BEH. 410 - 02/26/2003

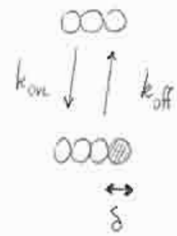
L#6

- Forces due to polymerization

- Bacteria (Listeria). comet of actin ($v \simeq 1\ \mu m.s^{-1}$)
  Cells actin at leading edge of motile cells ($v \simeq 0.1\ \mu m.s^{-1}$)
  Sperm: acrosomal process ($v \simeq 10\ \mu m.s^{-1}$)

- Polymerization : simple laws

Model = Einstein polymer model : polymer growing by addition of single monomers



$\delta = \dfrac{\text{monomer length}}{\text{number of strands in polymer}}$

(for actin, 2 stranded,  $\delta = \dfrac{5.5\ nm}{2}$)

$\dfrac{dn}{dt}$ = change in the number of monomers in a filament per unit of time

- capture $\dfrac{dn}{dt} = k_{on}\,[M]$ → concentration of free monomer
- release $\dfrac{dn}{dt} = -k_{off}$
- combined $\boxed{\dfrac{dn}{dt} = k_{on}\,[M] - k_{off}}$

- At equilibrium (no force) : $\dfrac{dn}{dt} = 0$ and $\dfrac{k_{off}}{k_{on}} = K^\circ = [M^c]^\circ$ → critical monomer concentration; K° ↓ dissociation constant

$K_{eq} = \dfrac{k_{on}}{k_{off}} = \exp\left(\dfrac{\Delta G^\circ}{kT}\right) = \dfrac{1}{K^\circ}$

"°" refers to "no force".

At equilibrium with force (state of equilibrium is changed by addition of a force)

$K_{eq} = K_{eq}^\circ \exp\left(\dfrac{f\,\Delta x}{kT}\right)$ force favors having longer filaments (recall RNA discussion)

$K = K^\circ \exp\left(\dfrac{-f\delta}{kT}\right) = [M^c(f)] = [M^c]^\circ \exp\left(\dfrac{-f\delta}{kT}\right)$ lower dissociation constant

positive force = pulling on molecule ⟹ longer filament

- Concept : equilibrium force

$f^{eq} = -f = \dfrac{-kT}{\delta} \ln \dfrac{[M^c(f)]}{[M^c]^\circ}$

force by polymer on outside world :
- when $f^{eq} = 0$ $[M^c(f)] = [M^c]^\circ$
- if $[M] > [M^c(f)]$, polymerization until $[M] = [M^c(f)]$
  if $[M] < [M^c(f)]$, depolymerization occurs until equilibrium

push or pull

▷ Actin : $\delta = \dfrac{5.5\ nm}{2} \simeq 3\ nm$
(monomer size = 5.5 nm , 2 strands)

suppose $[M] = 100\,[M^c]^\circ$ with $[M^c]^\circ \simeq 0.3\,\mu mol.L^{-1}$, huge reservoir $\Rightarrow [M^c(f)] = [M]$

$f^{eq} \simeq 7\,pN$ force that actin is able to withstand

note: here we didn't take into account actin-binding proteins

- Keypoints:
  - depending on your monomer reserve $[M]$, the system can "push or pull"
  - equilibrium force is at the core of this discussion
  - proteins can regulate $[M]$, k_{on}, k_{off}, can cap ends of filaments ...

Equilibrium tells us nothing about rates

□ Think about dynamics of polymerization

- Nonbrownian

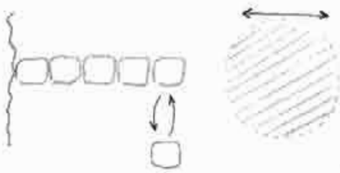
particle to push (virus, listeria)

← force f

→ ← space ≥ δ or polymerization process stops

- Brownian point of vue

Dynamic



↔ particle diffuses

← force

here, when particle diffuses far enough (≥ δ), monomer is added