Introduction to NEURON(90 Mins):

- 30 mins presentation
  - Who am I? (1 minute)
  - Why use NEURON? (5-10 mins)
    - Use-cases: What does it do?
      - What do i need to use it?
    - Resources
  - Basics of NEURON (20-25 mins):
    - 2 Parts: HOC and .mod files
      - GUI vs HOC
      - Example simulation: Single Compartment HH with current injection
    - Representing cell morphology

    - Using channels
    - Stimuli
    - Running the simulation
    - Plotting the results
- 45 mins exercise
    - Based on David Sterrat and Andrew Gillies tutorial
- 15 mins Wrap up
    - nrnivmodl
    - More things with NEURON: cvode,
    - Interfacing with Python (limitations)
    - other simulators - GENESIS, MOOSE
    - other options; morphforge, neuroml, nineml, neuronvisio, pynn;
    - Links to other tools

Why use NEURON (5-10 mins)

From the NEURON website (my bold type):

- is a flexible and powerful **simulator of neurons and networks**
- has important advantages over general-purpose simulators helps users **focus on important biological issues** rather than purely computational concerns
- has a convenient user interface
- has a **user-extendable** library of biophysical mechanisms
- has many enhancements for **efficient network modeling**
- offers customizable initialization and simulation flow control
- is widely used in neuroscience research by experimentalists and theoreticians
- is well-documented and **actively supported**
- is **free, open source**, and runs on (almost) everything

Use-cases - What does it do? I

- **Modelling of multicompartmental neurons**
    - keeps track of ion movements
- Connections between cells through synapses
- Defining your own channels & synapses
- If you are interested in large networks of 'simple', single compartement neurons, there are other options.

Use-cases - What does it do? II

- For a single compartment cell with simple HH dynamics, you can probably write your own solver using ODE solvers in matlab/python.
- As your models develop more complexity:
  - Current dependancies e.g. intracellular Ca2+ dependant K channels
  - Solving of Cable Equations for multicompartmental neurons
  - Connections via synapses & gap junctions
- You may find that you are reimplementing lots of mathematical solving, which has been already been done efficiently in NEURON.
- MOD files provide a standard for exchanging channel descriptions (e.g. modeldb)
- There is a python interface
- Highly parallelisable (e.g. BBP) for large networks

What do i need to use it?

- It runs on most operating systems (Windows/Linux/Mac). On the NEURON website:
  - Windows installer
  - Mac package
  - Linux .deb, .rpm package
- Eilif Muller has a precompiled binaries including Python support http://neuralensemble.org/people/eilifmuller/software.html

Resources

- Active questions board
- ModelDB
- The NEURON Book

Basics of NEURON (20-25 mins)

Overview

- NEURON is complex (I will cover a lot of material in the next slides, don't worry if you don't remember all the details its the concepts that are important)
- NEURON is old

2 Parts: HOC and NMODL files

- Two main types of language:
    - Interpreted languages (Python/matlab) are interactive, but slow
    - Compiled languages (Fortran/C/C++/...) are fast
- NEURON uses both:
    - 'HOC' - which controls the 'structure' of the simulation
    - 'NMODL' - a compiled language for specifying the dynamics of channels/synapses mathematically (e.g. Hodgkin-Huxley type channels).

HOC Interpreter

- HOC is an interactive interpreter which controls the 'structure' of the simulation:
  - creating morphologies
  - defining which channels to apply and changing certain parameters (channel densities)
  - creating stimuli: current clamps, voltage clamps
  - defining what you want to record: voltages, internal states
  - setting simulation parameters: stimulation time-steps,
  - running the simulation

NMODL

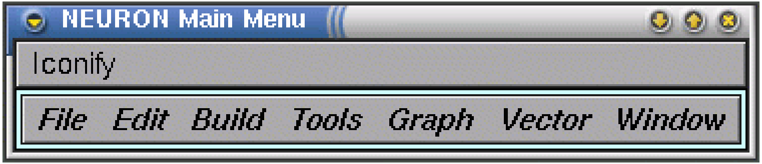
- We will discuss NMODL later...

HOC - Graphical User Interface

- NEURON can be used entirely from the commandline and with 'scripts':

```
$ nrnoc
$ oc>
```

- NEURON also has a graphical user interface



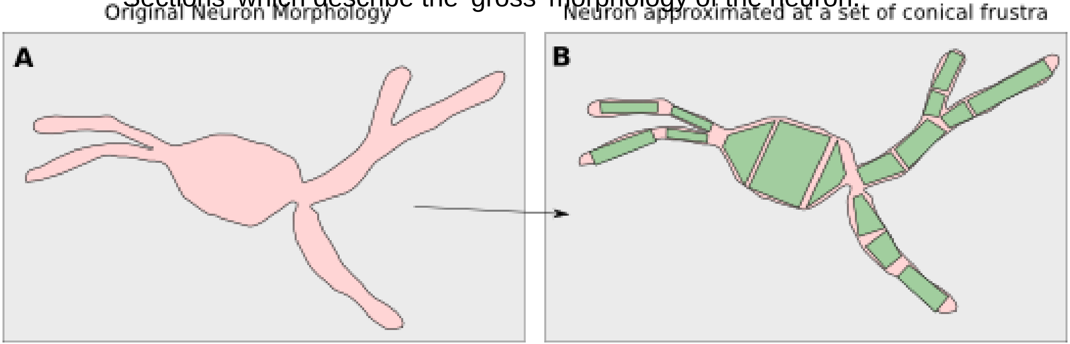
Overview of all the components

Example Simple simulation: Soma + Axon Compartment HH with current injection

TODO: Image:

Morphologies I (Overview)

- Neuron morphologies are represented as a tree of 'unbranched cylinders' called 'Sections' which describe the 'gross' morphology of the neuron.



Morphology II ((Building & Connecting Sections)

- 'Sections' are created with the *create <name>* command
- Section are connected together with the *connect* function.
- **L**ength and **diam**eter of the sections are set as properties for each section:

```
oc> create soma
oc> create axon_proximal
oc> create axon_distal

oc> connect soma(1.0), axon_proximal(0.0)
oc> connect axon_proximal(1.0), axon_distal(0.0)

oc> soma L = 12.3
oc> soma diam = 12.3

oc> axon_proximal diam = 1.0
oc> axon_proximal L = 50

oc> axon_proximal diam = 0.5
```

```
oc> axon_proximal L = 20
```

Morphologies III (Segmentation)

- NEURON separates the description of the overall morphology from the amount of discretisation of the simulation.
- To solve simulations more accuratly, Sections can be subdivided into 'segments'.
- Each segment has its own voltage and state variables
- (Hines & Carnevale recommend using an odd number of segments):

```
oc> axon_proximal nseg = 11
oc> axon_proximal nseg = 3
```

Channels I (Overview)

- Neurons are interesting because of their active membrane channels
- NEURON can handle many common use cases:
    - it is possible to define your own using NMODL files (not covered here)
  - it comes with some predefined channel definitions.

Channels II (Examples)

Channels III (Using channels)

- Channels are *insert*ed into each Section
- Channels can have parameters that can be changed in HOC, (e.g. conduction density)
- E.g.:

```
soma insert hh
soma insert hh
```

Stimuli

Running the simulation

Plotting the results