

The Channel Builder

Voltage- and ligand-gated channels

Kinetic schemes, HH-style differential equations

Optional stochastic gating mode for point processes

Faster than equivalent NMODL mechanisms

Much easier to use than writing NMODL code

Limited to channels

NMODL needed for pumps, buffers, diffusion, event-driven synaptic mechanisms, artificial spiking cells

Tutorial: see Documentation at NEURON's home page <http://www.neuron.yale.edu/>

Conceptualize the task

Ion selectivity	na, k, other, nonspecific i
I/V relationship	ohmic / GHK (constant field)
Description of dynamics	HH style / kinetic scheme
Gates	independent identical subunits fractional openness
Sensitivity	voltage / ligand
Transition style	alpha, beta / inf, tau functions / tables

Implementing the HH sodium channel with the Channel Builder

$$i_{\text{Na}} = g_{\text{Na}} (V - E_{\text{Na}}) \text{ where}$$

$$g_{\text{Na}} = \text{gbar}_{\text{Na}} m^3 h$$

$$\text{gbar}_{\text{Na}} = 0.12 \text{ S/cm}^2$$

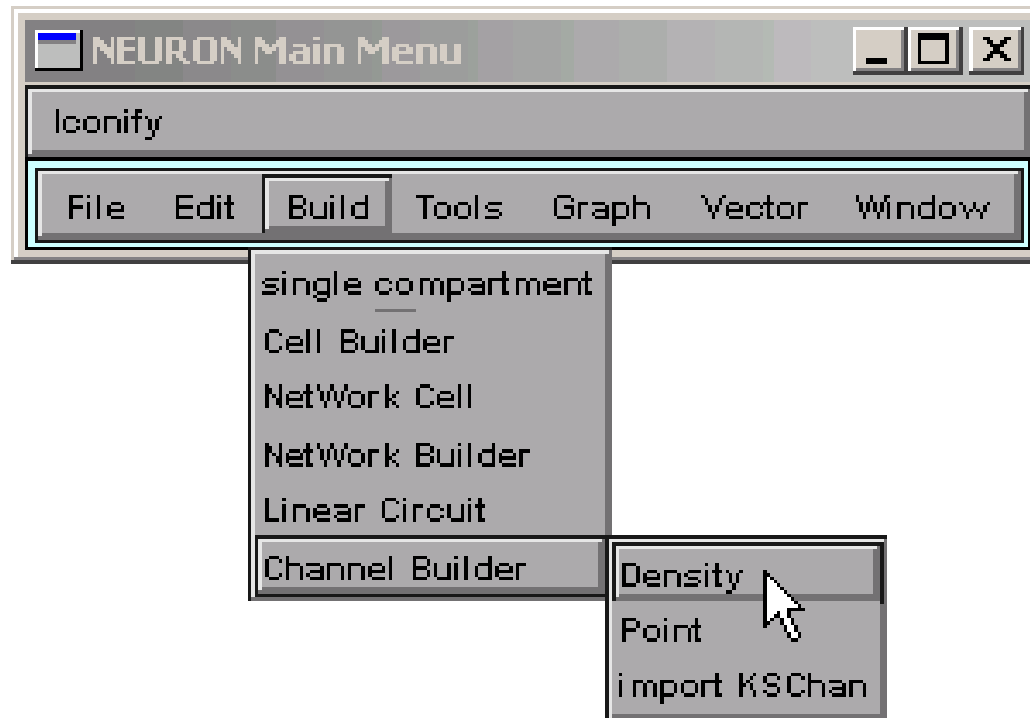
m and h are described by DEs of the form

$$dx/dt = \text{alpha} (1 - x) - \text{beta} x$$

How to proceed

1. Bring up a Channel Builder
2. Specify channel's basic properties
3. Specify channel gating
 - states
 - transitions (if a kinetic scheme)
 - effects of voltage and ligands

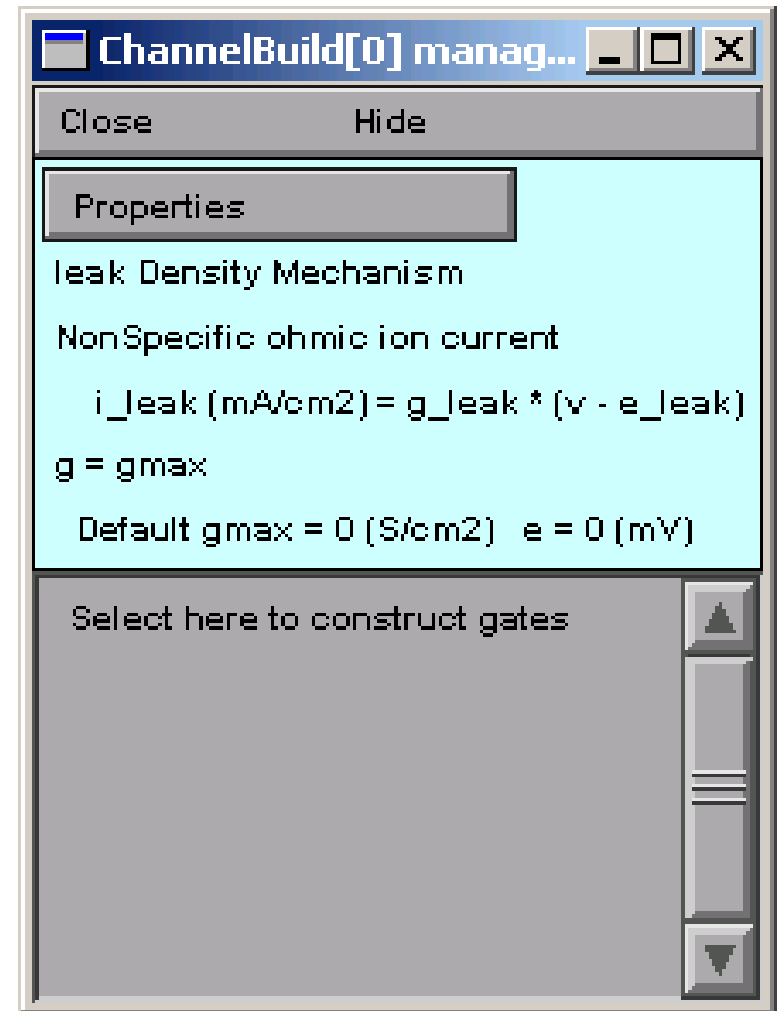
1. Bring up a Channel Builder



NEURON Main Menu / Build
/ Channel Builder / Density

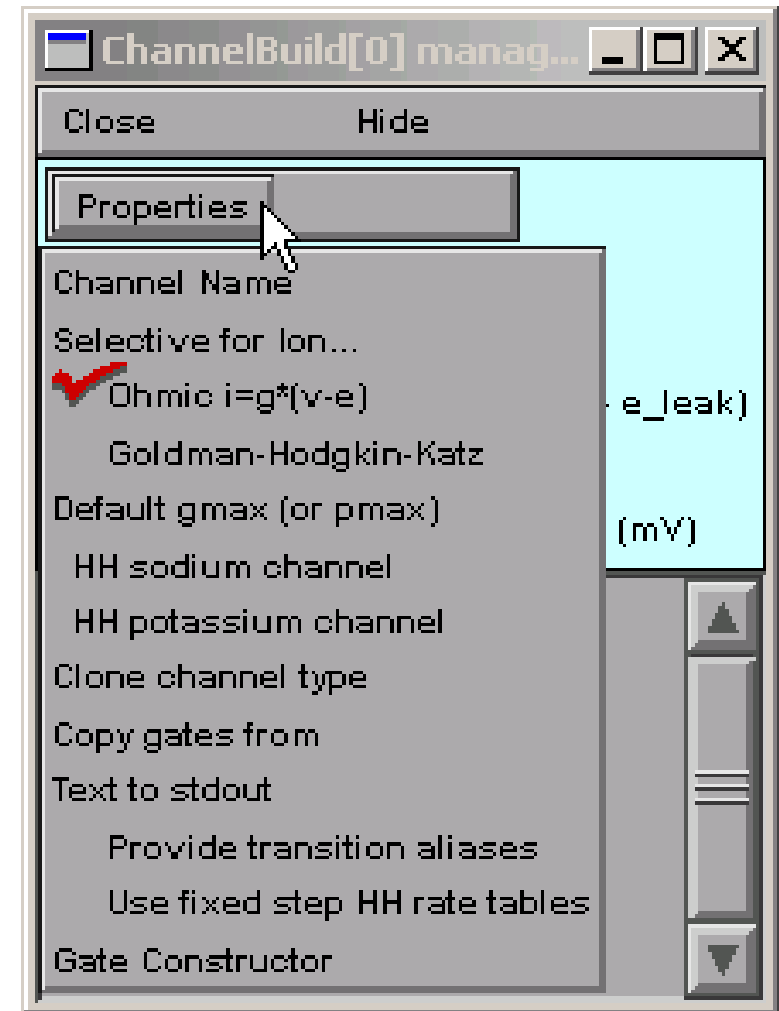
The Channel Builder

We need to change its name,
ion selectivity,
default conductance,
and equilibrium potential



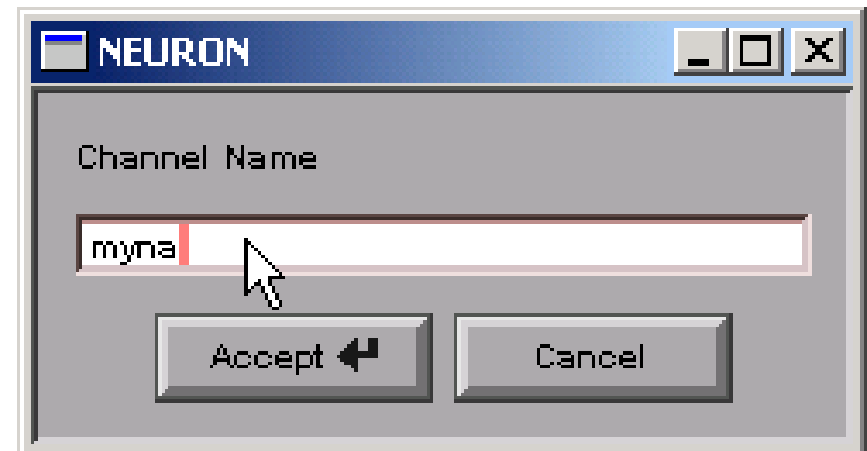
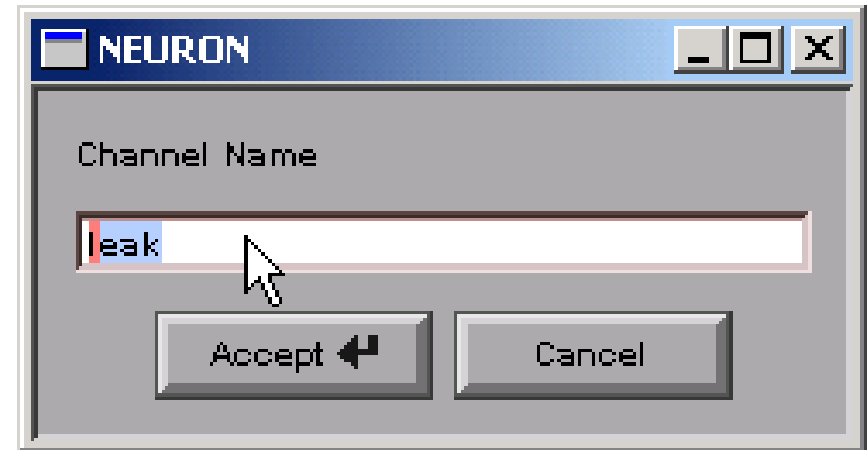
2. Specify channel's basic properties

Click on Properties,
then select item to change



Name

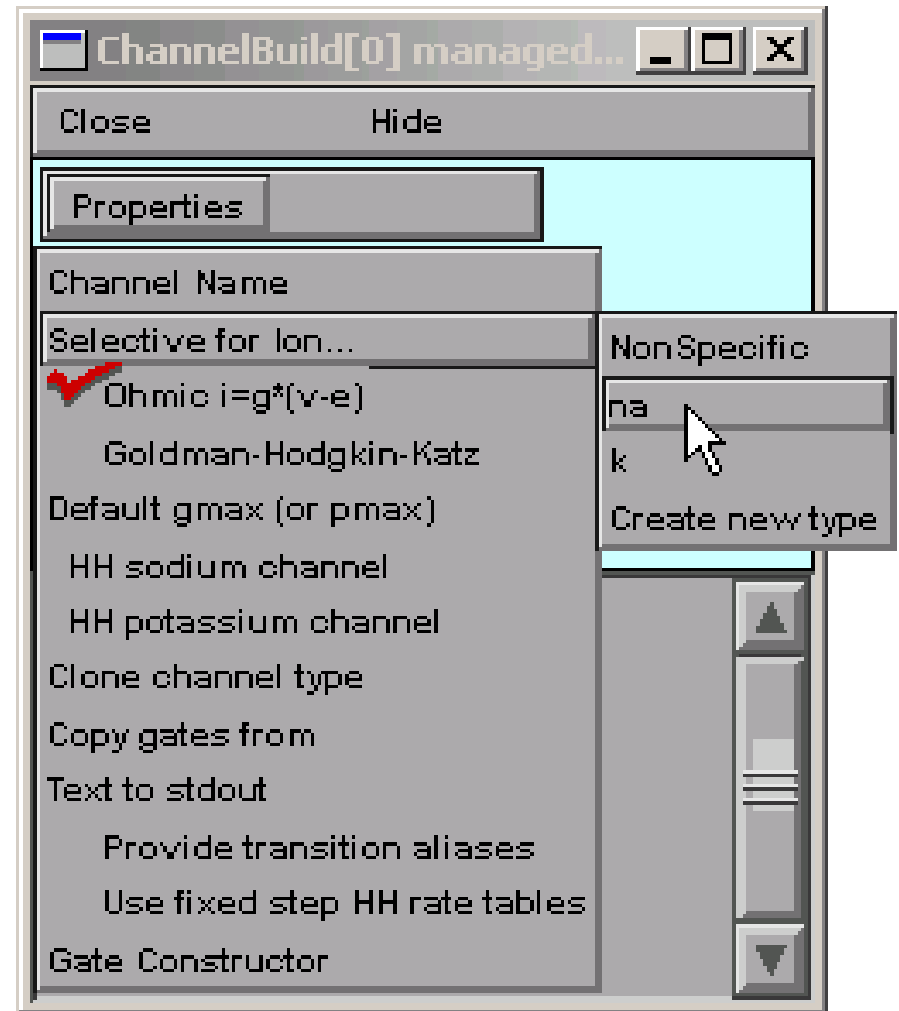
Properties / Channel Name
Then change leak to myna



Ion selectivity

Properties

/ Selective for Ion... / na



Default conductance and equilibrium potential

Properties / Default gmax

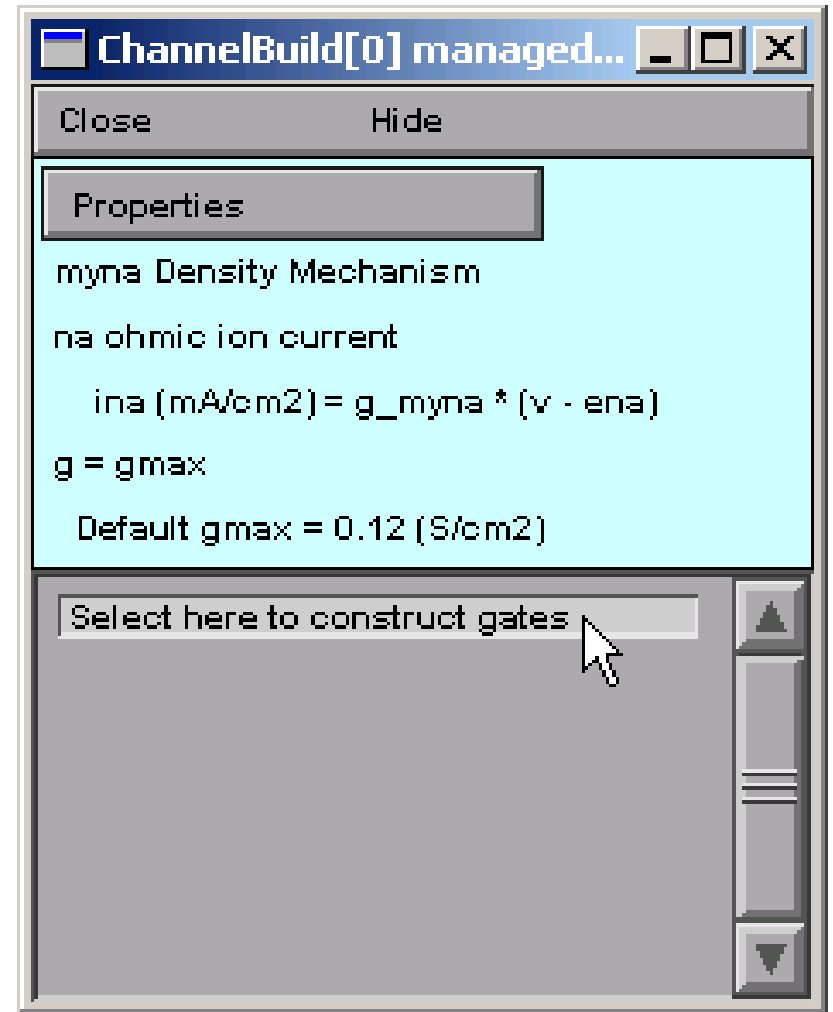
Specify 0.12 S/cm²



Equilibrium potential:
na has its own ena,
so nothing to do!

3. Specify channel gating

"Select here to construct gates"



"GateGUI": States page

The screenshot shows a software window titled "ChannelBuildGateGUI[0] for ChannelBuild[0]". The window is divided into four main sections:

- Top-left:** A tabbed interface with "States", "Transitions", and "Properties" tabs. The "States" tab is active, showing a canvas with the text "Drag new state from left. Drag off canvas to delete" and two state labels, "O" and "C".
- Top-right:** A light blue area displaying the text "no gate selected".
- Bottom-left:** A graph area with a vertical axis ranging from 0 to 1 and a horizontal axis ranging from -90 to 60. The graph is currently empty.
- Bottom-right:** A light blue area displaying the text "no KSTrans selected".

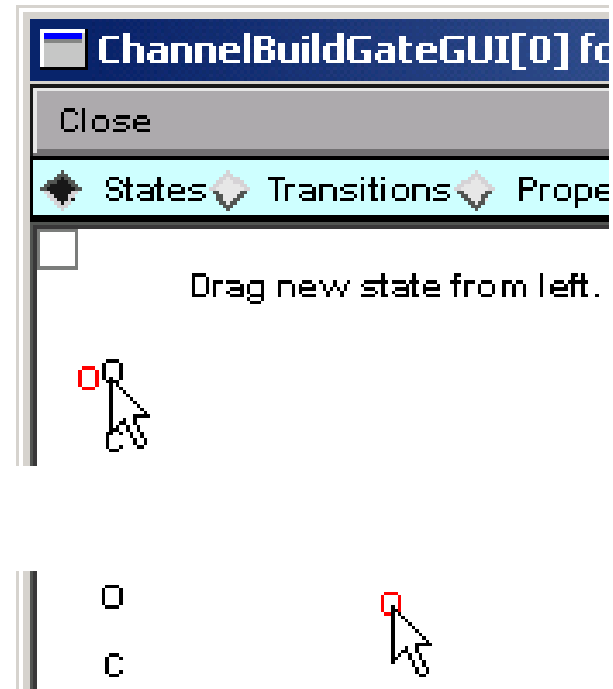
Additional controls include "Close" and "Hide" buttons at the top, and "Adjust" and "Run" buttons in the bottom-left section.

Spawn states

Click and drag O ("open")
from palette . . .

. . . to canvas.

Repeat for C ("closed")

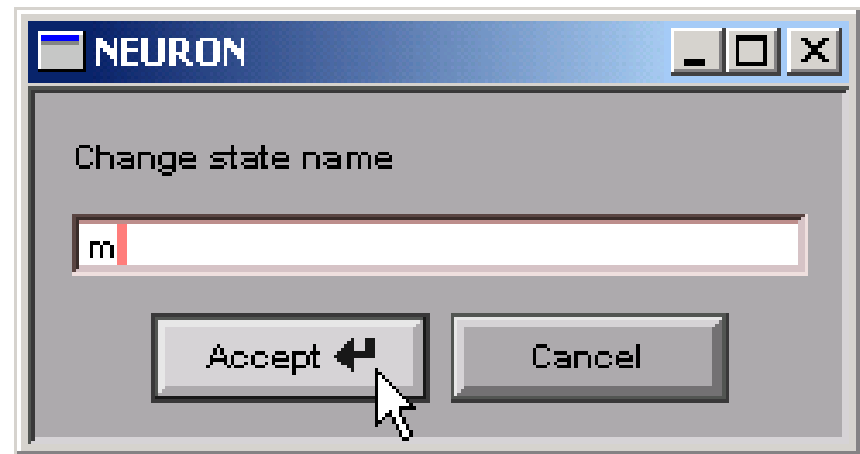


Rename states

Click O without dragging



Change to m



Change C to h



"GateGUI": Properties page

ChannelBuildGateGUI[0] for ChannelBuild[0]

Close Hide

States Transitions **Properties**

Select hh state or ks transition to change properties

m h

Select m ...

... to see all this

m

$m' = am*(1 - m) - bm*m$

Power 1

Fractional Conductance

m fraction 1

Adjust Run

m <-> m (a, b) (KSTrans[1])

Display inf, tau

am = A

A (/ms) 0

bm = A

A (/ms) 0

EquationType

1

0.8

0.6

0.4

0.2

0

-90 -40 10 60

am

bm

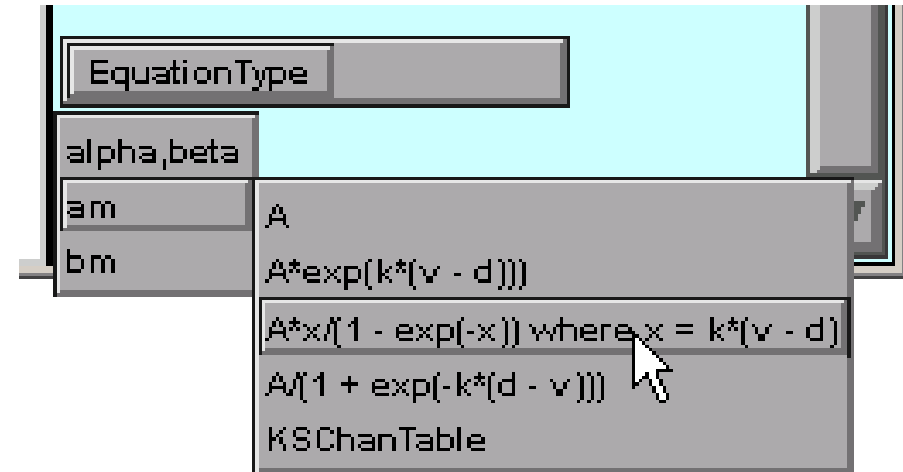
Set m exponent

Change Power to 3



Specify voltage dependence of am and bm

Choose functional form
for am



Set parameter values



Do same for bm

ChannelBuildGateGUI[0] for ChannelBuild[0]

Close Hide

States Transitions **Properties**

Select hh state or ks transition to change properties

m h

m properties

after configuring am and bm

m^3

$m' = am^2(1 - m) - bm^3$

Power 3

Fractional Conductance

m fraction 1

Adjust Run

$m \leftrightarrow m(a, b)$ (KSTrans[1])

Display inf, tau

$am = A * x / (1 + \exp(-x))$ where $x = k * (v - d)$

A (/ms) 1

k (/mV) 0.1

d (mV) -40

$bm = A * \exp(k * (v - d))$

A (/ms) 4

k (/mV) -0.055556

d (mV) -65

EquationType

ChannelBuildGateGUI[0] for ChannelBuild[0]

Close Hide

States Transitions Properties

Select hh state or ks transition to change properties

m h

h properties after configuring ah and bh

h
 $h' = ah*(1 - h) - bh*h$

Power 1

Fractional Conductance

h fraction 1

Adjust Run

ah
bh

h <-> h (a, b) (KSTrans[1])

Display inf, tau

$ah = A * \exp(k * (v - d))$

A (/ms) 0.07

k (/mV) -0.05

d (mV) -65

$bh = A / (1 + \exp(-k * (d - v)))$

A (/ms) 1

k (/mV) -0.1

d (mV) -35

EquationType

Testing

The screenshot displays the NEURON software interface with several windows open:

- NEURON Main Menu:** Includes an 'Iconify' button and a menu bar with 'File', 'Build', 'Tools', 'Graph', 'Vector', 'Window', and 'Help'.
- ChannelBuild[0] managed K:** Shows the 'Properties' tab with the following text:
myna Density Mechanism
na ohmic ion current
 $ina \text{ (mA/cm}^2\text{)} = g_myna * (v - ena)$
 $g = gmax * m^3 * h$
Default gmax = 0.12 (S/cm2)
 $m' = am*(1 - m) - bm*m$
 $h' = ah*(1 - h) - bh*h$
- RunControl:** Contains controls for simulation parameters:
 - Init (mV): -65
 - Buttons: Init & Run, Stop
 - Continue til (ms): 5
 - Continue for (ms): 1
 - Single Step
 - t (ms): 15
 - Tstop (ms): 15
 - dt (ms): 0.025
- Graph[1] Crosshair x: -1.5 : 16.5 y:** Displays a plot of membrane potential $v(5)$ over time. The y-axis ranges from -80 to 40 mV, and the x-axis ranges from 0 to 15 ms. The plot shows a sharp peak reaching approximately 40 mV at around 2 ms, followed by a decay to a steady state near -70 mV.
- CellBuild[0]:** Shows a diagram of a cell with a soma and a dendrite. The 'Biophysics' tab is active, displaying a list of mechanisms:
 - all
 - Ra
 - cm
 - x hh
 - x mynaThe 'Specify Strategy' section shows 'forsec all { insert myna' and 'gmax_myna (S/cm2) [0.12]'. A 'Hints' button is at the bottom.
- PointProcessManag:** A small window with 'SelectPointProcess' and 'Show' buttons. Below, it shows 'IClamp[0]' at 'soma(0.5)' with a visual representation of a current injection point on a cell segment.