

Hydrocarbons

Hydrocarbons are molecules which consist of multiple bonds of carbon and hydrogen atoms.

Functional Groups

Functional groups are specific groups of molecules that are responsible for the varying molecular properties and interactions. These molecules have unique characteristics and personalities, regardless of the individual atoms that compose them. Below are the main functional groups involved in Organic and Biochemistry.

- Hydrocarbon - composed of Carbon to Carbon, and Carbon to Hydrogen bonds
 - Alkane C-C - single bonds
 - Alkene C-C - double bonds
 - Alkyne C-C - triple bonds
- Benzene Ring (Phenyl)
- Amine
- Alcohol
- Ether
- Alkyl halide
- Ketone
- Amide
- Thiol
- Ester
- Carboxylic acid
- Aldehyde

Biological Molecules

Biological molecules are essential macromolecules that are composed of smaller organic molecules. Since all biomolecules are organic, their common factor is the presence of Carbon.

Biomolecules are *polymers*, meaning they are formed from the combination of *monomers* (single subunit molecules) via *dehydration synthesis*. This process describes the synthesis of new compounds while losing water. Dehydration synthesis is the opposite of *hydrolysis*.

Organic molecules are also capable of existing in more than one (1) form. Organic molecules which have the same molecular formula but exists in different forms are called *isomers*. Stereoisomers are a form of isomers whose skeletal

structure is the same; however, the arrangement and attachment of atoms are different.

The Four (4) Major Biological Molecules

CARBOHYDRATES		
CATEGORY	Subunit	Function
Macromolecule (example)		
Starch, Glycogen	Glucose	Energy storage
Cellulose	Glucose	Structural support (plants)
Chitin	Modified Glucose	Structural support (animals)
LIPIDS		
CATEGORY	Subunit	Function
Macromolecule (example)		
Triglycerides (Fat, Oil)	Glycerol and three (3) fatty acids	Energy storage
Phospholipids	Glycerol, two (2) fatty acids, phosphate, and non-polar R group	Cell membranes
Prostaglandins	Five (5) carbon rings with two (2) non-polar tails	Chemical messengers
Steroids	Four (4) fused carbon rings	Membranes, hormones
Terpenes	Long carbon chains	Pigments, Structural support
PROTEINS		
CATEGORY	Subunit	Function
Macromolecule (example)		
Functional	Amino acids	Catalysis, transport
Structural	Amino acids	Support
NUCLEIC ACIDS		
CATEGORY	Subunit	Function
Macromolecule (example)		
DNA	Nucleotides	Encodes genes
RNA	Nucleotides	Needed for gene expression

Carbohydrates

Carbohydrates are composed of carbon, hydrogen, and oxygen with a ratio of 1:2:1. They differ in the number of carbon atoms present. Their main function is storage due to the large amounts of C-H bonds, which can store large amounts of energy. Categories of carbohydrates depend on the complexity of their constituents.

Monosaccharides are the simplest unit of carbohydrates. These can be in ring structure or chain formation. Examples of these include Glyceraldehyde (3 carbon), Ribose and deoxyribose (5 carbon), and Glucose, fructose, and galactose (6 carbon).

Disaccharides are simply combinations of monosaccharides linked together by their fused -OH compounds, forming the glycosidic linkage. Examples include Sucrose (glucose and fructose), Lactose (glucose and galactose), and Maltose (glucose and glucose).

Polysaccharides are simply chains of disaccharides. These differ in the level of branching chains. Examples include Glycogen (seen in animals, formed from amylose chains), Amylopectin (seen in plants), and Amylose (seen in plants, formed from glucose).

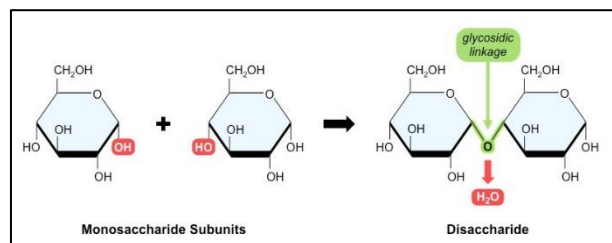


Figure 1. Structure of Mono- and Disaccharides

Source: <https://ib.bioninja.com.au>

Lipids

This group of molecules have multiple variations but have one (1) common characteristic: they are insoluble in water. In general, the main structure of lipids is a glycerol head and a fatty acid tail. Majority of lipids consist of one (1) glycerol and three (3) fatty acids tails. This is known as Triacylglycerol (triglyceride). Triglycerides can be categorized based on the C-H bonds of the fatty acid tails. If all tails have two (2) hydrogen atoms attached to each individual carbon (thereby only forming single C-C bonds), it is known as a saturated fatty

acid. However, if the carbons form double bonds and thereby reducing the number of hydrogen atoms attached, it is now known as an unsaturated fatty acid. In an unsaturated fatty acid, the double C-C bonds form kinks in the tails which prevent it from aligning with itself. Which is why these lipids are known as oils (those that stay liquid at room temperature), while saturated lipids are known as fats (those that become solid at room temperature).

Lipids can also have an additional group attached to the glycerol head. These additional groups cause the many variations of lipids. If a phosphate group is attached, it becomes a phospholipid. As mentioned before, due to the hydrophobic nature of the fatty acids and the hydrophilic nature of the phosphate group, these phospholipids are responsible for the fluid structure of the cell membrane.

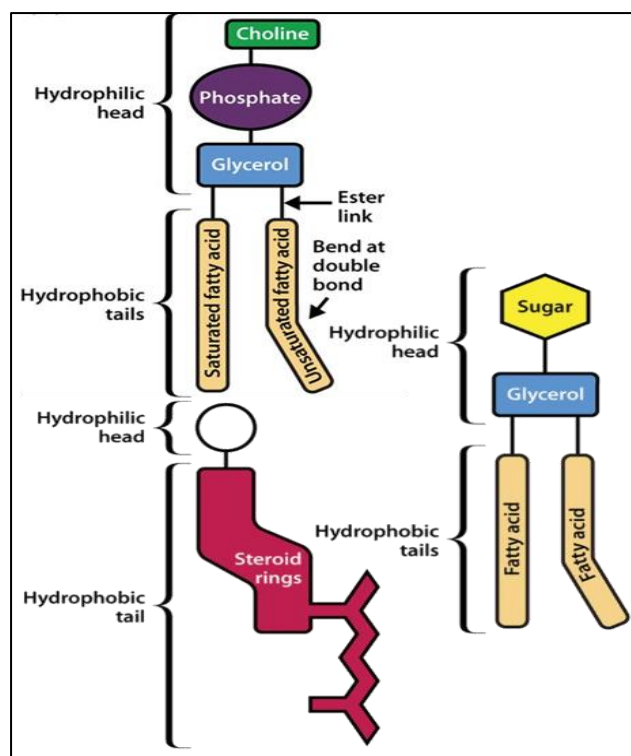


Figure 2. Structure of Phosphoglycerides, Steroids, and Glycerides

Source: <https://www.thoughtco.com>

Nucleic Acid

There are only two (2) variants of nucleic acids: Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA). Their main function is the storage and synthesis of genetic information of cells. Nucleic

acids are composed of repeating subunits called Nucleotides (polynucleotides are therefore chains of nucleotides). Each nucleotide is composed of three (3) main parts: the 5-carbon sugar, an organic nitrogen base, and a phosphate group. The 5-carbon sugar for DNA is deoxyribose, while in RNA it is simply ribose. Their main difference is the presence of an attached -OH group to the 2nd Carbon of RNA.

The nitrogen bases in DNA are Adenine (A), Guanine (G), Cytosine (C), and Thymine (T). The former two (2) are known as purines due to their two (2) ringed structure. The latter two (2) are known as pyrimidines due to their single ring structure.

RNA has a similar set of nitrogen bases to DNA. Except that instead of Thymine, it has Uracil (U).

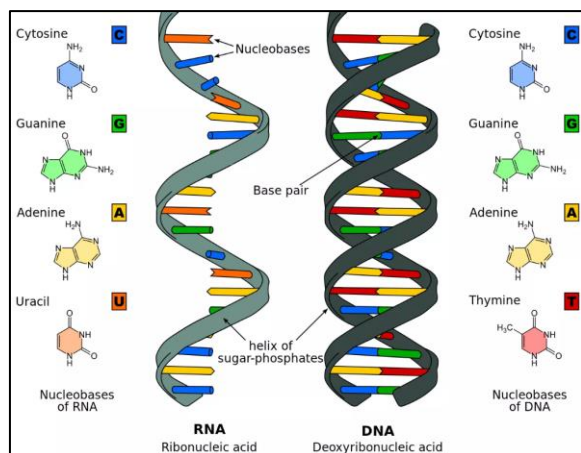


Figure 3. Structure of DNA, RNA, and Nitrogen Bases
Source: <https://www.thoughtco.com>

Proteins

Proteins are composed of amino acids linked together by peptide bonds. Polypeptides are chains of multiple amino acids. Proteins are multiple chains of polypeptides. A protein can have up to 20 or more polypeptide chains. If a protein is composed of only one (1) chain, it can also be referred to as a polypeptide.

Categories of proteins depend on their function. Refer to the table below for the list of functions and some examples.

FUNCTION	CLASS	EXAMPLE	USE
Enzyme Catalysis	Enzyme	Polymerase	Synthesize nucleic acids
Defense	Immunoglobulin	Antibodies	Mark foreign proteins
Transport	Membrane Transporters	Proton pump	Chemiosmosis
Support	Fibers	Keratin	Forms hair
Motion	Muscle	Actin Myosin	Contraction of muscle fibers
Regulation	Hormones	Insulin	Controls blood glucose
Storage	Ion binding	Casein	Stores ions in milk

Levels of Protein Structure

1. Primary
 - a. Arrangement of amino acids to form peptide groups
2. Secondary
 - a. Interaction of peptide groups to form helices (α -helix) or sheets (β -sheets)
3. Tertiary
 - a. Arrangement of polypeptides to form subunits
4. Quaternary
 - a. Arrangement of multiple subunits of proteins

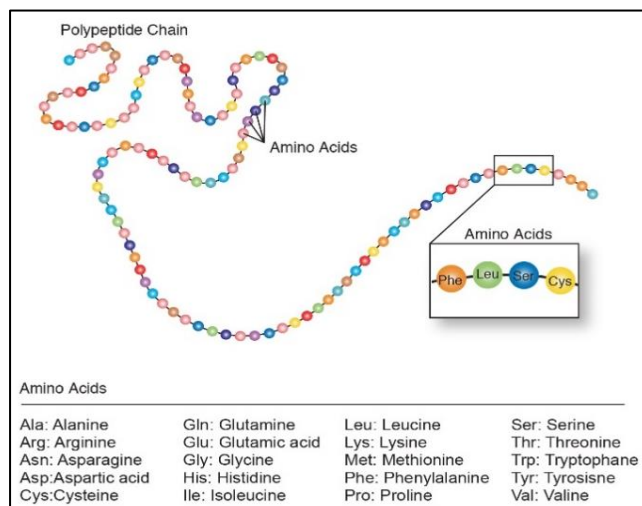


Figure 4. Structure of Polypeptides and Amino Acids
Source: <https://www.genome.gov>

Chemical Tests to Identify Biomolecules

1. Carbohydrates

- Benedict's Test

This test is meant to identify reducing sugars. Reducing sugars are those that have a free aldehyde or ketone group to transfer hydrogen atoms as part of the reduction process. Benedict's reagent is composed of Copper (II) sulfate (CuSO_4) and Sodium citrate ($\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$). The copper (II) in the solution gets reduced and forms copper (I), which results in the brick red color.

Positive Results:

Brick Red ppt. - Large amounts

Orange-Red ppt - Modest amounts

Green-Yellow ppt - Trace amounts

Negative Result: Blue Solution, no ppt



Image 1. Results for the Benedict's Test

Source: Lincoln High School - Wisconsin Rapids Public School

2. Proteins

- Biuret Test

This test identifies the presence of peptide bonds. A sample that has high amounts of peptide bonds (long chains) will give off a light to deep purple color. Meanwhile, samples that have short peptide bonds or amino acids will give off a pink color. If no peptide bonds are present, no color change will occur. The biuret reagent is composed mainly of Copper (II) sulfate (CuSO_4) and potassium sodium tartrate ($\text{KNaC}_4\text{H}_4\text{O}_6 \cdot \text{H}_2\text{O}$). Unlike the Benedict's Test, Copper (II) sulfate reacts with peptide bonds to form a chelate complex (wherein a metal atom is bound between two [2] non-metals). The potassium sodium tartrate is meant to stabilize the chelate complex.

Positive Result: Purple Color

Negative Result: Blue Color



Image 2. Results for the Biuret Test

Source: Lincoln High School - Wisconsin Rapids Public School

3. Lipids

- Spot Test

This test relies on the non-volatile nature of lipids. Using water as a control, the spot test determines that lipids are less volatile than water. Because of this, the lipids that get absorbed in the paper are not able to conduct enough heat for it to evaporate. This leaves a translucent spot on the paper.

Positive Result: Translucent spot

Negative Result: No spot remains



Image 3. Results for the Spot Test

Source: Lincoln High School - Wisconsin Rapids Public School

- Emulsion Test

The emulsion test requires a mixture of fat/oil with water. Sudan IV, which is a lipophilic molecule, acts as an indicator that forms micelles/droplets when added to the solution. If the solution contains lipids, the lipid molecules will congregate at the top layer due to the difference in density and will be stained red by the indicator. If the solution is free of lipids, the indicator will disperse throughout the solution evenly.

Positive Result: Distinct layers

Negative Result: Homogenous solution

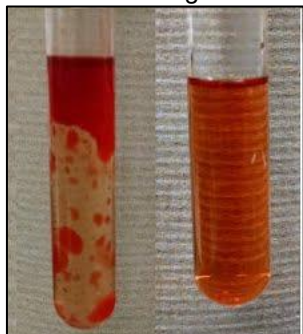


Image 4. Results for the Emulsion Test

Source: Lincoln High School - Wisconsin Rapids Public School

REFERENCES

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Wisconsin, USA: Wisconsin Rapids.

Mason, K. A., Losos, J. B., & Singer, S. R. (2017). *Biology*
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4. Nucleic Acids

• Dische Test

This is also referred to as the Diphenylamine test. This test identifies the presence of DNA based on the reaction between the Dische reagent (mainly diphenylamine) and the 2-deoxypentose sugar of DNA. The redox reaction forms a blue colored complex upon conversion of the pentose sugar. The concentration of DNA is proportional to the intensity of the blue color. Since RNA has a different sugar base, ribose, the reaction will not form a blue complex. Rather a green-colored complex will be shown. A clear result indicates the absence of DNA.

Positive Result: Blue color

Negative Result: Clear

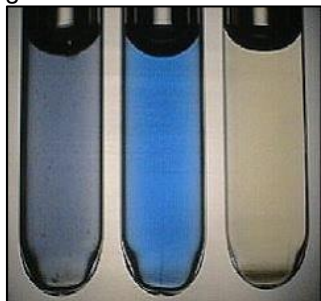


Image 5. Results for the Dische Test

Source: Lincoln High School - Wisconsin Rapids Public School