In this project, the membrane potential of barnacle giant muscle fibers was simulated under various conditions using the Morris-Lecar Model. Complex voltage behaviors were observed in the muscle's simple conductance system, which consists of only two types of non-inactivating voltage-dependent channels: voltage-dependent Ca^{2+} and K^{+} channels. Initially, the voltage behavior of the all-K+ condition was effectively simulated by setting g_{Ca} to 0, which exhibited the K^{+} resting behavior. Furthermore, the Ca^{2+} plateau behavior of the all-Ca^{2+} condition ($g_K = 0$) was successfully simulated using a nonlinear driving force expression that considered the electrodiffusion of Ca^{2+} ions. Additionally, different types of oscillations, such as damped and limit cycle oscillations, were effectively simulated when both Ca^{2+} and K^{+} channels were present. A phase diagram was generated to illustrate the limit cycle and damped oscillations.

The second part of this project aimed to investigate the effects of various parameters on voltage behavior. To simplify the analysis, the Ca^{2+} system was assumed to be much faster than the K^{+} system (i.e., assumes $M = M_{\infty}$), resulting in a reduced V, N system (i.e., a system that only considers membrane potential V and K open probability N). The impact of different injected currents on the membrane potential successfully demonstrated how the system entered and exited oscillations. Isoclines of V_dot = 0 and N_dot = 0 were also successfully generated under various current conditions. One intersection of the V_dot = 0 and N_dot = 0 isoclines was shown to be an unstable node, leading to stable (limit cycle) oscillations. The real and imaginary parts of the eigenvalues of the linearized V, N-reduced system were also examined. According to the paper, stable limit cycle oscillations occurred when the current was adjusted to make the real part of the eigenvalue positive. The imaginary part of the eigenvalue indicated the oscillation frequency. This project successfully generated a plot of the real and imaginary parts of the eigenvalues by calculating the eigenvalues of the Jacobian matrix at the steady state (V_dot = 0 and N_dot = 0).

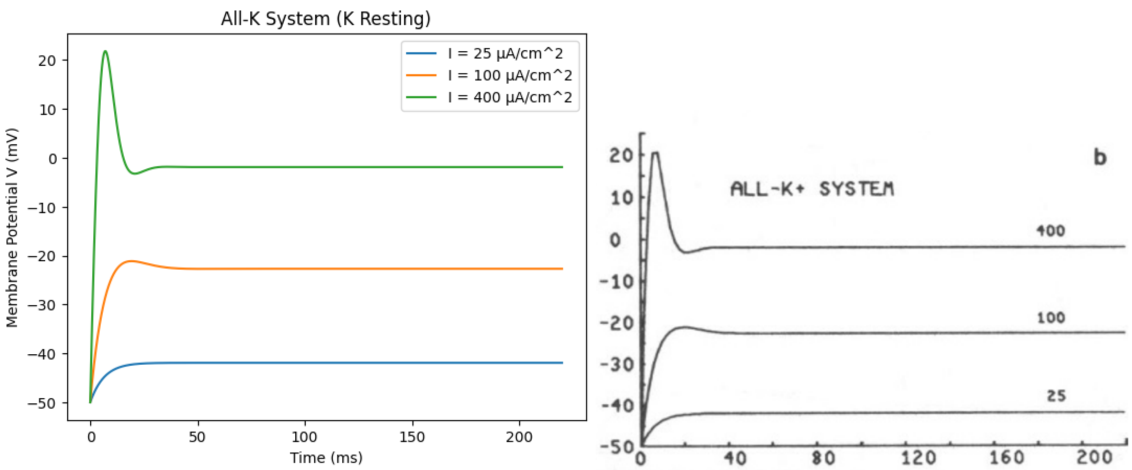


Figure 2b was replicated to show the plateau potentials of the all-K^+ system by setting the $g_{Ca} = 0$. All the parameters were given in the paper.

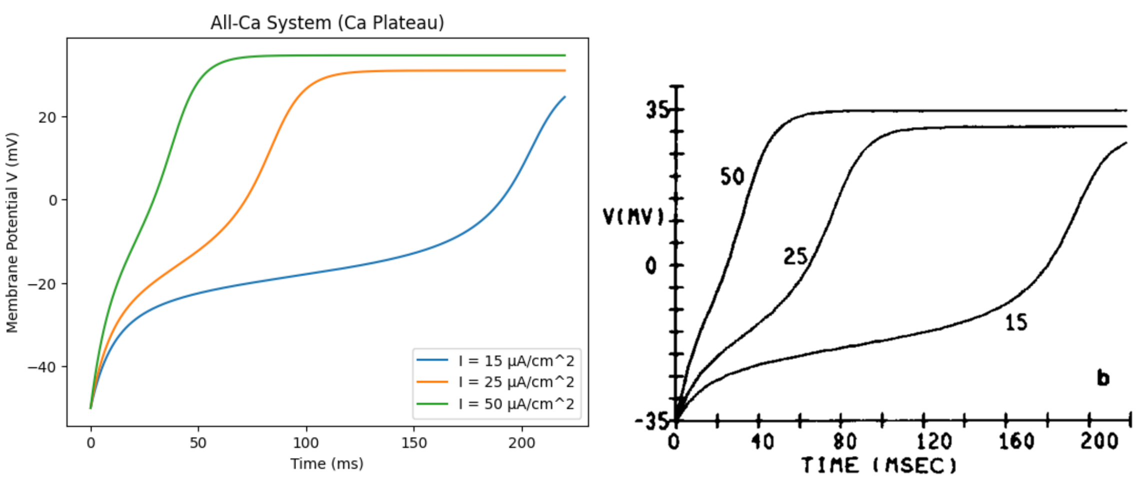
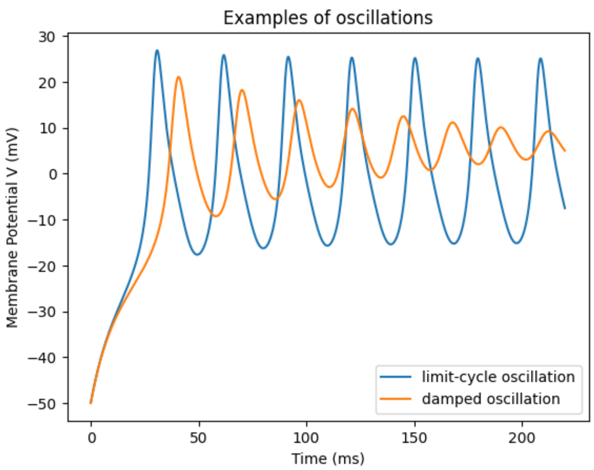
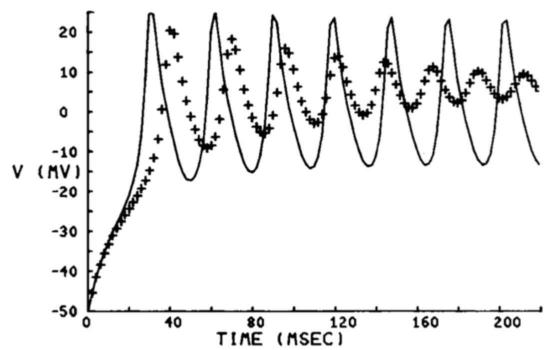


Figure 3b was replicated to show the plateau potentials of the all-Ca^{2+} system by setting the $g_K = 0$. All the parameters were given in the paper.





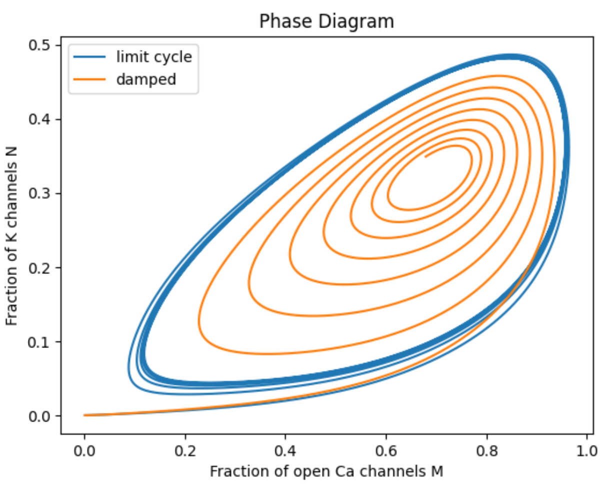
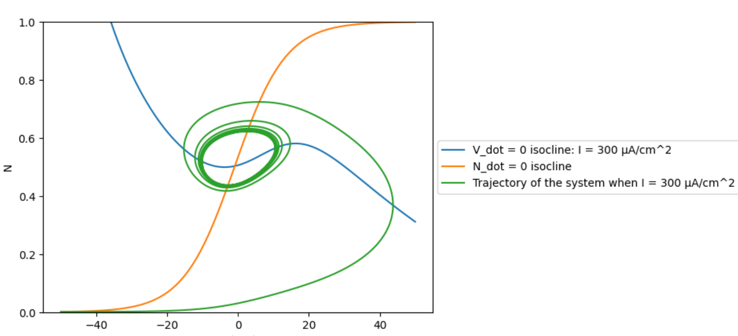


Figure 6 was replicated to show various types of oscillation computed from the V, M, N third-order system. Limit-cycle and damped oscillations were successfully generated. The phase diagram also indicated the two types of oscillations.



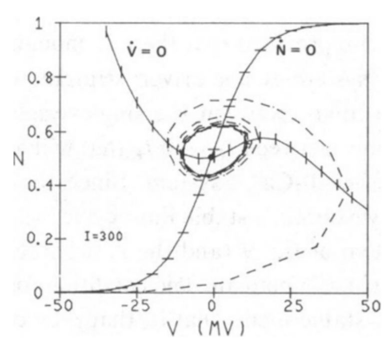
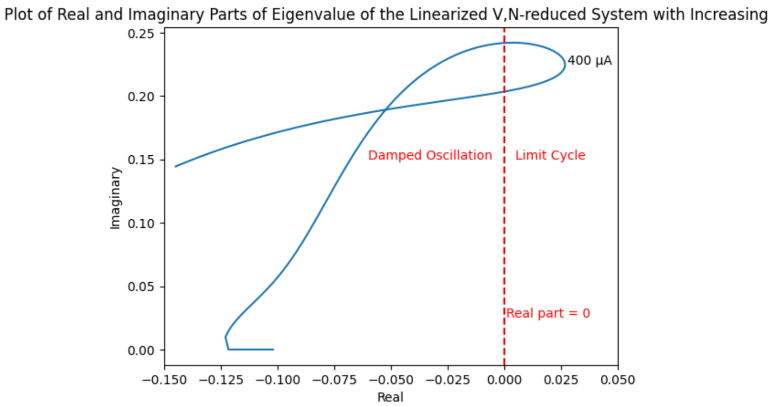


FIGURE 7

Figure 7 was replicated to show the trajectory of the V, N second-order reduced system with the nullclines in N and V. The unstable node (point at the intersection of the nullclines) gave a stable limit cycle.



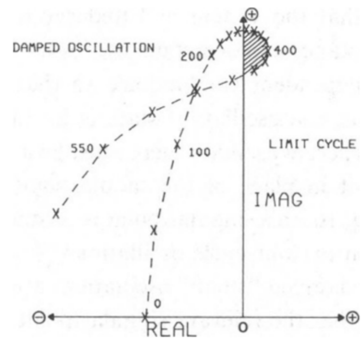
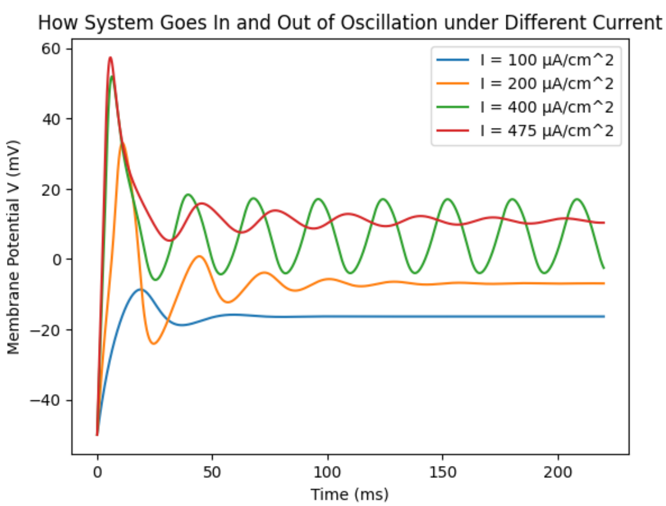


FIGURE 8

Figure 8 was replicated to show the real and imaginary parts of eigenvalue of the linearized V, N-reduced system with increasing current. The current increased from 0 to 550 µA/cm^2. A positive real part of the eigenvalue resulted in a stable limit cycle oscillation. The eigenvalues were calculated based on the Jacobian matrix of the V, N-reduced system at steady state (V_dot = 0 and N_dot = 0).



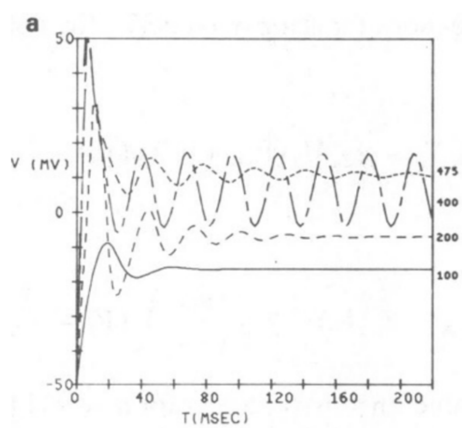


Figure 9A was replicated to illustrate how the V, N-reduced system entered and exited oscillation under varying current conditions. Parameters were given in the paper. This graph effectively demonstrated the impact of current on voltage oscillation, as shown in Figure 8. As the current I increased, the real part of the eigenvalue transitioned from negative to positive and then back to negative, causing the voltage to initiate and terminate oscillation.

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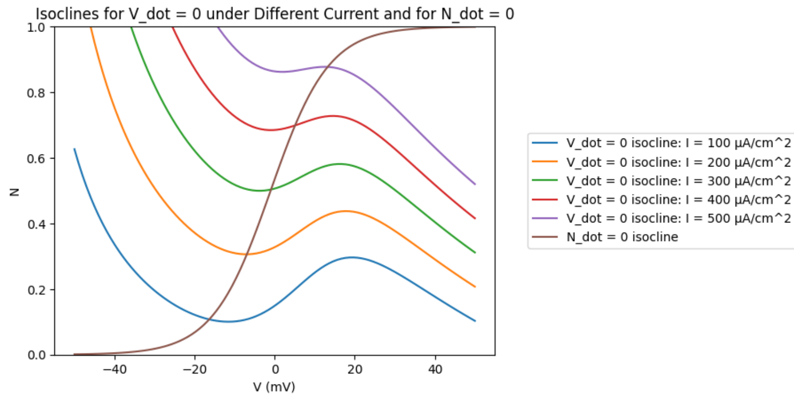

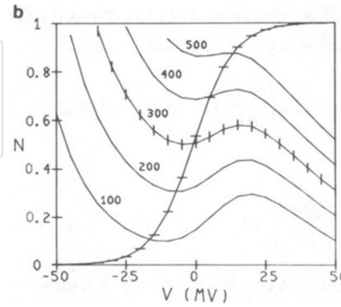

Figure 9B was replicated to show the change in V_dot = 0 isoclines under different current conditions in Figure 9A. Parameters were given in the paper.