SBML Model Report

Model name: "Westermark2003_Pancreatic-_GlycOsc_basic"

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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 Vijayalakshmi Chelliah[2] at July 27th 2009 at 5:50 p. m. and last time modified at May 28th 2014 at 0:48 a. m. Table 1 gives 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	5
events	0	constraints	0
reactions	3	function definitions	0
global parameters	19	unit definitions	6
rules	4	initial assignments	0

Model Notes

This is the basic model described in eq. 1 of the article:
A model of phosphofructokinase and glycolytic oscillations in the pancreatic beta-cell.
Westermark PO and Lansner A. Biophys J. 2003 Jul;85(1):126-39. PMID: 12829470, doi:10.1016/S0006-3495(03)74460-9

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Abstract:
We have constructed a model of the upper part of the glycolysis in the pancreatic beta-cell. The model comprises the enzymatic reactions from glucokinase to glyceraldehyde-3-phosphate dehydrogenase (GAPD). Our results show, for a substantial part of the parameter space, an oscillatory behavior of the glycolysis for a large range of glucose concentrations. We show how the occurrence of oscillations depends on glucokinase, aldolase and/or GAPD activities, and how the oscillation period depends on the phosphofructokinase activity. We propose that the ratio of glucokinase and aldolase and/or GAPD activities are adequate as characteristics of the glucose responsiveness, rather than only the glucokinase activity. We also propose that the rapid equilibrium between different oligomeric forms of phosphofructokinase may reduce the oscillation period sensitivity to phosphofructokinase activity. Methodologically, we show that a satisfying description of phosphofructokinase kinetics can be achieved using the irreversible Hill equation with allosteric modifiers. We emphasize the use of parameter ranges rather than fixed values, and the use of operationally well-defined parameters in order for this methodology to be feasible. The theoretical results presented in this study apply to the study of insulin secretion mechanisms, since glycolytic oscillations have been proposed as a cause of oscillations in the ATP/ADP ratio which is linked to insulin secretion.

2 Unit Definitions

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

2.1 Unit substance

Name mmole

Definition mmol

2.2 Unit time

Name seconds

Definition s

2.3 Unit mM

Name mM

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

2.4 Unit `g_per_ml`

Name gramm per ml

Definition $\mathrm{g} \cdot \mathrm{ml}^{-1}$

2.5 Unit `mM_per_s`

Name mM per sec

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

2.6 Unit `mmole_per_min_g`

Name mmole per (min kg)

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

2.7 Unit `volume`

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

Definition l

2.8 Unit `area`

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

Definition m^2

2.9 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
`comp`	compartment		3	1	litre	☑	

3.1 Compartment `comp`

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

Name compartment

4 Species

This model contains five species. The boundary condition of three of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 8 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
GLC	GLC	comp	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑	☑
G6P_F6P	G6P_F6P	comp	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
F6P	F6P	comp	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	☑
FBP	FBP	comp	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
G3P	G3P	comp	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑	☑

5 Parameters

This model contains 19 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vgk	Vgk		0.000	$\mathrm{mmol \cdot s^{-1} \cdot l^{-1}}$	☐
hGK	hGK		1.700	dimensionless	☑
KeqGPI	KeqGPI		0.300	dimensionless	☑
Vpfk	Vpfk		0.000	$\mathrm{mmol \cdot s^{-1} \cdot l^{-1}}$	☐
Vfba	Vfba		0.000	$\mathrm{mmol \cdot s^{-1} \cdot l^{-1}}$	☐
Sgk	Sgk		8.000	$\mathrm{mmol \cdot l^{-1}}$	☑
Spfk	Spfk		4.000	$\mathrm{mmol \cdot l^{-1}}$	☑
Sfba	Sfba		0.005	$\mathrm{mmol \cdot l^{-1}}$	☑
Xpfk	Xpfk		0.010	$\mathrm{mmol \cdot l^{-1}}$	☑
alpha	alpha		5.000	dimensionless	☑
hx	hx		2.500	dimensionless	☑
hpfk	hpfk		2.500	dimensionless	☑
hact	hact		1.000	dimensionless	☑
sigcorr	sigcorr		1.500		☑
dw_per_ml	dw_per_ml		0.333	$\mathrm{g \cdot ml^{-1}}$	☑
min_to_sec	min_to_sec		60.000	dimensionless	☑
Vgk_min	Vgk_min		10.000	$\mathrm{mmol \cdot (60\ s)^{-1} \cdot kg^{-1}}$	☑
Vpfk_min	Vpfk_min		100.000	$\mathrm{mmol \cdot (60\ s)^{-1} \cdot kg^{-1}}$	☑
Vfba_min	Vfba_min		25.000	$\mathrm{mmol \cdot (60\ s)^{-1} \cdot kg^{-1}}$	☑

6 Rules

This is an overview of four rules.

6.1 Rule Vgk

Rule Vgk is an assignment rule for parameter Vgk:

$$\mathrm{Vgk} = \frac{\mathrm{Vgk\_min} \cdot \mathrm{dw\_per\_ml}}{\mathrm{min\_to\_sec}} \tag{1}$$

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

6.2 Rule Vpfk

Rule Vpfk is an assignment rule for parameter Vpfk:

$$\text{Vpfk} = \frac{\text{Vpfk\_min} \cdot \text{dw\_per\_ml}}{\text{min\_to\_sec}} \tag{2}$$

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

6.3 Rule Vfba

Rule Vfba is an assignment rule for parameter Vfba:

$$\text{Vfba} = \frac{\text{Vfba\_min} \cdot \text{dw\_per\_ml}}{\text{min\_to\_sec}} \tag{3}$$

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

6.4 Rule F6P

Rule F6P is an assignment rule for species F6P:

$$\text{F6P} = \frac{[\text{G6P\_F6P}] \cdot \text{KeqGPI}}{1 + \text{KeqGPI}} \tag{4}$$

7 Reactions

This model contains three 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	`vgk`	vgk	$\mathrm{GLC} \longrightarrow \mathrm{G6P\_F6P}$	
2	`vpfk`	vpfk	$\mathrm{G6P\_F6P} \xrightarrow{\mathrm{F6P}} \mathrm{FBP}$	
3	`vfba`	vfba	$\mathrm{FBP} \longrightarrow \mathrm{G3P}$	

7.1 Reaction vgk

This is an irreversible reaction of one reactant forming one product.

Name vgk

Reaction equation

$$\mathrm{GLC} \longrightarrow \mathrm{G6P\_F6P} \tag{5}$$

Reactant

Table 6: Properties of each reactant.

Id	Name	SBO
GLC	GLC	

Product

Table 7: Properties of each product.

Id	Name	SBO
G6P_F6P	G6P_F6P	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \frac{\mathrm{vol}\left(\mathrm{comp}\right) \cdot \mathrm{Vgk} \cdot \left(\frac{[\mathrm{GLC}]}{\mathrm{Sgk}}\right)^{\mathrm{hGK}}}{1 + \left(\frac{[\mathrm{GLC}]}{\mathrm{Sgk}}\right)^{\mathrm{hGK}}} \tag{6}$$

7.2 Reaction vpfk

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

Name vpfk

Reaction equation

$$\mathrm{G6P\_F6P} \xrightarrow{\mathrm{F6P}} \mathrm{FBP} \tag{7}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
`G6P_F6P`	G6P_F6P	

Modifier

Table 9: Properties of each modifier.

Id	Name	SBO
`F6P`	F6P	

Product

Table 10: Properties of each product.

Id	Name	SBO
`FBP`	FBP	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \frac{\mathrm{vol}\left(\mathrm{comp}\right) \cdot \mathrm{Vpfk} \cdot \left(\frac{[\mathrm{F6P}]}{\mathrm{Spfk}}\right)^{\mathrm{hpfk}-(\mathrm{hpfk}-\mathrm{hact})\cdot\frac{\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}{1+\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}}}{\left(\frac{[\mathrm{F6P}]}{\mathrm{Spfk}}\right)^{\mathrm{hpfk}-(\mathrm{hpfk}-\mathrm{hact})\cdot\frac{\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}{1+\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}} + \frac{1+\left(\frac{[\mathrm{FBP}]}{\mathrm{Xpfk}}\right)^{\mathrm{hx}}}{1+\mathrm{alpha}^{\mathrm{hpfk}-(\mathrm{hpfk}-\mathrm{hact})\cdot\frac{\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}{1+\frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}} \cdot \left(\frac{[\mathrm{FBP}]}{\mathrm{Xpfk}}\right)^{\mathrm{hx}}}} \tag{8}$$

7.3 Reaction `vfba`

This is an irreversible reaction of one reactant forming one product.

Name vfba

Reaction equation

$$\mathrm{FBP} \longrightarrow \mathrm{G3P} \tag{9}$$

Reactant

Table 11: Properties of each reactant.

Id	Name	SBO
FBP	FBP	

Product

Table 12: Properties of each product.

Id	Name	SBO
G3P	G3P	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \frac{\mathrm{vol}\left(\mathrm{comp}\right) \cdot \mathrm{Vfba} \cdot \frac{[\mathrm{FBP}]}{\mathrm{Sfba}}}{\frac{[\mathrm{FBP}]}{\mathrm{Sfba}} + 1} \tag{10}$$

8 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.

8.1 Species GLC

Name GLC

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{GLC} = 0 \tag{11}$$

8.2 Species G6P_F6P

Name G6P_F6P

Initial concentration $3.71728\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in vpfk and as a product in vgk).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{G6P\_F6P} = v_1 - v_2 \tag{12}$$

8.3 Species F6P

Name F6P

Involved in rule F6P

This species takes part in one reaction (as a modifier in vpfk). Not this but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.4 Species FBP

Name FBP

Initial concentration $6.3612 \cdot 10^{-4}$ mmol $\cdot$ l^{-1}

This species takes part in two reactions (as a reactant in vfba and as a product in vpfk).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{FBP} = v_2 - v_3 \tag{13}$$

8.5 Species G3P

Name G3P

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{G3P} = 0 \tag{14}$$

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