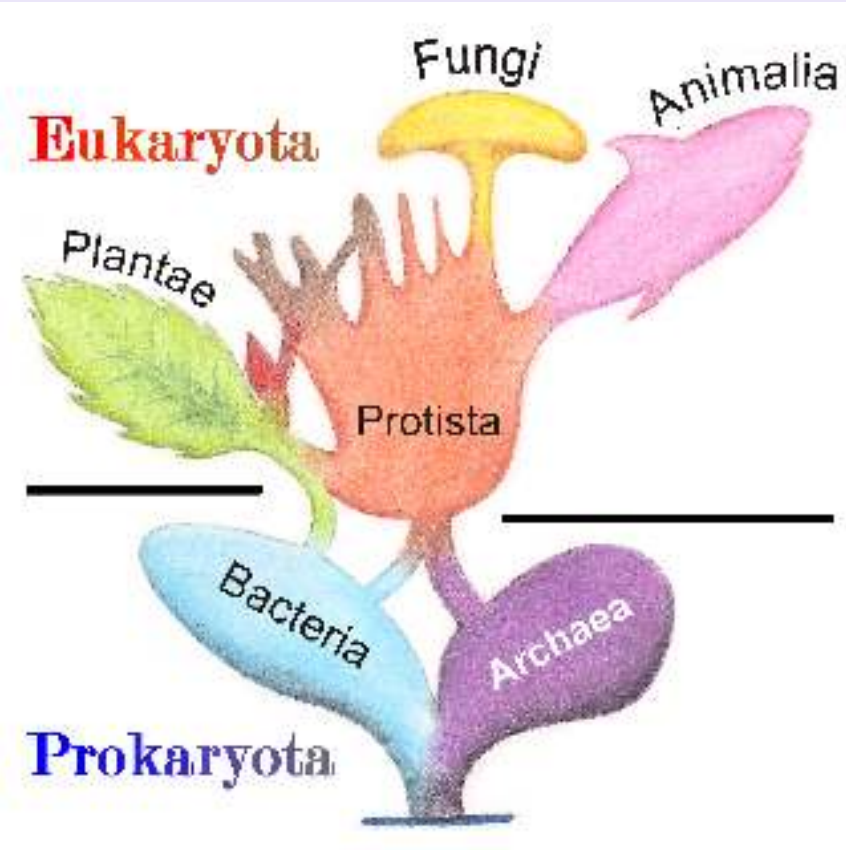
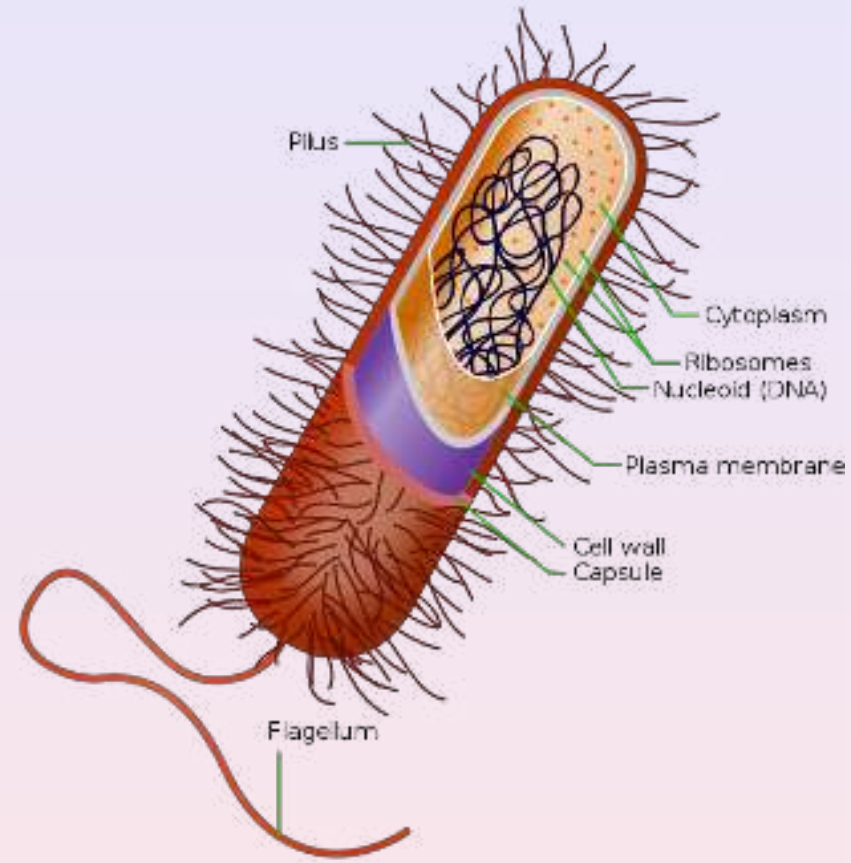
Prokaryotes and Eukaryotes



From [Wikimedia, Maulucioni y Doridí]

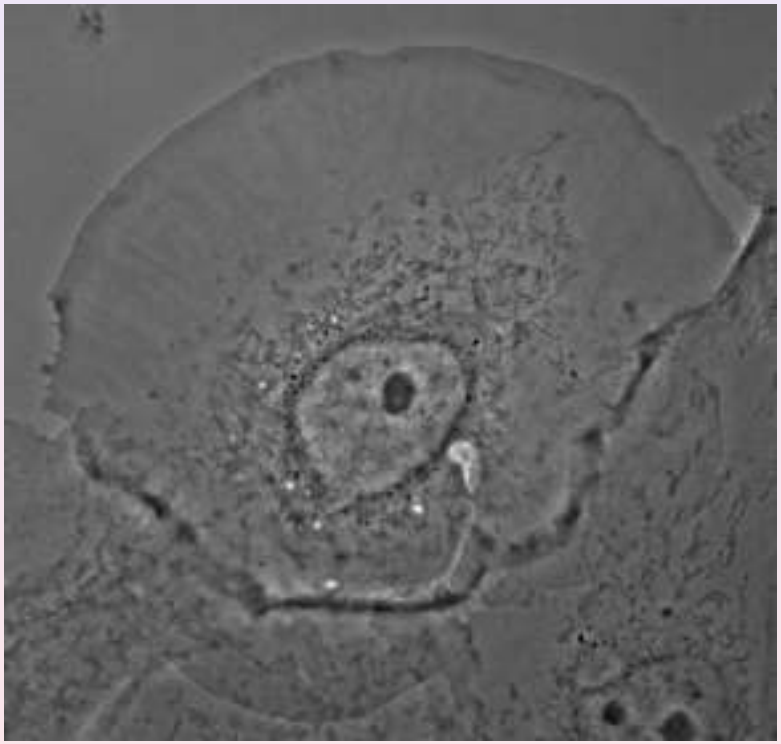


From [Wikimedia, Ali Zifan]

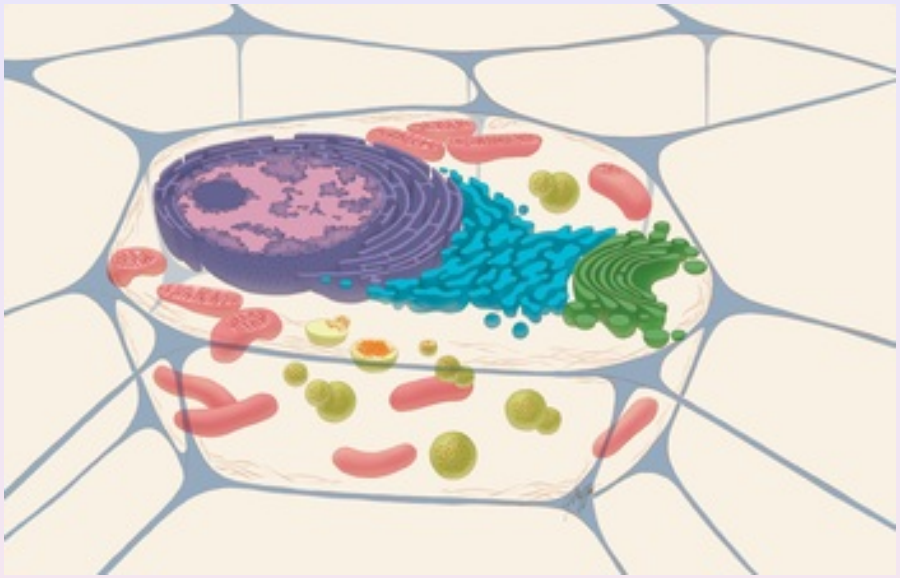
Prokaryote cell

Eukaryotes

- Eukaryotic cells



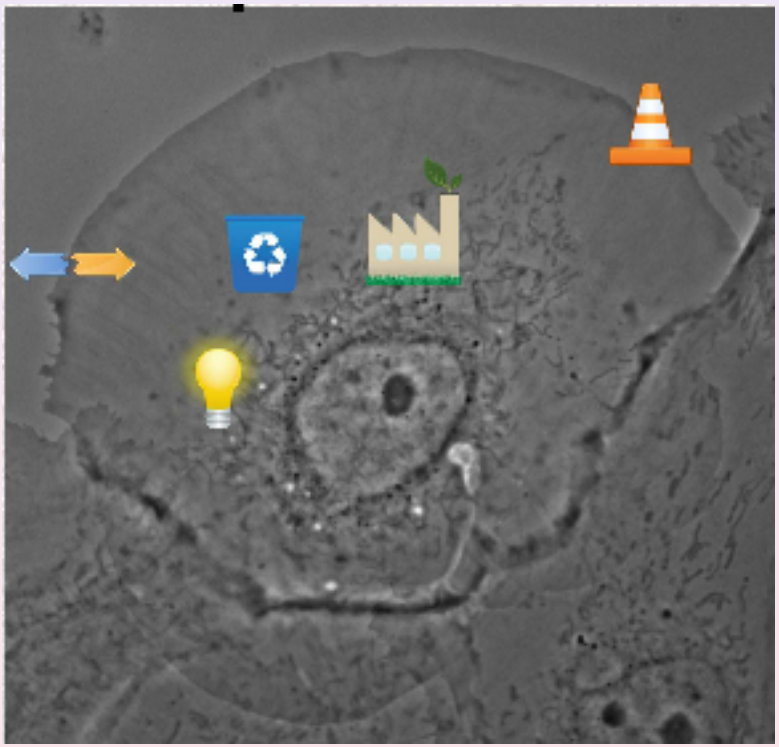
From [Wittmann et al, J. Cell Biol. 161:845 (2003)]



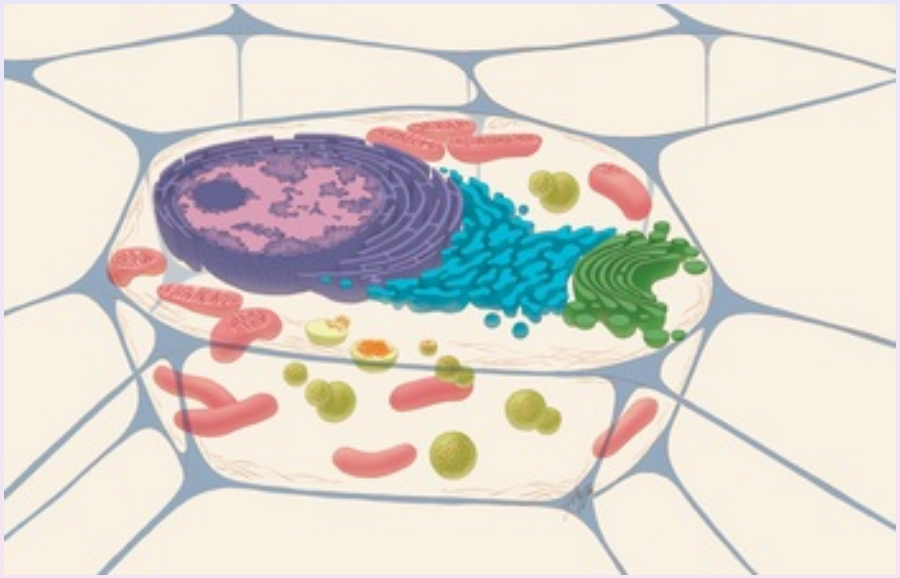
From [Judith Stoffer, NIGMS]

Eukaryotes

- Need for transport

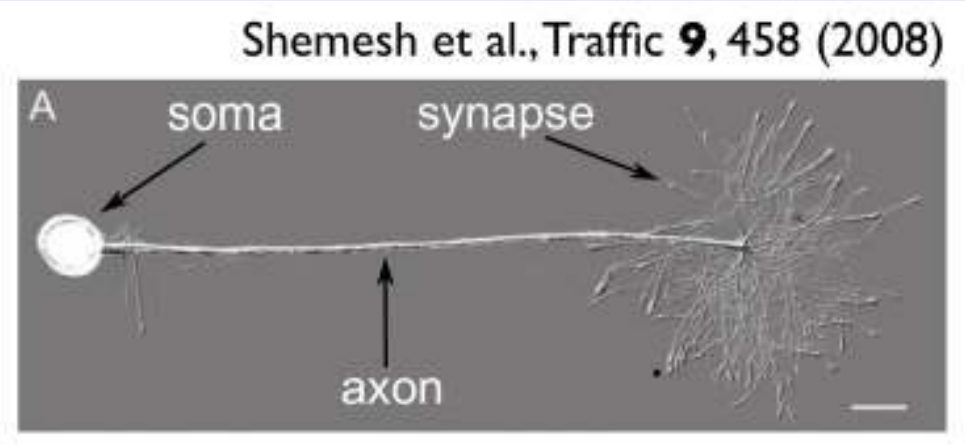


From [Wittmann et al, J. Cell Biol. 161:845 (2003)]

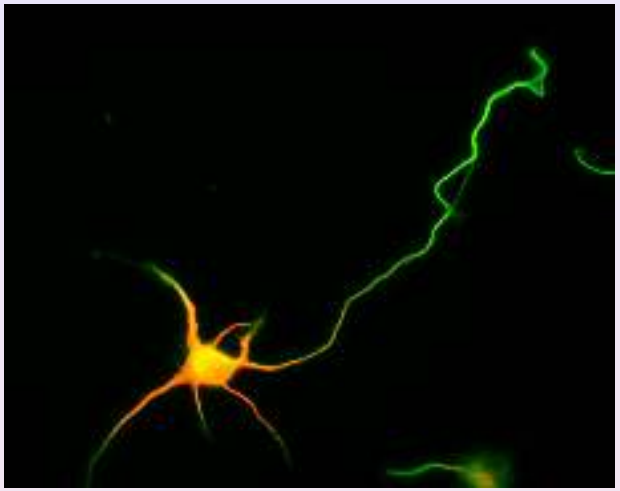


From [Judith Stoffer, NIGMS]

Intra-cellular transport



- Particular case: the axon
  - up to 1 m in human beings, a few microns for the diameter

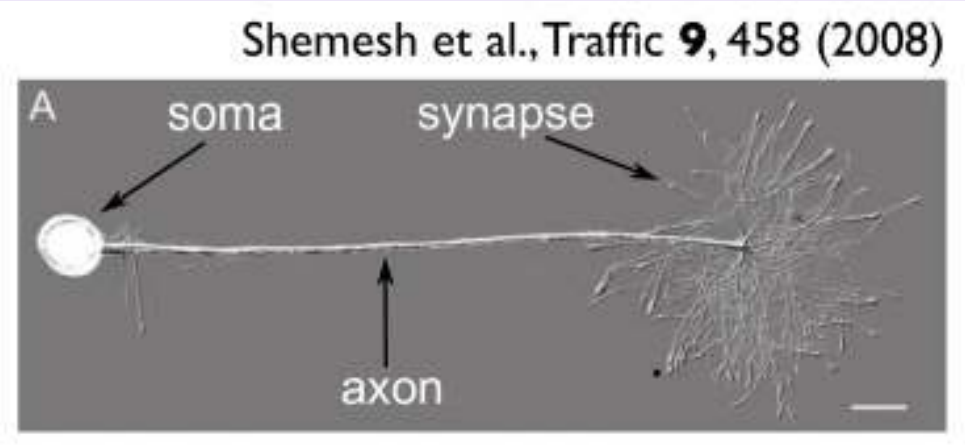


Hypocampal neuron

From [Dieter Brandner and Ginger Withers]

Red = MAP2, Green = MT

Intra-cellular transport



- Particular case: the axon
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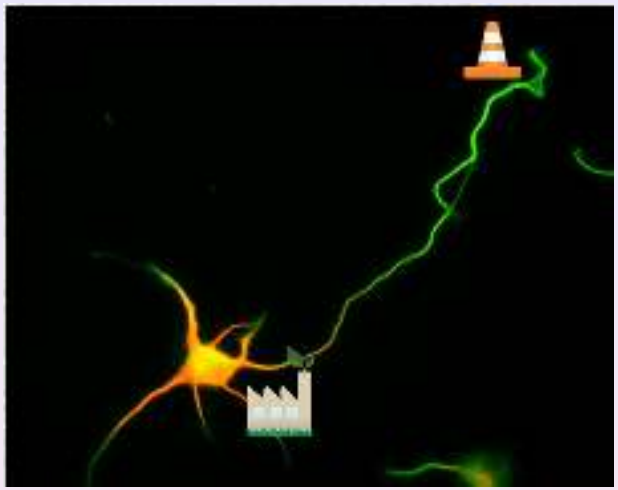

Hypocampal neuron

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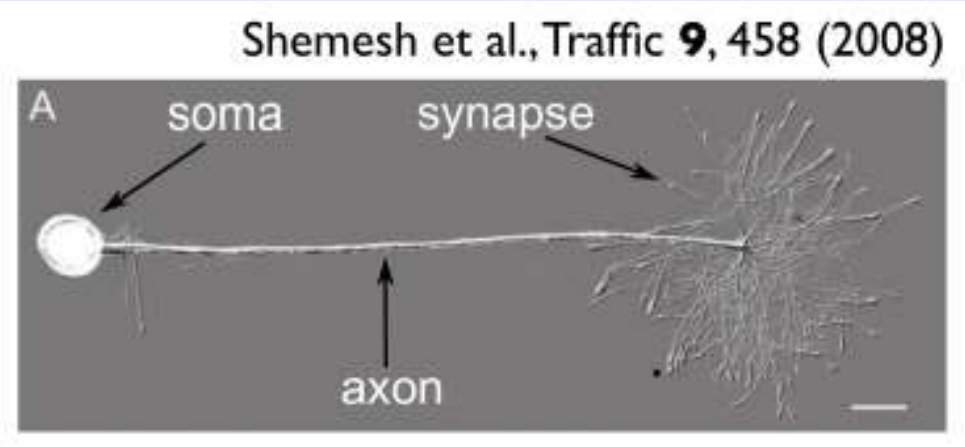
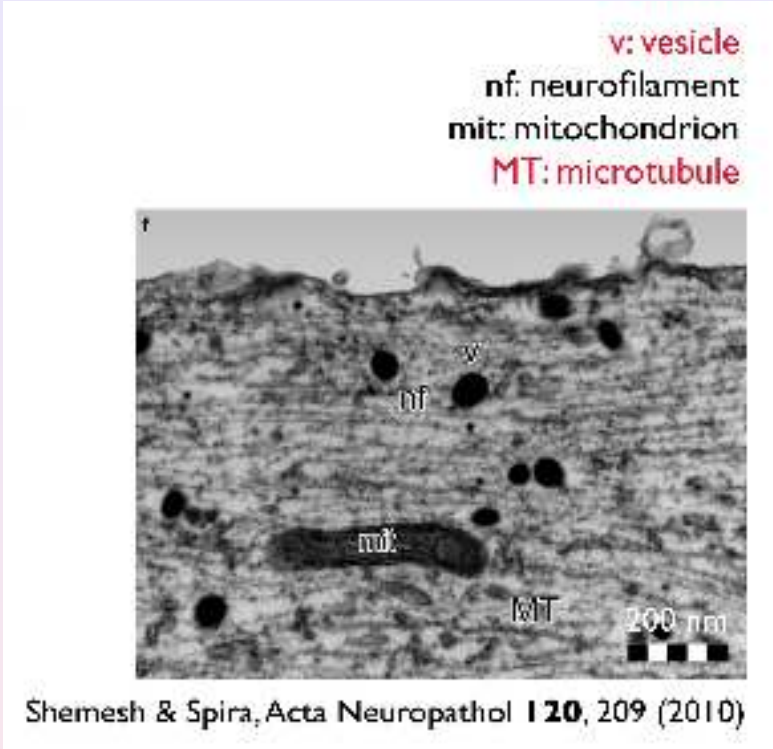
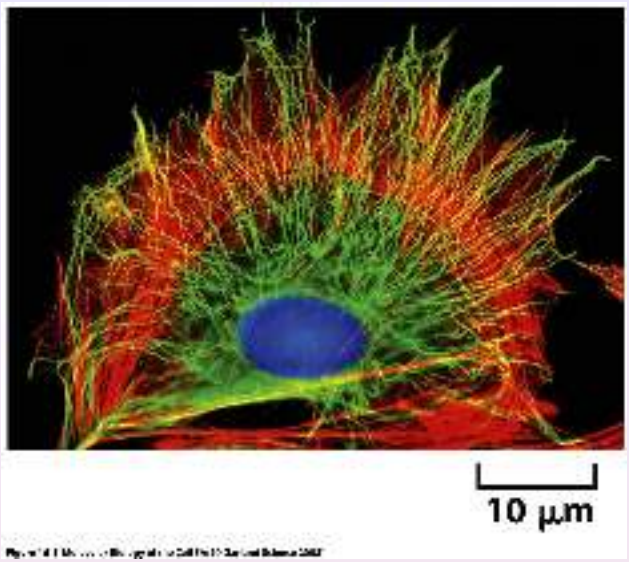
Intra-cellular transport



- Particular case: the axon
  - up to 1 m in human beings, a few microns for the diameter
  - crowded environment

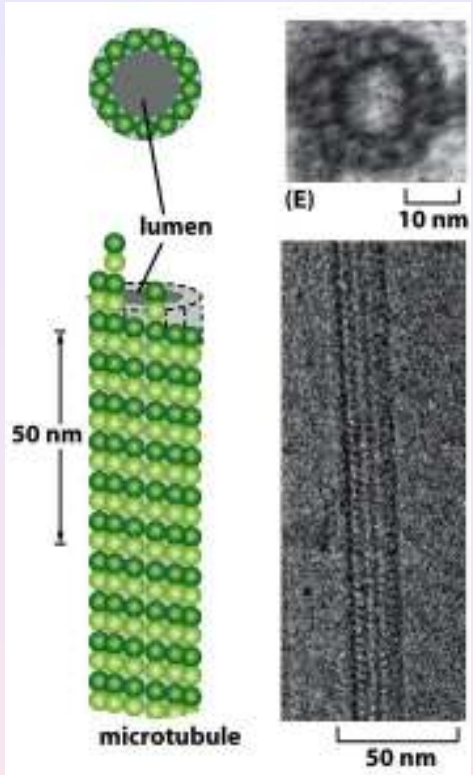


Cytoskeleton

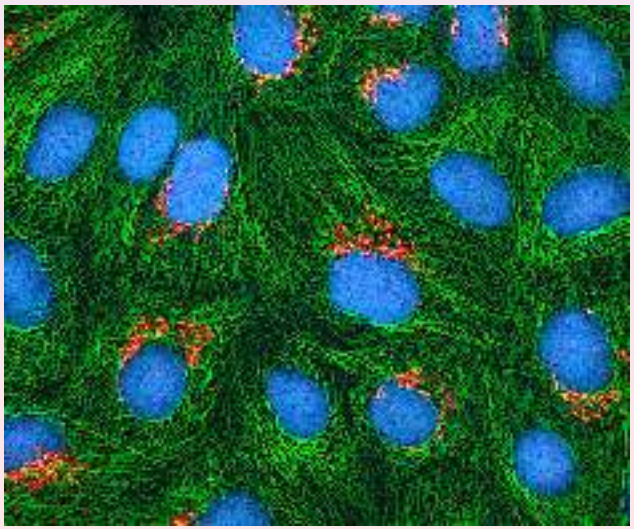


- Green = MT
- Red = Actin
- Blue = DNA

From [Alberts et al, *Molecular Biology of the Cell,* 5th ed. (2008)]



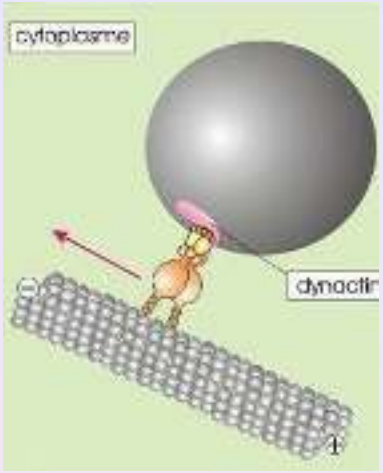
From [Alberts et al, *Molecular Biology of the Cell,* 5th ed. (2008)]



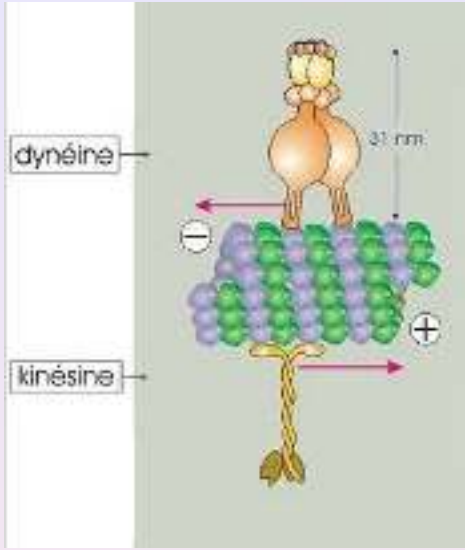
- Green = MT
- Orange = Golgi apparatus
- Cyan = DNA

From NIH, Multiphoton fluorescence image of cultured HeLa cells]

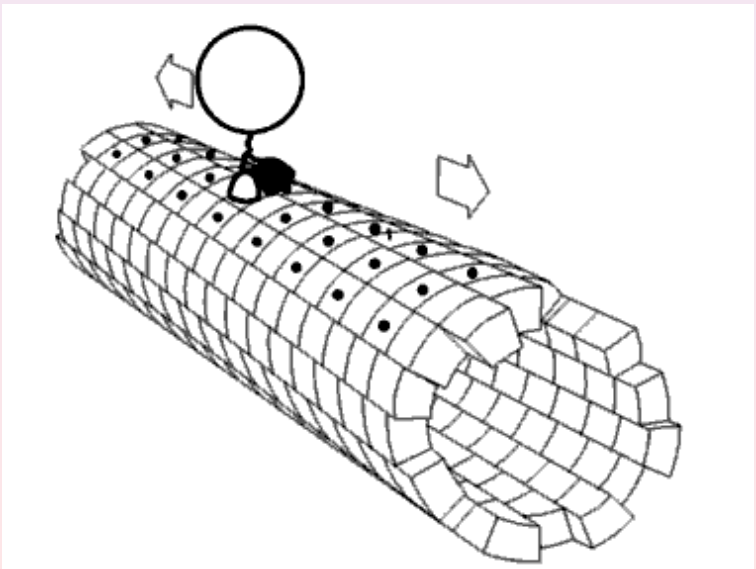
Intracellular transport



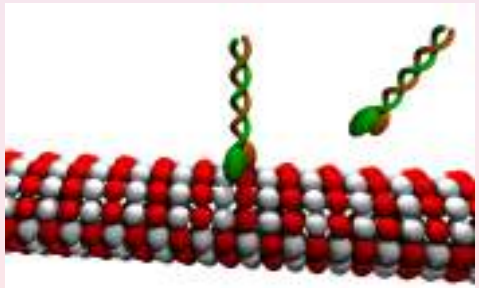
[From www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion]



[Modified from www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion]



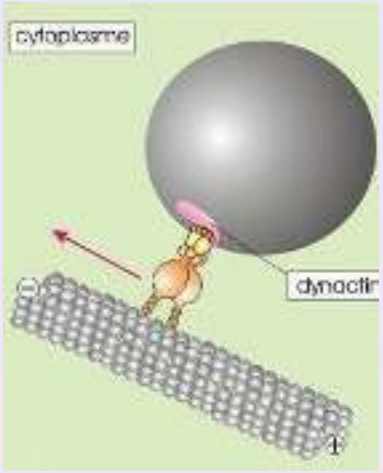
Microtubules are polarized



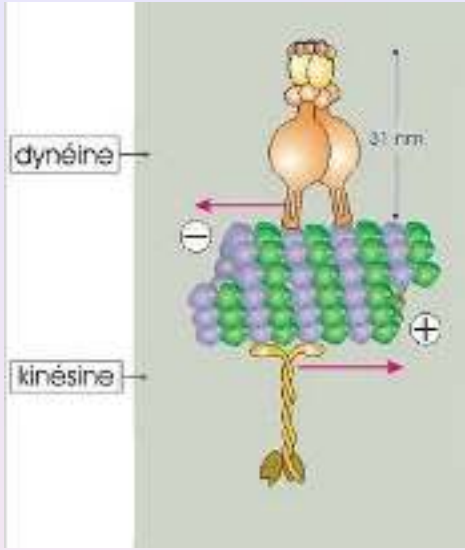
[Modified from a wikipedia image by Kebes]

Motors can attach and detach

Intracellular transport

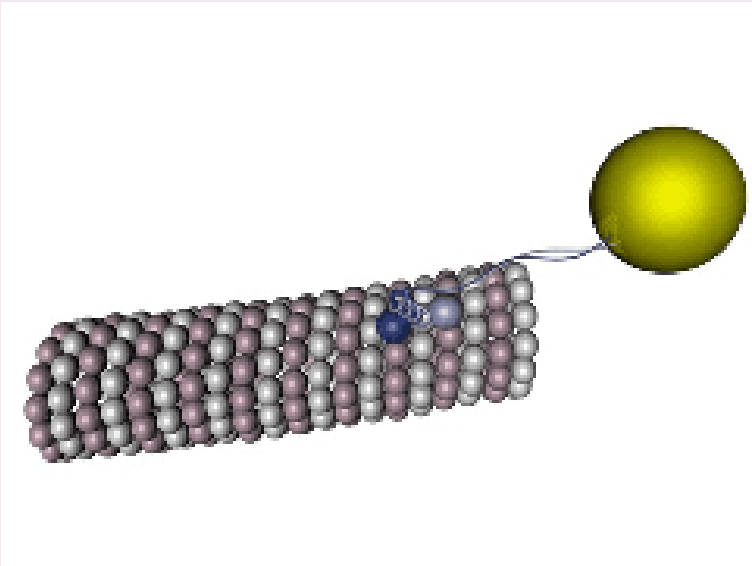


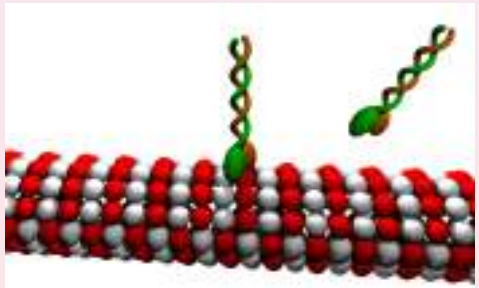
[From www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion]



[Modified from www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion]

Microtubules are polarized



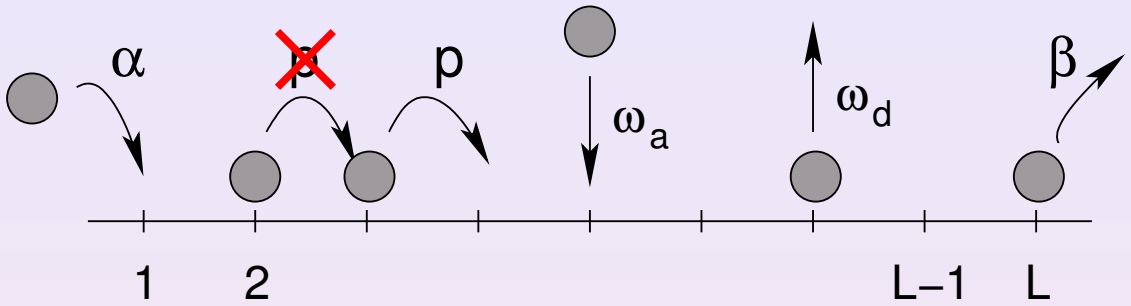


[Modified from a wikipedia image by Kebes]

Motors can attach and detach

Collective effects

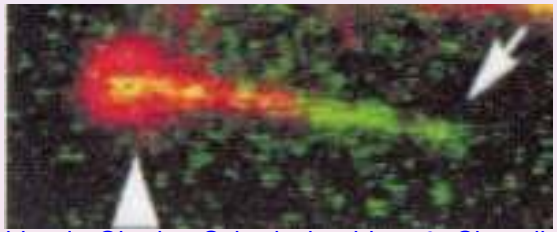
Cellular automata models with one type of motors



[Lipowsky, Klumpp, & Nieuwenhuizen, P.R.L. (2001)]
[Parmeggiani, Franosch, & Frey, P.R.L. (2003)]
[J. Tailleur, M. Evans, & Y. Kafri, P.R.L. (2009)]

In vitro

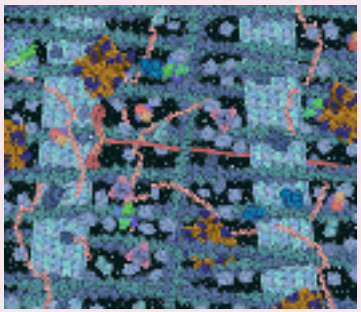
- well suited for motility assays, predicts the experimentally observed bulk localization of high and low density domains



[Nishinari, Okada, Schadschneider, & Chowdhury, P.R.L. (2005)]

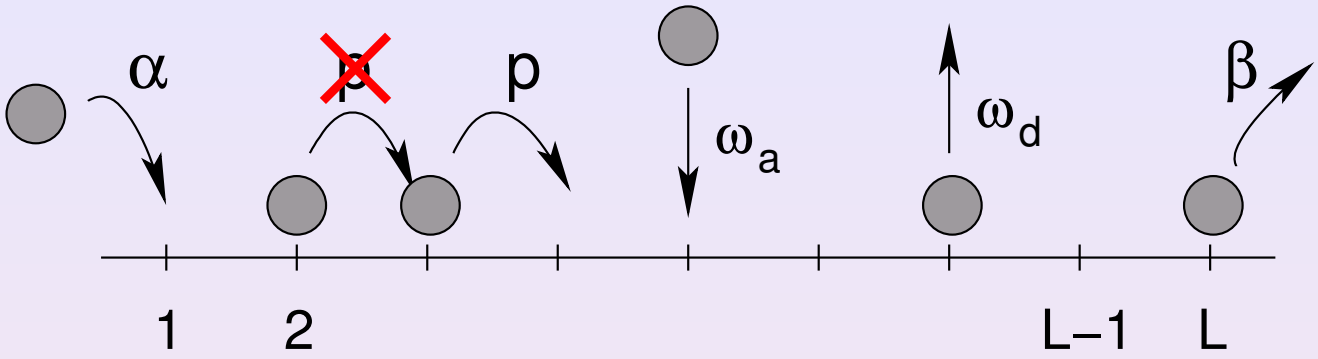
In vivo

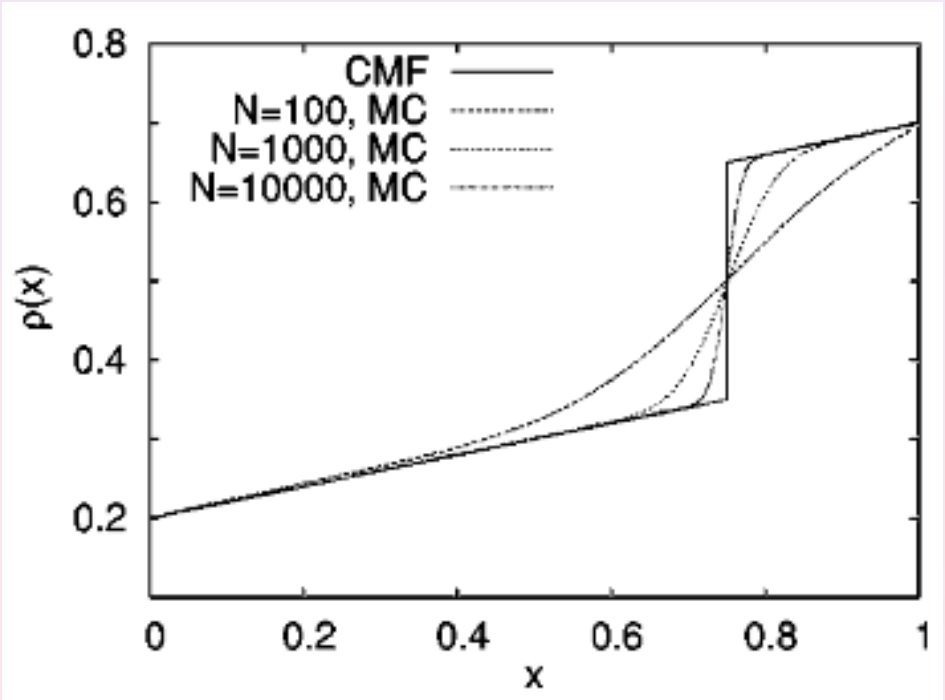
- Crowded environment
- No infinite diffusion



[by Tim Vickers]

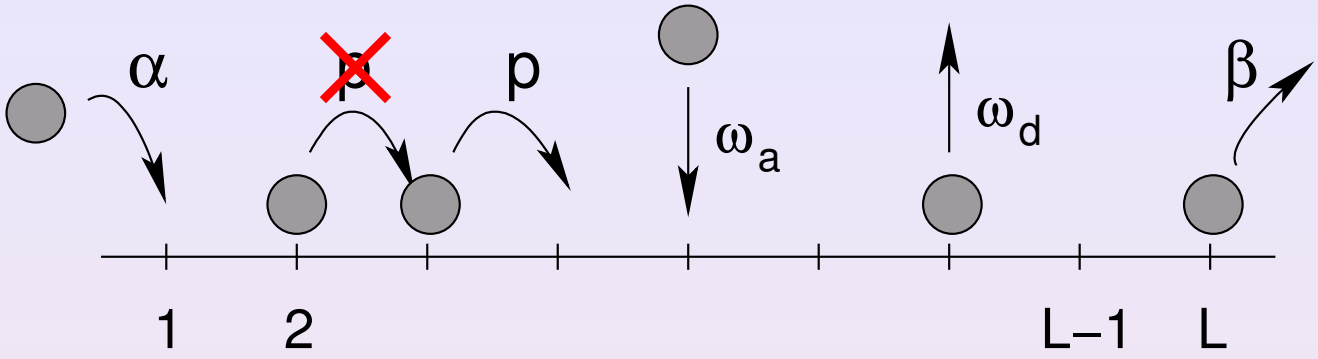
Langmuir kinetics

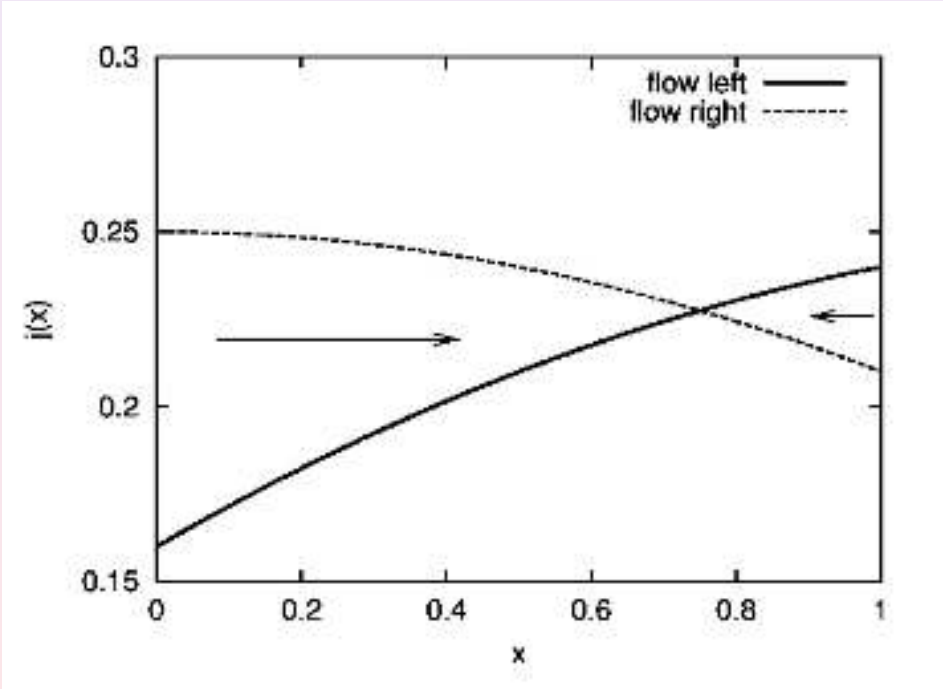




[Evans et al, PRE (2003)]

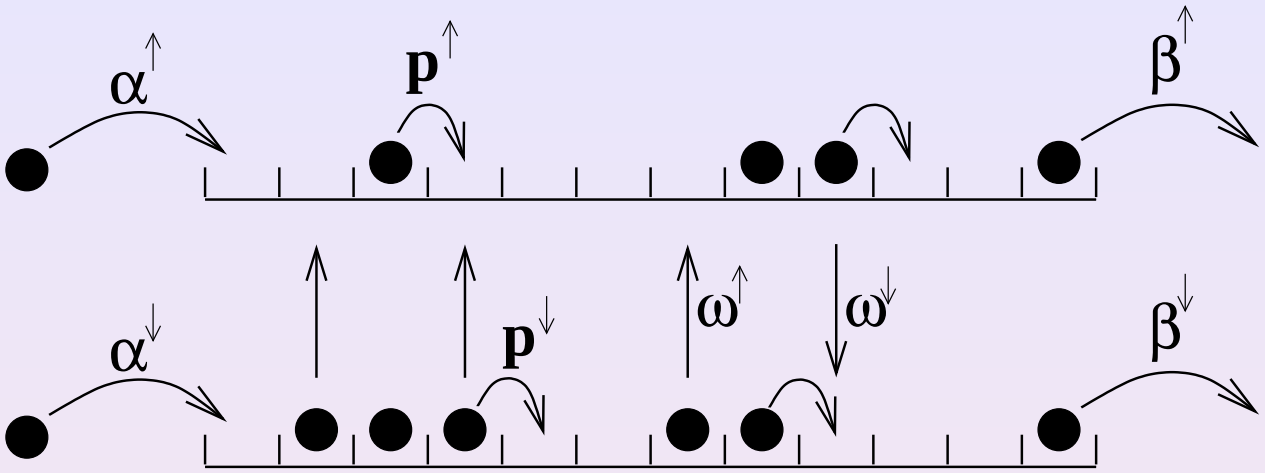
Langmuir kinetics



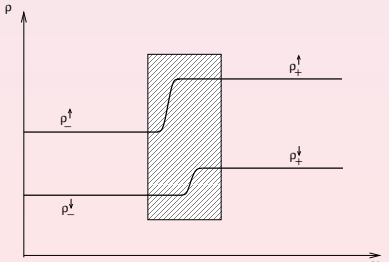


[Evans et al, PRE (2003)]

Two-lane systems

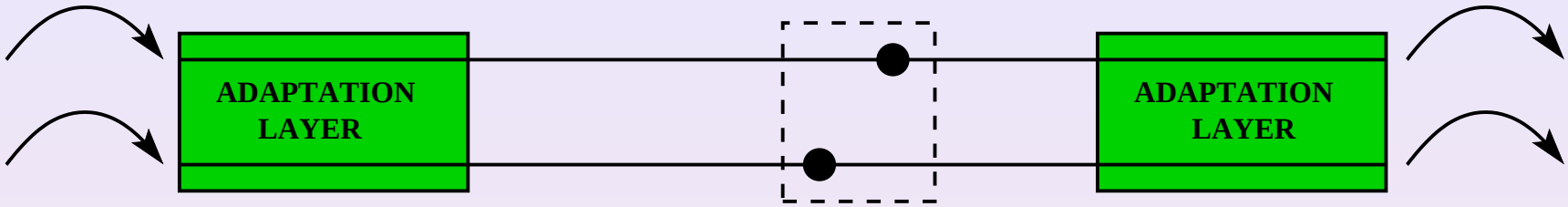


- Weak coupling ($\omega \sim 1/L$) – Molecular motors
  - [Reichenbach, Frey, & Franosch (2006,2007,2008)]
    - ✓ Mean-field
- Strong coupling ($\omega \sim 1$) – Road traffic
  - [Schiffmann et al, J. Stat. Mech. (2010)]



- ✓ Dynamics of pairs of walls

Adaptation layers



[Schiffmann et al, J. Stat. Mech. (2010)]

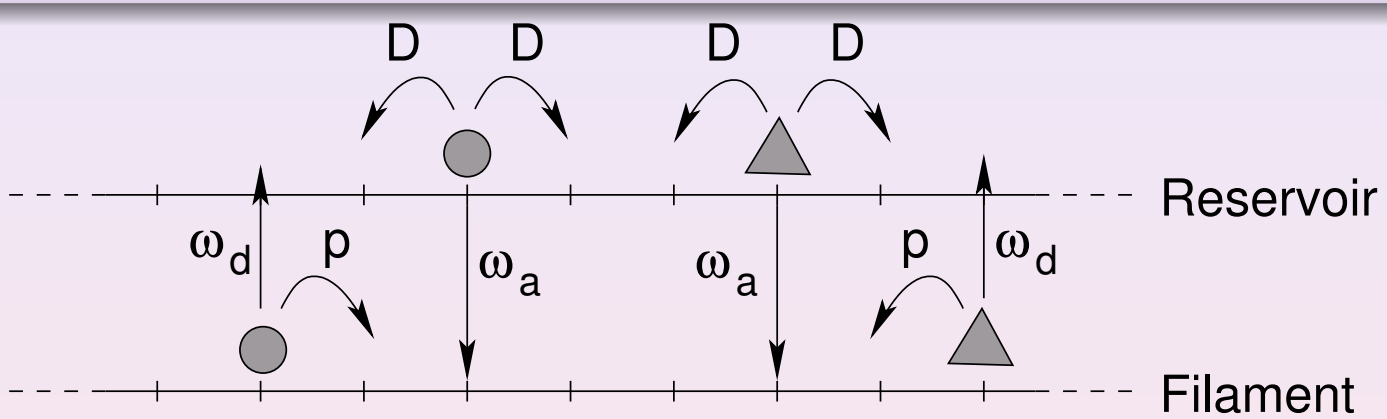
Adaptation layers

- extend over a non vanishing fraction of the system in the weak coupling case
  - localization in the bulk is possible
- have a finite size in the strong coupling case
  - localization in the bulk is not possible, only in the adaptation layer.

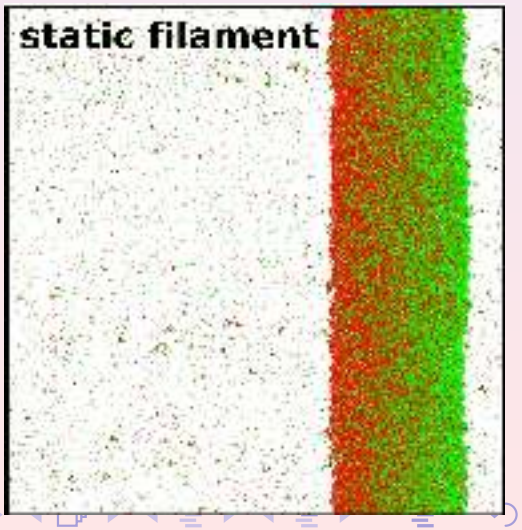
Collective effects in bidirectional intracellular transport

Ingredients

- Two types of complexes going in opposite directions
- Confined diffusion in the surrounding cytoplasm



[M. Ebbinghaus and L. Santen, J. Stat. Mech. (2009)]



Jamming

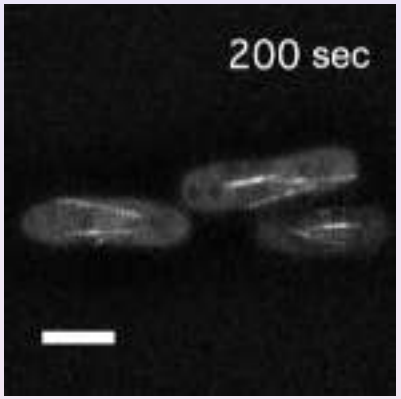
- ➥ No transport in thermodynamic limit
- ➥ Offering multiple filaments enhances cluster formation.

Intra-cellular traffic - Dynamic instability

MTs exhibit stochastic switching between a shrinking and a growing state

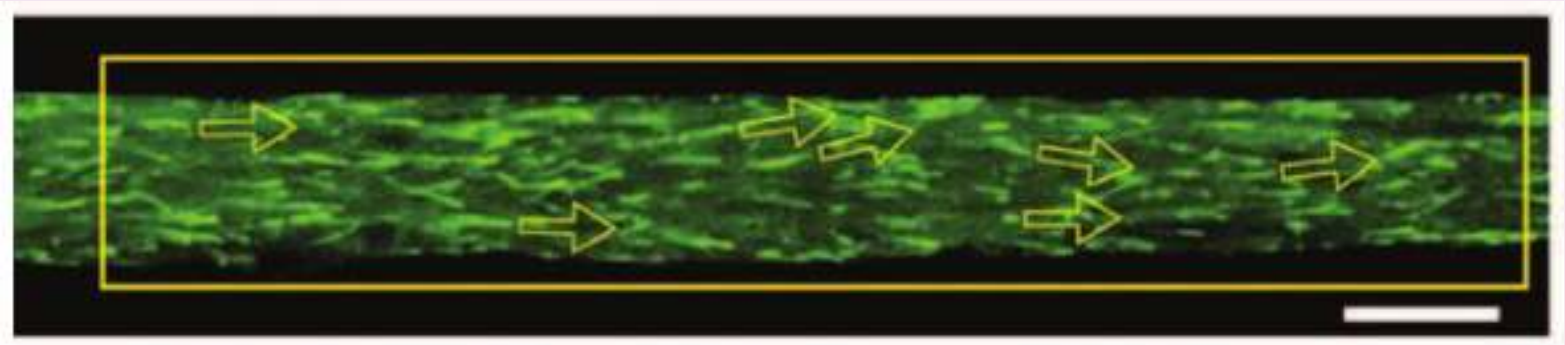
[A. Viel, R. A. Lue and J. Liebler, BioVisions project, http://multimedia.mcb.harvard.edu]

Microtubules seen by fluorescence in S. pombe (yeast)



[M. Erent, D.R. Drummond, R.A. Cross (2012) PLoS ONE 7(2): e30738]

Scale bar = 5 μm

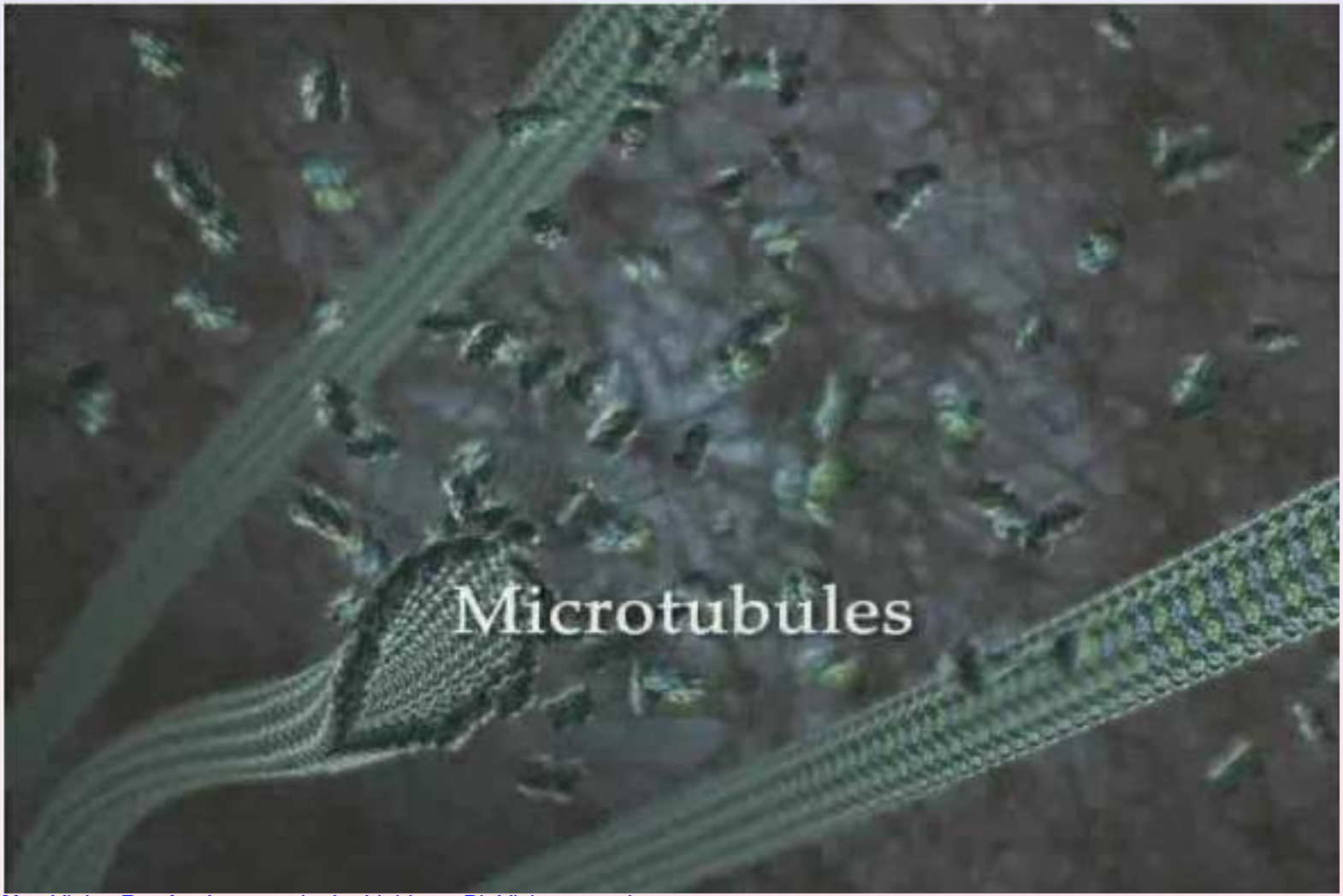


[*Shemesh, Erez, Ginzburg, Spira. Traffic (2008)*]

1s (video) = 120s (real time)
Scale bar = 10 μm

Intra-cellular traffic - Dynamic instability

MTs exhibit stochastic switching between a shrinking and a growing state



[A. Viel, R. A. Lue and J. Liebler, BioVisions project, http://multimedia.mcb.harvard.edu]

Bidirectional intracellular traffic

☞ Drugs modifying the dynamics of the microtubules induce jams

- video 1: microtubule dynamics with and without drugs (Paclitaxel)

[*Shemesh and Spira, Acta Neuropathol (2010) 119:235*]

Bidirectional intracellular traffic

☞ Drugs modifying the dynamics of the microtubules induce jams

- video 2: microtubule dynamics and pinocytotic vesicles transport without drugs

[*Shemesh and Spira, Acta Neuropathol (2010) 119:235*]

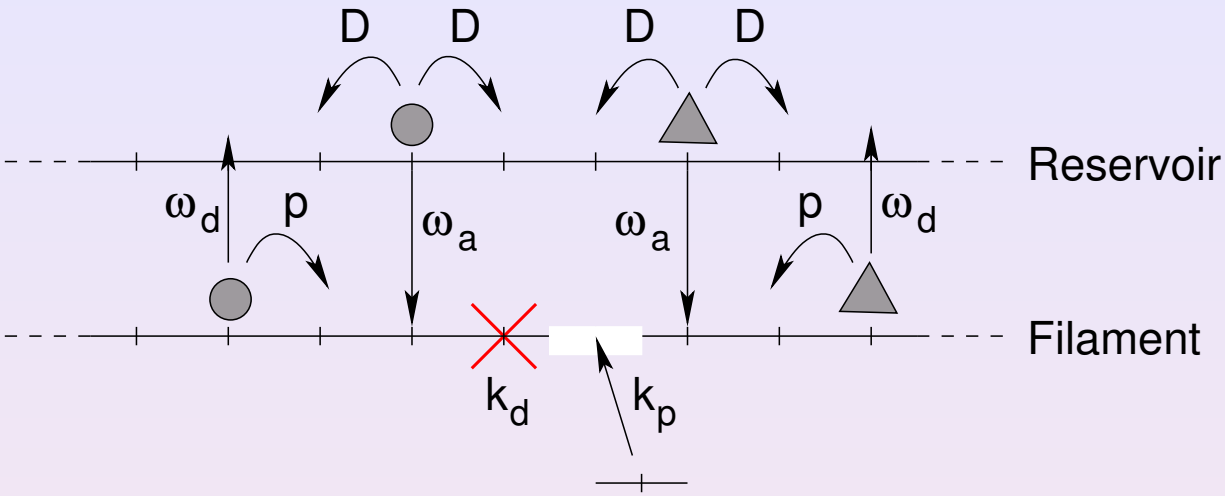
Bidirectional intracellular traffic

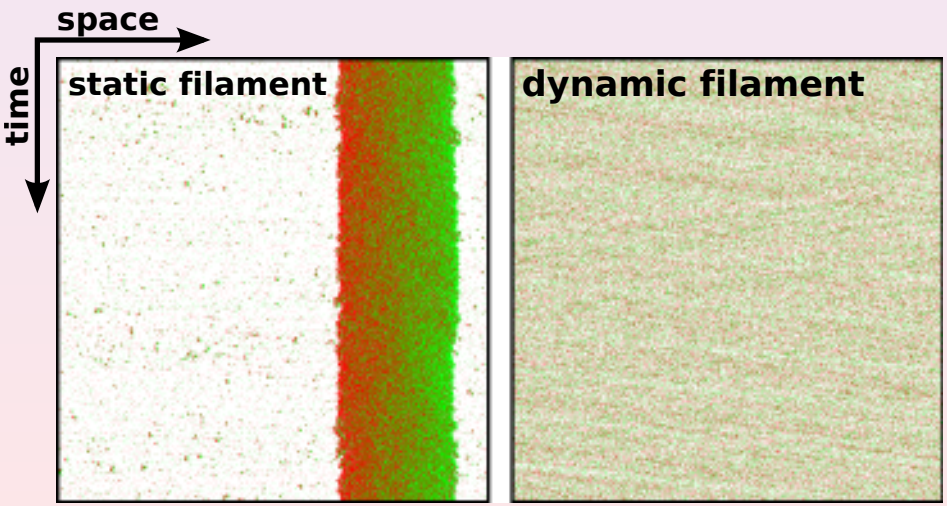
☞ Drugs modifying the dynamics of the microtubules induce jams

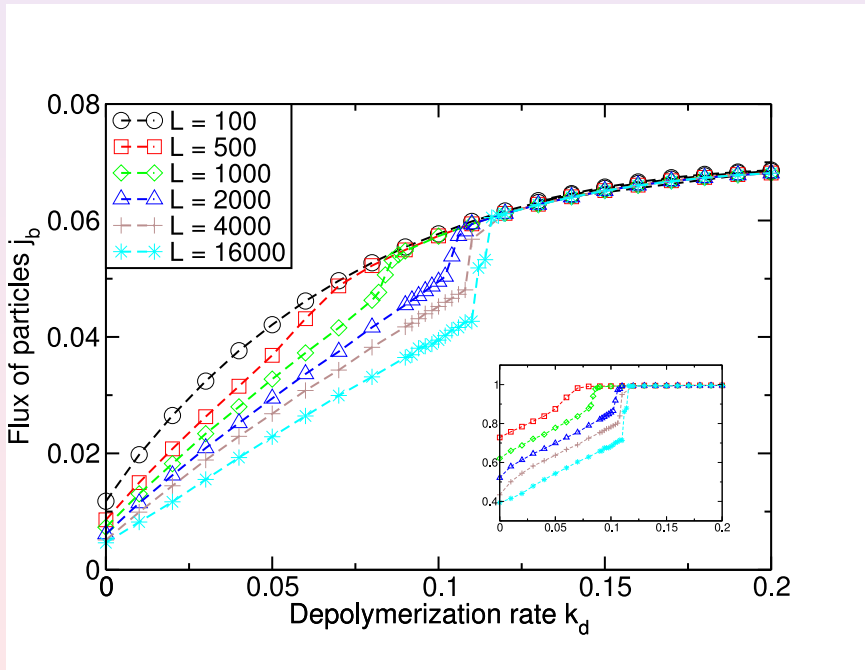
- video 3: microtubule dynamics and pinocytotic vesicles transport with drugs

[*Shemesh and Spira, Acta Neuropathol (2010) 119:235*]

Dynamics of the lattice







[Ebbinghaus et al, PRE 82 (2010) 040901]