A QUANTITATIVE DESCRIPTION OF THE INVASION OF BACTERIOPHAGE T4

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Bacteriophage T4 is a virus that attacks bacteria by a unique mechanism. It lands on the surface of the bacterium and attaches its baseplate to the cell wall. Aided by Brownian motion and chemical bonding, its tail fibers stick to the cell wall, producing a large moment on the baseplate. This triggers an amazing phase transformation in the tail sheath, of martensitic type, that causes it to shorten and fatten. The transformation strain is about 50%. With a thrusting and twisting motion, this transformation drives the stiff inner tail core through the cell wall of the bacterium. The DNA of the virus then enters the cell through the hollow tail core, leading to the invasion of the host.

This is a natural machine. As we ponder the possibility of making man-made machines that can have intimate interactions with natural ones, on the scale of biochemical processes, it is an interesting prototype. We present a mathematical theory of the martensitic transformation that occurs in T4 tail sheath. Following a suggestion of Pauling, we propose a theory of an active protein sheet with certain local interactions between molecules. The free energy is found to have a double-well structure. Using the explicit geometry of T4 tail sheath we introduce constraints to simplify the theory. Configurations corresponding to the two phases are found and a formula for the force generated by contraction is given. The predicted behavior of the sheet is completely unlike macroscopic sheets. To understand the position of this bioactuator relative to nonbiological actuators, the forces and energies are compared with those generated by inorganic actuators, including nonbiological martensitic transformations. Joint work with Wayne Falk, WF@ddt.biochem.umn.edu

References

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