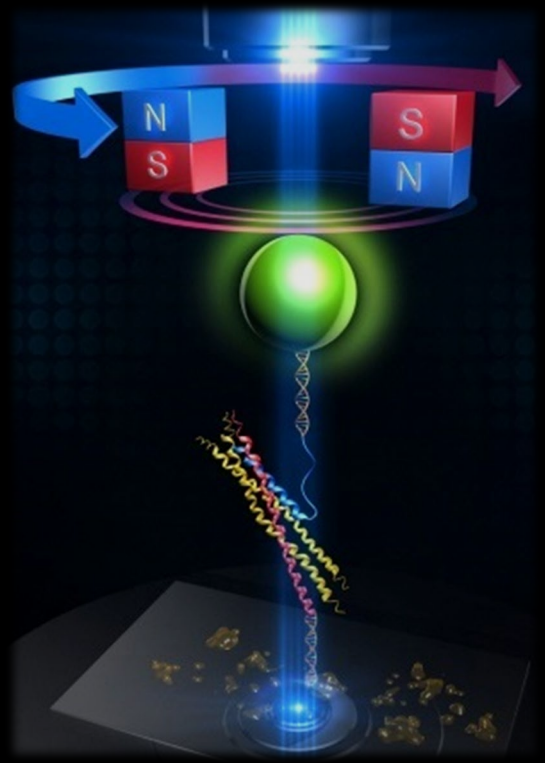
Nano-Precision
Mechano-Biology

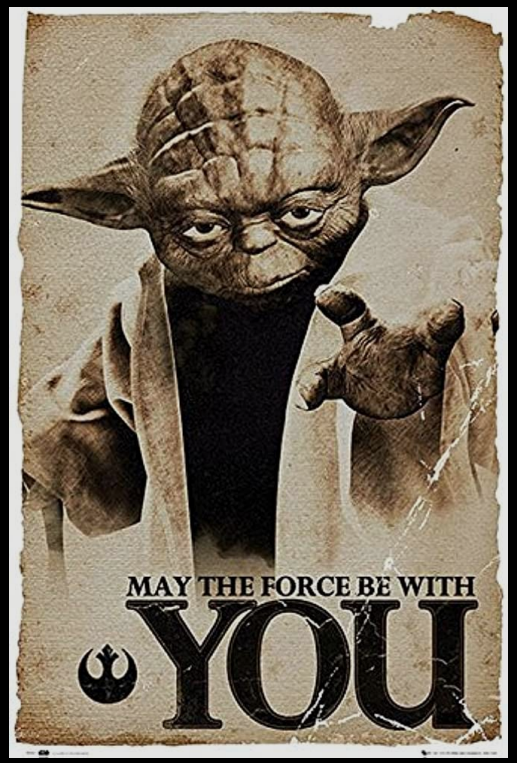


생체 분자 하나를 잡아당기는 방법
- 단분자 집게 기술 -

Min Ju Shon

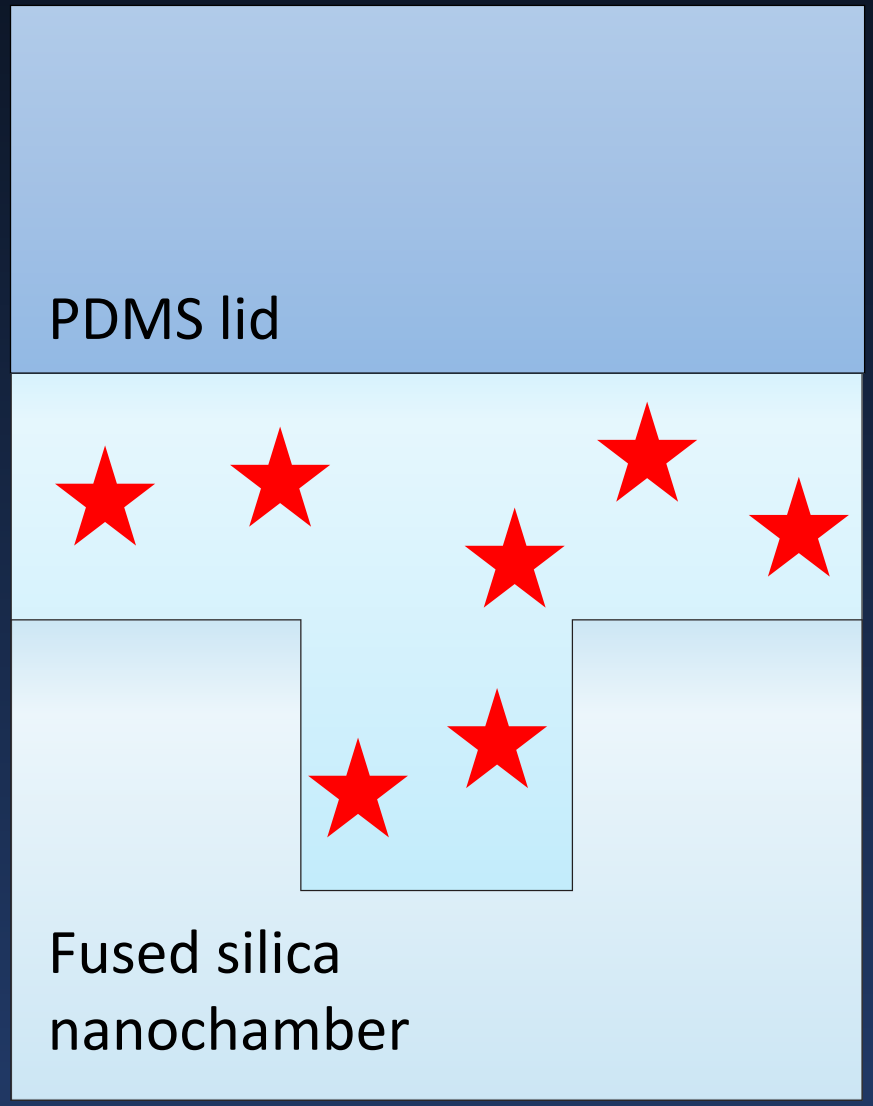
Department of Physics, and School of I-BIO

POSTECH

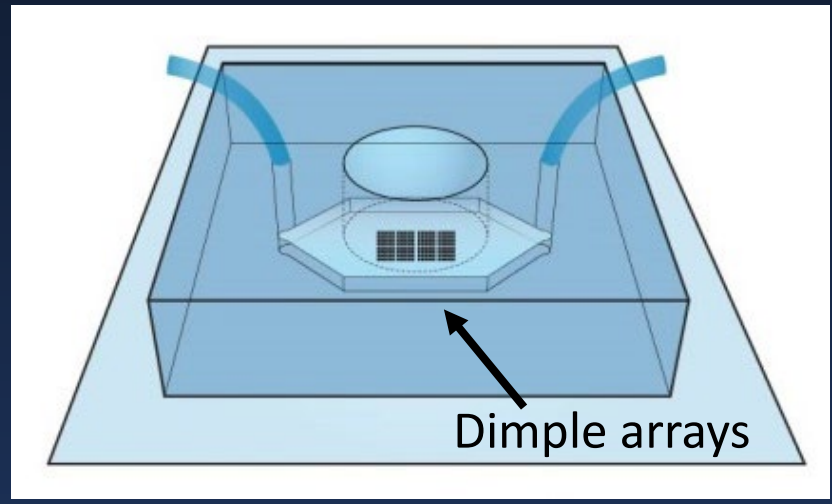


2023 생명물리 여름학교
07/04/2023

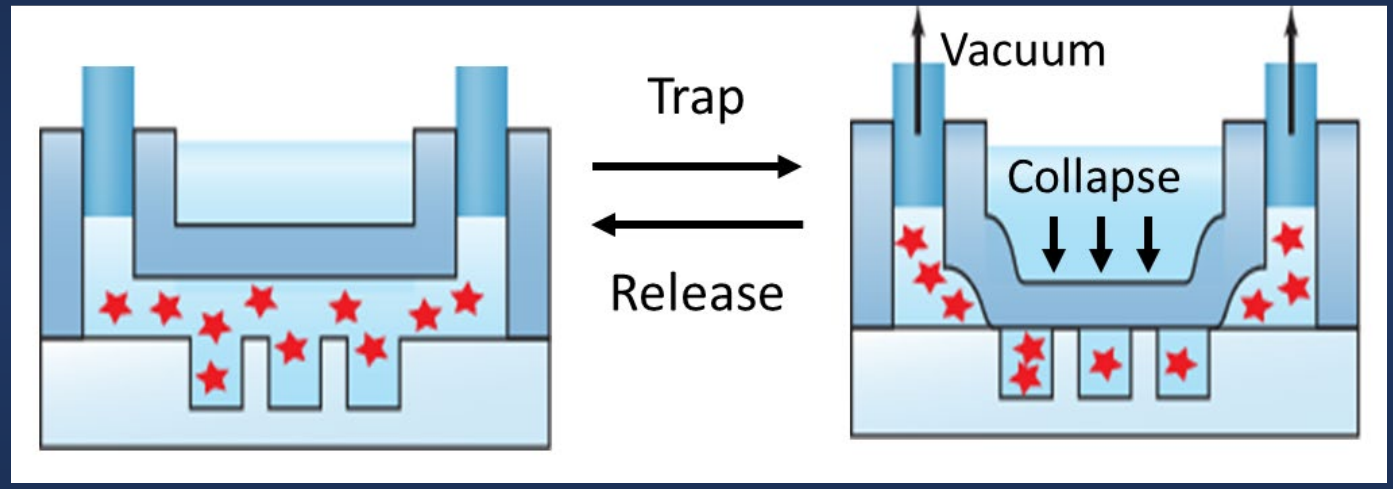
Trapping in nano-chamber



Shon and Cohen, *JACS* (2012)

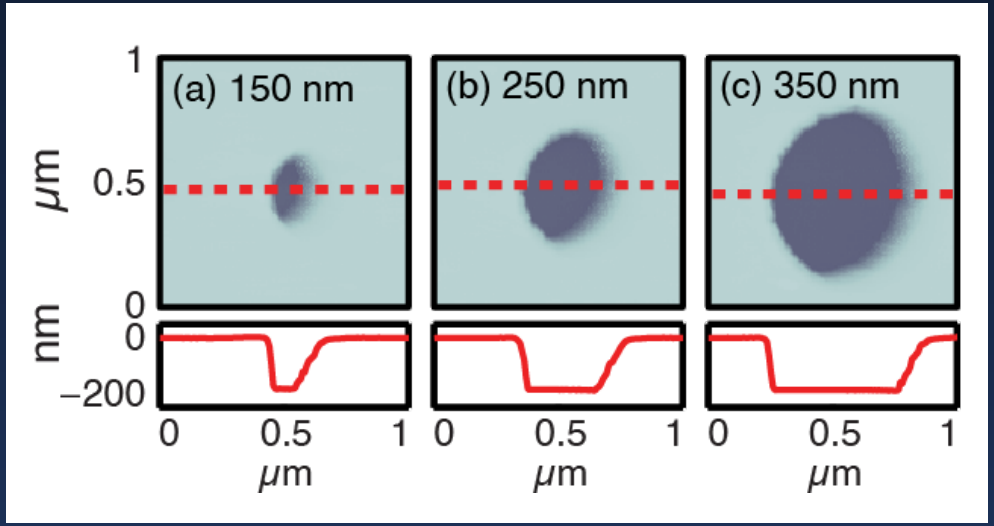


Microfluidic automation



Trapping in dimples

Atomic force microscope images



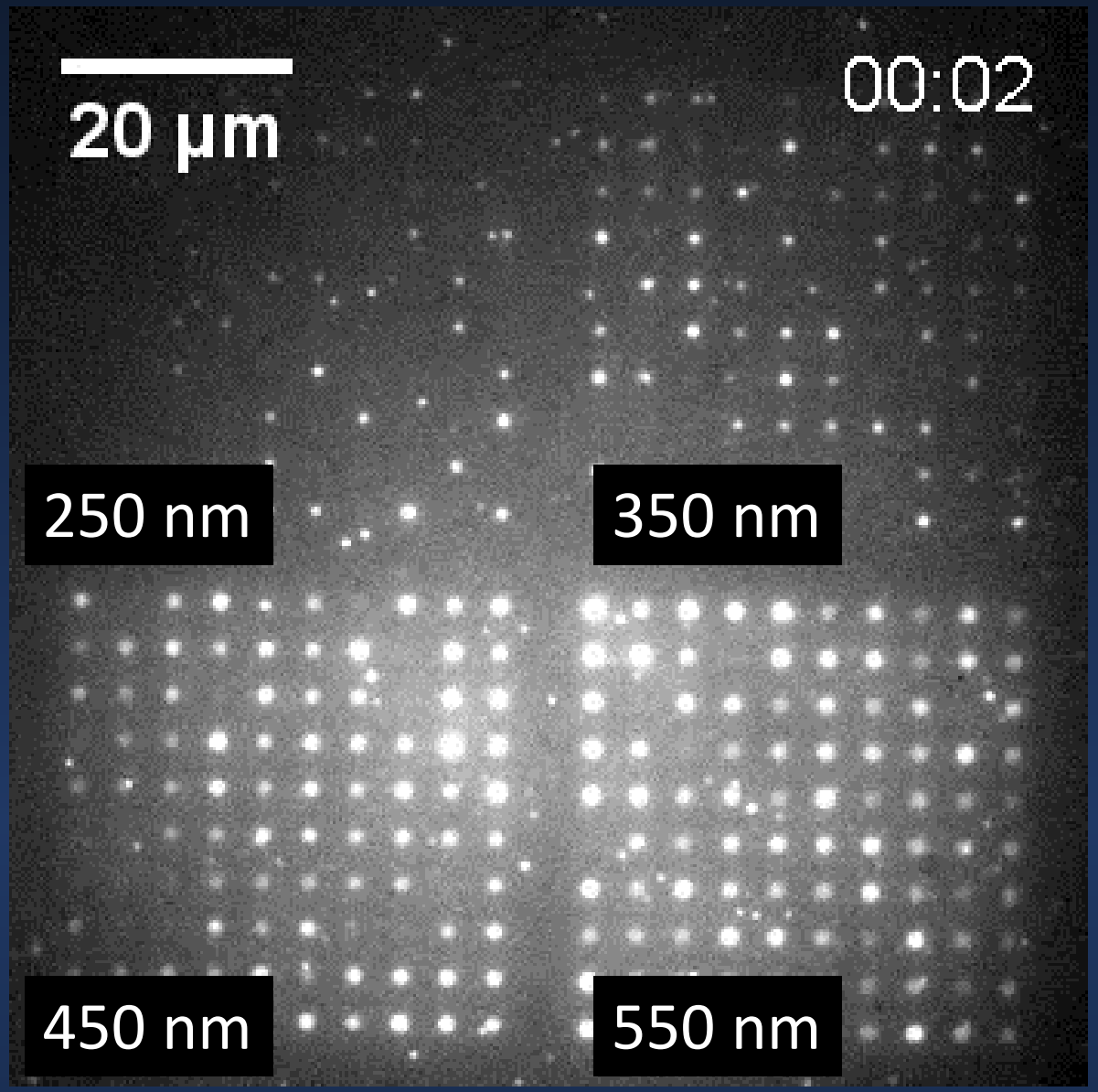
Fluorescence microscopy

30-nt oligo

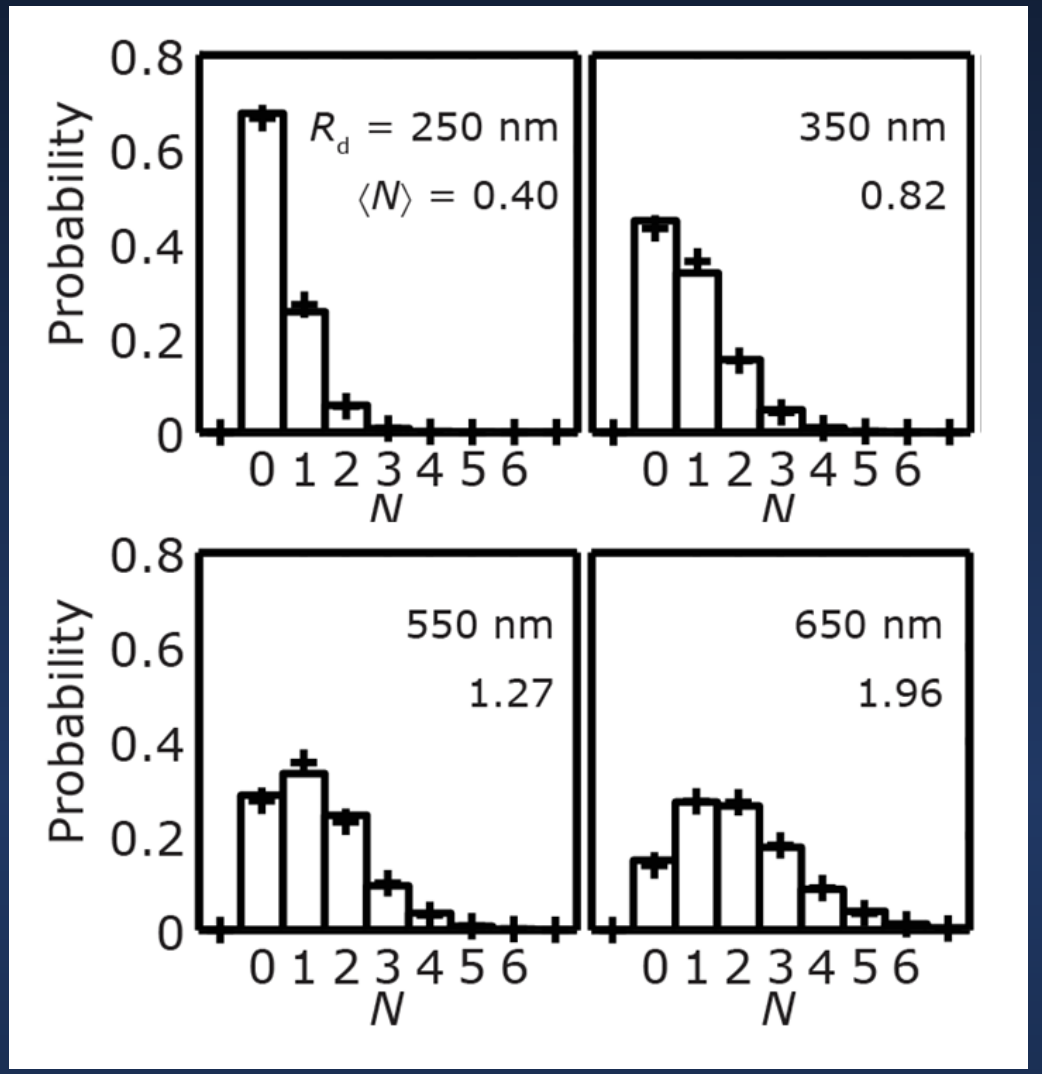
Fluorescent label

A few nm in radius

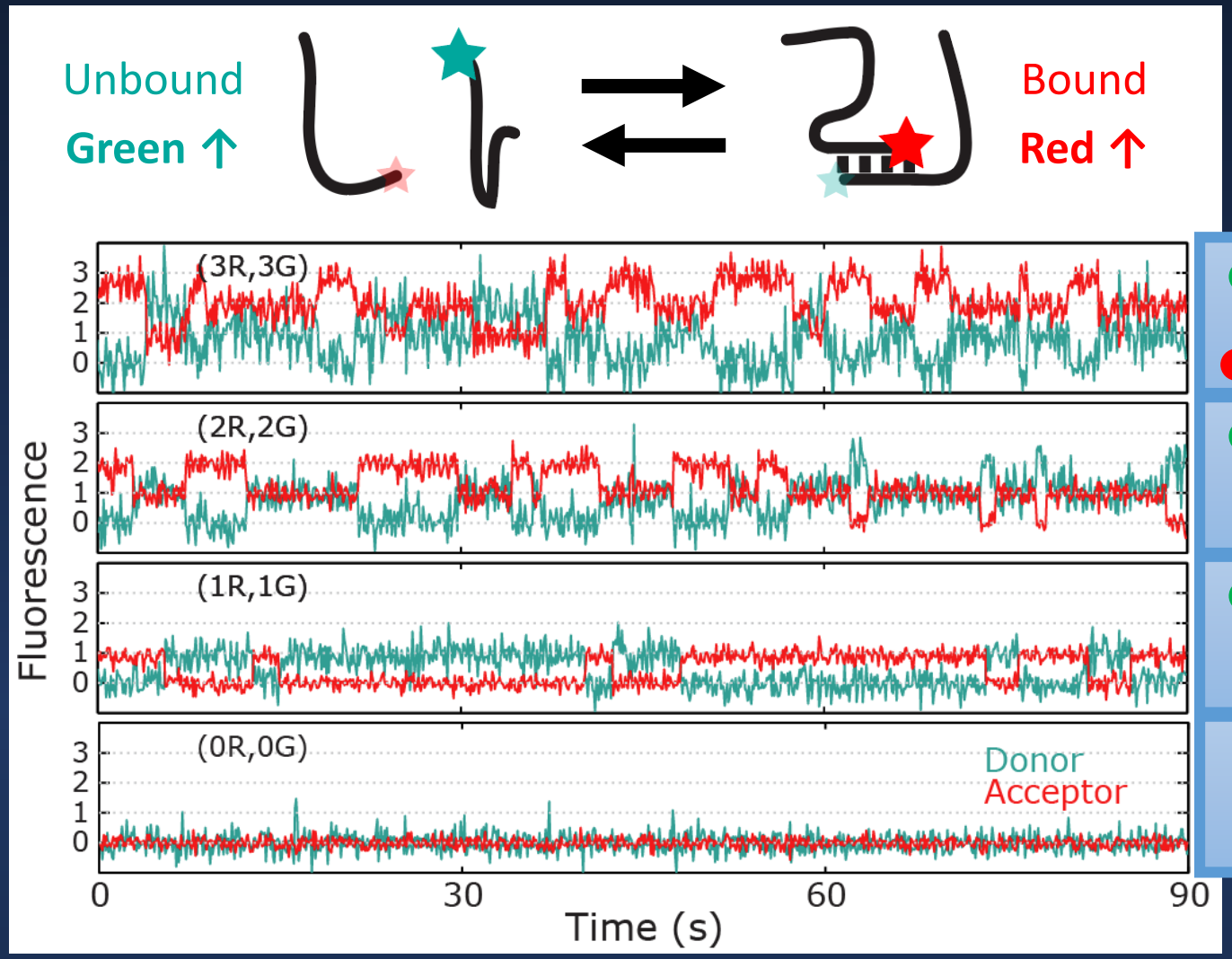
Counting single molecules

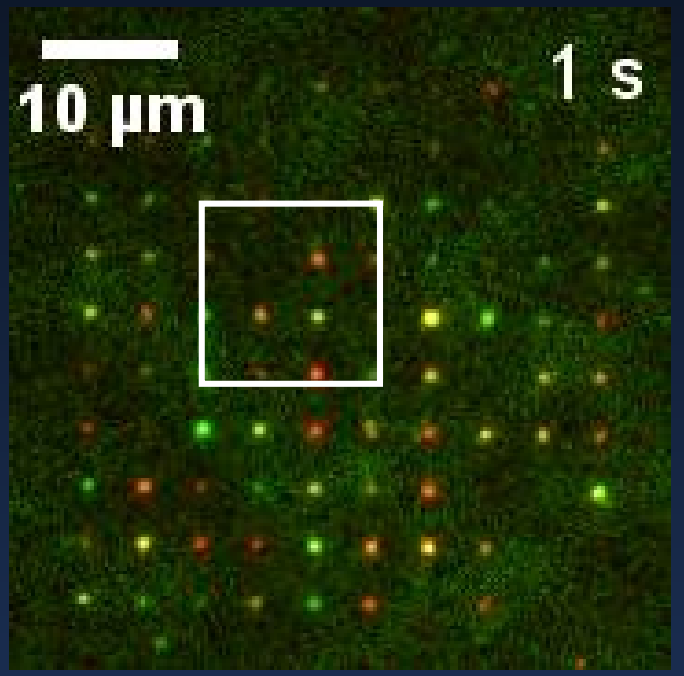


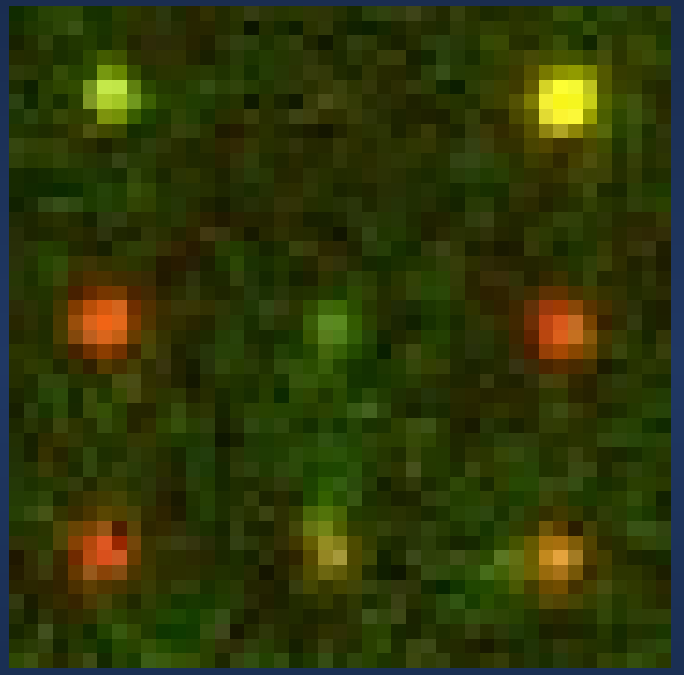
Poisson statistics of occupancy

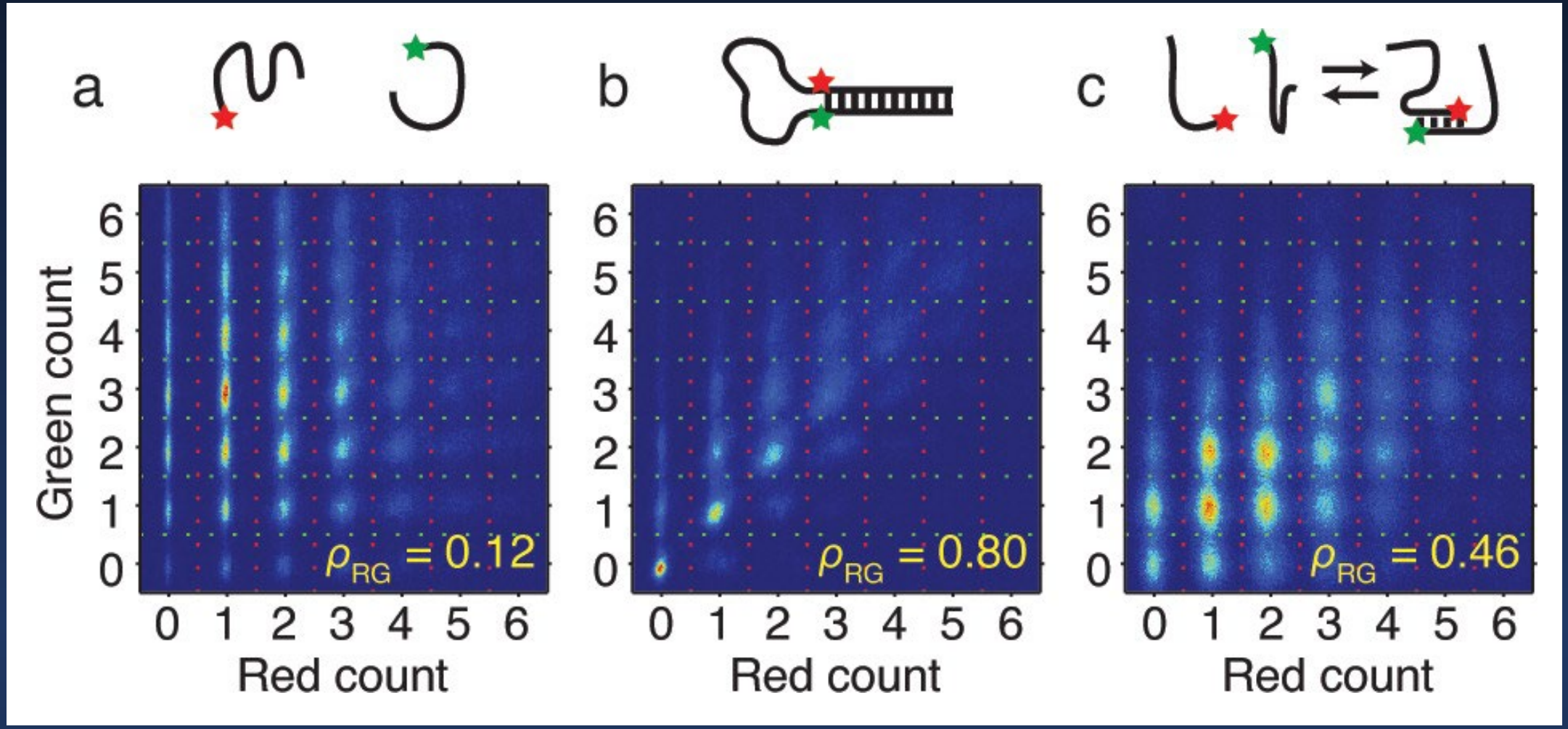


Interaction in nano-confinement



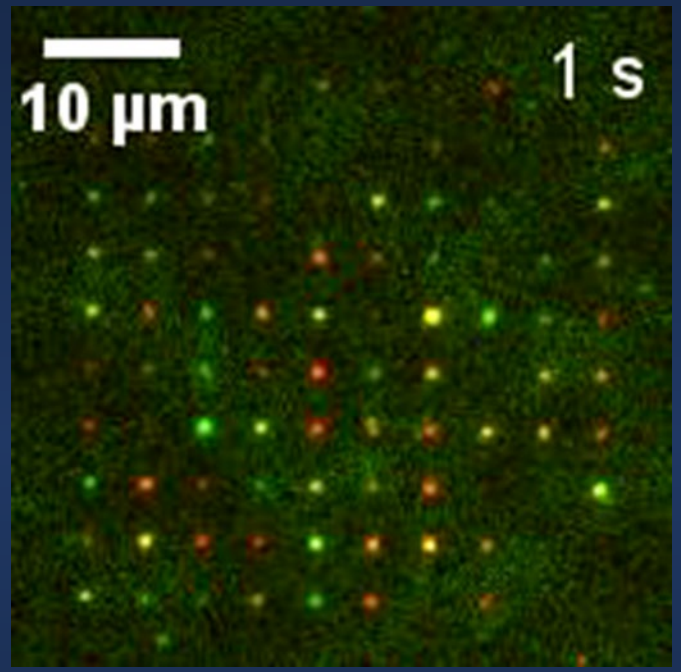




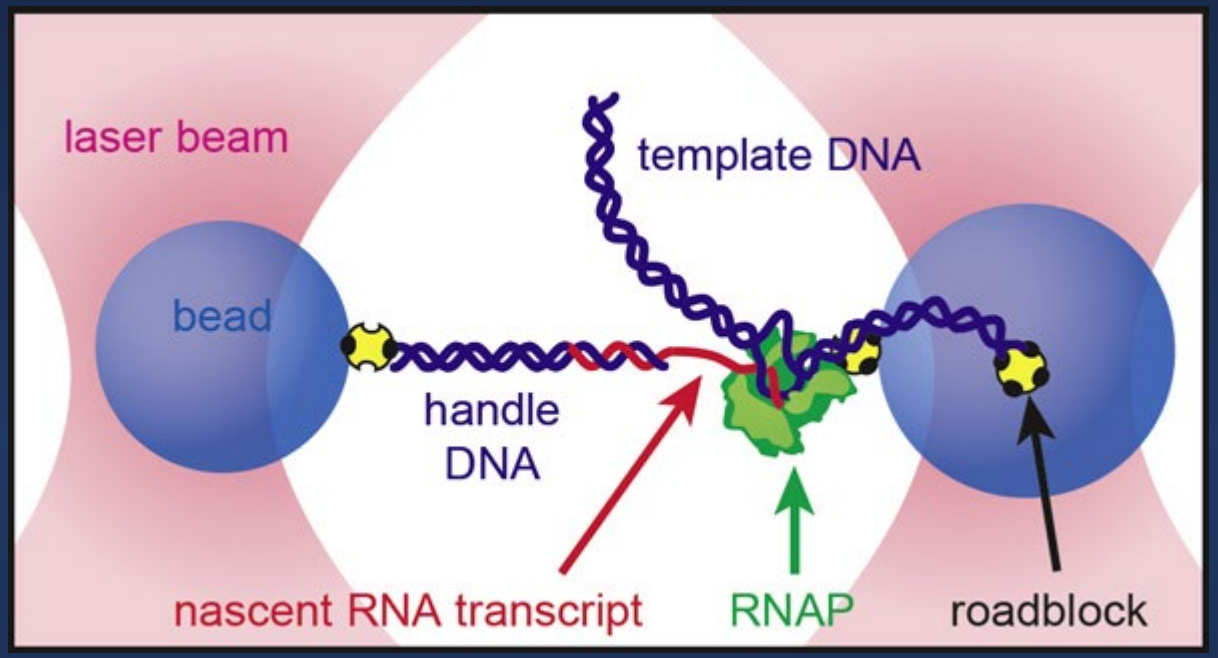

a
b
c
Green count
Red count
Red count
Red count
0
1
2
3
4
5
6
$\rho_{RG} = 0.12$
$\rho_{RG} = 0.80$
$\rho_{RG} = 0.46$

Single-molecule techniques

- **Fluorescence imaging**
  - Sensitive detection
  - Quantitative analysis

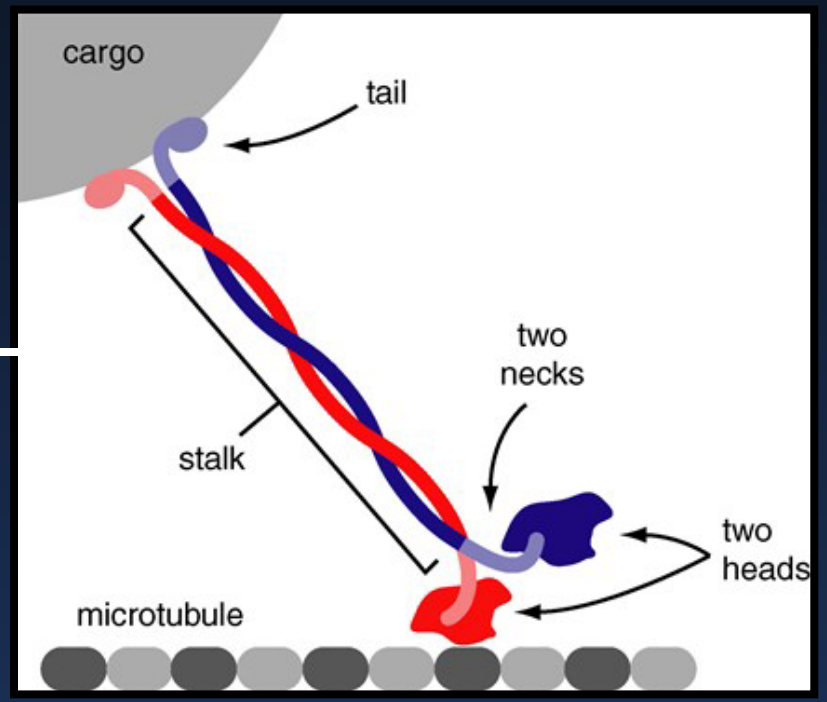


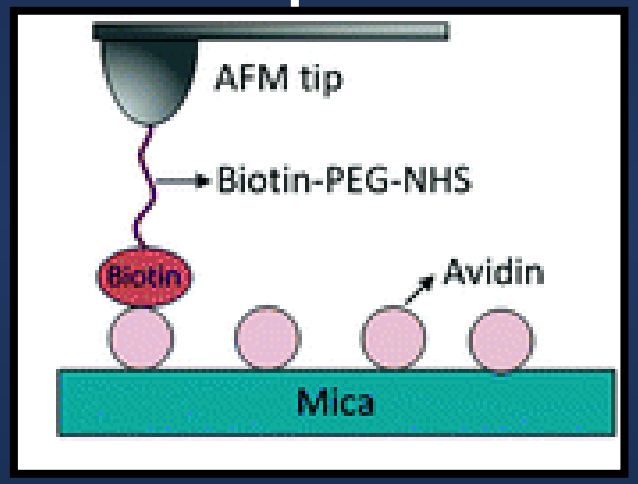
- **Force spectroscopy**
  - Mechanical manipulation
  - Structural information

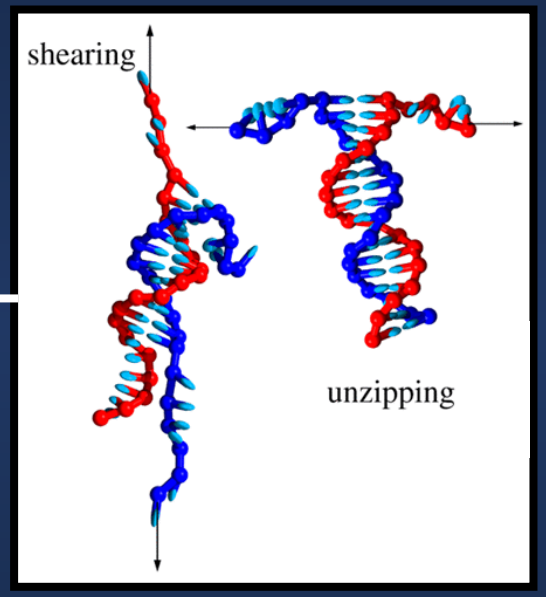


Mechanical Force in Biology

- **Molecular interaction**
  - Kinesin: ~5 pN
  - DNA unzipping: ~12 pN
  - DNA shearing: ~60 pN
  - Avidin-biotin: ~200 pN
  - Covalent bond: ~2 nN



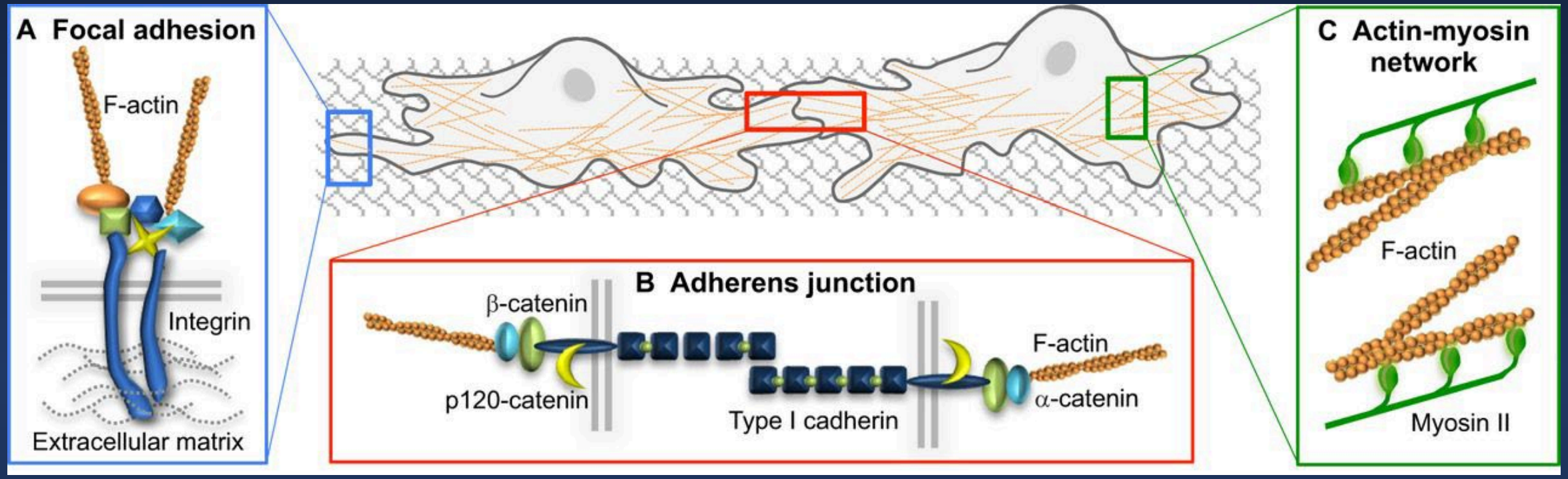




Mechanical Force in Biology

- **Cell-to-cell interaction**
  - Cell junctions: 0.05–100 nN

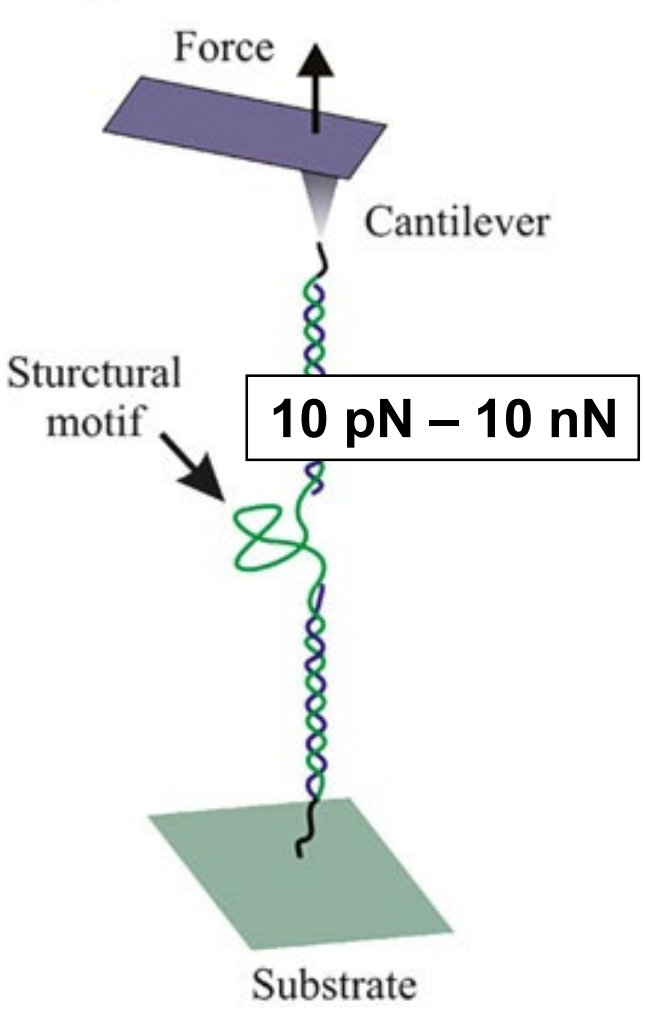
- Tissue-level mechanics
  - An ant on skin: ~10 μN
  - Cardiac muscle: ~1 mN
  - 1-kg dumbbell: ~10 N
  - Achilles heel: ~9 kN
  - Crocodile bites: ~30 kN



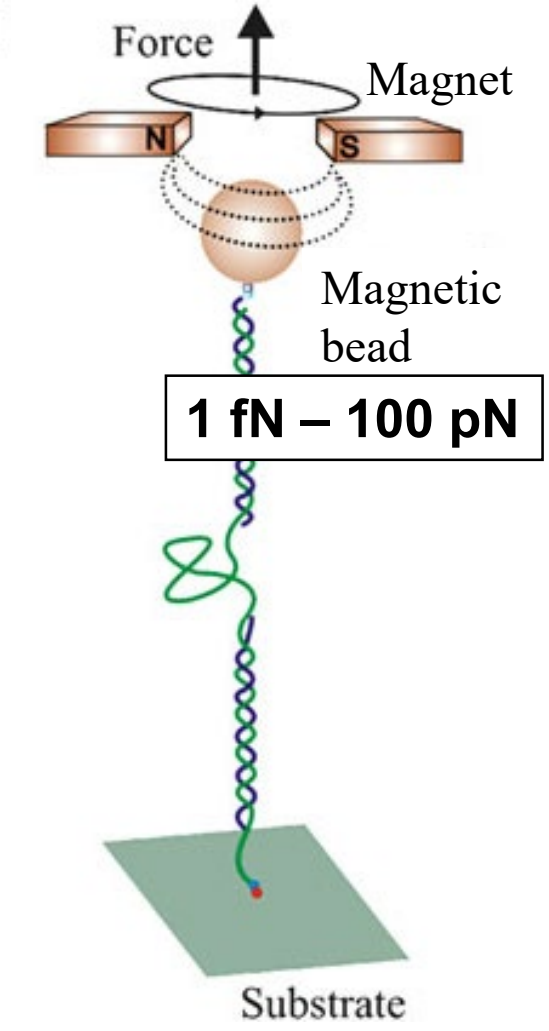
Mui et al. J Cell Sci (2016)

단분자 집게: 역학적 제어 실험

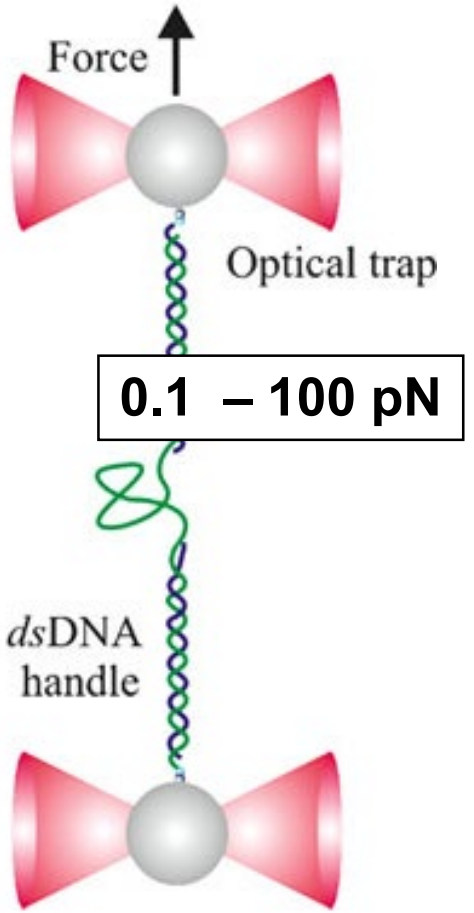
Atomic Force Microscope



Magnetic Tweezers

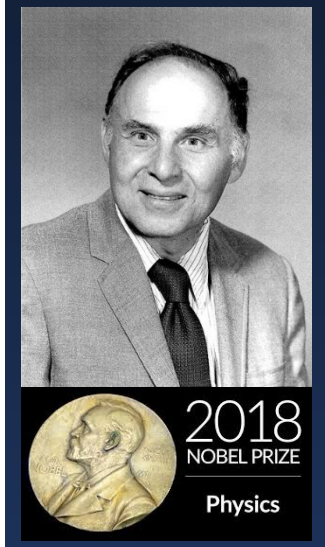


Optical Tweezers

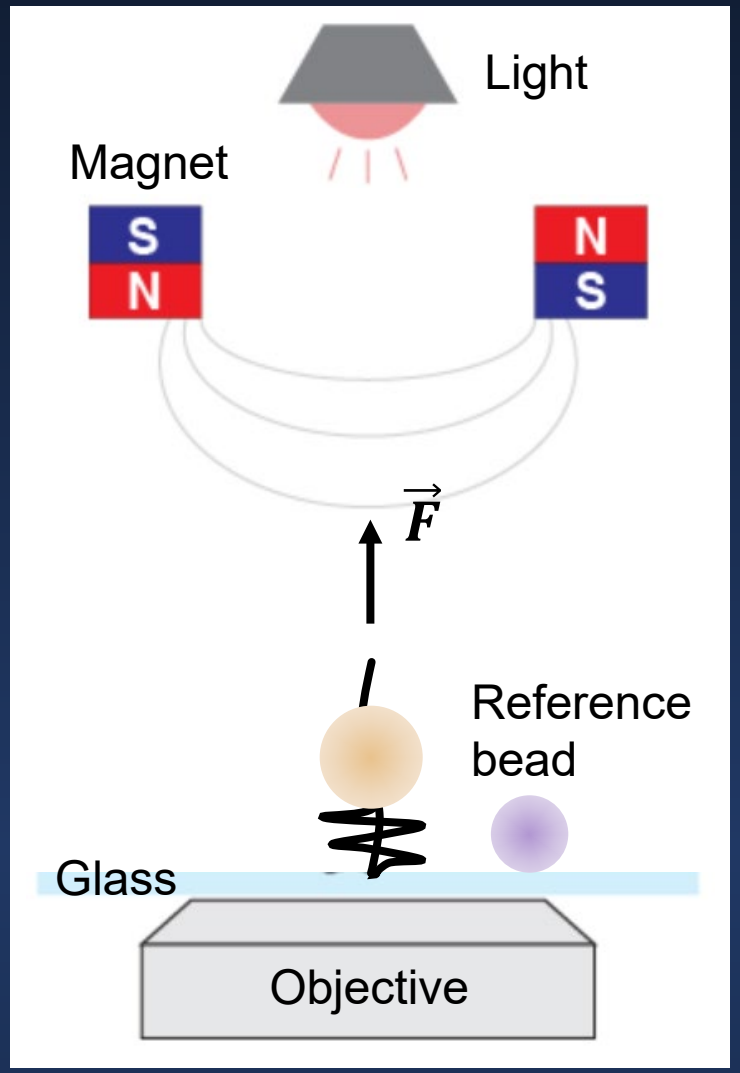


Erdmann et al.
"RNA and DNA Diagnostics" (2015)

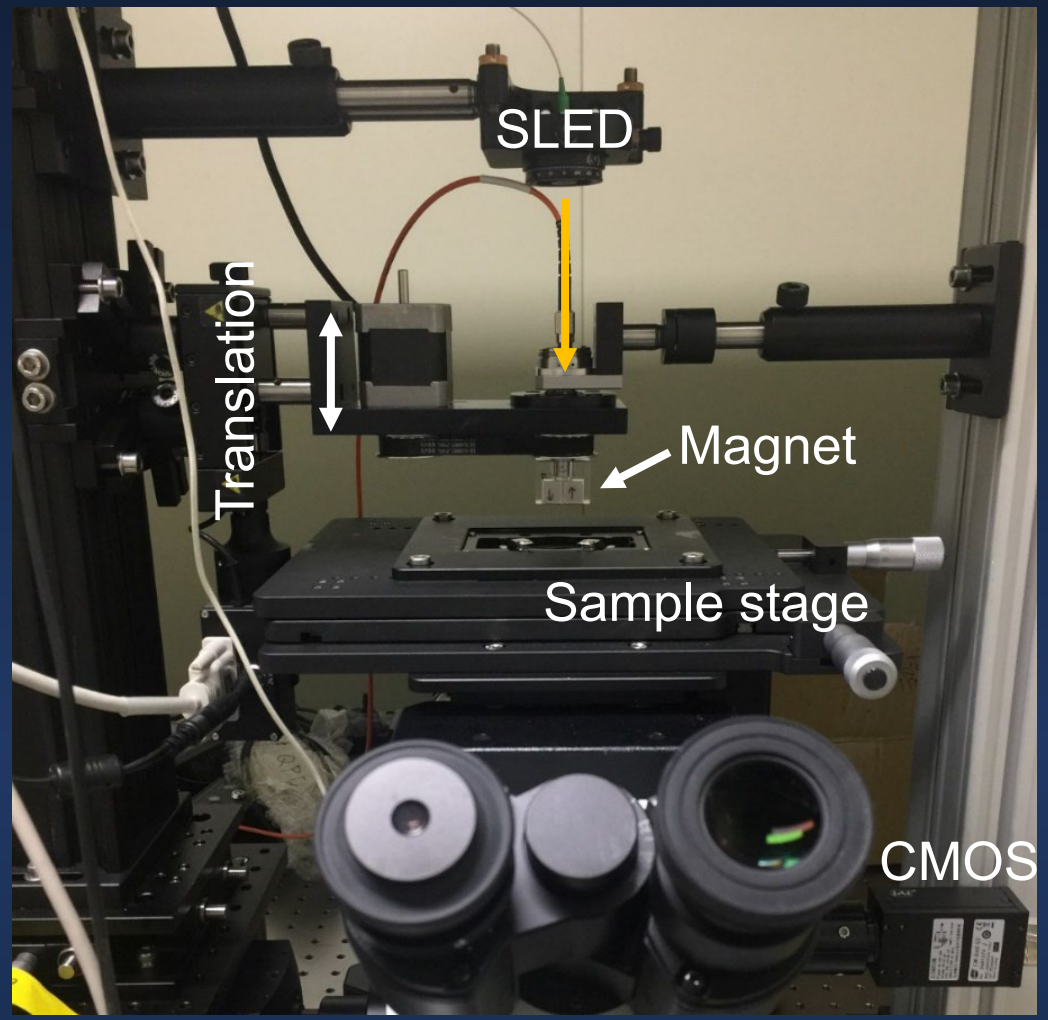
Arthur Ashkin



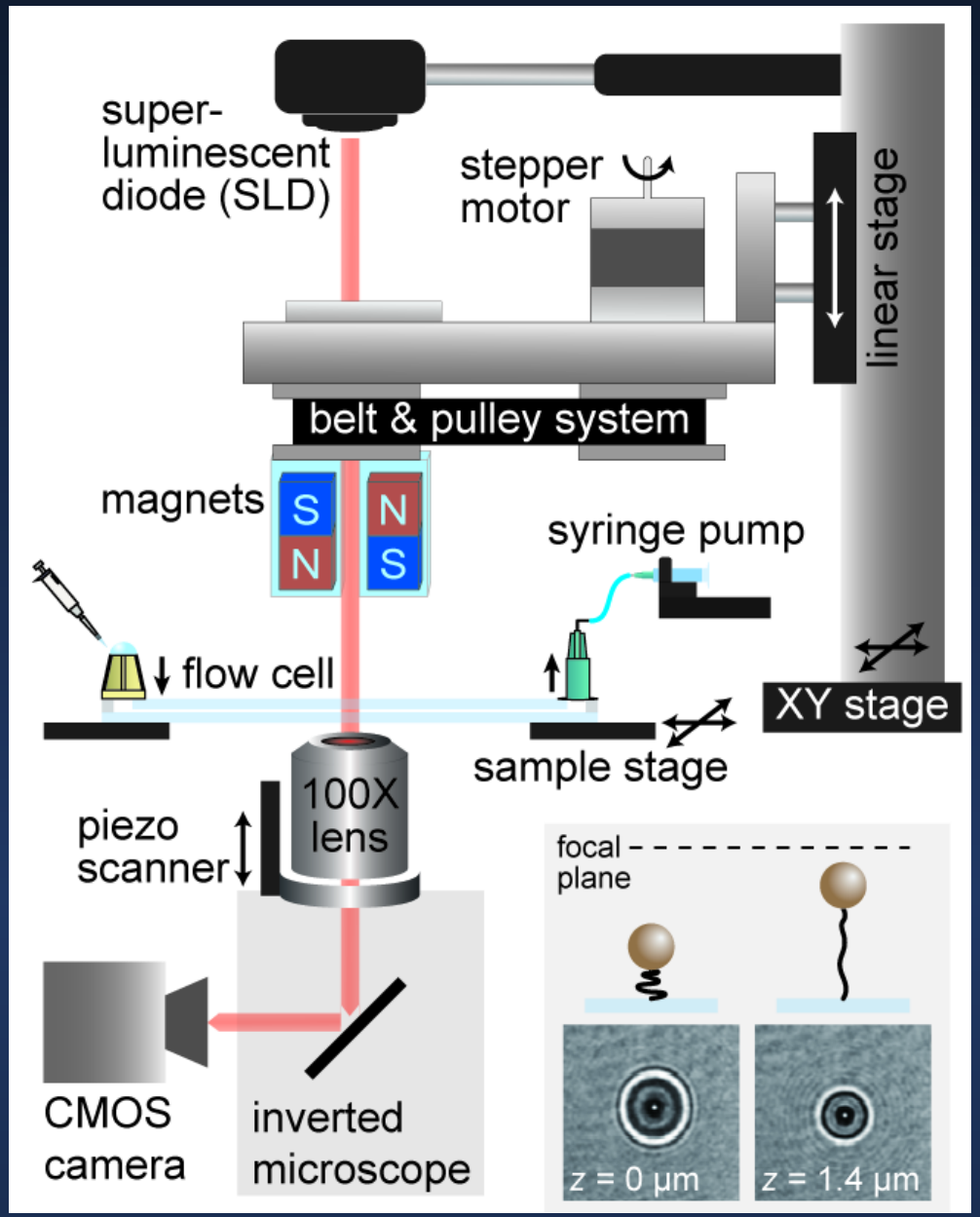
단분자 자기집게



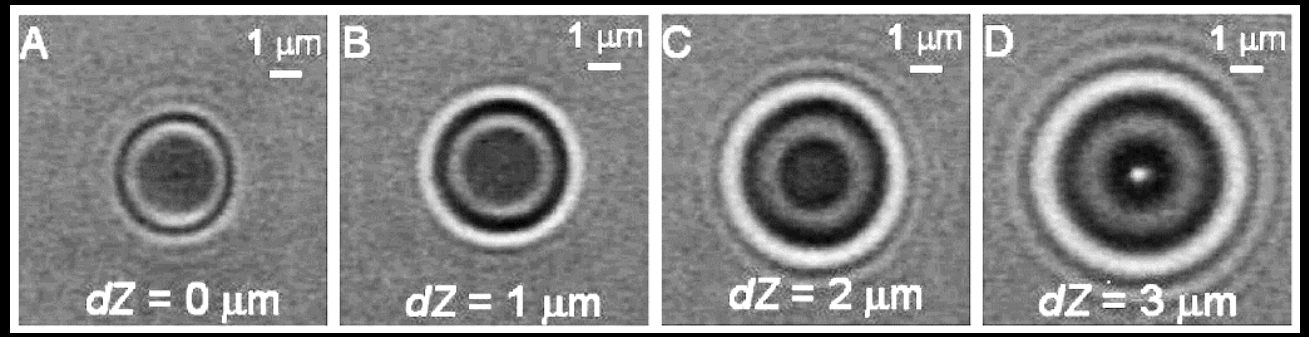
$$\vec{F} = \frac{1}{2}\vec{\nabla}\left(\vec{m}\cdot\vec{B}\right) = \frac{1}{2}\vec{\nabla}\left(\vec{m}_{sat}\cdot\vec{B}\right)$$ (in a strong field)



단분자 자기집게: 입자 위치 추적

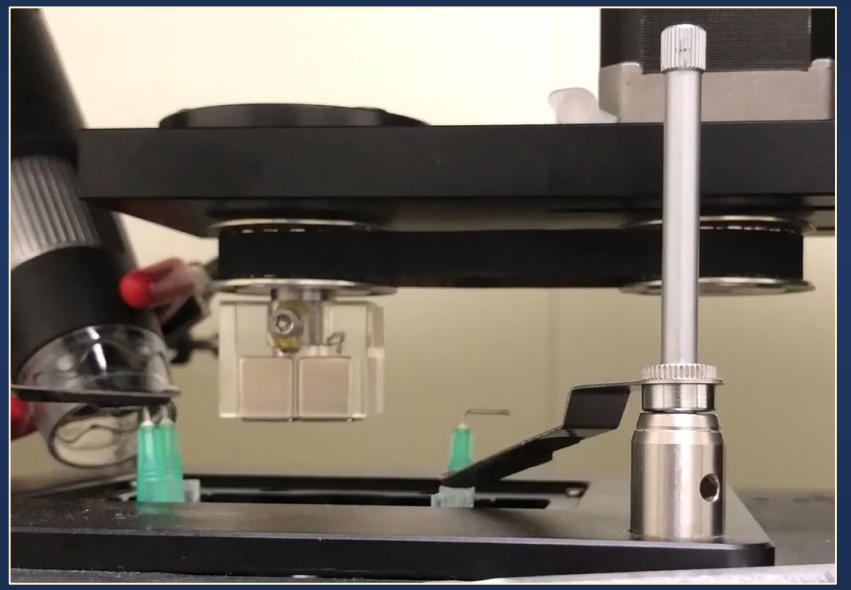


입자 위치 추적 ➔ 분자 구조 변화

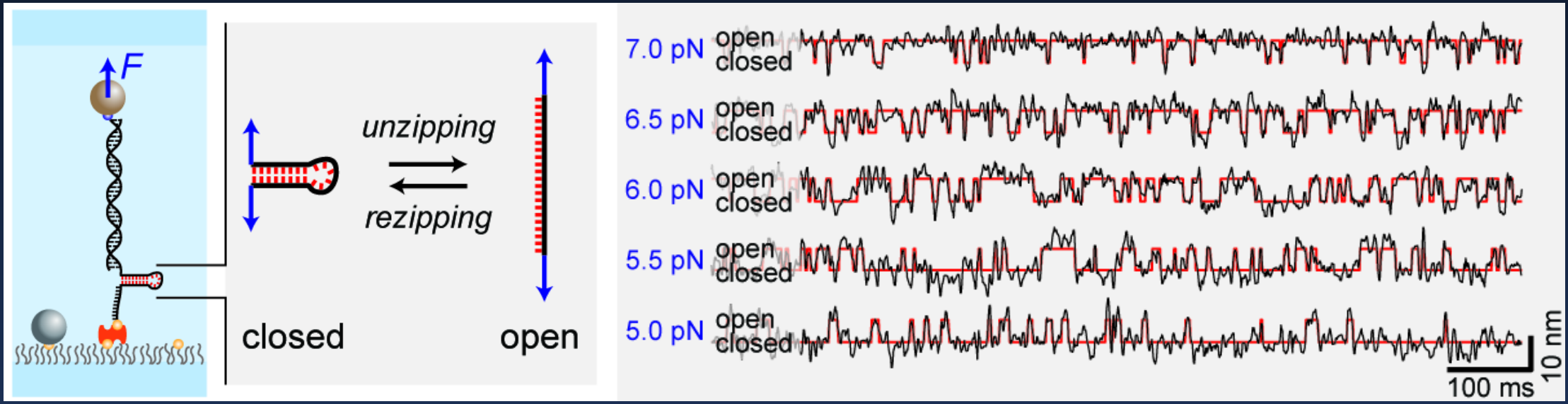


Vilfan *et al.* in *Handbook of Single-Molecule Biophysics*

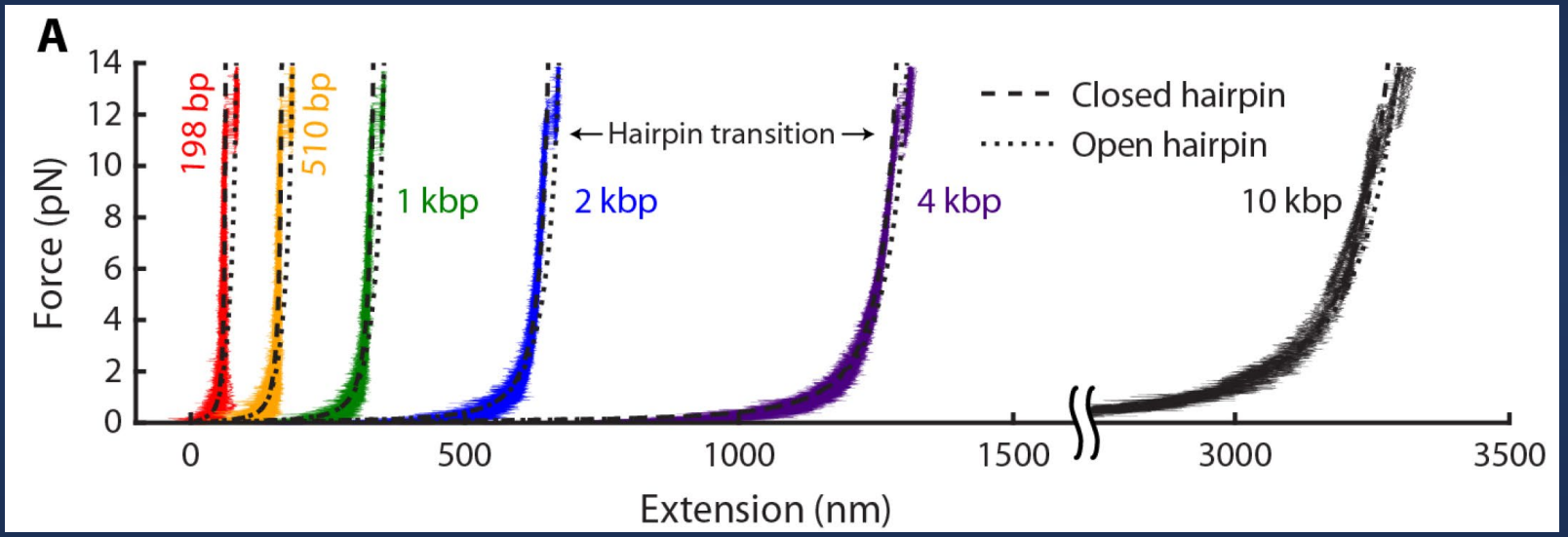
Mario MT



Example: Stretching DNA



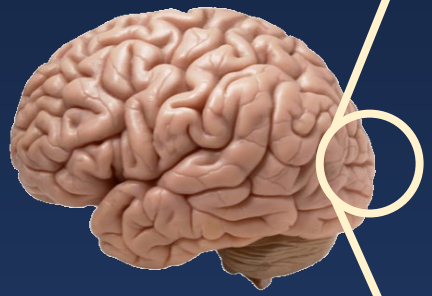
Park et al.
JoVE (2023)



Shon et al.
Sci Adv (2019)

Studying protein structure?

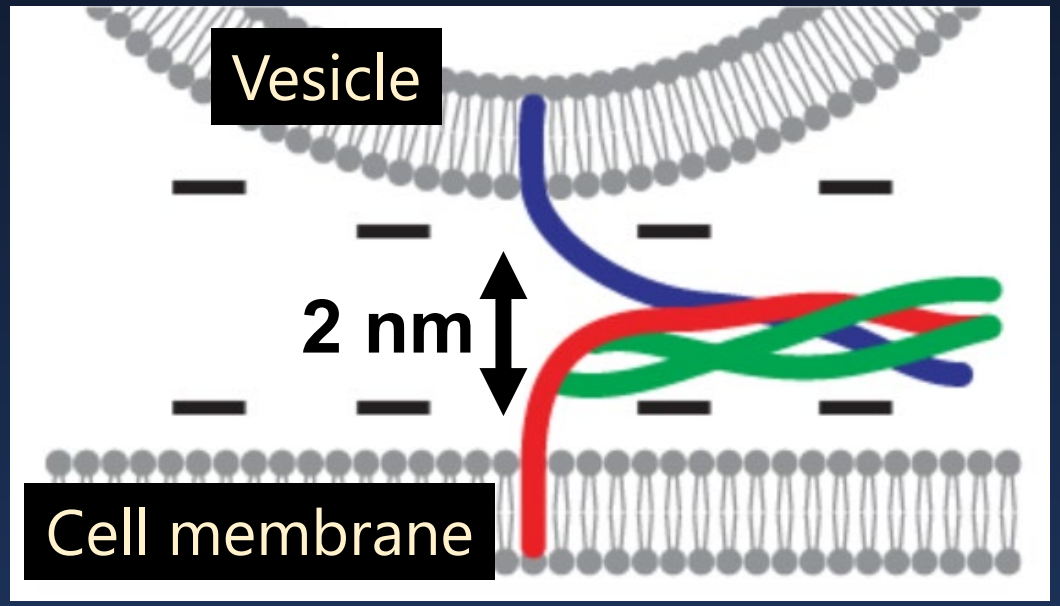
생물학적 시스템의 역학적 움직임

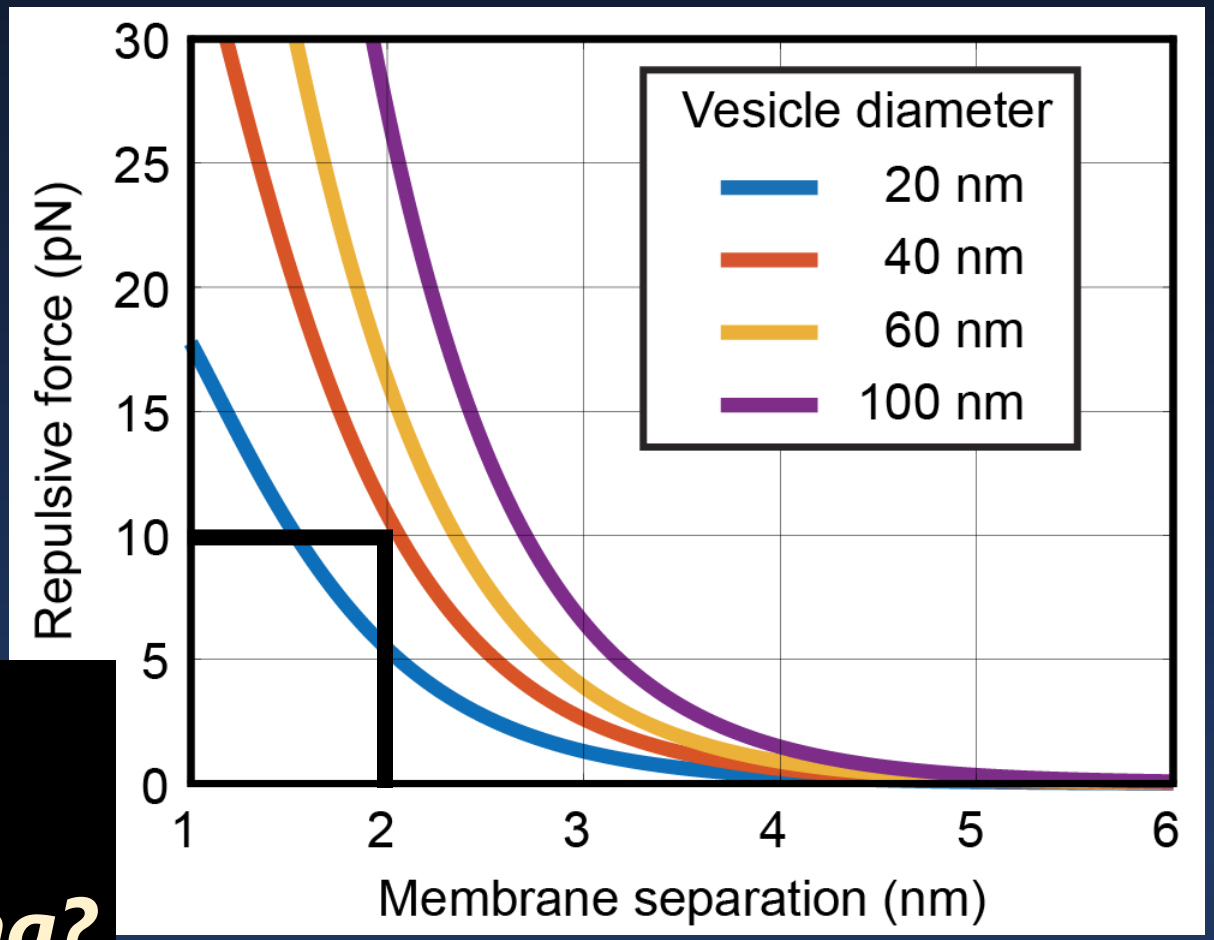


https://youtu.be/I145qaWjg1c

지질막 융합 ➔ 소포 방출 ➔ 신경신호전달

Electrostatic repulsion vs. SNAREs



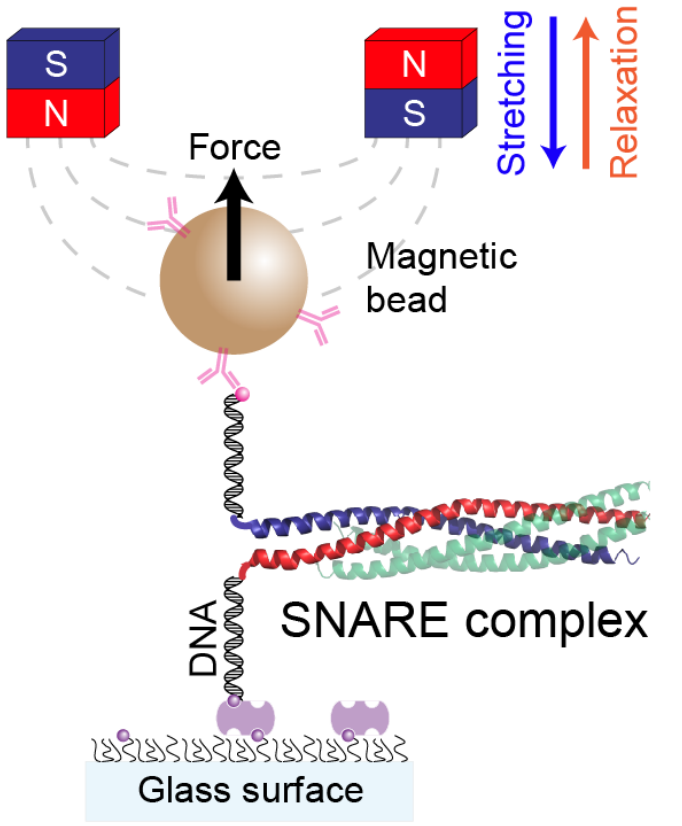


Q: How do external forces (i.e. tension in SNAREs) influence SNARE zippering?

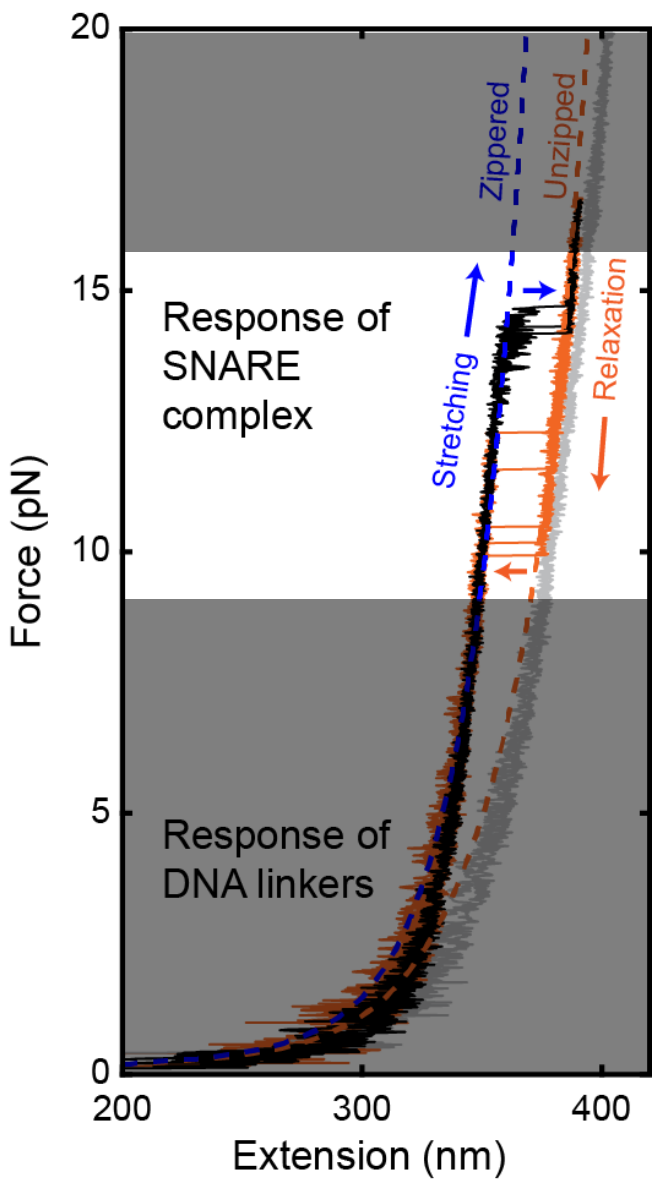
Shon *et al.*, *Nat. Commun.* (2018)

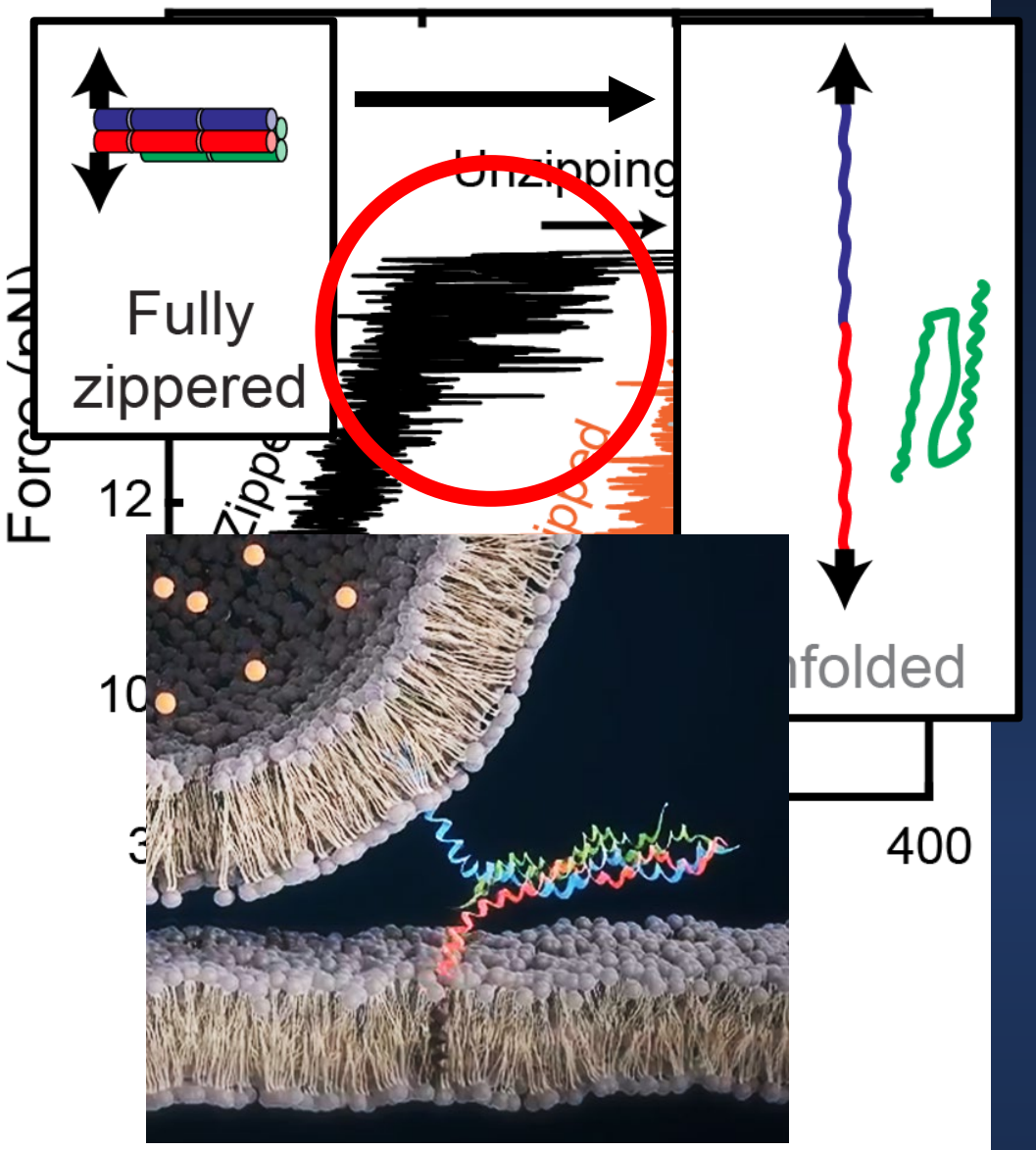
Calculation based on: Bykhovskaia *et al.*, *Biophys. J.* (2013)

Force-induced unzipping

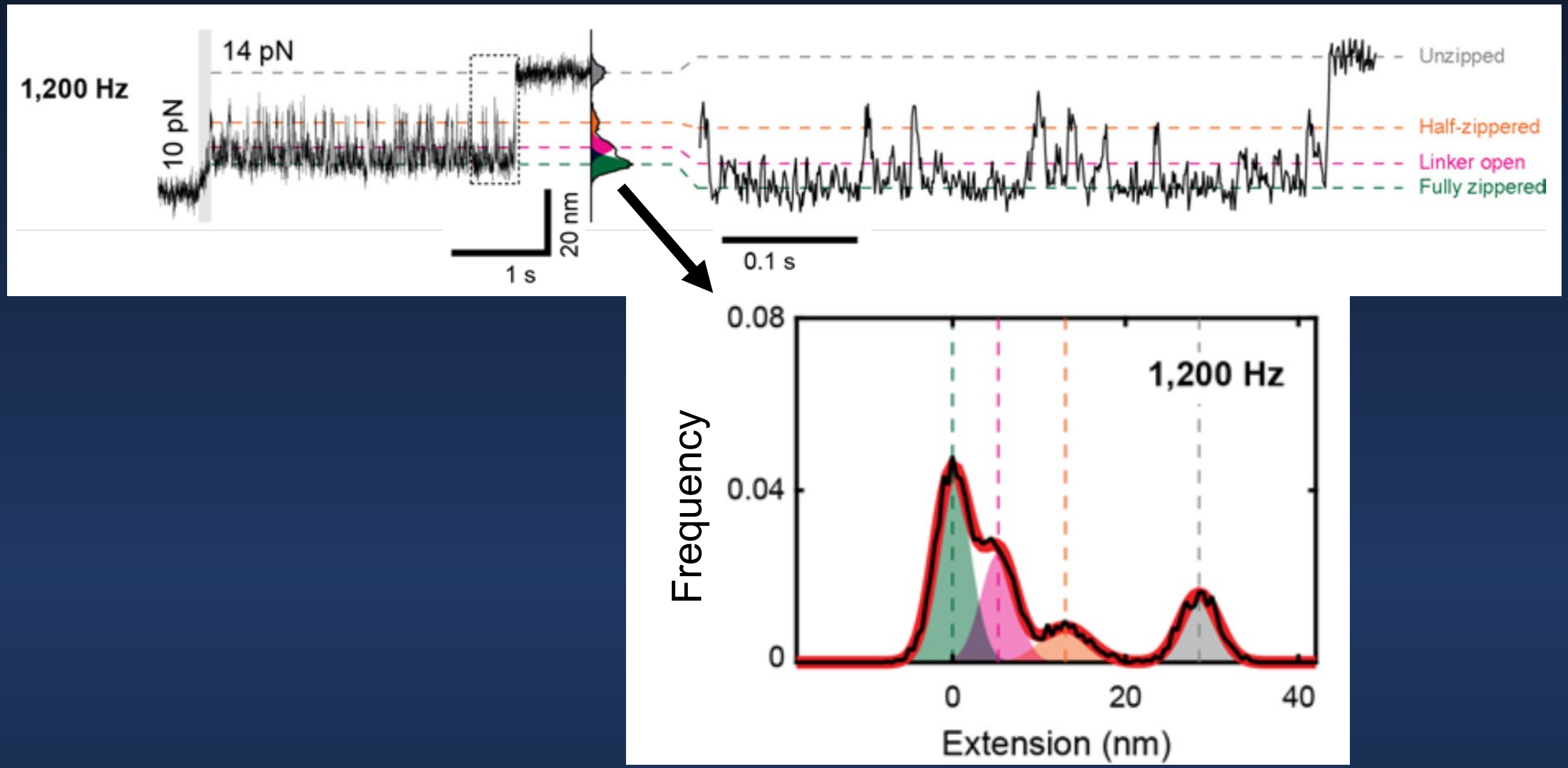


Shon *et al. Nat. Commun.* (2018)

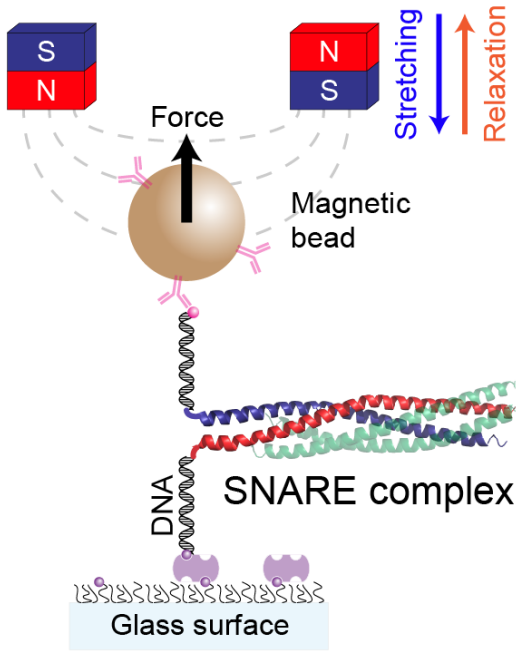


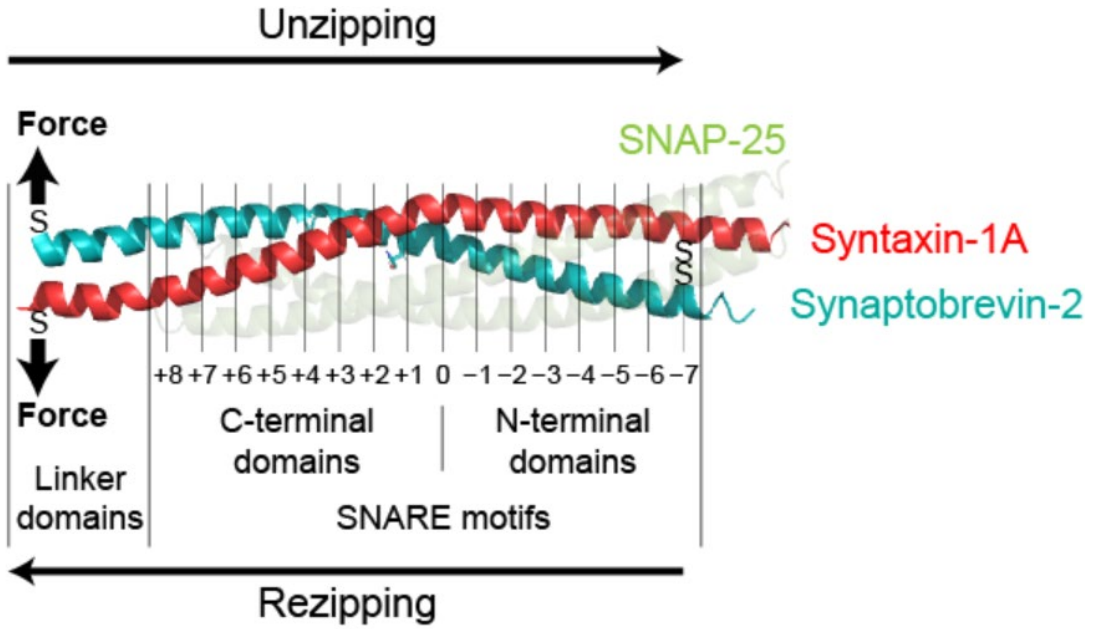


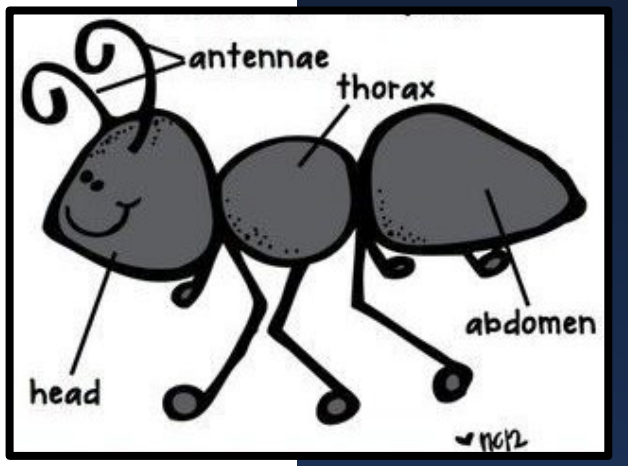
Technical breakthrough: High-speed tracking

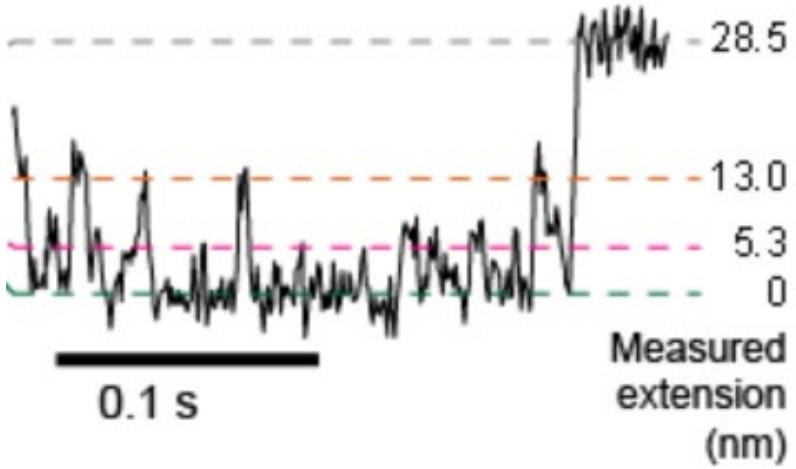


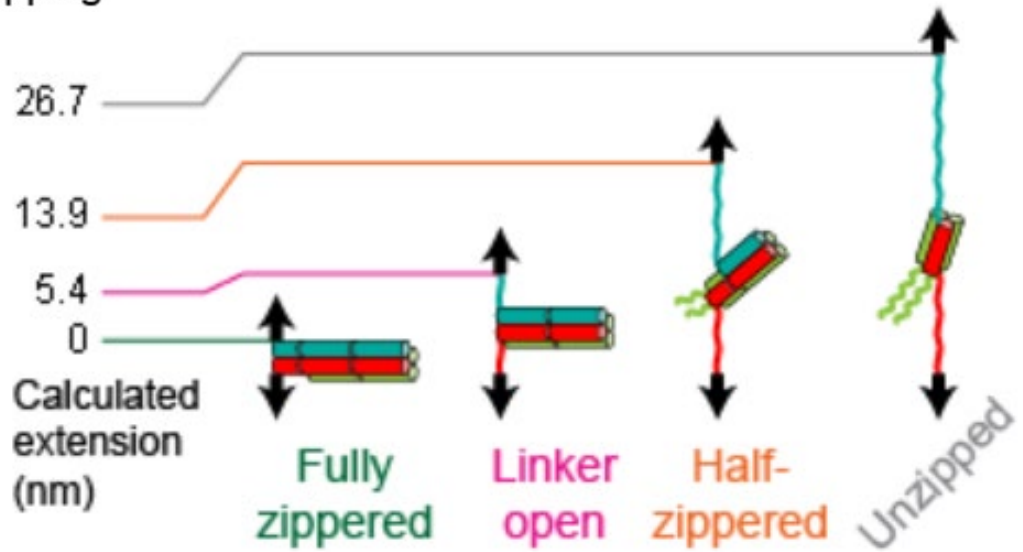
단백질이 찢어지는 단계





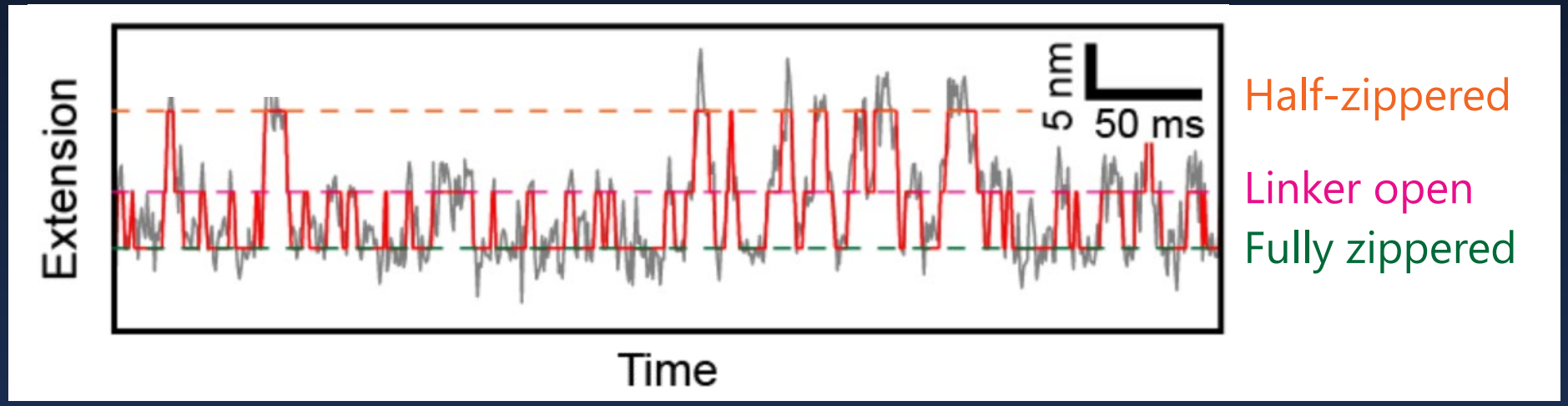




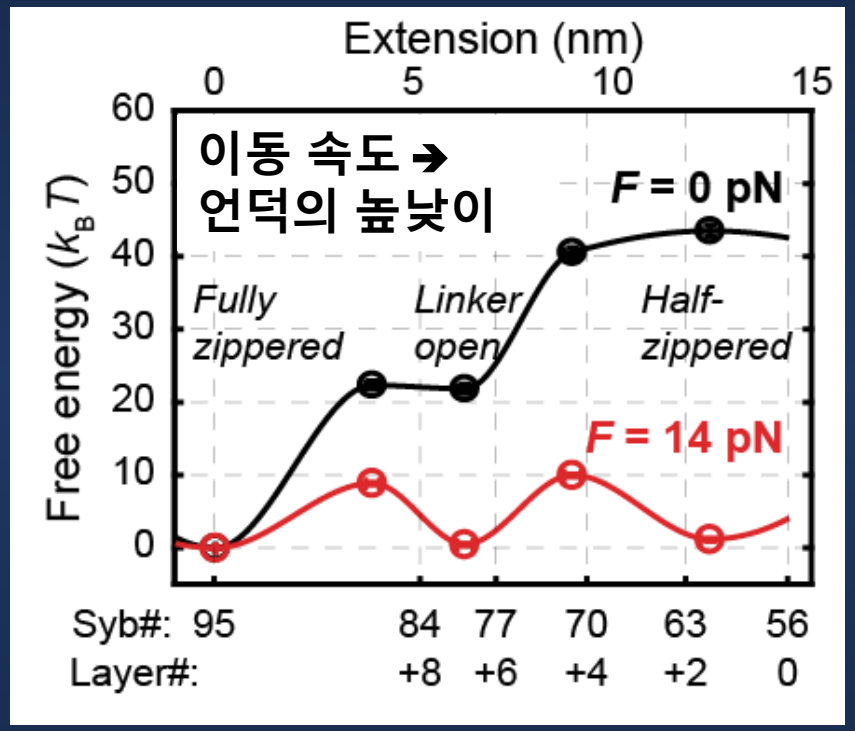


Shon *et al. Nat. Commun.* (2018)

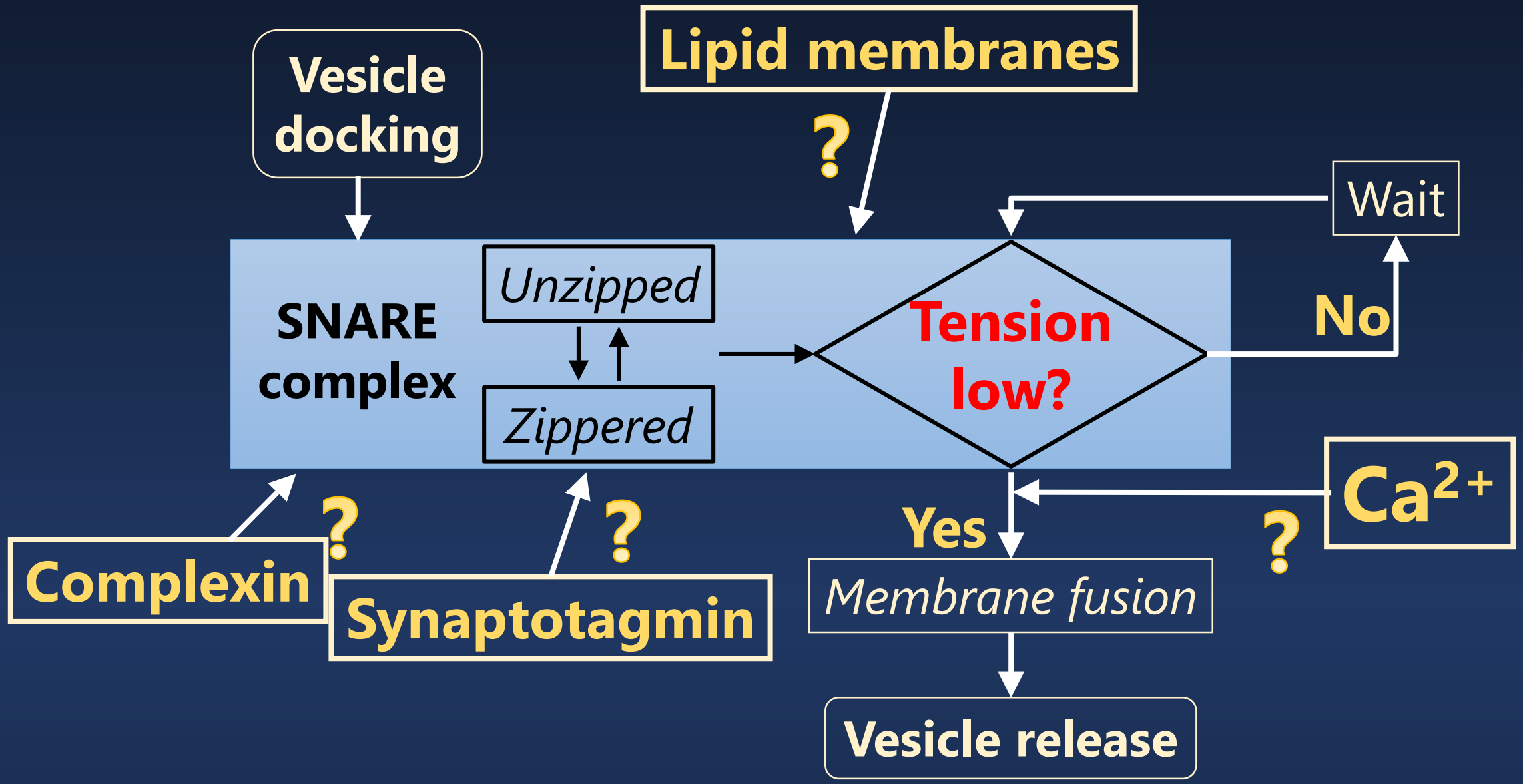
머신러닝 ➔ 상태 추적

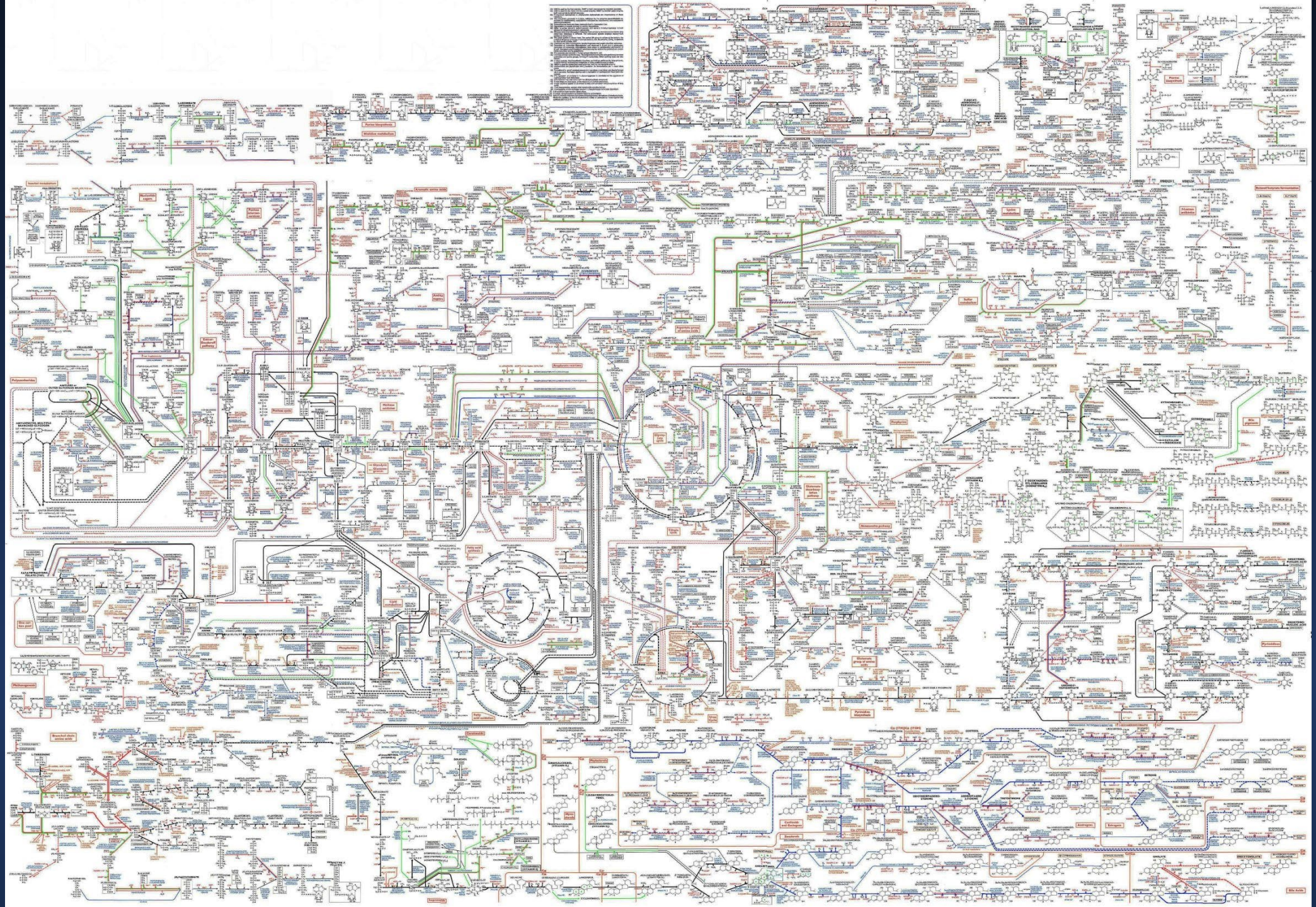


Shon *et al.* *Nat. Commun.* (2018)

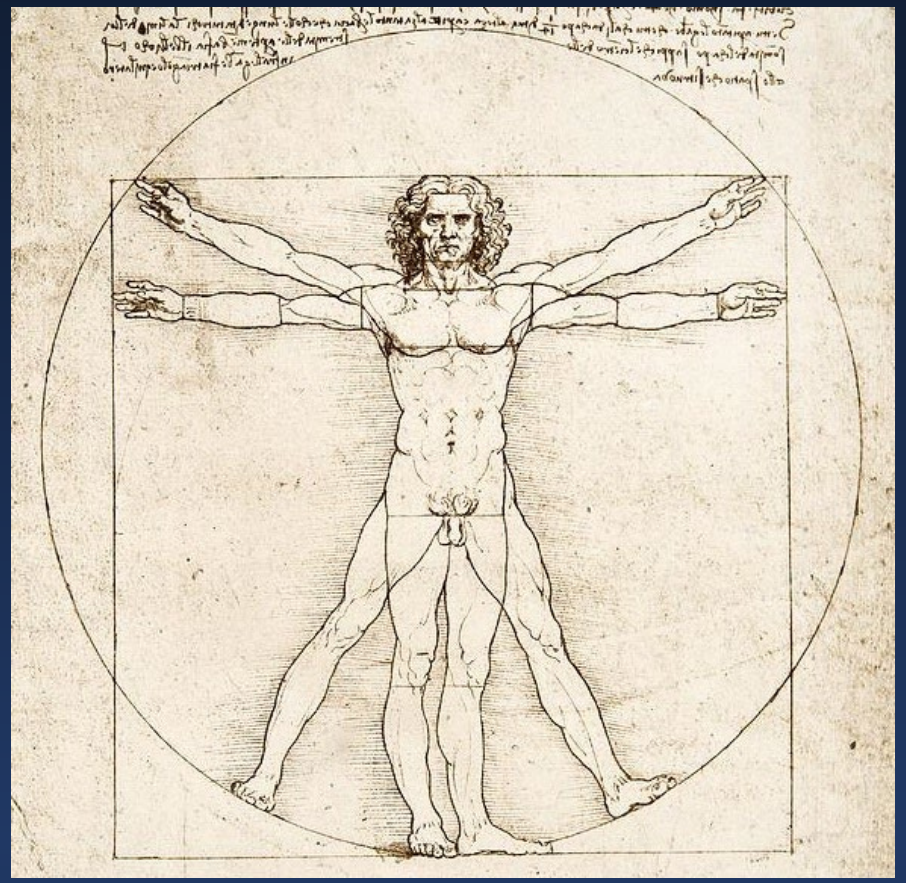


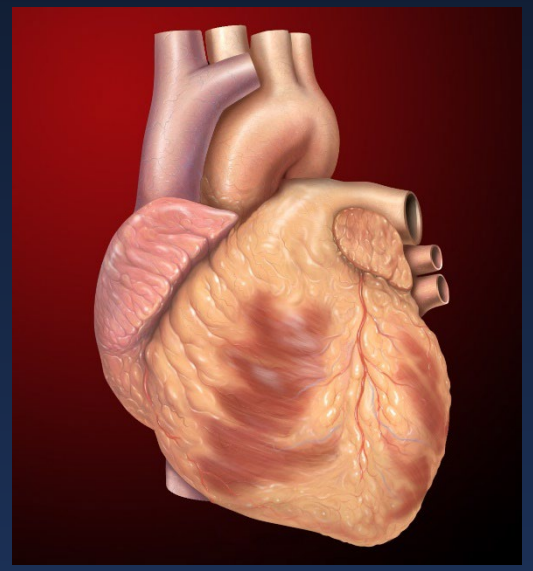
New look: Mechanical decision-making system

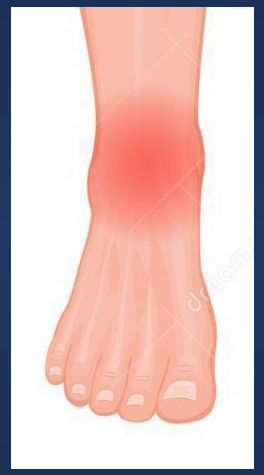




역학생물학 (Mechanobiology)







Mechanobiology

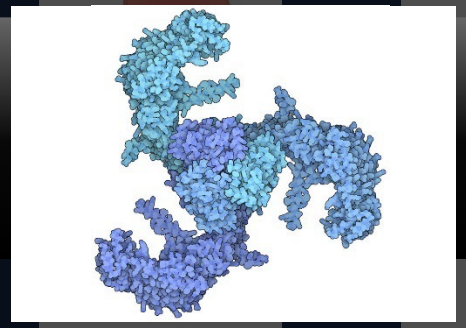
Tissue

Macroscopic

Cell

Mesoscopic

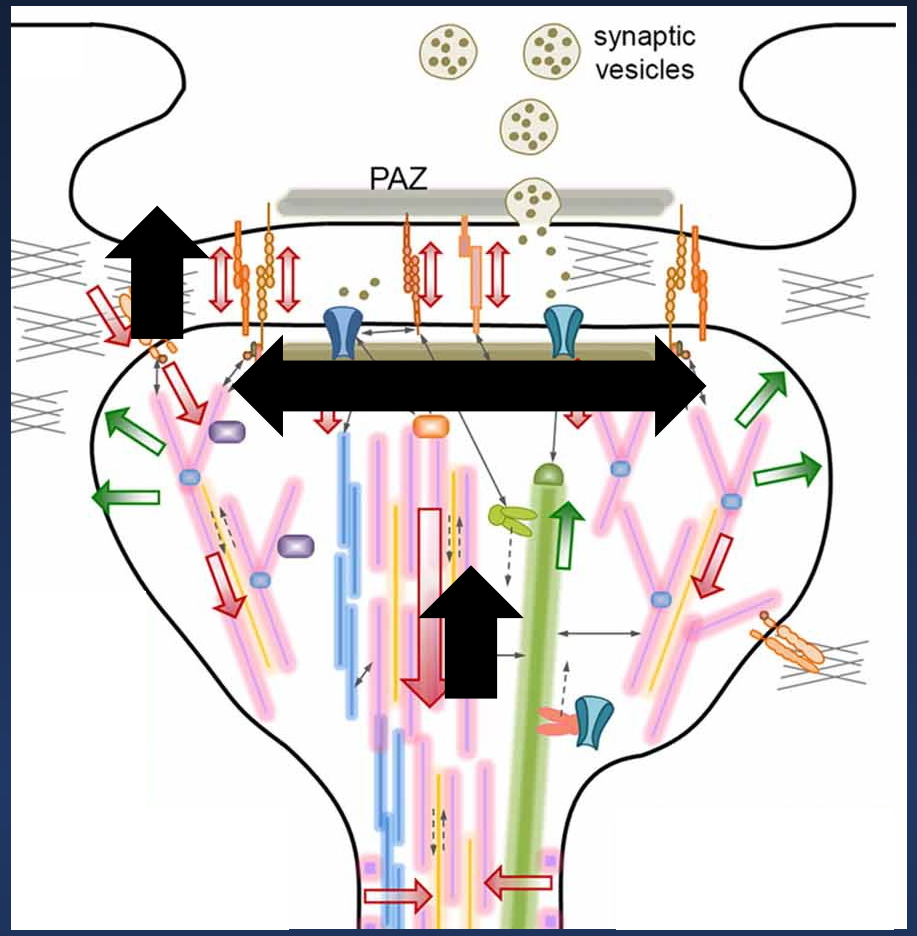
Molecule



Microscopic

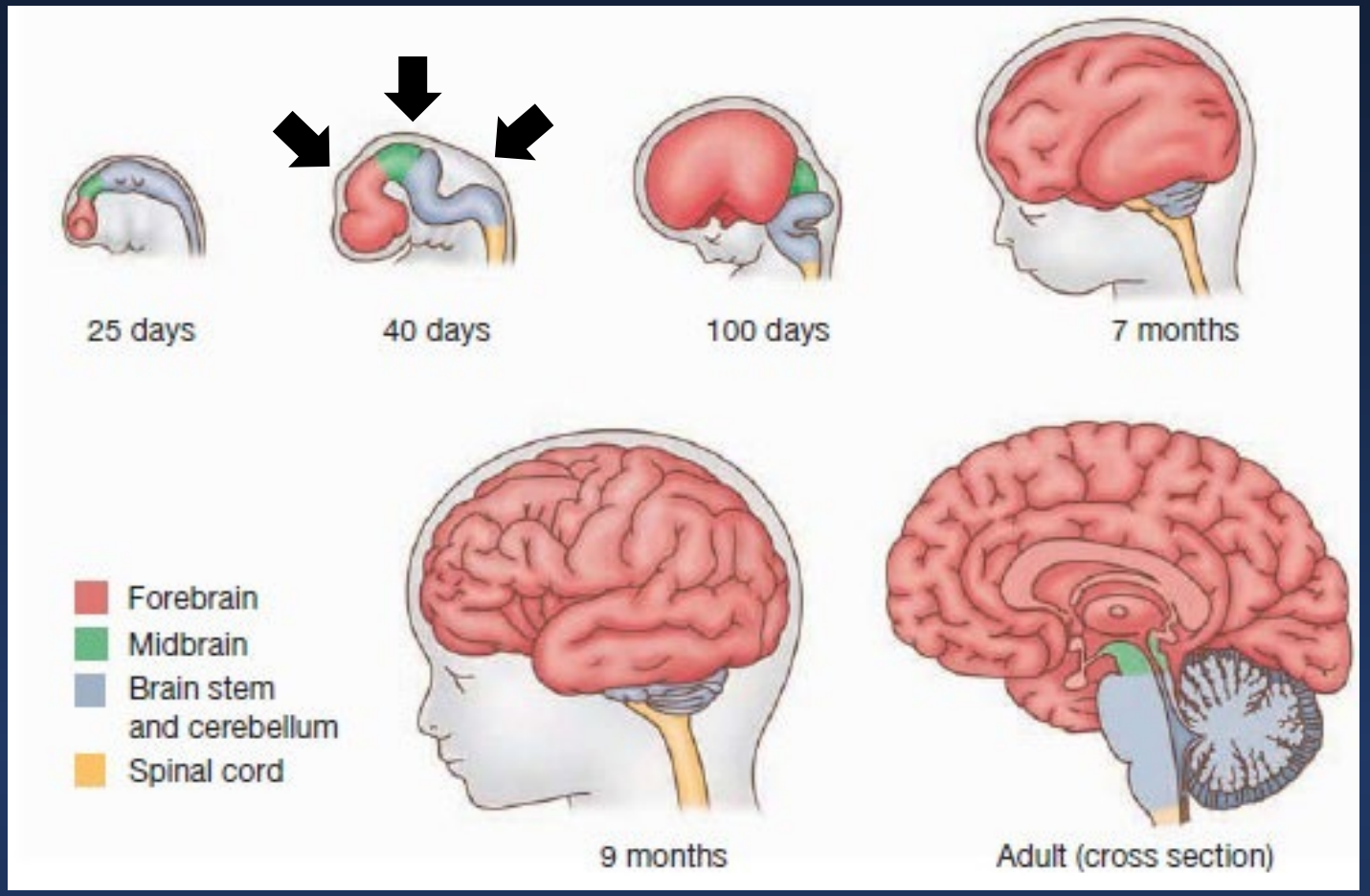
시냅스의 역학생물학

▪ 장기기억



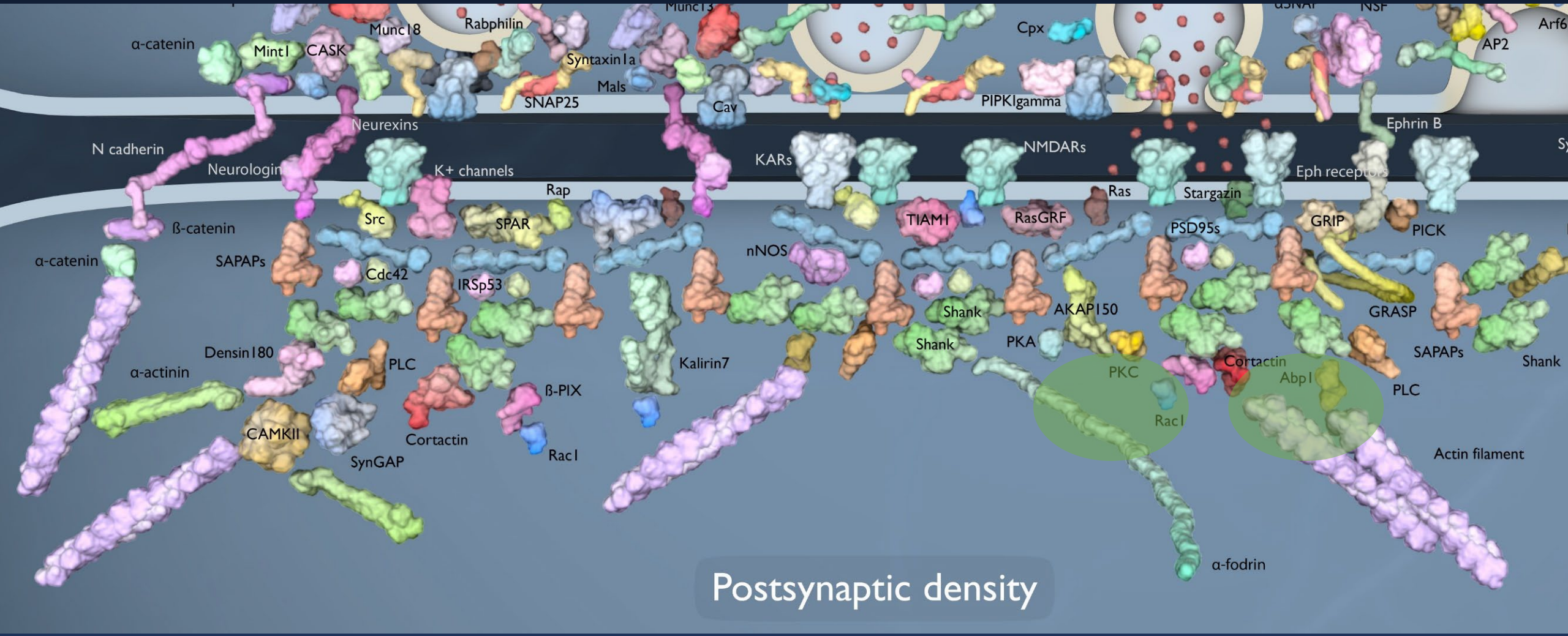
Kilinc, *Front. Cell. Neurosci.* (2018)

▪ 뇌의 형성



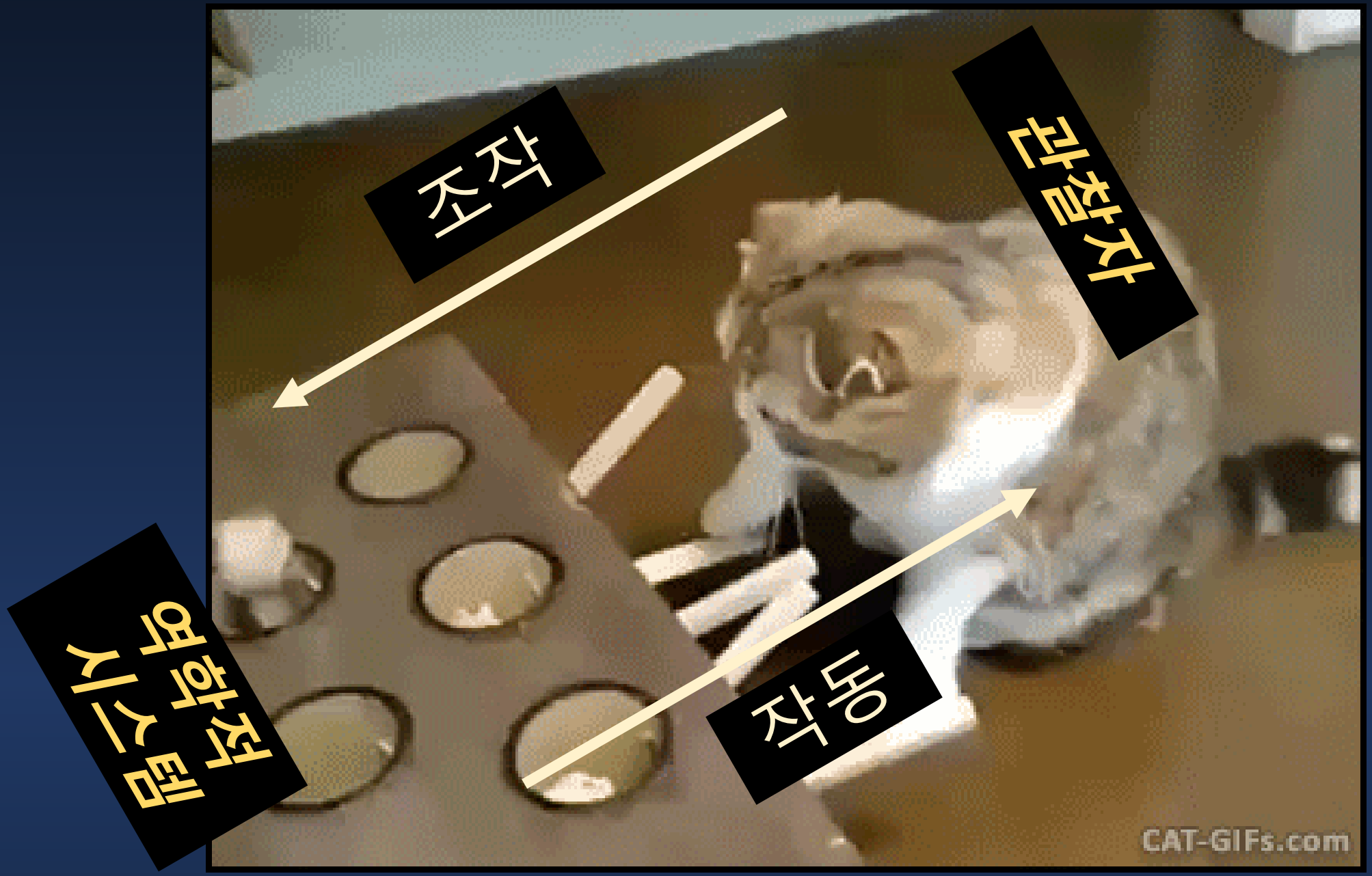
BrainKart.com

시냅스의 역학생물학



Collaboration with Prof. Jaewon Ko (DGIST)

Image: Synaptic Systems


조작
관찰자
작동
생물학적 시스템
CAT-GIFs.com

Vesicle–Protein Interactions

Extracellular Vesicles: Hormone-like role in cell-to-cell communication

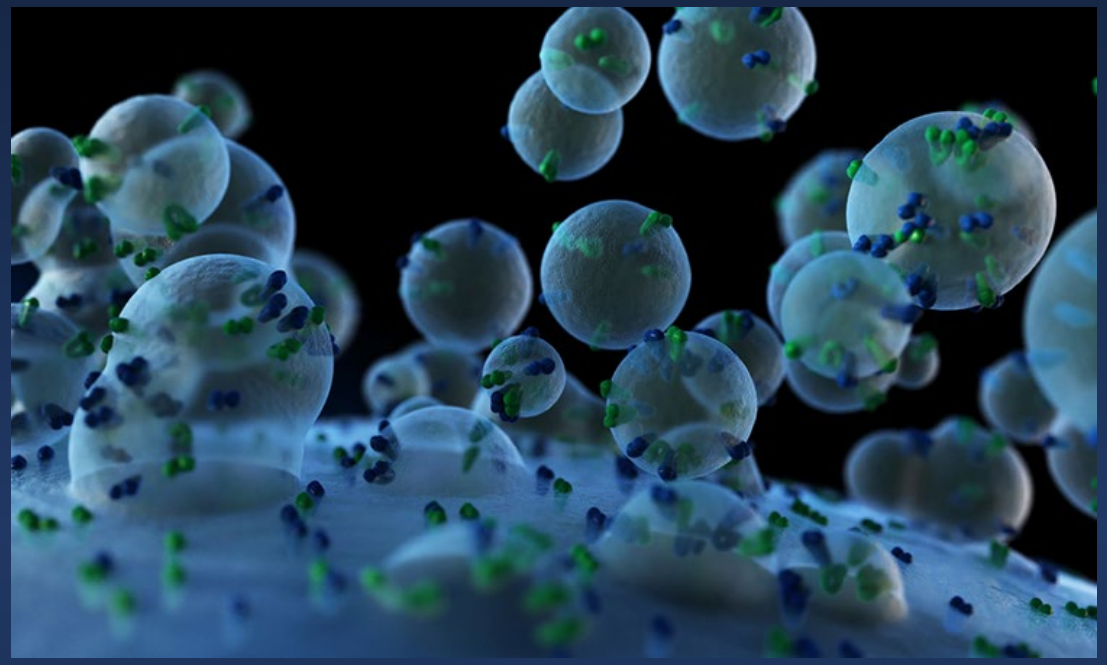
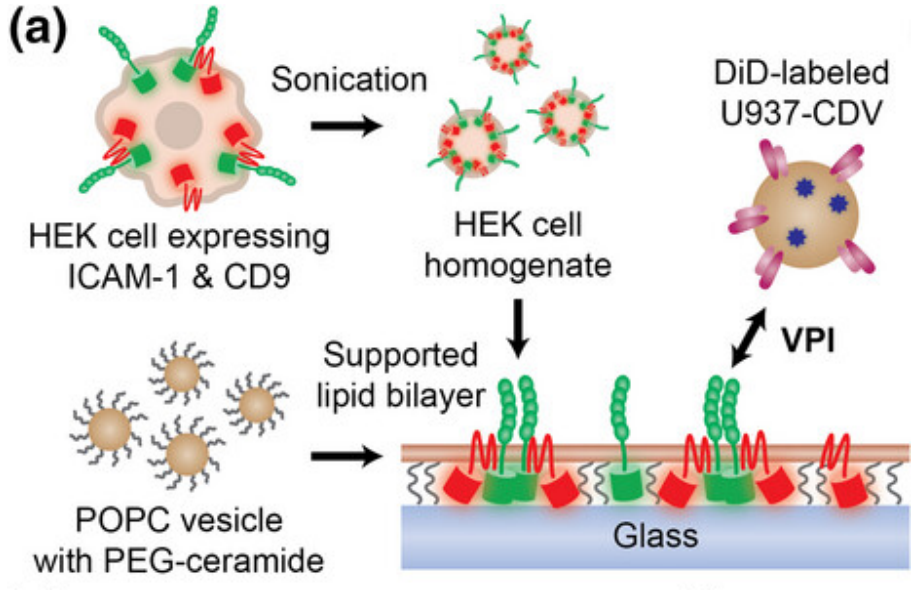
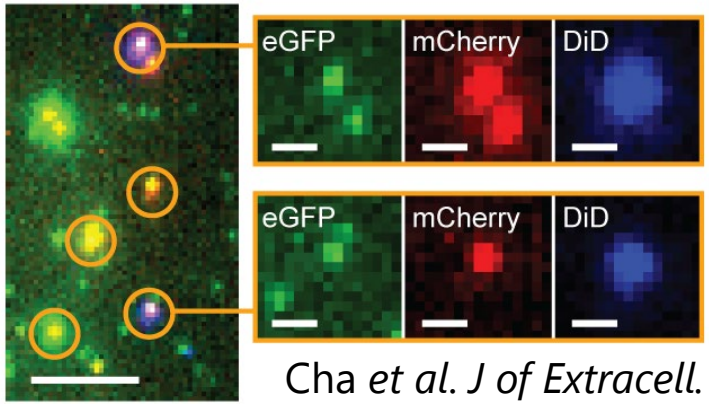


Image credit: www.drugtargetreview.com



Colocalization: ICAM-1/CD9/vesicle



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Acknowledgment

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Current projects:

- Synaptic protein LLPS & SNAREs
- Membrane proteins on free-standing lipid bilayer
- Single-molecule work on protein–DNA interactions
- T-cell receptor interactions