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Changing Internal Sodium Concentrations Effect on Action Potential Morphology using HH model in Neuron

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*Abstract*— Changing the internal sodium concentration directly affects the Nernst Potential for Sodium across the cell membrane. In an electrically small cell, decreases in the internal sodium concentration raise the peak Vm for action potentials and decrease the time to peak.

# INTRODUCTION

The Hodgkin Huxley model is a set of equations that describes the behavior of action potentials in neurons. Physiologically, this translates to the set of conditions under which ion channels are likely to open or close, and the dynamics of the gate states. Abstracting the ion channels into a parallel RC circuit with capacitance associated with the membrane itself, variable conductance that is dependent on time and membrane potential, and the Nernst equilibrium potentials of primarily sodium and potassium ions. The standard sodium intracellular and extracellular concentrations are 12mEq/L and 140mEq/L, respectively1.

The required voltage to stimulate an action potential produced by the Hodgkin-Huxley model will be decreased as the ratio of sodium concentration outside the cell to inside the cell increases. By modifying the intra and extracellular concentrations of sodium or potassium ions, we can change the Nernst equilibrium potentials and thus the resting membrane potential of the cell. This affects the kinetics of ion channels opening and closing, thus affecting both the time constants associated with the action potential and the probabilities at which the m, n, and h gates open and close, since they are influenced by the membrane potential. We expect that increasing the intracellular sodium concentration with respect to the extracellular sodium concentration will increase the stimulation voltage necessary to create an action potential, since membrane voltage will decrease as the sodium equilibrium potential decreases.

Further, changing the relative concentrations of ions will change the Nernst potential.2 When the sodium concentrations are higher, the morphology of the action potential. It will increase the activation rate of the activation gates to shorten the refractory period.

# Methods

We performed simulations using NEURON to vary the intracellular sodium concentration of an electrically small cell. We used a modified version of Hernandez’s axon testing hoc document to test our cell3. The intracellular sodium was measured between 0mEq/L and 280mEq/L and the extracellular concentration was held constant at 140mEq/L.

The cell used was an isolated soma displaying HH characteristics. It measured 25um in length, and 25um in diameter. The cytoplasmic resistivity (Ra) was 35.4 [Ω cm]

and the specific capacitance (Cm) was 1 [µF/cm2]. Throughout the testing, the other active parameters (GNa, Gk, [K]ext, [K]int) were held constant at .12 mS/cm2, .036 mS/cm2, 2.5mEq/L, and 54.4mEq/L respectively. The stimulus we used was a current impulse. We used a 0.1ms in duration 5nA in amplitude pulse.

We looked at gating variables m, n, and h. These affected the membrane voltage of our electrically small cell. This data was measured over 5ms, which captured the entire waveform. The data was processed in Matlab.

# Results

Data was gathered for [Na]int ranging from 0mEq/L to 280mEq/L.

\*\*\*\*\*The full width of the action potential, time to peak from full width half max, and the slope between the base and peak of the potential were measured.

[graphs]

[data table]

|  |  |  |
| --- | --- | --- |
| [Na]int (mEq/L) | VNa (mV) | Vm peak (mV) |
| 1e-12 | 784.34 |  |
| 2 | 102.3 |  |
| 10 | 63.548 |  |
| 20 | 46.857 |  |
| 30 | 37.094 |  |
| 140 | 0 |  |
| 280 | -16.691 |  |

It was found with\_\_\_\_ that \_\_\_\_.

# Discussion

We got consistent trends for the peak of the …….until we got to “0”Vm

Looked at capacitive current

# Conclusion

Changing the intracellular concentration of sodium directly affected the sodium Nernst potential. When this was greater than 0, the potential had a typical looking action potential. When the sodium Nernst potential was less than 0m the capacitive current dominated. In further work we would like to investigate the effects of capacitance and resistivity due to sodium concentrations as well.

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References

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