# Competition

Build a network of 3 all-to-all connected neurons (FitzHugh-Nagumo). Each neuron inhibits the other two. Each neuron receives an external drive (current).

1. What will happen if there is no external drive?
2. What kind of activity pattern do you observe (eg: one neuron fires, rest all silent; all fire randomly; activity switch from one neuron to another; etc)
3. How does the activity pattern change with strength of inhibition and external drive?
4. Explain the emergence of the observed pattern based on the property of the neurons and the connectivity.
5. What if the connectivity is changed to a ring network (A->B->C->A; all inhibitory)
6. How does the dynamics change if we introduce more number of neurons?
7. Repeat F for different kinds of connectivity: random, all-to-all, ring, etc.

Reference:

* [Dynamical Encoding by Networks of Competing Neuron Groups: Winnerless Competition](https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.87.068102)
* [FitzHugh-Nagumo model](http://www.scholarpedia.org/article/FitzHugh-Nagumo_model)

# Information processing

## Part 1:

Compare information transfer (from neuron 1 to neuron 3) across the following motifs by injecting constant currents of varying amplitudes in the presence of noise:

1. Feed forward motif of 2 neurons (1-->3)
2. Feed forward motif of 3 neurons (1-->2-->3)
3. Motif with feed-forward inhibition (1-->3 and 1-->2--|3)
4. Feed-back inhibition (1-->3 and 3--|1)

---> excitation --| inhibition

You could use Mutual Information as the metric. The measurement variables could be voltage, firing rate, inter-spike intervals, etc

## Part 2:

Examine information transfer via ensembles in a feed-forward network of neurons. What happens to the transfer in the presence of motifs discussed above? Can we tune the properties for different statistics of incoming information (different input rates etc.) ?

<https://www.ncbi.nlm.nih.gov/pubmed/10591212>

# EI Balance in Networks

In networks balance manifests in several forms:

1. **Loose/Tight balance** : The balance is deemed tight if E and I inputs to single neurons balance each other on fast timescales, and loose otherwise.
2. **Global/Detailed balance :** When random subsets of inputs to a given neuron balance each other, it said to be detailed balance.

Step 1:

1. Analyse a single neuron’s response to excitatory and inhibitory inputs using Poisson spike train input
2. What happens to the balance in the presence of non-uniform weights

Step 2:

1. Create a feedword network with the following architecture:

E1 ----> E2 and E1---->I1-----|E2

Identify the nature of balance.

1. Predict how different parameters might affect the nature. The parameters you could play with are:
2. Inhibitory Gain
3. Synaptic delay
4. Connection probability
5. External drive
6. Synaptic weights

References:

<https://elifesciences.org/articles/43415>

<https://www.nature.com/articles/nn.2276>

# Transcending Scales

- Investigate how a neuron reacts to different types of inputs

- Based on that guess how a network of such neurons would behave

- Test your predictions using network simulations

Phase 1: Estimate the transfer function of a simple Integrate & Fire neuron for current injection

Inject different types of inputs current to the neuron and measure the neuron output.

-- Input: Use following types of inputs:

a. DC input (vary the amplitude)

b. Sinusoidal inputs (vary both the amplitude and frequency of the signal)

c. White noise (varying the mean and variance of the input)

-- Measure of neuron output

a. Spike count

b. spike pattern irregularity

c. mean and variance of the free membrane potential [this can be measured by setting the neuron spike threshold to a very high positive value]

-- How do the following parameters affect the neuron output

a. Spike threshold

b. Neuron time constant

c. Synapse model: current-based synapses vs conductance-based synapses.

Phase 2. Estimate the transfer function of a simple Integrate & Fire neuron different types of spike input

-- Input: Use following types of inputs:

a. Poisson type excitatory and inhibitory spikes

b. Sinusoidally modulated Poisson type spike trains for both excitatory and inhibitory inputs

c. Correlated spike trains [Connect 100+exc and 100+inh inputs and vary the correlation between the spike trains of E and I inputs]

-- Measure of neuron output

a. Spike count

b. spike pattern irregularity

c. mean and variance of the free membrane potential [this can be measured by setting the neuron spike threshold to a very high positive value]

-- How do the following parameters affect the neuron output

a. Spike threshold

b. Neuron time constant

c. Synapse model: current-based synapses vs conductance-based synapses.

Phase 3: Create a network of Integrate and fire neurons and investigate the dynamics

-- Network:

- Random topology

- Number of neurons about 5000

- Use one of the following configurations

5. purely inhibitory network i.e. all neurons are inhibitory

6. network with both excitatory and inhibitory network but no exc. to exc. connections

7. network with both excitatory and inhibitory network i.e. all connections are allowed

- For all configurations use weak synapses i.e. each synapse results in a about 0.1- 0.2 mV change in the membrane potential for each incoming spike

- For EI network balance the network by increasing the weight of the inhibitory synapses.

-- Input Poisson type uncorrelated spikes trains to all the neurons.

-- Control variables:

a. Vary the rate of the Poisson type inputs

b. Balance of excitation and inhibition [for EI networks]

b. Vary the recurrent inhibition strength [for II networks]

-- Measure of network output

a. Average spike count

b. Average spike pattern irregularity

c. Average synchrony or oscillations