

Supplementary Materials

December 27, 2008

Components of the stellate model

Properties of the model were determined using a variety of sources. The transient sodium current (NaT) and the delayed rectifier (Kdr) were modified from previous kinetic schemes (Hoffman DA, Magee JC, Colbert CM, Johnston D (1997) *Nature* 387: 869-875.) to give a threshold, amplitude and time course approximating action potentials recorded in: Nolan MF, Dudman JT, Dodson PD, Santoro B (2007) *J Neurosci* 27(46): 12440-12451. Properties and densities of the persistent sodium current were taken from: Magistretti J, Alonso A (1999) *J Gen Physiol* 114: 491-509. Single channel conductances for potassium currents were based upon: Chen X, Johnston D (2004) *J Physiol* 559(Pt 1): 187-203. Gating properties and single channel conductance of the leak current were derived from: Bockenhauer D, Zilberberg N, Goldstein SA (2001) *Nat Neurosci.* 4(5):486-91. The AHP current was modeled as a spike dependent current with a small single channel conductance similar to SK channels: Bond CT, Herson PS, Strassmaier T, Hammond R, Stackman R et al. (2004) *J Neurosci* 24: 5301-5306. HCN current kinetics and density used a simplified 2-state model based upon data from: Nolan MF, Dudman JT, Dodson PD, Santoro B (2007) *J Neurosci* 27(46): 12440-12451. The small single channel conductance was based upon classic measurements by DiFrancesco and colleagues (see Robinson RB, Siegelbaum SA (2003) *Annu Rev Physiol* 65: 453-480) and more recent measurements: Kole MHP, Hallermann S, Stuart GJ (2006) *J Neurosci* 26: 1677-1687.

Membrane properties

$$\text{Specific Capacitance} = 1.67 \frac{\mu F}{cm^2}$$

$$\text{Membrane surface area} = 7.85 \times 10^{-5} \text{ cm}^2$$

Specific channel densities ($\mu S/cm^2$)

$$\text{NaT} = 24,000$$

$$\text{NaP} = 75$$

$$\text{Kdr} = 11,000$$

$$\text{KaF} = 100$$

$$\text{KaS} = 500$$

$$\text{H-fast} = 500$$

$$\text{H-slow} = 40$$

$$\text{K-AHP} = 425$$

K-leak = 150

Specific channel counts

NaT = 75,399

NaP = 236

Kdr = 34,558

KaF = 1,309

KaS = 2,182

H-fast = 39,270

H-slow = 5,498

K-AHP = 1,335

K-leak = 147

Single channel conductances (pS)

$\gamma_{nap} = 25$

$\gamma_{nat} = 25$

$\gamma_{kdr} = 25$

$\gamma_{kaf} = 6$

$\gamma_{kas} = 18$

$\gamma_h = 1$

$\gamma_{ahp} = 25$

$\gamma_{leak} = 80$

Reversal potentials (mV)

NaT = 55

NaP = 55

Kdr = -85

K-slow = -85

K-AHP = -85

H-fast = -30

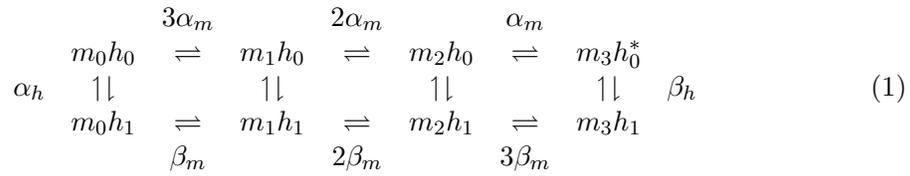
H-slow = -30

K-leak = -85

State-models used for the stochastic conductances

In all cases the conducting state of the channel is indicated with an *

Transient sodium conductance



where,

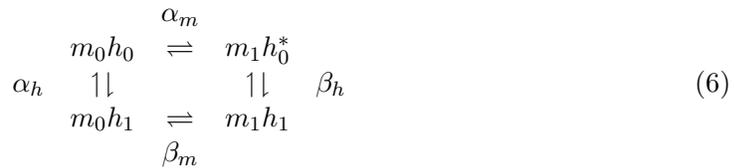
$$\alpha_m = \frac{0.38(V_m + 33)}{1 - e^{-\frac{(V_m+33)}{9}}} \quad (2)$$

$$\beta_m = \frac{-2.3(V_m + 58)}{1 - e^{-\frac{V_m+58}{12}}} \quad (3)$$

$$\alpha_h = \frac{-0.03(V_m + 48)}{1 - e^{-\frac{V_m+48}{12}}} \quad (4)$$

$$\beta_h = \frac{0.05(V_m + 21)}{1 - e^{-\frac{(V_m+21)}{9}}} \quad (5)$$

Persistent sodium conductance



where,

$$\alpha_m = \frac{1.5}{1 + e^{-\frac{42.1}{3} V_m}} \quad (7)$$

$$\beta_m = \frac{1}{1 + e^{-\frac{42.1}{3} V_m}} \quad (8)$$

$$\alpha_h = \frac{1.6 \times 10^{-4} \times (0.38 \times (V_m + 64.409))}{1 - e^{-0.38023(V_m + 64.409)}} \quad (9)$$

$$\beta_h = \frac{1.2 \times 10^{-4} \times (-0.216 \times (V_m + 17.014))}{1 - e^{0.21598(V_m + 17.014)}} \quad (10)$$

Delayed-rectifier potassium conductance

$$\begin{array}{ccccccc} & 4\alpha_n & & 3\alpha_n & & 2\alpha_n & & \alpha_n \\ n_0 & \rightleftharpoons & n_1 & \rightleftharpoons & n_2 & \rightleftharpoons & n_3 & \rightleftharpoons & n_4^* \\ & \beta_n & & 2\beta_n & & 3\beta_n & & 4\beta_n \end{array} \quad (11)$$

where,

$$\alpha_n = \frac{0.02(V_m + 38)}{1 - e^{-\frac{(V_m + 38)}{10}}} \quad (12)$$

$$\beta_n = \frac{-0.018(V_m + 47)}{1 - e^{-\frac{(V_m + 47)}{35}}} \quad (13)$$

Fast inactivating potassium conductance (A-type)

$$\begin{array}{ccccccc} & & & \alpha_m & & & \\ & m_0 h_0 & \rightleftharpoons & m_1 h_0^* & & & \\ \alpha_h & \updownarrow & & \updownarrow & & \beta_h & \\ & m_0 h_1 & \rightleftharpoons & m_1 h_1 & & & \\ & & & \beta_m & & & \end{array} \quad (14)$$

where,

$$\alpha_m = \frac{0.01(V_m + 18.3)}{1 - e^{-0.067(V_m + 18.3)}} \quad (15)$$

$$\beta_m = \frac{-0.01(V_m + 18.3)}{1 - e^{0.067(V_m + 18.3)}} \quad (16)$$

$$\alpha_h = \frac{-0.01(V_m + 58)}{1 - e^{0.122(V_m + 58)}} \quad (17)$$

$$\beta_h = \frac{0.01(V_m + 58)}{1 - e^{-0.122(V_m + 58)}} \quad (18)$$

Slowly inactivating potassium conductance (A-type)

A scaled version of the fast gating channel where activation kinetics were scaled by 0.1 and inactivation kinetics were scaled by 0.0067.

Hyperpolarization-activated, non-specific conductance (“wild-type”)

$$n_0 \stackrel{\alpha_n}{\rightleftharpoons} n_1^* \quad \beta_n \quad (19)$$

where,

$$\alpha_n = \frac{18.3 \times 10^{-3}}{1 + e^{\frac{(V_m + 114.2)}{20.33}}} \quad (20)$$

$$\beta_n = \frac{3.3 \times 10^{-2}}{1 + e^{\frac{(V_m + 51.5)}{10.94}}} \quad (21)$$

Hyperpolarization-activated, non-specific conductance (“knock-out”)

$$n_0 \stackrel{\alpha_n}{\rightleftharpoons} n_1^* \quad \beta_n \quad (22)$$

where,

$$\alpha_n = \frac{3.6 \times 10^{-3}}{1 + e^{\frac{(V_m + 148.7)}{22.45}}} \quad (23)$$

$$\beta_n = \frac{3.6 \times 10^{-3}}{1 + e^{\frac{(V_m + 50.7)}{12.49}}} \quad (24)$$

Voltage-gated AHP-like conductance

$$n_0 \stackrel{3\alpha_n}{\rightleftharpoons} n_1 \stackrel{2\alpha_n}{\rightleftharpoons} n_2 \stackrel{\alpha_n}{\rightleftharpoons} n_3^* \quad \beta_n \quad (25)$$

where,

$$\alpha_n = 1.5e^{\frac{t_{spike} - t}{25}} \quad (26)$$

$$\beta_n = 1.6 \quad (27)$$

Potassium conducting, voltage-independent leak conductance

$$n_0 \stackrel{\alpha_n}{\rightleftharpoons} n_1^* \quad (28)$$
$$\beta_n$$

where,

$$\alpha_n = 4 \quad (29)$$

$$\beta_n = 1 \quad (30)$$