Abstract for an Invited Paper
for the MAR10 Meeting of
The American Physical Society

Dendritic Actin Nucleation Causes Traveling Waves and Patches[1]

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Reversible polymerization of the intracellular protein actin into semiflexible filaments is crucial for cell motion and environmental sensing. Recent studies have shown that polymerized actin can spontaneously form traveling waves and/or moving patches. I investigate possible mechanisms for such phenomena by numerically simulating the "dendritic nucleation" model of actin network growth. The simulations treat the growth of an actin network on a flat portion of a cell membrane, using a stochastic-growth method which calculates an explicit three-dimensional network structure. The calculations treat processes including filament growth, capping, branching, severing, and Brownian motion. The dynamics of membrane proteins stimulating actin polymerization are also included: they diffuse in the membrane, and detach/deactivate in the presence of polymerized actin. The simulations show three types of polymerized-actin behavior: 1) traveling waves, 2) coherently moving patches, and 3) random fluctuations with occasional moving patches. Wave formation is favored at low free-actin concentrations by a long reattachment time for the membrane proteins, and by weakness of the attractive interaction between filaments and the membrane. Raising the free-actin concentration results in a randomly varying distribution of polymerized actin. Lowering the free-actin concentration below the optimal value for waves causes the waves to break up into patches which, however, move coherently. Effects of similar magnitude are predicted when other intracellular protein concentrations are varied. Diffusion of the membrane proteins slows the waves, and, if fast enough, stops them completely, resulting in the formation of a static spot.

[1]This work was supported by the National Institutes of Health under Grant R01-GM086882