SBML Model Report

Model name: “Novak1993 - Cell cycle M-phase control”

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: Nicolas Le Novre[1], Harish Dharuri[2] and Vijayalakshmi Chelliah[3] at April fifth 2007 at 8:42 a. m. and last time modified at March 15th 2016 at 4:57 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	14
events	0	constraints	0
reactions	23	function definitions	0
global parameters	36	unit definitions	2
rules	10	initial assignments	0

Model Notes

Novak1993 - Cell cycle M-phase controlThe model reproduces Figure 9 of the paper. Please note that active MPF and cyclin concentrations in the paper are given relative to total cdc2 concentration (100nM). Active MPF (dimer_p) is the cyclin-cdc2 complex that is phosphorylated at

[1]EMBL-EBI, lenov@ebi.ac.uk
[2]California Institute of Technology, hdharuri@cds.caltech.edu
[3]EMBL-EBI, viji@ebi.ac.uk

Thr161. The earlier versions of the model was successfully tested on MathSBML and Jarnac, and the current version was checked in Copasi.

This model is described in the article:Numerical analysis of a comprehensive model of M-phase control in Xenopus oocyte extracts and intact embryos. Novak B, Tyson JJ. J. Cell. Sci. 1993 Dec; 106 (Pt 4): 1153-1168

Abstract:

To contribute to a deeper understanding of M-phase control in eukaryotic cells, we have constructed a model based on the biochemistry of M-phase promoting factor (MPF) in Xenopus oocyte extracts, where there is evidence for two positive feedback loops (MPF stimulates its own production by activating Cdc25 and inhibiting Wee1) and a negative feedback loop (MPF stimulates its own destruction by indirectly activating the ubiquitin pathway that degrades its cyclin subunit). To uncover the full dynamical possibilities of the control system, we translate the regulatory network into a set of differential equations and study these equations by graphical techniques and computer simulation. The positive feedback loops in the model account for thresholds and time lags in cyclin-induced and MPF-induced activation of MPF, and the model can be fitted quantitatively to these experimental observations. The negative feedback loop is consistent with observed time lags in MPF-induced cyclin degradation. Furthermore, our model indicates that there are two possible mechanisms for autonomous oscillations. One is driven by the positive feedback loops, resulting in phosphorylation and abrupt dephosphorylation of the Cdc2 subunit at an inhibitory tyrosine residue. These oscillations are typical of oocyte extracts. The other type is driven by the negative feedback loop, involving rapid cyclin turnover and negligible phosphorylation of the tyrosine residue of Cdc2. The early mitotic cycles of intact embryos exhibit such characteristics. In addition, by assuming that unreplicated DNA interferes with M-phase initiation by activating the phosphatases that oppose MPF in the positive feedback loops, we can simulate the effect of addition of sperm nuclei to oocyte extracts, and the lengthening of cycle times at the mid-blastula transition of intact embryos.

This model is hosted on BioModels Database and identified by: BIOMD0000000107.

To cite BioModels Database, please use: BioModels: ten-year anniversary .

2 Unit Definitions

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

2.1 Unit `substance`

Name nanomole

Definition nmol

2.2 Unit time

Name minutes

Definition 60 s

2.3 Unit volume

Notes Litre is the predefined SBML unit for volume.

Definition l

2.4 Unit area

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

Definition m^2

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
cytoplasm	cytoplasm		3	1	litre	☑	

3.1 Compartment cytoplasm

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

Name cytoplasm

4 Species

This model contains 14 species. The boundary condition of five 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
`cyclin`	cyclin	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`dimer`	cyclin-cdc2 dimer	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`dimer_p`	Thr161 phosphorylated dimer(active MPF)	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`p_dimer`	Tyr15 phosphorylated dimer	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`p_dimer_p`	Thr161-Tyr15 phosphorylated dimer	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`cdc25_p`	phosphorylated cdc25	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`wee1_p`	phosphorylated wee1	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`IE_p`	phosphorylated intermediary enzyme	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`UbE_star`	ubiquitin conjugating enzyme	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	⊟
`cdc2`	cdc2	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	☑
`cdc25`	cdc25	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	☑
`wee1`	wee1	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	☑
`IE`	intermediary enzyme	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	☑
`UbE`	ubiquitin conjugating enzyme	`cytoplasm`	$\mathrm{nmol} \cdot \mathrm{l}^{-1}$	⊟	☑

5 Parameters

This model contains 36 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
total_cdc2			100.000		☑
total_cdc25			1.000		☑
total_wee1			1.000		☑
total_IE			1.000		☑
total_UbE			1.000		☑
k25			0.000		☐
V25_prime			0.100		☑
V25_double-_prime			2.000		☑
kwee			0.000		☐
Vwee_prime			0.100		☑
Vwee_double-_prime			1.000		☑
k2			0.000		☐
V2_prime			0.015		☑
V2_double-_prime			1.000		☑
k1AA			1.000		☑
k3			0.010		☑
kinh			0.025		☑
kcak			0.250		☑
ka			0.010		☑
K_a			0.100		☑
kbPPase			0.125		☑
K_b			0.100		☑
ke			0.013		☑
K_e			0.300		☑
kfPPase			0.100		☑
K_f			0.300		☑
kg			0.007		☑
K_g			0.010		☑
khPPAse			0.087		☑
K_h			0.010		☑
kc			0.100		☑
K_c			0.010		☑
kd_anti_IE			0.095		☑
K_d			0.010		☑

Id	Name	SBO	Value	Unit	Constant
total_cyclin			0.000		⊟
Y15P			0.000		⊟

6 Rules

This is an overview of ten rules.

6.1 Rule cdc2

Rule cdc2 is an assignment rule for species cdc2:

$$\text{cdc2} = \text{total\_cdc2} - ([\text{dimer}] + [\text{p\_dimer}] + [\text{p\_dimer\_p}] + [\text{dimer\_p}]) \tag{1}$$

6.2 Rule cdc25

Rule cdc25 is an assignment rule for species cdc25:

$$\text{cdc25} = \text{total\_cdc25} - [\text{cdc25\_p}] \tag{2}$$

6.3 Rule wee1

Rule wee1 is an assignment rule for species wee1:

$$\text{wee1} = \text{total\_wee1} - [\text{wee1\_p}] \tag{3}$$

6.4 Rule IE

Rule IE is an assignment rule for species IE:

$$\text{IE} = \text{total\_IE} - [\text{IE\_p}] \tag{4}$$

6.5 Rule UbE

Rule UbE is an assignment rule for species UbE:

$$\text{UbE} = \text{total\_UbE} - [\text{UbE\_star}] \tag{5}$$

6.6 Rule k25

Rule k25 is an assignment rule for parameter k25:

$$\text{k25} = \text{V25\_prime} \cdot (\text{total\_cdc25} - [\text{cdc25\_p}]) + \text{V25\_double\_prime} \cdot [\text{cdc25\_p}] \tag{6}$$

6.7 Rule kwee

Rule kwee is an assignment rule for parameter kwee:

$$\text{kwee} = \text{Vwee\_prime} \cdot [\text{wee1\_p}] + \text{Vwee\_double\_prime} \cdot (\text{total\_wee1} - [\text{wee1\_p}]) \quad (7)$$

6.8 Rule k2

Rule k2 is an assignment rule for parameter k2:

$$\text{k2} = \text{V2\_prime} \cdot (\text{total\_UbE} - [\text{UbE\_star}]) + \text{V2\_double\_prime} \cdot [\text{UbE\_star}] \quad (8)$$

6.9 Rule total_cyclin

Rule total_cyclin is an assignment rule for parameter total_cyclin:

$$\text{total\_cyclin} = [\text{cyclin}] + [\text{dimer}] + [\text{dimer\_p}] + [\text{p\_dimer}] + [\text{p\_dimer\_p}] \quad (9)$$

Derived unit $\text{nmol} \cdot \text{l}^{-1}$

6.10 Rule Y15P

Rule Y15P is an assignment rule for parameter Y15P:

$$\text{Y15P} = [\text{p\_dimer}] + [\text{p\_dimer\_p}] \quad (10)$$

Derived unit $\text{nmol} \cdot \text{l}^{-1}$

7 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

№	Id	Name	Reaction Equation	SBO
1	R1	cyclin synthesis	$\emptyset \longrightarrow \text{cyclin}$	
2	R2	cyclin degradation	$\text{cyclin} \longrightarrow \emptyset$	
3	R3	cyclin-cdc2 dimer formation	$\text{cyclin} + \text{cdc2} \longrightarrow \text{dimer}$	
4	R4	Thr161 dephosphorylation	$\text{dimer\_p} \longrightarrow \text{dimer}$	
5	R5	Tyr15 phosphorylation	$\text{dimer} \longrightarrow \text{p\_dimer}$	
6	R6	Thr161 phosphorylation	$\text{dimer} \longrightarrow \text{dimer\_p}$	
7	R7	cyclin degradation	$\text{dimer} \longrightarrow \emptyset$	
8	R8	Tyr15 dephosphorylation	$\text{p\_dimer} \longrightarrow \text{dimer}$	
9	R9	Thr161 phosphorylation	$\text{p\_dimer} \longrightarrow \text{p\_dimer\_p}$	
10	R10	cyclin degradation	$\text{p\_dimer} \longrightarrow \emptyset$	
11	R11	Thr161 dephosphorylation	$\text{p\_dimer\_p} \longrightarrow \text{p\_dimer}$	
12	R12	Tyr15 phosphorylation	$\text{dimer\_p} \xrightarrow{\text{wee1}} \text{p\_dimer\_p}$	
13	R13	Tyr15 dephosphorylation	$\text{p\_dimer\_p} \xrightarrow{\text{cdc25}} \text{dimer\_p}$	
14	R14	cyclin degradation	$\text{p\_dimer\_p} \longrightarrow \emptyset$	
15	R15	cyclin degradation	$\text{dimer\_p} \longrightarrow \emptyset$	
16	R17	cdc25 activation	$\text{cdc25} \xrightarrow{\text{dimer\_p}} \text{cdc25\_p}$	
17	R18	cdc25 deactivation	$\text{cdc25\_p} \longrightarrow \text{cdc25}$	
18	R19	wee1 deactivation	$\text{wee1} \xrightarrow{\text{dimer\_p}} \text{wee1\_p}$	
19	R20	wee1 activation	$\text{wee1\_p} \longrightarrow \text{wee1}$	
20	R21	intermediary enzyme activation	$\text{IE} \xrightarrow{\text{dimer\_p}} \text{IE\_p}$	
21	R22	intermediary enzyme deactivation	$\text{IE\_p} \longrightarrow \text{IE}$	

№	Id	Name	Reaction Equation	SBO
22	R23	ubiquitin conjugating enzyme activation	$\mathrm{UbE} \xrightarrow{\mathrm{IE\_p}} \mathrm{UbE\_star}$	
23	R24	ubiquitin conjugating enzyme deactivation	$\mathrm{UbE\_star} \longrightarrow \mathrm{UbE}$	

7.1 Reaction R1

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

Name cyclin synthesis

Reaction equation

$$\emptyset \longrightarrow \text{cyclin} \tag{11}$$

Product

Table 6: Properties of each product.

Id	Name	SBO
cyclin	cyclin	

Kinetic Law

Derived unit not available

$$v_1 = \text{k1AA} \tag{12}$$

7.2 Reaction R2

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

Name cyclin degradation

Reaction equation

$$\text{cyclin} \longrightarrow \emptyset \tag{13}$$

Reactant

Table 7: Properties of each reactant.

Id	Name	SBO
cyclin	cyclin	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \text{k2} \cdot [\text{cyclin}] \tag{14}$$

7.3 Reaction R3

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

Name cyclin-cdc2 dimer formation

Reaction equation

$$\text{cyclin} + \text{cdc2} \longrightarrow \text{dimer} \tag{15}$$

Reactants

Table 8: Properties of each reactant.

Id	Name	SBO
cyclin	cyclin	
cdc2	cdc2	

Product

Table 9: Properties of each product.

Id	Name	SBO
dimer	cyclin-cdc2 dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \text{k3} \cdot [\text{cyclin}] \cdot [\text{cdc2}] \tag{16}$$

7.4 Reaction R4

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

Name Thr161 dephosphorylation

Reaction equation

$$\text{dimer\_p} \longrightarrow \text{dimer} \tag{17}$$

Reactant

Table 10: Properties of each reactant.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Product

Table 11: Properties of each product.

Id	Name	SBO
dimer	cyclin-cdc2 dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \text{kinh} \cdot [\text{dimer\_p}] \tag{18}$$

7.5 Reaction R5

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

Name Tyr15 phosphorylation

Reaction equation

$$\text{dimer} \longrightarrow \text{p\_dimer} \tag{19}$$

Reactant

Table 12: Properties of each reactant.

Id	Name	SBO
dimer	cyclin-cdc2 dimer	

Product

Table 13: Properties of each product.

Id	Name	SBO
p_dimer	Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \text{kwee} \cdot [\text{dimer}] \tag{20}$$

7.6 Reaction R6

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

Name Thr161 phosphorylation

Reaction equation

$$\text{dimer} \longrightarrow \text{dimer\_p} \tag{21}$$

Reactant

Table 14: Properties of each reactant.

Id	Name	SBO
`dimer`	cyclin-cdc2 dimer	

Product

Table 15: Properties of each product.

Id	Name	SBO
`dimer_p`	Thr161 phosphorylated dimer(active MPF)	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \text{kcak} \cdot [\text{dimer}] \tag{22}$$

7.7 Reaction R7

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

Name cyclin degradation

Reaction equation

$$\text{dimer} \longrightarrow \emptyset \tag{23}$$

Reactant

Table 16: Properties of each reactant.

Id	Name	SBO
`dimer`	cyclin-cdc2 dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \mathrm{k2} \cdot [\mathrm{dimer}] \tag{24}$$

7.8 Reaction R8

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

Name Tyr15 dephosphorylation

Reaction equation

$$\mathrm{p\_dimer} \longrightarrow \mathrm{dimer} \tag{25}$$

Reactant

Table 17: Properties of each reactant.

Id	Name	SBO
`p_dimer`	Tyr15 phosphorylated dimer	

Product

Table 18: Properties of each product.

Id	Name	SBO
`dimer`	cyclin-cdc2 dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \mathrm{k25} \cdot [\mathrm{p\_dimer}] \tag{26}$$

7.9 Reaction R9

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

Name Thr161 phosphorylation

Reaction equation

$$\text{p\_dimer} \longrightarrow \text{p\_dimer\_p} \tag{27}$$

Reactant

Table 19: Properties of each reactant.

Id	Name	SBO
p_dimer	Tyr15 phosphorylated dimer	

Product

Table 20: Properties of each product.

Id	Name	SBO
p_dimer_p	Thr161-Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \text{kcak} \cdot [\text{p\_dimer}] \tag{28}$$

7.10 Reaction R10

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

Name cyclin degradation

Reaction equation

$$\text{p\_dimer} \longrightarrow \emptyset \tag{29}$$

Reactant

Table 21: Properties of each reactant.

Id	Name	SBO
p_dimer	Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \text{k2} \cdot [\text{p\_dimer}] \tag{30}$$

7.11 Reaction R11

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

Name Thr161 dephosphorylation

Reaction equation

$$\text{p\_dimer\_p} \longrightarrow \text{p\_dimer} \tag{31}$$

Reactant

Table 22: Properties of each reactant.

Id	Name	SBO
p_dimer_p	Thr161-Tyr15 phosphorylated dimer	

Product

Table 23: Properties of each product.

Id	Name	SBO
p_dimer	Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \text{kinh} \cdot [\text{p\_dimer\_p}] \tag{32}$$

7.12 Reaction R12

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

Name Tyr15 phosphorylation

Reaction equation

$$\text{dimer\_p} \xrightarrow{\text{wee1}} \text{p\_dimer\_p} \tag{33}$$

Reactant

Table 24: Properties of each reactant.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Modifier

Table 25: Properties of each modifier.

Id	Name	SBO
wee1	wee1	

Product

Table 26: Properties of each product.

Id	Name	SBO
p_dimer_p	Thr161-Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \text{kwee} \cdot [\text{dimer\_p}] \tag{34}$$

7.13 Reaction R13

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

Name Tyr15 dephosphorylation

Reaction equation

$$\text{p\_dimer\_p} \xrightarrow{\text{cdc25}} \text{dimer\_p} \tag{35}$$

Reactant

Table 27: Properties of each reactant.

Id	Name	SBO
p_dimer_p	Thr161-Tyr15 phosphorylated dimer	

Modifier

Table 28: Properties of each modifier.

Id	Name	SBO
cdc25	cdc25	

Product

Table 29: Properties of each product.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \text{k25} \cdot [\text{p\_dimer\_p}] \tag{36}$$

7.14 Reaction R14

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

Name cyclin degradation

Reaction equation

$$\text{p\_dimer\_p} \longrightarrow \emptyset \tag{37}$$

Reactant

Table 30: Properties of each reactant.

Id	Name	SBO
p_dimer_p	Thr161-Tyr15 phosphorylated dimer	

Kinetic Law

Derived unit contains undeclared units

$$v_{14} = \mathrm{k2} \cdot [\mathrm{p\_dimer\_p}] \tag{38}$$

7.15 Reaction R15

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

Name cyclin degradation

Reaction equation

$$\mathrm{dimer\_p} \longrightarrow \emptyset \tag{39}$$

Reactant

Table 31: Properties of each reactant.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \mathrm{k2} \cdot [\mathrm{dimer\_p}] \tag{40}$$

7.16 Reaction R17

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

Name cdc25 activation

Reaction equation

$$\mathrm{cdc25} \xrightarrow{\mathrm{dimer\_p}} \mathrm{cdc25\_p} \tag{41}$$

Reactant

Table 32: Properties of each reactant.

Id	Name	SBO
cdc25	cdc25	

Modifier

Table 33: Properties of each modifier.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Product

Table 34: Properties of each product.

Id	Name	SBO
cdc25_p	phosphorylated cdc25	

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = \frac{\text{ka} \cdot [\text{dimer\_p}] \cdot (\text{total\_cdc25} - [\text{cdc25\_p}])}{\text{K\_a} + \text{total\_cdc25} - [\text{cdc25\_p}]} \tag{42}$$

7.17 Reaction R18

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

Name cdc25 deactivation

Reaction equation

$$\text{cdc25\_p} \longrightarrow \text{cdc25} \tag{43}$$

Reactant

Table 35: Properties of each reactant.

Id	Name	SBO
cdc25_p	phosphorylated cdc25	

Product

Table 36: Properties of each product.

Id	Name	SBO
cdc25	cdc25	

Kinetic Law

Derived unit contains undeclared units

$$v_{17} = \frac{\text{kbPPase} \cdot [\text{cdc25\_p}]}{\text{K\_b} + [\text{cdc25\_p}]} \tag{44}$$

7.18 Reaction R19

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

Name wee1 deactivation

Reaction equation

$$\text{wee1} \xrightarrow{\text{dimer\_p}} \text{wee1\_p} \tag{45}$$

Reactant

Table 37: Properties of each reactant.

Id	Name	SBO
wee1	wee1	

Modifier

Table 38: Properties of each modifier.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Product

Table 39: Properties of each product.

Id	Name	SBO
wee1_p	phosphorylated wee1	

Kinetic Law

Derived unit contains undeclared units

$$v_{18} = \frac{\text{ke} \cdot [\text{dimer\_p}] \cdot (\text{total\_wee1} - [\text{wee1\_p}])}{\text{K\_e} + \text{total\_wee1} - [\text{wee1\_p}]} \tag{46}$$

7.19 Reaction R20

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

Name wee1 activation

Reaction equation

$$\text{wee1\_p} \longrightarrow \text{wee1} \tag{47}$$

Reactant

Table 40: Properties of each reactant.

Id	Name	SBO
wee1_p	phosphorylated wee1	

Product

Table 41: Properties of each product.

Id	Name	SBO
wee1	wee1	

Id	Name	SBO

Kinetic Law

Derived unit contains undeclared units

$$v_{19} = \frac{\text{kfPPase} \cdot [\text{wee1\_p}]}{\text{K\_f} + [\text{wee1\_p}]} \tag{48}$$

7.20 Reaction R21

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

Name intermediary enzyme activation

Reaction equation

$$\text{IE} \xrightarrow{\text{dimer\_p}} \text{IE\_p} \tag{49}$$

Reactant

Table 42: Properties of each reactant.

Id	Name	SBO
IE	intermediary enzyme	

Modifier

Table 43: Properties of each modifier.

Id	Name	SBO
dimer_p	Thr161 phosphorylated dimer(active MPF)	

Product

Table 44: Properties of each product.

Id	Name	SBO
IE_p	phosphorylated intermediary enzyme	

Kinetic Law

Derived unit contains undeclared units

$$v_{20} = \frac{\mathrm{kg} \cdot [\mathrm{dimer\_p}] \cdot (\mathrm{total\_IE} - [\mathrm{IE\_p}])}{\mathrm{K\_g} + \mathrm{total\_IE} - [\mathrm{IE\_p}]} \tag{50}$$

7.21 Reaction R22

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

Name intermediary enzyme deactivation

Reaction equation

$$\mathrm{IE\_p} \longrightarrow \mathrm{IE} \tag{51}$$

Reactant

Table 45: Properties of each reactant.

Id	Name	SBO
IE_p	phosphorylated intermediary enzyme	

Product

Table 46: Properties of each product.

Id	Name	SBO
IE	intermediary enzyme	

Kinetic Law

Derived unit contains undeclared units

$$v_{21} = \frac{\mathrm{khPPAse} \cdot [\mathrm{IE\_p}]}{\mathrm{K\_h} + [\mathrm{IE\_p}]} \tag{52}$$

7.22 Reaction R23

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

Name ubiquitin conjugating enzyme activation

Reaction equation

$$\text{UbE} \xrightarrow{\text{IE\_p}} \text{UbE\_star} \tag{53}$$

Reactant

Table 47: Properties of each reactant.

Id	Name	SBO
UbE	ubiquitin conjugating enzyme	

Modifier

Table 48: Properties of each modifier.

Id	Name	SBO
IE_p	phosphorylated intermediary enzyme	

Product

Table 49: Properties of each product.

Id	Name	SBO
UbE_star	ubiquitin conjugating enzyme	

Kinetic Law

Derived unit contains undeclared units

$$v_{22} = \frac{\text{kc} \cdot [\text{IE\_p}] \cdot (\text{total\_UbE} - [\text{UbE\_star}])}{\text{K\_c} + \text{total\_UbE} - [\text{UbE\_star}]} \tag{54}$$

7.23 Reaction R24

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

Name ubiquitin conjugating enzyme deactivation

Reaction equation

$$\text{UbE\_star} \longrightarrow \text{UbE} \tag{55}$$

Reactant

Table 50: Properties of each reactant.

Id	Name	SBO
UbE_star	ubiquitin conjugating enzyme	

Product

Table 51: Properties of each product.

Id	Name	SBO
UbE	ubiquitin conjugating enzyme	

Kinetic Law

Derived unit contains undeclared units

$$v_{23} = \frac{\text{kd\_anti\_IE} \cdot [\text{UbE\_star}]}{\text{K\_d} + [\text{UbE\_star}]} \tag{56}$$

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.

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.

8.1 Species `cyclin`

Name cyclin

Initial concentration $100\ \text{nmol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in R2, R3 and as a product in R1).

$$\frac{\text{d}}{\text{d}t}\text{cyclin} = v_1 - v_2 - v_3 \tag{57}$$

8.2 Species dimer

Name cyclin-cdc2 dimer

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

This species takes part in six reactions (as a reactant in R5, R6, R7 and as a product in R3, R4, R8).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{dimer} = v_3 + v_4 + v_8 - v_5 - v_6 - v_7 \tag{58}$$

8.3 Species dimer_p

Name Thr161 phosphorylated dimer(active MPF)

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

This species takes part in eight reactions (as a reactant in R4, R12, R15 and as a product in R6, R13 and as a modifier in R17, R19, R21).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{dimer\_p} = v_6 + v_{13} - v_4 - v_{12} - v_{15} \tag{59}$$

8.4 Species p_dimer

Name Tyr15 phosphorylated dimer

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

This species takes part in five reactions (as a reactant in R8, R9, R10 and as a product in R5, R11).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{p\_dimer} = v_5 + v_{11} - v_8 - v_9 - v_{10} \tag{60}$$

8.5 Species p_dimer_p

Name Thr161-Tyr15 phosphorylated dimer

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

This species takes part in five reactions (as a reactant in R11, R13, R14 and as a product in R9, R12).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{p\_dimer\_p} = v_9 + v_{12} - v_{11} - v_{13} - v_{14} \tag{61}$$

8.6 Species cdc25_p

Name phosphorylated cdc25

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

This species takes part in two reactions (as a reactant in R18 and as a product in R17).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{cdc25\_p} = v_{16} - v_{17} \tag{62}$$

8.7 Species wee1_p

Name phosphorylated wee1

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

This species takes part in two reactions (as a reactant in R20 and as a product in R19).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{wee1\_p} = v_{18} - v_{19} \tag{63}$$

8.8 Species IE_p

Name phosphorylated intermediary enzyme

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

This species takes part in three reactions (as a reactant in R22 and as a product in R21 and as a modifier in R23).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IE\_p} = v_{20} - v_{21} \tag{64}$$

8.9 Species UbE_star

Name ubiquitin conjugating enzyme

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

This species takes part in two reactions (as a reactant in R24 and as a product in R23).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{UbE\_star} = v_{22} - v_{23} \tag{65}$$

8.10 Species cdc2

Name cdc2

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

Involved in rule cdc2

This species takes part in one reaction (as a reactant in R3). Not this but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.11 Species cdc25

Name cdc25

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

Involved in rule cdc25

This species takes part in three reactions (as a reactant in R17 and as a product in R18 and as a modifier in R13). Not these but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.12 Species wee1

Name wee1

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

Involved in rule wee1

This species takes part in three reactions (as a reactant in R19 and as a product in R20 and as a modifier in R12). Not these but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.13 Species IE

Name intermediary enzyme

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

Involved in rule IE

This species takes part in two reactions (as a reactant in R21 and as a product in R22). Not these but one rule determines the species' quantity because this species is on the boundary of the reaction system.

8.14 Species UbE

Name ubiquitin conjugating enzyme

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

Involved in rule UbE

This species takes part in two reactions (as a reactant in R23 and as a product in R24). Not these but one rule determines the species' quantity because this species is on the boundary of the reaction system.

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