Transistor-like behavior of ionic conductivity of protein filaments

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ABSTRACT:

In this talk we discuss the empirical evidence for nano-scale conducting properties of several key sub-cellular components such as microtubules, actin filaments, proteins associated with them and ion channels. We also present a number of theoretical aspects of both intrinsic electronic and ionic conductance characteristics of these basic elements. Furthermore, we outline an integrative view of the functioning of a living cell and propose a new signaling mechanism in the cell, especially in neurons from the point of view of a bio-electronic circuit. Recently, we have investigated the conditions enabling actin filaments to act as electrical transmission lines for ion flows along their lengths and proposed a model in which each actin monomer is an electric element with a capacitive, inductive and resistive property due to the molecular structure of the actin filament and viscosity of the aqueous solution. Based on Kirchhoff's laws taken in the continuum limit, a non-linear partial differential equation has been derived for the propagation of ionic waves. We solved this equation and found solitary waves that may explain the earlier experimental observations. Subsequently, we showed that isolated, taxol-stabilized microtubules (MTs) behave as bio-molecular transistors capable of amplifying electrical signals. Here, we demonstrate that luminal (cytoplasmic) calcium concentration modulates these electrodynamic properties of MTs. We observe that a decrease in luminal calcium by chelation with EGTA had little effect on the electrical coupling by the MT, while an increase in calcium largely enhances electrical amplification by MTs. Our data indicate that electrical amplification by MTs is modulated by MT-interacting divalent cations, thus supporting the hypothesis that cations absorbed onto the polymer's surface play an important role in the electrical properties of MTs in solution.

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