Ion Channels, Devices of Molecular Biology

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Abstract: Ion channels are proteins with holes down their middle that function as devices to control the flow of ions, and thus electricity, in and out of cells. Ion channels control an enormous range of biological function, and are studied for that reason by literally thousands of laboratories every day, yet they can be analyzed by typical engineering methods of applied mathematics: the structure of channels is unchanging on the time scale of their function, once they are open, and orbital delocalization (i.e., 'chemistry') is not involved. In fact, ions in channels can be analyzed as holes and electrons are analyzed in semiconductor devices, as a compressible plasma of charged particles, provided the significant size of the particles is included in the physics. We will discuss the past success and future promise of this approach, showing physical and mathematical scientists how they can use the existing tools of their profession to address biological and medical problems of the greatest importance, and how these tools need to be refined and extended. Ion channels are devices. They form open systems, with spatially nonuniform boundary conditions needed to describe their inputs and outputs. Atomic detail controls some of their functions, but the power supply and many inputs and outputs function on a macroscale. Thus, the physical and mathematical challenge is to describe a multiscale nonequilibrium system using just enough atomic detail to understand its function.