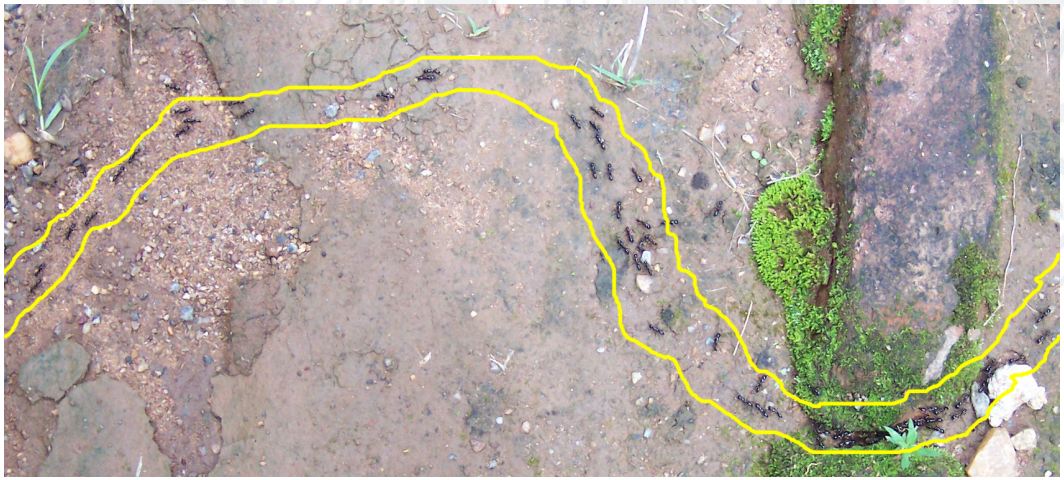
Traffic on Ant Trails

Ant trails

ants build “road” networks: trail system



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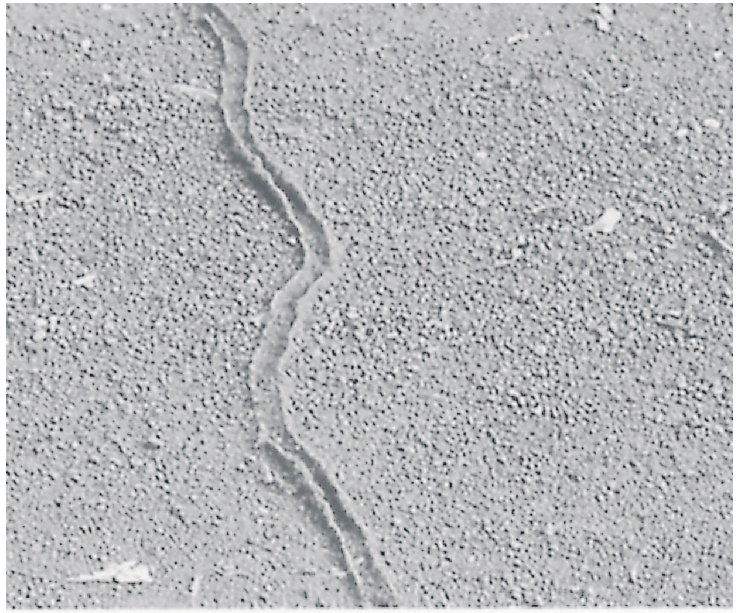
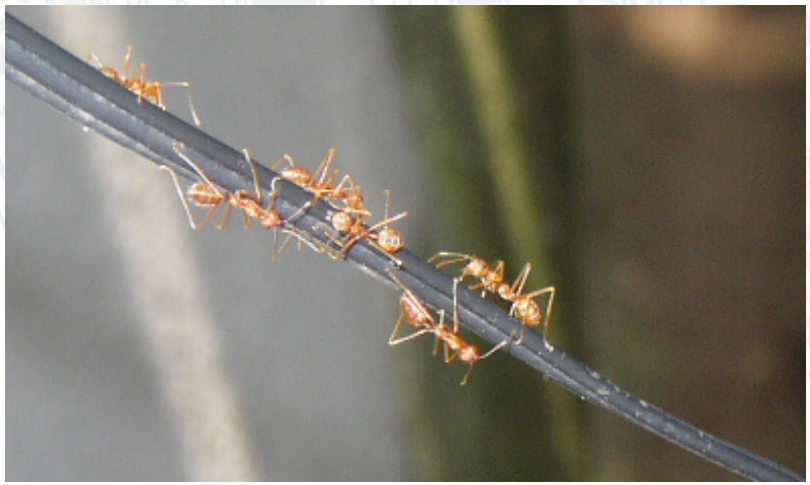




Chemotaxis

Ants can communicate on a chemical basis: **chemotaxis**

Ants create a chemical trace of **pheromones**

- trace can be “smelled” by other
- ants follow trace to food source etc.

Chemotaxis

chemical trace:
pheromones

chemotaxis: *long-ranged* interactions are translated into *local* interactions with *"memory"*

Ant trail model

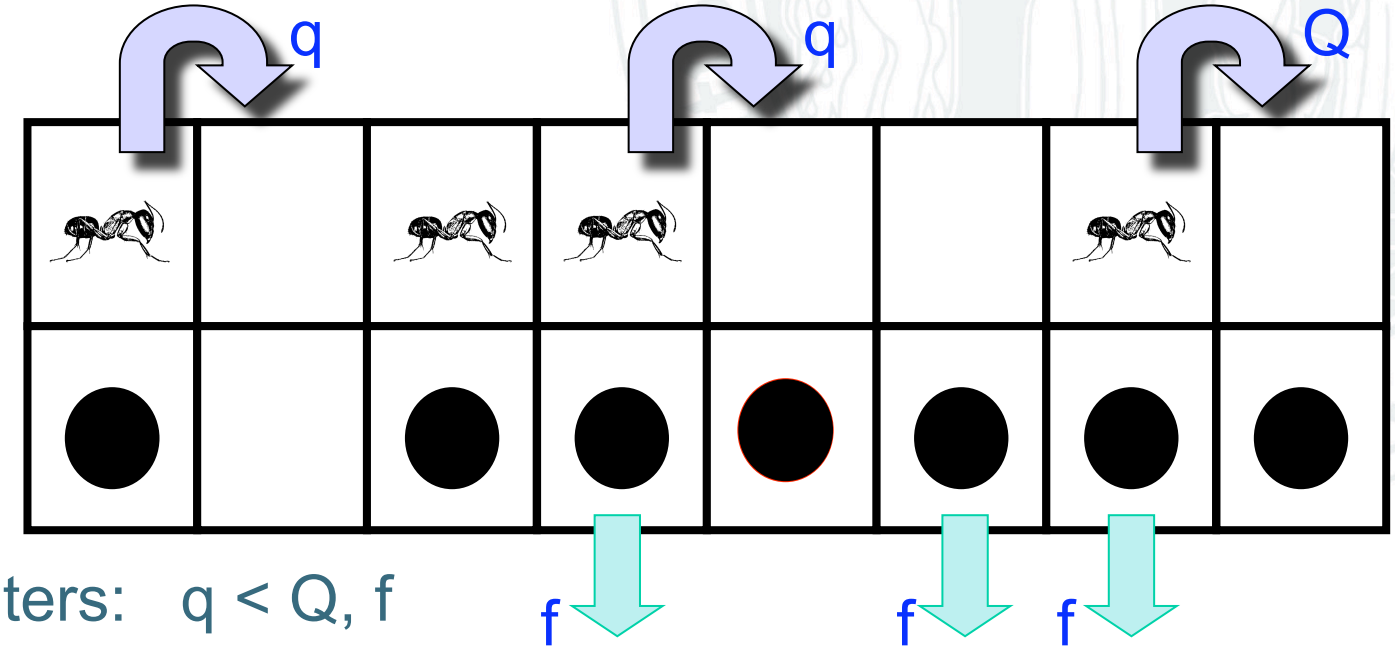
Basic ant trail model: ASEP + pheromone dynamics

- **hopping probability depends on density of pheromones**
- **distinguish only presence/absence of pheromones**
- **ants create pheromones**
- **‘free’ pheromones evaporate**

Ant Trail Model

Dynamics:

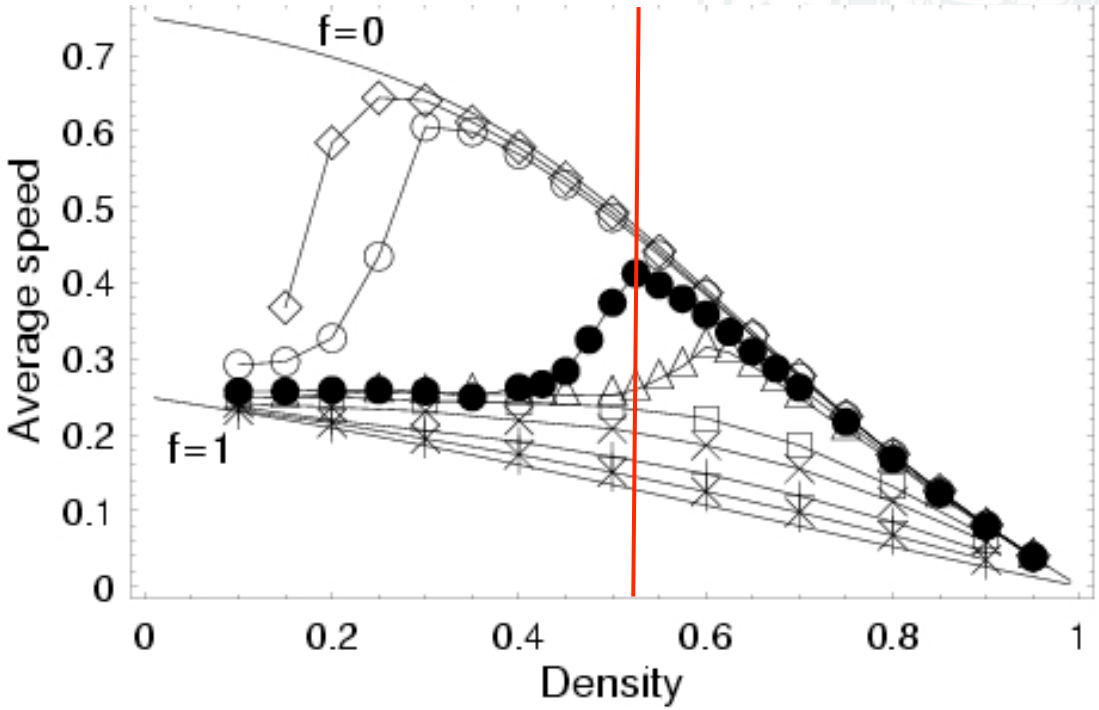
1. **motion of ants**
2. **pheromone update (creation + evaporation)**



parameters: q < Q, f

Fundamental diagram of ant trails

velocity vs. density



non-monotonicity at small evaporation rates!!

Experiments:

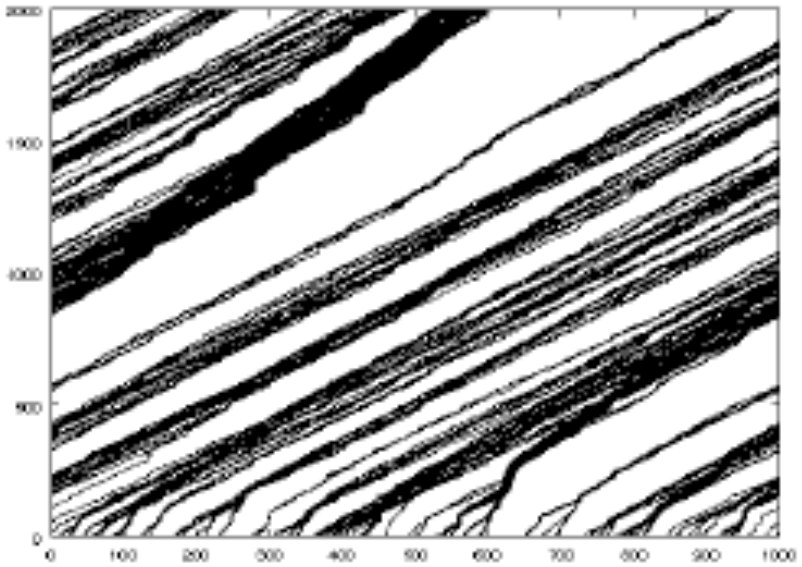
Burd et al. (2002, 2005)

John et al. (2006)

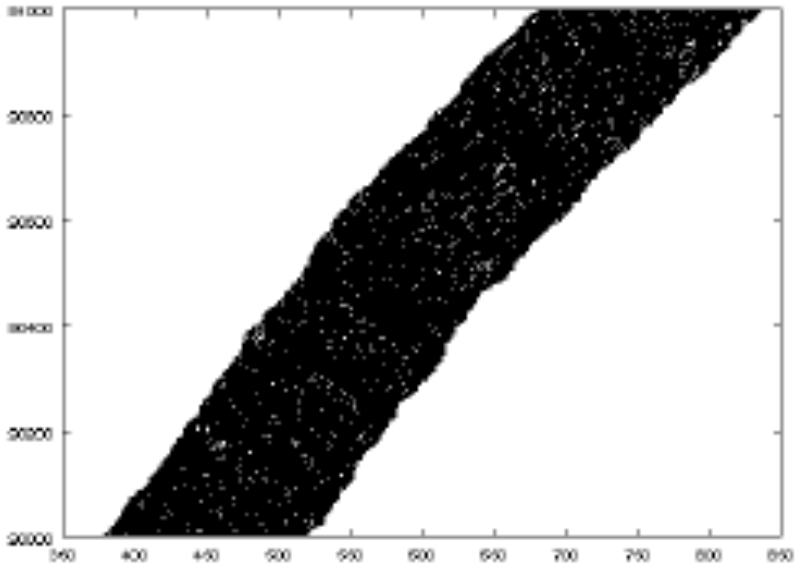
different from highway traffic: no egoism

Spatio-temporal organization

formation of “loose clusters”



early times



steady state

coarsening dynamics: cluster velocity ~ gap to preceding cluster

Traffic on Ant Trails

formation of clusters

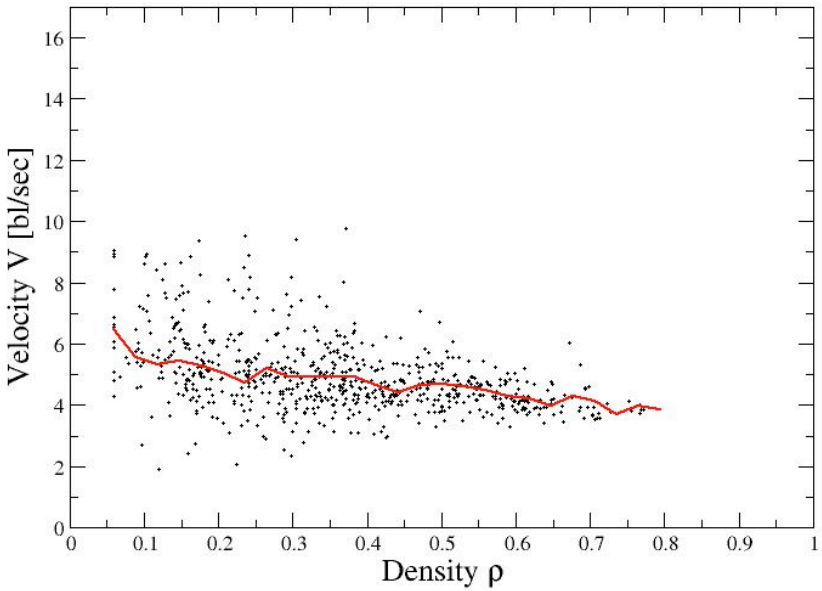
Field Studies: Empirical Results

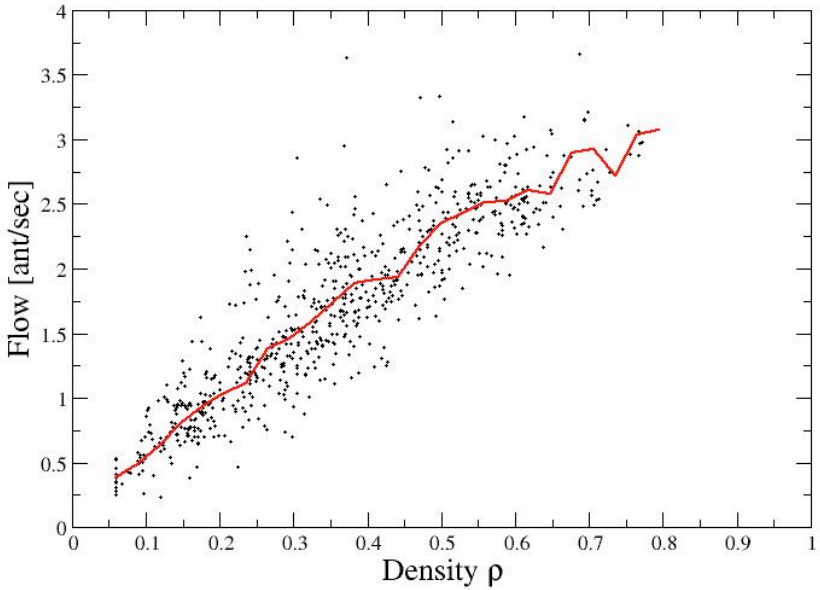
Fundamental Diagrams

- no overtaking
- average velocity shows only weak density dependence
- slight decrease of average velocity leading to non-linear increase of flow

Main Observation:

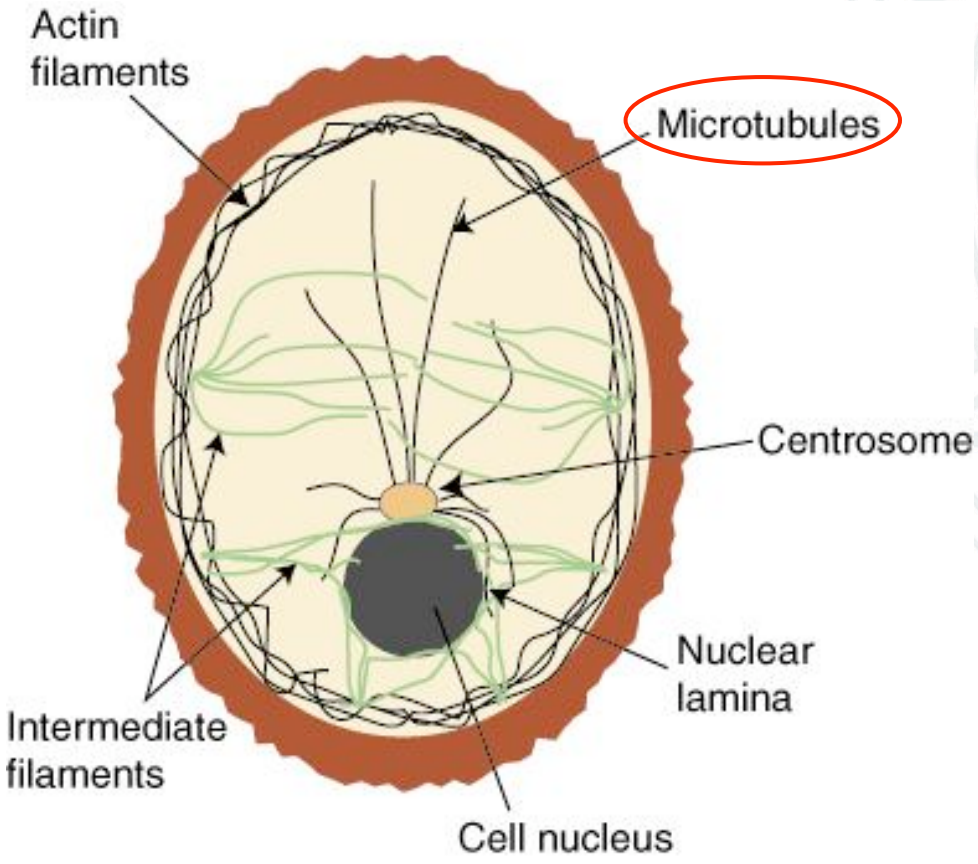
- mutual blocking seems to be suppressed (no congested state)





Intracellular Transport

Transport in Cells

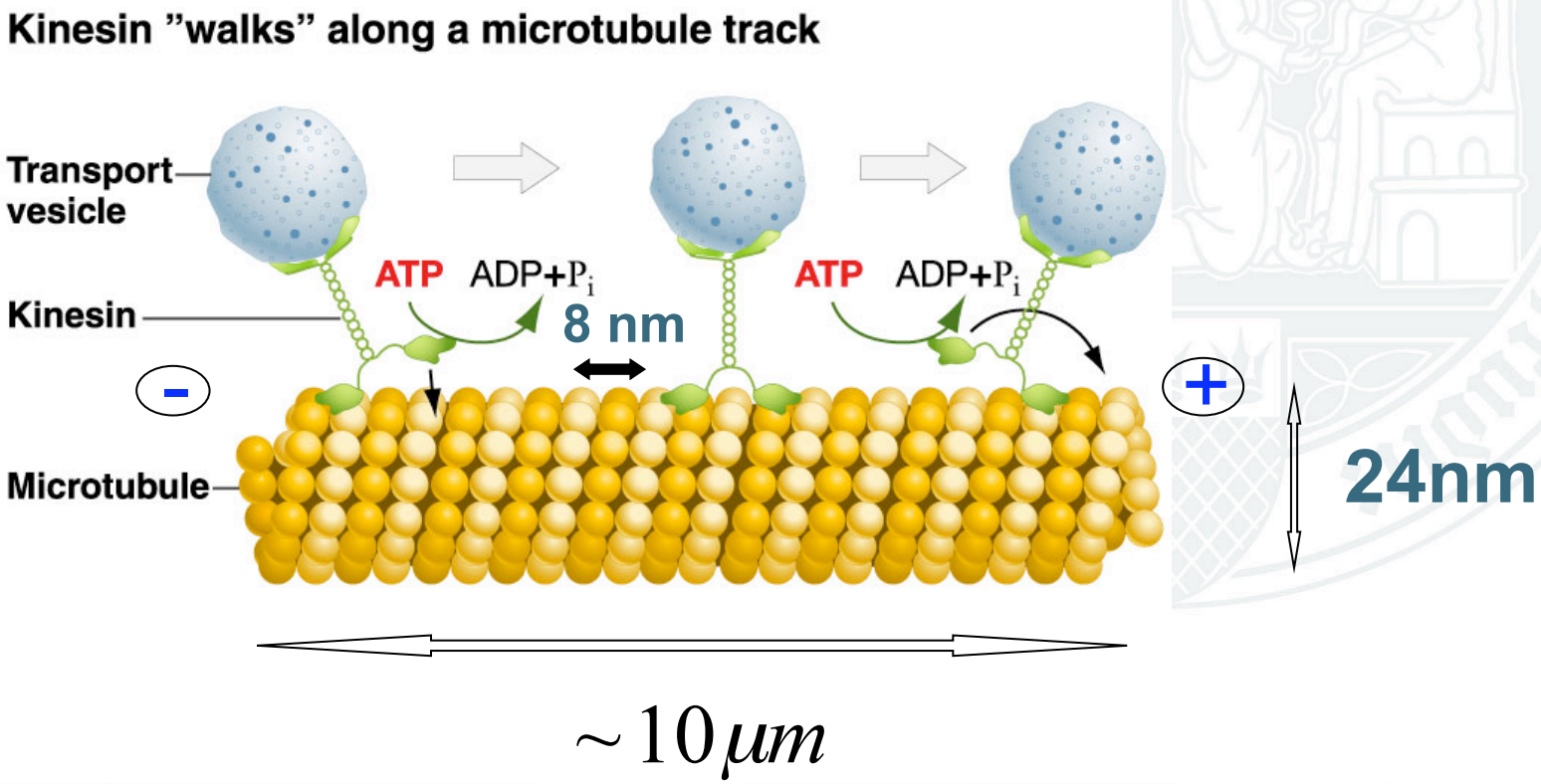


- microtubule = highway
- molecular motor (proteins) = trucks
- ATP = fuel

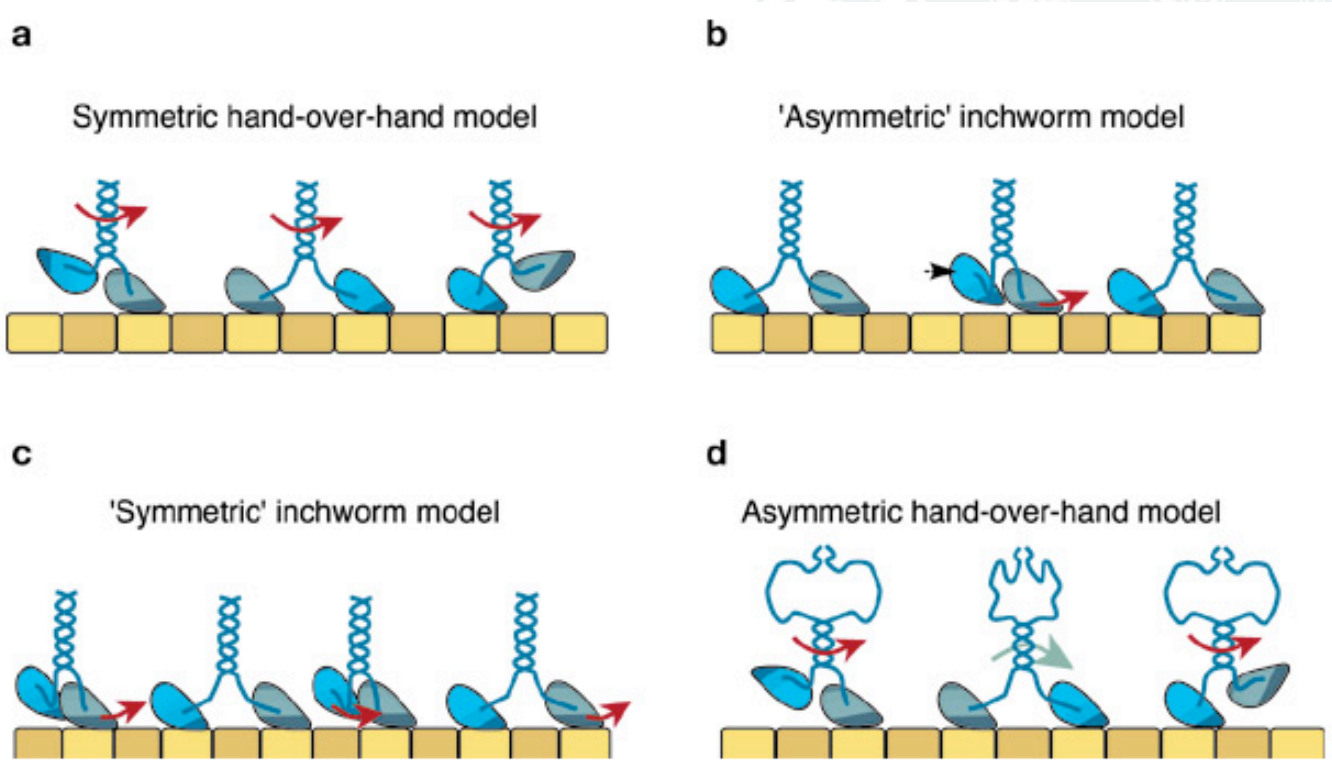
Molecular Motors

- **DNA**, **RNA** polymerases: move along DNA; **duplicate** and **transcribe** DNA into RNA
- **Membrane pumps**: transport ions and small molecules across membranes
- **Myosin**: work collectively in muscles
- **Kinesin, Dynein**: processive enzyms, walk along filaments (directed); important for intracellular transport, cell division, cell locomotion

Microtubule



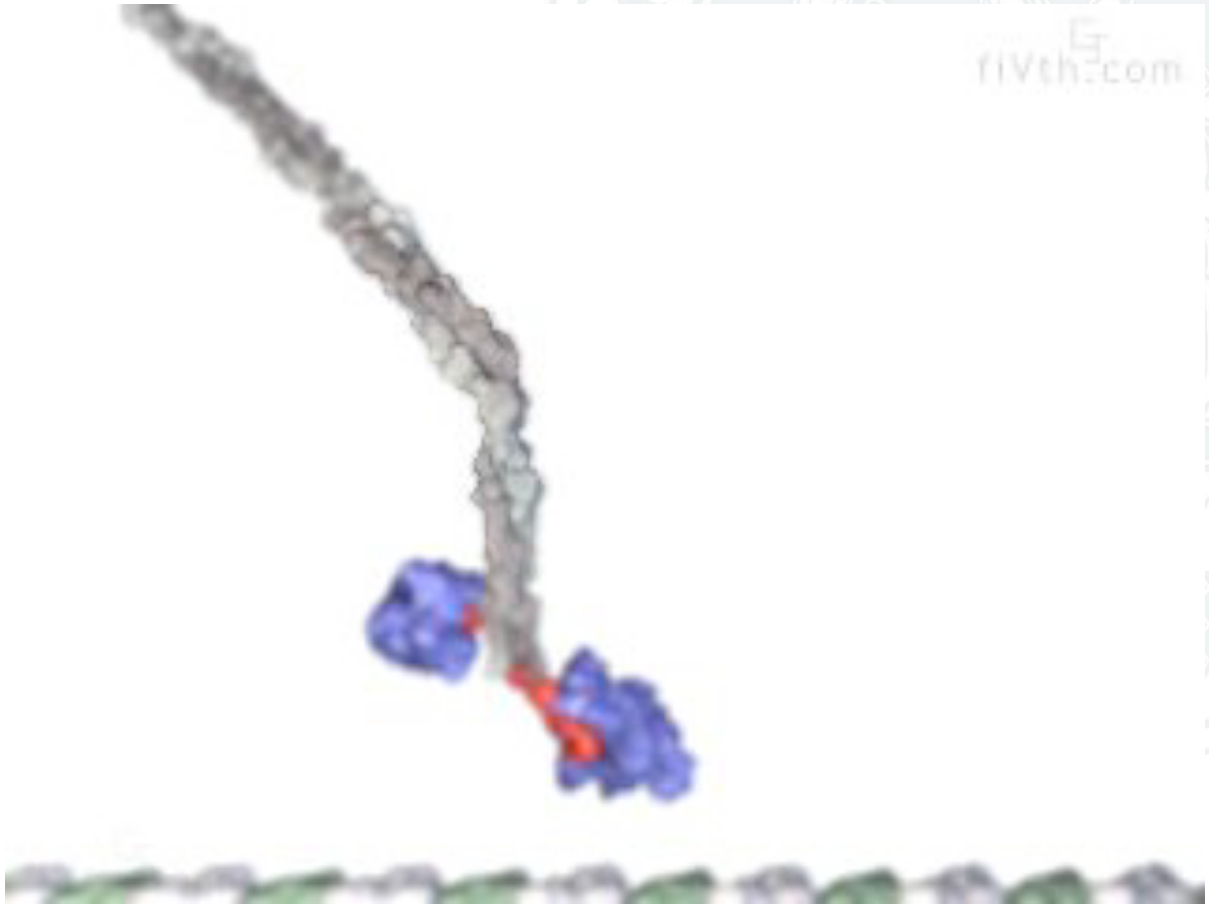
Mechanism of Motion



- **inchworm:** leading and trailing head fixed
- **hand-over-hand:** leading and trailing head change

Movie

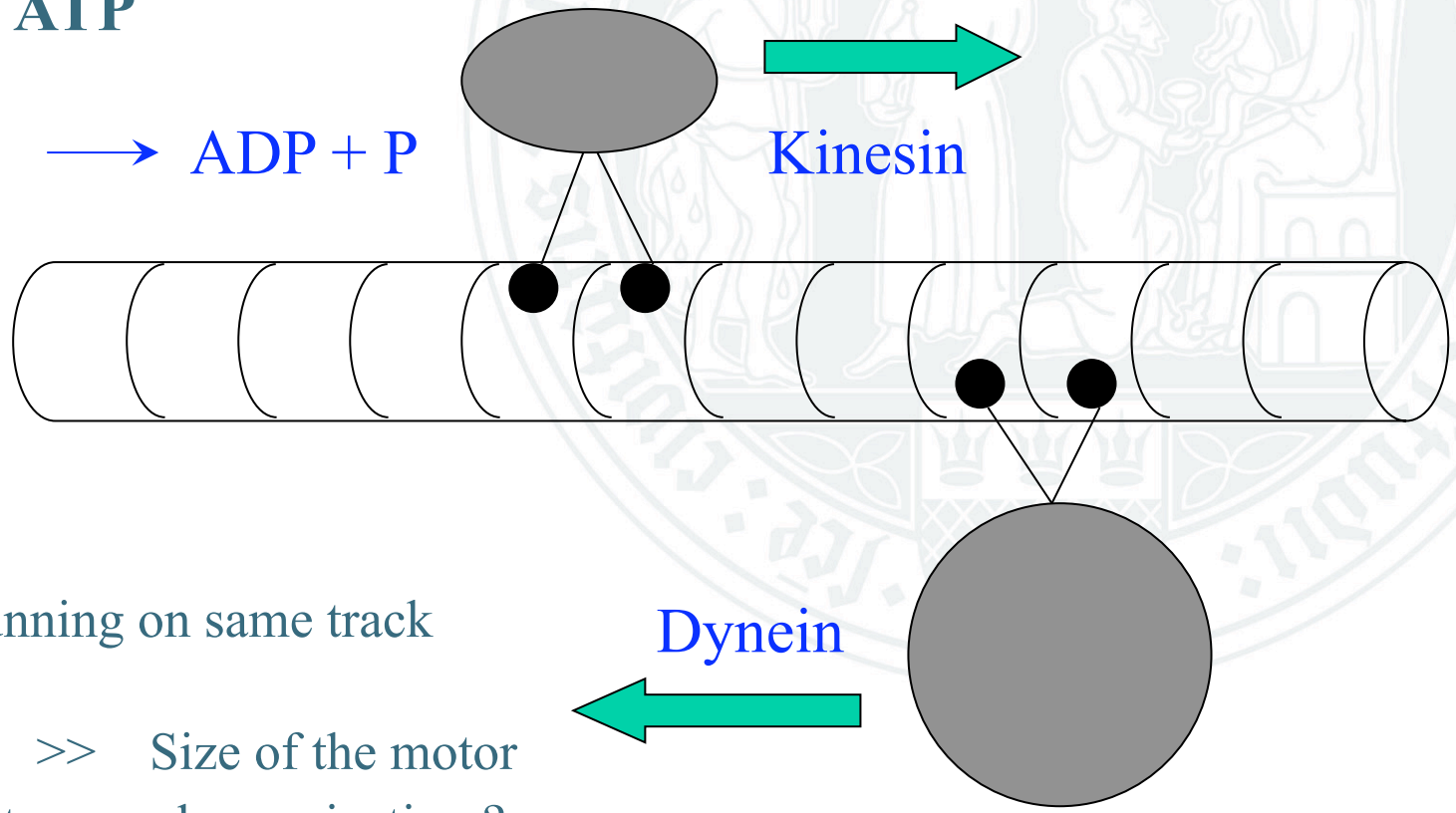
Mechanism of Motion



Kinesin and Dynein: Cytoskeletal motors

Fuel: ATP

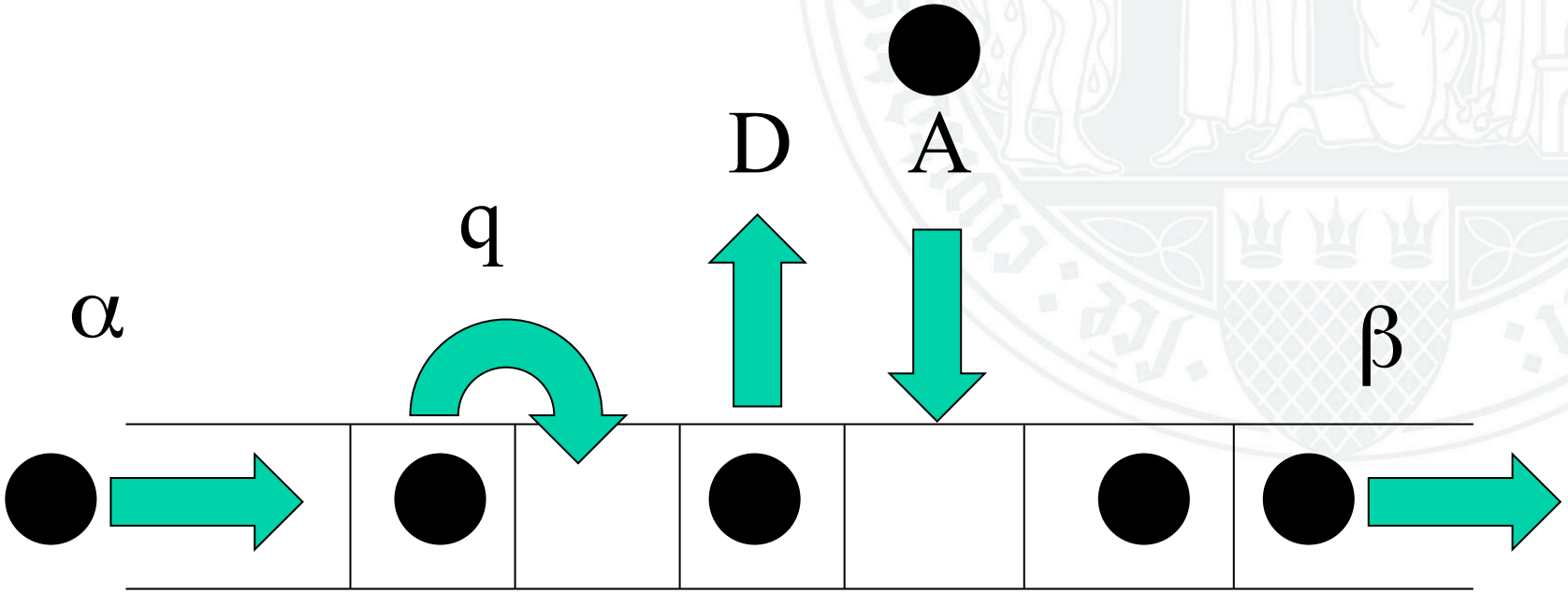
ATP $\longrightarrow$ ADP + P



- Several motors running on same track simultaneously
- Size of the cargo >> Size of the motor
- Collective spatio-temporal organization ?

ASEP-like Model of Molecular Motor-Traffic

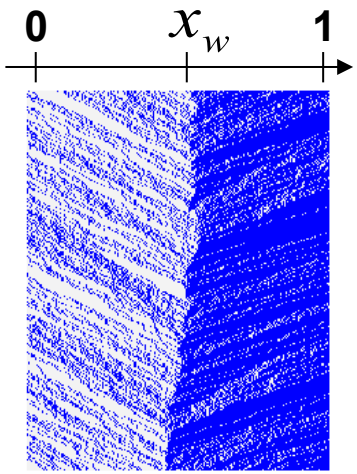
ASEP + Langmuir-like adsorption-desorption

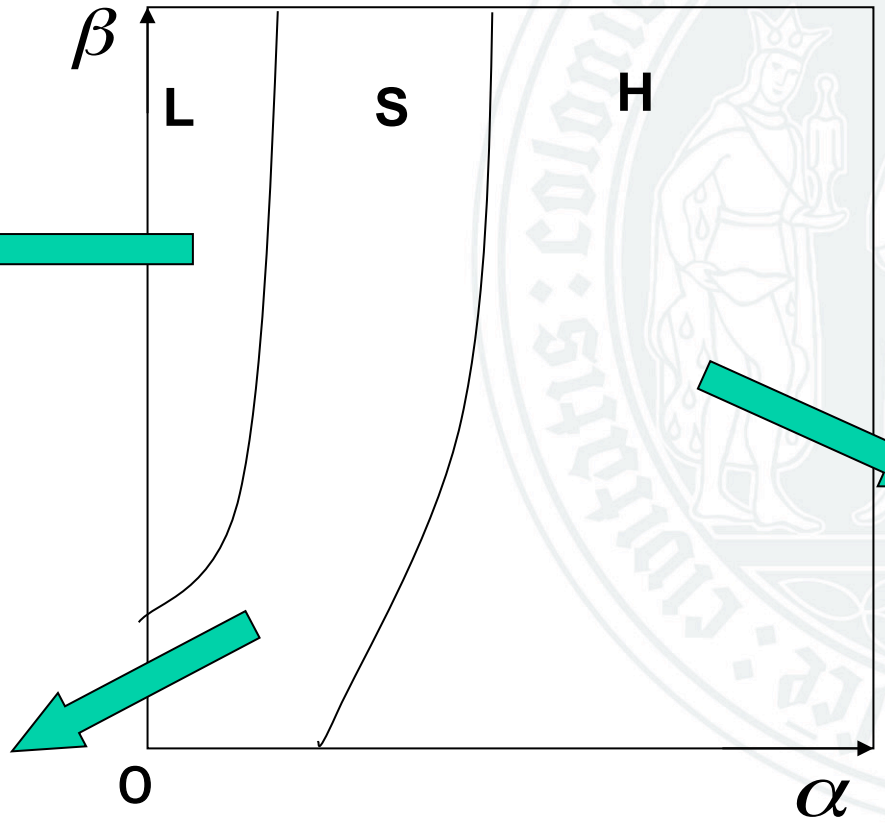


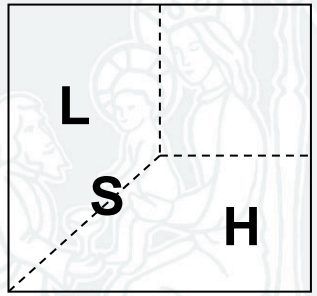
Parmeggiani, Franosc, Frey (2003)

Evans, Juhasz, Santen (2003)

Phases



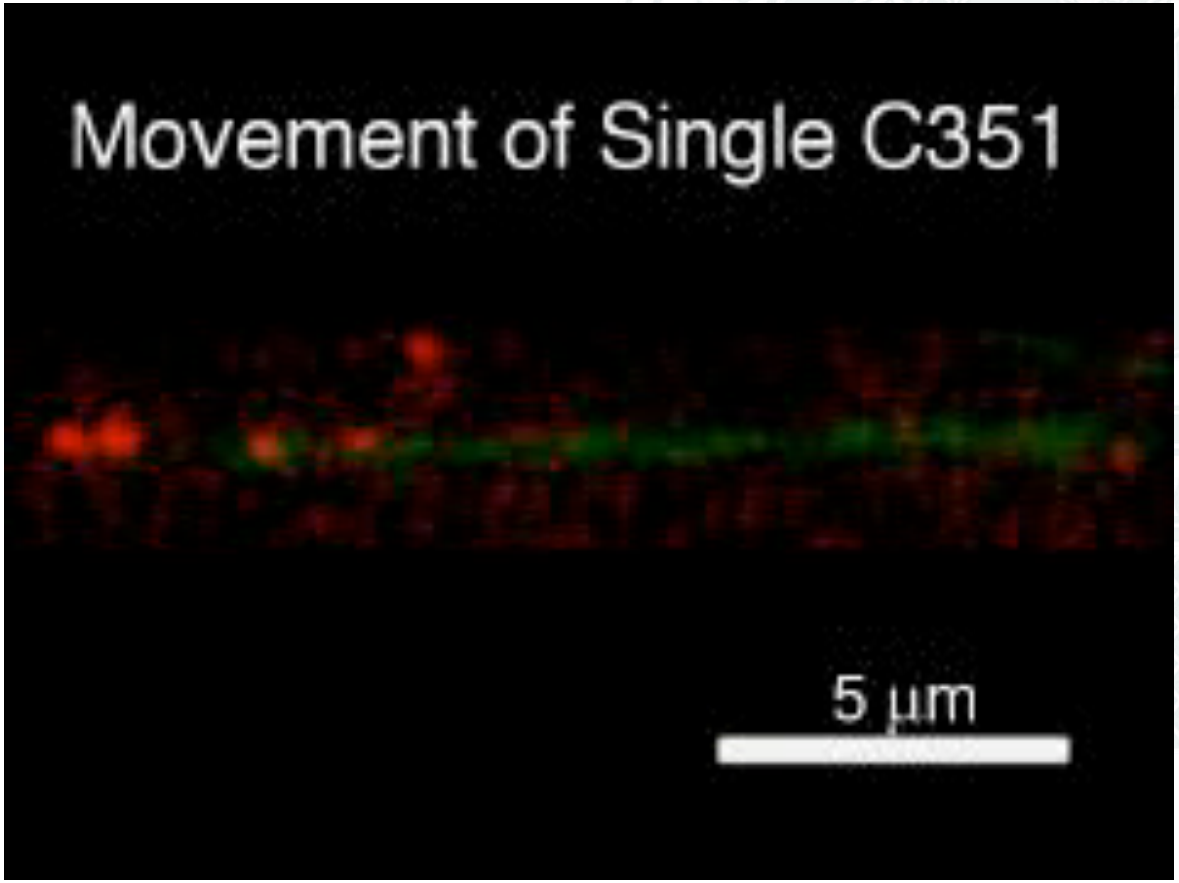




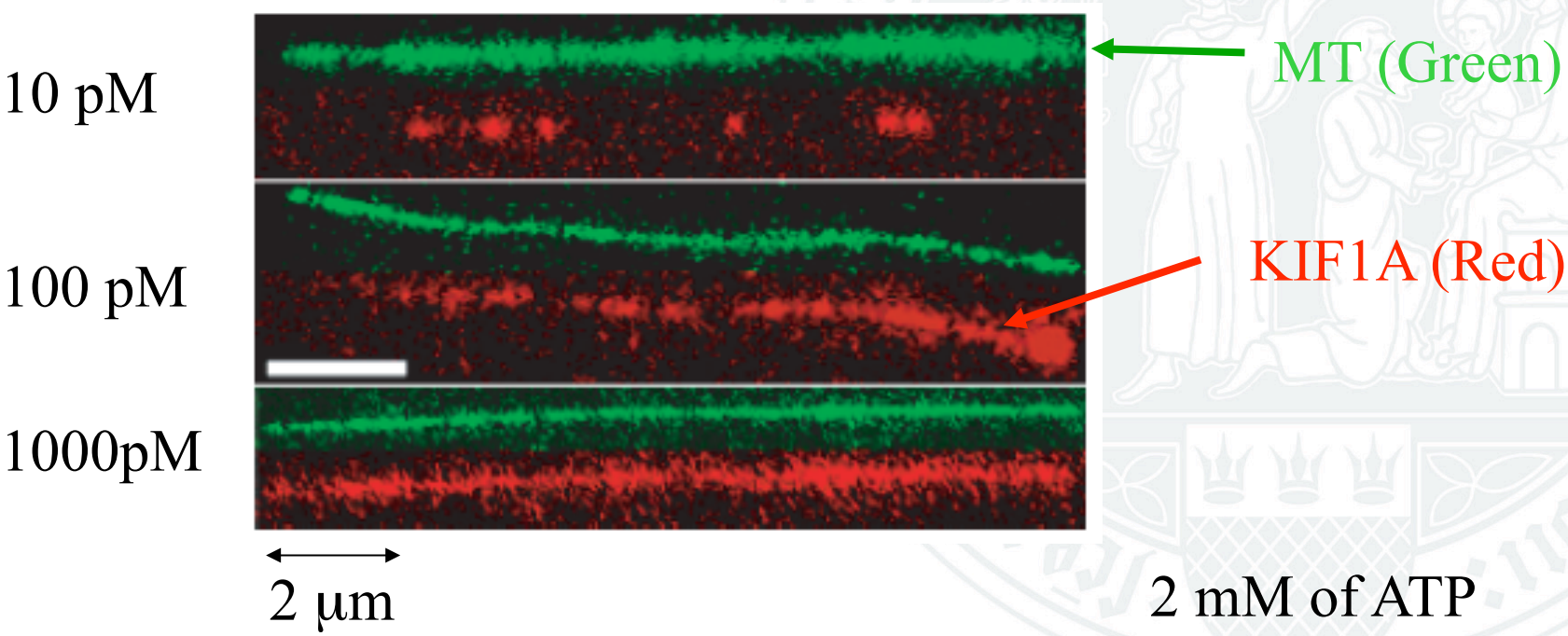
cf. ASEP

Position of shock is x=1 when SH
x=0 when LS

Single-headed kinesin KIF1A



Spatial organization of KIF1A motors: experiment



position of domain wall can be measured
as a function of controllable parameters

Nishinari, Okada, Schadschneider, Chowdhury, Phys. Rev. Lett. (2005)