Hodgkin-Huxley

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This is a demo for simulating simulating the Hodgkin-Huxley equations. There are two simulations in this demo: 1: constant current 2: current pulses

```
source('./HH_sim.R', chdir=T)
```

We use the package deSolve to simulate the differential equations.

1. simulation with constant input

Constant current is injected in a neuron of 20 μm diameter with Hodgkin-Huxley channels. Try to change the injected current and find the AP threshold!

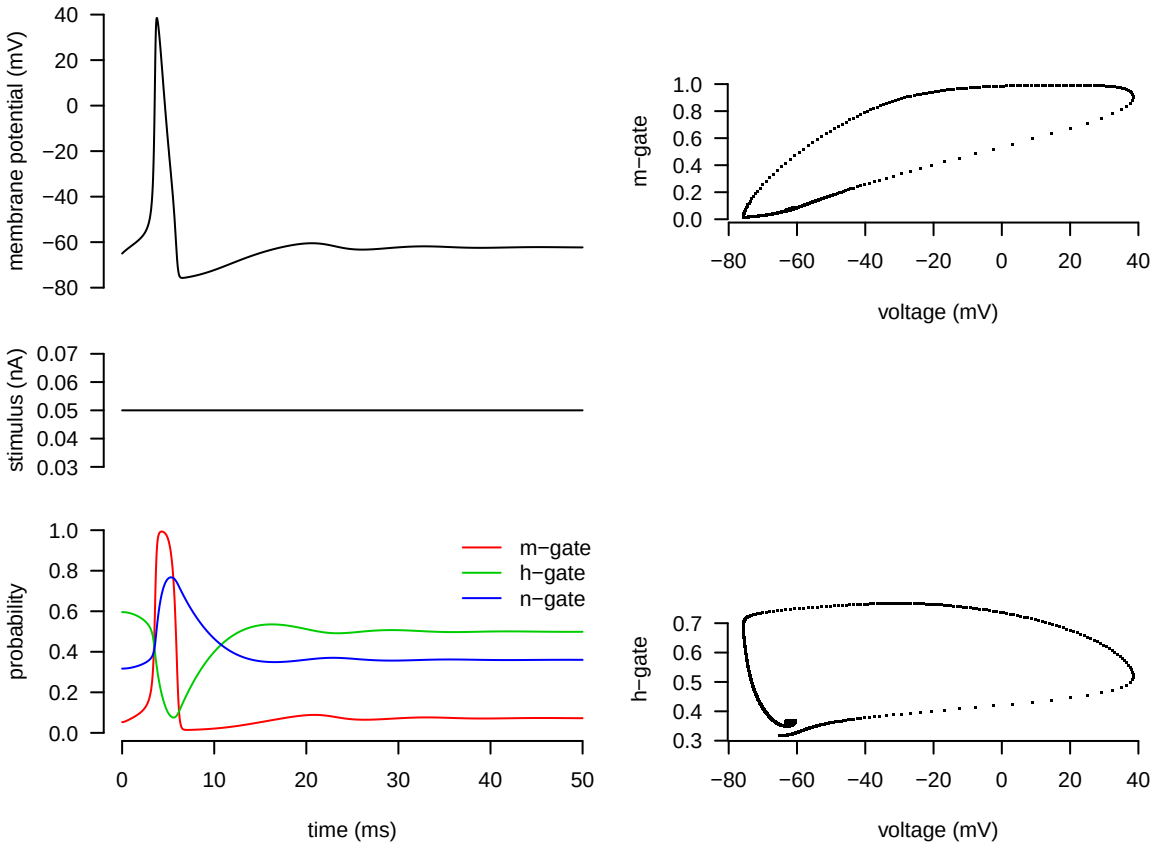
```
I0 <- 1/20/1000 # change this to change the input current!
## meaningful range is between [-1/5, 1] / 1000

times <-  seq(0,50, by=0.02) # the time points for the simulation - in ms!
input <- cbind(times, rep(I0, length(times))) # set the input current, a matrix with two column: [time,
I.ext <- approxfun(input[,1], input[,2], method = "linear", rule = 2) # this is necessary to provide in

params <- c(gK=gK, gNa=gNa, gL=gL, cm=cm, E.Na=E.Na, E.K=E.K, E.L=E.L) # parameters of the system.
# gK, gNa, gL: K, Na and leak maximal conductance in mS,
# cm: membrane capacitance in uF
# E.K, E.Na, E.L: the reversal potential of the K, Na ions and the leak.
# For more details, see the demos/HH_consts.R file
state <- c(v=-65, m=.053, h=.596, n=.317) # initial state of the system
# v: membrane potential in mV
# m, h, n: the opening probability of the gates

out <- ode(y = state, times = times, func = sim.HH, parms = params) #ode is a function that simulates a
```

Now plot the results



2. simulation with a short current pulse

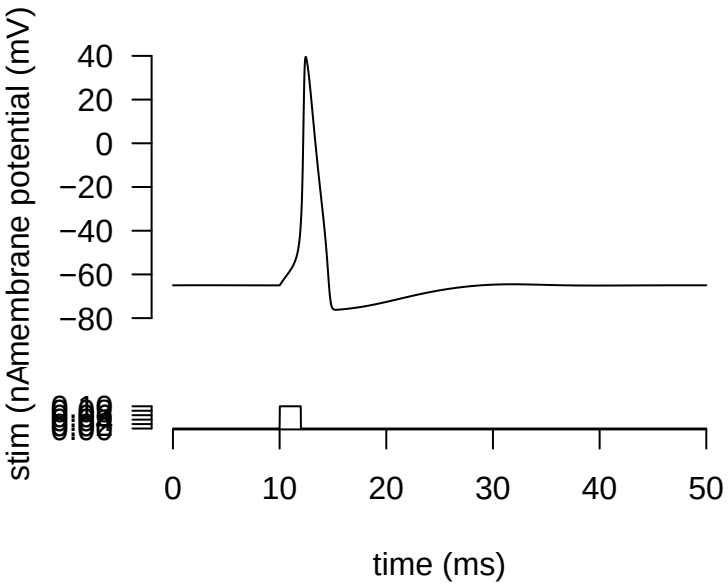
Short (2 ms) current pulse is injected in a neuron of 20 μm diameter with Hodgkin-Huxley Na and K channels. Try to change the current pulse amplitude and find the AP threshold! Try also negative currents, or trains of pulses!

```
I0 <-  0 # the background current
delay <- 10 # the delay of the pulse in ms
I.stim <- 1/10 / 1000 # change this to set the amplitude of the pulse
## meaningful range is between [-1/5, 1] / 1000
times <-  seq(0,50, by=0.02) # # the time points for the simulation - in ms!
input <- cbind(times, rep(I0, length(times))) # input current
input <- set.input(delay, delay+2, I.stim, input) # this function adds a square pulse on the top of con

I.ext <- approxfun(input[,1], input[,2], method = "linear", rule = 2) # input for the DE
params <- c(gK=gK, gNa=gNa, gL=gL, cm=cm, E.Na=E.Na, E.K=E.K, E.L=E.L) # parameters
# gK, gNa, gL: K, Na and leak maximal conductance in mS,
# cm: membrane capacitance in uF
# E.K, E.Na, E.L: the reversal potential of the K, Na ions and the leak.
state <- c(v=-65, m=.053, h=.596, n=.317) # initial state
# v: membrane potential in mV
# m, h, n: the opening probability of the gates

out2 <- ode(y = state, times = times, func = sim.HH, parms = params) ## solving the system of diff. Eqs
```

Now plot the results...



Homework

In some neurons there are no voltage sensitive (delayed rectifier) potassium channels. (These neurons still have K channels, but their conductance does not depend on the membrane potential.) How the action potential looks like in those neurons? What might be the role the the delayed rectifier potassium channels?

Simulate this, by setting the membrane conductance for the potassium to a constant gK=3e-5 mS value and stimulate the cell with I=0.5 nA current of 2 ms duration.