Measurements of Pressurized DNA in Phage Capsids

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Abstract

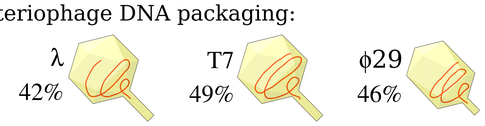
Bacteriophage λ packages its genome into a tiny capsid, creating an internal pressure of 10–20 atm. This pressure may be required during ejection to overcome the 3 atm of osmotic pressure inside the host cell. We induce ejection *in vitro* in the presence of an external osmotic pressure that mimics the cell interior. Using strains of λ with different genome length, we quantify the relationship

genome length → ejection pressure

We find that a parameter-free theoretical model can predict this relationship fairly well.

Phages are champion DNA packers

Bacteriophage DNA packaging:

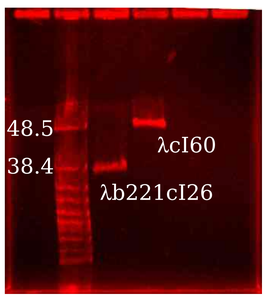


Human virus DNA/RNA packaging:

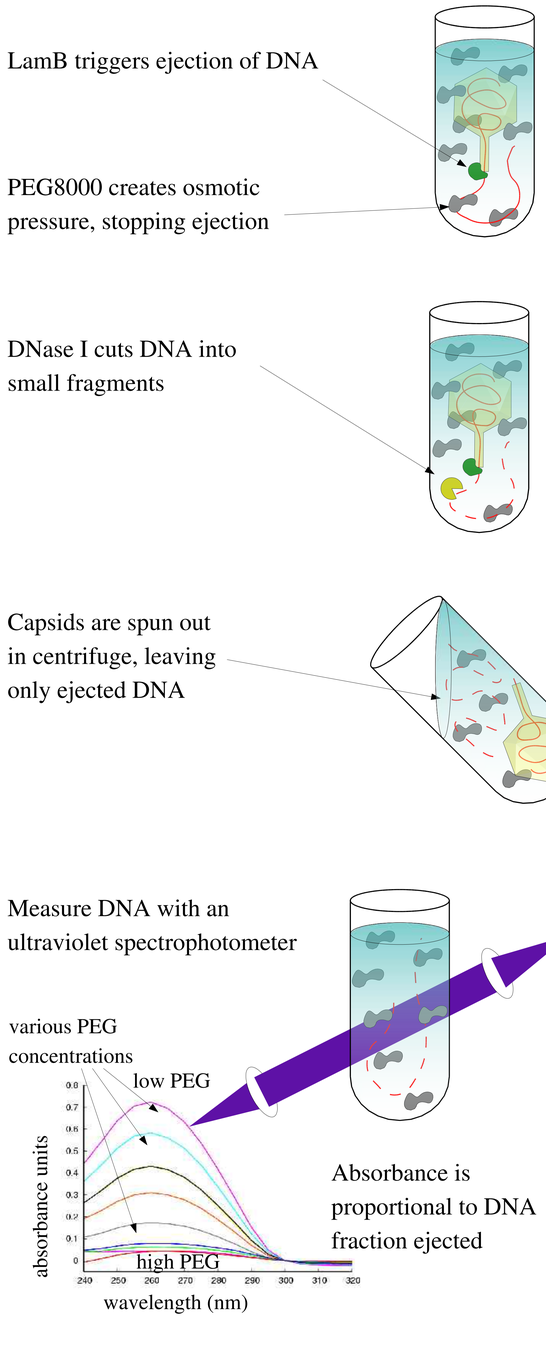
(assuming dsDNA is a 2 nm diameter cylinder and using published genome lengths and capsid sizes)

Phages with several genome lengths

We use two λ mutants differing only in genome length to reveal the relationship between genome length and ejection pressure.



The experiment: Osmotic pressure stops ejection

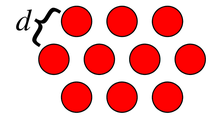


Theoretical Model

1: Electrostatic forces

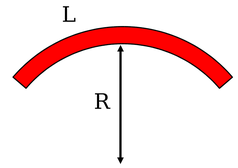
$$\Pi = F_0 \exp\left(\frac{d}{C}\right)$$

(X-ray scattering experiments by Rau, Lee, & Parsegian 1984)



2: Bending forces

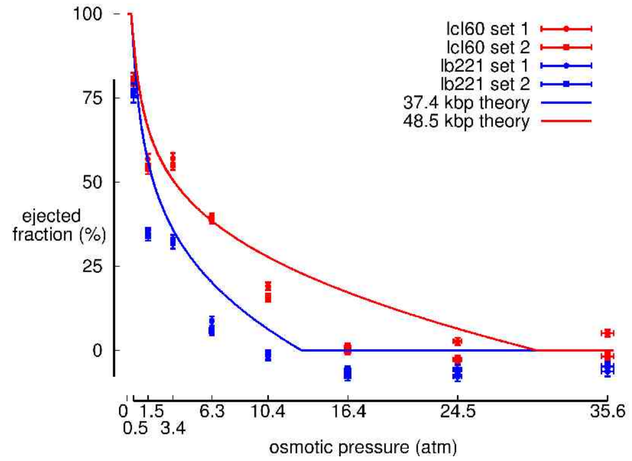
$$E = L\frac{L_0 kT}{R^2}$$



Minimize free energy as a function of d, differentiate energy to get the ejection force. Pressure = Force× π $(R_{DNA} + R_{PEG})^2$

Results: pressure vs. percent DNA ejected

The theoretical model makes quantitative predictions for the amount of DNA ejected at every pressure, with no free parameters, so we can compare it directly to the experiment:



The theory predicts the right magnitude for the pressures and explains the dependence of force on genome length.

Acknowledgments

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