Gold Nanoparticles enable Charge Transfer across Phospholipid Bilayer Membranes

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Charge transfer across biological membranes is the basis for many fundamental processes of life such as photosynthesis, the respiratory chain, ATP synthesis and neuronal signaling, to name a few. Since electroneutrality has to be maintained, transfer of positive and negative charge are not independent of each other but are energetically coupled. If mechanistically only one type of charge carrier can transfer the membrane, say as potassium ions through a specific channel, the transfer of a small number of ions leads to a build-up of a membrane potential, which prevents further transfer. While there are many natural and artificial charge carriers and ion channels there appears to be only preliminary evidence for the ability of metal nanoparticles to act as ion transfer mediators.[1]

Metallic particles do not occur naturally in biological systems and, besides ion transfer, offer mechanistically completely new routes of charge transfer across membranes, namely by direct metallic conduction of electrons. In nature, electron-transfer across or along membranes is mediated by small redox molecules, often quinones, which carry electrons between redox-proteins resident in the membrane. In principle, a metal particle could be far more efficient and act as a trans-membrane nanowire, provided that there are feasible mechanisms of heterogeneous electron transfer between the metal particle and the aqueous medium on both sides of the membrane. Future hybrid systems could benefit from the ability to “wire-up” cells or micro-organisms by enabling metallic conduction of electrons across their membranes. Here I will give an account of our current efforts in the development of ion and electron transfer systems based on gold nanoparticles. In particular, I will discuss gold nanoparticles capped with mercapto-carboranes, which selectively shuttle certain ions across supported phospholipid bilayers in an electrochemical cell and across the membrane of phospholipid vesicles. Charge transfer was either measured directly in potential step experiments, or indirectly by monitoring changes in membrane potential of the vesicle membrane by fluorescence spectroscopy. Coupled ion and electron transfer as a means of biomimetic energy conversion will be discussed.

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[1] Marcin P. Grzelczak, Alexander P. Hill, Domagoj Belic, Dan F. Bradley, Casper Kunstmann-Olsen and Mathias Brust. Faraday Discuss., 2016,191, 495-510.