ELEC ENG 3BB3:

Cellular Bioelectricity

Notes for Lecture 6

Friday, January 17, 2014

Effect of I_m *and* I_{ion} *on* V_m*:*

The total transmembrane current I_m can change because of current injected into a patch of membrane by an electrode in a physiological experiment or by a propagating potential under normal physiological operation.

Alternatively, the net ionic current I_{ion} can change because of ion channel gating, i.e., changes in g_p giving rise to a change in the membrane resistance R.

How do each of these factors contribute to changes in the transmembrane potential V_m?

Effect of I_m *and* I_{ion} *on* V_m *(cont.):*

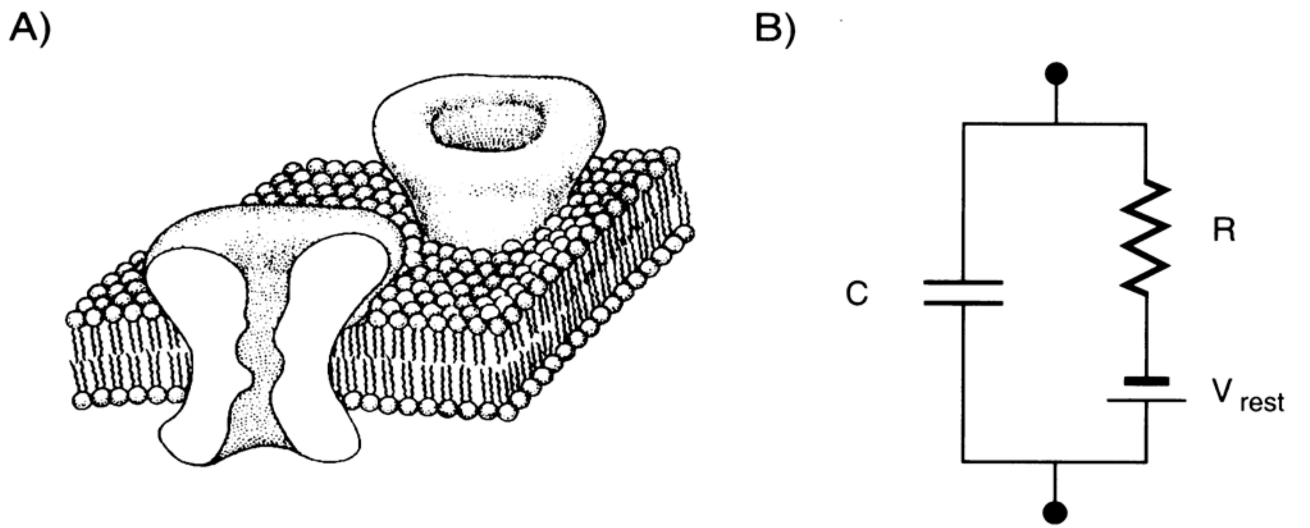


Fig. 1.1 Nature of the Passive Neuronal Membrane **(A)** Schematic representation of a small patch of membrane of the types enclosing all cells. The 30–50 Å thin bilayer of lipids isolates the extracellular side from the intracellular one. From an electrical point of view, the resultant separation of charge across the membrane acts akin to a capacitance. Proteins inserted into the membrane, here ionic channels, provide a conduit through the membrane. Reprinted by permission from Hille (1992). **(B)** Associated lumped electrical circuit for this patch, consisting of a capacitance and a resistance in series with a battery. The resistance mimics the behavior of voltage-independent ionic channels inserted throughout the membrane and the battery accounts for the cell's resting potential V_{rest}.

(from Koch)

Effect of I_m *and* I_{ion} *on* V_m *(cont.):*

The response of the transmembrane potential V_m for a patch of membrane with constant membrane resistance R initially at V_{rest} and then subjected to an intracellularly-injected current step of amplitude I_0 is:

$$V_m(t) = I_0 R \left(1 - \mathrm{e}^{-t/\tau}\right) + V_{\mathrm{rest}}$$

$$= V_0 \left(1 - \mathrm{e}^{-t/\tau}\right) + V_{\mathrm{rest}},$$

where τ = RC and V_0 = I_0R = V_m(t! 1)–V_{rest}.

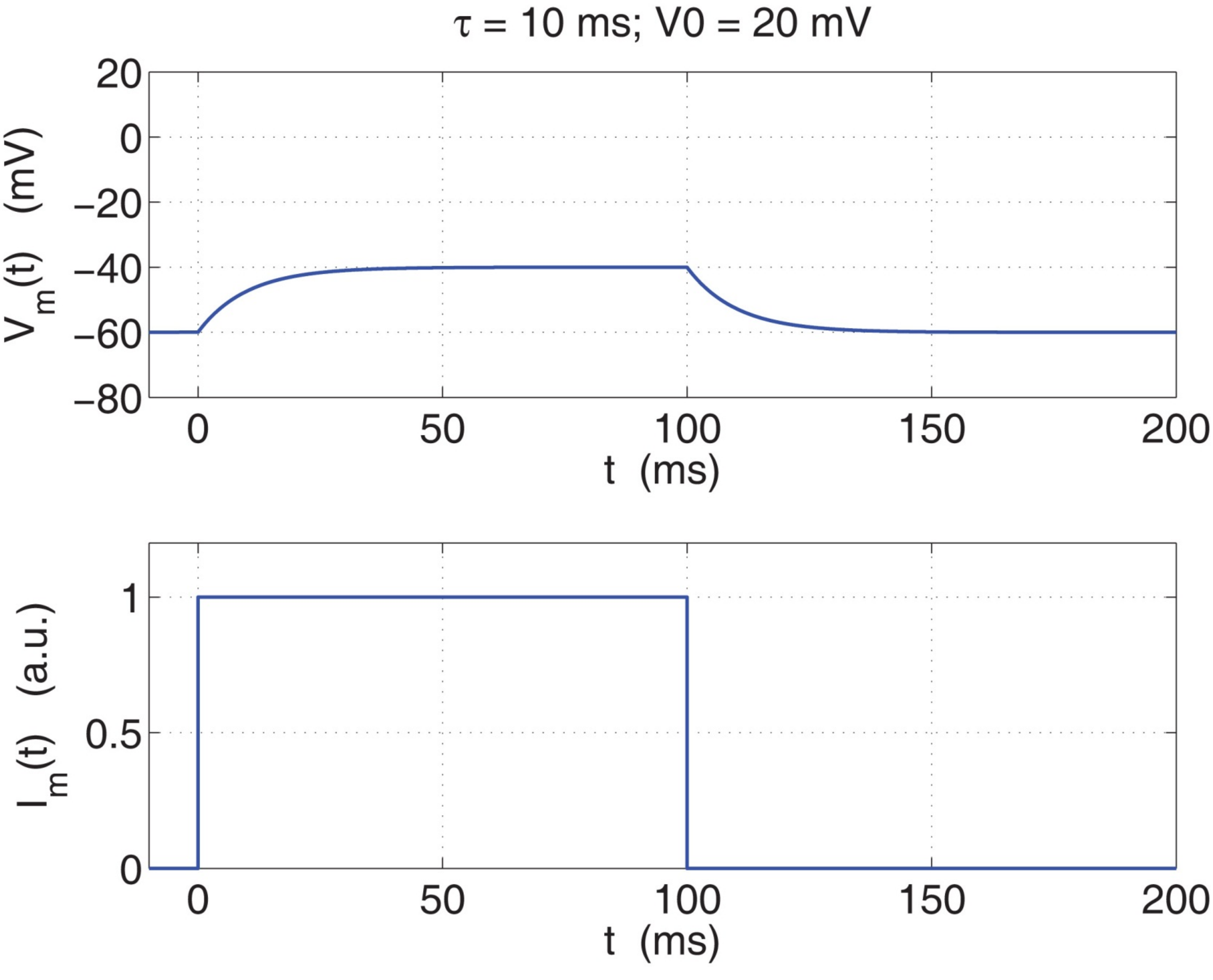
Effect of I_m *and* I_{ion} *on* V_m *(cont.):*

The transmembrane potential V_m for a patch of membrane with constant membrane resistance R initially at $V_m(t=0)$ and with no current injection returns to the resting potential according to:

$$V_m(t) = [V_m(0) - V_{\text{rest}}]\, \mathrm{e}^{-t/\tau} + V_{\text{rest}},$$

where $\tau = RC$.

Effect of I_m *and* I_{ion} *on* V_m *(cont.):*



Effect of I_m *and* I_{ion} *on* V_m *(cont.):*

Consider a parallel conductance model with sodium and potassium ionic channels. The response of the transmembrane potential V_m for a patch of membrane initially at V_{rest} and then subjected to an instantaneous change in the sodium conductance to $g_{Na}{}^0$ is:

$$V_m(t) = V_0\left(1 - \mathrm{e}^{-t/\tau\prime}\right) + V_{\mathrm{rest}},$$

where $\tau^0 = R^0C$ and $V_0 = V_m(t! \ 1 \ ) - V_{rest}$.

Effect of I_m *and* I_{ion} *on* V_m *(cont.):*

The new membrane conductance G^0 or its reciprocal the membrane resistance R^0 is given by:

$$G' = \frac{1}{R'} = g_{\mathsf{K}} + g'_{\mathsf{Na}},$$

and the new steady-state potential V_m(t! 1) is:

$$V_m(t \to \infty) = \frac{g_{\mathsf{K}} E_{\mathsf{K}} + g'_{\mathsf{Na}} E_{\mathsf{Na}}}{g_{\mathsf{K}} + g'_{\mathsf{Na}}}.$$