SBML Model Report

Model name: "Bray1993_chemotaxis"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following four authors: Nicolas Le Novre[1], Lukas Endler[2], Vijayalakshmi Chelliah[3] and Dennis Bray[4] at November third 2008 at 11:29 a. m. and last time modified at March eighth 2012 at 11:12 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	1
species types	0	species	29
events	2	constraints	0
reactions	35	function definitions	6
global parameters	7	unit definitions	0
rules	2	initial assignments	0

Model Notes

This version of the model is very close to the version described in the paper with one exception: the binding of aspartate to the various receptor complexes, as well as the formation of the different complexes are modeled using chemical kinetics (mass action law), rather than instant

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equilibrium. The qualitative behaviour of the model is unchanged. Note that in order to quantitatively replicate the figure 8b, and in particular to have a basal bias of 0.7, we have to change the rate constant of the aspartate-triggered dephosphorylation of CheY from 59000 to 70000. The peaks have then slightly different values.

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To cite BioModels Database, please use: Li C, Donizelli M, Rodriguez N, Dharuri H, Endler L, Chelliah V, Li L, He E, Henry A, Stefan MI, Snoep JL, Hucka M, Le Novre N, Laibe C (2010) BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models. BMC Syst Biol., 4:92.

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
`cell`	cell	0000290	3	$1.41 \cdot 10^{-15}$	l	☑	

3.1 Compartment `cell`

This is a three dimensional compartment with a constant size of $1.41 \cdot 10^{-15}$ litre.

Name cell

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 10 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
asp	asp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
ni	ni	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑
T	T	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tasp	Tasp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tni	Tni	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
W	W	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
TW	TW	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tasp_W	Tasp_W	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tni_W	Tni_W	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
TA	TA	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tasp_A	Tasp_A	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tni_A	Tni_A	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
WA	WA	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
TWA	TWA	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tasp_WA	Tasp_WA	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Tni_WA	Tni_WA	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
A	A	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Ap	Ap	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
B	B	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Bp	Bp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Z	Z	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
Y	Y	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
Yp	Yp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
M	M	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
MYp	MYp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
MYpYp	MYpYp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
MYpYpYp	MYpYpYp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
MYpYpYpYp	MYpYpYpYp	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
species_1	ATP	cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑

5 Parameters

This model contains seven global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
alpha	alpha		0.140		☑
kappa	kappa		$2.25 \cdot 10^{-7}$		☑
ka	ka		0.100		☑
Bias	Bias		0.701		⊟
parameter_1	asp_pulse		10^{-7}		☑
parameter_2	autoPhospho		0.997		⊟
parameter_3	KmATP		$3 \cdot 10^{-4}$		☑

6 Function definitions

This is an overview of six function definitions.

6.1 Function definition function_4_motor_r1

Name function_4_motor_r1

Arguments [M], [MYp], [Yp], vol (cell), ka, kappa

Mathematical Expression

$$\frac{\mathrm{ka} \cdot \left([\mathrm{M}] \cdot [\mathrm{Yp}] - \frac{\mathrm{kappa}}{4} \cdot [\mathrm{MYp}] \right)}{\mathrm{vol}\,(\mathrm{cell})} \tag{1}$$

6.2 Function definition function_4_motor_r2

Name function_4_motor_r2

Arguments [MYp], [MYpYp], [Yp], alpha, vol (cell), ka, kappa

Mathematical Expression

$$\frac{\mathrm{ka} \cdot \left([\mathrm{MYp}] \cdot [\mathrm{Yp}] - \frac{2 \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{3} \cdot [\mathrm{MYpYp}] \right)}{\mathrm{vol}\,(\mathrm{cell})} \tag{2}$$

6.3 Function definition function_4_motor_r3

Name function_4_motor_r3

Arguments [MYpYp], [MYpYpYp], [Yp], alpha, vol (cell), ka, kappa

Mathematical Expression

$$\frac{\mathrm{ka} \cdot \left([\mathrm{MYpYp}] \cdot [\mathrm{Yp}] - \frac{3 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{2} \cdot [\mathrm{MYpYpYp}] \right)}{\mathrm{vol}\,(\mathrm{cell})} \tag{3}$$

6.4 Function definition function_4_motor_r4

Name function_4_motor_r4

Arguments [MYpYpYp], [MYpYpYpYp], [Yp], alpha, vol (cell), ka, kappa

Mathematical Expression

$$\frac{\mathrm{ka} \cdot ([\mathrm{MYpYpYp}] \cdot [\mathrm{Yp}] - 4 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa} \cdot [\mathrm{MYpYpYpYp}])}{\mathrm{vol}\,(\mathrm{cell})} \tag{4}$$

6.5 Function definition Autophosphorylation

Name Autophosphorylation

Arguments kcat, correction, E

Mathematical Expression

$$\mathrm{kcat} \cdot \mathrm{correction} \cdot \mathrm{E} \tag{5}$$

6.6 Function definition ModAutophosphorylation

Name ModAutophosphorylation

Arguments [M], S, kcat, correction

Mathematical Expression

$$[\mathrm{M}] \cdot \mathrm{S} \cdot \mathrm{kcat} \cdot \mathrm{correction} \tag{6}$$

7 Rules

This is an overview of two rules.

7.1 Rule Bias

Rule Bias is an assignment rule for parameter Bias:

$$\text{Bias} = \frac{[\text{M}] + [\text{MYp}]}{[\text{M}] + [\text{MYp}] + [\text{MYpYp}] + [\text{MYpYpYp}] + [\text{MYpYpYpYp}]} \tag{7}$$

Derived unit dimensionless

7.2 Rule parameter_2

Rule parameter_2 is an assignment rule for parameter parameter_2:

$$\text{parameter\_2} = \frac{[\text{species\_1}]}{[\text{species\_1}] + \text{parameter\_3}} \tag{8}$$

8 Events

This is an overview of two events. Each event is initiated whenever its trigger condition switches from false to true. A delay function postpones the effects of an event to a later time point. At the time of execution, an event can assign values to species, parameters or compartments if these are not set to constant.

8.1 Event event_1

Name Add ASP

Trigger condition

$$\text{time} \geq 5 \tag{9}$$

Assignment

$$\text{asp} = \text{parameter\_1} \tag{10}$$

8.2 Event event_2

Name Remove ASP

Trigger condition

$$\text{time} \geq 10 \tag{11}$$

Assignment

$$\text{asp} = 0 \tag{12}$$

9 Reactions

This model contains 35 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	phosphorylation_r1	A->Ap	$A \longrightarrow Ap$	0000216
2	phosphorylation_r2	TWA+A->TWA+Ap	$A \xrightarrow{TWA} Ap$	0000216
3	phosphorylation_r3	Tni_WA+A->Tni_WA+Ap	$A \xrightarrow{Tni\_WA} Ap$	0000216
4	phosphorylation_r4	Tasp_WA+Yp->Tasp_WA+Y	$Tasp\_WA + Yp \longrightarrow Tasp\_WA + Y$	0000330
5	phosphorylation_r5	Ap+Y->A+Yp	$Ap + Y \longrightarrow A + Yp$	0000216
6	phosphorylation_r6	Y ->Yp	$Y \longrightarrow Yp$	0000216
7	phosphorylation_r7	Yp->Y	$Yp \longrightarrow Y$	0000330
8	phosphorylation_r8	Yp+Z->Y+Z	$Yp + Z \longrightarrow Y + Z$	0000330
9	phosphorylation_r9	Ap+B->A+Bp	$Ap + B \longrightarrow A + Bp$	0000402
10	phosphorylation_r10	Bp->B	$Bp \longrightarrow B$	0000330
11	regulatory_r1	T+asp<->Tasp	$T + asp \rightleftharpoons Tasp$	0000177
12	regulatory_r2	T+ni<->Tni	$T + ni \rightleftharpoons Tni$	0000177

№	Id	Name	Reaction Equation	SBO
13	regulatory_r3	T+W<->TW	$T + W \rightleftharpoons TW$	0000177
14	regulatory_r4	T+A<->TA	$T + A \rightleftharpoons TA$	0000177
15	regulatory_r5	W+A<->WA	$W + A \rightleftharpoons WA$	0000177
16	regulatory_r6	TW+A<->TWA	$TW + A \rightleftharpoons TWA$	0000177
17	regulatory_r7	TA+W<->TWA	$TA + W \rightleftharpoons TWA$	0000177
18	regulatory_r8	T+WA<->TWA	$T + WA \rightleftharpoons TWA$	0000177
19	regulatory_r9	Tasp+W<->Tasp_W	$Tasp + W \rightleftharpoons Tasp\_W$	0000177
20	regulatory_r10	Tasp+A<->Tasp_A	$Tasp + A \rightleftharpoons Tasp\_A$	0000177
21	regulatory_r11	Tasp_W+A<->Tasp_WA	$Tasp\_W + A \rightleftharpoons Tasp\_WA$	0000177
22	regulatory_r12	Tasp_A+W<->Tasp_WA	$Tasp\_A + W \rightleftharpoons Tasp\_WA$	0000177
23	regulatory_r13	Tasp+WA<->Tasp_WA	$Tasp + WA \rightleftharpoons Tasp\_WA$	0000177
24	regulatory_r14	Tni+W<->Tni_W	$Tni + W \rightleftharpoons Tni\_W$	0000177
25	regulatory_r15	Tni+A<->Tni_A	$Tni + A \rightleftharpoons Tni\_A$	0000177
26	regulatory_r16	Tni_W+A<->Tni_WA	$Tni\_W + A \rightleftharpoons Tni\_WA$	0000177
27	regulatory_r17	Tni_A+W<->Tni_WA	$Tni\_A + W \rightleftharpoons Tni\_WA$	0000177
28	regulatory_r18	Tni+WA<->Tni_WA	$Tni + WA \rightleftharpoons Tni\_WA$	0000177
29	motor_r1	M+Yp<->MYp	$M + Yp \rightleftharpoons MYp$	0000177
30	motor_r2	MYp+Yp<->MYpYp	$MYp + Yp \rightleftharpoons MYpYp$	0000177
31	motor_r3	MYpYp+Yp<->MYpYpYp	$MYpYp + Yp \rightleftharpoons MYpYpYp$	0000177
32	motor_r4	MYpYpYp+Yp<->MYpYpYpYp	$MYpYpYp + Yp \rightleftharpoons MYpYpYpYp$	0000177
33	reaction_1	TA + asp <-> Tasp_A	$TA + asp \rightleftharpoons Tasp\_A$	0000177
34	reaction_2	TW+asp <-> Tasp_W	$TW + asp \rightleftharpoons Tasp\_W$	0000177
35	reaction_3	TWA+asp <-> Tasp_WA	$TWA + asp \rightleftharpoons Tasp\_WA$	0000177

9.1 Reaction phosphorylation_r1

This is an irreversible reaction of one reactant forming one product.

Name A->Ap

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{A} \longrightarrow \mathrm{Ap} \tag{13}$$

Reactant

Table 6: Properties of each reactant.

Id	Name	SBO
A	A	

Product

Table 7: Properties of each product.

Id	Name	SBO
Ap	Ap	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{parameter\_2}, [\mathrm{A}]) \tag{14}$$

$$\mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{correction}, \mathrm{E}) = \mathrm{kcat} \cdot \mathrm{correction} \cdot \mathrm{E} \tag{15}$$

$$\mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{correction}, \mathrm{E}) = \mathrm{kcat} \cdot \mathrm{correction} \cdot \mathrm{E} \tag{16}$$

Table 8: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kcat	kcat		0.001		☑

9.2 Reaction phosphorylation_r2

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name TWA+A->TWA+Ap

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{A} \xrightarrow{\mathrm{TWA}} \mathrm{Ap} \tag{17}$$

Reactant

Table 9: Properties of each reactant.

Id	Name	SBO
A	A	

Modifier

Table 10: Properties of each modifier.

Id	Name	SBO
TWA	TWA	

Product

Table 11: Properties of each product.

Id	Name	SBO
Ap	Ap	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \mathrm{vol}(\mathrm{cell}) \cdot \mathrm{ModAutophosphorylation}([\mathrm{TWA}], [\mathrm{A}], \mathrm{kcat}, \mathrm{parameter\_2}) \tag{18}$$

$$\mathrm{ModAutophosphorylation}([\mathrm{M}], \mathrm{S}, \mathrm{kcat}, \mathrm{correction}) = [\mathrm{M}] \cdot \mathrm{S} \cdot \mathrm{kcat} \cdot \mathrm{correction} \tag{19}$$

$$\mathrm{ModAutophosphorylation}([\mathrm{M}], \mathrm{S}, \mathrm{kcat}, \mathrm{correction}) = [\mathrm{M}] \cdot \mathrm{S} \cdot \mathrm{kcat} \cdot \mathrm{correction} \tag{20}$$

Table 12: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kcat	kcat		75000.0		☑

9.3 Reaction phosphorylation_r3

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name Tni_WA+A->Tni_WA+Ap

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{A} \xrightarrow{\mathrm{Tni\_WA}} \mathrm{Ap} \tag{21}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
A	A	

Modifier

Table 14: Properties of each modifier.

Id	Name	SBO
Tni_WA	Tni_WA	

Product

Table 15: Properties of each product.

Id	Name	SBO
Ap	Ap	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{ModAutophosphorylation}\,([\mathrm{Tni\_WA}], [\mathrm{A}], \mathrm{kcat}, \mathrm{parameter\_2}) \quad (22)$$

$$\mathrm{ModAutophosphorylation}\,([\mathrm{M}], \mathrm{S}, \mathrm{kcat}, \mathrm{correction}) = [\mathrm{M}] \cdot \mathrm{S} \cdot \mathrm{kcat} \cdot \mathrm{correction} \quad (23)$$

$$\mathrm{ModAutophosphorylation}\,([\mathrm{M}], \mathrm{S}, \mathrm{kcat}, \mathrm{correction}) = [\mathrm{M}] \cdot \mathrm{S} \cdot \mathrm{kcat} \cdot \mathrm{correction} \quad (24)$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kcat	kcat		200000.0		☑

9.4 Reaction phosphorylation_r4

This is an irreversible reaction of two reactants forming two products.

Name Tasp_WA+Yp->Tasp_WA+Y

SBO:0000330 dephosphorylation

Reaction equation

$$\mathrm{Tasp\_WA} + \mathrm{Yp} \longrightarrow \mathrm{Tasp\_WA} + \mathrm{Y} \quad (25)$$

Reactants

Table 17: Properties of each reactant.

Id	Name	SBO
Tasp_WA	Tasp_WA	
Yp	Yp	

Products

Table 18: Properties of each product.

Id	Name	SBO
Tasp_WA	Tasp_WA	
Y	Y	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Tasp\_WA}] \cdot [\mathrm{Yp}] \tag{26}$$

Table 19: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		10^8		☑

9.5 Reaction phosphorylation_r5

This is an irreversible reaction of two reactants forming two products.

Name Ap+Y->A+Yp

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{Ap} + \mathrm{Y} \longrightarrow \mathrm{A} + \mathrm{Yp} \tag{27}$$

Reactants

Table 20: Properties of each reactant.

Id	Name	SBO
Ap	Ap	
Y	Y	

Products

Table 21: Properties of each product.

Id	Name	SBO
A	A	
Yp	Yp	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Ap}] \cdot [\mathrm{Y}] \tag{28}$$

Table 22: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		200000.0		☑

9.6 Reaction phosphorylation_r6

This is an irreversible reaction of one reactant forming one product.

Name Y ->Yp

SBO:0000216 phosphorylation

Reaction equation

$$\mathrm{Y} \longrightarrow \mathrm{Yp} \tag{29}$$

Reactant

Table 23: Properties of each reactant.

Id	Name	SBO
Y	Y	

Product

Table 24: Properties of each product.

Id	Name	SBO
Yp	Yp	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{parameter\_2}, [\mathrm{Y}]) \tag{30}$$

$$\mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{correction}, \mathrm{E}) = \mathrm{kcat} \cdot \mathrm{correction} \cdot \mathrm{E} \tag{31}$$

$$\mathrm{Autophosphorylation}\,(\mathrm{kcat}, \mathrm{correction}, \mathrm{E}) = \mathrm{kcat} \cdot \mathrm{correction} \cdot \mathrm{E} \tag{32}$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kcat	kcat		0.0		☑

9.7 Reaction phosphorylation_r7

This is an irreversible reaction of one reactant forming one product.

Name Yp->Y

SBO:0000330 dephosphorylation

Reaction equation

$$\mathrm{Yp} \longrightarrow \mathrm{Y} \tag{33}$$

Reactant

Table 26: Properties of each reactant.

Id	Name	SBO
Yp	Yp	

Product

Table 27: Properties of each product.

Id	Name	SBO
Y	Y	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Yp}] \tag{34}$$

Table 28: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.037		☑

9.8 Reaction phosphorylation_r8

This is an irreversible reaction of two reactants forming two products.

Name Yp+Z->Y+Z

SBO:0000330 dephosphorylation

Reaction equation

$$\mathrm{Yp} + \mathrm{Z} \longrightarrow \mathrm{Y} + \mathrm{Z} \tag{35}$$

Reactants

Table 29: Properties of each reactant.

Id	Name	SBO
Yp	Yp	
Z	Z	

Products

Table 30: Properties of each product.

Id	Name	SBO
Y	Y	
Z	Z	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Yp}] \cdot [\mathrm{Z}] \tag{36}$$

Table 31: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		500000.0		☑

9.9 Reaction phosphorylation_r9

This is an irreversible reaction of two reactants forming two products.

Name Ap+B->A+Bp

SBO:0000402 transfer of a chemical group

Reaction equation

$$\mathrm{Ap} + \mathrm{B} \longrightarrow \mathrm{A} + \mathrm{Bp} \tag{37}$$

Reactants

Table 32: Properties of each reactant.

Id	Name	SBO
Ap	Ap	
B	B	

Products

Table 33: Properties of each product.

Id	Name	SBO
A	A	
Bp	Bp	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Ap}] \cdot [\mathrm{B}] \tag{38}$$

Table 34: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000000.0		☑

9.10 Reaction phosphorylation_r10

This is an irreversible reaction of one reactant forming one product.

Name Bp->B

SBO:0000330 dephosphorylation

Reaction equation

$$\mathrm{Bp} \longrightarrow \mathrm{B} \tag{39}$$

Reactant

Table 35: Properties of each reactant.

Id	Name	SBO
Bp	Bp	

Product

Table 36: Properties of each product.

Id	Name	SBO
B	B	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \mathrm{vol}\,(\mathrm{cell}) \cdot \mathrm{k1} \cdot [\mathrm{Bp}] \tag{40}$$

Table 37: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1.0		☑

9.11 Reaction regulatory_r1

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

Name T+asp<->Tasp

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{T} + \mathrm{asp} \rightleftharpoons \mathrm{Tasp} \tag{41}$$

Reactants

Table 38: Properties of each reactant.

Id	Name	SBO
T	T	
asp	asp	

Product

Table 39: Properties of each product.

Id	Name	SBO
Tasp	Tasp	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{T}] \cdot [\mathrm{asp}] - \mathrm{k2} \cdot [\mathrm{Tasp}]) \tag{42}$$

Table 40: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000000.0		☑
k2	k2		1.0		☑

9.12 Reaction regulatory_r2

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

Name T+ni<->Tni

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{T} + \mathrm{ni} \rightleftharpoons \mathrm{Tni} \tag{43}$$

Reactants

Table 41: Properties of each reactant.

Id	Name	SBO
T	T	
ni	ni	

Product

Table 42: Properties of each product.

Id	Name	SBO
Tni	Tni	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{T}] \cdot [\mathrm{ni}] - \mathrm{k2} \cdot [\mathrm{Tni}]) \tag{44}$$

Table 43: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000.0		☑
k2	k2		1.0		☑

9.13 Reaction regulatory_r3

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

Name T+W<->TW

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{T} + \mathrm{W} \rightleftharpoons \mathrm{TW} \tag{45}$$

Reactants

Table 44: Properties of each reactant.

Id	Name	SBO
T	T	
W	W	

Product

Table 45: Properties of each product.

Id	Name	SBO
TW	TW	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{T}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{TW}]) \tag{46}$$

Table 46: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		100000.0		☑
k2	k2		1.0		☑

9.14 Reaction regulatory_r4

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

Name T+A<->TA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{T} + \mathrm{A} \rightleftharpoons \mathrm{TA} \tag{47}$$

Reactants

Table 47: Properties of each reactant.

Id	Name	SBO
T	T	
A	A	

Product

Table 48: Properties of each product.

Id	Name	SBO
TA	TA	

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{T}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{TA}]) \tag{48}$$

Table 49: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		10000.0		☑
k2	k2		1.0		☑

9.15 Reaction regulatory_r5

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

Name W+A<->WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{W} + \mathrm{A} \rightleftharpoons \mathrm{WA} \tag{49}$$

Reactants

Table 50: Properties of each reactant.

Id	Name	SBO
W	W	
A	A	

Product

Table 51: Properties of each product.

Id	Name	SBO
WA	WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{W}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{WA}]) \tag{50}$$

Table 52: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		100000.0		☑
k2	k2		1.0		☑

9.16 Reaction regulatory_r6

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

Name TW+A<->TWA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{TW} + \mathrm{A} \rightleftharpoons \mathrm{TWA} \tag{51}$$

Reactants

Table 53: Properties of each reactant.

Id	Name	SBO
TW	TW	
A	A	

Product

Table 54: Properties of each product.

Id	Name	SBO
TWA	TWA	

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{TW}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{TWA}]) \tag{52}$$

Table 55: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.17 Reaction regulatory_r7

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

Name TA+W<->TWA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{TA} + \mathrm{W} \rightleftharpoons \mathrm{TWA} \tag{53}$$

Reactants

Table 56: Properties of each reactant.

Id	Name	SBO
TA	TA	
W	W	

Product

Table 57: Properties of each product.

Id	Name	SBO
TWA	TWA	

Kinetic Law

Derived unit contains undeclared units

$$v_{17} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{TA}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{TWA}]) \tag{54}$$

Table 58: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.18 Reaction regulatory_r8

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

Name T+WA<->TWA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{T} + \mathrm{WA} \rightleftharpoons \mathrm{TWA} \tag{55}$$

Reactants

Table 59: Properties of each reactant.

Id	Name	SBO
T	T	
WA	WA	

Product

Table 60: Properties of each product.

Id	Name	SBO
TWA	TWA	

Kinetic Law

Derived unit contains undeclared units

$$v_{18} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{T}] \cdot [\mathrm{WA}] - \mathrm{k2} \cdot [\mathrm{TWA}]) \tag{56}$$

Table 61: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.19 Reaction regulatory_r9

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

Name Tasp+W<->Tasp_W

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tasp} + \mathrm{W} \rightleftharpoons \mathrm{Tasp\_W} \tag{57}$$

Reactants

Table 62: Properties of each reactant.

Id	Name	SBO
Tasp	Tasp	
W	W	

Product

Table 63: Properties of each product.

Id	Name	SBO
Tasp_W	Tasp_W	

Kinetic Law

Derived unit contains undeclared units

$$v_{19} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tasp}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{Tasp\_W}]) \tag{58}$$

Table 64: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		100000.0		☑
k2	k2		1.0		☑

9.20 Reaction regulatory_r10

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

Name Tasp+A<->Tasp_A

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tasp} + \mathrm{A} \rightleftharpoons \mathrm{Tasp\_A} \tag{59}$$

Reactants

Table 65: Properties of each reactant.

Id	Name	SBO
Tasp	Tasp	
A	A	

Product

Table 66: Properties of each product.

Id	Name	SBO
Tasp_A	Tasp_A	

Kinetic Law

Derived unit contains undeclared units

$$v_{20} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tasp}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{Tasp\_A}]) \tag{60}$$

Table 67: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		10000.0		☑
k2	k2		1.0		☑

9.21 Reaction regulatory_r11

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

Name Tasp_W+A<->Tasp_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tasp\_W} + \mathrm{A} \rightleftharpoons \mathrm{Tasp\_WA} \tag{61}$$

Reactants

Table 68: Properties of each reactant.

Id	Name	SBO
Tasp_W	Tasp_W	
A	A	

Product

Table 69: Properties of each product.

Id	Name	SBO
Tasp_WA	Tasp_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{21} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tasp\_W}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{Tasp\_WA}]) \tag{62}$$

Table 70: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.22 Reaction regulatory_r12

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

Name Tasp_A+W<->Tasp_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tasp\_A} + \mathrm{W} \rightleftharpoons \mathrm{Tasp\_WA} \tag{63}$$

Reactants

Table 71: Properties of each reactant.

Id	Name	SBO
Tasp_A	Tasp_A	
W	W	

Product

Table 72: Properties of each product.

Id	Name	SBO
Tasp_WA	Tasp_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{22} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tasp\_A}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{Tasp\_WA}]) \tag{64}$$

Table 73: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.23 Reaction regulatory_r13

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

Name Tasp+WA<->Tasp_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tasp} + \mathrm{WA} \rightleftharpoons \mathrm{Tasp\_WA} \tag{65}$$

Reactants

Table 74: Properties of each reactant.

Id	Name	SBO
Tasp	Tasp	
WA	WA	

Product

Table 75: Properties of each product.

Id	Name	SBO
Tasp_WA	Tasp_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{23} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tasp}] \cdot [\mathrm{WA}] - \mathrm{k2} \cdot [\mathrm{Tasp\_WA}]) \tag{66}$$

Table 76: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		400000.0		☑
k2	k2		1.0		☑

9.24 Reaction regulatory_r14

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

Name Tni+W<->Tni_W

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tni} + \mathrm{W} \rightleftharpoons \mathrm{Tni\_W} \tag{67}$$

Reactants

Table 77: Properties of each reactant.

Id	Name	SBO
Tni	Tni	
W	W	

Product

Table 78: Properties of each product.

Id	Name	SBO
Tni_W	Tni_W	

Kinetic Law

Derived unit contains undeclared units

$$v_{24} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tni}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{Tni\_W}]) \tag{68}$$

Table 79: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.1		☑
k2	k2		1.0		☑

9.25 Reaction regulatory_r15

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

Name Tni+A<->Tni_A

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tni} + \mathrm{A} \rightleftharpoons \mathrm{Tni\_A} \tag{69}$$

Reactants

Table 80: Properties of each reactant.

Id	Name	SBO
Tni	Tni	
A	A	

Product

Table 81: Properties of each product.

Id	Name	SBO
Tni_A	Tni_A	

Kinetic Law

Derived unit contains undeclared units

$$v_{25} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tni}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{Tni\_A}]) \tag{70}$$

Table 82: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.01		☑
k2	k2		1.00		☑

9.26 Reaction regulatory_r16

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

Name Tni_W+A<->Tni_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tni\_W} + \mathrm{A} \rightleftharpoons \mathrm{Tni\_WA} \tag{71}$$

Reactants

Table 83: Properties of each reactant.

Id	Name	SBO
Tni_W	Tni_W	
A	A	

Product

Table 84: Properties of each product.

Id	Name	SBO
Tni_WA	Tni_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{26} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tni\_W}] \cdot [\mathrm{A}] - \mathrm{k2} \cdot [\mathrm{Tni\_WA}]) \tag{72}$$

Table 85: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.4		☑
k2	k2		1.0		☑

9.27 Reaction regulatory_r17

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

Name Tni_A+W<->Tni_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tni\_A} + \mathrm{W} \rightleftharpoons \mathrm{Tni\_WA} \tag{73}$$

Reactants

Table 86: Properties of each reactant.

Id	Name	SBO
Tni_A	Tni_A	
W	W	

Product

Table 87: Properties of each product.

Id	Name	SBO
Tni_WA	Tni_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{27} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tni\_A}] \cdot [\mathrm{W}] - \mathrm{k2} \cdot [\mathrm{Tni\_WA}]) \tag{74}$$

Table 88: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.4		☑
k2	k2		1.0		☑

9.28 Reaction regulatory_r18

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

Name Tni+WA<->Tni_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{Tni} + \mathrm{WA} \rightleftharpoons \mathrm{Tni\_WA} \tag{75}$$

Reactants

Table 89: Properties of each reactant.

Id	Name	SBO
Tni	Tni	
WA	WA	

Product

Table 90: Properties of each product.

Id	Name	SBO
Tni_WA	Tni_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{28} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{Tni}] \cdot [\mathrm{WA}] - \mathrm{k2} \cdot [\mathrm{Tni\_WA}]) \tag{76}$$

Table 91: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		0.4		☑
k2	k2		1.0		☑

9.29 Reaction motor_r1

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

Name M+Yp<->MYp

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{M} + \mathrm{Yp} \rightleftharpoons \mathrm{MYp} \tag{77}$$

Reactants

Table 92: Properties of each reactant.

Id	Name	SBO
M	M	
Yp	Yp	

Product

Table 93: Properties of each product.

Id	Name	SBO
MYp	MYp	

Kinetic Law

Derived unit contains undeclared units

$$v_{29} = \mathrm{vol}\left(\mathrm{cell}\right) \cdot \mathrm{function\_4\_motor\_r1}\left(\left[\mathrm{M}\right], \left[\mathrm{MYp}\right], \left[\mathrm{Yp}\right], \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \tag{78}$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r1}\left(\left[\mathrm{M}\right], \left[\mathrm{MYp}\right], \left[\mathrm{Yp}\right], \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{M}\right] \cdot \left[\mathrm{Yp}\right] - \frac{\mathrm{kappa}}{4} \cdot \left[\mathrm{MYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \tag{79}$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r1}\left(\left[\mathrm{M}\right], \left[\mathrm{MYp}\right], \left[\mathrm{Yp}\right], \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{M}\right] \cdot \left[\mathrm{Yp}\right] - \frac{\mathrm{kappa}}{4} \cdot \left[\mathrm{MYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \tag{80}$$

9.30 Reaction motor_r2

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

Name MYp+Yp<->MYpYp

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{MYp} + \mathrm{Yp} \rightleftharpoons \mathrm{MYpYp} \tag{81}$$

Reactants

Table 94: Properties of each reactant.

Id	Name	SBO
MYp	MYp	
Yp	Yp	

Product

Table 95: Properties of each product.

Id	Name	SBO
MYpYp	MYpYp	

Kinetic Law

Derived unit contains undeclared units

$$v_{30} = \mathrm{vol}\left(\mathrm{cell}\right) \cdot \mathrm{function\_4\_motor\_r2}\left(\left[\mathrm{MYp}\right], \left[\mathrm{MYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \quad (82)$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r2}\left(\left[\mathrm{MYp}\right], \left[\mathrm{MYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYp}\right] \cdot \left[\mathrm{Yp}\right] - \frac{2 \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{3} \cdot \left[\mathrm{MYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \quad (83)$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r2}\left(\left[\mathrm{MYp}\right], \left[\mathrm{MYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYp}\right] \cdot \left[\mathrm{Yp}\right] - \frac{2 \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{3} \cdot \left[\mathrm{MYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \quad (84)$$

9.31 Reaction motor_r3

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

Name MYpYp+Yp<->MYpYpYp

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{MYpYp} + \mathrm{Yp} \rightleftharpoons \mathrm{MYpYpYp} \quad (85)$$

Reactants

Table 96: Properties of each reactant.

Id	Name	SBO
MYpYp	MYpYp	
Yp	Yp	

Product

Table 97: Properties of each product.

Id	Name	SBO
MYpYpYp	MYpYpYp	

Kinetic Law

Derived unit contains undeclared units

$$v_{31} = \mathrm{vol}\left(\mathrm{cell}\right) \cdot \mathrm{function\_4\_motor\_r3}\left(\left[\mathrm{MYpYp}\right], \left[\mathrm{MYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \tag{86}$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r3}\left(\left[\mathrm{MYpYp}\right], \left[\mathrm{MYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYpYp}\right] \cdot \left[\mathrm{Yp}\right] - \frac{3 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{2} \cdot \left[\mathrm{MYpYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \tag{87}$$

$$\begin{aligned} &\mathrm{function\_4\_motor\_r3}\left(\left[\mathrm{MYpYp}\right], \left[\mathrm{MYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \\ &= \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYpYp}\right] \cdot \left[\mathrm{Yp}\right] - \frac{3 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa}}{2} \cdot \left[\mathrm{MYpYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \end{aligned} \tag{88}$$

9.32 Reaction motor_r4

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

Name MYpYpYp+Yp<->MYpYpYpYp

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{MYpYpYp} + \mathrm{Yp} \rightleftharpoons \mathrm{MYpYpYpYp} \tag{89}$$

Reactants

Table 98: Properties of each reactant.

Id	Name	SBO
MYpYpYp	MYpYpYp	
Yp	Yp	

Product

Table 99: Properties of each product.

Id	Name	SBO
MYpYpYpYp	MYpYpYpYp	

Kinetic Law

Derived unit contains undeclared units

$$v_{32} = \mathrm{vol}\left(\mathrm{cell}\right) \cdot \mathrm{function\_4\_motor\_r4}\left(\left[\mathrm{MYpYpYp}\right], \left[\mathrm{MYpYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) \tag{90}$$

$$\mathrm{function\_4\_motor\_r4}\left(\left[\mathrm{MYpYpYp}\right], \left[\mathrm{MYpYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) = \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYpYpYp}\right] \cdot \left[\mathrm{Yp}\right] - 4 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa} \cdot \left[\mathrm{MYpYpYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \tag{91}$$

$$\mathrm{function\_4\_motor\_r4}\left(\left[\mathrm{MYpYpYp}\right], \left[\mathrm{MYpYpYpYp}\right], \left[\mathrm{Yp}\right], \mathrm{alpha}, \mathrm{vol}\left(\mathrm{cell}\right), \mathrm{ka}, \mathrm{kappa}\right) = \frac{\mathrm{ka} \cdot \left(\left[\mathrm{MYpYpYp}\right] \cdot \left[\mathrm{Yp}\right] - 4 \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{alpha} \cdot \mathrm{kappa} \cdot \left[\mathrm{MYpYpYpYp}\right]\right)}{\mathrm{vol}\left(\mathrm{cell}\right)} \tag{92}$$

9.33 Reaction reaction_1

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

Name TA + asp <-> Tasp_A

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{TA} + \mathrm{asp} \rightleftharpoons \mathrm{Tasp\_A} \tag{93}$$

Reactants

Table 100: Properties of each reactant.

Id	Name	SBO
TA	TA	
asp	asp	

Product

Table 101: Properties of each product.

Id	Name	SBO
Tasp_A	Tasp_A	

Kinetic Law

Derived unit contains undeclared units

$$v_{33} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{TA}] \cdot [\mathrm{asp}] - \mathrm{k2} \cdot [\mathrm{Tasp\_A}]) \tag{94}$$

Table 102: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000000.0		☑
k2	k2		1.0		☑

9.34 Reaction reaction_2

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

Name TW+asp <-> Tasp_W

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{TW} + \mathrm{asp} \rightleftharpoons \mathrm{Tasp\_W} \tag{95}$$

Reactants

Table 103: Properties of each reactant.

Id	Name	SBO
TW	TW	
asp	asp	

Product

Table 104: Properties of each product.

Id	Name	SBO
Tasp_W	Tasp_W	

Kinetic Law

Derived unit contains undeclared units

$$v_{34} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{TW}] \cdot [\mathrm{asp}] - \mathrm{k2} \cdot [\mathrm{Tasp\_W}]) \tag{96}$$

Table 105: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000000.0		☑
k2	k2		1.0		☑

9.35 Reaction reaction_3

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

Name TWA+asp <-> Tasp_WA

SBO:0000177 non-covalent binding

Reaction equation

$$\mathrm{TWA} + \mathrm{asp} \rightleftharpoons \mathrm{Tasp\_WA} \tag{97}$$

Reactants

Table 106: Properties of each reactant.

Id	Name	SBO
TWA	TWA	
asp	asp	

Product

Table 107: Properties of each product.

Id	Name	SBO
Tasp_WA	Tasp_WA	

Kinetic Law

Derived unit contains undeclared units

$$v_{35} = \mathrm{vol}\,(\mathrm{cell}) \cdot (\mathrm{k1} \cdot [\mathrm{TWA}] \cdot [\mathrm{asp}] - \mathrm{k2} \cdot [\mathrm{Tasp\_WA}]) \tag{98}$$

Table 108: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1		1000000.0		☑
k2	k2		1.0		☑

10 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.

10.1 Species `asp`

Name asp

SBO:0000247 simple chemical

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

Involved in events event_1, event_2

This species takes part in four reactions (as a reactant in regulatory_r1, reaction_1, reaction_2, reaction_3). Not these but two events influence the species' quantity because this species is on the boundary of the reaction system.

10.2 Species ni

Name ni

SBO:0000247 simple chemical

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

This species takes part in one reaction (as a reactant in regulatory_r2), which does not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ni} = 0 \tag{99}$$

10.3 Species T

Name T

SBO:0000245 macromolecule

Initial concentration $3.12\cdot10^{-6}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in regulatory_r1, regulatory_r2, regulatory_r3, regulatory_r4, regulatory_r8).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{T} = -v_{11} - v_{12} - v_{13} - v_{14} - v_{18} \tag{100}$$

10.4 Species Tasp

Name Tasp

SBO:0000253 non-covalent complex

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

This species takes part in four reactions (as a reactant in regulatory_r9, regulatory_r10, regulatory_r13 and as a product in regulatory_r1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tasp} = v_{11} - v_{19} - v_{20} - v_{23} \tag{101}$$

10.5 Species Tni

Name Tni

SBO:0000253 non-covalent complex

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

This species takes part in four reactions (as a reactant in regulatory_r14, regulatory_r15, regulatory_r18 and as a product in regulatory_r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tni} = v_{12} - v_{24} - v_{25} - v_{28} \tag{102}$$

10.6 Species W

Name W

SBO:0000245 macromolecule

Initial concentration $2.89\cdot10^{-6}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in seven reactions (as a reactant in regulatory_r3, regulatory_r5, regulatory_r7, regulatory_r9, regulatory_r12, regulatory_r14, regulatory_r17).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{W} = -v_{13} - v_{15} - v_{17} - v_{19} - v_{22} - v_{24} - v_{27} \tag{103}$$

10.7 Species TW

Name TW

SBO:0000253 non-covalent complex

Initial concentration $5.91\cdot10^{-7}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in regulatory_r6, reaction_2 and as a product in regulatory_r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TW} = v_{13} - v_{16} - v_{34} \tag{104}$$

10.8 Species Tasp_W

Name Tasp_W

SBO:0000253 non-covalent complex

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

This species takes part in three reactions (as a reactant in regulatory_r11 and as a product in regulatory_r9, reaction_2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tasp\_W} = v_{19} + v_{34} - v_{21} \tag{105}$$

10.9 Species Tni_W

Name Tni_W

SBO:0000253 non-covalent complex

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

This species takes part in two reactions (as a reactant in regulatory_r16 and as a product in regulatory_r14).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tni\_W} = v_{24} - v_{26} \tag{106}$$

10.10 Species TA

Name TA

SBO:0000253 non-covalent complex

Initial concentration $4.44\cdot 10^{-7}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in regulatory_r7, reaction_1 and as a product in regulatory_r4).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TA} = v_{14} - v_{17} - v_{33} \tag{107}$$

10.11 Species Tasp_A

Name Tasp_A

SBO:0000253 non-covalent complex

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

This species takes part in three reactions (as a reactant in regulatory_r12 and as a product in regulatory_r10, reaction_1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tasp\_A} = v_{20} + v_{33} - v_{22} \tag{108}$$

10.12 Species Tni_A

Name Tni_A

SBO:0000253 non-covalent complex

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

This species takes part in two reactions (as a reactant in regulatory_r17 and as a product in regulatory_r15).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tni\_A} = v_{25} - v_{27} \tag{109}$$

10.13 Species WA

Name WA

SBO:0000253 non-covalent complex

Initial concentration $6.78 \cdot 10^{-7}$ mol $\cdot$ l^{-1}

This species takes part in four reactions (as a reactant in regulatory_r8, regulatory_r13, regulatory_r18 and as a product in regulatory_r5).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{WA} = v_{15} - v_{18} - v_{23} - v_{28} \tag{110}$$

10.14 Species TWA

Name TWA

SBO:0000253 non-covalent complex

Initial concentration $8.47 \cdot 10^{-7}$ mol $\cdot$ l^{-1}

This species takes part in five reactions (as a reactant in reaction_3 and as a product in regulatory_r6, regulatory_r7, regulatory_r8 and as a modifier in phosphorylation_r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TWA} = v_{16} + v_{17} + v_{18} - v_{35} \tag{111}$$

10.15 Species Tasp_WA

Name Tasp_WA

SBO:0000253 non-covalent complex

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

This species takes part in six reactions (as a reactant in phosphorylation_r4 and as a product in phosphorylation_r4, regulatory_r11, regulatory_r12, regulatory_r13, reaction_3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tasp\_WA} = v_4 + v_{21} + v_{22} + v_{23} + v_{35} - v_4 \tag{112}$$

10.16 Species Tni_WA

Name Tni_WA

SBO:0000253 non-covalent complex

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

This species takes part in four reactions (as a product in regulatory_r16, regulatory_r17, regulatory_r18 and as a modifier in phosphorylation_r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tni\_WA} = v_{26} + v_{27} + v_{28} \tag{113}$$

10.17 Species A

Name A

SBO:0000245 macromolecule

Initial concentration $3\cdot 10^{-6}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in twelve reactions (as a reactant in phosphorylation_r1, phosphorylation_r2, phosphorylation_r3, regulatory_r4, regulatory_r5, regulatory_r6, regulatory_r10, regulatory_r11, regulatory_r15, regulatory_r16 and as a product in phosphorylation_r5, phosphorylation_r9).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{A} = v_5 + v_9 - v_1 - v_2 - v_3 - v_{14} - v_{15} - v_{16} - v_{20} - v_{21} - v_{25} - v_{26} \tag{114}$$

10.18 Species Ap

Name Ap

SBO:0000245 macromolecule

Initial concentration $3.48\cdot 10^{-8}\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in phosphorylation_r5, phosphorylation_r9 and as a product in phosphorylation_r1, phosphorylation_r2, phosphorylation_r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ap} = v_1 + v_2 + v_3 - v_5 - v_9 \tag{115}$$

10.19 Species B

Name B

SBO:0000245 macromolecule

Initial concentration $1.93 \cdot 10^{-6}$ mol $\cdot$ l^{-1}

This species takes part in two reactions (as a reactant in phosphorylation_r9 and as a product in phosphorylation_r10).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{B} = v_{10} - v_9 \tag{116}$$

10.20 Species Bp

Name Bp

Initial concentration $6.87 \cdot 10^{-8}$ mol $\cdot$ l^{-1}

This species takes part in two reactions (as a reactant in phosphorylation_r10 and as a product in phosphorylation_r9).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Bp} = v_9 - v_{10} \tag{117}$$

10.21 Species Z

Name Z

SBO:0000245 macromolecule

Initial concentration $2 \cdot 10^{-5}$ mol $\cdot$ l^{-1}

This species takes part in two reactions (as a reactant in phosphorylation_r8 and as a product in phosphorylation_r8).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Z} = v_8 - v_8 \tag{118}$$

10.22 Species Y

Name Y

SBO:0000245 macromolecule

Initial concentration $9.9 \cdot 10^{-6}$ mol $\cdot$ l^{-1}

This species takes part in five reactions (as a reactant in phosphorylation_r5, phosphorylation_r6 and as a product in phosphorylation_r4, phosphorylation_r7, phosphorylation_r8).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Y} = v_4 + v_7 + v_8 - v_5 - v_6 \tag{119}$$

10.23 Species Yp

Name Yp

Initial concentration $7 \cdot 10^{-9}$ mol · l^{-1}

This species takes part in nine reactions (as a reactant in phosphorylation_r4, phosphorylation_r7, phosphorylation_r8, motor_r1, motor_r2, motor_r3, motor_r4 and as a product in phosphorylation_r5, phosphorylation_r6).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Yp} = v_5 + v_6 - v_4 - v_7 - v_8 - v_{29} - v_{30} - v_{31} - v_{32} \tag{120}$$

10.24 Species M

Name M

SBO:0000245 macromolecule

Initial concentration $6.24 \cdot 10^{-9}$ mol · l^{-1}

This species takes part in one reaction (as a reactant in motor_r1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{M} = -v_{29} \tag{121}$$

10.25 Species MYp

Name MYp

SBO:0000253 non-covalent complex

Initial concentration $7.77 \cdot 10^{-10}$ mol · l^{-1}

This species takes part in two reactions (as a reactant in motor_r2 and as a product in motor_r1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{MYp} = v_{29} - v_{30} \tag{122}$$

10.26 Species MYpYp

Name MYpYp

SBO:0000253 non-covalent complex

Initial concentration $2.99 \cdot 10^{-10}$ mol · l^{-1}

This species takes part in two reactions (as a reactant in motor_r3 and as a product in motor_r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{MYpYp} = v_{30} - v_{31} \tag{123}$$

10.27 Species MYpYpYp

Name MYpYpYp

SBO:0000253 non-covalent complex

Initial concentration $3.78 \cdot 10^{-10}$ mol $\cdot$ l^{-1}

This species takes part in two reactions (as a reactant in motor_r4 and as a product in motor_r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{MYpYpYp} = v_{31} - v_{32} \tag{124}$$

10.28 Species MYpYpYpYp

Name MYpYpYpYp

SBO:0000253 non-covalent complex

Initial concentration $2.31 \cdot 10^{-9}$ mol $\cdot$ l^{-1}

This species takes part in one reaction (as a product in motor_r4).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{MYpYpYpYp} = v_{32} \tag{125}$$

10.29 Species species_1

Name ATP

SBO:0000247 simple chemical

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{species\_1} = 0 \tag{126}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000177 non-covalent binding: Interaction between several biochemical entities that results in the formation of a non-covalent comple

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

SBO:0000245 macromolecule: Molecular entity mainly built-up by the repetition of pseudo-identical units. CHEBI:3383

SBO:0000247 simple chemical: Simple, non-repetitive chemical entity

SBO:0000253 non-covalent complex: Entity composed of several independant components that are not linked by covalent bonds

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:0000330 dephosphorylation: Removal of a phosphate group (-H2PO4) from a chemical entity.

SBO:0000402 transfer of a chemical group: Covalent reaction that results in the transfer of a chemical group from one molecule to another

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