SBML Model Report

Model name: “Grigolon2018 - Feedback Loop in ARF and IAA Response”

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1 General Overview

This is a document in SBML Level 2 Version 3 format. This model was created by the following three authors: Silvia Grigolon[1], Olivier Martin[2] and Barbara Bravi[3] at June seventh 2017 at 10:42 a. m. Table 1 provides an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

Element	Quantity	Element	Quantity
compartment types	0	compartments	1
species types	0	species	11
events	0	constraints	0
reactions	16	function definitions	0
global parameters	19	unit definitions	0
rules	0	initial assignments	0

Model Notes

Grigolon2018 - Feedback Loop in ARF and IAAResponse

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This model is described in the article:Responses to auxin signals: an operating principle for dynamical sensitivity yet high resilience.Grigolon S, Bravi B, Martin OC.R Soc Open Sci 2018 Jan; 5(1): 172098

Abstract:

Plants depend on the signalling of the phytohormone auxin for their development and for responding to environmental perturbations. The associated biomolecular signalling network involves a negative feedback on Aux/IAA proteins which mediate the influence of auxin (the signal) on the auxin response factor (ARF) transcription factors (the drivers of the response). To probe the role of this feedback, we consider alternative in silico signalling networks implementing different operating principles. By a comparative analysis, we find that the presence of a negative feedback allows the system to have a far larger sensitivity in its dynamical response to auxin and that this sensitivity does not prevent the system from being highly resilient. Given this insight, we build a new biomolecular signalling model for quantitatively describing such Aux/IAA and ARF responses.

This model is hosted on BioModels Database and identified by: MODEL1706070000.

To cite BioModels Database, please use: Chelliah V et al. BioModels: ten-year anniversary. Nucl. Acids Res. 2015, 43(Database issue):D542-8.

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`	Cell		3	1	litre	☑	

3.1 Compartment `Cell`

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

Name Cell

4 Species

This model contains eleven 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 7 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
aux	aux	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
IAAm	IAAm	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
IAAp	IAAp	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
ARF	ARF	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
null	null	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑
ARFIAA	ARFIAA	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
ARF2	ARF2	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
auxTIR1	auxTIR1	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
auxTIR1IAA	auxTIR1IAA	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
TIR1	TIR1	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
IAAstar	IAAstar	Cell	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐

5 Parameters

This model contains 19 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Sauxin	Sauxin		0.020		☑
muaux	muaux		0.100		☑
lambda1	lambda1		0.480		☑
thetaARF	thetaARF		100.000		☑
thetaARF2	thetaARF2		100.000		☑
thetaARFIAA	thetaARFIAA		100.000		☑
muIAAm	muIAAm		0.003		☑
muIAA	muIAA		0.003		☑
delta	delta		4.000		☑
qa	qa		0.500		☑
qd	qd		0.440		☑
pa	pa		1.000		☑
pd	pd		0.072		☑
ka	ka		$8.2 \cdot 10^{-4}$		☑
kd	kd		0.330		☑
la	la		5.750		☑
ld	ld		0.045		☑
lm	lm		0.900		☑
muIAAstar	muIAAstar		0.100		☑

6 Reactions

This model contains 16 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	auxin_production	auxin_production	$\text{null} \rightleftharpoons \text{aux}$	
2	auxin_degradation	auxin_degradation	$\text{aux} \rightleftharpoons \text{null}$	
3	mRNA_production	mRNA_production	$\text{null} \overset{\text{ARF, ARF2, ARFIAA}}{\rightleftharpoons} \text{IAAm}$	
4	mRNA_degradation	mRNA_degradation	$\text{IAAm} \rightleftharpoons \text{null}$	
5	IAA_degradation	IAA_degradation	$\text{IAAp} \rightleftharpoons \text{null}$	
6	mRNA_translation	mRNA_translation	$\text{IAAm} \rightleftharpoons \text{IAAm} + \text{IAAp}$	
7	ARF2_formation	ARF2_formation	$2\,\text{ARF} \rightleftharpoons \text{ARF2}$	
8	ARF2_dissociation	ARF2_dissociation	$\text{ARF2} \rightleftharpoons 2\,\text{ARF}$	
9	ARFIAA_formation	ARFIAA_formation	$\text{ARF} + \text{IAAp} \rightleftharpoons \text{ARFIAA}$	
10	ARFIAA_dissociation	ARFIAA_dissociation	$\text{ARFIAA} \rightleftharpoons \text{ARF} + \text{IAAp}$	
11	auxTIR1_formation	auxTIR1_formation	$\text{aux} + \text{TIR1} \rightleftharpoons \text{auxTIR1}$	
12	auxTIR1_dissociation	auxTIR1_dissociation	$\text{auxTIR1} \rightleftharpoons \text{aux} + \text{TIR1}$	

№	Id	Name	Reaction Equation	SBO
13	auxTIR1IAA-_formation	auxTIR1IAA_formation	auxTIR1 + IAAp $\rightleftharpoons$ auxTIR1IAA	
14	auxTIR1IAA-_dissociation	auxTIR1IAA_dissociation	auxTIR1IAA $\rightleftharpoons$ auxTIR1 + IAAp	
15	IAA-_ubiquitination	IAA_ubiquitination	auxTIR1IAA $\rightleftharpoons$ auxTIR1 + IAAstar	
16	IAAstar-_degradation	IAAstar_degradation	IAAstar $\rightleftharpoons$ null	

6.1 Reaction auxin_production

This is a reversible reaction of one reactant forming one product.

Name auxin_production

Reaction equation

$$\text{null} \rightleftharpoons \text{aux} \tag{1}$$

Reactant

Table 6: Properties of each reactant.

Id	Name	SBO
null	null	

Product

Table 7: Properties of each product.

Id	Name	SBO
aux	aux	

Kinetic Law

Derived unit not available

$$v_1 = \text{Sauxin} \tag{2}$$

6.2 Reaction auxin_degradation

This is a reversible reaction of one reactant forming one product.

Name auxin_degradation

Reaction equation

$$\text{aux} \rightleftharpoons \text{null} \tag{3}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
aux	aux	

Product

Table 9: Properties of each product.

Id	Name	SBO
null	null	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = [\text{aux}] \cdot \text{muaux} \tag{4}$$

6.3 Reaction mRNA_production

This is a reversible reaction of one reactant forming one product influenced by three modifiers.

Name mRNA_production

Reaction equation

$$\text{null} \xrightleftharpoons{\text{ARF, ARF2, ARFIAA}} \text{IAAm} \tag{5}$$

Reactant

Table 10: Properties of each reactant.

Id	Name	SBO
null	null	

Modifiers

Table 11: Properties of each modifier.

Id	Name	SBO
ARF	ARF	
ARF2	ARF2	
ARFIAA	ARFIAA	

Product

Table 12: Properties of each product.

Id	Name	SBO
IAAm	IAAm	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = [\mathrm{ARF}] \cdot \mathrm{lambda1} \cdot \big(\mathrm{thetaARF} \cdot \big([\mathrm{ARF}] \cdot \mathrm{thetaARF}^{-1} + [\mathrm{ARF2}] \cdot \mathrm{thetaARF2}^{-1} + [\mathrm{ARFIAA}] \cdot \mathrm{thetaARFIAA}^{-1} + 1\big)\big)^{-1} \tag{6}$$

6.4 Reaction mRNA_degradation

This is a reversible reaction of one reactant forming one product.

Name mRNA_degradation

Reaction equation

$$\mathrm{IAAm} \rightleftharpoons \mathrm{null} \tag{7}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
IAAm	IAAm	

Product

Table 14: Properties of each product.

Id	Name	SBO
null	null	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = [\text{IAAm}] \cdot \text{muIAAm} \tag{8}$$

6.5 Reaction IAA_degradation

This is a reversible reaction of one reactant forming one product.

Name IAA_degradation

Reaction equation

$$\text{IAAp} \rightleftharpoons \text{null} \tag{9}$$

Reactant

Table 15: Properties of each reactant.

Id	Name	SBO
IAAp	IAAp	

Product

Table 16: Properties of each product.

Id	Name	SBO
null	null	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = [\mathrm{IAAp}] \cdot \mathrm{muIAA} \tag{10}$$

6.6 Reaction `mRNA_translation`

This is a reversible reaction of one reactant forming two products.

Name mRNA_translation

Reaction equation

$$\mathrm{IAAm} \rightleftharpoons \mathrm{IAAm} + \mathrm{IAAp} \tag{11}$$

Reactant

Table 17: Properties of each reactant.

Id	Name	SBO
`IAAm`	IAAm	

Products

Table 18: Properties of each product.

Id	Name	SBO
`IAAm`	IAAm	
`IAAp`	IAAp	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{delta} \cdot [\mathrm{IAAm}] \tag{12}$$

6.7 Reaction `ARF2_formation`

This is a reversible reaction of one reactant forming one product.

Name ARF2_formation

Reaction equation

$$2\,\mathrm{ARF} \rightleftharpoons \mathrm{ARF2} \tag{13}$$

Reactant

Table 19: Properties of each reactant.

Id	Name	SBO
ARF	ARF	

Product

Table 20: Properties of each product.

Id	Name	SBO
ARF2	ARF2	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = [\mathrm{ARF}]^2 \cdot \mathrm{qa} \tag{14}$$

6.8 Reaction ARF2_dissociation

This is a reversible reaction of one reactant forming one product.

Name ARF2_dissociation

Reaction equation

$$\mathrm{ARF2} \rightleftharpoons 2\,\mathrm{ARF} \tag{15}$$

Reactant

Table 21: Properties of each reactant.

Id	Name	SBO
ARF2	ARF2	

Product

Table 22: Properties of each product.

Id	Name	SBO
ARF	ARF	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = [\text{ARF2}] \cdot \text{qd} \tag{16}$$

6.9 Reaction ARFIAA_formation

This is a reversible reaction of two reactants forming one product.

Name ARFIAA_formation

Reaction equation

$$\text{ARF} + \text{IAAp} \rightleftharpoons \text{ARFIAA} \tag{17}$$

Reactants

Table 23: Properties of each reactant.

Id	Name	SBO
ARF	ARF	
IAAp	IAAp	

Product

Table 24: Properties of each product.

Id	Name	SBO
ARFIAA	ARFIAA	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = [\text{ARF}] \cdot [\text{IAAp}] \cdot \text{pa} \tag{18}$$

6.10 Reaction ARFIAA_dissociation

This is a reversible reaction of one reactant forming two products.

Name ARFIAA_dissociation

Reaction equation

$$\mathrm{ARFIAA} \rightleftharpoons \mathrm{ARF} + \mathrm{IAAp} \tag{19}$$

Reactant

Table 25: Properties of each reactant.

Id	Name	SBO
ARFIAA	ARFIAA	

Products

Table 26: Properties of each product.

Id	Name	SBO
ARF	ARF	
IAAp	IAAp	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = [\mathrm{ARFIAA}] \cdot \mathrm{pd} \tag{20}$$

6.11 Reaction auxTIR1_formation

This is a reversible reaction of two reactants forming one product.

Name auxTIR1_formation

Reaction equation

$$\mathrm{aux} + \mathrm{TIR1} \rightleftharpoons \mathrm{auxTIR1} \tag{21}$$

Reactants

Table 27: Properties of each reactant.

Id	Name	SBO
aux	aux	
TIR1	TIR1	

Product

Table 28: Properties of each product.

Id	Name	SBO
auxTIR1	auxTIR1	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = [\text{aux}] \cdot \text{ka} \cdot [\text{TIR1}] \tag{22}$$

6.12 Reaction auxTIR1_dissociation

This is a reversible reaction of one reactant forming two products.

Name auxTIR1_dissociation

Reaction equation

$$\text{auxTIR1} \rightleftharpoons \text{aux} + \text{TIR1} \tag{23}$$

Reactant

Table 29: Properties of each reactant.

Id	Name	SBO
auxTIR1	auxTIR1	

Products

Table 30: Properties of each product.

Id	Name	SBO
aux	aux	
TIR1	TIR1	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = [\text{auxTIR1}] \cdot \text{kd} \tag{24}$$

6.13 Reaction auxTIR1IAA_formation

This is a reversible reaction of two reactants forming one product.

Name auxTIR1IAA_formation

Reaction equation

$$\text{auxTIR1} + \text{IAAp} \rightleftharpoons \text{auxTIR1IAA} \tag{25}$$

Reactants

Table 31: Properties of each reactant.

Id	Name	SBO
auxTIR1	auxTIR1	
IAAp	IAAp	

Product

Table 32: Properties of each product.

Id	Name	SBO
auxTIR1IAA	auxTIR1IAA	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = [\text{auxTIR1}] \cdot [\text{IAAp}] \cdot \text{la} \tag{26}$$

6.14 Reaction auxTIR1IAA_dissociation

This is a reversible reaction of one reactant forming two products.

Name auxTIR1IAA_dissociation

Reaction equation

$$\text{auxTIR1IAA} \rightleftharpoons \text{auxTIR1} + \text{IAAp} \tag{27}$$

Reactant

Table 33: Properties of each reactant.

Id	Name	SBO
auxTIR1IAA	auxTIR1IAA	

Products

Table 34: Properties of each product.

Id	Name	SBO
auxTIR1 IAAp	auxTIR1 IAAp	

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = [\text{auxTIR1IAA}] \cdot \text{ld} \tag{28}$$

6.15 Reaction IAA_ubiquitination

This is a reversible reaction of one reactant forming two products.

Name IAA_ubiquitination

Reaction equation

$$\text{auxTIR1IAA} \rightleftharpoons \text{auxTIR1} + \text{IAAstar} \tag{29}$$

Reactant

Table 35: Properties of each reactant.

Id	Name	SBO
auxTIR1IAA	auxTIR1IAA	

Products

Table 36: Properties of each product.

Id	Name	SBO
auxTIR1	auxTIR1	
IAAstar	IAAstar	

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = [\text{auxTIR1IAA}] \cdot \text{lm} \tag{30}$$

6.16 Reaction IAAstar_degradation

This is a reversible reaction of one reactant forming one product.

Name IAAstar_degradation

Reaction equation

$$\text{IAAstar} \rightleftharpoons \text{null} \tag{31}$$

Reactant

Table 37: Properties of each reactant.

Id	Name	SBO
IAAstar	IAAstar	

Product

Table 38: Properties of each product.

Id	Name	SBO
null	null	

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = [\text{IAAstar}] \cdot \text{muIAAstar} \tag{32}$$

7 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

Identifiers for kinetic laws highlighted in gray cannot be verified to evaluate to units of SBML `substance` per `time`. As a result, some SBML interpreters may not be able to verify the consistency of the units on quantities in the model. Please check if

- parameters without an unit definition are involved or
- volume correction is necessary because the `hasOnlySubstanceUnits` flag may be set to `false` and `spacialDimensions`> 0 for certain species.

7.1 Species aux

Name aux

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

This species takes part in four reactions (as a reactant in auxin_degradation, auxTIR1_formation and as a product in auxin_production, auxTIR1_dissociation).

$$\frac{\text{d}}{\text{d}t}\text{aux} = v_1 + v_{12} - v_2 - v_{11} \tag{33}$$

7.2 Species IAAm

Name IAAm

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

This species takes part in four reactions (as a reactant in mRNA_degradation, mRNA_translation and as a product in mRNA_production, mRNA_translation).

$$\frac{\text{d}}{\text{d}t}\text{IAAm} = v_3 + v_6 - v_4 - v_6 \tag{34}$$

7.3 Species IAAp

Name IAAp

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

This species takes part in six reactions (as a reactant in IAA_degradation, ARFIAA_formation, auxTIR1IAA_formation and as a product in mRNA_translation, ARFIAA_dissociation, auxTIR1IAA_dissociation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAAp} = v_6 + v_{10} + v_{14} - v_5 - v_9 - v_{13} \tag{35}$$

7.4 Species ARF

Name ARF

Initial concentration $10\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in ARF2_formation, ARFIAA_formation and as a product in ARF2_dissociation, ARFIAA_dissociation and as a modifier in mRNA_production).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARF} = 2\,v_8 + v_{10} - 2\,v_7 - v_9 \tag{36}$$

7.5 Species null

Name null

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

This species takes part in six reactions (as a reactant in auxin_production, mRNA_production and as a product in auxin_degradation, mRNA_degradation, IAA_degradation, IAAstar_degradation), which do not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{null} = 0 \tag{37}$$

7.6 Species ARFIAA

Name ARFIAA

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

This species takes part in three reactions (as a reactant in ARFIAA_dissociation and as a product in ARFIAA_formation and as a modifier in mRNA_production).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARFIAA} = v_9 - v_{10} \tag{38}$$

7.7 Species ARF2

Name ARF2

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

This species takes part in three reactions (as a reactant in ARF2_dissociation and as a product in ARF2_formation and as a modifier in mRNA_production).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARF2} = v_7 - v_8 \tag{39}$$

7.8 Species auxTIR1

Name auxTIR1

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

This species takes part in five reactions (as a reactant in auxTIR1_dissociation, auxTIR1IAA_formation and as a product in auxTIR1_formation, auxTIR1IAA_dissociation, IAA_ubiquitination).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{auxTIR1} = v_{11} + v_{14} + v_{15} - v_{12} - v_{13} \tag{40}$$

7.9 Species auxTIR1IAA

Name auxTIR1IAA

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

This species takes part in three reactions (as a reactant in auxTIR1IAA_dissociation, IAA_ubiquitination and as a product in auxTIR1IAA_formation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{auxTIR1IAA} = v_{13} - v_{14} - v_{15} \tag{41}$$

7.10 Species TIR1

Name TIR1

Initial concentration $18.51\ \mathrm{mol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in auxTIR1_formation and as a product in auxTIR1_dissociation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TIR1} = v_{12} - v_{11} \tag{42}$$

7.11 Species IAAstar

Name IAAstar

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

This species takes part in two reactions (as a reactant in IAAstar_degradation and as a product in IAA_ubiquitination).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAAstar} = v_{15} - v_{16} \tag{43}$$

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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