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

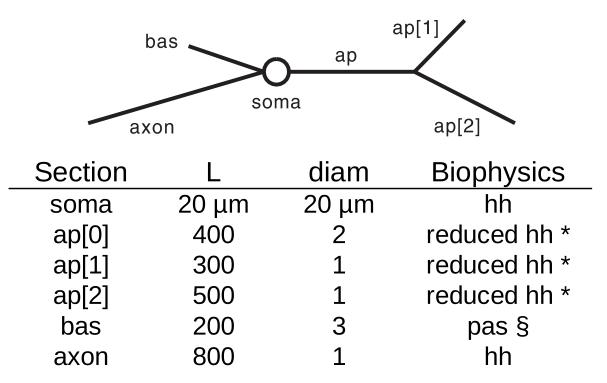
Create cells (instances of cell classes)

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



* 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 μ f / cm²

Launch NEURON with its GUI library

nrngui

Oľ

python
from neuron import h, gui

Oľ

click on nrngui icon (MSWin, MacOS)

Bring up a CellBuilder

NEURON	Main Menu			
loonify				
File Edit	Build To-	ols Grap	h Vector	Window
	single comp	artment		
	Cell Builder			
	NetWork Ce	u k}		
	NetWork Bu	ilder		
	Linear Circu	Jit		
	Channel Bui	ilder		

NEURON Main Menu / Build / Cell Builder

The CellBuilder

Close	
🕈 About 🔶 T	opology 💊 Subsets 💸 Geometry 💸 Biophysics 💸 Management 📃 Continuous Create
Topology refer	s to section names, connections, and 2d orientation
without rega	rd to section length or diameter.
Short sectio	ns are represented in that tool as circles, longer ones as lines.
Subsets allows	one to define named section subsets as functional
groups for t	ne purpose of specifying membrane properties.
Geometry refer	s to specification of L and diam (microns), and nseg
for each sec	tion (or subset) in the topology of the cell.
Biophysics is u	sed to insert membrane density mechanisms and specify their parameters.
Management sj	pecifies how to actually bring the cell into existence for simulation.
The default	is to first build the entire cell and export it to the top level
Or else spec	ify it as a cell type for use in networks,
lt also allows	s you to import the existing top level cell into this builder
for modific:	ation.
lf "Continuous	Create" is checked, the spec is continuously instantiated
at the top le	vel as it is changed.

Use buttons from left to right.

Topology

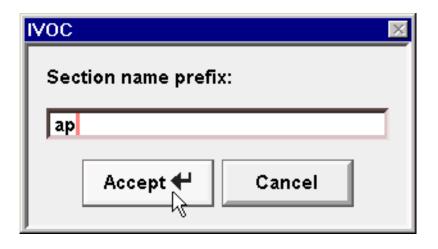
CellBuild[0]	
Close Hide	
🔷 About 🔶 Topology 🔷 Subsets 💠 Geometry 🔷 Biophys	sics 💠 Management 🗾 Continuous Create
s@a	Basename: dend Undo Last Click and drag to Make Section Copy Subtree Reconnect Subtree Reposition Move Label Click to Delete Section Delete Section Delete Subtree Change Name Hints

CB starts with a "soma" section. We want to create new sections.

Specifying the "Basename"

Basename: dend	<u>h</u> č
----------------	------------

IVOC	×
Section name prefix	x:
dend 💦	
Accept 🕂	Cancel



Making a new section

Place cursor near end of existing section

Click to start new section



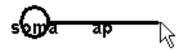
soma

Drag to desired length



 \mathbb{R}

Release mouse button

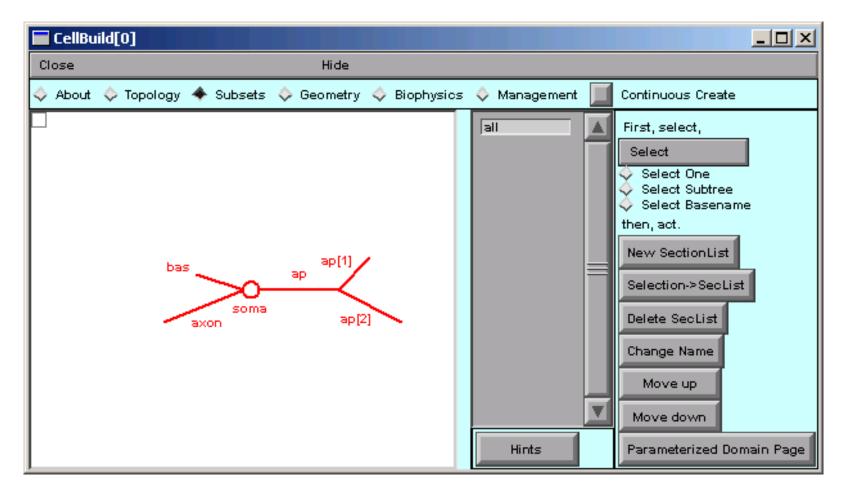


Save your work as you make progress!

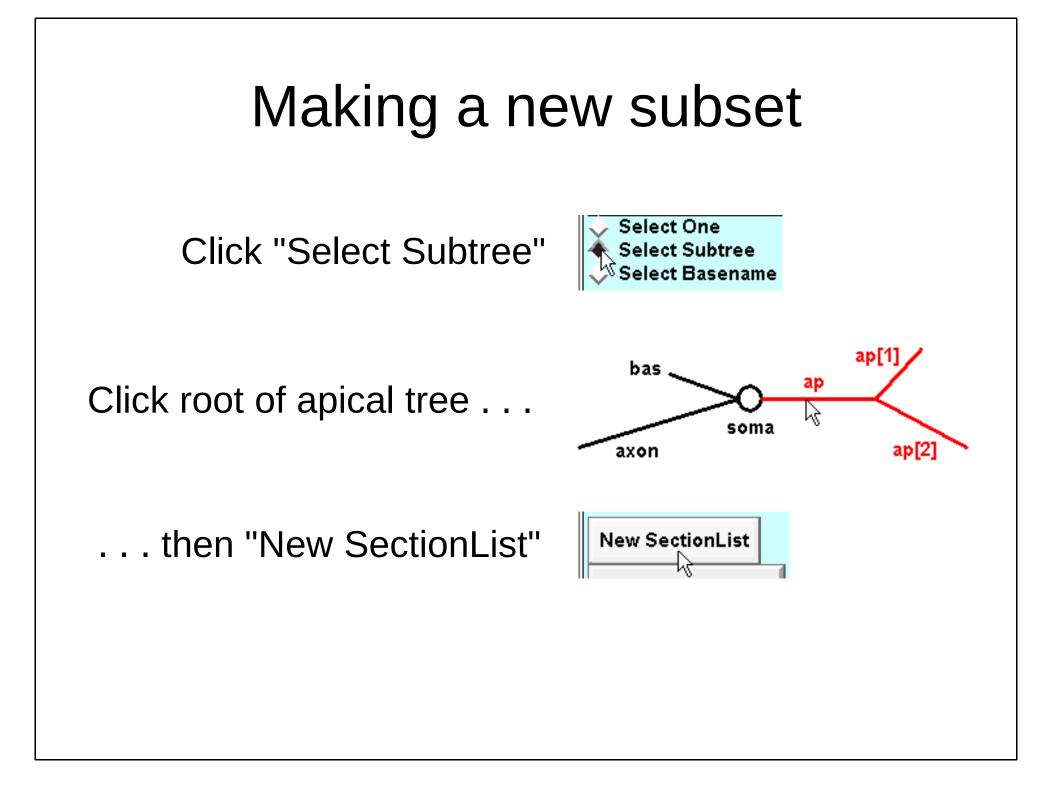
	JR.ON N	Main M	enu			
loonit	у					
File	Edit	Build	Tools	Graph	Vector	Window
load s	ession					
load h	oc					
load d	II					
saves	sessiq	1				
workin	ng dir k	5				
recent	dir					
Print						
Quit						

NEURON Main Menu / File / save session

Subsets



Group sections that have shared properties. We want to make an "apicals" subset.

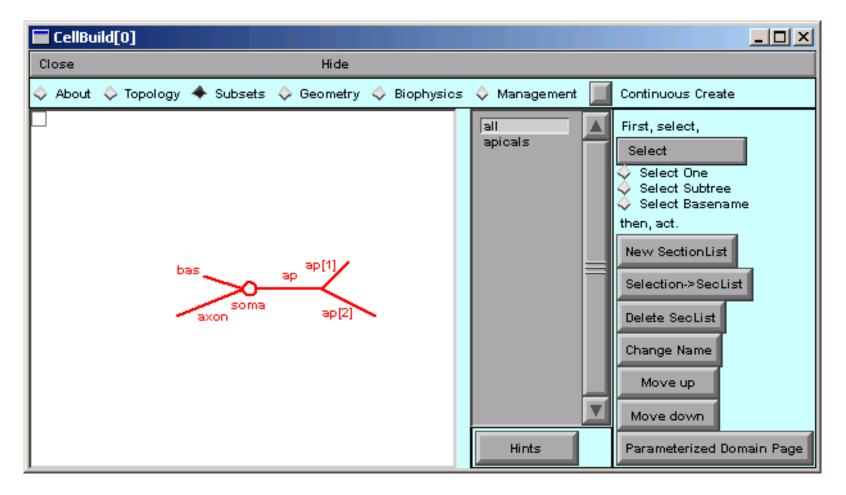


Making a new subset continued

IVOC			×
New	SectionList na	me	
all	R.		
	Accept 🕂	Cancel	

IVOC	×
New SectionList na	me
apicals	
Accept	Cancel

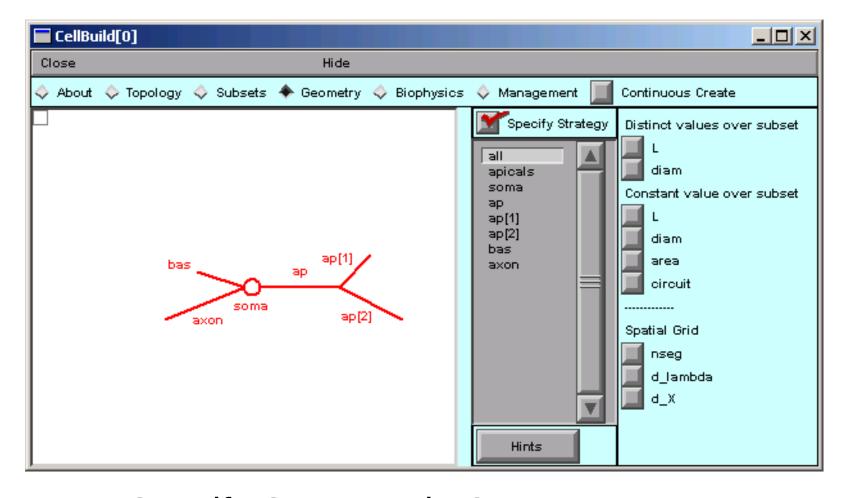
Subsets finished



Note "apicals".

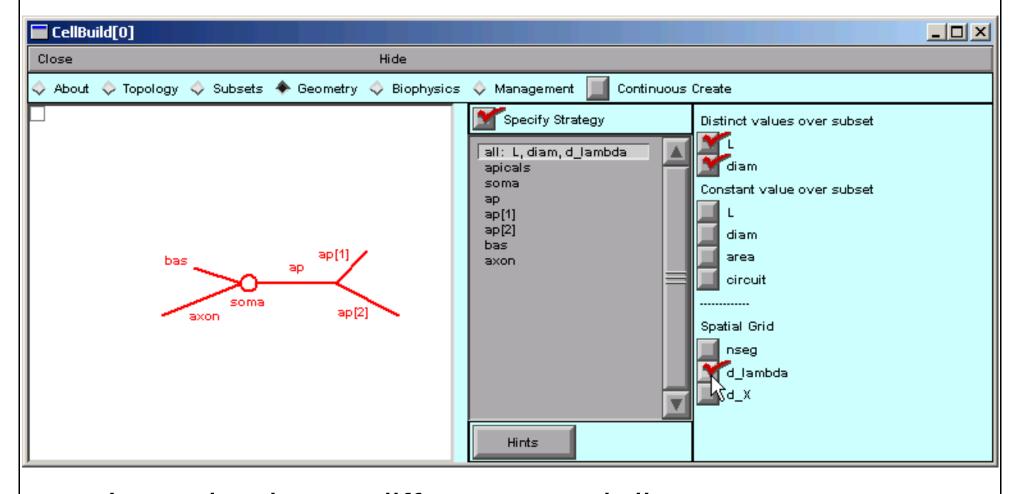
Time to save a new session file.

Geometry



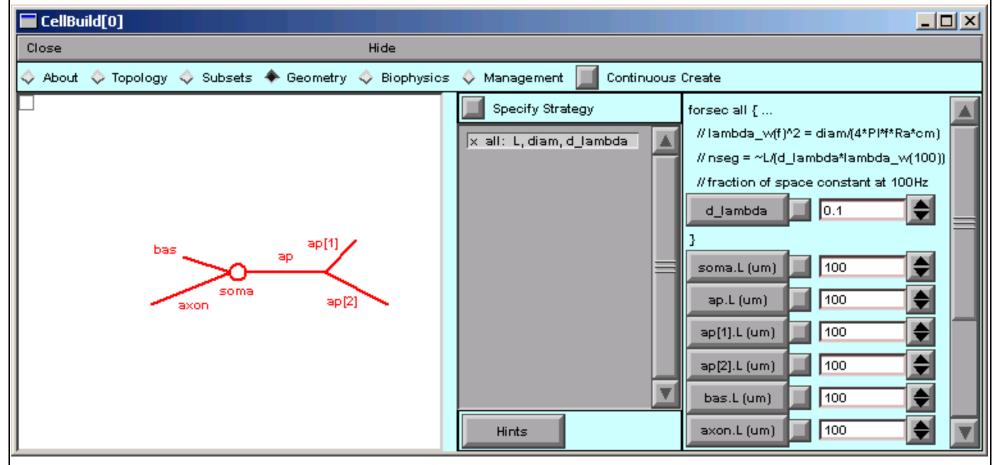
"Specify Strategy" is ON. A good strategy is a concise strategy.

Geometry strategy



Each section has a different L and diam. Compartmentalize according to $\lambda_{100 \text{ Hz}}$ (d_lambda rule).

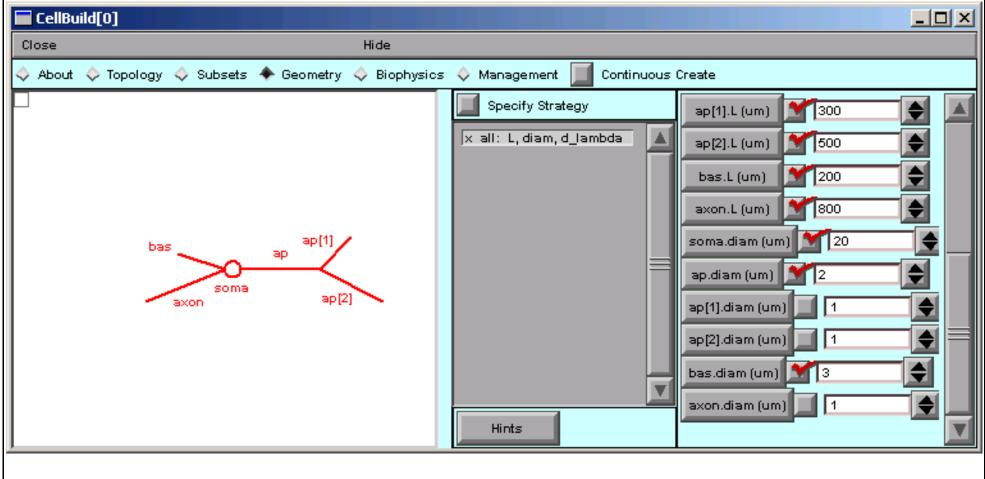
Implementing geometry strategy



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

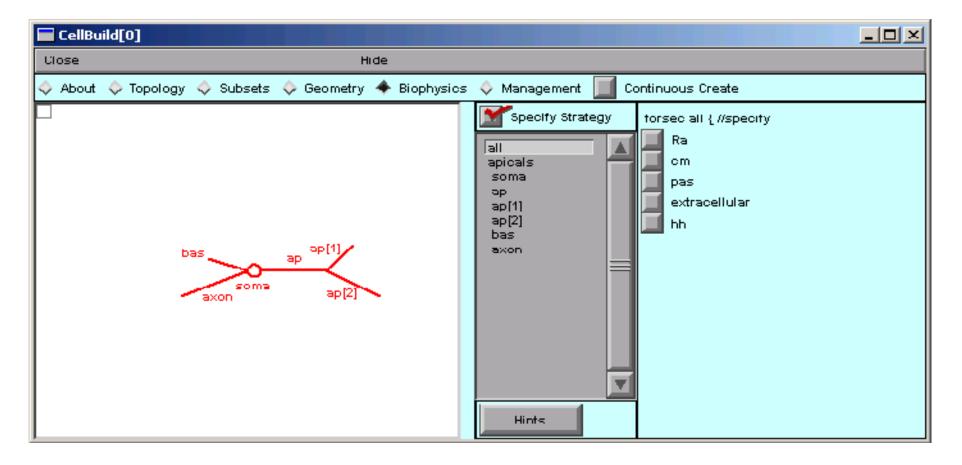
d_lambda = 0.1 at 100 Hz usually gives good spatial accuracy.

Implementing geometry continued



Set L and diam for all sections. *Time to save to a session file!*

Biophysics



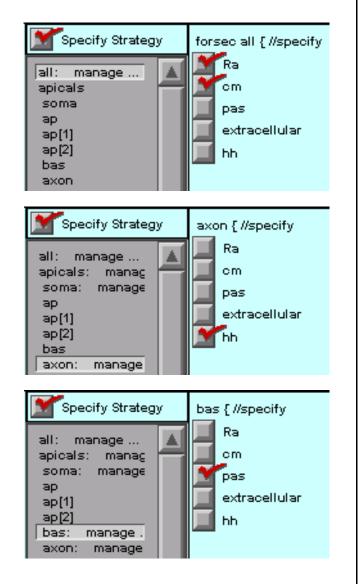
"Specify Strategy" is ON. Base the plan on shared properties.

Biophysics strategy



apicals, soma and axon have hh

bas has pas

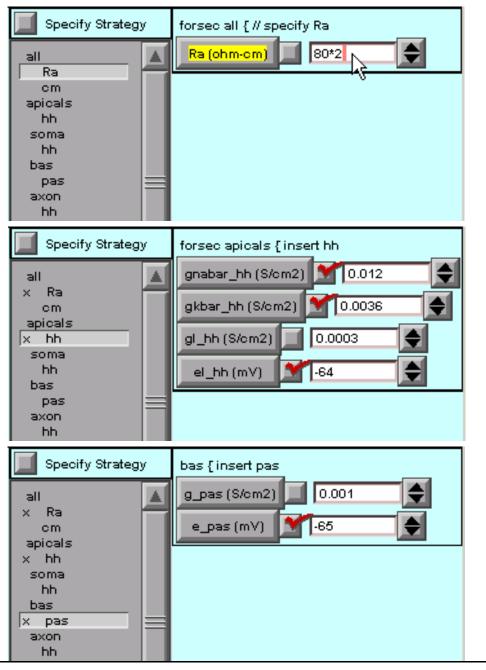


Implementing biophysics strategy

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 📃 Continuous Create					
🛧 Cell Type 🔷 Export 🔷 Import	Hints				
This is necessary only if the cell is used	d in a network				
This creates a file that declares a cell ty with the current specification Such a cell class is usable in networks					
can be employed by the network build	er tool.				
Classname					
Cell					
Select Output soma.v(1)					
Save hoc code in file					

Management continued

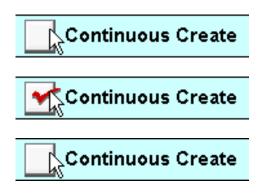
Option 2: save as hoc file

🔶 Management 📃 Continuous Crea	te
🔷 Cell Type 🔺 Export 杀 Import	Hints
Export to file (or top level with "Continu	uous'')
i.e. does not encapsulate the cell in ar	ı object.
Kind of information exported	
Topology (Destroys all existing top Subsets Geometry Membrane	level sections)
Export to file	

Management continued

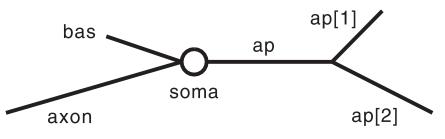
Option 3: export to interpreter

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

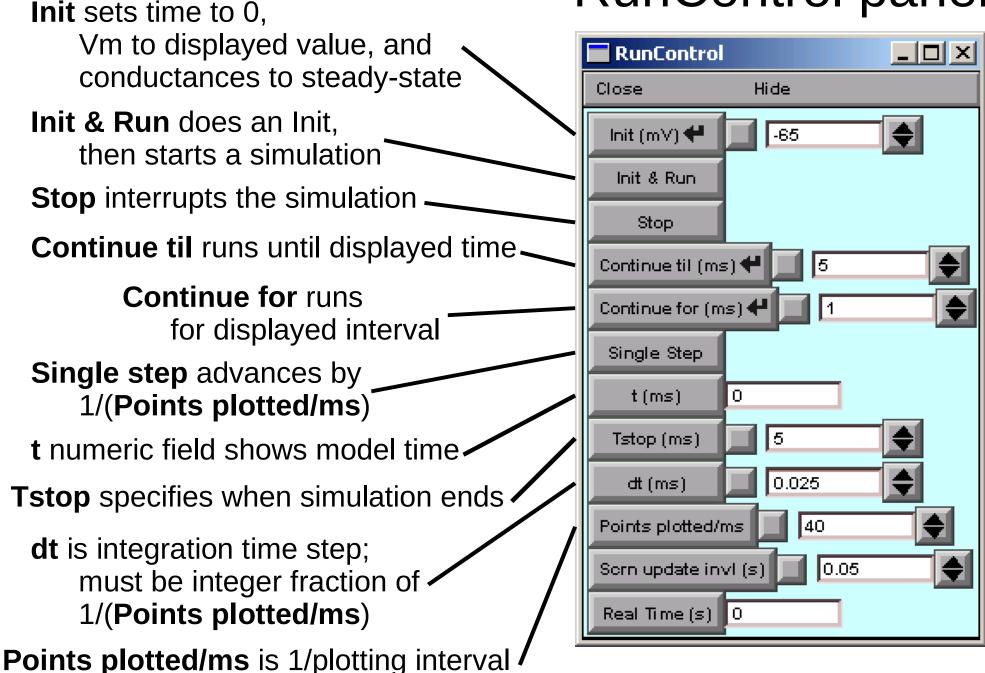
- a "Run" button
- graphs to plot results
- a stimulator

Get a "Run" button

NEURON Mair	Menu			
leonify				
File Edit Bui	ld Tools	Graph	Vector	Window
	Point Pr	on StepCont ocesses ted Mech nce fiew Run		

NEURON Main Menu / Tools / RunControl

RunControl panel

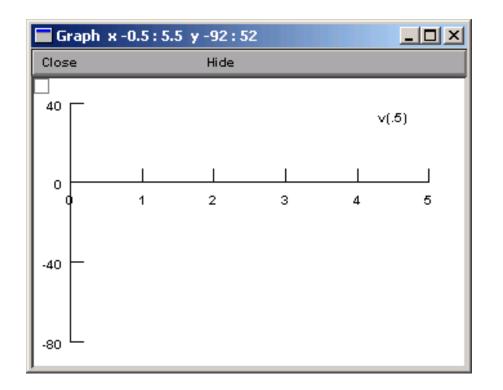


We need to plot Vm(t) at soma

NEURON Main Menu						
loonif;	У					
File	Edit	Build	Tools	Graph	Vector	Window
				Voltage a	axis	
				Current a	ixis hŠ	
				State a×i	s	
				Shape pl	ot	
				Vector m	ovie	
				Phase Pl	ane	
				Grapher		

NEURON Main Menu / Graph / Voltage axis

Graph window



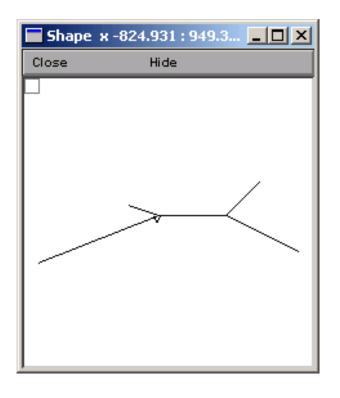
v(.5) is Vm at middle of default section (first section in the CellBuilder)

We need to plot Vm along a path

NEURON Main Menu						
Iconify						
File	Edit	Build	Tools	Graph	Vector	· Window
				Voltage axis Current axis State axis Shape plot Vector movie Phase Plane Grapher		

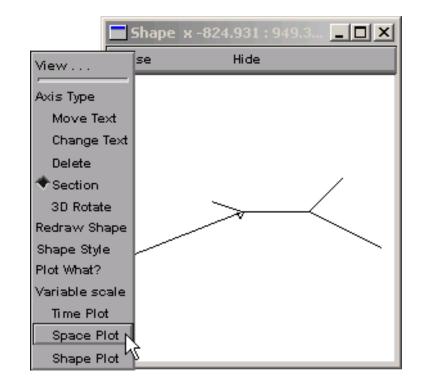
NEURON Main Menu / Graph / Shape plot

Bringing up a space plot



Use this "shape plot" to create a "space plot". Click on its "menu box" . . .

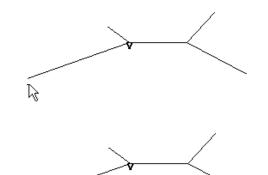
Bringing up a space plot continued



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

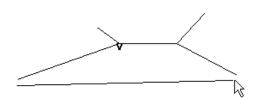
Bringing up a space plot continued

Click just left of the shape



Hold button down while dragging from left . . .

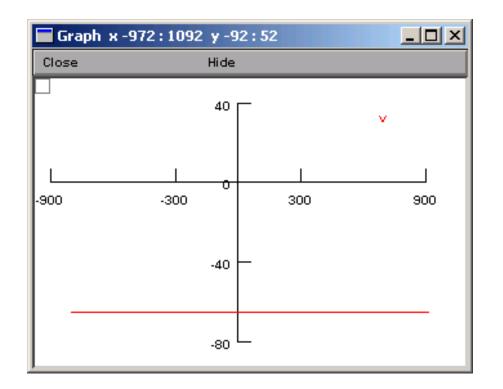
... to right ...



... 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					_ 🗆 ×	
leonify						
File Edi	t Build	Tools	Graph	Vector	Window	
		Run Cont Run Butto Vari able		rol		
		Point Processes Distributed Mechanisms Fitting Impedance Model View Movie Run Miscellaneous		Managers Viewers	Point Manager Point Group Electrode	

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

PointProcessManager window

PointProcess	Manager	
Close	Hide	
SelectPointProc	ess	
Show		_
None		
at: soma(0.5)		
	>	

To make this an IClamp . . .

Creating an IClamp

PointProcessManager					
Close Hide					
SelectPointProcess					
none					
IClamp					
AlphaSynSpse					
ExpSyn					
Exp2Syn					
SEClamp					
VClamp					
OClamp					
APCount					
NetStim	\vdash				
IntFire1					
IntFire2					
IntFire4					
PointProcessMark					
1					

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

IClamp parameter panel

PointProces	ssManager	
Close	Hide	
SelectPointPro	ocess	
Show		
lClamp[0]		
at: soma(0.5)		
lClamp[0]	_	
del (ms)	0	
dur (ms)		
amp (nA)	0	
i (nA)	0	

Next: set parameter values.

Entering values into numeric fields

Direct entry



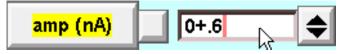
Note yellow highlight on button

Spinner

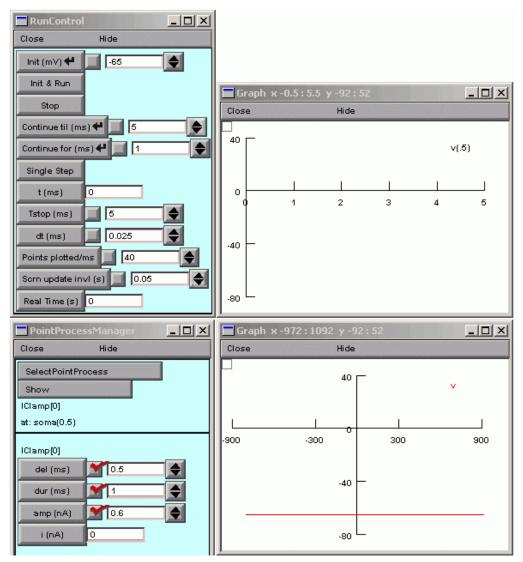


Red check means value has been changed from default

Mathematical expression

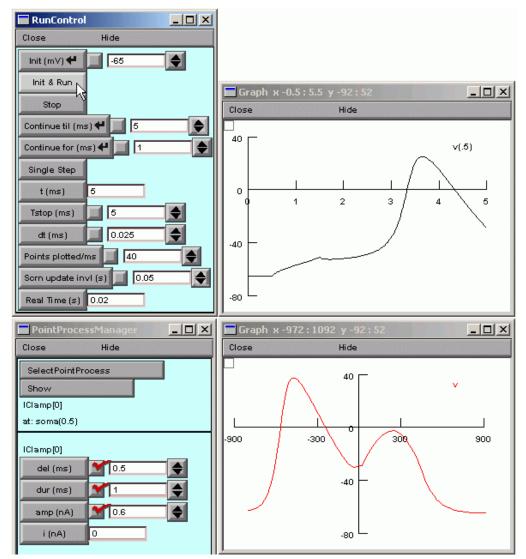


Our user interface



Time to save to a new session file!

It works!



How to get nice space plot "movies"

NEURON Main Menu						
leonify	ý					
File	Edit	Build	Tools	Graph	Vector	Window
			RunCont	rol	ľ	
			RunButto	on		
			Variable	StepCon	rol	
			Point Pr	ocesses		
			Distribut	ed Mech	anisms	
			Fitting			
			Impedar	nce		
			Model V	iew		
			Movie R	un N		
			Miscella	aneouski		

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

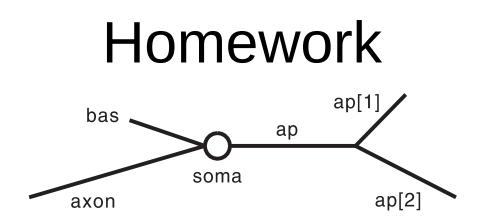
zoom in and verify section/tree to be deleted Select "Delete Section" or "Delete Subtree" click to delete

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()

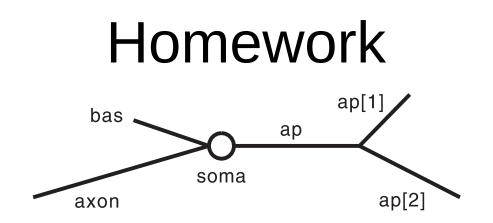


Using this model cell with "reduced hh" in the apical dendrites:

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).



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).

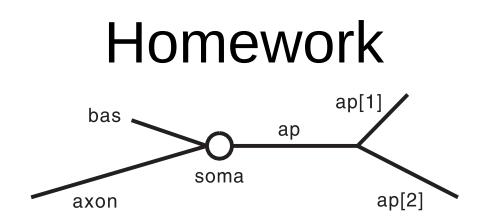
Finally, repeat with the synapse at bas(1).

Organize your results in a table like this:

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

. . etc. . . .

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



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?