The mechanics of shape change in the Drosophila embryo

Eric F. Wieschaus[1,2], Adam C. Martin[5], Bing He[2], Matthias Kaschube[3,4], Oleg Polyakov[4]

[1]Howard Hughes Medical Institute, USA
[2]Department of Molecular Biology, Princeton University, USA
[3]Lewis-Sigler Institute for Integrative Genomics, Princeton University, USA
[4]Joseph Henry Laboratories of Physics, Princeton University, USA
[5]Department of Biology, Massachusetts Institute of Technology, USA
efw@princeton.edu

Abstract

With the first three hours of development, the Drosophila embryo establishes a precise pattern of transcription factors that divides the blastoderm into groups of cells destined to form different organs and tissues in the adult. Along the dorsal ventral axis, the first and perhaps most important of these cell fate decisions is the establishment of mesoderm controlled by expression of the Twist and Snail transcription factors. These cell fates decisions are immediately translated in changes in the shapes and physical properties of the 800 mesodermal cells and result in the formation of the furrow that translocates them to the interior. Although at the cellular level these changes involve a re-organization of the cytoskeleton, adhesion and motor activities to achieve distinct shape we are interested in the underlying physical parameters that govern behavior.

In my talk I will discuss the relationship between the initial transcription profiles and a novel pulsating reorganization of the Actin/Myosin cytoskeleton in the apical region of cells that will make the ventral furrow. We show that the resultant contractile pulses drive cell shape changes in the entire mesodermal primordium. The individual contractions appear to be unpolarized but they result in polarized wedge-like constrictions because global tension in the sheet is polarized along the AP axis. We analyze the force distributions in the mesodermal primordia using a combination of genetics and RNAi to lower adhesive strengths between cells, and laser dissections to locally disrupt the cytoskeleton.

We have developed analytical tools that allow tracking surface areas and volumes of all 800 mesodermal cells during the process of furrow formation. We find that cell volume is essentially constant during the process and that global cell shape changes are pulsed in synchrony with the Actin/Myosin contractions in the apical surface. We envision that force generated apically is transmitted over large distances by the non-compressible nature of the cytoplasm and suggest that similar mechanism that may underlie many morphogenetic movements.