SBML Model Report

Model name: "Schulz2009_Th1_differentiation"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 3 format. This model was created by the following two authors: Vijayalakshmi Chelliah[1] and Edda Schulz[2] at June tenth 2009 at 2:32 p. m. and last time modified at October tenth 2014 at 10:51 a. 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	7
events	0	constraints	0
reactions	14	function definitions	6
global parameters	0	unit definitions	1
rules	1	initial assignments	0

Model Notes

This a model from the article:
Sequential polarization and imprinting of type 1 T helper lymphocytes by interferon-gamma and interleukin-12.
Schulz EG, Mariani L, Radbruch A, Hfer T. Immunity.2009;30(5):666-8. 19409816,

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Abstract:
Differentiation of naive T lymphocytes into type I T helper (Th1) cells requires interferon-gamma and interleukin-12. It is puzzling that interferon-gamma induces the Th1 transcription factor T-bet, whereas interleukin-12 mediates Th1 cell lineage differentiation. We use mathematical modeling to analyze the expression kinetics of T-bet, interferon-gamma, and the IL-12 receptor beta2 chain (IL-12Rbeta2) during Th1 cell differentiation, in the presence or absence of interleukin-12 or interferon-gamma signaling. We show that interferon-gamma induced initial T-bet expression, whereas IL-12Rbeta2 was repressed by T cell receptor (TCR) signaling. The termination of TCR signaling permitted upregulation of IL-12Rbeta2 by T-bet and interleukin-12 signaling that maintained T-bet expression. This late expression of T-bet, accompanied by the upregulation of the transcription factors Runx3 and Hlx, was required to imprint the Th cell for interferon-gamma re-expression. Thus initial polarization and subsequent imprinting of Th1 cells are mediated by interlinked, sequentially acting positive feedback loops of TCR-interferon-gamma-Stat1-T-bet and interleukin-12-Stat4-T-bet signaling.

The original model was created by:
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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 `time`

Definition 3600 s

2.2 Unit `substance`

Notes Mole is the predefined SBML unit for `substance`.

Definition mol

2.3 Unit volume

Notes Litre is the predefined SBML unit for volume.

Definition l

2.4 Unit area

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

Definition m^2

2.5 Unit length

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

Definition m

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	1	litre	☑	

3.1 Compartment compartment

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

Name compartment

SBO:0000290 physical compartment

4 Species

This model contains seven species. The boundary condition of one of these species is set to `true` so that this 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
`Tbet_mRNA`	Tbet_mRNA	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
`Ifn_mRNA`	Ifn_mRNA	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
`Ag`	Ag	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
`Ifn_Prot`	Ifn_Prot	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
`Rec_Prot`	Rec_Prot	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
`Tbet_Prot`	Tbet_Prot	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
`Rec_mRNA`	Rec_mRNA	`compartment`	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐

5 Function definitions

This is an overview of six function definitions.

5.1 Function definition `function_1`

Name Rate Law for Tbet IFNg dependent transcription

Arguments [Ag], K1, [Ifn_Prot], K2, a2

Mathematical Expression

$$\mathrm{a2} \cdot \frac{[\mathrm{Ag}]}{\mathrm{K1} + [\mathrm{Ag}]} \cdot \frac{[\mathrm{Ifn\_Prot}]}{\mathrm{K2} + [\mathrm{Ifn\_Prot}]} \tag{1}$$

5.2 Function definition `function_3`

Name Rate Law for Tbet basal expression

Argument a1

Mathematical Expression

$$\mathrm{a1} \tag{2}$$

5.3 Function definition `function_2`

Name Rate Law for Rec dependent transcription of TBet

Arguments a3, [Rec_Prot]

Mathematical Expression

$$\mathrm{a3} \cdot [\mathrm{Rec\_Prot}] \tag{3}$$

5.4 Function definition `function_4`

Name Translation rate law

Arguments b, mRNA

Mathematical Expression

$$\mathrm{b} \cdot \mathrm{mRNA} \tag{4}$$

5.5 Function definition `function_5`

Name Rate Law for Rec Transcription

Arguments a4, [Tbet_Prot], K4, [Ag]

Mathematical Expression

$$\mathrm{a4} \cdot [\mathrm{Tbet\_Prot}] \cdot \frac{\mathrm{K4}}{\mathrm{K4} + [\mathrm{Ag}]} \tag{5}$$

5.6 Function definition `function_6`

Name Rate Law for IFN transcription

Arguments a5, [Tbet_Prot], K5, [Rec_Prot], K6, [Ag], K7

Mathematical Expression

$$\mathrm{a5} \cdot \frac{[\mathrm{Tbet\_Prot}]}{\mathrm{K5} + [\mathrm{Tbet\_Prot}]} \cdot \frac{[\mathrm{Rec\_Prot}]}{\mathrm{K6} + [\mathrm{Rec\_Prot}]} \cdot \frac{[\mathrm{Ag}]}{\mathrm{K7} + [\mathrm{Ag}]} \tag{6}$$

6 Rule

This is an overview of one rule.

6.1 Rule `Ag`

Rule `Ag` is an assignment rule for species `Ag`:

$$\mathrm{Ag} = 1 - \frac{\mathrm{time}^{10}}{34^{10} + \mathrm{time}^{10}} \tag{7}$$

7 Reactions

This model contains 14 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	vtrnldeg	Tbet IFN dependend transcription	$\emptyset \xrightarrow{\text{Ag, Ifn\_Prot}} \text{Tbet\_mRNA}$	0000183
2	reaction_1	Tbet Receptor dependent transcription	$\emptyset \xrightarrow{\text{Rec\_Prot}} \text{Tbet\_mRNA}$	0000183
3	reaction_2	Tbet basal expression	$\emptyset \longrightarrow \text{Tbet\_mRNA}$	0000183
4	reaction_3	Tbet mRNA degradation	$\text{Tbet\_mRNA} \longrightarrow \emptyset$	0000179
5	reaction_4	Tbet protein degradation	$\text{Tbet\_Prot} \longrightarrow \emptyset$	0000179
6	reaction_5	Rec_mRNA degradation	$\text{Rec\_mRNA} \longrightarrow \emptyset$	0000179
7	reaction_6	Rec_Prot degradation	$\text{Rec\_Prot} \longrightarrow \emptyset$	0000179
8	reaction_7	IFN_mRNA degradation	$\text{Ifn\_mRNA} \longrightarrow \emptyset$	0000179
9	reaction_8	IFN_Prot degradation	$\text{Ifn\_Prot} \longrightarrow \emptyset$	0000179
10	reaction_9	Tbet Translation	$\emptyset \xrightarrow{\text{Tbet\_mRNA}} \text{Tbet\_Prot}$	0000184
11	reaction_10	IFN tranlation	$\emptyset \xrightarrow{\text{Ifn\_mRNA}} \text{Ifn\_Prot}$	0000184
12	reaction_11	Rec translation	$\emptyset \xrightarrow{\text{Rec\_mRNA}} \text{Rec\_Prot}$	0000184
13	reaction_12	Rec Transcription	$\emptyset \xrightarrow{\text{Tbet\_Prot, Ag}} \text{Rec\_mRNA}$	0000183
14	reaction_13	IFN transcription	$\emptyset \xrightarrow{\text{Tbet\_Prot, Rec\_Prot, Ag}} \text{Ifn\_mRNA}$	0000183

7.1 Reaction `vtrnldeg`

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

Name Tbet IFN dependend transcription

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightarrow{\text{Ag, Ifn\_Prot}} \text{Tbet\_mRNA} \tag{8}$$

Modifiers

Table 5: Properties of each modifier.

Id	Name	SBO
`Ag`	Ag	
`Ifn_Prot`	Ifn_Prot	

Product

Table 6: Properties of each product.

Id	Name	SBO
`Tbet_mRNA`	Tbet_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \text{vol}\left(\text{compartment}\right) \cdot \text{function\_1}\left(\left[\text{Ag}\right], \text{K1}, \left[\text{Ifn\_Prot}\right], \text{K2}, \text{a2}\right) \tag{9}$$

$$\text{function\_1}\left(\left[\text{Ag}\right], \text{K1}, \left[\text{Ifn\_Prot}\right], \text{K2}, \text{a2}\right) = \text{a2} \cdot \frac{\left[\text{Ag}\right]}{\text{K1} + \left[\text{Ag}\right]} \cdot \frac{\left[\text{Ifn\_Prot}\right]}{\text{K2} + \left[\text{Ifn\_Prot}\right]} \tag{10}$$

$$\text{function\_1}\left(\left[\text{Ag}\right], \text{K1}, \left[\text{Ifn\_Prot}\right], \text{K2}, \text{a2}\right) = \text{a2} \cdot \frac{\left[\text{Ag}\right]}{\text{K1} + \left[\text{Ag}\right]} \cdot \frac{\left[\text{Ifn\_Prot}\right]}{\text{K2} + \left[\text{Ifn\_Prot}\right]} \tag{11}$$

Table 7: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
K1		0000363	0.46		☑
K2		0000363	2.10		☑
a2		0000048	0.42		☑

7.2 Reaction reaction_1

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

Name Tbet Receptor dependent transcription

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightarrow{\text{Rec\_Prot}} \text{Tbet\_mRNA} \tag{12}$$

Modifier

Table 8: Properties of each modifier.

Id	Name	SBO
Rec_Prot	Rec_Prot	

Product

Table 9: Properties of each product.

Id	Name	SBO
Tbet_mRNA	Tbet_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \text{vol}\,(\text{compartment}) \cdot \text{function\_2}\,(\text{a3}, [\text{Rec\_Prot}]) \tag{13}$$

$$\text{function\_2}\,(\text{a3}, [\text{Rec\_Prot}]) = \text{a3} \cdot [\text{Rec\_Prot}] \tag{14}$$

$$\text{function\_2}\,(\text{a3}, [\text{Rec\_Prot}]) = \text{a3} \cdot [\text{Rec\_Prot}] \tag{15}$$

Table 10: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a3			$5.1 \cdot 10^{-4}$		☑

7.3 Reaction reaction_2

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

Name Tbet basal expression

SBO:0000183 transcription

Reaction equation

$$\emptyset \longrightarrow \text{Tbet\_mRNA} \tag{16}$$

Product

Table 11: Properties of each product.

Id	Name	SBO
Tbet_mRNA	Tbet_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \text{vol}\left(\text{compartment}\right) \cdot \text{function\_3}\left(\text{a1}\right) \tag{17}$$

$$\text{function\_3}\left(\text{a1}\right) = \text{a1} \tag{18}$$

$$\text{function\_3}\left(\text{a1}\right) = \text{a1} \tag{19}$$

Table 12: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a1			0.044		☑

7.4 Reaction reaction_3

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

Name Tbet mRNA degradation

SBO:0000179 degradation

Reaction equation

$$\text{Tbet\_mRNA} \longrightarrow \emptyset \tag{20}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
Tbet_mRNA	Tbet_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \text{vol}\,(\text{compartment}) \cdot \text{gamma\_Tbet} \cdot [\text{Tbet\_mRNA}] \tag{21}$$

Table 14: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gamma_Tbet			1.0		☑

7.5 Reaction reaction_4

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

Name Tbet protein degradation

SBO:0000179 degradation

Reaction equation

$$\text{Tbet\_Prot} \longrightarrow \emptyset \tag{22}$$

Reactant

Table 15: Properties of each reactant.

Id	Name	SBO
Tbet_Prot	Tbet_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{delta\_Tbet} \cdot [\mathrm{Tbet\_Prot}] \tag{23}$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
delta_Tbet			0.1		☑

7.6 Reaction reaction_5

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

Name Rec_mRNA degradation

SBO:0000179 degradation

Reaction equation

$$\mathrm{Rec\_mRNA} \longrightarrow \emptyset \tag{24}$$

Reactant

Table 17: Properties of each reactant.

Id	Name	SBO
Rec_mRNA	Rec_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{gamma\_Rec} \cdot [\mathrm{Rec\_mRNA}] \tag{25}$$

Table 18: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gamma_Rec			1.0		☑

7.7 Reaction reaction_6

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

Name Rec_Prot degradation

SBO:0000179 degradation

Reaction equation

$$\text{Rec\_Prot} \longrightarrow \emptyset \tag{26}$$

Reactant

Table 19: Properties of each reactant.

Id	Name	SBO
Rec_Prot	Rec_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \text{vol}\,(\text{compartment}) \cdot \text{delta\_Rec} \cdot [\text{Rec\_Prot}] \tag{27}$$

Table 20: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
delta_Rec			0.1		☑

7.8 Reaction reaction_7

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

Name IFN_mRNA degradation

SBO:0000179 degradation

Reaction equation

$$\text{Ifn\_mRNA} \longrightarrow \emptyset \tag{28}$$

Reactant

Table 21: Properties of each reactant.

Id	Name	SBO
Ifn_mRNA	Ifn_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \text{vol}\,(\text{compartment}) \cdot \text{gamma\_IFN} \cdot [\text{Ifn\_mRNA}] \tag{29}$$

Table 22: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gamma_IFN			1.0		☑

7.9 Reaction reaction_8

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

Name IFN_Prot degradation

SBO:0000179 degradation

Reaction equation

$$\text{Ifn\_Prot} \longrightarrow \emptyset \tag{30}$$

Reactant

Table 23: Properties of each reactant.

Id	Name	SBO
Ifn_Prot	Ifn_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{delta\_IFN} \cdot [\mathrm{Ifn\_Prot}] \tag{31}$$

Table 24: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
`delta_IFN`			1.0		☑

7.10 Reaction `reaction_9`

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

Name Tbet Translation

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightarrow{\mathrm{Tbet\_mRNA}} \mathrm{Tbet\_Prot} \tag{32}$$

Modifier

Table 25: Properties of each modifier.

Id	Name	SBO
`Tbet_mRNA`	Tbet_mRNA	

Product

Table 26: Properties of each product.

Id	Name	SBO
`Tbet_Prot`	Tbet_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \mathrm{vol}\,(\mathrm{compartment}) \cdot \mathrm{function\_4}\,(\mathrm{b}, [\mathrm{Tbet\_mRNA}]) \tag{33}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{34}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{35}$$

Table 27: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
b			100.0		☑

7.11 Reaction reaction_10

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

Name IFN tranlation

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightarrow{\text{Ifn\_mRNA}} \text{Ifn\_Prot} \tag{36}$$

Modifier

Table 28: Properties of each modifier.

Id	Name	SBO
Ifn_mRNA	Ifn_mRNA	

Product

Table 29: Properties of each product.

Id	Name	SBO
Ifn_Prot	Ifn_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \text{vol}\,(\text{compartment}) \cdot \text{function\_4}\,(\text{b}, [\text{Ifn\_mRNA}]) \tag{37}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{38}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{39}$$

Table 30: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
b			100.0		☑

7.12 Reaction reaction_11

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

Name Rec translation

SBO:0000184 translation

Reaction equation

$$\emptyset \xrightarrow{\text{Rec\_mRNA}} \text{Rec\_Prot} \tag{40}$$

Modifier

Table 31: Properties of each modifier.

Id	Name	SBO
Rec_mRNA	Rec_mRNA	

Product

Table 32: Properties of each product.

Id	Name	SBO
Rec_Prot	Rec_Prot	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \text{vol}\,(\text{compartment}) \cdot \text{function\_4}\,(\text{b}, [\text{Rec\_mRNA}]) \tag{41}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{42}$$

$$\text{function\_4}\,(\text{b}, \text{mRNA}) = \text{b} \cdot \text{mRNA} \tag{43}$$

Table 33: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
b			100.0		☑

7.13 Reaction reaction_12

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

Name Rec Transcription

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightarrow{\text{Tbet\_Prot, Ag}} \text{Rec\_mRNA} \tag{44}$$

Modifiers

Table 34: Properties of each modifier.

Id	Name	SBO
Tbet_Prot	Tbet_Prot	
Ag	Ag	

Product

Table 35: Properties of each product.

Id	Name	SBO
Rec_mRNA	Rec_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \text{vol}\left(\text{compartment}\right) \cdot \text{function\_5}\left(\text{a4}, [\text{Tbet\_Prot}], \text{K4}, [\text{Ag}]\right) \tag{45}$$

$$\text{function\_5}\left(\text{a4}, [\text{Tbet\_Prot}], \text{K4}, [\text{Ag}]\right) = \text{a4} \cdot [\text{Tbet\_Prot}] \cdot \frac{\text{K4}}{\text{K4} + [\text{Ag}]} \tag{46}$$

$$\text{function\_5}\left(\text{a4}, [\text{Tbet\_Prot}], \text{K4}, [\text{Ag}]\right) = \text{a4} \cdot [\text{Tbet\_Prot}] \cdot \frac{\text{K4}}{\text{K4} + [\text{Ag}]} \tag{47}$$

Table 36: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a4			0.003		☑
K4			0.013		☑

7.14 Reaction reaction_13

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

Name IFN transcription

SBO:0000183 transcription

Reaction equation

$$\emptyset \xrightarrow{\text{Tbet\_Prot, Rec\_Prot, Ag}} \text{Ifn\_mRNA} \tag{48}$$

Modifiers

Table 37: Properties of each modifier.

Id	Name	SBO
Tbet_Prot	Tbet_Prot	
Rec_Prot	Rec_Prot	
Ag	Ag	

Product

Table 38: Properties of each product.

Id	Name	SBO
Ifn_mRNA	Ifn_mRNA	

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \text{vol}\,(\text{compartment}) \cdot \text{function\_6}\,(\text{a5}, [\text{Tbet\_Prot}], \text{K5}, [\text{Rec\_Prot}], \text{K6}, [\text{Ag}], \text{K7}) \tag{49}$$

$$\begin{aligned} &\text{function\_6}\,(\text{a5}, [\text{Tbet\_Prot}], \text{K5}, [\text{Rec\_Prot}], \text{K6}, [\text{Ag}], \text{K7}) \\ &= \text{a5} \cdot \frac{[\text{Tbet\_Prot}]}{\text{K5} + [\text{Tbet\_Prot}]} \cdot \frac{[\text{Rec\_Prot}]}{\text{K6} + [\text{Rec\_Prot}]} \cdot \frac{[\text{Ag}]}{\text{K7} + [\text{Ag}]} \end{aligned} \tag{50}$$

$$\begin{aligned}&\text{function\_6}\left(\text{a5}, [\text{Tbet\_Prot}], \text{K5}, [\text{Rec\_Prot}], \text{K6}, [\text{Ag}], \text{K7}\right)\\&= \text{a5} \cdot \frac{[\text{Tbet\_Prot}]}{\text{K5} + [\text{Tbet\_Prot}]} \cdot \frac{[\text{Rec\_Prot}]}{\text{K6} + [\text{Rec\_Prot}]} \cdot \frac{[\text{Ag}]}{\text{K7} + [\text{Ag}]}\end{aligned} \tag{51}$$

Table 39: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a5			3.700		☑
K5			0.029		☑
K6			66.000		☑
K7			0.014		☑

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 `Tbet_mRNA`

Name Tbet_mRNA

SBO:0000278 messenger RNA

Initial concentration $0.0440000000000001\ \text{mol} \cdot \text{l}^{-1}$

This species takes part in five reactions (as a reactant in `reaction_3` and as a product in `vtrnldeg`, `reaction_1`, `reaction_2` and as a modifier in `reaction_9`).

$$\frac{\text{d}}{\text{d}t}\text{Tbet\_mRNA} = v_1 + v_2 + v_3 - v_4 \tag{52}$$

8.2 Species `Ifn_mRNA`

Name Ifn_mRNA

SBO:0000278 messenger RNA

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

This species takes part in three reactions (as a reactant in reaction_7 and as a product in reaction_13 and as a modifier in reaction_10).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ifn\_mRNA} = v_{14} - v_8 \tag{53}$$

8.3 Species Ag

Name Ag

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

Involved in rule Ag

This species takes part in three reactions (as a modifier in vtrnldeg, reaction_12, reaction_13). Not these but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.4 Species Ifn_Prot

Name Ifn_Prot

SBO:0000252 polypeptide chain

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

This species takes part in three reactions (as a reactant in reaction_8 and as a product in reaction_10 and as a modifier in vtrnldeg).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ifn\_Prot} = v_{11} - v_9 \tag{54}$$

8.5 Species Rec_Prot

Name Rec_Prot

SBO:0000252 polypeptide chain

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

This species takes part in four reactions (as a reactant in reaction_6 and as a product in reaction_11 and as a modifier in reaction_1, reaction_13).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Rec\_Prot} = v_{12} - v_7 \tag{55}$$

8.6 Species Tbet_Prot

Name Tbet_Prot

SBO:0000252 polypeptide chain

Initial concentration $44.0000000000001\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in four reactions (as a reactant in reaction_4 and as a product in reaction_9 and as a modifier in reaction_12, reaction_13).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Tbet\_Prot} = v_{10} - v_5 \tag{56}$$

8.7 Species Rec_mRNA

Name Rec_mRNA

SBO:0000278 messenger RNA

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

This species takes part in three reactions (as a reactant in reaction_5 and as a product in reaction_12 and as a modifier in reaction_11).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Rec\_mRNA} = v_{13} - v_6 \tag{57}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000048 forward zeroth order rate constant, continuous case: Numerical parameter that quantifies the forward velocity of a chemical reaction independant of the reactant quantities. This parameter encompasses all the contributions to the velocity. It is to be used in a reaction modelled using a continuous framework.

SBO:0000179 degradation: Complete disappearance of a physical entity

SBO:0000183 transcription: Process through which a DNA sequence is copied to produce a complementary RNA

SBO:0000184 translation: Process in which a polypeptide chain is produced from a messenger RNA

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:0000278 messenger RNA: A messenger RNA is a ribonucleic acid synthesized during the transcription of a gene, and that carries the information to encode one or several proteins

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:0000363 activation constant: Dissociation constant of a potentiator (activator) from a target (e.g. an enzyme) of which it activates the function

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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