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 dendiritic compartments

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

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

For soma/axon compartments

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

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

For all compartments

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

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

$$Q = \frac{F}{RT} \tag{11}$$

The delayed rectifier current is given by:

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

For dendiritic compartments

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

For soma/axon compartments

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

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

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

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

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

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

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

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

The hyperpolarizing H-current is given by:

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

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

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

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

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

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

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

The slow after-hyperpolarizing current, IsAHP

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

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

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

$$C_{Ca} = \Big(\frac{[Ca^{2+}]_{in}}{0.025}\Big)^2 \tag{30}$$

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

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

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

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

The somatic high-voltage activated (HVA) L-type Ca2$+$ current is given by

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

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

$$\beta_b = 4.7\ exp\Big(\frac{V + 63.01}{-17}\Big) \tag{36}$$

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

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

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

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

$$\alpha_c = ? \tag{40}$$

$$\beta_c = ? \tag{41}$$

$$\tau_b = 3.6 \tag{42}$$

$$\tau_c = 29 \tag{43}$$

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

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

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

$$\beta_d = 0.46 exp(-V/22.73) \tag{46}$$

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

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

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

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

equations for dendritic CaR channels are:

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

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

while for the somatic CaR channels:

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

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

Dynamic of calcium concention

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

0.2 Интернейроны

0.2.1 CavL

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

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

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

$$\beta_m = 0.29 \cdot exp\Big(\frac{-V}{10.86}\Big) \tag{58}$$

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

0.2.2 CavN

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

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

$$\beta_c = 0.046 \cdot exp\Big(\frac{-V}{20.73}\Big) \tag{62}$$

$$\alpha_d = 0.00016 \cdot exp\Big(\frac{-V}{48.4}\Big) \tag{63}$$

$$\beta_d = \frac{1}{exp(0.1(39 - V)) + 1} exp\Big(\frac{-V}{20.73}\Big) \tag{64}$$

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

0.2.3 HCN

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

$$\tau_h = \frac{1}{q_{10}} \cdot \left(120 + \frac{129.5}{1 + exp(1.2\ (V + 59.3))}\right) \tag{67}$$

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

0.2.4 HCNolm

$$I_{Holm} = g_{max,Holm} \cdot r \cdot (V - E_H) \tag{69}$$

$$r_\infty = \frac{1}{1 + exp(0.98\ (V + 84.1))} \tag{70}$$

$$\tau_r = 100 + \frac{1}{exp(-(17.9 + 0.116V)) + exp(0.09V - 1.84)} \tag{71}$$

0.2.5 KCaS

$$I_{KCaS} = g_{max,KCaS} \cdot q^2 \cdot (V - E_K) \tag{72}$$

$$\alpha_q = q_{10} \cdot 15 \cdot ([Ca^{2+}]_{in})^2 \;\; \beta_q = q_{10} \cdot 0.00025 \tag{73}$$

0.2.6 Kdrfast

$$I_{Kdrfast} = g_{max,Kdrfast} \cdot n^4 \cdot (V - E_K) \tag{74}$$

$$\alpha_n = \frac{-0.07(V + 18)}{exp(\frac{V+18}{-6}) - 1} \tag{75}$$

$$\beta_n = 0.264 \cdot exp\left(\frac{V + 43}{40}\right) \tag{76}$$

0.2.7 Kdrfastngf

$$I_{Kdrfastngf} = g_{max,Kdrfastngf} \cdot n^4 \cdot (V - E_K) \tag{77}$$

$$\alpha_n = \frac{-0.07(V + 8)}{exp(\frac{V+8}{-6}) - 1} \tag{78}$$

$$\beta_n = 0.264 \cdot exp\left(\frac{V + 33}{40}\right) \tag{79}$$

0.2.8 Kdrslow

$$I_{Kdrslow} = g_{max,Kdrslow} \cdot n^4 \cdot (V - E_K) \tag{80}$$

$$\alpha_n = \frac{-0.028(V + 30)}{exp(\frac{V+30}{-6}) - 1} \tag{81}$$

$$\beta_n = 0.1056 \cdot exp\left(\frac{V + 55}{40}\right) \tag{82}$$

0.2.9 KvA

$$I_{kvA} = g_{max,kvA} \cdot n \cdot l \cdot (V - E_K) \tag{83}$$

$$n_\infty = \frac{1}{1 + exp(-21(V + 33.6)/T} \tag{84}$$

$$\tau_n = \frac{exp(-21(V + 33.6)/T)}{q_{10} \cdot 0.02 \cdot (1 + exp(-21(V + 33.6)/T))} \tag{85}$$

$$l_\infty = \frac{1}{1 + exp(46.41(V + 83)/T)} \tag{86}$$

$$\tau_l = \frac{exp(46.41(V + 83)/T)}{q_{10} \cdot 0.08 \cdot (1 + exp(46.41(V + 83)/T))} \tag{87}$$

0.2.10 KvAngf

$$I_{KvAngf} = g_{max,KvAngf} \cdot n \cdot l \cdot (V - E_K) \tag{88}$$

$$n_\infty = \frac{1}{1 + exp(-34.8(V + 23.6)/T} \tag{89}$$

$$\tau_n = \frac{exp(-34.8(V + 23.6))}{q_{10} \cdot 0.02 \cdot (1 + exp(-34.8(V + 23.6)/T))} \tag{90}$$

$$l_\infty = \frac{1}{1 + exp(46.41(V + 83)/T)} \tag{91}$$

$$\tau_l = \frac{exp(46.41(V + 83))}{q_{10} \cdot 0.08 \cdot (1 + exp(46.41(V + 83)/T))} \tag{92}$$

0.2.11 KvAolm

$$I_{KvAolm} = g_{max,KvAolm} \cdot a \cdot b \cdot (V - E_K) \tag{93}$$

$$a_\infty = \frac{1}{1 + exp(\frac{V+14}{-16.6})} \quad \tau_a = 5 \tag{94}$$

$$b_\infty = \frac{1}{1 + exp(\frac{V+71}{7.3})} \tag{95}$$

$$\tau_b = \frac{1}{\frac{0.000009}{exp(\frac{V-26}{18.5})} + \frac{0.014}{exp(\frac{V+70}{-11})+0.2}} \tag{96}$$

0.2.12 KvCaB

$$I_{KvCaB} = g_{max,KvCaB} \cdot n \cdot (V - E_K) \tag{97}$$

$$\alpha_n = \frac{0.28 \cdot [Ca_{2+}]_{in}}{[Ca_{2+}]_{in} + 0.00048 \cdot exp(\frac{-1.68 \cdot F \cdot V}{RT})} \tag{98}$$

$$\beta_n = \frac{0.48}{1 + 130000 \cdot [Ca_{2+}]_{in} \cdot exp(\frac{2 \cdot F \cdot V}{RT})} \tag{99}$$

0.2.13 KvGroup

$$I_{KvGroup} = g_{max,KvGroup} \cdot n \cdot (V - E_K) \tag{100}$$

$$\alpha_n = \frac{-0.0189324 \cdot (V - 4.18371)}{exp(-0.15562 \cdot (V - 4.18371)) - 1} \tag{101}$$

0.2.14 KvM

$$I_{KvM} = g_{max,KvM} \cdot m \cdot (V - E_K) \tag{102}$$

$$m_\infty = \frac{1}{1 + exp(-0.1(V + 40))} \tag{103}$$

$$\tau_m = 120 + \frac{0.10584 \cdot (V + 42)}{0.009 \cdot exp(0.2646 \cdot (V + 42))} \tag{104}$$

0.2.15 Nav

$$I_{Nav} = g_{max,Nav} \cdot m^3 \cdot h \cdot (V - E_{Na}) \tag{105}$$

$$\alpha_m = \frac{-0.3 \cdot (V + 43)}{exp(-0.2 \cdot (V + 43)) - 1} \tag{106}$$

$$\beta_m = \frac{0.3 \cdot (V + 15)}{exp(0.2 \cdot (V + 15)) - 1} \tag{107}$$

$$\alpha_h = \frac{0.23}{exp(0.05 \cdot (V + 65))} \tag{108}$$

$$\beta_h = \frac{3.33}{exp(-0.1 \cdot (V + 12.5)) + 1} \tag{109}$$

0.2.16 Navcck

$$I_{Navcck} = g_{max,Navcck} \cdot m^3 \cdot h \cdot s \cdot (V - E_{Na}) \tag{110}$$

$$\alpha_m = \frac{-0.5 \cdot (V + 42)}{exp(-0.2 \cdot (V + 42)) - 1} \tag{111}$$

$$\beta_m = \frac{0.3 \cdot (V + 13)}{exp(0.2 \cdot (V + 13)) - 1} \tag{112}$$

$$\alpha_h = \frac{0.6}{exp(0.05 \cdot (V + 65))} \tag{113}$$

$$\beta_h = \frac{1.31}{exp(-0.1 \cdot (V + 12.5)) + 1} \tag{114}$$

$$\alpha_s = \frac{0.003}{exp(\frac{V+45}{6})} \tag{115}$$

$$\beta_s = \frac{0.005}{exp(-0.05 \cdot (V + 35))} \tag{116}$$

0.2.17 Navngf

$$I_{Navngf} = g_{max,Navngf} \cdot m^3 \cdot h \cdot (V - E_{Na}) \tag{117}$$

$$\alpha_m = \frac{-0.34133 \cdot (V + 24)}{exp(-0.2 \cdot (V + 24)) - 1} \tag{118}$$

$$\beta_m = \frac{0.28483 \cdot (V - 4)}{exp(0.2 \cdot (V - 4)) - 1} \tag{119}$$

$$\alpha_h = \frac{0.29648}{exp(0.05 \cdot (V + 64.4184))} \tag{120}$$

$$\beta_h = \frac{3.0931}{exp(-0.1 \cdot (V + 12.1463)) + 1} \tag{121}$$

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	—	0.000031635	0.000031635	0.000031635	0.0031635	0.0031635	—
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	—