Nuclei go with the flow to stay in sync

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Video Abstract

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Abstract

Like a symphony, the earliest moments of life play out with incredible precision. Take the fruit fly embryo. Unlike a human embryo, where a single cell becomes many through repeated rounds of cell division, the early embryo of the fruit fly starts as a single nucleus that then divides into thousands of nuclei, all within the same cell. During these divisions, the nuclei must navigate through the embryo to highly specific locations before they become separated into the thousands of cells that will eventually develop into an adult fly. A new report in *Cell* describes how these nuclei steer themselves to where they need to be. To uncover the mechanisms that drive nuclear positioning and cell cycle synchronization, the team developed state-of-the-art imaging and computational tools to manipulate and track cell cycle and cytoskeletal dynamics in early embryogenesis. Additionally, the team used optogenetic methods to manipulate cytoskeletal contractility with spatial and temporal accuracy. Their experiments revealed that nuclei provide a spatial landmark for both biochemical and mechanical signaling. Oscillations of cyclin-dependent kinase 1 were observed in the immediate vicinity of nuclei, while protein phosphatase 1 spread through a region around 50 microns away. This generated myosin II gradients that were closely linked to the position of the nuclear cloud. These gradients later converged toward the top of the nuclear cloud, generating cytoplasmic streaming in the exact direction needed to distribute nuclei along the embryo. The work demonstrates that nuclei can organize cytoplasmic flows and, in turn, regulate their spreading, indicating that nuclei use a self-organized mechanism to position themselves precisely and evenly throughout the embryo. This ensures that all nuclei undergo the same number of divisions to retain cell cycle synchrony when initiating cellularization. Studying cell division and nuclear positioning in fly embryos provides unique insights into the mechanisms that integrate biochemical signals and mechanical properties over large spatial scales. Uncovering these mechanisms in early embryogenesis may help reveal general principles for such integration in other complex tissues.