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IDEA TO WATCH

Thoughts & Opinion

Origin of the roles of potassium in biology

Korolev[1] points out the high potassium:sodium ratio in cells despite the almost universal[2] higher concentration of sodium than potassium in the environment of cells, and bases the requirement for potassium movement into the cytosol of bacteria on the chemiosmotic mechanism of energy transduction. Here oxidation-reduction reactions in the plasma membrane pump protons from the cytosol into the external medium, generating a proton electrochemical potential difference or proton motive force (PMF) comprised of an electrical potential difference (inside negative) and a pH difference (inside alkaline). Downhill proton influx through the ATP synthase converts ADP and inorganic phosphate into ATP and completes the proton cycle. A slightly smaller influx than efflux of protons means a pH increase in the cytosol; this pH increase is small as a result of the pH buffer capacity of the cytosol.[1] The net efflux of the positively charged protons also means that the inside negative electrical potential difference across the plasma membrane increases according to the capacitance of the plasma membrane, and rapidly becomes so large that the membrane undergoes dielectric breakdown.[1] This can be avoided by the voltage-driven influx of a cation or efflux of an anion. Korolev[1] shows that potassium influx was favored in evolution for this role, as a result of relatively low concentration meaning that avoiding hyperpolarization does not lead to large increases in intracellular concentrations of solutes, and because potassium-selective channels can evolve amplifying small potassium-selectivity of fixed negative changes by having a number of them in series in the channel

The early evolution of chemiosmotic energy coupling is a feature of some models of the origin of life, e.g. in marine hydrothermal vents,[1] and also for the last universal common ancestor (LUCA) of present-day organisms.[3] While the model[1] using enzymes and transporters that molecular phylogeny shows to be ancient has sodium as the cycling ion in the chemiosmotic ATP production, there is the same requirement for a means of offsetting very large inside-negative electrical potentials as for proton-coupled ATP generation.[1] Work on ion-pumping rhodopsins shows a relatively facile evolutionary interconversion among protons, sodium and chloride as the actively transported ion.[3,4]

Korolev[1] focused on high osmolarity cellular environments, cells in seawater and in metazoans; the same principles apply to organisms in freshwater bacteria, e.g. the cyanobacterium *Gloeobacter*, with photosynthetic, respiratory and proton-pumping rhodopsin-based chemiosmotic coupling at the plasma membrane.[5] These principles also apply to regulating the PMF in chemiosmotic coupling at the plasma membrane of[5] intracellular membranes such as the membrane separating the thylakoid lumen from the cytosol of cyanobacteria other than *Gloeobacter*, and the chloroplast stroma of eukaryotic oxygenic photosynthetic organisms. Here the acidic and electropositive compartment is the thylakoid lumen, and potassium channels, and also chloride channels, regulate the components of the PMF, with important implications for other photosynthetic processes.[5]

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DATA AVAILABILITY STATEMENT

There are no data related to this paper.

CONFLICT OF INTEREST

The author has no conflict of interest.

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REFERENCES

1. Korolev, N. (2021). How potassium came to be the dominant biological cation: of metabolism, chemiosmosis, and cation selectivity since the beginnings of life. *BioEssays*, *43*, e2000108.
2. Sudjaroen, Y., Thougkao, K., & Suwannahong K. (2015). Characteristics of mineral water from nature hot springs in Ranong Province, Thailand. *Ann. Trop. Med. Pub. Health*, *10*, 366.
3. Weiss, M. C., Preiser, M., Xavier, X. C., Zimoski, V., & Martin, W. F. (2018). The last universal common ancestor between ancient Earth chemistry and the onset of genetics. *PLoS Genet.*, *14*, e1007518.

4. Raven, J. A., & Beardall, J. (2020). Energizing the plasmalemma of marine photosynthetic organisms: the role of primary active transport. *J. Mar. Bol. Assoc. UK.*, *100*, 333.
5. Raven, J. A. (2020). Chloride involvement in the synthesis, functioning and repair of the photosynthetic apparatus in vivo. *New Phytologist*, *227*, 334.

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