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Substrate deformation induces change in crawling direction of fish keratocyte

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Crawling movement of fish keratocytes, one of the cell types exhibiting remarkable motility, is driven by coordinated cycles of actin polymerization at the leading edge and adhesion to the substrate, under the balance of forces acting on the cell membrane and the cytoskeleton. It is reported that biomechanical factors play important roles in cellular motility. For example, assembly and disassembly of actin filaments are well coordinated to produce forces through a self-reorganization mechanism. Depolymerization of actin filament is initiated by the release of intracellular tension. Controlled focal adhesion distribution on a micropatterned substrate consisting of cell adhesive and non-adhesive regions leads to polarized cell shape with specific orientation.

In this study, first, to evaluate the effects of focal adhesion distribution on the crawling direction of keratocytes, distribution of focal adhesions was controlled using a rectangular (10 μm × 1.5 μm with 4 μm intervals) fibronectin-micropatterned substrate. Second, to observe change in the crawling direction due to perturbation of the mechanical condition of the actin filament, compressive strain parallel to the long axis of the rectangular pattern was applied to the cells.

Before strain application, keratocytes on a micropatterned substrate were aligned perpendicularly to the long axis of the rectangular pattern, although cells on a normal substrate had no preferred direction. This result indicates that the crawling direction depends on the distribution of focal adhesions. Furthermore, shortly after strain application, the orientation direction changed and became parallel to the strain direction which corresponds to the long axis of the rectangular pattern. Thereafter, the crawling direction gradually returned to the original perpendicular direction. These results suggest that focal adhesions play a steering role and that the applied strain enhances polymerization and depolymerization rates of actin filaments. Therefore, it can be concluded that the biomechanical factors' regulation of driving forces and their balance determines the cell shape polarity and directional motility.

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