Where to learn more

The NEURON Book

`NEURON's web site`

- `neuron.yale.edu`
- Documentation
  - hints and tutorials
  - FAQ list
  - key papers about NEURON
- Programmer's Reference

`The NEURON Forum`

- `neuron.yale.edu/phpBB`
- Getting started
- Hot tips
- Announcements (new releases, courses)

Construction and Use of Models

Cell models

- Specify topology: create and connect sections
- Specify geometry: stylized (L & diam)
  or 3D (x,y,z,diam)
- Specify biophysics: insert density mechanisms,
  attach "biological" point processes (synapses)

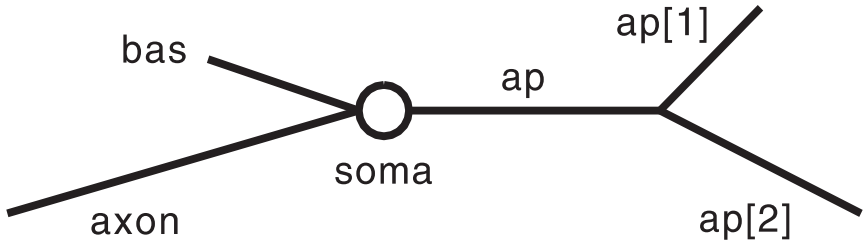
Network models

- Define cell classes
- Create cells (instances of cell classes)
- Connect cells

Step 0: Conceptualize the task

- Shape
  - stick figure / anatomically detailed
- Channel distribution
  - uniform / nonuniform
  - whole cell / region / individual neurite
- Creation
  - single cell / use in a network

Step 1: using the CellBuilder to make a stylized model



Section	L	diam	Biophysics
soma	20 µm	20 µm	hh
ap[0]	400	2	reduced hh *
ap[1]	300	1	reduced hh *
ap[2]	500	1	reduced hh *
bas	200	3	pas §
axon	800	1	hh

* gnabar_hh and gkbar_hh reduced to 10%, el_hh = - 64 mV

§ e_pas = - 65 mV

Throughout the cell Ra = 160 W cm, cm = 1 µf / cm^2

Launch NEURON with its GUI library

```
nrngui
```

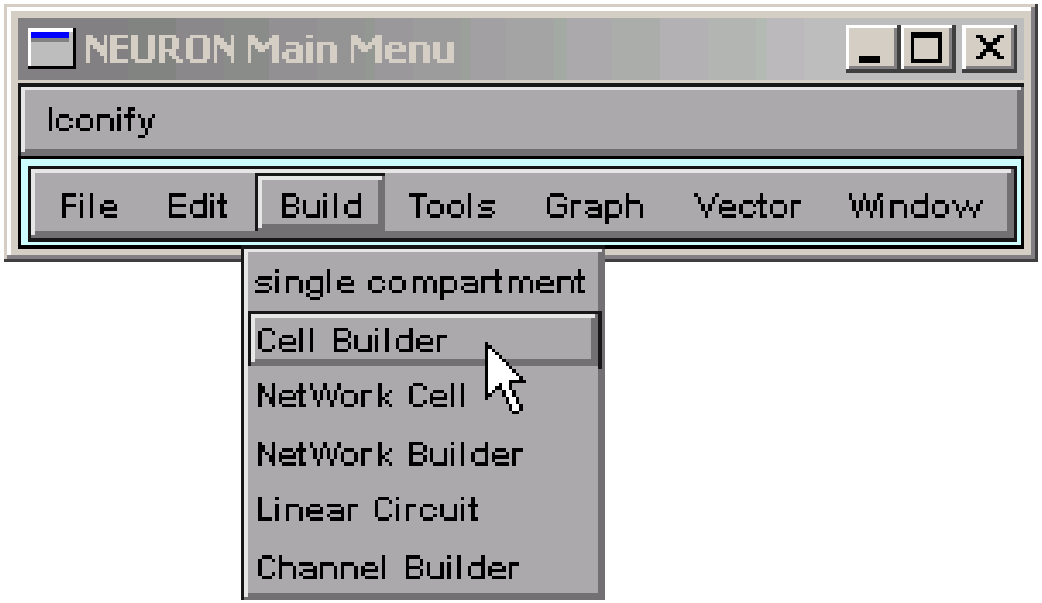
or

```
python
from neuron import h, gui
```

or

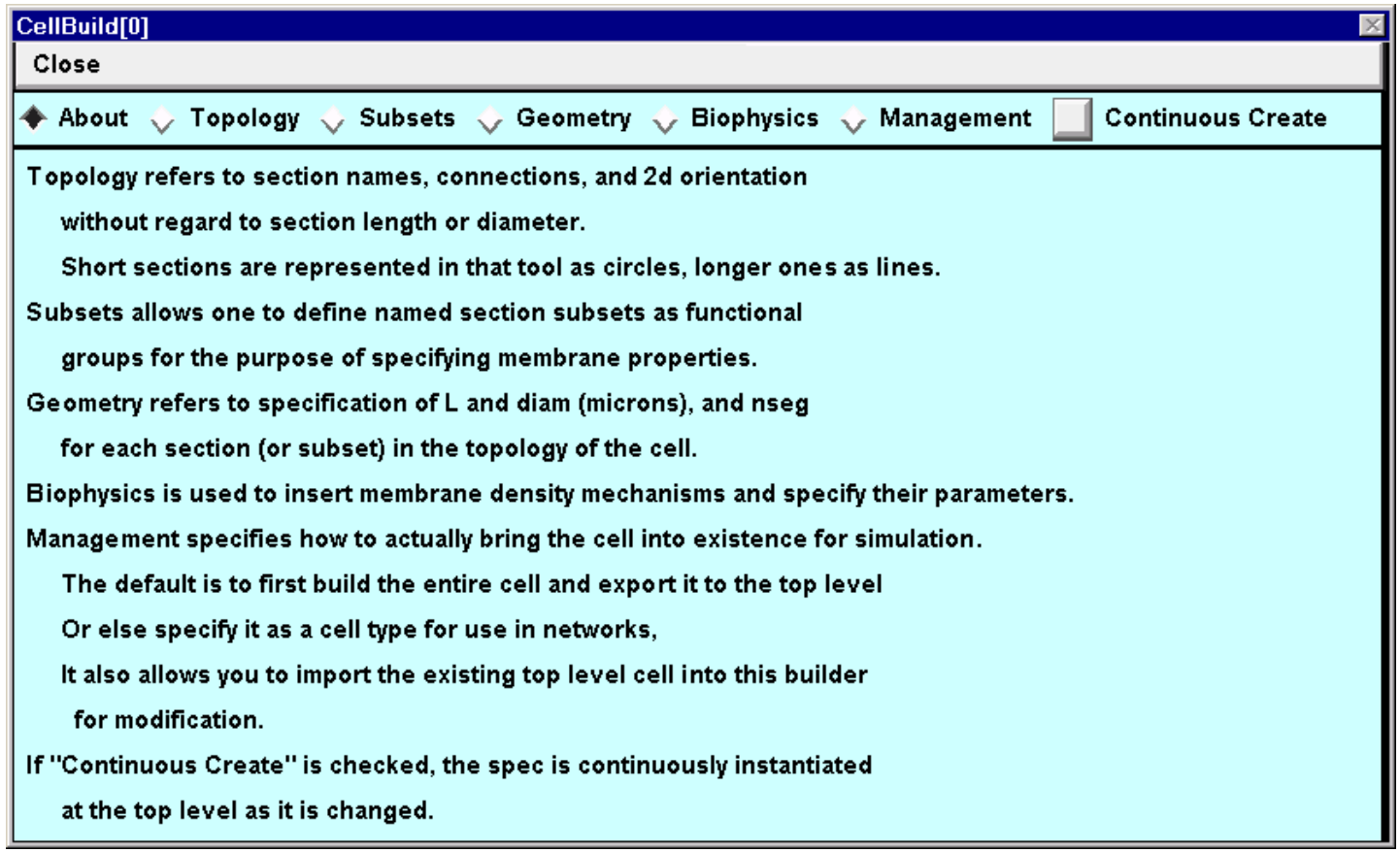
click on `nrngui` icon (MSWin, MacOS)

Bring up a CellBuilder



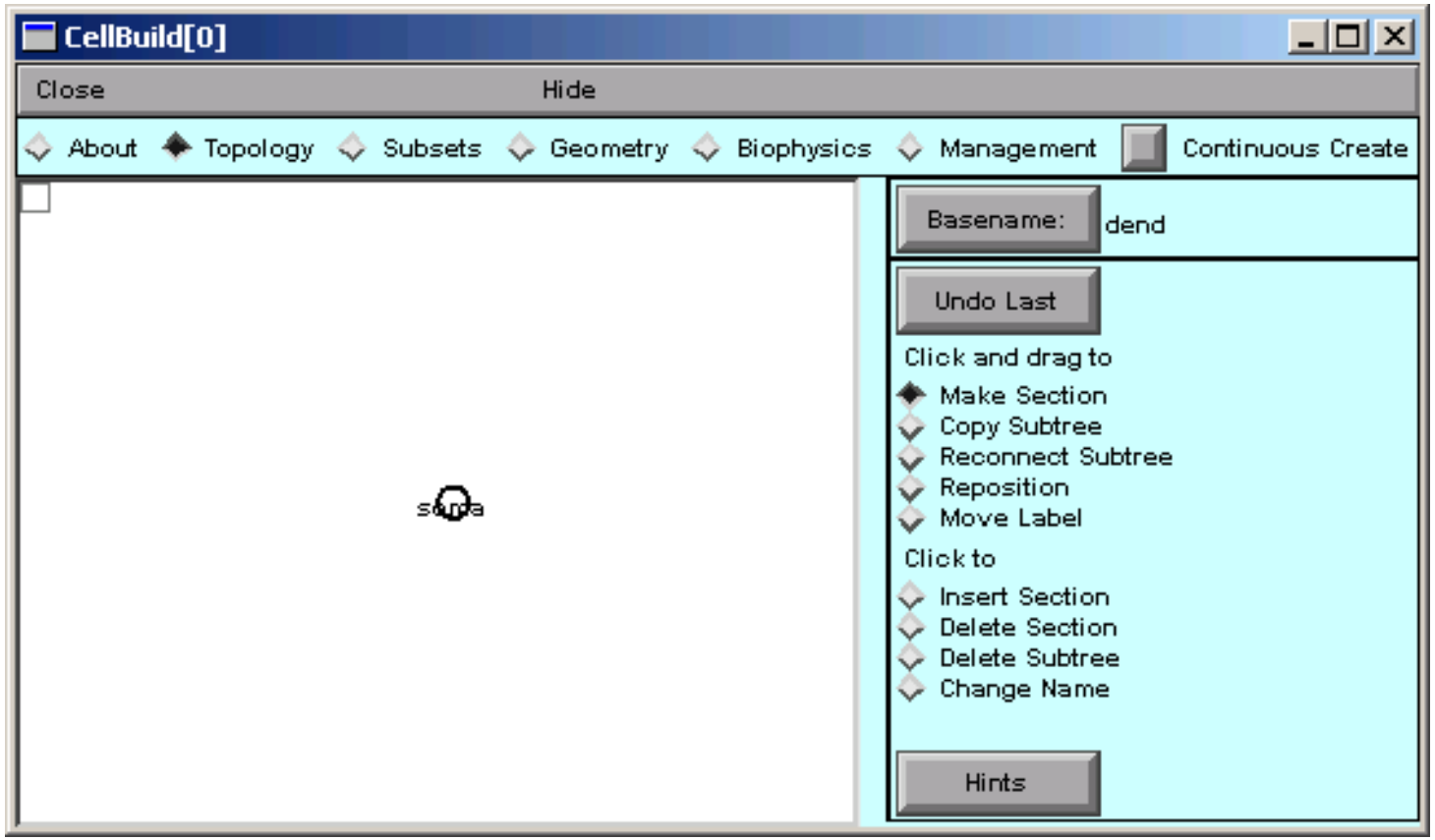
NEURON Main Menu / Build / Cell Builder

The CellBuilder



Use buttons from left to right.

Topology



CB starts with a "soma" section.

We want to create new sections.

Specifying the "Basename"

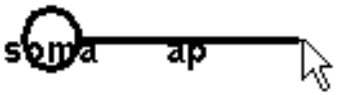
Making a new section

Place cursor near end of existing section

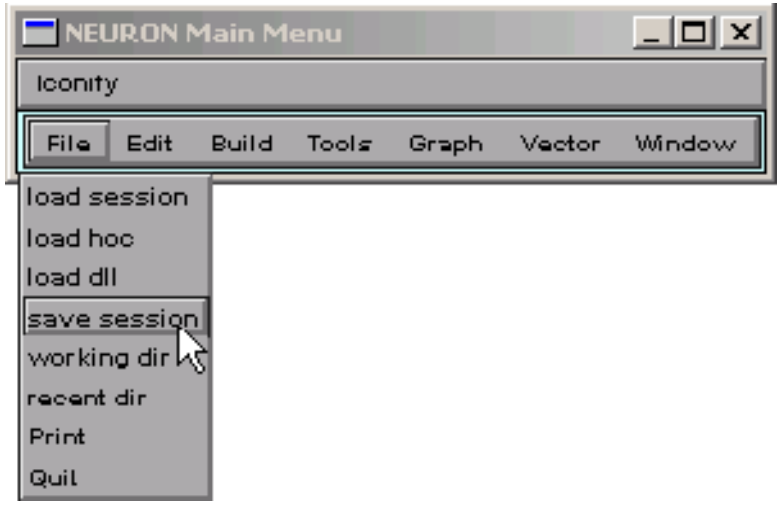
Click to start new section

Drag to desired length

Release mouse button

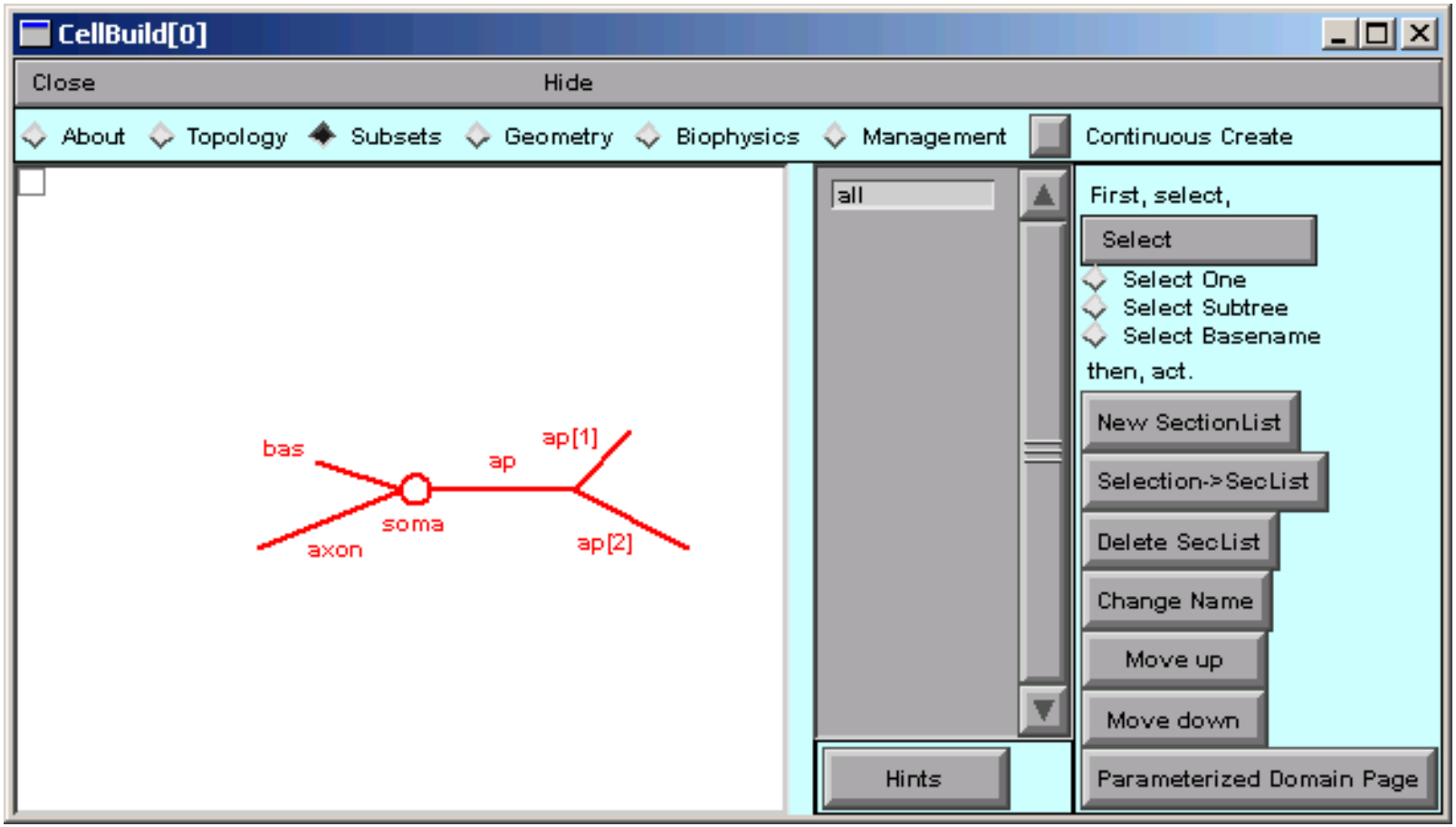


Save your work as you make progress!



NEURON Main Menu / File / save session

Subsets

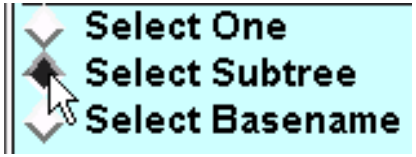


Group sections that have shared properties.

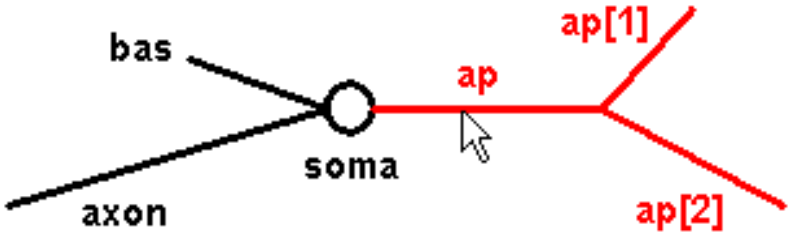
We want to make an "apicals" subset.

Making a new subset

Click "Select Subtree"

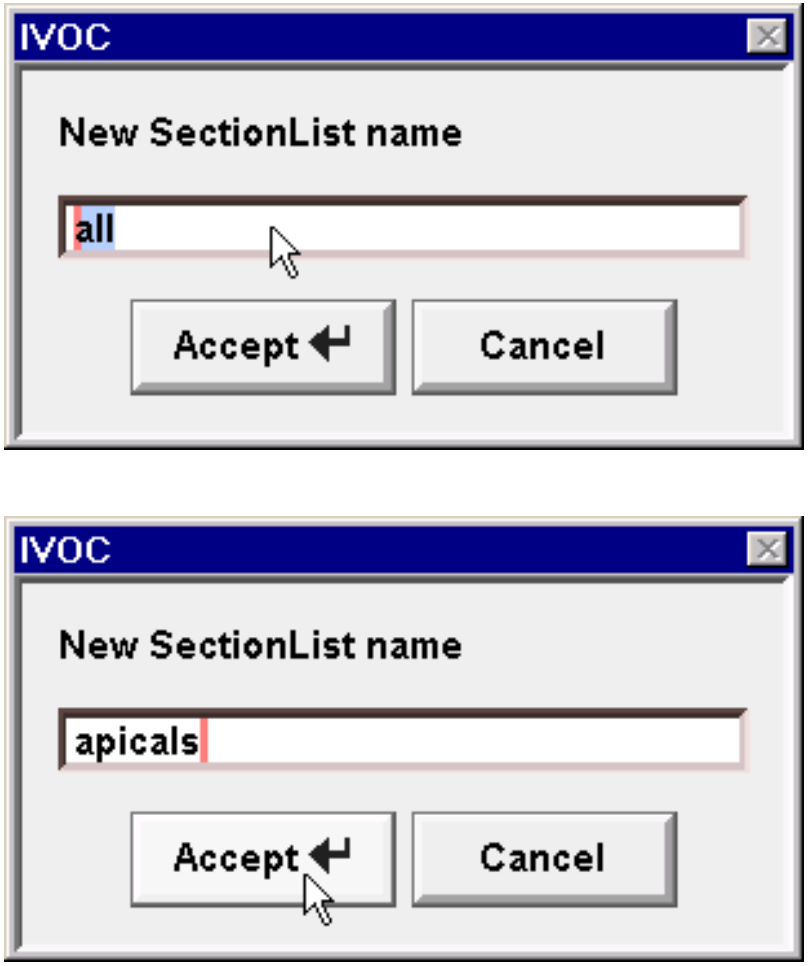


Click root of apical tree . . .

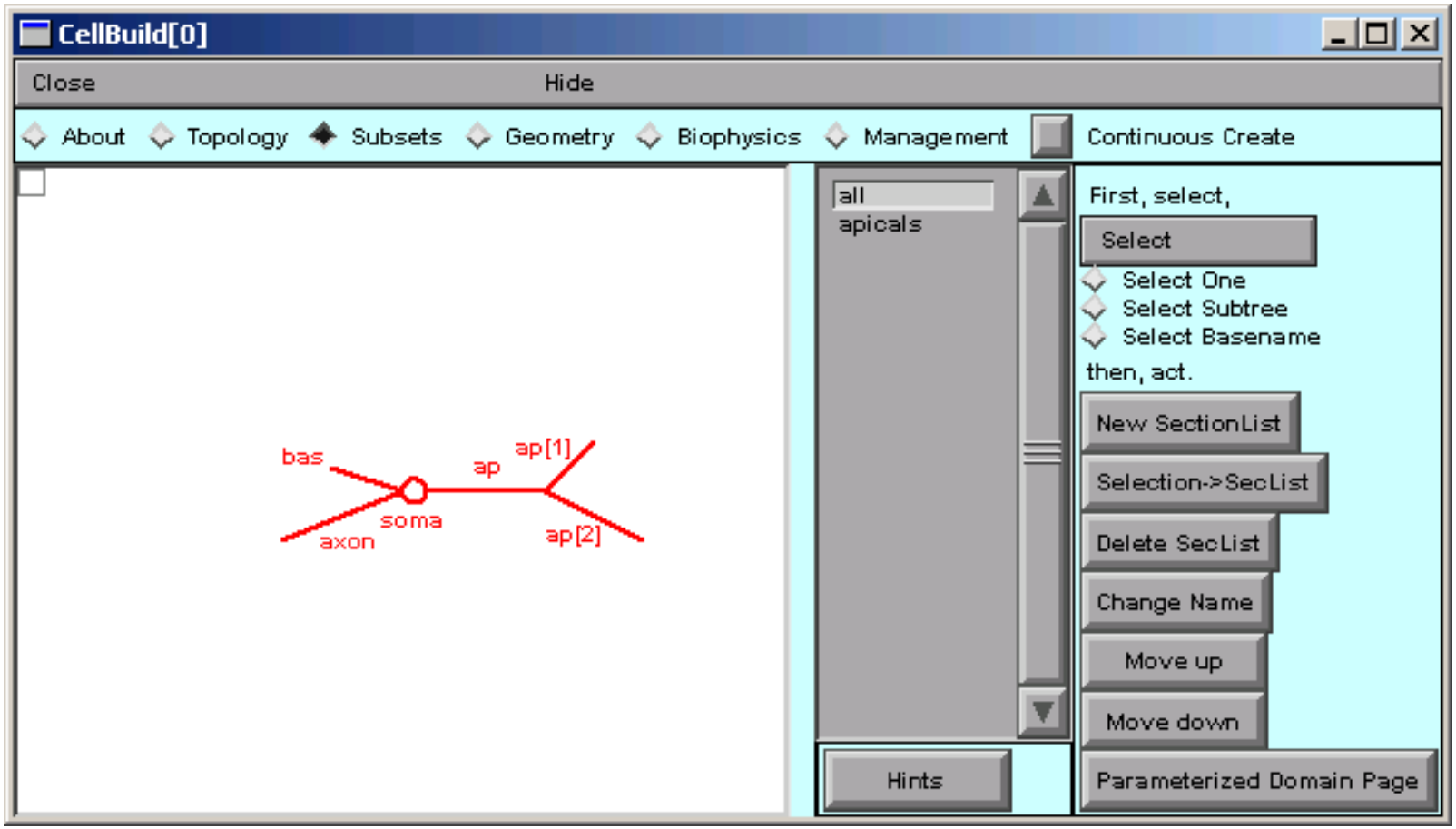


. . . then "New SectionList"

Making a new subset *continued*



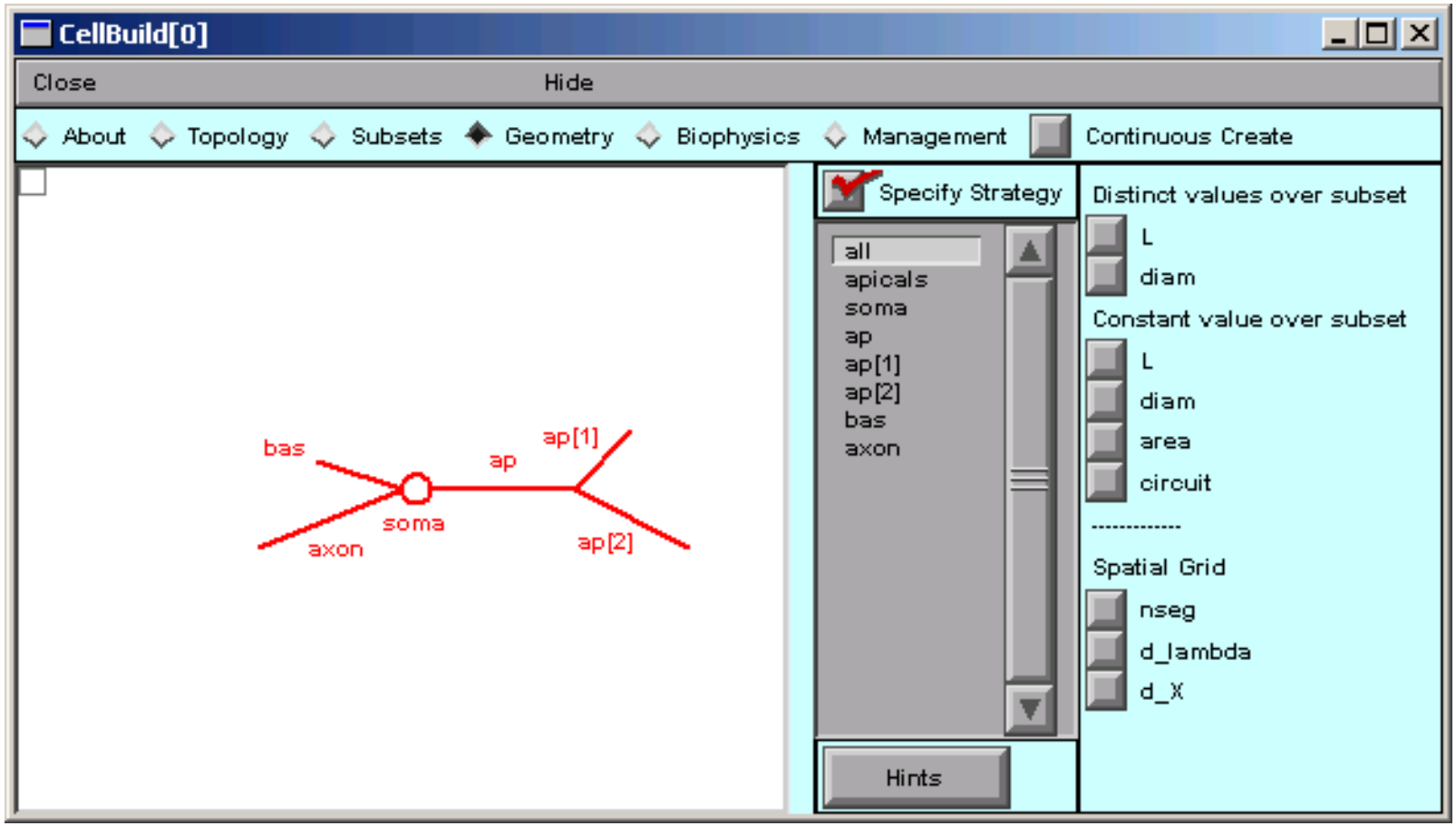
Subsets finished



Note "apicals".

Time to save a new session file.

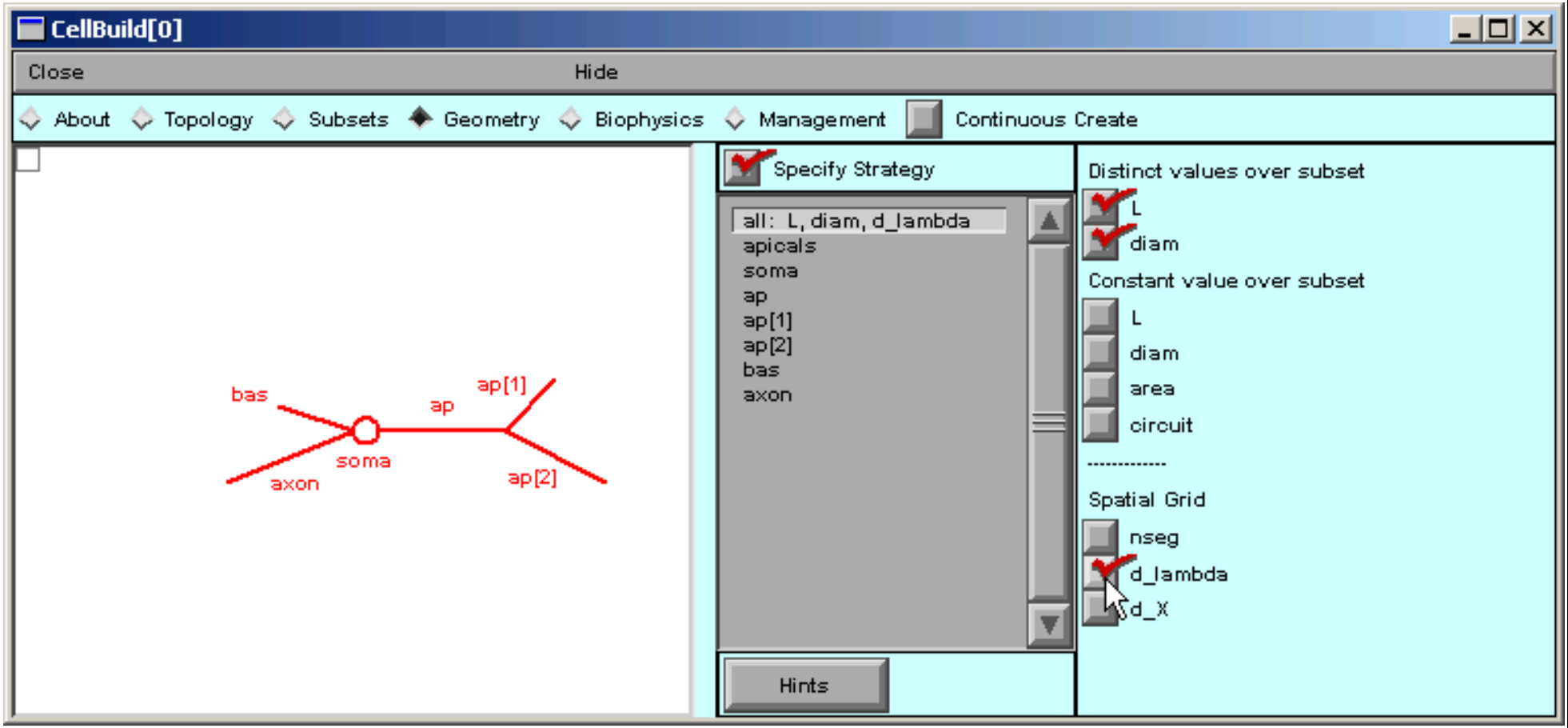
Geometry



"Specify Strategy" is ON.

A good strategy is a concise strategy.

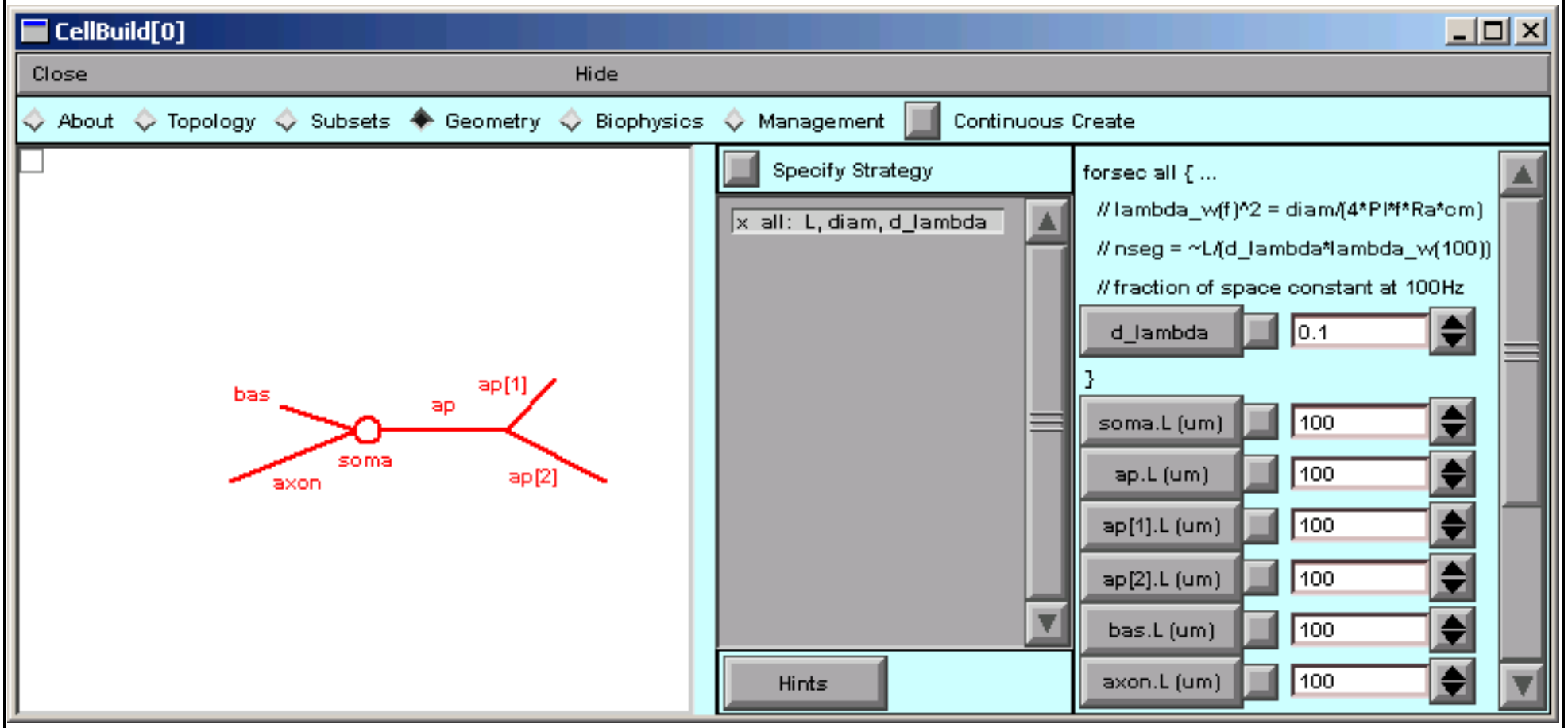
Geometry strategy



Each section has a different L and diam.

Compartmentalize according to $\lambda_{100\ Hz}$ (d_lambda rule).

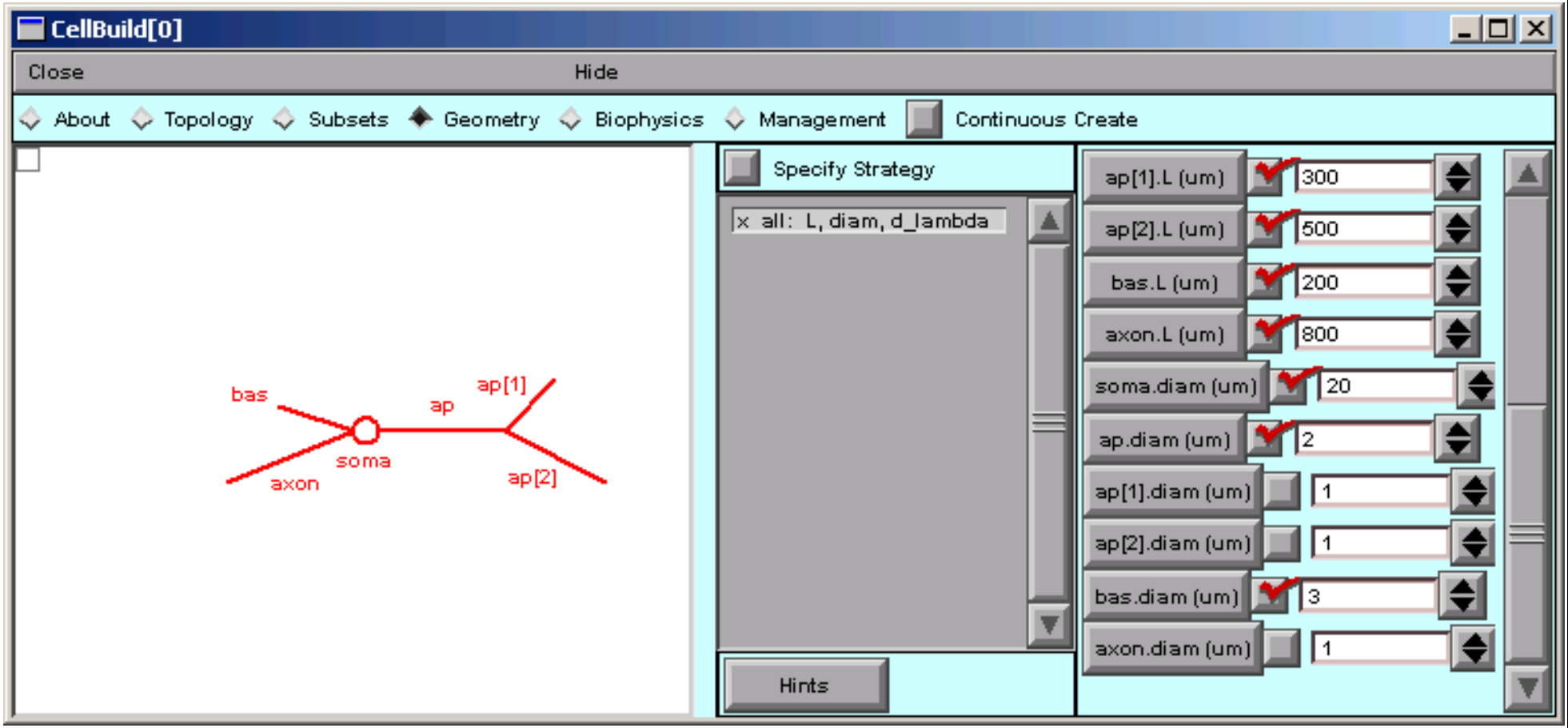
Implementing geometry strategy



When strategy is complete, turn "Specify Strategy" OFF and start assigning values to parameters.

d_lambda = 0.1 at 100 Hz usually gives good spatial accuracy.

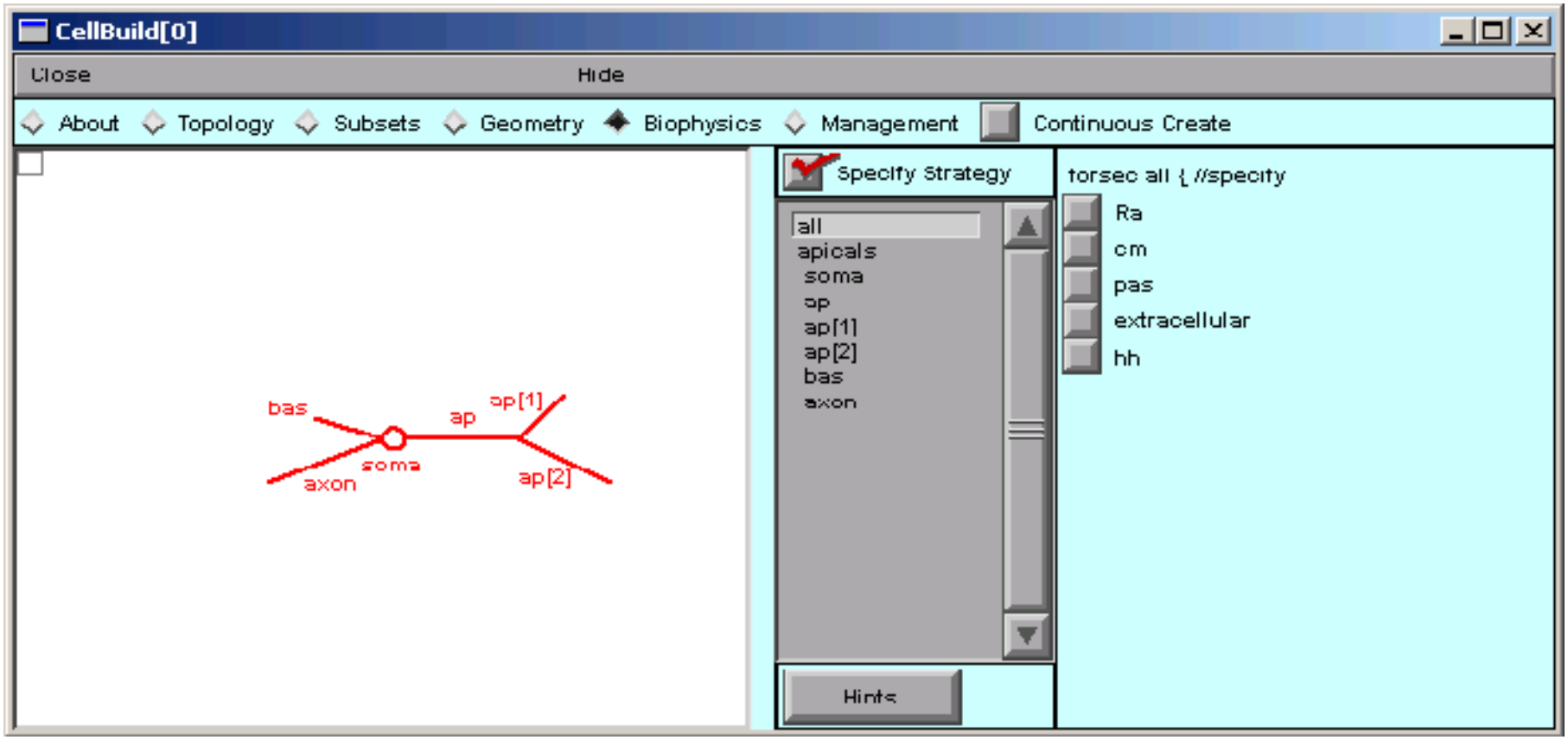
Implementing geometry *continued*



Set L and diam for all sections.

Time to save to a session file!

Biophysics

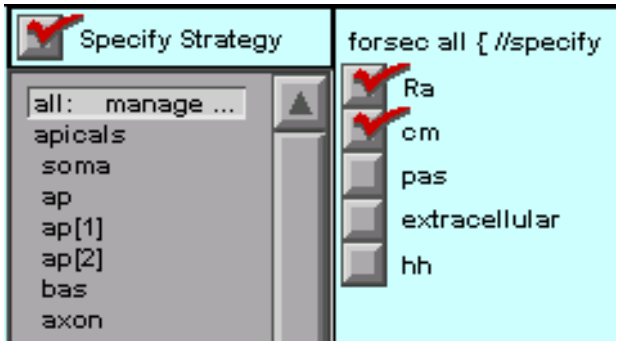


"Specify Strategy" is ON.

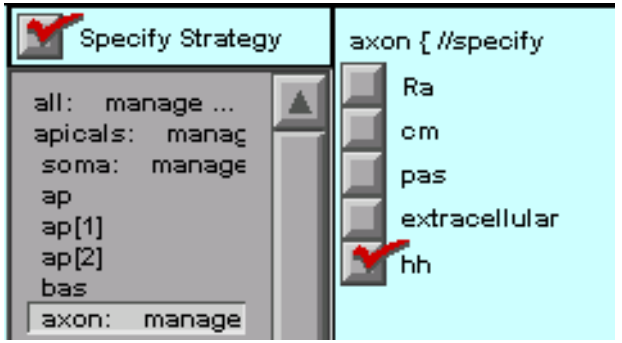
Base the plan on shared properties.

Biophysics strategy

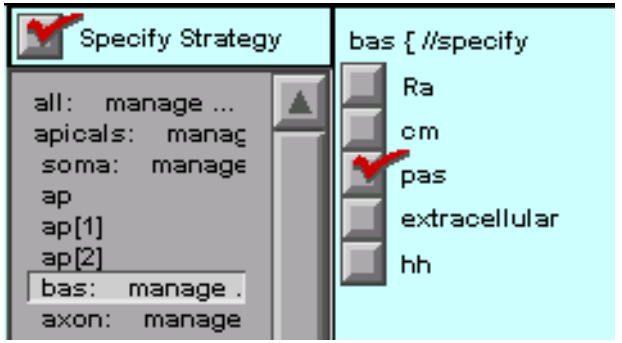
Ra and cm are homogeneous



apicals, soma and axon have hh



bas has pas

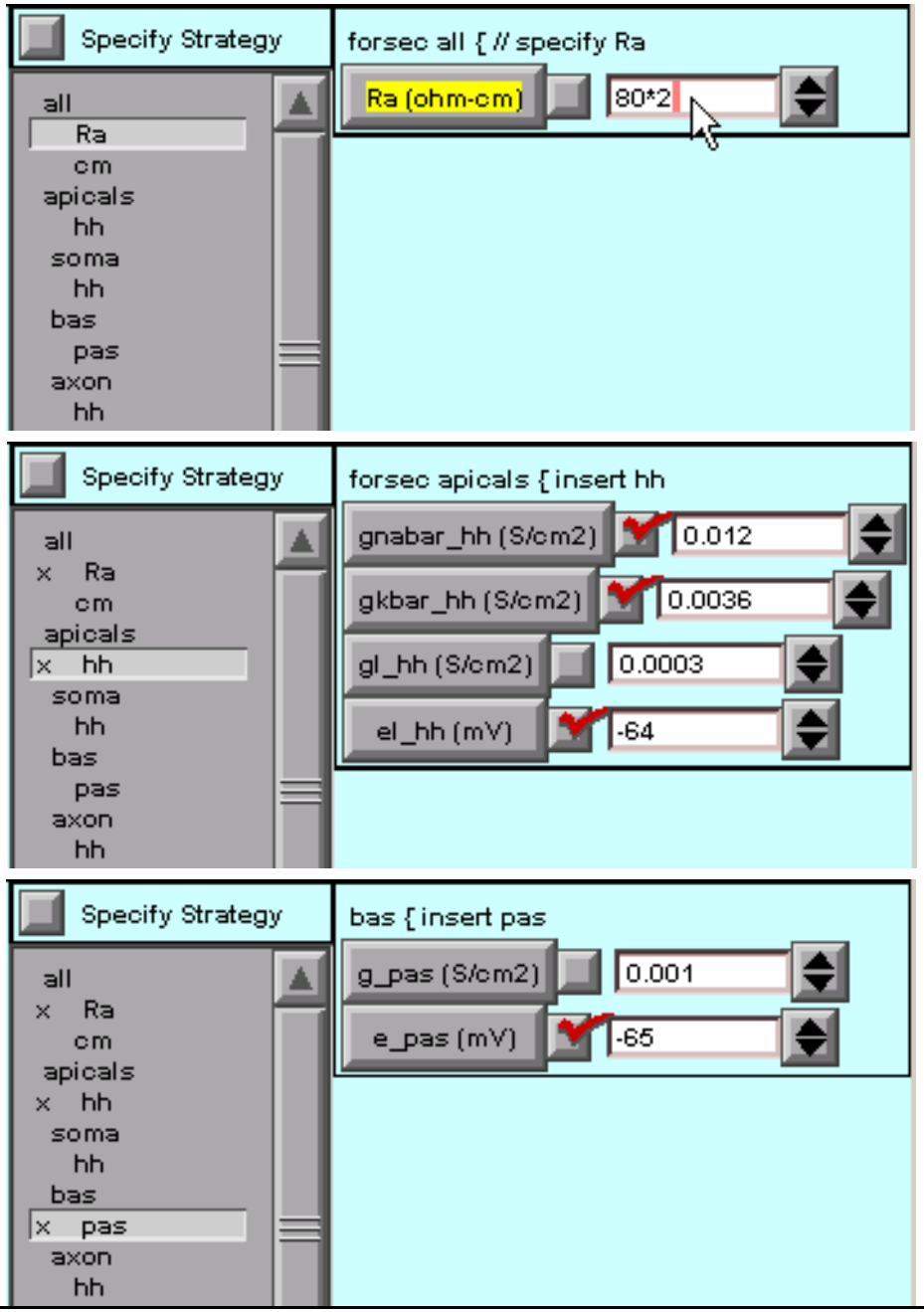


Implementing biophysics strategy

Double Ra

Fix apicals hh params

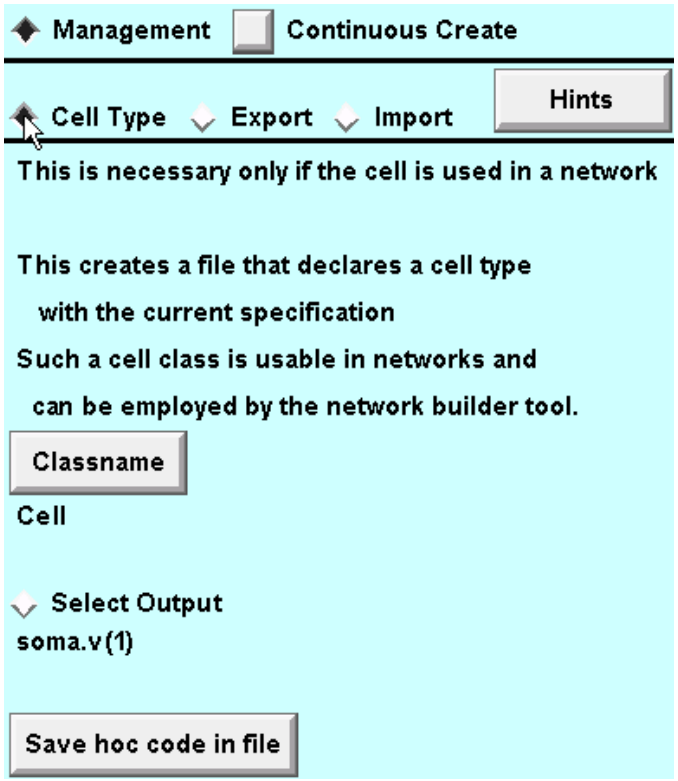
Shift e_pas in bas



Save another session file!!

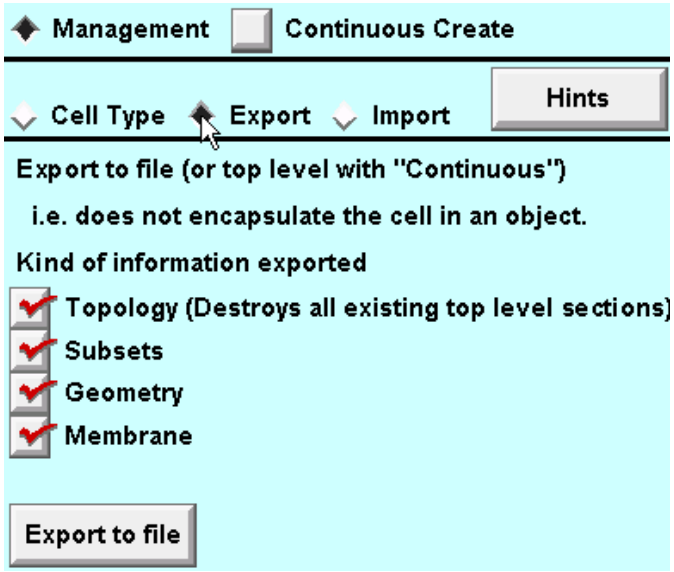
Management

Option 1: save as a Cell Type for use in a network



Management *continued*

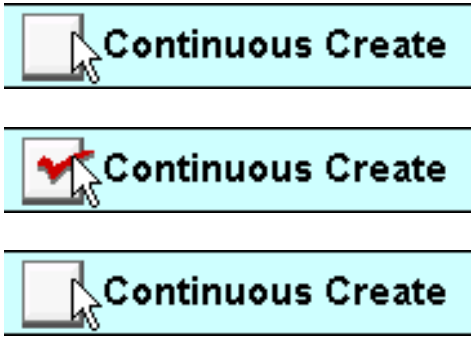
Option 2: save as hoc file



Management *continued*

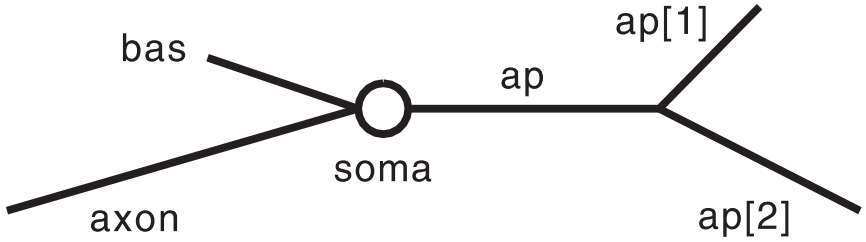
Option 3: export to interpreter

Toggle Continuous Create ON and OFF



or just leave it ON all the time.

Step 2: creating and using an interface for running simulations



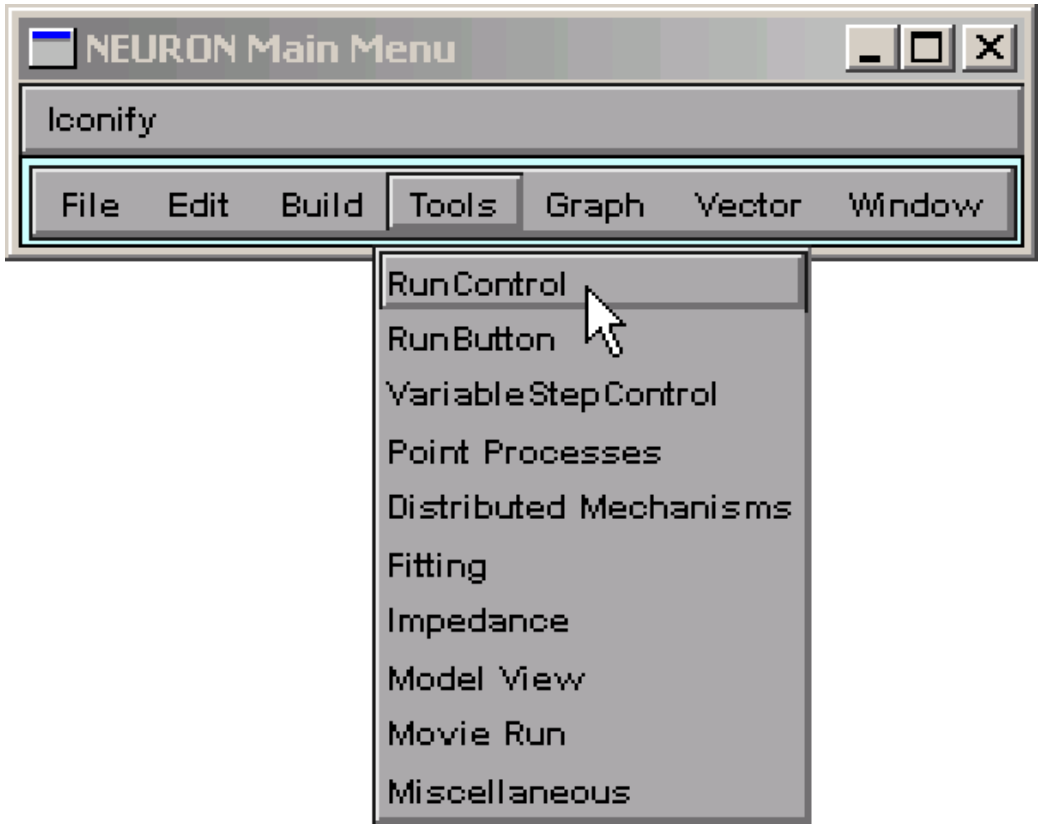
We want to

- attach a stimulating electrode
- evoke an action potential
- show time course of Vm at soma
- show Vm along a path from one end of the cell to the other

We need

- a "Run" button
- graphs to plot results
- a stimulator

Get a "Run" button



NEURON Main Menu / Tools / RunControl

RunControl panel

Init sets time to 0,
Vm to displayed value, and
conductances to steady-state

Init & Run does an Init,
then starts a simulation

Stop interrupts the simulation

Continue til runs until displayed time

Continue for runs
for displayed interval

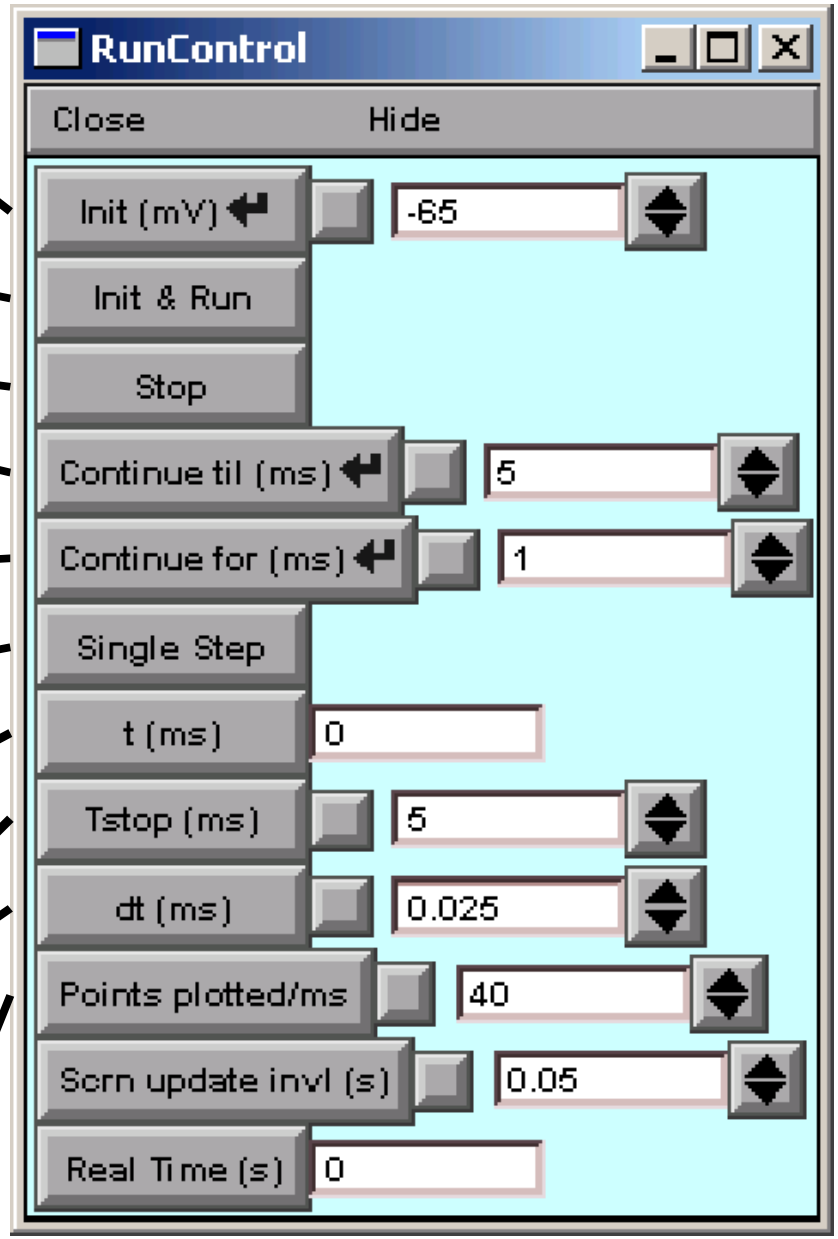
Single step advances by
1/(**Points plotted/ms**)

t numeric field shows model time

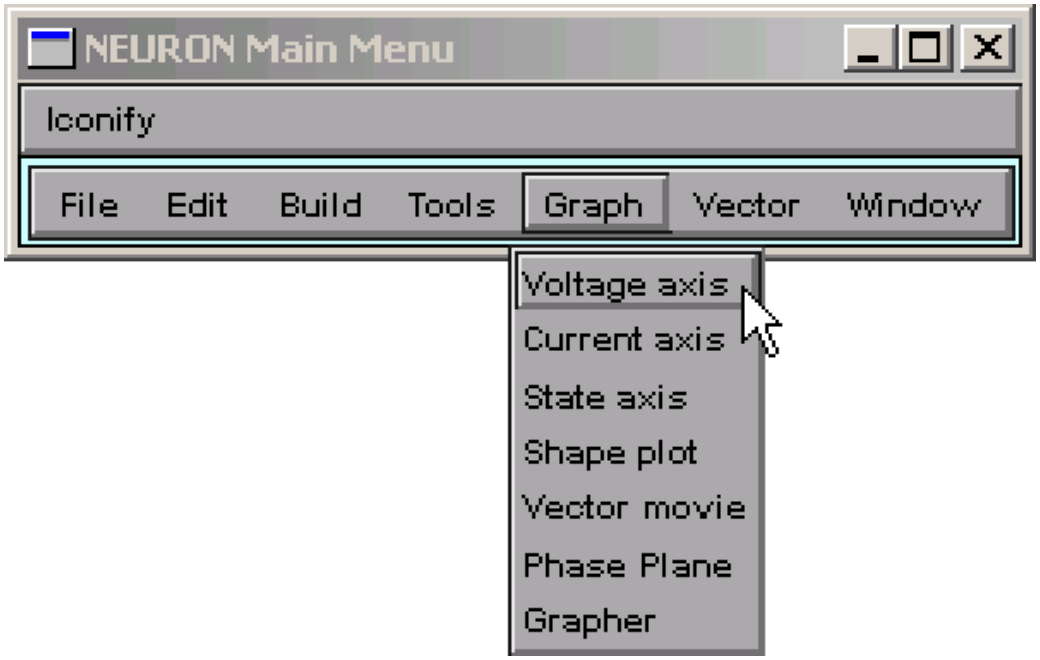
Tstop specifies when simulation ends

dt is integration time step;
must be integer fraction of
1/(**Points plotted/ms**)

Points plotted/ms is 1/plotting interval

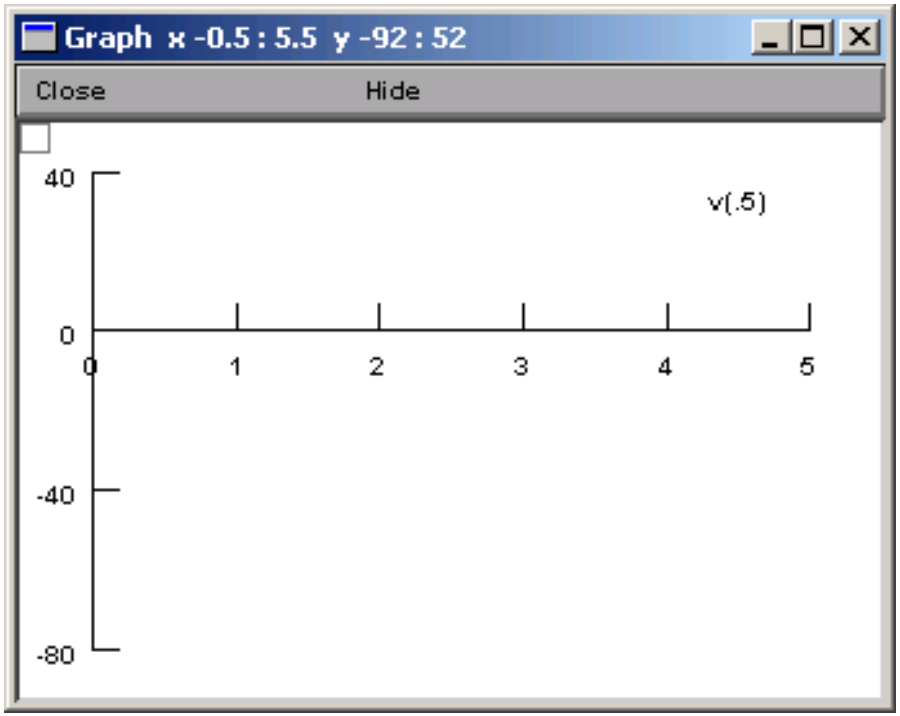


We need to plot Vm(t) at soma



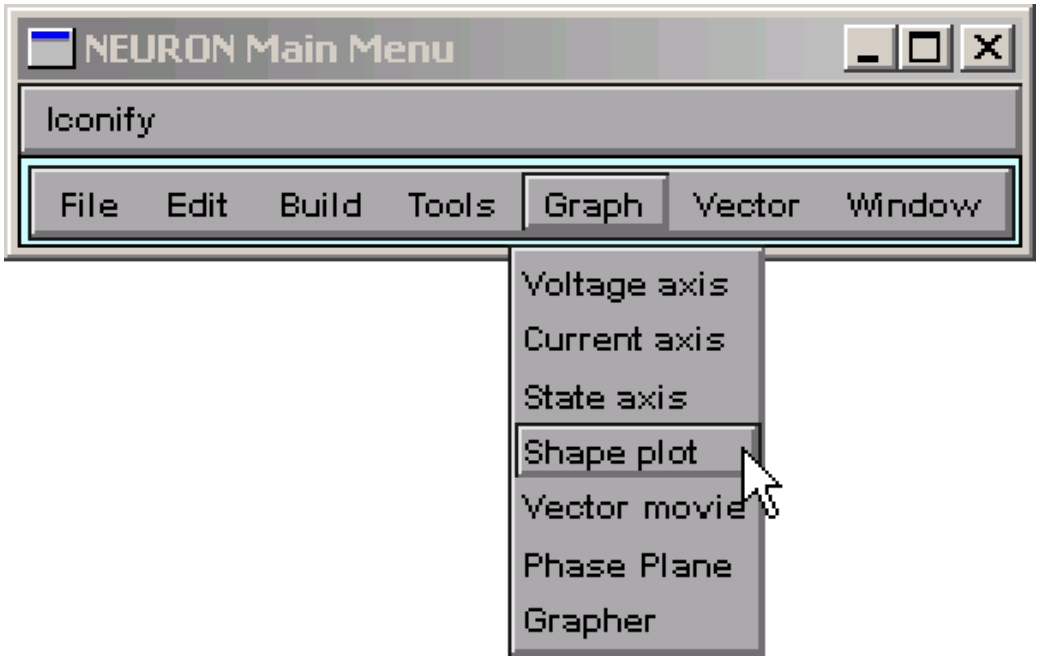
NEURON Main Menu / Graph / Voltage axis

Graph window



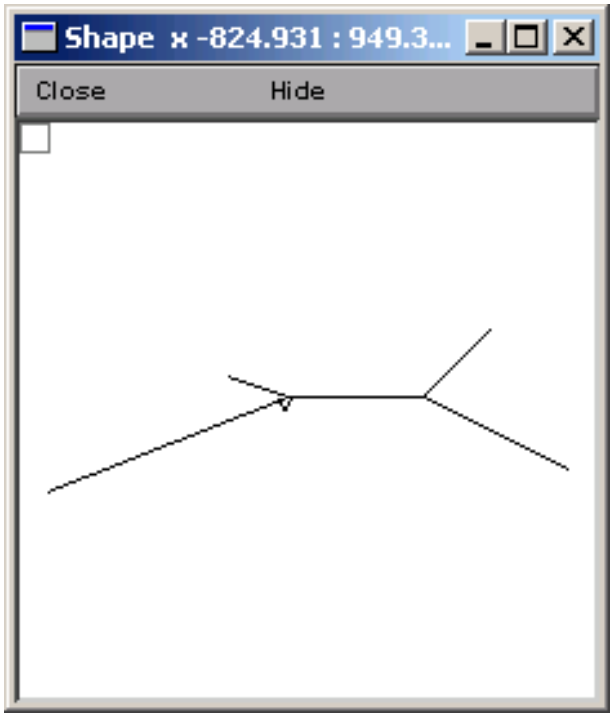
v(.5) is Vm at middle of default section
(first section in the CellBuilder)

We need to plot Vm along a path



NEURON Main Menu / Graph / Shape plot

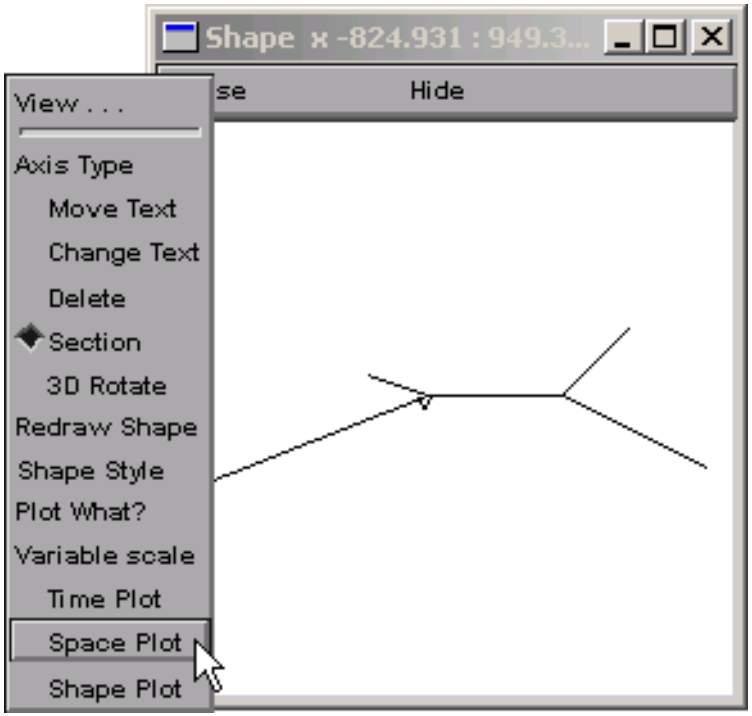
Bringing up a space plot



Use this "shape plot" to create a "space plot".

Click on its "menu box" . . .

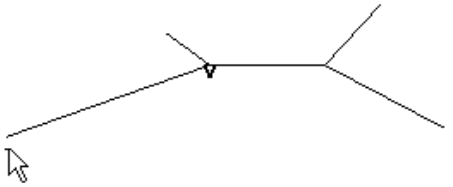
Bringing up a space plot *continued*



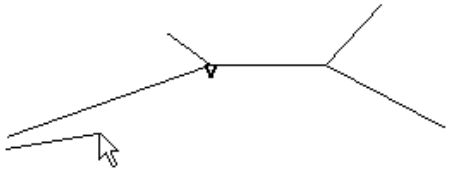
. . . and scroll down to "Space Plot".

Bringing up a space plot *continued*

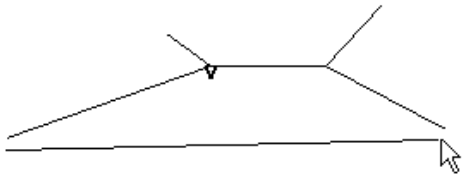
Click just left of the shape



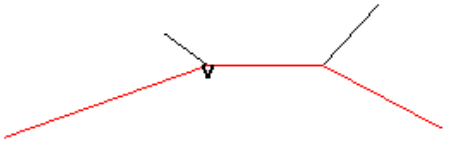
Hold button down while dragging from left . . .



. . . to right . . .

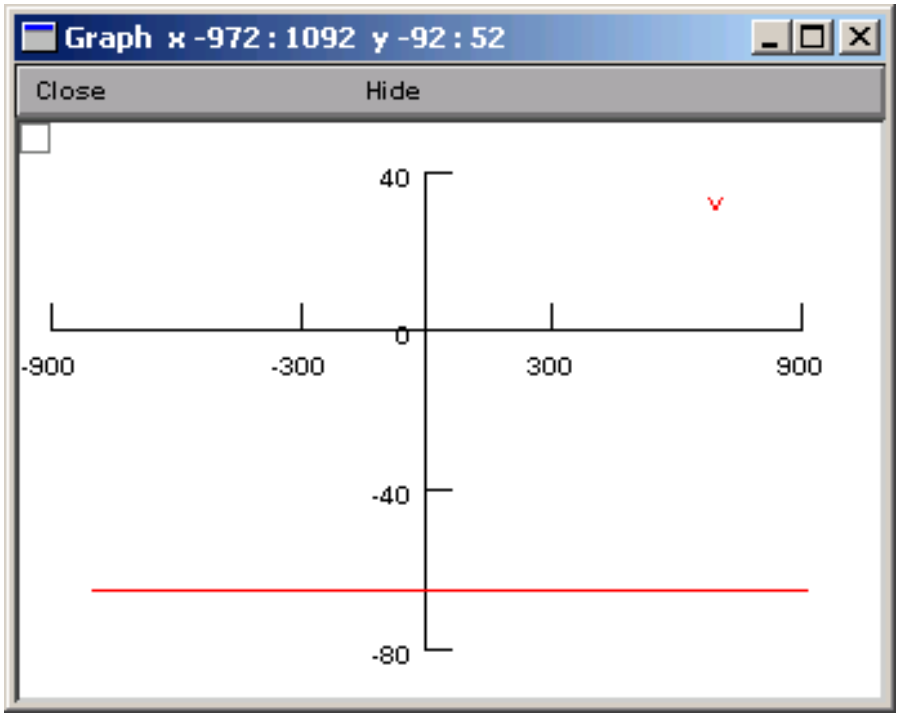


. . . then release button.



This pops up . . .

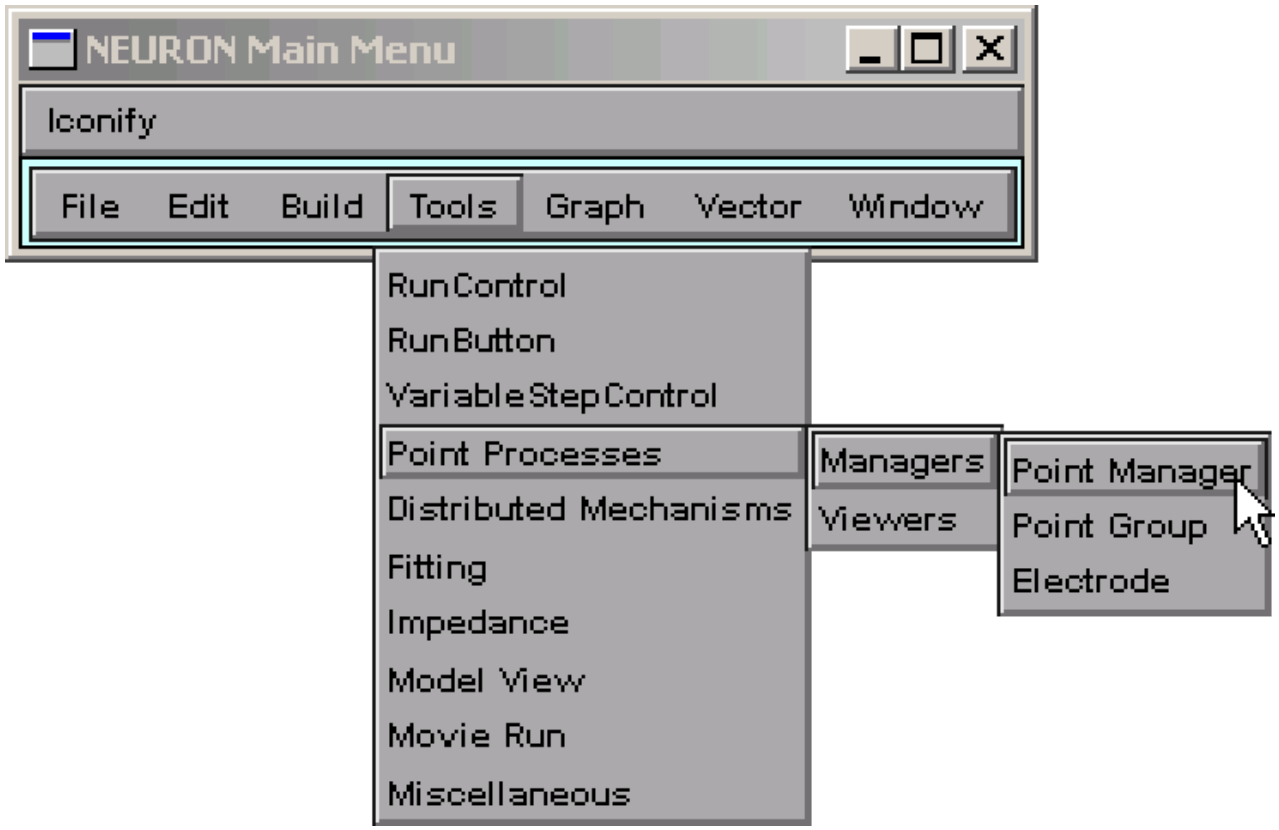
Space plot



. . . a plot of Vm vs. distance along a path.

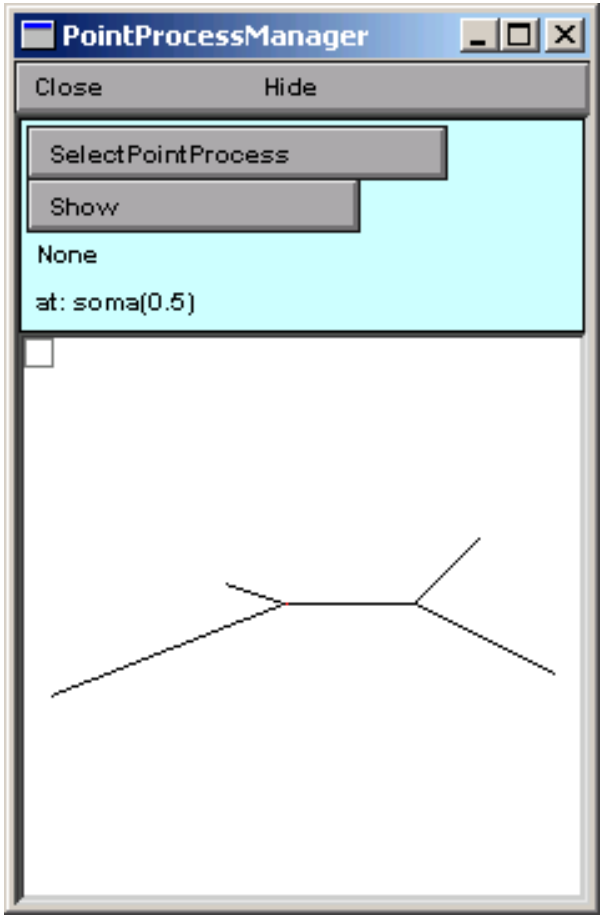
Better save a session file.

We need a stimulator



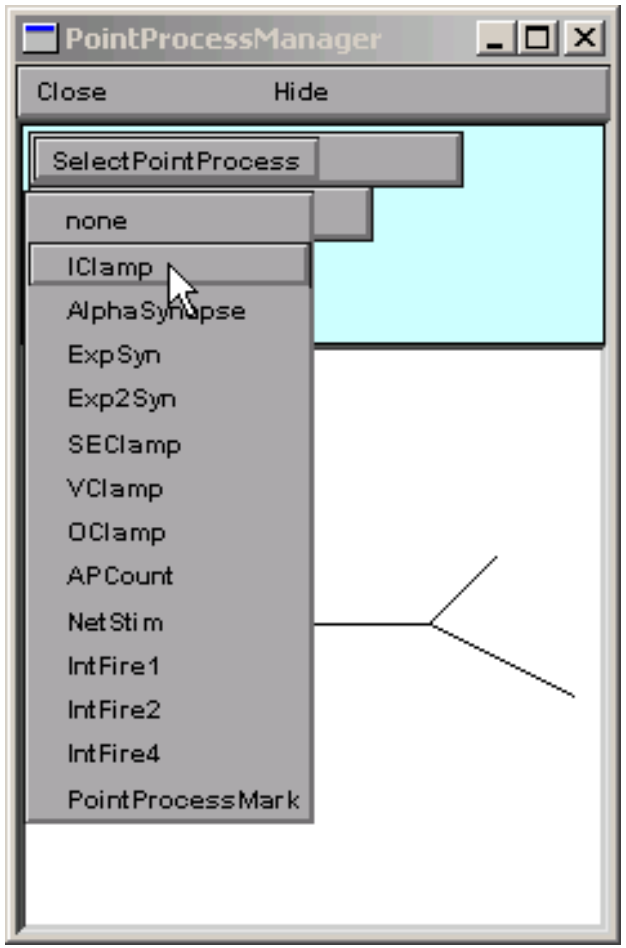
NEURON Main Menu / Tools / Point Processes / Managers / Point Manager

PointProcessManager window



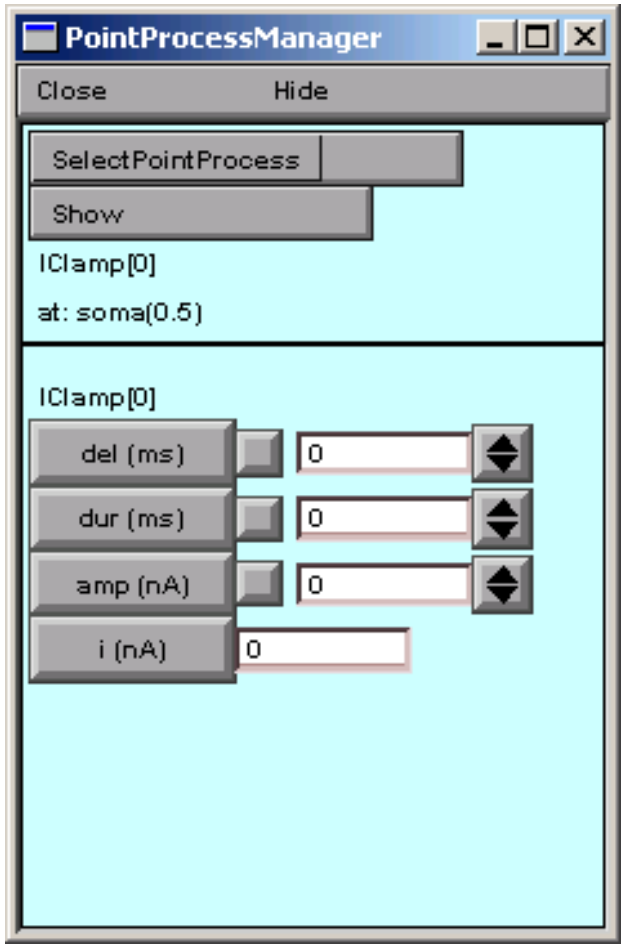
To make this an IClamp . . .

Creating an IClamp



. . . click on SelectPointProcess and scroll down to IClamp.

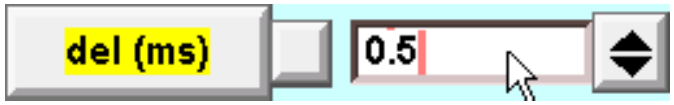
IClamp parameter panel



Next: set parameter values.

Entering values into numeric fields

Direct entry

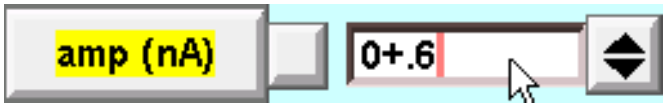


Note yellow highlight on button

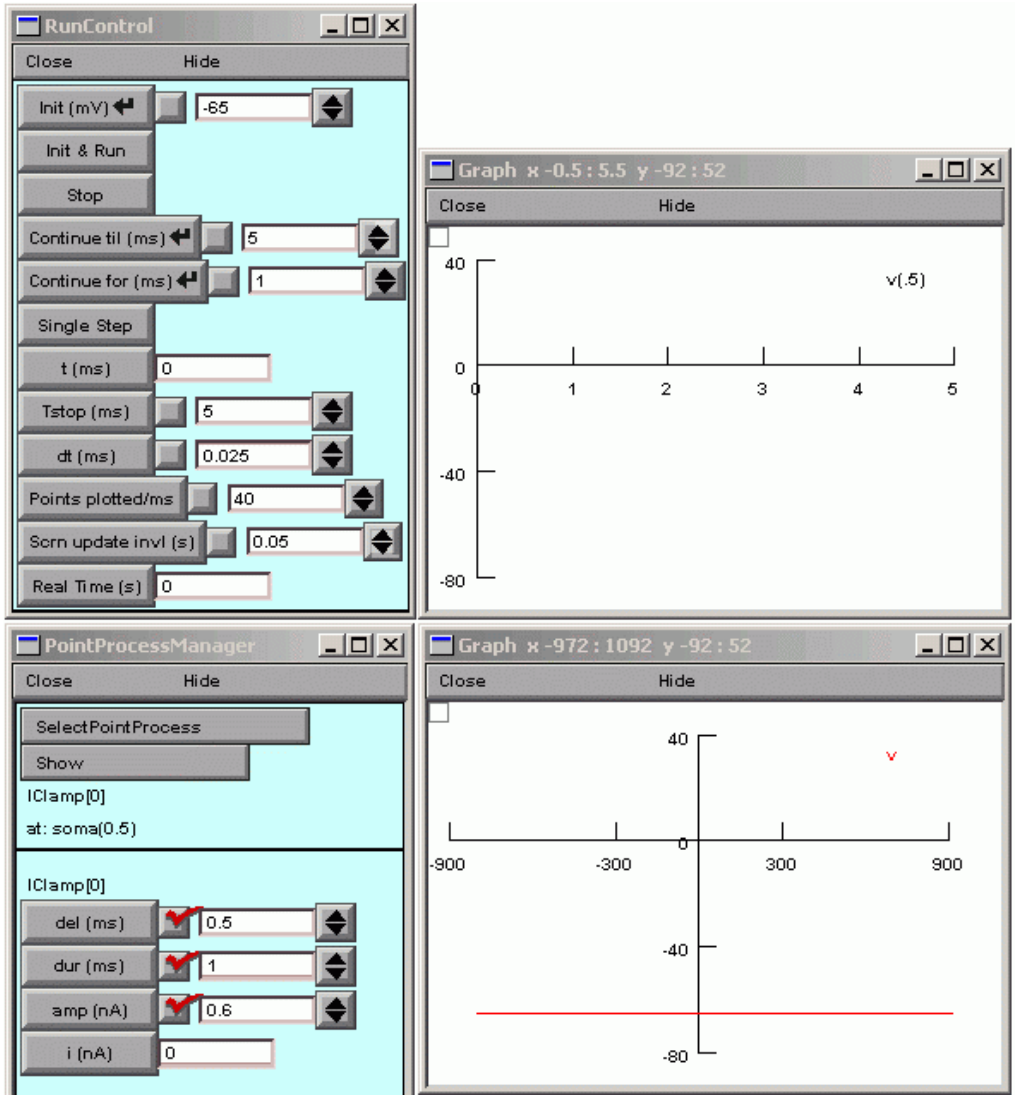
Spinner

Red check means value has been changed from default

Mathematical expression

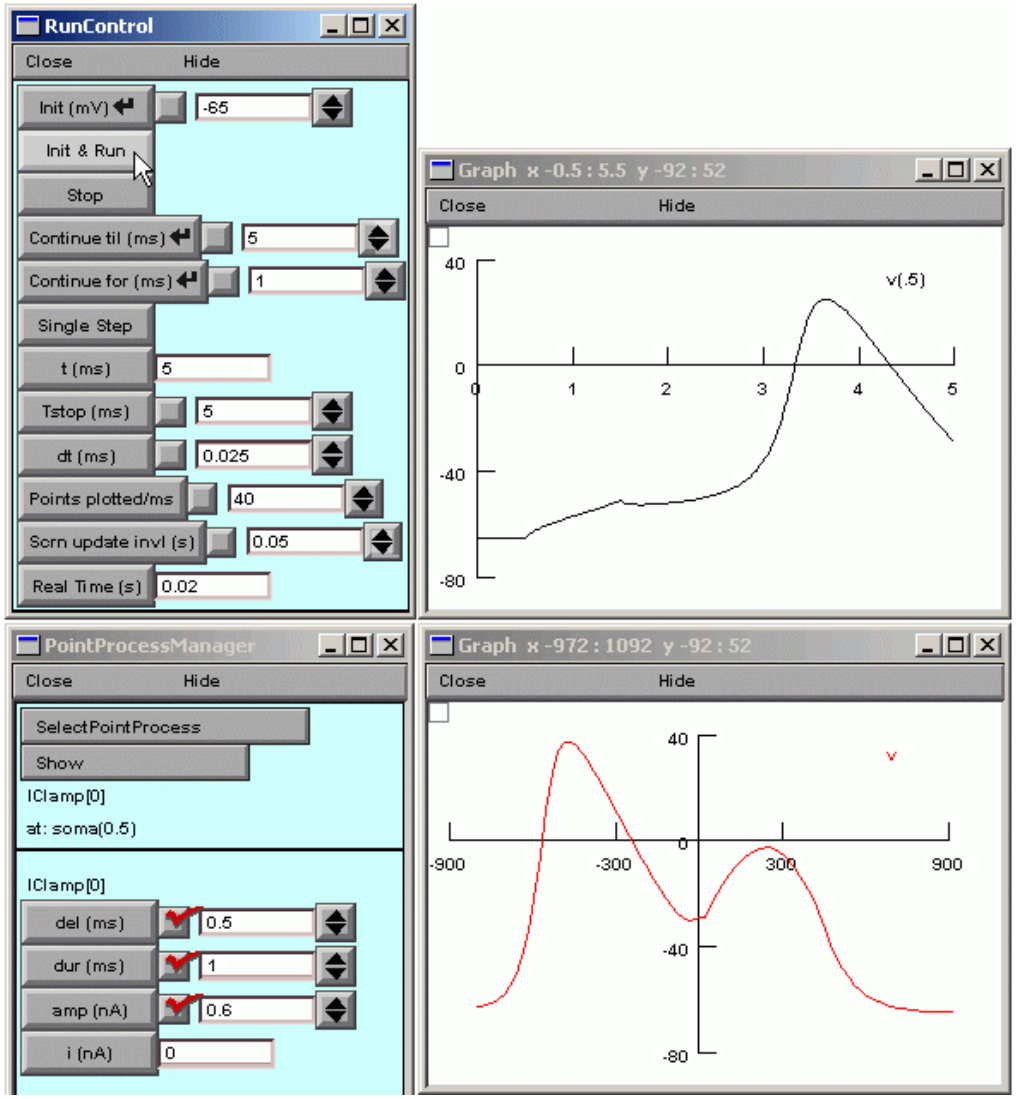


Our user interface

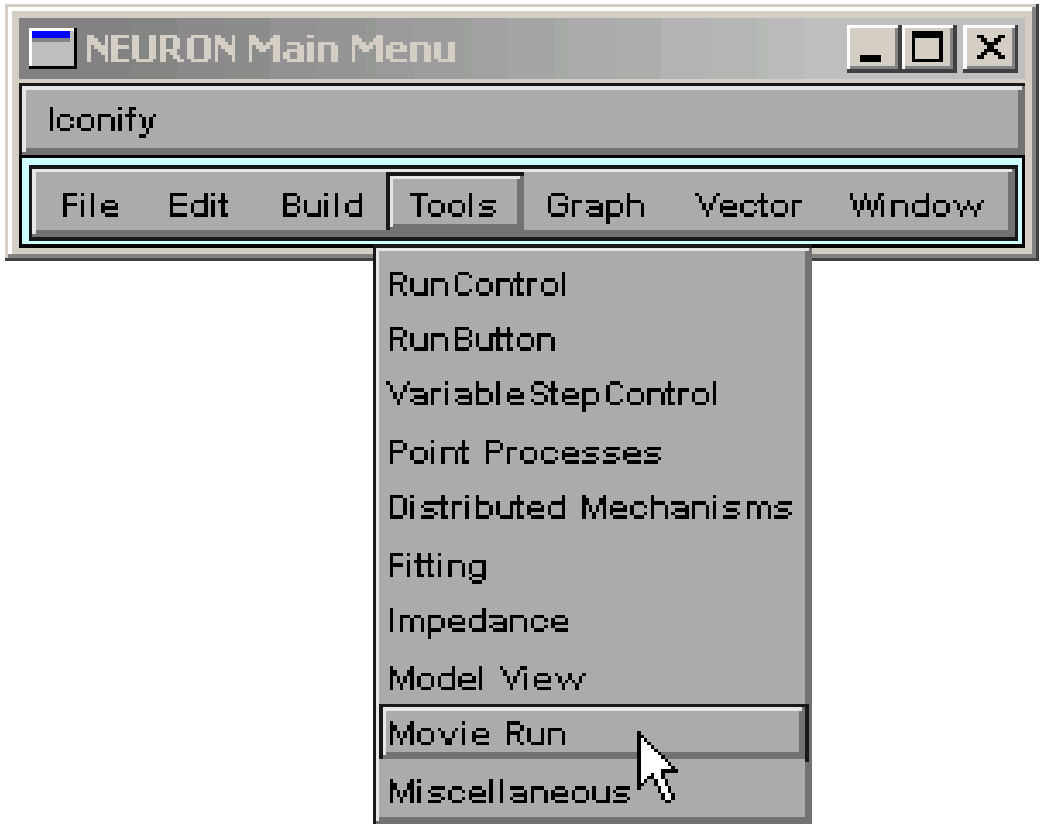


Time to save to a new session file!

It works!


RunControl
Close
Hide
Init (mV)
-65
Init & Run
Stop
Continue til (ms)
5
Continue for (ms)
1
Single Step
t (ms)
5
Tstop (ms)
5
dt (ms)
0.025
Points plotted/ms
40
Scrn update invl (s)
0.05
Real Time (s)
0.02
Graph x -0.5 : 5.5 y -92 : 52
Close
Hide
40
0
-40
-80
0
1
2
3
4
5
v(.5)
PointProcessManager
Close
Hide
SelectPointProcess
Show
IClamp[0]
at: soma(0.5)
IClamp[0]
del (ms)
0.5
dur (ms)
1
amp (nA)
0.6
i (nA)
0
Graph x -972 : 1092 y -92 : 52
Close
Hide
40
0
-40
-80
-900
-300
300
900
v

How to get nice space plot "movies"



NEURON Main Menu / Tools / Movie Run

Space plot "movies" *continued*

Movie Run / Init & Run

CellBuilder advanced usage

- Management of complex morphologies
  - Specifying subsets, e.g.
    - neurondemo's "ugly cell"
    - cells from Import3d
  - "Cell surgery"
    - example: removing/substituting axon
- Using exported (hoc) code in Python

Specifying subsets

neurondemo's "ugly cell"

just an example of a subset-free morphology

Subsets page

* zoom in to identify and "tag" somatic, axonal, and apical dendrites
* Management / Import / "Don't draw short sections as circles" may be helpful
* refer to Shape plot as necessary
* helpful: Select One, Select Subtree, Select / Xor, Select / Subtract etc.

When done, save to new session file!

Export new cell class as necessary

Cell surgery

Example: removing axon

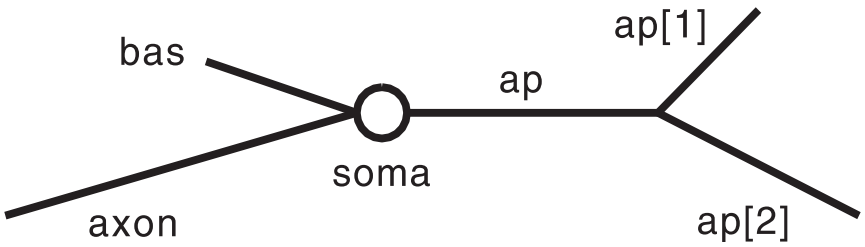
With Continuous Create off

- Identify axon sections on Topology
  - or Subsets page (latter is usually best)
- Topology page
  - zoom in and verify section/tree to be deleted
  - Select "Delete Section" or "Delete Subtree"
  - click to delete
- Save CellBuilder to a new ses file
- Export new cell class as necessary

Using exported (hoc) code in Python

```
# NPyr.hoc, exported from CellBuilder
# defines the NPyr class
h.load_file("NPyr.hoc")
npcell = h.Npyr()
# verify
h.topology()
```

Homework



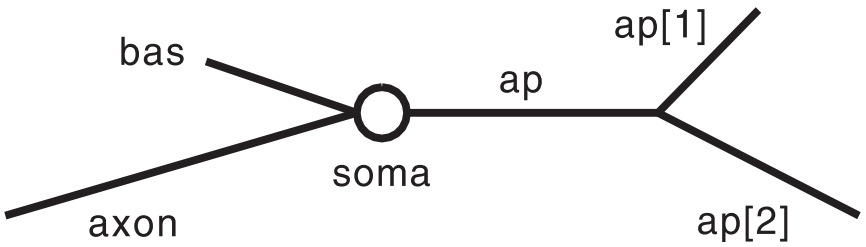
Using this model cell with "reduced hh" in the apical dendrites:

For a 0.1 ms depolarizing current pulse applied to soma(0.5) starting at t = 1 ms, what is the smallest amplitude that will elicit a spike? (2 significant figures)

Replace the IClamp with an AlphaSynapse with tau = 1 ms, onset = 1 ms, and e = 0 mV. What is the smallest gmax (peak conductance) that will elicit a spike? (2 significant figures)

What gmax elicits a 1 mV epsp at the soma? How much of the epsp spreads to ap(0.5)? ap[2](0.5)? bas(1)? (2 significant figs).

Homework



Move the AlphaSynapse to ap(0.5) but don't change its tau, onset, e, or gmax. How big is the epsp at ap(0.5), and how big is it after it spreads to the soma? (2 significant figures)

Repeat with the synapse at ap[2](0.5).

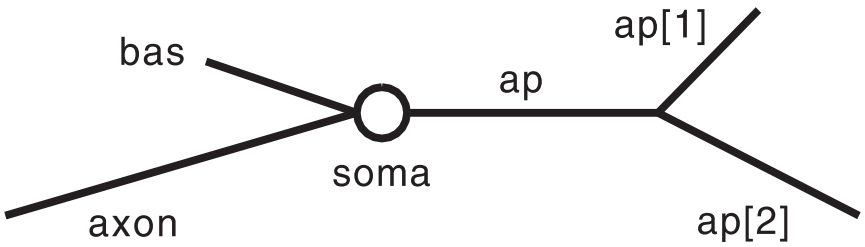
Finally, repeat with the synapse at bas(1).

Organize your results in a table like this:

Synaptic location	**EPSP at synapse**	**"Downstream" location**	**EPSP downstream**
`soma(0.5)`	`1 mV`	`ap(0.5)`	*value observed*
. . . etc. . . .			

("Downstream" means away from the point of synaptic attachment)

Homework



The properties of the AlphaSynapse are very similar to those of an AMPAergic excitatory synapse. Based on your observations,

1. Does an excitatory synapse act more like a voltage source or a current source?

2. What is the range of epsps amplitudes observed at the soma, and what is the range seen at the synaptic locations?

3. Is there approximate reciprocity between a given pair of locations? (i.e. is the downstream epsp relatively unaffected by swapping the synaptic and downstream locations) Does this surprise you?