Contribution ID: **1251** Type: **Oral (Non-Student) / orale (non-étudiant)**

Modeling the high frequency electric organ discharge in the weakly electric fish, Eigenmannia

Tuesday 14 June 2016 14:15 (15 minutes)

In the murky waters of the tropics, live weakly electric fish which use a continuous high frequency electric organ discharge (EOD) to sense nearby objects and communicate with conspecifics. Eigenmannia's characteristic frequency is within the species range of 250 to 600 Hz which it shifts when necessary to avoid jamming. The nearly dipolar oscillating electric field is generated by parallel columns of identical, synchronously discharging electrocyte cells. Recent findings from whole fish respirometry (during high-frequency signaling over a range of frequencies) have renewed interest in the frequency-dependent energetics of the EODs (Lewis et al 2014 J Neurosci 34:197). Although some modeling for that analysis has been performed, many aspects of in vivo electrocyte operation remain unclear, including the role of each compartment of the electrocyte, the amplitude of the oscillatory excursions in voltage, and the optimal way to spread the cost between stimulus and AP generation. In this talk we focus on our model of the neurally-driven electrocyte action potentials (APs) in the innervated posterior membrane that underlie the EOD. Redressing excitability-related Na+ entry constitutes the major ATP-cost for electrocytes and thus for the electric organ. To guide experimental investigation we explored several mechanisms for the generation of the synchronous string of APs. Each scenario has characteristic properties that can be tested experimentally. A highly efficient mechanism involves a tonic subthreshold stimulus mixed with a pulsatile stimulus at the required frequency. This mechanism would reveal a devil's staircase of responses with steps at periods multiple of the driving frequency and intermediate regions with more complex behavior, if the pulsatile component is insufficient to create a discharge at the required frequency.

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Session Classification: T2-2 Nonlinear Dynamics (DPMB) / Dynamiques non linéaires (DPMB)

Track Classification: Physics in Medicine and Biology / Physique en médecine et en biologie (DPMB-DPMB)