EAST POINT COLLEGE OF PHARMACY
East Point Campus, Jnana Prabha, Virgo Nagar Post,
Bengaluru – 560049, Karnataka

Types of Organic Molecule Synthesis

https://www.shutterstock.com/image-photo/chemical-laboratory-reagents-illegal-pills-drug-1253111212.

Organic synthesis refers to the process of creating organic compounds from simpler molecules, typically through a series of chemical reactions. This process involves the combination of atoms, such as carbon, hydrogen, oxygen, and nitrogen, to form more complex molecules. Organic synthesis is used to produce a wide range of compounds, including pharmaceuticals, polymers, and agrochemicals. The goal of organic synthesis is to create molecules with specific properties, such as biological activity, desired structures, and optimal functions. Organic synthesis is a crucial step in the development of many products, and it requires a deep understanding of chemical reactions and molecular structures.

Organic synthesis encompasses a variety of techniques and methodologies used to construct organic molecules. Here are some key types and approaches:

1. **Classical Synthesis**:

   Classical synthesis is a traditional approach to synthesizing organic molecules, involving multiple steps and chemical reactions. This method is often used in combination with contemporary methodologies to produce novel compounds. The process typically begins with the selection of a suitable starting material, followed by a series of transformations, including functional group manipulation, substitutions, and eliminations. Classical synthesis is commonly employed in the development of pharmaceuticals, agrochemicals, and materials science. It requires a deep understanding of organic chemistry principles and involves painstaking experimentation to optimize reactants and conditions. Classical synthesis includes:

- **Functional Group Interconversion:** It is "the process of converting one functional group into another by substitution, addition, elimination, oxidation or reduction, and the reverse process used in (retrosynthetic) analysis." This process allows for the diversification of molecules and is crucial in synthetic chemistry. Common interconversions include alkylation, acylation, hydrolysis, oxidation, and reduction. For instance, the conversion of a hydroxyl (-OH) group to a carboxyl (-COOH) group is achieved through oxidation reactions, such as the Sarett oxidation. Understanding functional group interconversions is essential for designing and synthesizing complex molecules, which has numerous applications in pharmaceuticals, materials science, and biotechnology.
- **Retrosynthetic Analysis**: Retrosynthetic analysis is a problem-solving technique for the synthesis of complex molecules. It is a valuable tool in organic chemistry that involves breaking down a complex molecule into simpler compounds to identify potential synthesis routes. This technique is useful for understanding the structural relationships within a molecule, identifying key functional groups, and planning the synthesis of new compounds. By tracing the molecule's structure "backward" in time, retrosynthetic analysis can provide insight into the chemical reactions and transformations required to construct the original molecule. This approach is essential in the discovery of new pharmaceuticals, materials, and other organic compounds. For example, the retrosynthetic analysis for the anti-inflammatory drug ibuprofen involves breaking it down into a carboxylic acid and a substituted cyclohexene, which can be synthesized through a series of chemical reactions.
- **Reagents and Conditions**: In organic chemistry, ‘reagents’ are substances used to facilitate chemical reactions, while ‘conditions’ refer to the operational parameters, such as temperature, pressure, and solvent, that influence the reaction outcome. In

general, reagents can be broadly classified as catalysts, oxidizing agents, reducing agents, and dehydrating agents. For instance, sodium azide (NaN_3) is a common nucleophile used to react with alkenes to form azides. Conditions like refluxing in toluene with sodium hydride (NaH) can be used to reduce esters to aldehydes. These are just a few examples, and the choice of reagent and condition depends on the specific

2. Modern Synthetic Methods:

Modern synthetic methods for organic molecules refer to advanced techniques used to construct complex organic compounds. These methods have revolutionized the field of chemistry, enabling the efficient synthesis of molecules with precise structural and functional properties. Some notable examples include palladium-catalyzed cross-coupling reactions, Heck reactions, Suzuki reactions, and microwave-assisted synthetic methods. These techniques have facilitated the development of novel drugs, agrochemicals, and materials with unique properties. They also allow for the modification of existing molecules, enabling the creation of new compounds with tailored characteristics. There are three main modern synthetic methods for organic molecules

- **Catalysis:** Catalytic asymmetric synthesis uses catalysis to favor the formation of a specific diastereomer or enantiomer. Enantioselective synthesis is a key process in pharmaceuticals.
- **Electrophilic addition:** Most reactions adding to alkenes follow this mechanism, like the Prins reaction. Halogenation is another example, where adding chlorine or bromine to alkenes creates dichloro- or dibromo-alkanes
- **Organometallic chemistry:** Organometallic compounds contain a carbon atom bonded to a metal atom. Synthetic methods are grouped into two types: reactions between metal species and ligands or ligand precursors, and reactions of ligands in organometallic compounds that produce new ligands. Other modern synthetic methods include:

- ✓ **Combinatorial synthesis:** Synthesizes thousands of compounds in a few reactions, helping to identify chemical leads and optimize them through biological screening.
- ✓ **Carbamate formation:** A mild and high-conversion reaction between the amine and the BOC (tert-butyloxycarbonyl) protecting group.

- ✓ **Microwave-assisted method:** Used for the synthesis of organic and nanoporous inorganic materials, with advantages like short reaction time and high yield.
- ✓ **Domino and multicomponent reaction:** A new synthetic method that predicts important advances in chemistry.
- ✓ **Deep eutectic solvent:** A new synthetic method.

3. Green Chemistry:

Green chemistry is a field of chemistry that focuses on designing products and processes that minimize the use of hazardous substances. Green chemistry aims to: Maximize desired products, minimize by-products, simplify chemical production operations, prevent waste, maximize atom economy, Design less hazardous chemical syntheses, Design safer chemicals and products, and use safer solvents and reaction conditions. Here are some ways green chemistry is used in organic synthesis:

- **Green solvents**: Water is a natural, inexpensive, and environmentally friendly solvent that can accelerate reactions. Supercritical CO2 is another natural solvent that is renewable, non-flammable and evaporates quickly.
- **Microwave, ultrasound, and UV-assisted reactions**: These physical approaches can reduce pollution and shorten synthesis times without using harmful solvents.
- **C–H bond activation**: This is a green technique used in organic chemistry.
- **Bio- and asymmetric catalysis**: These are green techniques used in organic chemistry.
- **Ionic liquids:** These are green solvents that can be used in organic chemistry.
- **Solid-supported synthesis:** This is a green technique used in organic chemistry.

4. Stereoselective Synthesis:

Stereoselective synthesis is a crucial concept in organic chemistry, referring to the production of a single stereoisomeric product from a mixture of possible stereoisomers. This approach is essential for synthesizing complex organic molecules with specific structures and properties. Stereoselective synthesis techniques, such as chiral catalysts, chiral auxiliaries, and asymmetric reactions, help control the spatial arrangement of atoms in a molecule. By using stereoselective methods, chemists can efficiently create enantiomerically pure compounds, which are vital for developing new pharmaceuticals, agrochemicals, and materials. There are several types of stereoselective synthesis, including:

- **Diastereoselective synthesis:** where a single diastereomer is produced from a mixture of diastereomers.
- **Enantioselective synthesis:** where a single enantiomer is produced.
- **Asymmetric synthesis:** where a non-racemic mixture of enantiomers is produced.
- **Catalytic asymmetric synthesis:** where a chiral catalyst is used to promote the reaction.
- **Chiral pool synthesis:** where a chiral pool of starting materials is used to produce a chiral molecule.

5. Total Synthesis:

The flagship of organic synthesis is total synthesis, the endeavors of synthesizing the molecules of living nature in the laboratory. The ability of man to replicate the molecules of living creatures, and create other molecules like them, is a remarkable development in human history. The goal of total synthesis is to reproduce a natural product, pharmaceutical, or other complex molecule using only feasible chemical reactions. The process involves breaking down the target molecule into smaller fragments, synthesizing each fragment, and then combining them to form the final compound. Total synthesis requires careful planning, precise reactions, and multidisciplinary expertise in organic chemistry, physical organic chemistry, and analytical techniques. Here are some types of organic synthesis:

- **Industrial applications**: Focuses on products that have practical or commercial applications and can be mass-produced cost-effectively
- **Semisynthesis**: Also known as partial synthesis, this process starts with organic compounds found in nature and are isolated from living organisms. These substances are usually intended for medicinal applications
- **Retrosynthesis:** This method involves breaking down a target molecule into its simple starting materials to assess the best synthetic route
- **Biomimetic synthesis:** This area of organic chemical synthesis is inspired by biology
- **Electrocatalysis:** This method allows for a decrease in the redox potential needed for a functional group transformation, which can increase the reaction rate

- **Organocatalytic asymmetric synthesis:** These reactions can be performed under mild conditions
- **Biosynthesis:** This method supplies many building blocks for chemical synthesis

6. Diversity-Oriented Synthesis:

Diversity-Oriented Synthesis (DOS) is a medicinal chemistry approach that emphasizes the creation of diverse molecule libraries through a single synthetic strategy. This contrasts with traditional combinatorial chemistry, which focuses on iterative synthesis of individual compounds. DOS aims to generate a comprehensive collection of molecules with diverse chemical structures, potentially leading to the discovery of novel biological activities and therapeutic leads. The method involves a modular synthesis pathway, where a set of building blocks are connected in various ways to produce a large array of unique molecules, thereby enhancing the likelihood of finding hits with desired properties. There are several types of DOS methods, including:

- **Library-based DOS:** Involves the synthesis of a large library of molecules with varying structures and properties.
- **Ligand-based DOS:** Involves the design and synthesis of molecules with specific binding properties.
- **Target-based DOS:** Involves the design and synthesis of molecules with specific biological properties.
- **Fragment-based DOS:** Involves the combination of smaller molecular fragments to generate diverse molecule structures.

These approaches enable the efficient discovery of novel organic molecules with specific properties.

7. Microwave-Assisted Synthesis:

Microwave-assisted synthesis is a rapidly growing area of research in organic chemistry. This method involves using microwave irradiation to accelerate chemical reactions, often resulting in faster reaction times, improved yields, and reduced byproduct formation. Microwave-assisted synthesis has been applied to a wide range of organic transformations, including carbon-carbon bond formation, nucleophilic substitution, and oxidation reactions. The use of microwaves can also increase the scope of reactions that can be performed, as it allows for the rapid heating of reactants to high temperatures. This technique has significant implications for the discovery and development of new organic molecules. It offers several advantages over traditional chemical synthesis methods, including:

- **Faster reaction rates:** Microwave-assisted synthesis can be faster than traditional methods, for example, producing 97% of benzyl alcohol in three minutes, compared to 35 minutes using traditional methods.
- **Greener approach:** MAOS can use greener solvents, like water, or solvent-free reactions.
- **Higher efficiency:** MAOS is highly efficient and can achieve homogeneous heating.
- **Shorter synthesis times:** MAOS can shorten the time required for synthesis.

Some other advantages of MAOS include Fast crystallization, Uniform nucleation, Easy control of morphology, Phase selectivity, Decrease in particle size, and Narrower particle size distribution.

8. Photochemical Synthesis:

Photochemical synthesis is a method of synthesizing organic molecules using light as a reactant or energy source. This process involves the manipulation of photons to initiate chemical reactions, resulting in the formation of new molecules. In this context, photochemical synthesis can be applied to create a wide range of organic compounds, including pharmaceuticals, pesticides, and materials. The advantages of photochemical synthesis include reduced environmental impact, increased efficiency, and the potential to create complex molecules not achievable through traditional methods. Researchers continue to explore the applications and limitations of this innovative approach. There are several types of photochemical synthesis, including:

- **Photoredox catalysis:** utilizes transition metal complexes to generate radical species, which then react to form organic compounds.
- **Photorearrangement:** employs UV light to induce rearrangements in organic molecules, forming new structures.
- **Photo_cypbatic reactions:** involves the use of visible light to catalyze reactions between two species, leading to the formation of new compounds.

- **Laser-induced synthesis:** utilizes high-intensity laser pulses to trigger chemical reactions and form organic molecules.

These methods have numerous applications in the production of complex organic molecules. Some examples of organic molecules obtained through photochemical synthesis include Anthocyanins, responsible for the red, purple, and blue colors of fruits and flowers, and Vitamin D, produced in the skin upon sun exposure. Squalene, a precursor to steroids, is obtained from photosynthetic organisms like certain species of bacteria and plants. Flavonoids, a class of compounds with antioxidant properties, commonly found in plants and fruits