Neural Dynamics

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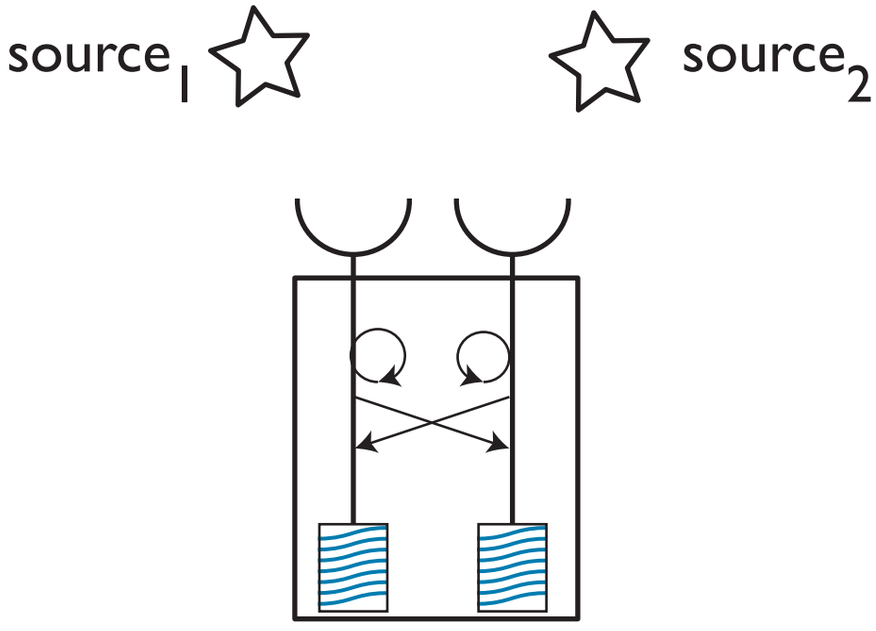
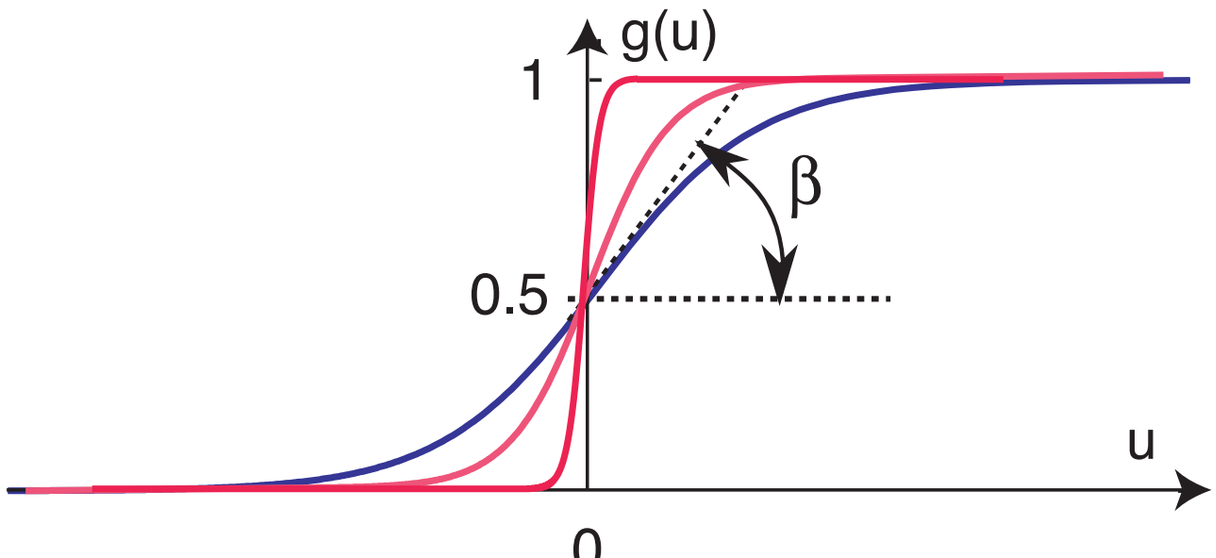
Activation

- how to represent the inner state of the Central Nervous System?
- => activation concept



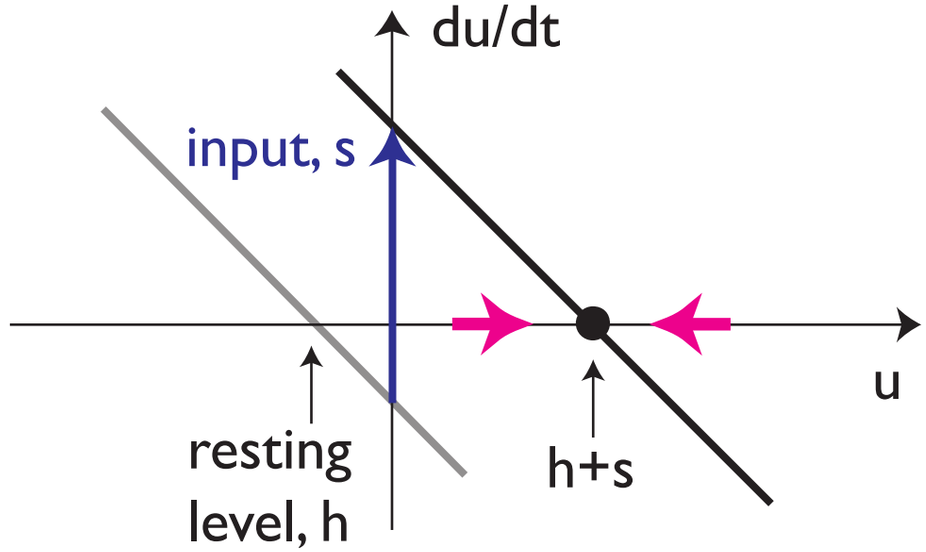
Activation

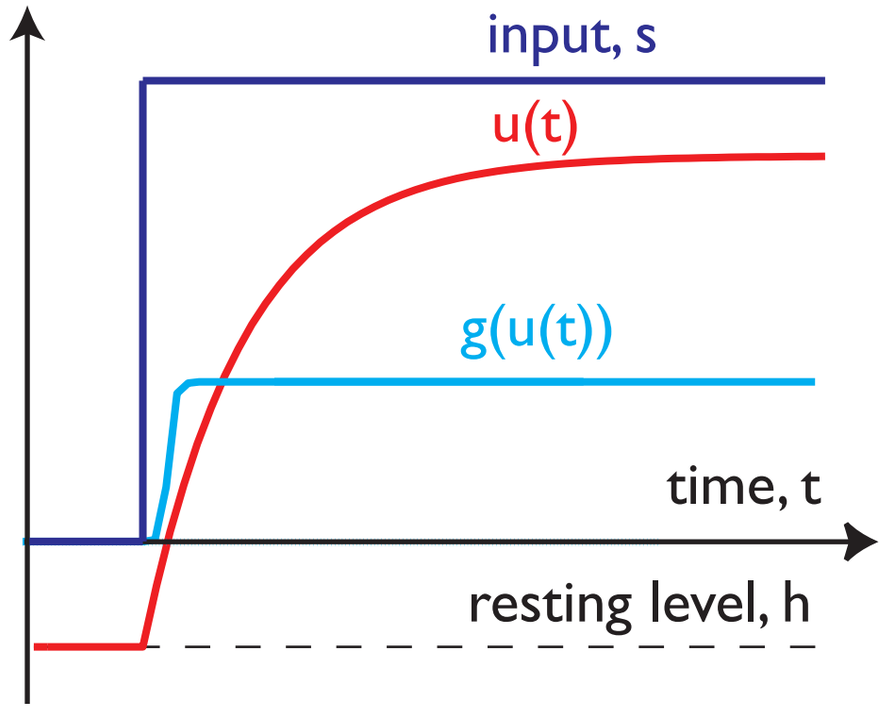
- activation as a real number, abstracting from biophysical details
  - low levels of activation: not transmitted to other systems (e.g., to motor systems)
  - high levels of activation: transmitted to other systems
  - as described by sigmoidal threshold function
  - zero activation defined as threshold of that function



Neuronal dynamics

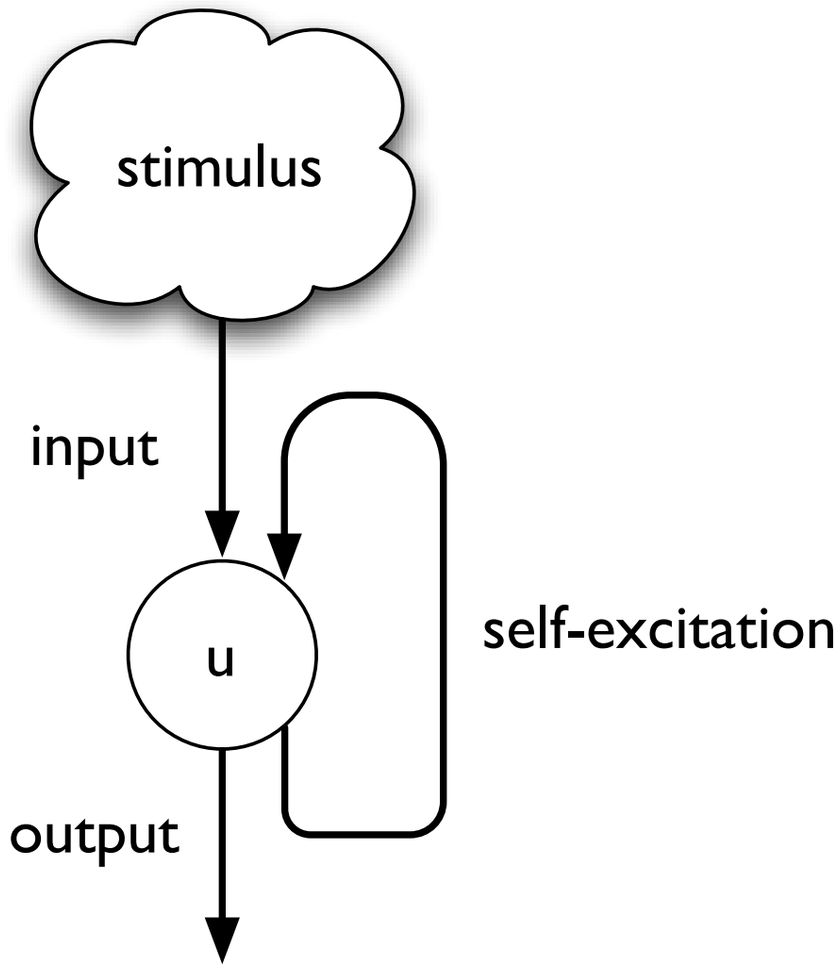
- inputs=contributions to the rate of change
  - positive: excitatory
  - negative: inhibitory
- => shifts the attractor
- activation tracks this shift (stability)

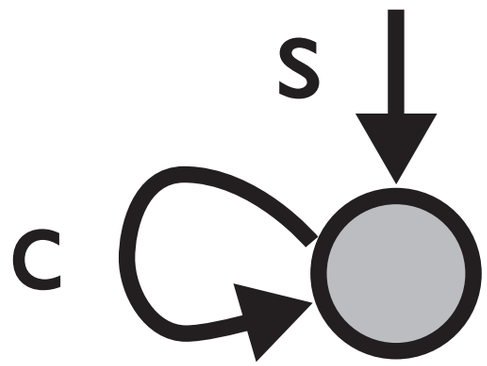




$$\tau \dot{u}(t) = -u(t) + h + \text{ inputs(t)}$$

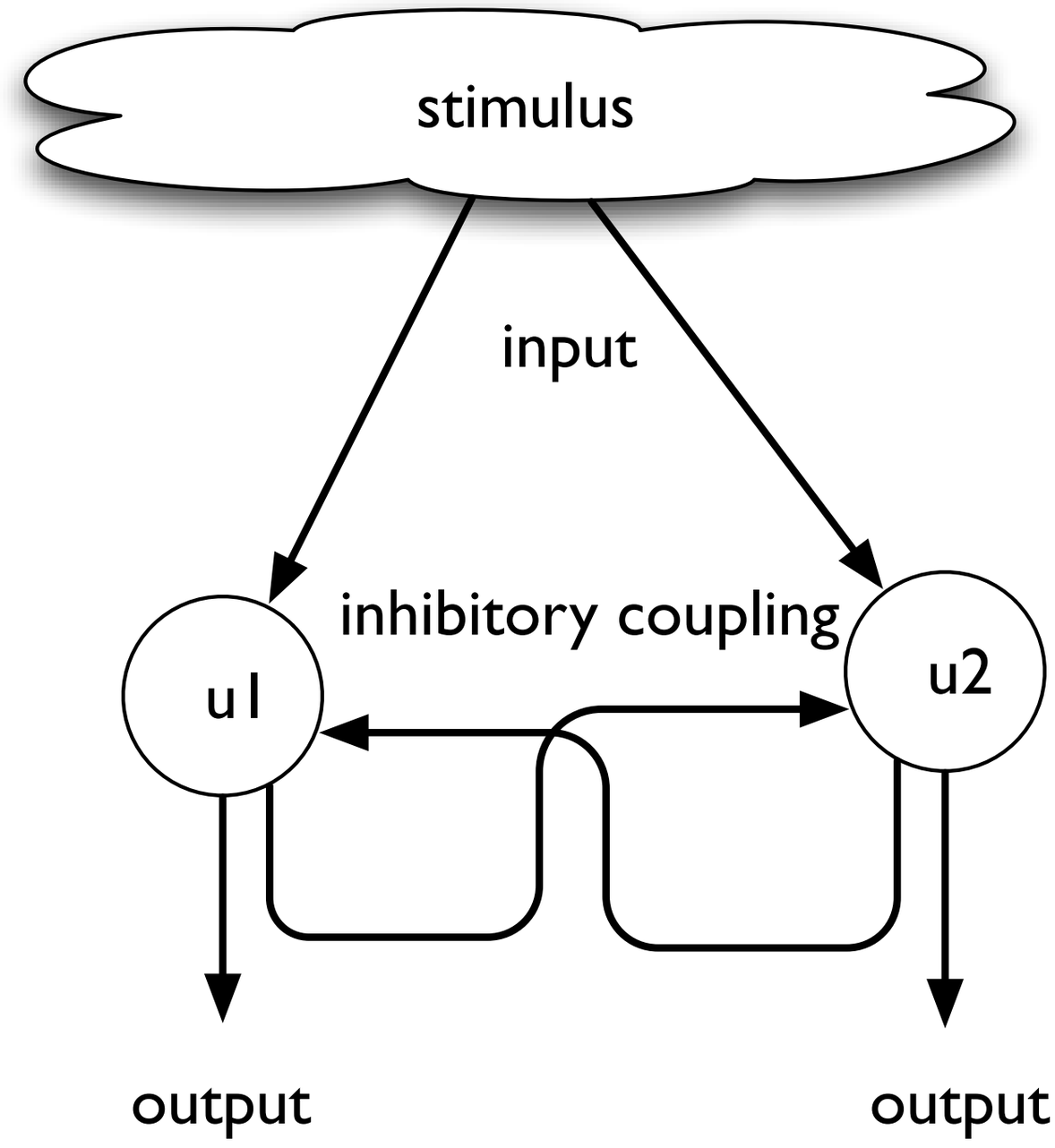
Neuronal dynamics with self-excitation





$$\tau \dot{u}(t) = -u(t) + h + s(t) + c\ g(u(t))$$

Neuronal dynamics with competition



$$\tau_1 \, \dot{u}_1(t) = -u_1(t) + h_1 + s_1(t) - c_{12} \, g(u_2(t))$$

$$\tau_2 \, \dot{u}_2(t) = -u_2(t) + h_2 + s_2(t) - c_{21} \, g(u_1(t))$$

Neuronal dynamics with competition

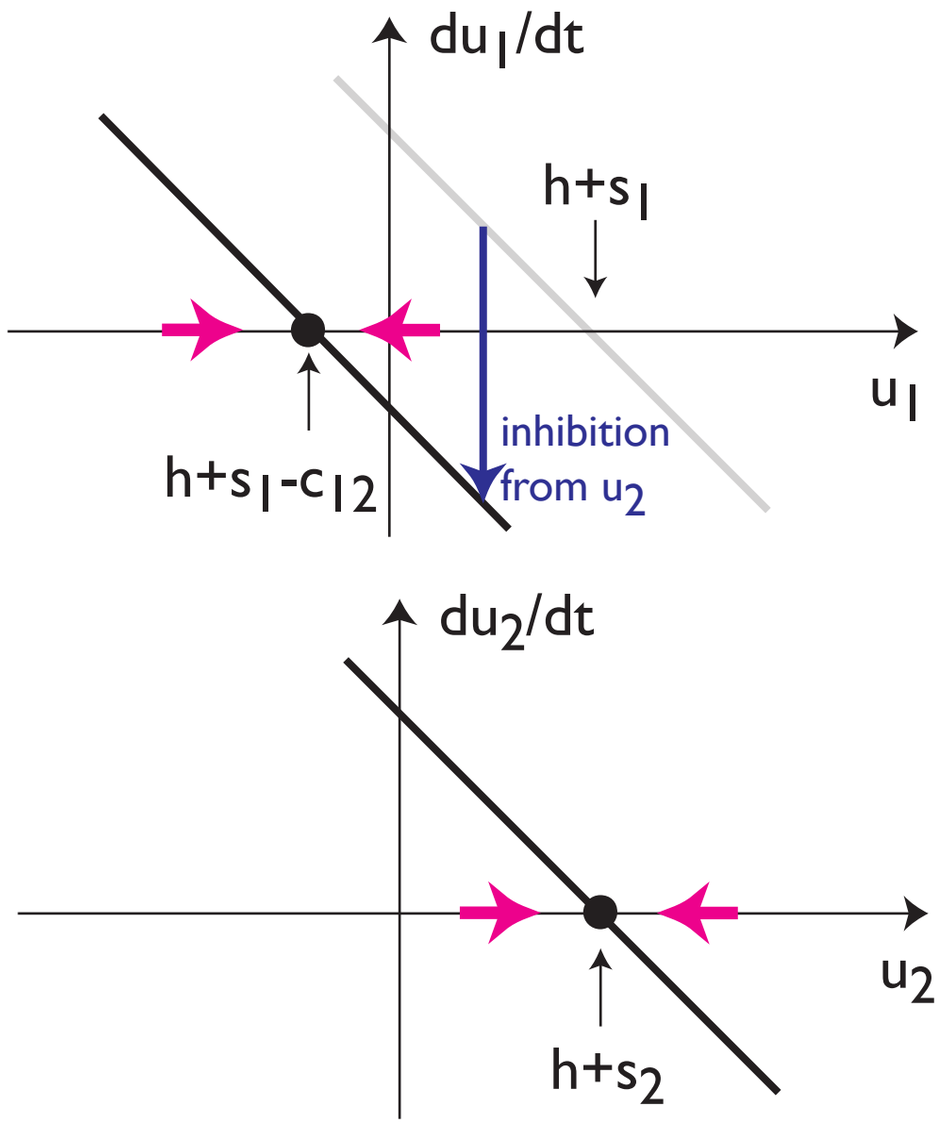
- the rate of change of activation at one site depends on the level of activation at the other site
- mutual inhibition

$$\tau_1 \, \dot{u}_1(t) = -u_1(t) + h_1 + s_1(t) - c_{12} \, g(u_2(t))$$
$$\tau_2 \, \dot{u}_2(t) = -u_2(t) + h_2 + s_2(t) - c_{21} \, g(u_1(t))$$

sigmoidal nonlinearity

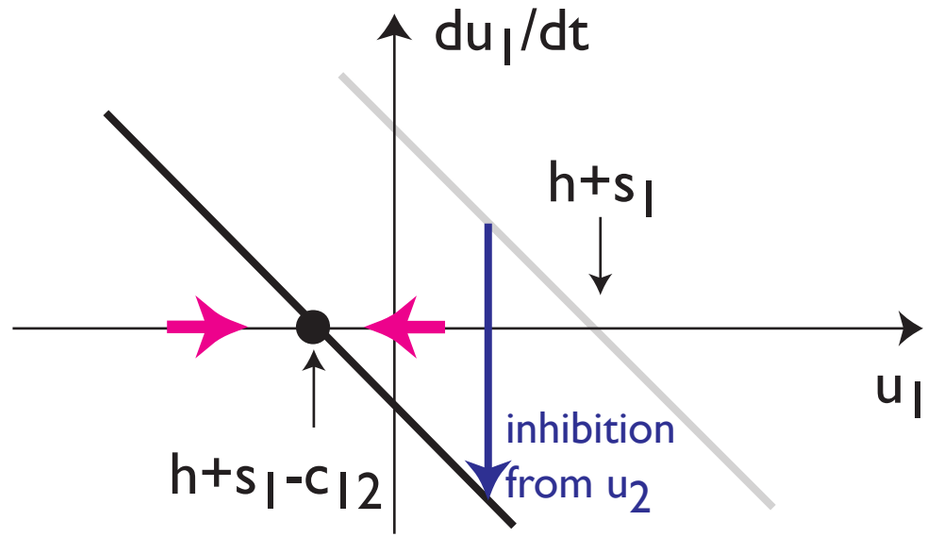
Neuronal dynamics with competition

- to visualize, assume that u_2 has been activated by input to positive level
- => then u_1 is suppressed

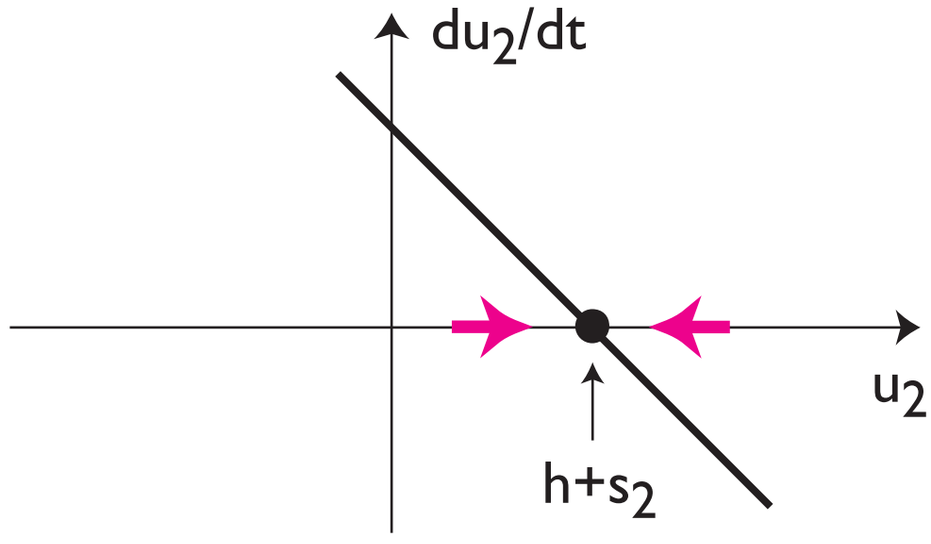


Neuronal dynamics with competition

- why would u_2 be positive before u_1 is? E.g., it grew faster than u_1 because its inputs are stronger/inputs match better

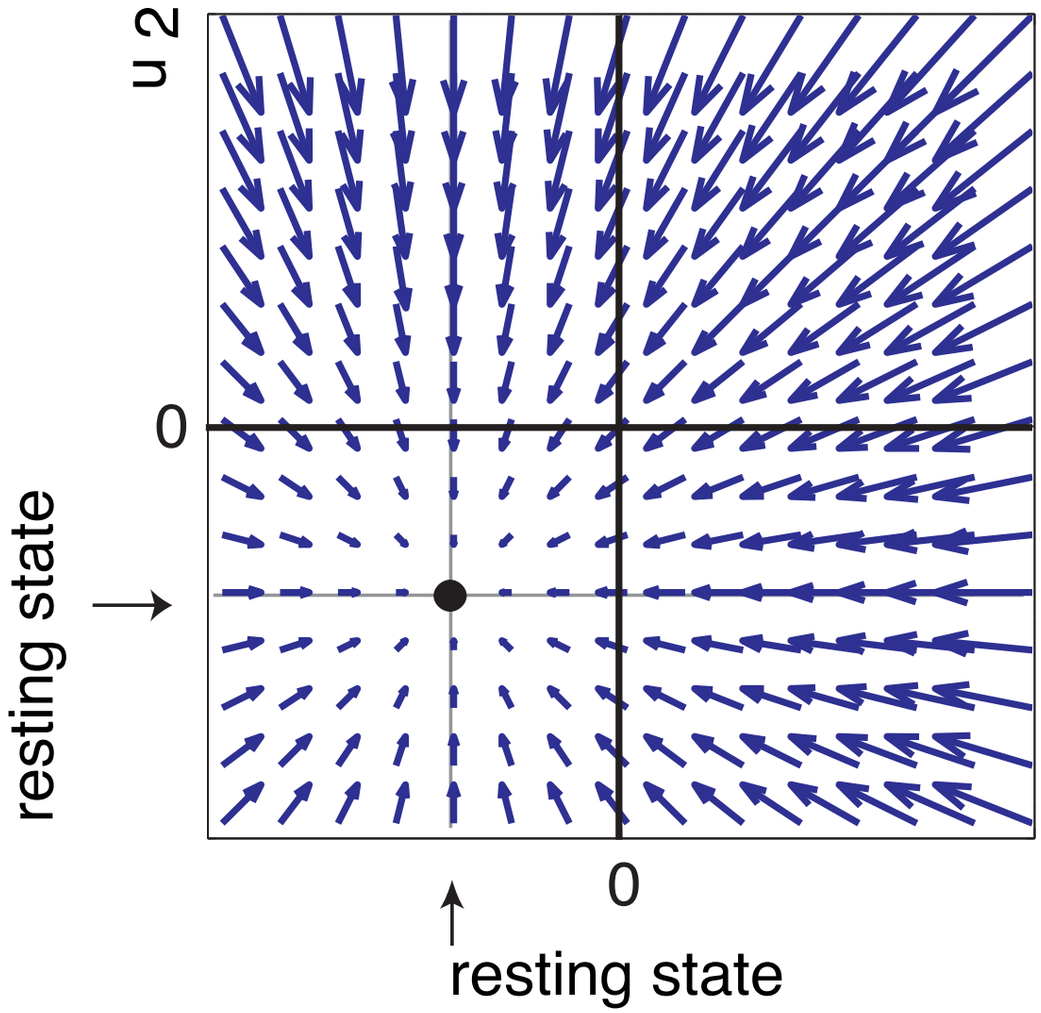


- => input advantage translates into time advantage which translates into competitive advantage

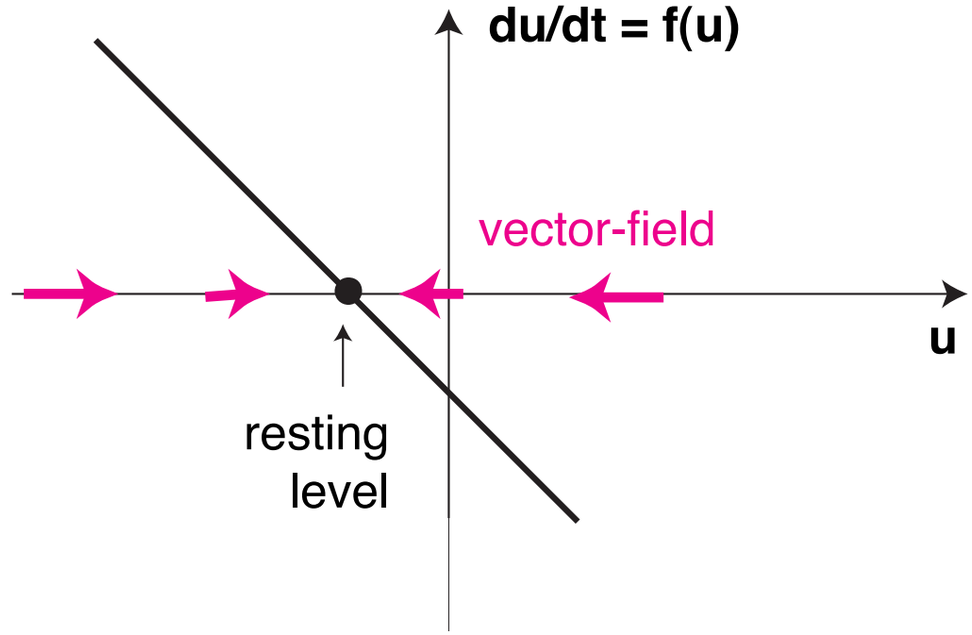


Neuronal dynamics with competition

vector-field in the absence of input

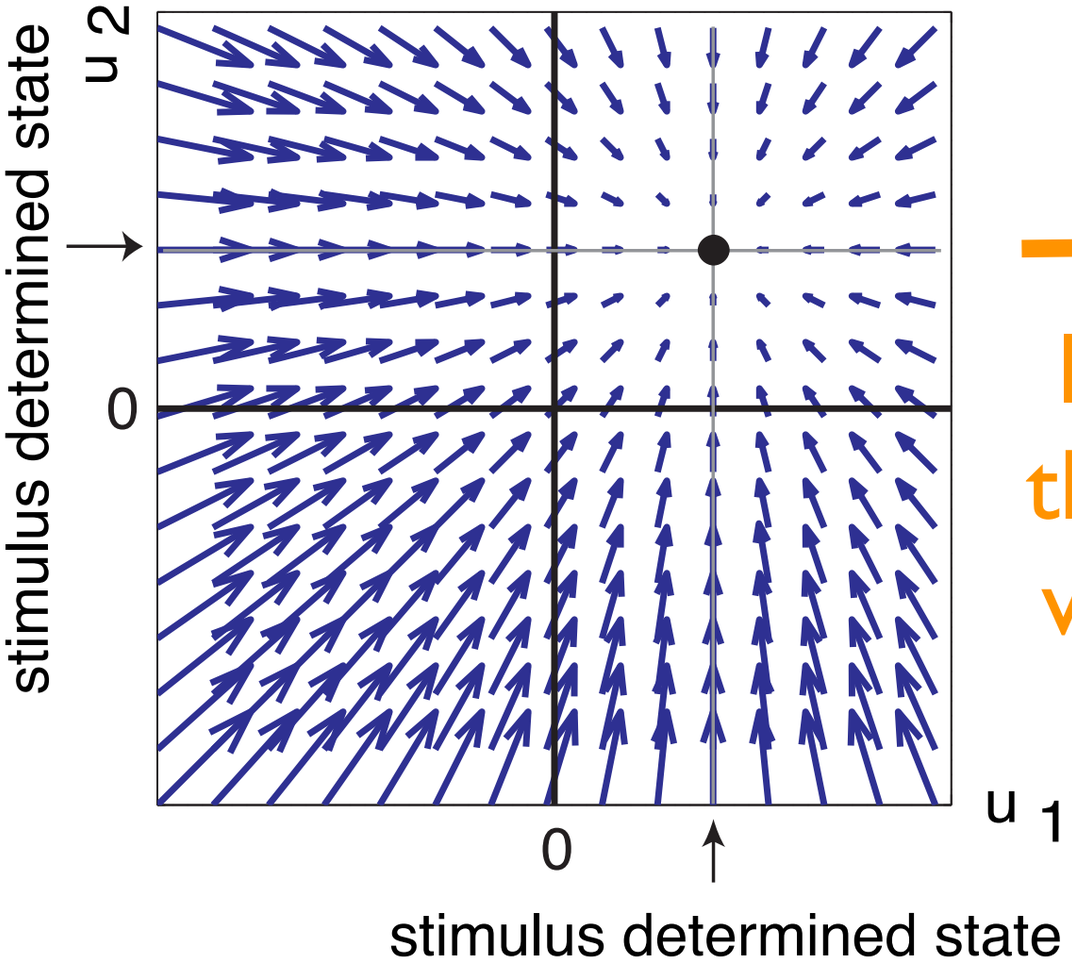


1D cut through vector-field

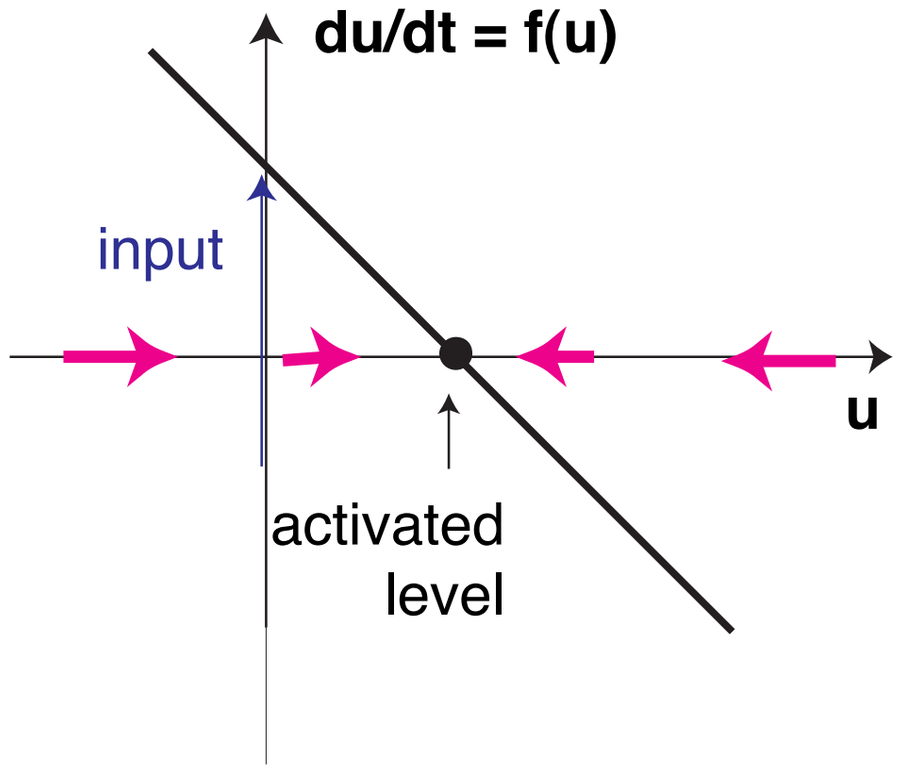


Neuronal dynamics with competition

vector-field (without interaction) when both neurons receive input



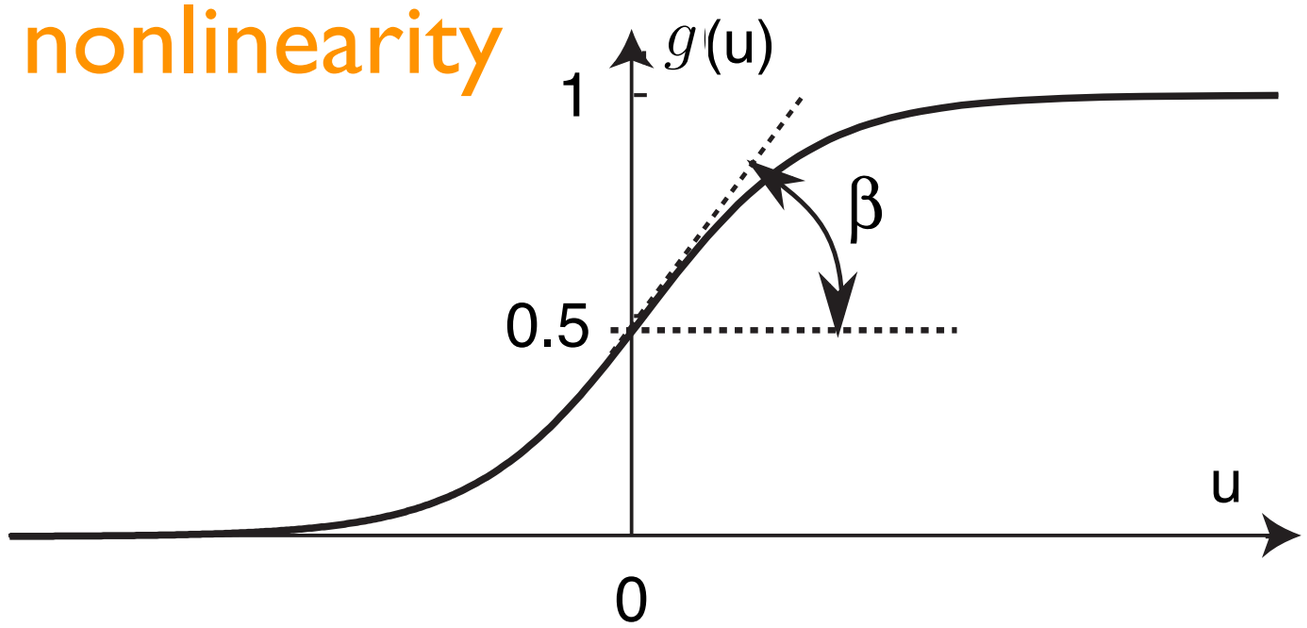
1D cut through vector-field



Neuronal dynamics with competition

- only activated neurons participate in interaction!

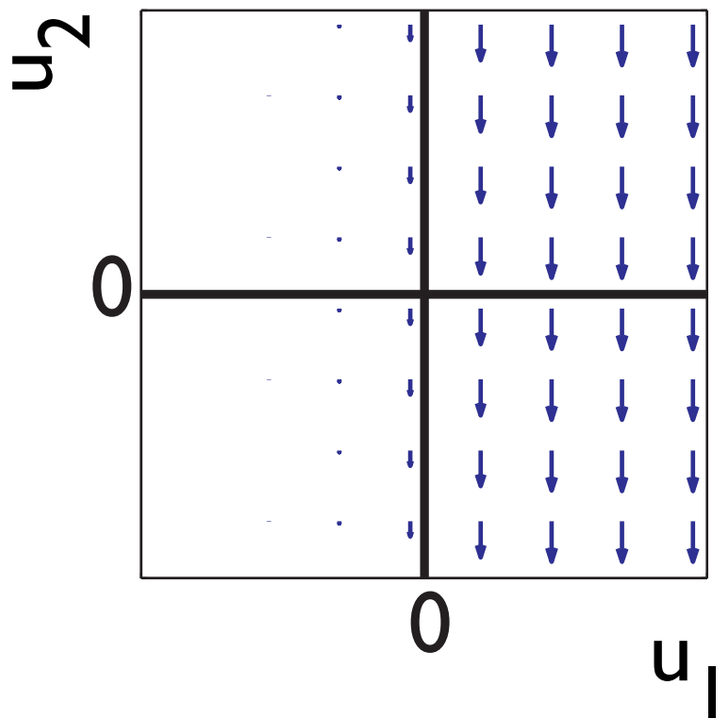
sigmoidal nonlinearity



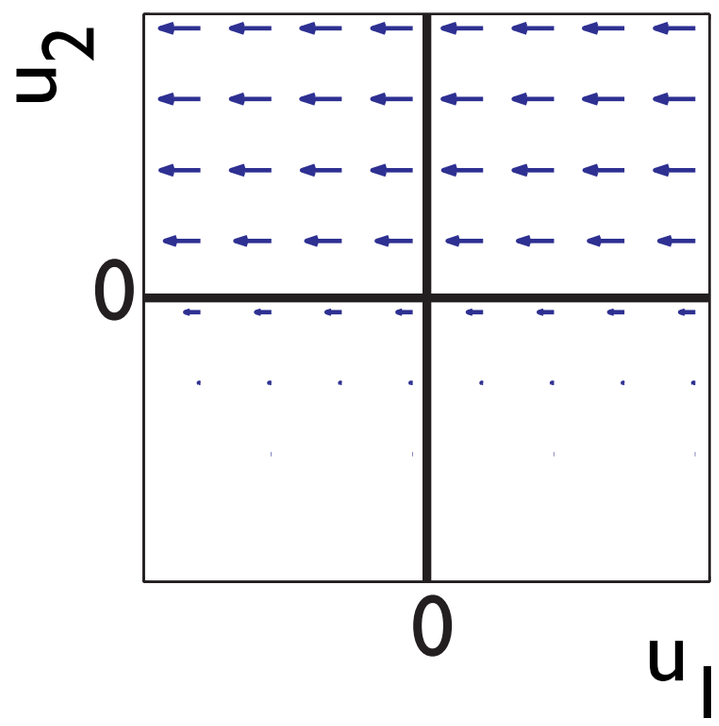
Neuronal dynamics with competition

- vector-field of mutual inhibition

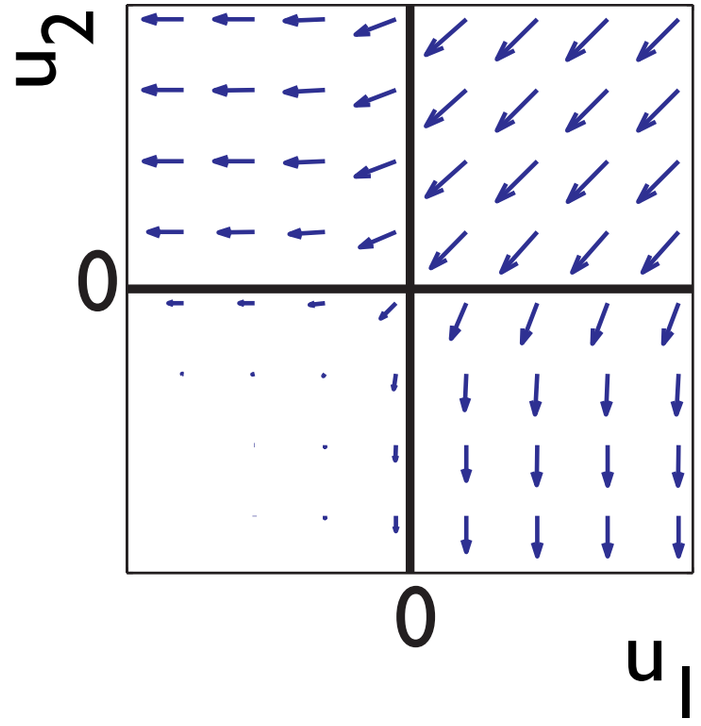
site 1 inhibits site 2



site 2 inhibits site 1



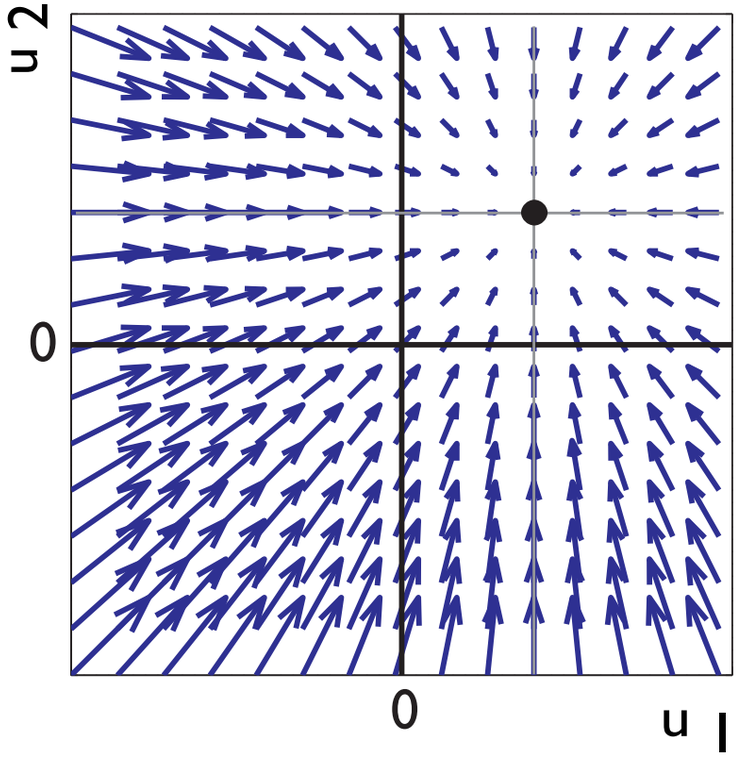
interaction combined



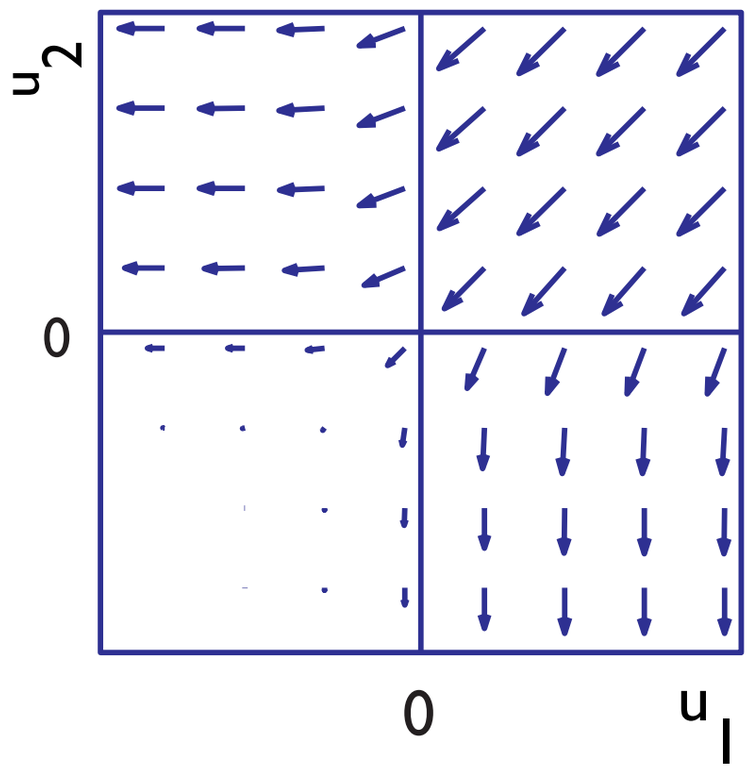
Neuronal dynamics with competition

vector-field with strong mutual inhibition: bistable

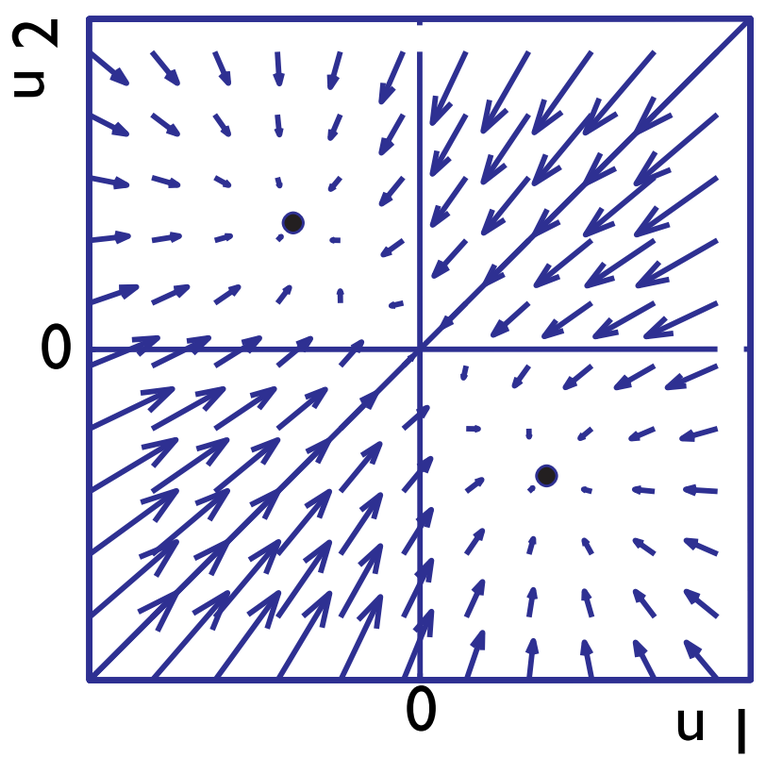
input



interaction

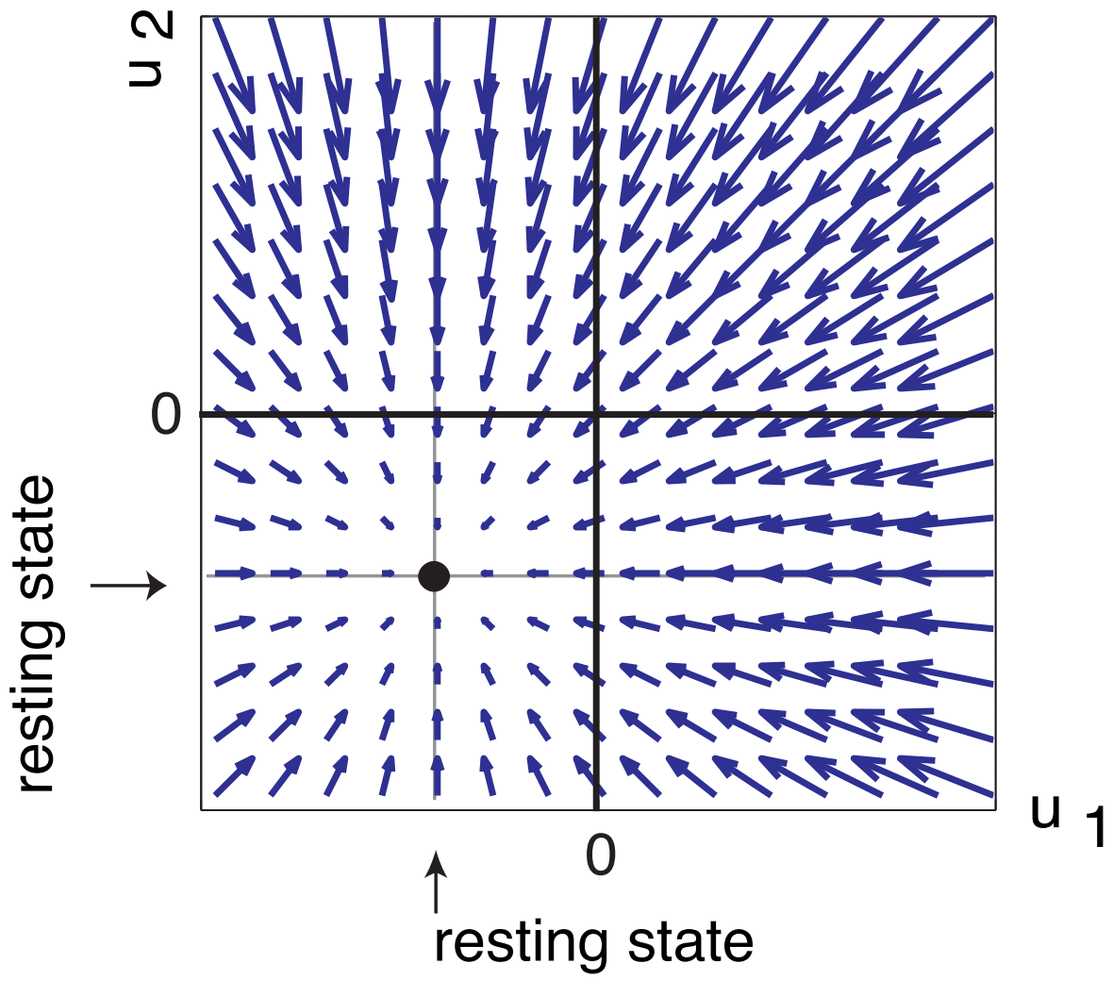


total

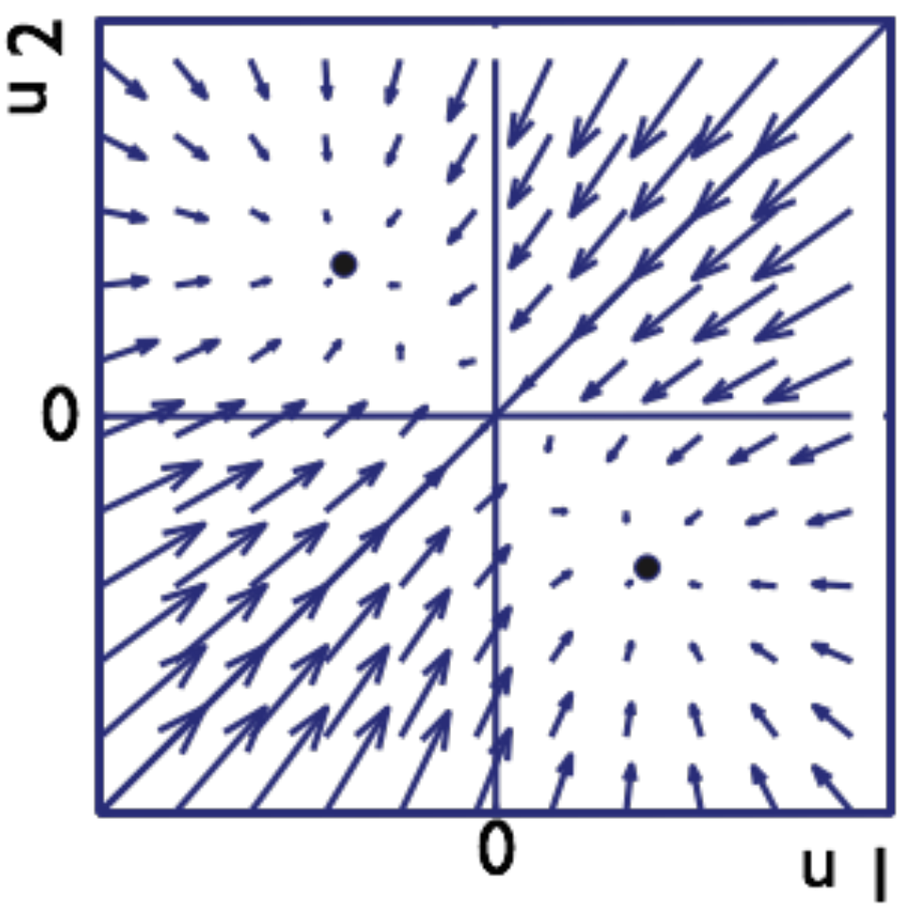


Neuronal dynamics with competition

before input is presented



after input is presented

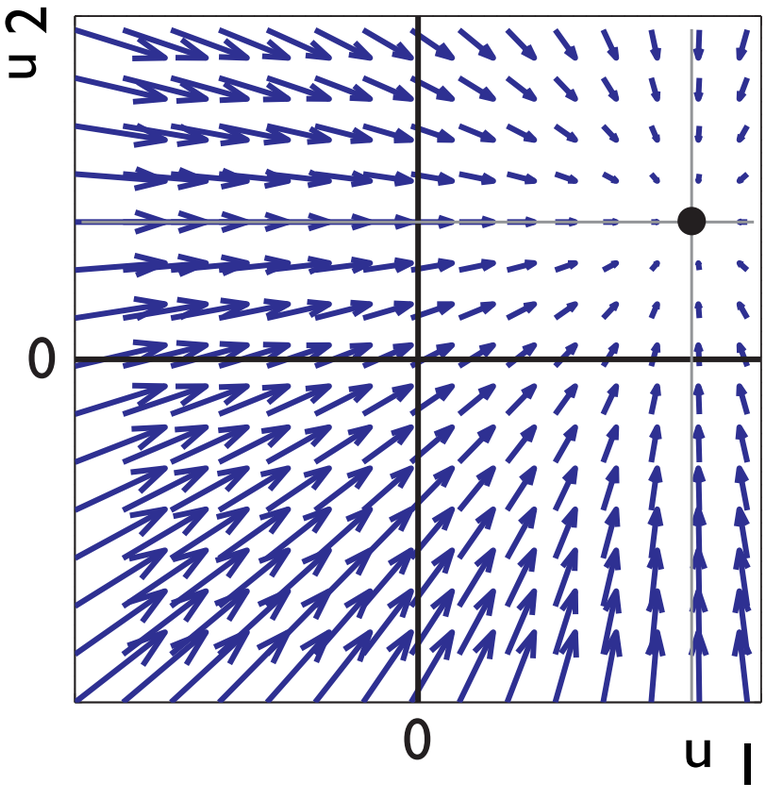


Neuronal dynamics with competition

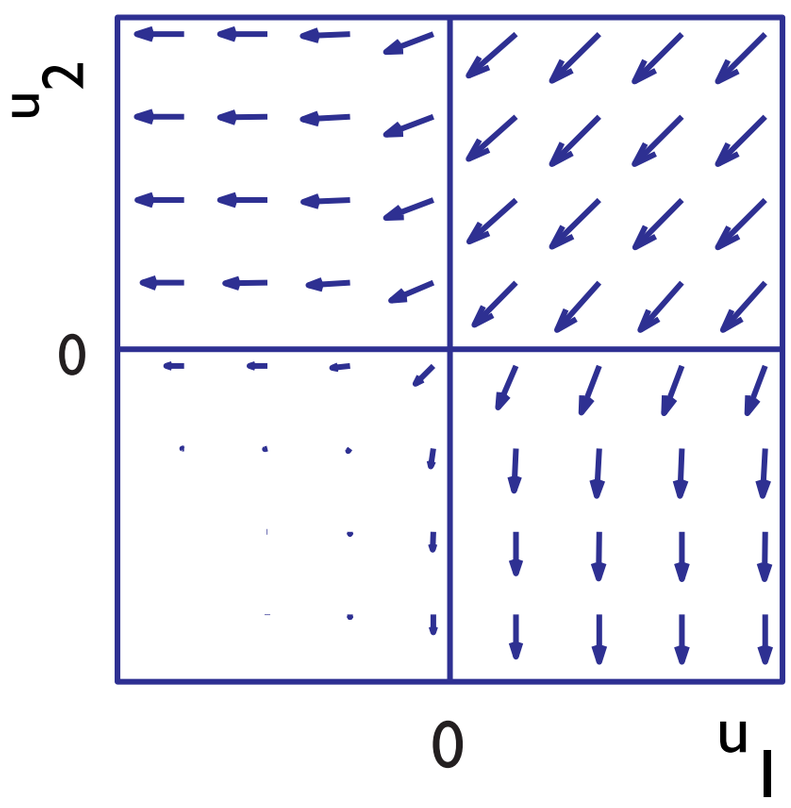
=>biased competition

stronger input to site 1:
attractor with activated u_1 stronger,
attractor with activated u_2 weaker, may become unstable

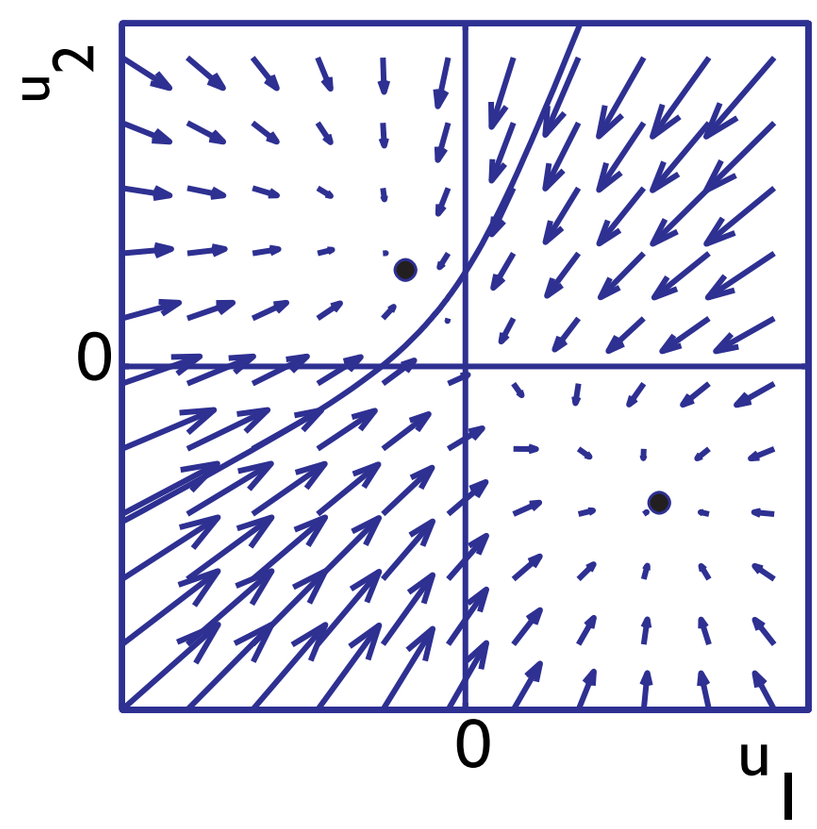
input



interaction

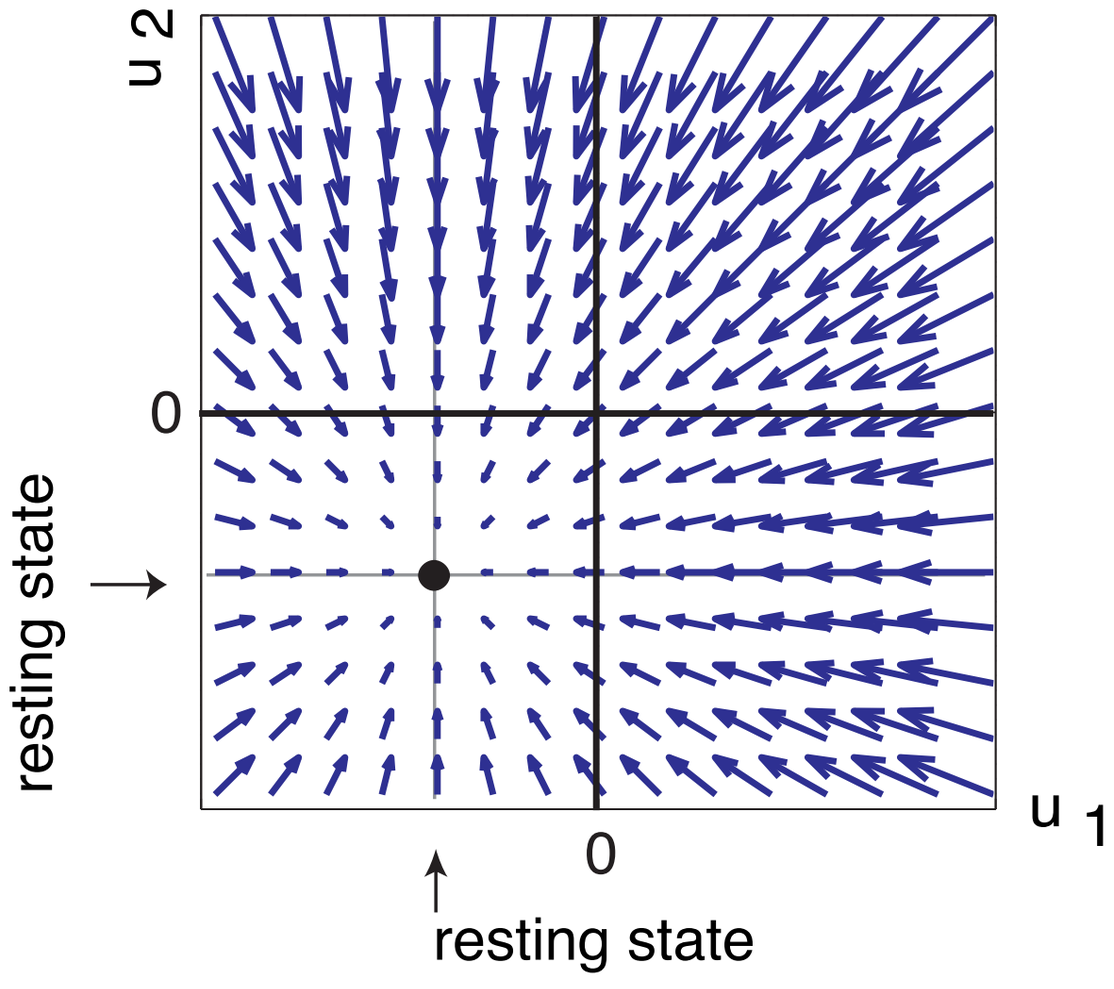


total

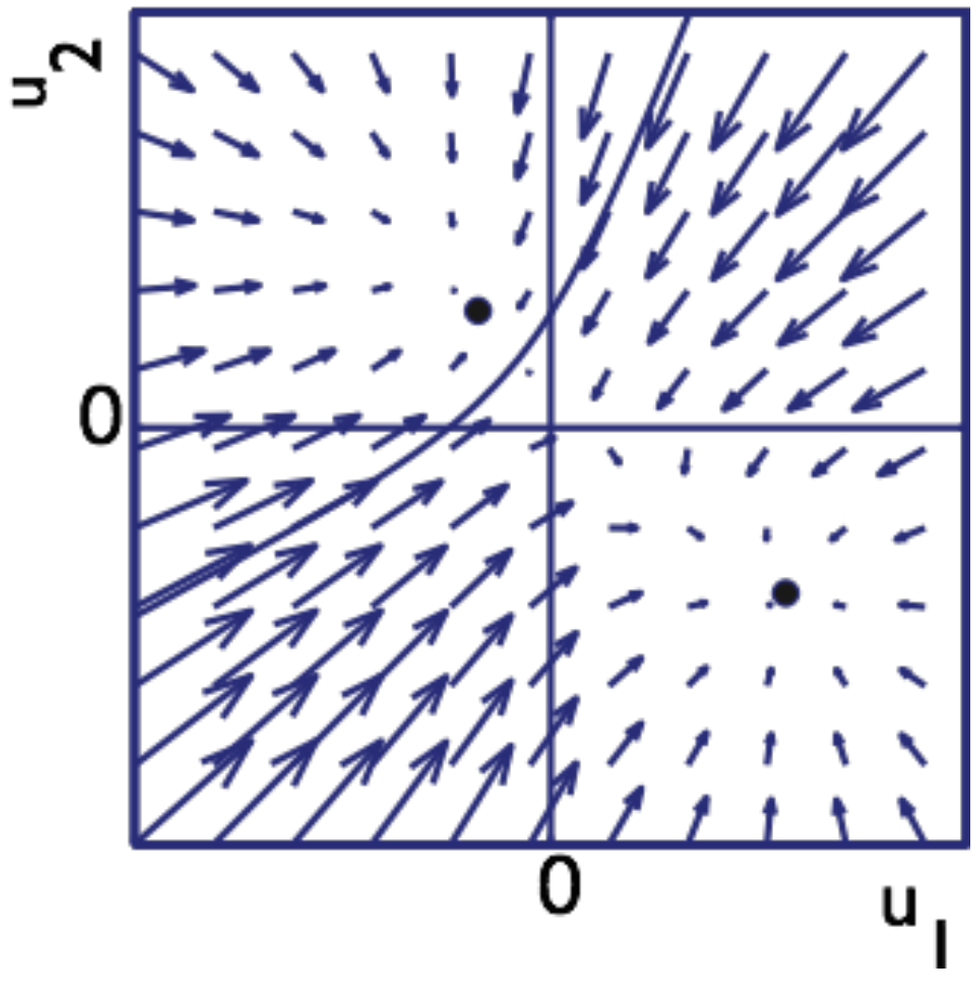


Neuronal dynamics with competition =>biased competition

before input is presented



after input is presented



- => simulation in live exercise session

- where do activation variables come from?
- how do discrete activation variables reflect continuous behaviors?
- => DFT lecture