**BMEN E4001x: Quantitative Physiology I / Molecular and Cellular Systems**
**Notes 12 – Dynamics of cytoskeletal structures**
**B&B, Small part of Chapter 2. Growth dynamics from Boal.**

# Numerical treatment of growing/shrinking fibers

## *Simplest process, defining:*

- n = length of filament, in numbers of units
- [M] = concentration of monomer, at the moment unaffected by GTP/ATP/other factors

$$\frac{dn}{dt} = +k_{on}[M] - k_{off}$$

One factor is dependent on monomer concentration, the other is not.

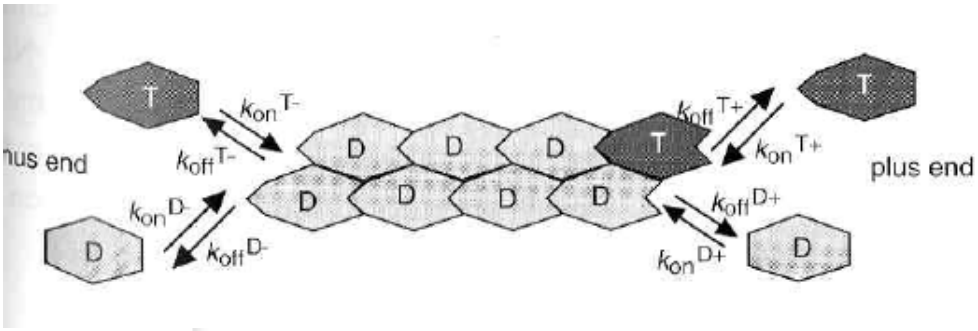
This does lead to an interesting behavior, the critical concentration:

$$[M]_C = \frac{k_{off}}{k_{on}}$$

below which, the filament shrinks, and above which, the filament grows. Very cool, suggesting that local concentration may be one way of controlling filament assembly.

## *More complexity, GTP/ATP manipulations:*

We commented on the role of ATP/ADP and GTP/GDP in modulating monomer affinity, and also noted on the polarity of the various structures. This leads to a more complex, and interesting, model of filament assembly.

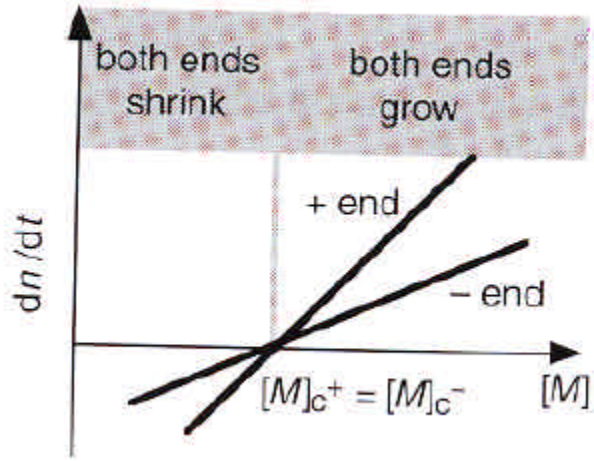



These can be measured for free monomers. For tubulin:

| | plus end | | | minus end | | |
|---|---|---|---|---|---|---|
| | $k_{on}$, $(\mu m*s)^{-1}$ | $k_{off}$, $s^{-1}$ | $M_C$, μM | $k_{on}$ | $k_{off}$ | $M_C$ |
| growing (GTP) | 8.9±3 | 44±14 | 4.9±1.6 | 4.3±0.3 | 23±9 | 5.3±2.1 |
| disassembly (GDP) | 0 | 733±23 | N/A | 0 | 915±72 | N/A |

from Boal, Mechanics of the Cell

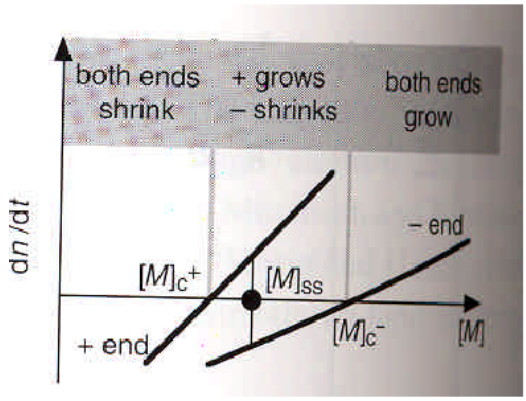
What does this imply? Look at growth and disassembly at each end, as function of GTP form only:




How about actin?

| | plus end | | | minus end | | |
|---|---|---|---|---|---|---|
| | $k_{on}$, $(\mu m^*s)^{-1}$ | $k_{off}$, $s^{-1}$ | $M_C$, µM | $k_{on}$ | $k_{off}$ | $M_C$ |
| ATP-actin | 11.6±1.2 | 1.4±0.8 | 0.12±0.07 | 1.3±0.2 | 0.8±0.3 | 0.6±.17 |
| ADP-actin | 3.8 | 7.2 | 1.9 | 0.16 | 0.27 | 1.7 |

Again, for ATP form only.




Interesting, in that there are clearly the growth and shrinkage phases, but there is also a treadmilling phase. This can actually be seen for a GFP-modified actin molecule. This is not observed for tubulin, or for the ADP form of actin to a large extent.

While it is not definitely shown, actin filament growth is on the scale of that important for crawling cells.

| | |
|---|---|
| actin filament growth | 0.01-1 µm/s |
| crawling cell | 0.01-1 µm/s |
| fast transport | 1-4 µm/s |

So, these results demonstrate modulation of filament behavior as a function of monomer concentration in free solution. Clearly, other modifications of the basic rate processes could

also lead to modification microtubule and thin filament rates. This includes salt concentration and any enzymes in that region. Clearly control over these processes requires micrometer-scale control over proteins within the cell regions; thus another place where diffusion really helps the cell. Other methods include capping the ends of the growing filaments, which clearly limit assembly and disassembly of the structures.