Proton migration along membranes: retention and local energy transfer

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Lateral proton diffusion along membranes can couple proton-generating and proton-consuming proteins, supporting processes ranging from ATP synthesis to solute transport. Such local coupling requires protons to reach their target proteins before equilibrating with the surrounding solution. The molecular basis of proton retention near membranes, and how the migrating signal extends into the adjacent water, remain unclear (Knyazev et al. 2023).

We show that both the magnitude and timing of maximum acidification differ across just a few molecular layers of water next to the membrane. These measurements reveal that the laterally propagating proton pulse has a distinct spatial structure perpendicular to the surface, with adjacent water layers remaining out of local equilibrium. By perturbing the structure of membrane hydration layers with membrane-anchored sugars, we show that lateral proton migration can be slowed while proton retention is largely preserved, highlighting the role of interfacial water organization in regulating transport (Maznichenko and Pohl 2026).

Together with the previously demonstrated independence of proton migration from titratable membrane residues (Springer et al. 2011; Zhang et al. 2012) and its weak dependence on membrane charge (Weichselbaum et al. 2023), these findings implicate interfacial water in controlling proton mobility and retention. Local proton delivery may therefore contribute broadly to membrane transport and energy conversion, providing a possible evolutionary advantage of proton-based over sodium-based coupling.

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