SBML Model Report

Model name: "Muraro2014 - Vascular patterning in Arabidopsis roots"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following three authors: Vijayalakshmi Chelliah[1], Daniele Muraro[2] and Nathan Mellor[3] at March eleventh 2014 at 3:56 p. m. and last time modified at March twelveth 2014 at 12:15 a. m. Table 1 shows an overview of the quantities of all components of this model.

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

Element	Quantity	Element	Quantity
compartment types	0	compartments	1
species types	0	species	16
events	0	constraints	0
reactions	0	function definitions	0
global parameters	69	unit definitions	0
rules	22	initial assignments	0

Model Notes

Muraro2014 - Vascular patterning in Arabidopsis roots

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Using a multicellular model, maintanence of vascular patterning in Arabidopsis roots has been studied. The model that is provided here is the single-cell version of the model. The two-cell and multicellular models described in the paper can be downloaded as python scripts (follow the curation tab to get these files).

This model is described in the article:Integration of hormonal signaling networks and mobile microRNAs is required for vascular patterning in Arabidopsis roots.Muraro D, Mellor N, Pound MP, Help H, Lucas M, Chopard J, Byrne HM, Godin C, Hodgman TC, King JR, Pridmore TP, Helariutta Y, Bennett MJ, Bishopp A.Proc Natl Acad Sci U S A. 2014 Jan 14;111(2):857-62.

Abstract:

As multicellular organisms grow, positional information is continually needed to regulate the pattern in which cells are arranged. In the Arabidopsis root, most cell types are organized in a radially symmetric pattern; however, a symmetry-breaking event generates bisymmetric auxin and cytokinin signaling domains in the stele. Bidirectional cross-talk between the stele and the surrounding tissues involving a mobile transcription factor, SHORT ROOT (SHR), and mobile microRNA species also determines vascular pattern, but it is currently unclear how these signals integrate. We use a multicellular model to determine a minimal set of components necessary for maintaining a stable vascular pattern. Simulations perturbing the signaling network show that, in addition to the mutually inhibitory interaction between auxin and cytokinin, signaling through SHR, microRNA165/6, and PHABULOSA is required to maintain a stable bisymmetric pattern. We have verified this prediction by observing loss of bisymmetry in shr mutants. The model reveals the importance of several features of the network, namely the mutual degradation of microRNA165/6 and PHABULOSA and the existence of an additional negative regulator of cytokinin signaling. These components form a plausible mechanism capable of patterning vascular tissues in the absence of positional inputs provided by the transport of hormones from the shoot.

This model is hosted on BioModels Database and identifiedby: BIOMD0000000522 .

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resourcefor published quantitative kinetic models .

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
`compartment`	compartment	0000290	3	1	litre	☑	

3.1 Compartment `compartment`

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

Name compartment

SBO:0000290 physical compartment

4 Species

This model contains 16 species. 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
Auxin	Auxin	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
Cytokinin	Cytokinin	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
AHP6m	AHP6m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
AHP6p	AHP6p	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
IAA2m	IAA2m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
IAA2p	IAA2p	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
ARR5m	ARR5m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
ARR5p	ARR5p	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
PHBm	PHBm	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
PHBp	PHBp	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
CKX3m	CKX3m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
CKX3p	CKX3p	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
PIN3m	PIN3m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
PIN1m	PIN1m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
PIN7m	PIN7m	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐
miRNA	miRNA	compartment	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☐

5 Parameters

This model contains 69 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
F_AHP6	F_AHP6		0.00		☐
F_CK	F_CK		0.00		☐
F_IAA2	F_IAA2		0.00		☐
F_ARR5	F_ARR5		0.00		☐
F_PIN1	F_PIN1		0.00		☐
F_PIN7	F_PIN7		0.00		☐
F_PIN3	F_PIN3		0.00		☐
p_ax	p_ax		0.06		☑
p_ck	p_ck		2.00		☑
d_ax	d_ax		1.00		☑
d_ck	d_ck		10.00		☑
phloem_rate_ax	phloem_rate_ax		1.00		☑
all_section_rate_ax	all_section_rate_ax		1.00		☑
phloem_rate_ck	phloem_rate_ck		1.00		☑
all_section_rate_ck	all_section_rate_ck		1.00		☑
lambda_AHP6	lambda_AHP6		2.00		☑
lambda_IAA2	lambda_IAA2		10.00		☑
lambda_ARR5	lambda_ARR5		20.00		☑
lambda_PIN1	lambda_PIN1		0.00		☑
lambda_PIN3	lambda_PIN3		0.00		☑
lambda_PIN7	lambda_PIN7		1.00		☑
mu_m_PHB	mu_m_PHB		1.00		☑
mu_m_AHP6	mu_m_AHP6		1.00		☑
mu_m_IAA2	mu_m_IAA2		10.00		☑
mu_m_ARR5	mu_m_ARR5		10.00		☑
mu_m_PIN1	mu_m_PIN1		0.00		☑
mu_m_PIN3	mu_m_PIN3		0.00		☑
mu_m_PIN7	mu_m_PIN7		1.00		☑
delta_PHB	delta_PHB		1.00		☑
delta_AHP6	delta_AHP6		1.00		☑
delta_IAA2	delta_IAA2		10.00		☑
delta_ARR5	delta_ARR5		10.00		☑
delta_PIN1	delta_PIN1		0.00		☑

Id	Name	SBO	Value	Unit	Constant
delta_PIN3	delta_PIN3		0.00		☑
delta_PIN7	delta_PIN7		5.00		☑
delta_CKX3	delta_CKX3		1.00		☑
mu_p_PHB	mu_p_PHB		1.00		☑
mu_p_AHP6	mu_p_AHP6		1.00		☑
mu_p_IAA2	mu_p_IAA2		10.00		☑
mu_p_ARR5	mu_p_ARR5		10.00		☑
mu_p_PIN1	mu_p_PIN1		0.00		☑
mu_p_PIN3	mu_p_PIN3		0.00		☑
mu_p_PIN7	mu_p_PIN7		1.00		☑
mu_p_CKX3	mu_p_CKX3		1.00		☑
theta_Ax	theta_Ax		0.25		☑
theta_Ck	theta_Ck		0.50		☑
theta_AHP6	theta_AHP6		0.04		☑
theta_ARR5	theta_ARR5		0.10		☑
theta_PHB	theta_PHB		0.40		☑
theta_CKX3	theta_CKX3		0.05		☑
p_phb	p_phb		2.00		☑
d_phb	d_phb		1.00		☑
p_mirna	p_mirna		32.50		☑
d_mirna	d_mirna		1.00		☑
d_mirna_mrna	d_mirna_mrna		10.00		☑
p_ckx3	p_ckx3		5.00		☑
d_ckx3	d_ckx3		1.00		☑
b_pin3	b_pin3		1.00		☑
b_pin1	b_pin1		0.00		☑
b_pin7	b_pin7		0.00		☑
b_ahp6	b_ahp6		0.00		☑
b_arr5	b_arr5		0.00		☑
b_iaa2	b_iaa2		0.00		☑
hill_ax	hill_ax		2.00		☑
hill_ck	hill_ck		2.00		☑
hill_arr5	hill_arr5		3.00		☑
hill_ckx3	hill_ckx3		5.00		☑
hill_ahp6	hill_ahp6		3.00		☑
hill_phb	hill_phb		3.00		☑

6 Rules

This is an overview of 22 rules.

6.1 Rule F_AHP6

Rule F_AHP6 is an assignment rule for parameter F_AHP6:

$$\text{F\_AHP6} = \frac{\text{b\_ahp6} + \left(\frac{[\text{Auxin}]}{\text{theta\_Ax}}\right)^{\text{hill\_ax}}}{1 + \left(\frac{[\text{Auxin}]}{\text{theta\_Ax}}\right)^{\text{hill\_ax}} + \left(\frac{[\text{PHBp}]}{\text{theta\_PHB}}\right)^{\text{hill\_phb}}} \tag{1}$$

6.2 Rule F_ARR5

Rule F_ARR5 is an assignment rule for parameter F_ARR5:

$$\text{F\_ARR5} = \frac{\text{b\_arr5} + \left(\frac{[\text{Cytokinin}]}{\text{theta\_Ck}}\right)^{\text{hill\_ck}}}{1 + \left(\frac{[\text{Cytokinin}]}{\text{theta\_Ck}}\right)^{\text{hill\_ck}} + \left(\frac{[\text{AHP6p}]}{\text{theta\_AHP6}}\right)^{\text{hill\_ahp6}}} \tag{2}$$

6.3 Rule F_CK

Rule F_CK is an assignment rule for parameter F_CK:

$$\text{F\_CK} = \frac{1}{1 + \left(\frac{[\text{CKX3p}]}{\text{theta\_CKX3}}\right)^{\text{hill\_ckx3}}} \tag{3}$$

6.4 Rule F_IAA2

Rule F_IAA2 is an assignment rule for parameter F_IAA2:

$$\text{F\_IAA2} = \frac{\text{b\_iaa2} + \left(\frac{[\text{Auxin}]}{\text{theta\_Ax}}\right)^{\text{hill\_ax}}}{1 + \left(\frac{[\text{Auxin}]}{\text{theta\_Ax}}\right)^{\text{hill\_ax}}} \tag{4}$$

6.5 Rule F_PIN1

Rule F_PIN1 is an assignment rule for parameter F_PIN1:

$$\text{F\_PIN1} = \frac{\text{b\_pin1} + \left(\frac{[\text{ARR5p}]}{\text{theta\_ARR5}}\right)^{\text{hill\_arr5}}}{1 + \left(\frac{[\text{ARR5p}]}{\text{theta\_ARR5}}\right)^{\text{hill\_arr5}}} \tag{5}$$

6.6 Rule F_PIN3

Rule F_PIN3 is an assignment rule for parameter F_PIN3:

$$\text{F\_PIN3} = \text{b\_pin3} \tag{6}$$

6.7 Rule F_PIN7

Rule F_PIN7 is an assignment rule for parameter F_PIN7:

$$\text{F\_PIN7} = \frac{\text{b\_pin7} + \left(\frac{[\text{ARR5p}]}{\text{theta\_ARR5}}\right)^{\text{hill\_arr5}}}{1 + \left(\frac{[\text{ARR5p}]}{\text{theta\_ARR5}}\right)^{\text{hill\_arr5}}} \tag{7}$$

6.8 Rule Auxin

Rule Auxin is a rate rule for species Auxin:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Auxin} = \text{phloem\_rate\_ax} \cdot \text{p\_ax} - \text{d\_ax} \cdot [\text{Auxin}] \tag{8}$$

6.9 Rule Cytokinin

Rule Cytokinin is a rate rule for species Cytokinin:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Cytokinin} = \text{phloem\_rate\_ck} \cdot \text{p\_ck} \cdot \text{F\_CK} - \text{d\_ck} \cdot [\text{Cytokinin}] \tag{9}$$

6.10 Rule miRNA

Rule miRNA is a rate rule for species miRNA:

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

6.11 Rule PHBm

Rule PHBm is a rate rule for species PHBm:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{PHBm} = \text{p\_phb} - \text{d\_phb} \cdot [\text{PHBm}] - \text{d\_mirna\_mrna} \cdot [\text{PHBm}] \cdot [\text{miRNA}] \tag{11}$$

6.12 Rule AHP6m

Rule AHP6m is a rate rule for species AHP6m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{AHP6m} = \text{lambda\_AHP6} \cdot \text{F\_AHP6} - \text{mu\_m\_AHP6} \cdot [\text{AHP6m}] \tag{12}$$

6.13 Rule IAA2m

Rule IAA2m is a rate rule for species IAA2m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{IAA2m} = \text{lambda\_IAA2} \cdot \text{F\_IAA2} - \text{mu\_m\_IAA2} \cdot [\text{IAA2m}] \tag{13}$$

6.14 Rule ARR5m

Rule ARR5m is a rate rule for species ARR5m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARR5m} = \mathrm{lambda\_ARR5} \cdot \mathrm{F\_ARR5} - \mathrm{mu\_m\_ARR5} \cdot [\mathrm{ARR5m}] \tag{14}$$

6.15 Rule PIN1m

Rule PIN1m is a rate rule for species PIN1m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PIN1m} = \mathrm{lambda\_PIN1} \cdot \mathrm{F\_PIN1} - \mathrm{mu\_m\_PIN1} \cdot [\mathrm{PIN1m}] \tag{15}$$

6.16 Rule PIN3m

Rule PIN3m is a rate rule for species PIN3m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PIN3m} = \mathrm{lambda\_PIN3} \cdot \mathrm{F\_PIN3} - \mathrm{mu\_m\_PIN3} \cdot [\mathrm{PIN3m}] \tag{16}$$

6.17 Rule PIN7m

Rule PIN7m is a rate rule for species PIN7m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PIN7m} = \mathrm{lambda\_PIN7} \cdot \mathrm{F\_PIN7} - \mathrm{mu\_m\_PIN7} \cdot [\mathrm{PIN7m}] \tag{17}$$

6.18 Rule AHP6p

Rule AHP6p is a rate rule for species AHP6p:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{AHP6p} = \mathrm{delta\_AHP6} \cdot [\mathrm{AHP6m}] - \mathrm{mu\_p\_AHP6} \cdot [\mathrm{AHP6p}] \tag{18}$$

6.19 Rule IAA2p

Rule IAA2p is a rate rule for species IAA2p:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IAA2p} = \mathrm{delta\_IAA2} \cdot [\mathrm{IAA2m}] - \mathrm{mu\_p\_IAA2} \cdot [\mathrm{IAA2p}] \tag{19}$$

6.20 Rule ARR5p

Rule ARR5p is a rate rule for species ARR5p:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ARR5p} = \mathrm{delta\_ARR5} \cdot [\mathrm{ARR5m}] - \mathrm{mu\_p\_ARR5} \cdot [\mathrm{ARR5p}] \tag{20}$$

6.21 Rule PHBp

Rule PHBp is a rate rule for species PHBp:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PHBp} = \mathrm{delta\_PHB} \cdot [\mathrm{PHBm}] - \mathrm{mu\_p\_PHB} \cdot [\mathrm{PHBp}] \tag{21}$$

6.22 Rule CKX3p

Rule CKX3p is a rate rule for species CKX3p:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CKX3p} = \mathrm{delta\_CKX3} \cdot [\mathrm{CKX3m}] - \mathrm{mu\_p\_CKX3} \cdot [\mathrm{CKX3p}] \tag{22}$$

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.

7.1 Species Auxin

Name Auxin

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

Involved in rule Auxin

One rule which determines this species' quantity.

7.2 Species Cytokinin

Name Cytokinin

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

Involved in rule Cytokinin

One rule which determines this species' quantity.

7.3 Species AHP6m

Name AHP6m

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

Involved in rule AHP6m

One rule which determines this species' quantity.

7.4 Species AHP6p

Name AHP6p

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

Involved in rule AHP6p

One rule which determines this species' quantity.

7.5 Species IAA2m

Name IAA2m

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

Involved in rule IAA2m

One rule which determines this species' quantity.

7.6 Species IAA2p

Name IAA2p

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

Involved in rule IAA2p

One rule which determines this species' quantity.

7.7 Species ARR5m

Name ARR5m

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

Involved in rule ARR5m

One rule which determines this species' quantity.

7.8 Species ARR5p

Name ARR5p

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

Involved in rule ARR5p

One rule which determines this species' quantity.

7.9 Species PHBm

Name PHBm

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

Involved in rule PHBm

One rule which determines this species' quantity.

7.10 Species PHBp

Name PHBp

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

Involved in rule PHBp

One rule which determines this species' quantity.

7.11 Species CKX3m

Name CKX3m

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

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CKX3m} = 0 \tag{23}$$

7.12 Species CKX3p

Name CKX3p

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

Involved in rule CKX3p

One rule which determines this species' quantity.

7.13 Species PIN3m

Name PIN3m

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

Involved in rule PIN3m

One rule which determines this species' quantity.

7.14 Species PIN1m

Name PIN1m

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

Involved in rule PIN1m

One rule which determines this species' quantity.

7.15 Species PIN7m

Name PIN7m

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

Involved in rule PIN7m

One rule which determines this species' quantity.

7.16 Species miRNA

Name miRNA

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

Involved in rule miRNA

One rule which determines this species' quantity.

A Glossary of Systems Biology Ontology Terms

SBO:0000290 physical compartment: Specific location of space, that can be bounded or not. A physical compartment can have 1, 2 or 3 dimensions

SBML2LaTeX was developed by Andreas Dräger[a], Hannes Planatscher[a], Dieudonné M Wouamba[a], Adrian Schröder[a], Michael Hucka[b], Lukas Endler[c], Martin Golebiewski[d] and Andreas Zell[a]. Please see http://www.ra.cs.uni-tuebingen.de/software/SBML2LaTeX for more information.

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