SBML Model Report

Model name: "Vasalou2010_Pacemaker_Neuron_SCN"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by Lukas Endler[1] at April eighth 2010 at 11:39 p. m. and last time modified at February 21st 2014 at 10:11 a. m. Table 1 provides an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

Element	Quantity	Element	Quantity
compartment types	0	compartments	4
species types	0	species	29
events	0	constraints	0
reactions	41	function definitions	0
global parameters	163	unit definitions	19
rules	34	initial assignments	3

Model Notes

This the single cell model from the article:
A multiscale model to investigate circadian rhythmicity of pacemaker neurons in the suprachiasmatic nucleus.
Vasalou C, Henson MA. PLoS Comput Biol 2010 Mar 12;6(3):e1000706. PMID: 20300645 , DOI: 10.1371/journal.pcbi.1000706 ;

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Abstract:
The suprachiasmatic nucleus (SCN) of the hypothalamus is a multicellular system that drives daily rhythms in mammalian behavior and physiology. Although the gene regulatory network that produces daily oscillations within individual neurons is well characterized, less is known about the electrophysiology of the SCN cells and how firing rate correlates with circadian gene expression. We developed a firing rate code model to incorporate known electrophysiological properties of SCN pacemaker cells, including circadian dependent changes in membrane voltage and ion conductances. Calcium dynamics were included in the model as the putative link between electrical firing and gene expression. Individual ion currents exhibited oscillatory patterns matching experimental data both in current levels and phase relationships. VIP and GABA neurotransmitters, which encode synaptic signals across the SCN, were found to play critical roles in daily oscillations of membrane excitability and gene expression. Blocking various mechanisms of intracellular calcium accumulation by simulated pharmacological agents (nimodipine, IP3- and ryanodine-blockers) reproduced experimentally observed trends in firing rate dynamics and core-clock gene transcription. The intracellular calcium concentration was shown to regulate diverse circadian processes such as firing frequency, gene expression and system periodicity. The model predicted a direct relationship between firing frequency and gene expression amplitudes, demonstrated the importance of intracellular pathways for single cell behavior and provided a novel multiscale framework which captured characteristics of the SCN at both the electrophysiological and gene regulatory levels.

Originally created by libAntimony v1.3 (using libSBML 4.1.0-b1)

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To cite BioModels Database, please use Le Novre N., Bornstein B., Broicher A., Courtot M., Donizelli M., Dharuri H., Li L., Sauro H., Schilstra M., Shapiro B., Snoep J.L., Hucka M. (2006) BioModels Database: A Free, Centralized Database of Curated, Published, Quantitative Kinetic Models of Biochemical and Cellular Systems Nucleic Acids Res., 34: D689-D691.

2 Unit Definitions

This is an overview of 22 unit definitions of which three are predefined by SBML and not mentioned in the model.

2.1 Unit `substance`

Name nmole

Definition nmol

2.2 Unit `umole`

Name micromole

Definition µmol

2.3 Unit `mmole`

Name millimole

Definition mmol

2.4 Unit `time`

Name hour

Definition 3600 s

2.5 Unit `mV`

Name milliVolt

Definition mV

2.6 Unit `nS`

Name nanoSievert

Definition nSv

2.7 Unit `uA`

Name microAmpere

Definition µA

2.8 Unit `nF`

Name nanoFarrad

Definition nF

2.9 Unit `nM`

Name nM

Definition $\mathrm{nmol} \cdot \mathrm{l}^{-1}$

2.10 Unit `per_nM`

Name per_nM

Definition $\mathrm{nmol}^{-1} \cdot \mathrm{l}$

2.11 Unit per_nM_2

Name per_nM_2

Definition $\text{nmol}^{-2} \cdot \text{l}$

2.12 Unit per_uM

Name per_uM

Definition $\mu\text{mol}^{-1} \cdot \text{l}$

2.13 Unit mM

Name mM

Definition $\text{mmol} \cdot \text{l}^{-1}$

2.14 Unit uM

Name uM

Definition $\mu\text{mol} \cdot \text{l}^{-1}$

2.15 Unit per_h

Name per_h

Definition $(3600\ \text{s})^{-1}$

2.16 Unit uM_per_h

Name uM_per_h

Definition $\mu\text{mol} \cdot \text{l}^{-1} \cdot (3600\ \text{s})^{-1}$

2.17 Unit nM_per_h

Name nM_per_h

Definition $\text{nmol} \cdot \text{l}^{-1} \cdot (3600\ \text{s})^{-1}$

2.18 Unit per_uM_per_h

Name per_uM_per_h

Definition $\mu\text{mol}^{-1} \cdot \text{l} \cdot (3600\ \text{s})^{-1}$

2.19 Unit per_nM_per_h

Name per_nM_per_h

Definition $\mathrm{nmol}^{-1} \cdot \mathrm{l} \cdot (3600\ \mathrm{s})^{-1}$

2.20 Unit volume

Notes Litre is the predefined SBML unit for `volume`.

Definition l

2.21 Unit area

Notes Square metre is the predefined SBML unit for `area` since SBML Level 2 Version 1.

Definition m^2

2.22 Unit length

Notes Metre is the predefined SBML unit for `length` since SBML Level 2 Version 1.

Definition m

3 Compartments

This model contains four compartments.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
extra		0000290	3	1	litre	☑	
cytoplasm		0000290	3	1	litre	☑	
store		0000290	3	1	litre	☑	
nucleus		0000290	3	1	litre	☑	

3.1 Compartment extra

This is a three dimensional compartment with a constant size of one litre.

SBO:0000290 physical compartment

3.2 Compartment cytoplasm

This is a three dimensional compartment with a constant size of one litre.

SBO:0000290 physical compartment

3.3 Compartment `store`

This is a three dimensional compartment with a constant size of one litre.

SBO:0000290 physical compartment

3.4 Compartment `nucleus`

This is a three dimensional compartment with a constant size of one litre.

SBO:0000290 physical compartment

4 Species

This model contains 29 species. The boundary condition of three of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 9 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
Ca_in		cytoplasm	$\mu\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
Ca_store		store	$\mu\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
Ca_ex		extra	$\mu\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
M_P	M_P	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
M_C	M_C	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
M_B	M_B	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
P_C	P_C	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
C_C	C_C	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
P_CP	P_CP	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
C_CP	C_CP	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PC_C	PC_C	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PC_N	PC_N	nucleus	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PC_CP	PC_CP	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PC_NP	PC_NP	nucleus	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
B_C	B_C	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
B_CP	B_CP	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
B_N	B_N	nucleus	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
B_NP	B_NP	nucleus	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
I_N	I_N	nucleus	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
CB	CB	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
VIP	VIP	cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$

Produced by SBML2LaTeX

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
Cl_ex		extra	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
Cl_o		cytoplasm	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
GABA		cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☐	☑
GABA_o		cytoplasm	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☐	☐
K_in		cytoplasm	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☑
K_ex		extra	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
Na_in		cytoplasm	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☑
Na_ex		extra	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐

Produced by SBML2LaTeX

5 Parameters

This model contains 163 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
v_vo			0.090	$\mu mol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
n_vo			4.500	dimensionless	☑
K_vo			4.500	$nmol \cdot l^{-1}$	☑
v_kk			3.300	$\mu mol^{-1} \cdot l \cdot (3600\ s)^{-1}$	☑
n_kk			0.100	dimensionless	☑
K_kk			0.020	$nmol \cdot l^{-1}$	☑
n_kCa			2.000	dimensionless	☑
V_M1	V_M1		$3 \cdot 10^{-4}$	$\mu mol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
beta_IP3	beta_IP3		0.500	dimensionless	☑
V_M2	V_M2		149.500	$\mu mol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
n_M2	n_M2		2.200	dimensionless	☑
K_2	K_2		5.000	$\mu mol \cdot l^{-1}$	☑
V_M3	V_M3		400.000	$\mu mol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
n_M3	n_M3		6.000	dimensionless	☑
K_R_Ca	K_R_Ca		3.000	$\mu mol \cdot l^{-1}$	☑
p_A	p_A		4.200	dimensionless	☑
K_A	K_A		0.670	$\mu mol \cdot l^{-1}$	☑
k_f	k_f		0.001	$(3600\ s)^{-1}$	☑
v_sP0	v_sP0		1.000	$nmol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
C_T	C_T		1.600	$nmol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
K_C	K_C		0.150	$nmol \cdot l^{-1}$	☑
n_BN			4.000	dimensionless	☑
K_AP	K_AP		0.600	$nmol \cdot l^{-1}$	☑
v_mP	v_mP		1.100	$nmol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑
K_mP	K_mP		0.310	$nmol \cdot l^{-1}$	☑
kd_mP	kd_mP		0.010	$(3600\ s)^{-1}$	☑
v_sC	v_sC		1.100	$nmol \cdot l^{-1} \cdot (3600\ s)^{-1}$	☑

Id	Name	SBO	Value	Unit	Constant
K_sC	K_sC		0.600	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
v_mC	v_mC		1.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_mC	K_mC		0.400	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
kd_mC	kd_mC		0.010	$(3600\ \mathrm{s})^{-1}$	☑
v_sB	v_sB		1.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_IB	K_IB		2.200	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
m_BN			2.000	dimensionless	☑
v_mB	v_mB		0.800	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_mB	K_mB		0.400	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
kd_mB	kd_mB		0.010	$(3600\ \mathrm{s})^{-1}$	☑
ks_P	ks_P		0.600	$(3600\ \mathrm{s})^{-1}$	☑
kd_n	kd_n		0.010	$(3600\ \mathrm{s})^{-1}$	☑
V1_P	V1_P		0.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_p	K_p		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
V2_P	V2_P		0.300	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_dp	K_dp		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
k3	k3		0.400	$\mathrm{nmol}^{-1} \cdot \mathrm{l} \cdot (3600\ \mathrm{s})^{-1}$	☑
k4	k4		0.200	$(3600\ \mathrm{s})^{-1}$	☑
ks_C	ks_C		1.600	$(3600\ \mathrm{s})^{-1}$	☑
kd_nc	kd_nc		0.120	$(3600\ \mathrm{s})^{-1}$	☑
V1_C	V1_C		0.600	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V2_C	V2_C		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
v_dPC	v_dPC		0.700	$\mathrm{nmol}^{-1} \cdot \mathrm{l} \cdot (3600\ \mathrm{s})^{-1}$	☑
Kd	Kd		0.300	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
v_dCC	v_dCC		0.700	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
k1			0.450	$(3600\ \mathrm{s})^{-1}$	☑
k2			0.200	$(3600\ \mathrm{s})^{-1}$	☑
V1_PC	V1_PC		0.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V2_PC	V2_PC		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑

Id	Name	SBO	Value	Unit	Constant
vd_PCC	vd_PCC		0.700	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V3_PC	V3_PC		0.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V4_PC	V4_PC		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
vd_PCN	vd_PCN		0.700	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
k7			0.500	$\mathrm{nmol}^{-1} \cdot \mathrm{l} \cdot (3600\ \mathrm{s})^{-1}$	☑
k8			0.100	$(3600\ \mathrm{s})^{-1}$	☑
vd_IN	vd_IN		0.800	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
ksB			0.120		☑
V1_B	V1_B		0.500	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V2_B	V2_B		0.100	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
k5			0.400		☑
k6			0.200		☑
vd_BC	vd_BC		0.500	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V3_B	V3_B		0.500	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
V4_B	V4_B		0.200	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
vd_BN	vd_BN		0.600	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
v_K	v_K		0.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	⊟
K_1_CB			0.010	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
vP			1.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
K_2_CB			0.010	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
WT			1.000	dimensionless	☑
v_VIP			0.500	$\mathrm{nmol} \cdot \mathrm{l}^{-1} \cdot (3600\ \mathrm{s})^{-1}$	☑
f_r			0.000	Hz	⊟
n_VIP			1.900	dimensionless	☑
K_VIP			15.000		☑
k_dVIP			0.500		☑
n_dVIP			0.200	dimensionless	☑

Id	Name	SBO	Value	Unit	Constant
v_GABA			19.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
K_GABA			3.000	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	☑
beta			0.000	dimensionless	☐
K_D	K_D		0.080		☑
v_sPc	v_sPc		0.000		☐
V_MK	V_MK		5.000		☑
k_MK	k_MK		2.900		☑
V_b			2.000		☑
k_b			2.000		☑
E_Na	E_Na		0.000	mV	☐
E_Na_0	E_Na_0		45.000	mV	☑
T			37.000	K	☑
T_abs			273.150	K	☑
T_room			22.000	K	☑
E_K	E_K		0.000	mV	☐
E_K_0	E_K_0		−97.000	mV	☑
E_L	E_L		0.000	mV	☐
E_L_0	E_L_0		−29.000	mV	☑
E_Ca	E_Ca		0.000	mV	☐
k_q			$8.75 \cdot 10^{-5}$		☑
Cl_in			0.000		☐
K_Cl1	K_Cl1		4.000		☑
v_Cl1	v_Cl1		15.500		☑
n_Cl	n_Cl		−0.200		☑
K_Cl2	K_Cl2		1.000		☑
v_Cl2	v_Cl2		19.000		☑
E_inhib			0.000	mV	☐
P_K	P_K		0.000		☐
v_PK	v_PK		1.900		☑
n_PK	n_PK		−2.000		☑
K_PK	K_PK		1.000		☑
theta_Na	theta_Na		0.000	mV	☐
theta_K	theta_K		0.000	mV	☐
alpha			0.000		☐
P_Ca	P_Ca		0.050		☑
P_Na	P_Na		0.036		☑
P_Cl	P_Cl		0.300		☑
beta_a	beta_a		0.000		☐
c			0.000		☐
psi			0.000		☐
V_rest	V_rest		0.000	mV	☐
R_g	R_g		8.314		☑

Id	Name	SBO	Value	Unit	Constant
Faraday	Faraday		96485.000		☑
theta			0.000	mV	☐
V_theta			20.000	mV	☑
V_reset	V_reset		0.000	mV	☐
R			0.000		☐
V_R			0.410		☑
K_R			34.000	mV	☑
I_Na	I_Na		0.000	µA	☐
g_Na	g_Na		36.000	nSv	☑
g_K	g_K		0.000	nSv	☐
g_K_0	g_K_0		9.700	nSv	☑
K_gk	K_gk		10.000	$\text{nmol} \cdot \text{l}^{-1}$	☑
v_gk	v_gk		10.000	nSv	☑
I_Na_abs	I_Na_abs		0.000	µA	☐
g_ex			0.000	nSv	☐
V_ex1	V_ex1		105.000		☑
n_ex1	n_ex1		2.500		☑
K_ex1	K_ex1		$5.7405 \cdot 10^{8}$	µA	☑
n_ex2	n_ex2		-1.000		☑
K_ex2	K_ex2		1.000	$\mu\text{mol}^{-1} \cdot \text{l}$	☑
V_ex2	V_ex2		4.400		☑
g_L	g_L		0.000		☐
g_Ca	g_Ca		0.000		☐
v_Ca	v_Ca		12.300		☑
n_Ca	n_Ca		2.200		☑
K_Ca	K_Ca		22.000		☑
gK_Ca	gK_Ca		0.000		☐
VK_Ca	VK_Ca		3.000		☑
n_KCa	n_KCa		-1.000		☑
K_KCa	K_KCa		0.160		☑
I_star			0.000	µA	☐
g_inhib			12.300	nSv	☑
E_ex			0.000	mV	☑
R_star			0.000		☐
tau_m			0.000		☐
Cm			5.000		☑
PK_o			1.100		☑
V_phos	V_phos		0.400		☑

6 Initialassignments

This is an overview of three initialassignments.

6.1 Initialassignment V1_P

Derived unit contains undeclared units

Math V_phos

6.2 Initialassignment V1_PC

Derived unit contains undeclared units

Math V_phos

6.3 Initialassignment V3_PC

Derived unit contains undeclared units

Math V_phos

7 Rules

This is an overview of 34 rules.

7.1 Rule GABA

Rule GABA is an assignment rule for species GABA:

$$\mathrm{GABA} = [\mathrm{GABA\_o}] + \frac{\mathrm{v\_GABA} \cdot [\mathrm{VIP}]}{\mathrm{K\_GABA} + [\mathrm{VIP}]} \tag{1}$$

Derived unit $\mathrm{nmol} \cdot \mathrm{l}^{-1}$

7.2 Rule K_in

Rule K_in is an assignment rule for species K_in:

$$\mathrm{K\_in} = \frac{[\mathrm{K\_ex}]}{\mathrm{theta\_K}} \tag{2}$$

Derived unit $\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot \mathrm{mV}^{-1}$

7.3 Rule Na_in

Rule Na_in is an assignment rule for species Na_in:

$$\text{Na\_in} = \frac{[\text{Na\_ex}]}{\text{theta\_Na}} \tag{3}$$

Derived unit $\text{mmol} \cdot \text{l}^{-1} \cdot \text{mV}^{-1}$

7.4 Rule v_K

Rule v_K is an assignment rule for parameter v_K:

$$\text{v\_K} = \frac{\text{V\_MK} \cdot [\text{Ca\_in}]}{\text{k\_MK} + [\text{Ca\_in}]} + \frac{\text{V\_b} \cdot \text{beta}}{\text{k\_b} + \text{beta}} \tag{4}$$

7.5 Rule f_r

Rule f_r is an assignment rule for parameter f_r:

$$\text{f\_r} = \frac{-1}{\text{tau\_m} \cdot \left(\frac{\text{theta} - \text{R\_star} \cdot \text{I\_star}}{\text{V\_reset} - \text{R\_star} \cdot \text{I\_star}}\right)} \tag{5}$$

7.6 Rule beta

Rule beta is an assignment rule for parameter beta:

$$\text{beta} = \frac{[\text{VIP}]}{[\text{VIP}] + \text{K\_D}} \tag{6}$$

7.7 Rule v_sPc

Rule v_sPc is an assignment rule for parameter v_sPc:

$$\text{v\_sPc} = \text{v\_sP0} + \frac{\text{C\_T} \cdot [\text{CB}]}{\text{K\_C} + [\text{CB}]} \tag{7}$$

Derived unit $\text{nmol} \cdot \text{l}^{-1} \cdot (3600\ \text{s})^{-1}$

7.8 Rule E_Na

Rule E_Na is an assignment rule for parameter E_Na:

$$\text{E\_Na} = \frac{\text{E\_Na\_0} \cdot (\text{T} + \text{T\_abs})}{\text{T\_room} + \text{T\_abs}} \tag{8}$$

Derived unit mV

7.9 Rule E_K

Rule E_K is an assignment rule for parameter E_K:

$$\text{E\_K} = \frac{\text{E\_K\_0} \cdot (\text{T} + \text{T\_abs})}{\text{T\_room} + \text{T\_abs}} \tag{9}$$

Derived unit mV

7.10 Rule E_L

Rule E_L is an assignment rule for parameter E_L:

$$\text{E\_L} = \frac{\text{E\_L\_0} \cdot (\text{T} + \text{T\_abs})}{\text{T\_room} + \text{T\_abs}} \tag{10}$$

Derived unit mV

7.11 Rule E_Ca

Rule E_Ca is an assignment rule for parameter E_Ca:

$$\text{E\_Ca} = \frac{\text{k\_q} \cdot (\text{T} + \text{T\_abs})}{2} \cdot \left(\frac{[\text{Ca\_ex}]}{[\text{Ca\_in}]}\right) \cdot 1000 \tag{11}$$

7.12 Rule Cl_in

Rule Cl_in is an assignment rule for parameter Cl_in:

$$\text{Cl\_in} = [\text{Cl\_o}] + \frac{[\text{M\_P}]}{\text{K\_Cl1} + [\text{M\_P}]} \cdot \text{v\_Cl1} + \frac{[\text{GABA}]^{\text{n\_Cl}}}{\text{K\_Cl2} + [\text{GABA}]^{\text{n\_Cl}}} \cdot \text{v\_Cl2} \tag{12}$$

7.13 Rule E_inhib

Rule E_inhib is an assignment rule for parameter E_inhib:

$$\text{E\_inhib} = \text{k\_q} \cdot (\text{T} + \text{T\_abs}) \cdot \left(\frac{[\text{Cl\_ex}]}{\text{Cl\_in}}\right) \cdot 1000 \tag{13}$$

7.14 Rule P_K

Rule P_K is an assignment rule for parameter P_K:

$$\text{P\_K} = \frac{\text{v\_PK} \cdot [\text{B\_C}]^{\text{n\_PK}}}{\text{K\_PK} + [\text{B\_C}]^{\text{n\_PK}}} \tag{14}$$

7.15 Rule theta_Na

Rule theta_Na is an assignment rule for parameter theta_Na:

$$\text{theta\_Na} = \exp\left(\frac{\text{E\_Na}}{\text{k\_q} \cdot (\text{T} + \text{T\_abs}) \cdot 1000}\right) \tag{15}$$

Derived unit dimensionless

7.16 Rule theta_K

Rule theta_K is an assignment rule for parameter theta_K:

$$\text{theta\_K} = \exp\left(\frac{\text{E\_K}}{\text{k\_q} \cdot (\text{T} + \text{T\_abs}) \cdot 1000}\right) \tag{16}$$

Derived unit dimensionless

7.17 Rule alpha

Rule alpha is an assignment rule for parameter alpha:

$$\text{alpha} = 4 \cdot \text{P\_Ca} \cdot [\text{Ca\_in}] \cdot 10^{-3} + \text{P\_K} \cdot [\text{K\_in}] + \text{P\_Na} \cdot [\text{Na\_in}] + \text{P\_Cl} \cdot [\text{Cl\_ex}] \tag{17}$$

7.18 Rule beta_a

Rule beta_a is an assignment rule for parameter beta_a:

$$\begin{aligned}\text{beta\_a} = \text{P\_K} \cdot [\text{K\_in}] - \text{P\_K} \cdot [\text{K\_ex}] + \text{P\_Na} \cdot [\text{Na\_in}] \\ - \text{P\_Na} \cdot [\text{Na\_ex}] + \text{P\_Cl} \cdot [\text{Cl\_ex}] - \text{P\_Cl} \cdot \text{Cl\_in}\end{aligned} \tag{18}$$

7.19 Rule c

Rule c is an assignment rule for parameter c:

$$\text{c} = \left(4 \cdot \text{P\_Ca} \cdot [\text{Ca\_ex}] \cdot 10^{-3} + \text{P\_K} \cdot [\text{K\_ex}] + \text{P\_Na} \cdot [\text{Na\_ex}] + \text{P\_Cl} \cdot \text{Cl\_in}\right) \tag{19}$$

7.20 Rule psi

Rule psi is an assignment rule for parameter psi:

$$\text{psi} = \frac{\sqrt{2} - \text{beta\_a}}{2 \cdot \text{alpha}} \tag{20}$$

7.21 Rule V_rest

Rule V_rest is an assignment rule for parameter V_rest:

$$\text{V\_rest} = \frac{\text{R\_g} \cdot (\text{T} + \text{T\_abs})}{\text{Faraday}} \cdot \ln \text{psi} \cdot 1000 \tag{21}$$

7.22 Rule theta

Rule theta is an assignment rule for parameter theta:

$$\text{theta} = \text{V\_rest} + \text{V\_theta} \tag{22}$$

Derived unit mV

7.23 Rule V_reset

Rule V_reset is an assignment rule for parameter V_reset:

$$\text{V\_reset} = \text{V\_rest} + 4 \tag{23}$$

7.24 Rule R

Rule R is an assignment rule for parameter R:

$$\text{R} = \frac{\text{V\_R} \cdot \text{V\_rest}}{\text{K\_R} + \text{V\_rest}} \tag{24}$$

7.25 Rule I_Na

Rule I_Na is an assignment rule for parameter I_Na:

$$\text{I\_Na} = \text{g\_Na} \cdot (\text{V\_rest} - \text{E\_Na}) \tag{25}$$

Derived unit $\mathrm{nSv} \cdot \mathrm{mV}$

7.26 Rule g_K

Rule g_K is an assignment rule for parameter g_K:

$$\text{g\_K} = \text{g\_K\_0} + \frac{[\text{M\_P}]}{\text{K\_gk} + [\text{M\_P}]} \cdot \text{v\_gk} \tag{26}$$

Derived unit nSv

7.27 Rule I_Na_abs

Rule I_Na_abs is an assignment rule for parameter I_Na_abs:

$$\text{I\_Na\_abs} = \sqrt{2} \tag{27}$$

Derived unit µA

7.28 Rule g_ex

Rule g_ex is an assignment rule for parameter g_ex:

$$\mathrm{g\_ex} = \frac{\mathrm{V\_ex1} \cdot \mathrm{I\_Na\_abs}^{\mathrm{n\_ex1}}}{\mathrm{K\_ex1} + \mathrm{I\_Na\_abs}^{\mathrm{n\_ex1}}} + \frac{[\mathrm{Ca\_in}]^{\mathrm{n\_ex2}}}{\mathrm{K\_ex2} + [\mathrm{Ca\_in}]^{\mathrm{n\_ex2}}} \cdot \mathrm{V\_ex2} \tag{28}$$

7.29 Rule g_L

Rule g_L is an assignment rule for parameter g_L:

$$\mathrm{g\_L} = \frac{1}{\mathrm{R}} \tag{29}$$

7.30 Rule g_Ca

Rule g_Ca is an assignment rule for parameter g_Ca:

$$\mathrm{g\_Ca} = \mathrm{v\_Ca} \cdot \frac{[\mathrm{M\_P}]^{\mathrm{n\_Ca}}}{\mathrm{K\_Ca} + [\mathrm{M\_P}]^{\mathrm{n\_Ca}}} \tag{30}$$

7.31 Rule gK_Ca

Rule gK_Ca is an assignment rule for parameter gK_Ca:

$$\mathrm{gK\_Ca} = \mathrm{VK\_Ca} \cdot \frac{[\mathrm{C\_C}]^{\mathrm{n\_KCa}}}{\mathrm{K\_KCa} + [\mathrm{C\_C}]^{\mathrm{n\_KCa}}} \tag{31}$$

7.32 Rule I_star

Rule I_star is an assignment rule for parameter I_star:

$$\begin{aligned} \mathrm{I\_star} = {} & \mathrm{g\_Na} \cdot \mathrm{E\_Na} + \mathrm{g\_Ca} \cdot \mathrm{E\_Ca} + \mathrm{g\_K} \cdot \mathrm{E\_K} + \mathrm{g\_L} \cdot \mathrm{E\_L} \\ & + \mathrm{gK\_Ca} \cdot \mathrm{E\_K} - \mathrm{g\_inhib} \cdot \mathrm{E\_inhib} - \mathrm{g\_ex} \cdot \mathrm{E\_ex} \end{aligned} \tag{32}$$

7.33 Rule R_star

Rule R_star is an assignment rule for parameter R_star:

$$\mathrm{R\_star} = \frac{1}{\mathrm{g\_Na} + \mathrm{g\_K} + \mathrm{g\_L} + \mathrm{g\_Ca} + \mathrm{gK\_Ca} - \mathrm{g\_inhib} - \mathrm{g\_ex}} \tag{33}$$

7.34 Rule tau_m

Rule tau_m is an assignment rule for parameter tau_m:

$$\mathrm{tau\_m} = \mathrm{Cm} \cdot \mathrm{R\_star} \tag{34}$$

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8 Reactions

This model contains 41 reactions. All reactions are listed in the following table and are subsequently described in detail. If a reaction is affected by a modifier, the identifier of this species is written above the reaction arrow.

Table 5: Overview of all reactions

№	Id	Name	Reaction Equation	SBO
1	vo		$\emptyset \xrightleftharpoons{\text{B\_C}} 0 \cdot 0010\,\text{Ca\_in}$	0000185
2	v_ca_out		$0 \cdot 0010\,\text{Ca\_in} \xrightleftharpoons{\text{C\_C}} \emptyset$	0000185
3	v1		$\emptyset \rightleftharpoons 0 \cdot 0010\,\text{Ca\_in}$	0000185
4	v2		$0 \cdot 0010\,\text{Ca\_in} \rightleftharpoons 0 \cdot 0010\,\text{Ca\_store}$	0000185
5	v3		$0 \cdot 0010\,\text{Ca\_store} \rightleftharpoons 0 \cdot 0010\,\text{Ca\_in}$	0000185
6	v_Ca_leak		$0 \cdot 0010\,\text{Ca\_store} \rightleftharpoons 0 \cdot 0010\,\text{Ca\_in}$	0000185
7	MP-_transcription		$\emptyset \xrightleftharpoons{\text{CB, B\_N}} \text{M\_P}$	0000183
8	MP_decay		$\text{M\_P} \rightleftharpoons \emptyset$	0000179
9	MC-_transcription		$\emptyset \xrightleftharpoons{\text{B\_N}} \text{M\_C}$	0000183
10	MC_decay		$\text{M\_C} \rightleftharpoons \emptyset$	0000179
11	MB-_transcription		$\emptyset \xrightleftharpoons{\text{B\_N}} \text{M\_B}$	0000183
12	MB_decay		$\text{M\_B} \rightleftharpoons \emptyset$	0000179
13	PC_translation		$\emptyset \xrightleftharpoons{\text{M\_P}} \text{P\_C}$	0000184
14	PC_degradation		$\text{P\_C} \rightleftharpoons \emptyset$	0000179
15	PC-_phosphorylation		$\text{P\_C} \rightleftharpoons \text{P\_CP}$	0000216
16	PCC_formation		$\text{P\_C} + \text{C\_C} \rightleftharpoons \text{PC\_C}$	0000526

№	Id	Name	Reaction Equation	SBO
17	CC_translation		$\emptyset \xrightleftharpoons{\text{M\_C}} \text{C\_C}$	0000184
18	CC_degradation		$\text{C\_C} \rightleftharpoons \emptyset$	0000179
19	CC-_phosphorylation		$\text{C\_C} \rightleftharpoons \text{C\_CP}$	0000216
20	PCP_degradation		$\text{P\_CP} \rightleftharpoons \emptyset$	0000179
21	CCP_degradation		$\text{C\_CP} \rightleftharpoons \emptyset$	0000179
22	PCC_shuttling		$\text{PC\_C} \rightleftharpoons \text{PC\_N}$	
23	PCC-_phosphorylation		$\text{PC\_C} \rightleftharpoons \text{PC\_CP}$	0000216
24	PCC_degradation		$\text{PC\_C} \rightleftharpoons \emptyset$	0000179
25	PCCP-_degradation		$\text{PC\_CP} \rightleftharpoons \emptyset$	0000179
26	PCN-_phosphorylation		$\text{PC\_N} \rightleftharpoons \text{PC\_NP}$	0000216
27	PCN_degradation		$\text{PC\_N} \rightleftharpoons \emptyset$	0000179
28	PCNP-_degradation		$\text{PC\_NP} \rightleftharpoons \emptyset$	0000179
29	IN_formation		$\text{B\_N} + \text{PC\_N} \rightleftharpoons \text{I\_N}$	0000526
30	IN_degradation		$\text{I\_N} \rightleftharpoons \emptyset$	0000179
31	BC_translation		$\emptyset \xrightleftharpoons{\text{M\_B}} \text{B\_C}$	0000184
32	BC-_phosphorylation		$\text{B\_C} \rightleftharpoons \text{B\_CP}$	0000216
33	BC_shuttling		$\text{B\_C} \rightleftharpoons \text{B\_N}$	
34	BC_degradation		$\text{B\_C} \rightleftharpoons \emptyset$	0000179
35	BCP_degradation		$\text{B\_CP} \rightleftharpoons \emptyset$	0000179
36	BN-_phosphorylation		$\text{B\_N} \rightleftharpoons \text{B\_NP}$	0000216
37	BN_degradation		$\text{B\_N} \rightleftharpoons \emptyset$	0000179

№	Id	Name	Reaction Equation	SBO
38	BNP_degradation		B_NP $\rightleftharpoons \emptyset$	0000179
39	CB_activation		$\emptyset \rightleftharpoons$ CB	
40	VIP_accumulation		$\emptyset \rightleftharpoons$ VIP	
41	VIP_depletion		VIP $\rightleftharpoons \emptyset$	0000179

Produced by SBML2LaTeX

8.1 Reaction vo

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000185 transport reaction

Reaction equation

$$\emptyset \xrightleftharpoons{\text{B\_C}} 0.0010\,\text{Ca\_in} \tag{35}$$

Modifier

Table 6: Properties of each modifier.

Id	Name	SBO
B_C	B_C	

Product

Table 7: Properties of each product.

Id	Name	SBO
Ca_in		

Kinetic Law

Derived unit contains undeclared units

$$v_1 = 1000 \cdot \text{vol}(\text{cytoplasm}) \cdot \frac{\text{v\_vo} \cdot [\text{B\_C}]^{\text{n\_vo}}}{\text{K\_vo} + [\text{B\_C}]^{\text{n\_vo}}} \tag{36}$$

8.2 Reaction v_ca_out

This is a reversible reaction of one reactant forming no product influenced by one modifier.

SBO:0000185 transport reaction

Reaction equation

$$0.0010\,\text{Ca\_in} \xrightleftharpoons{\text{C\_C}} \emptyset \tag{37}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
Ca_in		

Modifier

Table 9: Properties of each modifier.

Id	Name	SBO
C_C	C_C	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \frac{1000 \cdot \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{v\_kk} \cdot [\mathrm{C\_C}]^{\mathrm{n\_kk}}}{\mathrm{K\_kk} + [\mathrm{C\_C}]^{\mathrm{n\_kk}}} \cdot [\mathrm{Ca\_in}]^{\mathrm{n\_kCa}} \tag{38}$$

8.3 Reaction v1

This is a reversible reaction of no reactant forming one product.

SBO:0000185 transport reaction

Reaction equation

$$\emptyset \rightleftharpoons 0.0010 \, \mathrm{Ca\_in} \tag{39}$$

Product

Table 10: Properties of each product.

Id	Name	SBO
Ca_in		

Kinetic Law

Derived unit contains undeclared units

$$v_3 = 1000 \cdot \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{V\_M1} \cdot \mathrm{beta\_IP3} \tag{40}$$

8.4 Reaction v2

This is a reversible reaction of one reactant forming one product.

SBO:0000185 transport reaction

Reaction equation

$$0.0010 \, \mathrm{Ca\_in} \rightleftharpoons 0.0010 \, \mathrm{Ca\_store} \tag{41}$$

Reactant

Table 11: Properties of each reactant.

Id	Name	SBO
Ca_in		

Product

Table 12: Properties of each product.

Id	Name	SBO
Ca_store		

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \frac{1000 \cdot \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{V\_M2} \cdot [\mathrm{Ca\_in}]^{\mathrm{n\_M2}}}{\mathrm{K\_2}^{\mathrm{n\_M2}} + [\mathrm{Ca\_in}]^{\mathrm{n\_M2}}} \tag{42}$$

8.5 Reaction v3

This is a reversible reaction of one reactant forming one product.

SBO:0000185 transport reaction

Reaction equation

$$0.0010 \, \mathrm{Ca\_store} \rightleftharpoons 0.0010 \, \mathrm{Ca\_in} \tag{43}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
Ca_store		

Product

Table 14: Properties of each product.

Id	Name	SBO
Ca_in		

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \frac{1000 \cdot \mathrm{vol}\left(\mathrm{store}\right) \cdot \frac{\mathrm{V\_M3} \cdot [\mathrm{Ca\_store}]^{\mathrm{n\_M3}}}{\mathrm{K\_R\_Ca}^{\mathrm{n\_M3}} + [\mathrm{Ca\_store}]^{\mathrm{n\_M3}}} \cdot [\mathrm{Ca\_in}]^{\mathrm{p\_A}}}{\mathrm{K\_A}^{\mathrm{p\_A}} + [\mathrm{Ca\_in}]^{\mathrm{p\_A}}} \tag{44}$$

8.6 Reaction v_Ca_leak

This is a reversible reaction of one reactant forming one product.

SBO:0000185 transport reaction

Reaction equation

$$0.0010\,\mathrm{Ca\_store} \rightleftharpoons 0.0010\,\mathrm{Ca\_in} \tag{45}$$

Reactant

Table 15: Properties of each reactant.

Id	Name	SBO
Ca_store		

Product

Table 16: Properties of each product.

Id	Name	SBO
Ca_in		

Kinetic Law

Derived unit contains undeclared units

$$v_6 = 1000 \cdot \mathrm{vol}\,(\mathrm{store}) \cdot \mathrm{k\_f} \cdot [\mathrm{Ca\_store}] \tag{46}$$

8.7 Reaction MP_transcription

This is a reversible reaction of no reactant forming one product influenced by two modifiers.

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightleftharpoons{\mathrm{CB},\, \mathrm{B\_N}} \mathrm{M\_P} \tag{47}$$

Modifiers

Table 17: Properties of each modifier.

Id	Name	SBO
CB	CB	
B_N	B_N	

Product

Table 18: Properties of each product.

Id	Name	SBO
M_P	M_P	

Kinetic Law

Derived unit $9.99999999999994 \cdot 10^{-10}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_7 = \frac{\mathrm{vol}\,(\mathrm{cytoplasm}) \cdot \left(\mathrm{v\_sP0} + \frac{\mathrm{C\_T} \cdot [\mathrm{CB}]}{\mathrm{K\_C} + [\mathrm{CB}]}\right) \cdot [\mathrm{B\_N}]^{\mathrm{n\_BN}}}{\mathrm{K\_AP}^{\mathrm{n\_BN}} + [\mathrm{B\_N}]^{\mathrm{n\_BN}}} \tag{48}$$

8.8 Reaction MP_decay

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{M\_P} \rightleftharpoons \emptyset \tag{49}$$

Reactant

Table 19: Properties of each reactant.

Id	Name	SBO
M_P	M_P	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_8 = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{v\_mP} \cdot [\mathrm{M\_P}]}{\mathrm{K\_mP} + [\mathrm{M\_P}]} + \mathrm{kd\_mP} \cdot [\mathrm{M\_P}]\right) \tag{50}$$

8.9 Reaction MC_transcription

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightleftharpoons{\mathrm{B\_N}} \mathrm{M\_C} \tag{51}$$

Modifier

Table 20: Properties of each modifier.

Id	Name	SBO
B_N	B_N	

Product

Table 21: Properties of each product.

Id	Name	SBO
M_C	M_C	

Kinetic Law

Derived unit $9.99999999999994 \cdot 10^{-10}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_9 = \frac{\mathrm{vol}\,(\mathrm{cytoplasm}) \cdot \mathrm{v\_sC} \cdot [\mathrm{B\_N}]^{\mathrm{n\_BN}}}{\mathrm{K\_sC}^{\mathrm{n\_BN}} + [\mathrm{B\_N}]^{\mathrm{n\_BN}}} \tag{52}$$

8.10 Reaction MC_decay

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{M\_C} \rightleftharpoons \emptyset \tag{53}$$

Reactant

Table 22: Properties of each reactant.

Id	Name	SBO
M_C	M_C	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_{10} = \mathrm{vol}\,(\mathrm{cytoplasm}) \cdot \left(\frac{\mathrm{v\_mC} \cdot [\mathrm{M\_C}]}{\mathrm{K\_mC} + [\mathrm{M\_C}]} + \mathrm{kd\_mC} \cdot [\mathrm{M\_C}]\right) \tag{54}$$

8.11 Reaction MB_transcription

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightleftharpoons{\text{B\_N}} \text{M\_B} \tag{55}$$

Modifier

Table 23: Properties of each modifier.

Id	Name	SBO
B_N	B_N	

Product

Table 24: Properties of each product.

Id	Name	SBO
M_B	M_B	

Kinetic Law

Derived unit $1.0000000000000038 \cdot 10^{-9}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_{11} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \frac{\mathrm{v\_sB} \cdot \mathrm{K\_IB}^{\mathrm{m\_BN}}}{\mathrm{K\_IB}^{\mathrm{m\_BN}} + [\mathrm{B\_N}]^{\mathrm{m\_BN}}} \tag{56}$$

8.12 Reaction MB_decay

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\text{M\_B} \rightleftharpoons \emptyset \tag{57}$$

Reactant

Table 25: Properties of each reactant.

Id	Name	SBO
M_B	M_B	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot (3600 \text{ s})^{-1}$

$$v_{12} = \text{vol}(\text{cytoplasm}) \cdot \left(\frac{\text{v\_mB} \cdot [\text{M\_B}]}{\text{K\_mB} + [\text{M\_B}]} + \text{kd\_mB} \cdot [\text{M\_B}] \right) \tag{58}$$

8.13 Reaction `PC_translation`

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightleftharpoons{\text{M\_P}} \text{P\_C} \tag{59}$$

Modifier

Table 26: Properties of each modifier.

Id	Name	SBO
`M_P`	M_P	

Product

Table 27: Properties of each product.

Id	Name	SBO
`P_C`	P_C	

Kinetic Law

Derived unit $(3600 \text{ s})^{-1} \cdot$ nmol

$$v_{13} = \text{vol}(\text{cytoplasm}) \cdot \text{ks\_P} \cdot [\text{M\_P}] \tag{60}$$

8.14 Reaction `PC_degradation`

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\text{P\_C} \rightleftharpoons \emptyset \tag{61}$$

Reactant

Table 28: Properties of each reactant.

Id	Name	SBO
P_C	P_C	

Kinetic Law

Derived unit $(3600\ \text{s})^{-1} \cdot \text{nmol}$

$$v_{14} = \text{vol}\left(\text{cytoplasm}\right) \cdot \text{kd\_n} \cdot [\text{P\_C}] \tag{62}$$

8.15 Reaction `PC_phosphorylation`

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\text{P\_C} \rightleftharpoons \text{P\_CP} \tag{63}$$

Reactant

Table 29: Properties of each reactant.

Id	Name	SBO
P_C	P_C	

Product

Table 30: Properties of each product.

Id	Name	SBO
P_CP	P_CP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot (3600\ \mathrm{s})^{-1}$

$$v_{15} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{V1\_P} \cdot [\mathrm{P\_C}]}{\mathrm{K\_p} + [\mathrm{P\_C}]} - \frac{\mathrm{V2\_P} \cdot [\mathrm{P\_CP}]}{\mathrm{K\_dp} + [\mathrm{P\_CP}]}\right) \tag{64}$$

8.16 Reaction PCC_formation

This is a reversible reaction of two reactants forming one product.

SBO:0000526 protein complex formation

Reaction equation

$$\mathrm{P\_C} + \mathrm{C\_C} \rightleftharpoons \mathrm{PC\_C} \tag{65}$$

Reactants

Table 31: Properties of each reactant.

Id	Name	SBO
P_C	P_C	
C_C	C_C	

Product

Table 32: Properties of each product.

Id	Name	SBO
PC_C	PC_C	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{16} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\mathrm{k3} \cdot [\mathrm{P\_C}] \cdot [\mathrm{C\_C}] - \mathrm{k4} \cdot [\mathrm{PC\_C}]\right) \tag{66}$$

8.17 Reaction CC_translation

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightleftharpoons{\text{M\_C}} \text{C\_C} \tag{67}$$

Modifier

Table 33: Properties of each modifier.

Id	Name	SBO
M_C	M_C	

Product

Table 34: Properties of each product.

Id	Name	SBO
C_C	C_C	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{17} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{ks\_C} \cdot [\mathrm{M\_C}] \tag{68}$$

8.18 Reaction CC_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\text{C\_C} \rightleftharpoons \emptyset \tag{69}$$

Reactant

Table 35: Properties of each reactant.

Id	Name	SBO
C_C	C_C	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{18} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{kd\_nc} \cdot [\mathrm{C\_C}] \tag{70}$$

8.19 Reaction CC_phosphorylation

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{C\_C} \rightleftharpoons \mathrm{C\_CP} \tag{71}$$

Reactant

Table 36: Properties of each reactant.

Id	Name	SBO
C_C	C_C	

Product

Table 37: Properties of each product.

Id	Name	SBO
C_CP	C_CP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{19} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{V1\_C} \cdot [\mathrm{C\_C}]}{\mathrm{K\_p} + [\mathrm{C\_C}]} - \frac{\mathrm{V2\_C} \cdot [\mathrm{C\_CP}]}{\mathrm{K\_dp} + [\mathrm{C\_CP}]}\right) \tag{72}$$

8.20 Reaction PCP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{P\_CP} \rightleftharpoons \emptyset \tag{73}$$

Reactant

Table 38: Properties of each reactant.

Id	Name	SBO
P_CP	P_CP	

Kinetic Law

Derived unit $\mathrm{l}^2 \cdot (3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}^{-1}$

$$v_{20} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{v\_dPC} \cdot [\mathrm{P\_CP}]}{\mathrm{Kd} + [\mathrm{P\_CP}]} + \mathrm{kd\_n} \cdot [\mathrm{P\_CP}]\right) \tag{74}$$

8.21 Reaction CCP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{C\_CP} \rightleftharpoons \emptyset \tag{75}$$

Reactant

Table 39: Properties of each reactant.

Id	Name	SBO
C_CP	C_CP	

Kinetic Law

Derived unit $9.9999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{21} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{v\_dCC} \cdot [\mathrm{C\_CP}]}{\mathrm{Kd} + [\mathrm{C\_CP}]} + \mathrm{kd\_n} \cdot [\mathrm{C\_CP}]\right) \tag{76}$$

8.22 Reaction PCC_shuttling

This is a reversible reaction of one reactant forming one product.

Reaction equation

$$\text{PC\_C} \rightleftharpoons \text{PC\_N} \tag{77}$$

Reactant

Table 40: Properties of each reactant.

Id	Name	SBO
PC_C	PC_C	

Product

Table 41: Properties of each product.

Id	Name	SBO
PC_N	PC_N	

Kinetic Law

Derived unit $(3600\text{ s})^{-1} \cdot \text{nmol}$

$$v_{22} = \text{vol}(\text{cytoplasm}) \cdot \text{k1} \cdot [\text{PC\_C}] - \text{vol}(\text{nucleus}) \cdot \text{k2} \cdot [\text{PC\_N}] \tag{78}$$

8.23 Reaction PCC_phosphorylation

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\text{PC\_C} \rightleftharpoons \text{PC\_CP} \tag{79}$$

Reactant

Table 42: Properties of each reactant.

Id	Name	SBO
PC_C	PC_C	

Product

Table 43: Properties of each product.

Id	Name	SBO
PC_CP	PC_CP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot$ $(3600\ \mathrm{s})^{-1}$

$$v_{23} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{V1\_PC} \cdot [\mathrm{PC\_C}]}{\mathrm{K\_p} + [\mathrm{PC\_C}]} - \frac{\mathrm{V2\_PC} \cdot [\mathrm{PC\_CP}]}{\mathrm{K\_dp} + [\mathrm{PC\_CP}]}\right) \tag{80}$$

8.24 Reaction PCC_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{PC\_C} \rightleftharpoons \emptyset \tag{81}$$

Reactant

Table 44: Properties of each reactant.

Id	Name	SBO
PC_C	PC_C	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{24} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{kd\_n} \cdot [\mathrm{PC\_C}] \tag{82}$$

8.25 Reaction PCCP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\text{PC\_CP} \rightleftharpoons \emptyset \tag{83}$$

Reactant

Table 45: Properties of each reactant.

Id	Name	SBO
PC_CP	PC_CP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot$ (3600 s)$^{-1}$

$$v_{25} = \text{vol}\left(\text{cytoplasm}\right) \cdot \left(\frac{\text{vd\_PCC} \cdot [\text{PC\_CP}]}{\text{Kd} + [\text{PC\_CP}]} + \text{kd\_n} \cdot [\text{PC\_CP}]\right) \tag{84}$$

8.26 Reaction PCN_phosphorylation

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\text{PC\_N} \rightleftharpoons \text{PC\_NP} \tag{85}$$

Reactant

Table 46: Properties of each reactant.

Id	Name	SBO
PC_N	PC_N	

Product

Table 47: Properties of each product.

Id	Name	SBO
PC_NP	PC_NP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot (3600\ \mathrm{s})^{-1}$

$$v_{26} = \mathrm{vol}(\mathrm{nucleus}) \cdot \left(\frac{\mathrm{V3\_PC} \cdot [\mathrm{PC\_N}]}{\mathrm{K\_p} + [\mathrm{PC\_N}]} - \frac{\mathrm{V4\_PC} \cdot [\mathrm{PC\_NP}]}{\mathrm{K\_dp} + [\mathrm{PC\_NP}]} \right) \tag{86}$$

8.27 Reaction PCN_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{PC\_N} \rightleftharpoons \emptyset \tag{87}$$

Reactant

Table 48: Properties of each reactant.

Id	Name	SBO
PC_N	PC_N	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot$ nmol

$$v_{27} = \mathrm{vol}(\mathrm{nucleus}) \cdot \mathrm{kd\_n} \cdot [\mathrm{PC\_N}] \tag{88}$$

8.28 Reaction PCNP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{PC\_NP} \rightleftharpoons \emptyset \tag{89}$$

Reactant

Table 49: Properties of each reactant.

Id	Name	SBO
PC_NP	PC_NP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}$ mol $\cdot (3600\ \mathrm{s})^{-1}$

$$v_{28} = \mathrm{vol}\left(\mathrm{nucleus}\right) \cdot \left(\frac{\mathrm{vd\_PCN} \cdot [\mathrm{PC\_NP}]}{\mathrm{Kd} + [\mathrm{PC\_NP}]} + \mathrm{kd\_n} \cdot [\mathrm{PC\_NP}]\right) \tag{90}$$

8.29 Reaction IN_formation

This is a reversible reaction of two reactants forming one product.

SBO:0000526 protein complex formation

Reaction equation

$$\mathrm{B\_N} + \mathrm{PC\_N} \rightleftharpoons \mathrm{I\_N} \tag{91}$$

Reactants

Table 50: Properties of each reactant.

Id	Name	SBO
B_N	B_N	
PC_N	PC_N	

Product

Table 51: Properties of each product.

Id	Name	SBO
I_N	I_N	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{29} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\mathrm{k7} \cdot [\mathrm{B\_N}] \cdot [\mathrm{PC\_N}] - \mathrm{k8} \cdot [\mathrm{I\_N}]\right) \tag{92}$$

8.30 Reaction IN_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{I\_N} \rightleftharpoons \emptyset \tag{93}$$

Reactant

Table 52: Properties of each reactant.

Id	Name	SBO
I_N	I_N	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{30} = \mathrm{vol}\left(\mathrm{nucleus}\right) \cdot \left(\frac{\mathrm{vd\_IN} \cdot [\mathrm{I\_N}]}{\mathrm{Kd} + [\mathrm{I\_N}]} + \mathrm{kd\_n} \cdot [\mathrm{I\_N}]\right) \tag{94}$$

8.31 Reaction BC_translation

This is a reversible reaction of no reactant forming one product influenced by one modifier.

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightleftharpoons{\mathrm{M\_B}} \mathrm{B\_C} \tag{95}$$

Modifier

Table 53: Properties of each modifier.

Id	Name	SBO
M_B	M_B	

Product

Table 54: Properties of each product.

Id	Name	SBO
B_C	B_C	

Kinetic Law

Derived unit contains undeclared units

$$v_{31} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{ksB} \cdot [\mathrm{M\_B}] \tag{96}$$

8.32 Reaction BC_phosphorylation

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{B\_C} \rightleftharpoons \mathrm{B\_CP} \tag{97}$$

Reactant

Table 55: Properties of each reactant.

Id	Name	SBO
B_C	B_C	

Product

Table 56: Properties of each product.

Id	Name	SBO
B_CP	B_CP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{32} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{V1\_B} \cdot [\mathrm{B\_C}]}{\mathrm{K\_p} + [\mathrm{B\_C}]} - \frac{\mathrm{V2\_B} \cdot [\mathrm{B\_CP}]}{\mathrm{K\_dp} + [\mathrm{B\_CP}]}\right) \tag{98}$$

8.33 Reaction BC_shuttling

This is a reversible reaction of one reactant forming one product.

Reaction equation

$$B\_C \rightleftharpoons B\_N \tag{99}$$

Reactant

Table 57: Properties of each reactant.

Id	Name	SBO
B_C	B_C	

Product

Table 58: Properties of each product.

Id	Name	SBO
B_N	B_N	

Kinetic Law

Derived unit contains undeclared units

$$v_{33} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{k5} \cdot [\mathrm{B\_C}] - \mathrm{vol}\left(\mathrm{nucleus}\right) \cdot \mathrm{k6} \cdot [\mathrm{B\_N}] \tag{100}$$

8.34 Reaction BC_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$B\_C \rightleftharpoons \emptyset \tag{101}$$

Reactant

Table 59: Properties of each reactant.

Id	Name	SBO
B_C	B_C	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot \mathrm{nmol}$

$$v_{34} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{kd\_n} \cdot [\mathrm{B\_C}] \tag{102}$$

8.35 Reaction BCP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{B\_CP} \rightleftharpoons \emptyset \tag{103}$$

Reactant

Table 60: Properties of each reactant.

Id	Name	SBO
B_CP	B_CP	

Kinetic Law

Derived unit $9.9999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{35} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{vd\_BC} \cdot [\mathrm{B\_CP}]}{\mathrm{Kd} + [\mathrm{B\_CP}]} + \mathrm{kd\_n} \cdot [\mathrm{B\_CP}]\right) \tag{104}$$

8.36 Reaction BN_phosphorylation

This is a reversible reaction of one reactant forming one product.

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{B\_N} \rightleftharpoons \mathrm{B\_NP} \tag{105}$$

Reactant

Table 61: Properties of each reactant.

Id	Name	SBO
B_N	B_N	

Product

Table 62: Properties of each product.

Id	Name	SBO
B_NP	B_NP	

Kinetic Law

Derived unit $9.9999999999999998 \cdot 10^{-10}$ mol $\cdot (3600\ \mathrm{s})^{-1}$

$$v_{36} = \mathrm{vol}\left(\mathrm{nucleus}\right) \cdot \left(\frac{\mathrm{V3\_B} \cdot [\mathrm{B\_N}]}{\mathrm{K\_p} + [\mathrm{B\_N}]} - \frac{\mathrm{V4\_B} \cdot [\mathrm{B\_NP}]}{\mathrm{K\_dp} + [\mathrm{B\_NP}]}\right) \tag{106}$$

8.37 Reaction BN_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{B\_N} \rightleftharpoons \emptyset \tag{107}$$

Reactant

Table 63: Properties of each reactant.

Id	Name	SBO
B_N	B_N	

Kinetic Law

Derived unit $(3600\ \mathrm{s})^{-1} \cdot$ nmol

$$v_{37} = \mathrm{vol}(\mathrm{nucleus}) \cdot \mathrm{kd\_n} \cdot [\mathrm{B\_N}] \tag{108}$$

8.38 Reaction BNP_degradation

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{B\_NP} \rightleftharpoons \emptyset \tag{109}$$

Reactant

Table 64: Properties of each reactant.

Id	Name	SBO
B_NP	B_NP	

Kinetic Law

Derived unit $9.999999999999998 \cdot 10^{-10}\ \mathrm{mol} \cdot (3600\ \mathrm{s})^{-1}$

$$v_{38} = \mathrm{vol}(\mathrm{nucleus}) \cdot \left(\frac{\mathrm{vd\_BN} \cdot [\mathrm{B\_NP}]}{\mathrm{Kd} + [\mathrm{B\_NP}]} + \mathrm{kd\_n} \cdot [\mathrm{B\_NP}]\right) \tag{110}$$

8.39 Reaction CB_activation

This is a reversible reaction of no reactant forming one product.

Reaction equation

$$\emptyset \rightleftharpoons \mathrm{CB} \tag{111}$$

Product

Table 65: Properties of each product.

Id	Name	SBO
CB	CB	

Kinetic Law

Derived unit contains undeclared units

$$v_{39} = \frac{\mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \left(\frac{\mathrm{v\_K} \cdot (1-[\mathrm{CB}])}{\mathrm{K\_1\_CB}+1-[\mathrm{CB}]} - \frac{\mathrm{vP} \cdot [\mathrm{CB}]}{\mathrm{K\_2\_CB}+[\mathrm{CB}]}\right)}{\mathrm{WT}} \tag{112}$$

8.40 Reaction VIP_accumulation

This is a reversible reaction of no reactant forming one product.

Reaction equation

$$\emptyset \rightleftharpoons \mathrm{VIP} \tag{113}$$

Product

Table 66: Properties of each product.

Id	Name	SBO
VIP	VIP	

Kinetic Law

Derived unit contains undeclared units

$$v_{40} = \frac{\mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{v\_VIP} \cdot \mathrm{f\_r}^{\mathrm{n\_VIP}}}{\mathrm{K\_VIP} + \mathrm{f\_r}^{\mathrm{n\_VIP}}} \tag{114}$$

8.41 Reaction VIP_depletion

This is a reversible reaction of one reactant forming no product.

SBO:0000179 degradation

Reaction equation

$$\mathrm{VIP} \rightleftharpoons \emptyset \tag{115}$$

Reactant

Table 67: Properties of each reactant.

Id	Name	SBO
VIP	VIP	

Kinetic Law

Derived unit contains undeclared units

$$v_{41} = \mathrm{vol}\left(\mathrm{cytoplasm}\right) \cdot \mathrm{k\_dVIP} \cdot [\mathrm{VIP}]^{\mathrm{n\_dVIP}} \tag{116}$$

9 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

Identifiers for kinetic laws highlighted in gray cannot be verified to evaluate to units of SBML substance per time. As a result, some SBML interpreters may not be able to verify the consistency of the units on quantities in the model. Please check if

- parameters without an unit definition are involved or
- volume correction is necessary because the hasOnlySubstanceUnits flag may be set to false and spacialDimensions> 0 for certain species.

9.1 Species Ca_in

SBO:0000327 non-macromolecular ion

Initial concentration $0.1\ \mu\mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in six reactions (as a reactant in v_ca_out, v2 and as a product in vo, v1, v3, v_Ca_leak).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_in} = 0.0010 v_{1} + 0.0010 v_{3} + 0.0010 v_{5} + 0.0010 v_{6} - 0.0010 v_{2} - 0.0010 v_{4} \tag{117}$$

9.2 Species Ca_store

SBO:0000327 non-macromolecular ion

Initial concentration $0.1\ \mu\mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in v3, v_Ca_leak and as a product in v2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_store} = 0.0010 v_{4} - 0.0010 v_{5} - 0.0010 v_{6} \tag{118}$$

9.3 Species Ca_ex

SBO:0000327 non-macromolecular ion

Initial concentration $5\ \mu\text{mol} \cdot \text{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Ca\_ex} = 0 \tag{119}$$

9.4 Species M_P

Name M_P

SBO:0000278 messenger RNA

Initial concentration $2.8\ \text{nmol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in MP_decay and as a product in MP_transcription and as a modifier in PC_translation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{M\_P} = v_7 - v_8 \tag{120}$$

9.5 Species M_C

Name M_C

SBO:0000278 messenger RNA

Initial concentration $2\ \text{nmol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in MC_decay and as a product in MC_transcription and as a modifier in CC_translation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{M\_C} = v_9 - v_{10} \tag{121}$$

9.6 Species M_B

Name M_B

SBO:0000278 messenger RNA

Initial concentration $7.94\ \text{nmol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in MB_decay and as a product in MB_transcription and as a modifier in BC_translation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{M\_B} = v_{11} - v_{12} \tag{122}$$

9.7 Species P_C

Name P_C

SBO:0000252 polypeptide chain

Initial concentration $0.4 \text{ nmol} \cdot \text{l}^{-1}$

This species takes part in four reactions (as a reactant in PC_degradation, PC_phosphorylation, PCC_formation and as a product in PC_translation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{P\_C} = v_{13} - v_{14} - v_{15} - v_{16} \tag{123}$$

9.8 Species C_C

Name C_C

SBO:0000252 polypeptide chain

Initial concentration $12 \text{ nmol} \cdot \text{l}^{-1}$

This species takes part in five reactions (as a reactant in PCC_formation, CC_degradation, CC_phosphorylation and as a product in CC_translation and as a modifier in v_ca_out).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{C\_C} = v_{17} - v_{16} - v_{18} - v_{19} \tag{124}$$

9.9 Species P_CP

Name P_CP

SBO:0000252 polypeptide chain

Initial concentration $0.13 \text{ nmol} \cdot \text{l}^{-1}$

This species takes part in two reactions (as a reactant in PCP_degradation and as a product in PC_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{P\_CP} = v_{15} - v_{20} \tag{125}$$

9.10 Species C_CP

Name C_CP

SBO:0000252 polypeptide chain

Initial concentration $9 \text{ nmol} \cdot \text{l}^{-1}$

This species takes part in two reactions (as a reactant in CCP_degradation and as a product in CC_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{C\_CP} = v_{19} - v_{21} \tag{126}$$

9.11 Species PC_C

Name PC_C

SBO:0000297 protein complex

Initial concentration $1.26\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in four reactions (as a reactant in PCC_shuttling, PCC_phosphorylation, PCC_degradation and as a product in PCC_formation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PC\_C} = v_{16} - v_{22} - v_{23} - v_{24} \tag{127}$$

9.12 Species PC_N

Name PC_N

SBO:0000297 protein complex

Initial concentration $0.16\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in four reactions (as a reactant in PCN_phosphorylation, PCN_degradation, IN_formation and as a product in PCC_shuttling).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PC\_N} = v_{22} - v_{26} - v_{27} - v_{29} \tag{128}$$

9.13 Species PC_CP

Name PC_CP

SBO:0000297 protein complex

Initial concentration $0.2\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in PCCP_degradation and as a product in PCC_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PC\_CP} = v_{23} - v_{25} \tag{129}$$

9.14 Species PC_NP

Name PC_NP

SBO:0000297 protein complex

Initial concentration $0.091\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in PCNP_degradation and as a product in PCN_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PC\_NP} = v_{26} - v_{28} \tag{130}$$

9.15 Species B_C

Name B_C

SBO:0000252 polypeptide chain

Initial concentration $2.41\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in BC_phosphorylation, BC_shuttling, BC_degradation and as a product in BC_translation and as a modifier in vo).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{B\_C} = v_{31} - v_{32} - v_{33} - v_{34} \tag{131}$$

9.16 Species B_CP

Name B_CP

SBO:0000252 polypeptide chain

Initial concentration $0.48\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in BCP_degradation and as a product in BC_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{B\_CP} = v_{32} - v_{35} \tag{132}$$

9.17 Species B_N

Name B_N

SBO:0000252 polypeptide chain

Initial concentration $1.94\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in seven reactions (as a reactant in IN_formation, BN_phosphorylation, BN_degradation and as a product in BC_shuttling and as a modifier in MP_transcription, MC_transcription, MB_transcription).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{B\_N} = v_{33} - v_{29} - v_{36} - v_{37} \tag{133}$$

9.18 Species B_NP

Name B_NP

SBO:0000252 polypeptide chain

Initial concentration $0.32\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in BNP_degradation and as a product in BN_phosphorylation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{B\_NP} = v_{36} - v_{38} \tag{134}$$

9.19 Species I_N

Name I_N

Initial concentration $0.05\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in IN_degradation and as a product in IN_formation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{I\_N} = v_{29} - v_{30} \tag{135}$$

9.20 Species CB

Name CB

SBO:0000252 polypeptide chain

Initial concentration $0.12\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a product in CB_activation and as a modifier in MP_transcription).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CB} = v_{39} \tag{136}$$

9.21 Species VIP

Name VIP

SBO:0000244 receptor

Initial concentration $0\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in VIP_depletion and as a product in VIP_accumulation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{VIP} = v_{40} - v_{41} \tag{137}$$

9.22 Species Cl_ex

SBO:0000327 non-macromolecular ion

Initial concentration $114.5 \text{ mmol} \cdot \text{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Cl\_ex} = 0 \tag{138}$$

9.23 Species Cl_o

SBO:0000327 non-macromolecular ion

Initial concentration $1 \text{ mmol} \cdot \text{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Cl\_o} = 0 \tag{139}$$

9.24 Species GABA

SBO:0000327 non-macromolecular ion

Involved in rule GABA

One rule determines the species' quantity.

9.25 Species GABA_o

SBO:0000327 non-macromolecular ion

Initial concentration $0.2 \text{ nmol} \cdot \text{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{GABA\_o} = 0 \tag{140}$$

9.26 Species K_in

SBO:0000327 non-macromolecular ion

Involved in rule K_in

One rule determines the species' quantity.

9.27 Species K_ex

SBO:0000327 non-macromolecular ion

Initial concentration $1\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{K\_ex} = 0 \tag{141}$$

9.28 Species Na_in

SBO:0000327 non-macromolecular ion

Involved in rule Na_in

One rule determines the species' quantity.

9.29 Species Na_ex

SBO:0000327 non-macromolecular ion

Initial concentration $145\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Na\_ex} = 0 \tag{142}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000179 **degradation:** Complete disappearance of a physical entity

SBO:0000183 **transcription:** Process through which a DNA sequence is copied to produce a complementary RNA

SBO:0000184 **translation:** Process in which a polypeptide chain is produced from a messenger RNA

SBO:0000185 **transport reaction:** Movement of a physical entity without modification of the structure of the entity

SBO:0000216 **phosphorylation:** Addition of a phosphate group (-H2PO4) to a chemical entity

SBO:0000244 receptor: Participating entity that binds to a specific physical entity and initiates the response to that physical entity.The original concept of the receptor was introduced independently at the end of the 19th century by John Newport Langley (1852-1925) and Paul Ehrlich (1854-1915). Langley JN.On the reaction of cells and of nerve-endings to certain poisons, chiefly as regards the reaction of striated muscle to nicotine and to curari. J Physiol. 1905 Dec 30;33(4-5):374-413

SBO:0000252 polypeptide chain: Naturally occurring macromolecule formed by the repetition of amino-acid residues linked by peptidic bonds. A polypeptide chain is synthesized by the ribosome. CHEBI:1654

SBO:0000278 messenger RNA: A messenger RNA is a ribonucleic acid synthesized during the transcription of a gene, and that carries the information to encode one or several proteins

SBO:0000290 physical compartment: Specific location of space, that can be bounded or not. A physical compartment can have 1, 2 or 3 dimensions

SBO:0000297 protein complex: Macromolecular complex containing one or more polypeptide chains possibly associated with simple chemicals. CHEBI:3608

SBO:0000327 non-macromolecular ion: Chemical entity having a net electric charge

SBO:0000526 protein complex formation: The process by which two or more proteins interact non-covalently to form a protein complex (SBO:0000297)

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