SBML Model Report

Model name: "hodgkin-huxley squid-axon 1952"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 3 format. This model was created by the following three authors: Maria Schilstra[1], Catherine Lloyd[2] and Lukas Endler[3] at March 31st 2005 at 1:09 p. m. and last time modified at February second 2011 at eleven o' clock in the afternoon. Table 1 provides 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	0
events	0	constraints	0
reactions	0	function definitions	0
global parameters	27	unit definitions	2
rules	18	initial assignments	0

Model Notes

This is an implementation of the Hodgkin-Huxley model of the electrical behavior of the squid axon membrane from:

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A quantitative description of membrane current and its application to conduction and excitation in nerve.
A. L. Hodgkin and A. F. Huxley. (1952) Journal of Physiology 119(4): pp 500-544; pmID: 12991237 .

Abstract:
This article concludes a series of papers concerned with the flow of electric current through the surface membrane of a giant nerve fibre (Hodgkin,Huxley & Katz, 1952; Hodgkin & Huxley, 1952 a-c). Its general object is to discuss the results of the preceding papers (Part I), to put them into mathematical form (Part II) and to show that they will account for conduction and excitation in quantitative terms (Part III).

This SBML model uses the same formalism as the one described in the paper, contrary to modern versions:
* V describes the the membrane depolarisation relative to the resting potential of the membrane
* opposing to modern practice, depolarization is negative , not positive , so the sign of V is different
* inward transmembrane currents are considered positive (inward current positive), contrary to modern use
The changeable parameters are the equilibrium potentials(E_R, E_K, E_L, E_Na), the membrane depolarization (V) and the initial sodium and potassium channel activation and inactivation coefficients (m,h,n). The initial values of m,h,n for the model were calculated for V = 0 using the equations from the article: $n_{t=0} = \_n_{V=0} /(\_n_{V=0} + \_n_{V=0})$ and equivalent expressions for h and m .
For single excitations apply a negative membrane depolarization ($V < 0$). To achieve oscillatory behavior either change the resting potential to a more positive value or apply a constant negative ionic current ($I < 0$).
Two assignments for parameters in the model, alpha_n and alpha_m, are not defined at V=-10 resp. -25 mV. We did not change this to keep the formulas similar to the original publication and as most integrators seem not to have any problem with it. The limits at V=-10 and -25 mV are 0.1 for alpha_n resp. 1 for alpha_m.
We thank Mark W. Johnson for finding a bug in the model and his helpful comments.

2 Unit Definitions

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

2.1 Unit `time`

Name millisecond

Definition ms

2.2 Unit `mV`

Name mV

Definition mV

2.3 Unit `substance`

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

Definition mol

2.4 Unit `volume`

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

Definition l

2.5 Unit `area`

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

Definition m^2

2.6 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
`unit_compartment`	unit_compartment		3	1	litre	☑	

3.1 Compartment unit_compartment

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

Name unit_compartment

4 Parameters

This model contains 27 global parameters.

Table 3: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
V	V	0000259	0.000	mV	☐
V_neg	V_neg	0000259	0.000	mV	☐
E	E	0000259	0.000	mV	☐
I	I		0.000		☑
i_Na	i_Na		0.000		☐
i_K	i_K		0.000		☐
i_L	i_L		0.000		☐
m	m		0.053		☐
h	h		0.596		☐
n	n		0.318		☐
E_R	E_R	0000259	−75.000	mV	☑
Cm	Cm	0000258	1.000		☑
g_Na	g_Na	0000257	120.000		☑
g_K	g_K	0000257	36.000		☑
g_L	g_L	0000257	0.300		☑
E_Na	E_Na	0000259	−190.000	mV	☑
E_K	E_K	0000259	−63.000	mV	☑
E_L	E_L	0000259	−85.613	mV	☑
V_Na	V_Na	0000259	−115.000	mV	☐
V_K	V_K	0000259	12.000	mV	☐
V_L	V_L	0000259	−10.613	mV	☐
alpha_m	alpha_m		0.000		☐
beta_m	beta_m		0.000		☐
alpha_h	auxiliary alpha_h		0.000		☐
beta_h	beta_h		0.000		☐
alpha_n	alpha_n		0.000		☐
beta_n	beta_n		0.000		☐

5 Rules

This is an overview of 18 rules.

5.1 Rule V_neg

Rule V_neg is an assignment rule for parameter V_neg:

$$\text{V\_neg} = \text{V} \tag{1}$$

Derived unit mV

Notes V_neg = -V

5.2 Rule E

Rule E is an assignment rule for parameter E:

$$\text{E} = \text{V} + \text{E\_R} \tag{2}$$

Derived unit mV

Notes E = V + E_R

5.3 Rule V_L

Rule V_L is an assignment rule for parameter V_L:

$$\text{V\_L} = \text{E\_L} - \text{E\_R} \tag{3}$$

Derived unit mV

Notes V_L = E_L - E_R

5.4 Rule beta_n

Rule beta_n is an assignment rule for parameter beta_n:

$$\text{beta\_n} = 0.125 \cdot \exp\left(\frac{\text{V}}{80}\right) \tag{4}$$

Notes beta_n = 0.125 * exp[V / 80.0]

5.5 Rule alpha_h

Rule alpha_h is an assignment rule for parameter alpha_h:

$$\text{alpha\_h} = 0.07 \cdot \exp\left(\frac{\text{V}}{20}\right) \tag{5}$$

Notes alpha_h = 0.07 * exp[V / 20.0]

5.6 Rule V_Na

Rule V_Na is an assignment rule for parameter V_Na:

$$V\_Na = E\_Na - E\_R \tag{6}$$

Derived unit mV

Notes V_Na = E_Na - E_R

5.7 Rule V_K

Rule V_K is an assignment rule for parameter V_K:

$$V\_K = E\_K - E\_R \tag{7}$$

Derived unit mV

Notes V_K = E_K - E_R

5.8 Rule i_K

Rule i_K is an assignment rule for parameter i_K:

$$i\_K = g\_K \cdot n^4 \cdot (V - V\_K) \tag{8}$$

Notes i_K = g_K * n^4.0 * (V - V_K)

5.9 Rule i_Na

Rule i_Na is an assignment rule for parameter i_Na:

$$i\_Na = g\_Na \cdot m^3 \cdot h \cdot (V - V\_Na) \tag{9}$$

Notes i_Na = g_Na * m^3.0 * h * (V - V_Na)

5.10 Rule i_L

Rule i_L is an assignment rule for parameter i_L:

$$i\_L = g\_L \cdot (V - V\_L) \tag{10}$$

Notes i_L = g_L * (V - V_L)

5.11 Rule beta_m

Rule beta_m is an assignment rule for parameter beta_m:

$$beta\_m = 4 \cdot \exp\left(\frac{V}{18}\right) \tag{11}$$

Notes beta_m = 4.0 * exp[V / 18.0]

5.12 Rule alpha_n

Rule alpha_n is an assignment rule for parameter alpha_n:

$$\text{alpha\_n} = \frac{0.01 \cdot (\text{V} + 10)}{\exp\left(\frac{\text{V}+10}{10}\right) - 1} \tag{12}$$

Notes alpha_n = 0.01 * (V + 10.0)/(exp[0.1 * (V + 10.0)] - 1.0)

5.13 Rule alpha_m

Rule alpha_m is an assignment rule for parameter alpha_m:

$$\text{alpha\_m} = \frac{0.1 \cdot (\text{V} + 25)}{\exp\left(\frac{\text{V}+25}{10}\right) - 1} \tag{13}$$

Notes alpha_m = 0.1 * (V + 25.0)/(exp[0.1 * (V + 25.0)] - 1.0)

5.14 Rule beta_h

Rule beta_h is an assignment rule for parameter beta_h:

$$\text{beta\_h} = \frac{1}{\exp\left(\frac{\text{V}+30}{10}\right) + 1} \tag{14}$$

Notes beta_h = 1.0 /(exp[0.1 * (V + 30.0)] + 1.0)

5.15 Rule V

Rule V is a rate rule for parameter V:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{V} = \frac{\text{I} - (\text{i\_Na} + \text{i\_K} + \text{i\_L})}{\text{Cm}} \tag{15}$$

Notes dV/dt = (I - (i_Na + i_K + i_L))/Cm

5.16 Rule m

Rule m is a rate rule for parameter m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{m} = \text{alpha\_m} \cdot (1 - \text{m}) - \text{beta\_m} \cdot \text{m} \tag{16}$$

Notes dm/dt = alpha_m * (1.0 - m) - beta_m * m

5.17 Rule h

Rule h is a rate rule for parameter h:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{h} = \text{alpha\_h} \cdot (1 - \text{h}) - \text{beta\_h} \cdot \text{h} \tag{17}$$

Notes dh/dt = alpha_h * (1.0 - h) - beta_h * h

5.18 Rule n

Rule n is a rate rule for parameter n:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{n} = \mathrm{alpha\_n} \cdot (1 - \mathrm{n}) - \mathrm{beta\_n} \cdot \mathrm{n} \tag{18}$$

Notes dn/dt = alpha_n * (1.0 - n) - beta_n * n

A Glossary of Systems Biology Ontology Terms

SBO:0000257 conductance: Measure of how easily electricity flows along a certain path through an electrical element. The SI derived unit of conductance is the Siemens

SBO:0000258 capacitance: Measure of the amount of electric charge stored (or separated) for a given electric potential. The unit of capacitance id the Farad

SBO:0000259 voltage: Difference of electrical potential between two points of an electrical network, expressed in volts

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.

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