Chapter 10
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Natural Products Chemistry: Emerging Trends and Projected Goals

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ABSTRACT

The chemistry of natural products is anticipated to offer significant opportunities for the growth of the pharmaceutical, green chemical, and novel therapeutic industries in the future. Researchers are increasingly employing contemporary technologies such as genomics, metabolomics, and synthetic biology in traditional bio-prospecting and natural product discovery. This approach enhances the potential for identifying more complex bioactive compounds and elucidating their biosynthetic pathways. Furthermore, it is essential to prioritize a sustainable and conservation-oriented approach in the utilization of natural materials, ensuring that raw materials are sustainable for extended durability. The new initiative aimed at systematic research in natural product chemistry is projected to serve as a significant foundation for global health and sustainable environmental utilization.

Keywords: Drug discovery and development; economics; pharmacopoeias; computation and data mining.

10.1 INTRODUCTION- ORIGINS, EFFECTS, RANGE, AND OUTREACH

There has been an unmatched upsurge of interest in natural products and their chemistry, as well as how they impact many fields of scientific knowledge, technical advancements, and economic activity. The thrust has become more popular again after it nearly faded away. The factors that contribute to the decline in interest include a lack of focus, a lack of precise tools and techniques that hinder, a lack of interest, outdated analytical tools, a lack of more extensive academic and industrial programs, and inadequate funding for opportunities for research and

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development that result in new discoveries and applications. The development of this intriguing field of study has also been impeded by a lack of funds for research and development [1]. This decrease had an impact on multiple important areas.

Learning progress: There has been a discernible fall in our comprehension of how natural products affect the biological and physical sciences, as well as how they interact with other academic disciplines and have economic ramifications [2].

Technical progress: Analytical, biotechnical, and pharmaceutical sciences encountered major obstacles to technological advancement for a considerable amount of time [3].

Disciplinary validity: The discipline's ability to function as a contemporary research instrument in the chemical sciences for a range of applications as well as its credibility both declined [4].

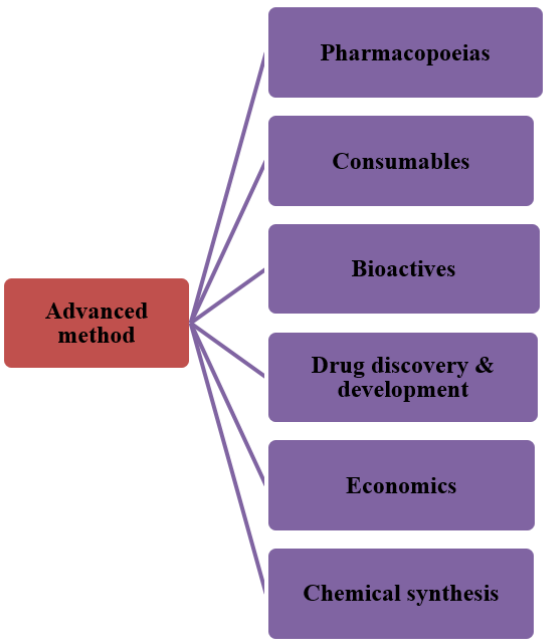

Fig. 10.1. Advancement in the field of natural products chemistry

Table 10.1. Achievements and developments made possible by the field of natural products chemistry

S. No.	Advance method	Application
1.	Drug discovery & development, semi-synthetics	Historically, pharmaceutical substances and medicines have been made from herbal sources; before synthetic alternatives became available, most early medications were plant-based. The advent of semi-synthetic pharmaceuticals presents a workable and affordable approach to drug development. Nearly half of drugs on the market today come from natural sources, and ongoing developments in drug design keep revealing novel chemical entities and molecular structures.
2.	Chemical synthesis	Access to complicated molecular frameworks has been substantially improved by biogenetic synthesis through retrograde analysis, complete synthesis based on biomimetic principles, and the identification of new pathways and templates. These methods have sparked innovation in chemical biology and drug discovery by making it feasible to synthesize complex structures that were previously unattainable.
4.	Bioactives	The following include substances that affect the nervous system, heart-related agents, cholesterol-lowering agents, liver-protective agents, anti-inflammatory drugs, antimicrobial agents, cancer-preventive agents, antioxidants, diabetes control agents, pain relievers, antispasmodics, digestive stimulants, laxatives, ulcer treatments, libido enhancers, and anti-allergy substances.
5.	Consumables	Natural dyes, fatty acids, gums, aromatic compounds, alkaloids, tannins, plant-based pigments, essential oils, nutraceutical goods, spices, sauces and more.
6.	Economics	The economies of developing nations, the advancement of economies of countries with plentiful resources, global trade, domestic consumption, economies dependent on forests, and sustainable practices are all important factors to take into account.
9.	Pharmacopoeias, medical treatise, and alternative medicines	An extensive range of plant-based healing systems and medicinal practices can be found in various traditions, including Chinese, African, Shamanic, Native American, Unani, and Ayurvedic. Other unique methods of treating medical conditions include homoeopathy, aromatherapy, and the Siddha system.

Technological understanding: There has been a considerable amount of progress in our knowledge of biotic and abiotic processes, ecosystems, environmental interactions, and the study of metabolites and natural products.

Nonetheless, the development of analytical methods, purification procedures, structural identification, and functional analysis has been fuelled by the study of natural products and their chemical characteristics. These developments have improved our capacity to investigate related chemical dynamics, pharmaceutical uses, and other areas of application. Consequently, the area has experienced unparalleled expansion, providing enhanced perspectives on intricate natural substances and their uses in analytical, bioengineering, and medical sciences.

10.2 DRUGS AND DRUG DISCOVERY

The increasing interest in natural resources, with their pharmacologically active compounds, structural diversity, and complex templates that offer opportunities for medicinal development and impact pharmaceutical interests and related economic sectors, has played a major role in the field's advancement. The search for small molecule medications using bio- and chemically-diverse natural resources has propelled the development of new drugs and templates from terrestrial and marine sources. Technological developments in the areas of test scaffold fabrication and the separation, purification, and characterization of compounds both free and bound to ligands have provided additional support for this. Additionally, chemists now have new routes to pursue in their quest for novel pharmaceuticals and health-related goods thanks to the traditional herbal expertise found in ethnobotany and ethnopharmacology. Nowadays, 60% of effective leads for anticancer medications come from natural product sources rather than synthetic ones [5].

A systematic approach to bioassay-guided fractionation and the localization of bioactive ingredients has been made possible by nature's products, which have been the foundation of medicine for a large portion of the world's indigenous populations. This has encouraged additional research into traditional medicinal knowledge. Because natural products' templates provide the basic structures for semi-synthesis and medication design, they have also aided in these fields. They have also given researchers a platform to create new medicinal molecules, some of which differ from the biological actions of the original substance [6].

10.3 THE PERSPECTIVES OF ECOLOGY, ENVIRONMENT, AND CHEMISTRY

Changes in the environment and ecology, as well as the presence or lack of active mono- and poly-constituents in a variety of natural sources, have had a substantial impact on the quality of natural products and essential oils, as well as other items derived from plants, and the availability of genuine raw materials, herbal formulations, and chemical profiling results. Lesser roles have been played by environmental chemical pollution, the harmful impacts of xenobiotics, and elements like the introduction of synthetic chemicals into food chains and ecosystems. The protection, cultivation, and promotion of biodiversity have been improved by using natural approaches for alternate identification and restoration. From a chemical perspective, ecological implications are drawing more and more attention from

biologists and chemists. Thus, in the future, models based on phyto, marine and microbial chemistry will be able to contribute more effectively to our understanding of the biochemical and biomechanistic components of ecology [7].

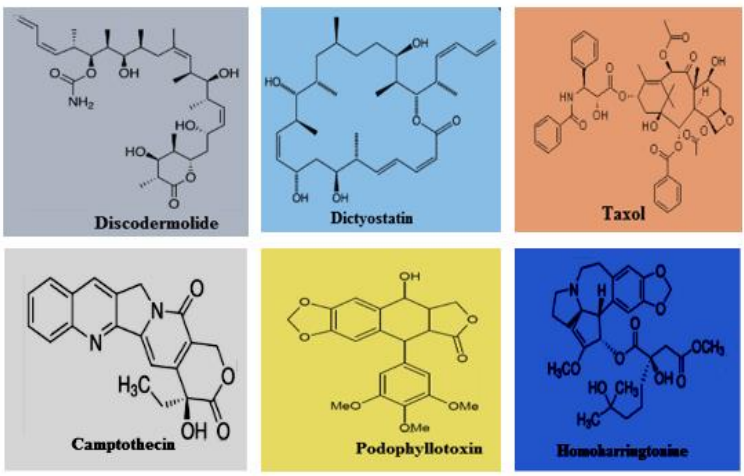

Fig. 10.2. Structures of some medicines derived from natural products

Finding leads for the natural resource-dependent agrochemical, nutraceutical, and food industries is another subject receiving a lot of attention. This includes the development of highly nutritious foods, customized food components, and their procurement, purification, and formulation for particular nutritional values and metabolic characteristics for personalized nutrition. It also includes the preparation and production of alternative and specialized natural food products and their formulations. Traditional diets' health benefits are being confirmed, and dietary plants' bioactivity is becoming more widely acknowledged [8].

10.4 POLYMERIC AND TECHNICAL GOODS

Researchers in the biomedical sciences, biofuels, and environmentally friendly material development for industrial and biomedical applications are constantly looking for natural substitutes for synthetic molecules like polymers, dendrimers, nanofibers, and crown ethers, as well as new templates. A vast array of genetic resources and biodiversity are covered by this investigation. From a phytochemical perspective, more data is required to understand the constituents, biological underpinnings, and bioactivity of phytochemicals obtained from agroforestry, genetically modified renewable plant resources, agroforestry design, genetic modification of human food, and both spontaneous and induced genetic modifications in microorganisms [9].

Table 10.2. Emerging Trends and Future Objectives in Natural Products Chemistry

S. No.	Emerging trends	Application
1.	Isolation, and Purification	1. Research on natural products has a strong emphasis on the value of separating compounds from various ecological zones, figuring out what bioactive ingredients are used in conventional medicine, and looking for innovative compound architectures. Technological developments in recent times have improved the ability to identify and characterize plant species' free and ligand-bound substrates.
		2. The demand for sophisticated separation methods that can swiftly and effectively separate bigger molecules while being stable and chemically inert is rising. In addition to preserving biological molecules' natural surroundings and interactions during the isolation process, these techniques must guarantee the purification of biological molecules while upholding their physical and chemical integrity.
2.	Designer and Alien Molecules, Structure Elucidation	1. Novel elemental combinations and atomic compositions originating from marine and extreme terrestrial plants have diverse architectures. 2. Applications for these naturally occurring modifications to manmade molecules include food, non-food goods, plant-based polymers, herbal fuels, carbon nanotubes, fullerenes, crown ethers, and non-reactive fibers. 3. Advances in spectro-analytical methods with tagging capabilities and other emerging approaches for structural elucidation are improving the analysis of these intricate structures.
3.	Drug Discovery, and Development	1. Nowadays, 50% of pharmaceuticals come from plant sources, but over the past few decades, the percentage of synthetic medications has risen dramatically. 2. The notion of low or zero toxicity is fuelling interest in phytochemicals as novel chemical entities (NCEs) for therapeutic development, as Plant-based compounds are known for their preventive effects.
		3. Plant medicines and bioactive compounds have naturally arisen as a result of small-molecule drug development. As a result, fresh themes and designs that draw inspiration from nature have been created. 4. One important class of plant-based medications is comprised of antibiotics and anti-cancer medicines. Prioritization, new method tactics, and insights into future drug development trends and their effects on phytopharmaceuticals worldwide are all needed.
4.	Bioactivity, Synergism,	1. The authenticity and integrity of basic natural products and their constituent parts are called into question

S. No.	Emerging trends	Application
	and High throughput screening	by observed ecological and environmental changes along with decreased and fragmented biological activity. This involves determining the degree of anthropogenic adulteration and pollution present in herbal goods. 2. The biological activity of single-component and multi-component plant-derived products can be compared, and the results show that multi-component formulations frequently exhibit synergistic effects without reducing the natural products' efficacy. 3. Significant prospects for finding new bioactive compounds are also presented by high-throughput screening of crude extracts and purified natural products for template selection.
5.	Biomechanics	1. Exploring how these processes differ or correlate with other known natural routes is made more fascinating by the discovery of new biosynthetic pathways and novel biogenetic technologies that use combinatorial techniques and self-assembly. 2. Enzyme-mimetic templates and big and small enzymes are used in phytochemistry to study alterations in the physicochemical and structural characteristics of enzymes. These studies also evaluate the effects of these modifications on the functional phases of substrates, encompassing their reactions, behaviours, structures, and biochemical properties. 3. Signal transduction is included in this range of biochemical processes, which also examines the electrochemical characteristics and molecular structures of natural signal regulators. The investigation also explores the structural and chemical evolution of biosystems. 4. This covers the ideas of ideal circumstances for crucial substrates or molecular structures, as well as biogenesis and chemical dynamics. In order to gain insight into the behaviour and interactions of natural substances, micromolecular entities, and contemporary biochemical products, their mobility is investigated in both in vivo and *In vitro* environments.
6.	Photochemistry	1. The diversity of photo-transformation processes and the critical role these reactions play in the development of final products are highlighted by the photochemical reactivity of natural products, including differences in their end-products. 2. The choice and operation of pathways during photochemical reactions are crucial in defining the precise results of these changes. 3. Plants and their derivatives are greatly impacted by solar radiation, which sets off intricate chemical

S. No.	Emerging trends	Application
		reactions inside plant systems. 4. These reactions highlight the complex link between light exposure and plant chemistry, influencing a wide range of biological activities, from changes in structural and functional features to the creation of secondary metabolites. Comprehending these mechanisms is essential to maximizing the use of natural products across a range of applications.
7.	Proteomics	1. Plant-based peptidomimetics, enzymes, and enzyme mimics have been widely used as chemozymes, demonstrating their efficacy as biocatalysts with similar reactivity in artificial and natural reaction settings. These biocatalysts are becoming more and more important in the creation of environmentally friendly and sustainable processes because of their clearly defined substrates and functions. 2. Furthermore, the synthesis of essential biomolecules and biodegradable polymeric materials, such as proteins, amino sugars, glycoproteins, polypeptides, and saccharide-based polymers, is particularly dependent on the employment of enzymes and their co-factors in the self-assembly of natural structures. This enzymatic self-assembly has potential uses in the creation of life-chemicals because it mimics biological processes.
		3. In functional proteomics, the study of protein interactions, structures, and functions is facilitated by the specific reactivity of natural products. This approach not only improves our comprehension of biochemical pathways but also holds promise for the development of novel therapeutic and industrial applications.
8.	Plant-Microbe Relations	1. Natural product development is greatly aided by the identification of chemicals in fermentation broths and the production of novel products from both terrestrial and aquatic plants and creatures. This covers products from cell suspension cultures and variant and induced microbial processes, which are frequently used in many biotechnological domains. 2. The production of distinct chemicals by microbial transformations and cell suspension cultures is crucial for progressing various biotechnological applications. Secondary metabolites are vital to many biological activities and have evolved through complex pathways. 3. Natural product chemistry relies heavily on biocatalysis, which makes it easier to synthesize and modify these molecules and spurs innovation in the field.
9.	Genomics	1. Sequential and non-sequential responses that are encoded for particular diseases must be applied and translated from human genome sequences for particular actions and reactions, along with the required

S. No.	Emerging trends	Application
		chemical information. This approach should serve as a go-between in studies pertaining to receptor-ligand binding. 2. The range of genetic advancement in terrestrial and marine plants, as well as other species, comprises ecology-assisted subtle, permanent, non-permanent, and ongoing changes to pathways, products, and organizational structures. 3. This covers the increasing complexity of products and the ensuing effects on acquired genomes and evolution patterns derived from filial genomes, all while keeping species in perspective and their distant relationships throughout the genomic tree. The development of designer forests, genetically engineered renewable plant resources, genetic alterations in human food, and self-induced genetic alterations in microbes are other noteworthy areas of focus.
10.	Ecology and Environment	1. Environmental contamination by chemicals, the effects of xenobiotic pollutants, the penetration of goods created by humans into natural systems, and the eventual assimilation of these items into the food chain. 2. Sustainable resource usage and developments in natural product-related green chemistry. Chemical blueprint ecological relationships between natural product entities and their constituents, as well as how these relationships affect the biogenesis of products in plants, their host species, and separate aquatic and terrestrial habitats.

In order to guarantee public safety and advance the creation of efficacious pharmaceuticals, a toxicological profile of popular natural formulations must be established. This is also necessary to develop antidotes and antivenins that are more potent and effective. Plants having preventive qualities against organ toxicity, especially nephrotoxicity and hepatotoxicity, have been found in a number of screening investigations. Research on plants known for their severe toxicity and poisonous nature could be helpful in further investigations into the toxicological effects and toxicokinetics of various constituents, fractions, and plant parts, including those from other naturally occurring sources in terrestrial and aquatic environments [10,11].

10.5 METHODS OF COMPUTATION AND DATA MINING

To keep up with the rapid breakthroughs in the domains of natural products chemistry and plant sciences, sophisticated technical developments in data mining, data management, and computational techniques are required. Better information repository administration, data mining, retrieval, and the safe, moral, and advantageous use of the generated data are all necessary [12]. This will help us better comprehend natural products chemistry's comprehensive influence on interdisciplinary sciences and a wide range of applications across sectors like veterinary and medical. It will also stimulate new leads, drug discovery and development, and diversity within the field. The results of natural product chemistry and chemists are starting to become evident. Future developments in biomechanical qualities, software engineering, product innovation, computational methodologies, and prediction strategies for different interactions with natural resources have a great deal of potential [13].

10.6 EFFECTS ON THE ECONOMY

The industrial, civilizational, and economic effects are expected to become much more prominent in the near and distant future, according to natural product chemists and the larger field of chemistry. Sustainable medicinal plants, various phytopharmaceuticals, dietary supplements, essential oils, and medications derived from natural sources are becoming more and more common. Significantly, natural product chemists have made vital contributions to cutting-edge techniques in a variety of sectors. It is anticipated that their work will have a significant impact on the future direction of chemistry and allied fields, as well as have wider ramifications for the macroeconomic environment [14-18].

10.7 DISCUSSION AND CONCLUSIONS

Because of their roles as comparators and co-products in a variety of biochemical situations and physiological effects, as well as their employment as scaffolds for discovery, the once negative opinions of natural products have started to change. This change includes secondary metabolites from unique biogenesis, ecological probe chemicals, and designer foods and their constituents. It also incorporates updated knowledge of traditional herbal remedies as well as observations from ethnobotany and ethnopharmacology in poor countries. Natural goods have shown

to be advantageous in a variety of contexts: they can be used as sources of various high-quality technological items, as a way to get economic benefits, as instruments for scientific research, and, most notably, in the biomedical industry as phytopharmaceuticals.

Natural product chemistry has made great scientific and technological strides, greatly advancing our understanding of the universe. The discipline has developed through its connections with other scientific fields, including the physicochemical sciences, medicine, and other bio- and techno-industrial technologies. Its approaches and discoveries are derived from both direct and indirect understanding. Interdisciplinary sciences, particularly in biological and chemical ecology research as well as biochemical and microbiological studies, were made possible by the historical contributions of natural products and their chemistry over the past century. These contributions were crucial to the early advancements of chemistry, medicine, and technology.

Natural product chemistry study has enormous promise and a wide range of uses in the biochemical, ecological, and medical domains, expanding our knowledge and comprehension as it develops. As science, technology, and economics evolve, the importance of natural product chemistry and the work of natural product chemists is becoming more widely acknowledged.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

No AI tool was used to design the chapter and standard paper was used to write this chapter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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