Supramolecular Chemical Approach to Construction of Artificial Cell

Department of Life and Coordination-Complex Molecular Science
Division of Biomolecular Functions

KURIHARA, Kensuke
Research Associate Professor
(OKAZAKI ORION Project)
[kkurihara@ims.ac.jp]

Education
2005 B.S. The University of Tokyo
2010 Ph.D. The University of Tokyo

Professional Employment
2010 Postdoctoral Fellow, The University of Tokyo
2013 Postdoctoral Fellow, Research & Education Platf orm for Dynamics Living States, The University of Tokyo
2014 Research Associate Professor, Institute for Molecular Science
Research Associate Prof essor, Okazaki Institute f or Integrative Bioscience (OKAZAKI ORION Project)

Keywords Artificial Cell, Supramolecular Chemistry, Giant Vesicle

Exploring the boundary between a living and non-living matter is one of the most challenging problems for scientists. In order to understand a cell, which is a minimum unit of life, synthesis of an artificial cell from supramolecular chemical approach is a plausible strategy. By using a giant vesicle (GV), which is a supramolecular assembly of amphiphiles, as compartment, we constructed an artificial cellular system in which self-reproduction of GV and the amplification of internal DNA were combined. Such a constructive approach would be a powerful method of elucidating not only the boundary but also the origin of life.

In our laboratory, we aim to construct the following artificial cells: An artificial cell having a cycle of proliferation and an artificial cell which can be self-organized according to its environment.

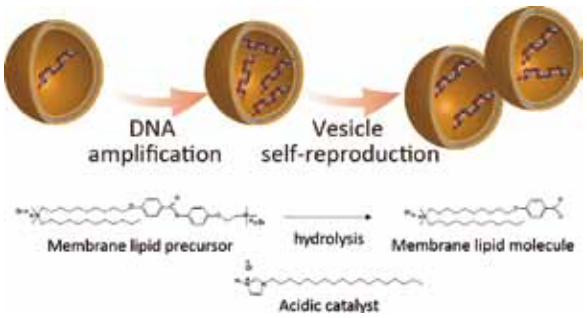

Figure 1. Proliferation of our artificial cellular system based on giant vesicle and structural formula of the molecules in the system.

Selected Publications

- K. Kurihara, M. Tamura, K-I. Shohda, T. Toyota, K. Suzuki and T. Sugawara, "Self-Reproduction of Supramolecular Giant Vesicles Combined with the Amplification of Encapsulated DNA," *Nat. Chem.* **3**, 775–781 (2011).
- T. Sugawara, K. Kurihara and K. Suzuki, "Constructive Approach towards Protocells," in *Engineering of chemical complexity*, world scientific lecture notes in complex systems, World Scientific Pub. Co. Inc., pp. 359–374 (2013).
- K. Kurihara, K. Takakura, K. Suzuki, T. Toyota and T. Sugawara, "Cell-Sorting of Robust Self-Reproducing Giant Vesicles Tolerant to a Highly Ionic Medium," *Soft Matter* **6**, 1888–1891 (2010).

1. An Artificial Cell Incorporating a Proliferation Cycle

One of the approaches for exploring the origin of life or elucidating of the functions of life is construction of an artificial cell from chemical approach.[1,2] We have constructed artificial cell which has three basic elements of a cell; information (DNA), compartment (giant vesicle: A supramolecular assembly of amphiphiles) and metabolism (synthetic catalyst).[3] The proliferation of the artificial cell was consisted of amplification of DNA and self-reproduction of GV. This vesicle is consisted of phospholipids, cationic synthesized molecules and cationic catalysts. Here, we added some phospholipids to the GVs for resistance of highly ionic medium and high temperature. First, we encapsulated template DNA and PCR reagents into the GVs and performed polymerase chain reaction to the GV dispersion and then the internal DNA was amplified. Second, we added a precursor of the GV membrane lipid molecule to the GV dispersion subjected to thermal cycles. After addition of the precursor, the GV proliferated accompanying with amplified DNA. From flow cytometric analysis, we found that the division of the GVs was accelerated by the amount of the amplified DNA in the GVs. We speculated that this complex formed by synthetic catalyst and the amplified DNA acted as an active scaffold of hydrolysis of membrane lipid precursor. This result means that information and compartment were combined.

However, this system ceased at the 2nd generation of GV because it does not have a cycle of growth and division. Now, we are constructing the recursive GV system with proliferation cycles, collaborating with Sugawara group (Kanagawa University). By using our vesicular transport system,[4] the 2nd generation of GVs which have no PCR reagents after self-reproduction was replenished by fusing with the conveyer GVs encapsulating the PCR reagents. The replenished GV can amplify the internal DNA and yield 3rd generation of the GV after addition of membrane lipid precursor. This system would lead to an evolvable artificial cellular system.

2. An Artificial Cell Incorporating a Cross-Catalysis System

A cell is a self-organized system which is able to maintain its state due to metabolism. The previous artificial cellular system have been so robust that it can self-reproduce only specific state in the any environments.

We aim to realize a new artificial cellular system in which the GV self-organize its own composition spontaneously according to the environment. In order for GV to self-reproduce and self-maintain, it is necessary to combine metabolism and compartment. We are constructing an artificial cell incorporating a cross-catalysis system. In this system, the GV was reproduced by the catalyst which catalyze the production of the GV membrane lipid molecule. The GV membrane provides the field where the catalyst is synthesized. In addition, by changing the packing parameter of the catalysts on the membrane, the GV collapse when the number of the catalyst increased substantially. This means that the artificial cell incorporating the negative feedback is realized.

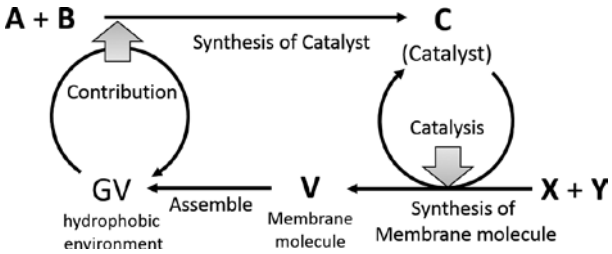

Figure 2. Scheme of new artificial cellular system. The membrane molecules of the GV was synthesized by the catalyst produced in the GV.

References

1) K. Takakura, T. Yamamoto, K. Kurihara, T. Toyota, K. Ohnuma and T. Sugawara, *Chem. Commun.* **50**, 2190–2192 (2014).
2) T. Sugawara, K. Kurihara and K. Suzuki, "Constructive approach towards protocells," in *Engineering of chemical complexity*, world scientific lecture notes in complex systems, World Scientific Pub. Co. Inc., pp. 359–374 (2013).
3) K. Kurihara, M. Tamura, K-I. Shohda, T. Toyota, K. Suzuki and T. Sugawara, *Nat. Chem.* **3**, 775–781 (2011).
4) K. Suzuki, R. Aboshi, k. Kurihara and T. Sugawara, *Chem. Lett.* **41**, 789–791 (2012).