Macromolecules

Carbs, Proteins, Lipids, and Nucleic Acids

Presentation by Laurie, Slides by Slidesgo

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Basic Chem

01

(Of which you don’t need to know much)

Carbon is Cool

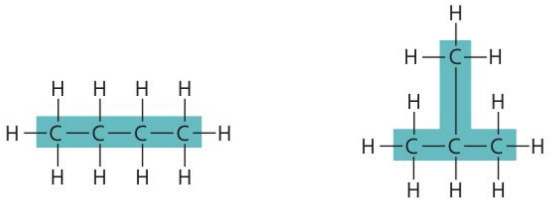
4 bonds → diversity

(a) Length

Ethane Propane

Carbon skeletons vary in length.

(b) Branching



Butane 2-Methylpropane (commonly called isobutane)

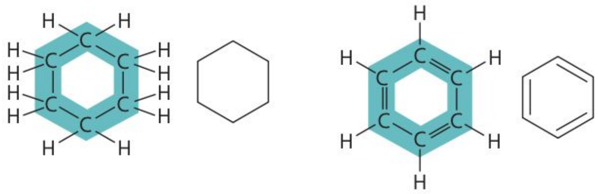
Skeletons may be unbranched or branched.

(c) Double bond position

1-Butene 2-Butene

The skeleton may have double bonds, which can vary in location.

(d) Presence of rings

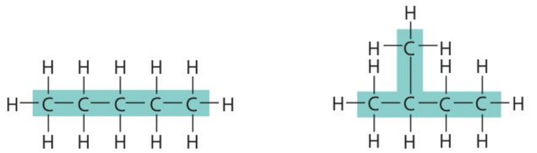


Cyclohexane Benzene

Some carbon skeletons are arranged in rings. In the abbreviated structural formula for each compound (to its right), each corner represents a carbon and its attached hydrogens.

Isomers

(a) Structural isomers



Pentane 2-Methylbutane

Structural isomers differ in the arrangement of covalent bonding partners, as shown in these two isomers of C_5H_{12}.

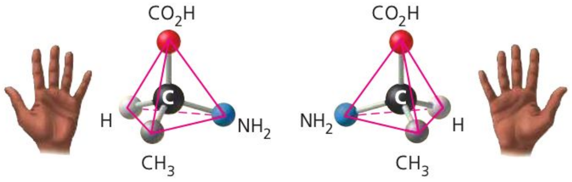
(b) *Cis-trans* isomers (also known as geometric isomers)

cis isomer: The two Xs are on the same side.

trans isomer: The two Xs are on opposite sides.

Cis-trans isomers differ in arrangement about a double bond. In these diagrams, X represents an atom or group of atoms attached to a double-bonded carbon.

(c) Enantiomers



L isomer D isomer

Enantiomers differ in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. The two isomers here are designated the L and D isomers from the Latin for "left" and "right" (*levo* and *dextro*). Enantiomers cannot be superimposed on each other.

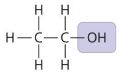
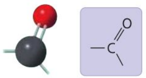
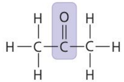
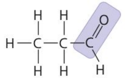
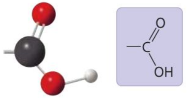
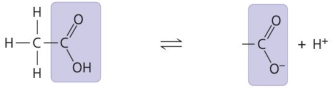
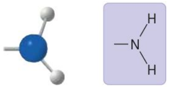
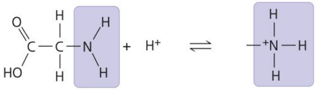
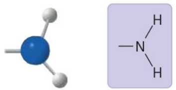
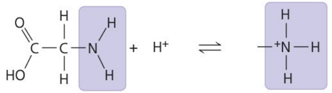
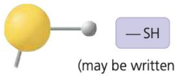
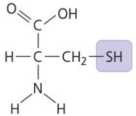
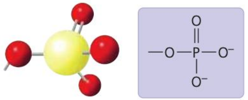
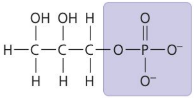
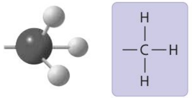
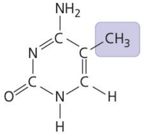
Structure = Function

Drug	Effects	Effective Enantiomer	Ineffective Enantiomer
Ibuprofen	Reduces inflammation and pain	 S-Ibuprofen	 R-Ibuprofen
Albuterol	Relaxes bronchial (airway) muscles, improving airflow in asthma patients	 R-Albuterol	 S-Albuterol

Sugars = D

Proteins = L

Functional Groups

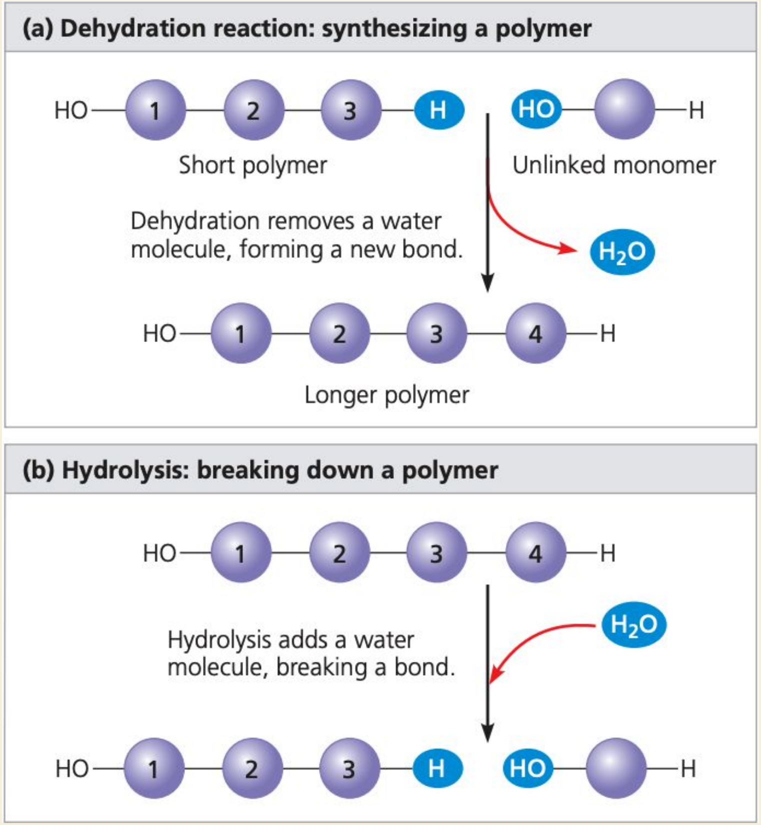
Chemical Group	Group Properties and Compound Name	Examples
Hydroxyl group (—OH)  (may be written HO—)	Is polar due to electronegative oxygen. Forms hydrogen bonds with water, helping dissolve compounds such as sugars. Compound name: **Alcohol** (specific name usually ends in *-ol*)	 **Ethanol**, the alcohol present in alcoholic beverages
Carbonyl group (>C=O) 	Sugars with ketone groups are called ketoses; those with aldehydes are called aldoses. Compound name: **Ketone** (carbonyl group is within a carbon skeleton) or **aldehyde** (carbonyl group is at the end of a carbon skeleton)	 **Acetone**, the simplest ketone  **Propanal**, an aldehyde
Carboxyl group (—COOH) 	Acts as an acid (can donate H^+) because the covalent bond between oxygen and hydrogen is so polar. Compound name: **Carboxylic acid**, or **organic acid**	 **Acetic acid**, which gives vinegar its sour taste; Ionized form of —COOH (carboxylate ion), found in cells
Amino group (—NH_2) 	Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms). Compound name: **Amine**	 **Glycine**, an amino acid (note its carboxyl group); Ionized form of —NH_2, found in cells
Amino group (—NH_2) 	Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms). Compound name: **Amine**	 **Glycine**, an amino acid (note its carboxyl group); Ionized form of —NH_2, found in cells
Sulfhydryl group (—SH)  (may be written HS —)	Two —SH groups can react, forming a "cross-link" that helps stabilize protein structure. Hair protein cross-links maintain the straightness or curliness of hair; in hair salons, "permanent" treatments break cross-links, then re-form them while the hair is in the desired shape. Compound name: **Thiol**	 **Cysteine**, a sulfur-containing amino acid
Phosphate group (—OPO_3^{2-}) 	Contributes negative charge (1– when positioned inside a chain of phosphates; 2– when at the end). When attached, confers on a molecule the ability to react with water, releasing energy. Compound name: **Organic phosphate**	 **Glycerol phosphate**, which takes part in many important chemical reactions in cells
Methyl group (—CH_3) 	Affects the expression of genes when bonded to DNA or to proteins that bind to DNA. Affects the shape and function of male and female sex hormones. Compound name: **Methylated compound**	 **5-Methylcytosine**: Cytosine, a component of DNA, has been modified by addition of a methyl group.

02

Macromolecules

Polymers and Monomers

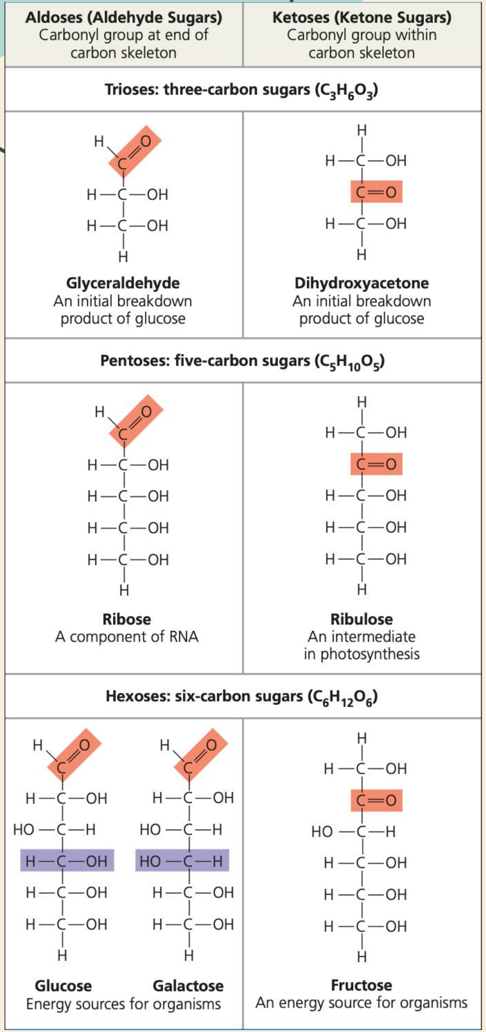
Condensation reaction



03

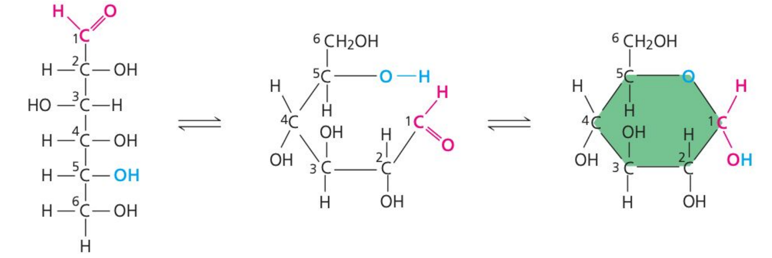
Sugars and Carbs

Sweet + simple

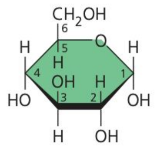


Monomer = Monosaccharide

1 Carbonyl, Multiple Hydroxyls



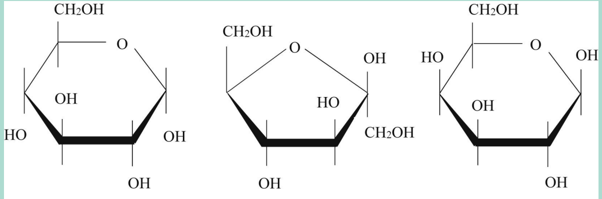
(a) Linear and ring forms. Chemical equilibrium between the linear and ring structures greatly favors the formation of rings. The carbons of the sugar are numbered 1 to 6, as shown. To form the glucose ring, carbon 1 (magenta) bonds to the oxygen (blue) attached to carbon 5.



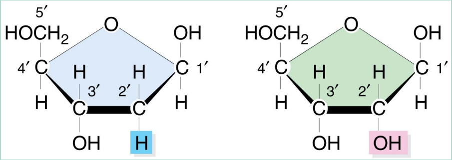
(b) Abbreviated ring structure. Each unlabeled corner represents a carbon. The ring's thicker edge indicates that you are looking at the ring edge-on; the components attached to the ring lie above or below the plane of the ring.

Examples:

Glucose Fructose Galactose



Deoxyribose Ribose



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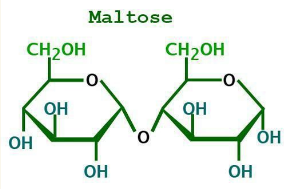
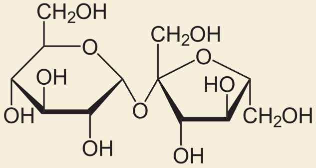
https://clinicalnutritionespen.com/cms/attachment/1e7ed9c9-dd29-4c21-879e-abcf97f96fcd/gr1_lrg.jpg

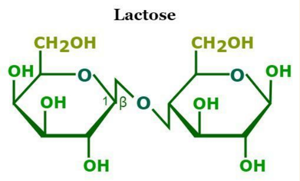
Polymer Examples

Disaccharides (2)

Maltose = glucose + glucose
Sucrose = glucose + fructose
Lactose = glucose + galactose





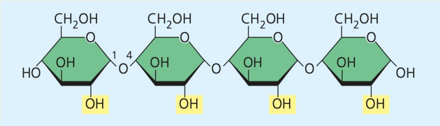


Oligosaccharides (3-10)

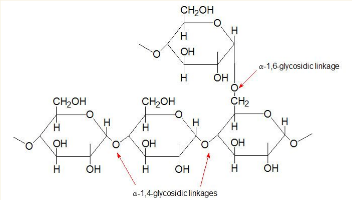
Raffinose = galactose + glucose + fructose

Polysaccharides (10+)

Starch

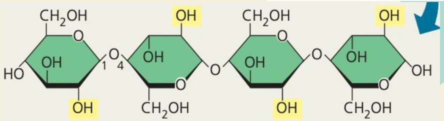


- **Amylose**
  - **1-4 linkages (more)**
- **Amylopectin**
  - **1-6 linkages (twist)**



Glycogen (most branched)

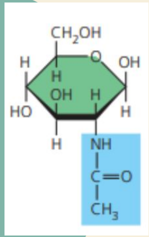
Cellulose



- β-glucose
- Most common organic molecule

Chitin (N-acetylglucosamine)

- Fungi, insects



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https://upload.wikimedia.org/wikipedia/commons/thumb/2/21/Amylose2.svg/1200px-Amylose2.svg.png
https://media.geeksforgeeks.org/wp-content/uploads/20220824235150/maltosestructure.jpg
https://media.geeksforgeeks.org/wp-content/uploads/20220929115448/lac.jpg
https://upload.wikimedia.org/wikipedia/commons/thumb/1/1a/Saccharose2.svg/1200px-Saccharose2.svg.png

04

Lipids

They can’t swim

Basic Properties

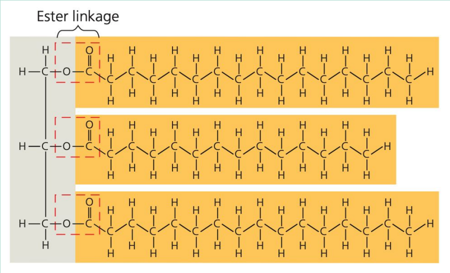
- Hydrophobic
  - Mostly C and H – C-H bonds are nonpolar
- Do not have true polymers
- Generally not big
- 3 important categories:
  - Fats
  - Phospholipids
  - Steroids

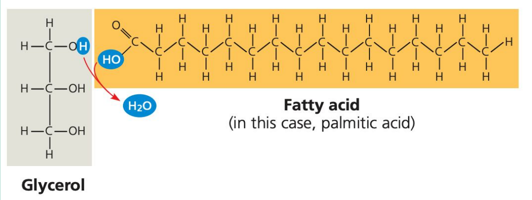
Functions

- Energy storage
  - 2x as much energy as polysaccharide
  - Useful for animals and seeds
- Cushions vital organs
- Insulation
  - Marine animals

Fats (Triacylglycerol, Triglyceride)

Fat = 1 glycerol + 3 fatty acids, synthesized through dehydration reaction





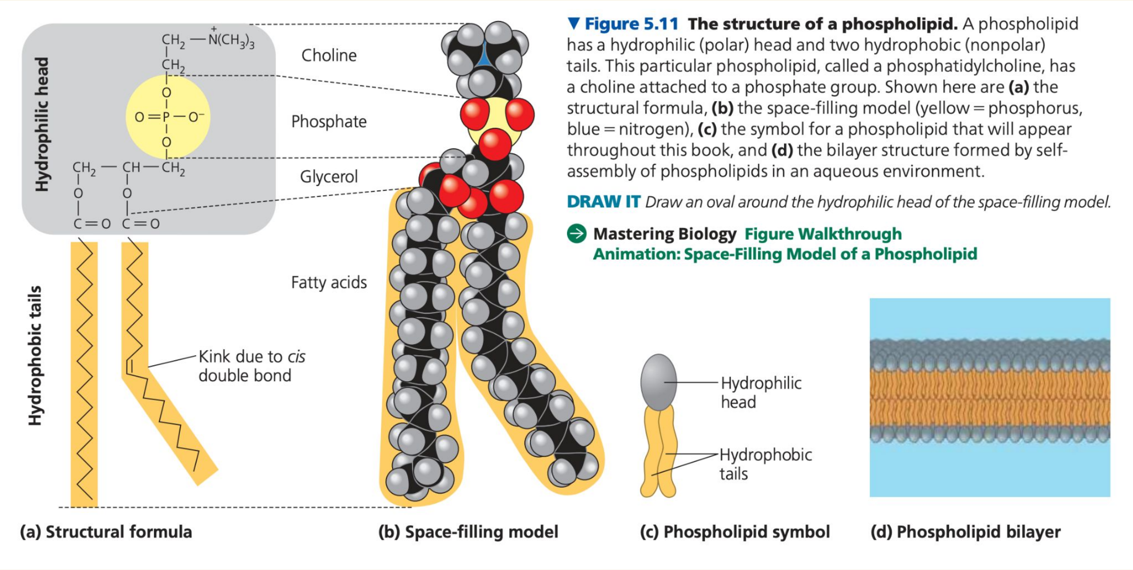
Saturated fat

- No double bonds
- Most animal fats
  - Lard
  - Butter
- Solid at room temp
  - Packing
- Hydrogenation

Unsaturated fat

- Double bonds
- Plant and fish fats (oils)
  - Olive oil
  - Cod liver oil

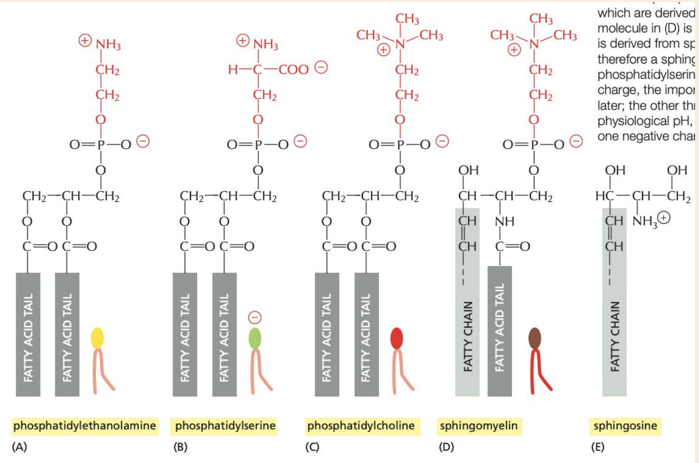
Phospholipids



▼ **Figure 5.11 The structure of a phospholipid.** A phospholipid has a hydrophilic (polar) head and two hydrophobic (nonpolar) tails. This particular phospholipid, called a phosphatidylcholine, has a choline attached to a phosphate group. Shown here are **(a)** the structural formula, **(b)** the space-filling model (yellow = phosphorus, blue = nitrogen), **(c)** the symbol for a phospholipid that will appear throughout this book, and **(d)** the bilayer structure formed by self-assembly of phospholipids in an aqueous environment.

DRAW IT *Draw an oval around the hydrophilic head of the space-filling model.*

Mastering Biology Figure Walkthrough
Animation: Space-Filling Model of a Phospholipid



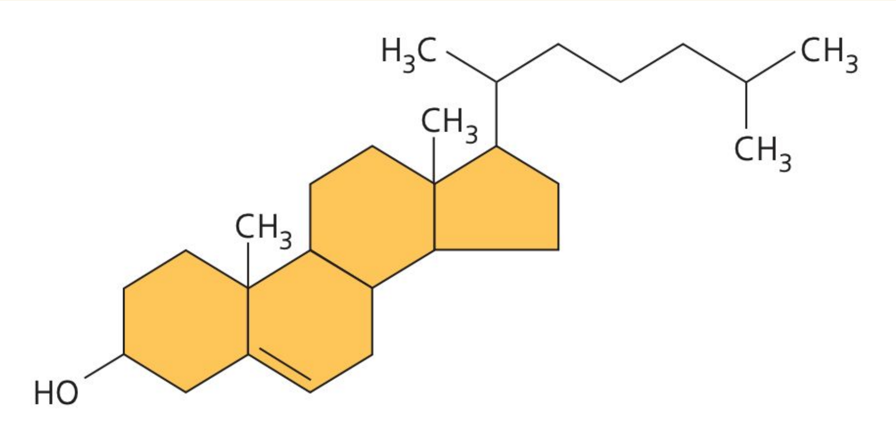
(Source: Albert's Molecular Biology of the Cell)

Steroids

Carbon skeleton made of 4 fused rings

Cholesterol

- Part of cell membranes
- Precursor for other steroids and hormones
- Made in liver and eaten from food



05

Proteins

Very well-rounded; good at everything

Functions

Enzymatic proteins

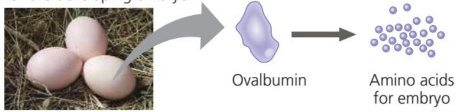
Function: Selective acceleration of chemical reactions

Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

Storage proteins

Function: Storage of amino acids

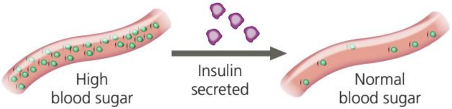
Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



Hormonal proteins

Function: Coordination of an organism's activities

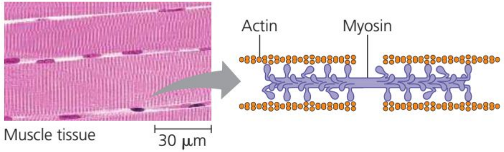
Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration.



Contractile and motor proteins

Function: Movement

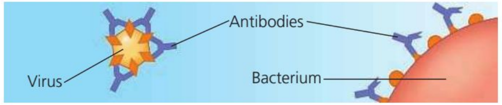
Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.



Defensive proteins

Function: Protection against disease

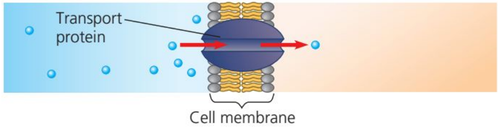
Example: Antibodies inactivate and help destroy viruses and bacteria.



Transport proteins

Function: Transport of substances

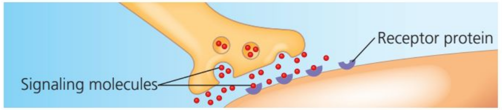
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across membranes, as shown here.



Receptor proteins

Function: Response of cell to chemical stimuli

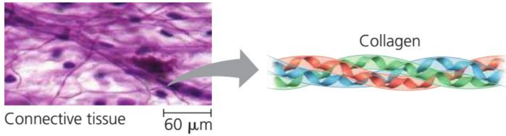
Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.



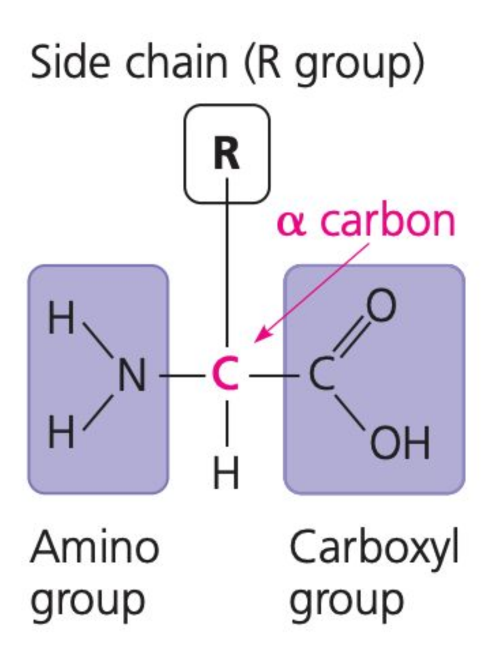
Structural proteins

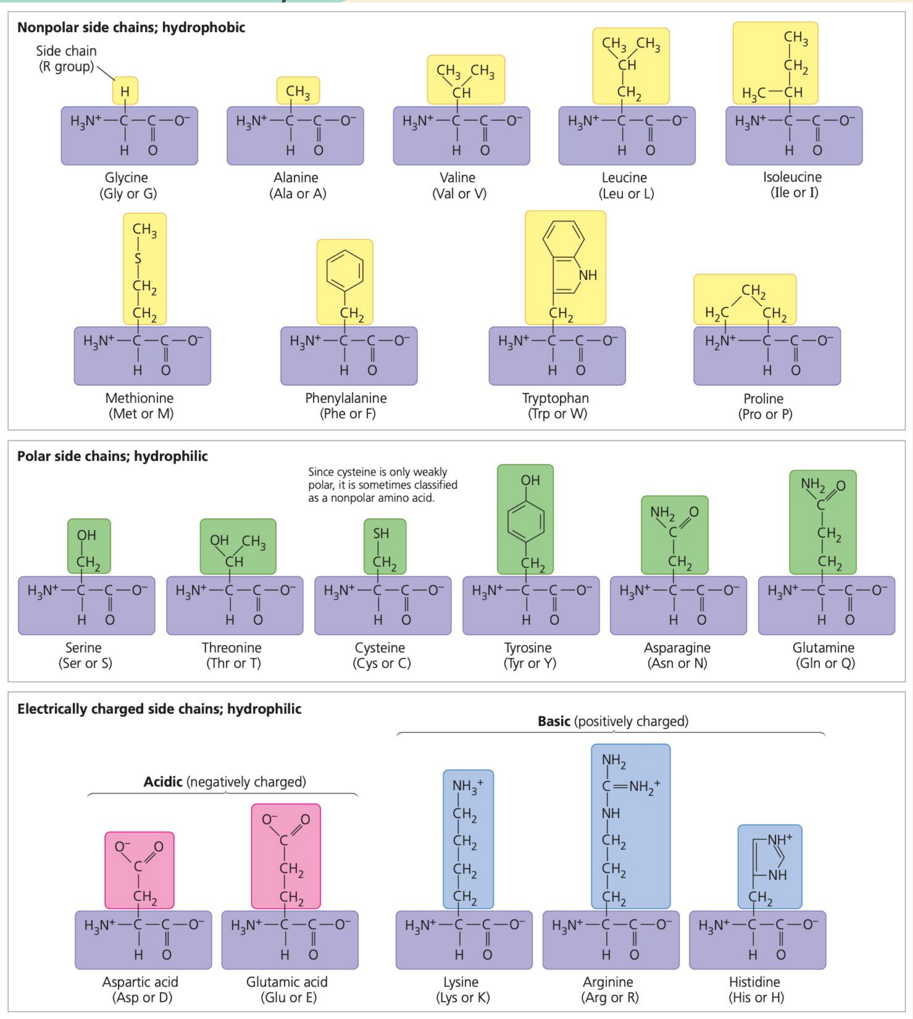
Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.



Monomers (Amino Acids)





Mnemonics

- Hydrophobic: **GLAMP FVIW**
- Hydrophilic: **S**anta **N**ever **Q**uits **C**hr**Y**s**T**mas
- Acidic: **DE**ath is negative
- Basic: **His Lys Arg** basic
- Essential: **VH MILK**? **WTF**?!
- Phosphorylated: **STY**
- Aromatic (absorb UV): **W**hi**F**f**Y**

Special cases

- Helix breakers – Proline and glycine
  - Proline is an imino acid
  - Glycine is too small
- Cysteine – disulfide bridges

Structure

Primary structure – chain of amino acids (polypeptide)
Secondary structure – formed by H-bonds between amino acids

- Alpha helices
- Beta-pleated sheets

Tertiary structure – 3D structure, caused by side chains

- Hydrophobic interaction
- Disulfide bridges

Quaternary structure – multiple subunits

Fibrous vs. Globular

Denaturation

- Caused by pH, change in temperature, chemical factors

In general, structure and proper folding is very important for function!

06

Nucleic Acids

Well-informed

Role

Two types

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

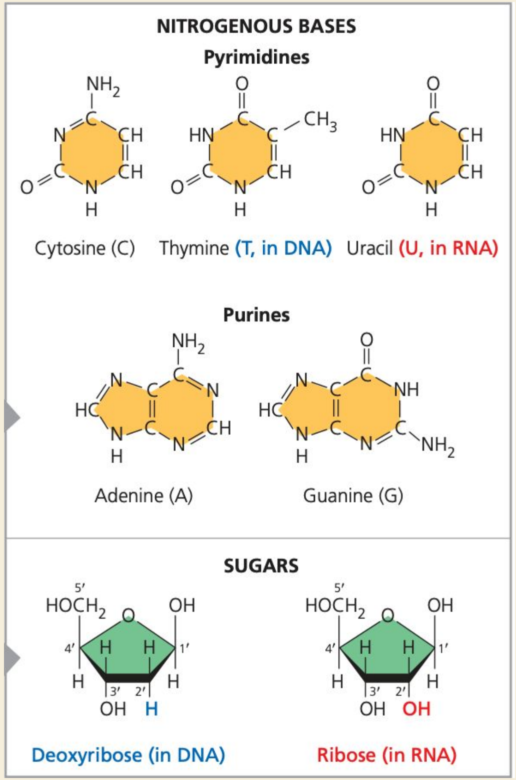
Main role is gene expression

- DNA is what's inherited
- DNA → mRNA → tRNA translates into protein

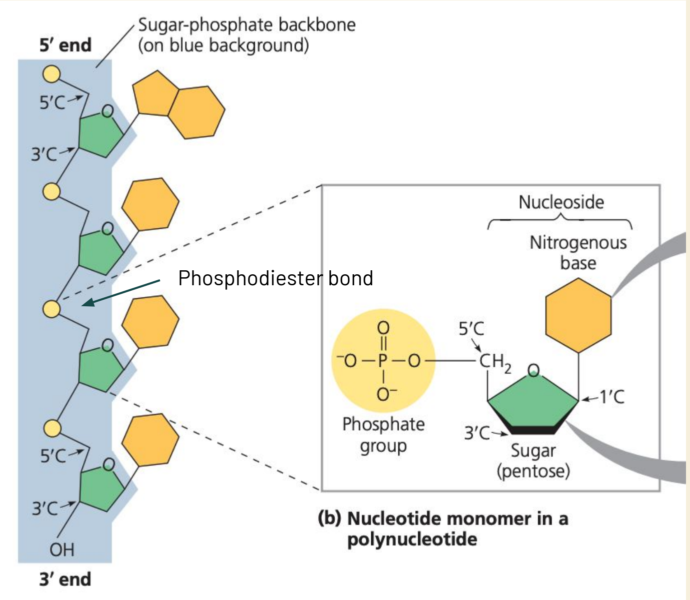
Structure

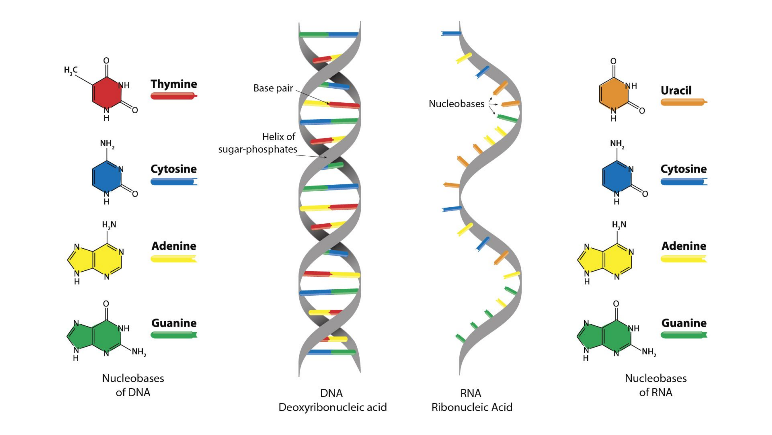
Monomer = nucleotide

- Structure
  - Five-carbon sugar (pentose) – ribose or deoxyribose
  - Nitrogenous base
    - Pyrimidine (1 ring) – C, T, U
    - Purine (2 rings) – A, G – **P**ure **A**s **G**old
  - 1-3 phosphate groups (not included in a nucleoside)
- Types
  - Adenine
  - Thymine
  - Uracil
  - Cytosine
  - Guanine



Structure





https://assets.technologynetworks.com/production/dynamic/images/content/296719/what-are-the-key-differences-between-dna-and-rna-296719-960x540.jpg?cb=12377480

DNA vs. RNA

- DNA has 2 strands, RNA has one
  - RNA can pair with itself
- RNA uses uracil instead of thymine

DNA is antiparallel