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RESEARCH TRENDS IN CHEMICAL SCIENCE

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PREFACE

Chemistry, as a discipline, is at the heart of scientific inquiry and technological innovation. From fundamental discoveries to practical applications, the contributions of chemical research are ubiquitous, touching every aspect of our lives. This book brings together a collection of chapters that reflect the diverse and interdisciplinary nature of contemporary chemical science.

Our esteemed contributors, experts in their respective fields, delve into a wide range of topics. They explore novel synthesis methods, investigate cutting-edge materials, and unravel the mysteries of complex chemical reactions. The exploration extends beyond traditional boundaries, encompassing interdisciplinary research that bridges chemistry with biology, physics, environmental science, and more.

As you navigate through the chapters, you will witness the transformative power of chemical science in addressing global challenges. From sustainable energy solutions to advancements in medicine and environmental stewardship, the impact of chemical research is profound. The authors provide insights into how chemical science continues to drive innovation and contribute to a sustainable and prosperous future.

Moreover, this book serves as a platform for fostering collaboration and knowledge exchange. Researchers, students, and professionals alike will find inspiration in the diverse perspectives presented here. The collective wisdom shared within these pages not only captures the current state of chemical science but also points towards exciting future directions.

We express our gratitude to the contributors who have shared their expertise and passion for chemical research in this volume. Their dedication to advancing the frontiers of knowledge is evident in the depth and breadth of the topics covered. We hope this book sparks curiosity, ignites intellectual discussions, and inspires the next generation of researchers to contribute to the rich tapestry of chemical science.

Embark on this journey through "Research Trends in Chemical Science" and discover the fascinating world of possibilities that chemical research unfolds. Together, let us explore, innovate, and contribute to the ever-evolving landscape of chemical science.

Editors

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A COMPREHENSIVE REVIEW OF PRINCIPLES, RECENT DEVELOPMENTS, CHALLENGES AND APPLICATIONS OF ORGANIC PHOTOCHEMISTRY

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Abstract:

Organic photochemistry is a fascinating and critical branch of chemistry that involves the study of chemical reactions initiated by the absorption of photons. This review paper delves into the fundamental principles and diverse applications of organic photochemistry. It provides an in-depth exploration of the underlying mechanisms, key concepts, and recent advancements in this field. Furthermore, it highlights the significance of organic photochemistry in various industrial, pharmaceutical, and environmental applications, emphasizing its potential for sustainable chemistry.

Introduction:

Organic photochemistry is a branch of chemistry that investigates the photochemical processes occurring in organic molecules when exposed to electromagnetic radiation, typically in the ultraviolet (UV) or visible regions of the electromagnetic spectrum. This field represents a vital intersection of physical chemistry, quantum mechanics, and organic synthesis, elucidating the intricate interplay between light and matter at the molecular level. Organic photochemistry has experienced a resurgence in recent years, driven by advances in photochemical methods, photoredox catalysis, and the development of new photoinitiators. These advancements have expanded the scope of photochemical reactions and their applications, making organic photochemistry an indispensable tool in modern chemistry and technology.

This research paper endeavors to provide a comprehensive overview of the principles that underlie organic photochemistry, elucidate the mechanisms governing photochemical reactions, explore the diverse applications across various scientific disciplines, and highlight recent advances and emerging trends in the field. By delving into the intricate world of organic photochemistry, we aim to shed light on its fundamental importance and its transformative potential in addressing current challenges in science, industry, and sustainability.

Keywords: Organic photochemistry, photophysics, photoreactions, applications, sustainability, photocatalysis, photomedicine, materials science, green chemistry.

Principles of Organic Photochemistry

Organic photochemistry is founded on a set of fundamental principles that govern the interaction between organic molecules and light. Understanding these principles is crucial for elucidating the mechanisms underlying photochemical reactions. The following subsections outline the key principles of organic photochemistry:

Absorption of Light

The foundation of organic photochemistry lies in the absorption of photons by organic molecules. When a molecule absorbs a photon, it undergoes an electronic transition from its ground state (S_0) to an excited state (S_1, S_2, etc.) corresponding to a higher energy level. The energy required for this transition is determined by the difference in energy between the ground and excited states, which is characteristic of the molecule's electronic structure.

Electronic Excitations

Electronic excitations result from the promotion of an electron from a lower-energy molecular orbital to a higher-energy orbital upon photon absorption. This promotion can occur within the same electron spin state (singlet) or between different spin states (triplet). Singlet excitations are more common in organic photochemistry due to their higher probability.

Singlet and Triplet Excited States

Singlet and triplet excited states are central to the photophysical processes in organic photochemistry. Singlet excited states have parallel electron spins, with total spin quantum number $S = 0$, and are short-lived, typically nanoseconds to microseconds. In contrast, triplet excited states have antiparallel spins, with $S = 1$, and are often longer-lived, lasting microseconds to milliseconds.

Photophysical Processes

Jablonski Diagram

The Jablonski diagram is a graphical representation of the electronic transitions and relaxation processes that occur after photon absorption. It illustrates the flow of energy within a molecule during a photochemical event. The diagram typically includes the ground state (S_0), singlet excited states (S_1, S_2, etc.), and triplet excited states (T_1, T_2, etc.), along with arrows representing radiative and non-radiative transitions.

Radiative and Non-radiative Transitions

Radiative transitions involve the emission of photons as the molecule returns to a lower-energy state (e.g., fluorescence in singlet-singlet transitions). Non-radiative transitions encompass a variety of processes, such as internal conversion, intersystem crossing, and vibrational relaxation, which dissipate the excess energy as heat rather than emitting photons. The competition between radiative and non-radiative pathways is critical in determining the fate of an excited molecule.

Photochemical Reactions

Photochemical reactions occur when the excited molecule undergoes chemical transformations as a result of its electronic excitation. These reactions are initiated by the absorption of light and are distinct from thermal reactions. Several types of photochemical reactions are observed in organic photochemistry:

Photodissociation

Photodissociation involves the breaking of chemical bonds in a molecule upon photon absorption. It often leads to the formation of radicals or fragments. Photodissociation reactions play a vital role in processes like photodegradation of pollutants and photolytic cleavage of chemical compounds.

Photoisomerization

Photoisomerization entails a change in the spatial arrangement of atoms in a molecule, typically involving the isomerization between cis and trans configurations. Common examples include cis-trans isomerizations in conjugated systems like azobenzenes or retinal molecules involved in vision.

Photoreduction and Photooxidation

Photoreduction involves the gain of electrons by a molecule during photoexcitation, while photooxidation involves the loss of electrons. These reactions are essential in the study of electron transfer processes and can be harnessed in applications like photocatalysis.

Photocycloaddition

Photocycloaddition reactions result in the formation of cyclic compounds through the concerted addition of two or more unsaturated molecules. These reactions have wide-ranging synthetic applications and are central to the synthesis of complex organic compounds.

Photodegradation

Photodegradation refers to the decomposition of molecules upon exposure to light. This process is of significance in fields such as photostability studies of pharmaceuticals and the breakdown of environmental pollutants under solar radiation.

Mechanisms of Organic Photochemical Reactions

The diverse array of photochemical reactions observed in organic chemistry is underpinned by specific mechanisms that govern how molecules transform under the influence of light. Understanding these mechanisms is essential for designing and controlling photochemical processes. This section delves into the mechanisms of various organic photochemical reactions:

Norrish Type I and II Reactions

Norrish Type I Reactions

Norrish Type I reactions are a class of photochemical reactions that involve the homolytic cleavage of a C-C or C-H bond upon excitation to a singlet excited state. This leads to the formation of two radicals, typically a carbonyl compound and an alkyl radical. A common example is the photolysis of ketones, where the cleavage occurs adjacent to the carbonyl group. The generated radicals can participate in subsequent reactions, making Norrish Type I reactions valuable for synthetic purposes.

Norrish Type II Reactions

In Norrish Type II reactions, the excitation to a singlet excited state induces the formation of a biradical intermediate without direct bond cleavage. This biradical intermediate can undergo various reactions, including cyclizations and rearrangements, leading to the formation of complex products. Notably, Norrish Type II reactions are essential in the synthesis of strained cyclic compounds and natural product synthesis.

Ene Reactions

Ene reactions, also known as the Alder-ene reaction, involve the [2+2] cycloaddition of a double bond (ene) to an alkene or alkyne under the influence of light. This photochemical process leads to the formation of a cyclobutane or cyclohexene ring. Ene reactions are characterized by their regioselectivity and can be employed for the selective synthesis of cyclic compounds with high efficiency.

Paternò-Büchi Reaction

The Paternò-Büchi reaction is a photochemical process that results in the formation of a cyclobutane ring between a carbonyl compound and an alkene. This reaction is

initiated by the excitation of the carbonyl group's π* orbital, followed by its interaction with the π electrons of the alkene. The reaction is highly regioselective, and its synthetic utility is well-documented in the construction of strained ring systems and the modification of functional groups.

Photocycloaddition Reactions

Photocycloaddition reactions are photochemical processes that involve the formation of cyclic compounds through the concerted addition of two or more unsaturated molecules. These reactions are classified into [2+2], [2+2+2], and other cycloaddition types based on the number of reacting unsaturated bonds. Photocycloadditions are highly valuable for the synthesis of complex organic compounds, including natural products and pharmaceuticals.

Photorearrangements

Photorearrangement reactions involve the isomerization of a molecule's structure upon photoexcitation. These reactions are diverse and can lead to ring expansion, contraction, or migration of functional groups. Notable examples include the ring expansion of cyclopropanes to cyclobutanes and the rearrangement of allylic systems to form more stable isomers.

Photodimerization

Photodimerization refers to the formation of covalent bonds between two identical or similar molecules upon exposure to light. This reaction type is essential in the formation of dimers, oligomers, and polymers and finds applications in materials science, particularly in the synthesis of photopolymerizable materials and the study of supramolecular chemistry.

Photoreduction and Photooxidation Mechanisms

Photoreduction and photooxidation reactions involve the transfer of electrons between molecules upon photoexcitation. In photoreduction, a molecule gains electrons, often leading to the formation of radicals or new chemical species. Photooxidation, on the other hand, involves the loss of electrons. Both types of reactions are vital in the study of electron transfer processes and have applications in areas like photocatalysis and photopharmacology.

Understanding the mechanisms of these organic photochemical reactions provides a foundation for designing and tailoring light-driven processes for various applications, from the synthesis of complex molecules to the development of new materials and technologies.

In the subsequent sections of this review, we will explore how these mechanisms are harnessed in different fields, showcasing the versatility and significance of organic photochemistry.

Applications of Organic Photochemistry

Organic photochemistry, with its ability to initiate and control chemical reactions using light as the driving force, has found a wide array of applications across multiple scientific disciplines and industrial sectors. In this section, we explore the diverse and impactful applications of organic photochemistry:

Photochemical Synthesis of Fine Chemicals

One of the most well-established applications of organic photochemistry is in the synthesis of fine chemicals and complex organic compounds. Photochemical reactions enable the construction of intricate molecular architectures and the selective formation of bonds that are often challenging to achieve through traditional thermal methods. For example, Norrish Type I and Type II reactions, photocycloadditions, and Paternò-Büchi reactions have all been utilized to create complex molecules with high regio- and stereoselectivity.

Photocatalysis

Photocatalysis involves the use of photoactive catalysts to facilitate chemical transformations under light irradiation. This field has gained significant attention due to its potential for sustainable and green chemistry. Photocatalytic reactions can drive a variety of transformations, including the synthesis of pharmaceutical intermediates, degradation of pollutants, and production of renewable fuels.

Photoresponsive Materials

Organic photochemistry plays a pivotal role in the design and synthesis of photoresponsive materials. These materials exhibit changes in their properties, such as color, shape, or conductivity, in response to light. Applications include photochromic eyeglass lenses, photomechanical actuators, and smart materials for sensors and displays.

Photopolymerization

Photopolymerization is widely used in the production of polymers and coatings. Ultraviolet (UV) photoinitiators or photoinitiating systems are employed to initiate the polymerization process upon exposure to UV light. This technique is essential in industries ranging from printing and adhesives to dental materials and 3D printing.

Photolithography

Photolithography is a key technology in semiconductor manufacturing and microfabrication. It relies on the selective exposure of a photosensitive resist to light, allowing for the precise patterning of semiconductor devices and integrated circuits. Organic photochemical reactions are at the heart of this process, enabling the creation of intricate microstructures.

Photomedicine and Photodynamic Therapy

Organic photochemistry has transformative potential in medicine. Photomedicine involves the use of light-activated drugs, known as photosensitizers, to target and treat specific cells or tissues. Photodynamic therapy (PDT) is a prime example, where photosensitizers are used to selectively destroy cancer cells, microbes, or vascular tissue upon light activation. PDT is a promising non-invasive treatment for various diseases.

Photodegradation of Pollutants

Organic pollutants, such as pesticides, dyes, and industrial chemicals, can be degraded and detoxified through photodegradation processes. Organic photochemistry, particularly the use of sunlight or UV light, can efficiently break down these pollutants into harmless or less toxic byproducts, offering a sustainable approach to environmental remediation.

Solar Energy Conversion

Organic photochemistry is integral to the development of photovoltaic devices and solar cells. Organic photovoltaics (OPVs) utilize organic semiconductors to convert sunlight into electricity. OPVs are lightweight, flexible, and can be produced using cost-effective methods, making them a promising technology for clean energy generation.

Recent Advances in Organic Photochemistry

Organic photochemistry has seen remarkable advancements in recent years, driven by cutting-edge research and technological innovations. These developments have expanded the scope of organic photochemistry and unlocked new possibilities for applications across various fields. In this section, we delve into some of the noteworthy recent advances in organic photochemistry:

Metal-Organic Frameworks (MOFs) as Photocatalysts

Metal-organic frameworks (MOFs) have emerged as promising photocatalysts due to their high surface area, tunable structures, and ability to host photoactive species. MOFs can enhance the efficiency of photoredox reactions by providing a stable and controlled

environment for catalysts and reactants. Recent research has explored MOFs in applications such as photocatalytic water splitting, CO2 reduction, and organic transformations.

Organic Photocatalysts

Advancements in the design of organic photocatalysts have led to more efficient and sustainable photochemical reactions. Novel organic catalysts with tailored electronic properties and redox potentials have been developed for applications like C-H functionalization, cross-coupling reactions, and visible-light-driven transformations. These catalysts enable greener and more selective synthetic routes.

Computational Photochemistry

Computational chemistry has become an indispensable tool for predicting and understanding photochemical reactions at the molecular level. Advances in computational methods, such as density functional theory (DFT) and time-dependent DFT (TD-DFT), have enabled researchers to simulate excited-state dynamics, predict reaction pathways, and design photoactive molecules with enhanced properties. Computational photochemistry accelerates the discovery of new photochemical reactions and mechanisms.

Machine Learning in Photoreactivity Prediction

Machine learning techniques, including neural networks and deep learning models, have been applied to predict the photoreactivity of organic compounds. These models can analyze large datasets of chemical structures and experimental data to identify patterns and trends in photochemical behavior. Such predictive tools assist in the efficient design of photoactive molecules for specific applications.

Light-Controlled Drug Delivery Systems

Recent developments in the field of light-controlled drug delivery systems have the potential to revolutionize precision medicine. Photoresponsive drug carriers and nanomaterials can release therapeutic agents at precise locations within the body upon exposure to light. This approach offers enhanced spatial and temporal control over drug delivery, minimizing side effects and improving therapeutic outcomes.

Organic Photodetectors and Solar Cells

Advancements in organic photodetectors and solar cells have contributed to the development of efficient and cost-effective photovoltaic devices. Organic photodetectors with improved sensitivity and response times find applications in imaging, optical communication, and environmental monitoring. Organic solar cells, particularly those

based on non-fullerene acceptors and tandem cell architectures, have achieved higher power conversion efficiencies, making them more competitive with traditional silicon solar cells.

Green Photochemistry for Sustainability

The pursuit of sustainable chemistry practices has spurred research into greener photochemical reactions. Green photochemistry aims to minimize the environmental impact of photochemical processes by using renewable energy sources, reducing or eliminating the need for hazardous reagents, and maximizing atom economy. Recent efforts include the development of solar-driven photochemical reactions and the design of eco-friendly photoinitiators for polymerization processes.

Challenges and Future Directions

While organic photochemistry has made significant strides in recent years, several challenges persist, and new avenues for exploration are emerging. Understanding these challenges and future directions is crucial for advancing the field and harnessing its full potential:

Controlling Regioselectivity and Stereoselectivity

Achieving high selectivity in photochemical reactions, particularly in complex molecules, remains a challenge. Developing strategies to control regioselectivity and stereoselectivity is essential to expand the toolbox of organic photochemistry. This requires a deeper understanding of the factors governing selectivity in excited states and the development of tailored catalysts and reaction conditions.

Overcoming Competing Pathways

Many photochemical reactions exhibit competing pathways, leading to the formation of multiple products. Enhancing control over these reactions to favor desired pathways while minimizing undesired side reactions is an ongoing challenge. Rational design, computational modeling, and innovative photoredox catalysts are areas of exploration to address this issue.

Scaling Up Photochemical Processes

Transitioning photochemical reactions from the laboratory to industrial-scale production poses practical challenges. Optimizing reaction conditions, reactor design, and light sources for scalability is essential to unlock the full potential of photochemical transformations in manufacturing processes. Developing continuous-flow photochemical reactors is one approach being explored to address this challenge.

Cost-Effective Photoredox Catalysis

The cost of photoredox catalysts and light sources can be prohibitive for large-scale applications. Research efforts are focused on developing cost-effective catalysts and exploring sustainable light sources, including LEDs and sunlight, to reduce production costs and make photochemical processes more accessible to industries.

Photoreactor Design for Solar Energy Conversion

Exploiting solar energy for photochemical reactions is an attractive approach for sustainability. Designing efficient photoreactors that can capture and utilize solar radiation effectively is a complex challenge. Researchers are working on the development of innovative photoreactor designs and materials for solar-driven photochemistry.

Environmental Impact Assessment

While organic photochemistry offers green and sustainable pathways for chemical transformations, the environmental impact of photochemical processes must be rigorously assessed. Evaluating factors such as energy consumption, waste generation, and the toxicity of photochemical reagents and byproducts is crucial to ensure the overall sustainability of photochemical methodologies.

Conclusion:

Organic photochemistry represents a dynamic and promising field with far-reaching implications across various disciplines. This review has provided a comprehensive overview of the principles and applications of organic photochemistry, highlighting its pivotal role in modern science and technology. The ongoing research and development in this field are expected to yield novel solutions for diverse challenges and contribute to sustainable chemistry practices in the future.

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REVIEW ON ENERGY STORAGE SYSTEMS AND THEIR APPLICATIONS: ISSUES AND CHALLENGES

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Abstract:

Energy storage systems (ESSs) are getting hold lot of interest due to the trend of increasing the use of renewable energies. Technologies for energy storage, including storage kinds, classifications, and comparisons, are evaluated critically. The majority of energy storage methods are taken into account, including chemical and hydrogen energy storage, electrochemical and battery energy storage, thermal and thermochemical energy storage, flywheel energy storage, compressed air energy storage, pumped energy storage, and magnetic energy storage. There is also recent research on new types of energy storage as well as significant improvements and innovations in energy storage. The energy storage form and the key pertinent technical criteria allowed the ESSs to be divided into different technological categories. The most popular classifications are presented, outlined, and contrasted in this review study based on those features. A particular attention on the categories of electrochemical ESSs, particularly battery energy storage systems, given their significance in the home market.

Introduction:

As a result of accelerating industrialisation, excessive technological advancements, and economic expansion in developing nations, the world's energy consumption has rapidly expanded. A recent International Energy Agency (IEA) study predicts that in 2021, the total amount of energy consumed would rise by 4.5%, or more than 1000 TWh (terawatt-hours). Additionally, the increase in global energy demand caused a 5% increase in CO2 emissions in 2021. Given the current situation, renewable energy systems are being used at an astounding rate to reduce the worldwide environmental problem of CO2 emissions because they emit no greenhouse gases or other polluting pollutants. ESSs are primarily made to gather energy from multiple sources, transform it, and store it for use in a variety of ways as needed. Electrical energy storage (EES) systems have proven to be particularly adept at managing a variety of crucial characteristics of power, such as hourly

fluctuations in demand and cost [1]. Instead of purchasing electricity at a higher price during peak hours, EES saves money by purchasing electricity during off-peak hours when its price is lower and storing it for use during peak hours [2]. To give us a clearer understanding of their distinctions, future uses, and current status, we need more comprehensive assessments of all the ESSs that are currently accessible. A detailed comparison based on technical and financial information was provided by Luo *et al.* [3], who also offered an overview of different electrical energy storage methods. Mechanical, electrochemical, chemical, and thermal energy storage system technological, economic, and environmental assessments were provided by Rahman *et al.* [4]. Ayegh and Rosen, Koohi [5]. A description of ESSs, including classifications, features, advantages, environmental implications, applications, and implementation alternatives, was published by Guney and Tepe [6]. Begdouri and Fadar [7] provided in-depth comparisons of various systems in terms of advantages, disadvantages, and application when reviewing the extensively used renewable energy storage technologies. The current state of mechanical, thermal, electrochemical, and chemical storage technologies was covered by Gur [8]. This essay makes an effort to address all of the fundamental ideas surrounding ESSs, including their history, in-depth classification, current state, traits, and applications. This comprehensive collection of data on ESSs will serve as a trustworthy resource for upcoming research in this area. This work will be an invaluable resource for any future research on ESSs because it has gathered most of the relevant data. Numerous review articles in the literature give a more in-depth analysis of a specific energy storage topic, such as thermal energy storage reviews, however the goal of the current article is to give a more comprehensive analysis of various energy storage kinds so that readers can compare their properties. As a result, a number of important publications that would have served the current article's goal better but whose level of information was too high may not have been included.

Role of EES:

Due to two characteristics of electricity, there are problems with its utilisation and a market need for EES. Power is initially consumed simultaneously with its creation. Power must be continuously provided in the right amount to meet the fluctuating demand. The second characteristic is that power facilities are frequently located far from areas where energy is used [9]. 1. Due to the constant need for power lines, it is difficult to supply power to mobile apps. If a line fails (due to congestion or any other reason), energy provision will be interrupted. 2. A significant quantity of power flow may be concentrated into a single

transmission line, leading to congestion, depending on the locations and amounts of power supply and demand.

Types of Electrical Energy Storage System (EES):

The many different types of energy storage can be broken down into many different categories, and in this article the majority of energy storage types are classified as chemical and hydrogen energy storage, electrochemical and battery energy storage, thermal energy storage, thermochemical energy storage, flywheel energy storage, compressed air energy storage, pumped energy storage, and energy storage.

Mechanical Storage Systems:

Mechanical energy storage systems use gravitational or kinetic forces to store received energy. These systems' high-quality components, sophisticated computer control mechanisms, and creative design make them effective in practical applications [10]. Compressors, turbines, and other machinery are used in complex systems that use heat, water, or air to store mechanical energy.

Pumped Hydro Storage (PHS):

More than 95% of the world's current electricity storage capacity is provided by pumped hydro storage power plants [11]. In pumped hydro storage systems, water is pumped between two reservoirs that are at different heights during off-peak hours (charged), and as needed, water flows from the top pool to the lower reservoir downstream, powering a turbine that generates energy (discharging). The PHS plant's efficiency ranges from 70% to 85% [12]. This system's key advantages are its extended lifespan and nearly infinite cycle stability, while its main disadvantages are its topography and intensive land use. As of December 2021, the largest PHS plants in the world have installed capacities of 3003 MW and 2400 MW, respectively.

Compressed Air Energy Storage (CAES):

Since the eighteenth century, CAES has been utilised in a variety of industrial applications. Air is compressed and stored using electricity in a subsurface structure or an above-ground network of pipes or containers. Tunnels, aquifers, and abandoned mines are examples of subsurface storage possibilities. Diabatic technology has a strong track record; the plants are extremely dependable and self-sufficient [13] (Figure 3). Although CAES has a big capacity, it has disadvantages including limited geographic coverage and poor round-trip performance (less than 50%).

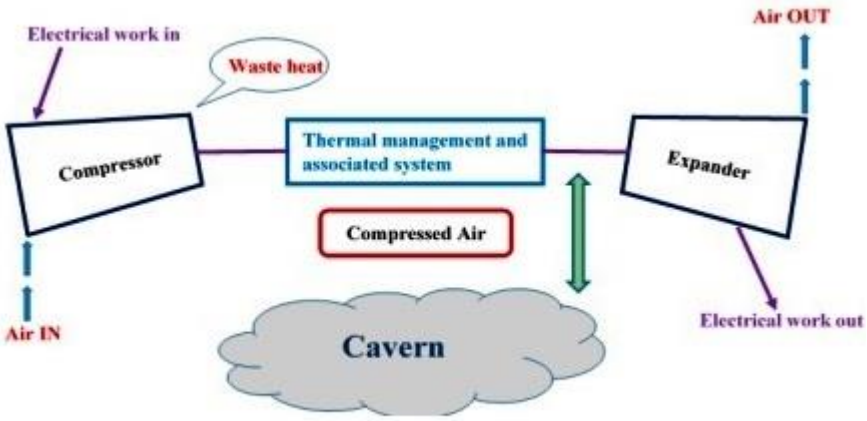

Figure 1. Compressed air energy storage system schematic.

Electrochemical Storage Systems:

Devices for electrochemical energy storage have the potential to significantly aid in the spread of renewable energy. Batteries or electrochemical capacitors, which have high power densities, are the foundation of electrochemical energy storage. Applications today and in the future will increasingly require high energy and high power densities in the same material [14,15].

Secondary Batteries:

A cell or group of cells with reversible cell processes is referred to as a secondary battery or charge accumulator. This suggests that enabling current to flow into the cell, i.e., charging from outside, can restore the original chemical conditions inside the cell [15]. Lead-Acid (LA) Battery Since about 1890, lead-acid batteries have been the most popular type of battery used worldwide. The normal service life is 6–15 years, with 1500 cycles at a % depth of discharge and an efficiency of 80–90% [15–17]. The drawbacks include a reduced energy density and the usage of lead, a hazardous substance that is sometimes outlawed or regulated. Benefits include a favourable cost-performance ratio, straightforward recycling, and an easy charging process. The improvement of lead-acid batteries' efficiency for micro-hybrid electric cars is the current area of focus. Batteries made of nickel-cadmium and nickel-metal hydride (NiCd, NiMH) Nickel-cadmium (NiCd) batteries had been in use since about 1915 before nickel-metal hydride (NiMH) batteries went on sale in 1995. With the exception of a 10-fold lower maximum nominal capacity, NiMH batteries have all the benefits of NiCd batteries, including greater power density, somewhat better energy density, and a higher number of cycles. They outperform lithium-ion batteries in terms of strength and security. However, its use for consumers has been

restricted since 2006 because of cadmium's toxicity. Currently, the price of NiMH batteries is comparable to that of Li-ion battery packs [16].

Flow Batteries:

Early in the 1970s, NASA developed flow batteries as an EES for prolonged space missions [18]. They have a power of many megawatts and the capacity to store energy for hours or days. Redox flow batteries and hybrid flow batteries are the two forms of flow batteries.

Redox Flow Battery (RFB):

Redox Flow Battery Anolyte and catholyte are the electrolytes found at the negative and positive electrodes of a redox flow battery. Active masses from the tanks are continuously supplied to the electrodes during discharge; after conversion, the product is returned to the tank. A current that passes between the electrodes during the charge exchange can be utilised by a battery-powered device. Electric vehicle redox flow batteries are being researched, but the electrolyte energy density has so far shown to be insufficient. By draining off the used electrolyte and substituting recharged electrolyte, an RFB may be "refilled" in a matter of minutes. Many redox couples have been researched and tested in RFBs today, including the Fe-Ti system and the poly S-Br system (shown in Figure 2) [19,20].

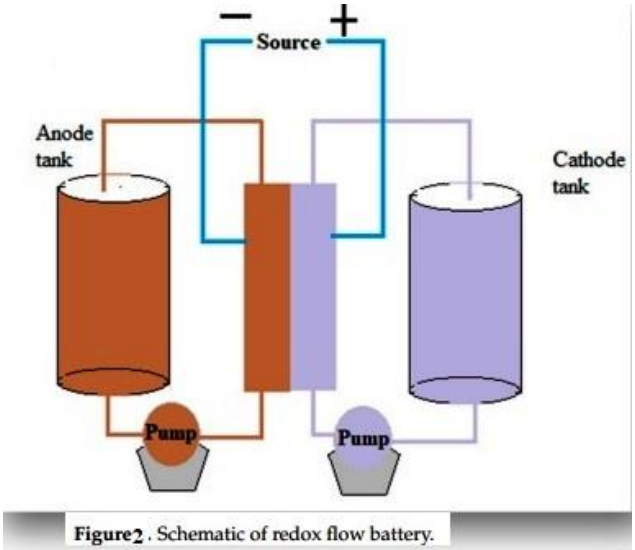

Figure2. Schematic of redox flow battery.

Hybrid Flow Battery (HFB):

In a hybrid flow battery (HFB), one active mass is kept inside the electrochemical cell while the other is kept outside. In HFBs, the advantages of traditional secondary batteries and RFBs are combined. The Zn-Ce and Zn-Br systems are examples of HFBs. The electrodes are largely carbon-plastic composites, and the anolyte is a Zn2+ ion-acid

solution. The Zn-Br hybrid flow battery was invented by Exxon in the early 1970s, and other businesses are actively commercialising it. Also being researched are 5 kW/20 kWh communal energy storage systems [16,20].

Chemical Energy Storage:

The only concept that enables the long-term storage of considerable amounts of energy, up to TWh, even as periodic buildup, is a chemical energy storage system. A variety of industries, including transportation, heating, and the chemical sector, may employ SNG and hydrogen. They are more cost-effective and efficient than standard batteries, although their total efficiency is lower than PHS and Li-ion storage systems [21].

Hydrogen (H_2):

An electrolyzer is a particular kind of electrochemical converter that uses electricity to split water into hydrogen and oxygen. Given that it is endothermic, heat is needed throughout the entire process. In petrol cans or tanks, hydrogen can be kept under pressure for essentially endless amounts of time. By using electrolysis to produce energy, oxygen from the air is released into the environment rather than being retained [21].

Synthetic Natural Gas (SNG):

To store energy, methane (also known as synthetic natural gas, or SNG), can be created. SNG can be injected directly into the gas infrastructure, kept in pressure tanks, or kept underground. Transporting CO2 and H2 to the methanation plant should be avoided to prevent energy losses. Due to conversion losses in electrolysis, methanation, storage, transport, and power generation, SNG has a low efficiency, which is its main drawback [9]. Compared to hydrogen, the overall AC-AC efficiency of 35% is much lower [19].

Electrical Storage Systems: Double-Layer Capacitors (DLC):

DLCs, commonly referred to as super-capacitors, are an electrochemical double-layer capacitor (DLC) technology that dates back 60 years. The two key characteristics are the extremely high capacitance values, on the order of thousands of farads, and the ability to charge and discharge very quickly due to extremely low inner resistance. This technology has a lot of room for development because it might produce capacitors with far higher capacitance and energy density than conventional capacitors, allowing for smaller designs. Additional advantages include longevity, dependability, lack of maintenance, robustness across a wide temperature range, and durability. The lifetime exceeds one million cycles without degradation, with the exception of the chemical used in capacitors, which degrades in 5–6 years regardless of the amount of cycles. The efficiency frequently

exceeds 90%, while discharge times range from a few seconds to several hours. Due to its high self-discharge rate, poor energy density, and high investment requirements, DLCs are not appropriate for long-term energy storage [21]. A DLC is good for bridging minor power outages like a UPS. A novel application for the electric car could be as a regenerative braking and acceleration buffer system [22].

Thermal Storage Systems:

Thermal storage systems collect heat from a variety of sources and store it for later use in both industrial and domestic uses. They are essential for the integration of renewable energy sources because thermal storage systems serve as an intermediary between the demand and supply of thermal energy [23]. Sensible heat storage, latent heat storage, and thermochemical adsorption and absorption storage are the three types of thermal storage [14]. Both liquids and solids can be used as storage media. Only by changing the storage medium's temperature can thermal energy be kept in reserve. The specific heat capacity and mass of the medium utilised are what determine a storage system's capacity. Phase change materials (PCMs) are used as storage media for latent heat storage. Such storage devices can also use inorganic (salt hydrates) or organic (paraffins) PCMs. The energy transferred during a phase shift, such as the melting of ice, is known as latent heat [14]. Since there is no temperature change during energy transmission, it is also known as "hidden" heat. The ice cooler, which employs ice in an insulated container or chamber to keep food cool on hot days, is the most popular latent heat—or cold—storage technique. The bulk of PCMs currently in use, such as molten salts utilised as a thermal storage technology for concentrated solar power (CSP) facilities, utilise the solid-liquid phase shift [24-32].

Superconducting Magnetic Energy Storage:

With very minimal energy loss, a superconducting magnetic energy storage system (SMES) stores electricity from the electrical grid inside the magnetic field of a coil made of superconducting wire. Power supply, control systems, and contingency systems are the three groups into which the SMES systems are divided [33].

Conclusions:

Currently, the electrical sector is working on more efficient and sustainable power supply, wise energy usage, and CO_2 reduction while the entire globe is concerned about the future of the planet in terms of lowering the carbon footprint and making it a greener one. While doing so, the primary topics of research are noted, including the expected increase in

renewable generation, the design of renewable technology for improved performance, the design and implementation of smart networks, and the integration of RNE into smart grids for improved energy demand management through optimisation approaches. The following factors are significant in the electrical system's current situation: In addition to being an integral part of the smart grid, energy storage technologies will be crucial for addressing emergency circumstances.

- When the smart grid and microgrids are implemented, the small and dispersed EES market is likely to be significant.
- The market for EES systems is expanding and will continue to expand alongside the renewable energy industry, especially for small and distributed systems.
- For upcoming efforts, cost, compatibility, and sustainability, as well as technical problems, may be crucial considerations.
- There is room to improve power quality, safety, and optimisation. It is apparent that expanding societal benefit will be aided by system profit maximisation and system generating cost and loss reduction when the future and investors' interests are taken into account.

This paper gives a thorough evaluation of the most current research developments in this field while looking at a variety of features of renewable integrated deregulated power systems. Future studies should identify the restrictions and boundaries of ESSs and discuss the ideal size of ESSs based on the application. Additionally, a study on how combining multiple ESSs to create a hybrid ESS may affect the effectiveness and performance of the entire system. Additionally, it is important to investigate the many typologies employed to connect these ESSs to the electrical grid. Finally, the price of ESSs should be considered, taking into consideration cheap energy with high efficiency.

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BINARY NANOCOMPOSITE MODIFIED ELECTROCHEMICAL SENSORS AND BIOSENSORS FOR FOOD SAFETY

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Abstract:

The technology of nanomaterials, which show promise to address the issues of biocompatibility and biofouling, will unavoidably be the focus of future advancements in biosensor research. Smart nanomaterials are being used to create biosensors that can quickly, precisely, sensitively, affordably, in-field, online, and/or in real-time detect pesticides, antibiotics, pathogens, toxins, proteins, microorganisms, plants, animals, foods, soil, air, and water. Therefore, biosensors are great analytical tools for monitoring pollution, which could successfully make it realistic to adopt legal regulations to protect our biosphere. The creation and miniaturisation of biosensors will be the focus of the current trends and difficulties with nanomaterials for various applications. All of these expanding regions will have a significant impact on the creation of new, ultrasensitive biosensing technologies to address the severe pollution issues that will arise in the future.

Keywords: Biosensor; Nanomaterials; hybrid nanoparticles

Introduction:

To create better materials and products, nanomaterials integrate current materials into systems at the nanoscale. Nanotechnology has found widespread use in a number of fields, including healthcare, implants, and prosthesis; smart textiles; energy generation and conservation using energy generating materials and extremely efficient batteries; defence; security; counterterrorism; and surveillance [1]. In the fields of life science and material science, bionanomaterials research has become a burgeoning, fascinating area of study. Applications in industry, defence, and clinical medicine have a huge potential because to great advancements in nanobiochip materials, nanoscale biomimetic materials, nanomotors, nanocomposite materials, interface biomaterials, and nanobiosensors. In nanoscience and nanotechnology, biomolecules play a crucial role. For instance, peptide nucleic acids (PNAs) replace DNA and serve as a biomolecular instrument or probe. A biosensor is made up of a transducer and a biosensing substance that can be used to detect

both biological and chemical substances. In contrast to transducers, which include electrochemical, optical, piezoelectric, thermal, and magnetic devices, biosensing materials, such as enzymes, antibodies, nucleic acid probes, cells, tissues, and organelles, selectively recognize the target analytes. Singh *et al.* reported a disposable biosensor using a CAT/PANi/ITO electrode as a bioelectrode for the quick measurement of both H_2O_2 and azide in biological samples. This film is extremely effective at holding onto the enzyme activity and preventing its leakage. It implies that this effective film can be used to immobilise other enzymes and bioactive compounds in addition to catalase, making it a suitable platform for the creation of biosensors [2], as depicted in Figure 1. A growing field of interdisciplinary research is biosensors. In order to detect different kinds of targeted biomolecules, several biosensor types are combined with various transducers, each of which has its own advantages and limits. A lot of nucleic acid components are used in nanobiotechnology (lab-on-a-chip, nanobiosensors array) [3-5], including aptamers, DNAzymes, aptazymes, and PNA.

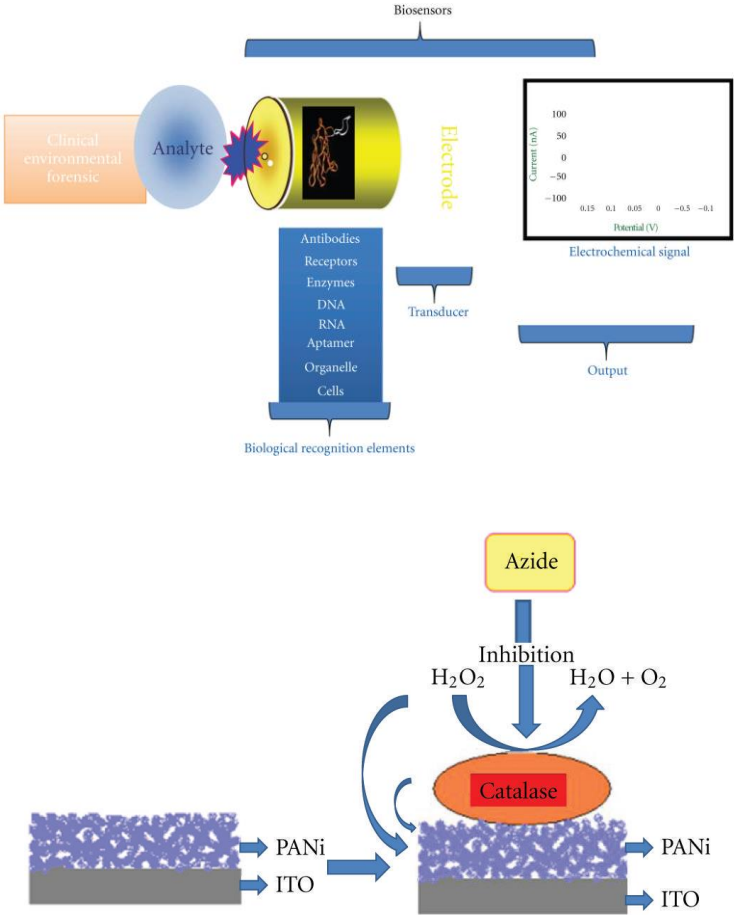

Figure 1: It shows schematic representation of bioelectrode in the development of biosensor for the H_2O_2 determination under optimal conditions

Additionally, the disposable polymer lab-on-a-chip can readily incorporate the nanobiosensor for a variety of biochemical analyses and clinical diagnostic applications. The concepts of coordinated nanobiosensors—which integrate the desirable properties of the individual components—include protein machinery for sensitivity and specificity of binding, peptide or nucleic acid chemistry for aligning the various electron transducing units, and nanoelectrodes for enhancing sensitivity in electronic detection. These recent developments in nanobiosensors and their applications in biology, particularly in medical diagnostics. Results from these systems concentrate on the prospective benefits of using nanoscale biosensor technology, which will fundamentally alter biomedical diagnosis and therapy.

Therefore, the creation and use of nano devices in biology and medicine will have a huge impact on society and human health. For quick, accurate, sensitive, low-cost, on-the-spot, in-field, and/or real-time detection as well as monitoring of pesticides, antibiotics, pathogens, toxins, proteins, microbes, plants, animals, foods, soil, air, and water, biosensors integrated with new technologies in molecular biology, microfluidics, and nanomaterials have applications in agricultural production, food processing, clinical care, and environment. As a result, ultrasensitive biosensors propose to be a great analytical tool for pollution monitoring, making it feasible to monitor the biosphere [6-7].

In the context of bioelectronics, nanotechnology, and biotechnology, future rising trends towards biosensor development appear to be all growing fields that will significantly affect the creation of new biosensing technologies. It is currently of interest to comprehend biological processes at the level of a single molecule and to apply them to potential future uses in nano biotechnology. Research opportunities have been provided by studies on single molecule enabled probe, particularly in nanoscience and nanotechnology for the creation of adaptable biomolecule detection technology [8]. Because of their large surface area, electrical characteristics, electrocatalytic activity, and outstanding biocompatibility, nanomaterials have made it possible to construct ultrasensitive biosensors. Direct connecting of enzymes to the electrode surface, electrochemical reaction promotion, and signal amplification of biorecognition events have all been accomplished using them.

The use of nanomaterials for biosensing, such as nanoparticles, nanowire, nanoneedles, nanosheets, nanotubes, nanorods, and nanobelts, has been documented in a number of research articles [9, 10]. The low-potential detection of NADH using CNT-

modified electrodes, gold nanoparticles for electrochemical immunosensors, carbon nanotube-based sensors, nanoparticle-based biosensing, and nanowire as sensing materials is a few noteworthy examples. Nanotubes, nanoparticles, nanorods, and many more nanoobjects are all members of the expanding family of nanoobjects, which also includes nanowires. The electrode or the connector between micro- and nanoelectronic devices can be made of nanowires.

There are fascinating possibilities for their interaction with biological species like cells, antibodies, DNA, and other proteins because their dimensions are sometimes on the same scale as biomolecules. Horseradish peroxidase (HRP) was first immobilized on positively charged Ni-Al layered double hydroxide nanosheets (Ni-Al LDHNS) in order to create enzyme electrodes for the study of direct electron transfer between the redox centres of proteins and supporting electrodes. In the reduction of hydrogen peroxide and trichloroacetic acid (TCA), the immobilized HRP in Ni-Al LDHNS on the surface of a glassy carbon electrode (GCE) demonstrated good direct electrochemical and electrocatalytic reactions.

According to the results of the linear detection, Ni-Al LDHNS offers a cutting-edge and effective platform for the immobilisation of enzymes and the creation of third-generation biosensors [11]. ZnO nanosheet and other metal oxides have been described by several researchers as sensing materials in electrochemical biosensors [12-15]. A perfect biosensing platform must be miniaturized, economically viable, and capable of simultaneously detecting many analytes. The probes, transducers, and their detection equipment have faced new technical hurdles as a result of the biorecognition arrays (microarrays). Small amounts of material that has separated on a substrate (such as plastic, glass, or a semiconductor) can be used in microarrays to analyse a huge number of biological molecules. Nucleic acids, proteins, peptides, antibodies, and carbohydrates are among the biological components that are deposited or synthesized on the chip surface. Physical spotting, piezoelectric deposition, and in situ synthesis are the techniques utilized to deposit materials onto the chip surface.

According to numerous researchers, DNA biosensor and DNA microarray developments have advanced significantly [16]. Gene chips, DNA chips, and biochips are all terms for DNA arrays that make use of complementary single-stranded nucleic acid sequences binding preferentially. DNA microarrays, as opposed to DNA biosensors, are constructed on glass, plastic, or silicon substrates that have tens to thousands of 10- to 100-

nanometer reaction sites on which specific oligonucleotide sequences have been immobilised [17]. In DNA biosensors, a DNA probe's immobilisation was accomplished by directly applying it to the transducer surface. The amount of DNA probes used varies depending on the application. One of the world's most promising materials is nanocomposite. There are numerous reviews on recent developments in nanomaterials, [8–10] and only a few on nanocomposite [11,12]. According to Vashist *et al.* [13], nanocomposites perform exceptionally well at immobilising biomolecules and preserving their bioactivities, particularly when it comes to boosting the stability of enzymes [14, 15].

Nanoparticles in Biosensing

Nanomaterials are being used to enhance the sensitivity and functionality of gadgets. Because their nanometer size gives rise to high reactivity and other enhanced beneficial physical properties (electrical, electrochemical, optical, and magnetic), as a result of nonlinearity after crossing the performance barrier threshold, nanomaterials with at least one of their dimensions ranging in scale from 1 to 100nm display unique and remarkably different characteristics as compared to their bulk. Biosensors that detect proteins, peptide nucleic acids, and nucleic acids have frequently employed nanoparticles [18–20]. Gold nanoparticles combined with silver have improved redox characteristics, which has led to their extensive use as electrochemical labels in the construction of biosensors with exceptional sensitivity [21, 22]. The DNA hybridization was observed using gold nanoparticles coated with streptavidin and ferrocenyl hexanethiol. High background signals due to nonspecific precipitation of silver onto the substrate electrode are a common issue with silver enhancement. To address the issue, various electrode surface treatments and electrochemically or enzymatically controlled deposition methods of silver have been reported. A new approach of electrochemical detection of DNA hybridization based on stripping voltammetry of enzymatically deposited silver has been developed in order to decrease the silver associated background signal and increase sensitivity. Target DNA and an immobilised biotinylated DNA probe combine to form a capture DNA probe that is attached to a gold electrode. The nonelectroactive substrate is changed into a reducing agent by neutravidin- (NA-) conjugated alkaline phosphatase by binding to the biotin of the detection probe on the electrode surface.

The latter decreases the concentration of metal ions in solutions, which causes metal to deposit on the electrode surface and DNA backbone [23, 24]. In order to increase the electrochemical sensitivity of biomolecular reactions, K'Owino *et al.* demonstrated for

the first time the underpotential deposition of an Ag monolayer. There have been reports of the use of metal-enhanced electrochemical sensing to detect PCBs and anticancer drug cisplatin at parts per trillion (ppt) levels employing immobilised metal layers in continuous films, particles, colloids, or monolayers [25]. Using Microcystis as a model for tracking DNA-cisplatin interactions, a modified metal-enhanced electrochemical detection (MED) approach was created for the detection of two base pair mismatches [26,27].

Other biomolecular processes such DNA hybridization, mismatch detection; DNA-protein, antigen-antibody, and DNA-RNA reactions have also been seen using the detection [28]. The synthetic nucleic acid ligand known as an aptamer is made up of single-stranded DNA or RNA sequences. It is commonly created in vitro using a process known as systematic evolution of ligands by exponential enrichment. By using a nanopore polycarbonate (PC) membrane and an electro deposition technique, gold nanowires with an average diameter of about 250 nm and a length of about 10 nm were created. The nanowires were produced, mixed with chitosan (CHIT) solution to immobilize them, and then they were stably applied to the glassy carbon electrode surface. The redesigned electrode enables rapid response times and high sensitivity hydrogen peroxide detection at low potentials. To create glucose, glucose oxidase was adsorbed onto the nanowire surface.

A perfect sensor would be one that can reliably detect all blood glucose fluctuations in real-time, continuously, over an extended length of time, and in challenging environments. Continuous glucose monitoring has been described by Wilson, which corrects the drawbacks of test strip-based metres and offers the chance to carry out quick and effective therapeutic interventions [29]. In addition, Wilson and Gifford have described a needle-type multi electrode array for the hypodermic continuous glucose-monitoring sensor that uses MEMS technology.

One counter (Pt) electrode, two working (Pt) electrodes, and one reference (Ag/AgCl) electrode made up the four electrodes of the newly created multielectrode sensor [30]. For the enzyme and nonenzyme electrodes, which assess glucose concentration and background current, Jung *et al.* have developed two functional electrodes. This would reduce diabetes-related short-term crises and long-term consequences, improving the quality and quantity of life for diabetics [31].

Biomaterials

A living building or biomedical device that performs or takes the place of a natural function may be composed entirely of natural materials or partially of artificial ones. They

are employed daily in surgical procedures, dental applications, and medicine delivery. An autograft, allograft, or xenograft utilized as a transplant material is another example of a biomaterial. Silicates in algae and diatoms, carbonates in invertebrates, calcium phosphates, and carbonates in vertebrates are examples of natural biomaterials. Highly organized structures include molecular crystals, liquid crystals, colloids, micelles, emulsions, phase separated polymers, thin films, and self-assembling monolayers [32]. Artificial materials have been implanted in human bodies to assess, repair, and improve physiologic performance as well as to improve survival and quality of life. For items like artificial heart valves (polymeric or carbon based), synthetic blood vessels, artificial hips (metallic or ceramic), medical adhesives, sutures, dental composites, and polymers for controlled slow drug delivery and polymeric (synthetic and natural) materials have typically been used.

Depending on the unique in vivo application, the biocompatible materials are integrated into the biological milieu and have various customised features [33]. The material of choice for degradable drug delivery systems has primarily been aliphatic polyester nanocomposites [34]. Poly(L-lactic acid) (PLLA), one of the polyesters with promise in biological sectors, is the most widely used. For example, nanocomposites used in dentistry applications have certain needs. Nanocomposites utilized in diverse biomedical applications have varied criteria.

As an additional illustration, thermoset methacrylate-based composites are frequently employed as dental restorative materials due to their good aesthetic features and relatively high cure efficiency through free radical polymerization. Nanocomposites in particular that have improved modulus, greater free radical polymerization efficiency, reduced water sorption, improved processability, and low shrinkage requirements. Better interactions at the filler matrix interphase may result from selective functionalization of the filler. Improved composite paste workability, greater filler loadings that result in better modulus values, and nanocomposites with lower polymer shrinkage are some of the practical benefits of dual silanization [35].

Carbon Nanotubes/Fullerenes/Graphene for Biosensing

Curl, Kroto, and Smalley's 1985 discovery of fullerenes led to their 1996 Nobel Prize. Fullerines, also known as Buckminster fullerenes, were created in honour of Buckminster Fuller, the geodesic domes creator and architect. The names come from the basic structure

of fullerenes, which is an elongated sphere of carbon atoms made up of interconnected six-member rings and twelve isolated five-member rings with hexagonal and pentagonal faces.

The first isolated and characterized fullerine, C60, has perfect icosahedral symmetry and has 20 hexagonal faces and 12 pentagonal faces, like a football [36]. High-density magnetic storage media have a lot of potential using magnetic nanoparticles (nanomagnetic materials). Due to their vast and varied uses and growing use in daily life, carbon-based nanomaterials are receiving attention from the field of nanotoxicology. According to their aspect ratio and surface chemistry, carbon-based nanomaterials (nanotubes, nanofibers, and nanowires) are poisonous and have potentially harmful effects [37]. By employing methylene blue (MB) as a DNA indicator, Li *et al.* have created a biosensor based on chitosan doped with carbon nanotubes (CNT) to find salmon sperm DNA.

Inorganic-Organic Hybrid Nanoparticles for Biosensing

Inorganic-organic hybrid composites are a promising new class of materials that are just starting to emerge. Materials are being created with the outstanding choice of functional group chemical reactivity associated with organic chemistry and the good physical qualities of ceramics. Because of their potential replacement of and compatibility with currently used silicon-based inorganics in the electronics, photonics, and other material technologies, new silicon containing organic polymers, in general, and polysilsesquioxanes, in particular, have attracted a lot of attention. For the simultaneous in situ synthesis and orderly assembly of metal nanoparticles on a periodic two-dimensional protein array, Puranik *et al.* have created an effective and simple approach. The template is the Bacillus subtilis S-layer protein, which has consistent pore size. Gold and silver nanoparticles that anchor to S-layer pores were created by chemically reducing the corresponding metal salt-loaded protein template that was used for biosensing [38]. For the detection of Vibrio cholerae O1, the CeO_2 nanowires-based immunosensor was investigated using various antibody immobilisation techniques [39].

Dendrimers: High-Performance Nanostructures for Biosensing

Dendrimers are a new structural family of organic polymer macromolecules with nanometer-sized, hyperbranched materials that have compact hydrodynamic volumes in solution and high surface functional group content. They are similar to organic nanoparticles. Although they may be water soluble, their compact dimensions prevent them from exhibiting the typical rheological thickening characteristics that many polymers

in solution do [40]. Three elements a central core, an internal dendritic structure (the branches), and an external surface (the end groups) define dendrimers. Nearly spherical structures, nanoscale diameters, many reactive end group functions, insulated inner gaps, and minimal systemic toxicity are the defining characteristics of dendrimers. They are the perfect candidates for potential nanotechnology applications in the biological and material sciences, including a wide range of fields like materials engineering, industrial, pharmaceutical, and biomedical, as well as for nanoscale catalysts, novel lithographic materials, rheology modifiers, targeted drug delivery systems, MRI contrast agents, and bioadhesives [41].

By alternately depositing PAMAM or PAMAM with ferrocenyl attached to it, periodate-oxidized glucose oxidase (GOX), and PAMAM, Yoon and Kim have created a glucose biosensor. Additionally, PAMAMs functionalized with ferrocenyl and biotin analogues were built layer by layer on the gold electrode to create a biosensor. The development of PAMAM dendrimers into self-assembled monolayers (SAMs) on a gold substrate for biosensors was also reported in several research [42]. According to Hianik, the polyamidoamine (PAMAM) dendrimer G1 is a good candidate for use in the creation of a glucose biosensor.

Conclusions:

The control of matter at the molecular level in scales smaller than 1 micrometre (i.e., 1 to 100 nm) and the creation of devices in that size range constitute the core themes of the fields of nanoscience and nanotechnology. Due to the fact that nanostructures, nanodevices, and nanosystems exhibit novel properties and functions as a result of their small size, it is a highly multidisciplinary field that includes topics like applied physics, materials science, colloidal science, device physics, supramolecular chemistry, and mechanical and electrical engineering. The nanosized systems perform specific electrical, mechanical, biological, chemical, or computing tasks based on this fact. This study focuses on the current trends and difficulties for nanomaterials in many applications, including importance in fields such as cancer diagnostics, pathogen detection, food safety, environmental measurements, and clinical applications. For the sensitive detection of Ab-Ag, DNADNA, DNA-drug, and DNA-toxin interactions, aptamer-based microarrays for the quantification of numerous protein analytes as well as a metal-enhanced electrochemical detection approach have been presented. Future challenges include meeting the rising demand for improved sensitivity and selectivity, which will enable real-time, low-cost monitoring of molecules in the

analysis of challenging clinical and environmental samples. The impact of nanotechnology on biosensors is also extensively covered in this study, along with the past, present, and future of these rapidly developing and burgeoning research endeavours. It is supported by the quick advancements in nanotechnology; these works of multidisciplinary research are progressing and starting to find their way to the market. The study emphasises the critical milestones accomplished and further explains the rising future prospects in this field by concentrating on the key advances from the views of novel smart materials, device topologies, and functions.

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AMINO ACIDS AS CHIRAL BUILDING BLOCK: APPLICATION TO THE ASYMMETRIC SYNTHESIS OF BIOACTIVE NATURAL PRODUCTS

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Abstract:

Enantiomerically pure α-amino acids are considered as a major source of chiral building blocks. Employment of the building blocks in the enantioselective synthesis of natural products has made enormous impact in the general organic synthesis. This chapter is an effort to discuss the state of the art of synthetic methodologies in which the α-amino acids have been transformed into bioactive natural products.

Keywords: Amino acids, chiral building blocks, natural products

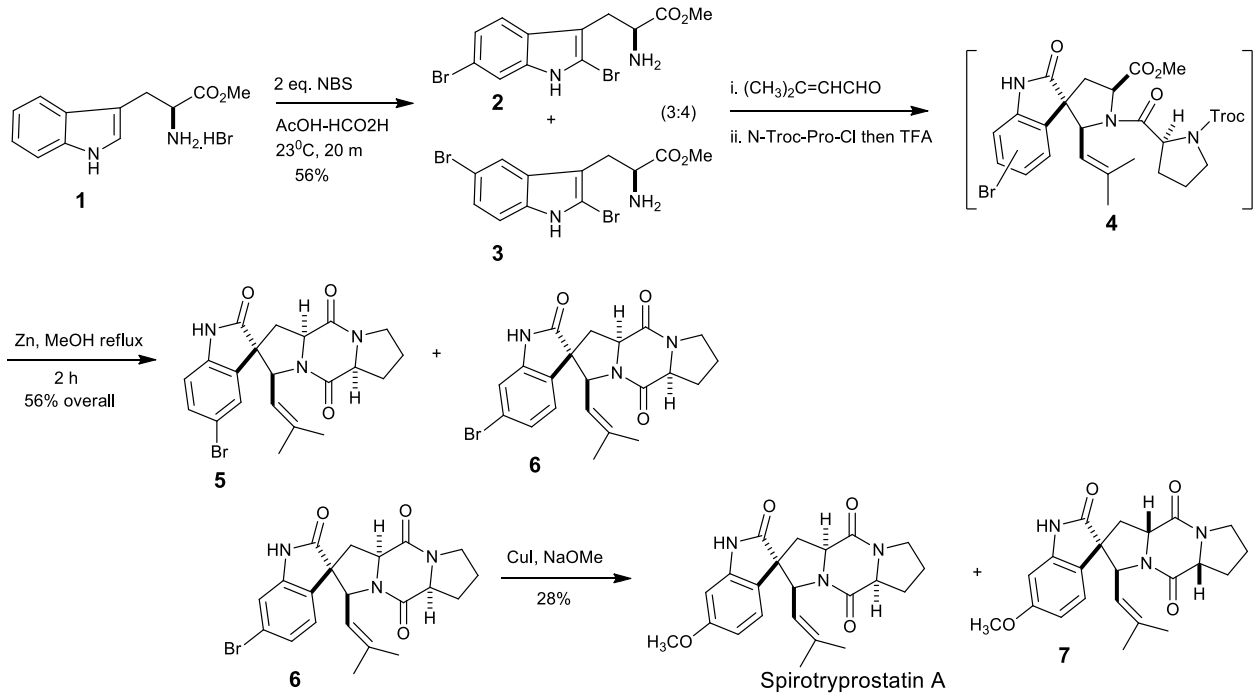
Introduction:

α-Amino acids (α-AAs) are the fundamental units of life, responsible for numerous biological functions in living organisms. It forms the main backbone of peptides and various other important biomolecules. Tailor-made α-AAs are increasingly utilized for preparation of various novel synthetic hormones, enzymes, and immunostimulants [Hunt *et al.,* 1985]. The growing interest of the pharmaceutical and agrochemical industries to access an optically pure compound has encouraged intensive research for synthesizing these chiral entities starting from readily available & optically pure compounds (i.e. chiral pool approach) usually amino acids or sugars, from which pieces containing the required chiral centres can be taken and incorporated into the product. Because, enantiomers of a chiral molecule show different biological activities, one enantiomer being active and the other exhibits either physiologically inactive or having profound toxicity. Synthetic Organic chemistry has played a central role during the entire part of twentieth century. Total chemical syntheses offers a significant role to access the most complex and worthwhile of nature's products as well as give an endless opportunity for future discovery and invention in chemical sciences. In this chapter, we discuss, starting from chiral amino acids; organic chemists are synthesized complex bioactive natural products.

Natural Product Synthesis:

We have described in general, the individual synthesis of bioactive natural products from a amino acid with pertinent transformations and reactions. Normally key synthetic steps are mentioned in each description of natural products for the benefit of future organic practitioners

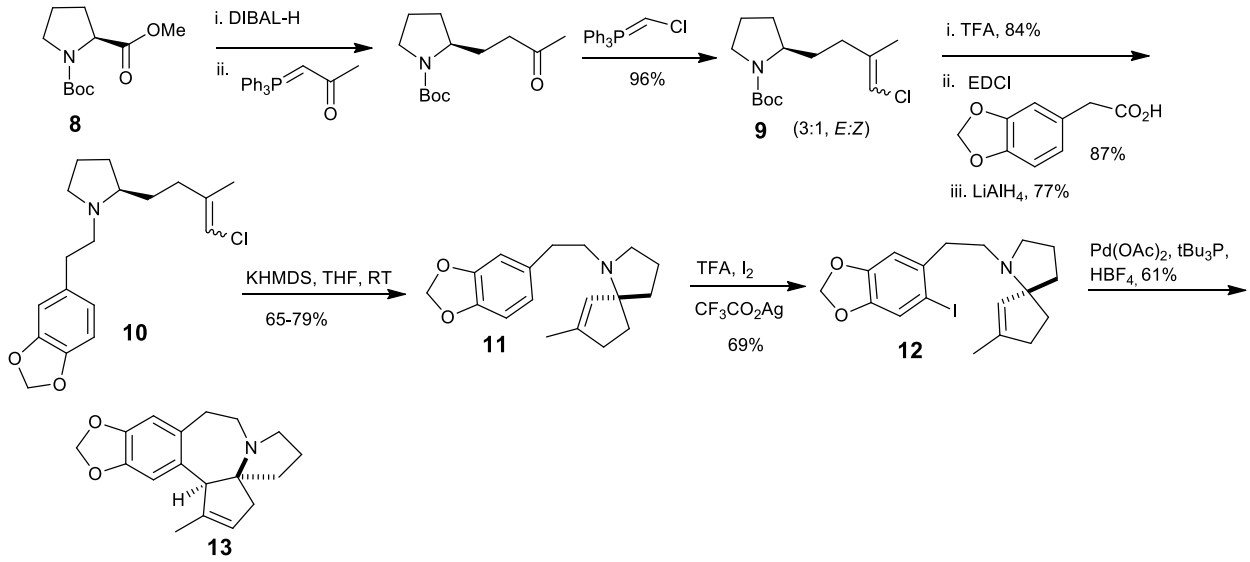
Miyake *et al.* [2004] implemented the methodology for the synthesis of spirotryprostatin A (**1**) begins with the dibromination of tryptophan methyl ester (**1**) (Scheme 1). Exposure of **1** with 2 eq. NBS produced isomeric indole dibromides 2,6- and 2,5-dibromotryptophan methyl esters (**2**) and (**3**) in 56% yield as a 3:4 mixture of regioisomers, respectively. Condensation of **2** and **3**, respectively, with prenyl aldehyde afforded the corresponding imines, followed by prolinyl chloride mediated spirocyclization and hydrolysis of the resulting chloroindolenine intermediate yielded oxindole **4**, which also were not isolated. Zn facilitated removal of the Troc group induced diketopiperazine formation to give 6-bromodemethoxyspirotryptrostatin A (**5**) (26%) and 5-bromodemethoxyspirotryprostatin A (**6**) (30%) respectively. Finally, spirotryprostatins A (11% yield) was accomplished under Cu-catalyzed methoxylation conditions along with other diastereomer **7** (17 % yield).



Scheme 1: Total synthesis of spirotryprostatin A

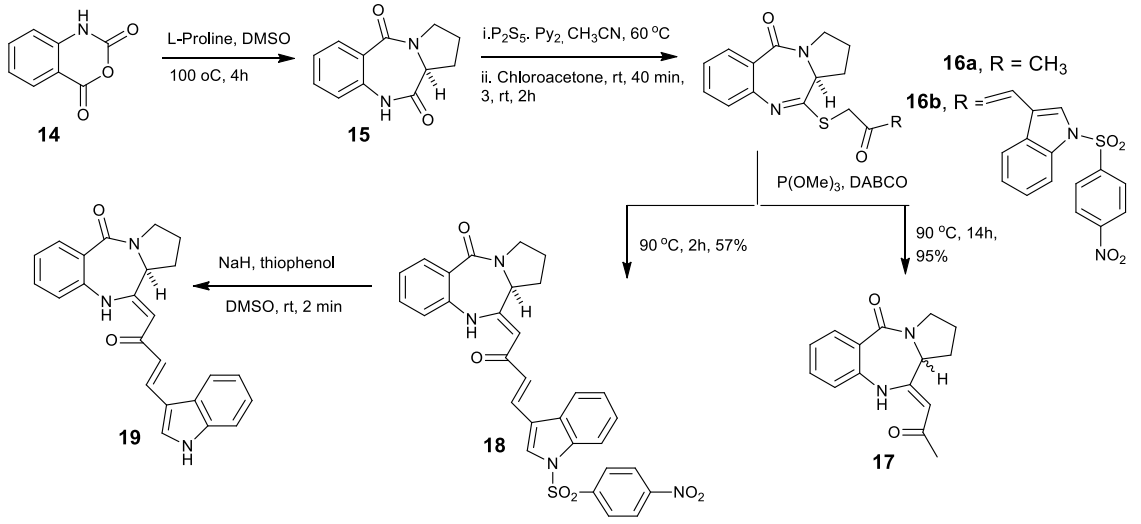
Esmieu *et al.* [2008] described an enantioselective formal synthesis of the alkaloid (-) cephalotaxine (Scheme 2). Carbene precursor the vinyl chloride **10**, was easily prepared

in seven steps from *N*-Boc-proline methyl ester **8**. Ester reduction of **8** with Dibal-H, homologation of aldehyde, and a second Wittig reaction afforded the vinyl chloride **9,** (3:1, *E*:*Z*) in good overall yield. Boc-deprotection, amide formation with the carboxylic acid, and reduction of the resulting amide ($LiAlH_4$) afforded the desired alkylidene carbene precursor **10**. The pivotal alkylidene carbene 1,5-CH insertion reaction was then effected by teatment of **10** with KHMDS at room temperature to afford the desired spiro [4.4]azanonane **13** in good yield (65-79%). Regioselective iodination of the aromatic compound **11** and a Heck-type cyclization of **12,** was used to accomplish the formal synthesis of tetrahydroazepine C-ring **13**. A selective epoxidation-rearrangement sequence was used to elaborate the E-ring and also to complete the total synthesis.



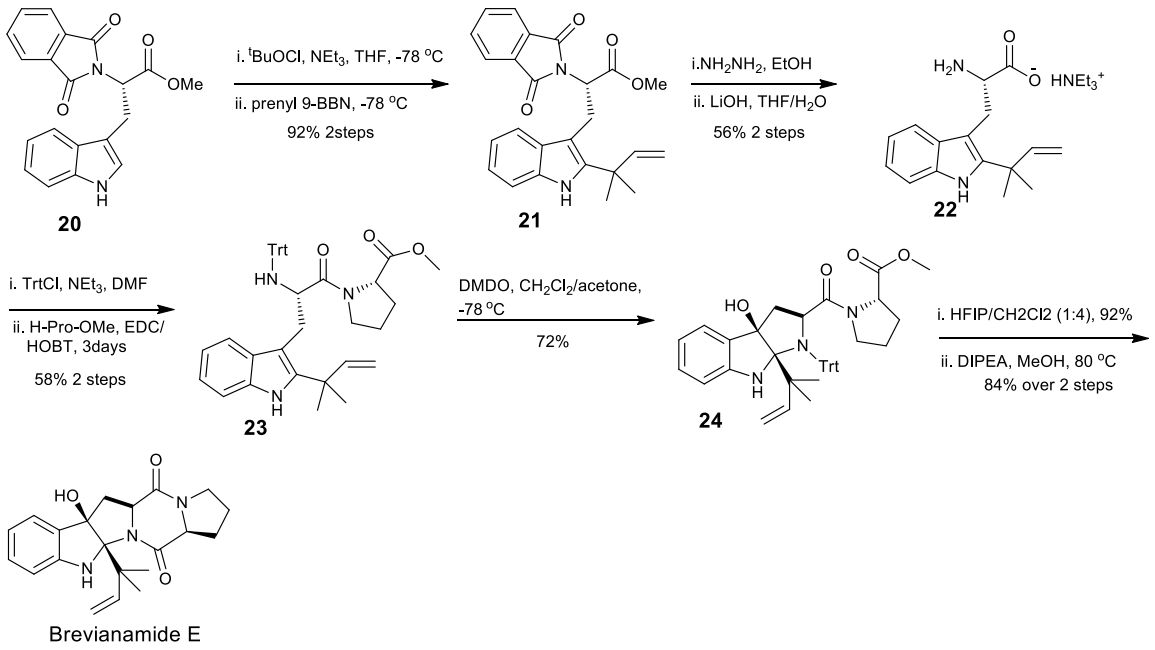
Scheme 2: Formal synthesis of the alkaloid (-) cephalotaxine

Pettersson *et al.* [2011] reported the total syntheses of the natural products fuligocandin A (4) and fuligocandin B (**19**) (Scheme 3). The key intermediates the pyrrolo-1,4-benzodiazepine derivative **15** was readily prepared by heating isatoic anhydride **14** and L-proline in DMSO. Monothione formation employing the P_2S_5-Py_2 complex, followed by coupling with chloroacetone **16a** and **16b** afforded fuligocandin A **(17)** and fuligocandin B derivative (**18**) *via* episulfide contraction. Fuligocandin B derivative was readily converted to Fuligocandin B **19** by p-nitrophenylsulfonyl group deprotection.



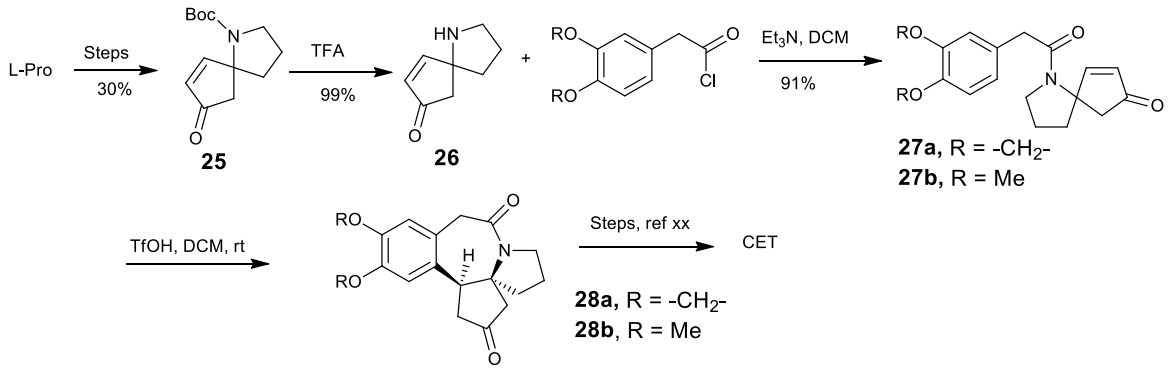
Scheme 3: Total syntheses of fuligocandin A & B

Zhao *et al.* [2012] described the concise stereoselective synthesis of pentacyclic natural product brevianamide E, via oxidative cyclization of intermediate **23** (Scheme 4). Prenylation of N$^{\alpha}$-phthaloyl-tryptophanmethyl ester **20,** and methyl groups deprotection, protection followed by reaction with proline methyl ester under standard EDC/HOBt coupling conditions gave dipeptide **23**which was then subjected to DMDO oxidation at low temperature resulting in a predominant product **24.** HFIP mediated removal of the trityl gave Hpi-dipeptide which, in the presence of DIPEA, cleanly gave brevianamide E.



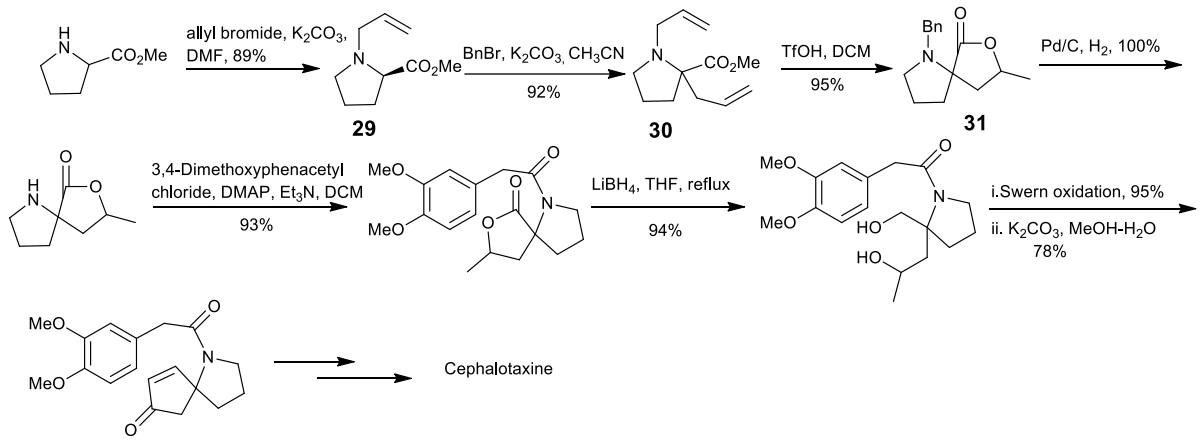
Scheme 4: Total synthesis of brevianamide E

Li *et al.* [2007] reported a novel formal synthesis of cephalotaxine (CET) (Scheme 5), via a facile Friedel-Crafts cyclization of the amino (or amido) spiro-cyclopentenone precursor (**27**) mediated by a protic acid leading to tetracyclic ketone **28**, which was readily transformed into CET. A remarkable stereoelectronic effect of the methylenedioxy substituent (*R*) was observed.



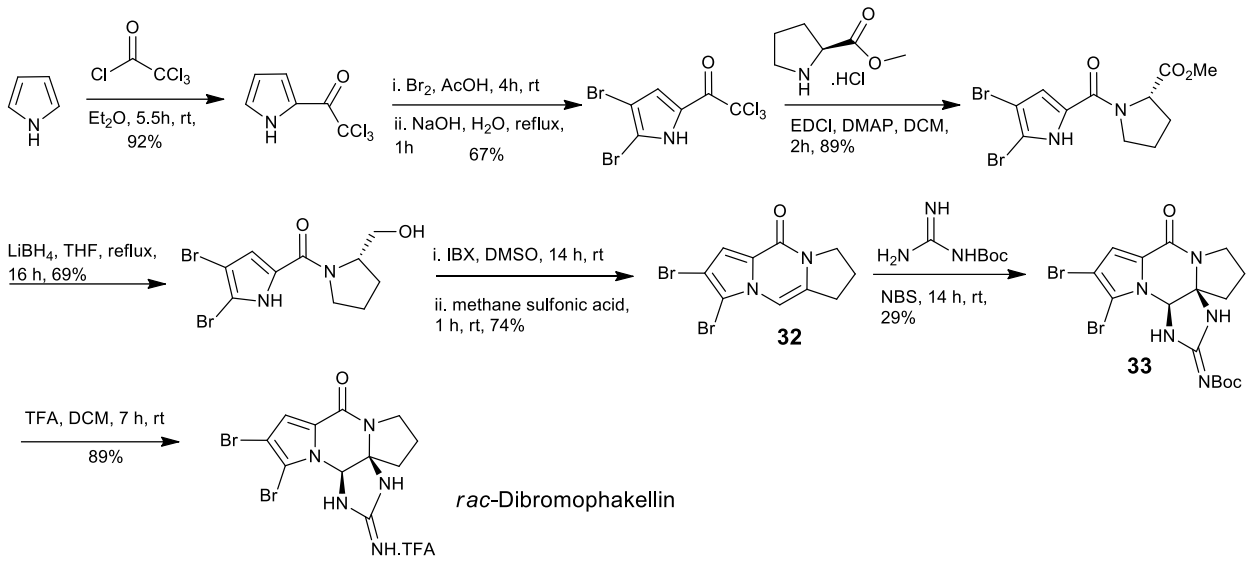
Scheme 5: Formal synthesis of cephalotaxine

Sun *et al.* [2009] described a highly efficient formal synthesis of Cephalotaxine employing the [2,3]-Stevens rearrangement of **29**, followed by acid mediated lactonization of **30** sequence as a key transformation from readily available (3,4-dimethoxyphenyl)acetic acid, allyl bromide, and methyl prolinate (Scheme 6).



Scheme 6: Formal synthesis of Cephalotaxine

Tepe *et al.* [2011] reported two steps total synthesis of natural product *racemic*-Dibromophakellin from a known alkene intermediate **32**, (Scheme 7). The key intermediate **32** was readily synthesized starting from pyrrole and L-proline methyl ester hydrochloride. The key step in the synthesis was the NBS olefin activation of **32**, to facilitate the addition of a guanidine molecule across the double bond.



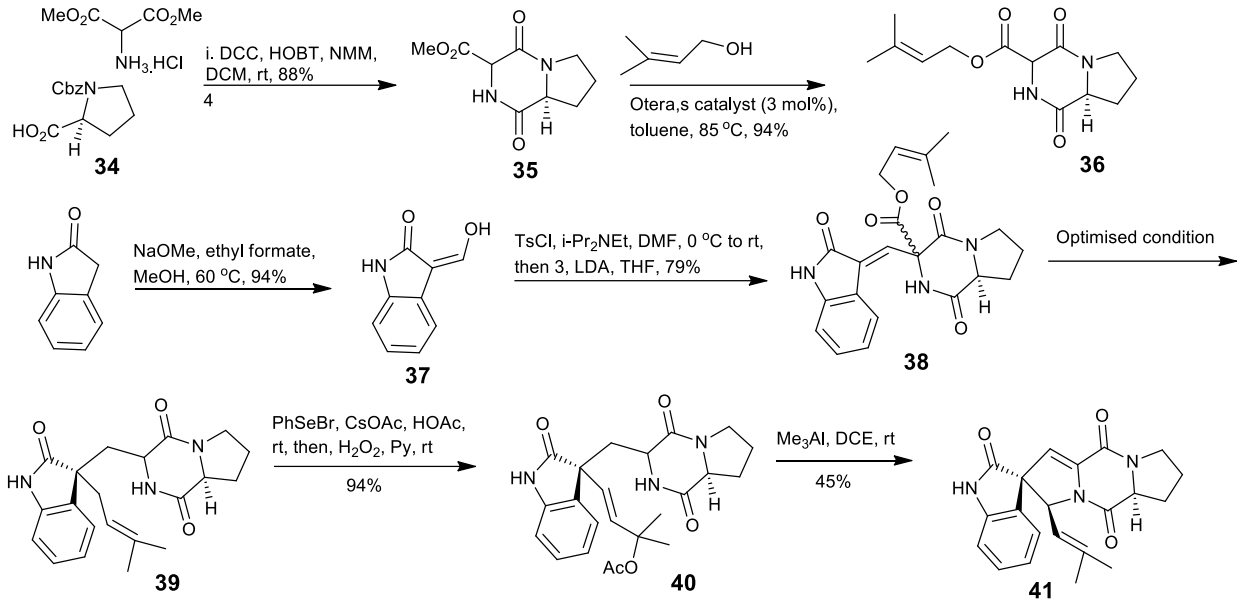
Scheme 7: Total synthesis of *racemic*-Dibromophakellin

Trost *et al.* [2007] reported the total synthesis of Spirotryprostatin B in eight steps starting with Cbz-proline and dimethyl aminomalonate hydrochloride (Scheme 8). Known diketopiperazine **35** was transesterified to prenylester **36** with use of Otera's catalyst. In a one-pot reaction, oxindole **37** was activated as its vinyl tosylate, then treated with the lithium salt of **36** affording the coupled product **38** in good yield as a 1:1.7 mixture of diastereomers. Pd (0) mediated decarboxylation-prenylation reaction of a substituted *β*-keto esters **38,** to construct the quaternary C3 stereocenter **39**, followed by selenium mediated allylic acetate formation **40**, which was radily cyclized to give spirotryprostatin B in 45% isolated yield along with minor amounts of isomers by the treatment with trimethylaluminum.

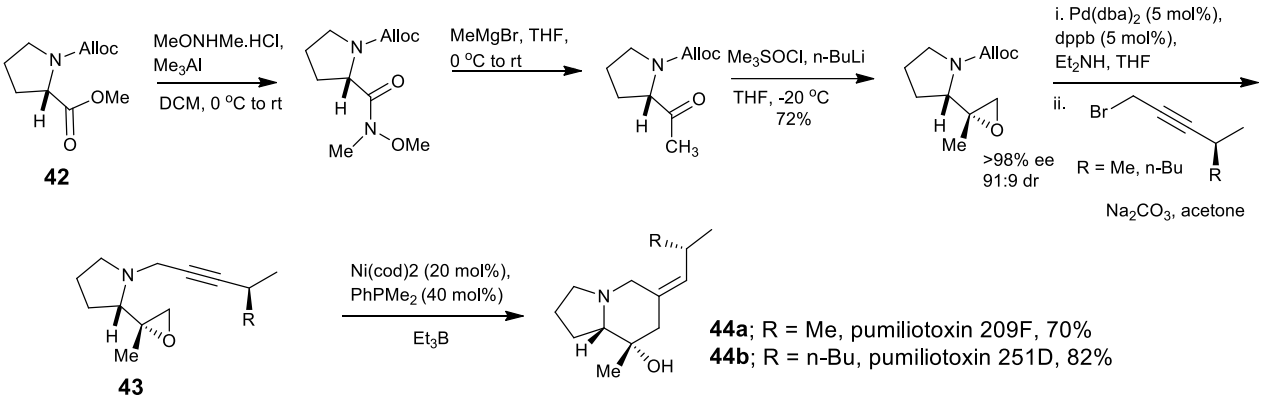
Jamison *et al.* [2007] reported the total synthesis of Pumiliotoxins 209F and 251D using highly selective nickel-catalyzed epoxide-alkyne reductive cyclizations **43**, as the final step. The epoxides were prepared using diastereoselective addition of a sulfoxonium anion to a proline-derived methyl ketone (Scheme 9).

Zhu *et al.* [2008] reported the total synthesis of (-)-Quinocarcin (**45**) in a longest linear sequence of 22 steps from 3-hydroxybenzaldehyde in 16% overall yield (Scheme 10). Tetrahydroisoquinoline **45** was prepared from 3-hydroxybenzaldehyde via a sequence of enantioselective alkylation and diastereoselective Pictet-Spengler reaction. The diazabicycle[3,2,1]-octane ring system of **50** was constructed by a silver tetrafluoroborate-promoted intramolecular Mannich reaction using amino thioether as a latent *N*-acyliminium species and tethered silyl enol ether of **49** as a nucleophile. From the bridged tetracyclic compound **50**, a sequence of oxidation of aldehyde to acid, global deprotection

under hydrogenolysis conditions, and one-pot partial reduction of lactam **51** to aminal/oxazolidine formation completed the total synthesis of the pentacyclic (-)-quinocarcine.



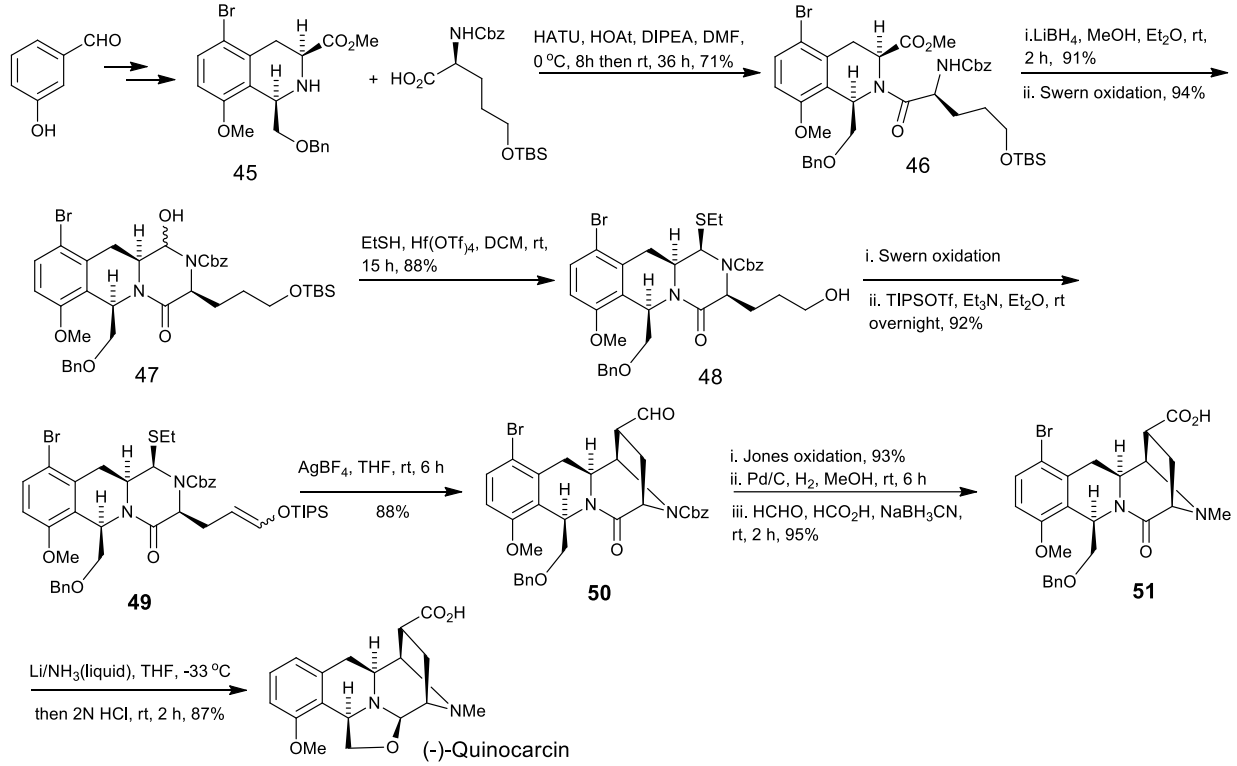
Scheme 8: Total synthesis of Spirotryprostatin B



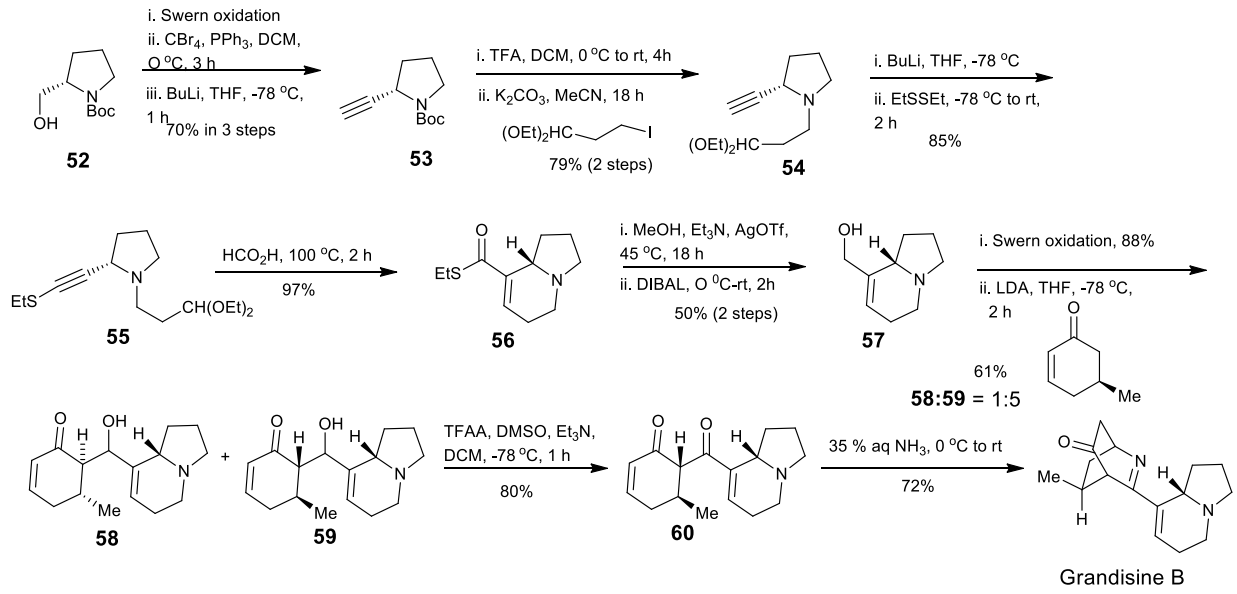
Scheme 9: Total synthesis of Pumiliotoxins 209F and 251D

Taylor *et al.* [2011] reported a biomimetic total synthesisthe of (-)-Grandisine B from (+)-Grandisine D (Scheme 11). The key indolizidine building block **57**, was readily accessed from commercially available N-Boc-prolinol **52**, using known procedures. Boc deprotection followed by N-alkylation with iodo-acetal proceeded readily to afford acetal **54**. Deprotonation of alkyne with n-butyllithium and trapping with ethyl disulfide followed by heating in formic acid solution afforded cyclized product **56.** The desired allylic alcohol **57**, was obtained by converting thioester into the corresponding methyl ester and then reduced using Dibal. Swern oxidation of alcohol **57** gave aldehyde which was reacted with

the lithium enolate derived from (*S*)-5-methyl-cyclohexenone giving desired product allylic alcohol **59** along with the diastereoisomer **58**, which was readily removed by chromatography. Oxidation of **59** using Swern conditions gave grandisine D which was treated with 35% aq. NH_3 to obtain grandisine B.

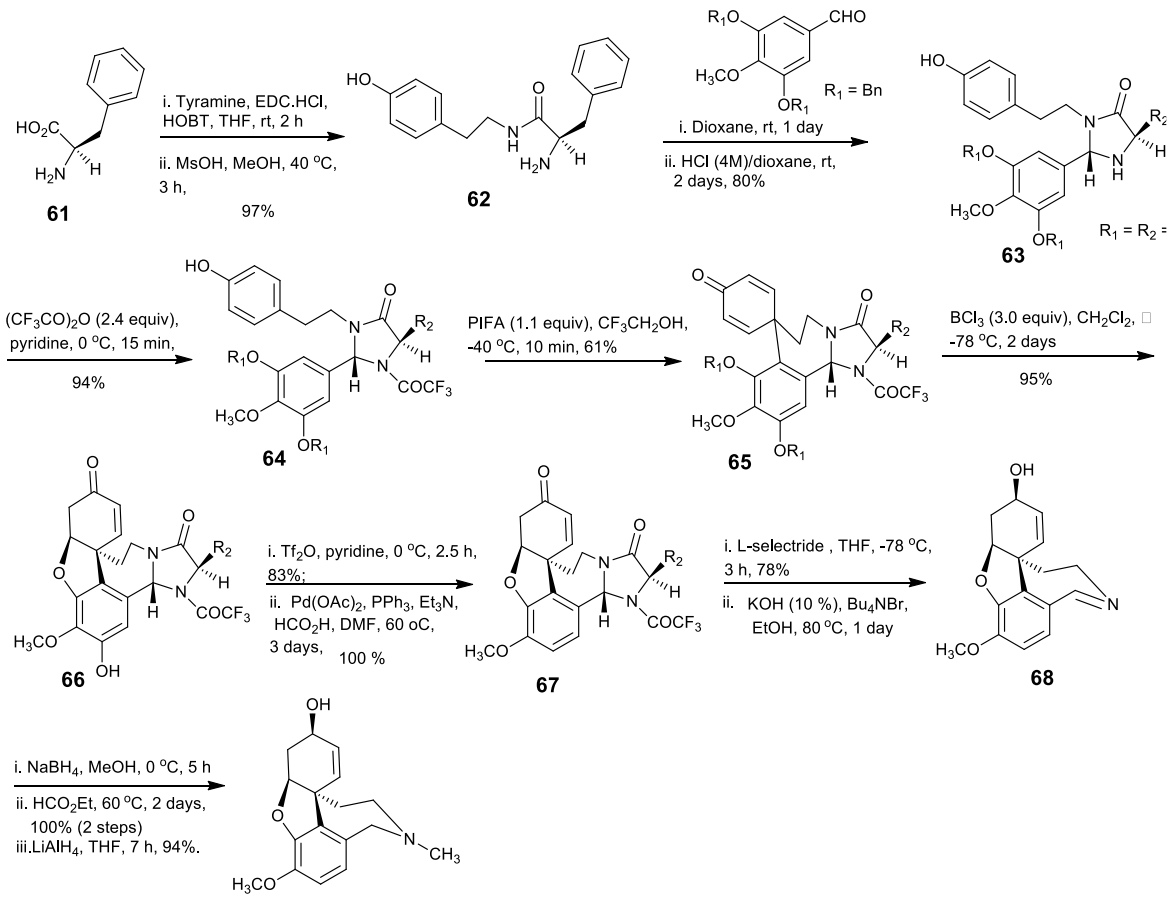


Scheme 10: Total synthesis of (-)-Quinocarcin



Scheme 11: A biomimetic total synthesisthe of (-)-Grandisine B from (+)-Grandisine D

Kodama *et al.* [2004] reported a new asymmetric synthesis of (-)-galanthamine through remote asymmetric induction with a chiral imidazolidinone auxiliary derived from phenylalanine (Scheme 12). (*R*)-N-Boc-D-phenylalanine (**61**) was first condensed with tyramine followed by removal of the N-Boc gaving the amine **62**. Upon treatment with 3,5-dibenzyloxy-4-methoxybenzaldehyde and in the presence of 4M hydrochloric acid, the amine was transformed into the desired imidazolidinone **63** 80% yield. The secondary amino group was protected with a trifluoroacetyl group which underwent PIFA mediated phenolic oxidative coupling in trifluoroethanol resulted in **65.** Debenzylation followed by an intramolecular Michael addition of **65** proceeded smoothly to give the single diastereomer **66**, which was readily converted to galanthamine after removal of phenolic hydroxy group, stereoselective reduction of the enone, alkaline hydrolysis of the chiral imidazolidinone auxiliary, reduction of the imine with sodium borohydride, and N-methylation of the product.

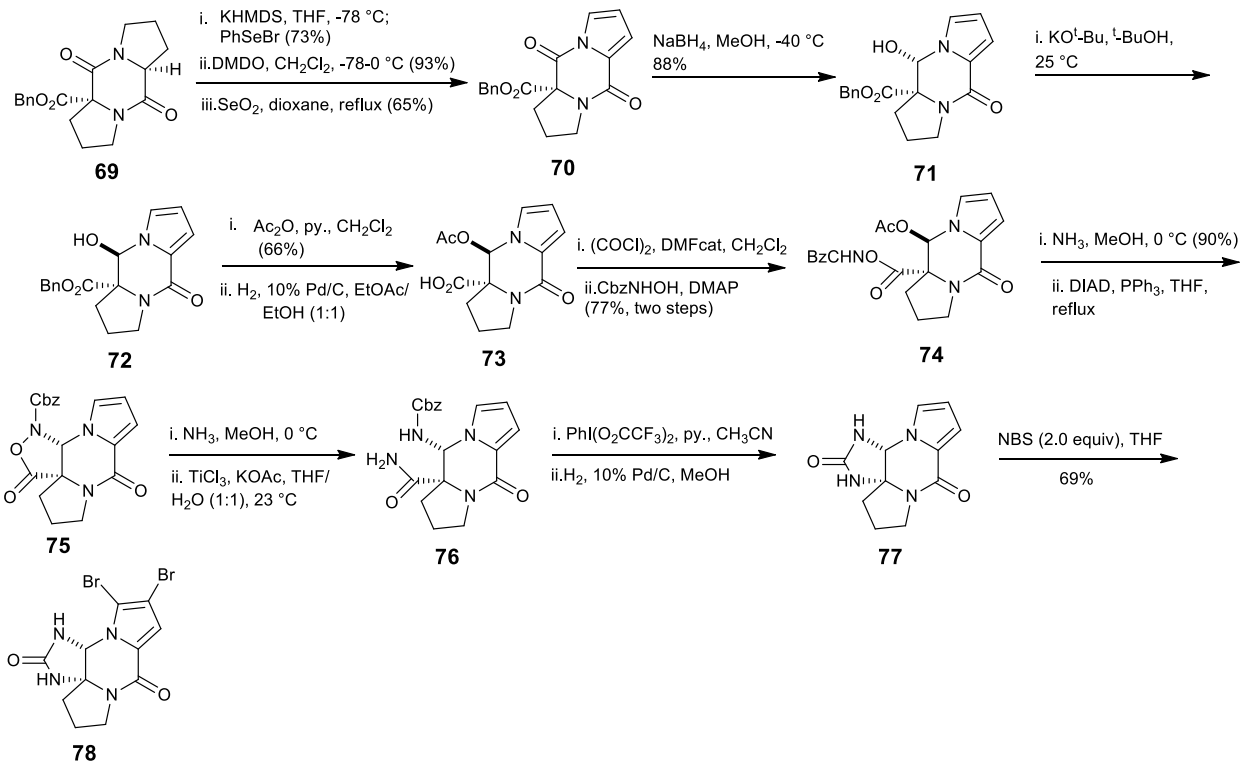


Scheme 12: Asymmetric synthesis of (-)-galanthamine

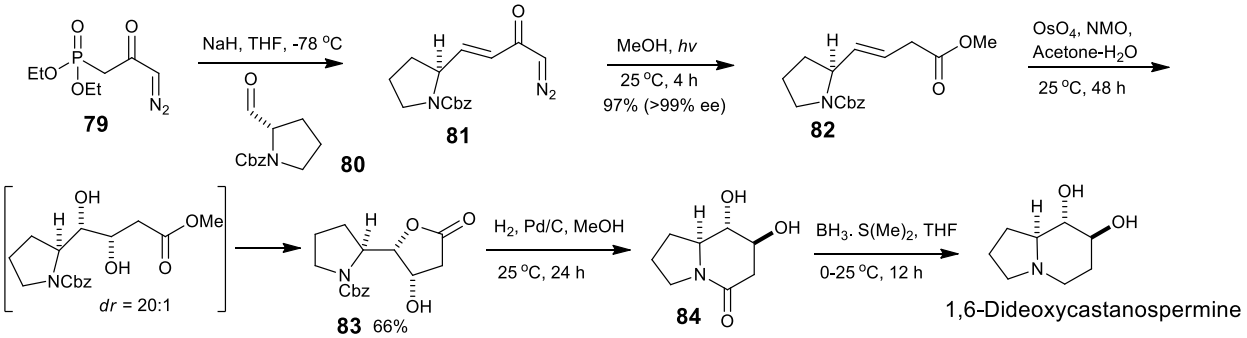
Poullennec *et al*. [2003] described enantioselective total synthesis of (+)-Dibromophakellstatin starting from (*S*,*S*)-cyclo (Pro, Pro) **69**, which was synthesized from

less expensive L-proline (Scheme 13). Acetylation and debenzyllation of **72,** which was subsequently coupled with benzyl *N*-hydroxycarbamate to give the hydroxamate **74**. Following aminolysis and exposure of the *N*-hydroxy ester to Mitsunobu conditions, obtained tetracyclic intermediate **75,** which was immediately subjected to aminolysis and then N-O bond cleavage with $TiCl_3$ to deliver β-amino amide **76**. Pleasingly, amide smoothly underwent Hofmann rearrangement and in situ cyclization which was hydrogenolyzed, followed by bromination directly to deliver (+)-dibromophakellstatin.

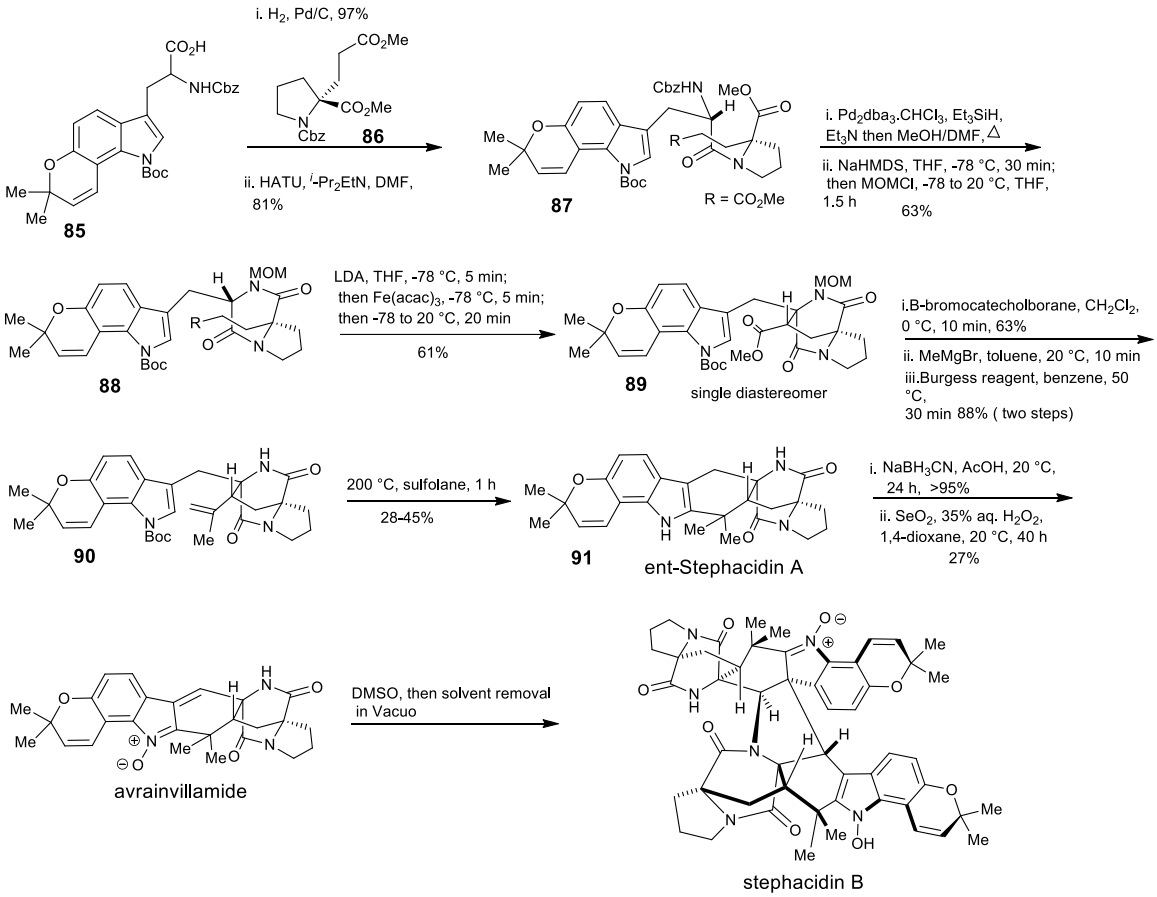
Bernardim *et al.* [2012] reported a versatile and concise approach for the stereoselective total synthesis of 1,6-dideoxyepicastanospermine and 1-deoxy-8,8a-diepicastanospermine and formal synthesis of pumiliotoxinin four to six steps from Cbz-prolinal **80**, and a diazophosphonate **79**. The key steps involved a Wolff rearrangement of **81**, in the presence of MeOH, followed by a stereoselective dihydroxylation with OsO_4/NMO to provide lactone **83.** The removal of the Cbz protecting group from lactone **83** in the presence of H_2/Pd, followed by amide reduction in the presence of $BH_3{\cdot}SMe_2$ furnished 1,6-dideoxyepicastanospermine in a 71% yield (Scheme 14).



Scheme 13: Total synthesis of (+)-Dibromophakellstatin



Scheme 14: Total synthesis of 1,6-dideoxyepicastanospermine

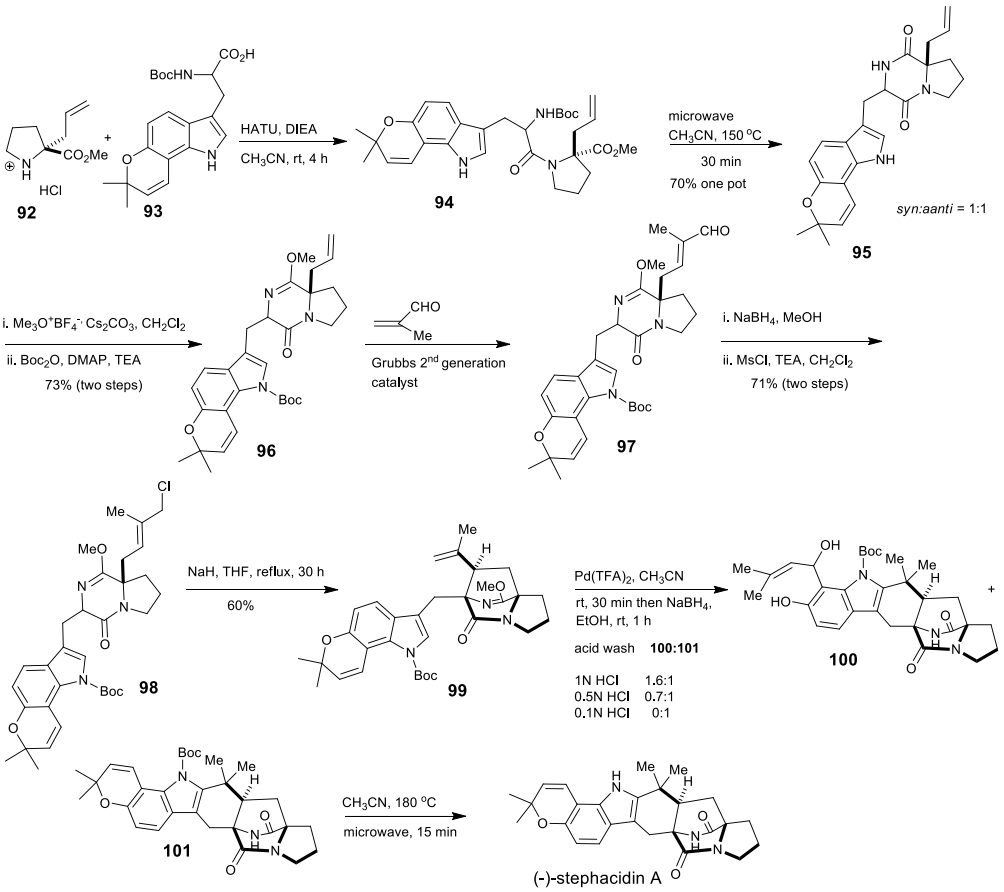


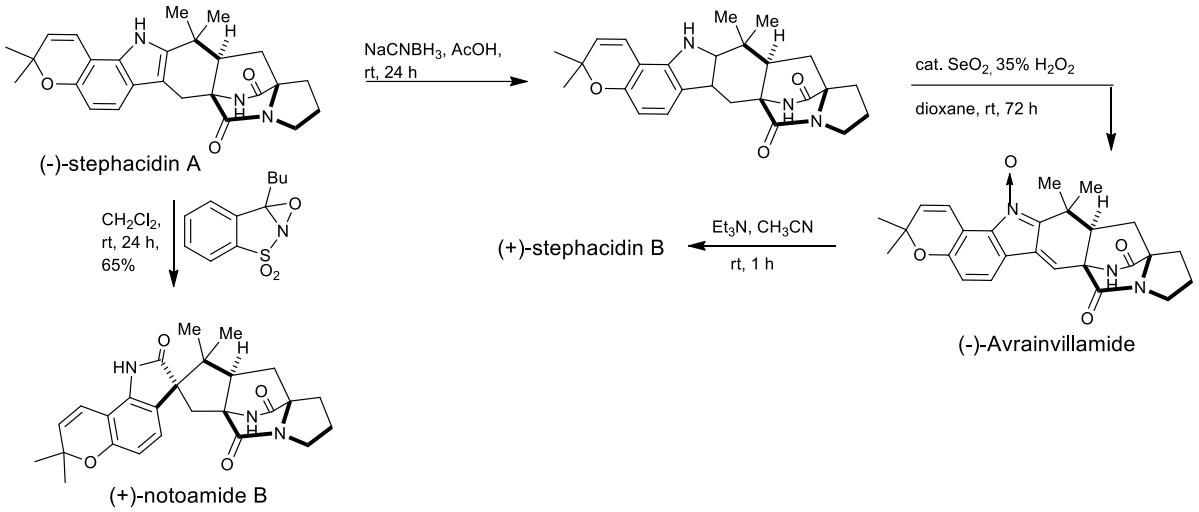
Scheme 15: Total synthesis of avrainvillamide and the stephacidins

Baran *et al.* [2006] presented a total synthesis of avrainvillamide and the stephacidins starting from the tryptophan **85**, and proline **86** derivatives (Scheme 15). The reductive removal of the Cbz group of **86** followed by peptide coupling with **85**, furnished amide **87.** Chemoselective deprotection of the Cbz group of **87,** followed by dissolution and heating in a mixed solvent system of methanol and DMF gave diketopiperazine (DKP) ring system **88**, which was protected with MOM group under standard conditions. The ester **88** reacted smoothly with LDA, followed by $Fe(acac)_3$ to furnish **89** as a single diastereomer in 61% yield. After MOM group deprotection, the resulting free DKP was treated with an

excess of MeMgBr to furnish an intermediate tertiary alcohol that dehydrated upon treatment with the Burgess reagent furnishing **90** in 88% overall yield which underwent Friedel-Crafts alkylation in the presence of sulfolane at 200 °C to isolate stephacidin A (**7**). Reduction of the indole in stephacidn A, followed by SeO_2/H_2O_2 mediated oxidation was capable of converting **91,** into avrainvillamide which was spontaneously dimerized to stephacidin B by simply dissolving in DMSO and drying *in* V*acuo*.

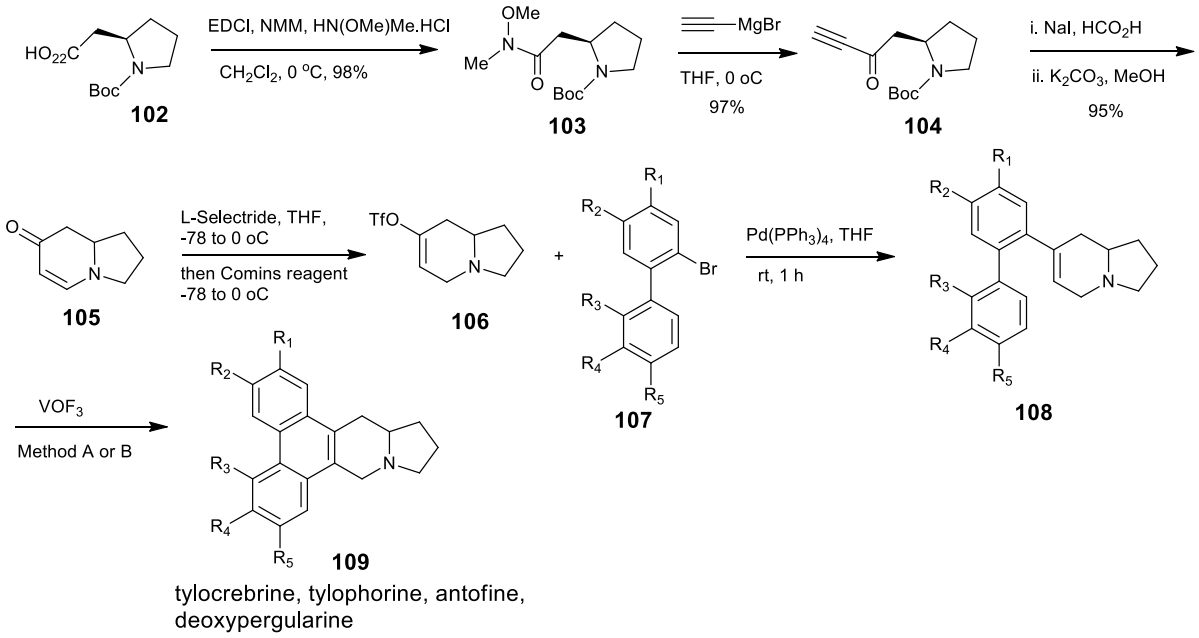
Williams *et al.* [2007] described a concise asymmetric total synthesis of the fungal metabolites (-)-stephacidin A, (+)-stephacidin B, and (+)-notoamide B (Scheme 16). Key features of these total syntheses included a facile synthesis of (*R*)-allyl proline methyl ester, (**92**) derived from (*S*)-proline, a revised route toward the pyranoindole ring system, (**93**) a novel cross metathesis strategy for the introduction of important functional groups in **97**, and an S_N2' cyclization to form the [2.2.2] bridged bicyclic ring system to afford **99**. The palladium-mediated cyclization of **99,** two products (**100/101**) was formed as an inseparable mixture following quenching with acid. Heating of the crude product in acetonitrile using the microwave reactor afforded (-)-stephacidin A (**92**) as an amorphous white powder. The (-)-stephacidin was used to complete the synthesis of (-)-avrainvillamide, (+)-stephacidin B, and (+)-notoamide B.





Scheme 16: Total syntheses of (-)-stephacidin A, (+)-stephacidin B, and (+)-notoamide B

Niphakis *et al,* described a highly convergent strategy to prepare phenanthroindolizidines **109**, involving Suzuki-Miyaura coupling to prepare biaryl **107**, Negishi coupling to synthesis **108** and in the final step, VOF_3-mediated aryl-alkene coupling of **108**, afforded regioselective preparation of C5-substituted phenanthroindolizidines for the first time. This strategy was applied to the synthesis of eight natural and unnatural members in this class and to explore structure-activity relationships (Scheme 17).



Scheme 17: Total synthesis of Tylocrebrine and related natural products

Conclusion:

Total chemical synthesis of natural products and related diversity will play a major role towards contribution in biology and medicine. Naturally demand will be to access bioactive compounds with single isomer. Towards this objective, the use of readily available, enantiomerically pure chiral pool has provided its utility as a platform for asymmetric total synthesis of bioactives. The medicinal and combinatorial organic chemists have devised so many ways in their quest for huge numbers of novel and diverse molecules for the human health care, but the source of chiral pool mainly α-amino acids to target molecules in chiral synthesis will be playing an important role which offers new biomedical breakthroughs and cures for disease.

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UNDERSTANDING ISOTOPES

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Abstract:

Isotopes, which are versions of elements varying in neutron numbers, have a crucial function in unraveling complex biological processes. Their unique atomic characteristics empower scientists to monitor and explore metabolic pathways, nutrient circulation, and cellular activities. This summary explores the diverse uses of isotopes in the realm of biology, underscoring their importance in pushing forward our comprehension of life's core mechanisms.

The biological applications of radioactivity had, therefore, to wait for the above development of such instruments as the cyclotron and the nuclear reactor that made possible production of artificial radioactive materials. Using the nuclear reactor, it became possible to produce radioisotopes for those elements, which are commonplace in biology. for example, carbon, phosphorous, sulphur, hydrogen etc. Since then, the use of radioactive isotopes in biology has become legion, so much so that it is difficult today to imagine of an experimental setup without their use.

Introduction:

Distinctive atomic properties of isotopes enable researchers to track and investigate metabolic pathways, nutrient cycling, and cellular dynamics. This abstract delves into the multifaceted applications of isotopes in biology, highlighting their significance in advancing our understanding of life's fundamental mechanisms. Isotopic ratios serve as tracers of environmental changes, aiding in the assessment of climate impacts on ecosystem structure and function. However, before describing their use and the instrument involved, it would be proper to consider the structure of the atom and ask why some atoms are radioactive.

An atom is composed of a positively charged nucleus around which the electrons settle into the charged clouds. The mass and the stability of the atom reside predominantly in the nucleus. Atomic nuclei are composed of two major components; protons which are

positively charged, and neutrons which are neutral. The number of electrons (negatively charged) in an atom is always equal to the number of protons in the nucleus thereby making the atom electrically neutral. This number is known as the atomic number (Z). Neutrons are uncharged particles with a mass approximately equal to that of a proton. The sum of protons and neutrons in a given nucleus is known as the mass number (A). Thus, A=Z+N Where N denotes the number of neutrons. Structure of atom figure 2 (reference internet).

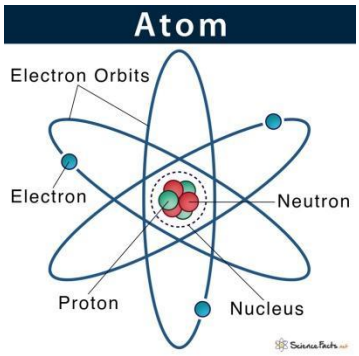

Figure 1: Structure of an atom

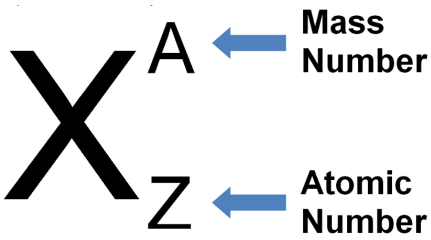

Figure 2: Representation of mass number and atomic number

Isotope

The word isotope is derived from the Greek 'iso' (same) and 'topos' (place) and thus signifies occupying the same position in the periodic table. It was the chemist Soddy in 1913 who first established the existence of atoms of the same element with different atomic weights and called them isotopes. Isotopes are atoms of a given element, with identical numbers therefore the same chemical characteristics, but with different number of neutrons and consequently different atomic mass. The number of stable isotopes that elements possess varies widely, for example, calcium possesses six, and carbon has three, while sodium has only one.

In below figure the isotopes of hydrogen are given:

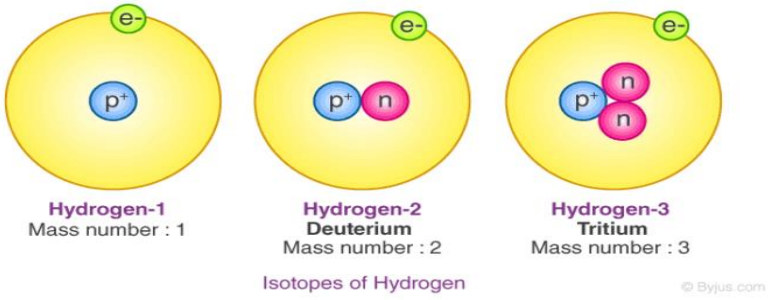

Figure 3: Isotopes of hydrogen

Isotopes are of two types:- stable and unstable (radioactive) isotopes. Stable isotopes are non-radioactive variants of elements that have the same number of protons but differing numbers of neutrons in their atomic nuclei. These isotopes do not undergo radioactive decay and remain stable over time. Stable isotopes play a crucial role in various scientific fields, including chemistry, biology, geology, and environmental science. They are used for tracing pathways, understanding nutrient cycling, studying climate change, and investigating metabolic processes. Radioisotopes, also known as radioactive isotopes, are variants of chemical elements that exhibit unstable atomic nuclei. This instability causes them to undergo radioactive decay, emitting particles and energy in the form of radiation as they transform into more stable isotopes. Radioisotopes have a range of applications in various fields, including medicine, industry, research, and environmental monitoring.

Radioactivity

As its name implies, radioactivity is the act of emitting radiation spontaneously. This is done by an atomic nucleus that, for some reason, is unstable; it "wants" to give up some energy in order to shift to a more stable nucleus.

An unstable nucleus will decompose spontaneously, or decay, into a more stable configuration but will do so only in a few specific ways by emitting certain particles or certain forms of electromagnetic energy. Radioactive decay is a property of several naturally occurring elements as well as of artificially produced isotopes of the elements. The rate at which a radioactive element decays is expressed in terms of its half-life; i.e., the time required for one-half of any given quantity of the isotope to decay. Half-lives range from more than 1024 years for some nuclei to less than 10−23 seconds. The product of a radioactive decay process—called the daughter of the parent isotope—may itself be unstable, in which case it, too, will decay. The process continues until a stable nuclide has been formed.

Detection techniques of radioactivity

It is the method by which radioactivity is measured or detected. When talking about radiation detection instruments, there are three types of detectors that are most commonly used, depending on the specific needs of the device. These are: Gas-Filled Detectors, Scintillators, and Solid State detectors.

1. GM Counter

Geiger counter is a device which is used to detect and measure particles in ionized gases. It is widely used in applications like radiological protection, radiation dosimetry, and

experimental physics. It is made up of a metallic tube, filled with gas and a high voltage range of multiples of 100V is applied to this gas. It detects alpha, beta, and gamma particles. When radioactive isotopes are used in medical research work on humans, it is important to make sure that the amount of radioactive material administered to human subjects is as little as possible. In order to achieve this, a very sensitive instrument is necessary to measure the radioactivity of materials. A 'particle detector' to measure the ionizing radiation was developed by Geiger and Muller in the year 1928 and they called it a 'Geiger Muller Counter' which in short is known as the 'GM counter'.

In the large and dominant use as a hand-held radiation survey instrument, it would be one of the planet's renowned radiation detection instruments. The Geiger counter would contain a Geiger-Müller tube, the element of sense that detects the radiation and the electronics that process and would provide the result. The Geiger-Müller tube is filled with a gas such as helium, neon, or argon at the pressure being the lowest, where there is an application of high voltage. There would be the conduction of the electrical charge on the tube when a particle or photon of incident radiation would turn the gas conductive by means of ionization.

2. Scintillation Counter

A scintillation Counter is an instrument that is used for measuring ionizing radiation. "It comprises the scintillator that generates photons in response to incident radiation", a PMT tube is used to convert an electronics and electric signal to process the signal.

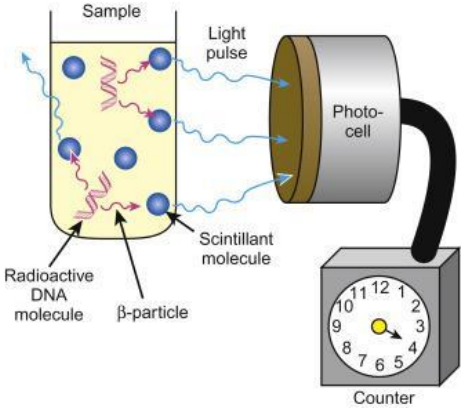

Figure 4: Scintillation counter

A scintillation counter is used to detect gamma rays and the presence of a particle. It can also measure the radiation in the scintillating medium, the energy loss, or the energy gain. The medium can either be gaseous, liquid, or solid. The scintillator counter is

generally comprised of transparent crystalline material such as glasses, liquids, or plastics. One sector of the scintillators is placed (optical contact) with the pin code.

A charged particle loses energy when passing through the scintillator thus leaving the trail of excited molecules and atoms. A rapid interatomic transfer of electronic excitation energy follows, which leads to the burst of scintillator material luminescence characteristics. The scintillation response, when a particle stops leading to the light output. The energy loss of a particle is measured when a particle passes completely through a scintillator.

Limitations of scintillator counter:

While the expense for each sample in scintillation counting holds significance, the benefits of versatility, sensitivity, simplicity, and precision outweigh this concern for the majority of applications. The major drawback associated with scintillation counting is quenching, which arises when the previously explained energy transfer process encounters disruption. The substantial cost of scintillation counting is largely attributed to the substantial effort needed to rectify this quenching effect.

Radiobiology

Radiobiology, also known as radiation biology, is a branch of science that deals with the study of the biological effects of ionizing and non-ionizing radiation on living organisms. The study of radiobiology has far-reaching implications, ranging from medical applications to environmental and occupational safety. For instance, it plays a crucial role in the development and refinement of radiation therapy for cancer treatment, where precise doses of radiation are used to target and destroy cancer cells while sparing healthy tissues. Additionally, radiobiology is essential in understanding the risks associated with exposure to ionizing radiation, guiding the establishment of radiation protection measures in medical, industrial, and environmental settings.

Ionization

Ionization is a fundamental process in which an atom or molecule gains or loses one or more electrons, resulting in the formation of charged particles known as ions. Radioactivity is a natural and spontaneous process by which certain unstable atomic nuclei emit radiation in the form of particles or electromagnetic waves. The first discovered radioactive elements were heavy elements like Uranium.

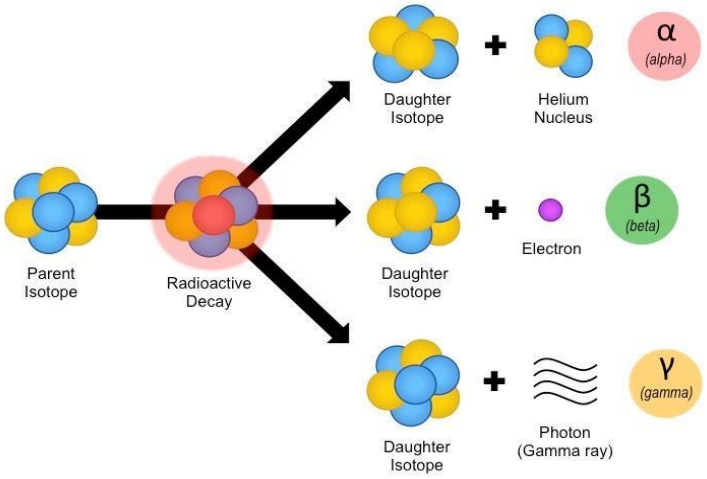

Figure 5: Representation of types of radioactive decay

- Alpha particle: It is composed of two protons and two neutrons, which together form a helium nucleus. It is heavier than other radiated particles. When alpha emission occurs in an atom, its atomic number (number of protons) and mass number (sum of number of protons and neutrons) decreases by 2 and 4 respectively.

$$Pu^{239}{}_{94} \rightarrow U^{235}{}_{92} + He^{4}{}_{2}$$

- Positron emission: Positron emission, also known as plus beta decay (β+ decay), is a type of radioactive decay that occurs in some unstable atomic nuclei. This process is controlled by weak nuclear forces. A proton gets converted into a neutron i.e. there is no change in mass number. Here the ratio of mass number to atomic number increases. For example:

$$K^{38}{}_{19} \rightarrow Ar^{38}{}_{18} + {}_{+1}{}^{0}\beta$$

- Negatron emission: Negatron emission takes place by release of β_{-ve} particle when a neutron gets converted to a proton. The ratio of mass number to atomic number decreases.

$$C^{14}{}_{6} \rightarrow N^{14}{}_{7} + {}_{-1}{}^{0}\beta$$

- Electron capture: Electron capture is another type of radioactive decay process that can occur in unstable atomic nuclei. Electrons from a k-shell are captured by protons. In this process either X-ray or γ-ray is emitted.

$$Ar^{38}{}_{18} + {}_{-1}{}^{0}e \rightarrow Cl^{38}{}_{17} + {}^{0}{}_{0}\nu$$

- Gamma emission: Gamma rays are high-energy electromagnetic waves, or photons, with no mass and no electric charge. They have high penetration power but show less degree of ionization.

$$Pu^{239}{}_{94} \rightarrow Pu^{239}{}_{94} + {}^{0}{}_{0}\gamma$$

Units of radioactivity

The curie (Ci) is the unit used to measure radioactivity. Its definition equates the rate of nuclear disintegrations per second in a given amount of radioactive material to the rate found in 1 gram of radium. The SI unit of radioactivity is becquerel (Bq). The curie is a substantial measurement, whereas tracer uses only require small amounts, specifically in millicuries (mCi). 1 curie = 3.7×10^{10} Bq.

Interaction with matter

Alpha-particles: Alpha-particles have energy of 3-8 MeV. They have low velocity due to higher mass and double positive charge. They show high interaction with electrons of atoms with which they collide and tend to ionize them. They have low penetration power but high ionizing power. They can travel only up to a few centimeters in the air. In majority of the cases, the result of alpha-particle interaction is ionization hence, classified as ionizing radiation.

Negatrons: Electrons are tiny particles that move swiftly and possess a solitary negative charge. Their interaction with matter leads to ionization. Their ionizing power is less and penetration power is more than alpha particles. The possibility of interaction of atoms with negatrons is less due to their small size. Negatrons emitting isotopes have a distinct energy spectrum. Also, the maximum energy level differs from one isotope to the other.

X-rays and γ-rays: X-rays and γ-rays are electromagnetic radiations. They do not have charge or mass. Their interaction with matter causes both excitation and ionization.

Bremsstrahlung radiation: Bremsstrahlung radiation refers to the electromagnetic radiation emitted when charged particles, such as electrons, experience acceleration or deceleration due to the electric fields of atomic nuclei as they pass through matter.

Use of isotopes in biology

Isotope dilution studies: Isotope dilution is a widely employed method in analytical chemistry and metrology for precisely establishing the concentration of a substance within a sample. This is a quantitative technique. It is done by addition of specific radioactive isotopes into the given sample or system followed by isolating it from the sample. Concentration of the isotope is calculated to determine its activity in the system.

Membrane transport studies: To study permeability of various membranes, isotopes can be used. Use of isotopes is preferred over organic compounds and electrolytes because concentration of the tracer does not affect the medium concentration. Membrane transport studies using isotopes involve utilizing isotopically labeled compounds to investigate how

substances move across cell membranes. Some examples are as follows: The evidence that in kidney, liver and RBCs, entry of phosphate into the cell is brought about by formation of ATP on the surface of the cell, was shown by using ^{32}P.

Metabolic studies: Isotopes are widely used in metabolic studies. Identification and mechanisms of various metabolic pathways like Nucleic and fatty acid synthesis, Kreb's cycle and cholesterol metabolism. The most widely used isotope is C^{14}. Acetate molecules labeled with C^{13}, C^{14} and deuterium have been used for cholesterol metabolism study by Bloch. By introducing acetate labeled with the 14C isotope, either on the methyl (CH_3) cluster or the carboxyl (COO) cluster, researchers have determined the source of carbon atoms within the complete structure of cholesterol molecules. Radioactive materials can be detected on paper or thin-layer chromatography using either a Geiger–Müller chromatograph scanner or through the method of autoradiography.

Mineral metabolism: Mineral metabolism refers to the processes by which minerals, also known as essential trace elements or micronutrients, are acquired, absorbed, transported, utilized, and excreted within the body. The reactions that take place in the bone relating to calcium and phosphorus have been studied using ^{45}C and ^{32}P. Isotopes are incorporated into mineral compounds and ingested by study participants. By monitoring the isotopic label, researchers can track how much of the ingested mineral is absorbed by the body and how quickly. Isotopes are used to investigate how minerals are utilized within cells and tissues. For instance, stable isotopes of metals like iron and zinc can be tracked as they bind to enzymes and participate in various biochemical reactions.

Determination of metabolic turnover times: Metabolic turnover time, alternatively termed metabolic half-life signifies the duration needed for a substance like a molecule, compound, or medication to undergo metabolism or be eliminated from the body through diverse physiological mechanisms. A collection of rats is administered a radioactive amino acid and observed for a 24-hour period, during which the majority of the amino acid becomes a part of proteins through assimilation. Subsequently, the rats are euthanized at appropriate intervals, and the radioactivity present in specific organs or tissues is measured. This approach allows for the determination of the pace at which protein metabolic turnover occurs. Liver cells typically exhibit a half-life of approximately 5 to 6 days. The technique can be equally employed for analyzing carbohydrates, lipids, and other components within cells.

Radiodating: "Radiodating," also referred to as radiometric dating, is an approach utilized to ascertain the age of geological materials such as rocks, minerals, fossils, and more. This methodology involves examining the decay process of radioactive isotopes. It is based on the principle that specific unstable isotopes of elements progressively undergo radioactive decay, leading to their transformation into more stable isotopes. Carbon-14 is used to date organic materials that were once part of living organisms, such as wood, bones, and textiles. It is effective for dating relatively recent events up to around 50,000 years ago.

Diagnosis: Different radioisotopes are chosen based on their characteristics and the target area of diagnosis. ^{133}I is used to analyze kidney functioning. ^{51}Cr is used to detect anemia and also to determine blood volume. Yttrium-90 is used for cancer therapy. Radioimmunoassay (RIA) is a highly precise laboratory method designed for quantifying the concentration of specific substances found within biological samples.

Autoradiography: Autoradiography is a laboratory technique used to visualize the distribution and localization of radioactively labeled molecules within a sample, such as cells or tissues. Isotopes that have been used for autoradiography include ^{3}H, ^{35}S, ^{14}C and ^{32}P. Periodically, samples are taken out from the solution. For smaller tissues, these samples are divided into sections and placed onto glass slides or grids. Autoradiography has been widely used in various fields, including molecular biology, cell biology, neurology, and pharmacology.

Metabolic turnover determination time: Metabolic turnover determination time refers to the period required to measure the rate at which a particular substance, such as a molecule or compound, undergoes turnover or transformation within a biological system.

Restrictions of radiotracer experiments

Different isotopes undergo the same reactions at different rates. This phenomenon is called isotope effect. While administering the tracer to the test organism, its chemical levels are altered and this may distort the results. Radiotracer experiments are subject to stringent regulations and licensing requirements to ensure proper handling, storage, and disposal of radioactive materials. As radioisotopes decay over time, their signal intensity decreases. This requires careful timing to capture accurate data.

Radiation safety limits: Absorbed radiations tend to cause release of free radicals. These are harmful as they affect the cellular components, mutating the genetic material and cause changes in protein structure. Radiation hazard is measured in ‘exposure’. Exposure is the ionization of the air. The therapeutic ratio is calculated by comparing the dose of a

treatment that produces a therapeutic effect (the minimum effective dose) to the dose that causes toxic or adverse effects (the minimum toxic dose). The unit of exposure is Rotagen. One Rotagen is the amount of radiation sufficient to produce a charge of 2.58 104 coulombs (kg air)1. Since this unit is based on X-rays or gamma rays, rad (radiation absorbed dose) was introduced. This unit describes the damage caused in living organisms more accurately. A correction factor W (weighing factor) is calculated by comparing effects of other types of radiation to that of X-rays.

A SI unit gray (Gy) equivalent to 100 rads was introduced. The unit of absorbed radiations ('sievert', represented as 'Sv') is the product of gray (Gy) and weighing factor (W). 'Dose rate' is the rate of delivery of the dose. The dose rate can vary depending on the type of radiation, the source of radiation, and the specific circumstances.

Cell survival curves

Cell survival curve is a plot of surviving cells against the dose. The curve is often sigmoid on a linear scale. Here terms such as ED50 and ED90 are used. ED50 (effective dose) refers to the dose that kills 50% of the cell population. Cell survival curves can be determined in-vivo as well as in-vitro. More frequently, the curves are plotted on a log scale as it allows comparing least cell survivals. The curve is affected by the radiation type. Heavily ionizing radiations show exponential dose function and turn out to be a straight line on a log-linear plot. Less ionizing radiations show a shoulder region preceded by a slope.

Types of radiation damage

Radiation can cause damage to cells in numerous ways. The damage can be lethal, resulting in complete cell death, sub-lethal, which can be repaired by the cell and lastly potentially lethal damage which can be repaired based on the environmental conditions of the cell. Radiations generate tissue level effect, carcinogenic effect as well as genetic effect.

Oxygen effect

Gray *et al.* (1953), Wright & Howard Flanders (1957) stated that the amount of molecular oxygen manipulates the response of cells to ionizing radiations. Oxygen enhancement ratio (OER) is the ratio of doses in absence of oxygen and in presence of oxygen to achieve the same results.

$$OER = \frac{Dose\ in\ absence\ of\ oxygen}{Dose\ in\ presence\ of\ oxygen}$$

Studies have shown that the X-ray OER is near to 3. The oxygen effect is based on the fact that oxygen plays a significant role in the repair mechanisms that cells use to recover from radiation damage. Tumors frequently contain sections characterized by inadequate oxygen levels, which are referred to as hypoxic regions. These areas show increased resilience to radiation therapy due to the diminished effectiveness of treatment caused by the reduction in oxygen-dependent damage from radiation. Reoxygenation refers to the mechanism wherein previously hypoxic cells become oxygenated following radiation exposure. This occurs as a result of the elimination of oxygen-sensitive cells from the tumors, which are responsive to radiation.

Conclusion:

Isotopes are utilized in a range of applications, including radiolabeling molecules for tracing metabolic pathways, studying DNA replication and protein synthesis, and investigating the dynamics of cellular components. Stringent safety protocols are in place to minimize risks associated with radiation exposure. Isotopes serve as indispensable tools that empower scientists to explore the intricacies of life processes, from molecular mechanisms to the broader ecosystem.

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PROMISE OF FUNCTIONALISED FULLERENES IN MEDICINE

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Abstract:

Functionalized fullerenes have shown immense relevance in the field of medicine and biology as a result of their distinctive physical, chemical and electronic properties. While fullerenes per se have a limitation of great hydrophobicity due to the presence of numerous carbon atoms, functionalizing them with certain chemical groups can adjust their polarities and further enable their water solubility and biological targeting properties. In this article, we focus on the promise of such functionalized fullerenes in medicine and drug delivery processes.

Keywords: fullerenes, functionalized fullerenes, hydrophobicity, medicine, drug delivery

Introduction:

About four decades ago, in 1985, a new allotrope of carbon i.e. fullerene was discovered by Kroto, Curl and Smalley [1]. More specifically, they discovered and provided the structure of C_{60} fullerene and named it as Buckminsterfullerene, after the name of architect Buckminster Fuller who popularized geodesic domes in the late 1940s. This also led to Kroto, Curl and Smalley winning the 1996 Nobel Prize for Chemistry.

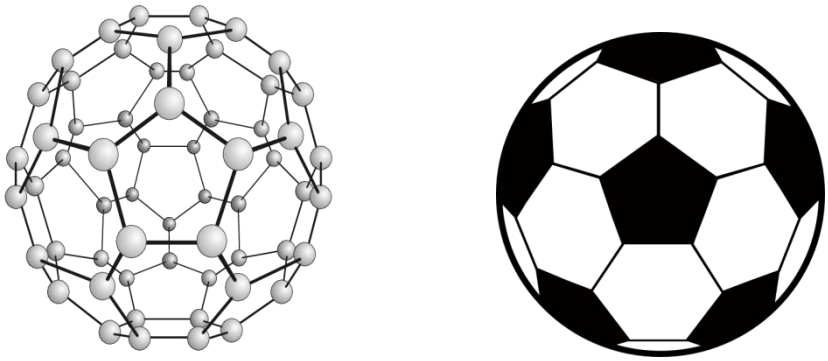


Figure 1: Structure of C_{60} molecule discovered by Kroto, Curl and Smalley compared to that of a football/soccer ball containing 12 pentagons and 20 hexagons: a truncated icosahedron structure

Since then, extensive research studies have been carried out on fullerenes leading to discoveries of types other than the C_{60} molecule: C_{70}, C_{76}, C_{84} and others. These carbon

clusters have attracted the attention of scientists across all disciplines because of their unique structure and unparalleled physico-chemical properties [2]. Chemically, it behaves equivalent to an electron deficient alkene giving cycloaddition reaction products [3].

A fullerene molecule gets readily soluble in hydrophobic organic solvents and shows negligible solubility in aqueous or biologically compatible solvents. In fact, fullerenes have been found to form aggregates in such polar solvents. This property poses as an obstacle for fullerenes to act as promising candidates for biomedical applications, given that the primary constituent of our blood is water and medicines when taken, need to get dissolved into blood for their proper action. Thus, the idea of functionalisation of fullerenes with hydrophilic groups came into being. These hydrophilic groups added to fullerenes participate in hydrogen bonding with water molecules, thus enhancing their water solubility and applicability in the field of biology and medicine.

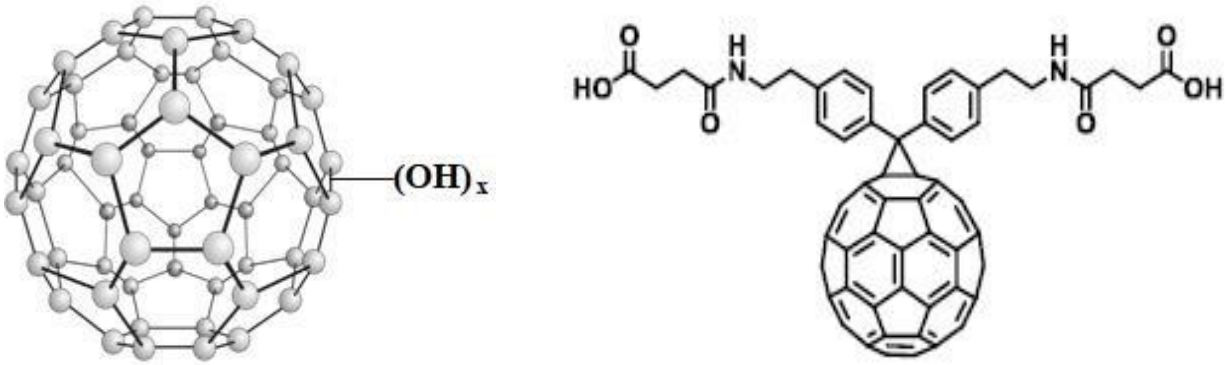
Figure 2: Schematic representing several promising applications of functionalized fullerenes in the field of biology and medicine

Exohedral and Endohedral Functionalisation

Functionalisation of fullerenes i.e. addition of chemical groups can either be carried out on the exterior of the fullerene cage (exohedral) or in the interior of the cage (endohedral).

An example of exohedral functionalisation is hydroxylation, wherein a number of hydroxyl (OH) groups are added to the fullerene cage leading to enhanced water solubility. The resulting molecules are called as Polyhydroxy Fullerenes (PHF) or fullerenols or fullerols. It is reported that PHFs have the ability to reduce oxidative stress in our body by scavenging reactive oxygen species (ROS) [4] which would otherwise lead to ageing, neuro-degeneration and premature death of cells.

An important water soluble functionalized fullerene (Fig.3(b)) was discovered by Wudl and coworkers in 1993 which has the potential to inhibit the human immunodeficiency virus-1 protease (HIVP) due to its steric as well as chemical complementarity with the active site. Apart from this interaction between fullerene and the active site of the enzyme, it has also been found that fullerenes inhibit HIV-1 by disrupting the maturation stage [5] of the virus as well.



(a) **(b)**

Figure 3: (a) Structure of a Polyhydroxy Fullerene (PHF) molecule, x= 12 to 26
(b)Functionalized Fullerene synthesised by Wudl and co-workers

Encapsulation of atoms and atomic clusters within the fullerene cage, known as endohedral functionalisation of fullerenes give rise to numerous novel functional molecules and materials. When the trapped atom is a metal, the resulting molecules are called endohedral metallofullerenes (EMFs) which are used in tumour therapy, although not extensively due to some risk of metal toxicity. The first metallofullerenes produced in macroscopic amounts were done by Chai *et.al* by using laser vaporisation techniques [6].
Literature suggests that majority of the synthesised EMFs are based on gadolinium atoms entrapped within the fullerene cage. These have found applications as contrast agents in

magnetic resonance imaging (MRI) as a result of their high paramagnetic and high relaxivity properties [7].

Even though most commonly used MRI contrast agents contain Gd (III) ions, but gadolinium in its ionic form is dangerous to the human body as it can accumulate in various internal organs and can block vital calcium channels. Murphy *et.al* encapsulated Gd_3N atomic cluster into a C_{80} fullerene cage to synthesise a molecule named $Gd_3N@C_{80}$ which was used in the *in vitro* labelling and *in vivo* tracking of human amniotic fluid-derived stem cells within lung tissue [8]. Wilson *et.al* reported the synthesis and use of water soluble gadolinium metallofullerenes, $Gd@C_{60}[C(COOH)_2]_{10}$ as MRI contrast agents [9].

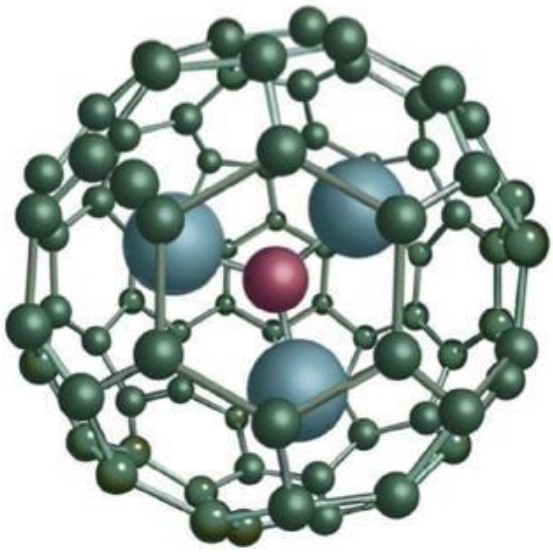


Figure 4: Structure of Gd_3N atomic cluster encapsulated into a C_{80} fullerene cage [8]

Photodynamic Therapy (PDT)

Photodynamic therapy involves the use of non toxic photosensitisers and non hazardous visible light to generate reactive oxygen species (ROS) which can further destroy unwanted cells (cytotoxic). This technique is used as cancer therapy for smaller lesions and carcinomas.

Fullerenes have immense potential to behave as excellent photosensitisers in photodynamic therapy. This is possible for two main reasons: firstly, they can absorb significant amount of visible light owing to the presence of condensed aromatic rings and extended conjugated system and secondly, efficient intersystem crossing to a long lived triplet state [10]. They can produce singlet oxygen with great efficiency. Mroz *et. al* has reported that C_{60} molecule when functionalized with a single pyrrolidinium group can

potentially behave as a remarkable photosensitiser and can mediate in killing a panel of mouse cancer cells [10] even at a low concentration of 2**μ**M.

Drug Delivery Processes by Functionalized Fullerenes

Owing to their antioxidant properties and their ability to interact with epidermal keratinocytes, fullerenes can efficiently be used for transdermal drug delivery processes. For the same reason, they can also be used in cosmetics.

Paclitaxel Embedded Buckysomes (PEBs) are self-assembled spherical nanostructures formed from amphiphilic fullerene subunits with the anti-cancer drug Paclitaxel embedded within its hydrophobic pocket. PEBs have the potential to directly deliver the hydrophobic drug to tumour sites and keeping the drug safe from any enzymatic degradation [11].

Future Prospects and Perspectives:

In this short article, we have tried to briefly illustrate that functionalized fullerenes are indeed promising candidates as antiviral agents, anticancerous agents, photosensitisers in photodynamic therapy, antioxidants and as drug delivery materials.

However, we also cannot overlook the numerous trials and research studies that they are yet to undergo so as to introduce them to the pharmaceutical industries in a large scale. The toxicity factor is even now a topic of great discussion, particularly regarding the routes of synthesis of these functionalized fullerenes. More experiments have to be carried out to prove their effectiveness and safety for practical applications. With these points taken care of by both scientists and pharmaceutical industries, it is anticipated that in the coming years, humankind can successfully rejoice the myriad benefits of functionalized fullerenes as biomedical tools.

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A REVIEW ON CADMIUM SELENIDE (CdSe) THIN FILMS DEPOSITION USING DIFFERENT TECHNIQUES AND ITS APPLICATIONS

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Abstract:

The present article describes the review on preparation of CdSe thin films using chemical bath deposition (CBD), successive ionic layer adsorption and reaction (SILAR) and spray pyrolysis techniques. This review article also presents the different applications of CdSe thin films.

Keywords: CdS, thin films, CBD, SILAR, Spray pyrolysis, applications

Introduction:

The metal chalcogenides thin films have been widely studied because of its potential applications in industry field [1].

Cadmium selenide in its wurtzite crystal phase has a bandgap of 1.80 eV, and in zinc blende phase has a bandgap of 1.71 eV [2]. The Cadmium selenide (CdSe) has number of applications in various fields like photovoltaic solar cells, photoconductors [3], photoconductive cell, optoelectronic devices [4], light amplifier, electrophotography [5], thin film transistor, gas sensors [6], LED, biomedical imaging [7].

Synthesis of Cadmium Selenide (CdSe) thin films:

The CdSe thin films were prepared using different techniques like chemical bath deposition, successive ionic layer adsorption reaction and spray pyrolysis methods.

1. Chemical Bath Deposition:

In chemical bath deposition technique the basic equipment, such as a hot plate and magnetic stirrer is required [8]. The chemical bath deposition method has been widely used for the formulation of sulphides, selenides, oxides as well as the ternary compound [9]. Deshpande *et al.* [10] reported the formulation of Cadmium selenide thin films using chemical bath deposition (CBD) method. Fekadu Gashaw Hone *et al.* [11] reported the formulation of cadmium selenide (CdSe) films via chemical bath deposition (CBD) route.

Asogwa *et al.* [12] reported the thin film formulation of CdSe materials through chemical bath deposition (CBD) method. Bijumon C C *et al.* [13] reported the synthesis of

CdSe thin films using chemical bath deposition technique. Paresh Saha *et al.* [14] reported the formulation of thin films CdSe on glass substrate through chemical bath deposition route. Paresh Saha *et al.* [15] reported the formulation of CdSe thin films via chemical bath deposition route.

2. Successive Ionic Layer Adsorption and Reaction (SILAR):

In Successive Ionic Layer Adsorption and Reaction **(**SILAR) technique, the substrate is repeatedly submerged into separately arranged cationic and anionic solutions alternatively in order to produce a thin films [16]. Pathan *et al.* [17] reported the synthesis of CdSe thin films through successive ionic layer adsorption and reaction (SILAR) route. Raut *et al.* [18] reported the formulation of CdSe thin films via SILAR route.

3. Spray pyrolysis method:

The spray paralysis route is used for producing thin as well as thick films, ceramic coatings, metal and metal oxide powders [19]. Betkar *et al.* [20] reported the formulation of thin films of Cadmium selenide (CdSe) by using spray pyrolysis approach. Logu *et al.* [21] reported the thin film synthesis of Pristine as well as Sb incorporated CdSe materials through chemical spray pyrolysis approach.

Ubale *et al.* [22] reported the formulation of thin film of CdSe: FeSe material using chemical spray pyrolysis method. Akolkar *et al.* [23] reported the preparation of cadmium selenide (CdSe) thin films through spray pyrolysis method. Meshram *et al.* [24] reported the synthesis of CdSe thin films on preheated glass substrate using spray pyrolysis appraoch.

Conclusions:

The present review article presents the review on synthesis techniques of CdSe thin films as well as the applications of CdSe thin films.

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CLIMATE CHANGE: A POTENTIALLY CATASTROPHIC HAZARD TO HUMAN HEALTH

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Abstract:

Human health has long been influenced by the climate and weather. Climatic change and climatic variability, particularly changes in weather extremes, have an impact on the environment that provides us with fresh air, food, water, shelter, and security. Human health and welfare are in danger from a variety of natural and man-made health stressors, including climate change. The global climate issue poses serious risks to public health through several exposure pathways, including heat waves, air pollution, famine, infectious diseases, and social unrest. At the same time, reducing greenhouse gas emissions and tackling the underlying causes of climate change have a favourable impact on the economy, health, and chronic illness rates.

Keywords: Human Health; Climate Change; Global Warming; Infectious Diseases; Heat Waves; Air Pollution.

Introduction:

Since the dawn of modern evolution, the Earth's climate has changed more quickly than ever before, largely as a result of human activity. Global climate change has already had a wide range of effects on every part of the nation and numerous economic sectors, many of which are expected to expand over the next few decades. Everyone agrees that human activity is mostly to blame for most of the warming of the world's climate. The increase in temperatures seen by the entire planet is one of the most visible results of global warming. While climate and weather have always had an impact on health, it is the change in climate and climatic unpredictability, particularly changes in extreme weather, that pose the greatest threat to human health as shown in Fig. 1.

Increased disease infections and major negative effects on brain health are also possible outcomes of climate change. rising sea levels and an increase in the frequency or severity of some extreme weather events. These effects have an impact on the food we consume, the water we drink, the air we breathe, and the weather we encounter, all of

which are harmful to our health. Where a person lives, how vulnerable they are to health threats, how much they are exposed to the effects of climate change, and how well they and their community can adapt to change will all have an impact on the effects.

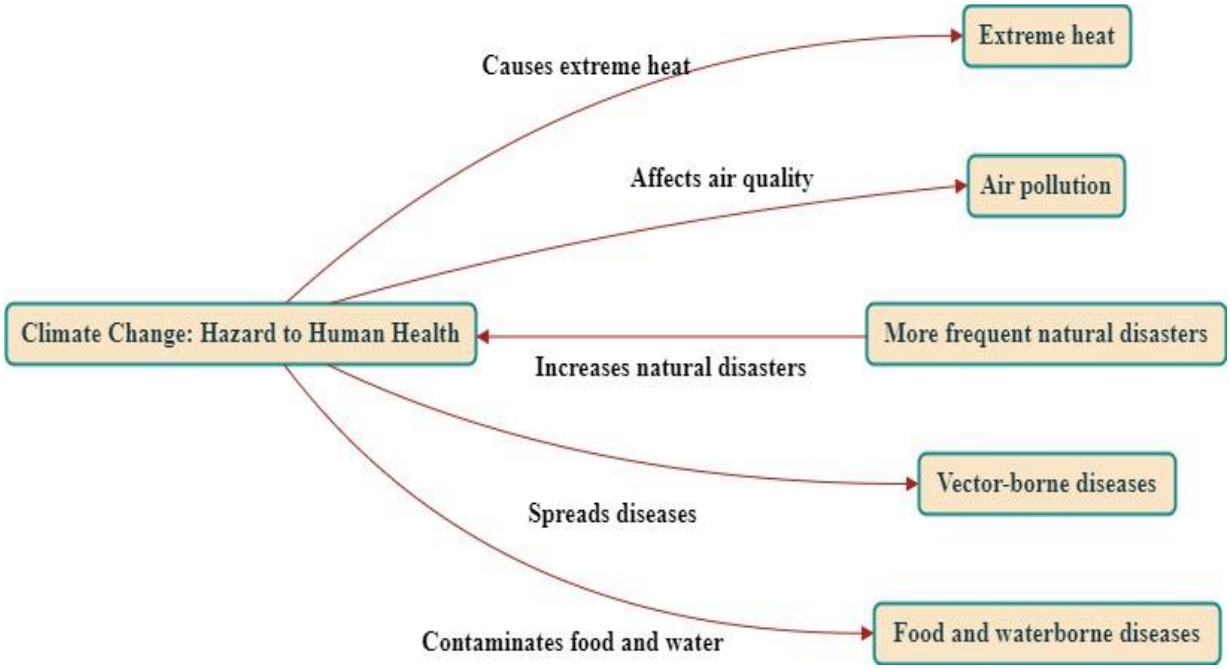

Figure 1: Climate Change: Hazard to Human Health

Warming temperatures, a rise in the frequency or severity of some extreme weather events, and rising sea levels are all effects of climate change. There are numerous and substantial impacts of weather and climate on human health. If the atmosphere does change as projected, this will represent an unprecedentedly quick change in the global environment and will have significant ramifications, including some significant effects on human health. They vary from linkages that might appear less obvious to the obvious hazards of temperature extremes and powerful storms. The total influence of climate change on human health also includes how it affects people's mental health and general well-being.

Causes of Climate Change

Everything happens for a reason. Even climatic change occurs due to various causes. Causes can vary from natural to man-made. Natural causes participate in climate change typically very slowly throughout thousands of years. Whereas Man-made causes affect the climate very drastically and suddenly. People are not just the recipients of the negative effects of climate change; they are also the main agents for rerouting development trajectories and the drivers of climate change. Natural factors such as changes in the Sun,

Emissions from volcanoes, Earth's orbital changes, and natural increase in CO_2. Volcanic emissions usually emit large volumes of CO_2 along with other aerosols that float in the atmosphere which can block the pathway of sunlight and cause cooling.

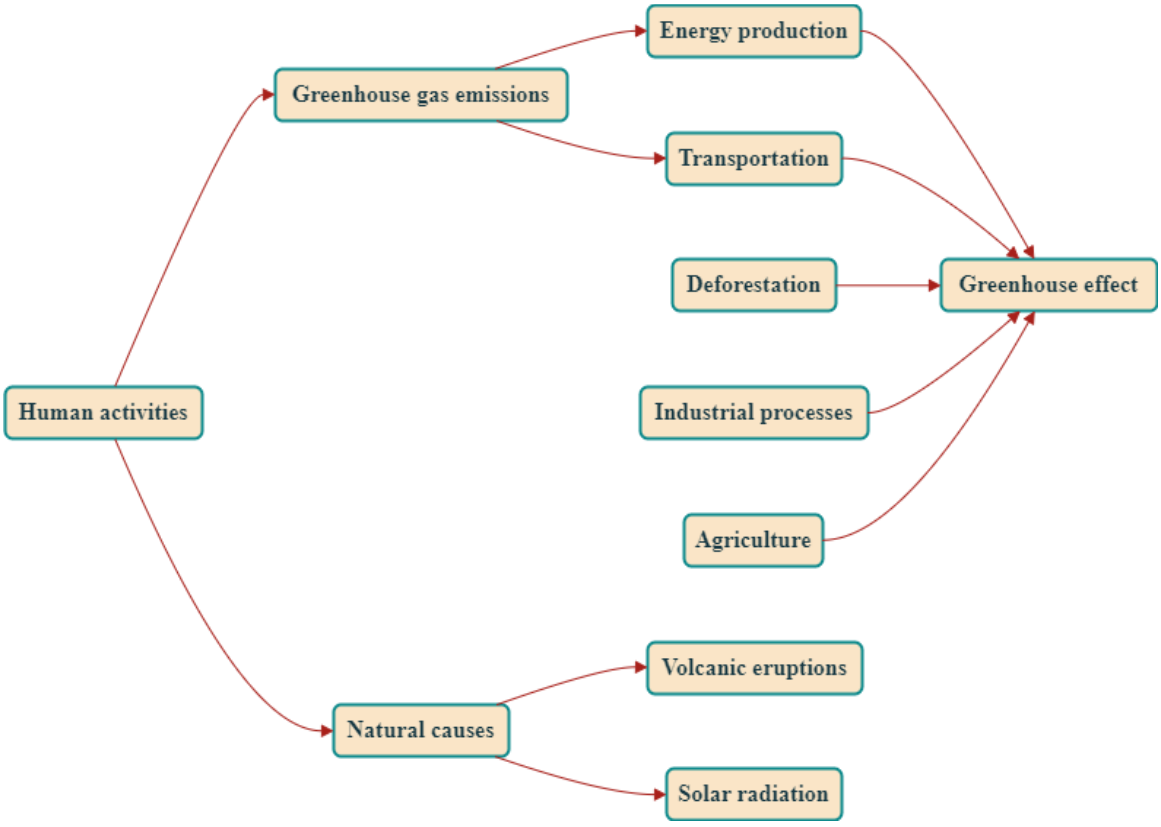

Figure 2: Primary Causes of Climate Change

The backbone of man-made climatic change is greenhouse gases. Not everything green could be good for nature as proven by the emission of greenhouse gases attacking directly humans. The accretion of greenhouse gases in the atmosphere, particularly CO_2, CH_4, N_2O, and Fluorinated gases such as halons, hydrofluorocarbons, chlorofluorocarbons, etc. is the key factor in the ongoing warming of the planet which is primarily due to human activities. Human-induced climate change includes industries that directly contribute to the inclination of 1°C from the pre-industrial era. The primary causes of climate change (shown in Fig. 2.) are listed below:

- **Burning Fossil Fuels:** The combustion of fossil fuels, such as coal, oil, and natural gas, for energy production and transportation is the largest contributor to greenhouse gas emissions in the form of CO_2, CH_4, N_2O, and Fluorinated gases.
- **Deforestation:** Cutting down forests reduces the Earth's capacity to absorb CO2, as trees and vegetation act as carbon sinks. Additionally, when forests are burned or cleared, the carbon stored in trees is released into the atmosphere.

- **Industrial Processes:** Many industrial processes release greenhouse gases as byproducts. For example, cement production generates a substantial amount of CO2.
- **Agriculture:** Agricultural activities, such as livestock production and rice cultivation, release methane (CH4), a potent greenhouse gas. The use of synthetic fertilizers also contributes to nitrous oxide (N2O) emissions. Large-scale, industrial agricultural practices can lead to deforestation, excessive use of fertilizers, and methane emissions from livestock.
- **Land Use Changes:** Urbanization and changes in land use, including the expansion of cities and agriculture, contribute to increased greenhouse gas emissions and reduced carbon sequestration.
- **Waste Management:** Landfills produce methane as organic waste decomposes. Inefficient waste management practices can result in higher methane emissions.
- **Transportation:** The transportation sector is a major source of CO2 emissions, primarily from cars, trucks, ships, and airplanes that burn fossil fuels.
- **Energy Production:** The generation of electricity and heat from fossil fuels and some forms of renewable energy (e.g., natural gas) also releases greenhouse gases.
- **Natural Sources:** While human activities are the primary drivers of recent climate change, natural sources like volcanic eruptions and variations in solar radiation can also influence climate to a lesser extent.

Climate Impacts on Human Health

Climate change is posing a growing threat to human health across the globe. The world's most vulnerable populations to health concerns may be those living in developing nations, yet climate change poses serious risks to health even in developed countries. Heat-related deaths will increase as temperatures shift. Asthma attacks and other respiratory and cardiovascular health issues can result from poor air quality, which can be exacerbated by warmer temperatures and unpredictable weather patterns. Warmer temperatures and rising carbon dioxide concentrations have an impact on airborne allergens like ragweed pollen. Through rising temperatures, more frequent heavy rains and runoff, and the consequences of storms, climate change raises the risk of illness.

Because bacteria grow more quickly in warm conditions, higher air temperatures may result in a rise in cases of food poisoning caused by Salmonella and other types of bacteria. These illnesses have the potential to result in severe gastrointestinal pain and even death. Even when the climate changes, good food safety practises can help prevent

these illnesses. The impacts of climate change on human health (shown in Fig. 3.) are as follows:

- **Extreme Weather Events:** The increasing frequency and intensity of extreme weather events such as hurricanes, heatwaves, floods, and wildfires are direct consequences of climate change. These events lead to injuries, displacement, and mental health issues among affected populations.
- **Mounting Temperatures:** Prolonged heatwaves due to climate change can cause heat-related illnesses and death, especially among vulnerable populations like the elderly, children, and those with preexisting health conditions.

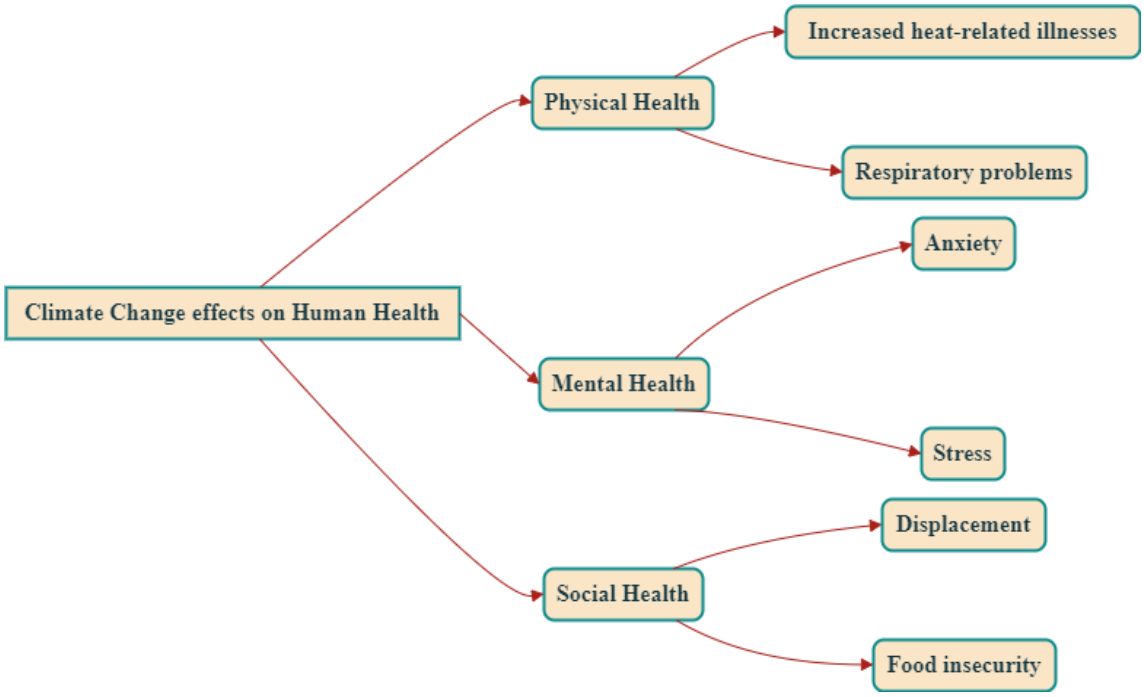

Figure 3: Effects of Climate Change on Human Health

- **Air Pollution:** Climate change exacerbates air pollution, which is linked to respiratory diseases such as asthma and bronchitis. Higher temperatures can also increase the production of ground-level ozone, a harmful air pollutant.
- **Vector-Borne Diseases:** Changes in temperature and precipitation patterns are expanding the geographic range of disease-carrying vectors like mosquitoes and ticks. This expansion is contributing to the spread of diseases like malaria, dengue fever, and Lyme disease.
- **Food and Water Security:** Climate change affects food production and water availability, leading to malnutrition and waterborne diseases in many regions. Crop failures and contaminated water sources are becoming more common.

- **Mental Health:** Disasters caused by climate change, loss of livelihoods, and displacement can lead to increased stress, anxiety, depression, and other mental health issues.
- **Health Inequities:** Climate change disproportionately affects vulnerable communities and exacerbates existing health inequities. Low-income communities often lack resources to cope with climate-related health risks.
- **Mitigation and Adaptation:** To address these health risks, efforts must focus on both mitigation (reducing greenhouse gas emissions) and adaptation (preparing communities for climate-related health challenges). These efforts include transitioning to clean energy sources, improving healthcare infrastructure, and developing early warning systems.

Measuring the Health Effects

Measuring the health effects of climate change is a complex and multidimensional task that involves assessing a wide range of direct and indirect impacts on human health. These effects can vary depending on geographical location, socioeconomic factors, and the extent of climate change. Here are some key methods and indicators used to measure the health effects of climate change:

- **Epidemiological Studies:** Epidemiologists conduct research to examine the relationship between climate change and health outcomes. They analyze historical data to identify trends in health conditions related to climate, such as heat-related illnesses, vector-borne diseases, respiratory problems, and more.
- **Temperature-Related Health Impacts:** Monitoring temperature changes and their effects on health is crucial. Key indicators include the number of heat-related illnesses and deaths, as well as changes in the distribution and severity of heatwaves.
- **Air Quality Monitoring:** Climate change can impact air quality through increased wildfires, higher temperatures, and changes in atmospheric conditions. Tracking air pollution levels, including particulate matter and ground-level ozone, can help assess health risks like respiratory diseases.
- **Food and Nutrition:** Climate change can impact food availability, quality, and distribution. Assessing changes in crop yields, food security, and nutritional deficiencies can help gauge health effects.

- **Vulnerable Populations:** Certain groups, such as the elderly, children, and low-income communities, are more susceptible to climate-related health risks. Identifying vulnerable populations and assessing their specific health needs is crucial.
- **Climate Vulnerability Index:** Some organizations and researchers have developed indices that combine various environmental, social, and health data to quantify a region's vulnerability to climate change and its associated health impacts.
- **Health Impact Assessment (HIA):** HIA is a structured process used to evaluate the potential health effects of policies, projects, or plans related to climate change mitigation or adaptation which can be utilized by policy makers.
- **Climate Models:** Climate models can project future climate scenarios, which can be used to estimate the potential health impacts under different climate change scenarios. These models incorporate factors like temperature, precipitation, and extreme weather events.
- **Surveillance Systems:** Establishing and maintaining surveillance systems for climate-sensitive health outcomes is crucial for early detection and response to climate-related health threats.

To effectively measure the health effects of climate change, interdisciplinary collaboration among epidemiologists, climatologists, public health officials, and policymakers is essential. Timely data collection, analysis, and proactive measures are critical for mitigating the adverse health impacts of climate change.

Indian Government Schemes

The Indian government had implemented several schemes and initiatives to address health issues arising from climate change which are mentioned below:

- **National Health Mission (NHM):** The NHM has incorporated climate change considerations into its programs. It focuses on strengthening healthcare infrastructure, providing better healthcare access to vulnerable populations, and promoting climate-resilient healthcare systems.
- **Pradhan Mantri Swasthya Suraksha Yojana (PMSSY):** This scheme aims to improve healthcare infrastructure, including setting up new AIIMS (All India Institutes of Medical Sciences) institutions in various parts of the country. Better healthcare facilities are critical in dealing with climate-induced health challenges.

- **National Disaster Management Plan:** The government has developed a comprehensive plan for disaster management, which includes strategies for dealing with health emergencies arising from extreme weather events and natural disasters linked to climate change.
- **National Action Plan on Climate Change (NAPCC):** The NAPCC outlines the Indian government's strategy to deal with climate change across various sectors as shown in Fig. 4. Under this plan, the government aims to assess the health impacts of climate change and take necessary actions to mitigate them.

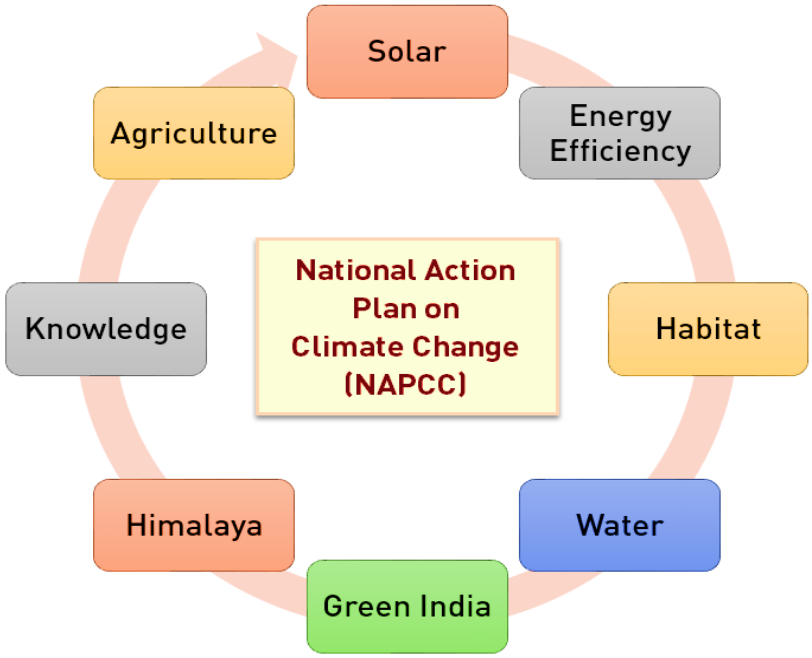

Figure 4: Indian National Action Plan on Climate Change

- **National Clean Air Programme (NCAP):** Air pollution is a significant health concern exacerbated by climate change. The NCAP aims to reduce air pollution levels in major cities and improve air quality, thereby reducing the burden of respiratory diseases.
- **Climate-Resilient Agriculture:** While not directly a health program, efforts to promote climate-resilient agriculture can indirectly impact health by ensuring food security and reducing the risk of malnutrition.
- **Capacity Building and Research:** The government has supported research and capacity-building initiatives to better understand the health impacts of climate change and develop appropriate adaptation and mitigation strategies.

- **Public Awareness Campaigns:** The government has run public awareness campaigns to educate citizens about the health risks associated with climate change and the steps they can take to protect themselves.

Possible Measures

Individuals can take several measures to contribute to addressing the climate change problem. While the most significant impacts will require collective action at the government and global levels, individual actions can still make a difference and set an example for others. Here are some steps individuals can take:

❖ **Reduce Energy Consumption**

- **Energy-efficient appliances:** Use energy-efficient appliances and light bulbs.
- **Insulation:** Properly insulate your home to reduce heating and cooling costs.
- **Unplug devices:** Turn off and unplug electronics when not in use.
- **Renewable energy:** If possible, switch to renewable energy sources like solar or wind power.

❖ **Reduce, Reuse, Recycle**

- **Reduce waste:** Minimize single-use items and buy products with minimal packaging.
- **Recycling:** Properly sort and recycle materials like paper, glass, and plastic.
- **Composting:** Start a compost pile for organic waste.

❖ **Transportation**

- **Carpooling and ridesharing:** Share rides with others to reduce the number of vehicles on the road.
- **Public transportation:** Use public transportation, walk, or bike when possible.
- **Fuel-efficient vehicles:** Choose a fuel-efficient or electric vehicle when purchasing a new one.

❖ **Conserve Water**

- Fix leaky faucets and pipes.
- Install low-flow fixtures and appliances.
- Collect rainwater for outdoor use.

❖ **Reduce Meat Consumption**

Consider reducing meat consumption or adopting a plant-based diet, as the meat industry is a significant contributor to greenhouse gas emissions.

❖ **Support Sustainable Practices**

Purchase products with eco-friendly certifications (e.g., Fair Trade, Energy Star, USDA Organic) and support eco-friendly businesses.

❖ **Reduce Air Travel**

If possible, choose alternative modes of transportation for long-distance travel to reduce your carbon footprint.

❖ **Educate Yourself and Others**

Share information and resources with friends and family to raise awareness.

❖ **Advocate for Change**

- Contact elected officials to express your concerns about climate change.
- Participate in climate marches, rallies, or local environmental organizations.

❖ **Reduce Plastics**

Decrease the usage of single-use plastics like bags, bottles, and straws, rather choose reusable alternatives like bamboo, glass, platinum silicone, beeswax-coated cloth, natural fibre cloth, sustainable steel etc.

❖ **Support Renewable Energy**

Invest in or support policies that promote the growth of renewable energy sources.

❖ **Plant Trees**

Participate in tree planting initiatives to help sequester carbon dioxide from the atmosphere.

❖ **Financial Investments**

Consider socially responsible investment options and divest from fossil fuels.

❖ **Reduce Food Waste**

Plan meals to minimize food waste and compost food scraps.

❖ **Sustainable Shopping**

Support sustainable and ethical brands and products.

❖ **Reduce Water Usage**

Fix leaks, use low-flow fixtures, and be mindful of water use in daily activities.

❖ **Green Gardening**

Choose native plants, use organic gardening practices, and minimize pesticide use. Individual actions, while important, are not a substitute for broader systemic changes. Encouraging and participating in collective efforts to address climate change is equally

crucial, including supporting policies that promote sustainability and holding corporations and governments accountable for their environmental impact.

Conclusion:

Climate change is not just an environmental issue; it is a serious threat to human health. The resulting effects of climate change include rising global temperatures, sea level rise, more frequent and severe weather events, disruptions to ecosystems, and impacts on human societies, including food and water security, health, and infrastructure. Additionally, shifting weather patterns can exacerbate the spread of vector-borne diseases like malaria and dengue fever, while extreme weather events such as hurricanes and floods can result in injuries and the displacement of communities, leading to mental health issues. To battle this challenge. a multi-faceted approach is required that includes reducing greenhouse gas emissions through measures like transitioning to renewable energy sources, improving energy efficiency, reforestation, sustainable land use practices, and adopting cleaner technologies in various sectors to mitigate the health hazards associated with a changing climate. Addressing climate change is not only crucial for safeguarding our planet but also for protecting the well-being of present and future generations.

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