SBML Model Report

Model name: “Xu2003 - Phosphoinositide turnover”

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 1 format. This model was created by the following two authors: Harish Dharuri[1] and Nick Juty[2] at October 23rd 2008 at 0:38 a. m. and last time modified at April eighth 2016 at 3:33 p. m. Table 1 gives 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	5
species types	0	species	13
events	0	constraints	0
reactions	8	function definitions	0
global parameters	24	unit definitions	16
rules	7	initial assignments	0

Model Notes

Xu2003 - Phosphoinositide turnover

The model reproduces the percentage change of PIP_PM, PIP2_PM and IP3_Cyt as depicted in Figure 1 of the paper. The model also contains the equations for the analysis of PH-GFP experiments, however the initial value of PH_GFP has been set to zero to more accurately reproduce

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Figure 1. The units of cytosolic species are given in molecules/umˆ3. In order to convert them to uM, divide the concentration by 602. For the analysis of PH_GFP experiments, one should plug in the values of PH_GFP, IP3_PHGFP and PIP2_PHGFP from Table AI in the appendix. The model was successfully tested on MathSBML.

This model has been generated by VCell

This model is described in the article:Kinetic analysis of receptor-activated phosphoinositide turnover.Xu C, Watras J, Loew LM.J. Cell Biol. 2003 May; 161(4): 779-791

Abstract:

We studied the bradykinin-induced changes in phosphoinositide composition of N1E-115 neuroblastoma cells using a combination of biochemistry, microscope imaging, and mathematical modeling. Phosphatidylinositol-4,5-bisphosphate (PIP2) decreased over the first 30 s, and then recovered over the following 2-3 min. However, the rate and amount of inositol-1,4,5-trisphosphate (InsP3) production were much greater than the rate or amount of PIP2 decline. A mathematical model of phosphoinositide turnover based on this data predicted that PIP2 synthesis is also stimulated by bradykinin, causing an early transient increase in its concentration. This was subsequently confirmed experimentally. Then, we used single-cell microscopy to further examine phosphoinositide turnover by following the translocation of the pleckstrin homology domain of PLCdelta1 fused to green fluorescent protein (PH-GFP). The observed time course could be simulated by incorporating binding of PIP2 and InsP3 to PH-GFP into the model that had been used to analyze the biochemistry. Furthermore, this analysis could help to resolve a controversy over whether the translocation of PH-GFP from membrane to cytosol is due to a decrease in PIP2 on the membrane or an increase in InsP3 in cytosol; by computationally clamping the concentrations of each of these compounds, the model shows how both contribute to the dynamics of probe translocation.

This model is hosted on BioModels Database and identified by: BIOMD0000000075 .

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models .

2 Unit Definitions

This is an overview of 18 unit definitions of which two are predefined by SBML and not mentioned in the model.

2.1 Unit `substance`

Definition item

2.2 Unit `volume`

Definition μm^3

2.3 Unit area

Definition μm^2

2.4 Unit molecules

Definition item

2.5 Unit umol_um3_litre_1

Definition 10^{-21} mol

2.6 Unit um2

Definition μm^2

2.7 Unit uM_um3_molecules_1

Definition 10^{-21} dimensionless $\cdot$ item^{-1} $\cdot$ mol

2.8 Unit molecules_um_2_s_1

Definition item $\cdot$ $\mu m^{-2} \cdot s^{-1}$

2.9 Unit pA_um_2

Definition dimensionless $\cdot$ A $\cdot$ m^{-2}

2.10 Unit s_1

Definition s^{-1}

2.11 Unit molecules_um_2

Definition item $\cdot$ μm^{-2}

2.12 Unit s

Definition s

2.13 Unit um2_molecules_1_s_1

Definition item^{-1} $\cdot$ $\mu m^2 \cdot s^{-1}$

2.14 Unit uM_s_1

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

2.15 Unit uM_1_s_1

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

2.16 Unit uM

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

2.17 Unit length

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

Definition m

2.18 Unit time

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

Definition s

3 Compartments

This model contains five compartments.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
Extracellular	Extracellular		3	0.277777777777778	μm^3	☑	
PM	PM		2	0.5555555555556	μm^2	☑	Extracellula
Cytosol	Cytosol		3	1	μm^3	☑	PM
NM	NM		2	0.111111111111111	μm^2	☑	Cytosol
Nucleus	Nucleus		3	0.111111111111111	μm^3	☑	NM

3.1 Compartment Extracellular

This is a three dimensional compartment with a constant size of 0.277777777777778 μm^3.

Name Extracellular

3.2 Compartment PM

This is a two dimensional compartment with a constant size of 0.5555555555556 μm^2, which is surrounded by `Extracellular` (Extracellular).

Name PM

3.3 Compartment `Cytosol`

This is a three dimensional compartment with a constant size of one μm^3, which is surrounded by `PM` (PM).

Name Cytosol

3.4 Compartment `NM`

This is a two dimensional compartment with a constant size of 0.111111111111111 μm^2, which is surrounded by `Cytosol` (Cytosol).

Name NM

3.5 Compartment `Nucleus`

This is a three dimensional compartment with a constant size of 0.111111111111111 μm^3, which is surrounded by `NM` (NM).

Name Nucleus

4 Species

This model contains 13 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 8 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
PIP2_PHGFP_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
PH_GFP_Cyt		Cytosol	$\text{item} \cdot \mu\text{m}^{-3}$	⊟	⊟
PI_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
stim_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	☑
IP3_PHGFP_Cyt		Cytosol	$\text{item} \cdot \mu\text{m}^{-3}$	⊟	⊟
PIP2_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
PIP_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
DAG_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
hv_Cytosol		Cytosol	$\text{item} \cdot \mu\text{m}^{-3}$	⊟	☑
IP3X_Cytosol		Cytosol	$\text{item} \cdot \mu\text{m}^{-3}$	⊟	☑
PLC_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
PLC_act_PM		PM	$\text{item} \cdot \mu\text{m}^{-2}$	⊟	⊟
IP3_Cyt		Cytosol	$\text{item} \cdot \mu\text{m}^{-3}$	⊟	⊟

5 Parameters

This model contains 24 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
KMOLE			0.002	10^{-21} dimensionless $\cdot$ item$^{-1} \cdot$ mol	☑
PIP_basal-_PIPSyn			2857.000	item $\cdot$ µm^{-2}	☑
kBasalSynPIP-_PIPSyn			0.006	s^{-1}	☑
kStimSynPIP-_PIPSyn			0.019	s^{-1}	☑
tauPIPsyn-_PIPSyn			0.050	s	☑
PIPsyndecay-_PIPSyn			1.000	s	☑
Ratebasal-_PIPsyn-_PIPSyn			0.000	s^{-1}	⊟
Ratestim-_PIPsyn-_PIPSyn			0.000	s^{-1}	⊟
tau0_PLCact			0.050	s	☑
stimdecay-_PLCact			1.000	s	☑
signal-_PLCact			0.000	dimensionless	⊟
kf_PIP2PH-_PIP2_PH			0.120	µmol$^{-1} \cdot$ s$^{-1} \cdot$ l	☑
KdPIP2PH-_PIP2_PH			2.000	µmol $\cdot$ l^{-1}	☑
kr_PIP2PH-_PIP2_PH			0.000	s^{-1}	⊟
kStimSynPIP2-_PIP2Syn			0.920	s^{-1}	☑
tauPIP2syn-_PIP2Syn			0.050	s	☑
PIP2syndecay-_PIP2Syn			1.000	s	☑
PIP2_basal-_PIP2Syn			4000.000	item $\cdot$ µm^{-2}	☑

Id	Name	SBO	Value	Unit	Constant
kBasalSynPIP2-_PIP2Syn			0.048	s^{-1}	☑
Rate-_PIP2Synbasal-_PIP2Syn			0.000	s^{-1}	⊟
Rate-_PIP2SynStim-_PIP2Syn			0.000	s^{-1}	⊟
kf_IP3PH-_IP3_PHGFP			10.000	$\mu mol^{-1} \cdot s^{-1} \cdot 1$	☑
KdIP3PH_IP3-_PHGFP			2.000	$\mu mol \cdot l^{-1}$	☑
kr_IP3PH-_IP3_PHGFP			0.000	s^{-1}	⊟

6 Rules

This is an overview of seven rules.

6.1 Rule Ratebasal_PIPsyn_PIPSyn

Rule Ratebasal_PIPsyn_PIPSyn is an assignment rule for parameter Ratebasal_PIPsyn-_PIPSyn:

Ratebasal_PIPsyn_PIPSyn (1)

$$= \begin{cases} 0.581 \cdot \text{kBasalSynPIP\_PIPSyn} \cdot \left(-1 + \exp\left((\text{PIP\_basal\_PIPSyn} + ([\text{PIP\_PM}])) \cdot \dfrac{1}{\text{PIP\_basal\_PIPSyn}} \right) \right) & \text{if [P} \\ 0 & \text{othe} \end{cases}$$

6.2 Rule Ratestim_PIPsyn_PIPSyn

Rule Ratestim_PIPsyn_PIPSyn is an assignment rule for parameter Ratestim_PIPsyn_PIPSyn:

Ratestim_PIPsyn_PIPSyn (2)

$$= \begin{cases} \text{kStimSynPIP\_PIPSyn} \cdot \exp\left(\left((\text{t} + (\text{tauPIPsyn\_PIPSyn})) \cdot \dfrac{1}{\text{PIPsyndecay\_PIPSyn}} \right) \right) & \text{if t} > \text{tauPIPsyn\_PIPSyn} \\ 0 & \text{otherwise} \end{cases}$$

6.3 Rule signal_PLCact

Rule signal_PLCact is an assignment rule for parameter signal_PLCact:

$$\text{signal\_PLCact} = \begin{cases} \exp\left(\left((\text{t} + (\text{tau0\_PLCact})) \cdot \dfrac{1}{\text{stimdecay\_PLCact}}\right)\right) & \text{if t} > \text{tau0\_PLCact} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

6.4 Rule kr_PIP2PH_PIP2_PH

Rule kr_PIP2PH_PIP2_PH is an assignment rule for parameter kr_PIP2PH_PIP2_PH:

$$\text{kr\_PIP2PH\_PIP2\_PH} = \text{kf\_PIP2PH\_PIP2\_PH} \cdot \text{KdPIP2PH\_PIP2\_PH} \tag{4}$$

Derived unit s^{-1}

6.5 Rule Rate_PIP2Synbasal_PIP2Syn

Rule Rate_PIP2Synbasal_PIP2Syn is an assignment rule for parameter Rate_PIP2Synbasal_PIP2Syn:

$$\text{Rate\_PIP2Synbasal\_PIP2Syn} \tag{5}$$
$$= \begin{cases} 0.581 \cdot \text{kBasalSynPIP2\_PIP2Syn} \cdot \left(-1 + \exp\left((\text{PIP2\_basal\_PIP2Syn} + ([\text{PIP2\_PM}])) \cdot \dfrac{1}{\text{PIP2\_basal\_PIP2Syn}}\right)\right. \\ 0 \end{cases}$$

6.6 Rule Rate_PIP2SynStim_PIP2Syn

Rule Rate_PIP2SynStim_PIP2Syn is an assignment rule for parameter Rate_PIP2SynStim_PIP2Syn:

$$\text{Rate\_PIP2SynStim\_PIP2Syn} \tag{6}$$
$$= \begin{cases} \text{kStimSynPIP2\_PIP2Syn} \cdot \exp\left(\left((\text{t} + (\text{tauPIP2syn\_PIP2Syn})) \cdot \dfrac{1}{\text{PIP2syndecay\_PIP2Syn}}\right)\right) & \text{if t} > \text{tauPIP2sy} \\ 0 & \text{otherwise} \end{cases}$$

6.7 Rule kr_IP3PH_IP3_PHGFP

Rule kr_IP3PH_IP3_PHGFP is an assignment rule for parameter kr_IP3PH_IP3_PHGFP:

$$\text{kr\_IP3PH\_IP3\_PHGFP} = \text{kf\_IP3PH\_IP3\_PHGFP} \cdot \text{KdIP3PH\_IP3\_PHGFP} \tag{7}$$

Derived unit s^{-1}

7 Reactions

This model contains eight 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	PIPSyn	PIPSyn	$\mathrm{PI\_PM} \rightleftharpoons \mathrm{PIP\_PM}$	
2	PIP2_hyd	PIP2_hyd	$\mathrm{PIP2\_PM} \overset{\mathrm{PLC\_act\_PM}}{\rightleftharpoons} \mathrm{DAG\_PM} + \mathrm{IP3\_Cyt}$	
3	PLCact	PLCact	$\mathrm{PLC\_PM} \overset{\mathrm{stim\_PM}}{\rightleftharpoons} \mathrm{PLC\_act\_PM}$	
4	PIP2_PH_hyd	PIP2_PH_hyd	$\mathrm{PIP2\_PHGFP\_PM} \overset{\mathrm{PLC\_act\_PM}}{\rightleftharpoons} \mathrm{PH\_GFP\_Cyt} + \mathrm{IP3\_Cyt} + \mathrm{DAG\_PM}$	
5	PIP2_PH	PIP2_PH	$\mathrm{PH\_GFP\_Cyt} + \mathrm{PIP2\_PM} \rightleftharpoons \mathrm{PIP2\_PHGFP\_PM}$	
6	IP3deg	IP3deg	$\mathrm{IP3\_Cyt} \rightleftharpoons \emptyset$	
7	PIP2Syn	PIP2Syn	$\mathrm{PIP\_PM} \rightleftharpoons \mathrm{PIP2\_PM}$	
8	IP3_PHGFP	IP3-PHGFP	$\mathrm{IP3\_Cyt} + \mathrm{PH\_GFP\_Cyt} \rightleftharpoons \mathrm{IP3\_PHGFP\_Cyt}$	

7.1 Reaction PIPSyn

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

Name PIPSyn

Reaction equation

$$\text{PI\_PM} \rightleftharpoons \text{PIP\_PM} \tag{8}$$

Reactant

Table 6: Properties of each reactant.

Id	Name	SBO
PI_PM		

Product

Table 7: Properties of each product.

Id	Name	SBO
PIP_PM		

Kinetic Law

Derived unit $\mathrm{s}^{-1} \cdot \mathrm{item}$

$$v_1 = (\text{Ratebasal\_PIPsyn\_PIPSyn} + \text{Ratestim\_PIPsyn\_PIPSyn}) \cdot [\text{PI\_PM}] \cdot \text{area}\,(\text{PM}) \tag{9}$$

Table 8: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.0	dimensionless · A · m^{-2}	☑

7.2 Reaction PIP2_hyd

This is a reversible reaction of one reactant forming two products influenced by one modifier.

Name PIP2_hyd

Reaction equation

$$\mathrm{PIP2\_PM} \xrightleftharpoons{\mathrm{PLC\_act\_PM}} \mathrm{DAG\_PM} + \mathrm{IP3\_Cyt} \tag{10}$$

Reactant

Table 9: Properties of each reactant.

Id	Name	SBO
PIP2_PM		

Modifier

Table 10: Properties of each modifier.

Id	Name	SBO
PLC_act_PM		

Products

Table 11: Properties of each product.

Id	Name	SBO
DAG_PM		
IP3_Cyt		

Kinetic Law

Derived unit $\mathrm{s}^{-1} \cdot \mathrm{item}$

$$v_2 = \mathrm{k\_PIP2hyd} \cdot [\mathrm{PIP2\_PM}] \cdot [\mathrm{PLC\_act\_PM}] \cdot \mathrm{area}\,(\mathrm{PM}) \tag{11}$$

Table 12: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.0	$\mathrm{dimensionless} \cdot \mathrm{A} \cdot \mathrm{m}^{-2}$	☑
k_PIP2hyd			2.4	$\mathrm{item}^{-1} \cdot \mu\mathrm{m}^2 \cdot \mathrm{s}^{-1}$	☑

7.3 Reaction PLCact

This is a reversible reaction of one reactant forming one product influenced by one modifier.

Name PLCact

Reaction equation

$$\mathrm{PLC\_PM} \overset{\mathrm{stim\_PM}}{\rightleftharpoons} \mathrm{PLC\_act\_PM} \tag{12}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
PLC_PM		

Modifier

Table 14: Properties of each modifier.

Id	Name	SBO
stim_PM		

Product

Table 15: Properties of each product.

Id	Name	SBO
PLC_act_PM		

Kinetic Law

Derived unit $\mathrm{s}^{-1} \cdot \mathrm{item}$

$$v_3 = (\mathrm{KfPLCact} \cdot [\mathrm{PLC\_PM}] \cdot [\mathrm{stim\_PM}] \cdot \mathrm{signal\_PLCact} + ((\mathrm{krPLCact} \cdot [\mathrm{PLC\_act\_PM}]))) \cdot \mathrm{area}(\mathrm{PM}) \tag{13}$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.000	dimensionless · A · m^{-2}	☑
KfPLCact			$5 \cdot 10^{-4}$	$item^{-1} \cdot \mu m^2 \cdot s^{-1}$	☑
krPLCact			0.100	s^{-1}	☑

7.4 Reaction PIP2_PH_hyd

This is a reversible reaction of one reactant forming three products influenced by one modifier.

Name PIP2_PH_hyd

Reaction equation

$$\text{PIP2\_PHGFP\_PM} \xrightleftharpoons{\text{PLC\_act\_PM}} \text{PH\_GFP\_Cyt} + \text{IP3\_Cyt} + \text{DAG\_PM} \tag{14}$$

Reactant

Table 17: Properties of each reactant.

Id	Name	SBO
PIP2_PHGFP_PM		

Modifier

Table 18: Properties of each modifier.

Id	Name	SBO
PLC_act_PM		

Products

Table 19: Properties of each product.

Id	Name	SBO
PH_GFP_Cyt		
IP3_Cyt		
DAG_PM		

Kinetic Law

Derived unit $\mathrm{s}^{-1} \cdot \mathrm{item}$

$$v_4 = \mathrm{k\_PIP2PHhyd} \cdot [\mathrm{PLC\_act\_PM}] \cdot [\mathrm{PIP2\_PHGFP\_PM}] \cdot \mathrm{area}\,(\mathrm{PM}) \tag{15}$$

Table 20: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.0	dimensionless · A · m^{-2}	☑
k_PIP2PHhyd			0.0	$\mathrm{item}^{-1} \cdot \mu\mathrm{m}^2 \cdot \mathrm{s}^{-1}$	☑

7.5 Reaction PIP2_PH

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

Name PIP2_PH

Reaction equation

$$\mathrm{PH\_GFP\_Cyt} + \mathrm{PIP2\_PM} \rightleftharpoons \mathrm{PIP2\_PHGFP\_PM} \tag{16}$$

Reactants

Table 21: Properties of each reactant.

Id	Name	SBO
PH_GFP_Cyt		
PIP2_PM		

Product

Table 22: Properties of each product.

Id	Name	SBO
PIP2_PHGFP_PM		

Kinetic Law

Derived unit contains undeclared units

$$v_5 = (\text{kf\_PIP2PH\_PIP2\_PH} \cdot 0.00166112956810631 \cdot [\text{PH\_GFP\_Cyt}] \cdot [\text{PIP2\_PM}] + ((\text{kr\_PIP2PH\_PIP2\_PH} \cdot [\text{PIP2\_PHGFP\_PM}]))) \cdot \text{area}(\text{PM}) \quad (17)$$

Table 23: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.0	dimensionless · A · m^{-2}	☑

7.6 Reaction IP3deg

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

Name IP3deg

Reaction equation

$$\text{IP3\_Cyt} \rightleftharpoons \emptyset \quad (18)$$

Reactant

Table 24: Properties of each reactant.

Id	Name	SBO
IP3_Cyt		

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \text{kIP3deg} \cdot (0.00166112956810631 \cdot [\text{IP3\_Cyt}] + (\text{IP3\_basal})) \cdot \text{vol}(\text{Cytosol}) \cdot 1 \cdot \frac{1}{\text{KMOLE}} \quad (19)$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kIP3deg			0.08	s^{-1}	☑
IP3_basal			0.16	$\mu mol \cdot l^{-1}$	☑

7.7 Reaction PIP2Syn

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

Name PIP2Syn

Reaction equation

$$\text{PIP\_PM} \rightleftharpoons \text{PIP2\_PM} \tag{20}$$

Reactant

Table 26: Properties of each reactant.

Id	Name	SBO
PIP_PM		

Product

Table 27: Properties of each product.

Id	Name	SBO
PIP2_PM		

Kinetic Law

Derived unit $\mathrm{s}^{-1} \cdot \mathrm{item}$

$$v_7 = (\text{Rate\_PIP2Synbasal\_PIP2Syn} + \text{Rate\_PIP2SynStim\_PIP2Syn}) \cdot [\text{PIP\_PM}] \cdot \text{area}(\text{PM}) \tag{21}$$

Table 28: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
I			0.0	dimensionless · A · m^{-2}	☑

7.8 Reaction IP3_PHGFP

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

Name IP3-PHGFP

Reaction equation

$$\text{IP3\_Cyt} + \text{PH\_GFP\_Cyt} \rightleftharpoons \text{IP3\_PHGFP\_Cyt} \tag{22}$$

Reactants

Table 29: Properties of each reactant.

Id	Name	SBO
IP3_Cyt		
PH_GFP_Cyt		

Product

Table 30: Properties of each product.

Id	Name	SBO
IP3_PHGFP_Cyt		

Kinetic Law

Derived unit contains undeclared units

$$\begin{aligned} v_8 = &(\text{kf\_IP3PH\_IP3\_PHGFP} \cdot 0.00166112956810631 \cdot [\text{IP3\_Cyt}] \cdot 0.00166112956810631 \\ &\cdot [\text{PH\_GFP\_Cyt}] + ((\text{kr\_IP3PH\_IP3\_PHGFP} \cdot 0.00166112956810631 \cdot [\text{IP3\_PHGFP\_Cyt}]))) \\ &\cdot \text{vol}(\text{Cytosol}) \cdot 1 \cdot \frac{1}{\text{KMOLE}} \end{aligned} \tag{23}$$

8 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.

8.1 Species PIP2_PHGFP_PM

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-2}$

This species takes part in two reactions (as a reactant in PIP2_PH_hyd and as a product in PIP2_PH).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PIP2\_PHGFP\_PM} = v_5 - v_4 \tag{24}$$

8.2 Species PH_GFP_Cyt

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-3}$

This species takes part in three reactions (as a reactant in PIP2_PH, IP3_PHGFP and as a product in PIP2_PH_hyd).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PH\_GFP\_Cyt} = v_4 - v_5 - v_8 \tag{25}$$

8.3 Species PI_PM

Initial concentration $142857\ \text{item} \cdot \mu\text{m}^{-2}$

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PI\_PM} = -v_1 \tag{26}$$

8.4 Species stim_PM

Initial concentration $1\ \text{item} \cdot \mu\text{m}^{-2}$

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{stim\_PM} = 0 \tag{27}$$

8.5 Species IP3_PHGFP_Cyt

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-3}$

This species takes part in one reaction (as a product in IP3_PHGFP).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{IP3\_PHGFP\_Cyt} = v_8 \tag{28}$$

8.6 Species PIP2_PM

Initial concentration $4000\ \text{item} \cdot \mu\text{m}^{-2}$

This species takes part in three reactions (as a reactant in PIP2_hyd, PIP2_PH and as a product in PIP2Syn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PIP2\_PM} = v_7 - v_2 - v_5 \tag{29}$$

8.7 Species PIP_PM

Initial concentration $2857\ \text{item} \cdot \mu\text{m}^{-2}$

This species takes part in two reactions (as a reactant in PIP2Syn and as a product in PIPSyn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PIP\_PM} = v_1 - v_7 \tag{30}$$

8.8 Species DAG_PM

Initial concentration $2000\ \text{item} \cdot \mu\text{m}^{-2}$

This species takes part in two reactions (as a product in PIP2_hyd, PIP2_PH_hyd).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{DAG\_PM} = v_2 + v_4 \tag{31}$$

8.9 Species hv_Cytosol

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-3}$

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{hv\_Cytosol} = 0 \tag{32}$$

8.10 Species IP3X_Cytosol

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-3}$

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{IP3X\_Cytosol} = 0 \tag{33}$$

8.11 Species PLC_PM

Initial concentration $100\ \text{item} \cdot \mu\text{m}^{-2}$

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PLC\_PM} = -v_3 \tag{34}$$

8.12 Species PLC_act_PM

Initial concentration $0\ \text{item} \cdot \mu\text{m}^{-2}$

This species takes part in three reactions (as a product in PLCact and as a modifier in PIP2_hyd, PIP2_PH_hyd).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PLC\_act\_PM} = v_3 \tag{35}$$

8.13 Species IP3_Cyt

Initial concentration $96.32\ \text{item} \cdot \mu\text{m}^{-3}$

This species takes part in four reactions (as a reactant in IP3deg, IP3_PHGFP and as a product in PIP2_hyd, PIP2_PH_hyd).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{IP3\_Cyt} = v_2 + v_4 - v_6 - v_8 \tag{36}$$

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