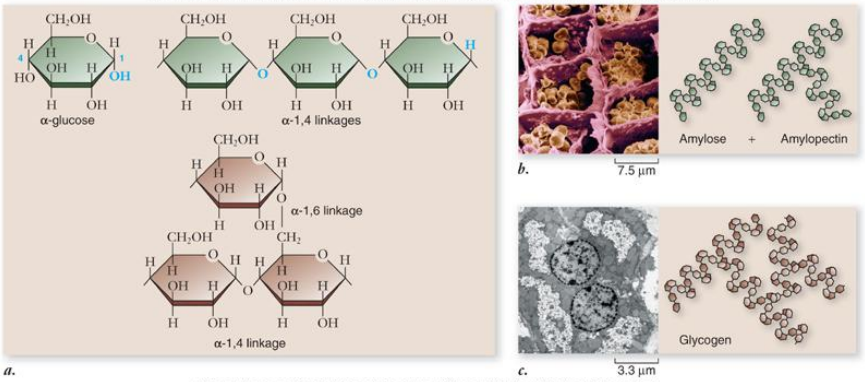
-used for energy storage

-plants use starch; animals use glycogen

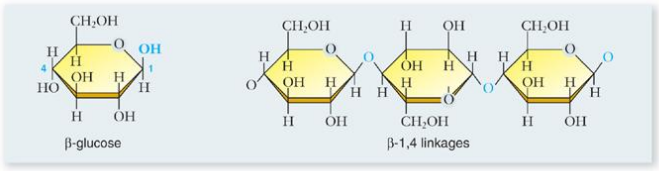
-used for structural support

-plants use cellulose; animals use chitin

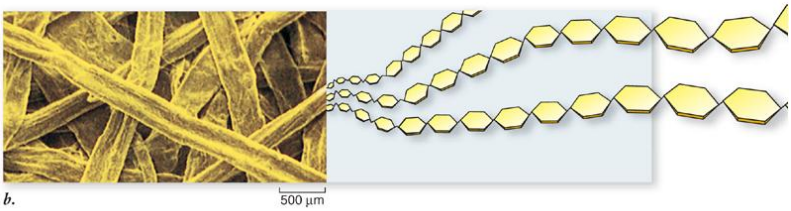
Carbohydrates



Carbohydrates



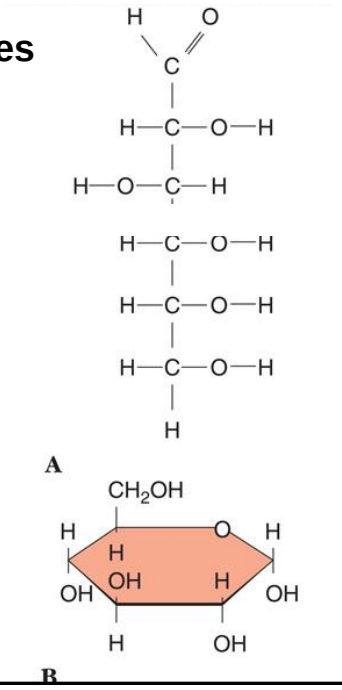
a.



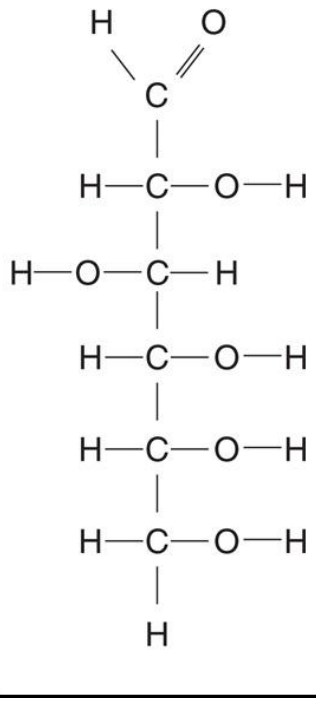
b.

Carbohydrates

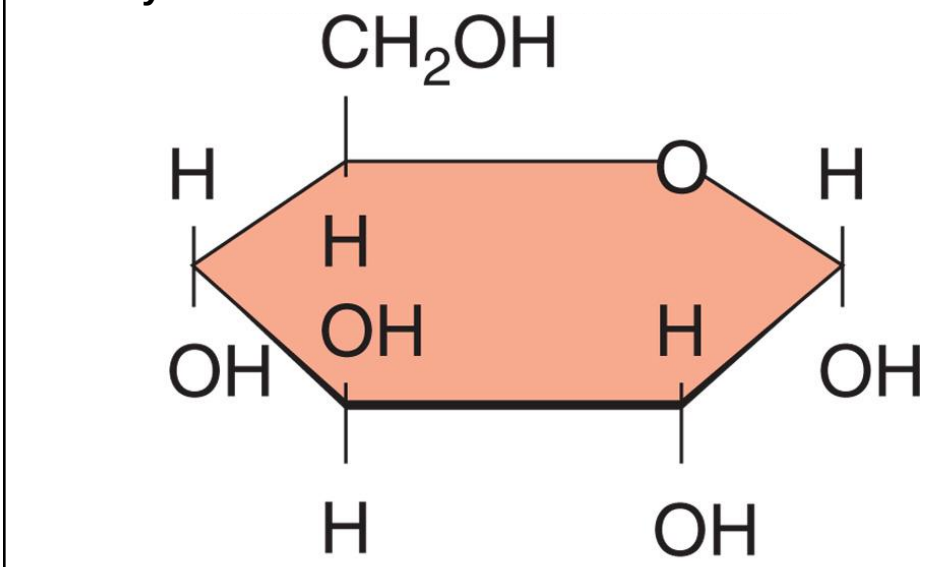
Carbohydrates



Carbohydrates

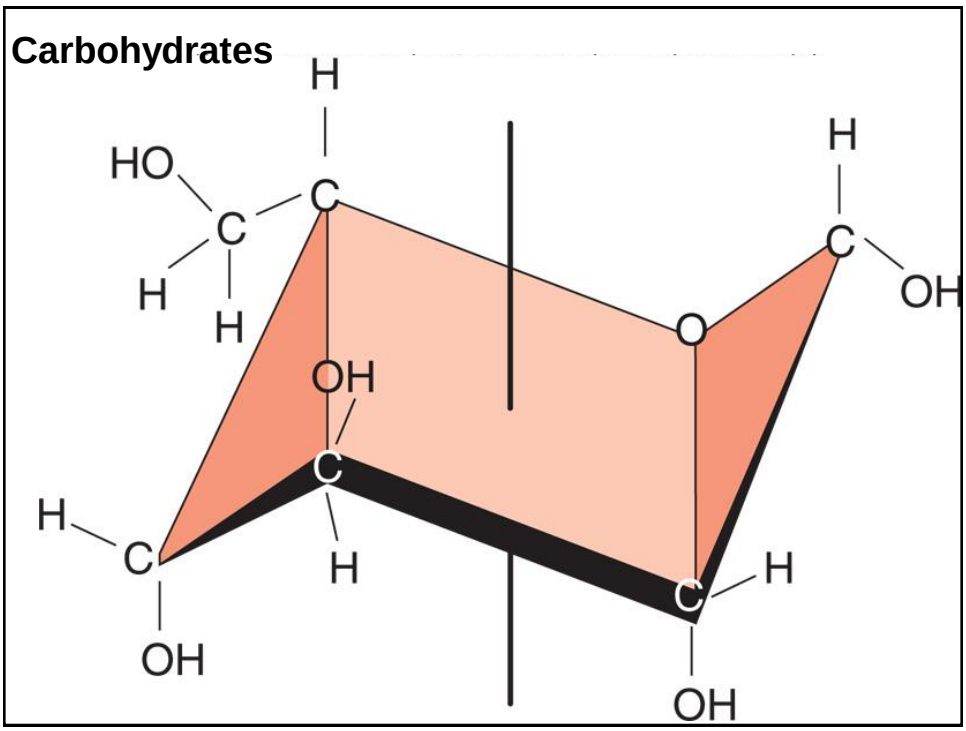


Carbohydrates

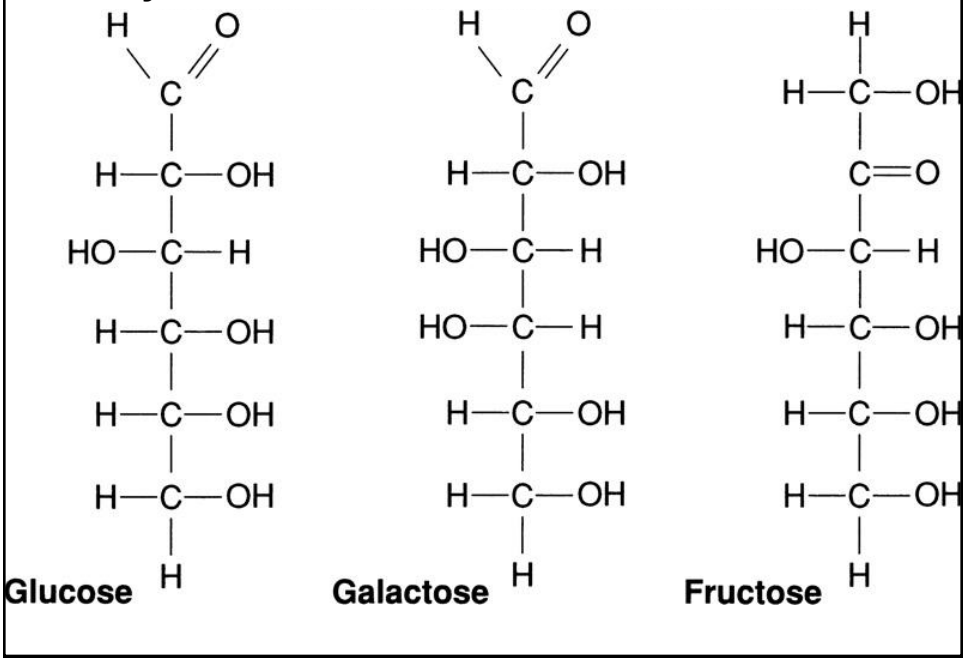


B

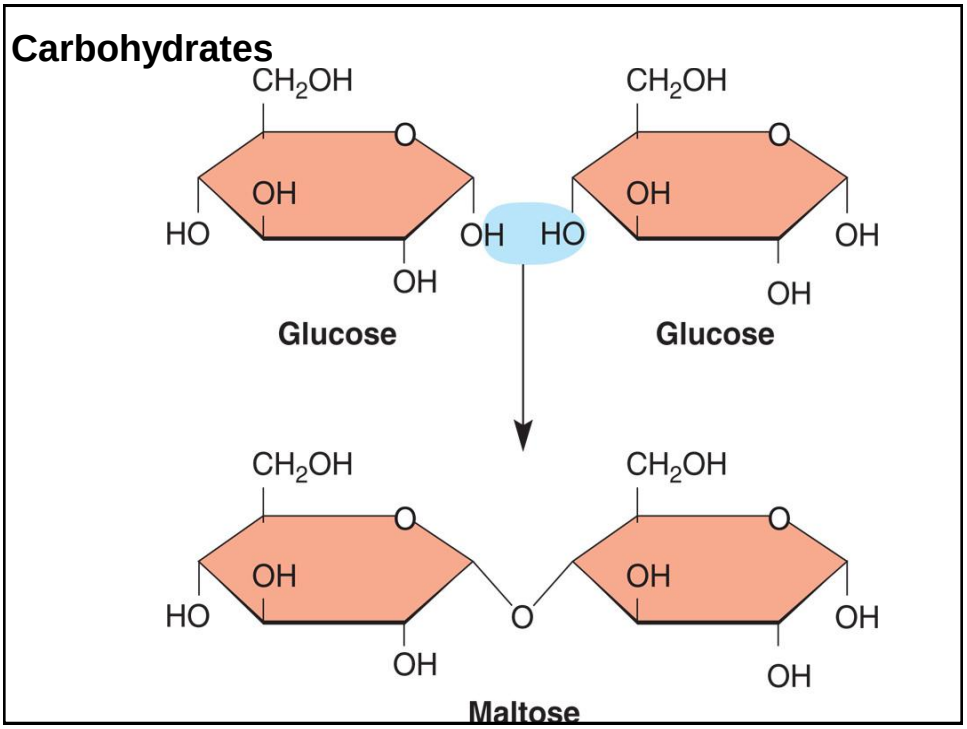
Carbohydrates



Carbohydrates



Carbohydrates



Lipids

Lipids are a group of molecules that are insoluble in water.

A high proportion of nonpolar C – H bonds causes the molecule to be hydrophobic.

Two main categories:

-fats (triglycerides)

-phospholipids

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Lipids

Triglycerides (fats)

-composed of 1 glycerol + 3 fatty acids

Fatty acids are long hydrocarbon chains which may be

-**saturated**

-**unsaturated**

-**polyunsaturated**

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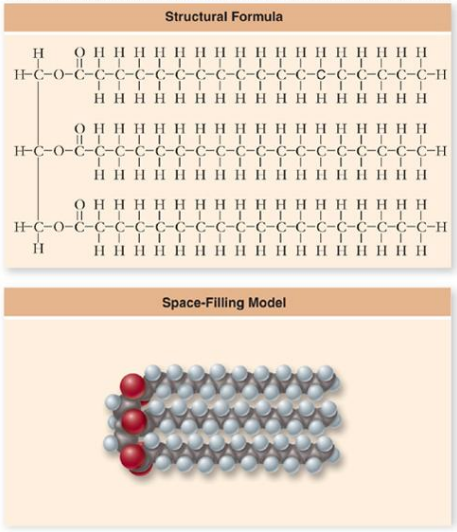
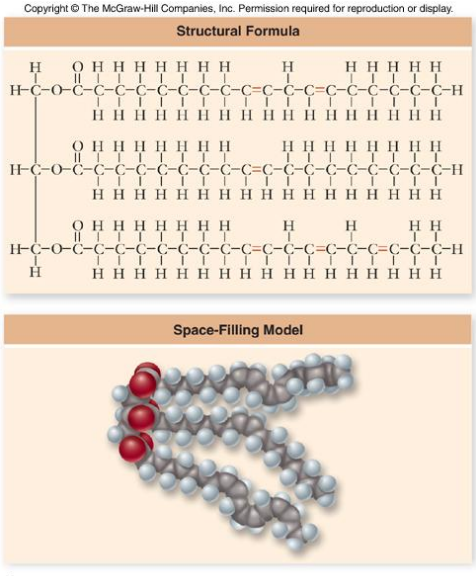
Lipids



a.

Lipids



b.

Lipids

Triglycerides

-an excellent molecule for energy storage

-store twice as much energy as carbohydrates

-animal fats are usually saturated fats and are solid at room temperature

-plant fats (oils) are usually unsaturated and are liquid at room temperature

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Lipids

Phospholipids -composed of:

-1 glycerol

-2 fatty acids

-a phosphate group

Phospholipids contain polar “heads” and nonpolar “tails”.

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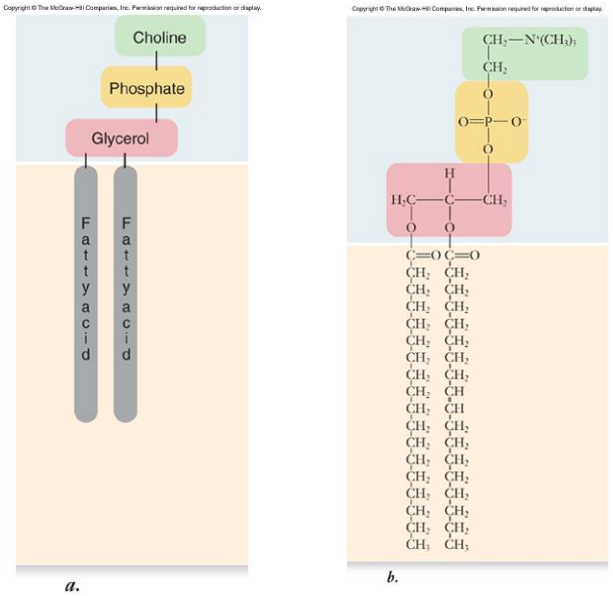
Lipids



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Lipids

Phospholipids spontaneously form **micelles** or **lipid bilayers**.

These structures cluster the hydrophobic regions of the phospholipid toward the inside and leave the hydrophilic regions exposed to the water environment.

Lipid bilayers are the basis of biological membranes.

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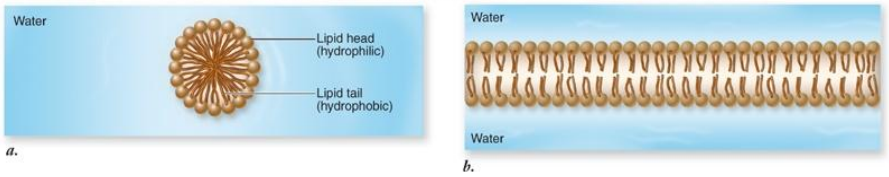
Lipids



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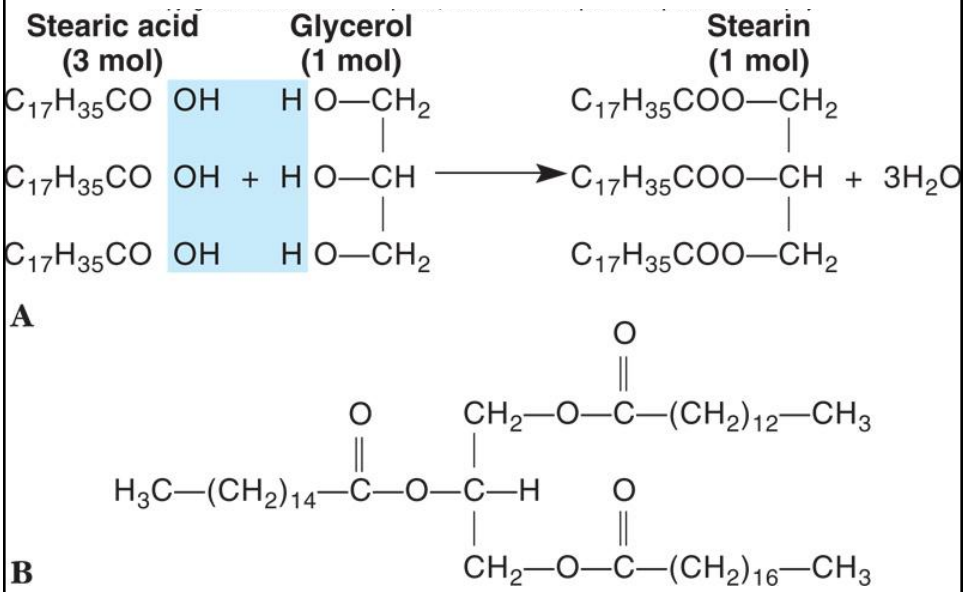
Neutral Fats



Unsaturated Fats

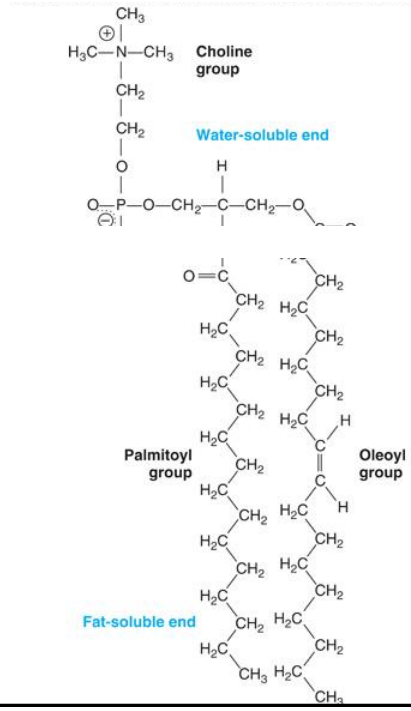
$CH_3—(CH_2)_7—CH=CH—(CH_2)_7—COOH$

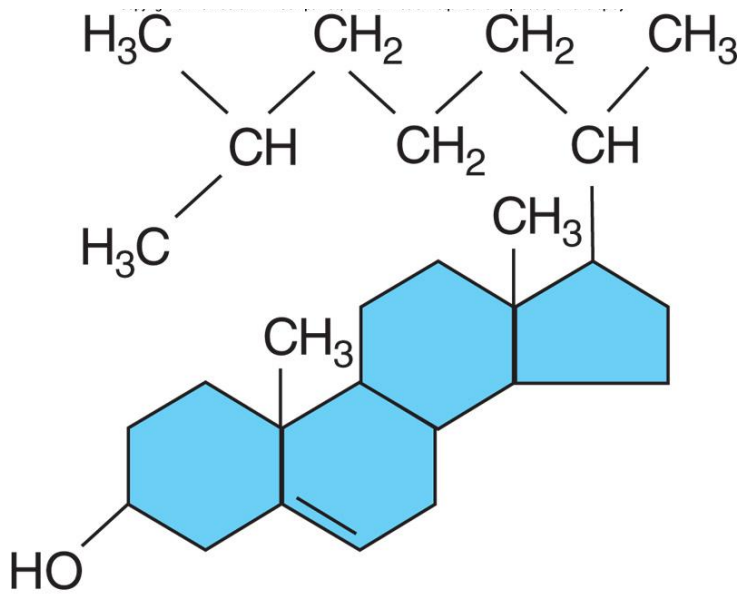
Oleic acid

$CH_3—(CH_2)_4—CH=CH—CH_2—CH=CH—(CH_2)_7—COOH$

Linoleic acid

Phospholipids





Cholesterol

Proteins

Protein functions include:

1. enzyme catalysts
2. defense
3. transport
4. support
5. motion
6. regulation
7. storage

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Proteins

Proteins are polymers of amino acids.

Amino acids

-20 different amino acids

-joined by dehydration synthesis

-**peptide bonds** form between adjacent amino acids

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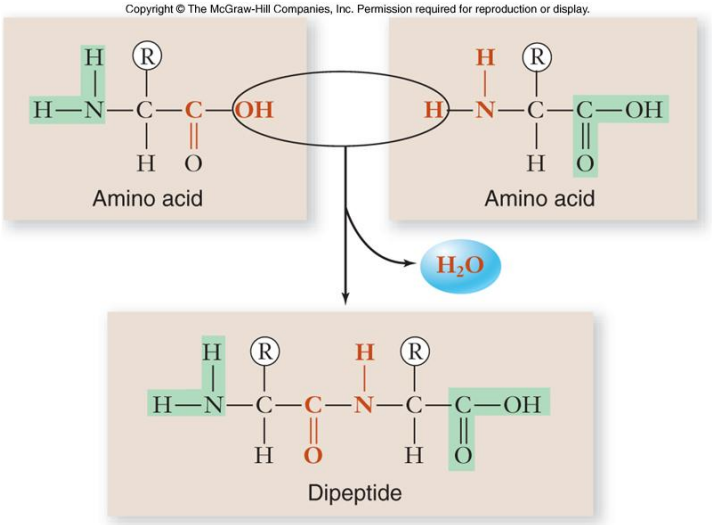
Proteins



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Proteins

Amino acid structure

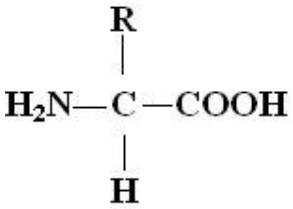
-central carbon atom surrounded by

-amino group

-carboxyl group

-single hydrogen

-variable **R group**



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Proteins

The structure of the R group dictates the chemical properties of the amino acid.

Amino acids can be classified as:

1. nonpolar
2. polar
3. charged
4. aromatic
5. special function

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Proteins

The shape of a protein determines its function.

-primary structure – sequence of amino acids

-secondary structure – interaction of groups in the peptide backbone

- **α helix**
- **β sheet**

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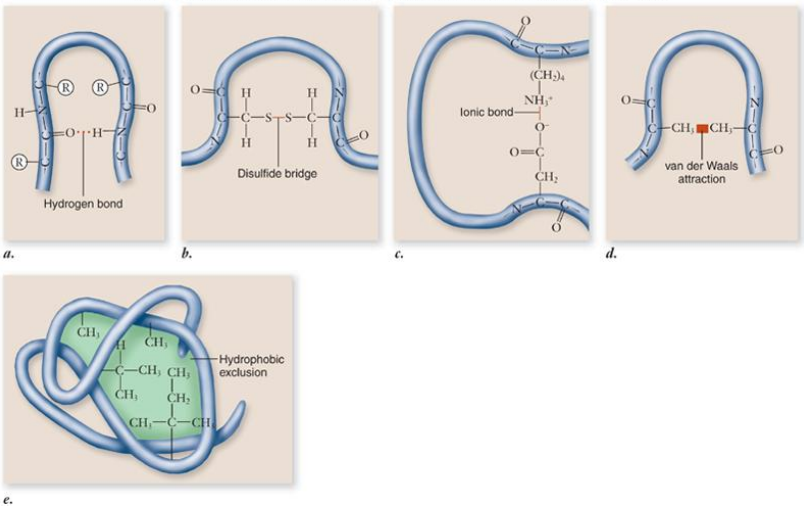
Proteins



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Proteins

Protein structure (continued)

-tertiary structure – folded shape of the polypeptide chain

-quaternary structure – interactions between multiple polypeptide subunits

Protein folding is aided by **chaperone proteins**.

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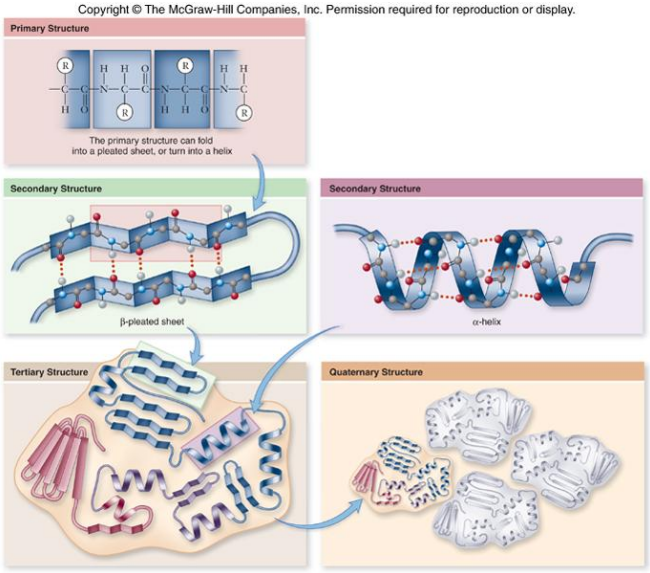
Proteins



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Proteins

Motifs are common elements of secondary structure seen in many polypeptides.

Domains are functional regions of a polypeptide.

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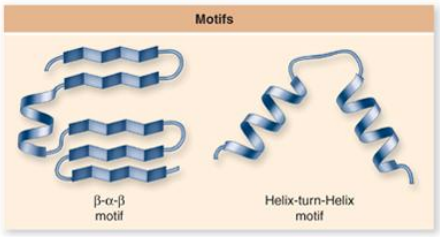
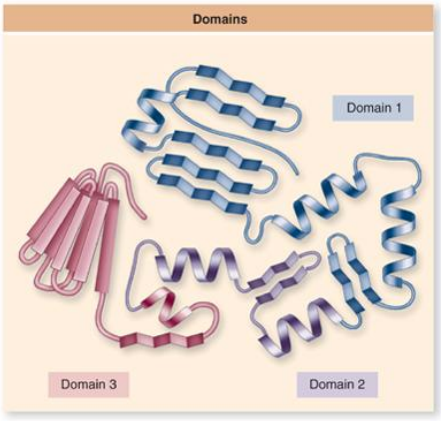
Proteins





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Proteins

Denaturation is a change in the shape of a protein, usually causing loss of function.

-may involve complete unfolding

-caused by changes in the protein's environment

-pH

-temperature

-salt concentration

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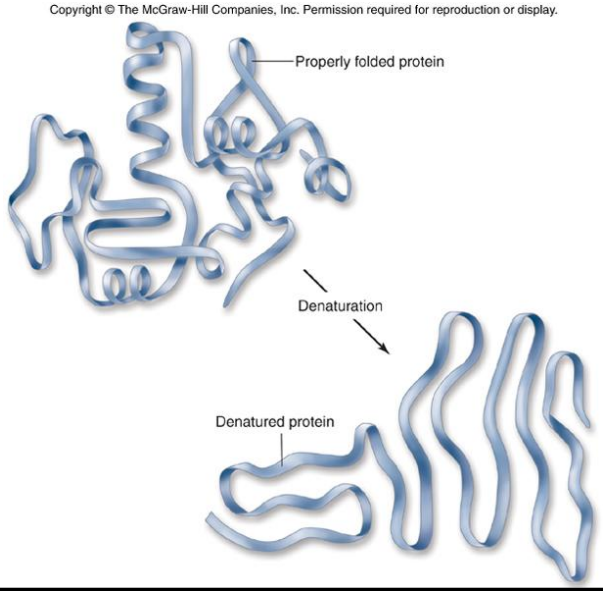
Proteins



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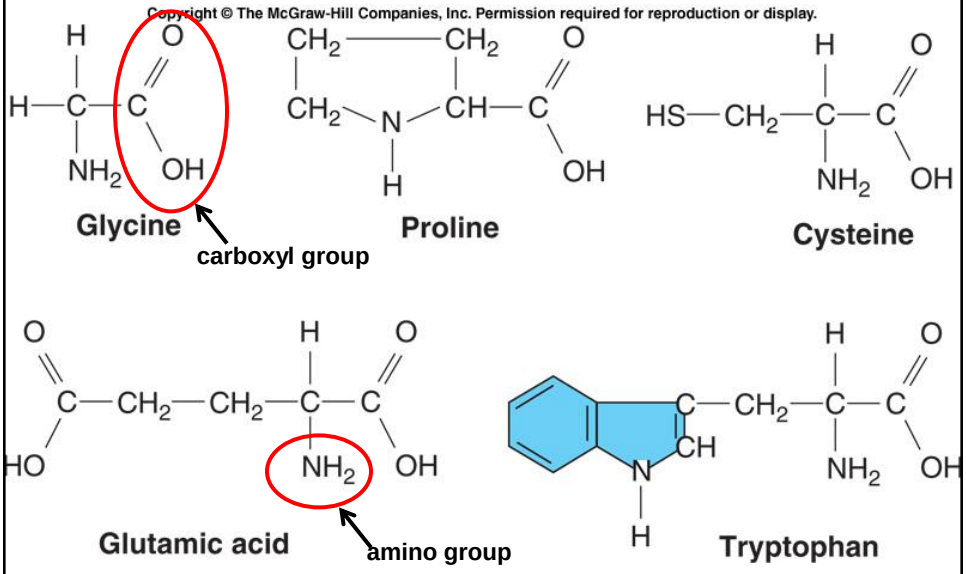
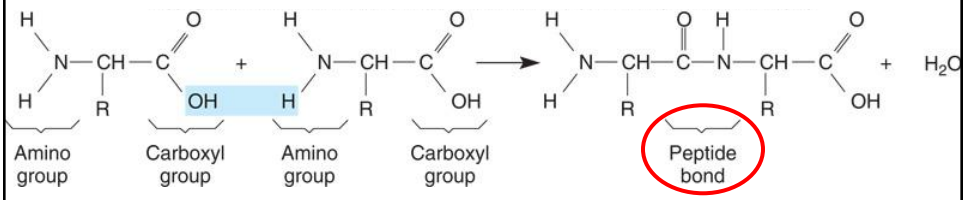
Amino Acids



amino acids strung together by peptide bonds to form peptides

smallest protein = minimum of 50 amino acids



Proteins have shape

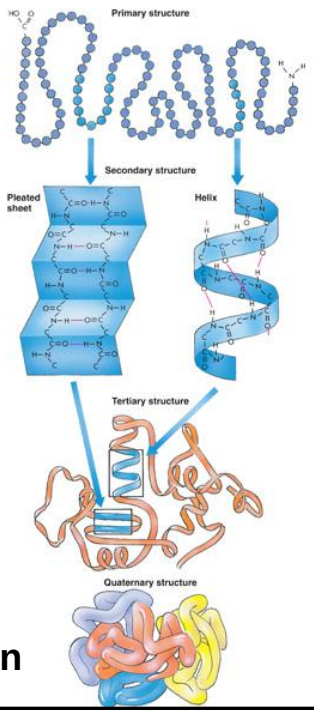
1-d

2-d

3-d

4-d

e.g. hemoglobin



Nucleic Acids

Two types: DNA and RNA

Functions: specialized for the storage, transmission, and use of genetic information

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Nucleic Acids

Nucleic acids are polymers of **nucleotides**.

-nucleotides:

sugar + phosphate + nitrogenous base

-sugar is **deoxyribose** in DNA

or **ribose** in RNA

-Nitrogenous bases include

-purines: adenine & guanine (2 rings)

-pyrimidines: thymine, cytosine, uracil (1 ring)

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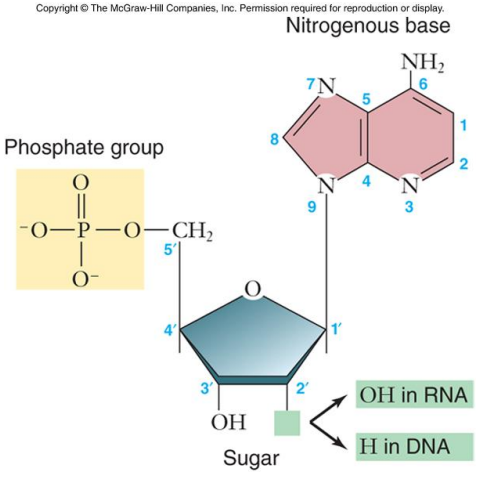
Nucleic Acids



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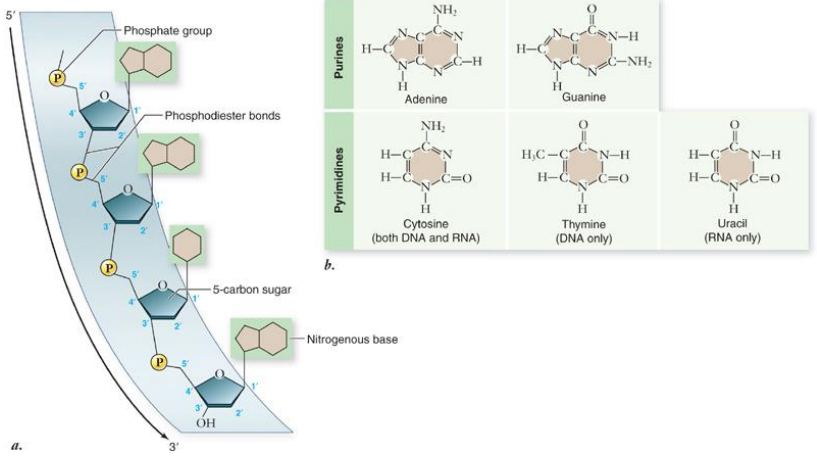
Nucleic Acids



Nucleic Acids

DNA

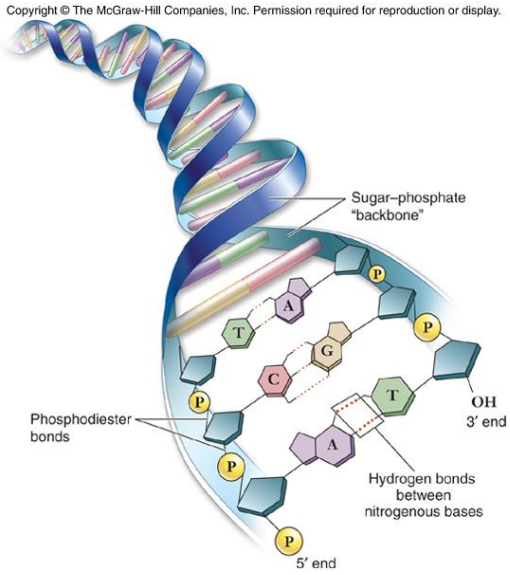
-nucleotides connected by **phosphodiester bonds**

- **double helix**: 2 polynucleotide strands connected by hydrogen bonds

-polynucleotide strands are **complementary**

-genetic information is carried in the sequence of nucleotides

Nucleic Acids



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Nucleic Acids

RNA

-contains ribose instead of deoxyribose

-contains uracil instead of thymine

-single polynucleotide strand

-functions:

  -read the genetic information in DNA

  -direct the synthesis of proteins

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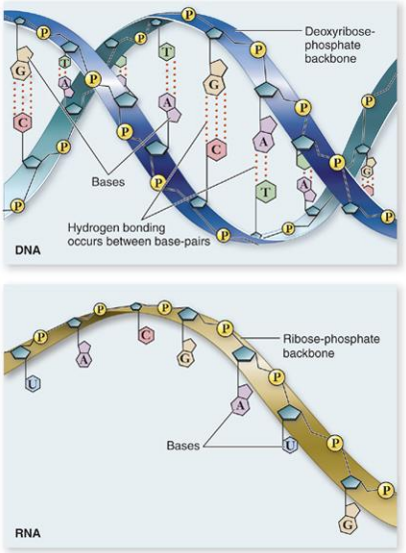
Nucleic Acids



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Nucleic Acids

Other nucleotides

-**ATP**: adenosine triphosphate

-primary energy currency of the cell

-**NAD^+** and **FAD**: electron carriers for many cellular reactions

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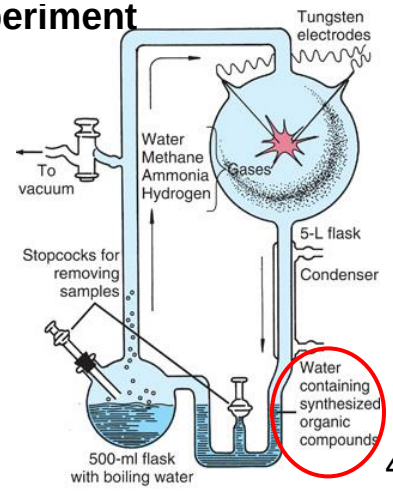
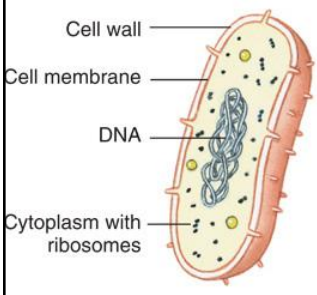
1953 Miller & Urey Experiment
Chemical Evolution

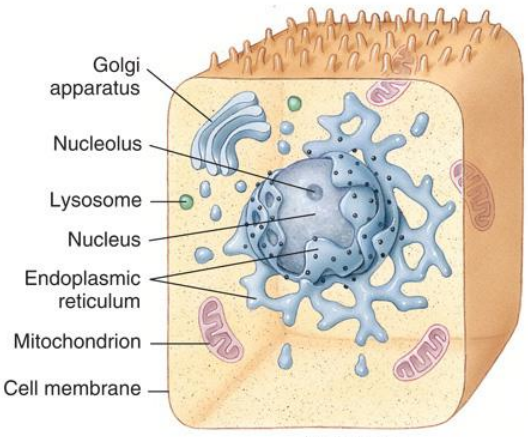
simulation of primitive earth conditions



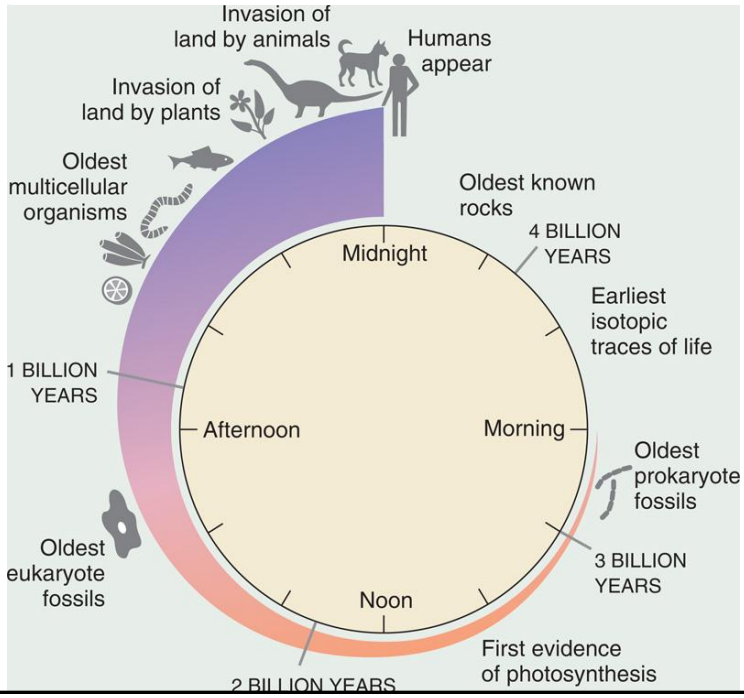
after 7 days
4 amino acids
urea
fatty acids



Prokaryote



Eukaryote


Invasion of land by animals
Humans appear
Invasion of land by plants
Oldest multicellular organisms
Oldest known rocks
4 BILLION YEARS
Midnight
Earliest isotopic traces of life
1 BILLION YEARS
Afternoon
Morning
Oldest prokaryote fossils
Oldest eukaryote fossils
3 BILLION YEARS
Noon
First evidence of photosynthesis
2 BILLION YEARS