Turing pattern formation without diffusion

Shigeru Kondo, Osaka University

The reaction-diffusion mechanism, presented by AM Turing more than 60 years ago, is currently the most popular theoretical model explaining the biological pattern formation including the skin pattern. This theory suggested an unexpected possibility that the skin pattern is a kind of stationary wave (Turing pattern or reaction-diffusion pattern) made by the combination of reaction and diffusion. At first, biologists were quite skeptical to this unusual idea. However, the accumulated simulation studies have proved that this mechanism can not only produce various 2D skin patterns very similar to the real ones, but also predict dynamic pattern change of skin pattern on the growing fish. Now the Turing's theory is accepted as a hopeful hypothesis, and experimental verification of it is awaited.

Using the pigmentation pattern of zebrafish as the experimental system, our group in Osaka University has been studying the molecular basis of Turing pattern formation. We have identified the genes related to the pigmentation, and visualized the interactions among the pigment cells. With these experimental data, it is possible to answer the crucial question, "How is the Turing pattern formed in the real organism?"

The pigmentation pattern of zebrafish is mainly made by the mutual interactions between the two types of pigment cells, melanophores and xanthophores. All of the interactions are transferred at the tip of the dendrites of pigment cells. In spite of the expectation of many theoretical biologists, there is no diffusion of the chemicals involved. However, we also found that the lengths of the dendrites are different among the interactions, which makes it possible to generate the conditions of Turing pattern formation, "local positive feedback and long range negative feedback". Therefore, we think it is appropriate to call the identified mechanism as a Turing mechanism although it does not contain any diffusion.