SBML Model Report

Model name: "Wilhelm2009_BistableReaction"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by Thomas Wilhelm[1] at June 30th 2009 at 5:26 p. m. and last time modified at February 25th 2015 at 12:43 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	4
events	0	constraints	0
reactions	4	function definitions	0
global parameters	0	unit definitions	0
rules	0	initial assignments	0

Model Notes

This a model from the article:
The smallest chemical reaction system with bistability
Thomas Wilhelm BMC Systems Biology2009;Sep 8;3:90. 19737387,
Abstract:
Background
Bistability underlies basic biological phenomena, such as cell division, differentiation, cancer

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onset, and apoptosis. So far biologists identified two necessary conditions for bistability: positive feedback and ultrasensitivity.
Results
Biological systems are based upon elementary mono- and bimolecular chemical reactions. In order to definitely clarify all necessary conditions for bistability we here present the corresponding minimal system. According to our definition, it contains the minimal number of (i) reactants, (ii) reactions, and (iii) terms in the corresponding ordinary differential equations (decreasing importance from i-iii). The minimal bistable system contains two reactants and four irreversible reactions (three bimolecular, one monomolecular).We discuss the roles of the reactions with respect to the necessary conditions for bistability: two reactions comprise the positive feedback loop, a third reaction filters out small stimuli thus enabling a stable 'off' state, and the fourth reaction prevents explosions. We argue that prevention of explosion is a third general necessary condition for bistability, which is so far lacking discussion in the literature.Moreover, in addition to proving that in two-component systems three steady states are necessary for bistability (five for tristability, etc.), we also present a simple general method to design such systems: one just needs one production and three different degradation mechanisms (one production, five degradations for tristability, etc.). This helps modelling multistable systems and it is important for corresponding synthetic biology projects.
Conclusion
The presented minimal bistable system finally clarifies the often discussed question for the necessary conditions for bistability. The three necessary conditions are: positive feedback, a mechanism to filter out small stimuli and a mechanism to prevent explosions. This is important for modelling bistability with simple systems and for synthetically designing new bistable systems. Our simple model system is also well suited for corresponding teaching purposes.

This is a Systems Biology Markup Language (SBML) file, generated by MathSBML 2.9.0 [8-Oct-2008] 30-Jun-2009 17:26:58(GMT+00:59). SBML is a form of XML, and most XML files will not display properly in an internet browser. To view the contents of an XML file use the „Page Source„ or equivalent button on you browser.

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
`batch`	batch	0000290	3	1	litre	☑	

3.1 Compartment `batch`

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

Name batch

SBO:0000290 physical compartment

4 Species

This model contains four species. The boundary condition of two of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 6 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
`S`	S	`batch`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑
`P`	P	`batch`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑
`X`	X	`batch`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`Y`	Y	`batch`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟

5 Reactions

This model contains four 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	$S+Y \longrightarrow 2X$	0000182
2	`r2`	r2	$2X \longrightarrow X+Y$	0000182
3	`r3`	r3	$X+Y \longrightarrow P+Y$	0000182
4	`r4`	r4	$X \longrightarrow P$	0000182

5.1 Reaction r1

This is an irreversible reaction of two reactants forming one product.

Name r1

SBO:0000182 conversion

Reaction equation

$$S + Y \longrightarrow 2X \tag{1}$$

Reactants

Table 5: Properties of each reactant.

Id	Name	SBO
S	S	
Y	Y	

Product

Table 6: Properties of each product.

Id	Name	SBO
X	X	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \mathrm{k1} \cdot [\mathrm{S}] \cdot [\mathrm{Y}] \tag{2}$$

Table 7: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1		0000036	8.0		☑

5.2 Reaction r2

This is an irreversible reaction of one reactant forming two products.

Name r2

SBO:0000182 conversion

Reaction equation

$$2\,X \longrightarrow X + Y \tag{3}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
X	X	

Products

Table 9: Properties of each product.

Id	Name	SBO
X	X	
Y	Y	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \mathrm{k2} \cdot [\mathrm{X}]^2 \tag{4}$$

Table 10: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k2		0000036	1.0		☑

5.3 Reaction r3

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

Name r3

SBO:0000182 conversion

Reaction equation

$$X + Y \longrightarrow P + Y \tag{5}$$

Reactants

Table 11: Properties of each reactant.

Id	Name	SBO
X	X	
Y	Y	

Products

Table 12: Properties of each product.

Id	Name	SBO
P	P	
Y	Y	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \mathrm{k3} \cdot [\mathrm{X}] \cdot [\mathrm{Y}] \tag{6}$$

Table 13: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k3		0000036	1.0		☑

5.4 Reaction r4

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

Name r4

SBO:0000182 conversion

Reaction equation

$$X \longrightarrow P \tag{7}$$

Reactant

Table 14: Properties of each reactant.

Id	Name	SBO
X	X	

Product

Table 15: Properties of each product.

Id	Name	SBO
P	P	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \mathrm{k4} \cdot [\mathrm{X}] \tag{8}$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k4		0000154	1.5		☑

6 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.

6.1 Species S

Name S

SBO:0000285 material entity of unspecified nature

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

This species takes part in one reaction (as a reactant in r1), which does not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{S} = 0 \tag{9}$$

6.2 Species P

Name P

SBO:0000285 material entity of unspecified nature

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

This species takes part in two reactions (as a product in r3, r4), which do not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{P} = 0 \tag{10}$$

6.3 Species X

Name X

SBO:0000285 material entity of unspecified nature

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

This species takes part in five reactions (as a reactant in r2, r3, r4 and as a product in r1, r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{X} = 2\, v_1 + v_2 - 2\, v_2 - v_3 - v_4 \tag{11}$$

6.4 Species Y

Name Y

SBO:0000285 material entity of unspecified nature

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

This species takes part in four reactions (as a reactant in r1, r3 and as a product in r2, r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Y} = v_2 + v_3 - v_1 - v_3 \tag{12}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000036 forward bimolecular rate constant, continuous case: Numerical parameter that quantifies the forward velocity of a chemical reaction involving two reactants. This parameter encompasses all the contributions to the velocity except the quantity of the reactants. It is to be used in a reaction modelled using a continuous framework

SBO:0000154 forward rate constant, continuous case: Numerical parameter that quantifies the forward velocity of a chemical reaction. This parameter encompasses all the contributions to the velocity except the quantity of the reactants. It is to be used in a reaction modelled using a continuous framework

SBO:0000182 conversion: Biochemical reaction that results in the modification of some covalent bonds

SBO:0000285 material entity of unspecified nature: Material entity whose nature is unknown or irrelevant

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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