3. Research Field: Life Science
4. Research Categories: Exploratory Research for Space Utilization
5. Research Theme: Amplified expression of the gravity effect on the spatio-temporal formation of bioconvective pattern
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8. Summary of Research

We proposed a research which aims to reveal a new concept concerning the effect of terrestrial gravity on the biological systems. Gravity has been considered as a kind of restrictive force which provides such as the mechanical limits of growth and morphology of the organisms. In the proposed research we would like to reveal the possibility for gravity to develop new functions of the biological systems through collective interactions between the elements of the system. Collective interactions, which are ubiquitous in nature, and the resultant dynamic instability of the system itself are known to have an ability to amplify the subtle effects of external forces, such as that of gravity on the biological event the cellular dimensions. In this research bioconvective pattern formation was focused as a research tool for our proposal, and several useful results were obtained which may lead to the development of the new research fields in space and gravitational biology.

1. Abrupt transition of bioconvective pattern (pattern alteration response) found in *Chlamydomonas*

Gravitactic microorganisms propel themselves preferentially upwards to form a dense accumulation at the top of the water column. When the top-heavy density gradient grows sufficiently large, an overturning convection occurs, leading to a formation of characteristic patterns, which involve highly concentrated aggregation of cells extended in two-dimensional structures. We found a quite interesting behavior of bioconvective pattern created in the suspension of the unicellular green algae, *Chlamydomonas reinhardtii*. The phenomenon, called the pattern alteration response, was characterized by a rapid decrease in the pattern size (Fig 1). It occurred, much like a phase transition found in the physical events, spontaneously all over the suspension which already showed steady pattern formation. It was also observed that the response was initiated locally and propagated with the speed much faster than the swimming velocity of *Chlamydomonas*. Quantitative analysis of the response would stimulate further thought and research concerning gravity-related effects in biology.

![Fig 1. Pattern alteration response recorded from the suspension of Chlamydomonas reinhardtii. (a) to (d) Plan views of the bioconvection pattern at 0.5 (a), 30 (b), 35 (c) and 40 min (d) after placing the suspension into the recording chamber. (e) Space-time plot of the bioconvective pattern formation. Density profiles measured on a linear portion at a given position in each sequential image (as indicated by faced triangles in a) are displayed side by side in a time sequence (from left to right) to form an image. Times for corresponding plan views are indicated by arrows.](image-url)
2. Responses of bioconvection pattern to the altered gravity

In order to assess the stability of the collective motion under the influence of gravity, responses were investigated of the bioconvection pattern of *Tetrahymena* and *Chlamydomonas* to the altered gravity during parabolic flight of an airplane. Responses were analyzed by means of either space-time plot or discrete two-dimensional fast Fourier transformation (2D-FFT). In *Tetrahymena*, patterns were observed to increase their size under hypergravity and disappeared under microgravity (Fig 2). In *Chlamydomonas*, changes in the pattern size under hypergravity was less clear, although the patterns were observed to be enhanced under hypergravity and tended to increase in the wave number. The patterns by *Chlamydomonas* remained less changed under microgravity. These differences in the response between organisms may be informative for the investigations for the development of the new research fields in space and gravitational biology.

The gravity dependent increase in the wave number observed in this research is almost in line with the response observed under the centrifugal hypergravity (Mogami et al, 2004, *J. Exp. Biol*. 207, 3349-3359), but not with those in the previous parabolic flight experiment (Noever, 1991, *Phys. Rev. A*, 44, 5279-5291).

![Fig 2. Responses of the bioconvection pattern by *Tetrahymena pyriformis* to the altered gravity during parabolic flight of the airplane (MU-300, Diamond Air Service). A, plan views of the convection pattern at the time indicated by arrows. Scale bar, 10mm. Dominant spatial frequency (wave number) calculated by 2D-FFT of convective patterns are shown in B in association with its amplitude (C). D, profiles of changes in gravity acceleration during the flight.](image)

9. Publication List


10. URL