Lecture 8: Diffusion in the cell

Goal: Role of Brownian motion in living systems. Compute the time to travel a distance, model diffusion in gradient.

- Brownian motion
- Concentration fields and diffusive dynamics

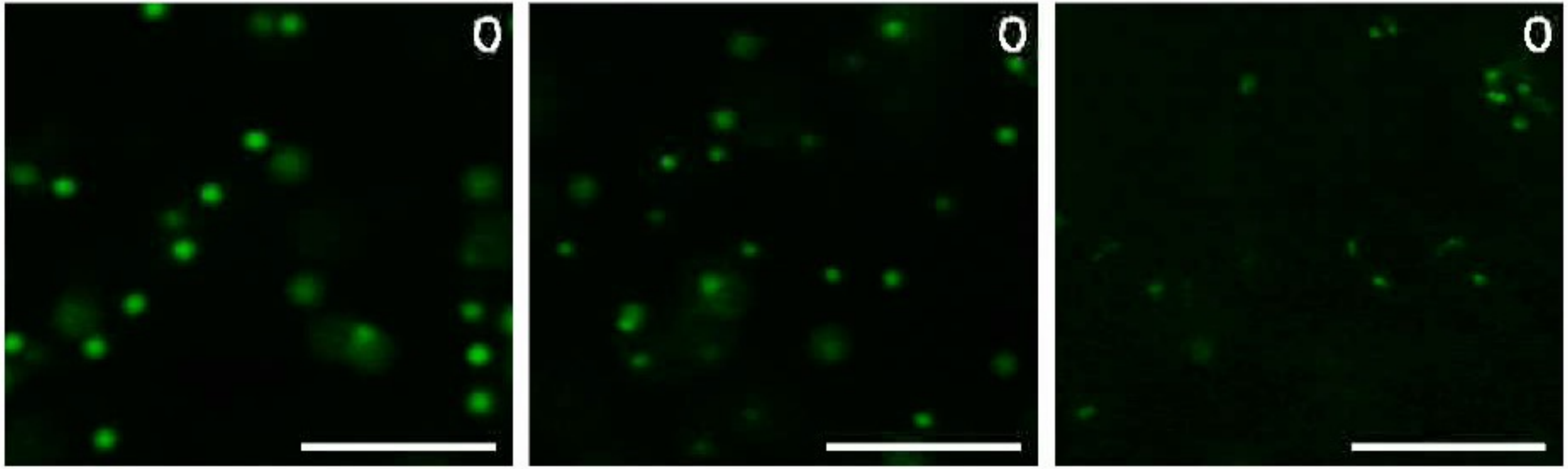
PBOC Chapter 13.1, 13.2.1-13.2.3

Diffusion in the cell

Active vs. passive transport

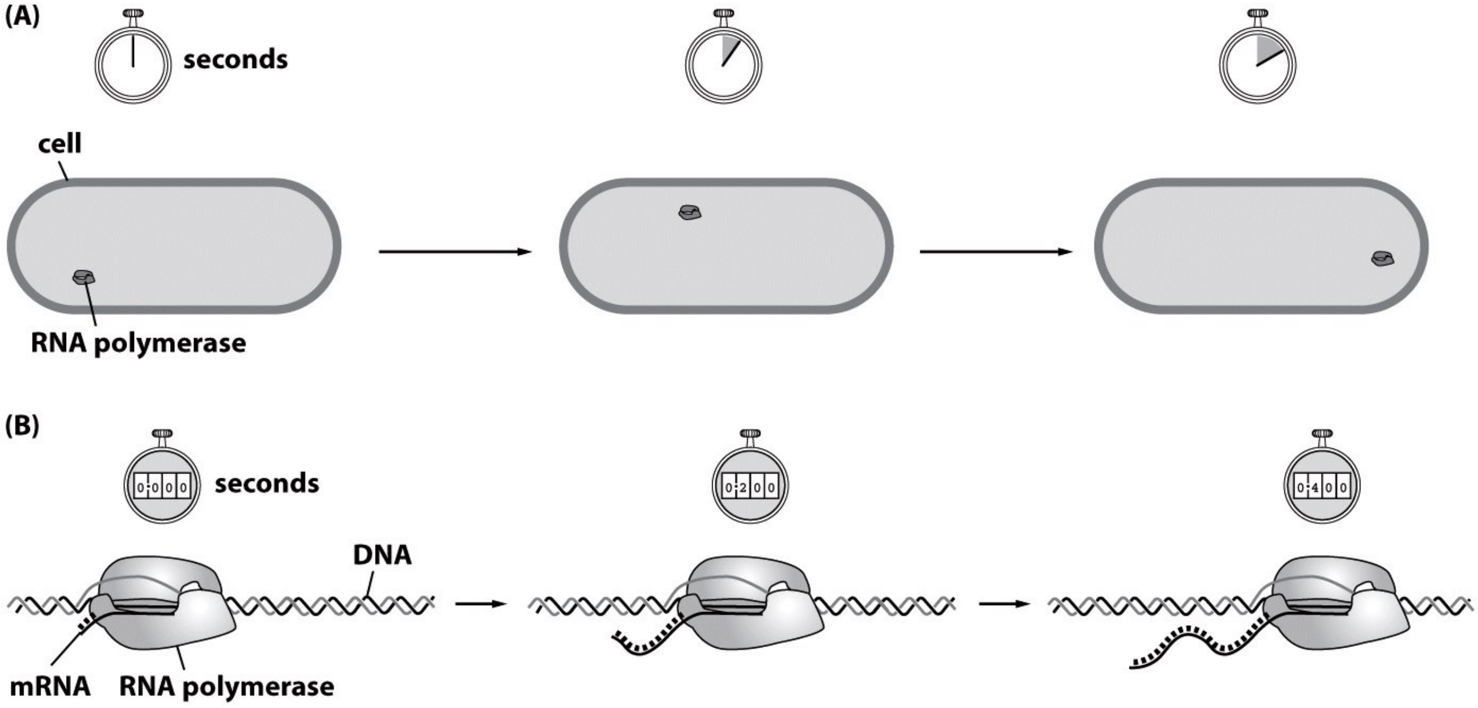
Diffusion in the cell

Particles in a fluid



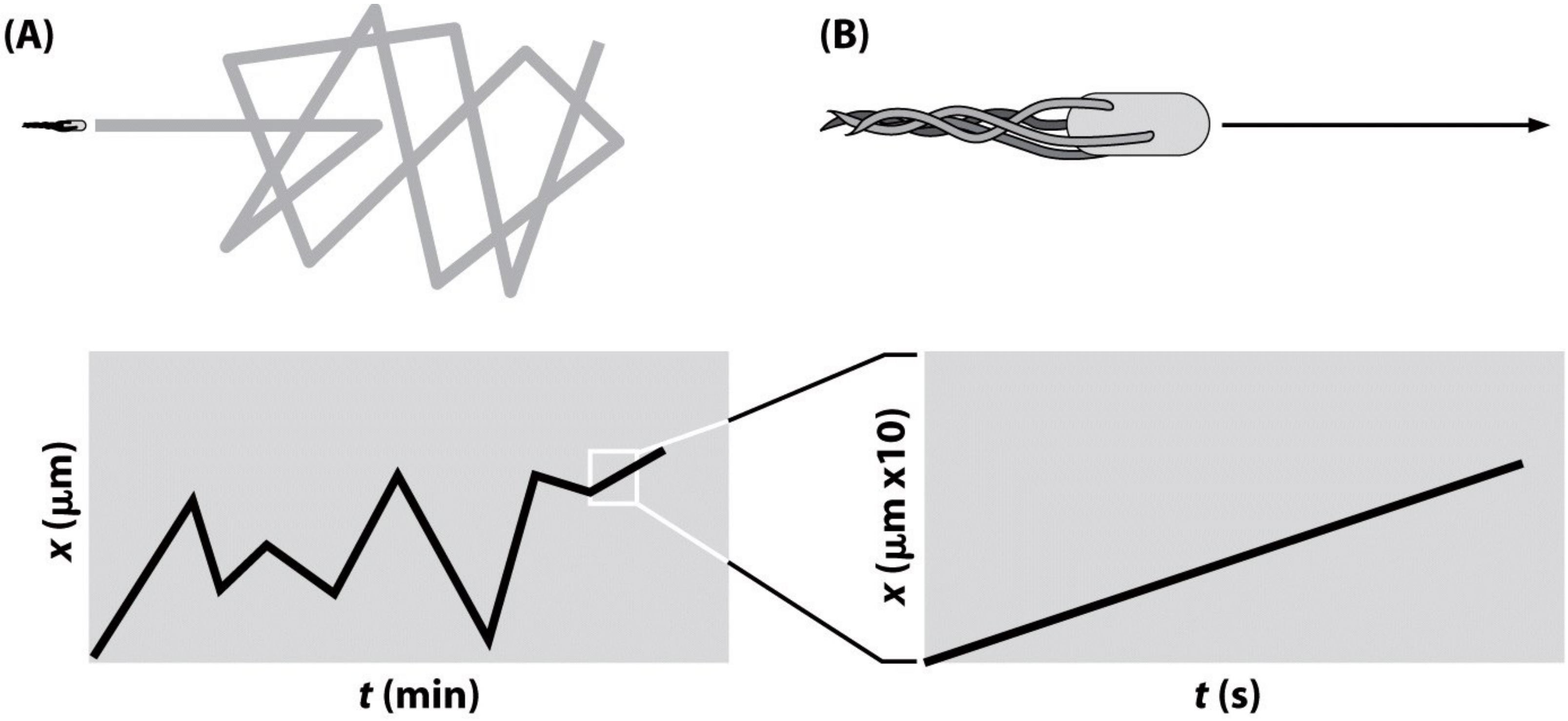
Diffusion in the cell

Active vs. passive transport



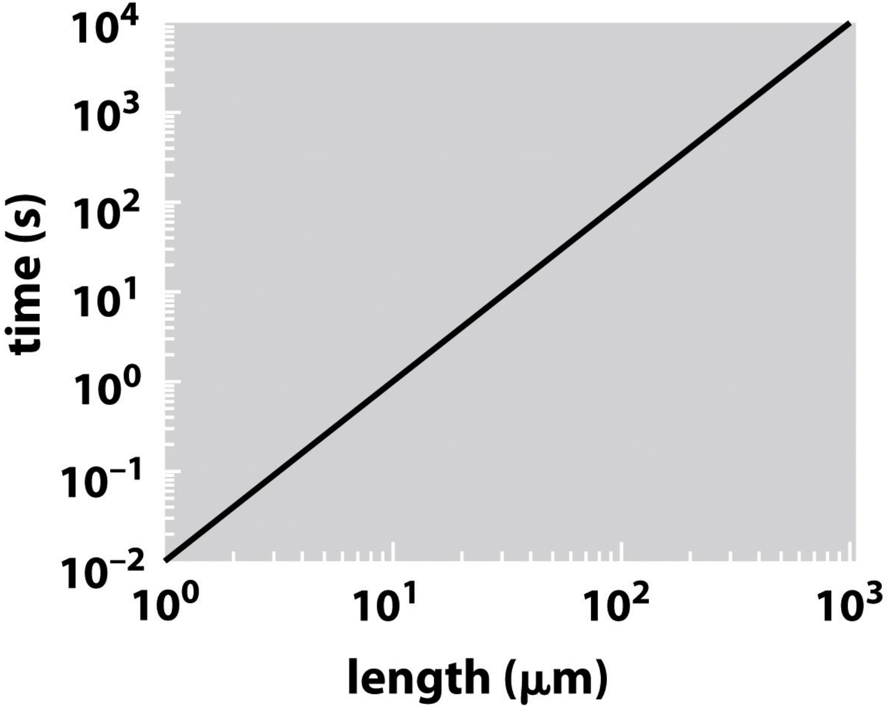
Diffusion in the cell

Active vs. passive transport



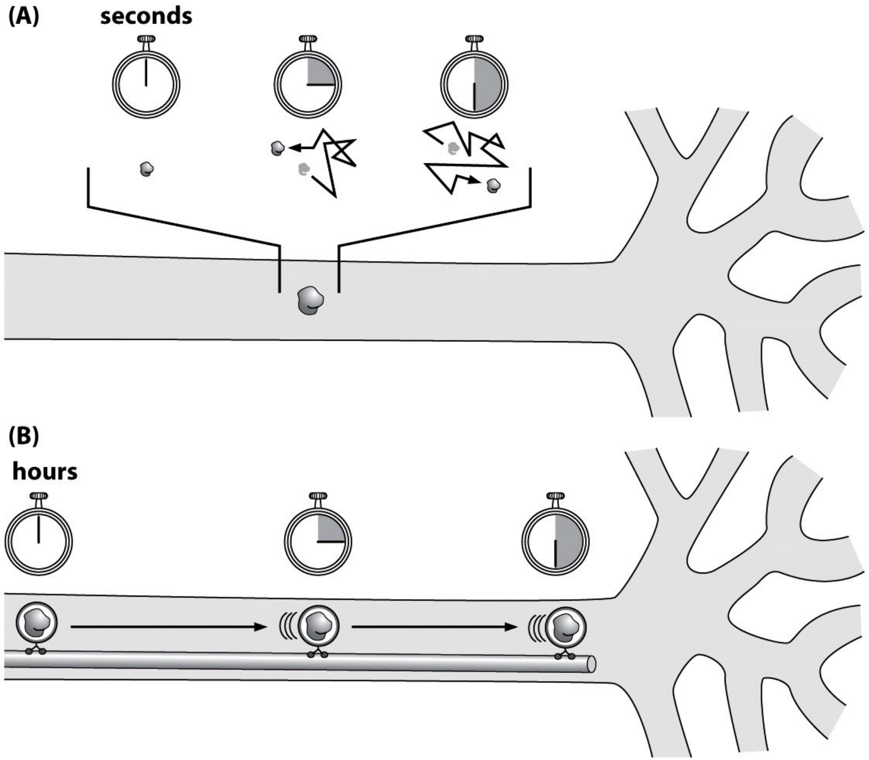
Diffusion in the cell

Time to diffuse biological distances



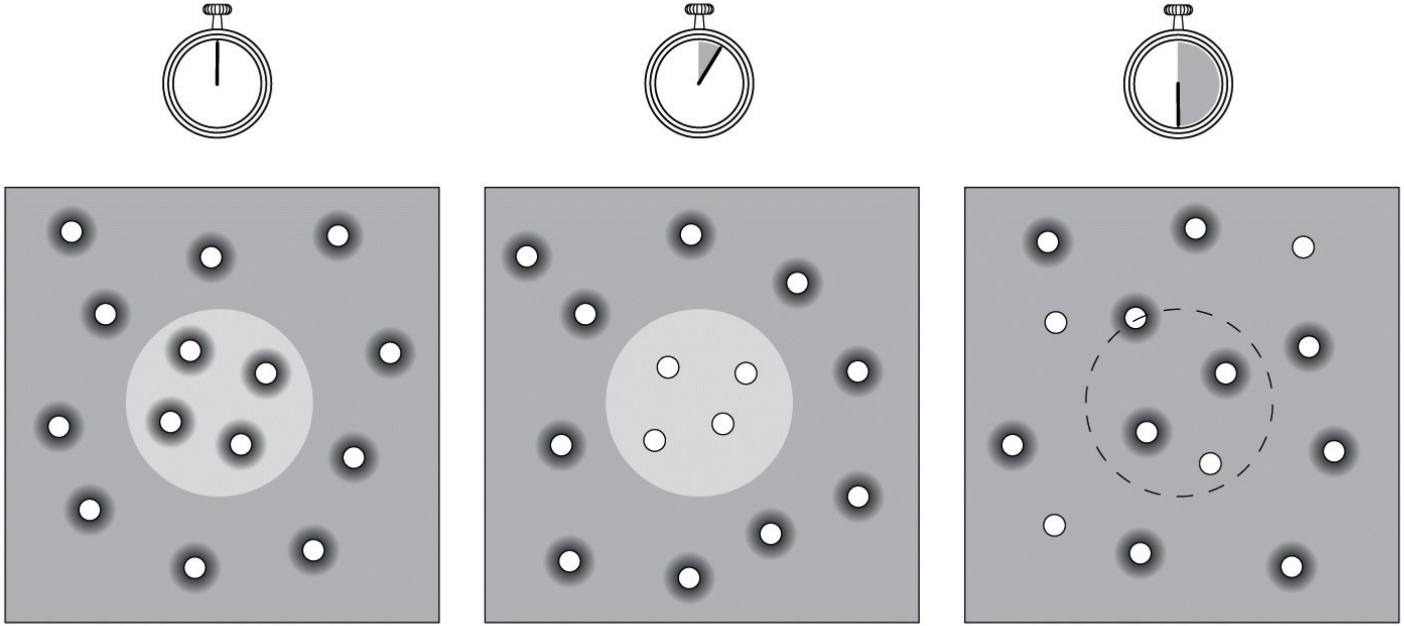
Diffusion in the cell

Time to diffuse biological distances



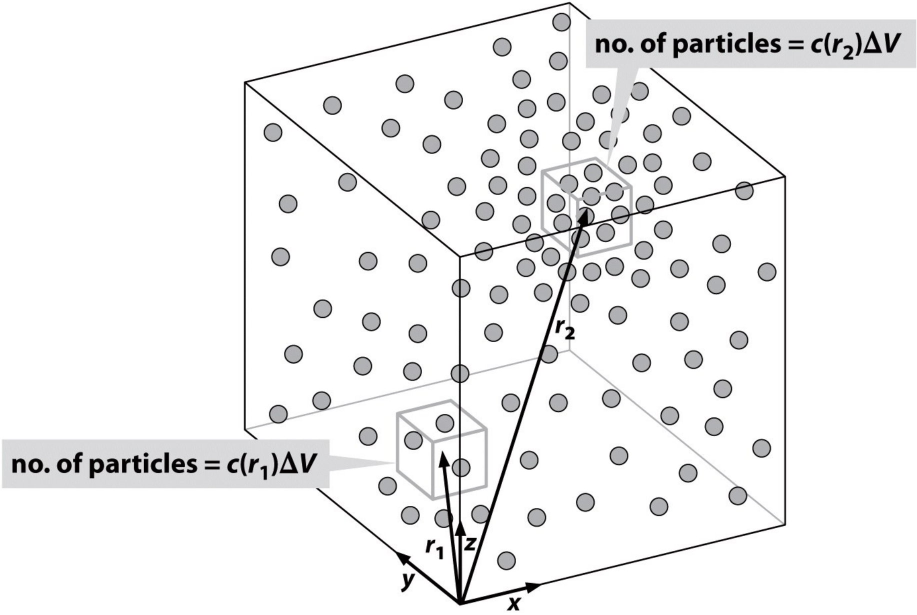
Diffusion in the cell

Time to diffuse biological distances



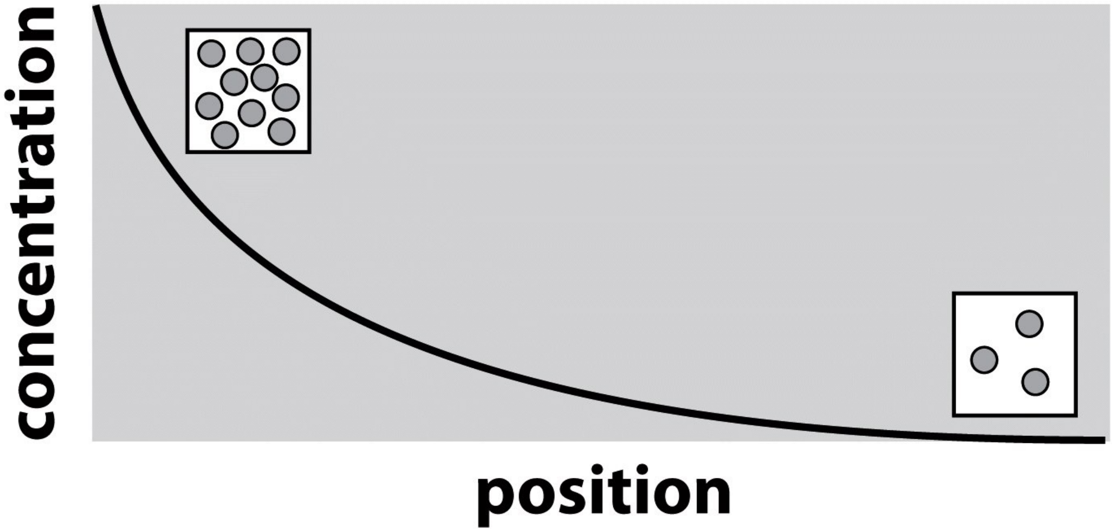
Diffusion in the cell

Concentration fields and diffusion



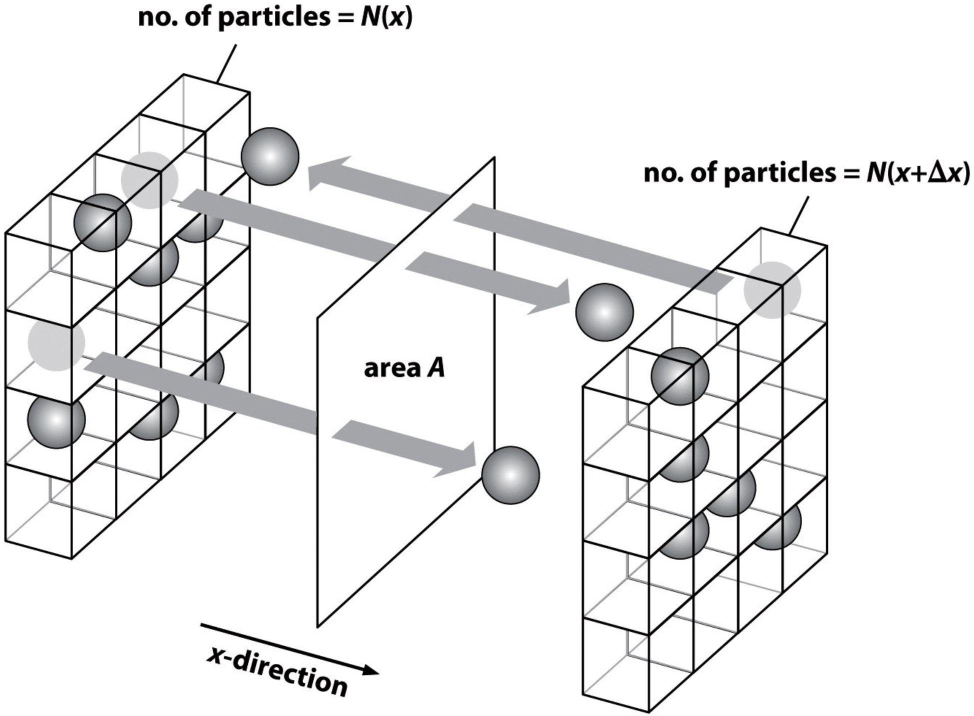
Diffusion in the cell

Concentration fields and diffusion



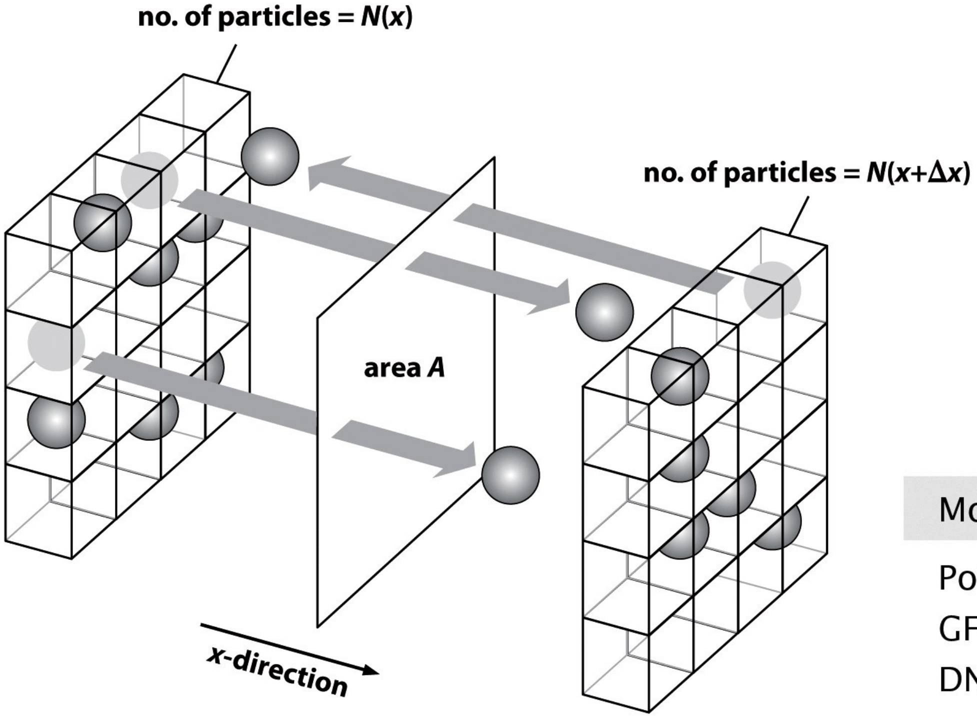
Diffusion in the cell

Concentration fields and diffusion: Fick's Law



Diffusion in the cell

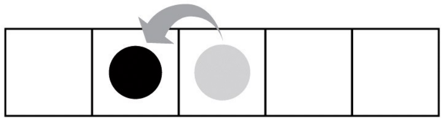
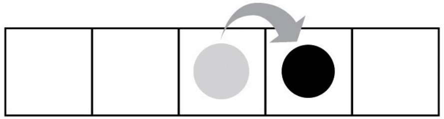
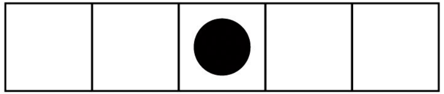
Concentration fields and diffusion: Fick's Law



Molecule	Diffusion coefficient
Potassium ion in water	$\approx 2000\,\mu m^2/s$
GFP in *E.coli*	$\approx 7\,\mu m^2/s$
DNA in yeast	$5 \times 10^{-4}\,\mu m^2/s$

Diffusion in the cell

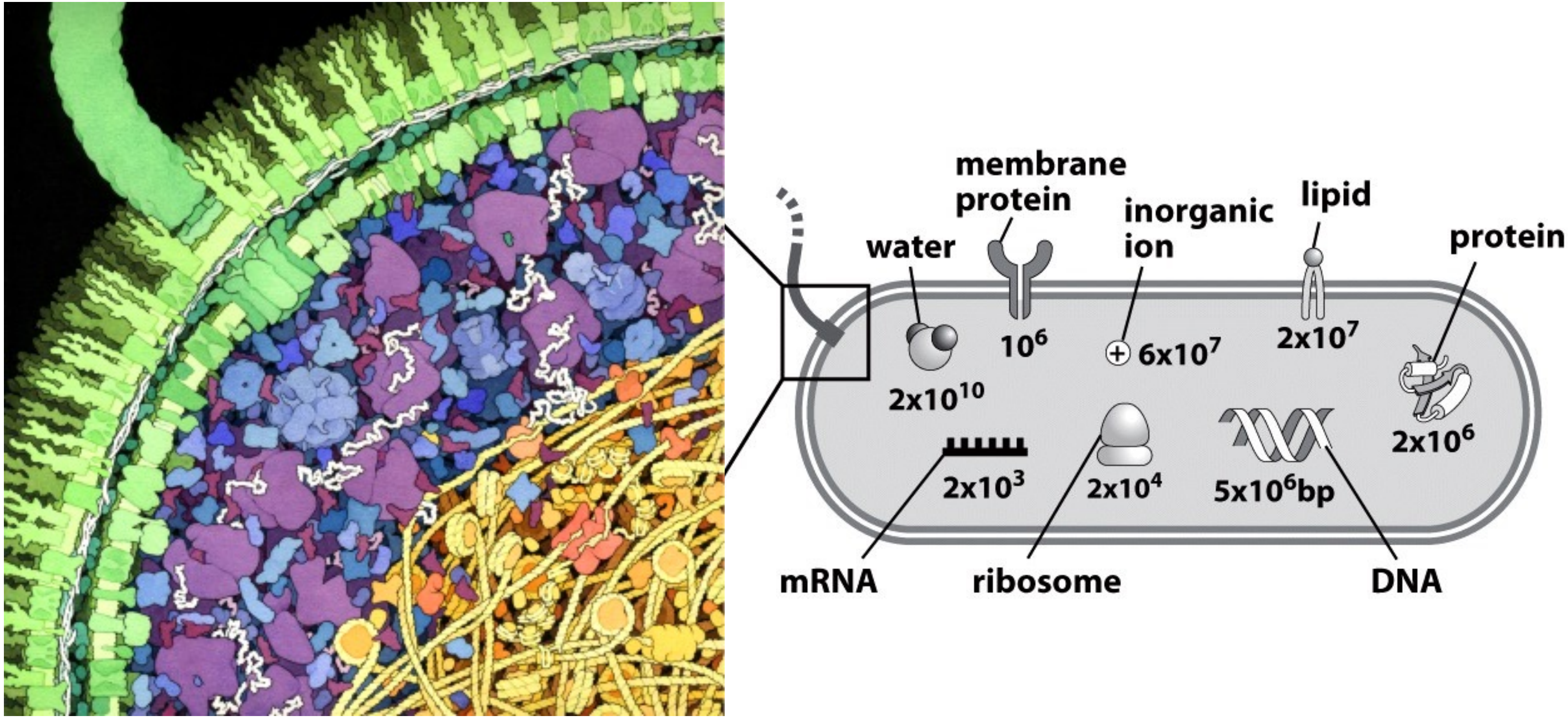
Summing over microtrajectories

TRAJECTORY	WEIGHT
	$k\Delta t$
	$k\Delta t$
	$1-2k\Delta t$

An ode to E. coli

Previously:

Molecular census



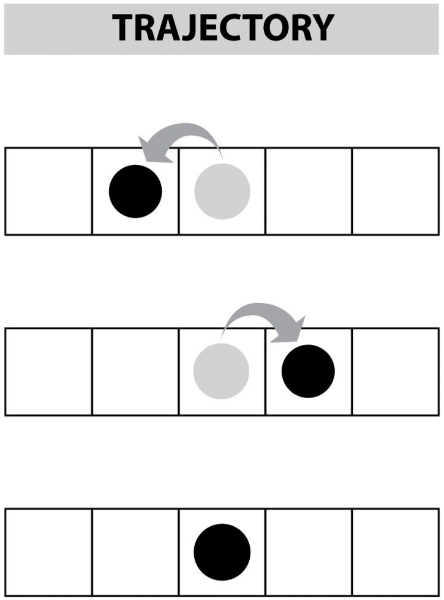
Diffusion in the cell

Diffusion in crowded environments

What is the diffusion coefficient associated with “crowded” random walk?
Assume fraction of occupied lattice sites φ

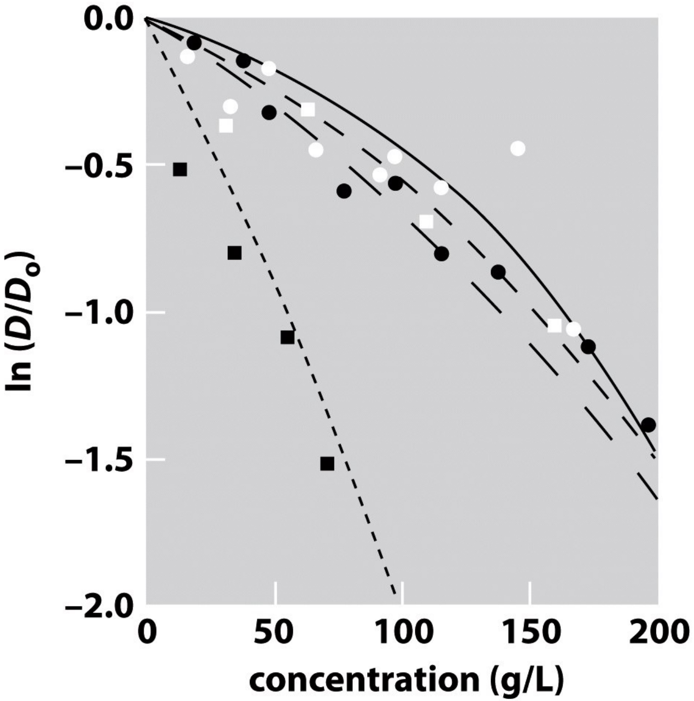
Diffusion in the cell

Summing over microtrajectories: Crowding (14.3.2)



Transport in cellular systems

Diffusion in crowded environments

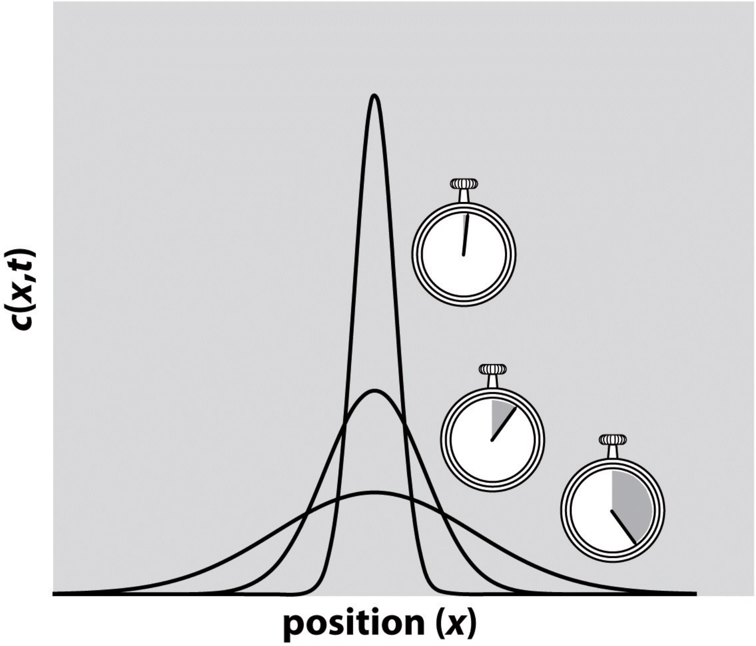


tracer diffusion in protein solution

	Molecular species	M_W [Da]	r
■	ribonuclease	12,400	2.3
□	ovalbumin	43,500	1.5
●	BSA	70,000	1.3
○	aldolase	150,000	1

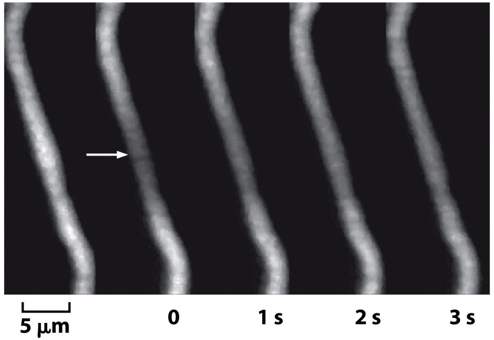
Diffusion in the cell

Solutions to the diffusion equation



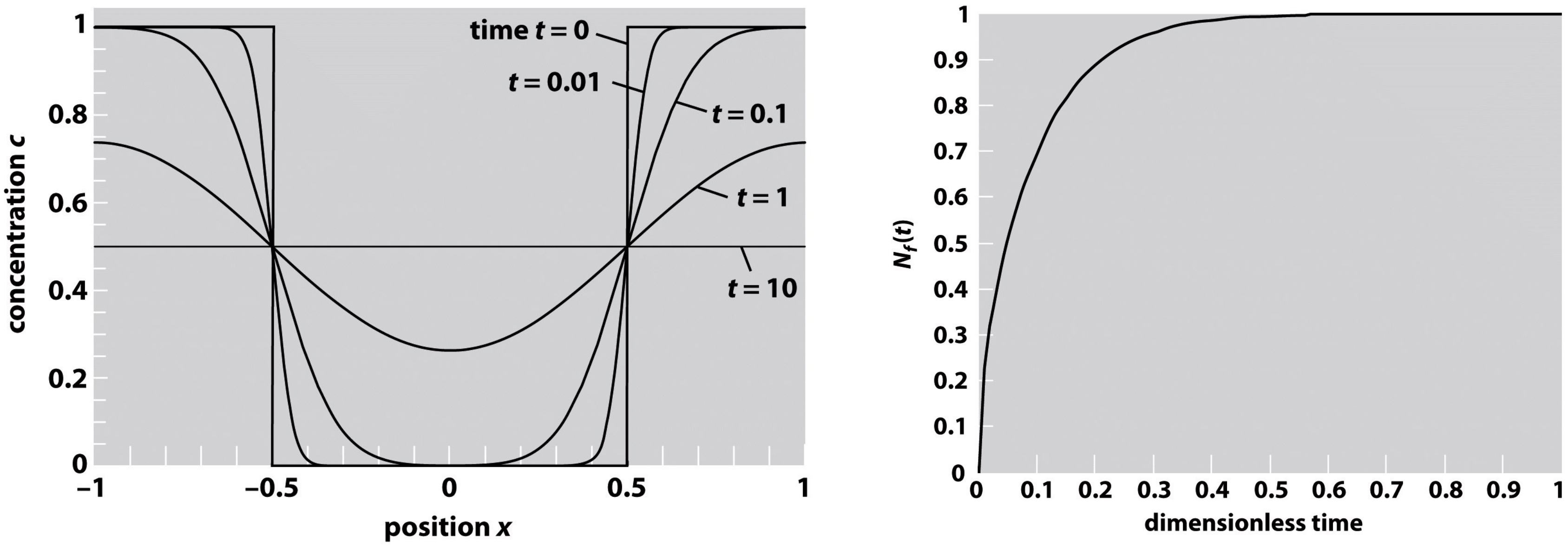
Diffusion in the cell

Solutions to the diffusion equation



Diffusion in the cell

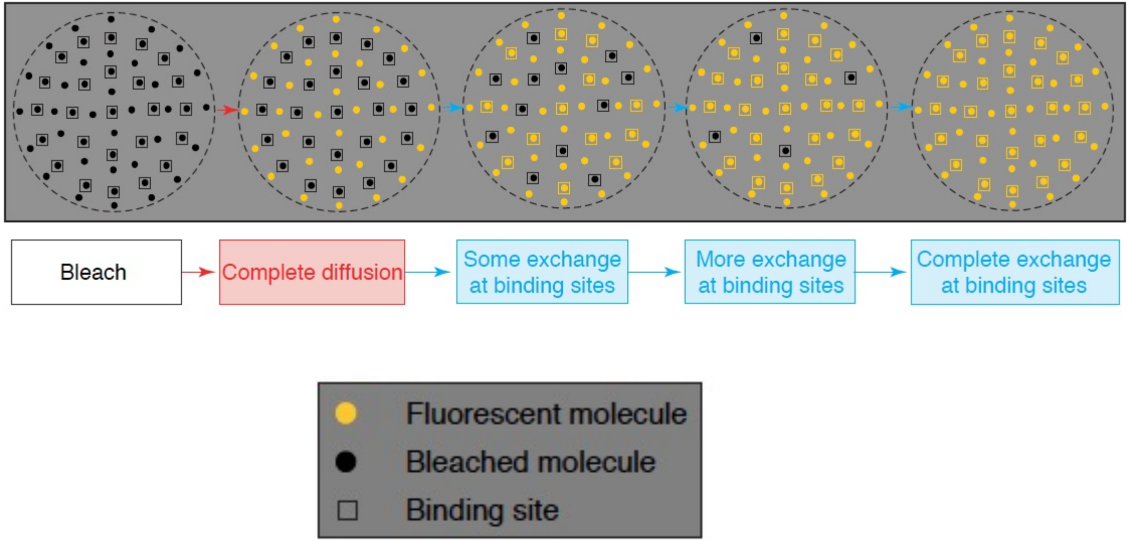
Solutions to the diffusion equation

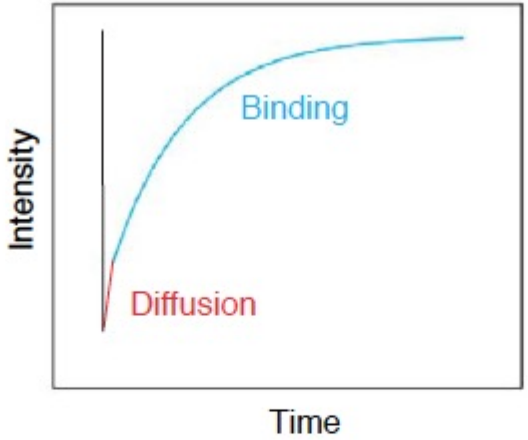


Diffusion in the cell

Complexity: diffusion + binding

Limit case ($t_{diff} << t_{binding}$): Two separable timescales

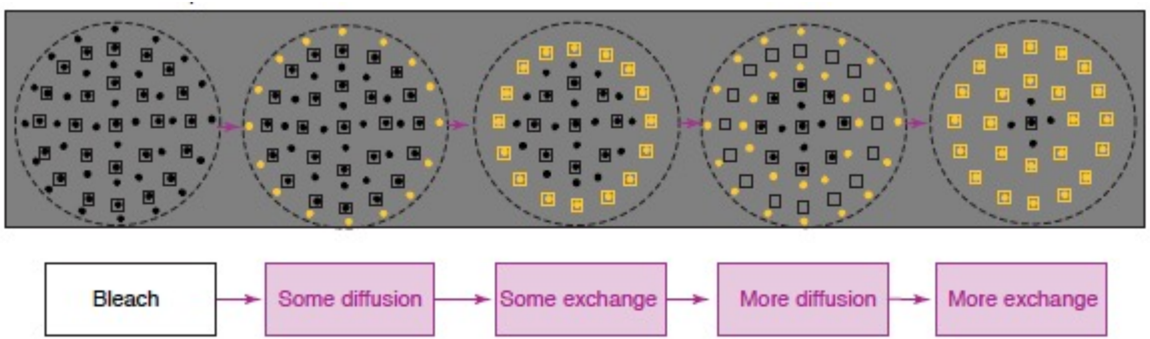


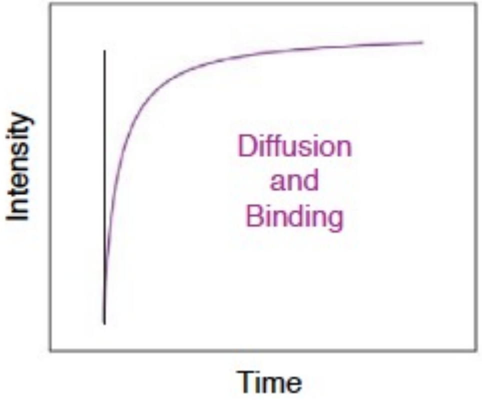


Diffusion in the cell

Complexity: diffusion + binding

Case ($t_{diff} \sim t_{binding}$): Mixing of dynamic modes





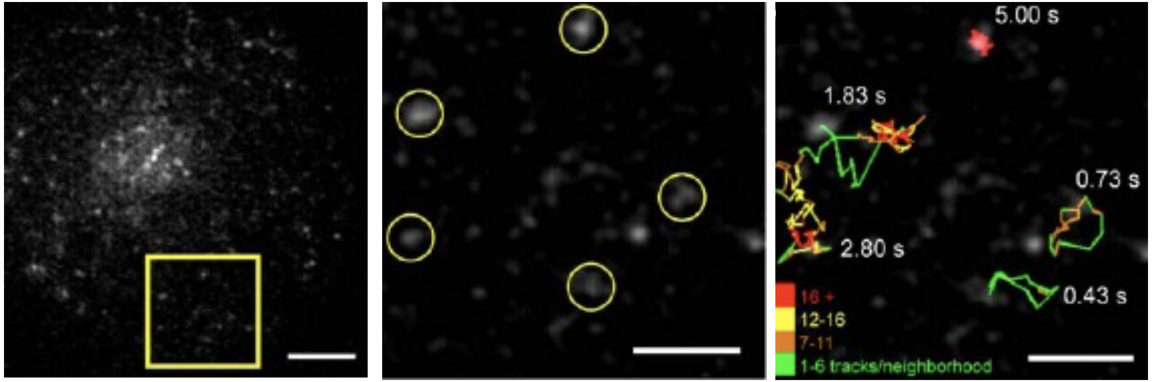
Anomalous diffusion:

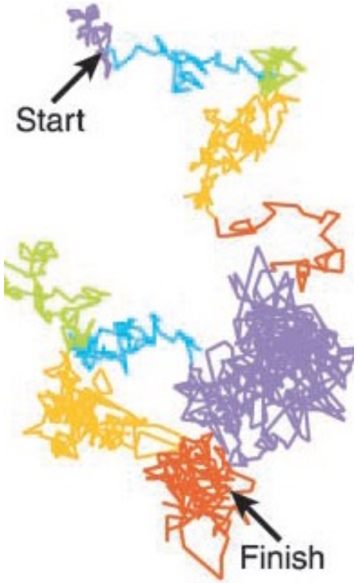
$$\langle r^2(\tau) \rangle = 6D\tau$$

$$\langle r^2(\tau) \rangle = 6D\tau^{\alpha} = 6D(\tau)\tau$$

Diffusion in the cell

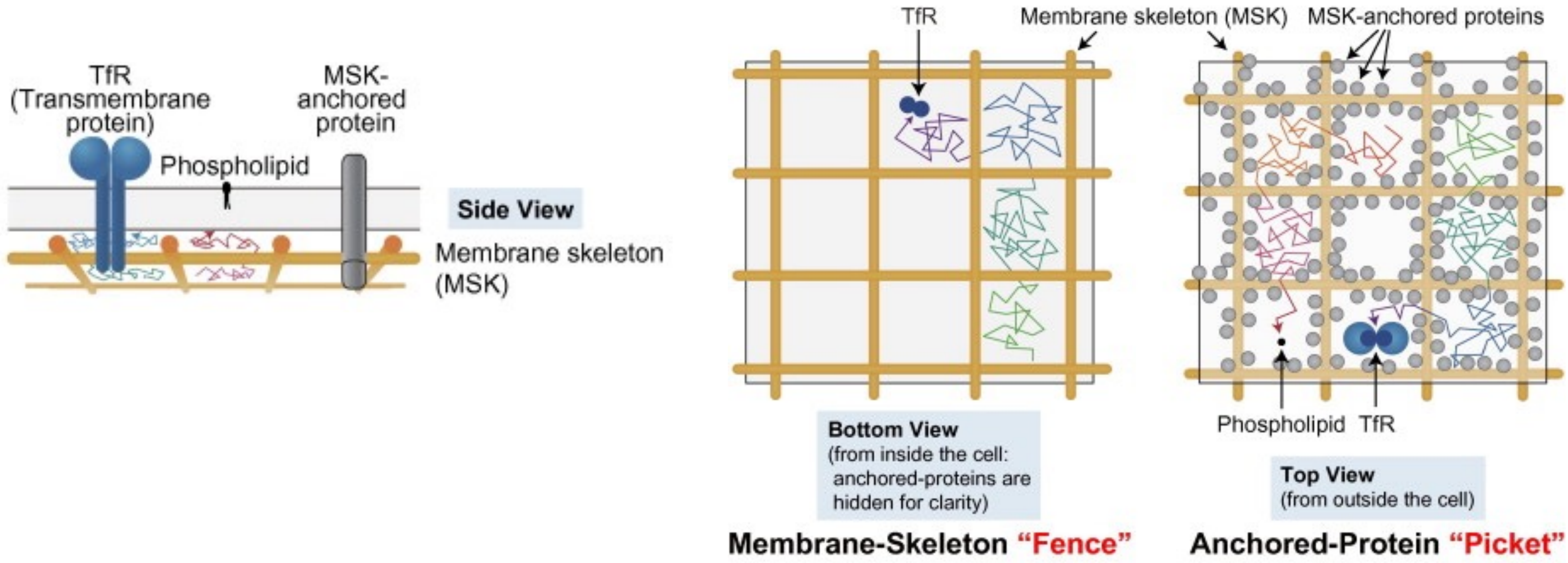
Membrane proteins





Diffusion in the cell

Complexity: Caged motion



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Summary: