SBML Model Report

Model name: "Bertram2007_IsletCell_Oscillations"

May 5, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following two authors: Ishan Ajmera[1] and Catherine Lloyd[2] at September 29th 2011 at 10:13 p. m. and last time modified at April eighth 2016 at 5:08 p. m. Table 1 shows 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	1
species types	0	species	11
events	0	constraints	0
reactions	0	function definitions	0
global parameters	151	unit definitions	0
rules	94	initial assignments	0

Model Notes

This is the model described in the article:
Interaction of glycolysis and mitochondrial respiration in metabolic oscillations of pancreatic islets.

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Bertram R, Satin LS, Pedersen MG, Luciani DS, Sherman A. Biophys J. 2007 Mar 1;92(5):1544-55. Pubmed ID: 17172305, doi: 10.1529/biophysj.106.097154.
Abstract:
Insulin secretion from pancreatic beta-cells is oscillatory, with a typical period of 2-7 min, reflecting oscillations in membrane potential and the cytosolic Ca(2+) concentration. Our central hypothesis is that the slow 2-7 min oscillations are due to glycolytic oscillations, whereas faster oscillations that are superimposed are due to Ca(2+) feedback onto metabolism or ion channels. We extend a previous mathematical model based on this hypothesis to include a more detailed description of mitochondrial metabolism. We demonstrate that this model can account for typical oscillatory patterns of membrane potential and Ca(2+) concentration in islets. It also accounts for temporal data on oxygen consumption in islets. A recent challenge to the notion that glycolytic oscillations drive slow Ca(2+) oscillations in islets are data showing that oscillations in Ca(2+), mitochondrial oxygen consumption, and NAD(P)H levels are all terminated by membrane hyperpolarization. We demonstrate that these data are in fact compatible with a model in which glycolytic oscillations are the key player in rhythmic islet activity. Finally, we use the model to address the recent finding that the activity of islets from some mice is uniformly fast, whereas that from islets of other mice is slow. We propose a mechanism for this dichotomy.

This model was taken from the CellML repository and automatically converted to SBML.
The original model was: **Bertram, Satin, Pedersen, Luciani, Sherman, 2007 version 02**
The original CellML model was created and curated by:
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2 Unit Definitions

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

2.1 Unit substance

Notes Mole is the predefined SBML unit for substance.

Definition mol

2.2 Unit `volume`

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

Definition l

2.3 Unit `area`

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

Definition m^2

2.4 Unit `length`

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

Definition m

2.5 Unit `time`

Notes Second is the predefined SBML unit for `time`.

Definition s

3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
`Compartment`	Compartment		3	1	litre	☑	

3.1 Compartment `Compartment`

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

Name Compartment

4 Species

This model contains eleven species. Section 7 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
`Vm`	Vm	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`n`	n	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`G6P`	G6P	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`FBP`	FBP	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`NADHm`	NADHm	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`delta_psi`	delta_psi	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`Cam`	Cam	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`ADPm`	ADPm	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`adp`	adp	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`c`	c	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`Caer`	Caer	`Compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟

5 Parameters

This model contains 151 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
cm	cm	0000258	5300.000		☑
Ik	Ik		0.000		☐
gK	gK	0000009	2700.000		☑
n_infinity	n_infinity		$1.50710358059757 \cdot 10^{-4}$		☐
tau_n	tau_n		20.000		☑
Ica	Ica		-2927.842		☐
gCa	gCa	0000009	1000.000		☑
m_infinity	m_infinity		0.034		☐
Ikca	Ikca		466.296		☐
gkCa	gkCa	0000009	300.000		☑
kd	kd	0000009	0.500		☑
Ikatp	Ikatp		2433.430		☐
gkATP_	gkATP_		16000.000		☑
katpo	katpo		0.010		☐
topo	topo		110.234		☐
bottomo	bottomo		10871.926		☐
mgadp	mgadp		187.605		☐
adp3m	adp3m		153.495		☐
atp4m	atp4m		68.150		☐
JGPDH	JGPDH		$7.34846922834953 \cdot 10^{-4}$		☐
kGPDH	kGPDH	0000009	$5 \cdot 10^{-4}$		☑
F6P	F6P		90.300		☐
JPFK	JPFK		0.374		☐
JPFK_ms	JPFK_ms		$3.74364085279847 \cdot 10^{-4}$		☐
bottom1	bottom1	0000009	1.000		☑
weight1	weight1	0000009	1.000		☑
topa1	topa1	0000009	0.000		☑
k1	k1	0000009	30.000		☑
k2	k2	0000009	1.000		☑
k3	k3	0000009	50000.000		☑
k4	k4	0000009	220.000		☑
VmaxPFK	VmaxPFK	0000009	5.000		☑
weight2	weight2		8444.405		☐
topa2	topa2		0.000		☐
bottom2	bottom2		8445.405		☐
topa3	topa3		0.163		☐
weight3	weight3		0.163		☐

Id	Name	SBO	Value	Unit	Constant
bottom3	bottom3		8445.568		☐
f13	f13	0000009	0.020		☑
f43	f43	0000009	20.000		☑
f23	f23	0000009	0.200		☑
f42	f42	0000009	20.000		☑
f41	f41	0000009	20.000		☑
weight4	weight4		68.856		☐
topa4	topa4		69.020		☐
bottom4	bottom4		8514.424		☐
weight5	weight5		2.160		☐
topa5	topa5		69.020		☐
bottom5	bottom5		8516.584		☐
weight6	weight6		911.996		☐
topa6	topa6		69.020		☐
bottom6	bottom6		9428.580		☐
weight7	weight7		1.761		☐
topa7	topa7		70.781		☐
bottom7	bottom7		9430.341		☐
weight8	weight8		37.182		☐
topa8	topa8		107.963		☐
bottom8	bottom8		9467.524		☐
weight9	weight9		16.667		☐
topa9	topa9		107.963		☐
bottom9	bottom9		9484.190		☐
weight10	weight10		7037.004		☐
topa10	topa10		107.963		☐
bottom10	bottom10		16521.194		☐
weight11	weight11		135.902		☐
topa11	topa11		243.865		☐
bottom11	bottom11		16657.095		☐
weight12	weight12		2869.018		☐
topa12	topa12		3112.883		☐
bottom12	bottom12		19526.114		☐
weight13	weight13		36.000		☐
topa13	topa13		3112.883		☐
bottom13	bottom13		19562.114		☐
weight14	weight14		759.996		☐
topa14	topa14		3112.883		☐
bottom14	bottom14		20322.110		☐
weight15	weight15		1467.736		☐
topa15	topa15		3112.883		☐
bottom15	bottom15		21789.846		☐

Id	Name	SBO	Value	Unit	Constant
weight16	weight16		1549.270		⊟
topa16	topa16		4662.153		⊟
bottom16	bottom16		23339.116		⊟
topb	topb		1467.736		⊟
lambda	lambda	0000009	0.060		☑
JPDH	JPDH	0000009	0.452		⊟
p1	p1	0000009	400.000		☑
p2	p2	0000009	1.000		☑
p3	p3	0000009	0.010		☑
JGPDHbas	JGPDHbas	0000009	$5 \cdot 10^{-4}$		☑
JO	JO		0.447		⊟
p4	p4	0000009	0.600		☑
p5	p5	0000009	0.100		☑
p6	p6	0000009	177.000		☑
p7	p7	0000009	5.000		☑
NADm	NADm		9.600		⊟
NADmtot	NADmtot	0000009	10.000		☑
Cmito	Cmito	0000009	1.800		☑
JHres	JHres		5.213		⊟
p8	p8	0000009	7.000		☑
p9	p9		0.100		☑
p10	p10	0000009	177.000		☑
p11	p11	0000009	5.000		☑
JF1F0	JF1F0		1.129		⊟
p13	p13		10.000		☑
p14	p14		190.000		☑
p15	p15	0000009	8.500		☑
p16	p16	0000009	35.000		☑
JHatp	JHatp		3.387		⊟
JGK_ms	JGK_ms		$4 \cdot 10^{-4}$		⊟
JGK	JGK	0000009	0.400		☑
JHleak	JHleak		0.298		⊟
p17	p17	0000009	0.002		☑
p18	p18	0000009	−0.030		☑
JANT	JANT		1.124		⊟
p19	p19	0000009	0.350		☑
p20	p20	0000009	2.000		☑
FRT	FRT	0000009	0.037		☑
RATm	RATm		0.351		⊟
Juni	Juni		0.158		⊟
p21	p21	0000009	0.040		☑
p22	p22	0000009	1.100		☑

Id	Name	SBO	Value	Unit	Constant
JNaCa	JNaCa		0.162		☐
p23	p23	0000009	0.010		☑
p24	p24	0000009	0.016		☑
fmito	fmito	0000009	0.010		☑
Jmito	Jmito		0.004		☐
ATPm	ATPm		3.900		☐
Amtot	Amtot	0000009	15.000		☑
Jhyd	Jhyd		0.080		☐
khyd	khyd	0000009	$5 \cdot 10^{-5}$		☑
khydbas	khydbas	0000009	$5 \cdot 10^{-5}$		☑
atp	atp		1363.000		☐
atot	atot	0000009	2500.000		☑
fcyt	fcyt	0000009	0.010		☑
Jmem	Jmem		0.001		☐
kPMCA	kPMCA	0000009	0.100		☑
alpha	alpha	0000009	$4.5 \cdot 10^{-6}$		☑
Cbas	Cbas	0000009	0.050		☑
Jleak	Jleak		0.069		☐
pleak	pleak	0000009	$2 \cdot 10^{-4}$		☑
JSERCA	JSERCA		0.068		☐
kSERCA	kSERCA	0000009	0.400		☑
Jer	Jer		$9.65999999999995 \cdot 10^{-4}$		☐
fer	fer	0000009	0.010		☑
Vc_Ver	Vc_Ver	0000009	31.000		☑
gamma	gamma	0000009	0.001		☑
kappa	kappa	0000009	0.001		☑
delta	delta		0.073		☐
VK	VK	0000009	−75.000		☑
VCa	VCa	0000009	25.000		☑
AMP	AMP	0000009	500.000		☑

6 Rules

This is an overview of 94 rules.

6.1 Rule Ik

Rule Ik is an assignment rule for parameter Ik:

$$\mathrm{Ik} = \mathrm{gK} \cdot [\mathrm{n}] \cdot ([\mathrm{Vm}] - \mathrm{VK}) \tag{1}$$

6.2 Rule n_infinity

Rule n_infinity is an assignment rule for parameter n_infinity:

$$\text{n\_infinity} = \frac{1}{1 + \exp\left(\frac{(16 + [\text{Vm}])}{5}\right)} \tag{2}$$

6.3 Rule m_infinity

Rule m_infinity is an assignment rule for parameter m_infinity:

$$\text{m\_infinity} = \frac{1}{1 + \exp\left(\frac{(20 + [\text{Vm}])}{12}\right)} \tag{3}$$

6.4 Rule Ica

Rule Ica is an assignment rule for parameter Ica:

$$\text{Ica} = \text{gCa} \cdot \text{m\_infinity} \cdot ([\text{Vm}] - \text{VCa}) \tag{4}$$

6.5 Rule Ikca

Rule Ikca is an assignment rule for parameter Ikca:

$$\text{Ikca} = \text{gkCa} \cdot \frac{[\text{c}]^2}{[\text{c}]^2 + \text{kd}^2} \cdot ([\text{Vm}] - \text{VK}) \tag{5}$$

6.6 Rule mgadp

Rule mgadp is an assignment rule for parameter mgadp:

$$\text{mgadp} = 0.165 \cdot [\text{adp}] \tag{6}$$

6.7 Rule topo

Rule topo is an assignment rule for parameter topo:

$$\text{topo} = 0.08 \cdot \left(1 + \frac{2 \cdot \text{mgadp}}{17}\right) + 0.89 \cdot \left(\frac{\text{mgadp}}{17}\right)^2 \tag{7}$$

6.8 Rule adp3m

Rule adp3m is an assignment rule for parameter adp3m:

$$\text{adp3m} = 0.135 \cdot [\text{adp}] \tag{8}$$

6.9 Rule JGPDH

Rule JGPDH is an assignment rule for parameter JGPDH:

$$\mathrm{JGPDH} = \mathrm{kGPDH} \cdot [\mathrm{FBP}]^{\frac{1}{2}} \tag{9}$$

6.10 Rule F6P

Rule F6P is an assignment rule for parameter F6P:

$$\mathrm{F6P} = 0.3 \cdot [\mathrm{G6P}] \tag{10}$$

6.11 Rule topa2

Rule topa2 is an assignment rule for parameter topa2:

$$\mathrm{topa2} = \mathrm{topa1} \tag{11}$$

6.12 Rule weight3

Rule weight3 is an assignment rule for parameter weight3:

$$\mathrm{weight3} = \frac{\mathrm{F6P}^2}{\mathrm{k3}} \tag{12}$$

6.13 Rule topa3

Rule topa3 is an assignment rule for parameter topa3:

$$\mathrm{topa3} = \mathrm{topa2} + \mathrm{weight3} \tag{13}$$

6.14 Rule weight5

Rule weight5 is an assignment rule for parameter weight5:

$$\mathrm{weight5} = \frac{[\mathrm{FBP}]}{\mathrm{k2}} \tag{14}$$

6.15 Rule weight7

Rule weight7 is an assignment rule for parameter weight7:

$$\mathrm{weight7} = \frac{[\mathrm{FBP}] \cdot \mathrm{F6P}^2}{\mathrm{k2} \cdot \mathrm{f23} \cdot \mathrm{k3}} \tag{15}$$

6.16 Rule weight9

Rule weight9 is an assignment rule for parameter weight9:

$$\mathrm{weight9} = \frac{\mathrm{AMP}}{\mathrm{k1}} \tag{16}$$

6.17 Rule weight11

Rule weight11 is an assignment rule for parameter weight11:

$$\text{weight11} = \frac{\text{AMP} \cdot \text{F6P}^2}{\text{k1} \cdot \text{k3} \cdot \text{f13}} \tag{17}$$

6.18 Rule weight13

Rule weight13 is an assignment rule for parameter weight13:

$$\text{weight13} = \frac{\text{AMP} \cdot [\text{FBP}]}{\text{k1} \cdot \text{k2}} \tag{18}$$

6.19 Rule weight15

Rule weight15 is an assignment rule for parameter weight15:

$$\text{weight15} = \frac{\text{AMP} \cdot [\text{FBP}] \cdot \text{F6P}^2}{\text{k1} \cdot \text{k2} \cdot \text{f23} \cdot \text{f13} \cdot \text{k3}} \tag{19}$$

6.20 Rule topb

Rule topb is an assignment rule for parameter topb:

$$\text{topb} = \text{weight15} \tag{20}$$

6.21 Rule JO

Rule JO is an assignment rule for parameter JO:

$$\text{JO} = \frac{\frac{\text{p4} \cdot [\text{NADHm}]}{\text{p5} + [\text{NADHm}]}}{1 + \exp\left(\frac{[\text{delta\_psi}] - \text{p6}}{\text{p7}}\right)} \tag{21}$$

6.22 Rule NADm

Rule NADm is an assignment rule for parameter NADm:

$$\text{NADm} = \text{NADmtot} - [\text{NADHm}] \tag{22}$$

6.23 Rule JPDH

Rule JPDH is an assignment rule for parameter JPDH:

$$\text{JPDH} = \frac{\text{p1}}{\text{p2} + \frac{[\text{NADHm}]}{\text{NADm}}} \cdot \frac{[\text{Cam}]}{\text{p3} + [\text{Cam}]} \cdot (\text{JGPDH} + \text{JGPDHbas}) \tag{23}$$

6.24 Rule JHres

Rule JHres is an assignment rule for parameter JHres:

$$\text{JHres} = \text{p8} \cdot \frac{[\text{NADHm}]}{\text{p9} + [\text{NADHm}]} \cdot \frac{1}{1 + \exp\left(\frac{[\text{delta\_psi}] - \text{p10}}{\text{p11}}\right)} \tag{24}$$

6.25 Rule JGK_ms

Rule JGK_ms is an assignment rule for parameter JGK_ms:

$$\text{JGK\_ms} = \text{kappa} \cdot \text{JGK} \tag{25}$$

6.26 Rule JHleak

Rule JHleak is an assignment rule for parameter JHleak:

$$\text{JHleak} = \text{p17} \cdot [\text{delta\_psi}] + \text{p18} \tag{26}$$

6.27 Rule Juni

Rule Juni is an assignment rule for parameter Juni:

$$\text{Juni} = (\text{p21} \cdot [\text{delta\_psi}] - \text{p22}) \cdot [\text{c}]^2 \tag{27}$$

6.28 Rule JNaCa

Rule JNaCa is an assignment rule for parameter JNaCa:

$$\text{JNaCa} = \text{p23} \cdot \frac{[\text{Cam}]}{[\text{c}]} \cdot \exp\left(\text{p24} \cdot [\text{delta\_psi}]\right) \tag{28}$$

6.29 Rule Jmito

Rule Jmito is an assignment rule for parameter Jmito:

$$\text{Jmito} = \text{JNaCa} - \text{Juni} \tag{29}$$

6.30 Rule ATPm

Rule ATPm is an assignment rule for parameter ATPm:

$$\text{ATPm} = \text{Amtot} - [\text{ADPm}] \tag{30}$$

6.31 Rule JF1F0

Rule JF1F0 is an assignment rule for parameter JF1F0:

$$\text{JF1F0} = \frac{\text{p16} \cdot \text{p13}}{\text{p13} + \text{ATPm}} \cdot \frac{1}{1 + \exp\left(\frac{\text{p14} - [\text{delta\_psi}]}{\text{p15}}\right)} \tag{31}$$

6.32 Rule JHatp

Rule JHatp is an assignment rule for parameter JHatp:

$$\text{JHatp} = 3 \cdot \text{JF1F0} \tag{32}$$

6.33 Rule RATm

Rule RATm is an assignment rule for parameter RATm:

$$\text{RATm} = \frac{\text{ATPm}}{[\text{ADPm}]} \tag{33}$$

6.34 Rule JANT

Rule JANT is an assignment rule for parameter JANT:

$$\text{JANT} = \text{p19} \cdot \frac{\text{RATm}}{\text{RATm} + \text{p20}} \cdot \exp\left(0.5 \cdot \text{FRT} \cdot [\text{delta\_psi}]\right) \tag{34}$$

6.35 Rule atp

Rule atp is an assignment rule for parameter atp:

$$\text{atp} = \text{atot} - [\text{adp}] \tag{35}$$

6.36 Rule atp4m

Rule atp4m is an assignment rule for parameter atp4m:

$$\text{atp4m} = 0.05 \cdot \text{atp} \tag{36}$$

6.37 Rule bottomo

Rule bottomo is an assignment rule for parameter bottomo:

$$\text{bottomo} = \left(1 + \frac{\text{mgadp}}{17}\right)^2 \cdot \left(1 + \frac{\text{adp3m}}{26} + \frac{\text{atp4m}}{1}\right) \tag{37}$$

6.38 Rule katpo

Rule katpo is an assignment rule for parameter katpo:

$$\text{katpo} = \frac{\text{topo}}{\text{bottomo}} \tag{38}$$

6.39 Rule Ikatp

Rule Ikatp is an assignment rule for parameter Ikatp:

$$\text{Ikatp} = \text{gkATP\_} \cdot \text{katpo} \cdot \left([\text{Vm}] - \text{VK}\right) \tag{39}$$

6.40 Rule `weight2`

Rule `weight2` is an assignment rule for parameter `weight2`:

$$\text{weight2} = \frac{\text{atp}^2}{\text{k4}} \tag{40}$$

6.41 Rule `bottom2`

Rule `bottom2` is an assignment rule for parameter `bottom2`:

$$\text{bottom2} = \text{bottom1} + \text{weight2} \tag{41}$$

6.42 Rule `bottom3`

Rule `bottom3` is an assignment rule for parameter `bottom3`:

$$\text{bottom3} = \text{bottom2} + \text{weight3} \tag{42}$$

6.43 Rule `weight4`

Rule `weight4` is an assignment rule for parameter `weight4`:

$$\text{weight4} = \frac{(\text{F6P} \cdot \text{atp})^2}{\text{k3} \cdot \text{k4} \cdot \text{f43}} \tag{43}$$

6.44 Rule `topa4`

Rule `topa4` is an assignment rule for parameter `topa4`:

$$\text{topa4} = \text{topa3} + \text{weight4} \tag{44}$$

6.45 Rule `bottom4`

Rule `bottom4` is an assignment rule for parameter `bottom4`:

$$\text{bottom4} = \text{bottom3} + \text{weight4} \tag{45}$$

6.46 Rule `topa5`

Rule `topa5` is an assignment rule for parameter `topa5`:

$$\text{topa5} = \text{topa4} \tag{46}$$

6.47 Rule `bottom5`

Rule `bottom5` is an assignment rule for parameter `bottom5`:

$$\text{bottom5} = \text{bottom4} + \text{weight5} \tag{47}$$

6.48 Rule weight6

Rule weight6 is an assignment rule for parameter weight6:

$$\mathrm{weight6} = \frac{[\mathrm{FBP}] \cdot \mathrm{atp}^2}{\mathrm{k2} \cdot \mathrm{f42} \cdot \mathrm{k4}} \tag{48}$$

6.49 Rule topa6

Rule topa6 is an assignment rule for parameter topa6:

$$\mathrm{topa6} = \mathrm{topa5} \tag{49}$$

6.50 Rule bottom6

Rule bottom6 is an assignment rule for parameter bottom6:

$$\mathrm{bottom6} = \mathrm{bottom5} + \mathrm{weight6} \tag{50}$$

6.51 Rule topa7

Rule topa7 is an assignment rule for parameter topa7:

$$\mathrm{topa7} = \mathrm{topa6} + \mathrm{weight7} \tag{51}$$

6.52 Rule bottom7

Rule bottom7 is an assignment rule for parameter bottom7:

$$\mathrm{bottom7} = \mathrm{bottom6} + \mathrm{weight7} \tag{52}$$

6.53 Rule weight8

Rule weight8 is an assignment rule for parameter weight8:

$$\mathrm{weight8} = \frac{[\mathrm{FBP}] \cdot \mathrm{F6P}^2 \cdot \mathrm{atp}^2}{\mathrm{k2} \cdot \mathrm{f23} \cdot \mathrm{f42} \cdot \mathrm{f43} \cdot \mathrm{k3} \cdot \mathrm{k4}} \tag{53}$$

6.54 Rule topa8

Rule topa8 is an assignment rule for parameter topa8:

$$\mathrm{topa8} = \mathrm{topa7} + \mathrm{weight8} \tag{54}$$

6.55 Rule topa9

Rule topa9 is an assignment rule for parameter topa9:

$$\mathrm{topa9} = \mathrm{topa8} \tag{55}$$

6.56 Rule `bottom8`

Rule `bottom8` is an assignment rule for parameter `bottom8`:

$$\mathrm{bottom8} = \mathrm{bottom7} + \mathrm{weight8} \tag{56}$$

6.57 Rule `bottom9`

Rule `bottom9` is an assignment rule for parameter `bottom9`:

$$\mathrm{bottom9} = \mathrm{bottom8} + \mathrm{weight9} \tag{57}$$

6.58 Rule `weight10`

Rule `weight10` is an assignment rule for parameter `weight10`:

$$\mathrm{weight10} = \frac{\mathrm{AMP} \cdot \mathrm{atp}^2}{\mathrm{k1} \cdot \mathrm{k4} \cdot \mathrm{f41}} \tag{58}$$

6.59 Rule `topa10`

Rule `topa10` is an assignment rule for parameter `topa10`:

$$\mathrm{topa10} = \mathrm{topa9} \tag{59}$$

6.60 Rule `bottom10`

Rule `bottom10` is an assignment rule for parameter `bottom10`:

$$\mathrm{bottom10} = \mathrm{bottom9} + \mathrm{weight10} \tag{60}$$

6.61 Rule `topa11`

Rule `topa11` is an assignment rule for parameter `topa11`:

$$\mathrm{topa11} = \mathrm{topa10} + \mathrm{weight11} \tag{61}$$

6.62 Rule `bottom11`

Rule `bottom11` is an assignment rule for parameter `bottom11`:

$$\mathrm{bottom11} = \mathrm{bottom10} + \mathrm{weight11} \tag{62}$$

6.63 Rule `weight12`

Rule `weight12` is an assignment rule for parameter `weight12`:

$$\mathrm{weight12} = \frac{\mathrm{AMP} \cdot \mathrm{F6P}^2 \cdot \mathrm{atp}^2}{\mathrm{k1} \cdot \mathrm{f13} \cdot \mathrm{f41} \cdot \mathrm{f43} \cdot \mathrm{k3} \cdot \mathrm{k4}} \tag{63}$$

6.64 Rule topa12

Rule `topa12` is an assignment rule for parameter `topa12`:

$$\mathrm{topa12} = \mathrm{topa11} + \mathrm{weight12} \tag{64}$$

6.65 Rule bottom12

Rule `bottom12` is an assignment rule for parameter `bottom12`:

$$\mathrm{bottom12} = \mathrm{bottom11} + \mathrm{weight12} \tag{65}$$

6.66 Rule topa13

Rule `topa13` is an assignment rule for parameter `topa13`:

$$\mathrm{topa13} = \mathrm{topa12} \tag{66}$$

6.67 Rule bottom13

Rule `bottom13` is an assignment rule for parameter `bottom13`:

$$\mathrm{bottom13} = \mathrm{bottom12} + \mathrm{weight13} \tag{67}$$

6.68 Rule weight14

Rule `weight14` is an assignment rule for parameter `weight14`:

$$\mathrm{weight14} = \frac{\mathrm{AMP} \cdot [\mathrm{FBP}] \cdot \mathrm{atp}^2}{\mathrm{k1} \cdot \mathrm{k2} \cdot \mathrm{f42} \cdot \mathrm{f41} \cdot \mathrm{k4}} \tag{68}$$

6.69 Rule topa14

Rule `topa14` is an assignment rule for parameter `topa14`:

$$\mathrm{topa14} = \mathrm{topa13} \tag{69}$$

6.70 Rule bottom14

Rule `bottom14` is an assignment rule for parameter `bottom14`:

$$\mathrm{bottom14} = \mathrm{bottom13} + \mathrm{weight14} \tag{70}$$

6.71 Rule topa15

Rule `topa15` is an assignment rule for parameter `topa15`:

$$\mathrm{topa15} = \mathrm{topa14} \tag{71}$$

6.72 Rule bottom15

Rule bottom15 is an assignment rule for parameter bottom15:

$$\text{bottom15} = \text{bottom14} + \text{weight15} \tag{72}$$

6.73 Rule weight16

Rule weight16 is an assignment rule for parameter weight16:

$$\text{weight16} = \frac{\text{AMP} \cdot [\text{FBP}] \cdot \text{F6P}^2 \cdot \text{atp}^2}{\text{k1} \cdot \text{k2} \cdot \text{k3} \cdot \text{k4} \cdot \text{f23} \cdot \text{f13} \cdot \text{f42} \cdot \text{f41} \cdot \text{f43}} \tag{73}$$

6.74 Rule topa16

Rule topa16 is an assignment rule for parameter topa16:

$$\text{topa16} = \text{topa15} + \text{weight16} \tag{74}$$

6.75 Rule bottom16

Rule bottom16 is an assignment rule for parameter bottom16:

$$\text{bottom16} = \text{bottom15} + \text{weight16} \tag{75}$$

6.76 Rule JPFK

Rule JPFK is an assignment rule for parameter JPFK:

$$\text{JPFK} = \frac{\text{VmaxPFK} \cdot \text{lambda} \cdot \text{topa16} + \text{VmaxPFK} \cdot \text{topb}}{\text{bottom16}} \tag{76}$$

6.77 Rule JPFK_ms

Rule JPFK_ms is an assignment rule for parameter JPFK_ms:

$$\text{JPFK\_ms} = \text{kappa} \cdot \text{JPFK} \tag{77}$$

6.78 Rule Jhyd

Rule Jhyd is an assignment rule for parameter Jhyd:

$$\text{Jhyd} = (\text{khyd} \cdot [\text{c}] + \text{khydbas}) \cdot \text{atp} \tag{78}$$

6.79 Rule Jmem

Rule Jmem is an assignment rule for parameter Jmem:

$$\text{Jmem} = (\text{alpha} \cdot \text{Ica} + \text{kPMCA} \cdot ([\text{c}] - \text{Cbas})) \tag{79}$$

6.80 Rule Jleak

Rule `Jleak` is an assignment rule for parameter `Jleak`:

$$\text{Jleak} = \text{pleak} \cdot ([\text{Caer}] - [\text{c}]) \tag{80}$$

6.81 Rule JSERCA

Rule `JSERCA` is an assignment rule for parameter `JSERCA`:

$$\text{JSERCA} = \text{kSERCA} \cdot [\text{c}] \tag{81}$$

6.82 Rule Jer

Rule `Jer` is an assignment rule for parameter `Jer`:

$$\text{Jer} = \text{Jleak} - \text{JSERCA} \tag{82}$$

6.83 Rule delta

Rule `delta` is an assignment rule for parameter `delta`:

$$\text{delta} = \frac{3.9}{53.2} \tag{83}$$

6.84 Rule Vm

Rule `Vm` is a rate rule for species `Vm`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Vm} = \frac{(\text{Ik} + \text{Ica} + \text{Ikca} + \text{Ikatp})}{\text{cm}} \tag{84}$$

6.85 Rule n

Rule `n` is a rate rule for species `n`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{n} = \frac{\text{n\_infinity} - [\text{n}]}{\text{tau\_n}} \tag{85}$$

6.86 Rule G6P

Rule `G6P` is a rate rule for species `G6P`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{G6P} = \text{JGK\_ms} - \text{JPFK\_ms} \tag{86}$$

6.87 Rule FBP

Rule `FBP` is a rate rule for species `FBP`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{FBP} = \text{JPFK\_ms} - 0.5 \cdot \text{JGPDH} \tag{87}$$

6.88 Rule NADHm

Rule NADHm is a rate rule for species NADHm:

$$\frac{d}{dt}\text{NADHm} = \text{gamma} \cdot (\text{JPDH} - \text{JO}) \tag{88}$$

6.89 Rule delta_psi

Rule delta_psi is a rate rule for species delta_psi:

$$\frac{d}{dt}\text{delta\_psi} = \frac{\text{JHres} - (\text{JHatp} + \text{JANT} + \text{JHleak} + \text{JNaCa} + 2 \cdot \text{Juni})}{\text{Cmito}} \tag{89}$$

6.90 Rule Cam

Rule Cam is a rate rule for species Cam:

$$\frac{d}{dt}\text{Cam} = \text{fmito} \cdot \text{Jmito} \tag{90}$$

6.91 Rule ADPm

Rule ADPm is a rate rule for species ADPm:

$$\frac{d}{dt}\text{ADPm} = \text{gamma} \cdot (\text{JANT} - \text{JF1F0}) \tag{91}$$

6.92 Rule adp

Rule adp is a rate rule for species adp:

$$\frac{d}{dt}\text{adp} = \text{delta} \cdot \text{JANT} + \text{Jhyd} \tag{92}$$

6.93 Rule c

Rule c is a rate rule for species c:

$$\frac{d}{dt}\text{c} = \text{fcyt} \cdot (\text{Jmem} + \text{Jer} + \text{delta} \cdot \text{Jmito}) \tag{93}$$

6.94 Rule Caer

Rule Caer is a rate rule for species Caer:

$$\frac{d}{dt}\text{Caer} = \text{fer} \cdot \text{Vc\_Ver} \cdot \text{Jer} \tag{94}$$

7 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.

7.1 Species Vm

Name Vm

Initial amount -60 mol

Involved in rule Vm

One rule which determines this species' quantity.

7.2 Species n

Name n

Initial amount 0 mol

Involved in rule n

One rule which determines this species' quantity.

7.3 Species G6P

Name G6P

Initial amount 301 mol

Involved in rule G6P

One rule which determines this species' quantity.

7.4 Species FBP

Name FBP

Initial amount 2.16 mol

Involved in rule FBP

One rule which determines this species' quantity.

7.5 Species NADHm

Name NADHm

Initial amount 0.4 mol

Involved in rule NADHm

One rule which determines this species' quantity.

7.6 Species delta_psi

Name delta_psi

SBO:0000009 kinetic constant

Initial amount 164 mol

Involved in rule delta_psi

One rule which determines this species' quantity.

7.7 Species Cam

Name Cam

Initial amount 0.2 mol

Involved in rule Cam

One rule which determines this species' quantity.

7.8 Species ADPm

Name ADPm

Initial amount 11.1 mol

Involved in rule ADPm

One rule which determines this species' quantity.

7.9 Species adp

Name adp

Initial amount 1137 mol

Involved in rule adp

One rule which determines this species' quantity.

7.10 Species c

Name c

Initial amount 0.17 mol

Involved in rule c

One rule which determines this species' quantity.

7.11 Species Caer

Name Caer

Initial amount 345 mol

Involved in rule Caer

One rule which determines this species' quantity.

A Glossary of Systems Biology Ontology Terms

SBO:0000009 kinetic constant: Numerical parameter that quantifies the velocity of a chemical reaction

SBO:0000258 capacitance: Measure of the amount of electric charge stored (or separated) for a given electric potential. The unit of capacitance id the Farad

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