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Nanomedicine-based Synthetic Biology

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Understanding the disease mechanisms of complex biological systems is still a significant challenge. Biological systems consist of hundreds of thousands of genes and proteins which are very hard to identify and whose behavior is difficult to correlate, understand and predict. The traditional hypothesis-driven basic research aims to study a certain gene/protein or a certain signaling pathway by taking a biological system apart in such a way that is strictly dependent on the scientific method applied. However, this approach cannot provide a systemic information broad enough to predict the complex dynamic consequences of altered gene and protein expression and, ultimately, drug effectiveness. Synthetic biology, in combination to classical methods, is recently emerging as an alternative method [1-6].

The term "Synthetic Biology" was firstly used to describe bacteria that had been genetically engineered using recombinant DNA technology [1]. This definition is now broadly used to describe the design and construction of new biological functions and systems which do not exist in nature. The ultimate goal of this new approach is to create an artificial system which helps understanding the hidden complexity of a biological entity. With the recent advances in new technologies such as nanoscale assembly and characterization as well as new discoveries in gene regulatory networks and signaling pathways, synthetic biology faces a new era where it may be possible to realize synthetic systems which function like a living body.

The complex properties of biology include robustness, modular and hierarchy structure, statistic-driven analysis, which make the biology difficult to understand. Recently, a systems biology approach has begun to be applied to understand the complexity of biological networks, such as protein-protein interaction, and metabolic/signaling/transcriptional regulatory networks [1-6]. Still a lot remains to be done to fully understand the secret rules of biology. The accumulated knowledge in biology can be used to design artificial nanoscale devices composed of biological components that mimic biological systems. With the recent advance in nanomedicine, this engineered synthetic system may provide new opportunities to elucidate the implications of a certain genetic regulation, to discover new signaling pathways and disease mechanisms, and to develop diagnostic and therapeutic tools [2].

Nanomedicine can design, build, manipulate, and optimize biological components at the nano-scale level. This includes the applications of nanomaterials and the fabrication of nanodevices to be used in nanodiagnositic, nanodrug delivery and drug discovery and regenerative nanomedicine. Nano-scale components can be artificially synthesized and self-assembled back into a system. This bottom-up approach uses the chemical and biological properties of single molecules to create a self-organized system. This artificial-synthetic system can function like a natural biological complex system. The principle of biological design using synthetic components can be applied to create a simplified biological system which functions like a living body, i.e. can process biological information, manipulate chemicals and bio-molecules, synthesize new compounds and produce energy.

Nanomedicine-based synthetic biology may produce the next generation of diagnostic tools such as novel synthetic contrast agents which can identify a disease in the earliest stage. These artificial systems could simultaneously diagnose, target and treat a certain disease with reduced toxicity. With the combination of synthetic biology and nano-biosensor technologies (e.g. microelectromechanical system (MEMS) technology, micro-fluidics, Lab-on-a-chip, micro-total analysis system), high sensitivity with ultra-low detection limits can be achieved which may allow detection of an established disease but also prediction of the possibility of developing a certain disease in the future. Another advantage of a nanomedicine-based synthetic biology is development of novel synthetic smart nanomaterials for regenerative medicine to be used in programmed tissue engineering, and cell/gene therapy [4].

This systemic synthetic biology can be integrated into a time-varying dynamic model which can simulate the exact nanomedicine-based synthetic systems and predict host-tissue/organ metabolism. *In silico* experiments can help to design novel artificial systems for multiple markers detection, drug delivery and targeting, which will eventually help to find hidden roles of a certain disease, fast drug discovery and screening.

As Richard Feynman said, "What I cannot create, I do not understand", the more we understand the complex behavior of biology, the more chance we will discover new drugs and control diseases. We envision that nanomedicine-based synthetic biology might revolutionize current biomedical science and technology in the future.

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