4. Growth Pattern in Biological and Nonbiological Systems

Yasuji Sawada

Research institute of Electrical Communication,
Tohoku University, Dendai 980 Japan

One decade has passed since J.S.Langer[1] wrote a review article on the dendritc crystal growth, which is a typical growth pattern in nonequilibrium systems and whose underlying mechanism for the pattrern selection has been an interesting target of the nonlinear physics in the system far from equilibrium.

Therefore, it may be amusing now to pay some attention on what has been understood and what has been left to be understood in the field of growth pattern in nonlinear systems far from equilibrium.

It has been by now agreed among researchers that the growth patterns in hydrodynamics such as a viscous fingering has the same physics and statistical characters with the crystal growth under certain conditions. Therefore we focus here only on the dendritic growth problem.

Here is my personal list of the problems which I feel are left to be understood.

1)What is the sidebranching mechanism?

The selection of the growth tip and the growth velocity of freely growing dendrite have been well understood as a nonlinear eigenvalue problem.[2] The sidebranching mechanism is only poorly understood theoretically and experimentally. It was found recently that the sidebranches are created by two different mechanisms: one is noise amplification mechanism and the other is dynamical oscillation. Figure 1 shows coexistence of two types of dendrites growing from the same seed in a supersaturated aceton solution of the succinonitrile.[3] It is not known what kind of noise is amplified to form the sidebranch in the first kind, and what causes oscillation in the second type.

2)Why are the fractal structures, such as metal leaves or even numerical DLA, stable? How is the theory of stability formalized? Dimensional analyses ,such as Tokuyama-Kawasaki,[4] and Honda-Toyoki-Matsushita[5] on DLA were successful in giving fractal dimension. Also there are much researches on the multi-fractal analysis or singularity spectrum analysis. But not much is discussed on the stability of the DLA pattern.

3)The growth velocity of the fractal patterns?
Acording to the recent numerical simulation and analysis of Uwaha and Saito,[6] the growth velocity of 'DLA pattern' growing in a finite particle concentration is proportional to 1/(spatial dimension -fractal dimension) power of the concentration. It was experimentally found that the linear growth speed of the fractal structure made by electro-chemical decomposition has no concentration dependence on the electrolyte concentration.[7]

Although it is classical that the geometric shape of electro-chemical decomposition has a strong similarity with DLA, dynamics of growth is not known yet.

4)What are the difference between the self-organizations of biological and non-biological systems.

We have for several years been studying regeneration of dissociated cell aggregate of Hydra.[8]

The regeneration process is devided into three stages. First is the cell sorting period. The second is the cavity formation period. The third is the structure formation period. Most of these processes would be explained physico-chemically. The pattern formation of bacteria colony recently studied by Matsushita et. al.[9] showed exciting similarity with DLA. In this sense the pattern formation in biological systems is not much different from "physical systems".

Biological systems utilize information to survive. The system must produce information to control the structure. Turbulence also produces information, but they are dissipated. Therefore, the biological pattern includes information producing structures such as neuronal network, which help coherent functioning of the structure. It would be interesting if a living structure can be mathematically distinguished from otherwise.

Reference

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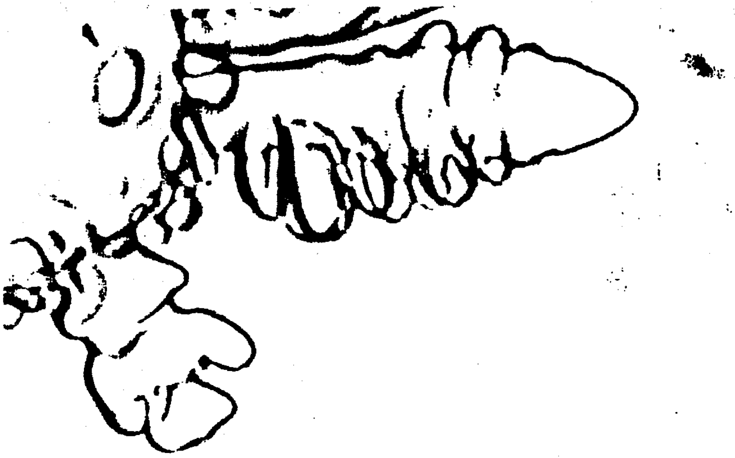

図1.　2種類の横枝発生機構の共存

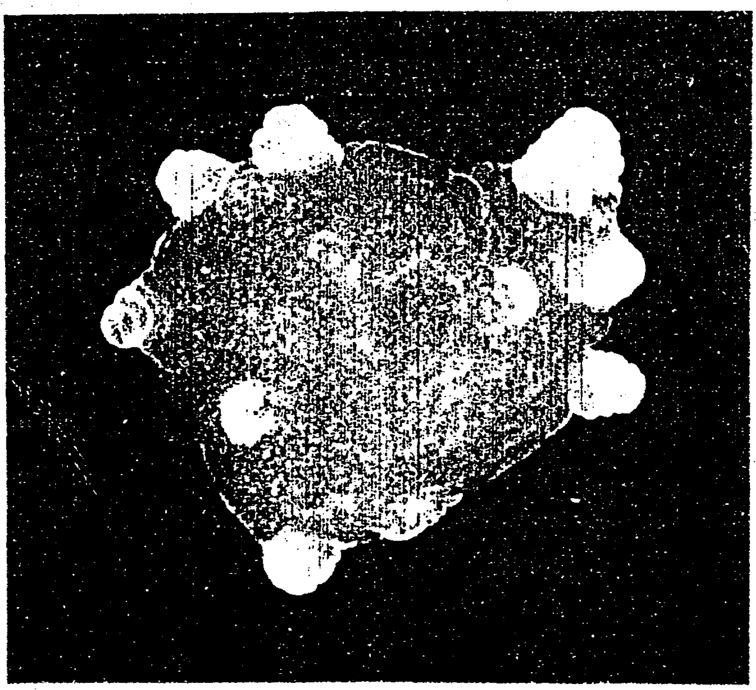

図2.　ヒドラ解離細胞集合体から再生中のヒドラ
（佐藤美香氏の提供による）