SBML Model Report

Model name: “Koschorreck2008_InsulinClearance”

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by Ishan Ajmera[1] at August fifth 2011 at 9:33 a. m. and last time modified at October tenth 2014 at 10:32 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	0	function definitions	0
global parameters	58	unit definitions	0
rules	52	initial assignments	0

Model Notes

This model is from the article:
Mathematical modeling and analysis of insulin clearance in vivo.
Koschorreck M, Gilles ED. BMC Syst Biol. 2008 May 13;2:43. 18477391,
Abstract:
BACKGROUND:Analyzing the dynamics of insulin concentration in the blood is necessary for a comprehensive understanding of the effects of insulin in vivo. Insulin removal from the blood

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has been addressed in many studies. The results are highly variable with respect to insulin clearance and the relative contributions of hepatic and renal insulin degradation.RESULTS:We present a dynamic mathematical model of insulin concentration in the blood and of insulin receptor activation in hepatocytes. The model describes renal and hepatic insulin degradation, pancreatic insulin secretion and nonspecific insulin binding in the liver. Hepatic insulin receptor activation by insulin binding, receptor internalization and autophosphorylation is explicitly included in the model. We present a detailed mathematical analysis of insulin degradation and insulin clearance. Stationary model analysis shows that degradation rates, relative contributions of the different tissues to total insulin degradation and insulin clearance highly depend on the insulin concentration.CONCLUSION:This study provides a detailed dynamic model of insulin concentration in the blood and of insulin receptor activation in hepatocytes. Experimental data sets from literature are used for the model validation. We show that essential dynamic and stationary characteristics of insulin degradation are nonlinear and depend on the actual insulin concentration.

To cite BioModels Database, please use: Li C, Donizelli M, Rodriguez N, Dharuri H, Endler L, Chelliah V, Li L, He E, Henry A, Stefan MI, Snoep JL, Hucka M, Le Novre N, Laibe C (2010) BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models. BMC Syst Biol., 4:92.

2 Unit Definitions

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

2.1 Unit `substance`

Notes Mole is the predefined SBML unit for `substance`.

Definition mol

2.2 Unit `volume`

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

Definition l

2.3 Unit `area`

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

Definition m^2

2.4 Unit `length`

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

Definition m

2.5 Unit `time`

Notes Second is the predefined SBML unit for `time`.

Definition s

3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
`compartment1`	compartment1		3	1	litre	☑	

3.1 Compartment `compartment1`

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

Name compartment1

4 Species

This model contains 13 species. The boundary condition of 13 of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 7 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
R	R	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
ins	ins	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☑	☑
IR	IR	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
I2R	I2R	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
Rp	Rp	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
IRp	IRp	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
I2Rp	I2Rp	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
Ren	Ren	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
IRen	IRen	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
I2Ren	I2Ren	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
RPen	RPen	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
IRPen	IRPen	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑
I2RPen	I2RPen	compartment1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	☐	☑

5 Parameters

This model contains 58 global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constan
kins	kins	0000009	0.001		☑
kins1d	kins1d	0000180	$4 \cdot 10^{-4}$		☑
kins2d	kins2d	0000180	0.040		☑
kins1den	kins1den	0000180	0.002		☑
kins2den	kins2den	0000180	0.004		☑
kyd	kyd	0000330	0.004		☑
kyden	kyden	0000330	0.007		☑
kyp	kyp	0000216	0.023		☑
intk1	intk1	0000009	$5.5 \cdot 10^{-4}$		☑
intk2	intk2	0000009	$2 \cdot 10^{-4}$		☑
reck1	reck1	0000009	0.002		☑
Rtotal	Rtotal	0000009	40.000		☑
k1ub	k1ub	0000009	0.350		☑
k2ub	k2ub	0000180	0.200		☑
pansec	pansec	0000009	0.002		☑
Kpan	Kpan	0000009	0.500		☑
mliver	mliver	0000504	10.000		☐
vp	vp	0000468	0.007		☐
rholiver	rholiver	0000226	1051.000		☑
vhep	vhep	0000468	0.007		☐
vd	vd	0000468	0.002		☐
mkidney	mkidney	0000504	1.478		☐
Kkidney	Kkidney	0000009	$3.32608695652174 \cdot 10^{-5}$		☐
r1	r1	0000009	3.538		☐
r2	r2	0000009	0.000		☐
r3	r3	0000009	0.000		☐
r4	r4	0000009	0.000		☐
r5	r5	0000009	0.000		☐
r6	r6	0000009	0.000		☐
r7	r7	0000009	0.000		☐
i1	i1	0000216	0.000		☐
i2	i2	0000216	0.000		☐
i3	i3	0000216	0.000		☐
i4	i4	0000216	$-1.70974345792274 \cdot 10^{-17}$		☐
i5	i5	0000216	0.000		☐
i6	i6	0000216	0.000		☐
i7	i7	0000216	$3.20632409511745 \cdot 10^{-17}$		☐

Id	Name	SBO	Value	Unit	Constan
f1	f1	0000009	$-4.78999999985533 \cdot 10^{-8}$		☐
f2	f2	0000009	0.000		☐
f3	f3	0000009	0.000		☐
f4	f4	0000009	0.000		☐
f5	f5	0000009	0.000		☐
f6	f6	0000009	0.000		☐
bw	bw	0000002	200.000		☑
parameter_1	rliv	0000179	3.890		☐
parameter_2	rkid	0000179	0.493		☐
parameter_3	Ratetotal	0000064	4.383		☐
parameter_4	Fracliver	0000009	88.758		☐
parameter_5	Frackidney	0000009	11.242		☐
parameter_6	Cliver	0000009	1.576		☐
parameter_7	Ckidney	0000009	0.200		☐
parameter_8	Ctotal	0000009	1.775		☐
parameter_9	ReceptorIns	0000064	$-1.11022302462516 \cdot 10^{-16}$		☐
parameter_10	ReceptorIns2	0000064	$-1.11022302462516 \cdot 10^{-16}$		☐
parameter_11	ReceptorInsPM	0000064	0.000		☐
parameter_12	ReceptorIns2PM	0000064	0.000		☐
parameter_13	ReceptorInsEN	0000064	$-1.11022302462516 \cdot 10^{-16}$		☐
parameter_14	ReceptorIns2EN	0000064	$-1.11022302462516 \cdot 10^{-16}$		☐

6 Rules

This is an overview of 52 rules.

6.1 Rule mkidney

Rule mkidney is an assignment rule for parameter mkidney:

$$\text{mkidney} = \frac{2 \cdot 0.85 \cdot \text{bw}}{230} \tag{1}$$

6.2 Rule mliver

Rule mliver is an assignment rule for parameter mliver:

$$\text{mliver} = 0.05 \cdot \text{bw} \tag{2}$$

6.3 Rule vp

Rule vp is an assignment rule for parameter vp:

$$\text{vp} = 0.03375 \cdot 10^{3} \cdot \text{bw} \tag{3}$$

6.4 Rule vhep

Rule vhep is an assignment rule for parameter vhep:

$$\mathrm{vhep} = \frac{\mathrm{mliver}}{\mathrm{rholiver}} \cdot 0.78 \tag{4}$$

6.5 Rule vd

Rule vd is an assignment rule for parameter vd:

$$\mathrm{vd} = 0.272 \cdot 10^{3} \cdot \mathrm{vhep} \cdot \mathrm{rholiver} \tag{5}$$

6.6 Rule I2RPen

Rule I2RPen is an assignment rule for species I2RPen:

$$\begin{aligned}\mathrm{I2RPen} = \mathrm{Rtotal} - [\mathrm{R}] - [\mathrm{IR}] - [\mathrm{I2R}] - [\mathrm{Rp}] - [\mathrm{IRp}] - [\mathrm{I2Rp}] \\ - [\mathrm{Ren}] - [\mathrm{IRen}] - [\mathrm{I2Ren}] - [\mathrm{RPen}] - [\mathrm{IRPen}]\end{aligned} \tag{6}$$

6.7 Rule Kkidney

Rule Kkidney is an assignment rule for parameter Kkidney:

$$\mathrm{Kkidney} = 0.0225 \cdot 10^{3} \cdot \mathrm{mkidney} \tag{7}$$

6.8 Rule r1

Rule r1 is an assignment rule for parameter r1:

$$\mathrm{r1} = \mathrm{kins} \cdot [\mathrm{R}] \cdot [\mathrm{ins}] - \mathrm{kins1d} \cdot [\mathrm{IR}] \tag{8}$$

6.9 Rule r2

Rule r2 is an assignment rule for parameter r2:

$$\mathrm{r2} = \mathrm{kins} \cdot [\mathrm{Rp}] \cdot [\mathrm{ins}] - \mathrm{kins1d} \cdot [\mathrm{IRp}] \tag{9}$$

6.10 Rule r3

Rule r3 is an assignment rule for parameter r3:

$$\mathrm{r3} = \mathrm{kins} \cdot [\mathrm{IR}] \cdot [\mathrm{ins}] - \mathrm{kins2d} \cdot [\mathrm{I2R}] \tag{10}$$

6.11 Rule r4

Rule r4 is an assignment rule for parameter r4:

$$\mathrm{r4} = \mathrm{kins} \cdot [\mathrm{IRp}] \cdot [\mathrm{ins}] - \mathrm{kins2d} \cdot [\mathrm{I2Rp}] \tag{11}$$

6.12 Rule r5

Rule r5 is an assignment rule for parameter r5:

$$r5 = \mathrm{kyd} \cdot [\mathrm{Rp}] \tag{12}$$

6.13 Rule r6

Rule r6 is an assignment rule for parameter r6:

$$r6 = \mathrm{kyp} \cdot [\mathrm{IR}] - \mathrm{kyd} \cdot [\mathrm{IRp}] \tag{13}$$

6.14 Rule r7

Rule r7 is an assignment rule for parameter r7:

$$r7 = \mathrm{kyp} \cdot [\mathrm{I2R}] - \mathrm{kyd} \cdot [\mathrm{I2Rp}] \tag{14}$$

6.15 Rule i1

Rule i1 is an assignment rule for parameter i1:

$$i1 = \mathrm{kins1den} \cdot [\mathrm{IRen}] \tag{15}$$

6.16 Rule i2

Rule i2 is an assignment rule for parameter i2:

$$i2 = \mathrm{kins1den} \cdot [\mathrm{IRPen}] \tag{16}$$

6.17 Rule i3

Rule i3 is an assignment rule for parameter i3:

$$i3 = \mathrm{kins2den} \cdot [\mathrm{I2Ren}] \tag{17}$$

6.18 Rule i4

Rule i4 is an assignment rule for parameter i4:

$$i4 = \mathrm{kins2den} \cdot [\mathrm{I2RPen}] \tag{18}$$

6.19 Rule i5

Rule i5 is an assignment rule for parameter i5:

$$i5 = \mathrm{kyden} \cdot [\mathrm{RPen}] \tag{19}$$

6.20 Rule i6

Rule i6 is an assignment rule for parameter i6:

$$\text{i6} = \text{kyp} \cdot [\text{IRen}] - \text{kyden} \cdot [\text{IRPen}] \tag{20}$$

6.21 Rule i7

Rule i7 is an assignment rule for parameter i7:

$$\text{i7} = \text{kyp} \cdot [\text{I2Ren}] - \text{kyden} \cdot [\text{I2RPen}] \tag{21}$$

6.22 Rule f1

Rule f1 is an assignment rule for parameter f1:

$$\text{f1} = \text{intk2} \cdot [\text{R}] - \text{reck1} \cdot [\text{Ren}] \tag{22}$$

6.23 Rule f2

Rule f2 is an assignment rule for parameter f2:

$$\text{f2} = \text{intk2} \cdot [\text{IR}] \tag{23}$$

6.24 Rule f3

Rule f3 is an assignment rule for parameter f3:

$$\text{f3} = \text{intk2} \cdot [\text{I2R}] \tag{24}$$

6.25 Rule f4

Rule f4 is an assignment rule for parameter f4:

$$\text{f4} = \text{intk1} \cdot [\text{Rp}] - \text{reck1} \cdot [\text{RPen}] \tag{25}$$

6.26 Rule f5

Rule f5 is an assignment rule for parameter f5:

$$\text{f5} = \text{intk1} \cdot [\text{IRp}] \tag{26}$$

6.27 Rule f6

Rule f6 is an assignment rule for parameter f6:

$$\text{f6} = \text{intk1} \cdot [\text{I2Rp}] \tag{27}$$

6.28 Rule `parameter_1`

Rule `parameter_1` is an assignment rule for parameter `parameter_1`:

$$\text{parameter\_1} = \frac{(\text{r1} - \text{r2} - \text{r3} - \text{r4}) \cdot \text{vhep}}{\text{vp}} \tag{28}$$

6.29 Rule `parameter_2`

Rule `parameter_2` is an assignment rule for parameter `parameter_2`:

$$\text{parameter\_2} = \frac{\text{Kkidney} \cdot [\text{ins}]}{\text{vp}} \tag{29}$$

6.30 Rule `parameter_3`

Rule `parameter_3` is an assignment rule for parameter `parameter_3`:

$$\text{parameter\_3} = \text{parameter\_2} + \text{parameter\_1} \tag{30}$$

6.31 Rule `parameter_4`

Rule `parameter_4` is an assignment rule for parameter `parameter_4`:

$$\text{parameter\_4} = \frac{\text{parameter\_1}}{\text{parameter\_1} + \text{parameter\_2}} \cdot 100 \tag{31}$$

6.32 Rule `parameter_5`

Rule `parameter_5` is an assignment rule for parameter `parameter_5`:

$$\text{parameter\_5} = \frac{\text{parameter\_2}}{\text{parameter\_2} + \text{parameter\_1}} \cdot 100 \tag{32}$$

6.33 Rule `parameter_6`

Rule `parameter_6` is an assignment rule for parameter `parameter_6`:

$$\text{parameter\_6} = \frac{\text{parameter\_1} \cdot \text{vp} \cdot 6000}{[\text{ins}]} \tag{33}$$

6.34 Rule `parameter_7`

Rule `parameter_7` is an assignment rule for parameter `parameter_7`:

$$\text{parameter\_7} = \frac{\text{parameter\_2} \cdot \text{vp} \cdot 6000}{[\text{ins}]} \tag{34}$$

6.35 Rule parameter_8

Rule parameter_8 is an assignment rule for parameter parameter_8:

$$\text{parameter\_8} = \text{parameter\_7} + \text{parameter\_6} \tag{35}$$

6.36 Rule parameter_9

Rule parameter_9 is an assignment rule for parameter parameter_9:

$$\text{parameter\_9} = \frac{\text{Rtotal} - [\text{R}] - [\text{Rp}] - [\text{Ren}] - [\text{RPen}]}{\text{Rtotal}} \tag{36}$$

6.37 Rule parameter_11

Rule parameter_11 is an assignment rule for parameter parameter_11:

$$\text{parameter\_11} = \frac{[\text{IR}] + [\text{I2R}] + [\text{IRp}] + [\text{I2Rp}]}{\text{Rtotal}} \tag{37}$$

6.38 Rule parameter_10

Rule parameter_10 is an assignment rule for parameter parameter_10:

$$\text{parameter\_10} = \frac{[\text{I2R}] + [\text{I2Ren}] + [\text{I2Rp}] + [\text{I2RPen}]}{\text{Rtotal}} \tag{38}$$

6.39 Rule parameter_12

Rule parameter_12 is an assignment rule for parameter parameter_12:

$$\text{parameter\_12} = \frac{[\text{I2R}] + [\text{I2Rp}]}{\text{Rtotal}} \tag{39}$$

6.40 Rule parameter_13

Rule parameter_13 is an assignment rule for parameter parameter_13:

$$\text{parameter\_13} = \text{parameter\_9} - \text{parameter\_11} \tag{40}$$

6.41 Rule parameter_14

Rule parameter_14 is an assignment rule for parameter parameter_14:

$$\text{parameter\_14} = \text{parameter\_10} - \text{parameter\_12} \tag{41}$$

6.42 Rule R

Rule R is a rate rule for species R:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{R} = \text{r1} + \text{r5} - \text{f1} \tag{42}$$

6.43 Rule IR

Rule IR is a rate rule for species IR:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IR} = \mathrm{r1} - \mathrm{r3} - \mathrm{r6} - \mathrm{f2} \tag{43}$$

6.44 Rule I2R

Rule I2R is a rate rule for species I2R:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{I2R} = \mathrm{r3} - \mathrm{r7} - \mathrm{f3} \tag{44}$$

6.45 Rule Rp

Rule Rp is a rate rule for species Rp:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Rp} = \mathrm{r2} - \mathrm{r5} - \mathrm{f4} \tag{45}$$

6.46 Rule IRp

Rule IRp is a rate rule for species IRp:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IRp} = \mathrm{r2} - \mathrm{r4} + \mathrm{r6} - \mathrm{f5} \tag{46}$$

6.47 Rule I2Rp

Rule I2Rp is a rate rule for species I2Rp:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{I2Rp} = \mathrm{r4} + \mathrm{r7} - \mathrm{f6} \tag{47}$$

6.48 Rule Ren

Rule Ren is a rate rule for species Ren:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ren} = \mathrm{i1} + \mathrm{i5} + \mathrm{f1} \tag{48}$$

6.49 Rule IRen

Rule IRen is a rate rule for species IRen:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IRen} = \mathrm{i1} + \mathrm{i3} - \mathrm{i6} + \mathrm{f2} \tag{49}$$

6.50 Rule I2Ren

Rule I2Ren is a rate rule for species I2Ren:

$$\frac{d}{dt}\text{I2Ren} = \text{i3} - \text{i7} + \text{f3} \tag{50}$$

6.51 Rule RPen

Rule RPen is a rate rule for species RPen:

$$\frac{d}{dt}\text{RPen} = \text{i2} - \text{i5} + \text{f4} \tag{51}$$

6.52 Rule IRPen

Rule IRPen is a rate rule for species IRPen:

$$\frac{d}{dt}\text{IRPen} = \text{i2} + \text{i4} + \text{i6} + \text{f5} \tag{52}$$

7 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

7.1 Species R

Name R

SBO:0000244 receptor

Initial concentration $35.3837 \text{ mol} \cdot \text{l}^{-1}$

Involved in rule R

One rule determines the species' quantity.

7.2 Species ins

Name ins

SBO:0000252 polypeptide chain

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

$$\frac{d}{dt}\text{ins} = 0 \tag{53}$$

7.3 Species IR

Name IR

SBO:0000297 protein complex

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

Involved in rule IR

One rule determines the species' quantity.

7.4 Species I2R

Name I2R

SBO:0000297 protein complex

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

Involved in rule I2R

One rule determines the species' quantity.

7.5 Species Rp

Name Rp

SBO:0000244 receptor

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

Involved in rule Rp

One rule determines the species' quantity.

7.6 Species IRp

Name IRp

SBO:0000297 protein complex

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

Involved in rule IRp

One rule determines the species' quantity.

7.7 Species I2Rp

Name I2Rp

SBO:0000297 protein complex

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

Involved in rule I2Rp

One rule determines the species' quantity.

7.8 Species Ren

Name Ren

SBO:0000244 receptor

Initial concentration $4.6163 \text{ mol} \cdot \text{l}^{-1}$

Involved in rule Ren

One rule determines the species' quantity.

7.9 Species IRen

Name IRen

SBO:0000297 protein complex

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

Involved in rule IRen

One rule determines the species' quantity.

7.10 Species I2Ren

Name I2Ren

SBO:0000297 protein complex

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

Involved in rule I2Ren

One rule determines the species' quantity.

7.11 Species RPen

Name RPen

SBO:0000297 protein complex

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

Involved in rule RPen

One rule determines the species' quantity.

7.12 Species IRPen

Name IRPen

SBO:0000297 protein complex

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

Involved in rule IRPen

One rule determines the species' quantity.

7.13 Species I2RPen

Name I2RPen

SBO:0000297 protein complex

Initial concentration $-4.44089209850063 \cdot 10^{-15} \text{ mol} \cdot \text{l}^{-1}$

Involved in rule I2RPen

One rule determines the species' quantity.

A Glossary of Systems Biology Ontology Terms

SBO:0000002 **quantitative systems description parameter:** A numerical value that defines certain characteristics of systems or system functions. It may be part of a calculation, but its value is not determined by the form of the equation itself, and may be arbitrarily assigned

SBO:0000009 **kinetic constant:** Numerical parameter that quantifies the velocity of a chemical reaction

SBO:0000064 **mathematical expression:** Formal representation of a calculus linking parameters and variables of a model

SBO:0000179 degradation: Complete disappearance of a physical entity

SBO:0000180 dissociation: Transformation of a non-covalent complex that results in the formation of several independent biochemical entitie

SBO:0000216 phosphorylation: Addition of a phosphate group (-H2PO4) to a chemical entity

SBO:0000226 density of an entity pool: A quantitative measure of an amount or property of an entity expressed in terms of another dimension, such as unit length, area or volume

SBO:0000244 receptor: Participating entity that binds to a specific physical entity and initiates the response to that physical entity.The original concept of the receptor was introduced independently at the end of the 19th century by John Newport Langley (1852-1925) and Paul Ehrlich (1854-1915). Langley JN.On the reaction of cells and of nerve-endings to certain poisons, chiefly as regards the reaction of striated muscle to nicotine and to curari. J Physiol. 1905 Dec 30;33(4-5):374-413

SBO:0000252 polypeptide chain: Naturally occurring macromolecule formed by the repetition of amino-acid residues linked by peptidic bonds. A polypeptide chain is synthesized by the ribosome. CHEBI:1654

SBO:0000297 protein complex: Macromolecular complex containing one or more polypeptide chains possibly associated with simple chemicals. CHEBI:3608

SBO:0000330 dephosphorylation: Removal of a phosphate group (-H2PO4) from a chemical entity.

SBO:0000468 volume: A quantity representing the three-dimensional space occupied by all or part of an object

SBO:0000504 mass of an entity pool: The mass that comprises an entity pool

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