SBML Model Report

Model name: "Singh2006_TCA_mtu_model1"

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: Vijayalakshmi Chelliah[1] and Vivek Kumar Singh[2] at September 29th 2006 at 10:48 p. m. and last time modified at December 20th 2010 at 9:46 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	13
events	0	constraints	0
reactions	15	function definitions	0
global parameters	0	unit definitions	4
rules	0	initial assignments	0

Model Notes

This a model from the article:
Kinetic modeling of tricarboxylic acid cycle and glyoxylate bypass in Mycobacterium tuberculosis, and its application to assessment of drug targets.
Singh VK , Ghosh I Theor Biol Med Model 2006 Aug 3;3:27 16887020 ,
Abstract:

[1]EMBL-EBI, viji@ebi.ac.uk
[2]University of Pune, vivek@bioinfo.ernet.in

BACKGROUND: Targeting persistent tubercule bacilli has become an important challenge in the development of anti-tuberculous drugs. As the glyoxylate bypass is essential for persistent bacilli, interference with it holds the potential for designing new antibacterial drugs. We have developed kinetic models of the tricarboxylic acid cycle and glyoxylate bypass in Escherichia coli and Mycobacterium tuberculosis, and studied the effects of inhibition of various enzymes in the M. tuberculosis model. RESULTS: We used E. coli to validate the pathway-modeling protocol and showed that changes in metabolic flux can be estimated from gene expression data. The M. tuberculosis model reproduced the observation that deletion of one of the two isocitrate lyase genes has little effect on bacterial growth in macrophages, but deletion of both genes leads to the elimination of the bacilli from the lungs. It also substantiated the inhibition of isocitrate lyases by 3-nitropropionate. On the basis of our simulation studies, we propose that: (i) fractional inactivation of both isocitrate dehydrogenase 1 and isocitrate dehydrogenase 2 is required for a flux through the glyoxylate bypass in persistent mycobacteria; and (ii) increasing the amount of active isocitrate dehydrogenases can stop the flux through the glyoxylate bypass, so the kinase that inactivates isocitrate dehydrogenase 1 and/or the proposed inactivator of isocitrate dehydrogenase 2 is a potential target for drugs against persistent mycobacteria. In addition, competitive inhibition of isocitrate lyases along with a reduction in the inactivation of isocitrate dehydrogenases appears to be a feasible strategy for targeting persistent mycobacteria. CONCLUSION: We used kinetic modeling of biochemical pathways to assess various potential anti-tuberculous drug targets that interfere with the glyoxylate bypass flux, and indicated the type of inhibition needed to eliminate the pathogen. The advantage of such an approach to the assessment of drug targets is that it facilitates the study of systemic effect(s) of the modulation of the target enzyme(s) in the cellular environment.

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 `time`

Name min

Definition 60 s

2.2 Unit substance

Name mmole

Definition mmol

2.3 Unit mmlmin

Name mM_per_min

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

2.4 Unit mml

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 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

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

3.1 Compartment `cell`

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

4 Species

This model contains 13 species. The boundary condition of four of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 6 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
aca		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	☑
oaa		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	☑
coa		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	☑
cit		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
icit		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
akg		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
ssa		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
suc		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
sca		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
fa		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
mal		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
gly		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
biosyn		cell	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	☑

5 Reactions

This model contains 15 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 4: Overview of all reactions

№	Id	Name	Reaction Equation	SBO
1	CS		$\mathrm{aca} + \mathrm{oaa} \rightleftharpoons \mathrm{coa} + \mathrm{cit}$	
2	ACN		$\mathrm{cit} \rightleftharpoons \mathrm{icit}$	
3	ICD1		$\mathrm{icit} \rightleftharpoons \mathrm{akg}$	
4	ICD2		$\mathrm{icit} \rightleftharpoons \mathrm{akg}$	
5	KDH		$\mathrm{akg} \rightleftharpoons \mathrm{sca}$	
6	KGD		$\mathrm{akg} \rightleftharpoons \mathrm{ssa}$	
7	SSADH		$\mathrm{ssa} \rightleftharpoons \mathrm{suc}$	
8	ScAS		$\mathrm{sca} \rightleftharpoons \mathrm{suc}$	
9	SDH		$\mathrm{suc} \rightleftharpoons \mathrm{fa}$	
10	FUM		$\mathrm{fa} \rightleftharpoons \mathrm{mal}$	
11	MDH		$\mathrm{mal} \rightleftharpoons \mathrm{oaa}$	
12	ICL1		$\mathrm{icit} \rightleftharpoons \mathrm{suc} + \mathrm{gly}$	
13	ICL2		$\mathrm{icit} \rightleftharpoons \mathrm{suc} + \mathrm{gly}$	
14	MS		$\mathrm{gly} + \mathrm{aca} \rightleftharpoons \mathrm{mal} + \mathrm{coa}$	
15	SYN		$\mathrm{akg} \overset{\mathrm{icit}}{\rightleftharpoons} \mathrm{biosyn}$	

5.1 Reaction CS

This is a reversible reaction of two reactants forming two products.

Reaction equation

$$\mathrm{aca} + \mathrm{oaa} \rightleftharpoons \mathrm{coa} + \mathrm{cit} \tag{1}$$

Reactants

Table 5: Properties of each reactant.

Id	Name	SBO
aca		
oaa		

Products

Table 6: Properties of each product.

Id	Name	SBO
coa		
cit		

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \mathrm{vol}\,(\mathrm{cell}) \cdot \frac{\mathrm{Vf\_cs} \cdot \frac{[\mathrm{aca}]}{\mathrm{Kaca\_cs}} \cdot \frac{[\mathrm{oaa}]}{\mathrm{Koaa\_cs}} - \mathrm{Vr\_cs} \cdot \frac{[\mathrm{coa}]}{\mathrm{Kcoa\_cs}} \cdot \frac{[\mathrm{cit}]}{\mathrm{Kcit\_cs}}}{\left(1 + \frac{[\mathrm{aca}]}{\mathrm{Kaca\_cs}} + \frac{[\mathrm{coa}]}{\mathrm{Kcoa\_cs}}\right) \cdot \left(1 + \frac{[\mathrm{oaa}]}{\mathrm{Koaa\_cs}} + \frac{[\mathrm{cit}]}{\mathrm{Kcit\_cs}}\right)} \tag{2}$$

Table 7: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_cs		0000350	64.800	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kaca_cs		0000322	0.050	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Koaa_cs		0000322	0.012	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Vr_cs		0000353	0.648	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kcoa_cs		0000323	0.500	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Kcit_cs		0000323	0.120	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑

5.2 Reaction ACN

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

Reaction equation

$$\text{cit} \rightleftharpoons \text{icit} \tag{3}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
cit		

Product

Table 9: Properties of each product.

Id	Name	SBO
icit		

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \text{vol}\,(\text{cell}) \cdot \frac{\text{Vf\_acn} \cdot \frac{[\text{cit}]}{\text{Kcit\_acn}} - \text{Vr\_acn} \cdot \frac{[\text{icit}]}{\text{Kicit\_acn}}}{1 + \frac{[\text{cit}]}{\text{Kcit\_acn}} + \frac{[\text{icit}]}{\text{Kicit\_acn}}} \tag{4}$$

Table 10: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_acn		0000350	31.200	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kcit_acn		0000322	1.700	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_acn		0000353	0.312	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_acn		0000323	0.700	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.3 Reaction ICD1

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

Reaction equation

$$\text{icit} \rightleftharpoons \text{akg} \tag{5}$$

Reactant

Table 11: Properties of each reactant.

Id	Name	SBO
icit		

Product

Table 12: Properties of each product.

Id	Name	SBO
akg		

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_icd1} \cdot \frac{[\text{icit}]}{\text{Kicit\_icd1}} - \text{Vr\_icd1} \cdot \frac{[\text{akg}]}{\text{Kakg\_icd1}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icd1}} + \frac{[\text{akg}]}{\text{Kakg\_icd1}}} \tag{6}$$

Table 13: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_icd1		0000350	10.200	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icd1		0000322	0.030	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icd1		0000353	0.102	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_icd1		0000323	0.300	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.4 Reaction ICD2

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

Reaction equation

$$\text{icit} \rightleftharpoons \text{akg} \tag{7}$$

Reactant

Table 14: Properties of each reactant.

Id	Name	SBO
icit		

Product

Table 15: Properties of each product.

Id	Name	SBO
akg		

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_icd2} \cdot \frac{[\text{icit}]}{\text{Kicit\_icd2}} - \text{Vr\_icd2} \cdot \frac{[\text{akg}]}{\text{Kakg\_icd2}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icd2}} + \frac{[\text{akg}]}{\text{Kakg\_icd2}}} \tag{8}$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_icd2		0000350	9.965	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icd2		0000322	0.060	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icd2		0000353	0.100	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_icd2		0000323	0.600	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.5 Reaction KDH

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

Reaction equation

$$\text{akg} \rightleftharpoons \text{sca} \tag{9}$$

Reactant

Table 17: Properties of each reactant.

Id	Name	SBO
akg		

Product

Table 18: Properties of each product.

Id	Name	SBO
sca		

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_kdh} \cdot \frac{[\text{akg}]}{\text{Kakg\_kdh}} - \text{Vr\_kdh} \cdot \frac{[\text{sca}]}{\text{Ksca\_kdh}}}{1 + \frac{[\text{akg}]}{\text{Kakg\_kdh}} + \frac{[\text{sca}]}{\text{Ksca\_kdh}}} \tag{10}$$

Table 19: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_kdh		0000350	57.344	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_kdh		0000322	0.100	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_kdh		0000353	0.573	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksca_kdh		0000323	1.000	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.6 Reaction KGD

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

Reaction equation

$$\text{akg} \rightleftharpoons \text{ssa} \tag{11}$$

Reactant

Table 20: Properties of each reactant.

Id	Name	SBO
akg		

Product

Table 21: Properties of each product.

Id	Name	SBO
ssa		

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \text{vol}\,(\text{cell}) \cdot \frac{\text{Vf\_kgd} \cdot \frac{[\text{akg}]}{\text{Kakg\_kgd}} - \text{Vr\_kgd} \cdot \frac{[\text{ssa}]}{\text{Kssa\_kgd}}}{1 + \frac{[\text{akg}]}{\text{Kakg\_kgd}} + \frac{[\text{ssa}]}{\text{Kssa\_kgd}}} \tag{12}$$

Table 22: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_kgd		0000350	48.300	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_kgd		0000322	0.480	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_kgd		0000353	0.483	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kssa_kgd		0000323	4.800	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.7 Reaction SSADH

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

Reaction equation

$$\text{ssa} \rightleftharpoons \text{suc} \tag{13}$$

Reactant

Table 23: Properties of each reactant.

Id	Name	SBO
ssa		

Product

Table 24: Properties of each product.

Id	Name	SBO
suc		

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_ssadh} \cdot \frac{[\text{ssa}]}{\text{Kssa\_ssadh}} - \text{Vr\_ssadh} \cdot \frac{[\text{suc}]}{\text{Ksuc\_ssadh}}}{1 + \frac{[\text{ssa}]}{\text{Kssa\_ssadh}} + \frac{[\text{suc}]}{\text{Ksuc\_ssadh}}} \tag{14}$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_ssadh		0000350	6.510	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kssa_ssadh		0000322	0.015	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_ssadh		0000353	0.065	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksuc_ssadh		0000323	0.150	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.8 Reaction ScAS

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

Reaction equation

$$\text{sca} \rightleftharpoons \text{suc} \tag{15}$$

Reactant

Table 26: Properties of each reactant.

Id	Name	SBO
sca		

Product

Table 27: Properties of each product.

Id	Name	SBO
suc		

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_scas} \cdot \frac{[\text{sca}]}{\text{Ksca\_scas}} - \text{Vr\_scas} \cdot \frac{[\text{suc}]}{\text{Ksuc\_scas}}}{1 + \frac{[\text{sca}]}{\text{Ksca\_scas}} + \frac{[\text{suc}]}{\text{Ksuc\_scas}}} \tag{16}$$

Table 28: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_scas		0000350	1.200	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksca_scas		0000322	0.020	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_scas		0000353	0.012	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksuc_scas		0000323	5.000	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.9 Reaction SDH

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

Reaction equation

$$\text{suc} \rightleftharpoons \text{fa} \tag{17}$$

Reactant

Table 29: Properties of each reactant.

Id	Name	SBO
suc		

Product

Table 30: Properties of each product.

Id	Name	SBO
fa		

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_sdh} \cdot \frac{[\text{suc}]}{\text{Ksuc\_sdh}} - \text{Vr\_sdh} \cdot \frac{[\text{fa}]}{\text{Kfa\_sdh}}}{1 + \frac{[\text{suc}]}{\text{Ksuc\_sdh}} + \frac{[\text{fa}]}{\text{Kfa\_sdh}}} \tag{18}$$

Table 31: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_sdh		0000350	1.02	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksuc_sdh		0000322	0.12	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_sdh		0000353	1.02	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kfa_sdh		0000323	0.15	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.10 Reaction FUM

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

Reaction equation

$$\mathrm{fa} \rightleftharpoons \mathrm{mal} \tag{19}$$

Reactant

Table 32: Properties of each reactant.

Id	Name	SBO
fa		

Product

Table 33: Properties of each product.

Id	Name	SBO
mal		

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \mathrm{vol}\,(\mathrm{cell}) \cdot \frac{\mathrm{Vf\_fum} \cdot \frac{[\mathrm{fa}]}{\mathrm{Kfa\_fum}} - \mathrm{Vr\_fum} \cdot \frac{[\mathrm{mal}]}{\mathrm{Kmal\_fum}}}{1 + \frac{[\mathrm{fa}]}{\mathrm{Kfa\_fum}} + \frac{[\mathrm{mal}]}{\mathrm{Kmal\_fum}}} \tag{20}$$

Table 34: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_fum		0000350	87.70	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kfa_fum		0000322	0.25	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Vr_fum		0000353	87.70	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kmal_fum		0000323	2.38	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑

5.11 Reaction MDH

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

Reaction equation

$$\text{mal} \rightleftharpoons \text{oaa} \tag{21}$$

Reactant

Table 35: Properties of each reactant.

Id	Name	SBO
mal		

Product

Table 36: Properties of each product.

Id	Name	SBO
oaa		

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_mdh} \cdot \frac{[\text{mal}]}{\text{Kmal\_mdh}} - \text{Vr\_mdh} \cdot \frac{[\text{oaa}]}{\text{Koaa\_mdh}}}{1 + \frac{[\text{mal}]}{\text{Kmal\_mdh}} + \frac{[\text{oaa}]}{\text{Koaa\_mdh}}} \tag{22}$$

Table 37: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_mdh		0000350	184.000	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kmal_mdh		0000322	0.833	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_mdh		0000353	184.000	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Koaa_mdh		0000323	0.044	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.12 Reaction ICL1

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

Reaction equation

$$\text{icit} \rightleftharpoons \text{suc} + \text{gly} \tag{23}$$

Reactant

Table 38: Properties of each reactant.

Id	Name	SBO
icit		

Products

Table 39: Properties of each product.

Id	Name	SBO
suc		
gly		

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_icl1} \cdot \frac{[\text{icit}]}{\text{Kicit\_icl1}} - \text{Vr\_icl1} \cdot \frac{[\text{suc}]}{\text{Ksuc\_icl1}} \cdot \frac{[\text{gly}]}{\text{Kgly\_icl1}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icl1}} + \frac{[\text{suc}]}{\text{Ksuc\_icl1}} + \frac{[\text{gly}]}{\text{Kgly\_icl1}} + \frac{[\text{icit}]}{\text{Kicit\_icl1}} \cdot \frac{[\text{suc}]}{\text{Ksuc\_icl1}} + \frac{[\text{suc}]}{\text{Ksuc\_icl1}} \cdot \frac{[\text{gly}]}{\text{Kgly\_icl1}}} \tag{24}$$

Table 40: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_icl1		0000350	1.172	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icl1		0000322	0.145	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icl1		0000353	0.012	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksuc_icl1		0000323	0.590	$\text{mmol} \cdot \text{l}^{-1}$	☑
Kgly_icl1		0000323	0.130	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.13 Reaction ICL2

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

Reaction equation

$$\text{icit} \rightleftharpoons \text{suc} + \text{gly} \tag{25}$$

Reactant

Table 41: Properties of each reactant.

Id	Name	SBO
icit		

Products

Table 42: Properties of each product.

Id	Name	SBO
suc		
gly		

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \text{vol}(\text{cell}) \cdot \frac{\text{Vf\_icl2} \cdot \frac{[\text{icit}]}{\text{Kicit\_icl2}} - \text{Vr\_icl2} \cdot \frac{[\text{suc}]}{\text{Ksuc\_icl2}} \cdot \frac{[\text{gly}]}{\text{Kgly\_icl2}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icl2}} + \frac{[\text{suc}]}{\text{Ksuc\_icl2}} + \frac{[\text{gly}]}{\text{Kgly\_icl2}} + \frac{[\text{icit}]}{\text{Kicit\_icl2}} \cdot \frac{[\text{suc}]}{\text{Ksuc\_icl2}} + \frac{[\text{suc}]}{\text{Ksuc\_icl2}} \cdot \frac{[\text{gly}]}{\text{Kgly\_icl2}}} \tag{26}$$

Table 43: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_icl2		0000350	0.391	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icl2		0000322	1.300	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icl2		0000353	0.004	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Ksuc_icl2		0000323	5.900	$\text{mmol} \cdot \text{l}^{-1}$	☑
Kgly_icl2		0000323	1.300	$\text{mmol} \cdot \text{l}^{-1}$	☑

5.14 Reaction MS

This is a reversible reaction of two reactants forming two products.

Reaction equation

$$\mathrm{gly} + \mathrm{aca} \rightleftharpoons \mathrm{mal} + \mathrm{coa} \tag{27}$$

Reactants

Table 44: Properties of each reactant.

Id	Name	SBO
gly		
aca		

Products

Table 45: Properties of each product.

Id	Name	SBO
mal		
coa		

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \mathrm{vol}(\mathrm{cell}) \cdot \frac{\mathrm{Vf\_ms} \cdot \frac{[\mathrm{gly}]}{\mathrm{Kgly\_ms}} \cdot \frac{[\mathrm{aca}]}{\mathrm{Kaca\_ms}} - \mathrm{Vr\_ms} \cdot \frac{[\mathrm{mal}]}{\mathrm{Kmal\_ms}} \cdot \frac{[\mathrm{coa}]}{\mathrm{Kcoa\_ms}}}{\left(1 + \frac{[\mathrm{gly}]}{\mathrm{Kgly\_ms}} + \frac{[\mathrm{mal}]}{\mathrm{Kmal\_ms}}\right) \cdot \left(1 + \frac{[\mathrm{aca}]}{\mathrm{Kaca\_ms}} + \frac{[\mathrm{coa}]}{\mathrm{Kcoa\_ms}}\right)} \tag{28}$$

Table 46: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_ms		0000350	20.000	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kgly_ms		0000322	0.057	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Kaca_ms		0000322	0.030	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Vr_ms		0000353	0.200	$\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot (60\ \mathrm{s})^{-1}$	☑
Kmal_ms		0000323	1.000	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑
Kcoa_ms		0000323	0.100	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑

5.15 Reaction SYN

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

Reaction equation

$$\text{akg} \overset{\text{icit}}{\rightleftharpoons} \text{biosyn} \tag{29}$$

Reactant

Table 47: Properties of each reactant.

Id	Name	SBO
akg		

Modifier

Table 48: Properties of each modifier.

Id	Name	SBO
icit		

Product

Table 49: Properties of each product.

Id	Name	SBO
biosyn		

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \text{vol}(\text{cell}) \cdot 0.0341 \cdot \left(\frac{\text{Vf\_icd1} \cdot \frac{[\text{icit}]}{\text{Kicit\_icd1}} - \text{Vr\_icd1} \cdot \frac{[\text{akg}]}{\text{Kakg\_icd1}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icd1}} + \frac{[\text{akg}]}{\text{Kakg\_icd1}}} + \frac{\text{Vf\_icd2} \cdot \frac{[\text{icit}]}{\text{Kicit\_icd2}} - \text{Vr\_icd2} \cdot \frac{[\text{akg}]}{\text{Kakg\_icd2}}}{1 + \frac{[\text{icit}]}{\text{Kicit\_icd2}} + \frac{[\text{akg}]}{\text{Kakg\_icd2}}} \right) \tag{30}$$

Table 50: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vf_icd1		0000350	10.200	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icd1		0000322	0.030	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icd1		0000353	0.102	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_icd1		0000323	0.300	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vf_icd2		0000350	9.965	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kicit_icd2		0000322	0.060	$\text{mmol} \cdot \text{l}^{-1}$	☑
Vr_icd2		0000353	0.100	$\text{mmol} \cdot \text{l}^{-1} \cdot (60\ \text{s})^{-1}$	☑
Kakg_icd2		0000323	0.600	$\text{mmol} \cdot \text{l}^{-1}$	☑

6 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.

6.1 Species aca

SBO:0000247 simple chemical

Initial concentration $0.5\ \text{mmol} \cdot \text{l}^{-1}$

This species takes part in two reactions (as a reactant in CS, MS), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{\text{d}}{\text{d}t}\text{aca} = 0 \tag{31}$$

6.2 Species oaa

SBO:0000247 simple chemical

Initial concentration $3 \cdot 10^{-4}\ \text{mmol} \cdot \text{l}^{-1}$

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

$$\frac{\text{d}}{\text{d}t}\text{oaa} = 0 \tag{32}$$

6.3 Species coa

SBO:0000247 simple chemical

Initial concentration $10^{-4}\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a product in CS, MS), which do not influence its rate of change because this species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{coa} = 0 \tag{33}$$

6.4 Species cit

SBO:0000247 simple chemical

Initial concentration $3.4\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in ACN and as a product in CS).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{cit} = v_1 - v_2 \tag{34}$$

6.5 Species icit

SBO:0000247 simple chemical

Initial concentration $0.06\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in six reactions (as a reactant in ICD1, ICD2, ICL1, ICL2 and as a product in ACN and as a modifier in SYN).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{icit} = v_2 - v_3 - v_4 - v_{12} - v_{13} \tag{35}$$

6.6 Species akg

SBO:0000247 simple chemical

Initial concentration $0.96\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in KDH, KGD, SYN and as a product in ICD1, ICD2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{akg} = v_3 + v_4 - v_5 - v_6 - v_{15} \tag{36}$$

6.7 Species ssa

SBO:0000247 simple chemical

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

This species takes part in two reactions (as a reactant in SSADH and as a product in KGD).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ssa} = v_6 - v_7 \tag{37}$$

6.8 Species suc

SBO:0000247 simple chemical

Initial concentration $2.464\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in SDH and as a product in SSADH, ScAS, ICL1, ICL2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{suc} = v_7 + v_8 + v_{12} + v_{13} - v_9 \tag{38}$$

6.9 Species sca

SBO:0000247 simple chemical

Initial concentration $0.04\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in ScAS and as a product in KDH).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{sca} = v_5 - v_8 \tag{39}$$

6.10 Species fa

SBO:0000247 simple chemical

Initial concentration $0.08528\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in FUM and as a product in SDH).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{fa} = v_9 - v_{10} \tag{40}$$

6.11 Species mal

SBO:0000247 simple chemical

Initial concentration $0.408\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in MDH and as a product in FUM, MS).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{mal} = v_{10} + v_{14} - v_{11} \tag{41}$$

6.12 Species gly

SBO:0000247 simple chemical

Initial concentration $0.114\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in MS and as a product in ICL1, ICL2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{gly} = v_{12} + v_{13} - v_{14} \tag{42}$$

6.13 Species biosyn

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{biosyn} = 0 \tag{43}$$

A Glossary of Systems Biology Ontology Terms

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

SBO:0000322 Michaelis constant for substrate: Substrate concentration at which the velocity of product production by the forward activity of a reversible enzyme is half its maximum.

SBO:0000323 Michaelis constant for product: Product concentration at which the velocity of substrate production by the reverse activity of a reversible enzyme is half its maximum.

SBO:0000350 forward reaction velocity: The speed of an enzymatic reaction at a defined concentration of substrate(s) and enzyme

SBO:0000353 reverse reaction velocity: The speed of an enzymatic reaction at a defined concentration of substrate(s) and enzyme.

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.

[a]Center for Bioinformatics Tübingen (ZBIT), Germany
[b]California Institute of Technology, Beckman Institute BNMC, Pasadena, United States
[c]European Bioinformatics Institute, Wellcome Trust Genome Campus, Hinxton, United Kingdom
[d]EML Research gGmbH, Heidelberg, Germany