

SBML Model Report

Model name: “Karapetyan2016 - Genetic oscillatory network - Activator Titration Circuit (ATC)”



May 5, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following three authors: Nick Juty¹, Vijayalakshmi Chelliah² and Sargis Karapetyan³ at January 26th 2015 at 5:46 p. m. and last time modified at March 17th 2016 at 1:18 p. 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	10
events	0	constraints	0
reactions	23	function definitions	1
global parameters	25	unit definitions	3
rules	9	initial assignments	6

Model Notes

Karapetyan2016 - Genetic oscillatory network - Activator Titration Circuit (ATC)

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This model is described in the article: [Role of DNA binding sites and slow unbinding kinetics in titration-based oscillators](#). Karapetyan S, Buchler NE. Phys Rev E Stat Nonlin Soft Matter Phys 2015 Dec; 92(6-1): 062712

Abstract:

Genetic oscillators, such as circadian clocks, are constantly perturbed by molecular noise arising from the small number of molecules involved in gene regulation. One of the strongest sources of stochasticity is the binary noise that arises from the binding of a regulatory protein to a promoter in the chromosomal DNA. In this study, we focus on two minimal oscillators based on activator titration and repressor titration to understand the key parameters that are important for oscillations and for overcoming binary noise. We show that the rate of unbinding from the DNA, despite traditionally being considered a fast parameter, needs to be slow to broaden the space of oscillatory solutions. The addition of multiple, independent DNA binding sites further expands the oscillatory parameter space for the repressor-titration oscillator and lengthens the period of both oscillators. This effect is a combination of increased effective delay of the unbinding kinetics due to multiple binding sites and increased promoter ultrasensitivity that is specific for repression. We then use stochastic simulation to show that multiple binding sites increase the coherence of oscillations by mitigating the binary noise. Slow values of DNA unbinding rate are also effective in alleviating molecular noise due to the increased distance from the bifurcation point. Our work demonstrates how the number of DNA binding sites and slow unbinding kinetics, which are often omitted in biophysical models of gene circuits, can have a significant impact on the temporal and stochastic dynamics of genetic oscillators.

This model is hosted on [BioModels Database](#) and identified by: [BIOMD0000000586](#).

To cite BioModels Database, please use: [BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models](#).

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2 Unit Definitions

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

2.1 Unit volume

Name volume

Definition dimensionless

2.2 Unit time

Name time

Definition 60 s

2.3 Unit substance

Name substance

Definition item

2.4 Unit area

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

Definition m²

2.5 Unit length

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

Definition m

3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
yeast	yeast	0000290	3	1	dimensionless	<input checked="" type="checkbox"/>	

3.1 Compartment yeast

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

Name yeast

SBO:0000290 physical compartment

4 Species

This model contains ten species. Section 10 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
G0	G0	yeast	item dimensionless ⁻¹	· ⊞	⊞
G1	G1	yeast	item dimensionless ⁻¹	· ⊞	⊞
rA	rA	yeast	item dimensionless ⁻¹	· ⊞	⊞
I	I	yeast	item dimensionless ⁻¹	· ⊞	⊞
rI	rI	yeast	item dimensionless ⁻¹	· ⊞	⊞
A	A	yeast	item dimensionless ⁻¹	· ⊞	⊞
AI	AI	yeast	item dimensionless ⁻¹	· ⊞	⊞
A2	A2	yeast	item dimensionless ⁻¹	· ⊞	⊞
G2	G2	yeast	item dimensionless ⁻¹	· ⊞	⊞
G3	G3	yeast	item dimensionless ⁻¹	· ⊞	⊞

5 Parameters

This model contains 25 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Theta	Theta	0000338	0.020		<input checked="" type="checkbox"/>
Alpha	Alpha		$2.49202551834131 \cdot 10^{-4}$		<input type="checkbox"/>
rho_f	rho_f		0.178		<input checked="" type="checkbox"/>
rho_b	rho_b		5.343		<input type="checkbox"/>
rho_0	rho_0		0.975		<input type="checkbox"/>
beta	beta		14.109		<input checked="" type="checkbox"/>
delta_m	delta_m		0.019		<input checked="" type="checkbox"/>
delta_p	delta_p		0.008		<input checked="" type="checkbox"/>
gamma	gamma		0.025		<input checked="" type="checkbox"/>
epsilon	epsilon		0.024		<input checked="" type="checkbox"/>
epsilon_1	epsilon_1		6.000		<input checked="" type="checkbox"/>
a_01	a_01		$2.49202551834131 \cdot 10^{-4}$		<input type="checkbox"/>
a_12	a_12		0.000		<input type="checkbox"/>
a_23	a_23		0.000		<input type="checkbox"/>
t_10	t_10		0.020		<input type="checkbox"/>
t_21	t_21		0.000		<input type="checkbox"/>
t_32	t_32		0.000		<input type="checkbox"/>
_3sites	3sites		0.000		<input checked="" type="checkbox"/>
f	f		30.000		<input checked="" type="checkbox"/>
ModelValue-_17	Initial for 3sites		0.000		<input checked="" type="checkbox"/>
ModelValue_1	Initial for Alpha		$2.49202551834131 \cdot 10^{-4}$		<input checked="" type="checkbox"/>
ModelValue_0	Initial for Theta		0.020		<input checked="" type="checkbox"/>
ModelValue-_18	Initial for f		30.000		<input checked="" type="checkbox"/>
ModelValue_3	Initial for rho_b		5.343		<input checked="" type="checkbox"/>
ModelValue_2	Initial for rho_f		0.178		<input checked="" type="checkbox"/>

6 Initialassignments

This is an overview of six initialassignments.

6.1 Initialassignment ModelValue_17

Derived unit contains undeclared units

Math $_3\text{sites}$

6.2 Initialassignment ModelValue_1

Derived unit contains undeclared units

Math Alpha

6.3 Initialassignment ModelValue_0

Derived unit contains undeclared units

Math Theta

6.4 Initialassignment ModelValue_18

Derived unit contains undeclared units

Math f

6.5 Initialassignment ModelValue_3

Derived unit contains undeclared units

Math rho_b

6.6 Initialassignment ModelValue_2

Derived unit contains undeclared units

Math rho_f

7 Function definition

This is an overview of one function definition.

7.1 Function definition Constant_flux_irreversible

Name Constant flux (irreversible)

Argument v

Mathematical Expression

v

(1)

8 Rules

This is an overview of nine rules.

8.1 Rule Alpha

Rule Alpha is an assignment rule for parameter Alpha:

$$\text{Alpha} = \frac{\text{ModelValue}_0}{24 \cdot 3.344} \quad (2)$$

8.2 Rule rho_b

Rule rho_b is an assignment rule for parameter rho_b:

$$\text{rho}_b = \text{ModelValue}_2 \cdot \text{ModelValue}_{18} \quad (3)$$

8.3 Rule rho_0

Rule rho_0 is an assignment rule for parameter rho_0:

$$\text{rho}_0 = \sqrt{2} \quad (4)$$

8.4 Rule a_01

Rule a_01 is an assignment rule for parameter a_01:

$$a_{01} = \begin{cases} 3 \cdot \text{ModelValue}_1 & \text{if } \text{ModelValue}_{17} = 1 \\ \text{ModelValue}_1 & \text{otherwise} \end{cases} \quad (5)$$

8.5 Rule a_12

Rule a_12 is an assignment rule for parameter a_12:

$$a_{12} = \begin{cases} 2 \cdot \text{ModelValue}_1 & \text{if } \text{ModelValue}_{17} = 1 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

8.6 Rule a_23

Rule a_23 is an assignment rule for parameter a_23:

$$a_{23} = \begin{cases} 1 \cdot \text{ModelValue}_1 & \text{if } \text{ModelValue}_{17} = 1 \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

8.7 Rule t_10

Rule t_10 is an assignment rule for parameter t_10:

$$t_{10} = \text{ModelValue}_0 \quad (8)$$

8.8 Rule t_{21}

Rule t_{21} is an assignment rule for parameter t_{21} :

$$t_{21} = \begin{cases} 2 \cdot \text{ModelValue}_0 & \text{if } \text{ModelValue}_{17} = 1 \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

8.9 Rule t_{32}

Rule t_{32} is an assignment rule for parameter t_{32} :

$$t_{32} = \begin{cases} 3 \cdot \text{ModelValue}_0 & \text{if } \text{ModelValue}_{17} = 1 \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

9 Reactions

This model contains 23 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	G1___G0___A2	G1 -> G0 + A2	$G1 \xrightarrow{G1} G0 + A2$	
2	G0___A2___G1	G0 + A2 -> G1	$G0 + A2 \xrightarrow{G0, A2} G1$	
3	G___G___rI	G -> G + rI	$G0 \xrightarrow{G0} G0 + rI$	
4	G1___G1___rI	G1 -> G1 + rI	$G1 \xrightarrow{G1} G1 + rI$	
5	rA___	rA ->	$rA \xrightarrow{rA} \emptyset$	
6	___rA	-> rA	$\emptyset \longrightarrow rA$	
7	rI___	rI ->	$rI \xrightarrow{rI} \emptyset$	
8	rA___rA___A	rA -> rA + A	$rA \xrightarrow{rA} rA + A$	
9	I___	I ->	$I \xrightarrow{I} \emptyset$	
10	rI___rI___I	rI -> rI + I	$rI \xrightarrow{rI} rI + I$	
11	A___	A ->	$A \xrightarrow{A} \emptyset$	
12	A___I___AI	A + I -> AI	$A + I \xrightarrow{A, I} AI$	
13	_2___A___A2	2 * A -> A2	$2 A \xrightarrow{A} A2$	
14	A2___2___A	A2 -> 2 * A	$A2 \xrightarrow{A2} 2 A$	
15	AI___A___I	AI -> A + I	$AI \xrightarrow{AI} A + I$	
16	AI___	AI ->	$AI \xrightarrow{AI} \emptyset$	
17	A2___	A2 ->	$A2 \xrightarrow{A2} \emptyset$	

Nº	Id	Name	Reaction Equation	SBO
18	G1___A2___G2	G1 + A2 -> G2	$G1 + A2 \xrightarrow{G1, A2} G2$	
19	G2___G1___A2	G2 -> G1 + A2	$G2 \xrightarrow{G2} G1 + A2$	
20	G2___G2___rI	G2 -> G2 + rI	$G2 \xrightarrow{G2} G2 + rI$	
21	G2___A2___G3	G2 + A2 -> G3	$G2 + A2 \xrightarrow{G2, A2} G3$	
22	G3___G2___A2	G3 -> G2 + A2	$G3 \xrightarrow{G3} G2 + A2$	
23	G3___G3___rI	G3 -> G3 + rI	$G3 \xrightarrow{G3} G3 + rI$	

9.1 Reaction G1----G0---A2

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

Name G1 -> G0 + A2

Reaction equation



Reactant

Table 6: Properties of each reactant.

Id	Name	SBO
G1	G1	

Modifier

Table 7: Properties of each modifier.

Id	Name	SBO
G1	G1	

Products

Table 8: Properties of each product.

Id	Name	SBO
G0	G0	
A2	A2	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \text{vol}(\text{yeast}) \cdot t_{10} \cdot [G1] \quad (12)$$

9.2 Reaction G0---A2----G1

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

Name G0 + A2 -> G1

Reaction equation



Reactants

Table 9: Properties of each reactant.

Id	Name	SBO
G0	G0	
A2	A2	

Modifiers

Table 10: Properties of each modifier.

Id	Name	SBO
G0	G0	
A2	A2	

Product

Table 11: Properties of each product.

Id	Name	SBO
G1	G1	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \text{vol}(\text{yeast}) \cdot a_{01} \cdot [G0] \cdot [A2] \quad (14)$$

9.3 Reaction G → G + rI

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

Name G → G + rI

Reaction equation



Reactant

Table 12: Properties of each reactant.

Id	Name	SBO
G0	G0	

Modifier

Table 13: Properties of each modifier.

Id	Name	SBO
G0	G0	

Products

Table 14: Properties of each product.

Id	Name	SBO
G0	G0	
rI	rI	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \text{vol}(\text{yeast}) \cdot \text{rho.f} \cdot [\text{G0}] \quad (16)$$

9.4 Reaction G1----G1---rI

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

Name G1 -> G1 + rI

Reaction equation



Reactant

Table 15: Properties of each reactant.

Id	Name	SBO
G1	G1	

Modifier

Table 16: Properties of each modifier.

Id	Name	SBO
G1	G1	

Products

Table 17: Properties of each product.

Id	Name	SBO
G1	G1	
rI	rI	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \text{vol}(\text{yeast}) \cdot \text{rho.b} \cdot [\text{G1}] \quad (18)$$

9.5 Reaction rA---

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

Name rA ->

Reaction equation



Reactant

Table 18: Properties of each reactant.

Id	Name	SBO
rA	rA	

Modifier

Table 19: Properties of each modifier.

Id	Name	SBO
rA	rA	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \text{vol}(\text{yeast}) \cdot \text{delta_m} \cdot [\text{rA}] \quad (20)$$

9.6 Reaction ----rA

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

Name -> rA

Reaction equation



Product

Table 20: Properties of each product.

Id	Name	SBO
rA	rA	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \text{vol}(\text{yeast}) \cdot \text{Constant_flux_irreversible}(\text{rho}_0) \quad (22)$$

$$\text{Constant_flux_irreversible}(v) = v \quad (23)$$

$$\text{Constant_flux_irreversible}(v) = v \quad (24)$$

9.7 Reaction $rI_$

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

Name $rI \rightarrow$

Reaction equation



Reactant

Table 21: Properties of each reactant.

Id	Name	SBO
rI	rI	

Modifier

Table 22: Properties of each modifier.

Id	Name	SBO
rI	rI	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \text{vol}(\text{yeast}) \cdot \text{delta_m} \cdot [rI] \quad (26)$$

9.8 Reaction rA_rA_A

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

Name $rA \rightarrow rA + A$

Reaction equation



Reactant

Table 23: Properties of each reactant.

Id	Name	SBO
rA	rA	

Modifier

Table 24: Properties of each modifier.

Id	Name	SBO
rA	rA	

Products

Table 25: Properties of each product.

Id	Name	SBO
rA	rA	
A	A	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \text{vol}(\text{yeast}) \cdot \text{beta} \cdot [\text{rA}] \tag{28}$$

9.9 Reaction I_---

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

Name I ->

Reaction equation



Reactant

Table 26: Properties of each reactant.

Id	Name	SBO
I	I	

Modifier

Table 27: Properties of each modifier.

Id	Name	SBO
I	I	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \text{vol}(\text{yeast}) \cdot \text{delta_p} \cdot [\text{I}] \quad (30)$$

9.10 Reaction $rI \xrightarrow{\text{rI}} rI + I$

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

Name $rI \rightarrow rI + I$

Reaction equation



Reactant

Table 28: Properties of each reactant.

Id	Name	SBO
rI	rI	

Modifier

Table 29: Properties of each modifier.

Id	Name	SBO
rI	rI	

Products

Table 30: Properties of each product.

Id	Name	SBO
rI	rI	
I	I	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \text{vol}(\text{yeast}) \cdot \text{beta} \cdot [\text{rI}] \quad (32)$$

9.11 Reaction A_>>

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

Name A ->

Reaction equation



Reactant

Table 31: Properties of each reactant.

Id	Name	SBO
A	A	

Modifier

Table 32: Properties of each modifier.

Id	Name	SBO
A	A	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \text{vol}(\text{yeast}) \cdot \text{delta_p} \cdot [\text{A}] \quad (34)$$

9.12 Reaction A---I---AI

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

Name A + I -> AI

Reaction equation



Reactants

Table 33: Properties of each reactant.

Id	Name	SBO
A	A	
I	I	

Modifiers

Table 34: Properties of each modifier.

Id	Name	SBO
A	A	
I	I	

Product

Table 35: Properties of each product.

Id	Name	SBO
AI	AI	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \text{vol}(\text{yeast}) \cdot \text{gamma} \cdot [\text{A}] \cdot [\text{I}] \quad (36)$$

9.13 Reaction $2 \text{ A} \rightarrow \text{A2}$

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

Name $2 * \text{A} \rightarrow \text{A2}$

Reaction equation



Reactant

Table 36: Properties of each reactant.

Id	Name	SBO
A	A	

Modifier

Table 37: Properties of each modifier.

Id	Name	SBO
A	A	

Product

Table 38: Properties of each product.

Id	Name	SBO
A2	A2	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \text{vol}(\text{yeast}) \cdot \text{gamma} \cdot [\text{A}]^2 \quad (38)$$

9.14 Reaction $\text{A2} \rightarrow 2 * \text{A}$

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

Name $\text{A2} \rightarrow 2 * \text{A}$

Reaction equation



Reactant

Table 39: Properties of each reactant.

Id	Name	SBO
A2	A2	

Modifier

Table 40: Properties of each modifier.

Id	Name	SBO
A2	A2	

Product

Table 41: Properties of each product.

Id	Name	SBO
A	A	

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \text{vol}(\text{yeast}) \cdot \text{epsilon_1} \cdot [A2] \quad (40)$$

9.15 Reaction AI → A + I

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

Name AI → A + I

Reaction equation



Reactant

Table 42: Properties of each reactant.

Id	Name	SBO
AI	AI	

Modifier

Table 43: Properties of each modifier.

Id	Name	SBO
AI	AI	

Products

Table 44: Properties of each product.

Id	Name	SBO
A	A	
I	I	

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \text{vol}(\text{yeast}) \cdot \text{epsilon} \cdot [\text{AI}] \tag{42}$$

9.16 Reaction AI---

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

Name AI ->

Reaction equation



Reactant

Table 45: Properties of each reactant.

Id	Name	SBO
AI	AI	

Modifier

Table 46: Properties of each modifier.

Id	Name	SBO
AI	AI	

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = \text{vol}(\text{yeast}) \cdot \text{delta.p} \cdot [\text{AI}] \quad (44)$$

9.17 Reaction A2_---

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

Name A2 ->

Reaction equation



Reactant

Table 47: Properties of each reactant.

Id	Name	SBO
A2	A2	

Modifier

Table 48: Properties of each modifier.

Id	Name	SBO
A2	A2	

Kinetic Law

Derived unit contains undeclared units

$$v_{17} = \text{vol}(\text{yeast}) \cdot \text{delta_p} \cdot [\text{A2}] \quad (46)$$

9.18 Reaction G1___A2___G2

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

Name G1 + A2 -> G2

Reaction equation



Reactants

Table 49: Properties of each reactant.

Id	Name	SBO
G1	G1	
A2	A2	

Modifiers

Table 50: Properties of each modifier.

Id	Name	SBO
G1	G1	
A2	A2	

Product

Table 51: Properties of each product.

Id	Name	SBO
G2	G2	

Kinetic Law

Derived unit contains undeclared units

$$v_{18} = \text{vol}(\text{yeast}) \cdot a_{12} \cdot [G1] \cdot [A2] \quad (48)$$

9.19 Reaction G2----G1--A2

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

Name G2 -> G1 + A2

Reaction equation



Reactant

Table 52: Properties of each reactant.

Id	Name	SBO
G2	G2	

Modifier

Table 53: Properties of each modifier.

Id	Name	SBO
G2	G2	

Products

Table 54: Properties of each product.

Id	Name	SBO
G1	G1	
A2	A2	

Kinetic Law

Derived unit contains undeclared units

$$v_{19} = \text{vol}(\text{yeast}) \cdot t_{21} \cdot [G2] \quad (50)$$

9.20 Reaction G2----G2--rI

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

Name G2 -> G2 + rI

Reaction equation



Reactant

Table 55: Properties of each reactant.

Id	Name	SBO
G2	G2	

Modifier

Table 56: Properties of each modifier.

Id	Name	SBO
G2	G2	

Products

Table 57: Properties of each product.

Id	Name	SBO
G2	G2	
rI	rI	

Kinetic Law

Derived unit contains undeclared units

$$v_{20} = \text{vol}(\text{yeast}) \cdot \text{rho_b} \cdot [G2] \quad (52)$$

9.21 Reaction G2___A2___G3

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

Name G2 + A2 -> G3

Reaction equation



Reactants

Table 58: Properties of each reactant.

Id	Name	SBO
G2	G2	
A2	A2	

Modifiers

Table 59: Properties of each modifier.

Id	Name	SBO
G2	G2	
A2	A2	

Product

Table 60: Properties of each product.

Id	Name	SBO
G3	G3	

Kinetic Law

Derived unit contains undeclared units

$$v_{21} = \text{vol}(\text{yeast}) \cdot a_{23} \cdot [\text{G2}] \cdot [\text{A2}] \quad (54)$$

9.22 Reaction G3 → G2 + A2

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

Name G3 → G2 + A2

Reaction equation



Reactant

Table 61: Properties of each reactant.

Id	Name	SBO
G3	G3	

Modifier

Table 62: Properties of each modifier.

Id	Name	SBO
G3	G3	

Products

Table 63: Properties of each product.

Id	Name	SBO
G2	G2	
A2	A2	

Kinetic Law

Derived unit contains undeclared units

$$v_{22} = \text{vol}(\text{yeast}) \cdot t_{.32} \cdot [\text{G3}] \quad (56)$$

9.23 Reaction G3----G3---rI

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

Name G3 -> G3 + rI

Reaction equation



Reactant

Table 64: Properties of each reactant.

Id	Name	SBO
G3	G3	

Modifier

Table 65: Properties of each modifier.

Id	Name	SBO
G3	G3	

Products

Table 66: Properties of each product.

Id	Name	SBO
G3	G3	
rI	rI	

Kinetic Law

Derived unit contains undeclared units

$$v_{23} = \text{vol}(\text{yeast}) \cdot \text{rho_b} \cdot [\text{G3}] \quad (58)$$

10 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.

10.1 Species G0

Name G0

SBO:0000196 concentration of an entity pool

Initial concentration 1 item · dimensionless⁻¹

This species takes part in six reactions (as a reactant in [G0___A2___G1](#), [G___G___rI](#) and as a product in [G1___G0___A2](#), [G___G___rI](#) and as a modifier in [G0___A2___G1](#), [G___G___rI](#)).

$$\frac{d}{dt}G0 = v_1 + v_3 - v_2 - v_3 \quad (59)$$

10.2 Species G1

Name G1

SBO:0000196 concentration of an entity pool

Initial concentration 0 item · dimensionless⁻¹

This species takes part in nine reactions (as a reactant in [G1___G0___A2](#), [G1___G1___rI](#), [G1___A2___G2](#) and as a product in [G0___A2___G1](#), [G1___G1___rI](#), [G2___G1___A2](#) and as a modifier in [G1___G0___A2](#), [G1___G1___rI](#), [G1___A2___G2](#)).

$$\frac{d}{dt}G1 = v_2 + v_4 + v_{19} - v_1 - v_4 - v_{18} \quad (60)$$

10.3 Species rA

Name rA

SBO:0000278 messenger RNA

Initial concentration 0 item · dimensionless⁻¹

This species takes part in six reactions (as a reactant in [rA___](#), [rA___rA___A](#) and as a product in [___rA](#), [rA___rA___A](#) and as a modifier in [rA___](#), [rA___rA___A](#)).

$$\frac{d}{dt}rA = v_6 + v_8 - v_5 - v_8 \quad (61)$$

10.4 Species I

Name I

SBO:0000020 inhibitor

Initial concentration 0 item · dimensionless⁻¹

This species takes part in six reactions (as a reactant in [I___](#), [A___I___AI](#) and as a product in [rI___rI___I](#), [AI___A___I](#) and as a modifier in [I___](#), [A___I___AI](#)).

$$\frac{d}{dt}I = v_{10} + v_{15} - v_9 - v_{12} \quad (62)$$

10.5 Species rI

Name rI

SBO:0000278 messenger RNA

Initial concentration 0 item · dimensionless⁻¹

This species takes part in nine reactions (as a reactant in [rI---](#), [rI---rI---I](#) and as a product in [G---G---rI](#), [G1---G1---rI](#), [rI---rI---I](#), [G2---G2---rI](#), [G3---G3---rI](#) and as a modifier in [rI---](#), [rI---rI---I](#)).

$$\frac{d}{dt}rI = v_3 + v_4 + v_{10} + v_{20} + v_{23} - v_7 - v_{10} \quad (63)$$

10.6 Species A

Name A

SBO:0000459 stimulator

Initial concentration 0 item · dimensionless⁻¹

This species takes part in nine reactions (as a reactant in [A---](#), [A---I---AI](#), [2---A---A2](#) and as a product in [rA---rA---A](#), [A2---2---A](#), [AI---A---I](#) and as a modifier in [A---](#), [A---I---AI](#), [2---A---A2](#)).

$$\frac{d}{dt}A = v_8 + 2v_{14} + v_{15} - v_{11} - v_{12} - 2v_{13} \quad (64)$$

10.7 Species AI

Name AI

SBO:0000609 heterodimer

Initial concentration 0 item · dimensionless⁻¹

This species takes part in five reactions (as a reactant in [AI---A---I](#), [AI---](#) and as a product in [A---I---AI](#) and as a modifier in [AI---A---I](#), [AI---](#)).

$$\frac{d}{dt}AI = v_{12} - v_{15} - v_{16} \quad (65)$$

10.8 Species A2

Name A2

SBO:0000608 homodimer

Initial concentration 0 item · dimensionless⁻¹

This species takes part in 14 reactions (as a reactant in [G0___A2___G1](#), [A2___2___A](#), [A2___](#), [G1___A2___G2](#), [G2___A2___G3](#) and as a product in [G1___G0___A2](#), [2___A___A2](#), [G2___G1___A2](#), [G3___G2___A2](#) and as a modifier in [G0___A2___G1](#), [A2___2___A](#), [A2___](#), [G1___A2___G2](#), [G2___A2___G3](#)).

$$\frac{d}{dt}A2 = v_1 + v_{13} + v_{19} + v_{22} - v_2 - v_{14} - v_{17} - v_{18} - v_{21} \quad (66)$$

10.9 Species G2

Name G2

SBO:0000196 concentration of an entity pool

Initial concentration 0 item · dimensionless⁻¹

This species takes part in nine reactions (as a reactant in [G2___G1___A2](#), [G2___G2___rI](#), [G2___A2___G3](#) and as a product in [G1___A2___G2](#), [G2___G2___rI](#), [G3___G2___A2](#) and as a modifier in [G2___G1___A2](#), [G2___G2___rI](#), [G2___A2___G3](#)).

$$\frac{d}{dt}G2 = v_{18} + v_{20} + v_{22} - v_{19} - v_{20} - v_{21} \quad (67)$$

10.10 Species G3

Name G3

SBO:0000196 concentration of an entity pool

Initial concentration 0 item · dimensionless⁻¹

This species takes part in six reactions (as a reactant in [G3___G2___A2](#), [G3___G3___rI](#) and as a product in [G2___A2___G3](#), [G3___G3___rI](#) and as a modifier in [G3___G2___A2](#), [G3___G3___rI](#)).

$$\frac{d}{dt}G3 = v_{21} + v_{23} - v_{22} - v_{23} \quad (68)$$

A Glossary of Systems Biology Ontology Terms

SBO:0000020 inhibitor: Substance that decreases the probability of a chemical reaction without itself being consumed or transformed by the reaction

SBO:0000196 concentration of an entity pool: The amount of an entity per unit of volume.

SBO:0000278 messenger RNA: A messenger RNA is a ribonucleic acid synthesized during the transcription of a gene, and that carries the information to encode one or several proteins

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

SBO:0000338 dissociation rate constant: Rate with which a complex dissociates into its components

SBO:0000459 stimulator: Substance that accelerates the velocity of a chemical reaction without itself being consumed or transformed.

SBO:0000608 homodimer: A macromolecular complex composed of precisely two identical monomeric units, which are usually non-covalently bound

SBO:0000609 heterodimer: A macromolecular complex composed of precisely two non-identical monomeric units, which are usually non-covalently bound

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