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The influence of astrocytic leaflet motility on ionic signalling and homeostasis at active synapses – Supplementary Material

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Table 1. Transmembrane currents used in the synaptic cradle model.

Current	Description	Equation(s)	Source
$I_{vgnc,pre}$	Voltage-gated Na ⁺ channel	$g_{vgnc,pre}m^3h(V_{pre} - E_{Na})$	1
$I_{vgkc,pre}$	Voltage-gated K ⁺ channel	$g_{vgkc,pre}n^4(V_{pre} - E_K)$	1
$I_{l,pre}$	Background leak channel	$g_{l,pre}(V_{pre} - E_l)$	1
$I_{vgcc,pre}$	Voltage-gated Ca ²⁺ channel	$g_{vgcc,pre}s(V_{pre} - E_{Ca})$	2
$\frac{dw}{dt}$	Voltage-gated (in)activation	$\alpha_w(1 - w) - \beta_w w$	1
α_m	Na ⁺ activation forward rate	$0.1 \left(\frac{25 - V_{pre}}{\exp\left(\frac{25 - V_{pre}}{10}\right) - 1} \right)$	Adapted from ¹
β_m	Na ⁺ activation backward rate	$4 \left(\frac{-V_{pre}}{18} \right)$	Adapted from ¹
α_h	Na ⁺ inactivation forward rate	$0.07 \exp\left(\frac{-V_{pre}}{20}\right)$	Adapted from ¹
β_h	Na ⁺ inactivation backward rate	$\left(\exp\left(\frac{30 - V_{pre}}{10}\right) + 1 \right)^{-1}$	Adapted from ¹
α_n	K ⁺ activation forward rate	$0.1 \left(\frac{10 - V_{pre}}{\exp\left(\frac{10 - V_{pre}}{10}\right) - 1} \right)$	Adapted from ¹
β_n	K ⁺ activation backward rate	$0.125 \left(\frac{-V_{pre}}{80} \right)$	Adapted from ¹
α_s	Ca ²⁺ activation forward rate	$\frac{1.6}{1 + \exp(-0.072(V_{pre} - 5))}$	Adapted from ²
β_s	Ca ²⁺ activation backward rate	$\frac{0.02(V_{pre} - 1.31)}{\exp\left(\frac{V_{pre} - 1.31}{5.36}\right) - 1}$	Adapted from ²
$I_{pmca,pre}$	Plasma-membrane Ca ²⁺ -ATPase (PMCA)	$\bar{I}_{pmca} \left(\frac{[Ca^{2+}]_{pre}}{K_{Ca,pre} + [Ca^{2+}]_{pre}} \right)$	3
$I_{nka,y}$	Na ⁺ -K ⁺ -ATPase (NKA)	$\bar{I}_{nka} \left(\frac{[Na^+]_y^{1.5}}{K_{Na,y}^{1.5} + [Na^+]_y^{1.5}} \times \frac{[K^+]_y}{K_{K,y} + [K^+]_y} \right)$	4
$I_{ampa,post}$	AMPA receptor	$g_{ampa}r(V_{post} - E_{ampa})$	5
$I_{nmda,post}$	NMDA receptor	$g_{ampa}B(V_{post})r(V_{post} - E_{ampa})$	5

Current	Description	Equation(s)	Source
$\frac{dr}{dt}$	AMPA/NMDA (in)activation	$\alpha_r [Glu]_{ecs} (1 - r) - \beta_r r$	5
$B(V_{post})$	NMDA magnesium block	$\left(1 + \exp(-0.062V_{post}) \frac{[Mg]_o}{3.57}\right)^{-1}$	6
$I_{eaat,psc}$	Excitatory amino-acid transporter (EAAT)	$\bar{I}_{eaat} \left(\frac{[Glu]_{ecs}}{K_{eaat} + [Glu]_{ecs}}\right)$	-
$I_{ncx,psc}$	Na ⁺ /Ca ²⁺ exchanger (NCX)	$\bar{I}_{ncx} \left(\left(\frac{[Na^+]_{psc}}{[Na^+]_{ecs}}\right)^3 \exp\left(\frac{\gamma F V_{psc}}{RT}\right) - \left(\frac{[Ca^{2+}]_{psc}}{[Ca^{2+}]_{ecs}}\right) \exp\left(\frac{(\gamma - 1) F V_{psc}}{RT}\right) \right)$	4,7
$I_{kir,psc}$	K ⁺ inward rectifier channel (K _i 4.1)	$g_{kir} \sqrt{[K^+]_{ecs}} (V_{psc} - E_{kir})$	8
$I_{pf,x}$	Leaflet diffusion	$K_{pf,x} \frac{-E_x}{l_{lf}} \exp\left(-\frac{Q \left(\varphi - \sqrt{\frac{Q(-E_x)}{l_{lf} \pi \epsilon}}\right)}{k_B T}\right)$	Adapted from 9
$I_{l,x,y}$	Passive channels	$g_{l,x,y} (V_y - E_x)$	3
$I_{ecs,x}$	ECS diffusion	$g_{ecs} \lambda (-E_{x,ecs})$	10
E_x	Equilibrium potential	$\frac{RT}{z_x F} \ln \frac{[x]_o}{[x]_i}$	3

Note: $w \in \{m, h, n, s\}$, $x \in \{Na, K, Ca\}$ and $y \in \{pre, post, psc\}$

Table 2. Parameters used in the synaptic cradle model.

Parameter	Description	Value	Unit(s)	Source
Constants				
dt	Time step	10	μs	-
F	Faraday's constant	96485	C/mol	-
R	Idela gas constant	8.314	J/mol.K	-
k_B	Boltzmann's constant	1.38×10^{-23}	J/K	-
T	Absolute temperature	310	K	-
Q	Elementary charge	1.6002×10^{-19}	C	-
z_K	Valency of K ⁺	1	-	-
z_{Na}	Valency of Na ⁺	1	-	-
z_{Ca}	Valency of Ca ²⁺	2	-	-
Neuronal parameters				

Parameter	Description	Value	Unit(s)	Source
V_{pre}	Presynaptic membrane potential	-70	mV	-
V_{post}	Postsynaptic membrane potential	-70	mV	-
C_m	Membrane capacitance	0.01	F/m ²	1
$g_{vgnc,pre}$	Maximal Na ⁺ conductance	120	mS/cm ²	1
E_{Na}	Na ⁺ equilibrium potential	45	mV	Adapted from ¹
$g_{vgkc,pre}$	Maximal K ⁺ conductance	36	mS/cm ²	1
E_K	K ⁺ equilibrium potential	-82	mV	Adapted from ¹
$g_{vgcc,pre}$	Maximal Ca ²⁺ conductance	0.1	mS/cm ²	Adapted from ²
E_{Ca}	Ca ²⁺ equilibrium potential	$\frac{RT}{z_{Ca}F} \ln \frac{[Ca^{2+}]_{ecs}}{[Ca^{2+}]_{pre}}$	V	-
$g_{l,pre}$	Maximal leak conductance	0.3	mS/cm ²	1
E_l	Leak equilibrium potential	-59	mV	Adapted from ¹
V_{max}	Maximal PMCA velocity	0.2×10^{-6}	mol/m ² s	3
\bar{I}_{pmca}	Maximal PMCA current	$V_{max}F$	A/m ²	3
$K_{Ca,pre}$	PMCA Ca ²⁺ affinity	0.2	μM	3
P_{max}	Maximal NKA velocity	1.12×10^{-2}	mol/m ² s	4
\bar{I}_{nka}	Maximal NKA current	$P_{max}F$	A/m ²	4
$K_{Na,pre/post}$	NKA Na ⁺ affinity	10	mM	14
$K_{K,pre/post}$	NKA K ⁺ affinity	0.6	mM	14
g_{ampa}	Maximal AMPA conductance	0.18	S/m ²	5
E_{ampa}	AMPA equilibrium potential	0	mV	5
α_{ampa}	AMPA activation rate	1.1×10^6	M ⁻¹ s ⁻¹	5
β_{ampa}	AMPA inactivation rate	190	s ⁻¹	5
g_{nmda}	Maximal NMDA conductance	0.26	S/m ²	6
E_{nmda}	NMDA equilibrium potential	0	mV	6
α_{nmda}	NMDA activation rate	7.4×10^4	M ⁻¹ s ⁻¹	6
β_{nmda}	NMDA inactivation rate	6.6	s ⁻¹	6
$g_{l,Na,pre}$	Na ⁺ leak conductance	1.4184	S/m ²	Calculated
$g_{l,K,pre}$	K ⁺ leak conductance	7.6113	S/m ²	Calculated
$g_{l,Ca,pre}$	Ca ²⁺ leak conductance	0.0186	S/m ²	Calculated
$g_{l,Na,post}$	Na ⁺ leak conductance	1.4184	S/m ²	Calculated
$g_{l,K,post}$	K ⁺ leak conductance	7.6113	S/m ²	Calculated
$g_{l,Ca,post}$	Ca ²⁺ leak conductance	0.0186	S/m ²	Calculated
Astrocytic parameters				

Parameter	Description	Value	Unit(s)	Source
V_{psc}	Membrane potential	-80.7	mV	10
V_{eaat}	Maximal EAAT velocity	3×10^{-6}	mol/m ² s	11
eff_{eaat}	Average EAAT efficiency	0.5	-	12
\bar{I}_{eaat}	Maximal EAAT current	$V_{eaat} eff_{eaat} F$	A/m ²	-
K_{eaat}	EAAT Glu affinity	20	μM	13
$K_{Na,psc}$	NKA Na ⁺ affinity	10	mM	14
$K_{K,psc}$	NKA K ⁺ affinity	3.6	mM	14
\bar{I}_{ncx}	Maximal NCX current	1	A/m ²	7
γ	NCX energy partition	0.5	-	7
g_{kir}	Maximal K _{ir} 4.1 conductance	144	S/m ²	10
E_{kir}	K _{ir} 4.1 equilibrium potential	$\frac{RT}{z_K F} \ln \frac{[K^+]_{ecs}}{[K^+]_{psc}}$	V	-
K_{pf}	Poole-Frenkel channel constant	0.018	S/m	9
φ	Well activation energy	10	J	9
ϵ	Dynamic permittivity	$\epsilon_0 \epsilon_r$	-	9
ϵ_0	Vacuum permittivity	8.85×10^{-12}	F/m	9
ϵ_r	Relative permittivity of brain tissue	0.82	F/m	9
$g_{l,Na,psc}$	Na ⁺ leak conductance	2.3771	S/m ²	Calculated
$g_{l,K,psc}$	K ⁺ leak conductance	33.0159	S/m ²	Calculated
$g_{l,Ca,psc}$	Ca ²⁺ leak conductance	1.6×10^{-11}	S/m ²	Calculated
Extracellular parameters				
g_{ecs}	Maximal diffusion conductance	1	S/m ²	10
λ	Conductance scaling factor	10	-	-
$E_{x,ecs}$	ECS equilibrium potential	$\frac{RT}{z_x F} \ln \frac{[x]_{gecs}}{[x]_{ecs}}$	V	10
Concentrations				
$[K^+]_{psc}$	Initial K ⁺ in PsC	100	mM	14
$[K^+]_{ecs}$	Initial K ⁺ in ECS	4	mM	14
$[K^+]_{pre}$	K ⁺ in Pre	100	mM	14
$[K^+]_{post}$	K ⁺ in Post	100	mM	14
$[K^+]_{gecs}$	K ⁺ in GECS	4	mM	14
$[Na^+]_{psc}$	Initial Na ⁺ in PsC	15	mM	14
$[Na^+]_{ecs}$	Initial Na ⁺ in ECS	135	mM	14
$[Na^+]_{pre}$	Na ⁺ in Pre	15	mM	14

Parameter	Description	Value	Unit(s)	Source
$[Na^+]_{post}$	Na ⁺ in Post	15	mM	14
$[Na^+]_{gecs}$	Na ⁺ in GECS	135	mM	14
$[Ca^{2+}]_{psc}$	Initial Ca ²⁺ in PsC	100	nM	14
$[Ca^{2+}]_{ecs}$	Initial Ca ²⁺ in ECS	1.5	mM	14
$[Ca^{2+}]_{pre}$	Initial Ca ²⁺ in Pre	50	nM	14
$[Ca^{2+}]_{post}$	Ca ²⁺ in Post	50	nM	14
$[Ca^{2+}]_{gecs}$	Ca ²⁺ in GECS	1.5	mM	14
Morphology parameters				
Vol_{psc}	PsC volume	0.031416	fL	Calculated
Vol_{pre}	Pre volume	0.014314	fL	Calculated
Vol_{post}	Post volume	0.014314	fL	Calculated
$Vol_{ecs,a}$	ECS volume (A configuration)	0.001145	fL	Calculated
$Vol_{ecs,b}$	ECS volume (B configuration)	0.00786	fL	Calculated
$Vol_{ecs,c}$	ECS volume (C configuration)	0.055022	fL	Calculated
SA_{psc}	PsC surface area	0.23562	μm^2	Calculated
SA_{pre}	Pre surface area	0.21206	μm^2	Calculated
SA_{post}	Post surface area	0.21206	μm^2	Calculated
SA_{ecs}	ECS diffusion surface area	0.015	μm^2	Calculated
CSA_{lf}	Leaflet cross-sectional area	0.007854	μm^2	Calculated
l_{lf}	Leaflet length	2	μm	-

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