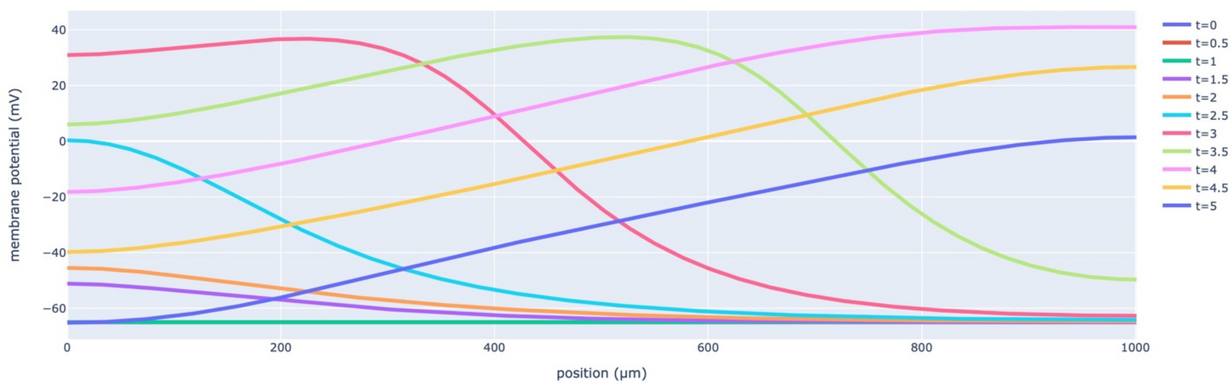
NEURON Scripting Exercises

Exercise 1:

Simulate and visualize a propagating action potential on a long cable ("axon") with Hodgkin-Huxley dynamics (`h.hh`) triggered by a current clamp. Plot membrane potential vs position at several time points.

Repeat the experiment but with `Ra=100` Ω cm. How does this change affect wave propagation?



Things to consider:

What is an appropriate diameter, length of cable, and current injection amplitude?

What discretization should you use?

Exercise 2:

Continuing with the previous exercise, record and plot the membrane potential, sodium current, and potassium current at the center of the cable as a function of time.

Hint: Use the `record` method of a `Vector`.

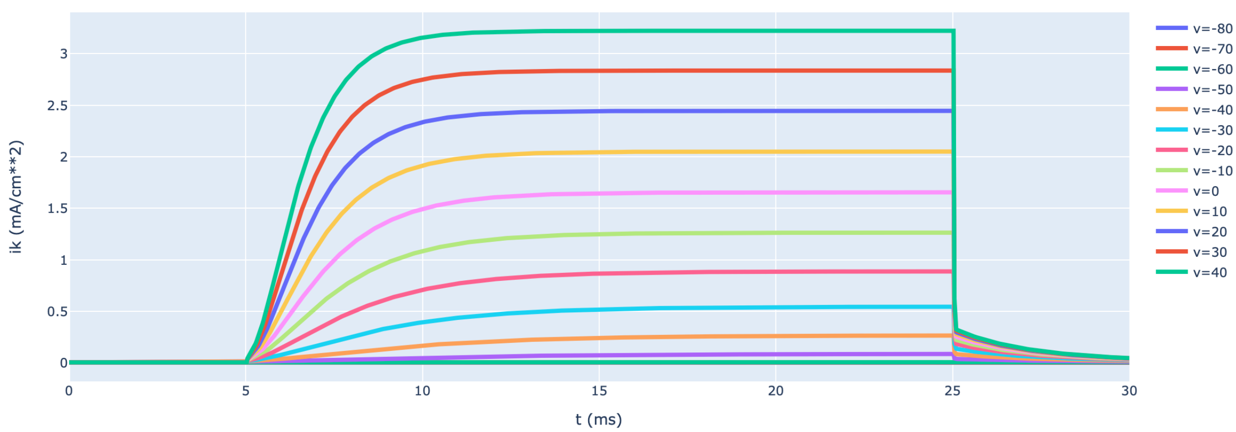
Things to consider:

How does the relationship between the sodium and potassium currents differ in a Hodgkin-Huxley simulation from the relationship in mammalian cells?

Exercise 3:

Compare the Hodgkin-Huxley sodium and potassium current responses to being voltage clamped at v = 0 mV.

Compare the response of Hodgkin-Huxley potassium current to being voltage clamped at various potentials.



Exercise 4:

Construct two Y-shaped cells, where each branch is 2 microns in diameter and 100 microns long. Add Hodgkin-Huxley channels with the default parameters. Inject current into one cell and ensure that you can generate a propagating action potential in that cell while the other one remains at rest.

Connect the two cells with a gap junction (see `halfgap.mod` on a later page) at locations of your choosing. (Point processes only directly affect the current at one location, so for a gap junction you will need to create two such point processes, one for each cell.) Connect the mechanisms to the membrane potentials on the other cell. A 3 MΩ resistance as in `halfgap.mod` should allow an action potential in one cell to initiate an action potential in the other. Verify this. What is the strongest resistance that still allows action potential initiation in the second cell?

Bonus challenge: Make each cell an instance of a Python `class`.

Bonus challenge: Modify the `class` to allow repositioning (moving and/or rotating) the cells.

Exercise 5:

NEURON's `ExpSyn` mechanism generates synaptic currents of the form

$$i = g(v - E_{syn})$$

where

$$g' = -g/\tau$$

What is the role of E_{syn}? How does it change for an excitatory vs an inhibitory synapse? (Note, this is the parameter `e` in an `ExpSyn`.)

Construct two single compartment neurons with Hodgkin-Huxley dynamics, one of which receives a strong excitatory stimulus at 2 ms (use a `NetStim`, a `NetCon`, and an `ExpSyn`) and another that receives a strong excitatory stimulus at 10 ms. Ensure that both cells fire action potentials after the input.

Now, using `NetCon` and `ExpSyn`, construct an inhibitory synapse between the two with the cell that fires later as the post-synaptic cell. Choose a delay and strength such that the post-synaptic cell is inhibited from firing. Plot the membrane potentials vs time.

halfgap.mod

```
NEURON {
  POINT_PROCESS HalfGap
  POINTER vgap
  RANGE r, i
  ELECTRODE_CURRENT i
}

PARAMETER {r = 3 (megohm)}

ASSIGNED {
  v (millivolt)
  vgap (millivolt)
  i (nanoamp)
}

BREAKPOINT { i = (vgap - v) / r }
```