Practice 3: Neural circuits

1-Build a HH neuron using your implementation of practice 1 substituting the constant current input with a synapse with 3 spikes delivered 10ms apart. Use the Destexhe et al. model for this implementation. Plot the voltage of the neuron and the synaptic current. Explain the results. Modify the parameters of the synapse to achieve spiking in the postsynaptic neuron

2-Build a neural circuit using the HR chaotic model with the following parameters:

$$\frac{dx_i(t)}{dt} = y_i(t) + 3x_i^2(t) - x_i^3(t) - z_i(t) + e_i$$

$$\frac{dy_i(t)}{dt} = 1 - 5x_i^2(t) - y_i(t)$$

$$\frac{1}{\mu}\frac{dz_i(t)}{dt} = -z_i(t) + S\left[x_i(t) + 1.6\right]$$

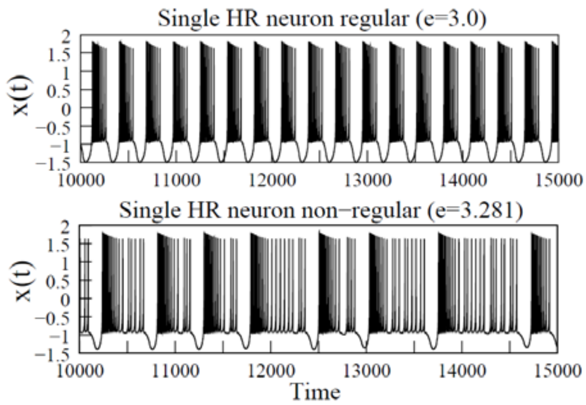
Regular activity:

$e_i = 3.0$, $\mu = 0.0021$ and $S = 4$

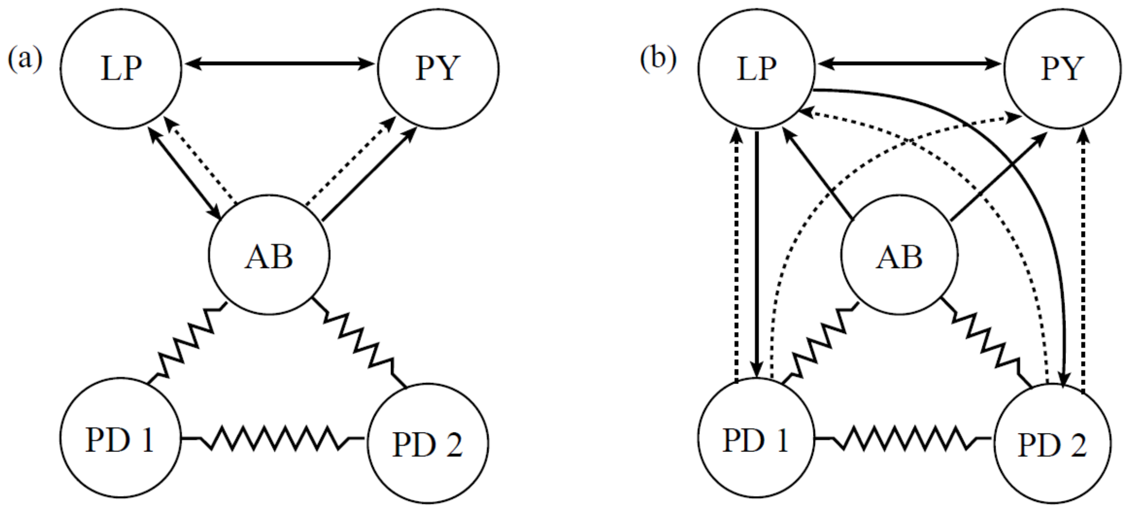
Irregular activity:

$e_i = 3.281$

Reproduce the figures on the right.



3-Once the model has been tested, build the following networks:



Resistors represent electrical synapses. Dotted lines represent slow graded chemical synapses and solid lines represent fast graded chemical connections. Both networks are built out of two subcircuits: the AB-PD-PD and the AB/PD-LP-PY. Circuit (a) and (b) are called reduced and complete, respectively, in the description below (Latorre et al., 2002; Golowasch et al., 1999).

The model for the graded synapses must have the following description :

$$I_{fastX} = \sum_{Y} \frac{g_{fastYX}(V_X - E_{syn})}{1.0 + exp(s_{fast}(V_{fast} - V_Y))}; I_{slowX} = \sum_{Y} g_{slowYX}\ m_{slowX}\ (V_X - E_{syn}) \tag{1}$$

The total synaptic current $I_{synX} = I_{slowX} + I_{fastX}$. Here m_{slowX} is given by:

$$\frac{dm_{slowX}}{dt} = \frac{k_1 X(1.0 - m_{slowX})}{1.0 + exp(s_{slow}(V_{slow} - V_{AB}))} - k_2 X\ m_{slowX} \tag{2}$$

Use the departing parameters specified below for the connections for the HR model:

Table 1		g_{ABPD1}	g_{PD1AB}	g_{ABPD2}	g_{PD2AB}	g_{PD1PD2}	g_{PD2PD1}
KK	(r)	0.0096	0.0096	0.0223	0.0223	0.0151	0.0151
	(c)	0.0096	0.0096	0.0223	0.0223	0.0151	0.0151
HR	(r)	0.325	0.325	0.548	0.548	0.332	0.332
	(c)	0.325	0.325	0.548	0.548	0.332	0.332

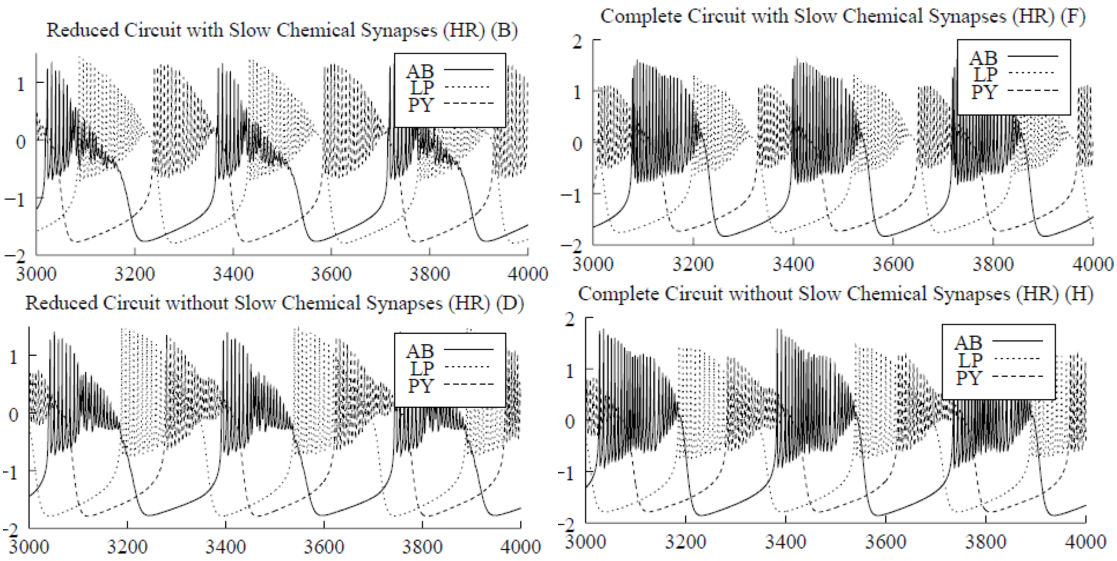
Table 2	E_{syn}	V_{fast}	s_{fast}	s_{slow}	V_{slow}	k_1LP	k_2LP	k_1PY	k_2PY
KK	-65.0	-44.7	0.31	1.0	-49.0	1.0	0.01	1.0	0.0275
HR	-1.92	-1.66	0.44	1.0	-1.74	0.74	0.007	0.74	0.015

Table 3		g_{ABLP}	g_{ABPY}	g_{LPAB}	g_{LPPD1}	g_{LPPD2}	g_{LPPY}	g_{PYLP}
KK	(r)	0.0446	0.0556	0.0578	–	–	0.0398	0.0311
	(c)	0.0446	0.0556	–	0.0211	0.0269	0.0398	0.0311
HR	(r)	0.112	0.120	0.585	–	–	0.241	0.186
	(c)	0.112	0.120	–	0.208	0.432	0.241	0.186

Table 4		g_{ABLP}	g_{ABPY}	g_{PD1LP}	g_{PD1PY}	g_{PD2LP}	g_{PD2PY}
KK	(r)	0.0043	0.0056	–	–	–	–
	(c)	–	–	0.0015	0.0023	0.0033	0.0028
HR	(r)	0.032	0.029	–	–	–	–
	(c)	–	–	0.046	0.065	0.038	0.035

Table 1. Values of maximal conductances of electrical synapses in the AB-PD-PD subnetwork. g_{XY} represents strength of electrical connection between X and Y neuron. Units are dimensionless for HR. (r) and (c) denote values for the reduced and complete circuits, respectively. Table 2. Values of AB/PD-LP-PY chemical synapse parameters for all topologies. Table 3. Values of AB/PD-LP-PY network maximal conductances of fast chemical connections. Table 4. Values ofAB/PD-LP-PY network maximal conductances for slow chemical connections.

Modify the parameters if necessary to reproduce the triphasic rhythm in the circuit as shown below:



References:

Golowasch, J., Casey, M., Abbott, L. F., and Marder, E. (1999). Network stability from activity-dependent regulation of neuronal conductances. *Neural Comput.* 11, 1079–1096. http://doi.dx.org/10.1162/089976699300016335

Latorre, R., Rodríguez, F. B., and Varona, P. (2002). Characterization of Triphasic Rhythms in Central Pattern Generators (I): Interspike Interval Analysis. *Lect. Notes Comput. Sci.* 2415, 167–173. http://dx.doi.org/10.1007/3-540-46084-5_27