Constructive Study of Proto Cell Evolution and Membrane Permselectivity

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In this thesis, we study the evolution of primitive cells concerning the membrane permselectivity through the constructive approach. Especially, we aim at showing that facilitated division plays an important role in the evolution of primitive cells and investigating permeability of cell membrane of at the origin.

The cell membrane produces a different physicochemical environment from the exterior by controlling inflow and outflow of chemicals. While membrane transportation depends on various membrane proteins in the present cells, it is hard to consider that such complicated proteins existed in the initial stage of the evolution. Before a cell acquires the function of the active transportation by membrane proteins, passive transportation may contribute to producing a special environmental in the cell. Here, we pay attention to the role of passive transportation in order to consider the evolution of primitive cells. Concretely, we compare behavior of cells with simple diffusion and those with facilitated diffusion. Simple diffusion is a kind of diffusion in which a chemical permeates depending only on the difference of concentration of the substance between inside and outside of a cell. In case of facilitated diffusion, permeation of a cell is promoted by other substances.

To model primitive cells, we use coupled dynamical systems with open phase space. In the coupled dynamical systems, low dimensional dynamical systems, which are thought of as elements of a large dimensional system, interact with each other. While the dimension of phase space is fixed in usual dynamical systems, the degree of freedom in a dynamical system with open phase space changes through time by adding and deleting elements. Since the phenomenon we treat is that the number of cells increases and decreases by division and extinction through interactions among cells, we should utilize a coupled dynamical system with open phase space.

Specifically, we make a proto-cell model. In the model, a cell has an autocatalytic reaction network in its inside and chemical substances permeate through membrane by diffusion. We analyze behavior of two cell types, with simple diffusion and with facilitated diffusion, by computer simulations.

By changing the permeability, we compare the number of cells, the times of division, and the life span between the two types. In a region of low permeability, the number of

cells and the times of division of the facilitated diffusion cell was larger than those of the simple diffusion cell. The life span of the facilitated diffusion cell is longer than that of the other type in the whole region of permeability.

We conducted in simulations in which cells with simple diffusion and facilitated diffusion proliferate in one culture medium. We observed that simple diffusion cells extinct unless the permeability of that type is more than twice of that of facilitated diffusion cells. That is, we found that the function of facilitated diffusion promotes the viability of cells when permeability is the same as or twice of the simple diffusion cells.

We made experiments of an evolutionary model in which permeability mutates at cell division with some probability. In a case of low initial permeability, diversity of the permeability becomes larger than a case of higher initial permeability. The permeability of chemicals varies depending on each of them if the initial permeability is low. On the other hand, when a system starting from high permeability, the diversity and the amplitude of fluctuation of permeability is relatively small.

These results mean the followings: The facilitated diffusion cell is more advantageous to survive than simple diffusion cells in the region of low permeability. The permeability at the origin of cells may be low and permselectivity of cell membrane may evolve for necessary substances to be permeated, since a variety of permeability corresponding to each substance is indispensable in order to produce special environment in the inside of cells.

Putting these results and arguments together, it is suggested that there was a stage of membrane evolution of selection permeability by facilitated diffusion, before the active transportation by complicated membrane proteins appears. Moreover, we can consider a possibility that the evolution of membrane permselectivity by the passive transportation made environment in cells specific and that the cells acquired higher function.