BioNanoPhysics

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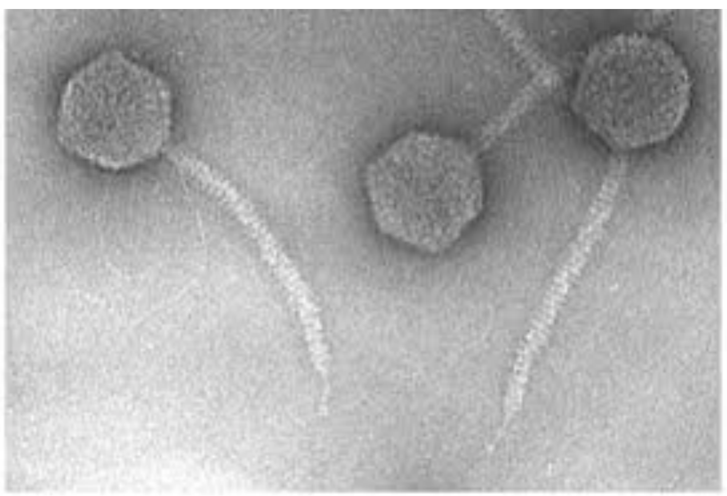
Concept and outline

- Present research topics in current biophysics
- Example of biology papers where concepts from physics turned out to be important
- One lecture = one paper + background material
- Most lectures will be by us, but students are encouraged to contribute

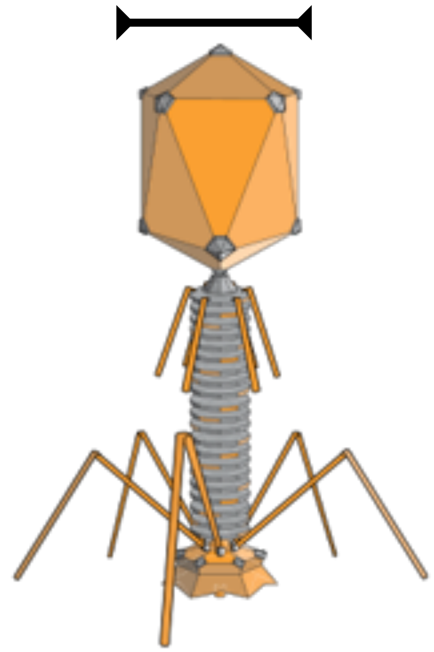
Date	Speaker	Title
12.10.		
19.10.	Richard Neher	**DNA packing into virus capsids** *[Grayson et al. Real-time observations of single bacteriophage lambda DNA ejections in vitro. Proceedings of the National Academy of Sciences of the United States of America (2007) vol. 104 (37) pp. 14652-7]*
26.10.	Fajun Zhang	**Protein crystallization: some physical insights (I)**
02.11.	Fajun Zhang	**Protein crystallization: some physical insights (II)**
09.11.	Richard Neher	**Gene regulation, diffusion, and developmental patterning** *[Gregor et al. Stability and nuclear dynamics of the bicoid morphogen gradient. Cell (2007) vol. 130 (1) pp. 141-52]*
16.11.	Richard Neher	**Oscillations in Biology** *[Di Talia et al. The effects of molecular noise and size control on variability in the budding yeast cell cycle. Nature (2007) vol. 448 (7156) pp. 947-51* *Charvin et al. Forced periodic expression of G1 cyclins phase-locks the budding yeast cell cycle. Proceedings of the National Academy of Sciences of the United States of America (2009) vol. 106 (16) pp. 6632-7]*
23.11.	Richard Neher	**Self-organized compartmentalization: liquid-liquid phase transitions within cells** *[Brangwynne et al. Germline P granules are liquid droplets that localize by controlled dissolution/condensation. Science (2009) vol. 324 (5935) pp. 1729-32]*
30.11.	Frank Schreiber	**Fractals in nature**
07.12.	Fajun Zhang	**Biofouling and anti-biofouling at interface**
14.12.	Frank Schreiber	**Growth processes and growth laws in nature (from bacteria to dinosaurs to snowflakes)**
21.12.	Richard Neher	**Polarity of tissues: Why do all the hairs point in the same direction?** *[Ma et al. Fidelity in planar cell polarity signalling. Nature (2003) vol. 421 (6922) pp. 543-7* *Burak and Shraiman. Order and stochastic dynamics in Drosophila planar cell polarity. PLoS Comput Biol (2009) vol. 5 (12) pp. e1000628]*
11.01.	F. Zhang/Student?	**DNA condensation, coacrevation**
18.01.	Richard Neher	**How do cells gets their shape?** *[Campàs and Mahadevan. Shape and dynamics of tip-growing cells. Curr Biol (2009) vol. 19 (24) pp. 2102-7]*
25.01.	Richard Neher	**The folding of the gut** *[Savin et al. On the growth and form of the gut. Nature (2011) vol. 476 (7358) pp. 57]*

Phages -- bacterial viruses



lambda phage

50 nm



T4 phage

phages attached to a bacterium

Phage -- hydrogen atom of Molecular Biology

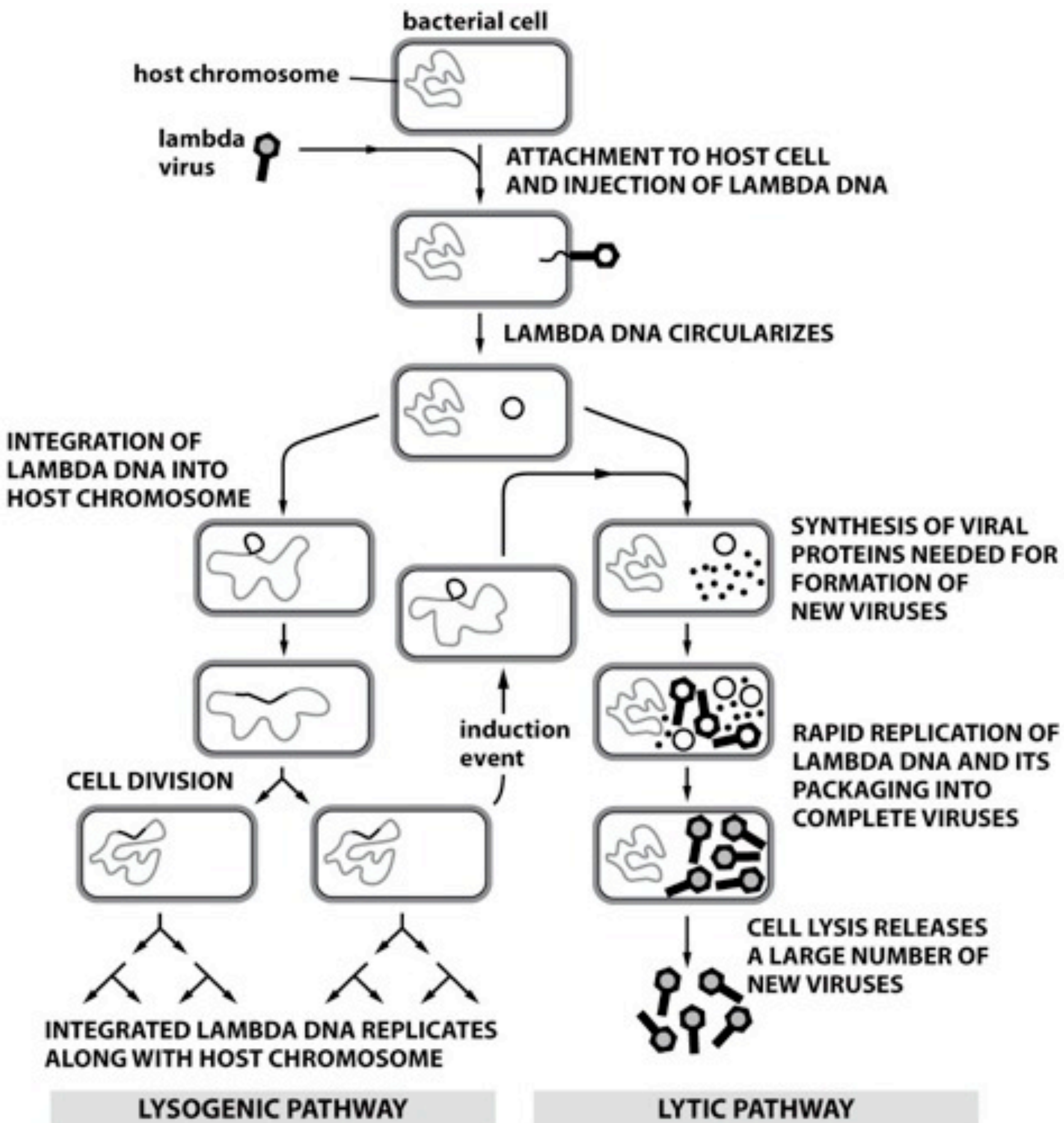
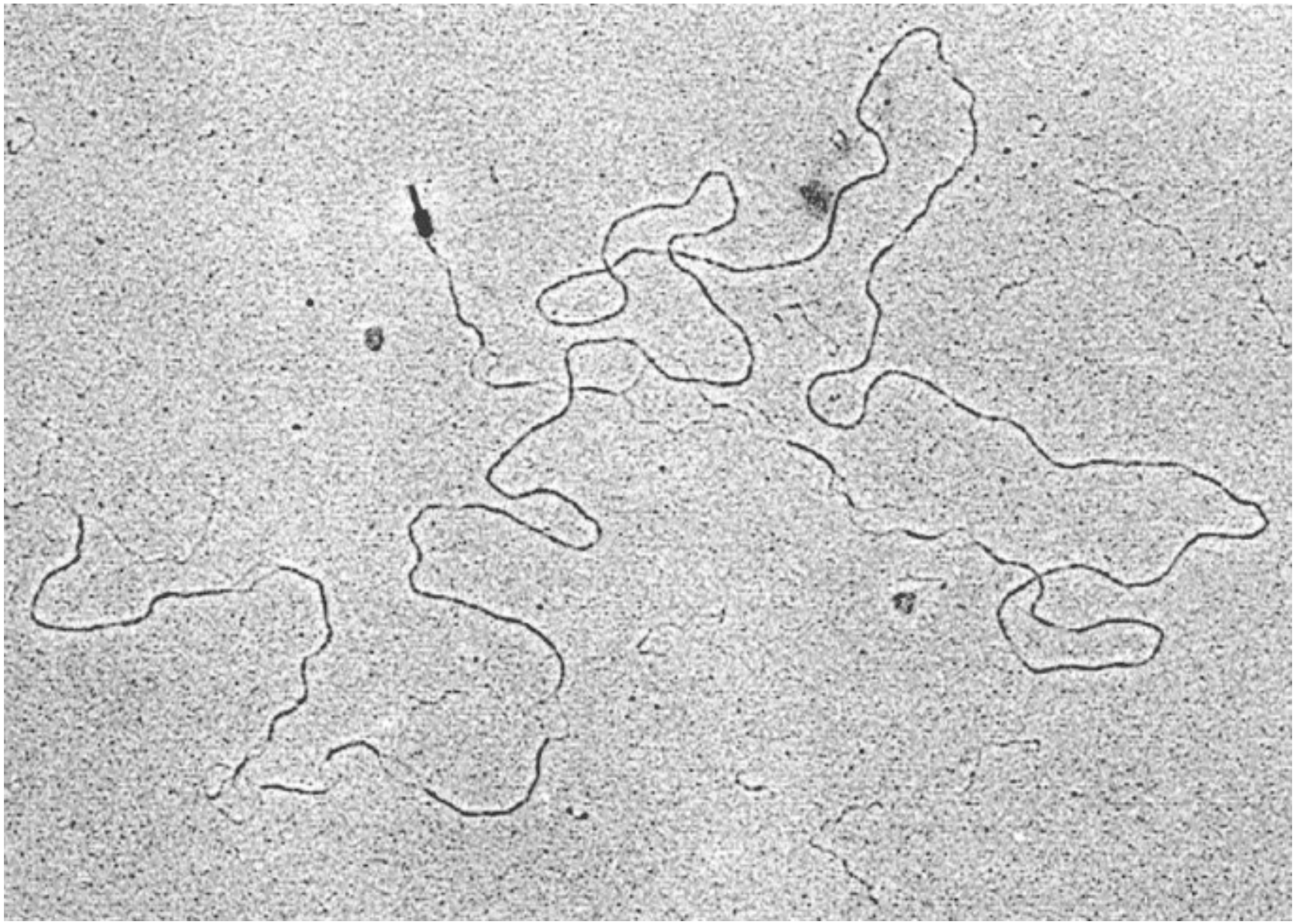


Figure 4.10 Physical Biology of the Cell (© Garland Science 2009)

- Discovery that DNA is the carrier of hereditary information
- Collinearity of DNA and protein
- Triplet nature of the genetic code
- the first organism to have its DNA sequenced

We continue to learn from phages!

The phage and its genome



- Diameter: 52nm
- Genome length: 50000bp = 15μm
- DNA is highly charged

→

Work has to be done to get the DNA inside: Molecular motor

Packing of DNA

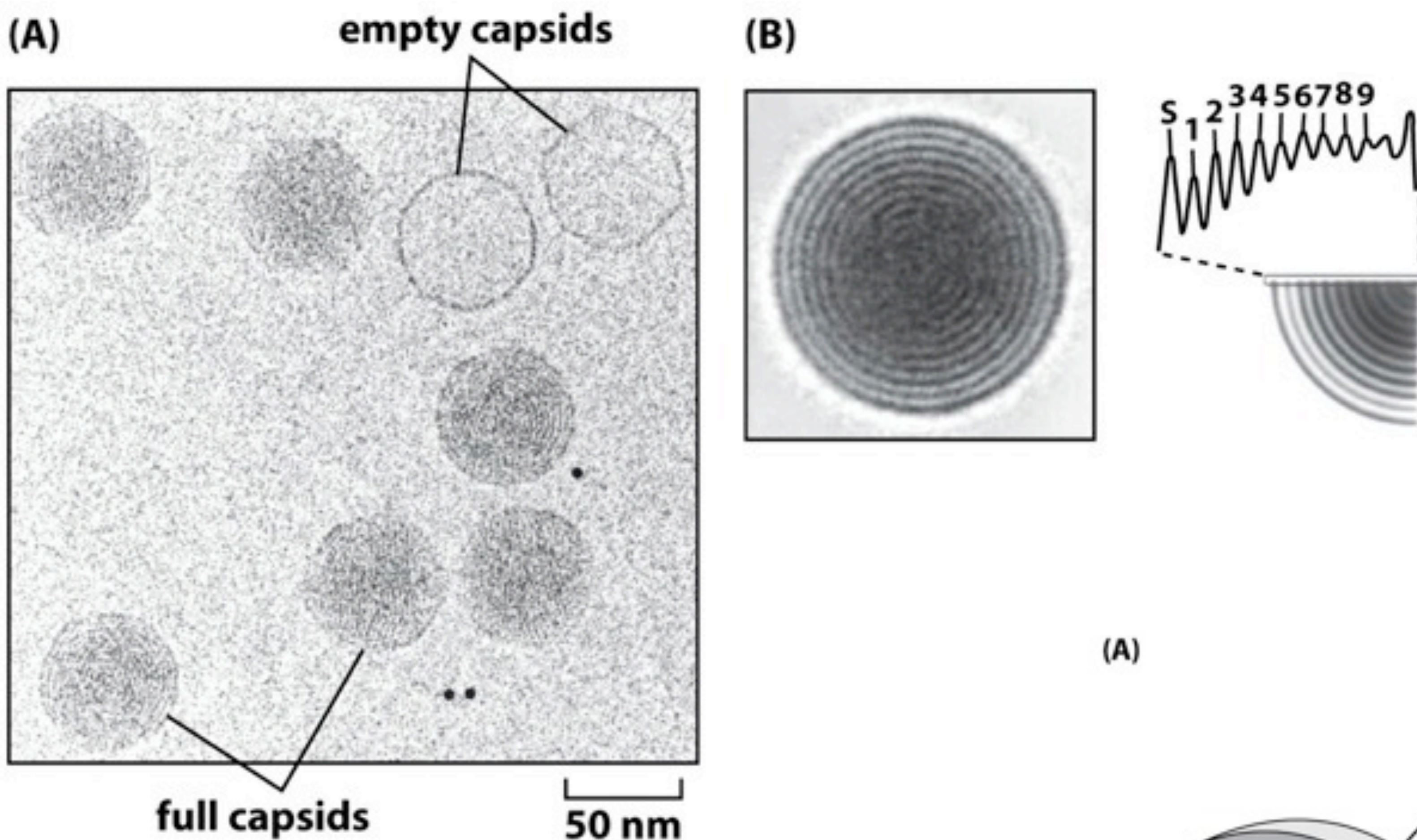


Figure 10.14 Physical Biology of the Cell (© Garland Science 2009)

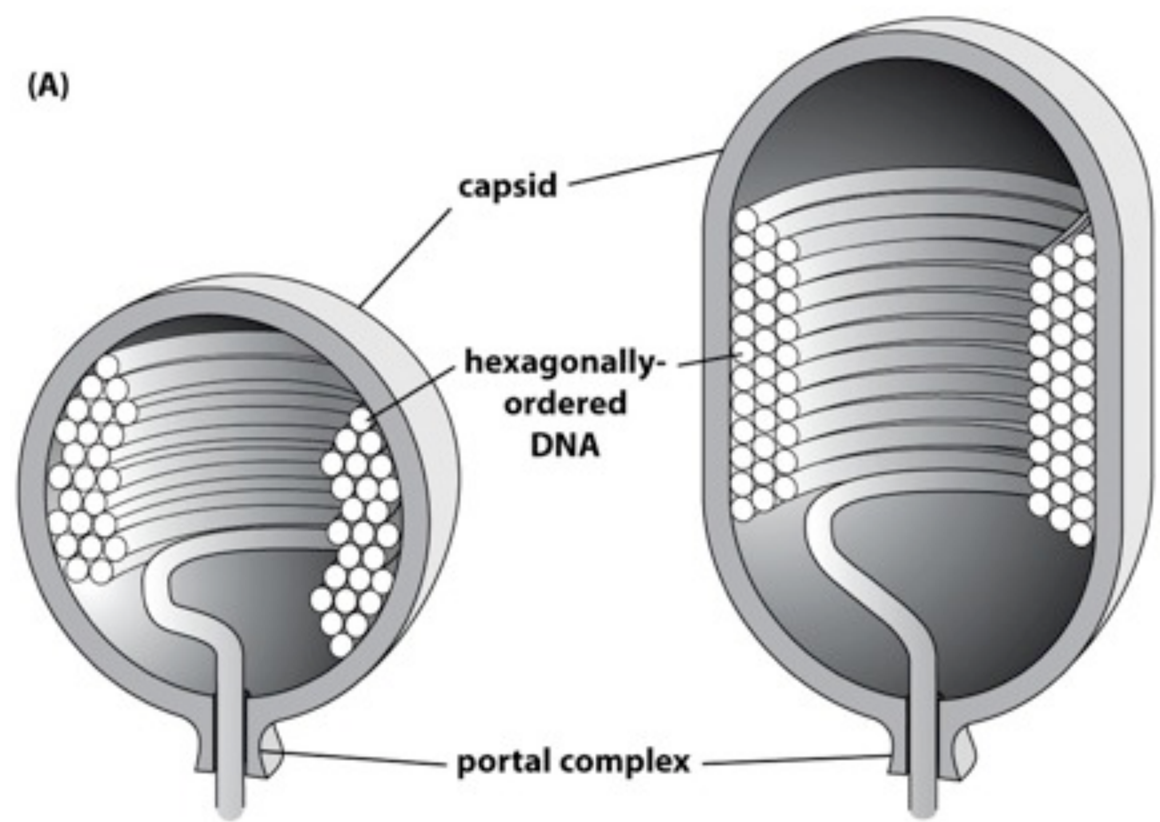
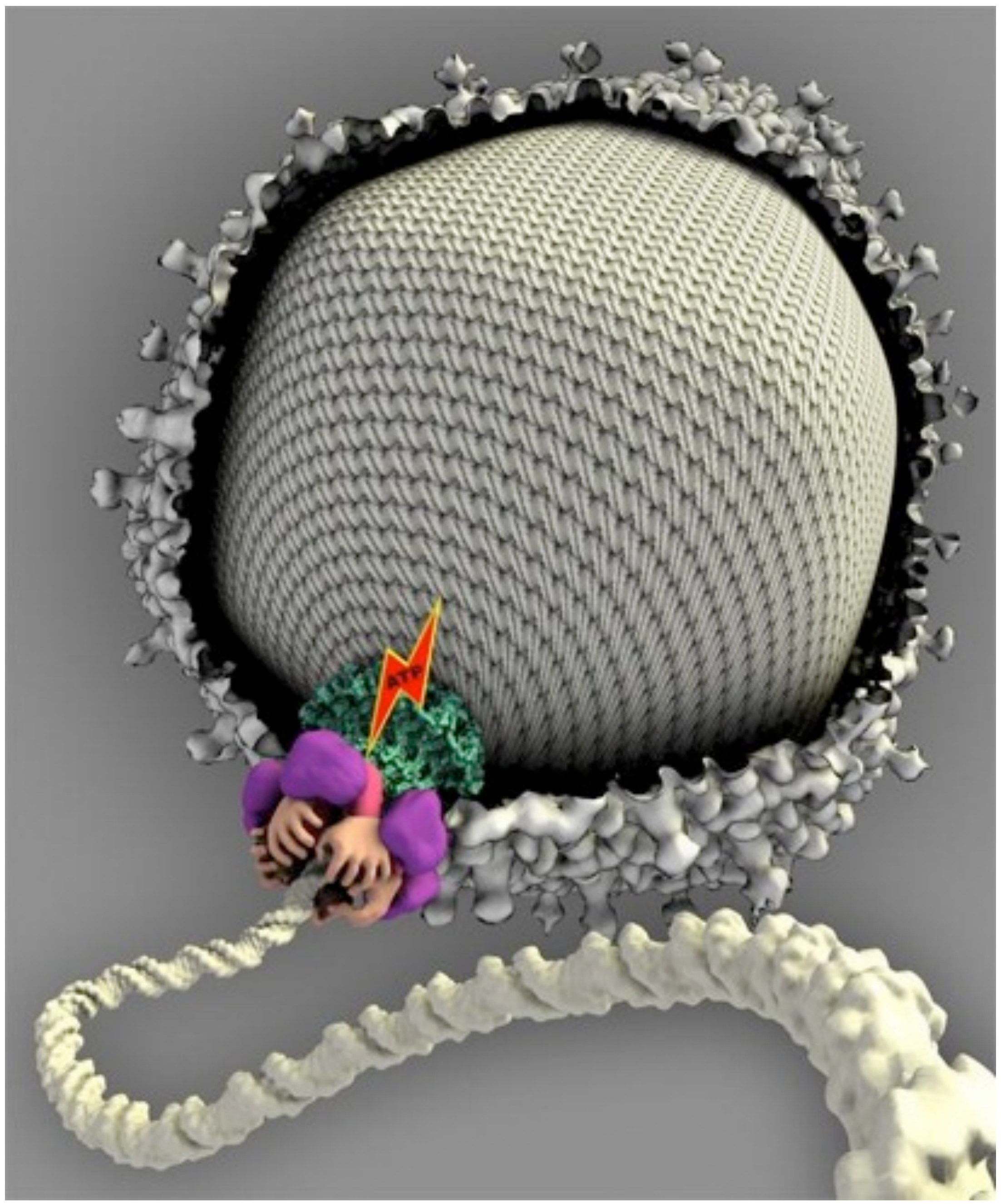
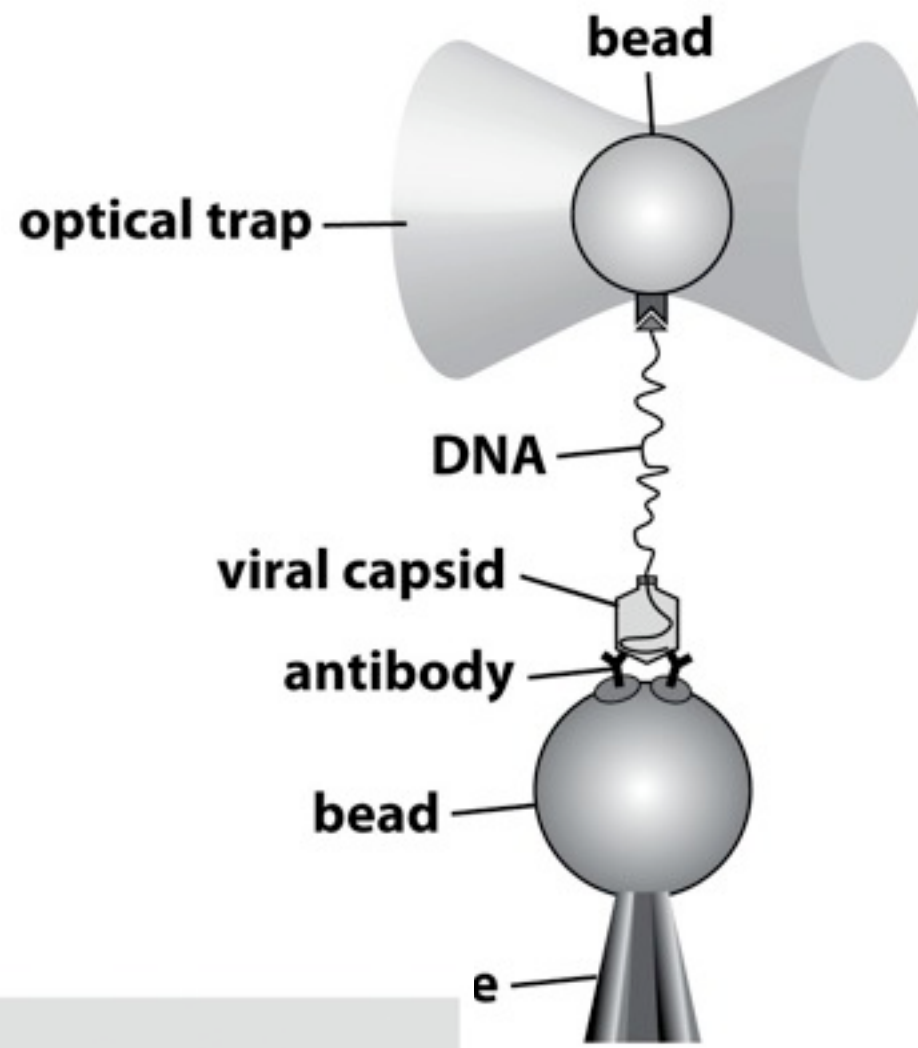
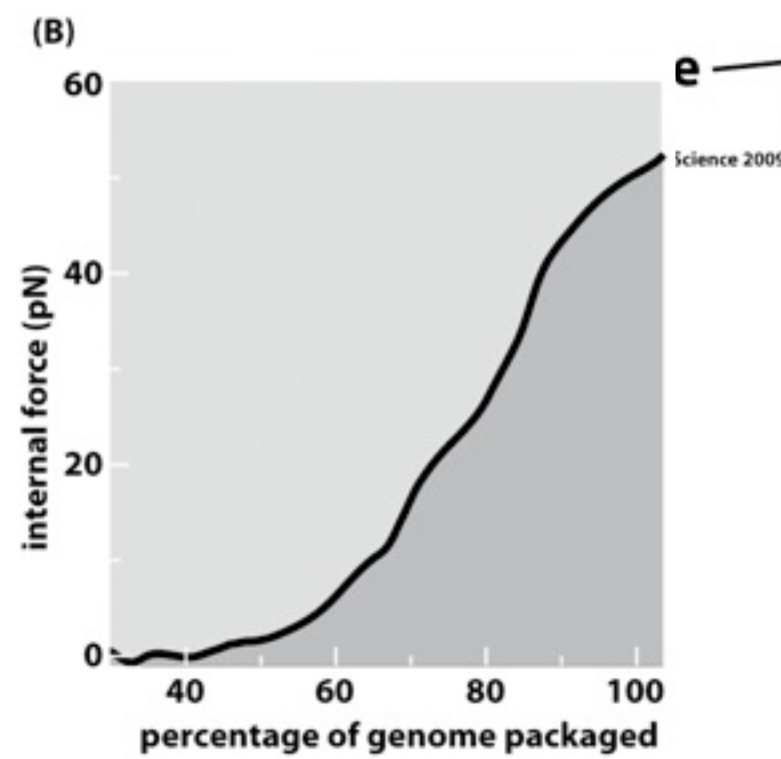


Figure 10.15 Physical Biology of the Cell (© Garland Science 2009)

How does it get in there?

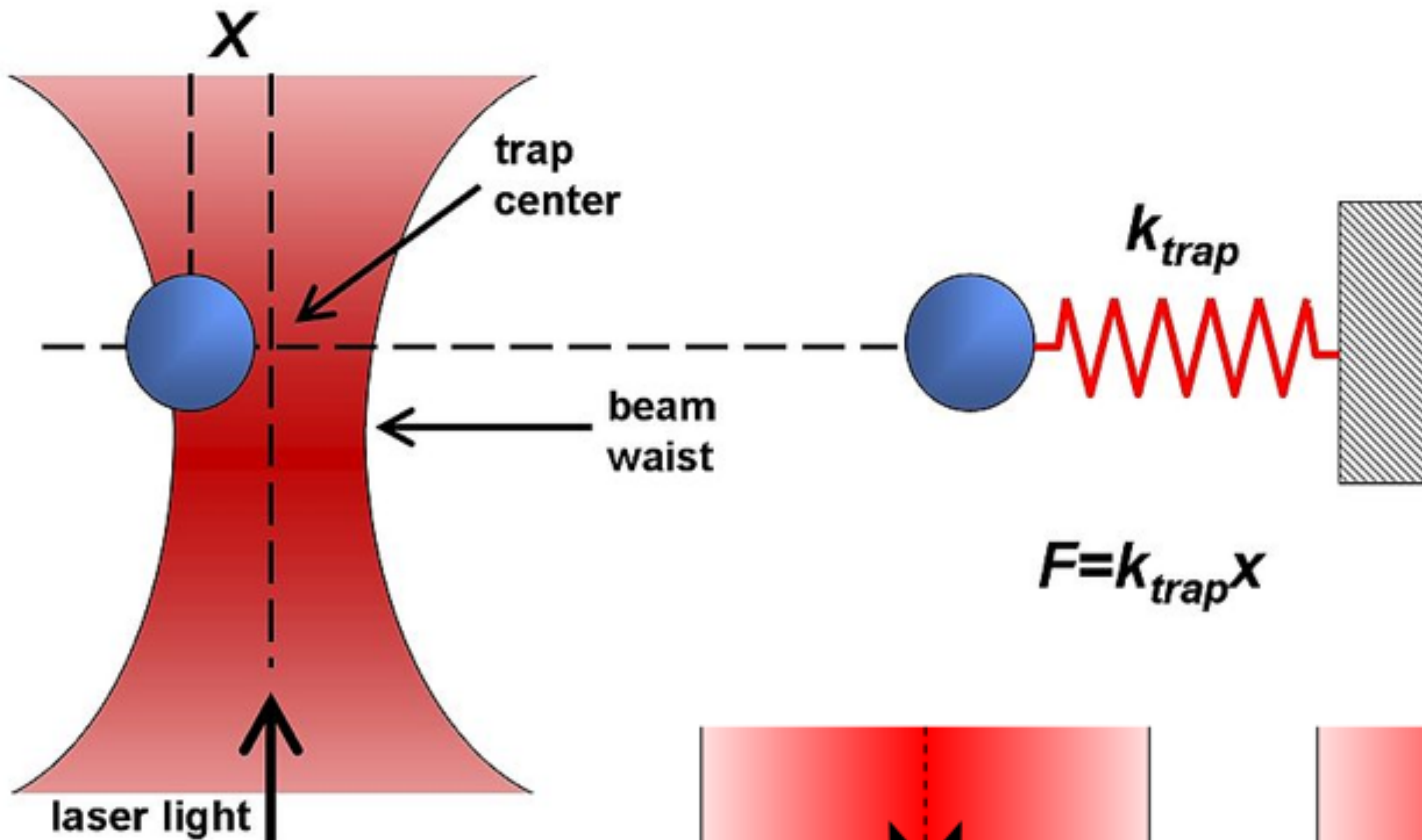




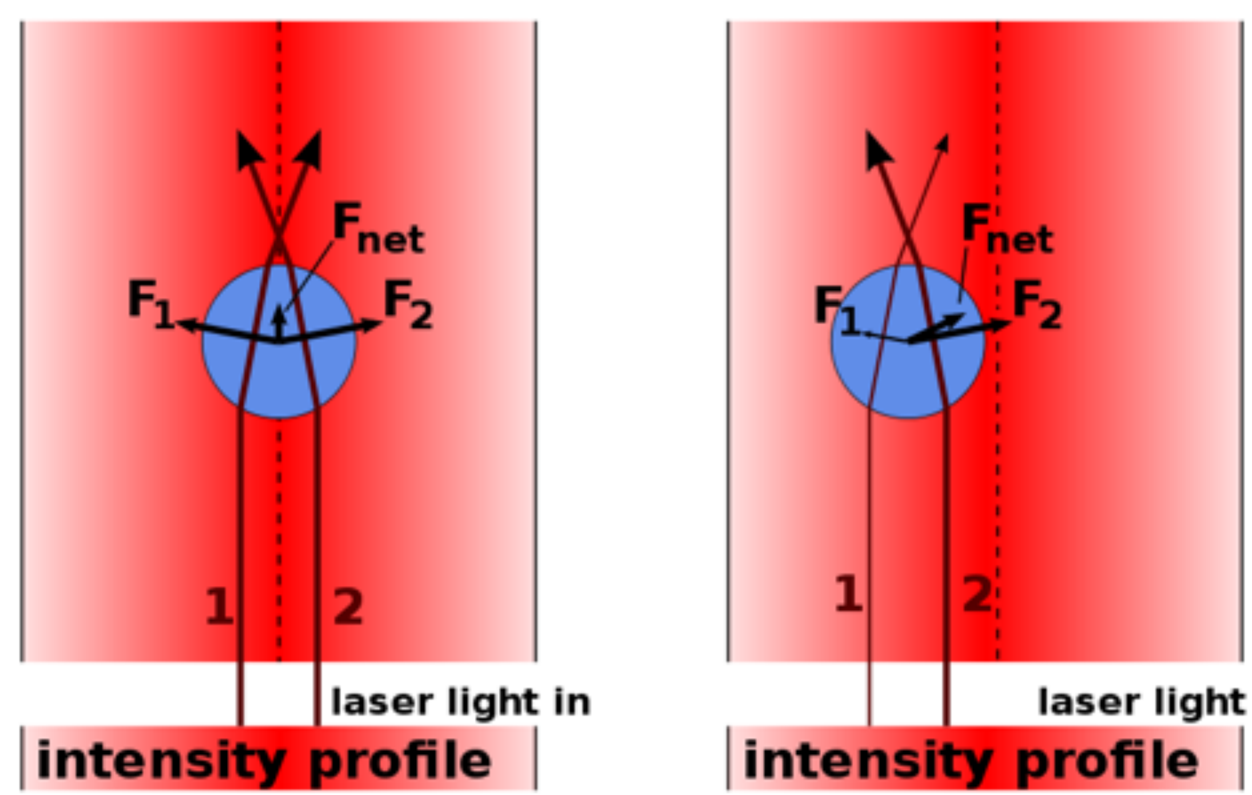


ATP hydrolysis = 25 kT
kT = 4 pN nm

Optical tweezers



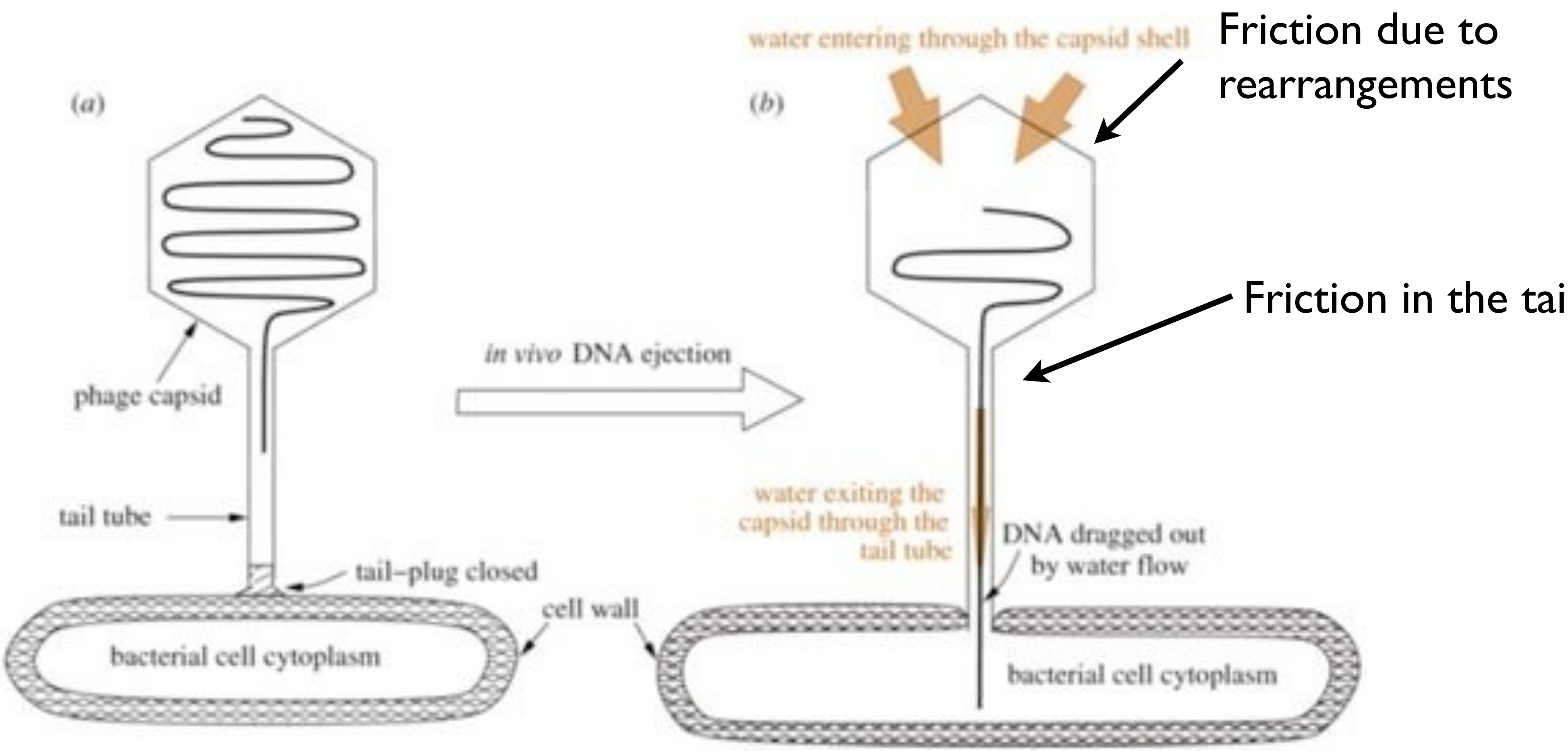
Force range: 150pN



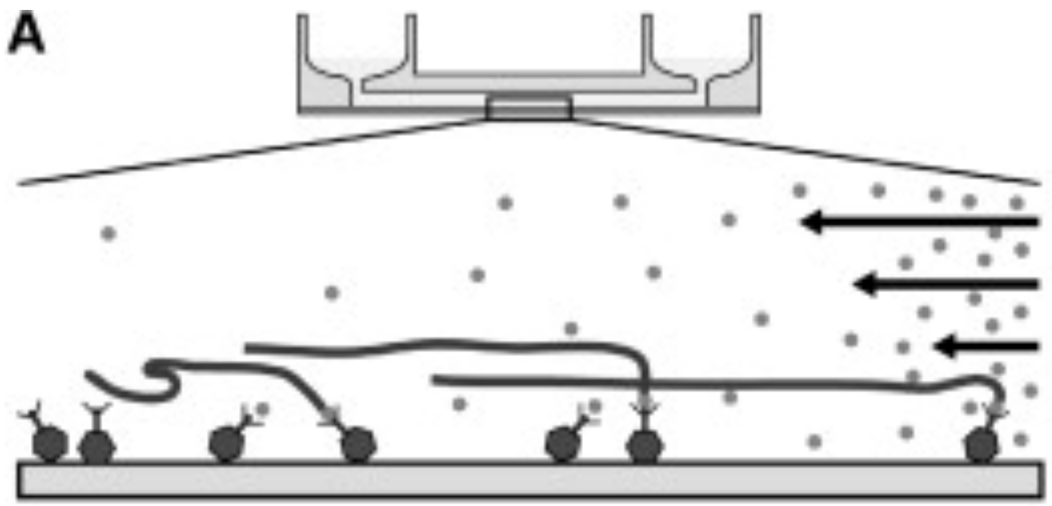
Images: Wikipedia

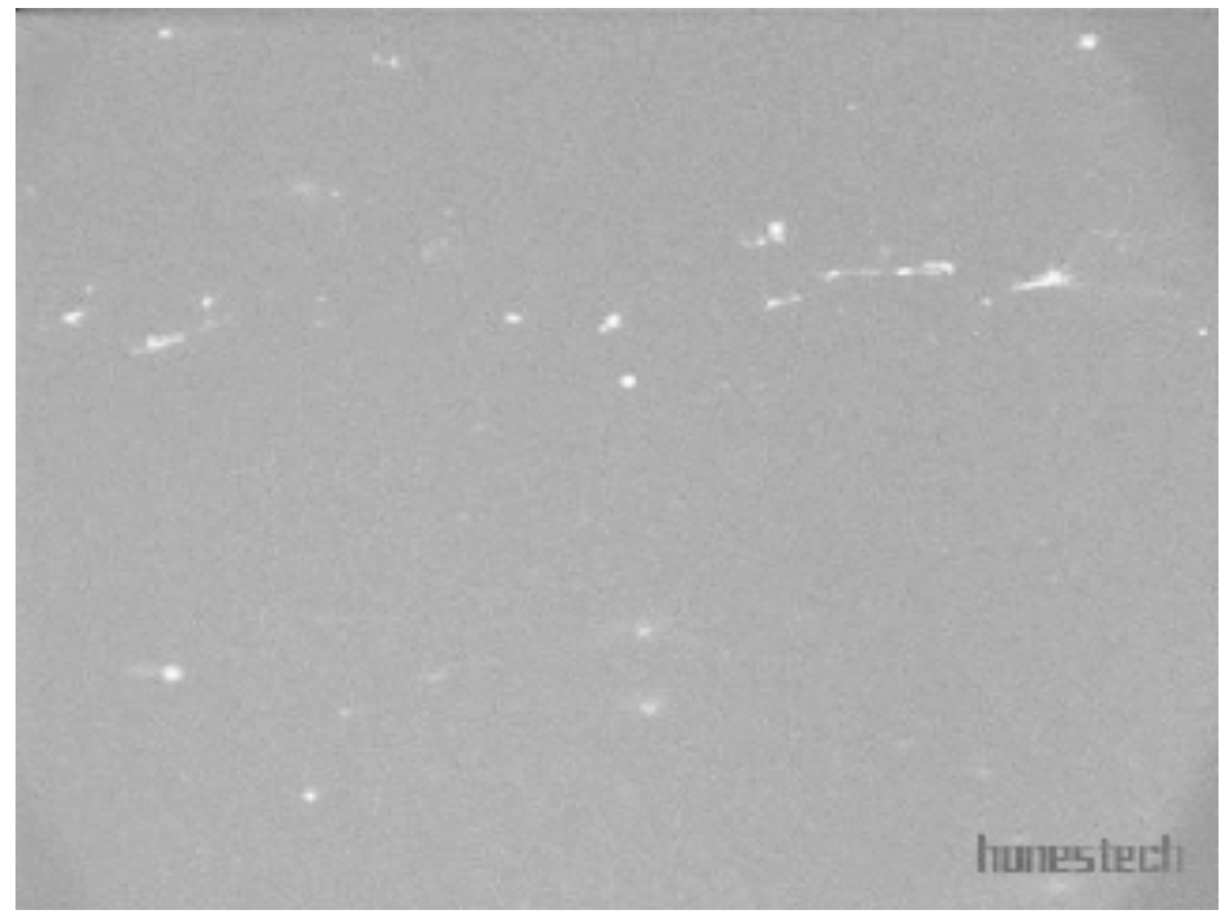
Ejection of DNA from the phage

- Passive process, driven by the work done during packaging
- "spring loaded"
- triggered by interaction with a protein on the bacterial surface



Dynamics of DNA ejection



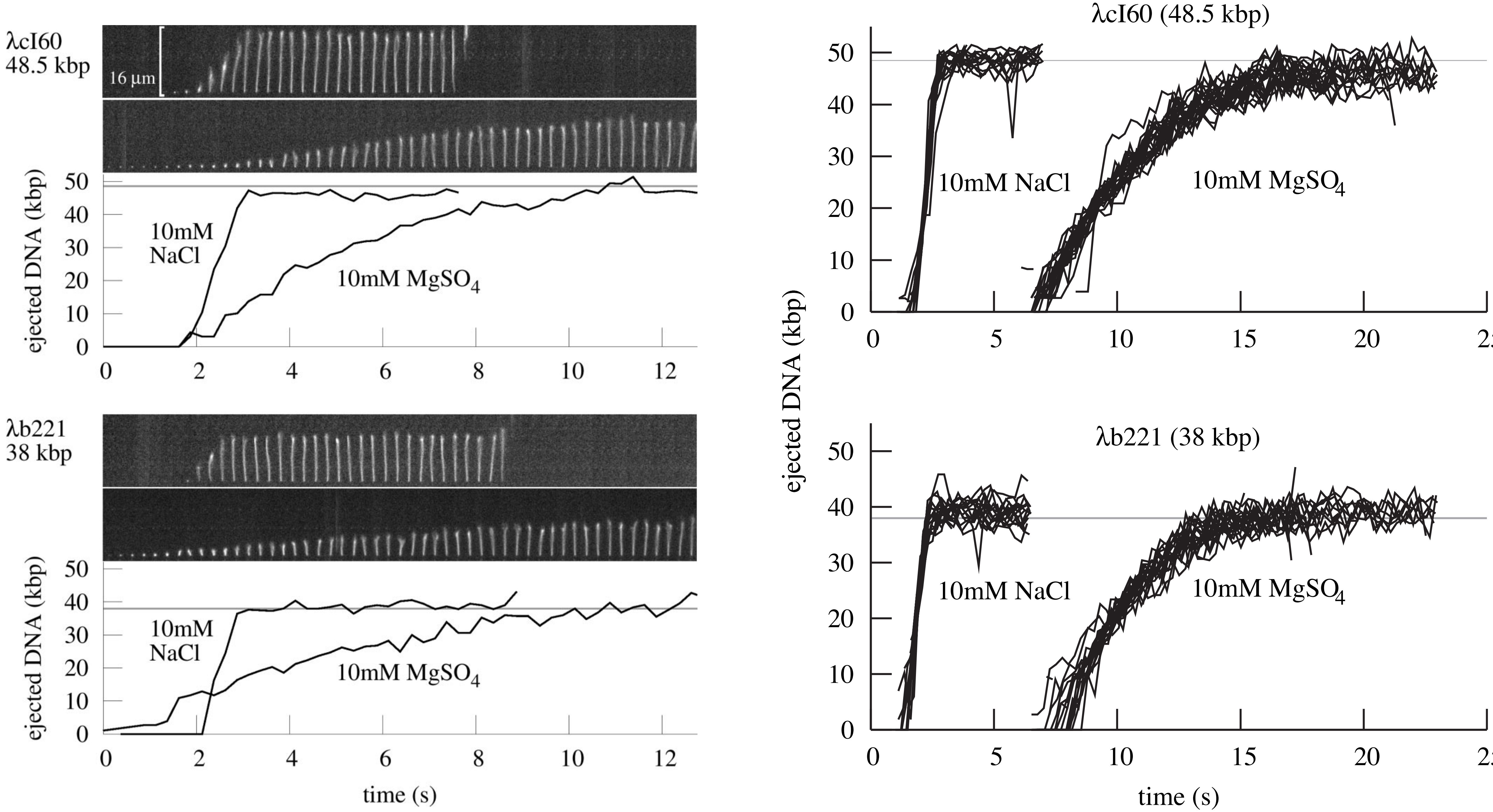


Control parameters

from: Mangenot et al, 2005

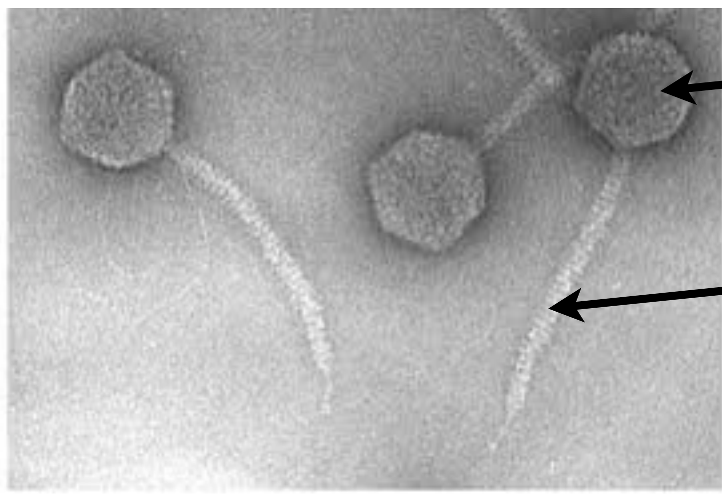
- Amount of DNA packed into the phage: 38kb vs 48.5kb
- ionic strength of surrounding solution: NaCl vs Mg SO4

Dynamics of DNA ejection



depends strongly on ionic strength, but not on total DNA length. Only on amount of DNA inside the virus.

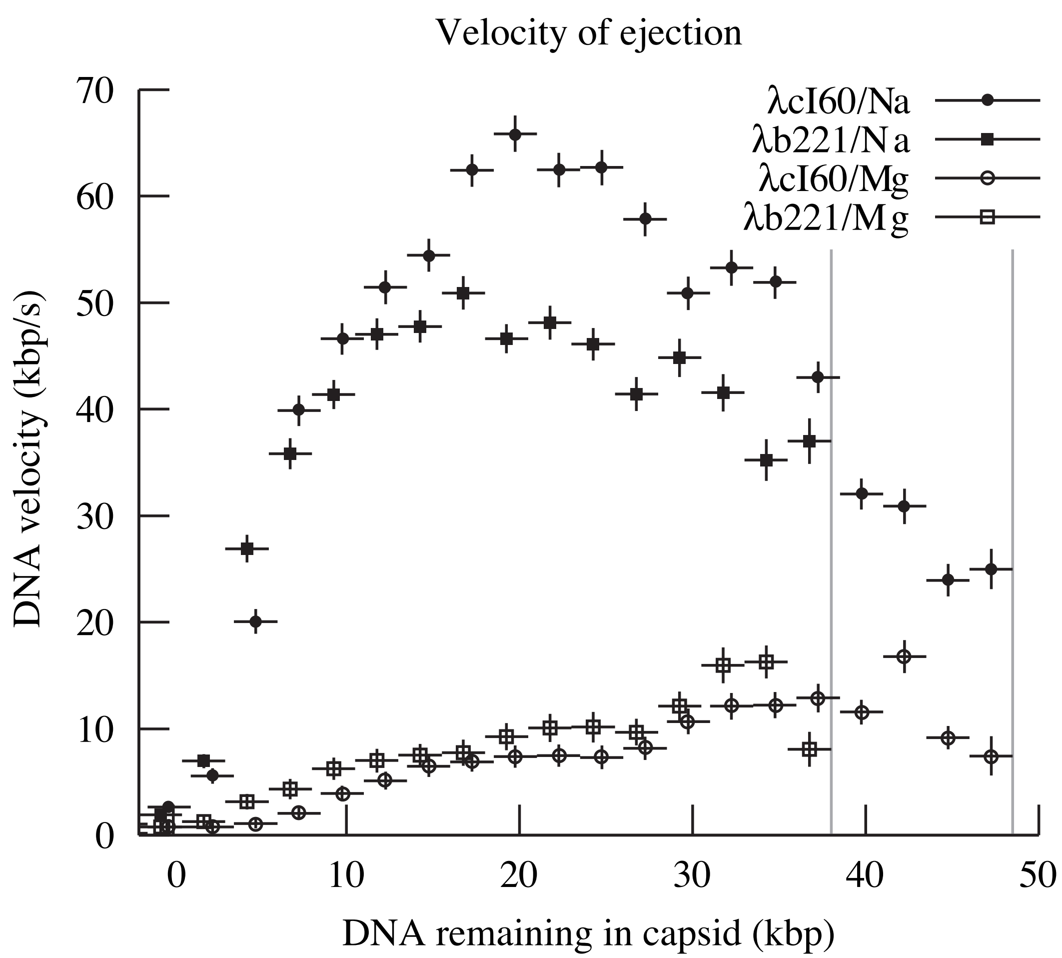
From where does the friction originate?



head

tail

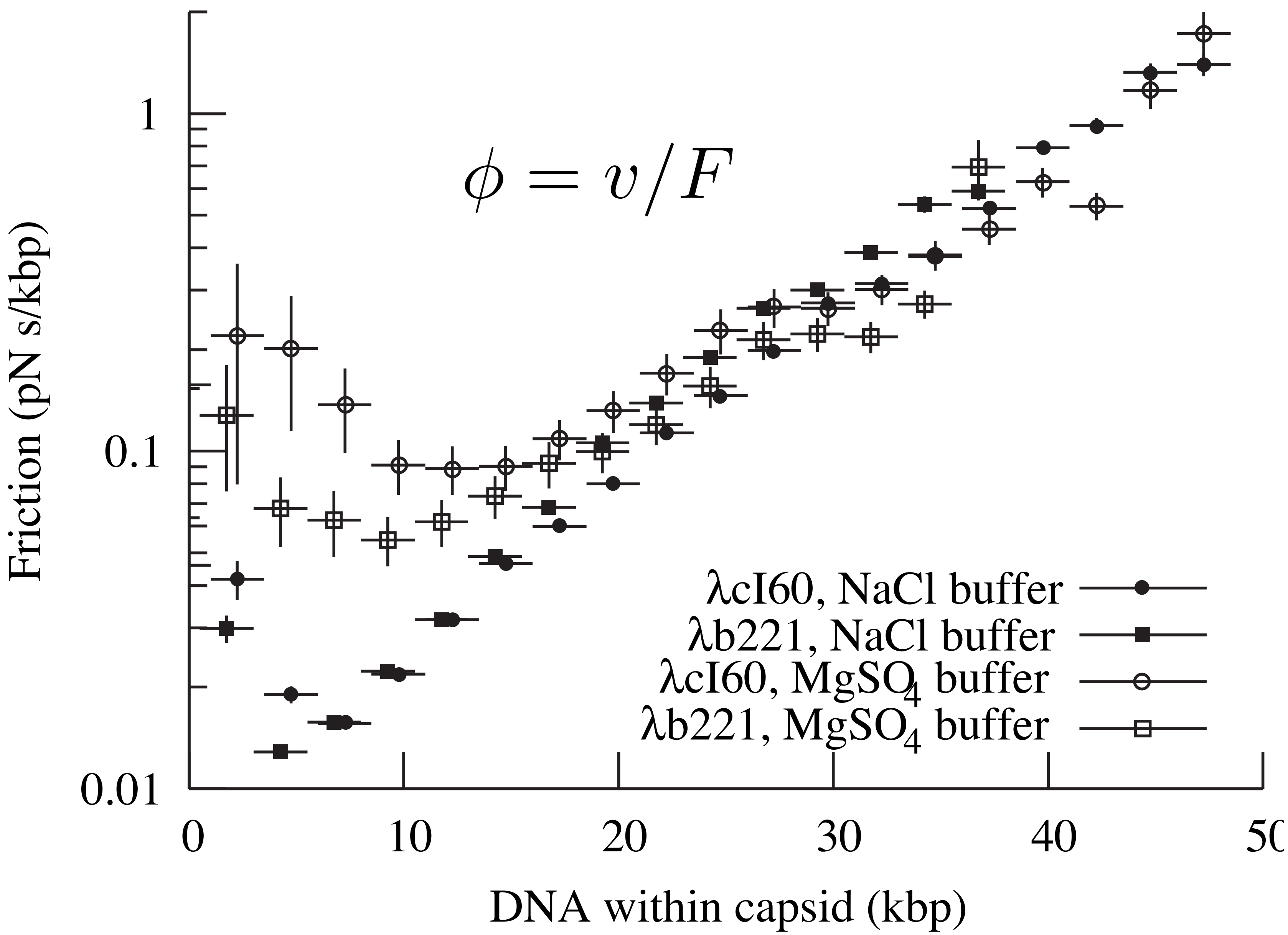
Overdamped motion: $v = \phi F$



- Friction in the tail: independent of arrangement in head
- Force is larger when there is more DNA in the head.
- But the velocity seems to peak at intermediate packing fractions

→ Tail probably not dominating

Friction is dominated by DNA in the capsid



Friction is a function of the DNA left in the head:
interstrand DNA friction seems to dominate the ejection process.

Conclusions

- Single molecule techniques used to elucidate phage DNA packaging and ejection
- physics of polymers and poly-electrolytes is necessary to understand these aspects of phage biology.
- physical constraints determine what is possible in the evolution of these simple viruses