外国語要旨 (English Abstract)

Dynamic properties of bioconvection: Approach from the detailed analysis of the pattern transition

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Motile aquatic microorganisms are known to self-organize into bioconvection patterns. The swimming activity of a population of microorganisms leads to the emergence of macroscopic patterns of population density under the influence of gravity. The patterns look like dots or stripes when viewed from above, the scale of which (mm or cm order) is about 100 times larger than that of the individual microorganisms (10-100 μm order). This pattern of density corresponds to two-directional flows of the microorganisms: when viewed in vertical section, the microorganisms sink as blobs in the dense region and move upwards in the sparse region. Originally called by biologists "aggregation", "pattern swimming" or just "pattern formation", the phenomenon is termed bioconvection due to its apparent resemblance to thermal (Rayleigh-Benard) convection.

The possibility has been proposed that bioconvection might have physiological functions such as promotion of gas or nutrient transport. Although long-term development of the bioconvection pattern is important in order to elucidate the possible integration of physiological functions of individual organisms through bioconvection pattern formation, little quantitative investigation has been carried out.

In this dissertation, I explore the dynamic properties of bioconvection through long-term behavior of bioconvection of *Chlamydomonas reinhardtii,* particularly focusing on the "pattern transition". The pattern transition is an abrupt breakdown of the steady bioconvection pattern followed by re-formation of the pattern with a decreased wavelength.

In Part I, I present the first quantitative long-term description of bioconvection of *C. reinhardtii*. I found three phases in the pattern formation of the bioconvection of *C. reinhardtii*: onset, steady-state 1 (before the transition) and steady-state 2 (after the transition). In onset, the wavelength of the bioconvection pattern increases with increasing depth, but not in steady-states 1 or 2. The newly developed two-axis view method revealed that the population of *C. reinhardtii* moves toward the bottom of the experimental chamber just before the pattern transition. This indicates that the pattern

transition could be caused by enhancement of the gyrotaxis of *C. reinhardtii* as a result of the changes in the balance between the gravitactic and gyrotactic torques. The changes in the torque balance might originate from the changes in the flagellar activity such as the changes in flagellar waveform during a beat cycle. In addition, the bioconvection pattern changed its wavelength in response to the intensity of red-light illumination, to which *C. reinhardtii* is phototactically insensitive. These facts suggest that the bioconvection pattern has a potential to drastically reorganize its convection structure in response to the physiological processes under the influence of environmental cues.

In Part II, I further explore bioconvection behavior of the flagellar mutants of *C. reinhardtii*, based on the working hypothesis that the flagellar waveform might change the torque balance. In addition to the wild type used in Part I, two flagellar mutants were chosen for the experiments: *ida1*, which shows abnormal flagellar waveform but normal beat frequency, and *oda2*, which shows normal waveform but lower beat frequency than the wild type. Bioconvection of *oda2* showed similar morphology to that of the wild type. *ida1*, in contrast, showed bioconvection with rather smaller wavelength than the wild type and *oda2*. In addition, settling blobs of *ida1* showed oscillatory movement, which was not observed in the bioconvection of the other two strains. From the individual swimming analysis, it turned out that both of the flagellar mutants swam at a speed less than half of the wild type and that *ida1* showed stronger negative gravitaxis than the wild type while *oda2* showed reduced gravitaxis. These facts imply that the flagellar waveform, not the swimming speed nor the beat frequency, should strongly affect bioconvection behavior of *C. reinhardtii*. Enhancement of gravitaxis in *ida1* could be attributed to the lack of the regulatory property of the inner dynein arm subspecies *f* in the flagellar axoneme.