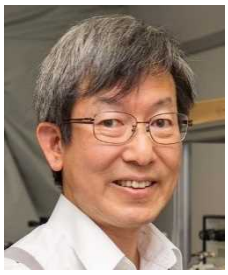
【Grant-in-Aid for Transformative Research Areas（A）】

Section Ⅳ



Title of Project： Molecular Cybernetics -Development of Minimal Artificial Brain by the Power of Chemistry

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【Purpose of the Research Project】

The project aims to establish a new methodology "how to assemble individual molecules and molecular devices into a system", by following the basic idea of the Innovative Area "Molecular Robotics" (2012-2016), but in far larger scale.

In practice, functional molecules acting as sensors, processors, or actuators are integrated to micrometer-sized compartment such as liposomes (artificial cells). The resulting artificial cells are further conjugated to each other to establish a methodology of engineering molecular systems with higher-ordered functions.

In contrast to typical robots or computers, which are assembled by wiring individual parts, the present "Molecular Systems Engineering" provides all the functions in bottom-up approach as chemical reactions between molecules in solutions.

【Content of the Research Project】

We construct micrometer-scale artificial molecular information processing system (Chemical AI or Minimal Artificial Brain), and make it process "Pavlovian Conditioned Reflex" to demonstrate the methodology of Molecular Cybernetics. To achieve this, we:

1. Develop microfluidic devices to align three individual artificial cells integrated with sensors, processors, and actuators in predetermined orders in each (Figure 1). They will be applied to a remotely controllable experimental system that records responses of the artificial cells exposed to various molecular stimuli. By sharing the system among the research community, we efficiently facilitate integration of research elements.
2. Develop "molecular information transfer devices (transducer)" to make artificial cells responsive to external stimuli or to transfer internal information of an artificial cell to adjacent one. To conjugate different kinds of artificial cells, proper transfer mechanisms of molecular information that do not require mixing of the internal solutions are necessary.
3. Establish design principle for molecular computing system with memory and learning ability using artificially synthesized nucleic acid molecules to demonstrate acquisition of "Pavlovian Conditioned Reflex" among aligned multiple artificial cells.
4. Develop "artificial actuator cells" to realize scalable information processing through formation of secondary connection (synapse) between multiple Minimal Artificial Brains by transforming their own shape.
5. Study the ethical, legal and social implications (ELSI) of Molecular Cybernetics through community-participating workshops and analyses on media and internet responses on the project.

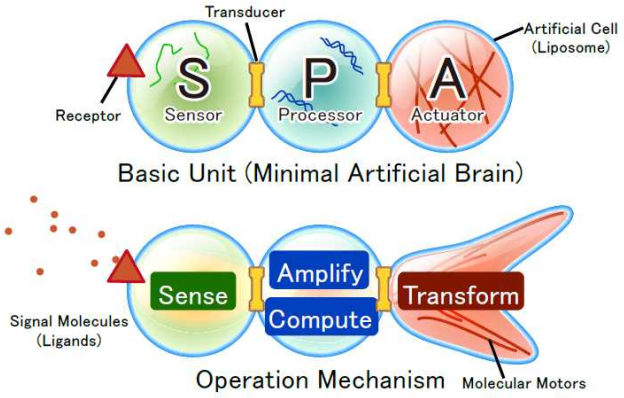

Figure 1 Chemical realization of Artificial Intelligence.

【Expected Research Achievements and Scientific Significance】

Molecular Cybernetics provide a foundation of versatile methodology to integrate various molecular devices into a system and may enable diverse application in the future. Feasible outcomes of the area include biosensors utilizing memory and learning function, artificial organs cultured as a hybrid between artificial and natural cells, and control of molecular swarm robots. Molecular Cybernetics is an attempt to reconstruct cybernetics (artificial intelligence) using principles in chemistry. This implies that cybernetics reach the level of molecules, that may revolutionize our outlook on matters and life.

【Key Words】

Molecular Cybernetics: A methodology to construct intelligent, information processing molecular systems by integrating individual molecular components or devices in large scale. Reconstruction of the concept of artificial intelligence in a material or molecular approach.

【Term of Project】 FY2020-2024

【Budget Allocation】 1,131,500 Thousand Yen

【Homepage Address and Other Contact Information】

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