18. Exchange Diffusion, Single Filing, and Gating in Macroscopic Channels of One Conformation

Duanpin Chen and Robert Eisenberg, Department of Physiology, Rush Medical College, Chicago, Illinois

Open channels are described by Nernst-Planck equations relating flux to the concentration of ions and their common electrical potential, usually assumed to be independent of concentration and flux. But potential is a variable arising from permanent and induced charge on the channel's wall and ions in the channel's pore. The fluxes in Nernst-Planck equations are coupled by the potential of Poisson's equation when boundary conditions ensure zero current with zero driving force. Similar models describe current flow in semiconductors and transistors (e.g., thyristors). We describe a channel as a macroscopic cylinder of fixed structure, of just one conformation; yet, four rings of permanent charge (a la Numa) produce phenomena reminiscent of exchange diffusion. Unidirectional efflux increases with increasing external concentration, although the channel remains in its one conformation.

Modest modifications in the charge produce phenomena reminiscent of single filing: unidirectional efflux declines with increasing external concentration, although these macroscopic Nernst-Planck equations allow ions to pass through each other. The coupled nonlinear equations of this theory have multiple solutions. Open, closed, and threshold current-voltage relations occur in open cylindrical pores without steric occlusions, with channel protein and permanent charge in their one conformation. We wonder if transitions between different current-voltage relations account for gating of single channels between zero, sub-, or full conductance states: either spontaneous opening/closing, flickering, or opening/ closing mediated by agonists and voltage. Transistors are complex distributions of permanent charge connected to power supplies. It will be interesting to see what happens in branched channels-with shapes like Y, Ψ, or Ж if energy sources like multiple ionic gradients or ATP/ATPase are present. [Supported by NSF grant DIR-9012294]