

- No net motion of media
- .. or at least laminar flow

$$\text{Re} = \frac{vL\rho}{\eta}$$

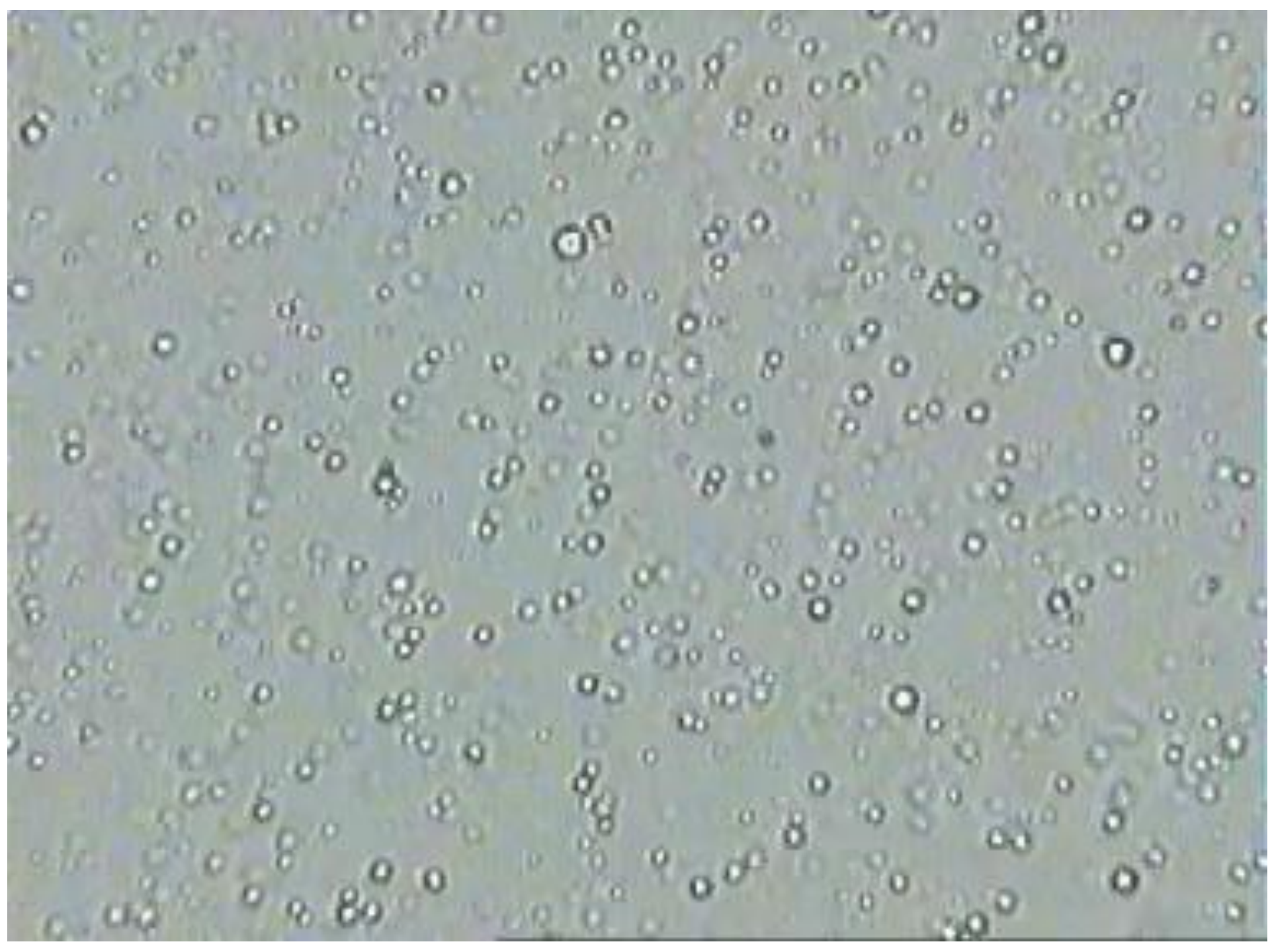
v=average velocity

L=characteristic length

$\rho$ =media density

$\eta$ =dynamic viscosity (1 poise = 1 g\*cm<sup>-1</sup>\*sec<sup>-1</sup>)

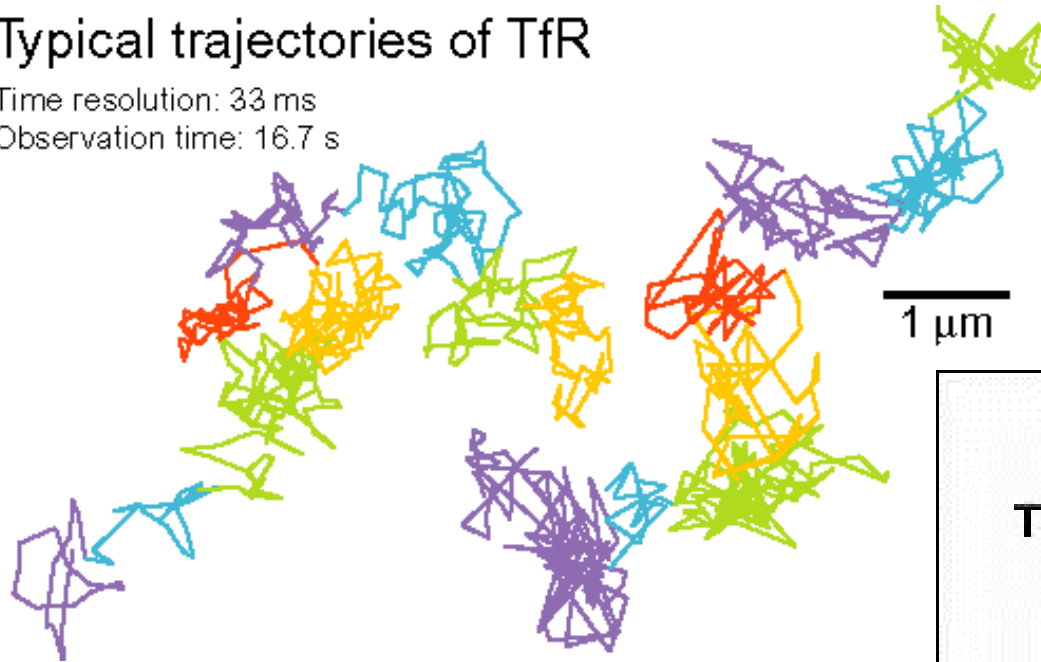
- fish swimming: (10 cm long, 100 cm/sec) Re=10<sup>5</sup>
- bacterium (10<sup>-4</sup> cm long, 10<sup>-3</sup> cm/sec) Re=10<sup>-5</sup>



# Particle tracking of transferrin receptor

## Typical trajectories of TfR

Time resolution: 33 ms  
Observation time: 16.7 s



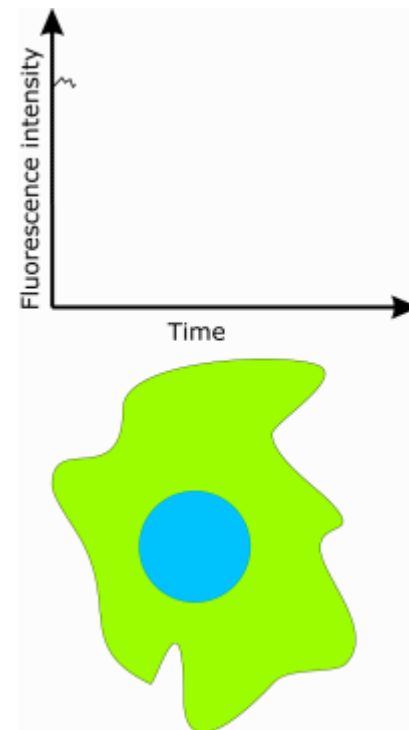
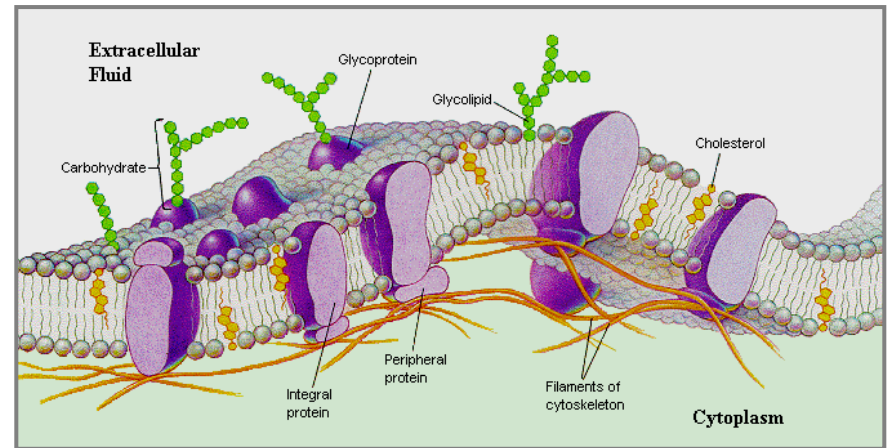
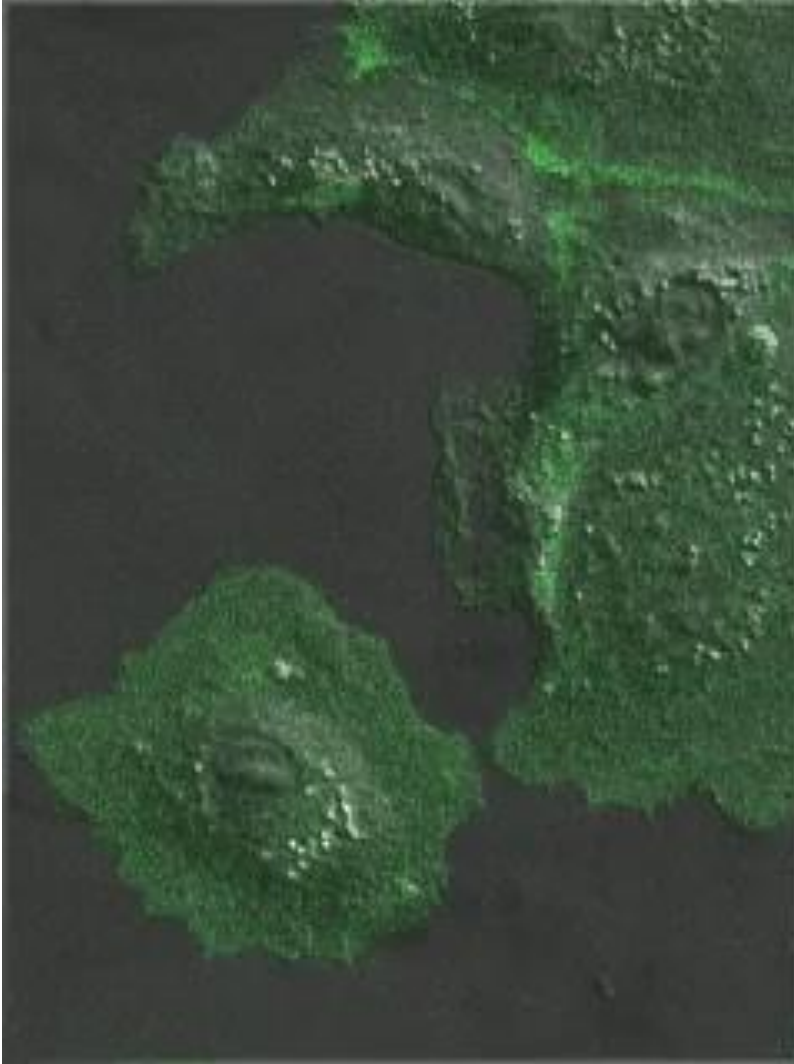
Transferrin receptor on NRK cell

Real time  
Scale = 1 μm

this and other images from the website of Akihiro Kusumi,  
<http://www.supra.bio.nagoya-u.ac.jp/lab/e.html>



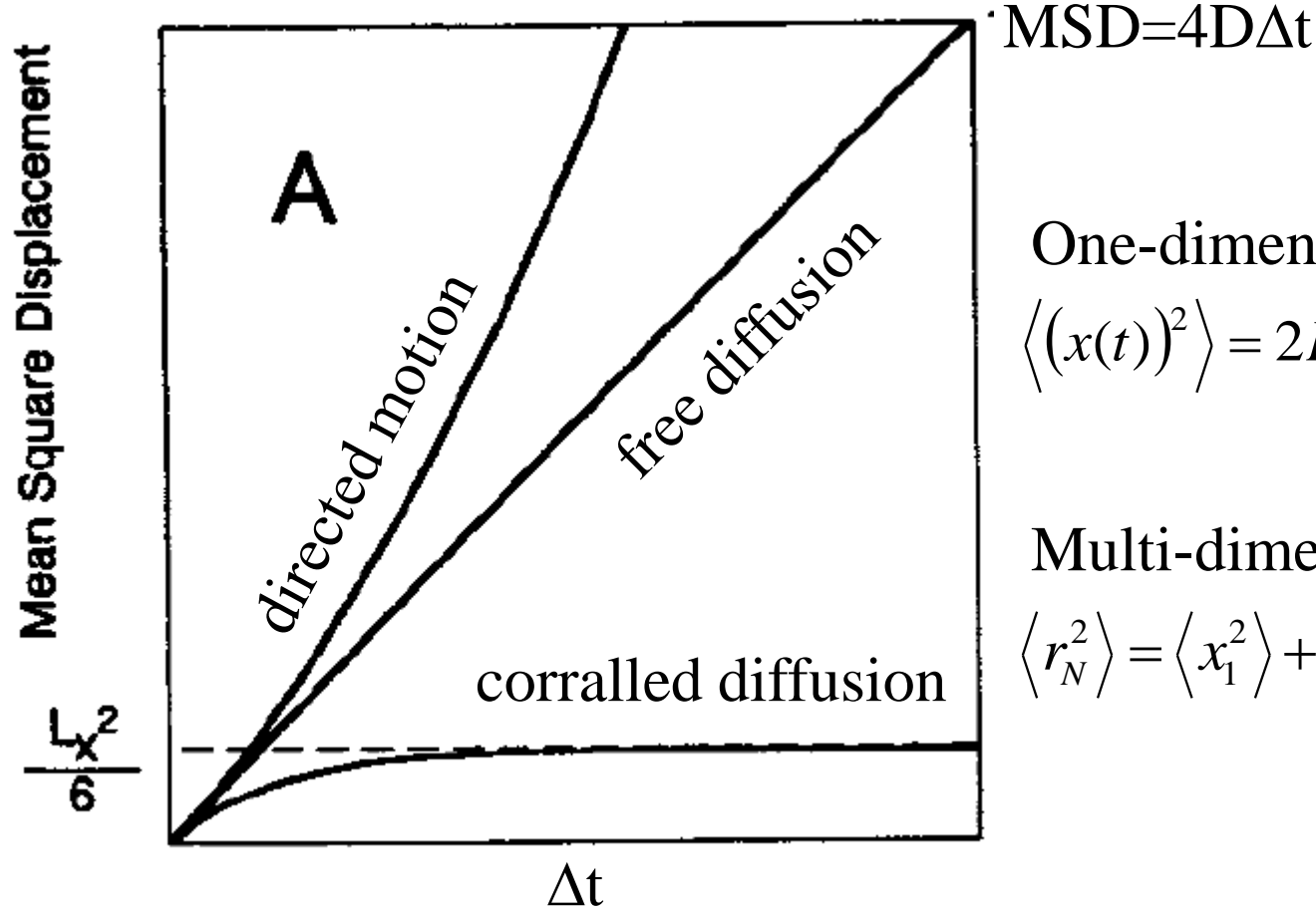
# Diffusion of membrane proteins – long range motion is orders of magnitude slower than predicted



# Our mission

- Two models of diffusion,
  - discrete space
  - continuum
- Two types of solutions
  - motion of an individual particle - time-dependent
  - bulk transport - steady-state

# Quantification of single particle traces



One-dimension:

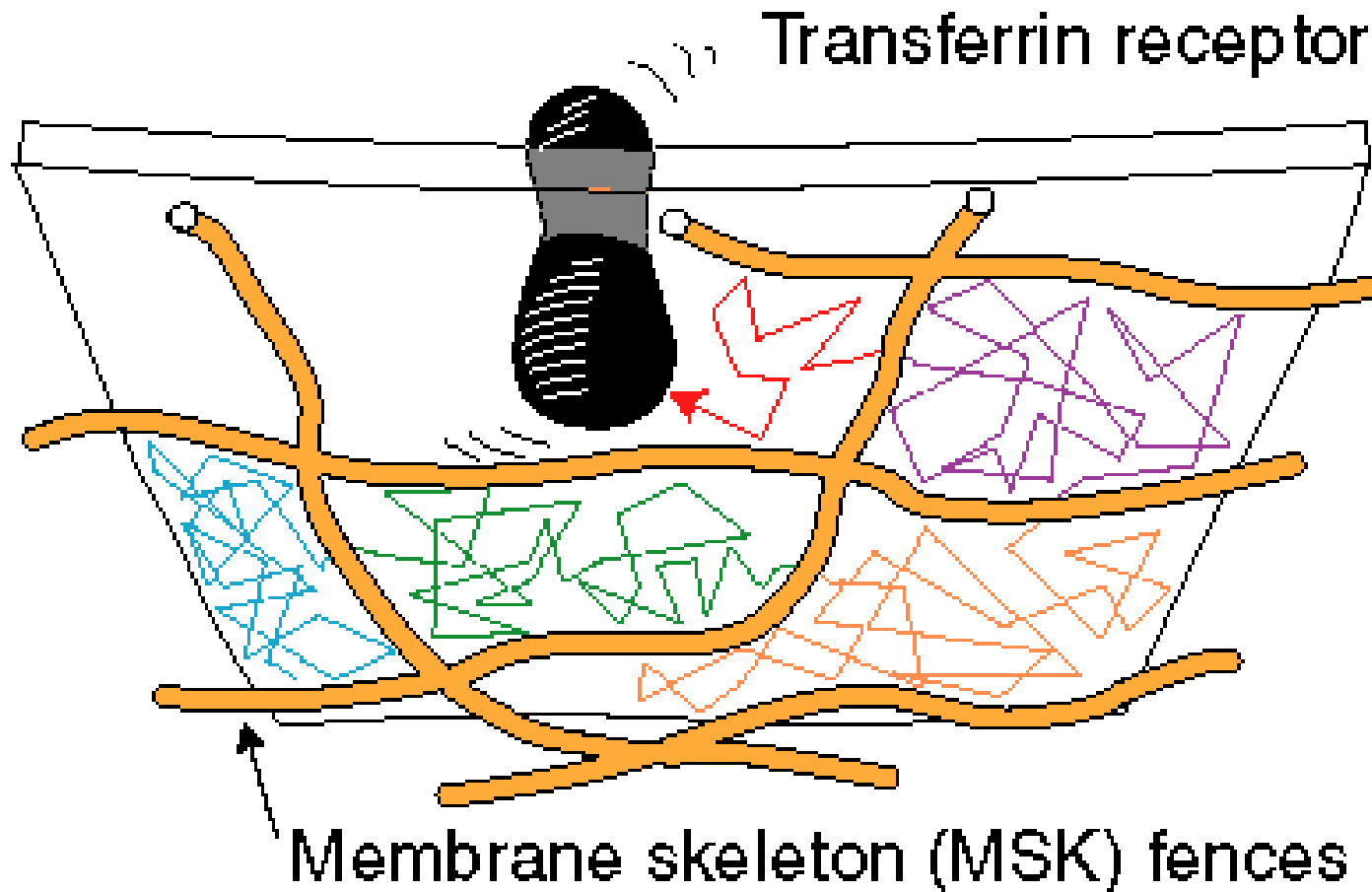
$$\langle (x(t))^2 \rangle = 2D * t$$

Multi-dimension diffusion:

$$\langle r_N^2 \rangle = \langle x_1^2 \rangle + \langle x_2^2 \rangle + \dots \langle x_N^2 \rangle = 2NDt$$

Kusumi, A, Sako, Y, and Yamamoto, M, *Biophys J* **65**, 2021 (1993).

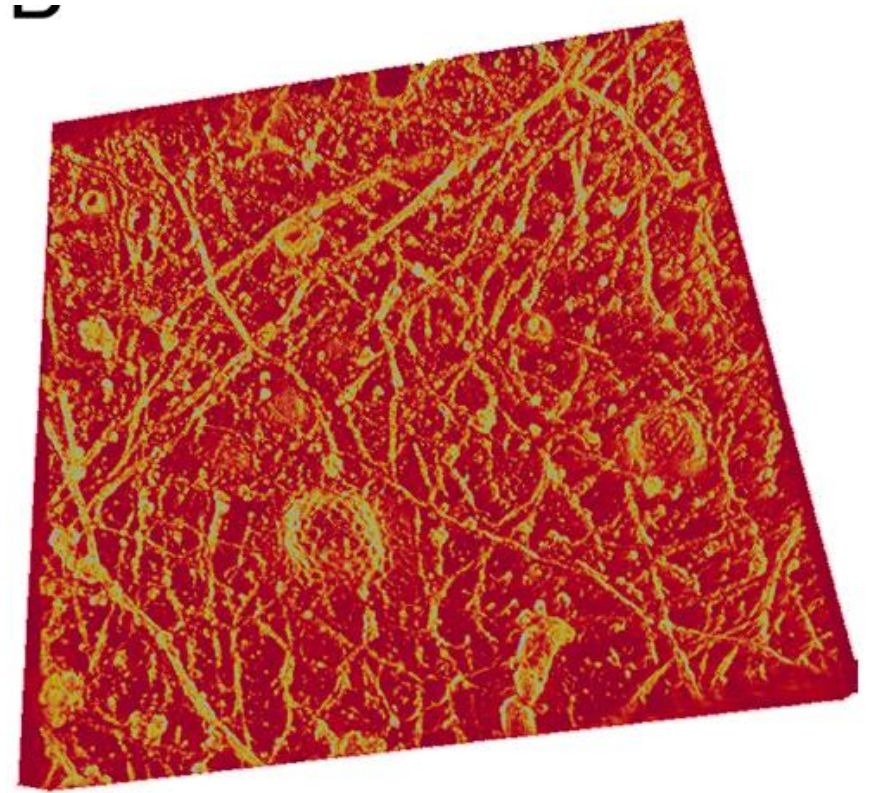
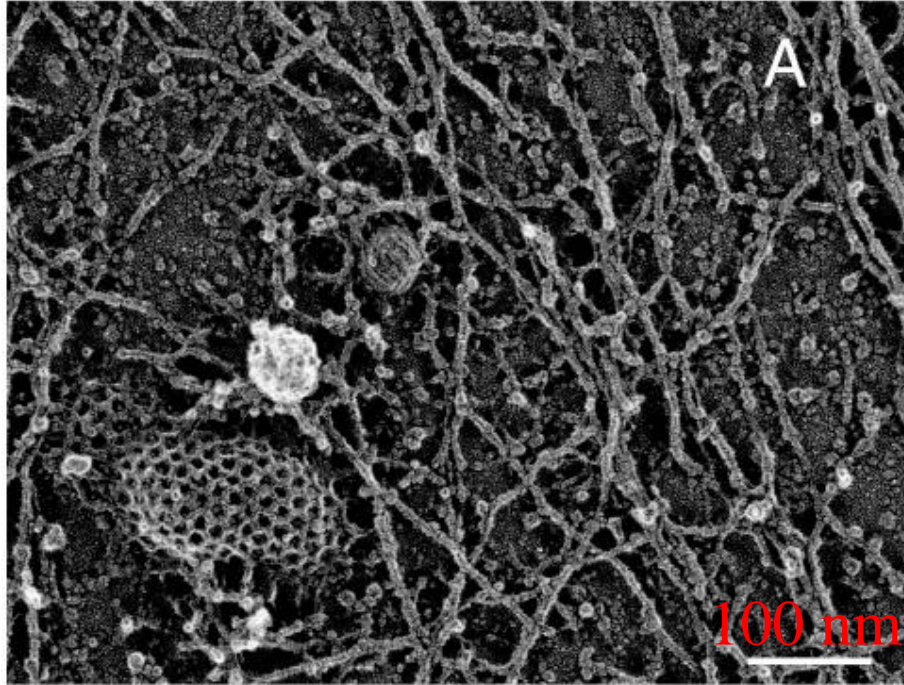
# Membrane Skeleton Fence





# Membrane cytoskeleton

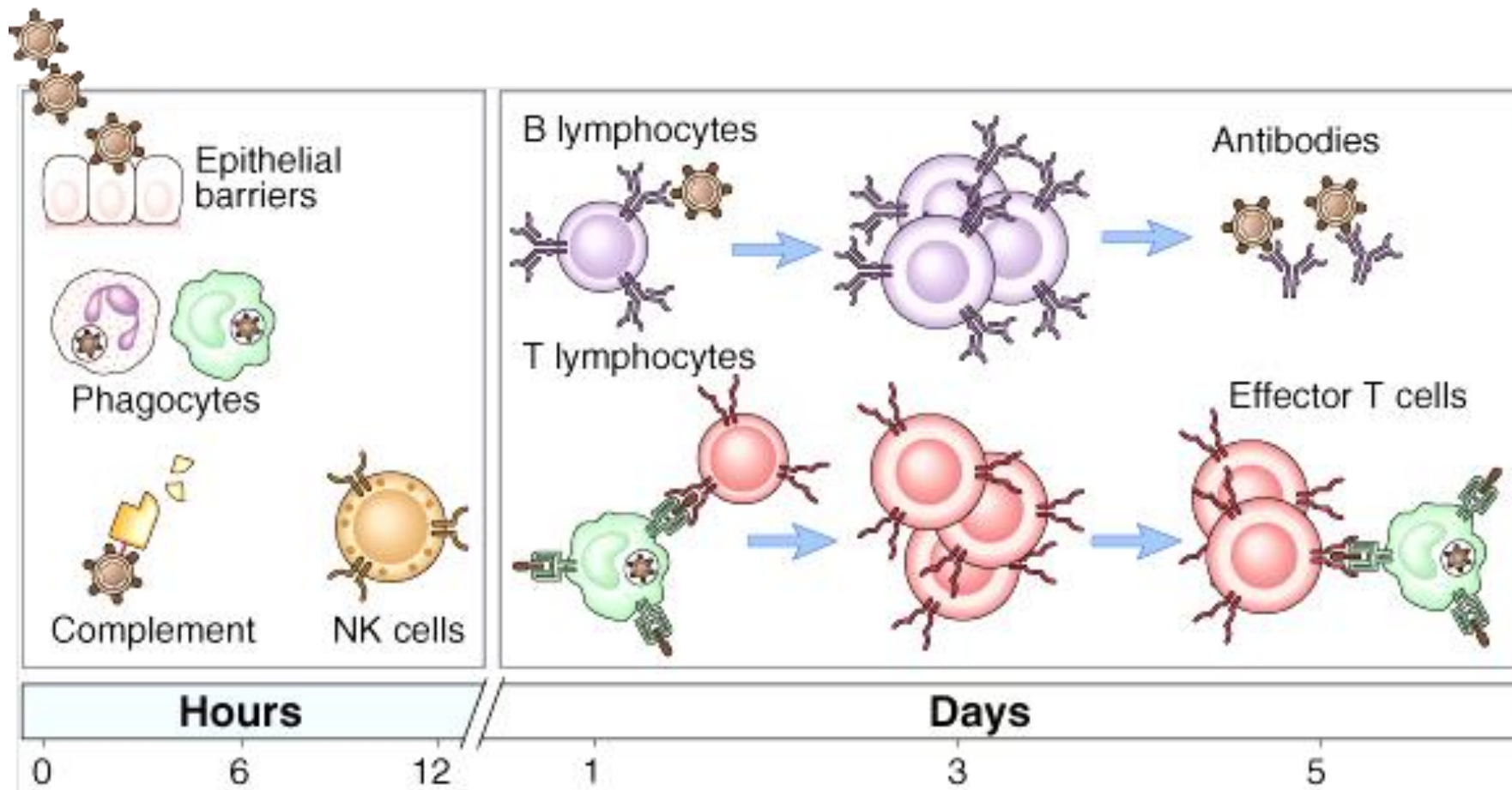
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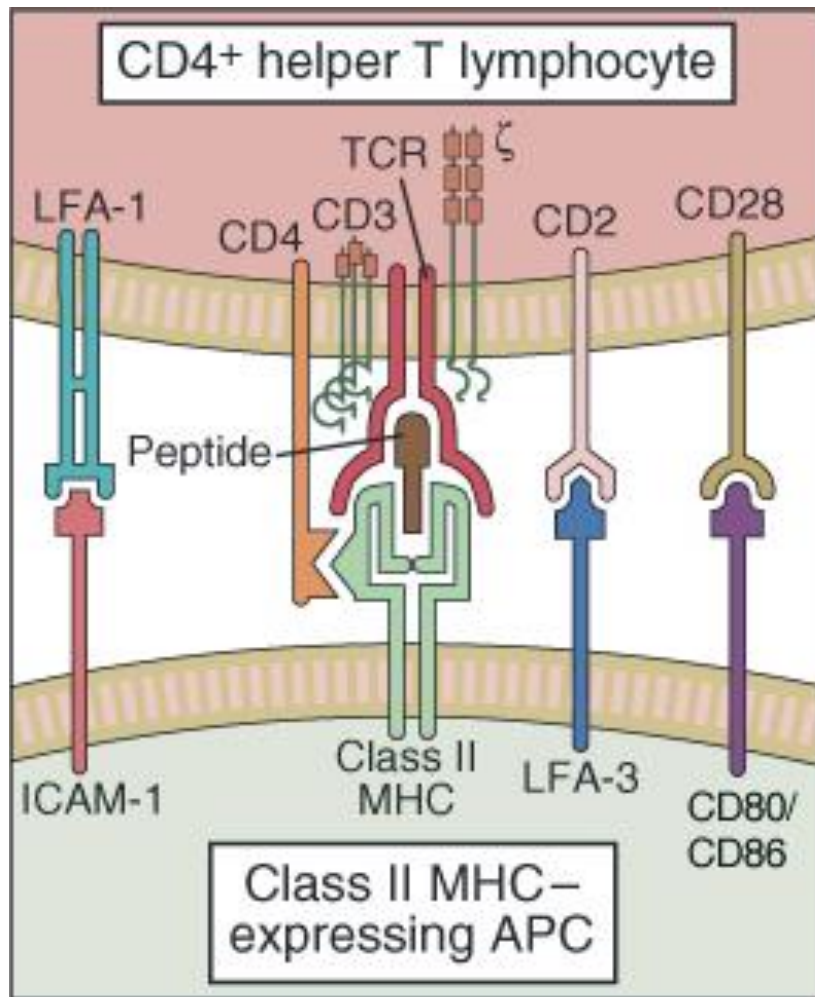
Morone *et al.*, J Cell Biol, **174**:851 (2006)

<http://www.jcb.org/cgi/content/full/jcb.200606007/DC1>

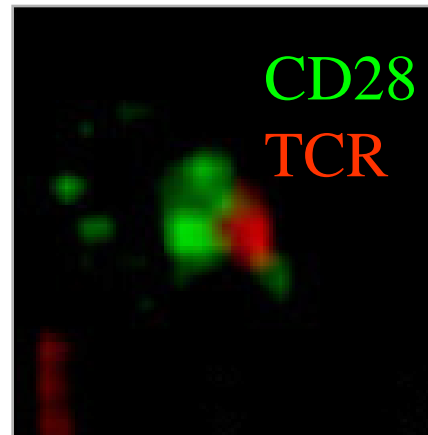
# T cells and adaptive immunity



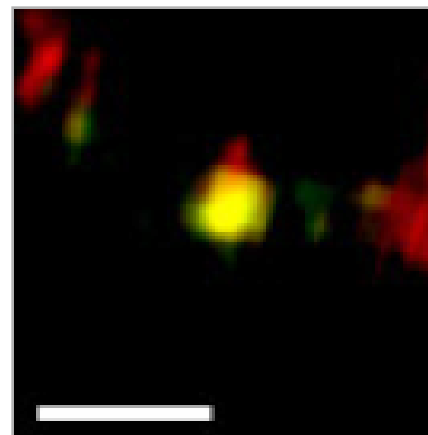
# Micropatterned costimulation of T cells



## Artificial APC:

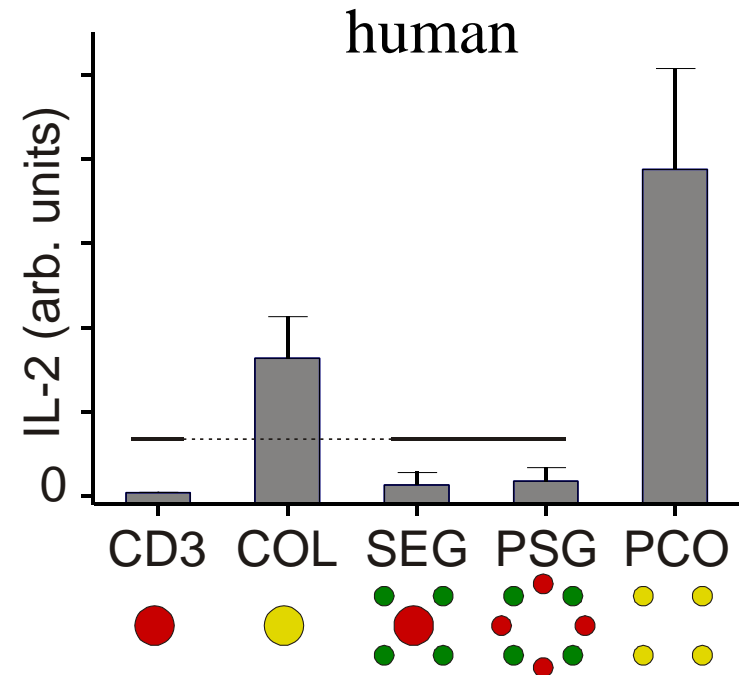
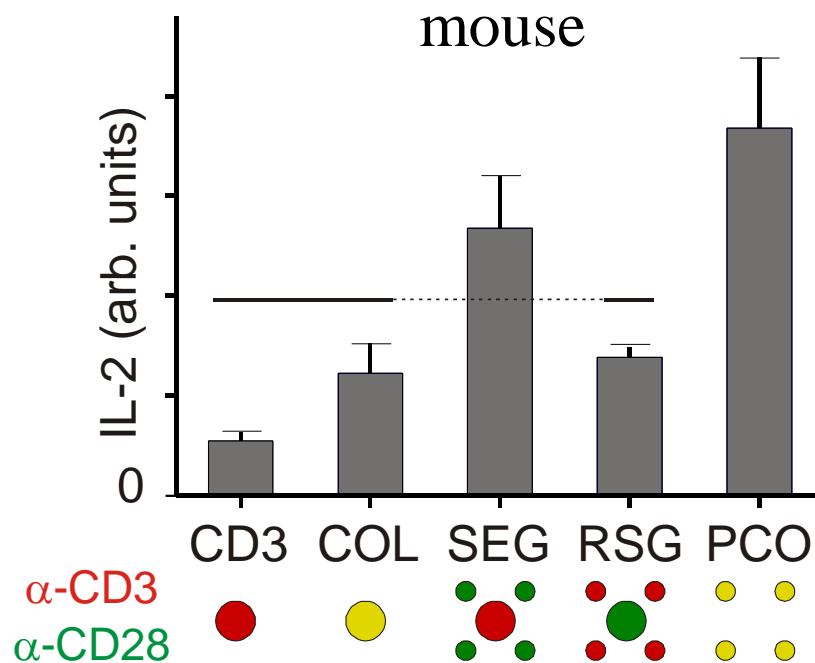
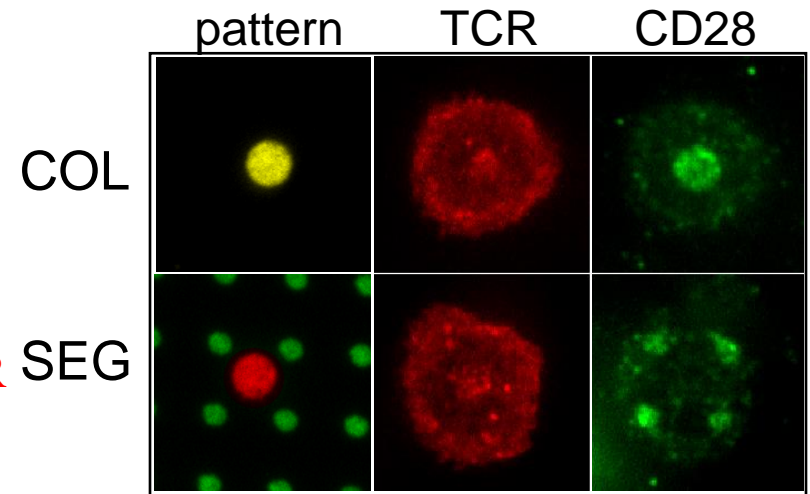
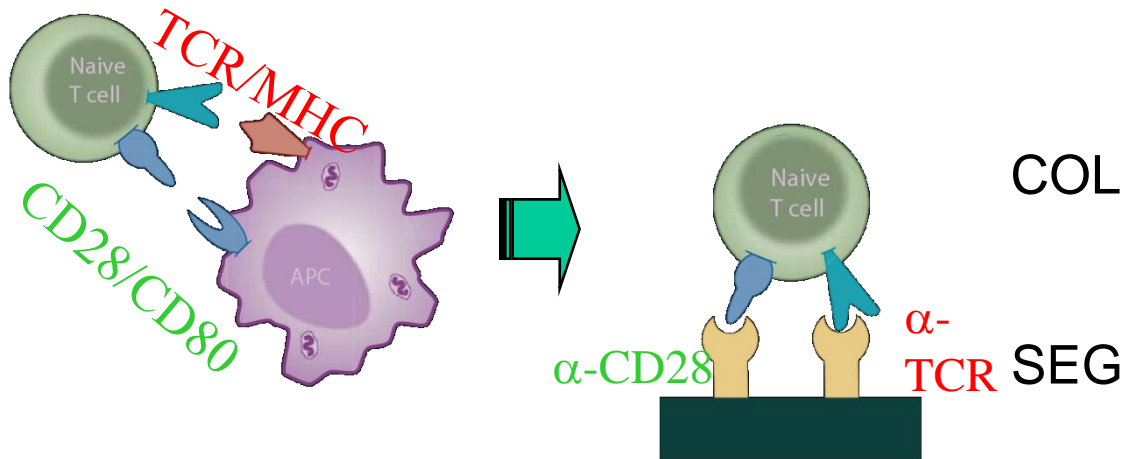


full length CD80  
good stimulus

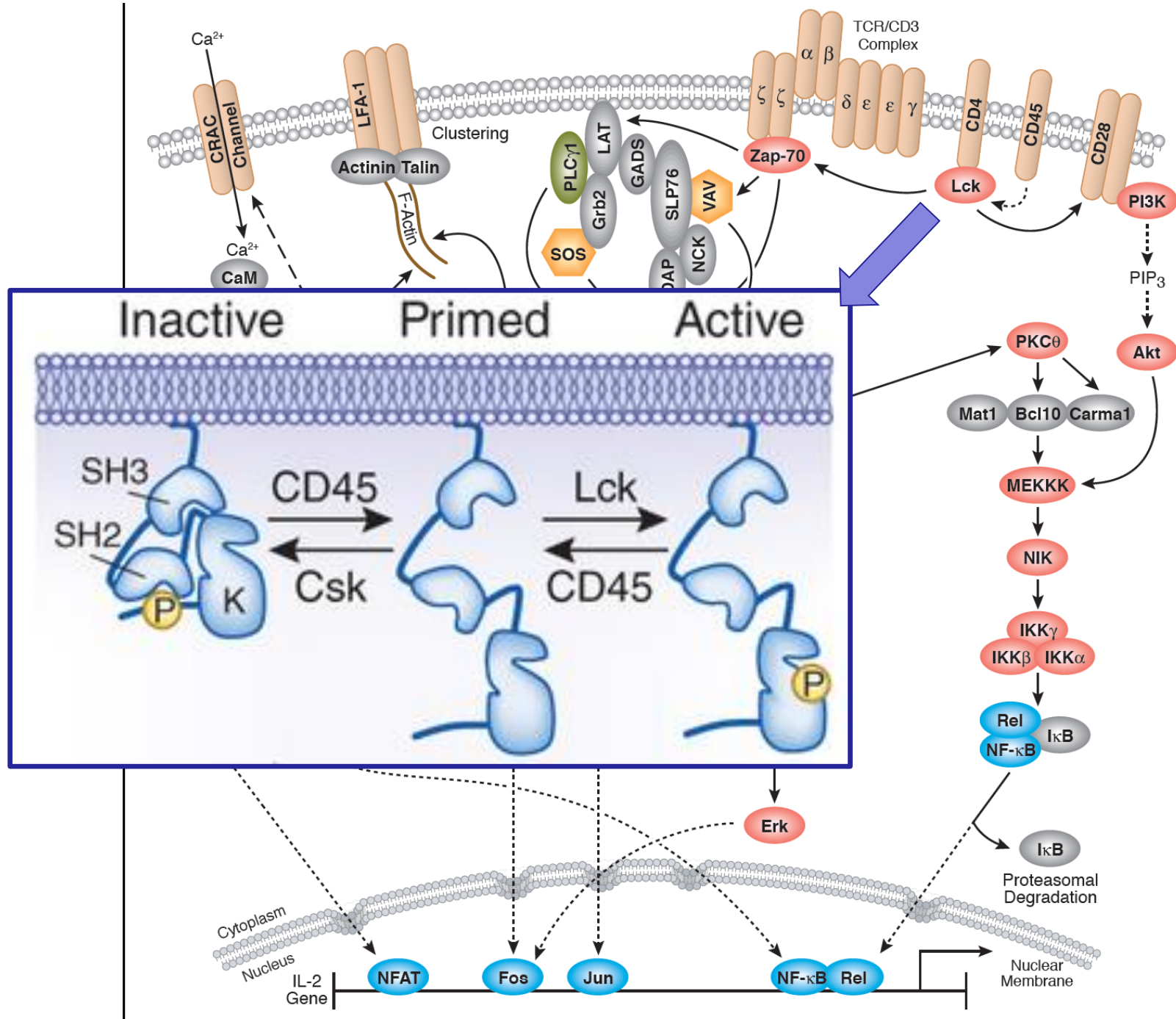


tail deleted CD80  
weaker stimulus

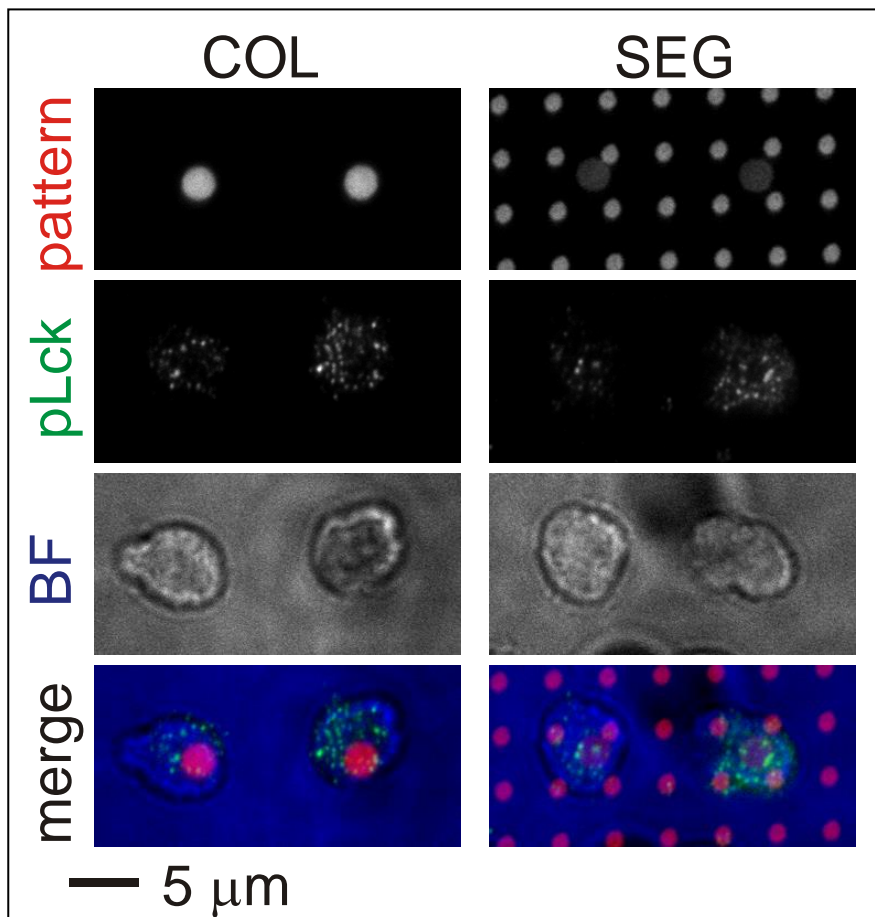
# Micropatterned costimulation of T cells



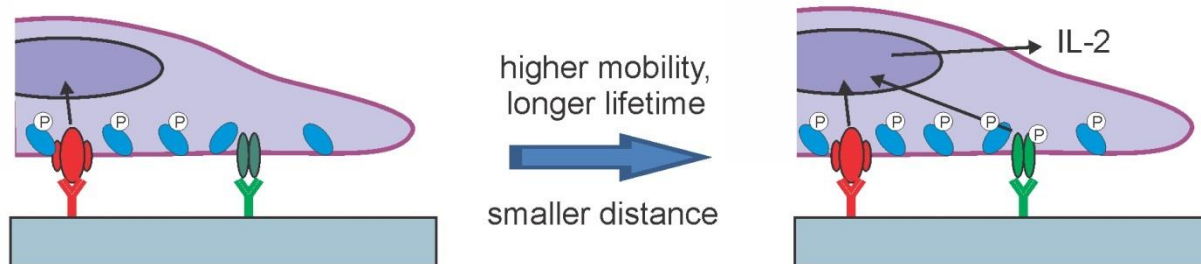
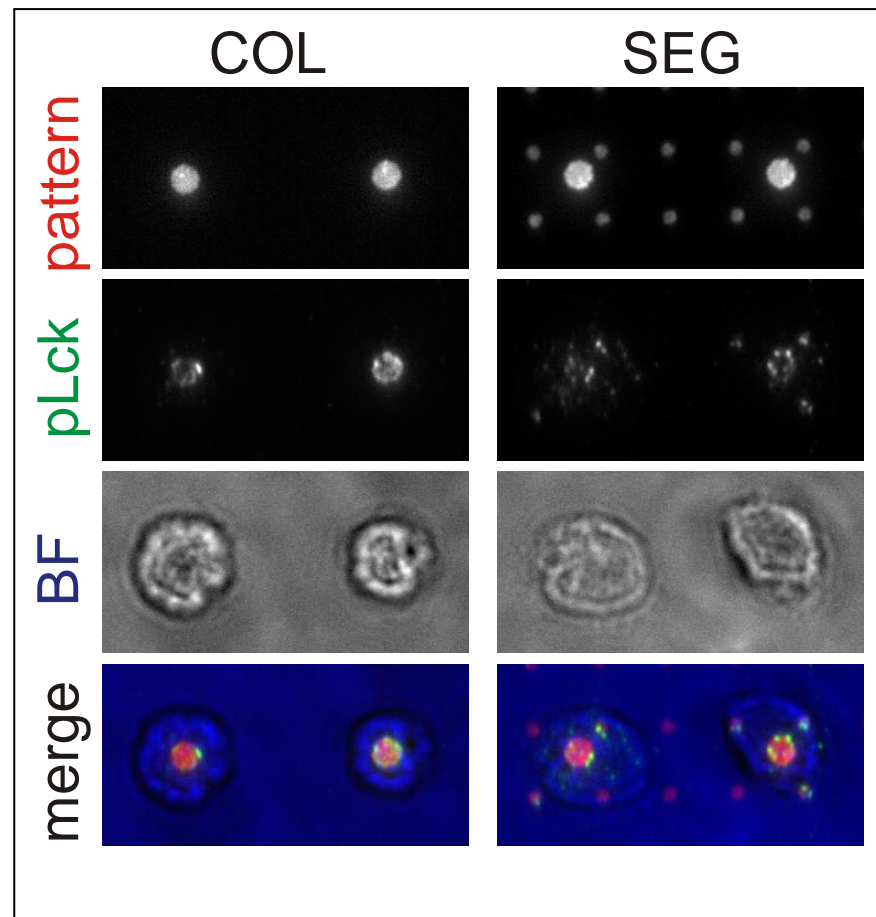




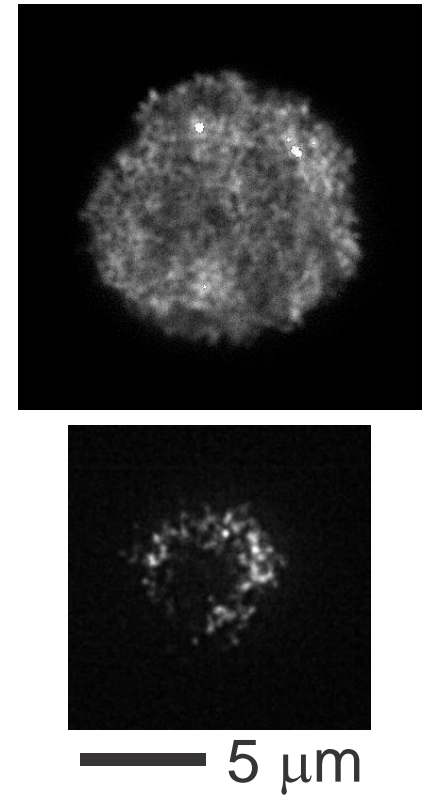
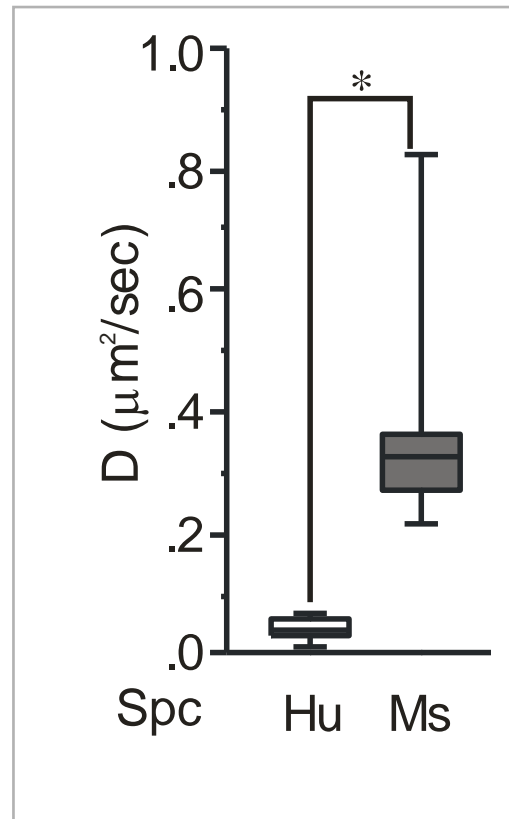
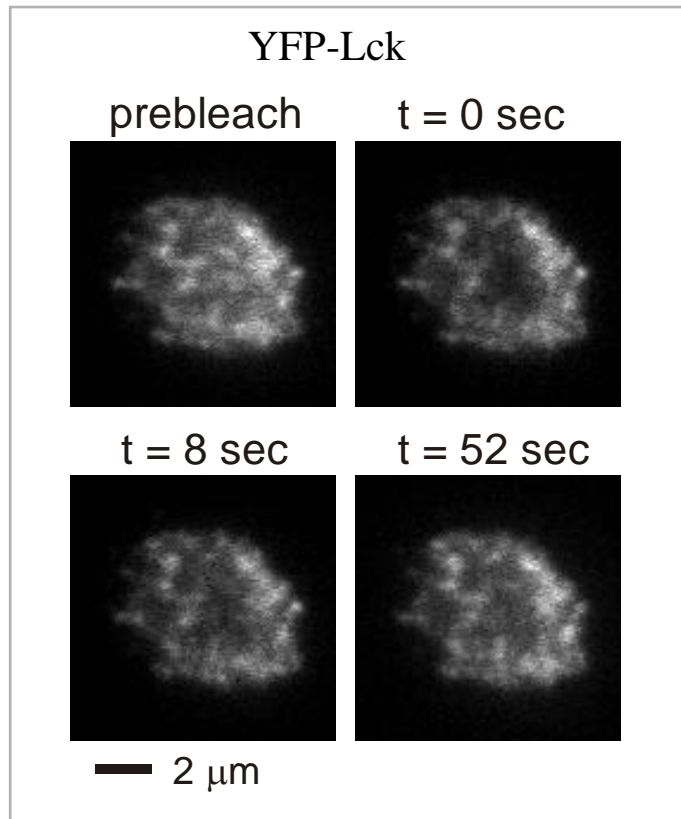
## Mouse



## Human

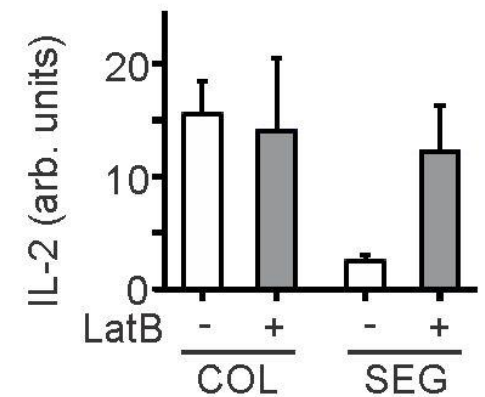
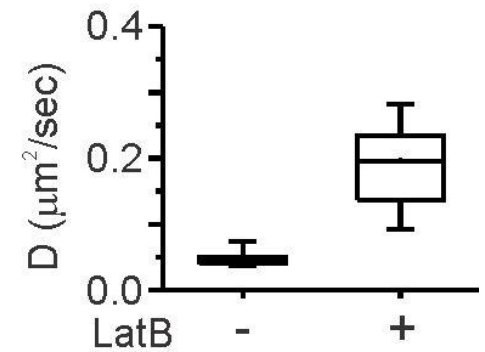
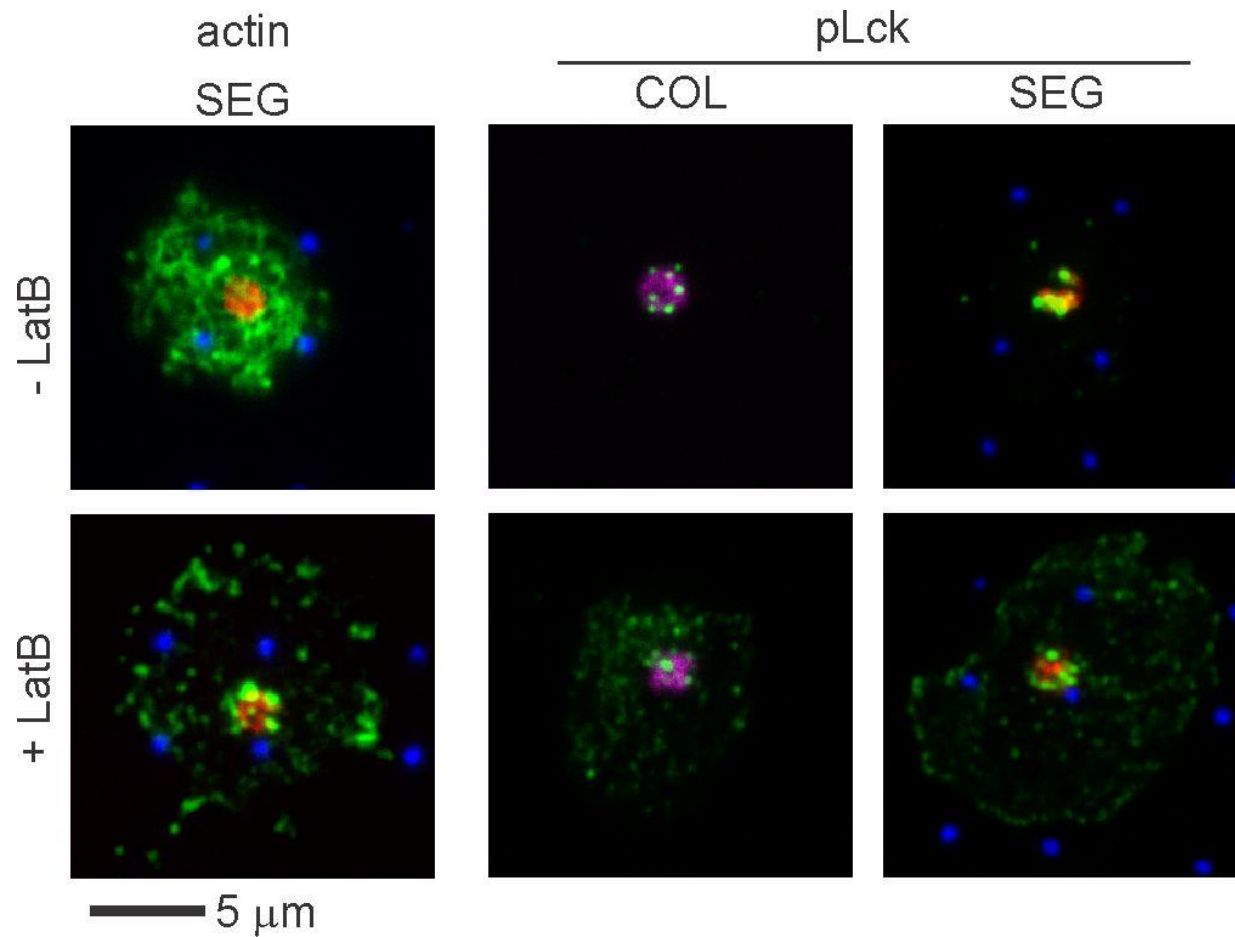


# Differential mobility of Lck





# Hindered diffusion in human cells



# Membrane proteins

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