Turnover Dynamics of Dendritic Actin Networks *In Silico*

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***Short Abstract* — Animal cells migration and morphology regulation depends on the rapid turnover of dendritic actin networks, and this process is controlled by arp2/3 complex and capping protein. To understand how regulatory protein mediates the turnover dynamics, we construct a 3D computational model coupling stochastic reaction-diffusion processes with polymer mechanics. Our model sheds light on the way the turnover dynamics is affected by arp2/3 and capping protein concentrations and kinetics. Additionally, we find that treadmilling of preexisting filaments dominates the turnover, but the *de novo* assembly of filaments becomes significant when dissociation rate is slow.**

***Keywords* — Cell migration, stochastic simulation, turnover, dendritic cytoskeleton, arp2/3 complex, capping protein.**

I. Introduction

The abilities of animal cells to move and adapt their shape to environment rely on the rapid turnover dynamics of dendritic cytoskeleton actin networks [1]. However, the regulation machinery of turnover dynamics is still poorly understood due to the insufficient resolution of fluorescent microscopy and lack of effective ways to control regulatory protein concentration and related reactions. By simulating the dendritic actin networks via MEDYAN, an advanced mechano-chemical simulation model combining stochastic reaction–diffusion with mechanical force field [2], we are able to qualitatively understand how turnover dynamics is regulated by arp2/3 complex and capping protein (CP).

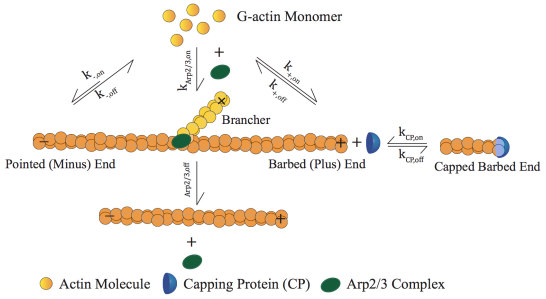

Figure 1. Featuring components and the corresponding reactions in the dendritic network model.

II. Results

Turnover is contributed by the treadmilling of preexisting filaments and the *de novo* assembly of filaments nucleated by arp2/3, but which subpopulation dominates turnover is still under debate [3-4]. By tracking the dynamics of each subpopulation, we find that existing filament treadmilling is the main contributor to turnover. Nevertheless, reducing CP dissociation rate promotes the *de novo* filament assembly without altering the turnover timescale.

It is generally believed that rapid turnover is accompanied by fast treadmilling process, but we show that filament length also plays a critical role. At low arp2/3 concentration, we observe the highest treadmilling rate, however, lack of sufficient nucleation creates long filaments that inhibits the turnover. Filament length decreases as arp2/3 concentration growth that enhance the turnover speed.

CP binds to free barbed end and terminates barbed end elongation. Although CP restricts filament treadmilling, nucleation is promoted by high critical actin concentration that creates short filaments and maintains rapid turnover. Consequently, CP does not affect turnover dynamics until a high fraction of barbed ends is capped. When the barbed end capping fraction is higher than 90%, the loss in free barbed end overweighs other factor and inhibits the turnover.

III. Conclusion

Insights of dendritic networks turnover dynamics allow us to relate cellular activities to intracellular cytoskeleton machinery. We find that turnover is cooperatively regulated by filament length and treadmilling, which can be tuned by arp2/3 and CP concentration. Preexisting filament treadmilling and *de novo* filament assembly can be altered by CP dissociation, which would potentially explain the force generation mechanism in dendritic networks with heterogeneous regulatory protein distribution.

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