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Creation of Simple Biochemical Systems to Study Early Cellular Life

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Abstract A constructive model of the minimal cell that can produce lipids internally was proposed by reconstructing a set of enzymes involved in phospholipid biosynthesis. This will be an promising approach to study not only for potential reconstruction of LUCA-like organisms but also for construction of artificial cells.

Keywords Minimal cell · Cell membrane · Fatty acid · ATP synthase

It is widely believed that every modern cell on the Earth has evolved from hypothetical common ancient cells, collectively called as Commonotes (Yamagishi et al. 1998) or LUCAs (Koonin 2003). The Commonotes provided a starting point for the evolution of modern cells several billion years ago. In contrast with protocells (Mansy et al. 2008), it is thought that Commonotes already possessed some basic cellular functions now found in modern cells, for example genetically directed protein synthesis, cell membranes, energy acquisition apparatuses, etc. An attempt to resurrect a Commonote in the laboratory has been implemented within the framework of minimal cell research (Luisi et al. 2006). Minimal cell is the hypothetical cell which consists of minimal set of genes and molecules for sustaining cell alive. On this research line, we have specially focused on the properties of the primitive cell membrane.

A constructive model of a minimal cell that can produce lipids internally was proposed by reconstructing a set of enzymes involved in phospholipid biosynthesis. First, fatty acids are synthesized from Malonyl-CoA by fatty acid biosynthesis enzymes (FabA, B, D, F, G, H, I, and Z), acyl carrier protein (ACP), and TesA. Subsequently, the fatty acid is processed by FadD to produce Acyl-CoA. Using acyl-CoA derivatives and glycerol-3-phosphate, Kuruma et al. have produced phospholipids by synthesizing two membrane-synthesizing enzymes, glycerol-3-phosphate acyltransferase and lysophosphatidic acid transferase, inside vesicles that

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encapsulate a cell-free protein synthesis system and the genes for both enzymes. The product phospholipid is the precursor of vesicle-forming lipids (Kuruma et al. 2009).

Such a constructive approach may be an important way to build self-reproducing minimal cells in the laboratory. We have also constructed an artificial cell organelle that can produce ATP by light irradiation. This is composed of a light-induced H^+-pump bacteriorhodopsin from *Halobacterium salinarum* and ΔpH-driven ATP synthase from thermophilic *Bacillus* PS3. Energy acquiring is important property of autonomous cell. We think this will be an interesting cell component not only for potential reconstruction of Commonote-like organisms but also for construction of artificial cells.

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