



Synthetic biology: Engineering life at the molecular level

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INTRODUCTION

Synthetic biology represents a revolutionary approach to engineering life at the molecular level, leveraging principles from biology, chemistry, and engineering to design and construct novel biological systems with desired functions. At its core, synthetic biology seeks to apply engineering principles to biology, enabling the rational design and manipulation of biological components to create new organisms, pathways, and cellular functions.

The field of synthetic biology has its roots in the emergence of recombinant DNA technology in the 1970's, which enabled scientists to manipulate and recombine DNA sequences from different organisms. Over the past few decades, advances in DNA synthesis, genome editing, and computational design have propelled synthetic biology into a rapidly evolving discipline with diverse applications in biotechnology, medicine, agriculture, and beyond.

DESCRIPTION

Central to synthetic biology is the concept of genetic engineering, which involves the modification of an organism's genetic material to introduce new traits or functions. Genetic engineering techniques enable researchers to design and construct DNA sequences encoding specific proteins, enzymes, or regulatory elements, which can then be inserted into host organisms to confer desired traits or behaviors. By assembling genetic parts and modules in a systematic and predictable manner, synthetic biologists can create customized biological systems tailored to meet diverse applications in industry, healthcare, and environmental remediation.

One of the key goals of synthetic biology is to develop biosynthetic pathways for the production of valuable chemicals, pharmaceuticals, and biofuels using engineered microorganisms. By rewiring metabolic pathways and cellular processes, synthetic biologists can convert renewable feedstock's, such as sugars or plant biomass, into high-value products with applications in pharmaceuticals, materials, and renewable energy. For example, engineered yeast strains can be used to produce biofuels, such as ethanol or butanol, from agricultural residues or industrial waste streams, offering sustainable alternatives to fossil fuels.

In addition to bio-manufacturing, synthetic biology holds promise for medical applications, including the development of novel therapeutics, diagnostics, and drug delivery systems. By engineering cells to produce therapeutic proteins, enzymes, or antibodies, synthetic biologists can create new treatments for a wide range of diseases, including cancer, infectious diseases, and genetic disorders. Moreover, synthetic biology approaches can

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be used to engineer immune cells, such as T-cells or dendritic cells, for adoptive cell therapy or cancer immunotherapy, enabling personalized treatments tailored to each patient's unique genetic makeup.

Furthermore, synthetic biology has applications in agriculture and food production, where engineered crops with enhanced traits, such as disease resistance, drought tolerance, or nutritional value, hold promise for addressing global food security challenges. By introducing genetic modifications into crop plants, synthetic biologists can improve yield, reduce pesticide use, and enhance nutritional content, leading to more sustainable and resilient agricultural systems. Moreover, synthetic biology approaches can be used to engineer probiotic bacteria or microbial communities for agricultural applications, such as soil remediation, crop protection, or nitrogen fixation.

In addition to its applications in industry and healthcare, synthetic biology has implications for environmental sustainability and conservation. Engineered microorganisms can be used to degrade environmental pollutants, such as oil spills or plastic waste, through the synthesis of enzymes or metabolic pathways capable of breaking down toxic compounds into harmless byproducts. Similarly, synthetic biology approaches can be used to engineer microbial communities for bioremediation, carbon sequestration, or wastewater treatment, contributing to efforts to mitigate climate change and protect ecosystems.

Despite its tremendous potential, synthetic biology also raises ethical, social, and regulatory considerations that must be carefully addressed. Concerns about biosafety, biosecurity, and ecological impact require robust risk assessment and mitigation strategies to ensure the responsible development and deployment of synthetic biology technologies. Moreover, questions about intellectual property rights, access to genetic resources, and equitable distribution of benefits highlight the need for transparent governance frameworks and inclusive decision-making processes that engage stakeholders from diverse sectors, include scientists, policymakers, ethicists, and the public.

CONCLUSION

Synthetic biology offers unprecedented opportunities to engineer life at the molecular level and create novel biological systems with a wide range of applications in industry, healthcare, agriculture, and environmental remediation. By applying engineering principles to biology, synthetic biologists can design and construct custom genetic circuits, metabolic pathways, and cellular functions that meet diverse societal needs and challenges. However, realizing the full potential of synthetic biology requires addressing ethical, social, and regulatory considerations, as well as promoting interdisciplinary collaboration and responsible innovation across the scientific community and beyond.