【Grant - in - Aid for Scientific Research on Innovative Areas(Research in a proposed research area)】
Biological Science

Title of Project : Discovery of the logic that establishes the 3D structure of organisms

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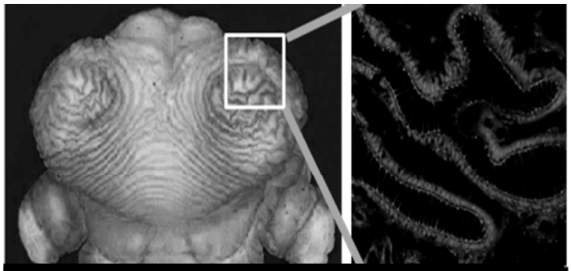
【Purpose of the Research Project】

In this research project, we approach morphological phenomena that cannot be understood without an explicit awareness of "three-dimensionality (3D)". Our aim is to explain the logics governing the creation of the three-dimensional form of living beings.

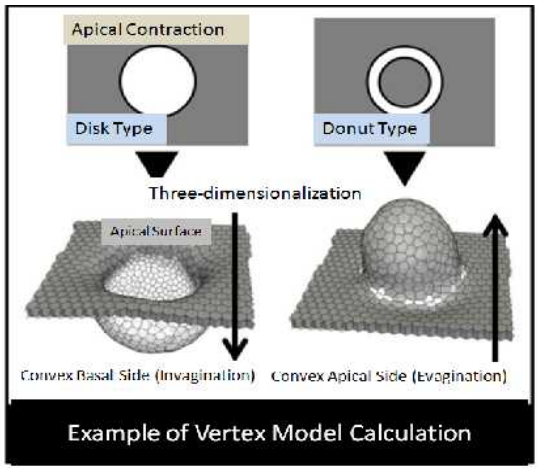
【Content of the Research Project】

There are two characteristics of this research project: (1) specialized research subjects in 3D morphogenesis; and (2) the integration of mathematical science.



Wrinkles on Rhinoceros Beetle Horn Primordium (Folds)

In the above picture of a rhinoceros beetle's horn primordium, a complex folded structure can be seen, but it is hard to correlate it with the completed form. To start, the creation of the elegant structure of the completed form in its fully-folded state can be considered all but impossible. From a mathematical perspective, it is difficult to answer the question, "In the real world, which doesn't allow for anything but a kolimited amount of expansion and contraction, how can an arbitrarily complex shape be folded out of the planar surface of a primordium?" Nevertheless, as long as one cannot answer the question posed by this spatial structure, one cannot truly know how organisms get their 3D form. Conversely, if one understood how to fold such complicated 3D shapes, then one could create any given shape.



Example of Vertex Model Calculation

Additionally, some of the research subjects we are working on include the 3D transformation of fish somites, chiral torsion in the hindgut of Drosophila, in vitro cultivation of epithelial cells showing 3D morphogenesis, and the 3D transformations occurring in the cell layer during neural tube formation in amphibian embryos.

If one uses an appropriate calculation system like a 3D vertex model, one can calculate the way in which forces generated in one section of the cell sheet transform the morphogenetic fields. If we combine this system with experimental data and extend it mathematically, then complete explanations of complex 3D structures such as that of the treehopper will no longer be mere dreams.

【Expected Research Achievements and Scientific Significance】

The extremely complicated structure of the treehopper helmet, like the horns of the rhinoceros beetle and the wings of insects, is formed from the folding of a cell sheet. Therefore, with a better understanding of the relationship between folding structures and 3D form, one can certainly claim to understand the mechanisms of the formation of the 3D shape of most insects and crustaceans. This is one of the primary goals of developmental biology.

【Key Words】 Three-dimensional form, Cell sheet, Origami theory
【Term of Project】 FY 2015-2019
【Budget Allocation】 1,102,300 Thousand Yen
【Homepage Address and Other Contact Information】
http://www.3d-logic.jp/