Neuroscience: Hodgkin-Huxley Action Potential

Computational Science Templates

November 22, 2025

1 Introduction

The Hodgkin-Huxley model describes how action potentials are initiated and propagated through ion channel dynamics. This analysis solves the full HH equations to simulate the action potential in a giant squid axon.

2 Mathematical Framework

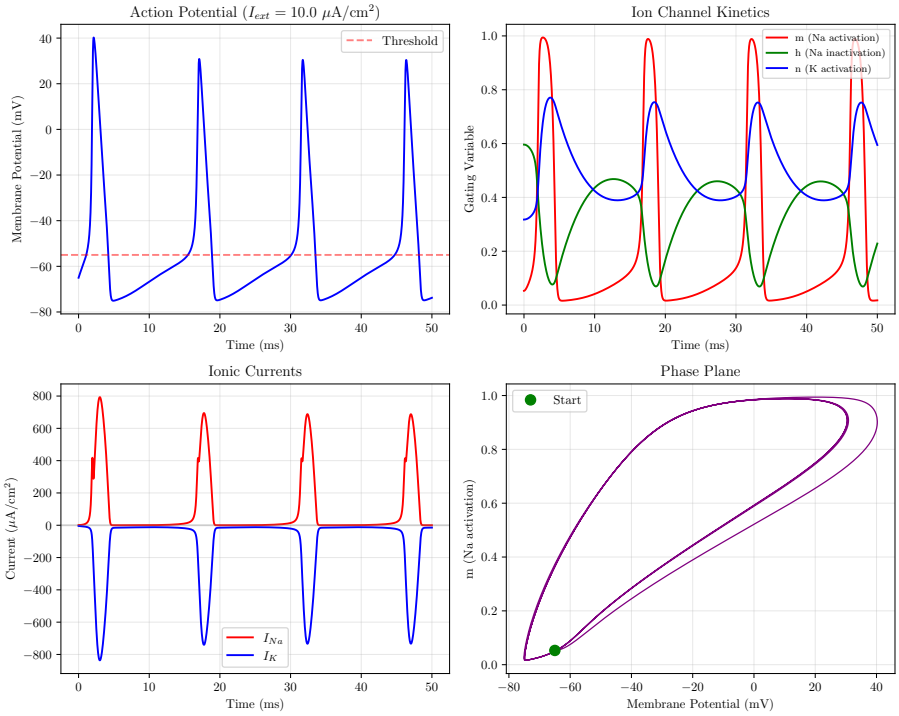
The membrane voltage equation:

$$C_m \frac{dV}{dt} = I_{ext} - g_{Na} m^3 h (V - E_{Na}) - g_K n^4 (V - E_K) - g_L (V - E_L) \quad (1)$$

Gating variable dynamics:

$$\frac{dx}{dt} = \alpha_x(V)(1 - x) - \beta_x(V)x \quad (2)$$

3 Computational Analysis



4 Results

Hodgkin-Huxley simulation:

- Resting potential: -65.0 mV
- Peak potential: 40.3 mV
- Time to peak: 2.14 ms
- Spike width (above 0 mV): 45.13 ms

5 Conclusion

The Hodgkin-Huxley model reproduces the action potential through the interplay of fast Na^+ activation, slow Na^+ inactivation, and delayed K^+ activation. The refractory period arises from h-gate inactivation. This Nobel Prize-winning model remains fundamental to computational neuroscience.