# Precision of cell length sensing via concentration gradients

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***Short Abstract* — How cell size is regulated is one of the outstanding questions in biology. In this work we analyze a mechanism of cell size regulation recently proposed to operate in fission yeast [1,2] consisting of bipolar protein gradients together with localized concentration detection at mid-cell. We estimate the precision with which this mechanism is able to measure cell length in the presence of intrinsic biochemical noise. We find that the use of concentration gradients allows for robust length sensing, and that observed protein gradients are typically close to the optimal parameter combinations for providing length information.**

***Keywords* — Noise, concentration gradients, cell size regulation, cell cycle checkpoint**

## I. Introduction

UNICELLULAR organisms are typically found to have a characteristic cell size. In order to maintain a homeostatic distribution of sizes over many generations, cell size must be sensed and regulated [3]. However, the molecular mechanisms by which size is controlled are not well understood. Recent experiments in fission yeast [1,2] have shown that cell length is regulated in part by spatial gradients of the protein Pom1. As the cell grows, the concentration of Pom1 at mid-cell decreases and mitosis is initiated. This system has many similarities to gradients of division inhibitor proteins in bacteria, such as MipZ in *Caulobacter* [4] and MinCD in *B. subtilis* [5], suggesting that this mechanism may be more generally used in diverse organisms.

The precision by which cell length can be measured will be limited by intrinsic noise in the reactions and other biophysical processes, such as diffusion, which lead to formation of the protein gradient [6], and in the reactions by which the gradient is read out [7]. Here we analyze a simple mathematical model of these bipolar gradient systems, and examine how reliably a particular threshold length can be measured given the inevitable biochemical noise.

## II. Results

We find that in biologically-relevant parameter regimes, bipolar concentration gradients with localized detection allow for more accurate measurement of cell length than a comparable spatially-uniform system. Additionally, through the use of spatial gradients cells are able to reliably sense their length even if the cell-wide average protein concentration remains constant as the cell grows, meaning that the cell cycle can be regulated by proteins whose expression is not itself under cell cycle control. We show that there are optimal choices for the diffusion constant and other model parameters which maximize the precision of length sensing. Furthermore, we examine the effect of noise in measuring the concentration of the gradient protein on downstream decision making. We find that the optimal precision of length sensing can be achieved when this concentration measurement is least precise.

## III. Conclusion

Our results show a number of advantages for the use of concentration gradients in the measurement of cell length. By exploiting the characteristic length-scale of a gradient, cells can achieve more accurate length sensing with a reduced regulatory cost compared to a similar spatially-uniform system. We also find that division-inhibitor gradient systems typically operate close to the optimal parameter combinations for which length sensing is most precise.

## References

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