SBML Model Report

Model name: "Muraro2011_Cytokinin-Auxin-_CrossRegulation"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following two authors: Vijayalakshmi Chelliah[1] and Daniele Muraro[2] at April tenth 2012 at 5:36 p. m. and last time modified at May 22nd 2014 at 7:02 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	1
species types	0	species	32
events	0	constraints	0
reactions	20	function definitions	0
global parameters	50	unit definitions	0
rules	12	initial assignments	0

Model Notes

This model is from the article:
The influence of cytokinin-auxin cross-regulation on cell-fate determination in Arabidopsis thaliana root development

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Muraro D, Byrne H, King J, Voss U, Kieber J, Bennett M. J Theor Biol.2011 Aug 21;283(1):152-67.PMID: 21640126,

Abstract:
Root growth and development in Arabidopsis thaliana are sustained by a specialised zone termed the meristem, which contains a population of dividing and differentiating cells that are functionally analogous to a stem cell niche in animals. The hormones auxin and cytokinin control meristem size antagonistically. Local accumulation of auxin promotes cell division and the initiation of a lateral root primordium. By contrast, high cytokinin concentrations disrupt the regular pattern of divisions that characterises lateral root development, and promote differentiation. The way in which the hormones interact is controlled by a genetic regulatory network. In this paper, we propose a deterministic mathematical model to describe this network and present model simulations that reproduce the experimentally observed effects of cytokinin on the expression of auxin regulated genes. We show how auxin response genes and auxin efflux transporters may be affected by the presence of cytokinin. We also analyse and compare the responses of the hormones auxin and cytokinin to changes in their supply with the responses obtained by genetic mutations of SHY2, which encodes a protein that plays a key role in balancing cytokinin and auxin regulation of meristem size. We show that although shy2 mutations can qualitatively reproduce the effect of varying auxin and cytokinin supply on their response genes, some elements of the network respond differently to changes in hormonal supply and to genetic mutations, implying a different, general response of the network. We conclude that an analysis based on the ratio between these two hormones may be misleading and that a mathematical model can serve as a useful tool for stimulate further experimental work by predicting the response of the network to changes in hormone levels and to other genetic mutations.

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`		0000290	3	1	litre	☑	

3.1 Compartment `cell`

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

SBO:0000290 physical compartment

4 Species

This model contains 32 species. 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
IAAm		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
IAAp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
AuxTIR1		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
AuxTIAA		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
IAAs		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARFIAA		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARF2		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
Aux		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PINm		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
PINp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARm		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
TIR1		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARF		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
CRm		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
CRp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
AHKph		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
Ck		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARRBph		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARRAph		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARRAm		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$
ARRAp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	$\boxminus$	$\boxminus$

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
ARRBp		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
CkAHKph		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
CkAHK		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F1		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F2		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F3		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F4		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F5a		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F5b		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F6		cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟

5 Parameters

This model contains 50 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
eps			0.01		☑
lambda1			0.10		☑
lambda3			0.02		☑
alphaAux			1.00		☑
alphaTIR1			1.00		☑
alphaARF			1.00		☑
phiIAAp			100.00		☑
phiARp			2.00		☑
phiPINp			100.00		☑
deltaIAAp			1.00		☑
deltaARp			1.00		☑
deltaPINp			1.00		☑
muAux			0.10		☑
muIAAs			1.00		☑
etaAuxTIR1			10.00		☑
etaARFIAA			1.00		☑
la			0.50		☑
ld			0.10		☑
pa			10.00		☑
pd			10.00		☑
ka			100.00		☑
kd			1.00		☑
qa			1.00		☑
qd			1.00		☑
thetaARF			0.10		☑
thetaARF2			0.01		☑
thARFIAA			0.10		☑
thetaIAAp			0.10		☑
thetaARp			0.10		☑
psiARFIAA			0.10		☑
psiARF			0.10		☑
alphaCk			1.00		☑
alphaARRB			2.00		☑
alphaAHK			1.00		☑
alphaPH			1.00		☑
phiCRp			2.00		☑
phiARRAp			100.00		☑

Id	Name	SBO	Value	Unit	Constant
deltaCRp			1.00		☑
deltaARRAp			1.00		☑
muCk			0.10		☑
etaAHKph			1.00		☑
etaCkPh			1.00		☑
ra			1.00		☑
rd			1.00		☑
ua			1.00		☑
ud			1.00		☑
sa			1.00		☑
sd			1.00		☑
thARRAph			0.10		☑
thARRBph			0.10		☑

6 Rules

This is an overview of twelve rules.

6.1 Rule TIR1

Rule TIR1 is an assignment rule for species TIR1:

$$\mathrm{TIR1} = \mathrm{alphaTIR1} - [\mathrm{AuxTIR1}] - [\mathrm{AuxTIAA}] \tag{1}$$

6.2 Rule ARF

Rule ARF is an assignment rule for species ARF:

$$\mathrm{ARF} = \mathrm{alphaARF} - 2 \cdot [\mathrm{ARF2}] - [\mathrm{ARFIAA}] \tag{2}$$

6.3 Rule ARRBp

Rule ARRBp is an assignment rule for species ARRBp:

$$\mathrm{ARRBp} = \mathrm{alphaARRB} - \mathrm{etaAHKph} \cdot [\mathrm{ARRBph}] \tag{3}$$

6.4 Rule CkAHKph

Rule CkAHKph is an assignment rule for species CkAHKph:

$$\mathrm{CkAHKph} = \mathrm{alphaPH} - [\mathrm{AHKph}] - [\mathrm{ARRAph}] - [\mathrm{ARRBph}] \tag{4}$$

6.5 Rule CkAHK

Rule CkAHK is an assignment rule for species CkAHK:

$$\mathrm{CkAHK} = \mathrm{alphaAHK} - \mathrm{etaAHKph} \cdot ([\mathrm{AHKph}] + [\mathrm{CkAHKph}]) \tag{5}$$

6.6 Rule F1

Rule F1 is an assignment rule for species F1:

$$\mathrm{F1} = \frac{\frac{[\mathrm{ARF}]}{\mathrm{thetaARF}}}{1 + \frac{[\mathrm{ARF}]}{\mathrm{thetaARF}} + \frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARFIAA}]}{\mathrm{thARFIAA}} + \frac{[\mathrm{ARF}]\cdot[\mathrm{IAAp}]}{\mathrm{psiARFIAA}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}} + \frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}} \tag{6}$$

6.7 Rule F2

Rule F2 is an assignment rule for species F2:

$$\mathrm{F2} = \frac{\frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}}}{1 + \frac{[\mathrm{ARF}]}{\mathrm{thetaARF}} + \frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARFIAA}]}{\mathrm{thARFIAA}} + \frac{[\mathrm{ARF}]\cdot[\mathrm{IAAp}]}{\mathrm{psiARFIAA}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}} + \frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}} \tag{7}$$

6.8 Rule F3

Rule F3 is an assignment rule for species F3:

$$\mathrm{F3} = \frac{\frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}}{1 + \frac{[\mathrm{ARF}]}{\mathrm{thetaARF}} + \frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARFIAA}]}{\mathrm{thARFIAA}} + \frac{[\mathrm{ARF}]\cdot[\mathrm{IAAp}]}{\mathrm{psiARFIAA}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}} + \frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}} \tag{8}$$

6.9 Rule F4

Rule F4 is an assignment rule for species F4:

$$\mathrm{F4} = \frac{\frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}}{1 + \frac{[\mathrm{ARRAph}]}{\mathrm{thARRAph}} + \frac{[\mathrm{ARRBph}]}{\mathrm{thARRBph}}} \tag{9}$$

6.10 Rule F5a

Rule F5a is an assignment rule for species F5a:

$$\mathrm{F5a} = \frac{\frac{[\mathrm{ARF}]}{\mathrm{thetaARF}}}{1 + \frac{[\mathrm{ARF}]}{\mathrm{thetaARF}} + \frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARFIAA}]}{\mathrm{thARFIAA}} + \frac{[\mathrm{ARF}]\cdot[\mathrm{IAAp}]}{\mathrm{psiARFIAA}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}}} \tag{10}$$

6.11 Rule F5b

Rule F5b is an assignment rule for species F5b:

$$\mathrm{F5b} = \frac{\frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}}}{1 + \frac{[\mathrm{ARF}]}{\mathrm{thetaARF}} + \frac{[\mathrm{ARF2}]}{\mathrm{thetaARF2}} + \frac{[\mathrm{ARFIAA}]}{\mathrm{thARFIAA}} + \frac{[\mathrm{ARF}]\cdot[\mathrm{IAAp}]}{\mathrm{psiARFIAA}} + \frac{[\mathrm{ARF}]^2}{\mathrm{psiARF}}} \tag{11}$$

6.12 Rule F6

Rule F6 is an assignment rule for species F6:

$$\mathrm{F6} = \frac{\frac{[\mathrm{ARp}]}{\mathrm{thetaARp}}}{1 + \frac{[\mathrm{ARp}]}{\mathrm{thetaARp}}} \tag{12}$$

7 Reactions

This model contains 20 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	r1		$\emptyset \xrightarrow{\text{F1, F2, F3}} \text{IAAm}$	
2	r2		$\emptyset \xrightarrow{\text{IAAm, AuxTIR1, AuxTIAA, ARFIAA, ARF}} \text{IAAp}$	
3	r3		$\emptyset \xrightarrow{\text{Aux, TIR1, AuxTIAA, IAAp}} \text{AuxTIR1}$	
4	r4		$\emptyset \xrightarrow{\text{AuxTIAA, IAAp, AuxTIR1}} \text{AuxTIAA}$	
5	r5		$\emptyset \xrightarrow{\text{AuxTIAA}} \text{IAAs}$	
6	r6		$\emptyset \xrightarrow{\text{ARF, IAAp}} \text{ARFIAA}$	
7	r7		$\emptyset \xrightarrow{\text{ARF}} \text{ARF2}$	
8	r8		$\emptyset \xrightarrow{\text{TIR1, AuxTIR1}} \text{Aux}$	
9	r9		$\emptyset \xrightarrow{\text{F5a, F5b}} \text{PINm}$	
10	r10		$\emptyset \xrightarrow{\text{PINm}} \text{PINp}$	
11	r11		$\emptyset \xrightarrow{\text{F5a, F5b}} \text{ARm}$	
12	r12		$\emptyset \xrightarrow{\text{ARm}} \text{ARp}$	
13	r13		$\emptyset \xrightarrow{\text{F4}} \text{CRm}$	
14	r14		$\emptyset \xrightarrow{\text{CRm}} \text{CRp}$	
15	r15		$\emptyset \xrightarrow{\text{CkAHKph, Ck}} \text{AHKph}$	
16	r16		$\emptyset \xrightarrow{\text{AHKph, CkAHKph}} \text{Ck}$	

№	Id	Name	Reaction Equation	SBO
17	`r17`		$\emptyset \xrightarrow{\text{CkAHKph, CkAHK, ARRBp}} \text{ARRBph}$	
18	`r18`		$\emptyset \xrightarrow{\text{CkAHKph, ARRAp, CkAHK, ARRAph}} \text{ARRAph}$	
19	`r19`		$\emptyset \xrightarrow{\text{F6}} \text{ARRAm}$	
20	`r20`		$\emptyset \xrightarrow{\text{ARRAm, CkAHK, ARRAph, CkAHKph}} \text{ARRAp}$	

7.1 Reaction `r1`

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

Reaction equation

$$\emptyset \xrightarrow{\text{F1, F2, F3}} \text{IAAm} \tag{13}$$

Modifiers

Table 6: Properties of each modifier.

Id	Name	SBO
F1		
F2		
F3		

Product

Table 7: Properties of each product.

Id	Name	SBO
IAAm		

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \text{phiIAAp} \cdot (\text{lambda1} \cdot [\text{F1}] + [\text{F2}] + \text{lambda3} \cdot [\text{F3}]) - [\text{IAAm}] \tag{14}$$

7.2 Reaction `r2`

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

Reaction equation

$$\emptyset \xrightarrow{\text{IAAm, AuxTIR1, AuxTIAA, ARFIAA, ARF}} \text{IAAp} \tag{15}$$

Modifiers

Table 8: Properties of each modifier.

Id	Name	SBO
IAAm		
AuxTIR1		
AuxTIAA		
ARFIAA		
ARF		

Product

Table 9: Properties of each product.

Id	Name	SBO
IAAp		

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \frac{1}{\mathrm{eps}} \cdot (\mathrm{deltaIAAp} \cdot [\mathrm{IAAm}] - \mathrm{la} \cdot [\mathrm{IAAp}] \cdot [\mathrm{AuxTIR1}] + \mathrm{ld} \cdot [\mathrm{AuxTIAA}]) + \mathrm{etaARFIAA} \cdot (\mathrm{pd} \cdot [\mathrm{ARFIAA}] - \mathrm{pa} \cdot [\mathrm{IAAp}] \cdot [\mathrm{ARF}]) \quad (16)$$

7.3 Reaction r3

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{Aux,\ TIR1,\ AuxTIAA,\ IAAp}} \mathrm{AuxTIR1} \quad (17)$$

Modifiers

Table 10: Properties of each modifier.

Id	Name	SBO
Aux		
TIR1		
AuxTIAA		
IAAp		

Product

Table 11: Properties of each product.

Id	Name	SBO
AuxTIR1		

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \frac{1}{\mathrm{eps}} \cdot (\mathrm{ka} \cdot [\mathrm{Aux}] \cdot [\mathrm{TIR1}] - \mathrm{kd} \cdot [\mathrm{AuxTIR1}] + (\mathrm{ld} + 1) \cdot [\mathrm{AuxTIAA}] - \mathrm{la} \cdot [\mathrm{AuxTIR1}] \cdot [\mathrm{IAAp}]) \tag{18}$$

7.4 Reaction `r4`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{AuxTIAA},\ \mathrm{IAAp},\ \mathrm{AuxTIR1}} \mathrm{AuxTIAA} \tag{19}$$

Modifiers

Table 12: Properties of each modifier.

Id	Name	SBO
AuxTIAA		
IAAp		
AuxTIR1		

Product

Table 13: Properties of each product.

Id	Name	SBO
AuxTIAA		

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \frac{1}{\text{eps}} \cdot (\text{la} \cdot [\text{IAAp}] \cdot [\text{AuxTIR1}] - (\text{ld} + 1) \cdot [\text{AuxTIAA}]) \tag{20}$$

7.5 Reaction `r5`

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

Reaction equation

$$\emptyset \xrightarrow{\text{AuxTIAA}} \text{IAAs} \tag{21}$$

Modifier

Table 14: Properties of each modifier.

Id	Name	SBO
`AuxTIAA`		

Product

Table 15: Properties of each product.

Id	Name	SBO
`IAAs`		

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \frac{1}{\text{eps}} \cdot ([\text{AuxTIAA}] - \text{muIAAs} \cdot [\text{IAAs}]) \tag{22}$$

7.6 Reaction `r6`

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

Reaction equation

$$\emptyset \xrightarrow{\text{ARF, IAAp}} \text{ARFIAA} \tag{23}$$

Modifiers

Table 16: Properties of each modifier.

Id	Name	SBO
ARF		
IAAp		

Product

Table 17: Properties of each product.

Id	Name	SBO
ARFIAA		

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{pa} \cdot [\mathrm{ARF}] \cdot [\mathrm{IAAp}] - \mathrm{pd} \cdot [\mathrm{ARFIAA}] \tag{24}$$

7.7 Reaction r7

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{ARF}} \mathrm{ARF2} \tag{25}$$

Modifier

Table 18: Properties of each modifier.

Id	Name	SBO
ARF		

Product

Table 19: Properties of each product.

Id	Name	SBO
ARF2		

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \mathrm{qa} \cdot [\mathrm{ARF}]^2 - \mathrm{qd} \cdot [\mathrm{ARF2}] \tag{26}$$

7.8 Reaction r8

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{TIR1},\ \mathrm{AuxTIR1}} \mathrm{Aux} \tag{27}$$

Modifiers

Table 20: Properties of each modifier.

Id	Name	SBO
TIR1		
AuxTIR1		

Product

Table 21: Properties of each product.

Id	Name	SBO
Aux		

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \mathrm{muAux} \cdot (\mathrm{alphaAux} - [\mathrm{Aux}]) - \frac{1}{\mathrm{eps}} \cdot \mathrm{etaAuxTIR1} \cdot (\mathrm{ka} \cdot [\mathrm{Aux}] \cdot [\mathrm{TIR1}] - \mathrm{kd} \cdot [\mathrm{AuxTIR1}]) \tag{28}$$

7.9 Reaction r9

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

Reaction equation

$$\emptyset \xrightarrow{\text{F5a, F5b}} \text{PINm} \tag{29}$$

Modifiers

Table 22: Properties of each modifier.

Id	Name	SBO
F5a		
F5b		

Product

Table 23: Properties of each product.

Id	Name	SBO
PINm		

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \text{phiPINp} \cdot (\text{lambda1} \cdot [\text{F5a}] + [\text{F5b}]) - [\text{PINm}] \tag{30}$$

7.10 Reaction r10

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

Reaction equation

$$\emptyset \xrightarrow{\text{PINm}} \text{PINp} \tag{31}$$

Modifier

Table 24: Properties of each modifier.

Id	Name	SBO
PINm		

Product

Table 25: Properties of each product.

Id	Name	SBO
PINp		

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \frac{1}{\text{eps}} \cdot (\text{deltaPINp} \cdot [\text{PINm}] - [\text{PINp}]) \quad (32)$$

7.11 Reaction r11

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

Reaction equation

$$\emptyset \xrightarrow{\text{F5a, F5b}} \text{ARm} \quad (33)$$

Modifiers

Table 26: Properties of each modifier.

Id	Name	SBO
F5a		
F5b		

Product

Table 27: Properties of each product.

Id	Name	SBO
ARm		

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \mathrm{phiARp} \cdot (\mathrm{lambda1} \cdot [\mathrm{F5a}] + [\mathrm{F5b}]) - [\mathrm{ARm}] \tag{34}$$

7.12 Reaction `r12`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{ARm}} \mathrm{ARp} \tag{35}$$

Modifier

Table 28: Properties of each modifier.

Id	Name	SBO
`ARm`		

Product

Table 29: Properties of each product.

Id	Name	SBO
`ARp`		

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \frac{1}{\mathrm{eps}} \cdot (\mathrm{deltaARp} \cdot [\mathrm{ARm}] - [\mathrm{ARp}]) \tag{36}$$

7.13 Reaction `r13`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{F4}} \mathrm{CRm} \tag{37}$$

Modifier

Table 30: Properties of each modifier.

Id	Name	SBO
F4		

Product

Table 31: Properties of each product.

Id	Name	SBO
CRm		

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \mathrm{phiCRp} \cdot [\mathrm{F4}] - [\mathrm{CRm}] \tag{38}$$

7.14 Reaction r14

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{CRm}} \mathrm{CRp} \tag{39}$$

Modifier

Table 32: Properties of each modifier.

Id	Name	SBO
CRm		

Product

Table 33: Properties of each product.

Id	Name	SBO
CRp		

Id	Name	SBO

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \frac{1}{\mathrm{eps}} \cdot (\mathrm{deltaCRp} \cdot [\mathrm{CRm}] - [\mathrm{CRp}]) \tag{40}$$

7.15 Reaction `r15`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{CkAHKph},\ \mathrm{Ck}} \mathrm{AHKph} \tag{41}$$

Modifiers

Table 34: Properties of each modifier.

Id	Name	SBO
`CkAHKph`		
`Ck`		

Product

Table 35: Properties of each product.

Id	Name	SBO
`AHKph`		

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \frac{1}{\mathrm{eps}} \cdot (\mathrm{rd} \cdot [\mathrm{CkAHKph}] - \mathrm{ra} \cdot [\mathrm{AHKph}] \cdot [\mathrm{Ck}]) \tag{42}$$

7.16 Reaction `r16`

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

Reaction equation

$$\emptyset \xrightarrow{\text{AHKph, CkAHKph}} \text{Ck} \tag{43}$$

Modifiers

Table 36: Properties of each modifier.

Id	Name	SBO
AHKph		
CkAHKph		

Product

Table 37: Properties of each product.

Id	Name	SBO
Ck		

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = \text{muCk} \cdot (\text{alphaCk} - [\text{Ck}]) - \frac{\text{etaCkPh}}{\text{eps}} \cdot (\text{ra} \cdot [\text{AHKph}] \cdot [\text{Ck}] - \text{rd} \cdot [\text{CkAHKph}]) \tag{44}$$

7.17 Reaction `r17`

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

Reaction equation

$$\emptyset \xrightarrow{\text{CkAHKph, CkAHK, ARRBp}} \text{ARRBph} \tag{45}$$

Modifiers

Table 38: Properties of each modifier.

Id	Name	SBO
CkAHKph		
CkAHK		
ARRBp		

Product

Table 39: Properties of each product.

Id	Name	SBO
ARRBph		

Kinetic Law

Derived unit contains undeclared units

$$v_{17} = \frac{1}{\mathrm{eps}} \cdot (\mathrm{ua} \cdot [\mathrm{CkAHKph}] \cdot [\mathrm{ARRBp}] - \mathrm{ud} \cdot [\mathrm{CkAHK}] \cdot [\mathrm{ARRBph}]) \tag{46}$$

7.18 Reaction `r18`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{CkAHKph},\ \mathrm{ARRAp},\ \mathrm{CkAHK},\ \mathrm{ARRAph}} \mathrm{ARRAph} \tag{47}$$

Modifiers

Table 40: Properties of each modifier.

Id	Name	SBO
CkAHKph		
ARRAp		
CkAHK		
ARRAph		

Product

Table 41: Properties of each product.

Id	Name	SBO
ARRAph		

Kinetic Law

Derived unit contains undeclared units

$$v_{18} = \frac{1}{\mathrm{eps}} \cdot (\mathrm{sa} \cdot [\mathrm{CkAHKph}] \cdot [\mathrm{ARRAp}] - \mathrm{sd} \cdot [\mathrm{CkAHK}] \cdot [\mathrm{ARRAph}]) \quad (48)$$

7.19 Reaction `r19`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{F6}} \mathrm{ARRAm} \quad (49)$$

Modifier

Table 42: Properties of each modifier.

Id	Name	SBO
`F6`		

Product

Table 43: Properties of each product.

Id	Name	SBO
`ARRAm`		

Kinetic Law

Derived unit contains undeclared units

$$v_{19} = \mathrm{phiARRAp} \cdot [\mathrm{F6}] - [\mathrm{ARRAm}] \quad (50)$$

7.20 Reaction `r20`

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

Reaction equation

$$\emptyset \xrightarrow{\mathrm{ARRAm},\ \mathrm{CkAHK},\ \mathrm{ARRAph},\ \mathrm{CkAHKph}} \mathrm{ARRAp} \quad (51)$$

Modifiers

Table 44: Properties of each modifier.

Id	Name	SBO
ARRAm		
CkAHK		
ARRAph		
CkAHKph		

Product

Table 45: Properties of each product.

Id	Name	SBO
ARRAp		

Kinetic Law

Derived unit contains undeclared units

$$v_{20} = \frac{1}{\text{eps}} \cdot (\text{deltaARRAp} \cdot [\text{ARRAm}] - [\text{ARRAp}] + \text{etaAHKph} \cdot (\text{sd} \cdot [\text{CkAHK}] \cdot [\text{ARRAph}] - \text{sa} \cdot [\text{CkAHKph}] \cdot [\text{ARRAp}])) \quad (52)$$

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 IAAm

SBO:0000278 messenger RNA

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

This species takes part in two reactions (as a product in r1 and as a modifier in r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAAm} = v_1 \tag{53}$$

8.2 Species IAAp

SBO:0000252 polypeptide chain

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

This species takes part in four reactions (as a product in r2 and as a modifier in r3, r4, r6).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAAp} = v_2 \tag{54}$$

8.3 Species AuxTIR1

SBO:0000296 macromolecular complex

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

This species takes part in four reactions (as a product in r3 and as a modifier in r2, r4, r8).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{AuxTIR1} = v_3 \tag{55}$$

8.4 Species AuxTIAA

SBO:0000296 macromolecular complex

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

This species takes part in five reactions (as a product in r4 and as a modifier in r2, r3, r4, r5).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{AuxTIAA} = v_4 \tag{56}$$

8.5 Species IAAs

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r5).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAAs} = v_5 \tag{57}$$

8.6 Species ARFIAA

SBO:0000297 protein complex

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

This species takes part in two reactions (as a product in r6 and as a modifier in r2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{ARFIAA} = v_6 \tag{58}$$

8.7 Species ARF2

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r7).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{ARF2} = v_7 \tag{59}$$

8.8 Species Aux

SBO:0000247 simple chemical

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

This species takes part in two reactions (as a product in r8 and as a modifier in r3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Aux} = v_8 \tag{60}$$

8.9 Species PINm

SBO:0000278 messenger RNA

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

This species takes part in two reactions (as a product in r9 and as a modifier in r10).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PINm} = v_9 \tag{61}$$

8.10 Species PINp

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r10).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PINp} = v_{10} \tag{62}$$

8.11 Species ARm

SBO:0000278 messenger RNA

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

This species takes part in two reactions (as a product in r11 and as a modifier in r12).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARm} = v_{11} \tag{63}$$

8.12 Species ARp

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r12).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARp} = v_{12} \tag{64}$$

8.13 Species TIR1

SBO:0000252 polypeptide chain

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

Involved in rule TIR1

This species takes part in two reactions (as a modifier in r3, r8) and is also involved in one rule which determines this species' quantity.

8.14 Species ARF

SBO:0000252 polypeptide chain

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

Involved in rule ARF

This species takes part in three reactions (as a modifier in r2, r6, r7) and is also involved in one rule which determines this species' quantity.

8.15 Species CRm

SBO:0000278 messenger RNA

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

This species takes part in two reactions (as a product in r13 and as a modifier in r14).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CRm} = v_{13} \tag{65}$$

8.16 Species CRp

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r14).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CRp} = v_{14} \tag{66}$$

8.17 Species AHKph

SBO:0000252 polypeptide chain

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

This species takes part in two reactions (as a product in r15 and as a modifier in r16).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{AHKph} = v_{15} \tag{67}$$

8.18 Species Ck

SBO:0000247 simple chemical

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

This species takes part in two reactions (as a product in r16 and as a modifier in r15).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ck} = v_{16} \tag{68}$$

8.19 Species ARRBph

SBO:0000252 polypeptide chain

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

This species takes part in one reaction (as a product in r17).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARRBph} = v_{17} \tag{69}$$

8.20 Species ARRAph

SBO:0000252 polypeptide chain

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

This species takes part in three reactions (as a product in r18 and as a modifier in r18, r20).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARRAph} = v_{18} \tag{70}$$

8.21 Species ARRAm

SBO:0000278 messenger RNA

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

This species takes part in two reactions (as a product in r19 and as a modifier in r20).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARRAm} = v_{19} \quad (71)$$

8.22 Species ARRAp

SBO:0000252 polypeptide chain

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

This species takes part in two reactions (as a product in r20 and as a modifier in r18).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARRAp} = v_{20} \quad (72)$$

8.23 Species ARRBp

SBO:0000252 polypeptide chain

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

Involved in rule ARRBp

This species takes part in one reaction (as a modifier in r17) and is also involved in one rule which determines this species' quantity.

8.24 Species CkAHKph

SBO:0000296 macromolecular complex

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

Involved in rule CkAHKph

This species takes part in five reactions (as a modifier in r15, r16, r17, r18, r20) and is also involved in one rule which determines this species' quantity.

8.25 Species CkAHK

SBO:0000296 macromolecular complex

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

Involved in rule CkAHK

This species takes part in three reactions (as a modifier in r17, r18, r20) and is also involved in one rule which determines this species' quantity.

8.26 Species F1

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

Involved in rule F1

This species takes part in one reaction (as a modifier in r1) and is also involved in one rule which determines this species' quantity.

8.27 Species F2

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

Involved in rule F2

This species takes part in one reaction (as a modifier in r1) and is also involved in one rule which determines this species' quantity.

8.28 Species F3

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

Involved in rule F3

This species takes part in one reaction (as a modifier in r1) and is also involved in one rule which determines this species' quantity.

8.29 Species F4

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

Involved in rule F4

This species takes part in one reaction (as a modifier in r13) and is also involved in one rule which determines this species' quantity.

8.30 Species F5a

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

Involved in rule F5a

This species takes part in two reactions (as a modifier in r9, r11) and is also involved in one rule which determines this species' quantity.

8.31 Species F5b

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

Involved in rule F5b

This species takes part in two reactions (as a modifier in r9, r11) and is also involved in one rule which determines this species' quantity.

8.32 Species F6

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

Involved in rule F6

This species takes part in one reaction (as a modifier in r19) and is also involved in one rule which determines this species' quantity.

A Glossary of Systems Biology Ontology Terms

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: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:0000296 **macromolecular complex:** Non-covalent complex of one or more macromolecules and zero or more simple chemicals

SBO:0000297 **protein complex:** Macromolecular complex containing one or more polypeptide chains possibly associated with simple chemicals. CHEBI:3608

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