Proton flux and the origin of life

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Energy conservation as electrochemical ion gradients over membranes is as universal as the genetic code, yet the origin of membrane bioenergetics remains obscure. Alkaline hydrothermal vents suggest possible solutions to early carbon and energy flux, by providing sustained far-from-equilibrium conditions, in which warm alkaline fluids rich in H2 interface with acidic oceans saturated in CO2. Natural proton gradients across catalytic Fe(Ni)S mineral walls give an electrical potential of ~150-300 mV, similar in polarity and magnitude to the membrane potential of modern autotrophs. But harnessing geochemical proton gradients raises problems: (i) how could natural proton gradients be harnessed in the absence of coupling proteins; and (ii) later, why and how would protocells dependent on natural proton gradients begin pumping ions to generate their own gradient? The energy metabolism of anaerobes living in hydrothermal environments today, specifically methanogens and acetogens that operate close to thermodynamic limits, offers clues to the origin of membrane bioenergetics. I will suggest a possible scenario that could explain the primordial dependence of autotrophic cells on proton gradients, the Na+/H+ promiscuity of many membrane proteins, the low intracellular Na+ concentration of cells relative to the oceans, and the deepest branch in the tree of life, the divergence between archaea and bacteria.