SBML Model Report

Model name: “Kummer2000 - Oscillations in Calcium Signalling”

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1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following three authors: Vijayalakshmi Chelliah[1], Pedro Mendes[2] and Ursula Kummer[3] at December eleventh 2014 at 3:35 p. m. and last time modified at December eleventh 2014 at 4:20 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	3
events	0	constraints	0
reactions	8	function definitions	4
global parameters	0	unit definitions	1
rules	0	initial assignments	0

Model Notes

Kummer2000 - Oscillations in CalciumSignalling

Simplified (3-variable) calcium oscillation model Kummer et al. (2000) Biophys. J. 79, 1188-1195 This model is defined in a small compartment with low concentrations. You can run it first

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with the LSODA ODE solver and then with the Gillespie Monte Carlo method (in Time Course widget). This illustrates that at low particle numbers, as here, the stochastic simulation and the ODE approach produce different results (the stochastic approach is more correct in these circumstances). This file also demonstrates the use of several different plots to visualize results, including a histogram.

This model is described in the article:Switching from simple to complex oscillations in calcium signaling.Kummer U, Olsen LF, Dixon CJ, Green AK, Bornberg-Bauer E, Baier G.Biophys. J. 2000 Sep; 79(3): 1188-1195

Abstract:

We present a new model for calcium oscillations based on experiments in hepatocytes. The model considers feedback inhibition on the initial agonist receptor complex by calcium and activated phospholipase C, as well as receptor type-dependent self-enhanced behavior of the activated G(alpha) subunit. It is able to show simple periodic oscillations and periodic bursting, and it is the first model to display chaotic bursting in response to agonist stimulations. Moreover, our model offers a possible explanation for the differences in dynamic behavior observed in response to different agonists in hepatocytes.

This model is hosted on BioModels Database and identified by: BIOMD0000000329.

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 five unit definitions of which four are predefined by SBML and not mentioned in the model.

2.1 Unit `substance`

Name substance

Definition nmol

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	0000290	3	10^{-13}	l	☑	

3.1 Compartment `compartment`

This is a three dimensional compartment with a constant size of 10^{-13} litre.

Name compartment

SBO:0000290 physical compartment

4 Species

This model contains three 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
a	G-alpha	compartment	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
b	activePLC	compartment	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
c	Calcium	compartment	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟

5 Function definitions

This is an overview of four function definitions.

5.1 Function definition Constant_flux__irreversible

Name Constant flux (irreversible)

Argument v

Mathematical Expression

$$\mathrm{v} \tag{1}$$

5.2 Function definition Henri_Michaelis_Menten__irreversible

Name Henri-Michaelis-Menten (irreversible)

Arguments substrate, Km, V

Mathematical Expression

$$\frac{\mathrm{V} \cdot \mathrm{substrate}}{\mathrm{Km} + \mathrm{substrate}} \tag{2}$$

5.3 Function definition Irr_Michaelis_Menten__enzyme__userdefined

Name Irr Michaelis-Menten (enzyme)[userdefined]

Arguments V, E, S, Km

Mathematical Expression

$$\frac{\mathrm{V} \cdot \mathrm{E} \cdot \mathrm{S}}{\mathrm{Km} + \mathrm{S}} \tag{3}$$

5.4 Function definition linear_activation

Name linear activation

Arguments constant, Activator

Mathematical Expression

$$\mathrm{constant} \cdot \mathrm{Activator} \tag{4}$$

6 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 4: Overview of all reactions

№	Id	Name	Reaction Equation	SBO
1	R1	R1	$\emptyset \longrightarrow a$	
2	R2	R2	$\emptyset \xrightarrow{a} a$	
3	R3	R3	$a \xrightarrow{b} \emptyset$	
4	R4	R4	$a \xrightarrow{c} \emptyset$	
5	R5	R5	$\emptyset \xrightarrow{a} b$	
6	R6	R6	$b \longrightarrow \emptyset$	
7	R7	R7	$\emptyset \xrightarrow{a} c$	
8	R8	R8	$c \longrightarrow \emptyset$	

6.1 Reaction R1

This is an irreversible reaction of no reactant forming one product.

Name R1

Reaction equation

$$\emptyset \longrightarrow \mathrm{a} \tag{5}$$

Product

Table 5: Properties of each product.

Id	Name	SBO
a	G-alpha	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Constant\_flux\_\_irreversible}\left(\mathrm{v}\right) \tag{6}$$

$$\mathrm{Constant\_flux\_\_irreversible}\left(\mathrm{v}\right) = \mathrm{v} \tag{7}$$

$$\mathrm{Constant\_flux\_\_irreversible}\left(\mathrm{v}\right) = \mathrm{v} \tag{8}$$

Table 6: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
v	v		0.212		☑

6.2 Reaction R2

This is an irreversible reaction of no reactant forming one product influenced by one modifier.

Name R2

Reaction equation

$$\emptyset \xrightarrow{\mathrm{a}} \mathrm{a} \tag{9}$$

Modifier

Table 7: Properties of each modifier.

Id	Name	SBO
a	G-alpha	

Product

Table 8: Properties of each product.

Id	Name	SBO
a	G-alpha	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{linear\_activation}\left(\mathrm{constant}, [\mathrm{a}]\right) \tag{10}$$

$$\mathrm{linear\_activation}\left(\mathrm{constant}, \mathrm{Activator}\right) = \mathrm{constant} \cdot \mathrm{Activator} \tag{11}$$

$$\mathrm{linear\_activation}\left(\mathrm{constant}, \mathrm{Activator}\right) = \mathrm{constant} \cdot \mathrm{Activator} \tag{12}$$

Table 9: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
constant	constant		2.9		☑

6.3 Reaction R3

This is an irreversible reaction of one reactant forming no product influenced by one modifier.

Name R3

Reaction equation

$$\mathrm{a} \xrightarrow{\mathrm{b}} \emptyset \tag{13}$$

Reactant

Table 10: Properties of each reactant.

Id	Name	SBO
a	G-alpha	

Modifier

Table 11: Properties of each modifier.

Id	Name	SBO
b	activePLC	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V},[\mathrm{b}],[\mathrm{a}],\mathrm{Km}) \quad (14)$$

$$\mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V},\mathrm{E},\mathrm{S},\mathrm{Km}) = \frac{\mathrm{V}\cdot\mathrm{E}\cdot\mathrm{S}}{\mathrm{Km}+\mathrm{S}} \quad (15)$$

$$\mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V},\mathrm{E},\mathrm{S},\mathrm{Km}) = \frac{\mathrm{V}\cdot\mathrm{E}\cdot\mathrm{S}}{\mathrm{Km}+\mathrm{S}} \quad (16)$$

Table 12: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
V	V		1.52		☑
Km	Km		0.19		☑

6.4 Reaction R4

This is an irreversible reaction of one reactant forming no product influenced by one modifier.

Name R4

Reaction equation

$$\mathrm{a} \xrightarrow{\mathrm{c}} \emptyset \quad (17)$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
a	G-alpha	

Modifier

Table 14: Properties of each modifier.

Id	Name	SBO
c	Calcium	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V}, [\mathrm{c}], [\mathrm{a}], \mathrm{Km}) \quad (18)$$

$$\mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V}, \mathrm{E}, \mathrm{S}, \mathrm{Km}) = \frac{\mathrm{V} \cdot \mathrm{E} \cdot \mathrm{S}}{\mathrm{Km} + \mathrm{S}} \quad (19)$$

$$\mathrm{Irr\_Michaelis\_Menten\_\_enzyme\_\_userdefined}\,(\mathrm{V}, \mathrm{E}, \mathrm{S}, \mathrm{Km}) = \frac{\mathrm{V} \cdot \mathrm{E} \cdot \mathrm{S}}{\mathrm{Km} + \mathrm{S}} \quad (20)$$

Table 15: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
V	V		4.88		☑
Km	Km		1.18		☑

6.5 Reaction R5

This is an irreversible reaction of no reactant forming one product influenced by one modifier.

Name R5

Reaction equation

$$\emptyset \xrightarrow{\mathrm{a}} \mathrm{b} \quad (21)$$

Modifier

Table 16: Properties of each modifier.

Id	Name	SBO
a	G-alpha	

Product

Table 17: Properties of each product.

Id	Name	SBO
b	activePLC	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{linear\_activation}\,(\mathrm{constant}, [\mathrm{a}]) \tag{22}$$

$$\mathrm{linear\_activation}\,(\mathrm{constant}, \mathrm{Activator}) = \mathrm{constant} \cdot \mathrm{Activator} \tag{23}$$

$$\mathrm{linear\_activation}\,(\mathrm{constant}, \mathrm{Activator}) = \mathrm{constant} \cdot \mathrm{Activator} \tag{24}$$

Table 18: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
constant	constant		1.24		☑

6.6 Reaction R6

This is an irreversible reaction of one reactant forming no product.

Name R6

Reaction equation

$$\mathrm{b} \longrightarrow \emptyset \tag{25}$$

Reactant

Table 19: Properties of each reactant.

Id	Name	SBO
b	activePLC	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,([\mathrm{b}], \mathrm{Km}, \mathrm{V}) \tag{26}$$

$$\mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,(\mathrm{substrate}, \mathrm{Km}, \mathrm{V}) = \frac{\mathrm{V} \cdot \mathrm{substrate}}{\mathrm{Km} + \mathrm{substrate}} \tag{27}$$

$$\mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,(\mathrm{substrate}, \mathrm{Km}, \mathrm{V}) = \frac{\mathrm{V} \cdot \mathrm{substrate}}{\mathrm{Km} + \mathrm{substrate}} \tag{28}$$

Table 20: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Km	Km		29.09		☑
V	V		32.24		☑

6.7 Reaction R7

This is an irreversible reaction of no reactant forming one product influenced by one modifier.

Name R7

Reaction equation

$$\emptyset \xrightarrow{\mathrm{a}} \mathrm{c} \tag{29}$$

Modifier

Table 21: Properties of each modifier.

Id	Name	SBO
a	G-alpha	

Product

Table 22: Properties of each product.

Id	Name	SBO
c	Calcium	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \text{vol}\left(\text{compartment}\right) \cdot \text{linear\_activation}\left(\text{constant}, [\text{a}]\right) \tag{30}$$

$$\text{linear\_activation}\left(\text{constant}, \text{Activator}\right) = \text{constant} \cdot \text{Activator} \tag{31}$$

$$\text{linear\_activation}\left(\text{constant}, \text{Activator}\right) = \text{constant} \cdot \text{Activator} \tag{32}$$

Table 23: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
constant	constant		13.58		☑

6.8 Reaction R8

This is an irreversible reaction of one reactant forming no product.

Name R8

Reaction equation

$$\text{c} \longrightarrow \emptyset \tag{33}$$

Reactant

Table 24: Properties of each reactant.

Id	Name	SBO
c	Calcium	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,([\mathrm{c}], \mathrm{Km}, \mathrm{V}) \tag{34}$$

$$\mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,(\mathrm{substrate}, \mathrm{Km}, \mathrm{V}) = \frac{\mathrm{V} \cdot \mathrm{substrate}}{\mathrm{Km} + \mathrm{substrate}} \tag{35}$$

$$\mathrm{Henri\_Michaelis\_Menten\_\_irreversible}\,(\mathrm{substrate}, \mathrm{Km}, \mathrm{V}) = \frac{\mathrm{V} \cdot \mathrm{substrate}}{\mathrm{Km} + \mathrm{substrate}} \tag{36}$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Km	Km		0.16		☑
V	V		153.00		☑

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.

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.

7.1 Species a

Name G-alpha

SBO:0000252 polypeptide chain

Initial concentration $0.01\ \mathrm{nmol} \cdot \mathrm{l}^{-1}$

This species takes part in seven reactions (as a reactant in R3, R4 and as a product in R1, R2 and as a modifier in R2, R5, R7).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{a} = v_1 + v_2 - v_3 - v_4 \tag{37}$$

7.2 Species b

Name activePLC

SBO:0000014 enzyme

Initial concentration $0.01\ \mathrm{nmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in R6 and as a product in R5 and as a modifier in R3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{b} = v_5 - v_6 \tag{38}$$

7.3 Species c

Name Calcium

SBO:0000247 simple chemical

Initial concentration $0.01\ \mathrm{nmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in R8 and as a product in R7 and as a modifier in R4).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{c} = v_7 - v_8 \tag{39}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000014 enzyme: A protein that catalyzes a chemical reaction. The word comes from en “a” or“i”) and simo “leave” or“yeas”)

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

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

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

SBML2LaTeX was developed by Andreas Dräger[a], Hannes Planatscher[a], Dieudonné M Wouamba[a], Adrian Schröder[a], Michael Hucka[b], Lukas Endler[c], Martin Golebiewski[d] and Andreas Zell[a]. Please see http://www.ra.cs.uni-tuebingen.de/software/SBML2LaTeX for more information.

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