

SBML Model Report

Model name:
“Middleton2012_GibberellinSignalling”



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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 two authors: Vijayalakshmi Chelliah¹ and Markus R. Owen² at July 20th 2012 at 5:39 p. m. and last time modified at August third 2012 at 1:19 p. 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	37
events	2	constraints	0
reactions	43	function definitions	0
global parameters	13	unit definitions	5
rules	1	initial assignments	0

Model Notes

This model is from the article:

Mathematical modeling elucidates the role of transcriptional feedback in gibberellin signaling.

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Middleton AM , beda-Toms S , Griffiths J , Holman T , Hedden P , Thomas SG , Phillips AL , Holdsworth MJ , Bennett MJ , King JR, Owen MR Proc. Natl. Acad. Sci. U.S.A. 2012 May; 109(19): 7571-6 [22523240](#) ,

Abstract:

The hormone gibberellin (GA) is a key regulator of plant growth. Many of the components of the gibberellin signal transduction [e.g., GIBBERELLIN INSENSITIVE DWARF 1 (GID1) and DELLA], biosynthesis [e.g., GA 20-oxidase (GA20ox) and GA3ox], and deactivation pathways have been identified. Gibberellin binds its receptor, GID1, to form a complex that mediates the degradation of DELLA proteins. In this way, gibberellin relieves DELLA-dependent growth repression. However, gibberellin regulates expression of GID1, GA20ox, and GA3ox, and there is also evidence that it regulates DELLA expression. In this paper, we use integrated mathematical modeling and experiments to understand how these feedback loops interact to control gibberellin signaling. Model simulations are in good agreement with in vitro data on the signal transduction and biosynthesis pathways and in vivo data on the expression levels of gibberellin-responsive genes. We find that GA-GID1 interactions are characterized by two timescales (because of a lid on GID1 that can open and close slowly relative to GA-GID1 binding and dissociation). Furthermore, the model accurately predicts the response to exogenous gibberellin after a number of chemical and genetic perturbations. Finally, we investigate the role of the various feedback loops in gibberellin signaling. We find that regulation of GA20ox transcription plays a significant role in both modulating the level of endogenous gibberellin and generating overshoots after the removal of exogenous gibberellin. Moreover, although the contribution of other individual feedback loops seems relatively small, GID1 and DELLA transcriptional regulation acts synergistically with GA20ox feedback.

2 Unit Definitions

This is an overview of five unit definitions.

2.1 Unit substance

Name substance

Definition mol

2.2 Unit volume

Name volume

Definition l

2.3 Unit area

Name area

Definition m²

2.4 Unit `length`

Name `length`

Definition `m`

2.5 Unit `time`

Name `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
<code>default</code>			3	1	litre	<input checked="" type="checkbox"/>	

3.1 Compartment `default`

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

4 Species

This model contains 37 species. The boundary condition of 15 of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 9 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
s1	GA4	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s2	GID	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s16	DELLA	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s22	DELLA_U	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s23	GA12	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s24	GA15	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s25	GA24	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s26	GA9	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s27	GA20ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s28	GA3ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s39	ga20ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s40	della	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s41	ga3ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s42	gid	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s65	GA4-GID	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s29	GA9-GA3ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s30	GA24-GA20ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s31	GA15-GA20ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s32	GA12-GA20ox	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s62	GA4-GID-closed	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s3	GA12_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
s5	GA3ox_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s6	GA20ox_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s7	DELLA_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s33	GID_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s11	ga20ox_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s15	gid_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s34	della_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s35	ga3ox_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s36	GA4-GID-DELLA2	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s45	GA4-GID-DELLA1	default	mol	<input type="checkbox"/>	<input type="checkbox"/>
s66	GA4_source	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s67	sa5_degraded	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s68	sa6_degraded	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s69	sa7_degraded	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s70	sa8_degraded	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>
s71	sa1_degraded	default	mol	<input type="checkbox"/>	<input checked="" type="checkbox"/>

5 Parameters

This model contains 13 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
muGA20ox	muGA20ox		0.048	mol	<input checked="" type="checkbox"/>
muGA3ox	muGA3ox		0.103	mol	<input checked="" type="checkbox"/>
muGID	muGID		0.046	mol	<input checked="" type="checkbox"/>
muDELLA	muDELLA		0.071	mol	<input checked="" type="checkbox"/>
Pmem	Pmem		2.667	mol	<input checked="" type="checkbox"/>
muGA	muGA		0.291	mol	<input checked="" type="checkbox"/>
omegaGA4	omegaGA4		0.000	mol	<input type="checkbox"/>
tGA4on	tGA4on		500.000	mol	<input checked="" type="checkbox"/>
tGA4off	tGA4off		620.000	mol	<input checked="" type="checkbox"/>
appliedGA4	appliedGA4		2.000	mol	<input checked="" type="checkbox"/>
omegaGA12ga13	omegaGA12ga13		0.007	mol	<input checked="" type="checkbox"/>
omegaGA12	omegaGA12		0.007	mol	<input type="checkbox"/>
R	R		1.000	mol	<input checked="" type="checkbox"/>

6 Rule

This is an overview of one rule.

6.1 Rule omegaGA12

Rule omegaGA12 is an assignment rule for parameter omegaGA12:

$$\text{omegaGA12} = R \cdot \text{omegaGA12ga13} \quad (1)$$

Derived unit mol²

7 Events

This is an overview of two events. Each event is initiated whenever its trigger condition switches from false to true. A delay function postpones the effects of an event to a later time point. At the time of execution, an event can assign values to species, parameters or compartments if these are not set to constant.

7.1 Event AddGA4

Name AddGA4

Trigger condition $\text{time} > \text{tGA4on}$ (2)

Assignment $\text{omegaGA4} = \text{appliedGA4}$ (3)

7.2 Event RemoveGA4

Name RemoveGA4

Trigger condition $\text{time} > \text{tGA4off}$ (4)

Assignment $\text{omegaGA4} = 0$ (5)

8 Reactions

This model contains 43 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

Nº	Id	Name	Reaction Equation	SBO
1	re1	GA4-GID association	$s1 + s2 \xrightarrow{s1, s2} s65$	
2	re2	GA4.GID dissociation	$s65 \xrightarrow{s65} s1 + s2$	
3	re3	GA4.GID-DELLA1 association	$s62 + s16 \xrightarrow{s62, s16} s45$	
4	re4	GA4.GID.DELLA1 dissociation	$s45 \xrightarrow{s45} s62 + s16$	
5	re5	DELLA ubiquitination	$s45 \xrightarrow{s45} s62 + s22$	
6	re6	GA12 supply	$s3 \longrightarrow s23$	
7	re7	GA12-GA20ox association	$s23 + s27 \xrightarrow{s23, s27} s32$	
8	re8	GA12.GA20ox dissociation	$s32 \xrightarrow{s32} s23 + s27$	
9	re9	GA15 production	$s32 \xrightarrow{s32} s27 + s24$	
10	re10	GA15-GA20ox association	$s24 + s27 \xrightarrow{s24, s27} s31$	
11	re11	GA15.GA20ox dissociation	$s31 \xrightarrow{s31} s24 + s27$	
12	re12	GA24 production	$s31 \xrightarrow{s31} s27 + s25$	
13	re13	GA24-GA20ox association	$s25 + s27 \xrightarrow{s25, s27} s30$	
14	re14	GA24.GA20ox dissociation	$s30 \xrightarrow{s30} s25 + s27$	
15	re15	GA9 production	$s30 \xrightarrow{s30} s27 + s26$	
16	re16	GA9-GA3ox association	$s26 + s28 \xrightarrow{s26, s28} s29$	

Nº	Id	Name	Reaction Equation	SBO
17	re17	GA9.GA3ox dissociation	$s_{29} \xrightarrow{s_{29}} s_{26} + s_{28}$	
18	re18	GA4 production	$s_{29} \xrightarrow{s_{29}} s_{28} + s_1$	
19	re19	GA4.GID lid closing	$s_{65} \xrightarrow{s_{65}} s_{62}$	
20	re20	GA4.GID-Closed lid opening	$s_{62} \xrightarrow{s_{62}} s_{65}$	
21	re21	della translation	$s_7 \xrightarrow{s_{40}, s_{40}} s_{16}$	
22	re22	ga20ox translation	$s_6 \xrightarrow{s_{39}, s_{39}} s_{27}$	
23	re23	ga3ox translation	$s_5 \xrightarrow{s_{41}, s_{41}} s_{28}$	
24	re24	gid translation	$s_{33} \xrightarrow{s_{42}, s_{42}} s_2$	
25	re27	ga20ox transcription (activated by DELLA)	$s_{11} \xrightarrow{s_{16}, s_{16}} s_{39}$	
26	re28	gid transcription (activated by DELLA)	$s_{15} \xrightarrow{s_{16}, s_{16}} s_{42}$	
27	re29	della transcription (repressed by DELLA)	$s_{34} \xrightarrow{s_{16}, s_{16}} s_{40}$	
28	re30	ga3ox transcription (activated by DELLA)	$s_{35} \xrightarrow{s_{16}, s_{16}} s_{41}$	
29	re31	della decay	$s_{40} \xrightarrow{s_{40}} s_{34}$	
30	re32	gid decay	$s_{42} \xrightarrow{s_{42}} s_{15}$	
31	re33	ga20ox decay	$s_{39} \xrightarrow{s_{39}} s_{11}$	
32	re34	ga3ox decay	$s_{41} \xrightarrow{s_{41}} s_{35}$	
33	re35	GA20ox decay	$s_{27} \xrightarrow{s_{27}} s_6$	
34	re37	GID decay	$s_2 \xrightarrow{s_2} s_{33}$	
35	re38	GA3ox decay	$s_{28} \xrightarrow{s_{28}} s_5$	
36	re39	GA4.GID-DELLA2 association	$s_{62} + s_{16} \xrightarrow{s_{62}, s_{16}} s_{36}$	
37	re40	GA4.GID.DELLA2 dissociation	$s_{36} \xrightarrow{s_{36}} s_{62} + s_{16}$	

Nº	Id	Name	Reaction Equation	SBO
38	re41	GA4 supply	$s66 \longrightarrow s1$	
39	re42	degradation of GA12	$s23 \xrightarrow{s23} s67$	
40	re43	degradation of GA15	$s24 \xrightarrow{s24} s68$	
41	re44	degradation of GA24	$s25 \xrightarrow{s25} s69$	
42	re45	degradation of GA9	$s26 \xrightarrow{s26} s70$	
43	re46	degradation of GA4	$s1 \xrightarrow{s1} s71$	

8.1 Reaction `re1`

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

Name GA4-GID association

Reaction equation



Reactants

Table 6: Properties of each reactant.

Id	Name	SBO
s1	GA4	
s2	GID	

Modifiers

Table 7: Properties of each modifier.

Id	Name	SBO
s1	GA4	
s2	GID	

Product

Table 8: Properties of each product.

Id	Name	SBO
s65	GA4-GID	

Kinetic Law

Derived unit mol^3

$$v_1 = k_a \cdot s1 \cdot s2 \quad (7)$$

Table 9: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
1a	1a		1.35	mol	<input checked="" type="checkbox"/>

8.2 Reaction re2

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

Name GA4.GID dissociation

Reaction equation



Reactant

Table 10: Properties of each reactant.

Id	Name	SBO
s65	GA4-GID	

Modifier

Table 11: Properties of each modifier.

Id	Name	SBO
s65	GA4-GID	

Products

Table 12: Properties of each product.

Id	Name	SBO
s1	GA4	
s2	GID	

Kinetic Law

Derived unit mol²

$$v_2 = 1d \cdot s65 \quad (9)$$

Table 13: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ld	ld		2.843	mol	<input checked="" type="checkbox"/>

8.3 Reaction re3

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

Name GA4.GID-DELLA1 association

Reaction equation



Reactants

Table 14: Properties of each reactant.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Modifiers

Table 15: Properties of each modifier.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Product

Table 16: Properties of each product.

Id	Name	SBO
s45	GA4-GID-DELLA1	

Kinetic Law

Derived unit mol³

$$v_3 = ua1 \cdot s62 \cdot s16 \quad (11)$$

Table 17: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ua1	ua1		10.0	mol	<input checked="" type="checkbox"/>

8.4 Reaction re4

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

Name GA4.GID.DELLA1 dissociation

Reaction equation



Reactant

Table 18: Properties of each reactant.

Id	Name	SBO
s45	GA4-GID-DELLA1	

Modifier

Table 19: Properties of each modifier.

Id	Name	SBO
s45	GA4-GID-DELLA1	

Products

Table 20: Properties of each product.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Kinetic Law

Derived unit mol^2

$$v_4 = \text{ud1} \cdot \text{s45} \quad (13)$$

Table 21: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ud1	ud1		0.133	mol	<input checked="" type="checkbox"/>

8.5 Reaction re5

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

Name DELLA ubiquitination

Reaction equation



Reactant

Table 22: Properties of each reactant.

Id	Name	SBO
s45	GA4-GID-DELLA1	

Modifier

Table 23: Properties of each modifier.

Id	Name	SBO
s45	GA4-GID-DELLA1	

Products

Table 24: Properties of each product.

Id	Name	SBO
s62	GA4-GID-closed	

Id	Name	SBO
s22	DELLA_U	

Kinetic Law

Derived unit mol²

$$v_5 = um \cdot s45 \quad (15)$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
um	um		6.922	mol	<input checked="" type="checkbox"/>

8.6 Reaction re6

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

Name GA12 supply

Reaction equation



Reactant

Table 26: Properties of each reactant.

Id	Name	SBO
s3	GA12_source	

Product

Table 27: Properties of each product.

Id	Name	SBO
s23	GA12	

Kinetic Law

Derived unit mol

$$v_6 = \text{omegaGA12} \quad (17)$$

8.7 Reaction re7

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

Name GA12-GA20ox association

Reaction equation



Reactants

Table 28: Properties of each reactant.

Id	Name	SBO
s23	GA12	
s27	GA20ox	

Modifiers

Table 29: Properties of each modifier.

Id	Name	SBO
s23	GA12	
s27	GA20ox	

Product

Table 30: Properties of each product.

Id	Name	SBO
s32	GA12-GA20ox	

Kinetic Law

Derived unit mol³

$$v_7 = \text{ka12} \cdot s23 \cdot s27 \quad (19)$$

Table 31: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ka12	ka12		2904.119	mol	<input checked="" type="checkbox"/>

8.8 Reaction re8

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

Name GA12.GA20ox dissociation

Reaction equation



Reactant

Table 32: Properties of each reactant.

Id	Name	SBO
s32	GA12-GA20ox	

Modifier

Table 33: Properties of each modifier.

Id	Name	SBO
s32	GA12-GA20ox	

Products

Table 34: Properties of each product.

Id	Name	SBO
s23	GA12	
s27	GA20ox	

Kinetic Law

Derived unit mol²

$$v_8 = kd12 \cdot s32 \quad (21)$$

Table 35: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kd12	kd12		2.673	mol	<input checked="" type="checkbox"/>

8.9 Reaction re9

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

Name GA15 production

Reaction equation



Reactant

Table 36: Properties of each reactant.

Id	Name	SBO
s32	GA12-GA20ox	

Modifier

Table 37: Properties of each modifier.

Id	Name	SBO
s32	GA12-GA20ox	

Products

Table 38: Properties of each product.

Id	Name	SBO
s27	GA20ox	
s24	GA15	

Kinetic Law

Derived unit mol²

$$v_9 = km12 \cdot s32 \quad (23)$$

Table 39: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
km12	km12		198.804	mol	<input checked="" type="checkbox"/>

8.10 Reaction `re10`

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

Name GA15-GA20ox association

Reaction equation



Reactants

Table 40: Properties of each reactant.

Id	Name	SBO
s24	GA15	
s27	GA20ox	

Modifiers

Table 41: Properties of each modifier.

Id	Name	SBO
s24	GA15	
s27	GA20ox	

Product

Table 42: Properties of each product.

Id	Name	SBO
s31	GA15-GA20ox	

Kinetic Law

Derived unit mol³

$$v_{10} = ka15 \cdot s24 \cdot s27 \quad (25)$$

Table 43: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ka15	ka15		2073.224	mol	<input checked="" type="checkbox"/>

8.11 Reaction `re11`

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

Name GA15.GA20ox dissociation

Reaction equation



Reactant

Table 44: Properties of each reactant.

Id	Name	SBO
s31	GA15-GA20ox	

Modifier

Table 45: Properties of each modifier.

Id	Name	SBO
s31	GA15-GA20ox	

Products

Table 46: Properties of each product.

Id	Name	SBO
s24	GA15	
s27	GA20ox	

Kinetic Law

Derived unit mol²

$$v_{11} = kd15 \cdot s31 \quad (27)$$

Table 47: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kd15	kd15		0.009	mol	<input checked="" type="checkbox"/>

8.12 Reaction re12

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

Name GA24 production

Reaction equation



Reactant

Table 48: Properties of each reactant.

Id	Name	SBO
s31	GA15-GA20ox	

Modifier

Table 49: Properties of each modifier.

Id	Name	SBO
s31	GA15-GA20ox	

Products

Table 50: Properties of each product.

Id	Name	SBO
s27	GA20ox	

Id	Name	SBO
s25	GA24	

Kinetic Law

Derived unit mol²

$$v_{12} = km15 \cdot s31 \quad (29)$$

Table 51: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
km15	km15		763.777	mol	<input checked="" type="checkbox"/>

8.13 Reaction re13

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

Name GA24-GA20ox association

Reaction equation



Reactants

Table 52: Properties of each reactant.

Id	Name	SBO
s25	GA24	
s27	GA20ox	

Modifiers

Table 53: Properties of each modifier.

Id	Name	SBO
s25	GA24	
s27	GA20ox	

Product

Table 54: Properties of each product.

Id	Name	SBO
s30	GA24-GA20ox	

Kinetic Law

Derived unit mol³

$$v_{13} = ka24 \cdot s25 \cdot s27 \quad (31)$$

Table 55: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ka24	ka24		3099.189	mol	<input checked="" type="checkbox"/>

8.14 Reaction re14

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

Name GA24.GA20ox dissociation

Reaction equation



Reactant

Table 56: Properties of each reactant.

Id	Name	SBO
s30	GA24-GA20ox	

Modifier

Table 57: Properties of each modifier.

Id	Name	SBO
s30	GA24-GA20ox	

Id	Name	SBO
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Products

Table 58: Properties of each product.

Id	Name	SBO
s25	GA24	
s27	GA20ox	

Kinetic Law

Derived unit mol²

$$v_{14} = kd24 \cdot s30 \quad (33)$$

Table 59: Properties of each parameter.

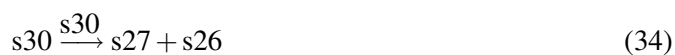
Id	Name	SBO	Value	Unit	Constant
kd24	kd24		0.016	mol	<input checked="" type="checkbox"/>

8.15 Reaction re15

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

Name GA9 production

Reaction equation



Reactant

Table 60: Properties of each reactant.

Id	Name	SBO
s30	GA24-GA20ox	

Modifier

Table 61: Properties of each modifier.

Id	Name	SBO
s30	GA24-GA20ox	

Products

Table 62: Properties of each product.

Id	Name	SBO
s27	GA20ox	
s26	GA9	

Kinetic Law

Derived unit mol²

$$v_{15} = km24 \cdot s30 \quad (35)$$

Table 63: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
km24	km24		2.588	mol	<input checked="" type="checkbox"/>

8.16 Reaction re16

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

Name GA9-GA3ox association

Reaction equation



Reactants

Table 64: Properties of each reactant.

Id	Name	SBO
s26	GA9	
s28	GA3ox	

Modifiers

Table 65: Properties of each modifier.

Id	Name	SBO
s26	GA9	
s28	GA3ox	

Product

Table 66: Properties of each product.

Id	Name	SBO
s29	GA9-GA3ox	

Kinetic Law

Derived unit mol³

$$v_{16} = ka9 \cdot s26 \cdot s28 \quad (37)$$

Table 67: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ka9	ka9		2073.224	mol	<input checked="" type="checkbox"/>

8.17 Reaction re17

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

Name GA9.GA3ox dissociation

Reaction equation



Reactant

Table 68: Properties of each reactant.

Id	Name	SBO
s29	GA9-GA3ox	

Modifier

Table 69: Properties of each modifier.

Id	Name	SBO
s29	GA9-GA3ox	

Products

Table 70: Properties of each product.

Id	Name	SBO
s26	GA9	
s28	GA3ox	

Kinetic Law

Derived unit mol²

$$v_{17} = kd9 \cdot s29 \quad (39)$$

Table 71: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
kd9	kd9		0.009	mol	<input checked="" type="checkbox"/>

8.18 Reaction re18

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

Name GA4 production

Reaction equation



Reactant

Table 72: Properties of each reactant.

Id	Name	SBO
s29	GA9-GA3ox	

Modifier

Table 73: Properties of each modifier.

Id	Name	SBO
s29	GA9-GA3ox	

Products

Table 74: Properties of each product.

Id	Name	SBO
s28	GA3ox	
s1	GA4	

Kinetic Law

Derived unit mol²

$$v_{18} = km9 \cdot s29 \quad (41)$$

Table 75: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
km9	km9		763.777	mol	<input checked="" type="checkbox"/>

8.19 Reaction re19

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name GA4.GID lid closing

Reaction equation



Reactant

Table 76: Properties of each reactant.

Id	Name	SBO
s65	GA4-GID	

Modifier

Table 77: Properties of each modifier.

Id	Name	SBO
s65	GA4-GID	

Product

Table 78: Properties of each product.

Id	Name	SBO
s62	GA4-GID-closed	

Kinetic Law

Derived unit mol²

$$v_{19} = q \cdot s65 \quad (43)$$

Table 79: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
q	q		0.025	mol	<input checked="" type="checkbox"/>

8.20 Reaction re20

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name GA4.GID-Closed lid opening

Reaction equation



Reactant

Table 80: Properties of each reactant.

Id	Name	SBO
s62	GA4-GID-closed	

Modifier

Table 81: Properties of each modifier.

Id	Name	SBO
s62	GA4-GID-closed	

Product

Table 82: Properties of each product.

Id	Name	SBO
s65	GA4-GID	

Kinetic Law

Derived unit mol²

$$v_{20} = p \cdot s62 \quad (45)$$

Table 83: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
p	p		0.078	mol	<input checked="" type="checkbox"/>

8.21 Reaction re21

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name della translation

Reaction equation



Reactant

Table 84: Properties of each reactant.

Id	Name	SBO
s7	DELLA_source	

Modifiers

Table 85: Properties of each modifier.

Id	Name	SBO
s40	della	
s40	della	

Product

Table 86: Properties of each product.

Id	Name	SBO
s16	DELLA	

Kinetic Law

Derived unit mol²

$$v_{21} = \text{deltaDELLA} \cdot s40$$

(47)

Table 87: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
deltaDELLA	deltaDELLA		$5.27749140286577 \cdot 10^{-4}$	mol	<input checked="" type="checkbox"/>

8.22 Reaction re22

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name ga20ox translation

Reaction equation



Reactant

Table 88: Properties of each reactant.

Id	Name	SBO
s6	GA20ox_source	

Modifiers

Table 89: Properties of each modifier.

Id	Name	SBO
s39	ga20ox	
s39	ga20ox	

Product

Table 90: Properties of each product.

Id	Name	SBO
s27	GA20ox	

Kinetic Law

Derived unit mol²

$$v_{22} = \text{deltaGA20ox} \cdot s39 \quad (49)$$

Table 91: Properties of each parameter.

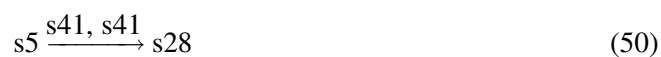
Id	Name	SBO	Value	Unit	Constant
deltaGA20ox	deltaGA20ox		0.193	mol	<input checked="" type="checkbox"/>

8.23 Reaction re23

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name ga3ox translation

Reaction equation



Reactant

Table 92: Properties of each reactant.

Id	Name	SBO
s5	GA3ox_source	

Modifiers

Table 93: Properties of each modifier.

Id	Name	SBO
s41	ga3ox	
s41	ga3ox	

Product

Table 94: Properties of each product.

Id	Name	SBO
s28	GA3ox	

Kinetic Law

Derived unit mol²

$$v_{23} = \text{deltaGA3ox} \cdot s41 \quad (51)$$

Table 95: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
deltaGA3ox	deltaGA3ox		0.019	mol	<input checked="" type="checkbox"/>

8.24 Reaction [re24](#)

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name gid translation

Reaction equation



Reactant

Table 96: Properties of each reactant.

Id	Name	SBO
s33	GID.source	

Modifiers

Table 97: Properties of each modifier.

Id	Name	SBO
s42	gid	
s42	gid	

Product

Table 98: Properties of each product.

Id	Name	SBO
s2	GID	

Kinetic Law

Derived unit mol²

$$v_{24} = \text{deltaGID} \cdot s42 \quad (53)$$

Table 99: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
deltaGID	deltaGA3ox		19.299	mol	<input checked="" type="checkbox"/>

8.25 Reaction re27

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name ga20ox transcription (activated by DELLA)

Reaction equation



Reactant

Table 100: Properties of each reactant.

Id	Name	SBO
s11	ga20ox_source	

Modifiers

Table 101: Properties of each modifier.

Id	Name	SBO
s16	DELLA	
s16	DELLA	

Product

Table 102: Properties of each product.

Id	Name	SBO
s39	ga20ox	

Kinetic Law

Derived unit mol

$$v_{25} = \frac{\text{muGA20ox} \cdot s_{16}}{s_{16} + \text{thetaGA20ox}} \quad (55)$$

Table 103: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
thetaGA20ox	thetaGA20ox		0.638	mol	<input checked="" type="checkbox"/>

8.26 Reaction re28

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name gid transcription (activated by DELLA)

Reaction equation



Reactant

Table 104: Properties of each reactant.

Id	Name	SBO
s15	gid_source	

Modifiers

Table 105: Properties of each modifier.

Id	Name	SBO
s16	DELLA	
s16	DELLA	

Product

Table 106: Properties of each product.

Id	Name	SBO
s42	gid	

Kinetic Law

Derived unit mol

$$v_{26} = \frac{\text{muGID} \cdot s_{16}}{s_{16} + \text{thetaGID}} \quad (57)$$

Table 107: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
thetaGID	thetaGID		$5.5995 \cdot 10^{-4}$	mol	<input checked="" type="checkbox"/>

8.27 Reaction re29

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name della transcription (repressed by DELLA)

Reaction equation



Reactant

Table 108: Properties of each reactant.

Id	Name	SBO
s34	della_source	

Modifiers

Table 109: Properties of each modifier.

Id	Name	SBO
s16	DELLA	
s16	DELLA	

Product

Table 110: Properties of each product.

Id	Name	SBO
s40	della	

Kinetic Law

Derived unit mol

$$v_{27} = \frac{\text{muDELLA} \cdot \text{thetaDELLA}}{\text{s16} + \text{thetaDELLA}} \quad (59)$$

Table 111: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
thetaDELLA	thetaDELLA		0.01	mol	<input checked="" type="checkbox"/>

8.28 Reaction re30

This is an irreversible reaction of one reactant forming one product influenced by two modifiers.

Name ga3ox transcription (activated by DELLA)

Reaction equation



Reactant

Table 112: Properties of each reactant.

Id	Name	SBO
s35	ga3ox_source	

Modifiers

Table 113: Properties of each modifier.

Id	Name	SBO
s16	DELLA	
s16	DELLA	

Id	Name	SBO
----	------	-----

Product

Table 114: Properties of each product.

Id	Name	SBO
s41	ga3ox	

Kinetic Law

Derived unit mol

$$v_{28} = \frac{\text{muGA3ox} \cdot \text{s16}}{\text{s16} + \text{thetaGA3ox}} \quad (61)$$

Table 115: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
thetaGA3ox	thetaGA3ox		0.008	mol	<input checked="" type="checkbox"/>

8.29 Reaction re31

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name della decay

Reaction equation



Reactant

Table 116: Properties of each reactant.

Id	Name	SBO
s40	della	

Modifier

Table 117: Properties of each modifier.

Id	Name	SBO
s40	della	

Product

Table 118: Properties of each product.

Id	Name	SBO
s34	della_source	

Kinetic Law

Derived unit mol²

$$v_{29} = \text{muDELLA} \cdot s_{40} \quad (63)$$

8.30 Reaction re32

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name gid decay

Reaction equation



Reactant

Table 119: Properties of each reactant.

Id	Name	SBO
s42	gid	

Modifier

Table 120: Properties of each modifier.

Id	Name	SBO
s42	gid	

Product

Table 121: Properties of each product.

Id	Name	SBO
s15	gid_source	

Kinetic Law

Derived unit mol²

$$v_{30} = \text{muGID} \cdot s_{42} \quad (65)$$

8.31 Reaction re33

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name ga20ox decay

Reaction equation



Reactant

Table 122: Properties of each reactant.

Id	Name	SBO
s39	ga20ox	

Modifier

Table 123: Properties of each modifier.

Id	Name	SBO
s39	ga20ox	

Product

Table 124: Properties of each product.

Id	Name	SBO
s11	ga20ox_source	

Kinetic Law**Derived unit** mol²

$$v_{31} = \text{muGA20ox} \cdot s_{39} \quad (67)$$

8.32 Reaction re34

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name ga3ox decay**Reaction equation****Reactant**

Table 125: Properties of each reactant.

Id	Name	SBO
s41	ga3ox	

Modifier

Table 126: Properties of each modifier.

Id	Name	SBO
s41	ga3ox	

Product

Table 127: Properties of each product.

Id	Name	SBO
s35	ga3ox_source	

Kinetic Law

Derived unit mol^2

$$v_{32} = \text{muGA3ox} \cdot s_{41} \quad (69)$$

8.33 Reaction re35

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name GA20ox decay

Reaction equation



Reactant

Table 128: Properties of each reactant.

Id	Name	SBO
s ₂₇	GA20ox	

Modifier

Table 129: Properties of each modifier.

Id	Name	SBO
s ₂₇	GA20ox	

Product

Table 130: Properties of each product.

Id	Name	SBO
s ₆	GA20ox_source	

Kinetic Law

Derived unit mol^2

$$v_{33} = \text{gammaGA20ox} \cdot s_{27} \quad (71)$$

Table 131: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gammaGA20ox	gammaGA20ox		3.514	mol	<input checked="" type="checkbox"/>

8.34 Reaction re37

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name GID decay

Reaction equation



Reactant

Table 132: Properties of each reactant.

Id	Name	SBO
s2	GID	

Modifier

Table 133: Properties of each modifier.

Id	Name	SBO
s2	GID	

Product

Table 134: Properties of each product.

Id	Name	SBO
s33	GID_source	

Kinetic Law

Derived unit mol²

$$v_{34} = \text{gammaGID} \cdot s2 \quad (73)$$

Table 135: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gammaGID	gammaGID		3.514	mol	<input checked="" type="checkbox"/>

8.35 Reaction re38

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name GA3ox decay

Reaction equation



Reactant

Table 136: Properties of each reactant.

Id	Name	SBO
s28	GA3ox	

Modifier

Table 137: Properties of each modifier.

Id	Name	SBO
s28	GA3ox	

Product

Table 138: Properties of each product.

Id	Name	SBO
s5	GA3ox_source	

Kinetic Law

Derived unit mol²

$$v_{35} = \text{gammaGA3ox} \cdot s28 \quad (75)$$

Table 139: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
gammaGA3ox	gammaGA3ox		3.514	mol	<input checked="" type="checkbox"/>

8.36 Reaction re39

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

Name GA4.GID-DELLA2 association

Reaction equation



Reactants

Table 140: Properties of each reactant.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Modifiers

Table 141: Properties of each modifier.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Product

Table 142: Properties of each product.

Id	Name	SBO
s36	GA4-GID-DELLA2	

Kinetic Law

Derived unit mol³

$$v_{36} = ua2 \cdot s62 \cdot s16 \quad (77)$$

Table 143: Properties of each parameter.

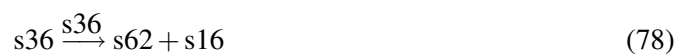
Id	Name	SBO	Value	Unit	Constant
ua2	ua2		316.228	mol	<input checked="" type="checkbox"/>

8.37 Reaction re40

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

Name GA4.GID.DELLA2 dissociation

Reaction equation



Reactant

Table 144: Properties of each reactant.

Id	Name	SBO
s36	GA4-GID-DELLA2	

Modifier

Table 145: Properties of each modifier.

Id	Name	SBO
s36	GA4-GID-DELLA2	

Products

Table 146: Properties of each product.

Id	Name	SBO
s62	GA4-GID-closed	
s16	DELLA	

Kinetic Law

Derived unit mol²

$$v_{37} = ud2 \cdot s36 \quad (79)$$

Table 147: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
ud2	ud2		2.818	mol	<input checked="" type="checkbox"/>

8.38 Reaction re41

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

Name GA4 supply

Reaction equation



Reactant

Table 148: Properties of each reactant.

Id	Name	SBO
s66	GA4_source	

Product

Table 149: Properties of each product.

Id	Name	SBO
s1	GA4	

Kinetic Law

Derived unit mol³

$$v_{38} = Pmem \cdot A1 \cdot omegaGA4 \quad (81)$$

Table 150: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
A1	A1		0.031	mol	<input checked="" type="checkbox"/>

8.39 Reaction [re42](#)

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name degradation of GA12

Reaction equation



Reactant

Table 151: Properties of each reactant.

Id	Name	SBO
s23	GA12	

Modifier

Table 152: Properties of each modifier.

Id	Name	SBO
s23	GA12	

Product

Table 153: Properties of each product.

Id	Name	SBO
s67	sa5_degraded	

Kinetic Law

Derived unit mol²

$$v_{39} = \text{muGA} \cdot s23 \quad (83)$$

8.40 Reaction re43

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name degradation of GA15

Reaction equation



Reactant

Table 154: Properties of each reactant.

Id	Name	SBO
s24	GA15	

Modifier

Table 155: Properties of each modifier.

Id	Name	SBO
s24	GA15	

Product

Table 156: Properties of each product.

Id	Name	SBO
s68	sa6_degraded	

Kinetic Law

Derived unit mol²

$$v_{40} = \text{muGA} \cdot s24 \quad (85)$$

8.41 Reaction re44

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name degradation of GA24

Reaction equation



Reactant

Table 157: Properties of each reactant.

Id	Name	SBO
s25	GA24	

Modifier

Table 158: Properties of each modifier.

Id	Name	SBO
s25	GA24	

Product

Table 159: Properties of each product.

Id	Name	SBO
s69	sa7_degraded	

Kinetic Law

Derived unit mol²

$$v_{41} = \text{muGA} \cdot s25$$

(87)

8.42 Reaction re45

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name degradation of GA9

Reaction equation



Reactant

Table 160: Properties of each reactant.

Id	Name	SBO
s26	GA9	

Modifier

Table 161: Properties of each modifier.

Id	Name	SBO
s26	GA9	

Product

Table 162: Properties of each product.

Id	Name	SBO
s70	sa8_degraded	

Kinetic Law

Derived unit mol²

$$v_{42} = \mu_{GA} \cdot s_{26} \quad (89)$$

8.43 Reaction re46

This is an irreversible reaction of one reactant forming one product influenced by one modifier.

Name degradation of GA4

Reaction equation



Reactant

Table 163: Properties of each reactant.

Id	Name	SBO
s1	GA4	

Modifier

Table 164: Properties of each modifier.

Id	Name	SBO
s1	GA4	

Product

Table 165: Properties of each product.

Id	Name	SBO
s71	sa1_degraded	

Kinetic Law

Derived unit mol²

$$v_{43} = (\text{muGA} + \text{Pmem} \cdot \text{B1}) \cdot \text{s1} \quad (91)$$

Table 166: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
B1	B1		$3.9795 \cdot 10^{-4}$	mol	<input checked="" type="checkbox"/>

9 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.

9.1 Species s1

Name GA4

Initial amount 0.01 mol

Charge 0

This species takes part in seven reactions (as a reactant in [re1](#), [re46](#) and as a product in [re2](#), [re18](#), [re41](#) and as a modifier in [re1](#), [re46](#)).

$$\frac{d}{dt}s1 = v_2 + v_{18} + v_{38} - v_1 - v_{43} \quad (92)$$

9.2 Species [s2](#)

Name GID

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in [re1](#), [re37](#) and as a product in [re2](#), [re24](#) and as a modifier in [re1](#), [re37](#)).

$$\frac{d}{dt}s2 = v_2 + v_{24} - v_1 - v_{34} \quad (93)$$

9.3 Species [s16](#)

Name DELLA

Initial amount 0.01 mol

Charge 0

This species takes part in 15 reactions (as a reactant in [re3](#), [re39](#) and as a product in [re4](#), [re21](#), [re40](#) and as a modifier in [re3](#), [re27](#), [re27](#), [re28](#), [re28](#), [re29](#), [re29](#), [re30](#), [re30](#), [re39](#)).

$$\frac{d}{dt}s16 = v_4 + v_{21} + v_{37} - v_3 - v_{36} \quad (94)$$

9.4 Species [s22](#)

Name DELLA_U

Initial amount 0.01 mol

Charge 0

This species takes part in one reaction (as a product in [re5](#)).

$$\frac{d}{dt}s22 = v_5 \quad (95)$$

9.5 Species s23

Name GA12

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in [re7](#), [re42](#) and as a product in [re6](#), [re8](#) and as a modifier in [re7](#), [re42](#)).

$$\frac{d}{dt}s_{23} = v_6 + v_8 - v_7 - v_{39} \quad (96)$$

9.6 Species s24

Name GA15

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in [re10](#), [re43](#) and as a product in [re9](#), [re11](#) and as a modifier in [re10](#), [re43](#)).

$$\frac{d}{dt}s_{24} = v_9 + v_{11} - v_{10} - v_{40} \quad (97)$$

9.7 Species s25

Name GA24

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in [re13](#), [re44](#) and as a product in [re12](#), [re14](#) and as a modifier in [re13](#), [re44](#)).

$$\frac{d}{dt}s_{25} = v_{12} + v_{14} - v_{13} - v_{41} \quad (98)$$

9.8 Species s26

Name GA9

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in [re16](#), [re45](#) and as a product in [re15](#), [re17](#) and as a modifier in [re16](#), [re45](#)).

$$\frac{d}{dt}s_{26} = v_{15} + v_{17} - v_{16} - v_{42} \quad (99)$$

9.9 Species s27

Name GA20ox

Initial amount 0.01 mol

Charge 0

This species takes part in 15 reactions (as a reactant in [re7](#), [re10](#), [re13](#), [re35](#) and as a product in [re8](#), [re9](#), [re11](#), [re12](#), [re14](#), [re15](#), [re22](#) and as a modifier in [re7](#), [re10](#), [re13](#), [re35](#)).

$$\frac{d}{dt}s_{27} = v_8 + v_9 + v_{11} + v_{12} + v_{14} + v_{15} + v_{22} - v_7 - v_{10} - v_{13} - v_{33} \quad (100)$$

9.10 Species s28

Name GA3ox

Initial amount 0.01 mol

Charge 0

This species takes part in seven reactions (as a reactant in [re16](#), [re38](#) and as a product in [re17](#), [re18](#), [re23](#) and as a modifier in [re16](#), [re38](#)).

$$\frac{d}{dt}s_{28} = v_{17} + v_{18} + v_{23} - v_{16} - v_{35} \quad (101)$$

9.11 Species s39

Name ga20ox

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re33](#) and as a product in [re27](#) and as a modifier in [re22](#), [re22](#), [re33](#)).

$$\frac{d}{dt}s_{39} = v_{25} - v_{31} \quad (102)$$

9.12 Species s40

Name della

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re31](#) and as a product in [re29](#) and as a modifier in [re21](#), [re21](#), [re31](#)).

$$\frac{d}{dt}s_{40} = v_{27} - v_{29} \quad (103)$$

9.13 Species s41

Name ga3ox

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in re34 and as a product in re30 and as a modifier in re23, re23, re34).

$$\frac{d}{dt}s_{41} = v_{28} - v_{32} \quad (104)$$

9.14 Species s42

Name gid

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in re32 and as a product in re28 and as a modifier in re24, re24, re32).

$$\frac{d}{dt}s_{42} = v_{26} - v_{30} \quad (105)$$

9.15 Species s65

Name GA4-GID

Initial amount 0.01 mol

Charge 0

This species takes part in six reactions (as a reactant in re2, re19 and as a product in re1, re20 and as a modifier in re2, re19).

$$\frac{d}{dt}s_{65} = v_1 + v_{20} - v_2 - v_{19} \quad (106)$$

9.16 Species s29

Name GA9-GA3ox

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in re17, re18 and as a product in re16 and as a modifier in re17, re18).

$$\frac{d}{dt}s_{29} = v_{16} - v_{17} - v_{18} \quad (107)$$

9.17 Species s30

Name GA24-GA20_{ox}

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re14](#), [re15](#) and as a product in [re13](#) and as a modifier in [re14](#), [re15](#)).

$$\frac{d}{dt}s30 = v_{13} - v_{14} - v_{15} \quad (108)$$

9.18 Species s31

Name GA15-GA20_{ox}

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re11](#), [re12](#) and as a product in [re10](#) and as a modifier in [re11](#), [re12](#)).

$$\frac{d}{dt}s31 = v_{10} - v_{11} - v_{12} \quad (109)$$

9.19 Species s32

Name GA12-GA20_{ox}

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re8](#), [re9](#) and as a product in [re7](#) and as a modifier in [re8](#), [re9](#)).

$$\frac{d}{dt}s32 = v_7 - v_8 - v_9 \quad (110)$$

9.20 Species s62

Name GA4-GID-closed

Initial amount 0.01 mol

Charge 0

This species takes part in ten reactions (as a reactant in [re3](#), [re20](#), [re39](#) and as a product in [re4](#), [re5](#), [re19](#), [re40](#) and as a modifier in [re3](#), [re20](#), [re39](#)).

$$\frac{d}{dt}s62 = v_4 + v_5 + v_{19} + v_{37} - v_3 - v_{20} - v_{36} \quad (111)$$

9.21 Species s3

Name GA12_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a reactant in [re6](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s3 = 0 \quad (112)$$

9.22 Species s5

Name GA3ox_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re23](#) and as a product in [re38](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s5 = 0 \quad (113)$$

9.23 Species s6

Name GA20ox_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re22](#) and as a product in [re35](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s6 = 0 \quad (114)$$

9.24 Species [s7](#)

Name DELLA_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a reactant in [re21](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s7 = 0 \quad (115)$$

9.25 Species [s33](#)

Name GID_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re24](#) and as a product in [re37](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s33 = 0 \quad (116)$$

9.26 Species [s11](#)

Name ga20ox_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re27](#) and as a product in [re33](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s11 = 0 \quad (117)$$

9.27 Species s15

Name gid_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re28](#) and as a product in [re32](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s_{15} = 0 \quad (118)$$

9.28 Species s34

Name della_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re29](#) and as a product in [re31](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s_{34} = 0 \quad (119)$$

9.29 Species s35

Name ga3ox_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in two reactions (as a reactant in [re30](#) and as a product in [re34](#)), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s_{35} = 0 \quad (120)$$

9.30 Species s36

Name GA4-GID-DELLA2

Initial amount 0.01 mol

Charge 0

This species takes part in three reactions (as a reactant in [re40](#) and as a product in [re39](#) and as a modifier in [re40](#)).

$$\frac{d}{dt}s_{36} = v_{36} - v_{37} \quad (121)$$

9.31 Species s45

Name GA4-GID-DELLA1

Initial amount 0.01 mol

Charge 0

This species takes part in five reactions (as a reactant in [re4](#), [re5](#) and as a product in [re3](#) and as a modifier in [re4](#), [re5](#)).

$$\frac{d}{dt}s_{45} = v_3 - v_4 - v_5 \quad (122)$$

9.32 Species s66

Name GA4_source

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a reactant in [re41](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s_{66} = 0 \quad (123)$$

9.33 Species s67

Name sa5_degraded

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a product in [re42](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s67 = 0 \quad (124)$$

9.34 Species s68

Name sa6_degraded

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a product in [re43](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s68 = 0 \quad (125)$$

9.35 Species s69

Name sa7_degraded

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a product in [re44](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s69 = 0 \quad (126)$$

9.36 Species s70

Name sa8_degraded

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a product in [re45](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s70 = 0 \quad (127)$$

9.37 Species s71

Name sa1_degraded

SBO:0000291 empty set

Initial amount 0 mol

Charge 0

This species takes part in one reaction (as a product in [re46](#)), which does not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{d}{dt}s71 = 0 \quad (128)$$

A Glossary of Systems Biology Ontology Terms

SBO:0000291 empty set: Entity defined by the absence of any actual object. An empty set is often used to represent the source of a creation process or the result of a degradation process.

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