SBML Model Report

Model name: “Voit2003_Trehalose_Cycle”

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: Lukas Endler[1] and Kieran Smallbone[2] at July 20th 2010 at no o’ clock in the morning. and last time modified at June fifth 2013 at 3:47 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	2
species types	0	species	8
events	0	constraints	0
reactions	0	function definitions	0
global parameters	29	unit definitions	4
rules	28	initial assignments	0

Model Notes

This is the S systems model described in the article:
Biochemical and genomic regulation of the trehalose cycle in yeast: review of observations and canonical model analysis
Eberhard O Voit, J Theor Biol 2003 223:55-78 PubmedID: 12782117 ; DOI: 10.1016/S0022-5193(03)00072-9

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Abstract:
The physiological hallmark of heat-shock response in yeast is a rapid, enormous increase in the concentration of trehalose. Normally found in growing yeast cells and other organisms only as traces, trehalose becomes a crucial protector of proteins and membranes against a variety of stresses, including heat, cold, starvation, desiccation, osmotic or oxidative stress, and exposure to toxicants. Trehalose is produced from glucose 6-phosphate and uridine diphosphate glucose in a two-step process, and recycled to glucose by trehalases. Even though the trehalose cycle consists of only a few metabolites and enzymatic steps, its regulatory structure and operation are surprisingly complex. The article begins with a review of experimental observations on the regulation of the trehalose cycle in yeast and proposes a canonical model for its analysis. The first part of this analysis demonstrates the benefits of the various regulatory features by means of controlled comparisons with models of otherwise equivalent pathways lacking these features. The second part elucidates the significance of the expression pattern of the trehalose cycle genes in response to heat shock. Interestingly, the genes contributing to trehalose formation are up-regulated to very different degrees, and even the trehalose degrading trehalases show drastically increased activity during heat-shock response. Again using the method of controlled comparisons, the model provides rationale for the observed pattern of gene expression and reveals benefits of the counterintuitive trehalase up-regulation.

To induce a heat shock, set the parameter heat_shock from 0 to 1. This changess the parameter values of X8 to X19 from 1 to the values given in table 3 of th eoriginal publication.
As this is an S-systems model, it does not contain any reactions encoded in SBML.

2 Unit Definitions

This is an overview of seven unit definitions of which three are predefined by SBML and not mentioned in the model.

2.1 Unit substance

Name milimole

Definition mmol

2.2 Unit time

Name minutes

Definition 60 s

2.3 Unit flux

Name mM per minute

Definition $\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$

2.4 Unit `mM`

Name mM

Definition $\mathrm{mmol} \cdot \mathrm{l}^{-1}$

2.5 Unit `volume`

Notes Litre is the predefined SBML unit for `volume`.

Definition l

2.6 Unit `area`

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

Definition m^2

2.7 Unit `length`

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

Definition m

3 Compartments

This model contains two compartments.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
`cell`	cell	0000290	3	1	litre	☑	`external`
`external`	external		3	1	litre	☑	

3.1 Compartment `cell`

This is a three dimensional compartment with a constant size of one litre, which is surrounded by `external` (external).

Name cell

SBO:0000290 physical compartment

3.2 Compartment `external`

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

Name external

4 Species

This model contains eight species. The boundary condition of eight of these species is set to `true` so that these 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
`X0`	glucose	`external`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X1`	glucose	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X2`	G6P	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X3`	G1P	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X4`	UDPG	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X5`	glycogen	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X6`	T6P	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑
`X7`	trehalose	`cell`	$\text{mmol} \cdot \text{l}^{-1}$	☐	☑

5 Parameters

This model contains 29 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
heat_shock			0.0	dimensionless	☑
X8	glucose transport into cell		0.0	dimensionless	☐
X9	hexokinase/glucokinase		0.0	dimensionless	☐
X10	phosphofructokinase		0.0	dimensionless	☐
X11	G6P dehydrogenase		0.0	dimensionless	☐
X12r	phoshpoglucomutase		0.0	dimensionless	☐
X12f	phoshpoglucomutase		0.0	dimensionless	☐
X13	UDPG pyrophosphorylase		0.0	dimensionless	☐
X14	glycogen synthase		0.0	dimensionless	☐
X15r	glycogen phosphorylase		0.0	dimensionless	☐
X15f	glycogen phosphorylase		0.0	dimensionless	☐
X16	glycogen use		0.0	dimensionless	☐
X17	alpha,alpha-T6P synthase		0.0	dimensionless	☐
X18	alpha,alpha–T6P phosphatase		0.0	dimensionless	☐
X19	trehalase		0.0	dimensionless	☐
flux_X1_in	flux_to_glucose		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X1_out	flux_from_glucose		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X2_in	flux_to_G6P		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X2_out	flux_from_G6P		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X3_in	flux_to_G1P		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X3_out	flux_from_G1P		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X4_in	flux_to_UDPG		0.0	$\mathrm{mmol} \cdot (60\,\mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐

Id	Name	SBO	Value	Unit	Constant
flux_X4_out	flux_from_UDPG		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X5_in	flux_to_glycogen		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X5_out	flux_from-_glucogen		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X6_in	flux_to_T6P		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X6_out	flux_from_T6P		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X7_in	flux_to_trehalose		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐
flux_X7_out	flux_from-_trehalose		0.0	$\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$	☐

6 Rules

This is an overview of 28 rules.

6.1 Rule flux_X1_in

Rule flux_X1_in is an assignment rule for parameter flux_X1_in:

$$\mathrm{flux\_X1\_in} = 31.912 \cdot [\mathrm{X0}]^{0.968} \cdot [\mathrm{X2}]^{-0.194} \cdot [\mathrm{X7}]^{0.00968} \cdot \mathrm{X8}^{0.968} \cdot \mathrm{X19}^{0.0323} \quad (1)$$

6.2 Rule flux_X1_out

Rule flux_X1_out is an assignment rule for parameter flux_X1_out:

$$\mathrm{flux\_X1\_out} = 89.935 \cdot [\mathrm{X1}]^{0.75} \cdot [\mathrm{X6}]^{-0.4} \cdot \mathrm{X9} \quad (2)$$

6.3 Rule X1

Rule X1 is a rate rule for species X1:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{X1} = \mathrm{flux\_X1\_in} - \mathrm{flux\_X1\_out} \quad (3)$$

Derived unit $\mathrm{mmol} \cdot (60\ \mathrm{s})^{-1} \cdot \mathrm{l}^{-1}$

6.4 Rule flux_X2_in

Rule flux_X2_in is an assignment rule for parameter flux_X2_in:

$$\mathrm{flux\_X2\_in} = 142.72 \cdot [\mathrm{X1}]^{0.517} \cdot [\mathrm{X2}]^{-0.179} \cdot [\mathrm{X3}]^{0.183} \cdot [\mathrm{X6}]^{-0.276} \cdot \mathrm{X9}^{0.689} \cdot \mathrm{X12r}^{0.311} \quad (4)$$

6.5 Rule flux_X2_out

Rule flux_X2_out is an assignment rule for parameter flux_X2_out:

$$\begin{aligned}\text{flux\_X2\_out} = 30.12 \cdot [\text{X1}]^{-0.00333} \cdot [\text{X2}]^{0.575} \cdot [\text{X3}]^{-0.17} \cdot [\text{X4}]^{0.00333} \\ \cdot \text{X10}^{0.5111} \cdot \text{X11}^{0.0667} \cdot \text{X12f}^{0.411} \cdot \text{X17}^{0.0111}\end{aligned} \tag{5}$$

6.6 Rule X2

Rule X2 is a rate rule for species X2:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{X2} = \text{flux\_X2\_in} - \text{flux\_X2\_out} \tag{6}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.7 Rule flux_X3_in

Rule flux_X3_in is an assignment rule for parameter flux_X3_in:

$$\text{flux\_X3\_in} = 7.8819 \cdot [\text{X2}]^{0.394} \cdot [\text{X3}]^{-0.392} \cdot [\text{X4}]^{-0.01} \cdot [\text{X5}]^{0.0128} \cdot \text{X12f}^{0.949} \cdot \text{X15r}^{0.0513} \tag{7}$$

6.8 Rule flux_X3_out

Rule flux_X3_out is an assignment rule for parameter flux_X3_out:

$$\text{flux\_X3\_out} = 76.434 \cdot [\text{X2}]^{-0.412} \cdot [\text{X3}]^{0.593} \cdot \text{X12r}^{0.718} \cdot \text{X13}^{0.18} \cdot \text{X15f}^{0.103} \tag{8}$$

6.9 Rule X3

Rule X3 is a rate rule for species X3:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{X3} = \text{flux\_X3\_in} - \text{flux\_X3\_out} \tag{9}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.10 Rule flux_X4_in

Rule flux_X4_in is an assignment rule for parameter flux_X4_in:

$$\text{flux\_X4\_in} = 11.07 \cdot [\text{X3}]^{0.5} \cdot \text{X13} \tag{10}$$

6.11 Rule flux_X4_out

Rule flux_X4_out is an assignment rule for parameter flux_X4_out:

$$\text{flux\_X4\_out} = 3.4556 \cdot [\text{X1}]^{-0.0429} \cdot [\text{X2}]^{0.214} \cdot [\text{X4}]^{0.386} \cdot \text{X14}^{0.857} \cdot \text{X17}^{0.143} \tag{11}$$

6.12 Rule X4

Rule X4 is a rate rule for species X4:

$$\frac{d}{dt}X4 = \text{flux\_X4\_in} - \text{flux\_X4\_out} \tag{12}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.13 Rule flux_X5_in

Rule flux_X5_in is an assignment rule for parameter flux_X5_in:

$$\text{flux\_X5\_in} = 11.06 \cdot [X2]^{0.04} \cdot [X3]^{0.32} \cdot [X4]^{0.16} \cdot X14^{0.6} \cdot X15f^{0.4} \tag{13}$$

6.14 Rule flux_X5_out

Rule flux_X5_out is an assignment rule for parameter flux_X5_out:

$$\text{flux\_X5\_out} = 4.929 \cdot [X2]^{-0.04} \cdot [X4]^{-0.04} \cdot [X5]^{0.25} \cdot X15r^{0.2} \cdot X16^{0.8} \tag{14}$$

6.15 Rule X5

Rule X5 is a rate rule for species X5:

$$\frac{d}{dt}X5 = \text{flux\_X5\_in} - \text{flux\_X5\_out} \tag{15}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.16 Rule flux_X6_in

Rule flux_X6_in is an assignment rule for parameter flux_X6_in:

$$\text{flux\_X6\_in} = 0.19424 \cdot [X1]^{-0.3} \cdot [X2]^{0.3} \cdot [X4]^{0.3} \cdot X17 \tag{16}$$

6.17 Rule flux_X6_out

Rule flux_X6_out is an assignment rule for parameter flux_X6_out:

$$\text{flux\_X6\_out} = 1.0939 \cdot [X6]^{0.2} \cdot X18 \tag{17}$$

6.18 Rule X6

Rule X6 is a rate rule for species X6:

$$\frac{d}{dt}X6 = \text{flux\_X6\_in} - \text{flux\_X6\_out} \tag{18}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.19 Rule `flux_X7_in`

Rule `flux_X7_in` is an assignment rule for parameter `flux_X7_in`:

$$\text{flux\_X7\_in} = 1.0939 \cdot [\text{X6}]^{0.2} \cdot \text{X18} \tag{19}$$

6.20 Rule `flux_X7_out`

Rule `flux_X7_out` is an assignment rule for parameter `flux_X7_out`:

$$\text{flux\_X7\_out} = 1.2288 \cdot [\text{X7}]^{0.3} \cdot \text{X19} \tag{20}$$

6.21 Rule `X7`

Rule `X7` is a rate rule for species `X7`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{X7} = \text{flux\_X7\_in} - \text{flux\_X7\_out} \tag{21}$$

Derived unit $\text{mmol} \cdot (60\ \text{s})^{-1} \cdot \text{l}^{-1}$

6.22 Rule `X8`

Rule `X8` is an assignment rule for parameter `X8`:

$$\text{X8} = \begin{cases} 8 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{22}$$

6.23 Rule `X10`

Rule `X10` is an assignment rule for parameter `X10`:

$$\text{X10} = \begin{cases} 1 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{23}$$

6.24 Rule `X12r`

Rule `X12r` is an assignment rule for parameter `X12r`:

$$\text{X12r} = \begin{cases} 16 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{24}$$

6.25 Rule `X13`

Rule `X13` is an assignment rule for parameter `X13`:

$$\text{X13} = \begin{cases} 16 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{25}$$

6.26 Rule X15r

Rule X15r is an assignment rule for parameter X15r:

$$\text{X15r} = \begin{cases} 50 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{26}$$

6.27 Rule X16

Rule X16 is an assignment rule for parameter X16:

$$\text{X16} = \begin{cases} 16 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{27}$$

6.28 Rule X18

Rule X18 is an assignment rule for parameter X18:

$$\text{X18} = \begin{cases} 18 & \text{if heat\_shock} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{28}$$

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 X0

Name glucose

SBO:0000247 simple chemical

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{X0} = 0 \tag{29}$$

7.2 Species X1

Name glucose

SBO:0000247 simple chemical

Initial concentration $0.03\ \text{mmol} \cdot \text{l}^{-1}$

Involved in rule X1

One rule determines the species' quantity.

7.3 Species X2

Name G6P

SBO:0000247 simple chemical

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

Involved in rule X2

One rule determines the species' quantity.

7.4 Species X3

Name G1P

SBO:0000247 simple chemical

Initial concentration $0.1 \text{ mmol} \cdot \text{l}^{-1}$

Involved in rule X3

One rule determines the species' quantity.

7.5 Species X4

Name UDPG

SBO:0000247 simple chemical

Initial concentration $0.7 \text{ mmol} \cdot \text{l}^{-1}$

Involved in rule X4

One rule determines the species' quantity.

7.6 Species X5

Name glycogen

SBO:0000247 simple chemical

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

Involved in rule X5

One rule determines the species' quantity.

7.7 Species X6

Name T6P

SBO:0000247 simple chemical

Initial concentration $0.02\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

Involved in rule X6

One rule determines the species' quantity.

7.8 Species X7

Name trehalose

SBO:0000247 simple chemical

Initial concentration $0.05\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

Involved in rule X7

One rule determines the species' quantity.

A Glossary of Systems Biology Ontology Terms

SBO:0000247 **simple chemical:** Simple, non-repetitive chemical entity

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

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