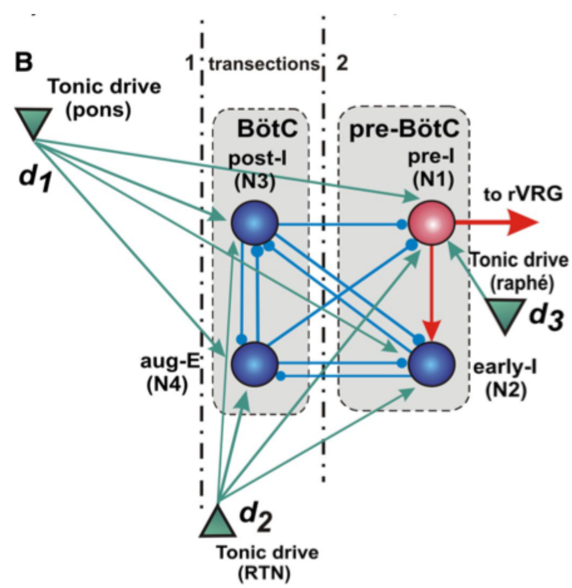
Introduction to Computational Neuroscience (Spring 2018)

A Mean Field Model for the Breathing Rhythm

In this project we explore the minimal model for the mammalian breathing rhythm published in Rubin *et al.*, J. Neurophysiology, 101:2146, 2009. This has four "mean field neurons", each of which represents the mean voltage of a population of neurons within the medulla of the brain stem. In particular,

- V_1: pre-I neurons of the pre-BötC
- V_2: early-I neurons of the pre-BötC
- V_3: post-I neurons of the BötC
- V_4: aug-E neurons of the BötC

These neurons are synaptically interconnected, with V_1 excitatory and the others inhibitory. A network diagram is shown below.



Exploration

(1) Download "breathing.ode" from my web site and run it. It should show you V_1 vs. time in seconds. If you add V_2 to the plot you will see that both of the pre-BötC voltages are in phase with one another. Check to see that the other two voltages are in phase with each other, but out of phase with the first two. To see the output from each of the four neural populations open a

second window and plot the output functions f_1, f_2, f_3, and f_4 (these range in value from 0 to 1).

(2) What shapes the V_1 dynamics? To see the input to this neuron you can plot the auxiliary variable INH1 (this ranges from 0 to 1). You can see what this is by clicking on the Equations window (or, of course, looking inside the computer code). Why does V_1 turn on/off when it does?

(3) V_1 declines during an active phase and rises during a silent phase. Why? Answer this in terms of the dynamics of the inactivation variable h. This variable is in the persistent Na^+ current that is found in this cell population. The current is $I_{NaP} = \bar{g}_{NaP} m_\infty h (V_1 - V_{Na})$.

(4) V_3 also declines during an active phase and rises during a silent phase. Why? Answer in terms of the dynamics of the activation variable m_3 found in the K^+ current in this cell: $I_{AD3} = \bar{g}_{AD} m_3 (V_3 - V_K)$.

(5) V_4 is the only voltage that rises during both silent and active phases. The rise during the active phase is why this mean field neuron is called the "aug-E" neuron, meaning augmentation during exhalation. Why does V_4 rise during both silent and active phases? This cell also has a slowly changing activation variable, m_4, that enters into a K^+ current as $I_{AD4} = \bar{g}_{AD} m_4 (V_4 - V_K)$. Does this account for the augmentation or is there more to it than that?

(6) Now simulate the effects of the first transection, which cut off input from the pons to the cells in the medulla. Do this by setting Drive1=0. What effect does this have on the voltages and the output functions? Why is there still an oscillation in V_3, but not f_3?

(7) Next simulate the second transection, which separates the pre-BötC from the BötC. Do this by setting the appropriate parameters to 0. Note that the synaptic weight from cell i to cell j is the parameter b_{ij}. Do you get the one-phase oscillation that occurs experimentally with this transection?