Single Actin Filaments Pushing Loads: Growth Kinetics and Fluctuations

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Cellular and Developmental Biology, Yale Univ — Many types of cellular motions
are driven by the polymerization and depolymerization of actin filaments growing or
shrinking against cellular loads. Actin growth involves polymerization of ATP-actin
monomers followed by fast ATP hydrolysis and slow phosphate release generating
unstable ADP-actin. We present Monte Carlo simulations and analytical theory de-
scribing growth kinetics of single filaments pushing against external loads. Our work
is related to earlier work by Mogilner and Oster (Biophys. J. 71, 3030, 1996). We find
the behavior near stall is influenced by (1) hydrolysis and phosphate release and (2)
fluctuations in growth rates. Fluctuations become important near stall conditions,
where growth rate vanishes. We find that under zero external load actin filaments
have a long fluctuation-stabilized ATP/ADP-Pi cap at the critical concentration
(the corresponding stall situation) whose origin is the slow rate of Pi release. As a
result, filament growth rate exhibits a smoothed slope discontinuity. Fluctuations,
described by the length diffusivity, exhibit a pronounced smoothed discontinuity in
magnitude whose origin is uncapping events exposing rapidly depolymerizing ADP-
actin. The presence of external loads perturbs the polymerization rate constants,
leading to modified kinetics which depend on filament length and imposed force-
distance profile.