# Mechanical Aspects of Cell Division

Noah Langowitz[*], Che-Hang Yu[*], Manqi Deng[**] & Daniel Needleman[***]
[*]*School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138*
[**]*Brighham and Women's Hospital, Ob Gyn, Boston MA 02115*
[***]*School of Engineering and Applied Sciences, Molecular and Cellular Biology, Center for Systems Biology, Harvard University, Cambridge, MA 02138*

*Summary* Cell division is essential for all life, plays a prominent role in animal development, and a variety of diseases are caused by its malfunction. When a cell divides, many of its internal constituents, including its DNA, are actively segregated into the daughter cells. Very little is known about the mechanics which drive these movements, even though the molecular components of the cell division machinery are becoming increasingly well understood. We are studying the first meiotic cell division of mouse oocytes using high resolution imaging, magnetic tweezers, and laser ablation to gain insight into the mechanics of cell division by determining the rheological properties of the cytoplasm and subcellular structures, and the sites of active stress generation.

## INTRODUCTION

The spindle is the molecular machine at the heart of cell division that both segregates chromosomes and determines the location of the cleavage plane [1]. Oocytes undergo two highly asymmetric cell divisions, giving rise to two small polar bodies and a very large egg. In both mouse and human, the spindle must migrate from where it assembles, in the middle of the oocyte, to the periphery, so that it can produce the required asymmetric division. After the spindle reaches the edge of the cell, it induces the two sequential divisions, each time placing half the DNA from the oocyte into the newly formed polar body. The mechanical processes responsible for positioning the spindle and segregating chromosomes are both poorly understood.

There are a number of possible models for spindle positioning in oocytes. It has been suggested that cytoplasm is a Newtonian fluid and large scale flows in the oocyte push the spindle to the periphery [2]. Alternatively, the spindle has been proposed to "swim" to the edge of the cell, either by pulling on a viscoelastic material throughout the cell [3] or by polymerizing filaments on its surface to push off of the cytoplasm [4].

## RESULTS AND DISCUSION

We are attempting to distinguish between the proposed models of spindle positioning in mouse oocytes using a combination of quantitative experiments and theory. We are tracking the motions of the spindle and the cytoplasm using high resolution transmitted light microscopy, spinning disk confocal microscopy, two-photon laser scanning confocal microscopy, and second harmonic generation imaging. These experiments will provide detailed information on the dynamic structural changes that occur during spindle migration. We are selectively eliminating cellular structures with laser ablation and genetic perturbations to study their role in moving the spindle. We are also using magnetic tweezers to perform rheological measurements of the cytoplasm and we plan to attach magnetic beads to the spindle [5] to directly measure the forces required to perturb its motion.

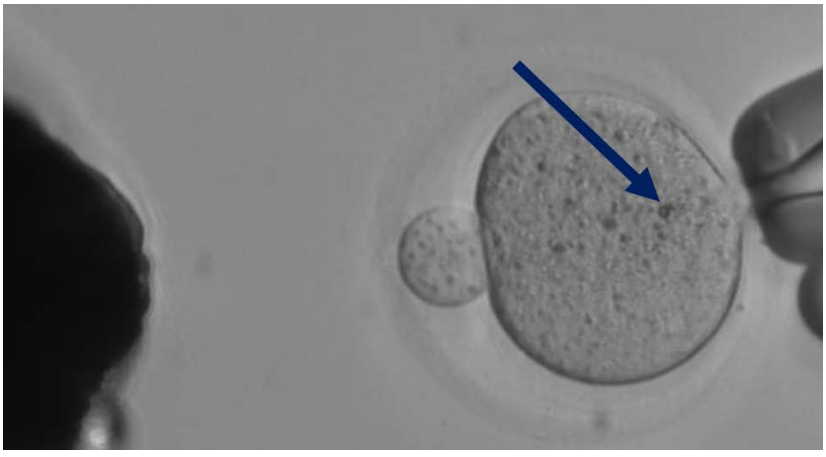

**Figure 1:** A mouse oocyte microinjected with a magnetic bead (blue arrow). The oocyte is held by a micropipette (right) while an electromagnet (left) exerts a force on the bead. This setup can be used to examine the rheology of the oocyte, and the forces which position the spindle and segregate chromosomes.

Our goal is to interpret these quantitative measurements with the aid of explicit mechanical models and simulations to differentiate between the proposed mechanisms of spindle positioning. Our preliminary results are very promising and suggest that a biomechanical approach can be used to provide insight into spindle positioning and cell division more broadly.

## CONCLUSIONS

Cell division is ultimately a mechanical process involving the motion and rearrangement of the cell interior. While the molecular genetics and biochemistry of cell division are becoming increasingly well understood, very little is still known about biomechanical aspects of this phenomena. This problem is of both fundamental and biomedical importance. We have a series of tools in place which are well suited to gain insight into these issues and we have obtained exciting preliminary results.

### References

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