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Perspective

Cell Free Synthetic Biology Transforming Medicine and Industry

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DESCRIPTION

Synthetic biology has emerged as one of the most exciting fields of modern science, offering the promise of novel approaches to biotechnology, medicine, and industrial processes. While traditional synthetic biology largely relies on the use of living cells as chassis for genetic circuits, Cell Free Synthetic Biology (CFSB) presents a paradigm shift by enabling the construction and operation of biological systems without the need for living cells. This technology harnesses the basic biochemical machinery found within cells such as enzymes, ribosomes, and RNA and reconfigures it to function outside of living organisms. By creating cell free environments, scientists can assemble, program and control biological systems with a level of precision and flexibility that was previously unimaginable.

Cell free synthetic biology is based on the concept of extracting the molecular machinery from cells and reassembling it into in vitro systems capable of performing biological functions. Traditional synthetic biology often involves inserting genes into living cells, using their native machinery to express proteins, replicate DNA and carry out biochemical reactions. In contrast, cell free systems bypass the need for living cells altogether, relying on cell extracts to provide the necessary biochemical components for the desired reactions. These are the aqueous solutions obtained by lysing cells (breaking open their membranes) and purifying the contents. The extracts contain all the essential cellular components for transcription, translation, and other biochemical processes, including enzymes, ribosomes, amino acids, nucleotides, and cofactors. The composition of the extract can be optimized for specific tasks, depending on the desired application.

DNA (or sometimes RNA) is used to encode the genetic instructions that will guide the biochemical reactions. This genetic material can be customized to program the system for specific tasks, such as producing a protein, carrying out chemical transformations, or assembling more complex biomolecules.Like living cells, cell free systems require energy to function. ATP (Adenosine Triphosphate) is the primary energy currency used to drive biochemical processes, such as protein synthesis, enzyme activity, and molecular assembly. To enhance the efficiency of reactions, cell free systems may include additional factors such as chaperones, ribosome binding sites, cofactors, and other small molecules that aid in the proper folding of proteins or facilitate specific chemical reactions. These basic components form the foundation of cell free synthetic biology, and through careful design and optimization, researchers can create highly customizable systems capable of performing a wide range of biological tasks.

Cell free systems allow for rapid prototyping and testing of genetic circuits and synthetic pathways. In traditional cell based systems, the process of introducing new genetic material into living cells, growing the cells, and confirming the success of the modifications can take several days or even weeks. In contrast, cell free systems operate in a matter of hours, enabling much faster experimentation and optimization. This speed is especially valuable for high throughput applications, such as screening large libraries of genetic constructs or testing multiple conditions in parallel. Cell free systems have significant potential in the development of diagnostic tools and biosensors. In particular, cell free systems can be used to design biosensors that detect specific molecules, pathogens, or environmental conditions. These systems could be deployed for rapid, point of care diagnostics, providing real time, on site testing with minimal equipment and no need for living cells.

One of the most established applications of cell free synthetic biology is the production of proteins. Cell free systems can be engineered to produce a wide variety of proteins, including therapeutic proteins, enzymes, and industrial enzymes, with greater efficiency and speed than traditional methods. Because cell free systems bypass the need for living cells, they offer a streamlined process for protein production that can be easily scaled up for industrial use.

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