

Supplement materials

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0.1 Pyramidal neurons

Уравнение для сомы, радиатума и ориенса

$$C \frac{dV_s}{dt} = -I_l - I_{Kdr} - I_{Na} - I_A - I_M - I_H - I_{CaL} - I_{sAHP} - I_{mAHP} - I_{CaR} - I_{buff} - I_{syn} + I_{ext} \quad (1)$$

Уравнение для аксона

$$C \frac{dV_a}{dt} = -I_l - I_{Kdr} - I_{Na} - I_M - I_{syn} \quad (2)$$

Уравнение для LM

$$C \frac{dV_{LM}}{dt} = -I_l - I_{Kdr} - I_{Na} - I_A - I_{syn} + I_{ext} \quad (3)$$

Натриевый каналы

$$I_{Na} = g_{max,Na} \cdot m^2 \cdot h \cdot s \cdot (V - E_{Na}) \quad (4)$$

For dendritic compartments

$$m_{\infty} = \frac{1}{1 + \exp(-\frac{V+40}{3})} \quad \tau_m = 0.05ms \quad (5)$$

$$h_{\infty} = \frac{1}{1 + \exp(-\frac{V+45}{3})} \quad \tau_h = 0.5ms \quad (6)$$

For soma/axon compartments

$$m_{\infty} = \frac{1}{1 + \exp(-\frac{V+44}{3})} \quad \tau_m = 0.05ms \quad (7)$$

$$h_{\infty} = \frac{1}{1 + \exp(-\frac{V+49}{3.5})} \quad \tau_h = 1ms \quad (8)$$

For all compartments

$$s_{\infty} = \frac{1 + Na_{att}\exp(0.5(V + 60))}{1 + \exp(0.5(V + 60))} \quad (9)$$

$$\tau_s = \frac{0.00333\exp(0.0024(V + 60)Q)}{1 + \exp(0.0012(V + 60)Q)} \quad (10)$$

$$Q = \frac{F}{RT} \quad (11)$$

The delayed rectifier current is given by:

$$I_{Kdr} = g_{max,Kdr} \cdot n^2 \cdot (V - E_K) \quad (12)$$

For dendritic compartments

$$n_{\infty} = \frac{1}{1 + \exp(-0.5(V + 42))} \quad \tau_n = 2.2ms \quad (13)$$

For soma/axon compartments

$$n_{\infty} = \frac{1}{1 + \exp(-0.3333(V + 46.3))} \quad \tau_n = 3.5ms \quad (14)$$

The fast inactivating A-type K⁺ current is described by

$$I_A = g_{max,A} \cdot n_A \cdot l \cdot (V - E_K) \quad (15)$$

$$\alpha_{n_A} = \frac{-0.01(V + 21.3)}{\exp(\frac{V+21.3}{-35}) - 1} \quad (16)$$

$$\beta_{n_A} = \frac{0.01(V + 21.3)}{\exp(\frac{V+21.3}{35}) - 1} \quad (17)$$

$$\alpha_l = \frac{-0.01(V + 58)}{\exp(\frac{V+58}{8.2}) - 1} \quad (18)$$

$$\beta_l = \frac{0.01(V + 58)}{\exp(\frac{V+58}{-8.2}) - 1} \quad (19)$$

$$\tau_l = \begin{cases} 5 + 0.26(V + 20) & \text{if } V > 20 \\ 5 & \text{otherwise} \end{cases} \quad (20)$$

The hyperpolarizing H-current is given by:

$$I_H = g_{max,H} \cdot H \cdot (V - E_H) \quad (21)$$

$$H_{\infty} = \frac{1}{1 + \exp(0.125(V + 75))} \quad (22)$$

$$\tau_H = \frac{\exp(0.033264(V + 75))}{0.35(1 + \exp(0.0083(V + 75)))} \quad (23)$$

The slowly activating voltage-dependent potassium current, I_M , is given by the equations:

$$I_M = g_{max,M} \cdot T_{adj} \cdot q \cdot (V - E_K) \quad T_{adj} = 10^{-4} \cdot 2.3^{0.1(T-296)} \quad (24)$$

$$\alpha_q = \frac{10^{-3}(V + 30)}{1 - \exp(\frac{V+30}{-9})} \quad (25)$$

$$\beta_q = \frac{-10^{-3}(V + 30)}{1 - \exp(\frac{V+30}{9})} \quad (26)$$

The slow after-hyperpolarizing current, I_{sAHP}

$$I_{sAHP} = g_{max,sAHP} \cdot p^3 \cdot (V - E_K) \quad (27)$$

$$\frac{dp}{dt} = \frac{C_{Ca} - p(1 + C_{Ca})}{\tau_p(1 + C_{Ca})} \quad (28)$$

$$\tau_p = \max\left(\frac{1}{0.003 \cdot (1 + C_{Ca})3^{0.1(T - 295)}}, 0.5\right) \quad (29)$$

$$C_{Ca} = \left(\frac{[Ca^{2+}]_{in}}{0.025}\right)^2 \quad (30)$$

The medium after-hyperpolarizing current, I_{mAHP} (Moczydlowski and Latorre, 1983), is given by:

$$I_{mAHP} = g_{max,mAHP} \cdot a \cdot (V - E_K) \quad (31)$$

$$\alpha_a = \frac{0.48}{1 + \frac{0.18 \cdot \exp(-1.68VQ)}{[Ca^{2+}]_{in}}} \quad (32)$$

$$\beta_a = \frac{0.28}{1 + \frac{[Ca^{2+}]_{in}}{0.011 \cdot \exp(-2VQ)}} \quad (33)$$

The somatic high-voltage activated (HVA) L-type Ca^{2+} current is given by

$$I_{CaL} = g_{max,somaCaL} \cdot b \cdot \frac{0.001}{0.001 + [Ca^{2+}]_{in}} \cdot (V - E_{Ca}) \quad (34)$$

$$\alpha_b = \frac{-5.055 (V + 27.01)}{\exp(\frac{(V+27.01)}{-3.8}) - 1} \quad (35)$$

$$\beta_b = 4.7 \exp\left(\frac{V + 63.01}{-17}\right) \quad (36)$$

whereas the dendritic L-type calcium channels have different kinetics:

$$I_{CaL} = g_{max,dendCaL} \cdot b^3 \cdot c \cdot (V - E_{Ca}) \quad (37)$$

$$\alpha_b = \frac{1}{1 + \exp(-(V + 37))} \quad (38)$$

$$\beta_b = \frac{1}{1 + \exp(2(V + 41))} \quad (39)$$

$$\alpha_c = ? \quad (40)$$

$$\beta_c = ? \quad (41)$$

$$\tau_b = 3.6 \quad (42)$$

$$\tau_c = 29 \quad (43)$$

The low-voltage activated (LVA) T-type Ca²⁺ channel kinetics are given by:

$$I_{CaT} = g_{max,somaCaT} \cdot d^2 \cdot r \cdot \frac{0.001}{0.001 + [Ca^{2+}]_{in}} \cdot (V - E_{Ca}) \quad (44)$$

$$\alpha_d = \frac{-0.196(V - 19.88)}{\exp(-0.1(V - 19.88)) - 1} \quad (45)$$

$$\beta_d = 0.46 \exp(-V/22.73) \quad (46)$$

$$\alpha_r = 0.00016 \exp\left(\frac{V + 57}{-19}\right) \quad (47)$$

$$\beta_r = \frac{1}{1 + \exp(-0.1(V - 15))} \quad (48)$$

The HVA R-type Ca²⁺ current is described by:

$$I_{CaR} = g_{max,CaR} \cdot w^3 \cdot j \cdot (V - E_{Ca}) \quad (49)$$

equations for dendritic CaR channels are:

$$w_{\infty} = \frac{1}{(1 + \exp(-0.3333(V + 48)))} \quad \tau_w = 50ms \quad (50)$$

$$j_{\infty} = \frac{1}{1 + \exp(V + 53)} \quad \tau_j = 5ms \quad (51)$$

while for the somatic CaR channels:

$$w_{\infty} = \frac{1}{(1 + \exp(-0.3333(V + 60)))} \quad \tau_w = 100ms \quad (52)$$

$$j_{\infty} = \frac{1}{1 + \exp(V + 62)} \quad \tau_j = 5ms \quad (53)$$

Dynamic of calcium concention

$$\frac{d[Ca^{2+}]_{in}}{dt} = \phi_{Ca} I_{sumCa} - \beta_{Ca} [Ca^{2+}]_{in} \quad (54)$$

0.2 Интернейроны

0.2.1 CavL

$$I_{CavL} = g_{max,CavL} \cdot m^2 \cdot h \cdot ghk(V, [[Ca_{2+}]_{in}, Ca_{2+}]_{out}) \quad (55)$$

$$h = \frac{0.001}{0.001 + [[Ca_{2+}]_{in}]} \quad (56)$$

$$\alpha_m = \frac{15.69 \cdot (81.5 - V)}{\exp(0.1(81.5 - V)) - 1} \quad (57)$$

$$\beta_m = 0.29 \cdot \exp\left(\frac{-V}{10.86}\right) \quad (58)$$

$$ghk = -f \cdot \left(1 - \left(\frac{[[Ca_{2+}]_{in}]}{Ca_{2+}]_{out}}\right) \cdot \exp\left(\frac{V}{f}\right)\right) \frac{V}{f \cdot \exp(V/f) - 1} \quad (59)$$

0.2.2 CavN

$$I_{CavN} = g_{max,CavN} \cdot c^2 \cdot c \cdot (V - E_{Ca}) \quad (60)$$

$$\alpha_c = \frac{-0.19 \cdot (V - 19.88)}{\exp(0.1(V - 19.88)) - 1} \quad (61)$$

$$\beta_c = 0.046 \cdot \exp\left(\frac{-V}{20.73}\right) \quad (62)$$

$$\alpha_d = 0.00016 \cdot \exp\left(\frac{-V}{48.4}\right) \quad (63)$$

$$\beta_d = \frac{1}{\exp(0.1(39 - V)) + 1} \exp\left(\frac{-V}{20.73}\right) \quad (64)$$

$$x_{t+\Delta t} = x_t + (1 - \exp(\Delta t/\tau_x)) \cdot (x_\infty - x_t) \quad (65)$$

0.2.3 HCN

$$I_H = g_{max,H} \cdot h^2 \cdot (V - E_H) \quad (66)$$

$$\tau_h = \left(120 + \frac{129.5}{1 + \exp(1.2 (V + 59.3))} \right) \quad (67)$$

$$h_\infty = \frac{1}{1 + \exp(0.1 (V + 91))} \quad (68)$$

Таблица 1: Parameters of pyramidal neurons

Parameter	Soma	Axon	OriProx	OriDist	RadProx	RadMed	RadDist	LM
Cm, mF/cm2	1	1	1	1	1	1	1	1
Rm, Ohm cm2	20000	20000	20000	20000	20000	20000	20000	20000
Ra, Ω cm	50	50	50	50	50	50	50	50
Leak conductance (S/cm2)	0.0002	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
Sodium conductance (S/cm2)	0.007	0.1	0.007	0.007	0.007	0.007	0.007	0.007
Delayed Rectifier K+ conductance (S/cm2)	0.0014	0.02	0.000868	0.000868	0.000868	0.000868	0.000868	0.000868
Proximal A-type K+ conductance (S/cm2)	0.0025	—	0.0075	0.0075	0.015	0	0	—
Distal A-type K+ conductance (S/cm2)	—	—	0	0	0	0.03	0.045	0.049
M-type K+ conductance (S/cm2)	0.06	0.03	0.06	0.06	0.06	0.06	0.06	—
Ih conductance [S/cm2]	0.00005	—	0.00005	0.0001	0.0001	0.0002	0.00035	—
Vhalf,h (mV)	-73	—	-81	-81	-82	-81	-81	—
L-type Ca2+ conductance (S/cm2)	0.0007	—	0.000031635000316350003163500031635	0.000031635000316350003163500031635	0.000031635000316350003163500031635	0.000031635000316350003163500031635	0.000031635000316350003163500031635	—
T-type Ca2+ conductance (S/cm2)	0.00005	—	0.0001	0.0001	0.0001	0.0001	0.0001	—
R-type Ca2+ conductance (S/cm2)	0.0003	—	0.00003	0.00003	0.00003	0.00003	0.00003	—