Ion Discrimination by Nanoscale Design

Susan Rempe,
Sandia National Laboratories

Natural systems excel at discriminating between molecules on the basis of subtle differences. Membrane-spanning protein channels, for example, are exquisitely designed to differentiate between Na+ (sodium) and K+ (potassium) ions despite their identical charges and only sub-Angstrom differences in size. Consequently nearly all cells can selectively transport these ions across their membranes, a process that underlies such diverse physiological tasks as nerve cell signaling, heart rhythm control, and kidney function. While scientists have long known that ion selectivity lies in the ability of the channel to satisfy or frustrate ion solvation requirements, the persistent question revolves around how channels and other biological structures give rise to such a subtle effect between Na+ and K+.

By understanding ion discrimination in natural systems, we can potentially learn how to harness nature’s design principles in nano-scale devices that mimic biological function for varied applications, including fast, efficient water desalination. Here we present a novel explanation for ion discrimination in the celebrated potassium-selective protein channels, we contrast this explanation of natural ion discrimination with the unexpectedly antithetical mechanism found in a natural potassium-selective ion carrier, and finally we describe current work toward implementing ion selectivity in synthetic channels.