Hodgkin-Huxley Summary

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- Membrane equation:

$$C\frac{dV}{dt} + I_{Na}(V,t) + I_K(V,t) + I_{leak} - I_{inject} = 0$$

- Leak current:

$$I_{leak}(V) = g_{leak}[V - E_{leak}]$$

- Ionic currents:

$$I_K(V,t) = g_K(V,t)\,[V(t) - E_K]$$
$$I_{Na}(V,t) = g_{Na}(V,t)\,[V(t) - E_{Na}]$$

- Ionic conductances:

$$g_K(V,t) = \overline{g_K}\,[n(V,t)]^4$$
$$g_{Na}(V,t) = \overline{g_{Na}}\,[m(V,t)]^3\,h(V,t)$$

- Potassium activation:

$$\frac{dn}{dt} = \alpha_n(V)\,(1-n) - \beta_n(V)\,n$$

$$\alpha_n(V) = .01\,\frac{(10-V)}{e^{(10-V)/10} - 1}$$
$$\beta_n(V) = 0.125\,e^{-V/80}$$

- Sodium activation:

$$\frac{dm}{dt} = \alpha_m(V)\,(1-m) - \beta_m(V)\,m$$

$$\alpha_m(V) = 0.1\,\frac{(25-V)}{e^{(25-V)/10} - 1}$$
$$\beta_m(V) = 4\,e^{-V/18}$$

- Sodium inactivation:

$$\frac{dh}{dt} = \alpha_h(V)\,(1-h) - \beta_h(V)\,h$$

$$\alpha_h(V) = .07\,e^{-V/20}$$

$$\beta_h(V) = \frac{1}{e^{(30-V)/10}+1}$$

- Potassium activation time constant (likewise for m and h):

$$\tau_n(V) = \frac{1}{\alpha_n(V)+\beta_n(V)}$$

- Steady state potassium activation (likewise for m and h):

$$n_\infty(V) = \frac{\alpha_n(V)}{\alpha_n(V)+\beta_n(V)}$$

- Parameters:

$V_{rest} = 0$ mV
$g_{leak} = 8.4 \times 10^{-3}$ uS
$C = 28 \times 10^{-3}$ nF
$E_{Na} = 115$ mV
$E_K = -12$ mV
$\overline{g_K} = 1.008$ uS
$\overline{g_{Na}} = 3.36$ uS

- Leak potential:

$$E_{leak} = -\frac{\overline{g_{Na}}\,m_\infty^3(0)\,h_\infty(0)\,E_{Na} + \overline{g_K}\,n_\infty^4(0)\,E_K}{g_{leak}} = 10.6$$

• Pseudo-code for Euler's method implementation:

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V[1]=0

n[1]=ninf(0)
and likewise for m[1] and h[1]

loop for i = 1 to Nsamples

    alpha_n = .01 * (10-V[i]) / (exp((10-V)/10)-1)
    and likewise for beta_n, alpha_m, beta_m, alpha_h, and beta_h

    n[i+1] = n[i] + deltaT*(alpha_n*(1-n[i])-beta_n*n[i])
    and likewise for m[i+1] and h[i+1]

    gK = gK_max * n^4
    gNa = gNa_max * m^3 * h

    IK = gK*(V[i]-EK)
    INa = gNa*(V[i]-ENa)
    Ileak = gleak*(V[i]-Eleak)

    V[i+1] = V[i] + (deltaT/C)*(Iinject[i]-IK-INa-Ileak)

endloop
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