Chapter 6

Synthetic Biology: Engineering Life for Medical Breakthroughs

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Abstract

The most recent developments in synthetic biology are covered in this article, along with the necessity of quick enactments as well as robust regulatory frameworks for the efficient management of bio-risks. The present investigation explores current developments in the application of synthetic biology in medicine, with an emphasis on how it may be employed to produce novel medications, diagnose and cure illnesses, and identify new therapeutic targets. The benefits and drawbacks of cutting-edge technology such as biological engineering are discussed in this article, along with the measures that must be taken to reduce dangers and the supervision that the international community should be contributing. Although the field of biological engineering envisions a world free from hunger, illness, and death, if neglected, it may endanger humankind and bring about its extinction. The exploration of possible applications for humans and the rest of the planet has been sparked by synthetic biology, which has transformed scientific thinking. The scientific comprehension of life has deepened and genetic manipulation skills have improved because to innovations in this sector. This area of research encourages more investigation into people's ways of living by providing both possibilities and challenges. By strengthening the therapeutic design, delivery vector, antigen, and vaccination, synthetic biology concepts could enhance RNA-based therapies and perhaps influence the development of future vaccines and treatments.

Keywords

Synthetic Biology, DNA Synthesis, Cell-Free Protein synthesis, Internet of Bio-Nano Things, Biomedical Engineering

1. Introduction

Governments and commercial investors have grown increasingly interested in synthetic biology research and technology translation since its potential for a bio-based economy which is sustainable and offers

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applications in bio-manufacturing, health, food, and agriculture [1]. With an emphasis on medicine, regenerative medicine, and product development, biomedical engineering is a multidisciplinary subject that integrates biomedical sciences with engineering concepts. For computer modeling and engineering, it provides printing technologies, simulation software, and 3D motion capture. This interdisciplinary field encompasses the fields of medicine, biology, chemistry, engineering, nanotechnology, and informatics [2]. Utilizing nano-materials in combination with bacteria, viruses, and their metabolites, synthetic biology-based medication delivery systems are becoming more and more prevalent in the treatment of diseases. Modular nano-components may self-assemble in these hybrid systems, which optimize biological processes and provide as a foundation for groundbreaking studies [3]. The objective of the multidisciplinary field of synthetic biology is to generate new biological systems and adapt existing ones for human consumption by integrating engineering and biology. Progress has been made possible by developments in genome transplantation, CRISPR-Cas9 system, DNA synthesis, assembly, sequencing, and synthesis [4]. The ability to manipulate DNA has enabled synthetic biology to advance biotechnology while rendering it possible to develop biological systems. Mass and energy conversion efficiency are still constraints for cellular systems, though. These limitations may be circumvented and synthetic biology advanced through the application of cell-free protein synthesis, or CFP [5]. The life sciences, industrial development, and environmental bio-remediation are only a handful of the categories where synthetic biology has achieved significant achievements. Bio-safety, bio-security, and cyber-bio-security are all vulnerable due to its possible abuse, unexpected applications, and undiscovered triggers, which might expose the environment and public health to unidentified risks [6]. Synthetic biology is showing possibilities as an avenue for advancing medication discovery and illness treatment. The fast growing number of diseases involves scientific investigation of new technologies for biomedicines and biotherapies [7].

2. Engineering Life for Medical Breakthroughs

After almost two decades, synthetic biology is finally being made public as a potential answer to society problems including infectious illnesses, inadequate food supply, and climate change. Scientists and business-people all over the world are striving to fulfill these promises [8]. With the ability to modify treatment material, dosage, and magnitude, synthetic biology offers a wide variety of tools for the development of genetic treatments and vaccinations. By improving the functionality and efficacy of pharmacological agent sequences, this discipline provides time and cost savings [9]. Science is able to create or predict attributes artificially for a variety of applications, including microorganism research, agriculture, environmental conservation, and economy, owing to the rapidly emerging field of synthetic biology, that integrates genetic engineering with physical and chemical experimentation technologies. Thus challenging conventional wisdom [10]. Utilizing synthetic biology, genetically manipulated cells offer certainty, selectivity, and adaptability in the treatment of diseases. In contrast to conventional pharmaceuticals, they regulate the location, time, and dosage of medical care, but they also raise developmental issues [11]. Multiple domains, including epidemiology, host-pathogen interactions, and pharmaceutical design, are undergoing significant modifications caused by artificial intelligence (AI). AI has substantially enhanced human life; its sophisticated algorithms are revolutionizing disciplines including medication administration, radiography, gene editing, drug development, and personalized medicine [12]. The innovation of natural products in the twenty-first century is being driven by synthetic biology and AI. For NSCLC patients, a customized medication selection method that integrates artificial intelligence and synthetic biology is suggested. By taking economic costs into account as a supplementary aspect in decision-making, the method forecasts the cost-effectiveness of drugs while guaranteeing their efficacy

[13]. Digital twins are revolutionizing the biotechnology industry by digitally depicting biological resources, microbes, drug development procedures, and medical applications. To overcome challenges, a paradigm combining advanced Internet of Things (IoT) infrastructure and computational techniques with the Internet of Bio-Nano Things (IoBNT) is proposed [14]. By delivering targeted therapies, exact workouts, and neural restoration for neurological conditions and brain traumas, assistive robots and synthetic biology have fundamentally altered the way medicine is practiced. Amputees' motor control can be enhanced and their discomfort is reduced with artificial prosthetic limbs equipped with synthetic sensory input [15]. Understanding cell varieties, behaviors, interactions, and tissue architecture is aided by the rapidly growing discipline of single-cell biology. Studying dynamic biological processes like tissue patterning and the choice of cell fate is where it genuinely flourishes. The study of infectious and cancerous illnesses employing single-cell methods has made it achievable to create more precise diagnostic tools and specialized therapies [16]. Cell-free systems are made conceivable by synthetic biology, which adapts biological systems through genetic reprogramming, the creation of designer cells for a variety of applications and the logical design of biological molecules [17]. While artificial cells currently lack the durability and behavioral complexity of biological cells, the synthetic biology community is investigating the possibilities of merging biological and artificial cells to produce hybrid synthetic systems that incorporate the advantages of all of them [18]. Emerging technologies in biological engineering include cancer-targeting synthetic viruses, self-repairing 3D-printed materials, and illnesses with detrimental characteristics. However, the whole community must come to a consensus on how to implement these innovations successfully without creating devastation, especially with artificial children and man-made pandemics in the future [19]. After consulting with funding agency heads, researchers, policymakers, and journal editors, a researcher proposes their idea for a new financing agency called ARPA-H. Their goals include influencing the biological sector of the future and educating the biotechnology community about the enormous influence of ARPA. [20]

3. Recommendations

We propose the following recommendations for future.

- The disciplines of synthetic biology and biomaterials may work collaboratively to encourage personalized medicine, modernize biomaterial research, and stimulate laboratory innovation—all of which will lead to revolutionary breakthroughs in the biomaterials domain.
- A research hotspot, anti-tumor drug development for the treatment of non-small cell lung cancer is continuously evolving. For a fair cost-effectiveness ratio, future research should concentrate on patient characteristics and medication combinations.
- In vivo monitoring and regulated medication distribution are the two primary domains of interest for synthetic biology in medical applications. But concerns like legal concerns, safety, and bioethics still exist. In consideration of the fact that medical therapies attempt to treat problems with human health, addressing these concerns is important.
- Significant scientific interest has been generated by the quick progress in synthetic biology made possible by CFPS, which could alter the dynamics in the discipline and lead to a wider range of applications.
- As science and society progress, future research endeavors attempt to augment synthetic biology by employing the biomaterials framework to personalized treatment and environmental monitoring.

- RNA vaccines can target various diseases and could potentially substitute conventional vaccinations by using artificial intelligence (AI) and machine learning, which can also overcome constraints in mRNA vaccines, such as the inability to express multi-domain or polysaccharide antigens.
- In the near future, the implementation of AI-based technology will make more precise diagnosis and economical treatment feasible.

Conclusion

Advanced biomaterials with programmable and self-regulating features are being researched in an emerging area involving synthetic biology with biomaterials. Bypassing conventional constraints, these materials could improve their ability to communicate with intricate tissue settings. A new class of multi-functional integrated biomaterials is anticipated in the future of these biomaterials. Biomedical engineering is a discipline which integrates engineering with medicine with the objective of enhancing healthcare through the development of revolutionary inventions, especially in the musculoskeletal system, medication management systems, and genetic testing, all of which aim to enhance the lives of critically ill or disabled people. In the biotechnology business, digital twins (DTs) are crucial, especially when it involves simulating complicated biological things like bacteria, as the study emphasizes. Enhancing the efficacy, dependability, and efficiency of drug delivery technologies (DTs) in the bio-manufacturing, healthcare, and pharmaceutical industries, it puts forth a framework that combines the IoBNT with cutting-edge machine learning techniques. To address challenges for humans, synthetic biology incorporates engineering and rational design concepts. In order to enhance human wellness, researchers have created an artificial intelligence medical aid system and suggested a drug screening framework by examining targeted medications for non-small cell lung cancer.

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