



# INTERNATIONAL JOURNAL OF TRENDS IN EMERGING RESEARCH AND DEVELOPMENT

INTERNATIONAL JOURNAL OF TRENDS IN EMERGING RESEARCH AND DEVELOPMENT

Volume 3; Issue 1; 2025; Page No. 204-209

Received: 21-10-2024  
Accepted: 30-12-2024

## Develop and Optimize Biosynthetic Pathways for Efficient Compound Production

<sup>1</sup>Vikrant Kumar and <sup>2</sup>Dr. Adi Nath Mishra

<sup>1</sup>Research Scholar, Mahakaushal University, Jabalpur, Madhya Pradesh, India

<sup>2</sup>Professor, Mahakaushal University, Jabalpur, Madhya Pradesh, India

DOI: <https://doi.org/10.5281/zenodo.18383764>

Corresponding Author: Vikrant Kumar

### Abstract

Medicinal plants may include essential pharmaceuticals and herbal products for the treatment of sickness. For the successful conservation of medicinal plants, biosynthesis of natural products is a very promising alternative to chemical synthesis and extraction. Its rapid development will greatly contribute to the conservation and sustainable use of medicinal plants. The biosynthetic processes and discuss developments in the production of certain beneficial natural products, demonstrating the promise of biotechnology in medicinal plants employing compounds like terpenoids and the alkaloid vindoline. Examples of metabolic networks that combine to create an integrated metabolic network include the tricarboxylic acid (TCA) pathway, glycolysis, the pentose phosphate route, and other anabolic activities. A metabolic pathway, often referred to as a biochemical route, is a sequence of interconnected biochemical processes, each of which is performed by a distinct enzyme. Changes in their activity can have profound repercussions that immediately impact the whole metabolic system due to their unique position. Organic compounds that are manufactured biosynthetically can also be grouped based on the biology that generated them.

**Keywords:** Biosynthetic, Pathways, Compound, Production and organic

### Introduction

Biosynthesis of organic compounds Biosynthesis of organic compounds the natural synthesis of complex organic molecules by living organisms out of simple inorganic or low-molecular-weight molecules Composite organic molecules complex organic molecules Composite organic molecules usually denotes complex organic molecules formed via the natural synthesis of organic molecules by living organisms. They are mediated by highly well-regulated biochemical pathways and enzyme catalyzed reactions which occur inside the cell. Biosynthesis plays a crucial role in the life because it is also known to participate in the production of the most important biomolecules carbohydrates, proteins, lipids, nucleic acids, vitamins, and secondary metabolites. Within recent decades biosynthesis has gained an enormous importance in the industrial and technological environment, as an alternative to the traditional chemical synthesis, a sustainable alternative. Organic compounds that are biologically produced are very important in the natural ecosystem as well as to the human

society. Of course, biosynthesis boosts growth, reproduction and adaptation of organisms. The uses of biosynthetically produced compounds are in industry in the pharmaceutical sector, in agriculture, food processing, energy generation and in the materials science sector. Compared to the traditional approach of chemical synthesis, biosynthesis can occur at low temperature and pressure conditions, can also consider renewable raw material and yields fewer toxic by-products per se, which is why it is environmentally friendly and economically desirable.

The molecular level biosynthesis involves the metabolic processes involved in the transformation of the simple materials such as carbon dioxide, water, ammonia and simple sugars to complex organic molecules. These transformations are mediated by enzymes, specific, efficient and regulated to biochemical reactions. There is an interrelation of metabolic networks such as glycolysis, tricarboxylic acid (TCA) pathway, pentose phosphate pathway and other anabolic pathways to compose an integrated metabolic network. This network maintains a

consistent supply of precursors, energy and lowering power to maintain biosynthetic reactions. Biosynthesis is separated to primary and secondary metabolism. Primary biosynthesis entails production of substances required to sustain cellular life such as amino acids, nucleotides, fatty acids and carbohydrates. They are the compounds that are prevalent in all organisms and they are directly involved in growth and metabolism. Secondary biosynthesis on the other hand leads to synthesis of the specialized organic molecules that also contain alkaloids, terpenoids, flavonoids and polyketides. These are secondary metabolites that do not contribute to their fundamental survival, but play a role in defense, signaling and adaptation as well as a significant number of which have immense industrial and medicinal relevance.

The notable sources of biosynthesized organic compounds are the microorganisms, plants and to a lesser extent animals. Specifically, microbial biosynthesis, as a branch of industrial biotechnology, has become possible, thanks to the rapid growth rate and genetic diversity, not to mention, microorganisms are simple to grow. Bacteria, yeast and fungi are typically used to produce antibiotics, enzymes, organic acids, vitamins and biofuels. Plant bio-synthesis is of significant importance to pharmaceuticals, agrochemicals and natural pigments and animal cell cultures are finding increasing application in complicated biopharmaceuticals. The necessity to go green in the production process has enhanced the quest in the area of biosynthesis. Researchers have been enabled by molecular biology, genetic engineering and metabolic engineering to engineer natural biosynthetic pathways to augment yield, efficiency and specificity of the product. Some of the methods that have enabled the process of producing high-value organic compounds that were challenging or expensive to produce chemically have been gene editing, recombinant DNA technology, and optimization of the pathway.

### Literature Review

Dr. Shuke Wu (2021) <sup>[1]</sup> Biocatalysis has multiple uses across diverse sectors as an alternative to chemical catalysis. The application of enzymes in organic synthesis, particularly for the production of chiral compounds in medicines and the flavors and fragrance sector, represents the most notable instances. Furthermore, biocatalysts are employed extensively in the production of specialized and bulk chemicals. This review aims to provide exemplary examples in the domain, particularly emphasizing scalable chemical manufacturing by enzymatic processes. The text examines the advantages and constraints of enzymatic synthesis via specific instances and offers a perspective on newly developing groups of enzymes.

Nising, Carl F. (2022) <sup>[2]</sup> It is important to acknowledge that although synthetic organic chemistry has attained significant sophistication-often no longer serving as a bottleneck in drug discovery (as compared to the translation of preclinical biological activity into clinical applications)-our synthetic chemistry capabilities remain imperfect. The Life Science industry is presently experiencing a transformative revolution, driven by the confluence of biology, technology, and data-informed insights. Photo redox chemistry facilitates late-stage functionalization of several chemical modalities, including peptides, as demonstrated have integrated photo redox catalysis with flow chemistry and

utilized this methodology in a crucial carbon-nitrogen bond formation step for the manufacture of Entrectinib (Politrak). Synthetic chemistry will substantially facilitate innovation in Life Sciences and broaden its scope considerably, encompassing abiotic RNA/DNA, amino acids/peptides, protein drug conjugates, PROTACs, alongside traditional small molecules.

Christoph K. Winkler (2021) <sup>[3]</sup> Biocatalysis, employing specific enzymes for chemical transformations, has emerged as a prevalent technique in organic synthesis, often utilized in industrial applications. The elevated activity and exceptional stereo-, regio-, and chemo selectivity noted in several biotransformation's stem from meticulous regulation of the reaction inside the active region of the biocatalyst. This control is attained by precise placement of the reagents inside a meticulously calibrated 3D environment, unique activating contacts between the chemicals and the protein, and nuanced motions of the catalyst. Enzyme engineering allows for the customization of catalysts to suit specific reactions and processes. A comprehensive biocatalytic toolkit is prepared for diverse reactions. Utilizing nonnatural reagents and circumstances, together with the evolution of biocatalysts, allows for the exploration of several possibilities for generating innovative reactions, therefore facilitating the development of efficient routes to target molecules. The simultaneous integration of many biocatalysts in a single vessel to execute various reactions enhances the efficiency of biocatalysis significantly.

Leonard Katz (2018) <sup>[4]</sup> Synthetic biology is a rational progression of recombinant DNA (rDNA) technology or genetic engineering, which has been in use since the 1970s. rDNA technology has catalyzed the emergence of a prosperous biotechnology sector, commencing with the commercialization of biosynthetic human insulin in the early 1980s. Synthetic biology possesses the potential to elevate the business further in the next years. Advancements in synthetic biology have been propelled by significant reductions in the costs of DNA sequencing and synthesis, the creation of advanced genome editing tools like CRISPR/Cas9, and improvements in informatics, computational tools, and infrastructure to enhance and scale analysis and design. Synthetic biology techniques have been utilized in the metabolic engineering of microbes for the synthesis of industrially significant compounds and in the modification of human cells to address medicinal conditions. It demonstrates significant potential to expedite the discovery and development of new secondary metabolites from microbes using classical, engineered, and combinatorial biosynthesis. We expect that synthetic biology will increasingly influence the biotechnology sector to tackle persistent challenges in human health, global food supply, renewable energy, and industrial chemicals and enzymes.

Muhammad Adeel Farooq (2021) <sup>[5]</sup> Amylase is one of the most essential enzymes with numerous uses in labs and businesses. Primarily,  $\alpha$ -amylase is produced by microorganisms including bacteria, fungus, and yeast. The production of  $\alpha$ -amylase may be augmented by recombinant DNA technology, diverse fermentation techniques, cost-effective carbon and nitrogen sources, and the optimization of fermentation parameters such as temperature, pH, and time. Diverse techniques are employed to quantify the

generation and activity of synthetic  $\alpha$ -amylase, including iodine, DNS, NS, and dextrinizing approaches. The activity of crude  $\alpha$ -amylase can be maximized by regulating temperature and pH. Certain metals, such as  $K^+$ ,  $Na^+$ ,  $Mg^{2+}$ , and  $Ca^{2+}$ , enhance the activity of  $\alpha$ -amylase. Certain sectors, including starch conversion, food, detergent, paper, textile, and fuel alcohol manufacturing, widely employ  $\alpha$ -amylase for diverse applications.

### Biochemical pathways in biosynthesis

A biochemical route, or metabolic pathway, is a sequential set of interrelated biochemical processes, with each step catalyzed by a distinct enzyme. In the sequence of chemical reactions, the substrate is transformed into a product, which then serves as a substrate for the following reaction. Consequently, a molecule or substrate is continually transformed into metabolic intermediates, ultimately producing a final product. Biochemical processes are equivalent to metabolic pathways. The term metabolism originates from the Greek word "metabolic," signifying change, and pertains to all the chemical processes occurring within an organism's body. These pathways are essential for sustaining the organism's homeostasis and ensuring its survival.

These pathways comprise a sequence of enzyme-catalyzed reactions in which the result of one reaction serves as the substrate for the subsequent reaction. These multistep pathways provide regulatory systems that can activate one route while inhibiting another. Currently, there are around 1,300 enzymes present in human cells, each encoded by a distinct gene. Metabolism occurs when these enzymes function synchronously, leading to chemical reactions at a rate of 37 trillion billion per second in the human body. Enzymes are essential as they uniquely facilitate minute alterations to a molecular layer by either cleaving or forming bonds.

### Types of Biochemical Pathways

There are basically two types of biochemical pathways:

1. Anabolic pathways
2. Catabolic pathways
3. Amphibolic pathways

### Anabolic Pathways

It is a metabolic route that necessitates energy for bond formation. The collective word for the pools of reactants, intermediates, and products is metabolites. The chemical events involved pertain to the synthesis of bigger, complex macromolecules from smaller macromolecules. An exemplary case is the production of glucose from carbon dioxide and water. Additional instances encompass the synthesis of fatty acids from acetyl CoA, the assembly of bigger proteins from amino acid precursors, and the formation of new DNA strands from nucleotides. These reactions occur continuously within the cell and are essential for its survival. These processes need energy input, supplied by adenosine triphosphate (ATP) and other high-energy molecules, including nicotinamide adenine dinucleotide (NADH) and nicotinamide adenine dinucleotide phosphate (NADPH). The absorbed energy will be retained in the carbon-carbon bonds of bigger molecules.

### List of examples for major anabolic pathways:

- Photosynthesis (synthesis of glucose from  $CO_2$  and  $H_2O$ )
- Pentose phosphate pathway (synthesis of pentoses and release of reducing the power needed for anabolic reactions)
- Gluconeogenesis (synthesis of glucose from non-carbohydrate sources, mainly used by the brain)
- Protein Biosynthesis
- Fatty acid synthesis
- Glycogenesis (synthesis of glycogen primarily from glucose occurs in liver and muscle)

### Catabolic Pathways

These routes involve chemical processes that decompose complicated macromolecules into smaller micro molecules, resulting in the release of substantial bond energy. An illustrative instance is the decomposition of sugar (glucose into  $CO_2$  and  $H_2O$ ). During these reactions, energy contained in covalent bonds, such as C-C bonds, is released. These pathways can also use energy-storing molecules like as lipids and glycogen to release energy and synthesize ATP.

### Amphibolic pathways

A multitude of metabolic pathways transpires in humans. The majority of these metabolic processes are interconnected with other reactions. These paths are either linear or circular in nature. An intermediate of one route (metabolite) may also serve as a precursor for another pathway. For instance, the catabolism of respiratory substrates like as glucose, proteins, and fatty acids.

When glucose serves as a respiratory substrate, it is first oxidized to pyruvate and then to acetyl CoA. Likewise, the beta-oxidation of fatty acids results in the production of acetyl CoA. Protein breakdown results in the formation of either pyruvate or acetyl CoA. However, when the cell requires the synthesis of glucose, fatty acids, or proteins, pyruvate or acetyl CoA can be extracted from the catabolic route and redirected for the production of these biomolecules. Therefore, a connection always exists between the synthesis process (anabolic) and the breakdown process (catabolic), which may be classified as the respiratory pathway, an amphibolic pathway.

### Regulation of Metabolic Pathways

Cells and organisms consistently exist in a dynamic equilibrium to sustain life. This indicates that, at the molecular level, for every metabolic reaction within a pathway, the substrate is supplied by the preceding reaction at the same rate as it is transformed into product. Consequently, despite alterations in the rate of metabolite or flux (whether augmented or diminished), the concentration of substrate S stays unchanged. This is referred to as steady-state. A transient disruption in the steady-state may arise from exogenous alterations. To sustain dynamic steady-state and homeostasis, each route possesses an own regulating mechanism. In simpler terms, biochemical pathways interact intricately to provide proper control. Reactions are activated or deactivated, and their rates are accelerated or decelerated based on the cell's immediate requirements and overall

functions. Biological systems possess two sophisticated strategies for controlling cellular metabolism to maintain homeostasis. One mechanism is enzymatic control, while the other is hormonal regulation.

#### Feedback Mechanism

- The feedback mechanism is essential as it prevents the unnecessary expenditure of energy in producing surplus end-products.
- Feedback inhibition transpires when the ultimate result of a process regulates its own synthesis rate by inhibiting the first stage.
- Enzyme inhibition refers to the cessation of enzyme activity. An inhibitor attaches to the enzyme's active site, obstructing substrate binding and thereby halting the metabolic pathway sequence. It is only a conformational alteration.
- The inhibitor just denatures the enzyme, rendering it inactive, however the interaction is transient. Upon the inhibitor's disengagement, the enzyme reverts to its active conformation and resumes its function on the substrate, so reactivating the pathways.
- Homeostasis is maintained about the quantity of final product generated in this manner.

#### Key Enzymes in Central Metabolic Pathways

In the intricate metabolic network of organisms, essential enzymes have a pivotal central place. They function as essential components in a precise mechanism, regulating the velocity and trajectory of metabolic processes. Key enzymes frequently catalyze the most distinctive first reaction in a sequence of events, serving as the catalyst that facilitates succeeding reactions. Owing to their unique position, alterations in their activity can produce extensive consequences, directly influencing the whole metabolic system. In the complex network of biochemical events, important enzymes, with their specific roles, are crucial for maintaining orderly metabolic processes, acting as vital regulators of biological activity.

#### Characteristics of key enzymes in central metabolic pathway

**Reaction speed:** Key enzymes facilitate processes at the slowest rate, which is their most distinguishing feature. In the intricate network of metabolic pathways, the reactions facilitated by pivotal enzymes serve as the weakest link, dictating the overall rate of operation. Subsequent processes rely on their products; so, if critical enzymes catalyze slowly, there will be an inadequate substrate supply for ensuing reactions, thereby decelerating the complete metabolic pathway. It resembles a manufacturing line; if a crucial phase is inefficient, the output of the product will be constrained. Consequently, the sluggish catalytic activity of pivotal enzymes is the critical determinant of the total metabolic rate, vital for sustaining metabolic equilibrium and physiological functioning.

**Reaction directionality:** Critical enzymes dictate the trajectory of metabolism by their capacity to catalyze unidirectional or non-equilibrium processes. Unidirectional processes are irreversible; once the main enzyme catalyzes the reaction, metabolism advances in a definitive direction.

Non-equilibrium reactions are affected by reaction circumstances and the concentrations of substrates and products, resulting in a preferential direction for the reaction. In a certain metabolic pathway, essential enzymes facilitate the transformation of substrates into designated products. The reaction's unidirectional or non-equilibrium characteristics let metabolism to occur solely in one direction, prohibiting reversal progression. This guarantees the organization of metabolic pathways, averting disorder and allowing cells to effectively execute certain physiological duties.

**Location of metabolic pathway:** Key enzymes are generally situated in the initiation or branching points of metabolic pathways, underscoring their relevance and importance. Initially, they function as the starter in a race, with their activity directly influencing the activation of the complete metabolic pathway. Upon activation, successive responses may occur in succession. At the branch sites, pivotal enzymes serve as indicators, directing the metabolic route toward one of its diverging branches. Diverse branches may yield distinct products, addressing unique cellular requirements. This strategic positioning enables organisms to accurately control metabolism, guiding metabolic pathways according to their specific needs, effectively generating essential compounds, and sustaining normal physiological functions.

**Diverse regulatory mechanisms:** The regulation of key enzyme activity is multifaceted, encompassing substrate management as well as different metabolites or modulators. Allosteric effects are prevalent; certain small molecule metabolites bind to regions beyond the active site of essential enzymes, modifying their spatial conformation and thus influencing their activity. For instance, as blood glucose levels increase, glucose functions as an allosteric modulator by binding to phosphofructokinase-1, therefore augmenting its activity and expediting glycolysis to facilitate glucose use. Covalent changes can affect enzyme activity; for example, glycogen synthase becomes inactive following phosphorylation, but glycogen phosphorylase reactivates upon phosphorylation. Moreover, hormones and other modulators can affect the activity of essential enzymes via signaling pathways, facilitating precise metabolic control.

#### Regulation mechanism of key enzymes in central metabolic pathway

**Enzyme allosteric regulation:** Allosteric control of enzymes is a complex regulatory process. Small compounds can selectively attach to particular places external to the active core of an enzyme molecule. This interaction induces changes in the spatial configuration of the enzyme molecule, thereby modifying its activity. These little molecules are referred to as allosteric effectors. When an allosteric effector attaches to an enzyme, it is termed a positive allosteric effect if it boosts the enzyme's activity, whereas it is referred to as a negative allosteric impact if it diminishes the enzyme's activity. In carbohydrate metabolism, citric acid functions as an allosteric inhibitor of phosphofructokinase-1. An increase in citric acid content within the cell binds to phosphofructokinase-1, inducing a conformational shift in

the enzyme that diminishes its activity and decelerates glycolysis. This regulatory system enables cells to modulate the activity of essential enzymes in accordance with the concentration of their metabolic byproducts, so preserving metabolic equilibrium.

**Covalent modification regulation:** Covalent modification is an essential mechanism for regulating enzyme activity. Certain groups on the polypeptide chain of enzyme proteins can engage in covalent bonding with specific chemical groups or detach previously bonded chemical groups through the catalysis of other enzymes, hence modifying enzyme activity. Prevalent covalent modification techniques including phosphorylation and dephosphorylation. For instance, glycogen synthase is phosphorylated by protein kinases, converting it from an active to an inactive state; conversely, glycogen phosphorylase is activated following phosphorylation. This reversible covalent modification method allows cells to swiftly and accurately modulate the activity of essential enzymes. Covalent modification regulation enables cells to rapidly activate or terminate metabolic pathways, so fulfilling their immediate metabolic control requirements and assuring efficient metabolic processes.

**Gene expression regulation:** The control of gene expression significantly influences the production of essential enzymes. Gene expression encompasses transcription and translation. By managing these two processes, the synthesis quantity of essential enzymes may be managed. When a cell's requirement for a certain essential enzyme escalates, the associated gene is activated, resulting in the transcription of more messenger ribonucleic acid (mRNA), which subsequently translates into an increased production of enzyme proteins at the ribosome. Conversely, when the concentration of this crucial enzyme within the cell is enough, gene expression is inhibited, leading to a decrease in enzyme production. This regulatory system serves a sustained function in metabolic control. In contrast to the swift mechanisms of allosteric regulation and covalent modification, gene expression regulation modulates the synthesis of essential enzymes at the foundational level, accommodating prolonged alterations in cellular metabolic requirements, thereby preserving the stability and equilibrium of cellular metabolism and ensuring the normal growth, development, and physiological functions of organisms.

### **Classification of biosynthetically derived organic compounds**

The organic molecules generated in the process of biosynthesis are vast in number, and they contain a myriad of molecules synthesized by life in some of the most highly structured metabolic pathways. The compounds have structural, functional, biological and industrial uses. It is also necessary that the biosynthetically produced organic compounds should be classified in a manner that they gain knowledge of the biochemical functions of biosynthetically produced organic compounds, synthesis and their current state of practical use in biotechnology as well as industry. In the majority of the cases, these compounds are vaguely divided into categories based on their metabolic activity, the

source of chemical and biosynthesis. Within the simplest nomenclature, a dichotomy between the biosynthetically produced organic molecules was drawn, between primary and secondary metabolites. The one that are directly related to normal growth, development and reproduction in organisms are known as primary metabolites. They are ubiquitous in the living systems, and are required to sustain the metabolism of the cells. These are carbohydrates, amino acids, fatty acids, nucleotides and organic acids. These are the building blocks of macromolecules energy giving sources and mediators of metabolism. These necessities are also found in primary metabolites since they are largely utilized in the industrial process like production of amino-acids, fermentation of organic acid and biofuels.

Specialized metabolites (also called secondary metabolites) are not directly involved in the survival of a cell and are also significant in defense, communication, environmental adaptation. They are species-specific compounds and are usually heterogeneous in structure. The major classes of metabolites are the alkaloids, terpenoids, phenolics, polyketide and non-ribosomal peptide. Most of the secondary metabolites are highly biological and, therefore, can be used in the fields of pharmaceutical, agricultural and medical applications. The secondary metabolite products generated biologically are the commonly known antibiotics, anticancer agents, pigments and plant toxins. Biosynthetic derivatives of organic compounds might be further classified into a number of sub-categories depending on chemical structure. Carbohydrates are sugars, starch, cellulosic and polysaccharides as the products of the photosynthesis and carbohydrate metabolism. The compounds are significant in the building materials and energy resources. The other significant group of proteins and amino acids are the ones biosynthesized by the amino acid production and it is the help of ribosome assembly that they are crucial in the enzyme activity, structural support and enzyme production within industries.

Lipids is an amorphous existed set of organic substances which is generated during the metabolic process of fatty acid and lipids. This category is further divided into subcategories of the fatty acids; triglycerides, the phospholipids and sterols. Lipids are important in the packing of membranes, storage of energy and signaling and are usually applied in food industries, cosmetics, bio fuels and pharmaceutical. Storage and transfer of energy Storing and transferring genetic information is done with the use of nucleotides and nucleic acids needed during biosynthetic routes of nucleotides. The other significant division is pegged on the biosynthetic pathway that is pursued in the formation of them. The compounds that are formed include some ethanol, lactic acid and citric acid due to the intake of carbohydrates. These that happen in routes of biosynthesis of amino acids produce amino acids and peptides and nitrogen bearing secondary metabolites. It results in a large family of biochemicals known as steroids, carotenoid and essential oils that are the product of isoprenoid or terpenoid pathways. Parallel to this, the polyketide and the shikimate pathways also take part in the production of the antibiotics, the aromatic products and the phenolics in plants.

Organic compounds that have been biosynthetically prepared can also be classified by their source of the biology. The microbial metabolites are biosynthesized by

bacteria, fungi, and yeast and form the basis of industrial biosynthesis as it is easy to grow and genetically engineer. These are anti-biotics, enzymes, organic acids and vitamins. The compounds present in the plants are alkaloids, flavonoids, terpenes and glycosides with most of them being used in the medical and agricultural field. Through cell cultures and recombinant methods, animal products in the form of biosynthetic products are being produced including hormones, antibodies and some enzymes.

### Conclusion

Organic compounds that are biologically produced are very important in the natural ecosystem as well as to the human society. Of course, biosynthesis boosts growth, reproduction and adaptation of organisms. Biochemical processes are equivalent to metabolic pathways. The term metabolism originates from the Greek word "metabolic," signifying change, and pertains to all the chemical processes occurring within an organism's body. In the intricate metabolic network of organisms, essential enzymes have a pivotal central place. They function as essential components in a precise mechanism, regulating the velocity and trajectory of metabolic processes. They are ubiquitous in the living systems, and are required to sustain the metabolism of the cells. These are carbohydrates, amino acids, fatty acids, nucleotides and organic acids. These are the building blocks of macromolecules energy giving sources and mediators of metabolism the biosynthetic approaches and discuss progress in the production of some valuable natural products, exemplifying compounds such as vindoline (alkaloid), and (terpenoids), to illustrate the power of biotechnology in medicinal plants.

### References

1. Wu S, Snajdrova R, Moore JC, Baldenius K, Bornscheuer UT. Biocatalysis: enzymatic synthesis for industrial applications. *Angewandte Chemie International Edition*. 2021;60(1):88–119.
2. Nising CF, von Nussbaum F. Industrial organic synthesis in life sciences-today and tomorrow. *European Journal of Organic Chemistry*. 2022;2022(17).
3. Winkler CK, Schrittwieser JH, Kroutil W. Power of biocatalysis for organic synthesis. *ACS Central Science*. 2021;7(1):55–71.
4. Katz L, Chen YY, Gonzalez R, Peterson TC, Zhao H, Baltz RH. Synthetic biology advances and applications in the biotechnology industry: a perspective. *Journal of Industrial Microbiology and Biotechnology*. 2018;45(7):449–461.
5. Farooq MA, Ali S, Hassan A, Tahir HM, Mumtaz S, Mumtaz S. Biosynthesis and industrial applications of  $\alpha$ -amylase: a review. *Archives of Microbiology*. 2021;203(4):1281–1292.
6. Zhang W, Cue BW, editors. *Green Techniques for Organic Synthesis and Medicinal Chemistry*. Hoboken (NJ): John Wiley & Sons; 2018.
7. Maham M, Nasrollahzadeh M, Sajadi SM, Nekoei M. Biosynthesis of Ag/reduced graphene oxide/Fe<sub>3</sub>O<sub>4</sub> using Lotus garcinii leaf extract and its application as a recyclable nanocatalyst for the reduction of 4-nitrophenol and organic dyes. *Journal of Colloid and Interface Science*. 2017;497:33–42.
8. Mortzfeld FB, Hashem C, Vranková K, Winkler M, Rudroff F. Pyrazines: synthesis and industrial application of these valuable flavor and fragrance compounds. *Biotechnology Journal*. 2020;15(11):2000064.
9. Laponi MJ, Rivero CW, Zinni MA, Britos CN, Trelles JA. New developments in nucleoside analogues biosynthesis: a review. *Journal of Molecular Catalysis B: Enzymatic*. 2016;133:218–233.
10. ul Hassan MN, Zainal Z, Ismail I. Green leaf volatiles: biosynthesis, biological functions and their applications in biotechnology. *Plant Biotechnology Journal*. 2015;13(6):727–739.
11. Honarmand M, Golmohammadi M, Naeimi A. Biosynthesis of tin oxide (SnO<sub>2</sub>) nanoparticles using jujube fruit for photocatalytic degradation of organic dyes. *Advanced Powder Technology*. 2019;30(8):1551–1557.
12. Li-Beisson Y, Nakamura Y, Harwood J. Lipids: from chemical structures, biosynthesis, and analyses to industrial applications. In: *Lipids in Plant and Algae Development*. Cham: Springer; 2016. p. 1–18.
13. Rufus A, Sreeju N, Philip D. Size tunable biosynthesis and luminescence quenching of nanostructured hematite ( $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>) for catalytic degradation of organic pollutants. *Journal of Physics and Chemistry of Solids*. 2019;124:221–234.
14. Wu ZY, Liang HW, Hu BC, Yu SH. Emerging carbon-nanofiber aerogels: chemosynthesis versus biosynthesis. *Angewandte Chemie International Edition*. 2018;57(48):15646–15662.
15. Guerriero G, Hausman JF, Strauss J, Ertan H, Siddiqui KS. Lignocellulosic biomass: biosynthesis, degradation, and industrial utilization. *Engineering in Life Sciences*. 2016;16(1):1–16.

### Creative Commons (CC) License

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) license. This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.