

Chapter 4: Carbon and the Molecular Diversity of Life

1. *Explain the elements of Stanley Miller's experiment, using arrows to indicate what occurs in various parts of the apparatus.* ✍

The water mixture in the "sea" at the bottom of the flask was heated; thus vapor entered the "atmosphere" of the flask (1), containing a mixture of hydrogen gas, methane, ammonia, and water vapor (2). Sparks were discharged to mimic lightning (3). A condenser cooled the "atmosphere," raining water molecules down into the "sea" (4). As material cycled through the apparatus, Miller periodically collected samples for analysis (5).

2. *What was collected in the sample for chemical analysis? What was concluded from the results of this experiment?*

Miller collected several organic compounds, both simple (such as formaldehyde) and complex (such as hydrocarbons), commonly found in organisms. Though his methodology is not undisputed, his results support the concept that abiotic synthesis of organic compounds could have been an early stage in the origin of life.

3. *Make an electron distribution diagram of carbon.* ✍

Carbon has 4 valence electrons, can bond to 4 items, and typically forms covalent bonds with other elements.

4. *Carbon chains form skeletons. List here the types of skeletons that can be formed.*

Carbon skeletons vary in length. The skeleton may have double bonds, which can vary in location. Skeletons may be branched or unbranched. Some carbon skeletons are arranged in rings.

5. *What is a hydrocarbon? Name two. Are hydrocarbons hydrophobic or hydrophilic?*

Hydrocarbons are hydrophobic molecules consisting of only carbon and hydrogen, such as benzene and methane.

6. *What is the difference between an isotope and an isomer?*

An isotope is an alternative form of the same element containing an equal number of protons but a different number of neutrons in its atomic nucleus, and thus some different properties. C-12, C-13 and C-14 are isotopes of the element carbon. An isomer is an alternative form of the same compound with the same formula but a different arrangement of atoms in the molecule, and thus different properties. Pentane and 2-methylbutane are structural isomers of each other.

7. *Identify the three types of isomers. For each type, give a key character and an example.*

Structural isomers such as pentane and 2-methylbutane differ in the covalent arrangements of their atoms; the locations of double bonds may also vary. Geometric isomers such as rhodopsin's have the same covalent partnerships, but differ in their spatial arrangements due to the inflexibility of double bonds, which must be reassembled as, unlike single bonds, they cannot simply be rotated. An atom or group of atoms attached to a double-bonded carbon may be on the same side (cis) or on opposite sides (trans). Enantiomers such as ibuprofen's differ in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images of each other and thus named L or D after the Latin terms for *left* and *right* (*levo* and *dextro*, respectively).

8. *Give one example of enantiomers that vary in their pharmacological effect.*

Albuterol is used to relax bronchial muscles, improving airflow in asthma patients. Only the effective *R*-Albuterol is marketed as the ineffective *S*-Albuterol form counteracts the active *R* form.

9. *Label the molecules testosterone and estradiol and identify the differences.* ✍

Testosterone has an O double-bonded to its first carbon ring, instead of estradiol's single-bonded OH (1). Estradiol has two more double-bonds in its first carbon ring than testosterone does (2). Finally, testosterone has a methyl group attached to it (3) which estradiol lacks.


10. *Define functional group.*

Functional groups affect molecular function by being directly involved in chemical reactions.

11. Complete the following chart of the seven functional groups.

	<i>Amino</i>	<i>Carbonyl</i>	<i>Carboxyl</i>	<i>Hydroxyl</i>
<i>Structure</i>	(–NH ₂): N atom bonded to two H atoms and to the C skeleton	(>CO): C atom joined to an O atom by a double bond	(–COOH): O atom double-bonded to a C atom also bonded to an –OH group	(–OH): H atom bonded to an O atom bonded to the C skeleton
<i>Example</i>	glycine	acetone, propanal	acetic acid	ethanol
<i>Properties</i>	hydrophilic; acts as base; ionized with +1 charge under cellular conditions	hydrophilic; ketone (within skeleton) and aldehyde (at end of skeleton) groups	hydrophilic; acidic properties; found in cells as carboxylate ion with 1– charge	hydrophilic; polar; can form H bonds with water molecules, helping dissolve organic compounds

	<i>Methyl</i>	<i>Phosphate</i>	<i>Sulfhydryl</i>
<i>Structure</i>	C bonded to three H atoms; not necessarily attached to a C atom	(–OPO ₃ ^{2–}): P atom bonded to four O atoms; one O bonded to the C skeleton; two Os carry negative charges	S atom bonded to H atom
<i>Example</i>	5-methyl cytidine	glycerol phosphate	cysteine
<i>Properties</i>	not reactive; often acts as a recognizable tag on biological molecules; addition to DNA affects gene expression; arrangement in sex hormones affects their shape and function	hydrophilic; contributes negative charge to molecule of which it is part; has potential energy to react with water, releasing energy	hydrophilic; two groups can react to form covalent bond: “cross-linking,” stabilizes protein structure

12. Circle and identify three functional groups in this molecule. 

Amino groups are written –NH₂. Sulfhydryl groups can form cross-links that stabilize protein structure. Phosphate is a key component of ATP. Methyl groups can affect gene expression and are written –CH₃. Hydroxyl is always polar. Carbonyl determines the two groups of sugars. Carboxyl has acidic properties and a carboxyl group is written –COOH. Amino acts as a base.