High-speed AFM and other special applications

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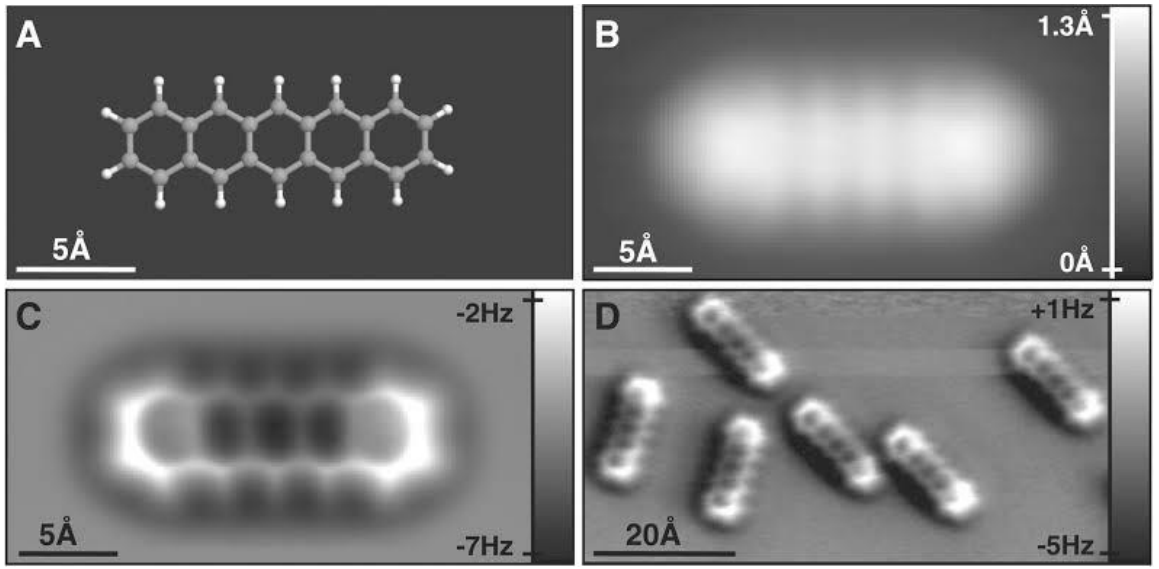
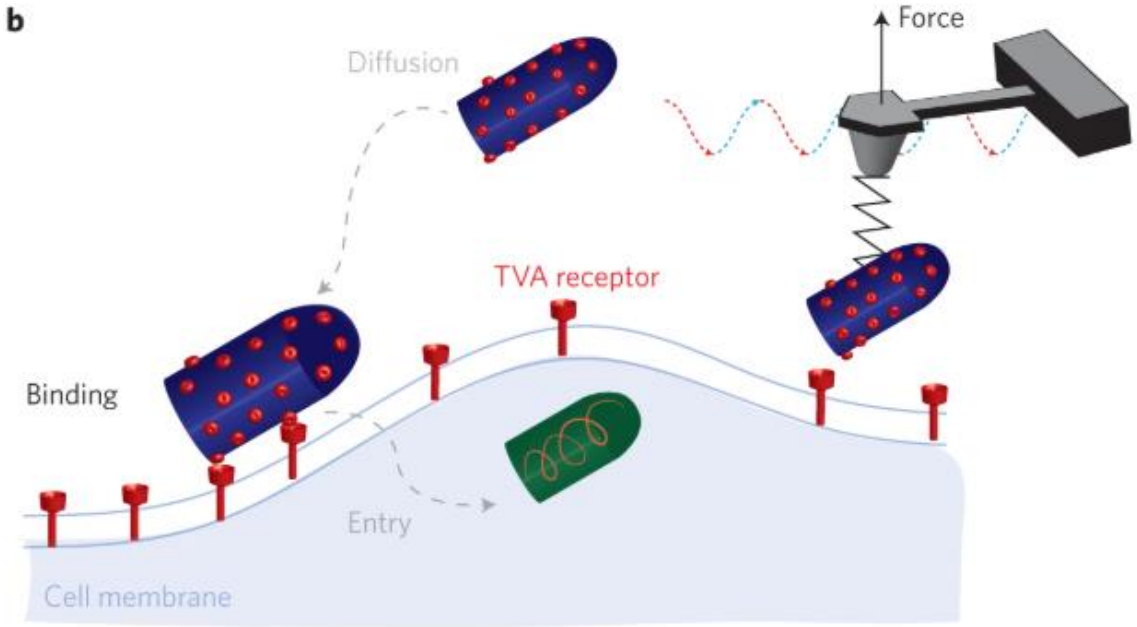
Special approaches in AFM

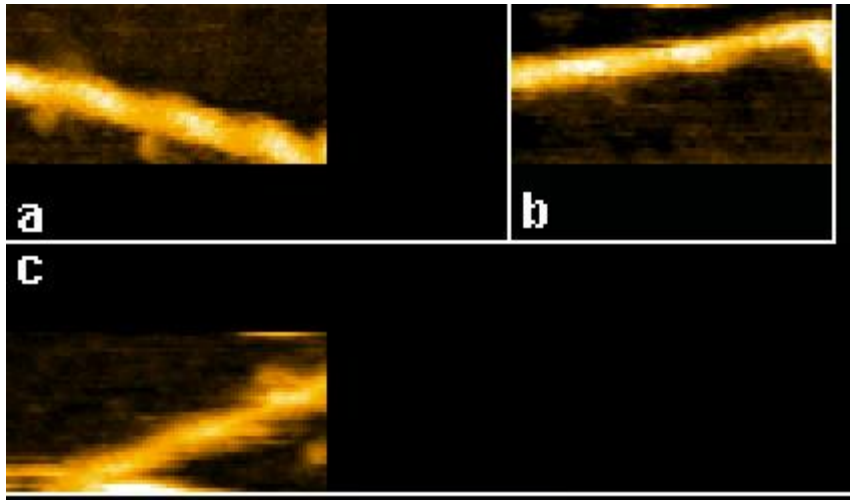
- Tip functionalization
- Surface modification
- Atomic resolution
- High-speed scanning
- Nanoendoscopy



Leo Gross et al. ,The Chemical Structure of a Molecule Resolved by Atomic Force Microscopy.Science325,1110-1114(2009).DOI:10.1126/science.1176210



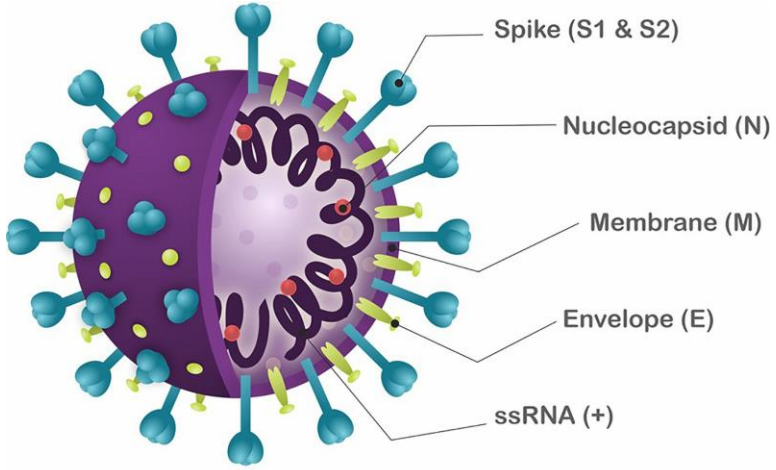
Alsteens, D., Newton, R., Schubert, R. *et al.* Nanomechanical mapping of first binding steps of a virus to animal cells. *Nature Nanotech* **12**, 177–183 (2017). https://doi.org/10.1038/nnano.2016.228

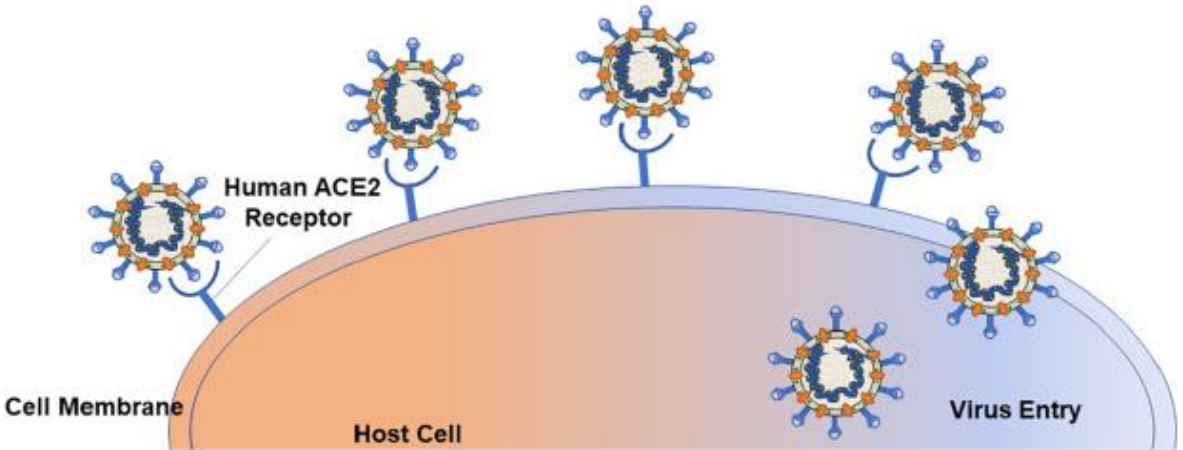


Kodera, N., Yamamoto, D., Ishikawa, R. et al. Video imaging of walking myosin V by high-speed atomic force microscopy. Nature 468, 72–76 (2010). https://doi.org/10.1038/nature09450

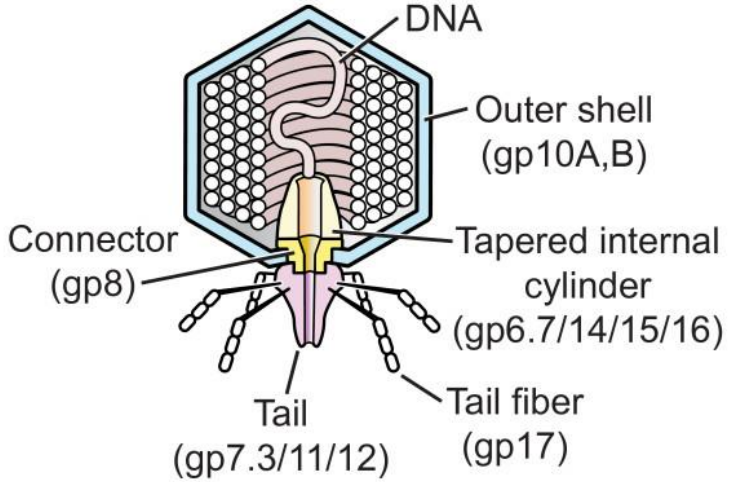
Two viruses with two different infection strategies

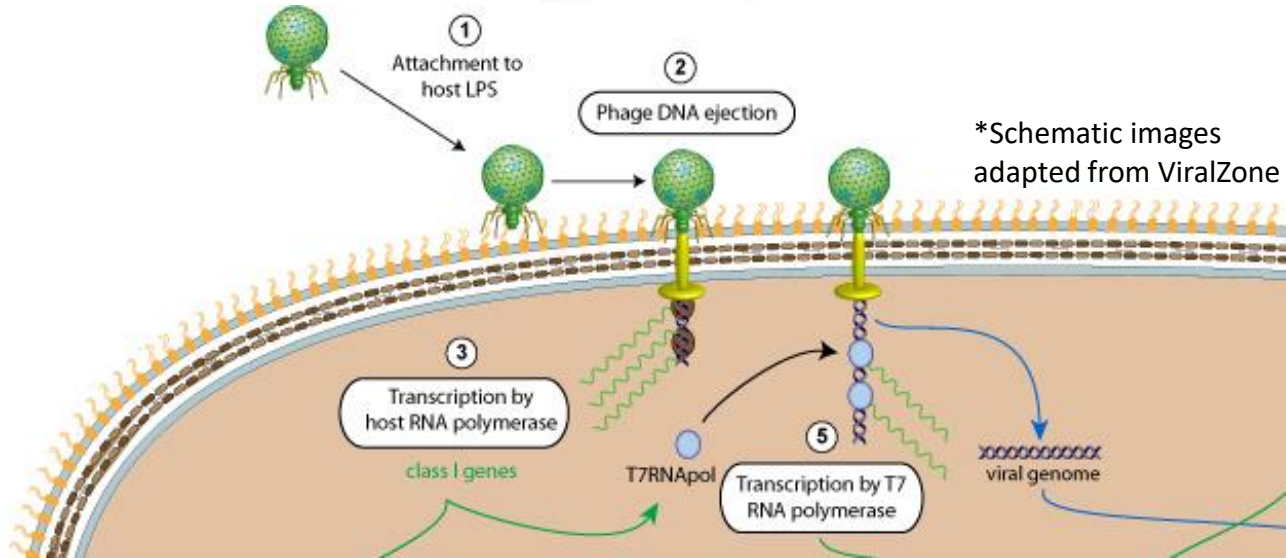
SARS-CoV-2





T7 bacteriophage

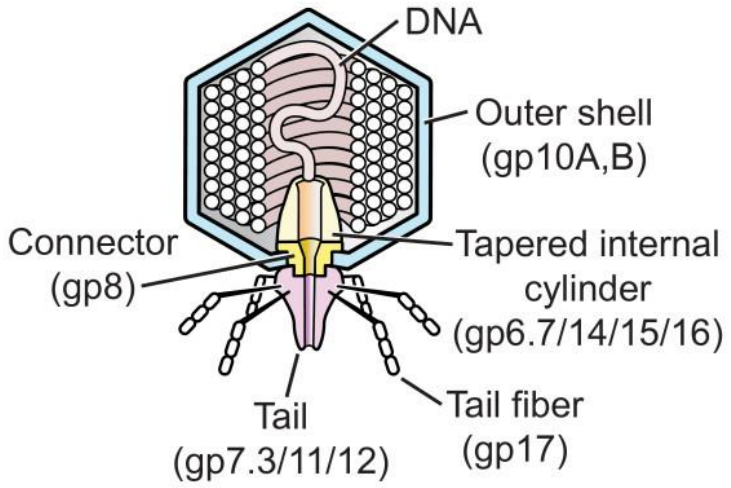


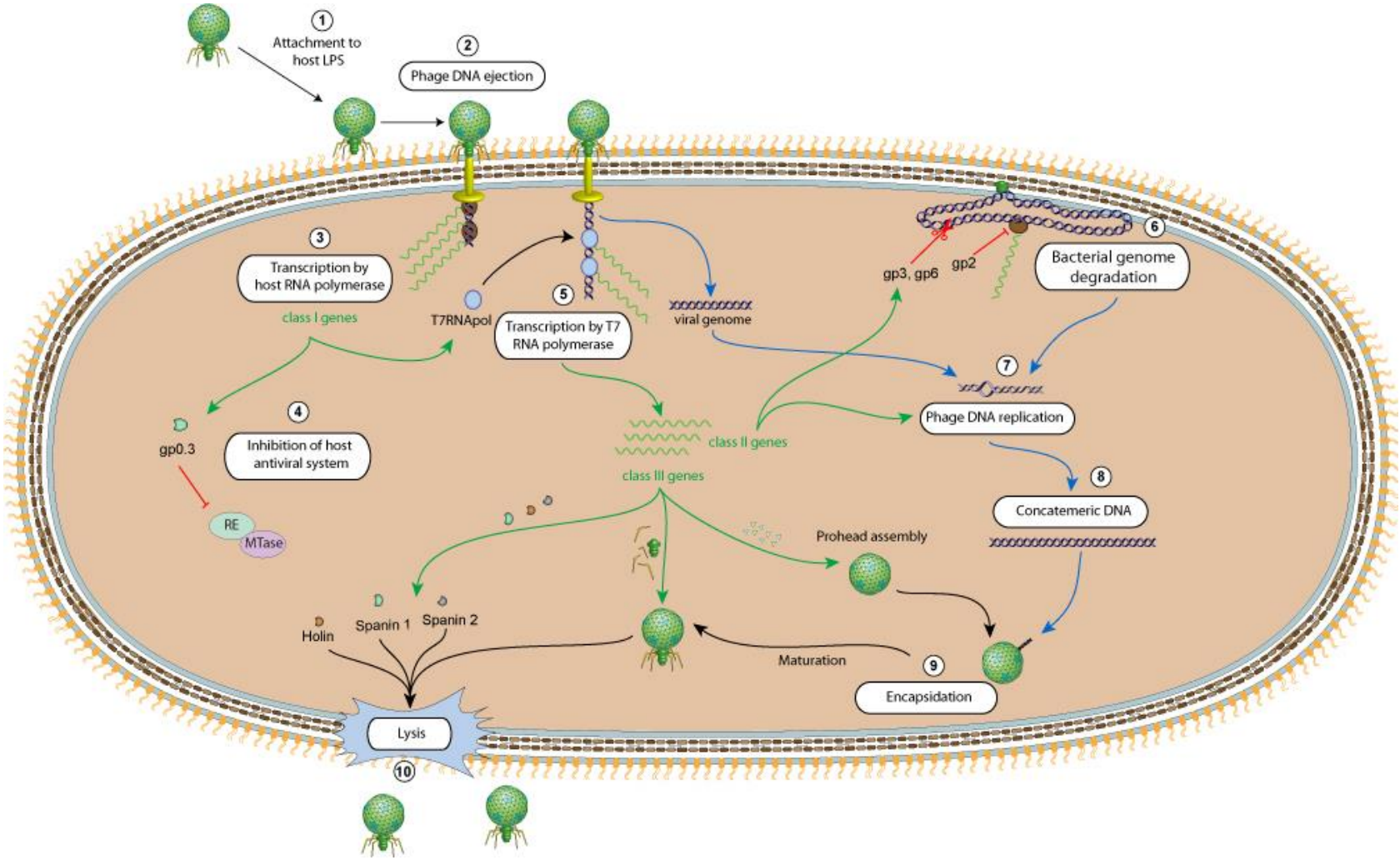


*Schematic images adapted from ViralZone

T7 structure and infection strategy

T7 bacteriophage

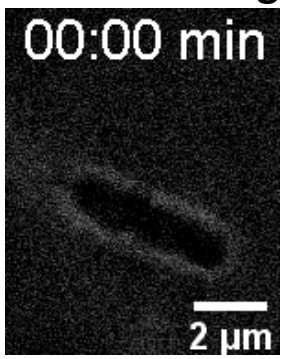


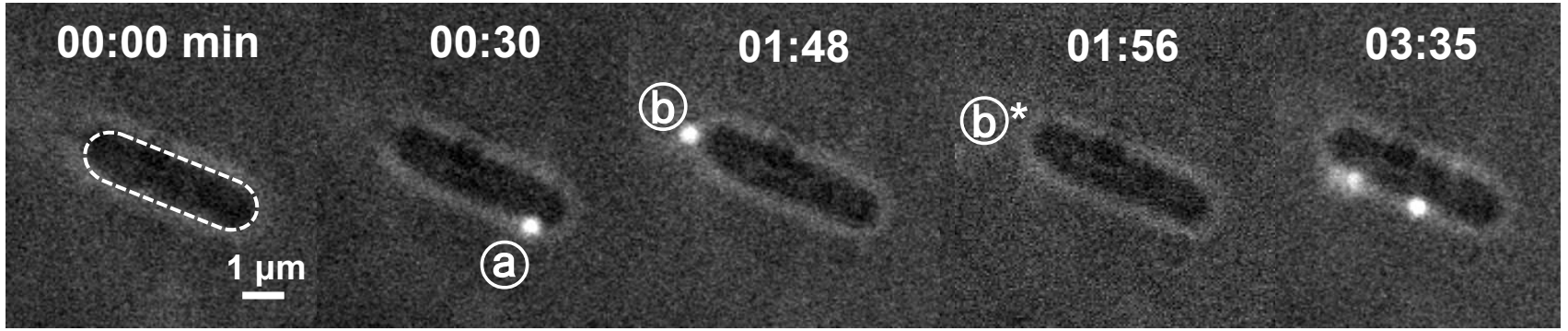


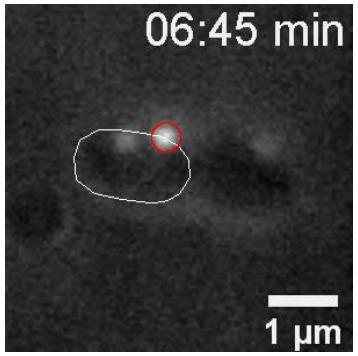
*Schematic images
adapted from ViralZone

T7 phage docking is a dynamic, two-dimensional searching process

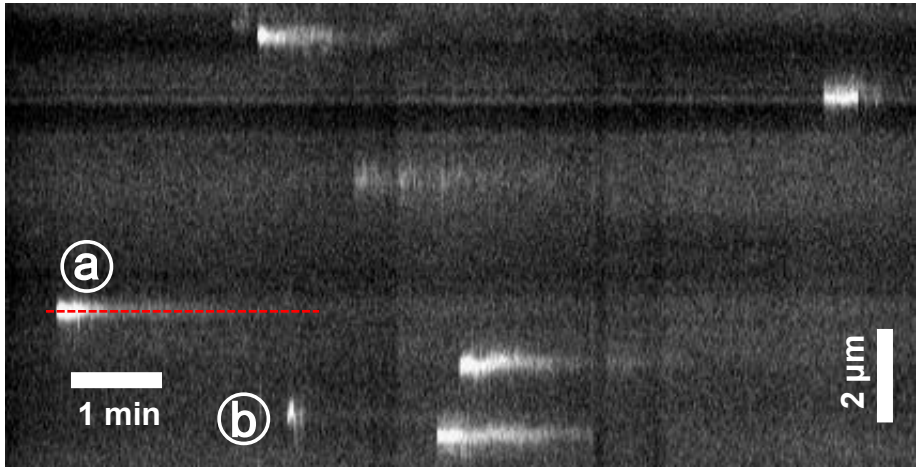
Surface binding

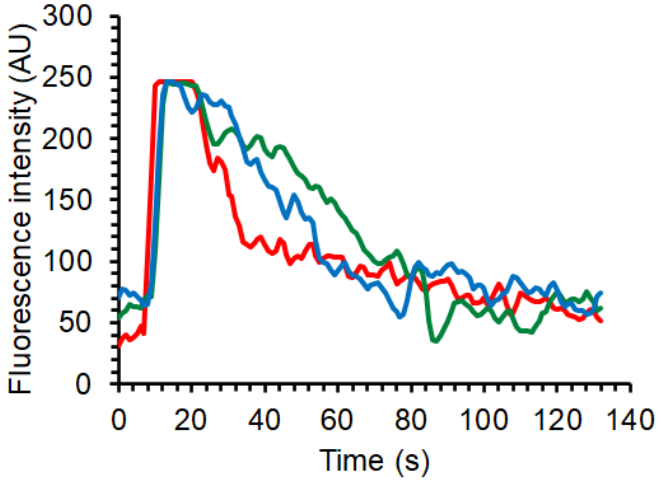




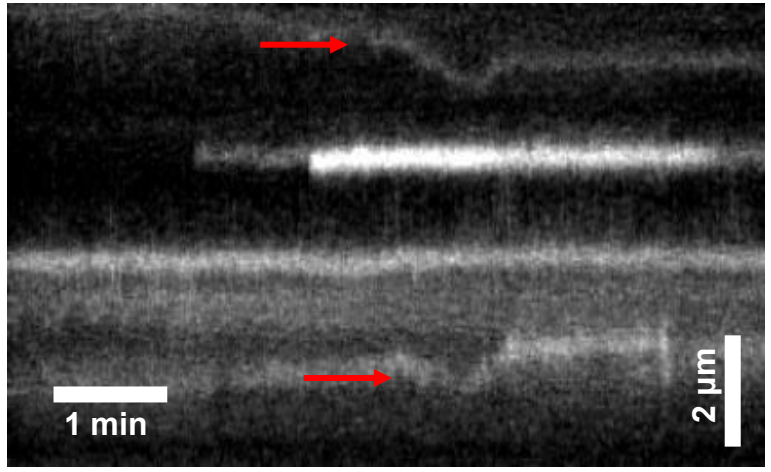


Docking and DNA injection



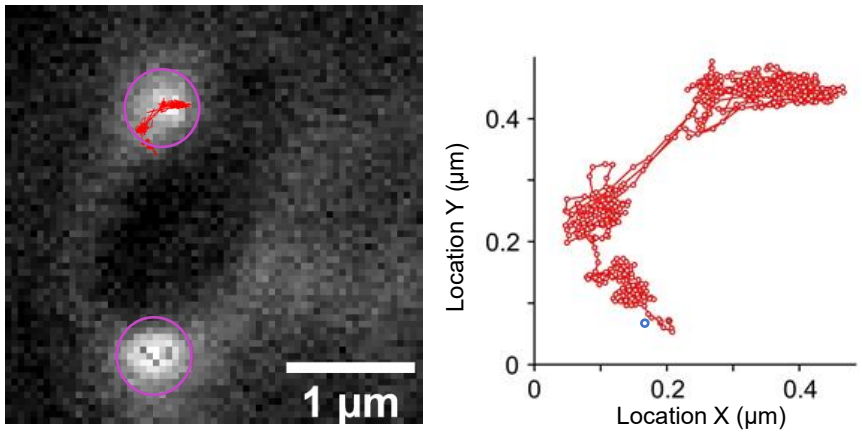


Surface exploration

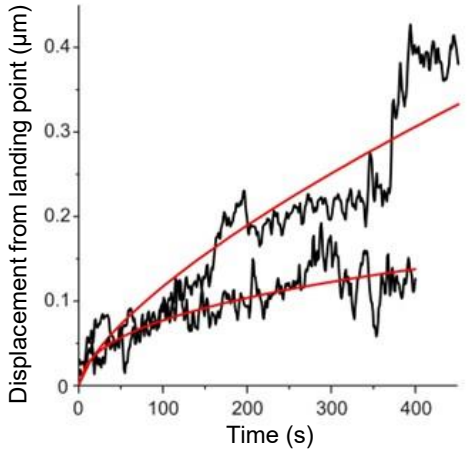


Phage docking is a dynamic, two-dimensional searching process

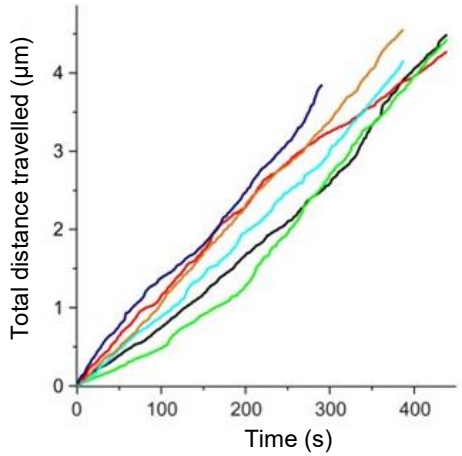
Exploration trajectory



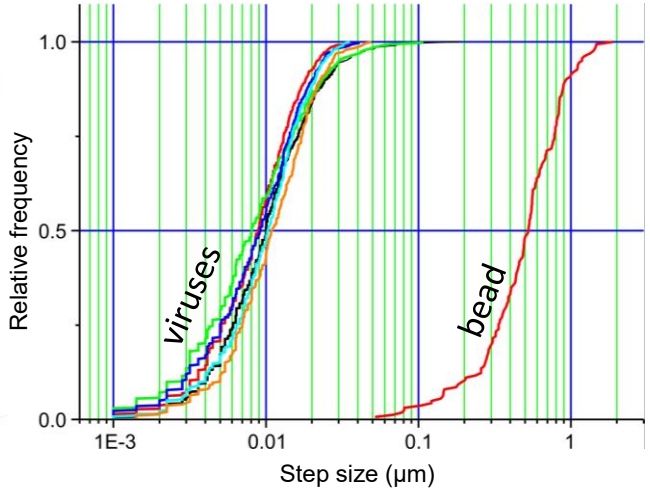
Displacement from landing



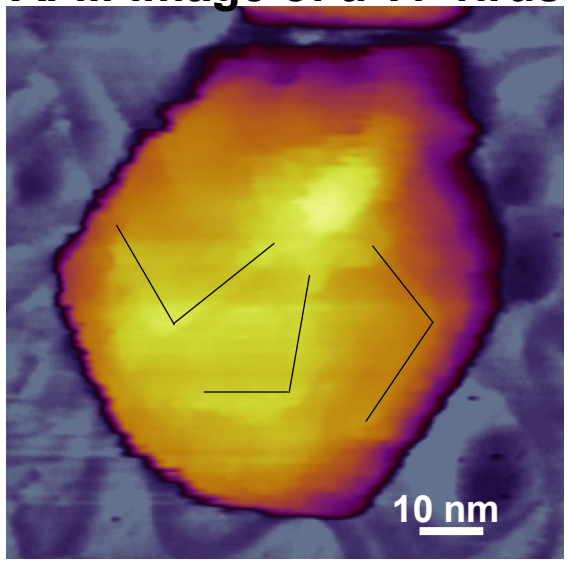
Distance travelled over time

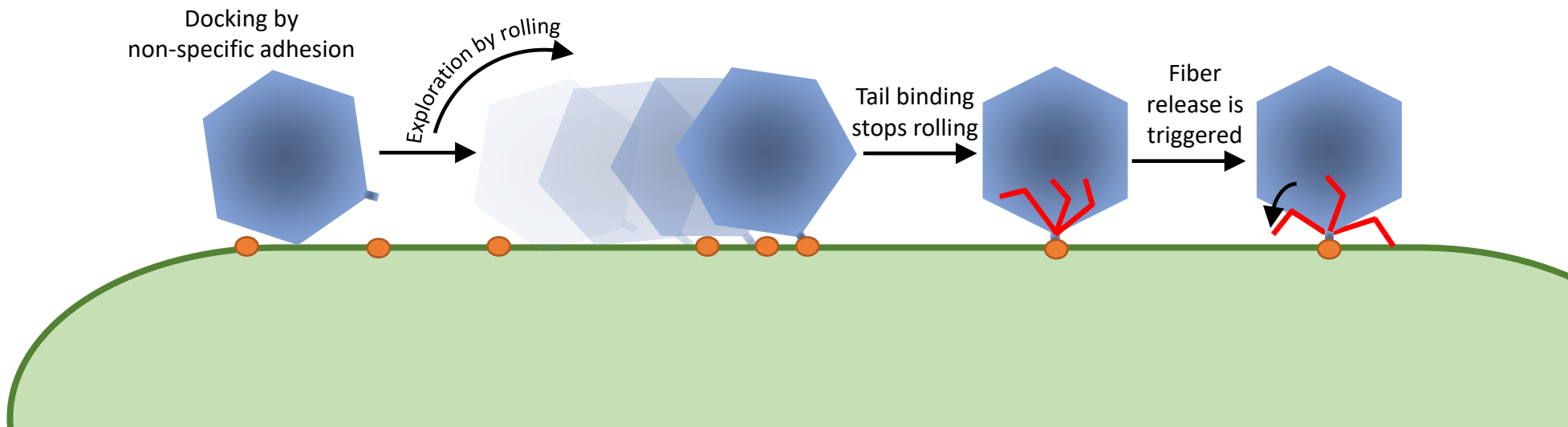


Nanoparticle step sizes

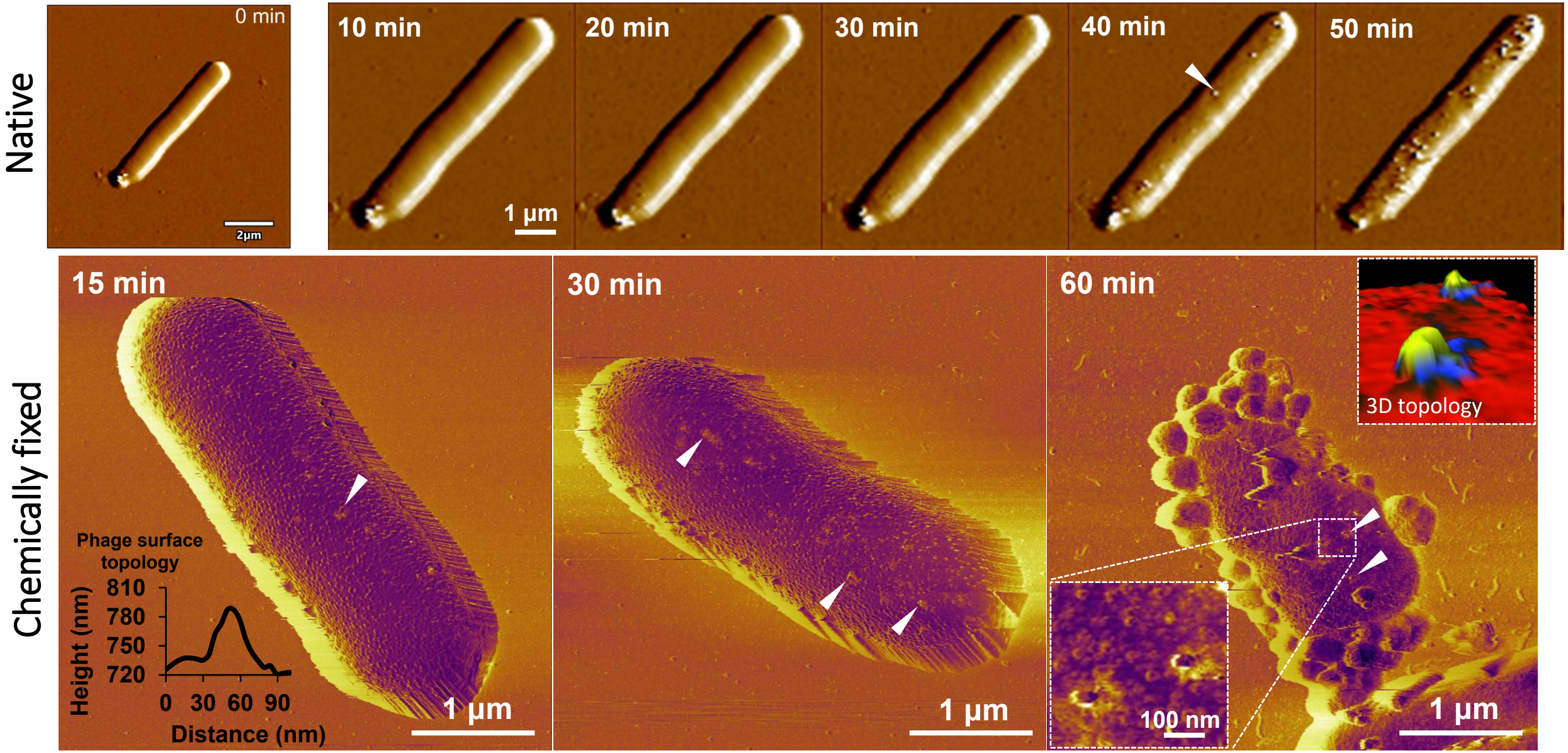


AFM image of a T7 virus



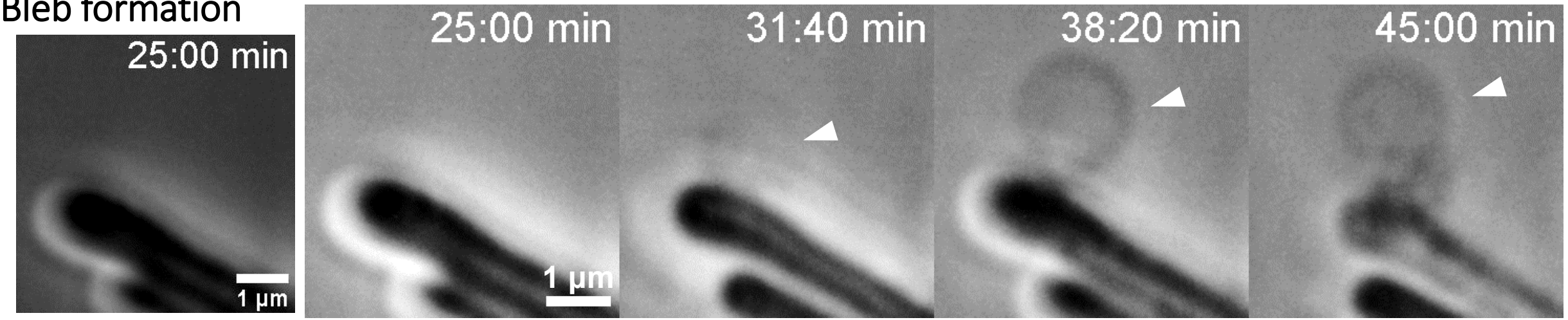


Phages saturate the bacterial surface by binding via their tail fibers

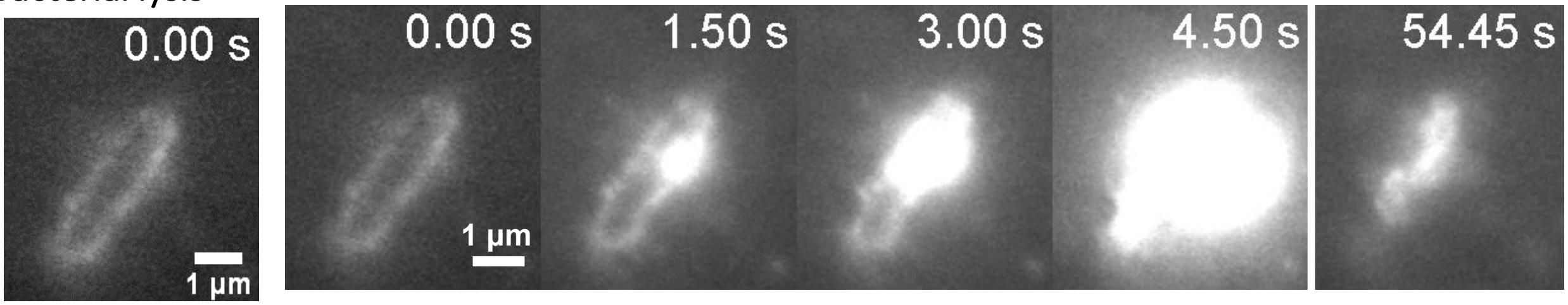


Viral infection leads to bleb formation and a violent host cell lysis

Bleb formation

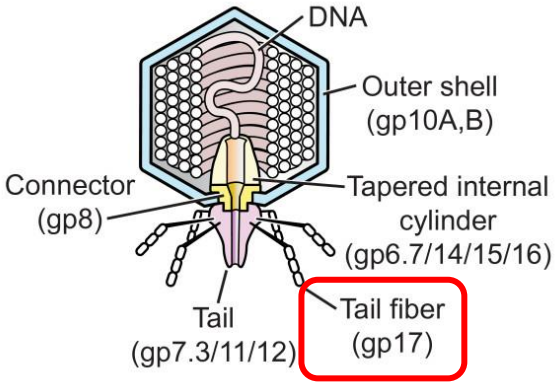


Bacterial lysis

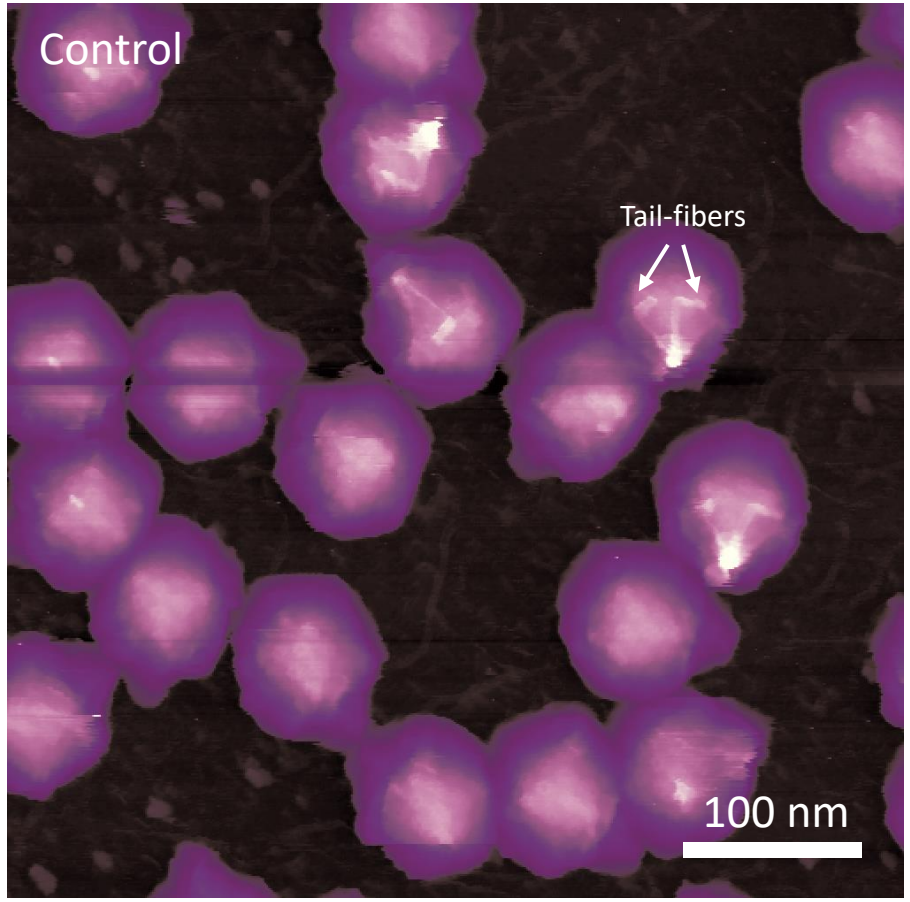


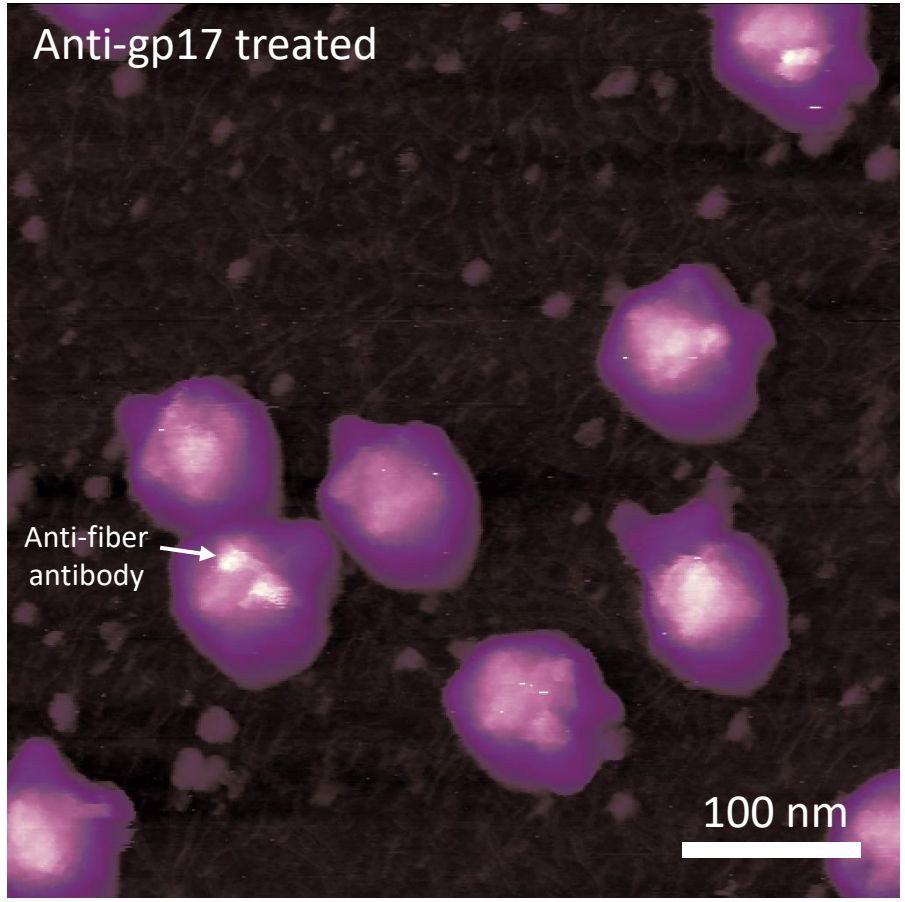
T7 tail fiber nanomechanics

T7 bacteriophage



Tail fiber specific antibody, but what is its exact target?

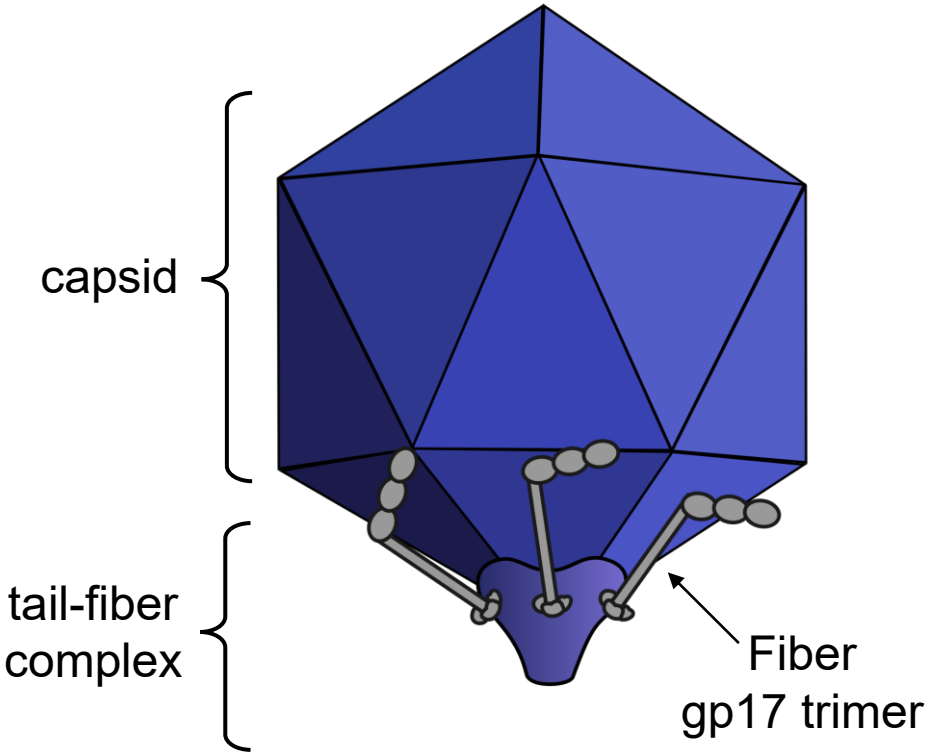




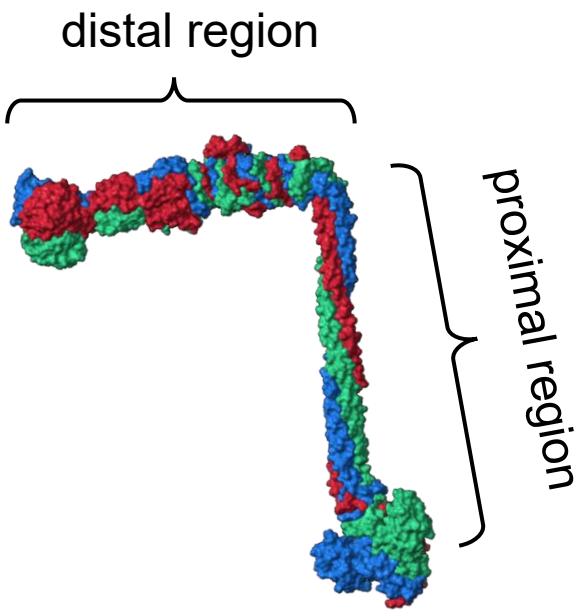
Antibody binds to the fibers' proximal region

T7 phage and fiber structure

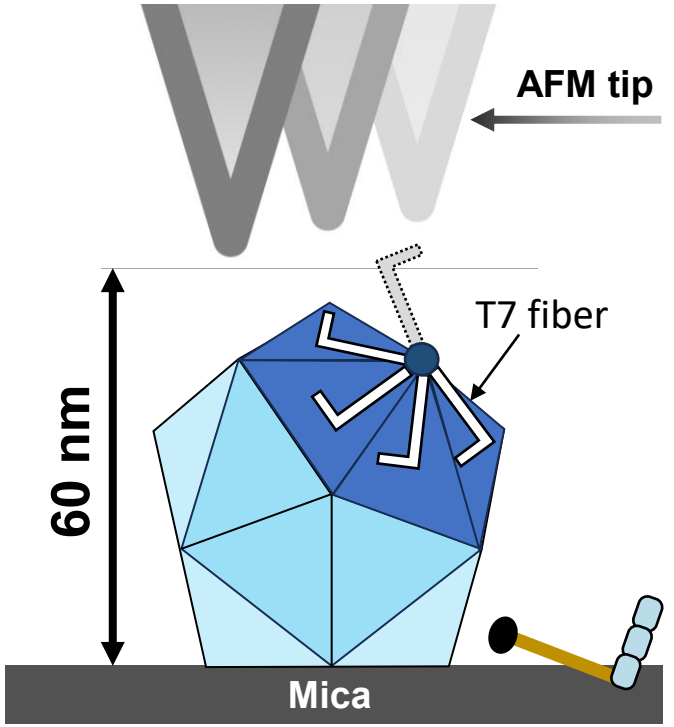
T7 structure

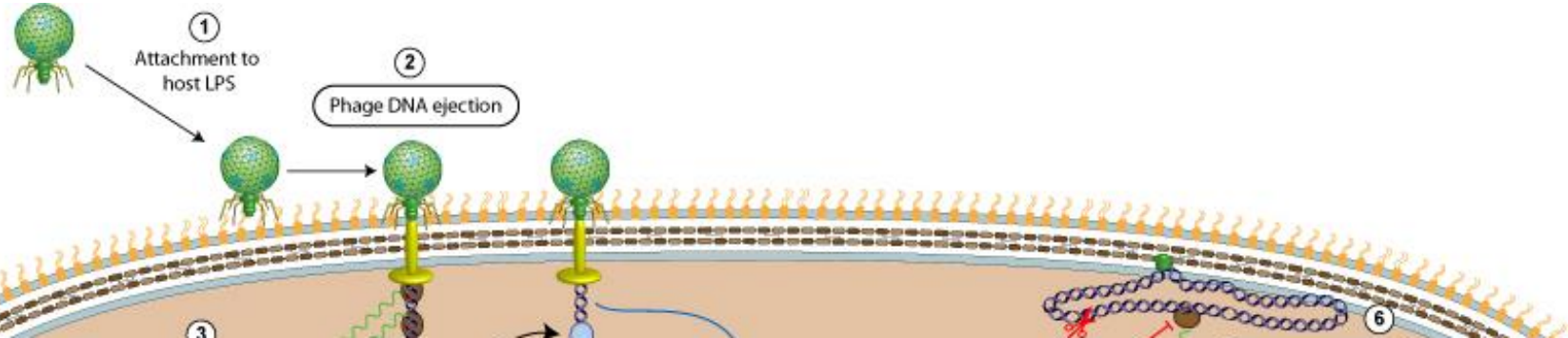


Fiber structure



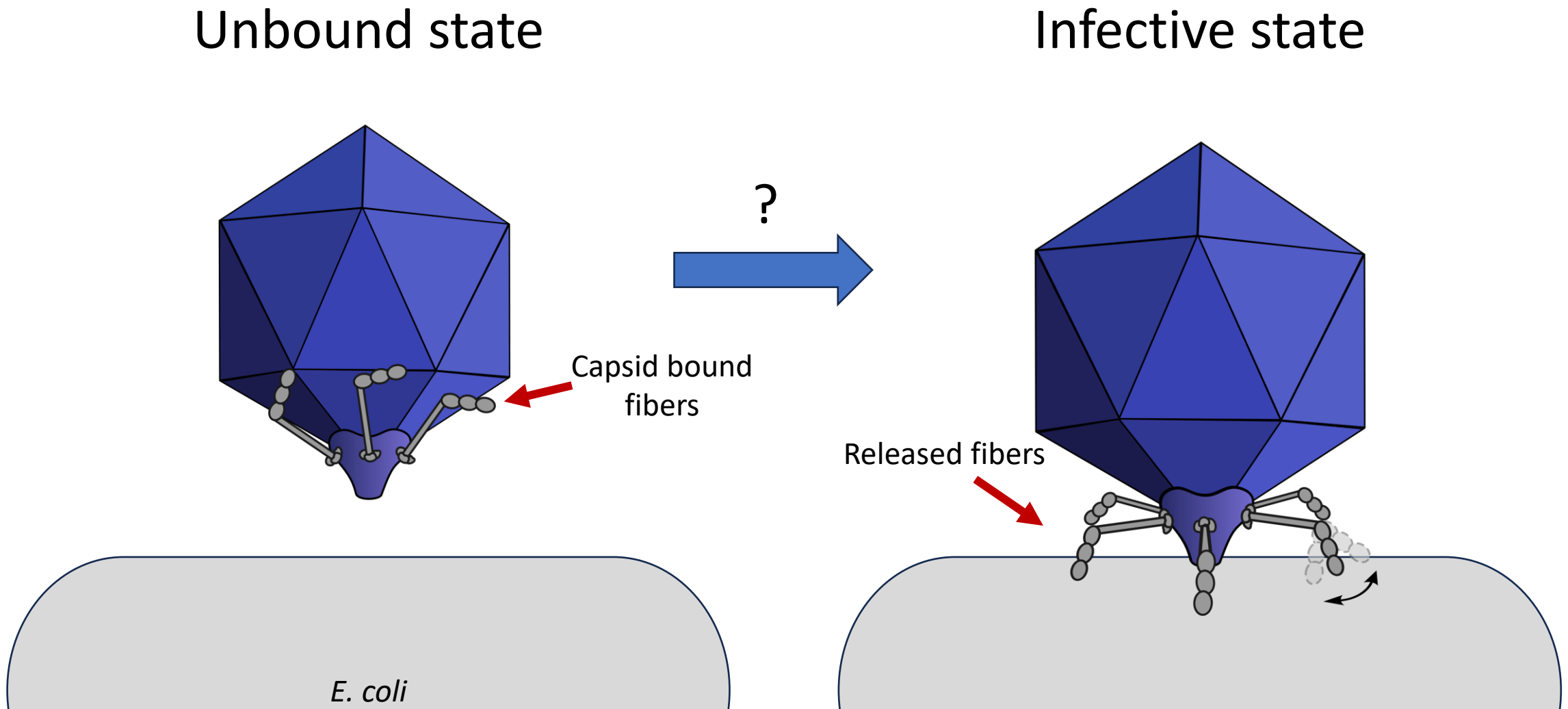
Imaging of single viruses and fibers



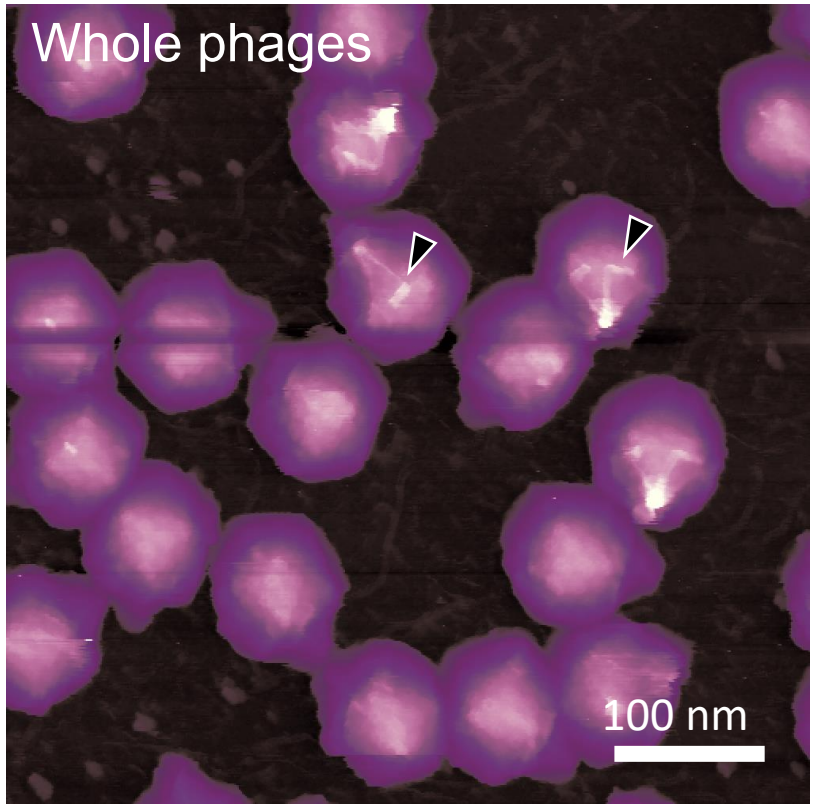


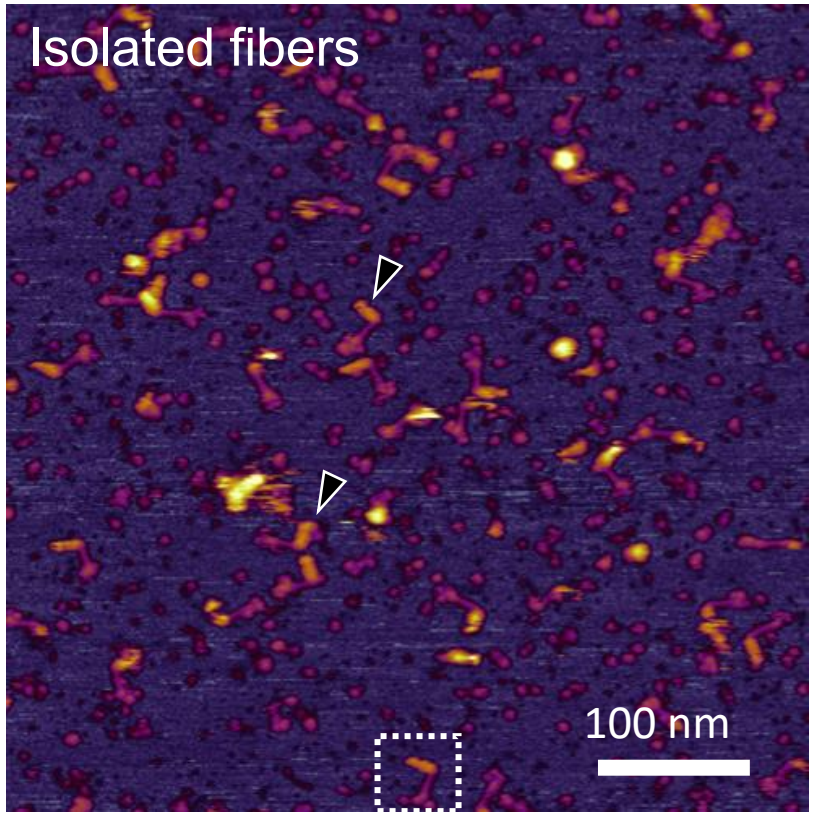
How do fibers transition into extended/infective state?

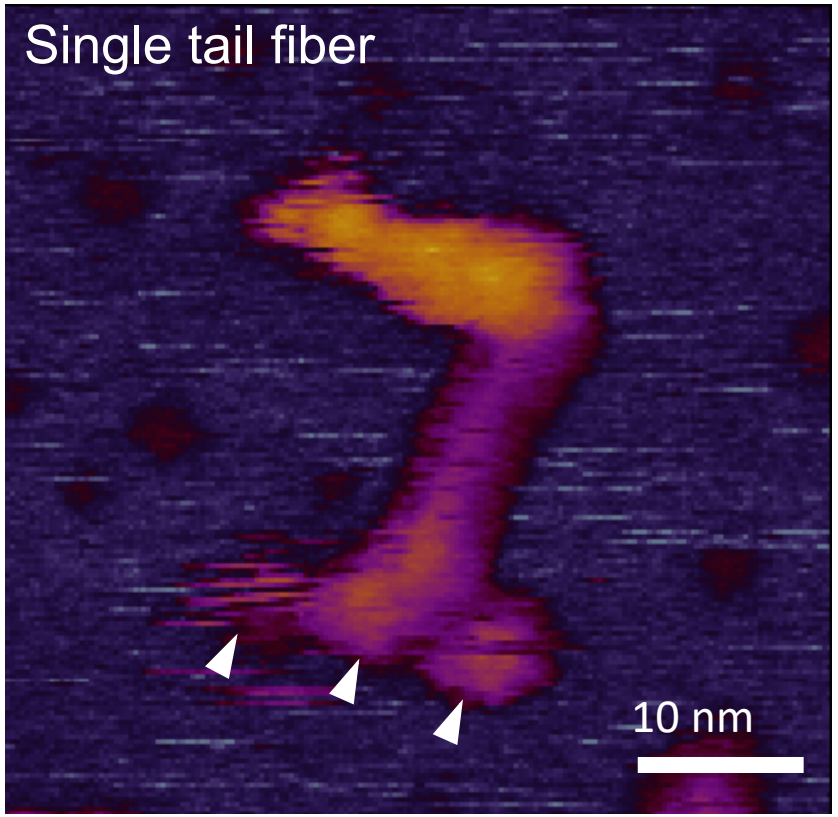
Is “walking” possible on the bacterial surface?



Isolated fibers of T7 bacteriophage

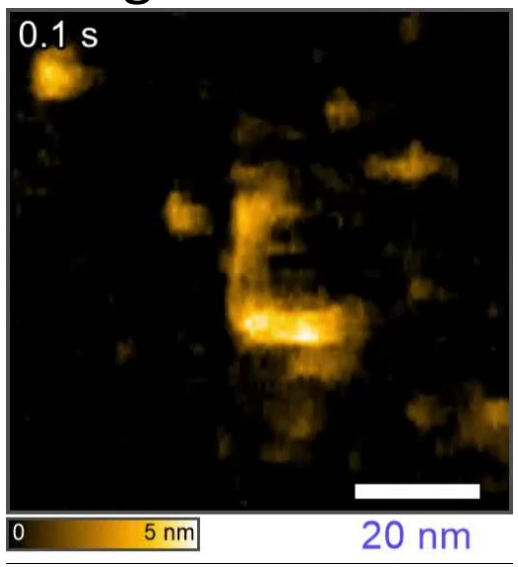


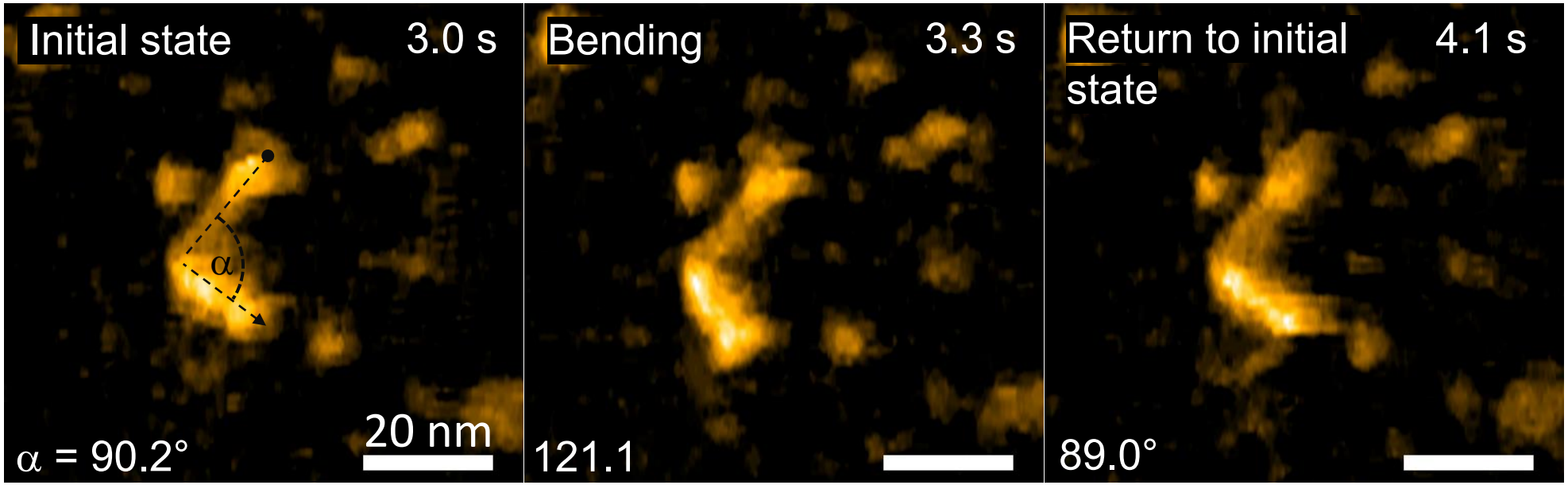




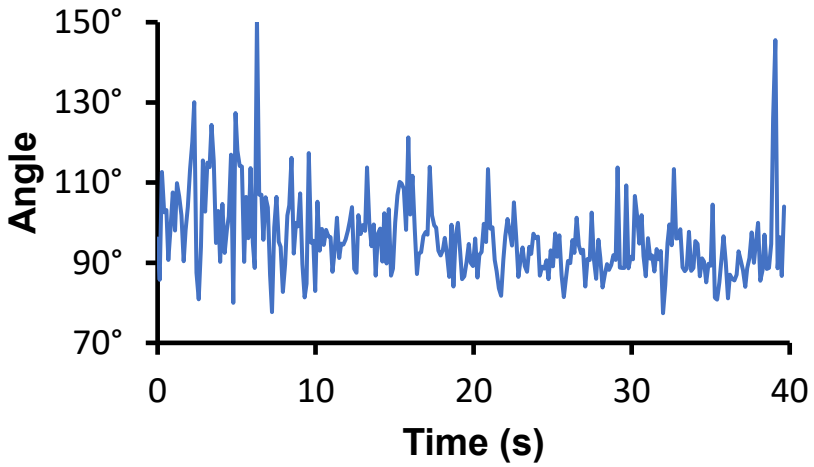
Fibers have a wide bending angle distribution

Hinge movement

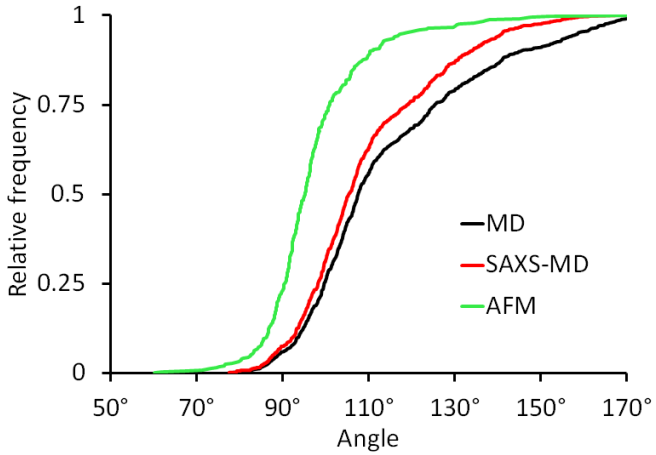




Bending angle over time

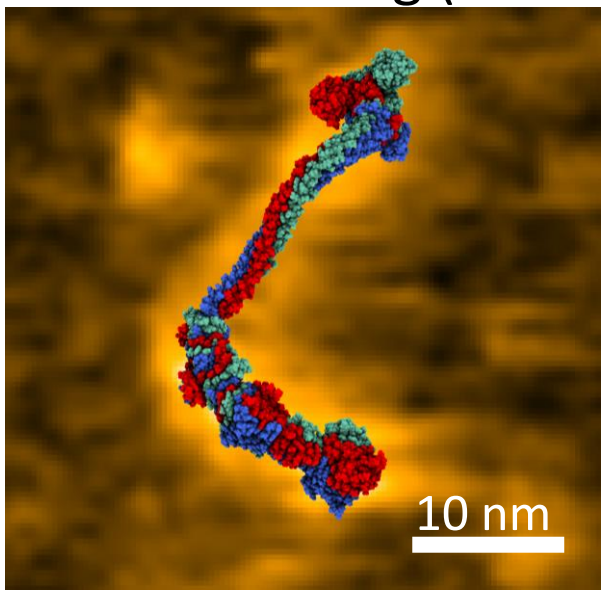


Bending angle distribution

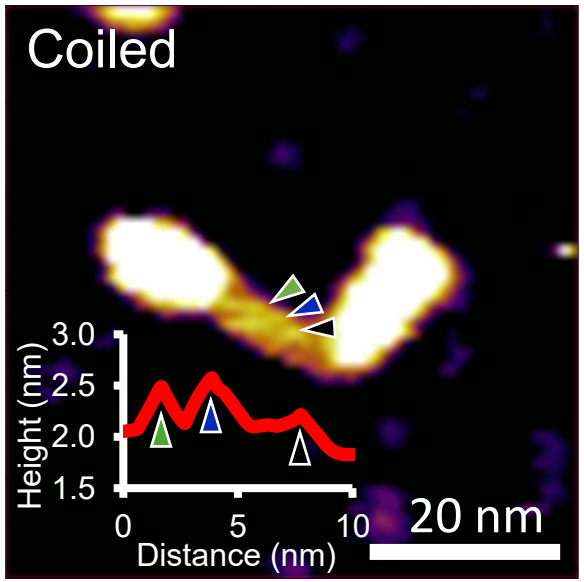


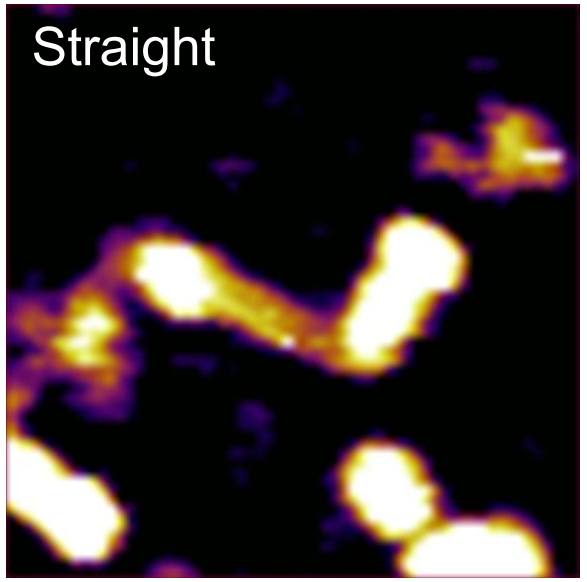
Fiber proximal section detailed structure

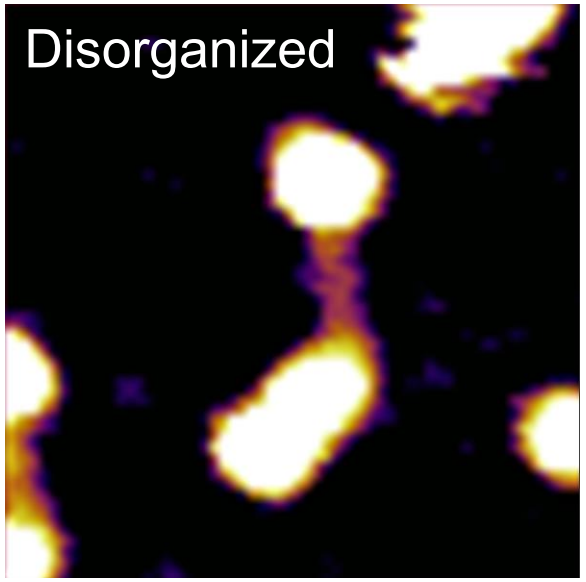
Structural fitting (NMFF)



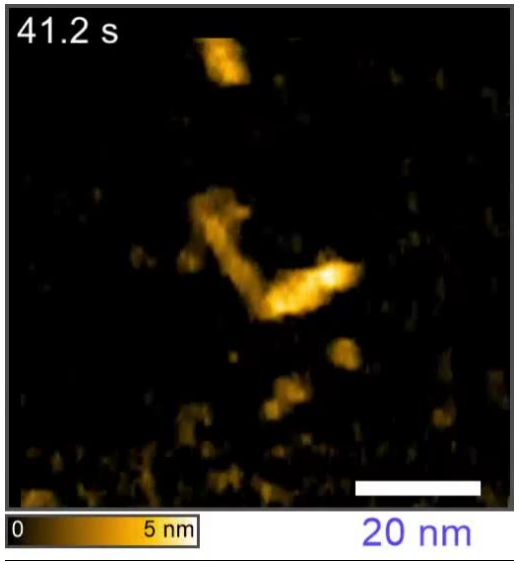
Fiber proximal section is a dynamic coiled-coil

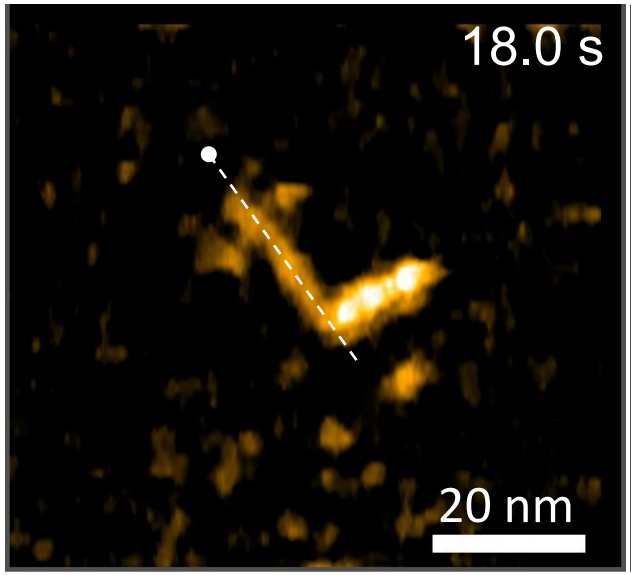


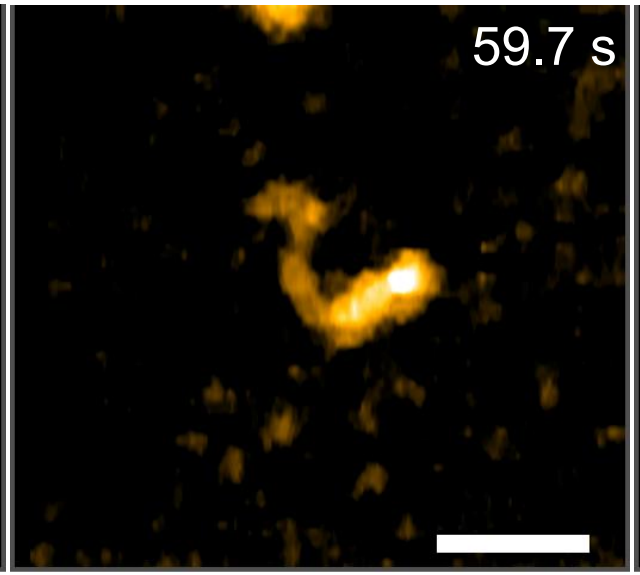


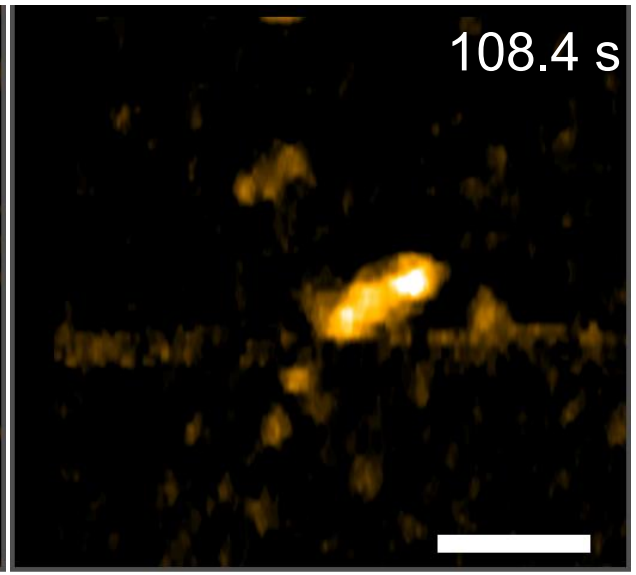


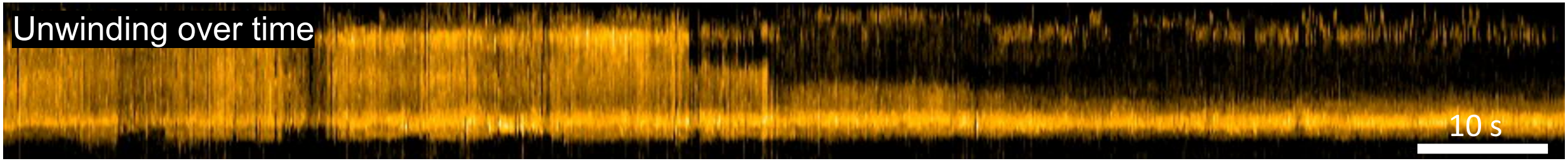
Fiber proximal section unwinding

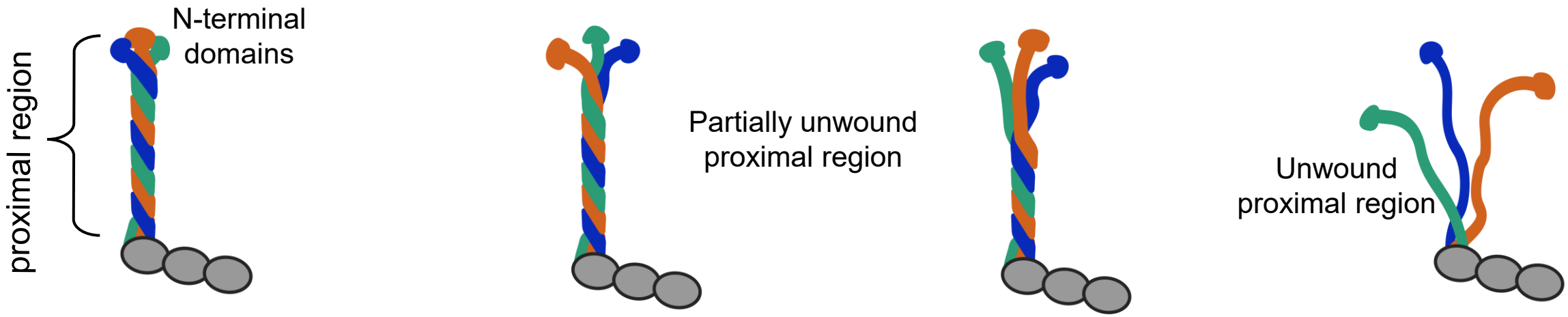




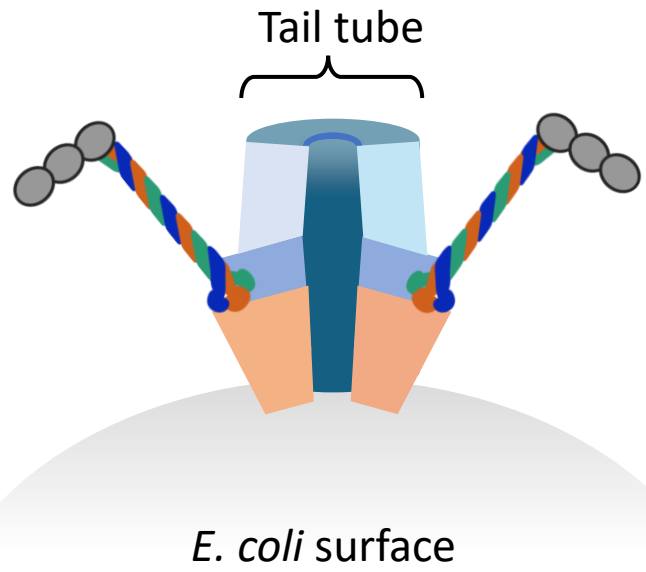




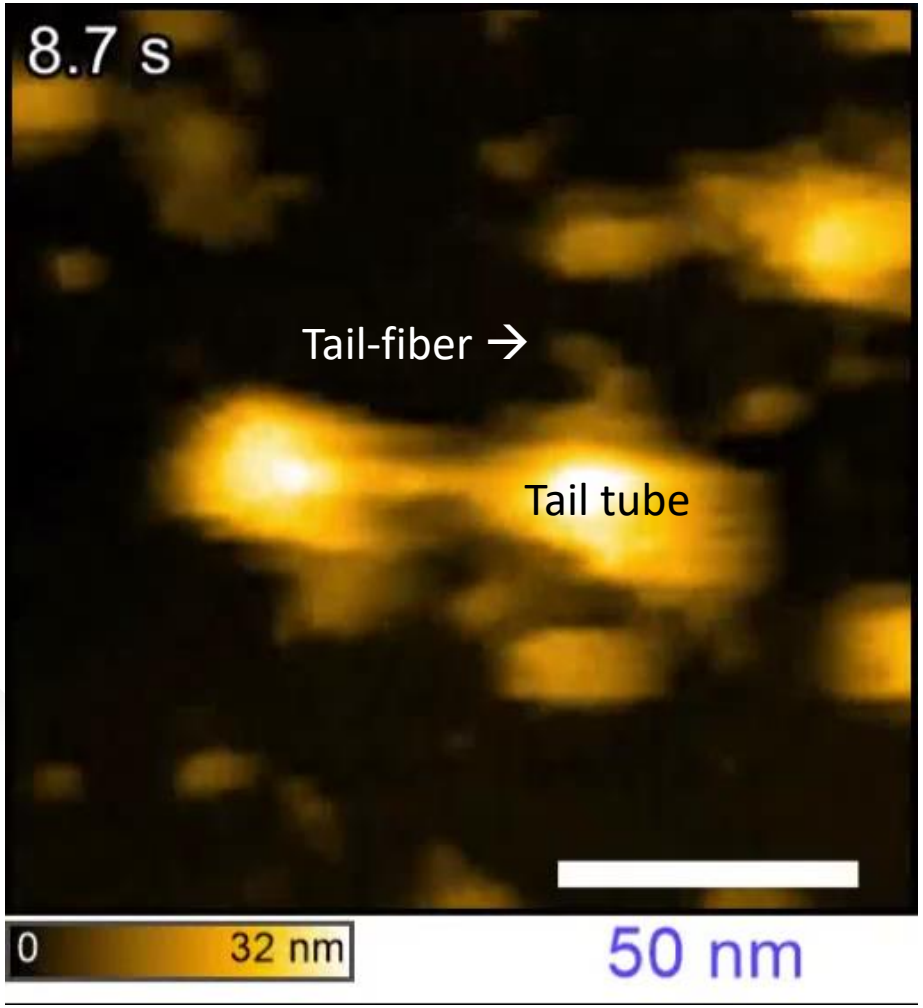




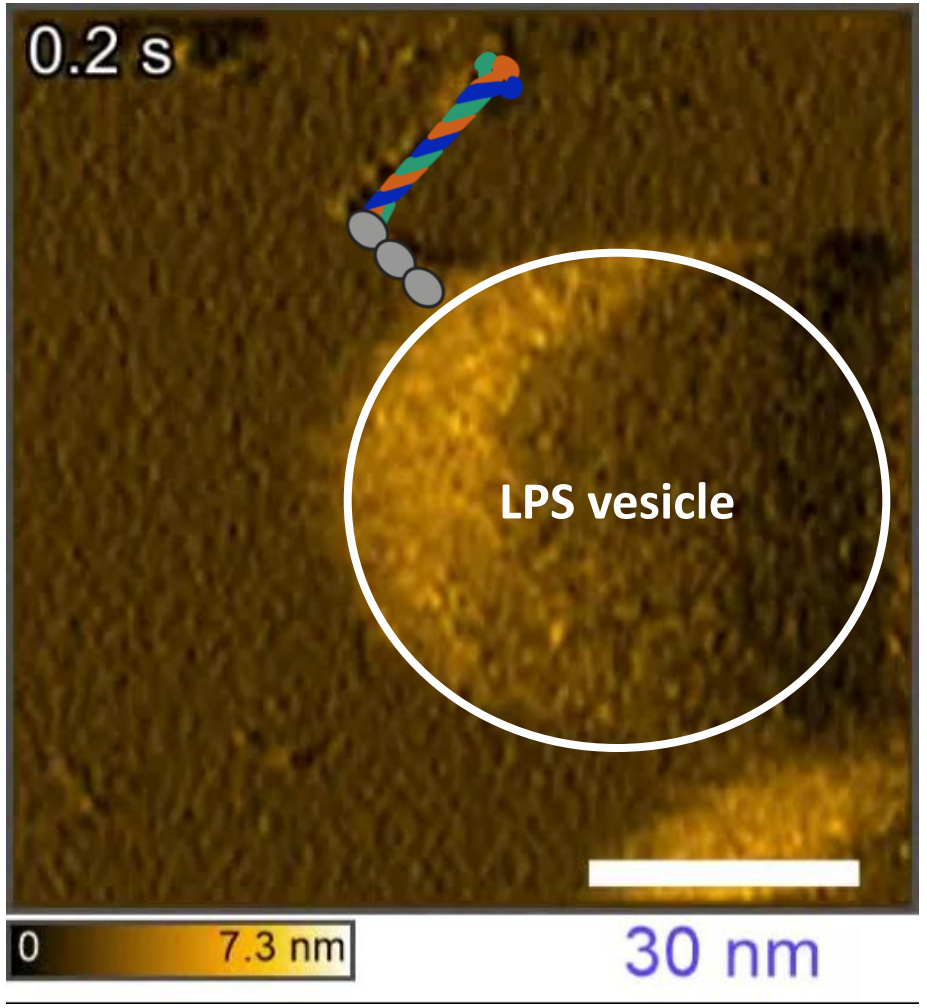
Fiber binding and motion in more “native” states



Tail tube bound fiber movement

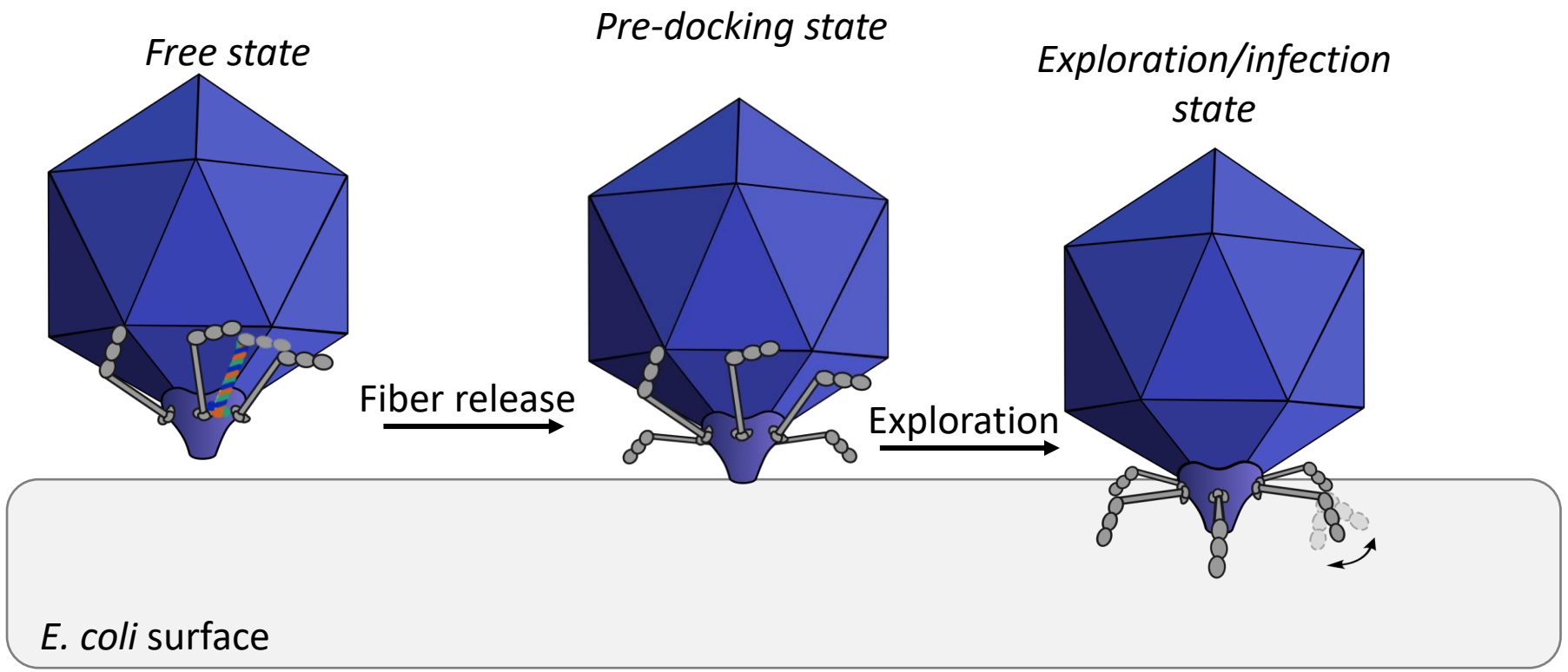


Fiber “jumping” on lipopolysaccharide vesicles

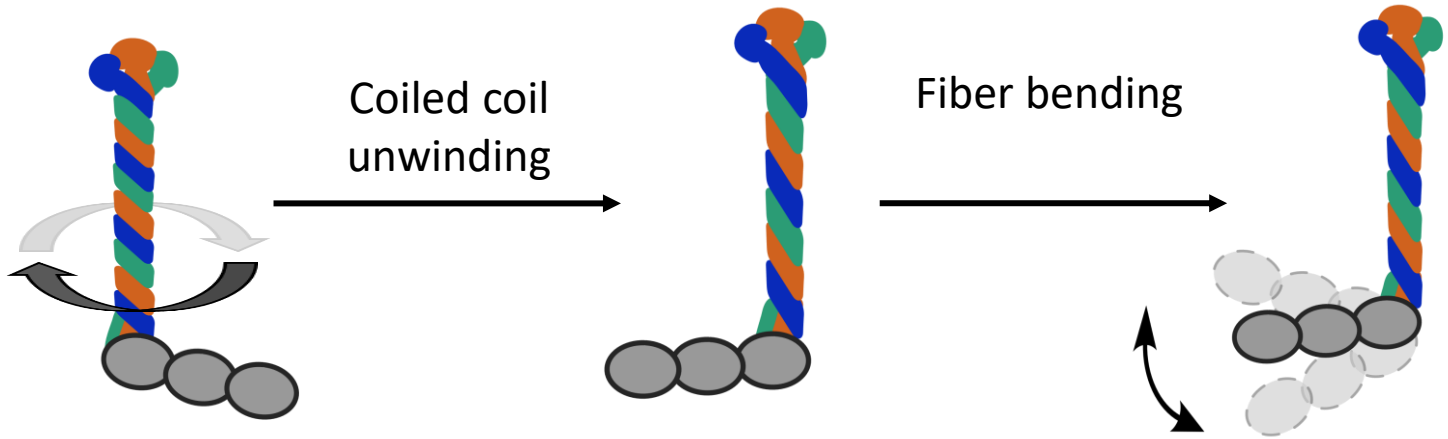


Role of fibers in target recognition and docking

Fiber bending:
Internal hinge region



Fiber rotation:
Dynamic coiled coil



Future plans…

- High-speed AFM imaging of whole tail fiber complexes
- Imaging fibers and tail-complexes on living bacteria
- Measuring virus-host interaction forces with optical tweezers

Special thanks to my students and colleagues:

Luca Kosik
PhD student

Miklós Cervenak
Student researcher

Dominik Sziklai
Postdoc researcher

And funders:

Nemzeti Kutatási, Fejlesztési és Innovációs Hivatal

HUN REN

金沢大学 Kanazawa University