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Synthetic Biology: A Good Choice for Medicinal Advances

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Introduction

Synthetic biology (SB) is primarily an application-focused field attempting to develop and apply a systematic engineering approach to the design and construction of new biological systems and cells at the genetic level [1,2]. It is a new area of biological research that integrates science and engineering with an aim to design and construct novel and useful biological systems which are not found in nature. SB comprises a broad expansion of the term biotechnology, with the ultimate goals of being able to design and build engineered biological systems that process information, manipulate chemicals, fabricate materials and structures, and maintain and enhance human health and our environment. SB has gained a lot of attention over the past several years due to its potential for scientific breakthroughs in public health and environment. It is a multidisciplinary effort of biologists, engineers, software developers, and others to collaborate on finding ways to understand how genetic parts work together, and combine them to produce useful applications and to design and build new biological organisms [3]. The hot field of SB uses tools and concepts from physics, engineering and computer science to build new biological systems. Moreover, understanding of genomic sequencing and molecular biology has accelerated the work in recent years.

SB is a relatively young field, begun only about ten years ago. But, it has made some astonishing progress in that short period including the improvements in ability to synthesize and sequence DNA. Designing biological systems requires a deep understanding of how genes and proteins are organized and interact in living cells [4]. In medicine, the community of SB is pushing the frontiers by designing microbes that will destroy tumors in the body. It also provides us a way to clean up our environment by creating organisms that are capable to consume toxic chemicals in water or soil that would not otherwise decompose [5]. In addition, we have also gained much greater understanding of the various parts of genome interactions; and now we can combine various genetic pieces to produce a range of consumer products from cosmetics to biofuels. Researchers at MIT-SBC are working to build a process that will allow plants to fix nitrogen. If successful, farmers will no longer require fertilizer for their crops. Therefore, new research is pioneering across many applications to ensure SB delivers transformative solutions for affordable and effective healthcare, food security, the production of novel materials [6].

SB seeks to improve biological systems in order to perform new functions and to model and construct biological 'parts' and processes that do not exist in nature. The current research is being carried out to explore applications of SB to understand fundamental mechanisms of health and disease, and also to pioneer new tools to ultimately improve human health. In addition, scientists also trying to use programmed stem cells as personalized medicines, create tests that are better at testing the safety of new medicines, and build tools to help identify new types of drugs to treat some devastating diseases integrating SB into medicine.

Significant Advancement

The field of SB has expanded into many applications including the rational optimization of complex pathways, construction and characterization of genetic circuits of increasing complexity and the functional design, construction, and modification of new and existing biological systems.

Synthesis of an anti-malarial drug artimisinin from synthetic chemicals is a land mark of SB. It's very important for those threatened by the malaria; it kills more than one million people and infects an additional 300-500 million people each year (it is 7% of the world's population). Artimisinin is not a new treatment for malaria, but it was produced first time in a lab through synthetic way instead of traditional drug isolation from Artemisia annua plant. Production of artemisinin is a milestone in science, too. It represents a watershed moment in particular for the emerging field of SB. However, much of the research focuses on reprogramming cells by changing their DNA. In this way, researchers are working to engineer biology much as they engineer high-tech machines, creating new and environmentally friendly fuels and less expensive and more potent drugs and biological therapies. Some such approaches utilize successful solutions found in nature as inspiration for designing artificial systems.

In terms of specific examples, there are currently several examples of sensors which have been developed to detect pathogenic biofilms two examples being the detection of urinary tract infection, and the detection of arsenic in drinking water [7,8]. Designs based on SB are also now being developed for the detection of parasites in water (e.g. a biosensor to detect schistosoma). Another strategy is to monitor metabolites which are correlated with productivity as an indirect measure of the best process conditions [9].

Recent Achievements

SB has shown spectacular achievements in the year 2014. Some of the most impressive accomplishments of the year are mentioned below:

Lab-made chromosome

In March 2014, Imperial College, London scientists reported that they had succeeded in building the first eukaryotic artificial chromosome, which was quite similar to the real deal, and appeared to function just fine in yeast. This feat "is a landmark in synthetic biology,"

Artificial DNA

In the year 2014, scientists at the Scripps Research Institute created two new DNA bases that, when incorporated into a plasmid, could replicate within in living bacteria. "Successfully prepared a cell that stably harbors increased genetic information".

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Making neurons

Chun Li-Zhang, scientist of the University of Texas Southwestern Medical Center and his colleagues managed to coax astrocytes into neurons within the spines of living mice. For years, scientists have been trying to fill in the gaps of the human nervous system's poor regenerative abilities by reprogramming somatic cells into neurons. Studies in mice in the year 2014 took the field a step further by succeeding in-vivo.

World's first artificial enzymes

In December 2014, Medical Research Council (MRC) scientists have created the world's first enzymes made from artificial genetic material. Their synthetic enzymes, which are made from molecules that do not occur anywhere in nature, are capable of triggering chemical reactions in the lab. This research gives new insights into the origins of life and could provide a starting point for an entirely new generation of drugs.

Utility of Synthetic Biology in Discovering Novel Chemical Structures

Synthetic biology has been heralded as a new bioengineering platform for the production of bulk and specialty chemicals, drugs, and fuels. Here, we report on the isolation of approx. 100 novel pharmaceutical compounds produced using a combinatorial genetics approach with artificial chromosomes in baker's yeast. Of the molecules found, >75% have not been described previously; 20% of the compounds exhibit novel scaffolds. Their structural and physicochemical properties comply with established rules of drug- and fragment-likeness and exhibit increased structural complexities compared to synthetically produced fragments. In summary, the synthetic biology approach described here represents a completely new, complementary strategy for hit and early lead identification that can be easily integrated into the existing drug discovery process.

Managing the Risks

SB may offer the potential for economic growth through trans-sectoral impacts, in areas such as energy, health, and the environment. At the same time, many concerns have arisen about the risks of SB. Emerging risks tend to be discussed under four main headings: biosafety; biosecurity; intellectual property and trade; and ethical concerns. In considering these emerging risks, it is also important to pay attention to potential benefits and to make a balanced assessment of the costs associated with different approaches to risk governance, including setting standards for research practices or for product or process safety. Another important consideration is the extent to which new developments could render some current risks obsolete (for example, through the more rapid development of new vaccines).

Although we have laid a very strong foundation for the field, we are still having many challenges to overcome. Like many things we do, SB comes with risks, especially in terms of safety and security. But consider this: we fly airplanes, we drive cars, we treat cancer with poison - all of these activities could be dangerous, but they also have benefits that far override the risks. We believe this is true of SB as well. Apart from this, synthetic biologists are also working hard to minimize potential adverse effects. For instance, Silver's lab (Harvard University) is working to create genetic self-destruct traits, termed "auto-delete," as a way to ensure that genetically modified organisms don't escape into the environment.

Anyhow SB has emerged relatively unscathed from much of the scrutiny, with the government commissions concluding that the appropriate safety nets are in place and the potential for positive health impacts are too great to halt progress. Additionally, some researchers have urged caution, fearing that scientists manipulating the DNA of living organisms are essentially "playing God" and have the ability to cause great harm to biological and ecological systems.

As Laurie Zoloth, a bioethicist at Northwestern University, said "Synthetic biology is like iron: You can make sewing needles and you can make spears. Of course, there is going to be dual use." She concluded that SB could be useful for extraordinary medical research that could address terribly intractable problems and of the potential for the powerful technology to be used in destructive ways. At the same time, she said many skeptics are concerned that the tools of the technology could get into the wrong hands.

As Pam Silver (Harvard scientist) said "the field is poised to explode, both in terms of what scientists can accomplish and what the public realizes is possible", we believe that one day we will be able to fully utilize biology's manufacturing capability.

There are no easy answers, but we can assure that the improvements of SB will benefit the public, solving global challenges, and making sure that we are well-equipped to live in the future bioeconomy. While it is important to ensure that we proceed cautiously with this technology and protect the public against its potential misuse.

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