Neural Dynamics
Part 2

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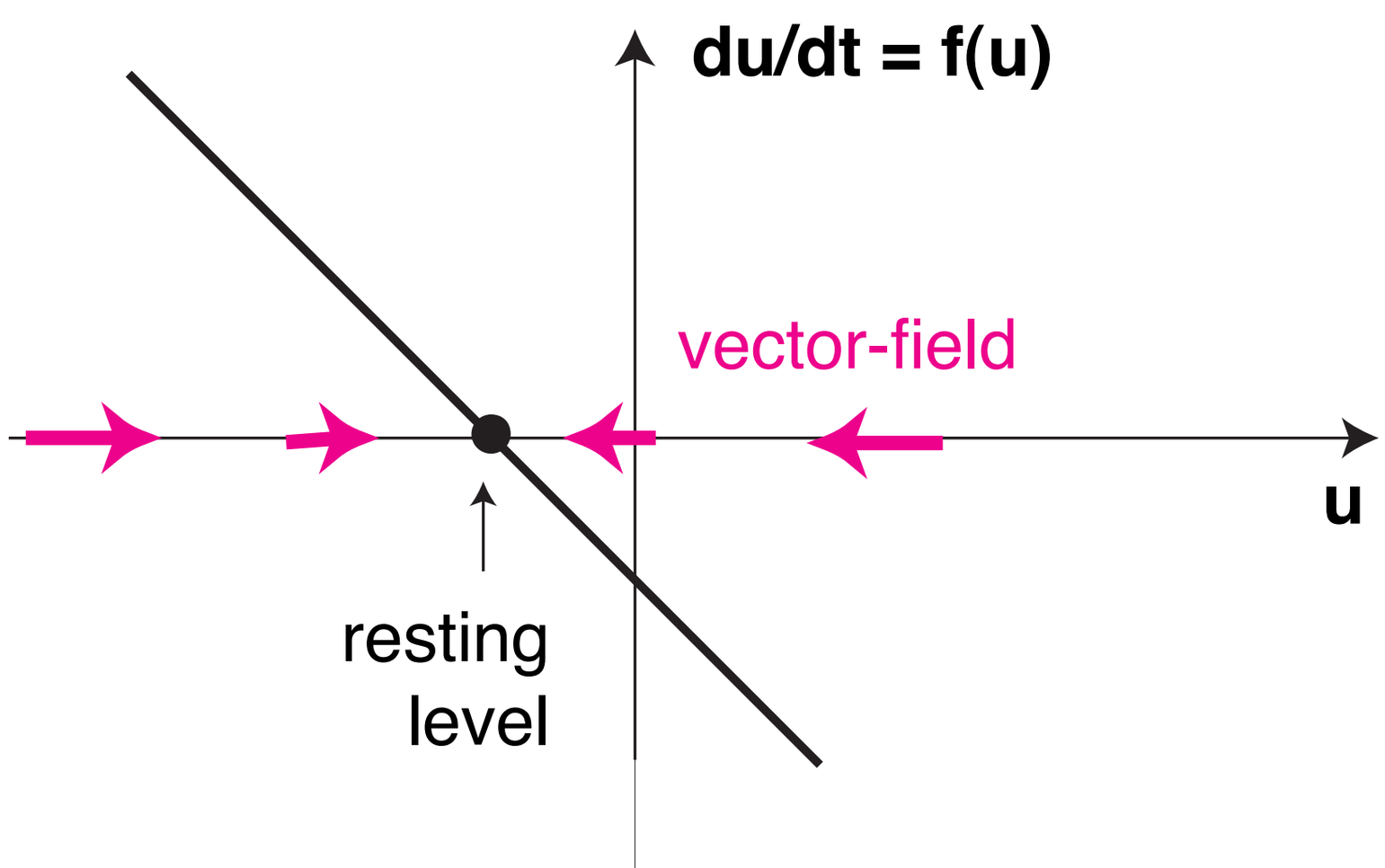
Activation dynamics

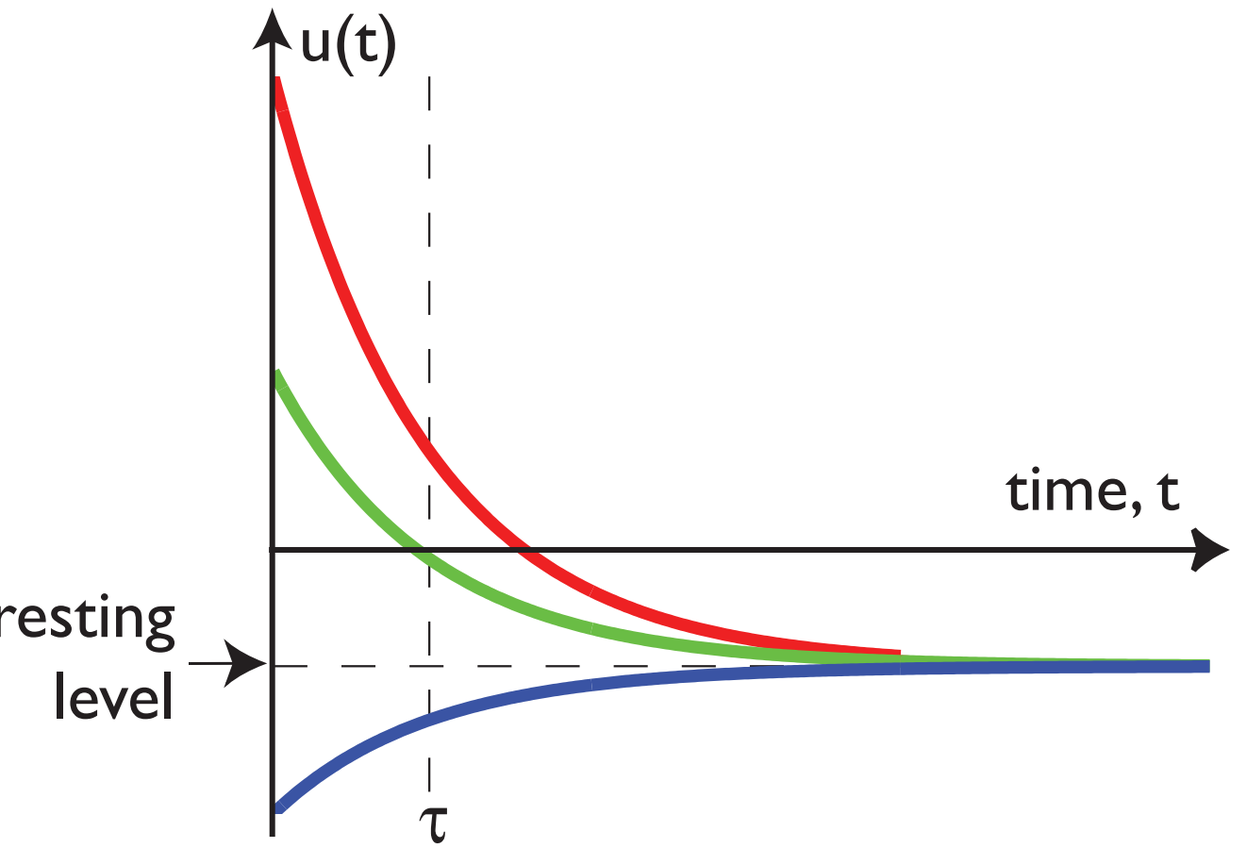
- activation, u(t), whose time course emerges from a neural dynamics

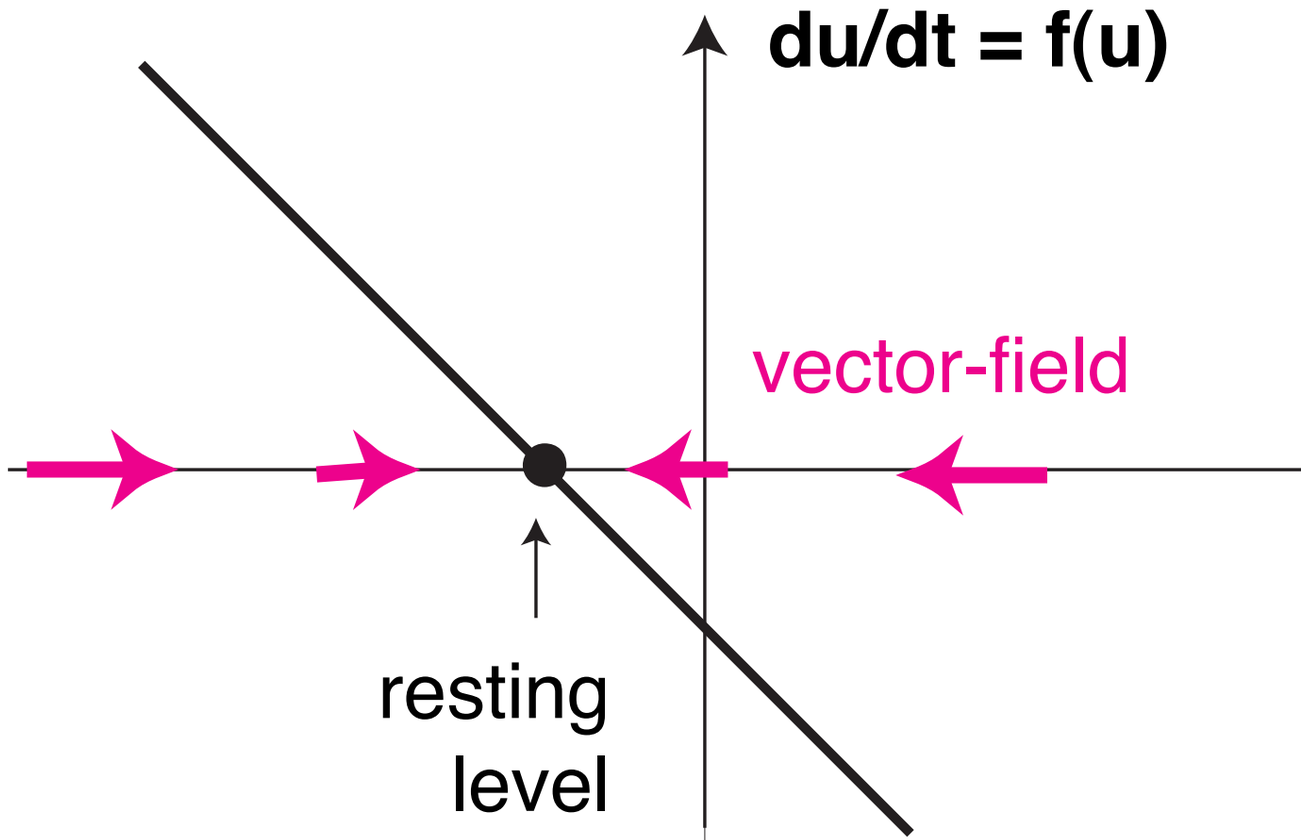
$$\frac{du(t)}{dt} = \dot{u}(t) = -u(t) + h \qquad (h < 0)$$



Neural dynamics

- has a stable fixed point (attractor) at all times
- to which activation relaxes



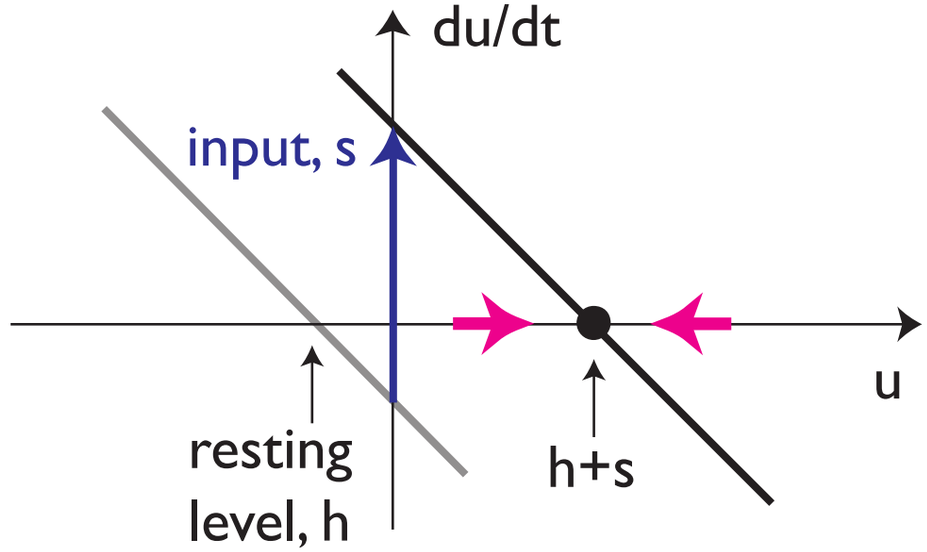


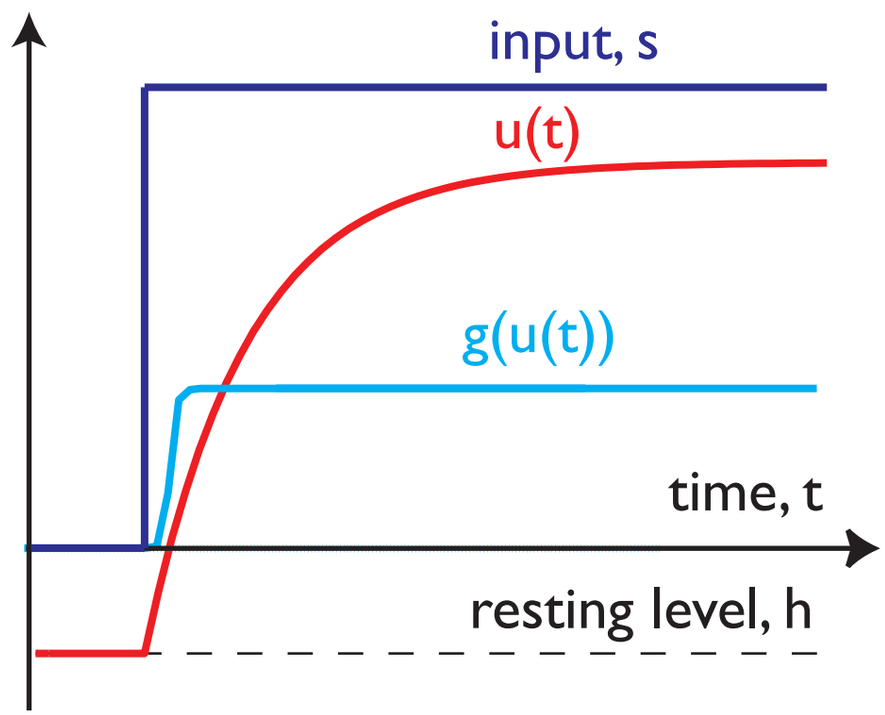
$$\tau \dot{u}(t) = -u(t) + h$$

Neuronal dynamics

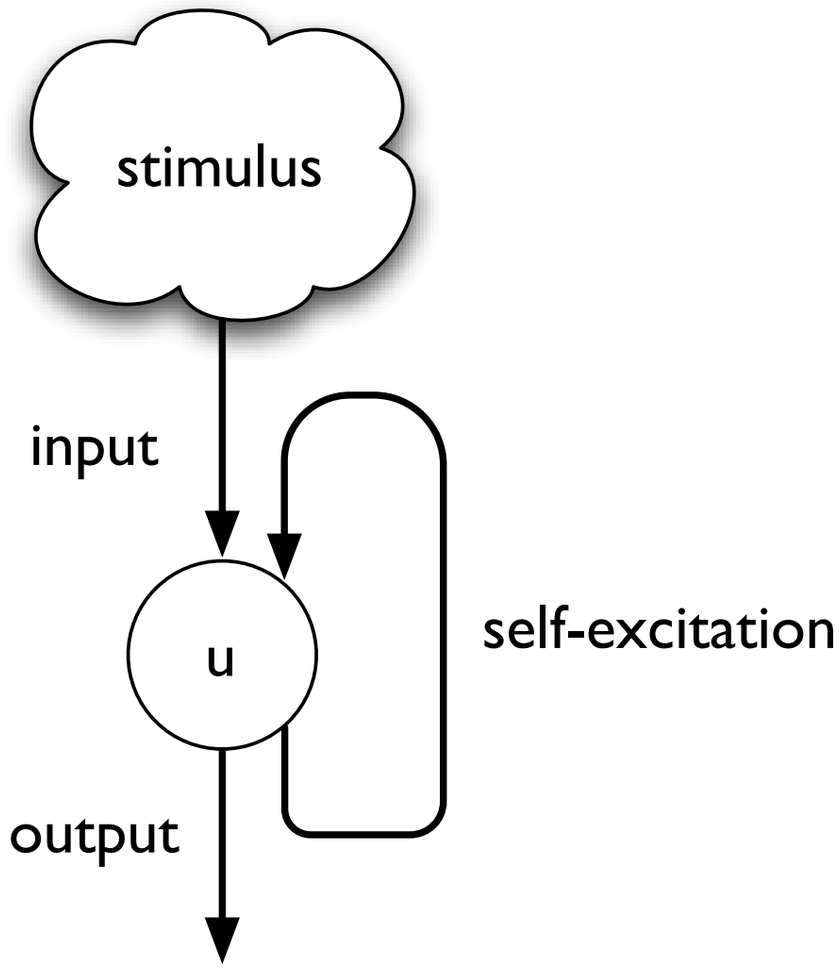
$$\tau \dot{u}(t) = -u(t) + h + \text{ inputs(t)}$$

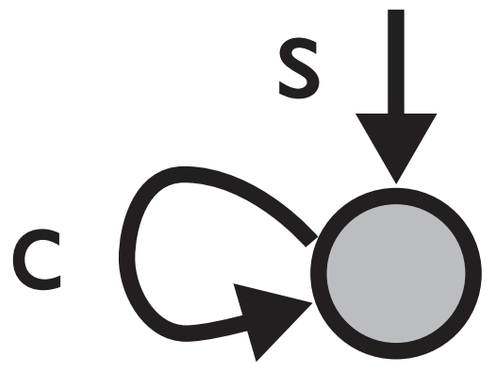
- inputs are contributions to the rate of change
  - positive: excitatory
  - negative: inhibitory
- that shift the attractor
- a shift which activation then tracks





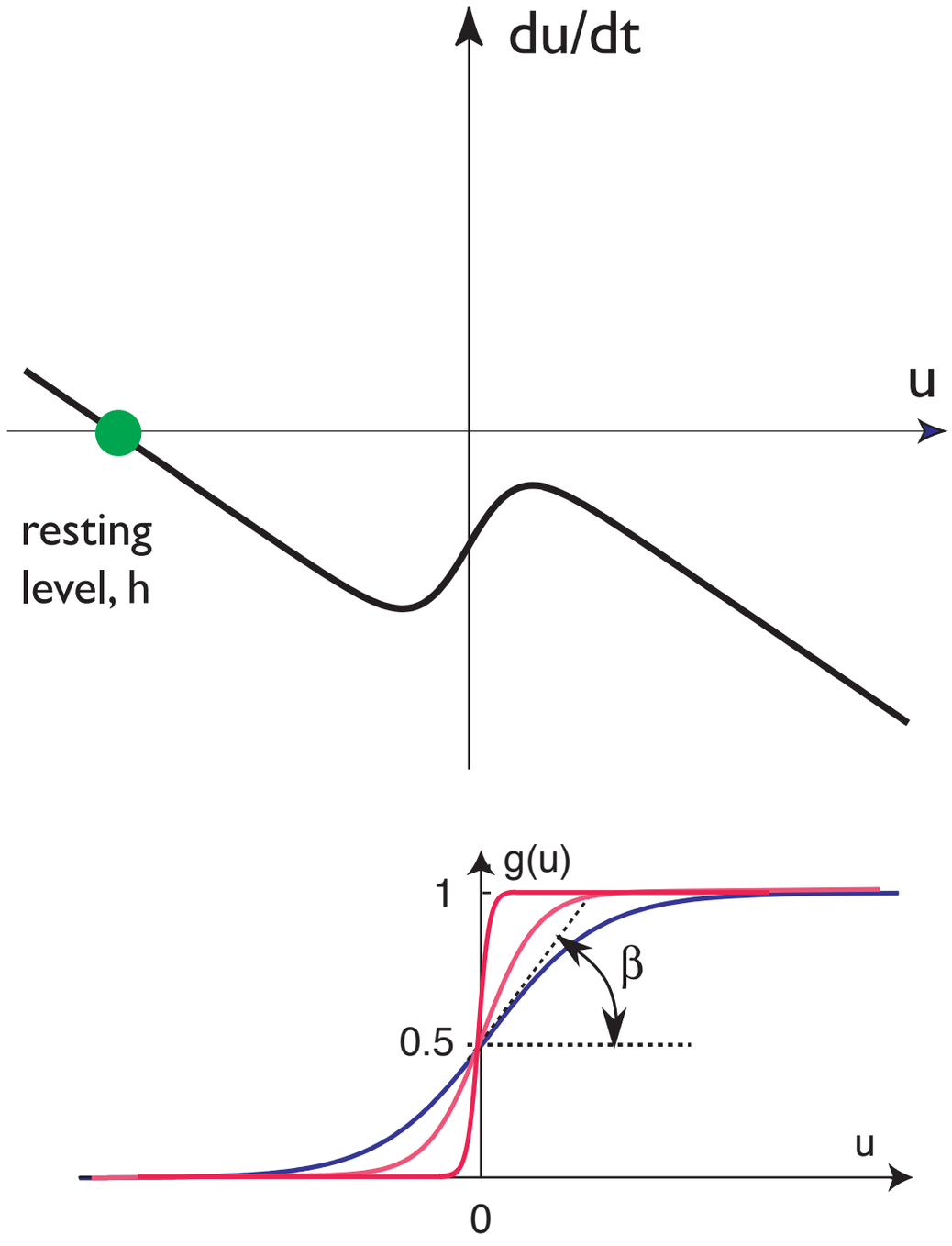
Neuronal dynamics with self-excitation





$$\tau \dot{u}(t) = -u(t) + h + S(t) + c\sigma(u(t))$$

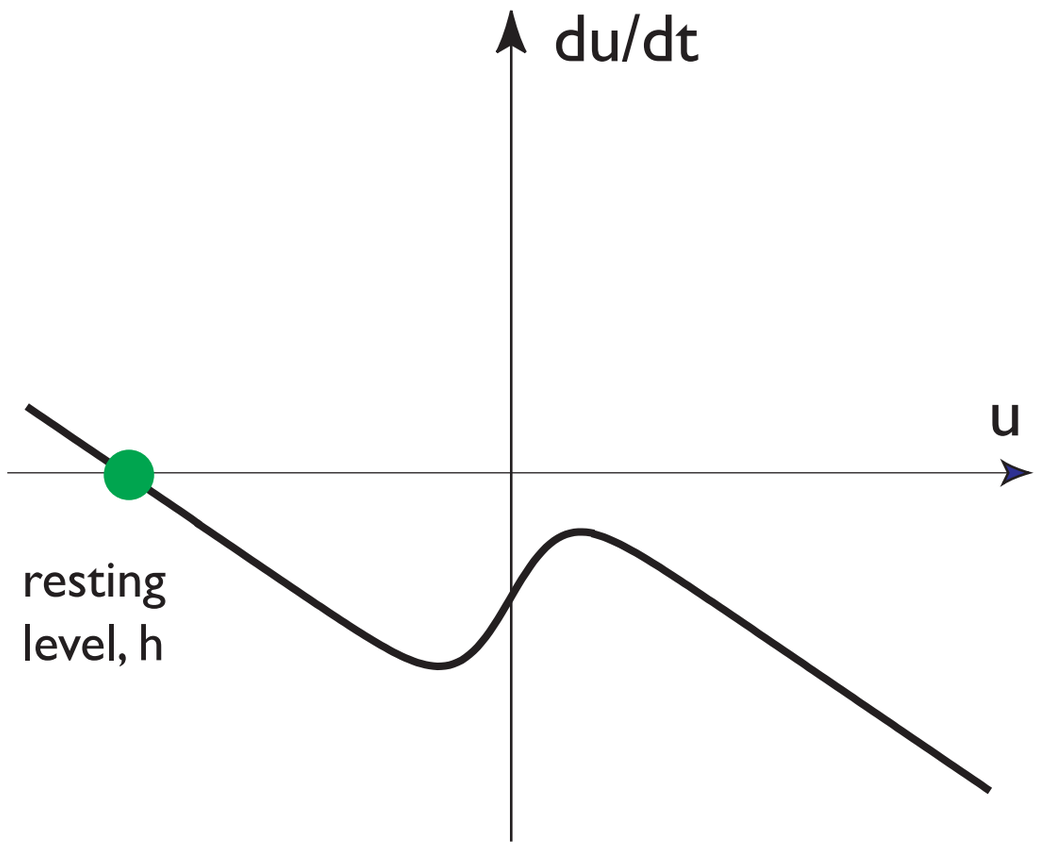
Neuronal dynamics with self-excitation



$$\tau \dot{u}(t) = -u(t) + h + S(t) + c\sigma(u(t))$$

Neuronal dynamics with self-excitation

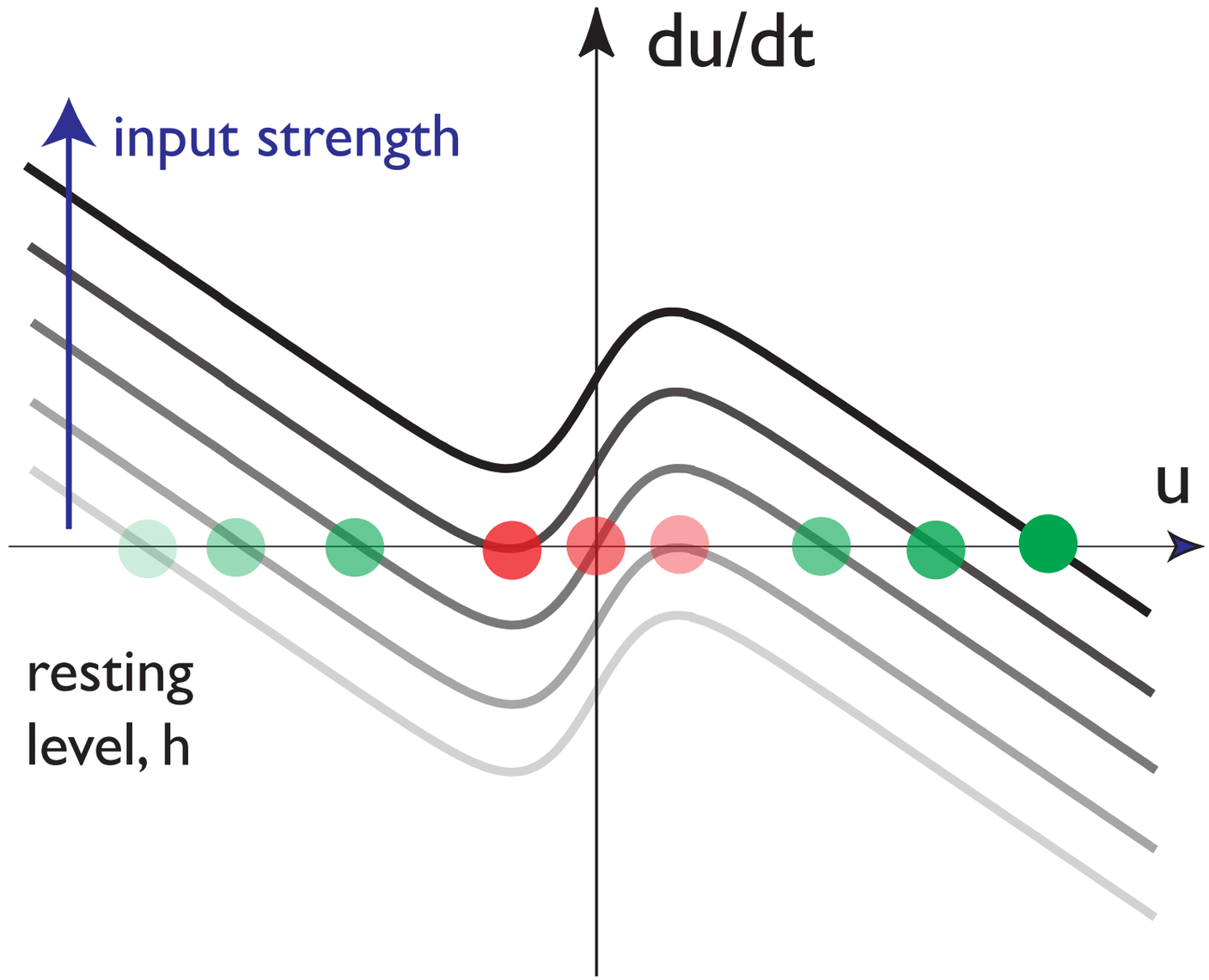
- => this is nonlinear dynamics!



$$\tau \dot{u}(t) = -u(t) + h + S(t) + c\sigma(u(t))$$

Neuronal dynamics with self-excitation

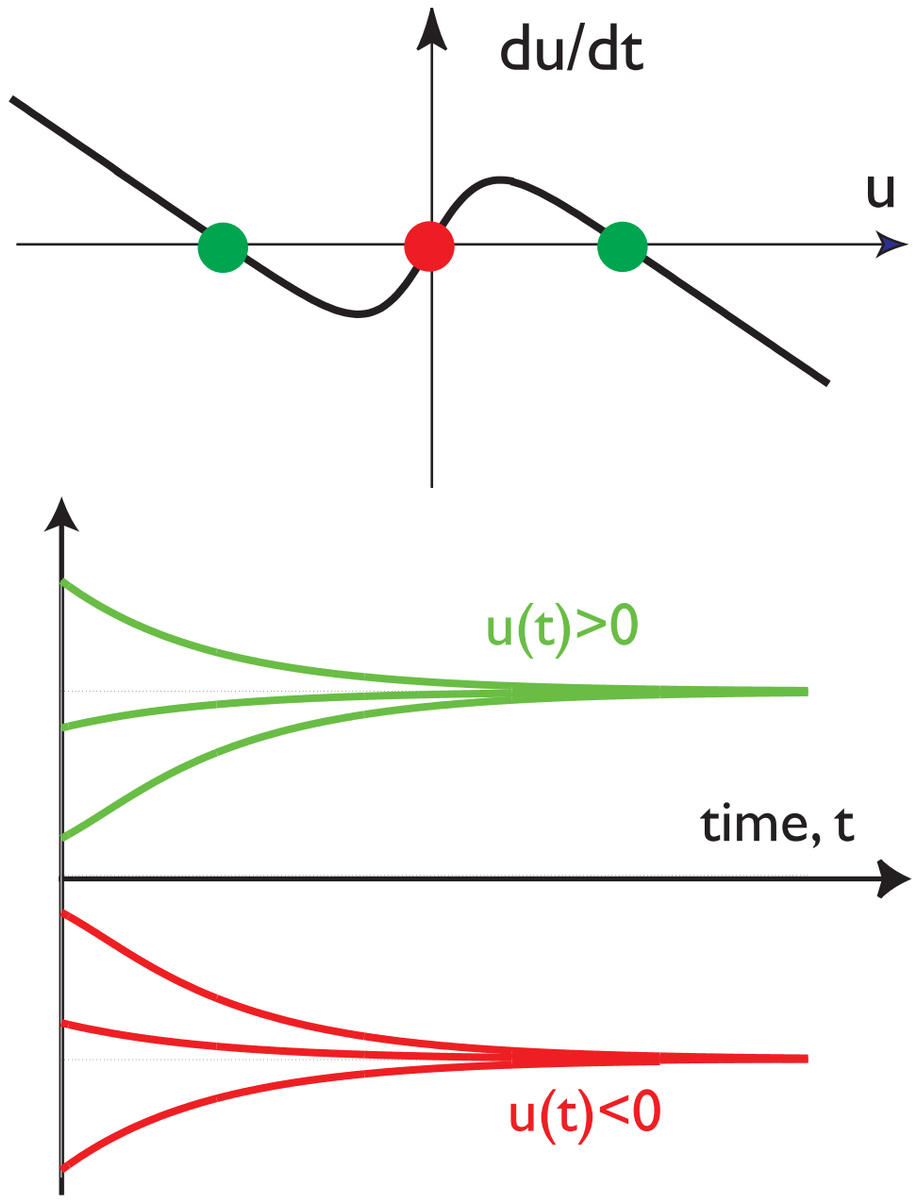
- stimulus input



$$\tau \dot{u}(t) = -u(t) + h + S(t) + c\sigma(u(t))$$

Neuronal dynamics with self-excitation

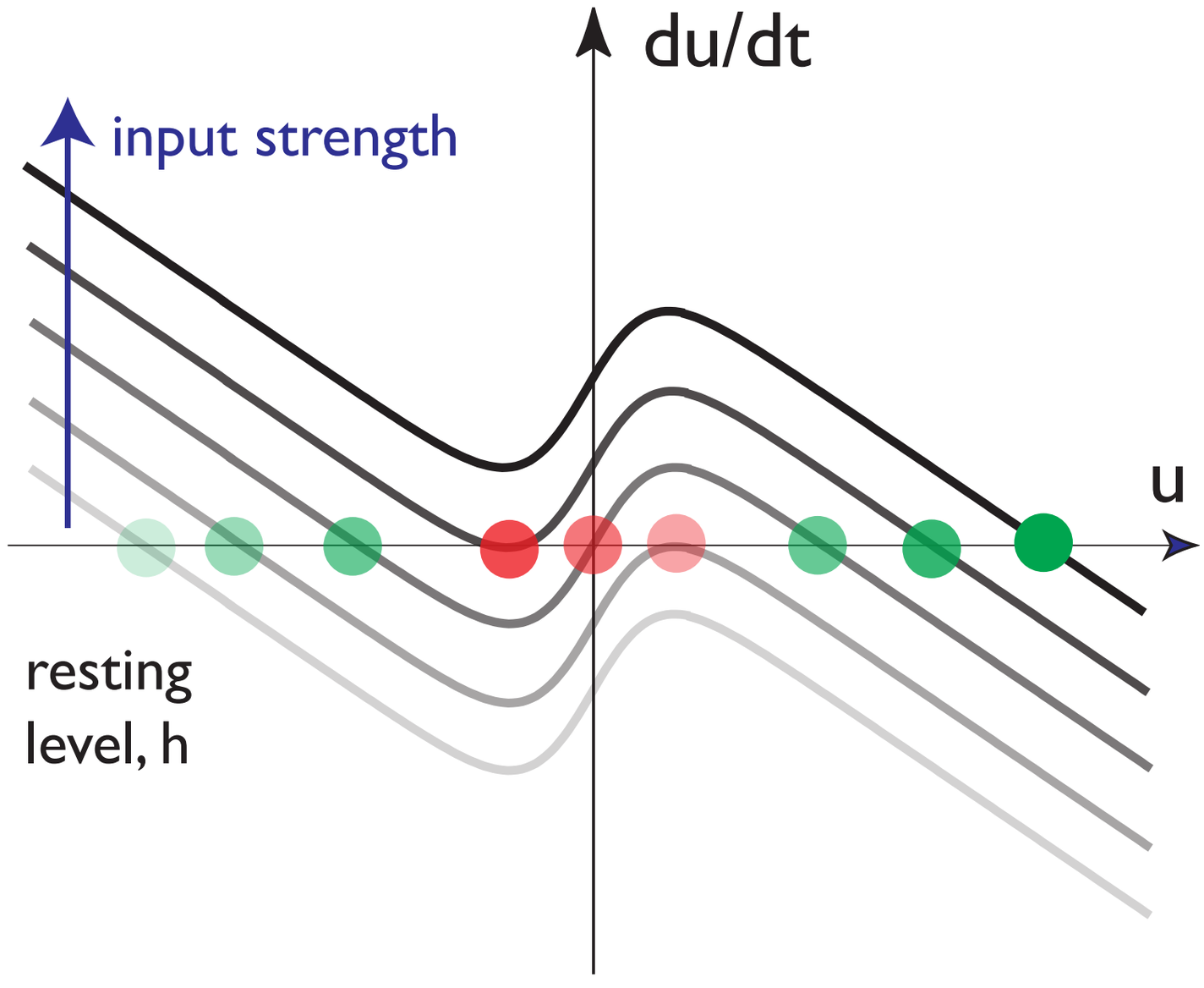
- at intermediate stimulus strength: bistable=> essential nonlinearity



$$\tau \dot{u}(t) = -u(t) + h + S(t) + c\sigma(u(t))$$

Neuronal dynamics with self-excitation

- with varying input strength system goes through two instabilities: the detection and the reverse detection instability



Neuronal dynamics with self-excitation

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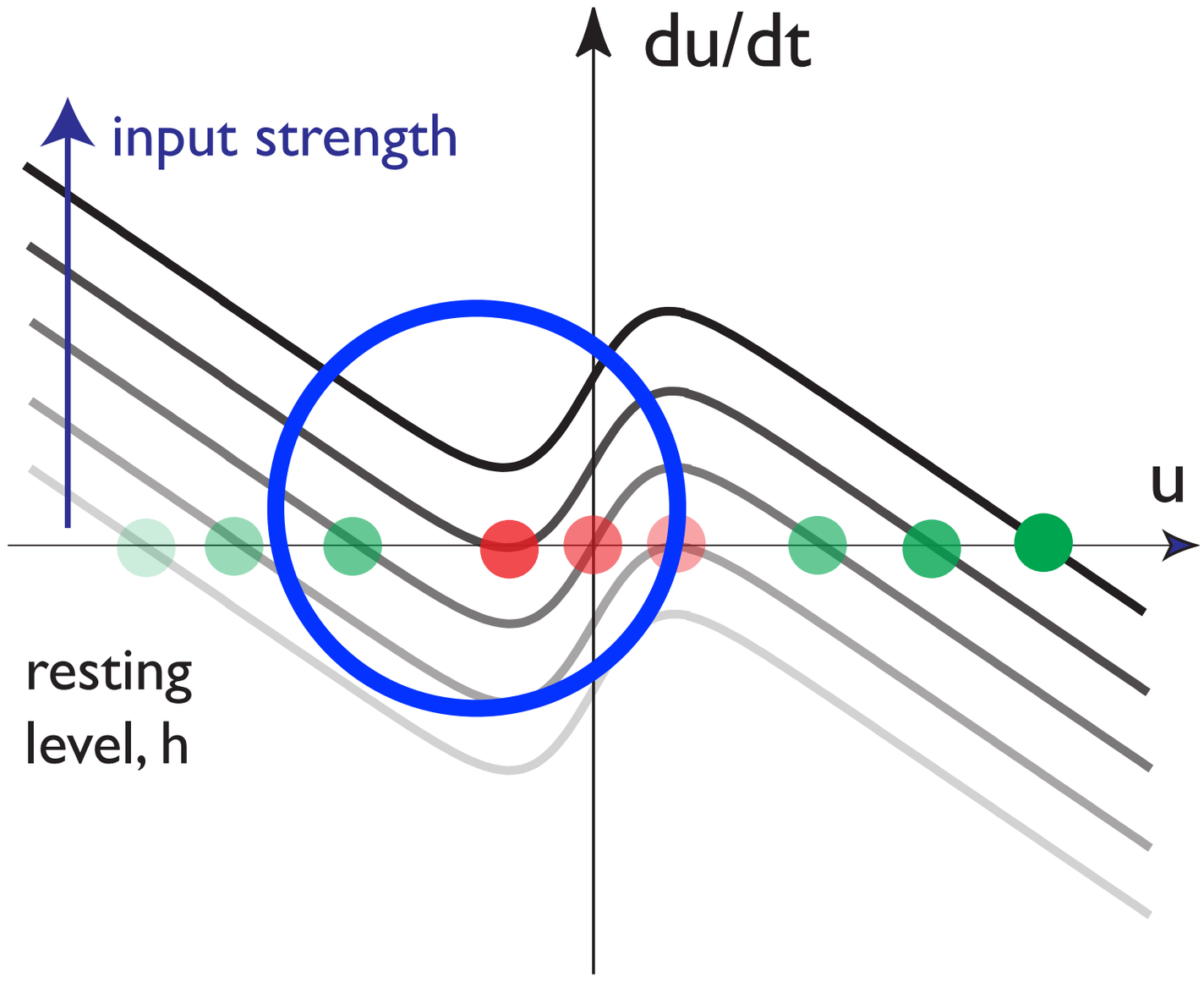
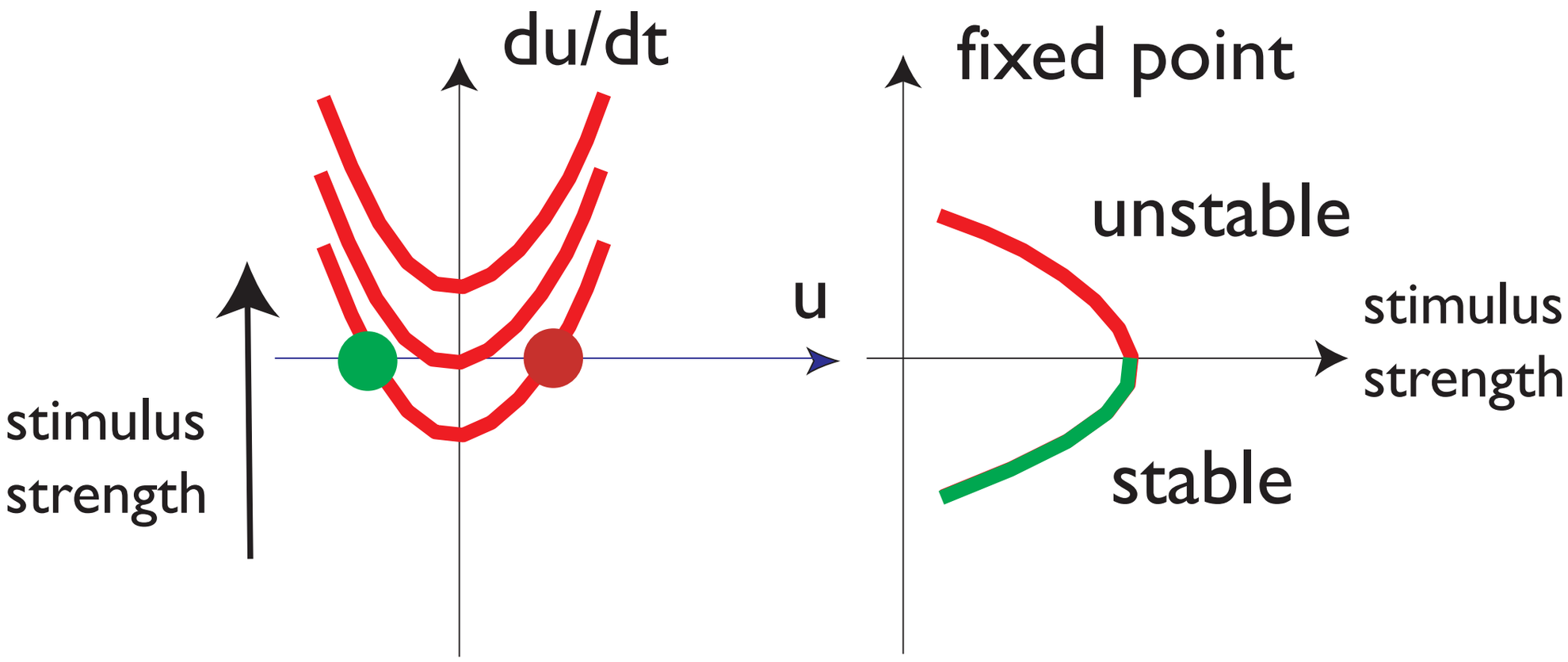


Neuronal dynamics with self-excitation

- detection instability



Neuronal dynamics with self-excitation

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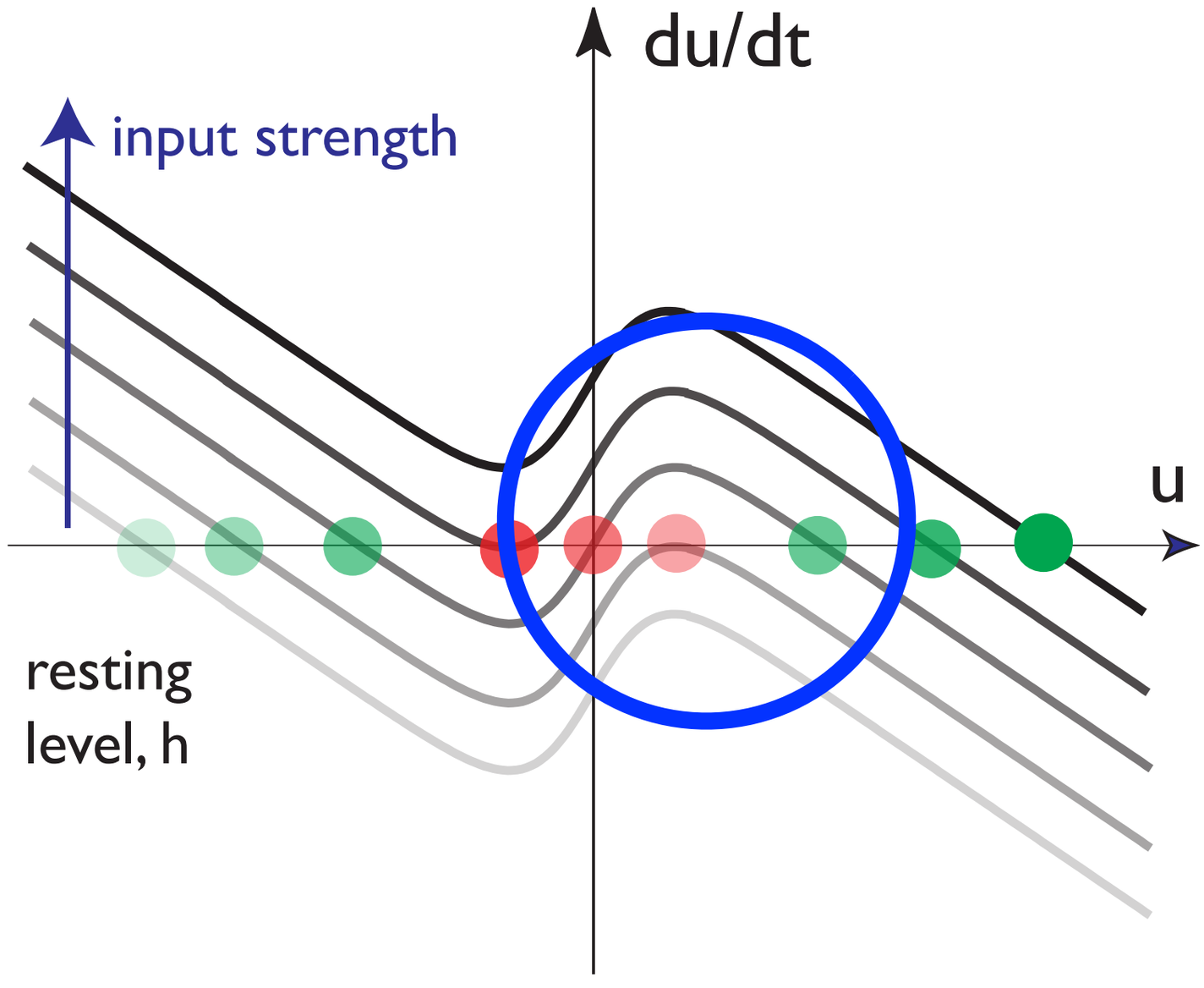
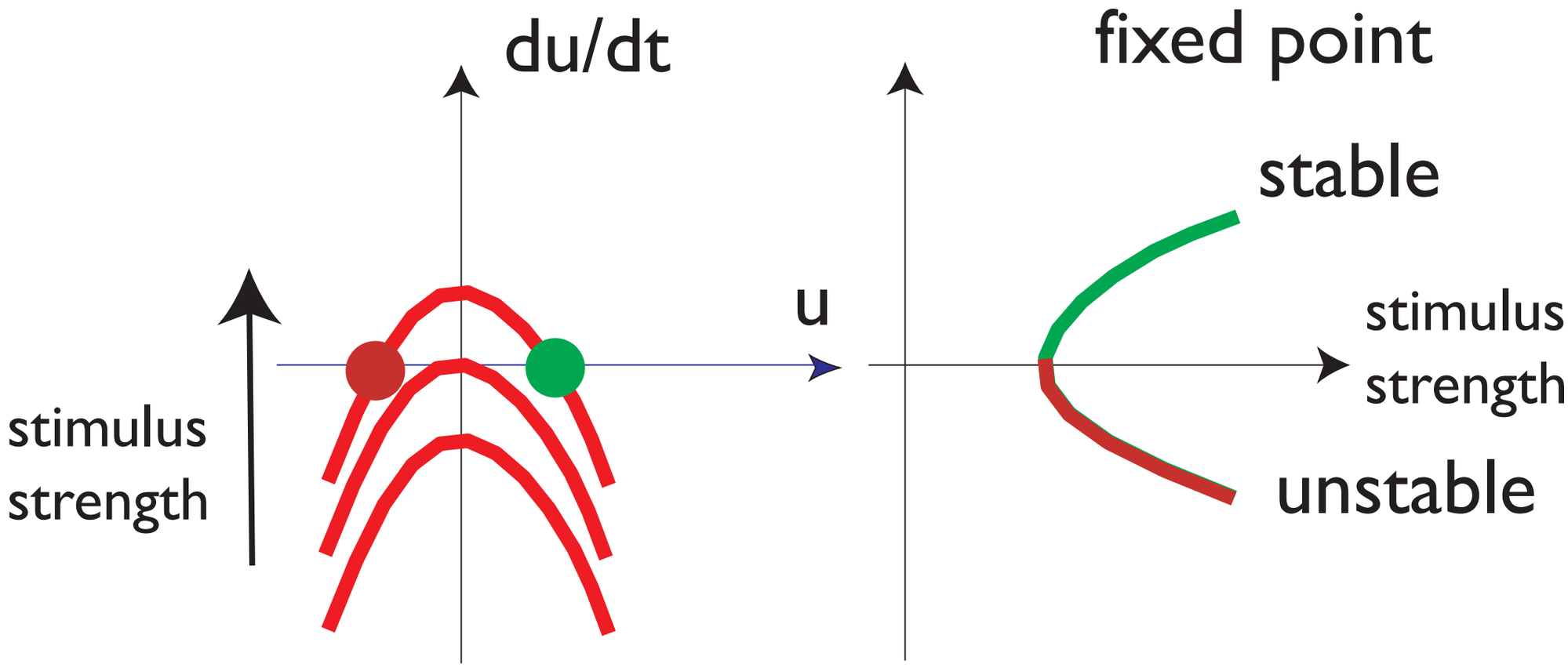


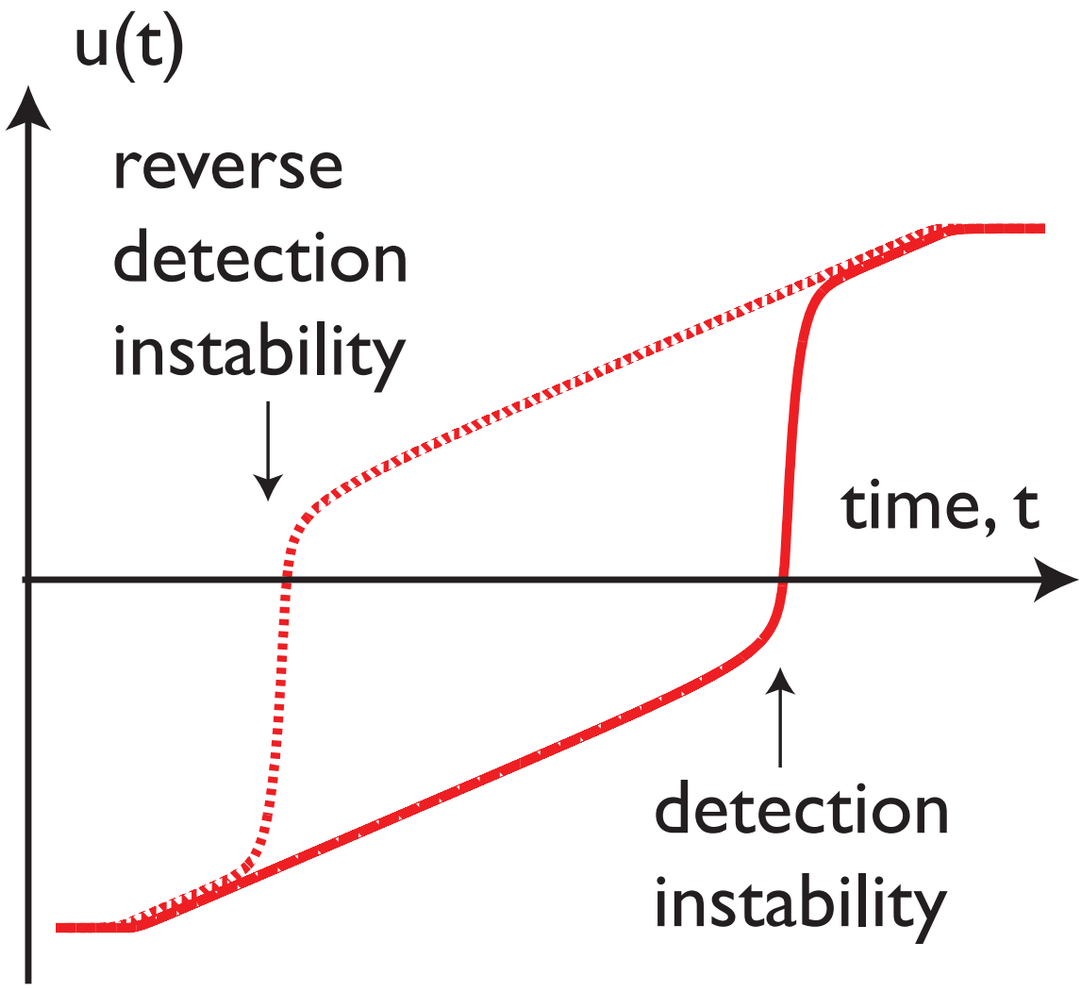
Neuronal dynamics with self-excitation

- reverse detection instability



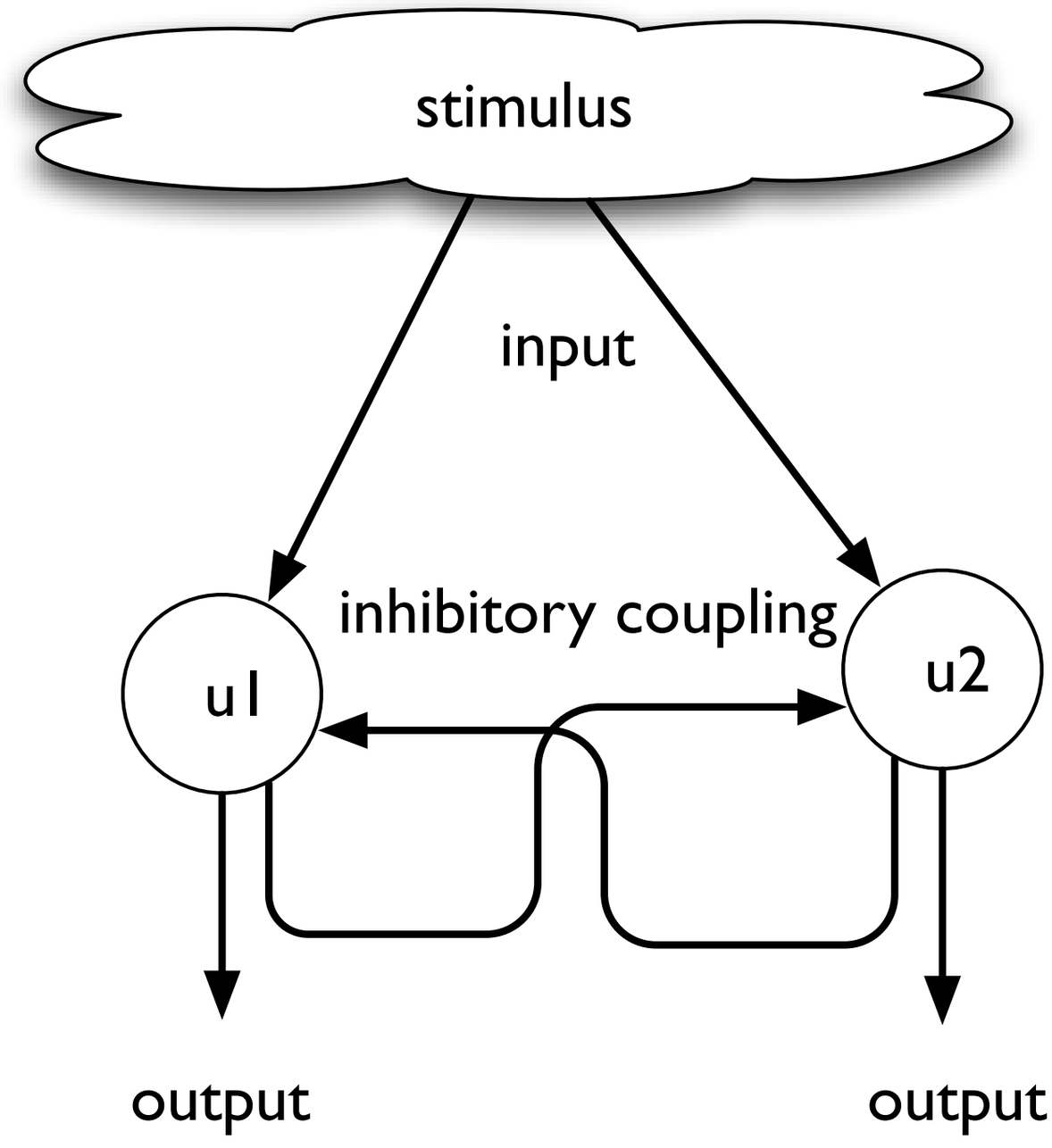
Neuronal dynamics with self-excitation

- signature of instabilities: hysteresis



- => simulation

Neuronal dynamics with competition



$$\tau \dot{u}_1(t) = -u_1(t) + h - \sigma(u_2(t)) + S_1$$
$$\tau \dot{u}_2(t) = -u_2(t) + h - \sigma(u_1(t)) + S_2$$

Neuronal dynamics with competition

- interaction: the rate of change of activation at one site depends on the level of activation at the other site

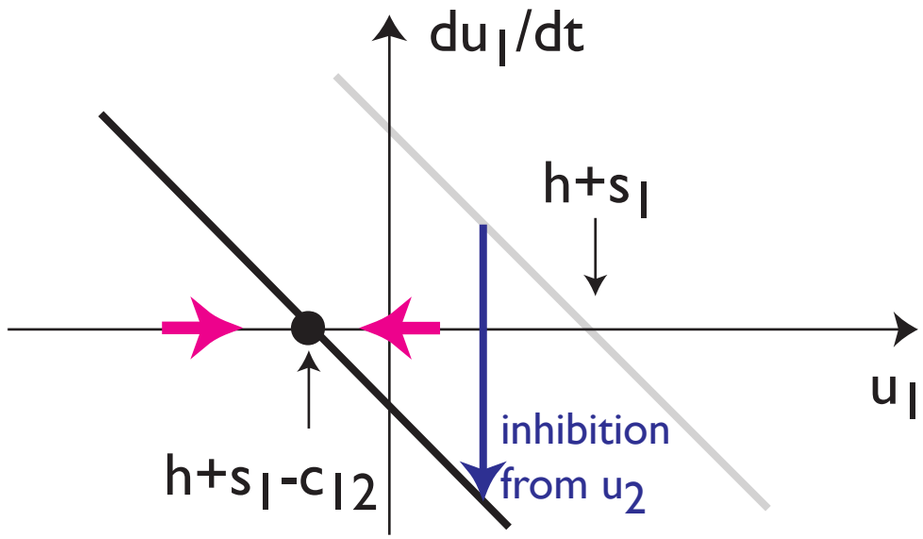
- mutual inhibition

$$\tau \dot{u}_1(t) = -u_1(t) + h - \sigma(u_2(t)) + S_1$$
$$\tau \dot{u}_2(t) = -u_2(t) + h - \sigma(u_1(t)) + S_2$$

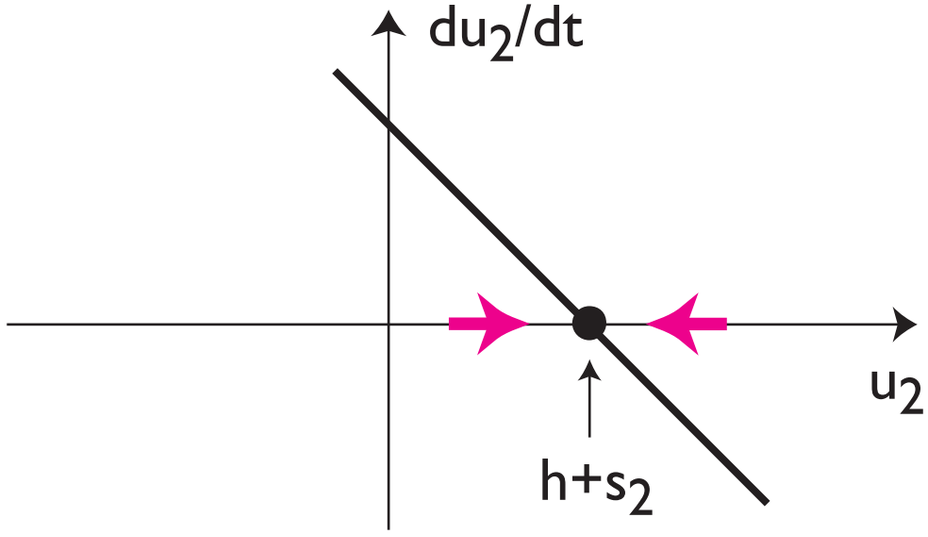
sigmoidal nonlinearity

Neuronal dynamics with competition

- to visualize, assume that u_2 has been activated by input to positive level

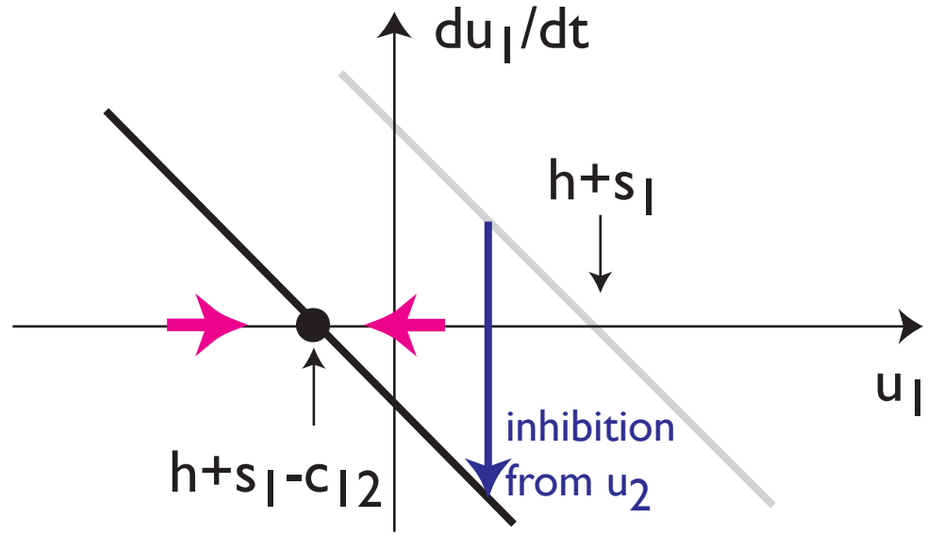


- => then u_1 is suppressed

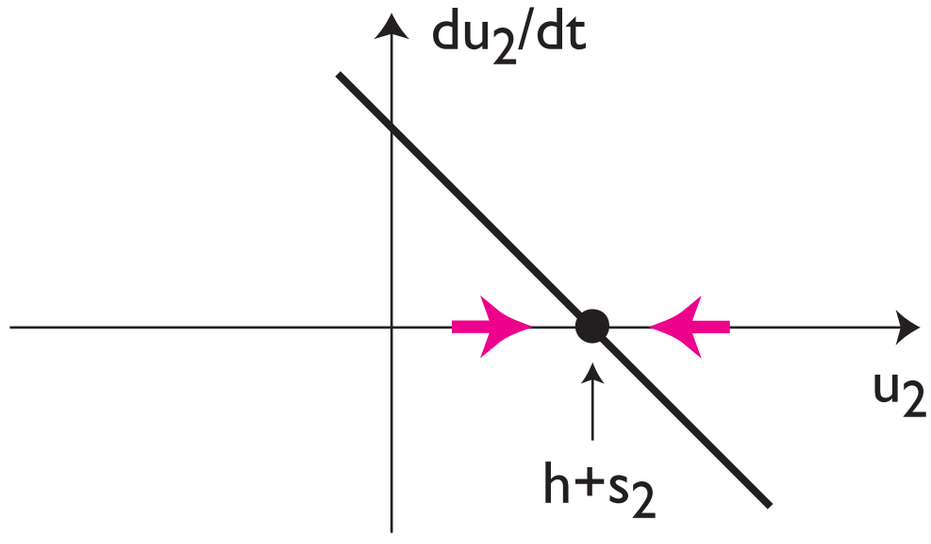


Neuronal dynamics with competition

- 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

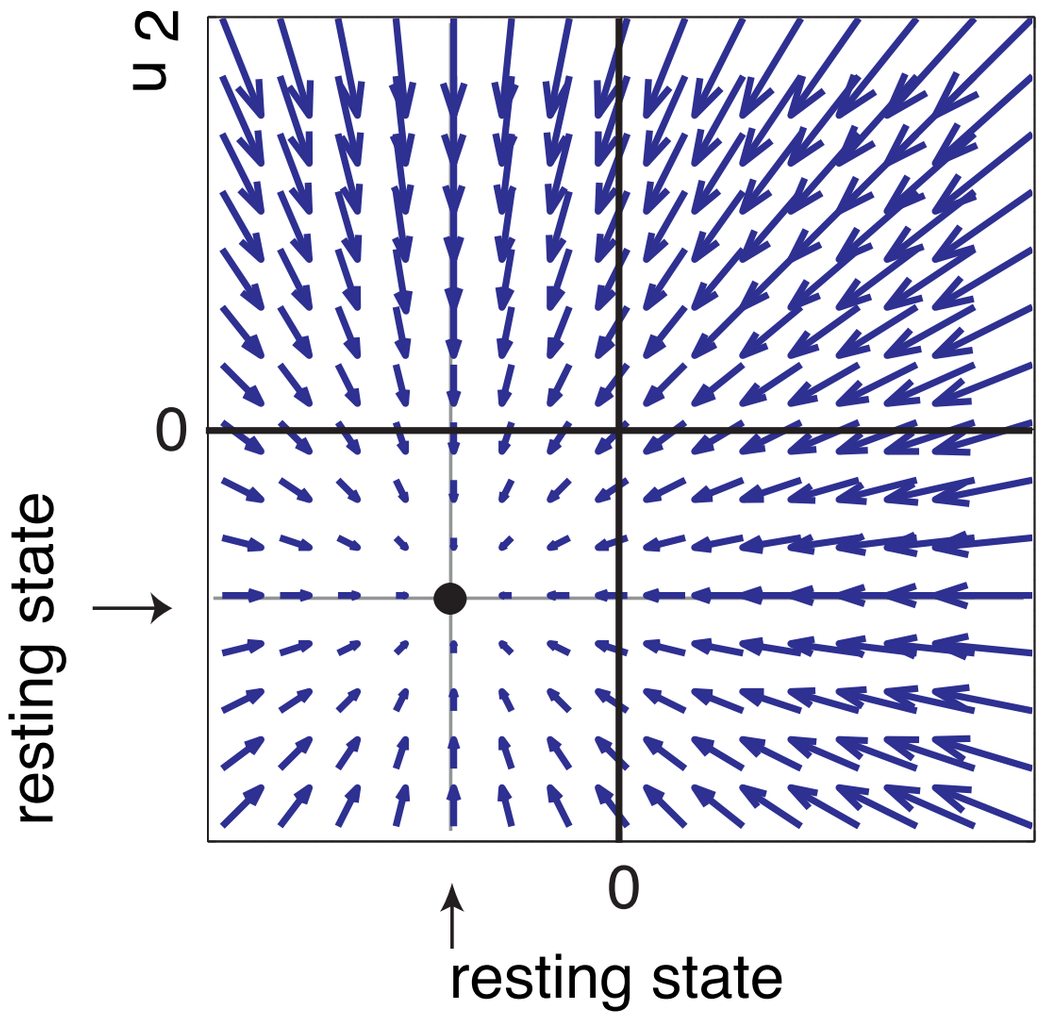


- => input advantage translates into time advantage which translates into competitive advantage

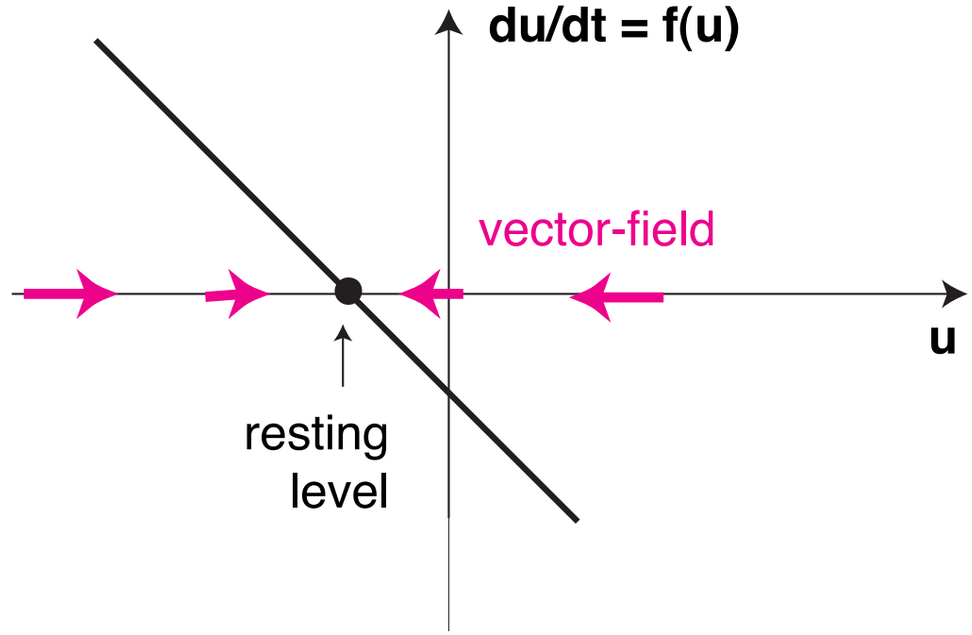


Neuronal dynamics with competition

vector-field in the absence of input

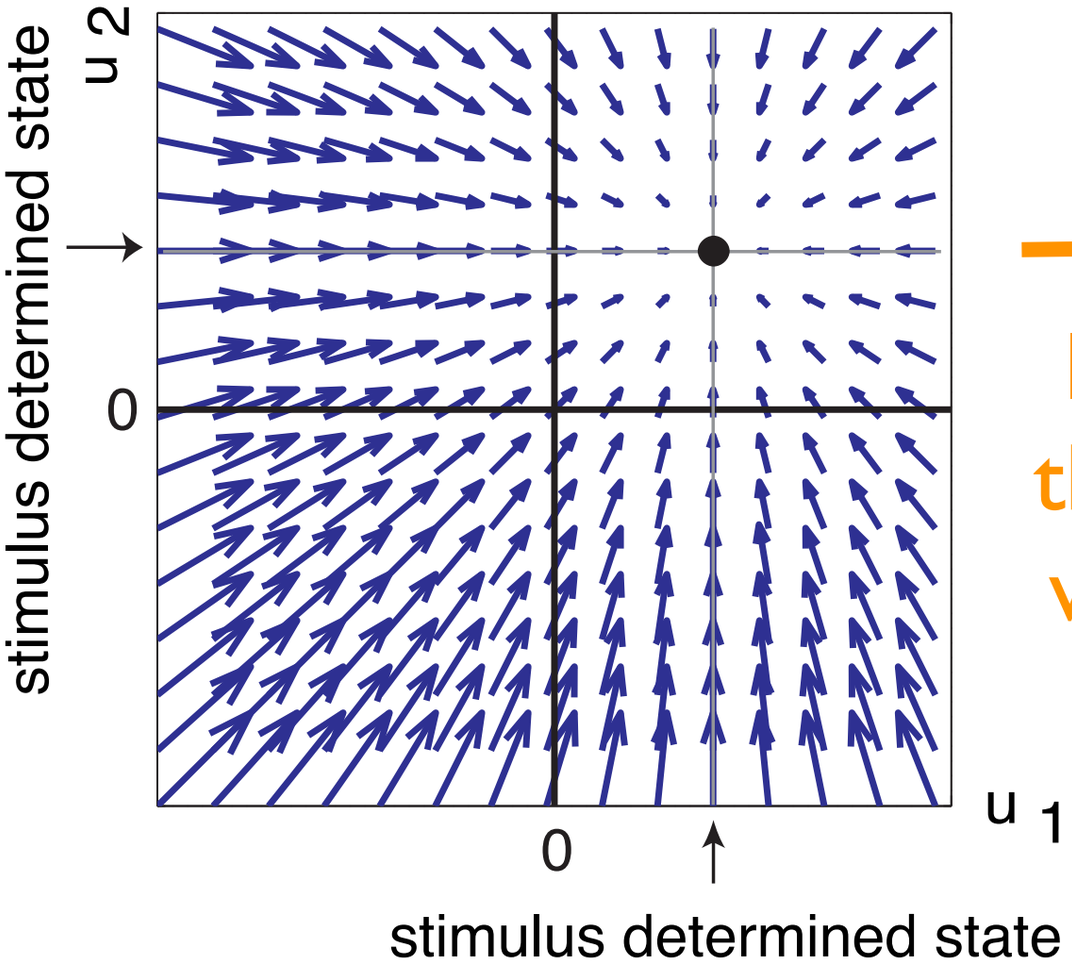


1D cut through vector-field

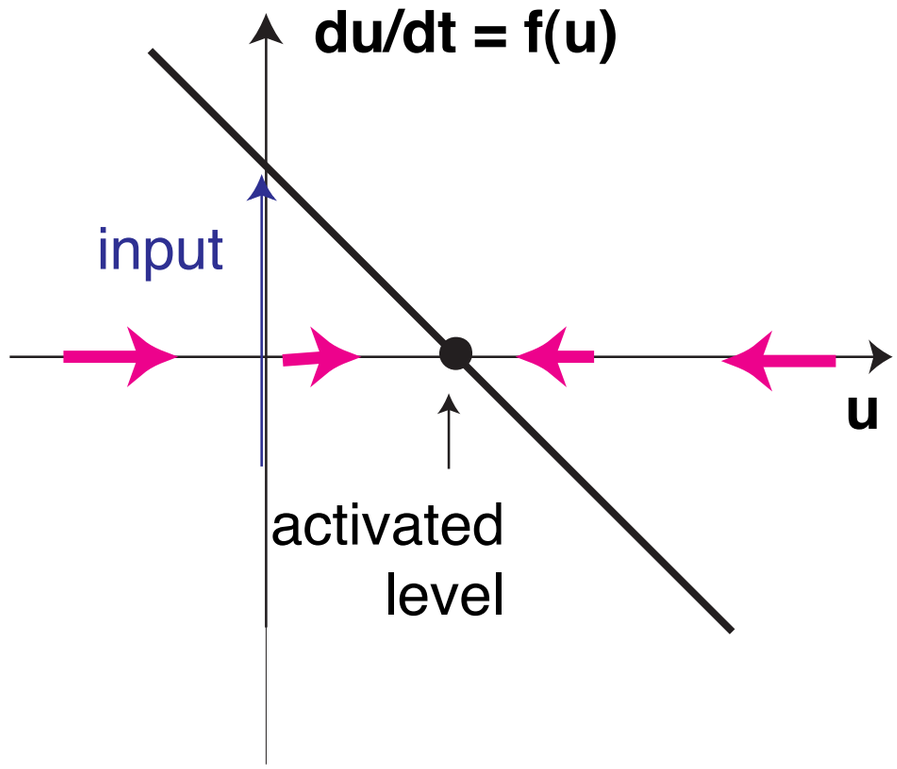


Neuronal dynamics with competition

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



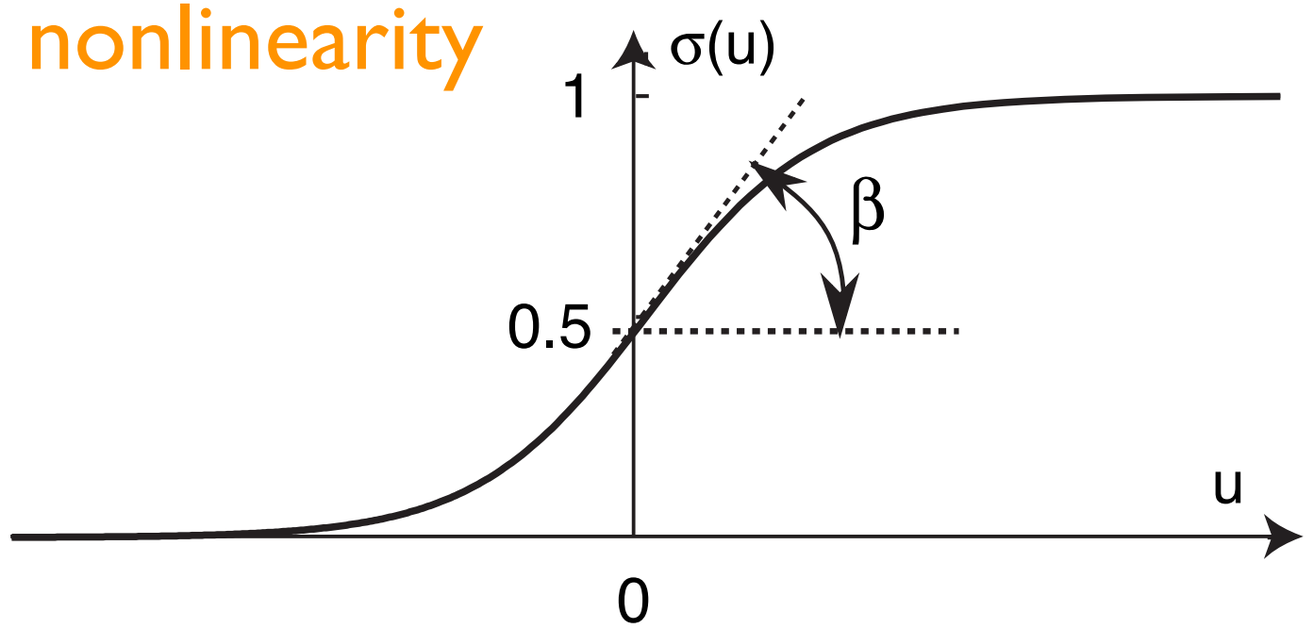
1D cut through vector-field



Neuronal dynamics with competition

- only activated neurons participate in interaction!

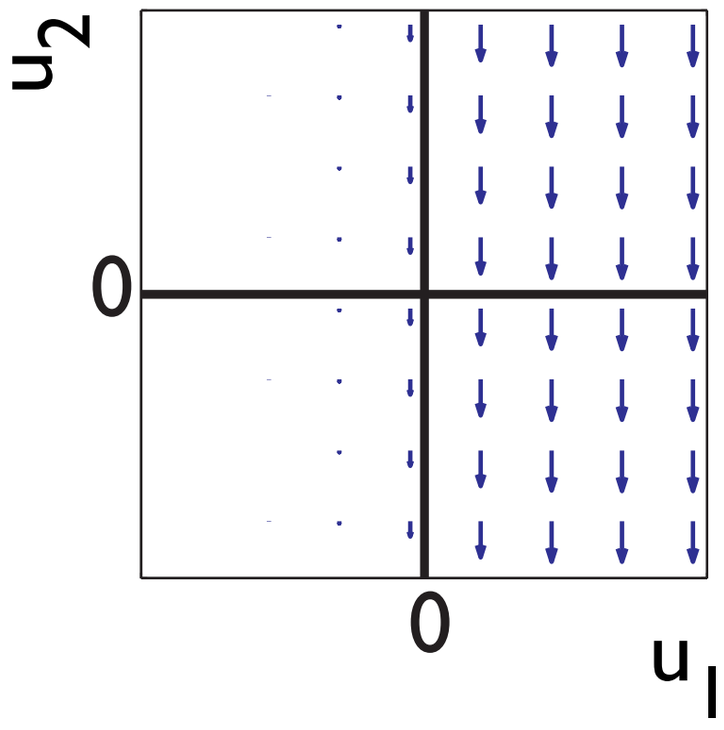
sigmoidal nonlinearity



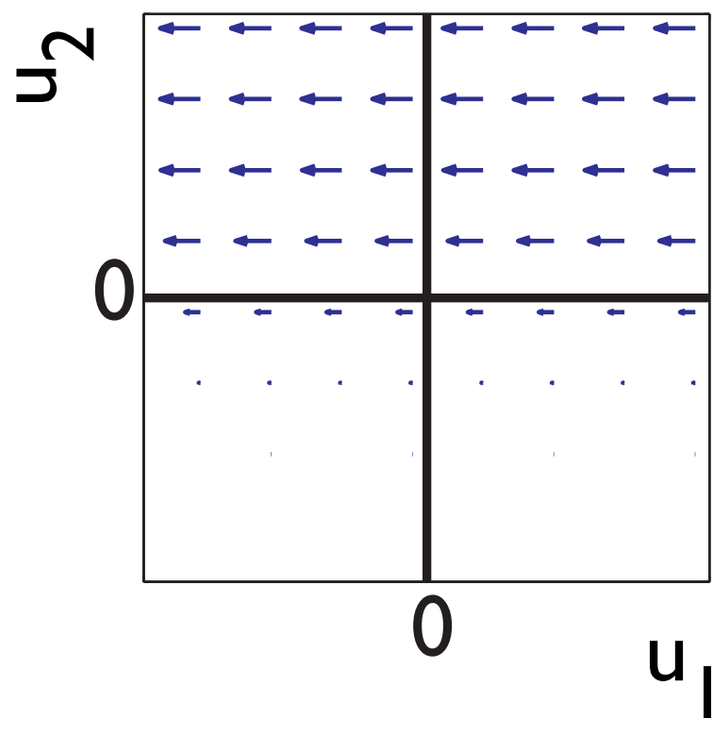
Neuronal dynamics with competition

- vector-field of mutual inhibition

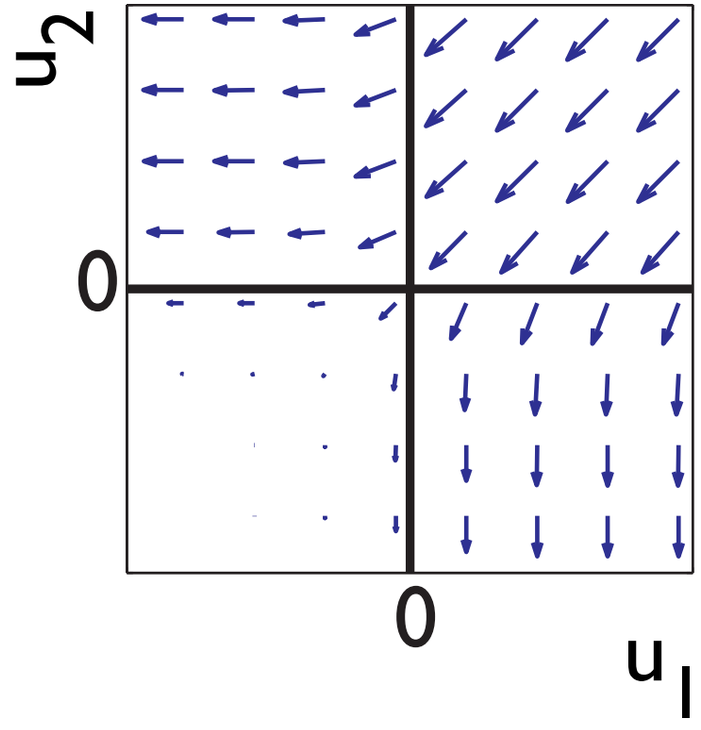
site 1 inhibits site 2



site 2 inhibits site 1



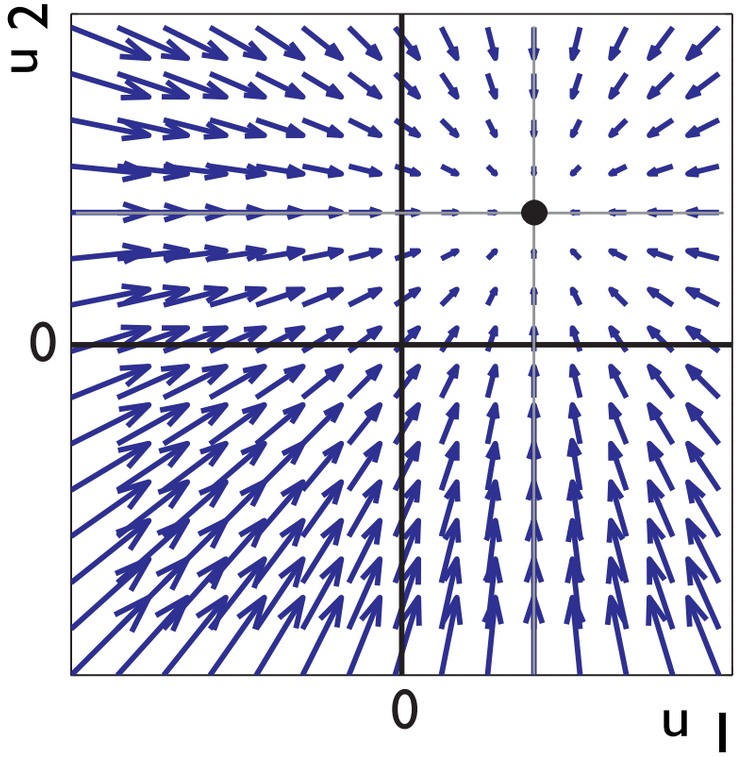
interaction combined



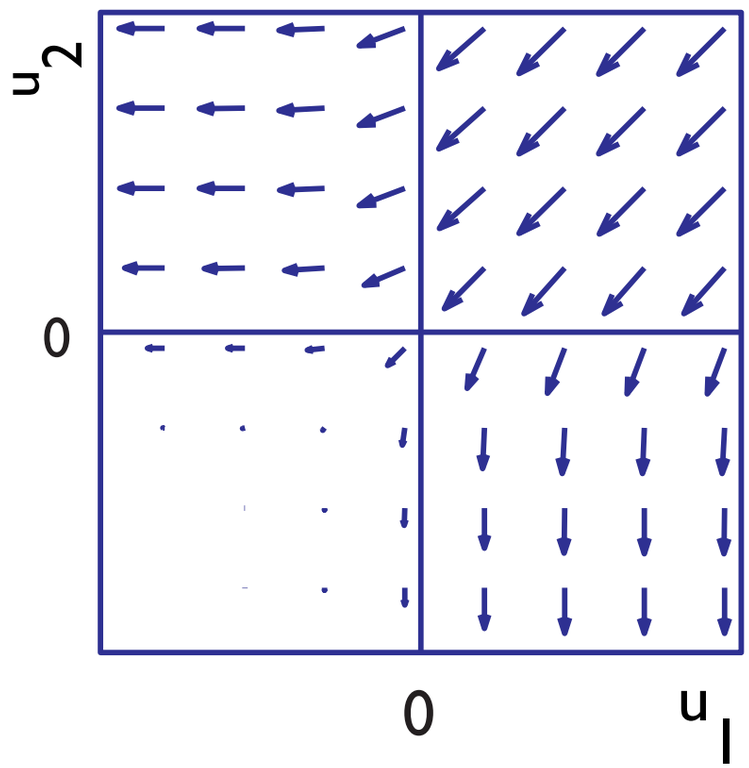
Neuronal dynamics with competition

vector-field with strong mutual inhibition: bistable

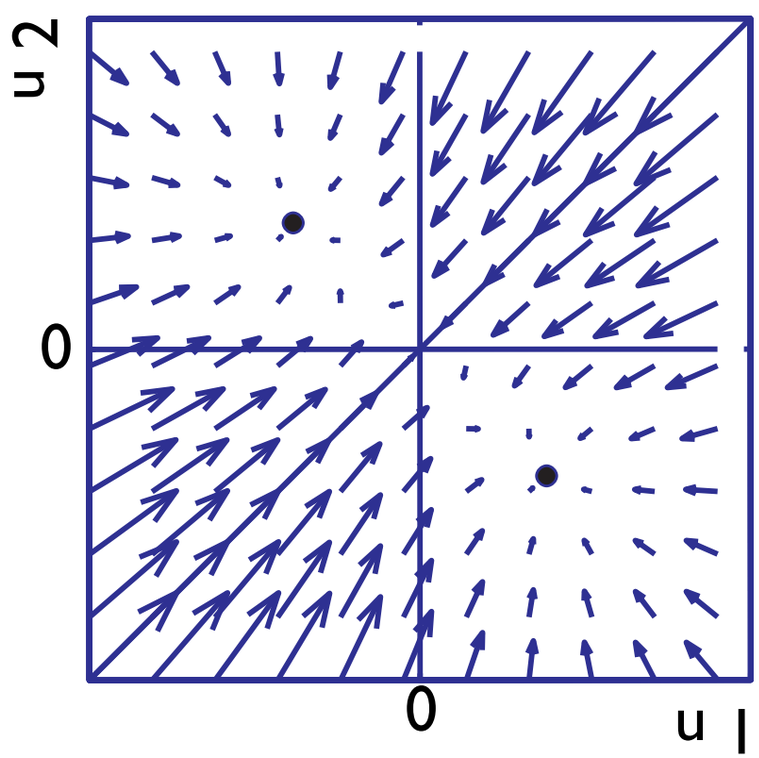
input



interaction

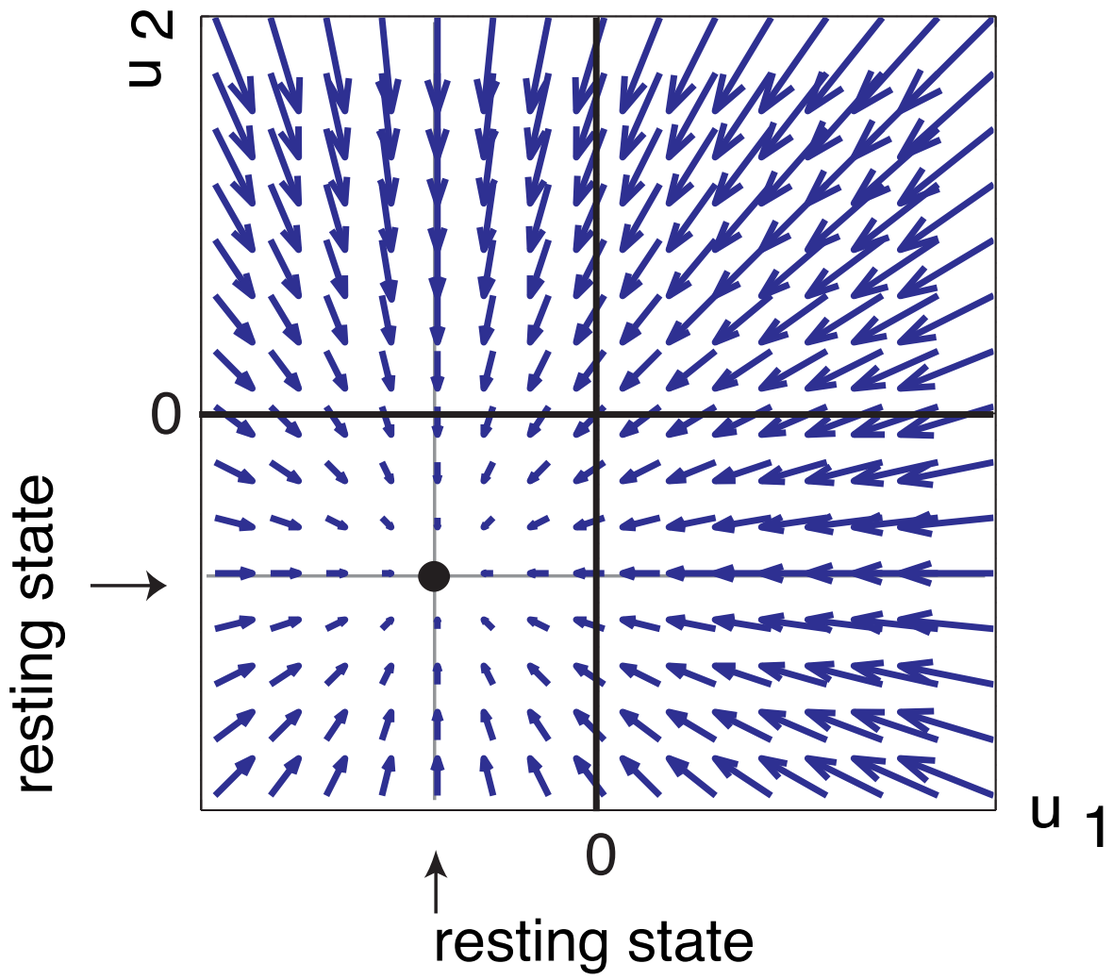


total

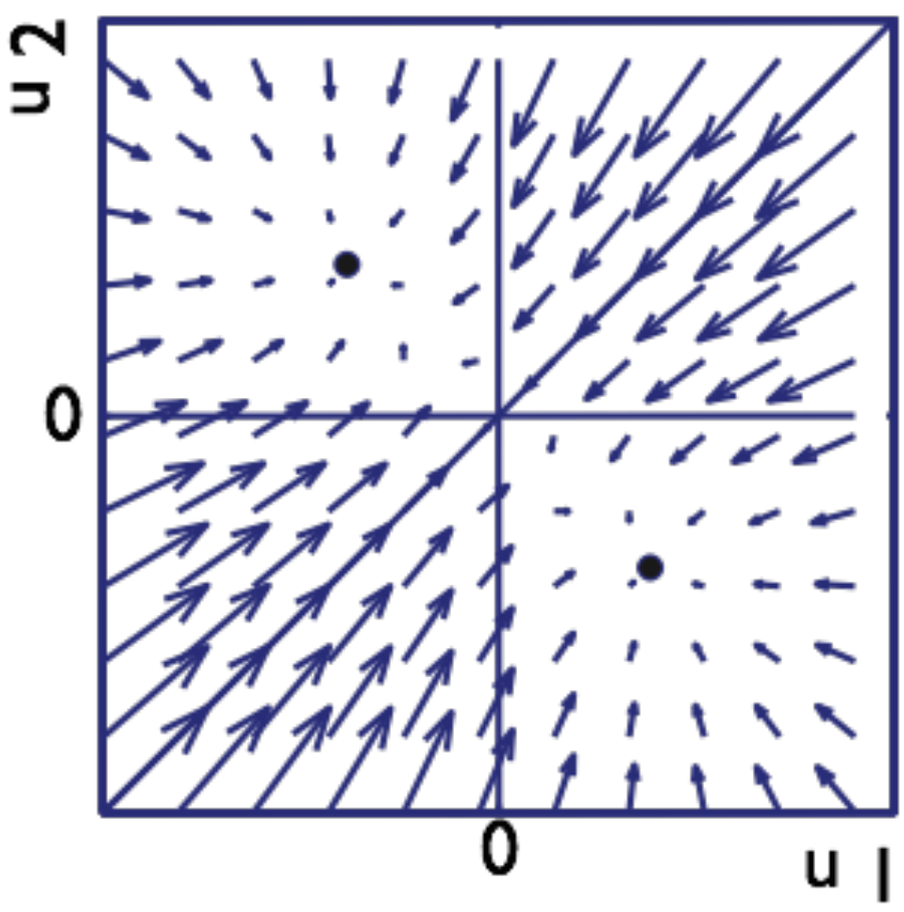


Neuronal dynamics with competition

before input is presented



after input is presented

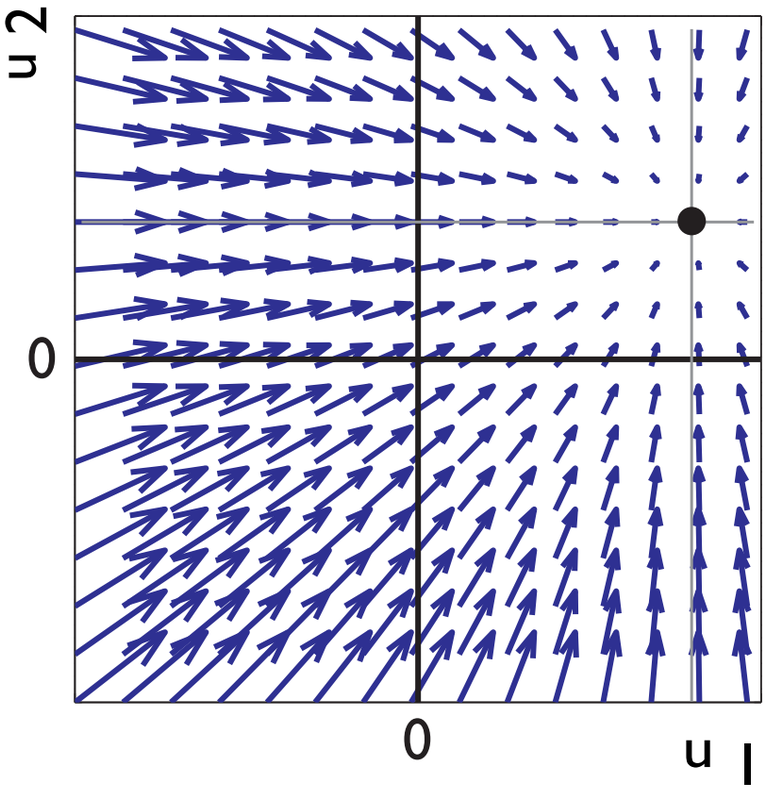


Neuronal dynamics with competition

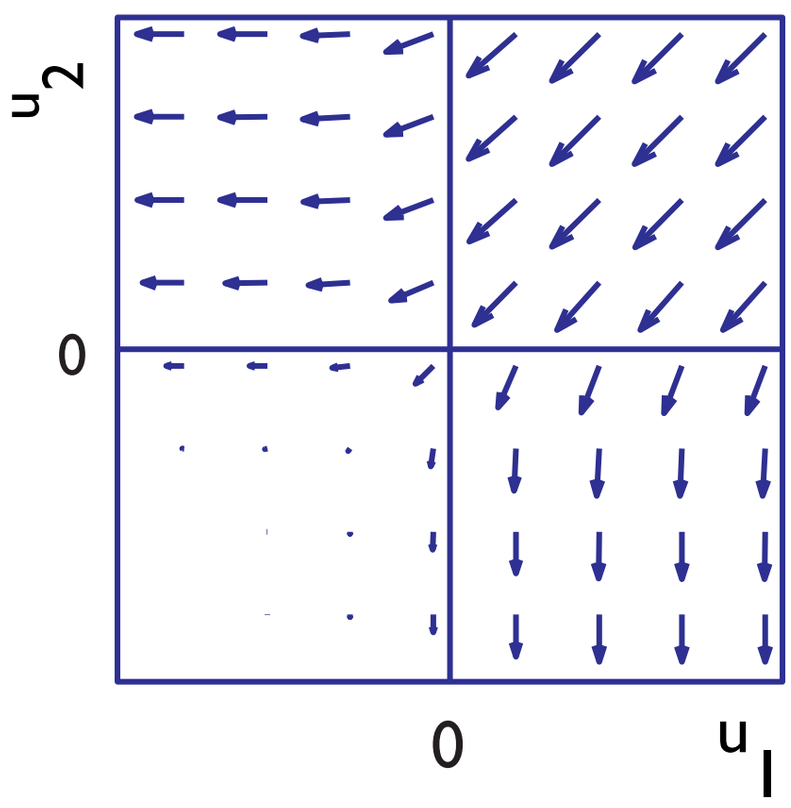
=>biased competition

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

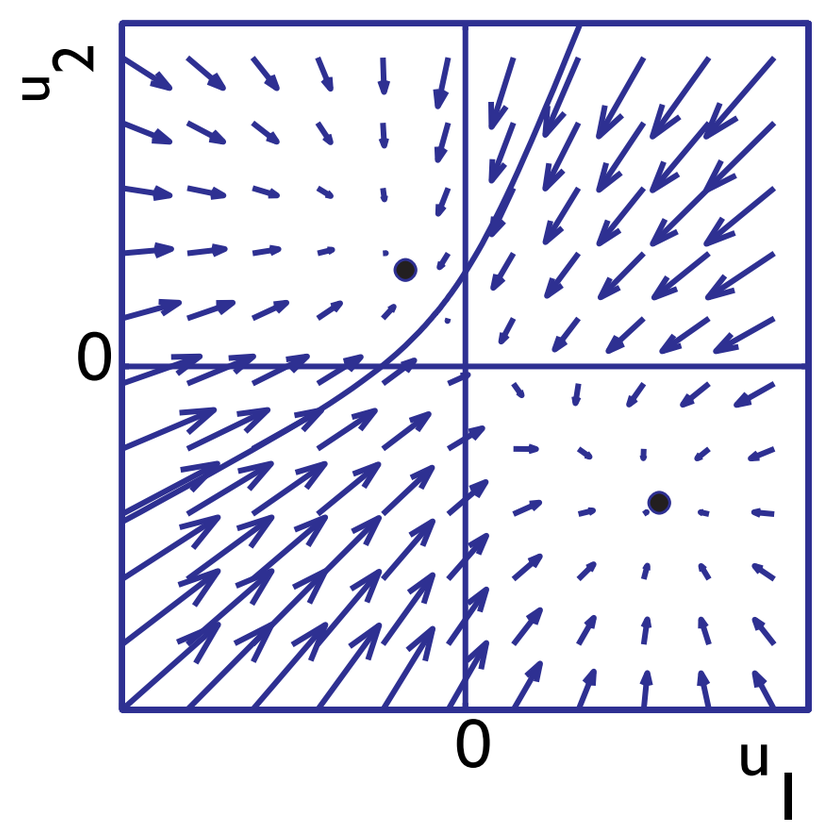
input



interaction



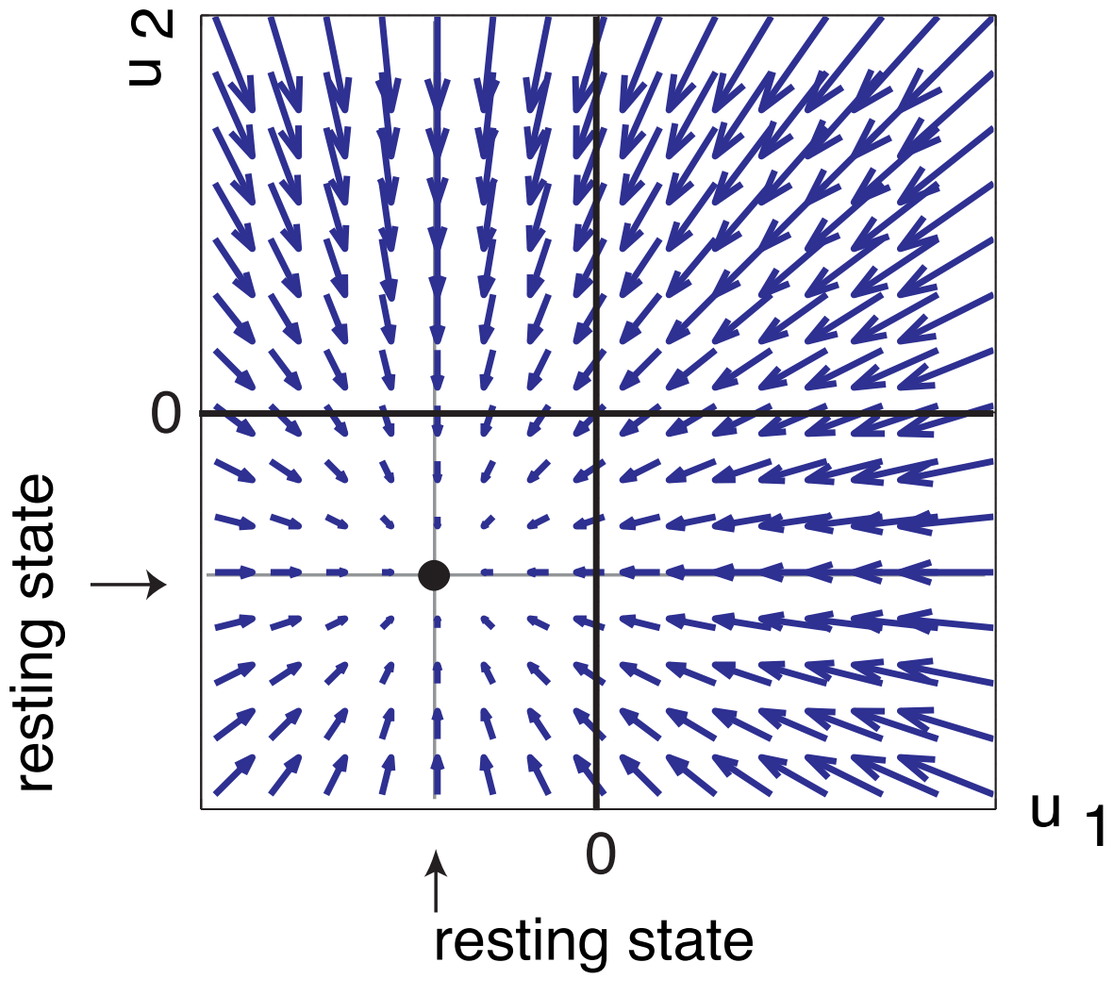
total



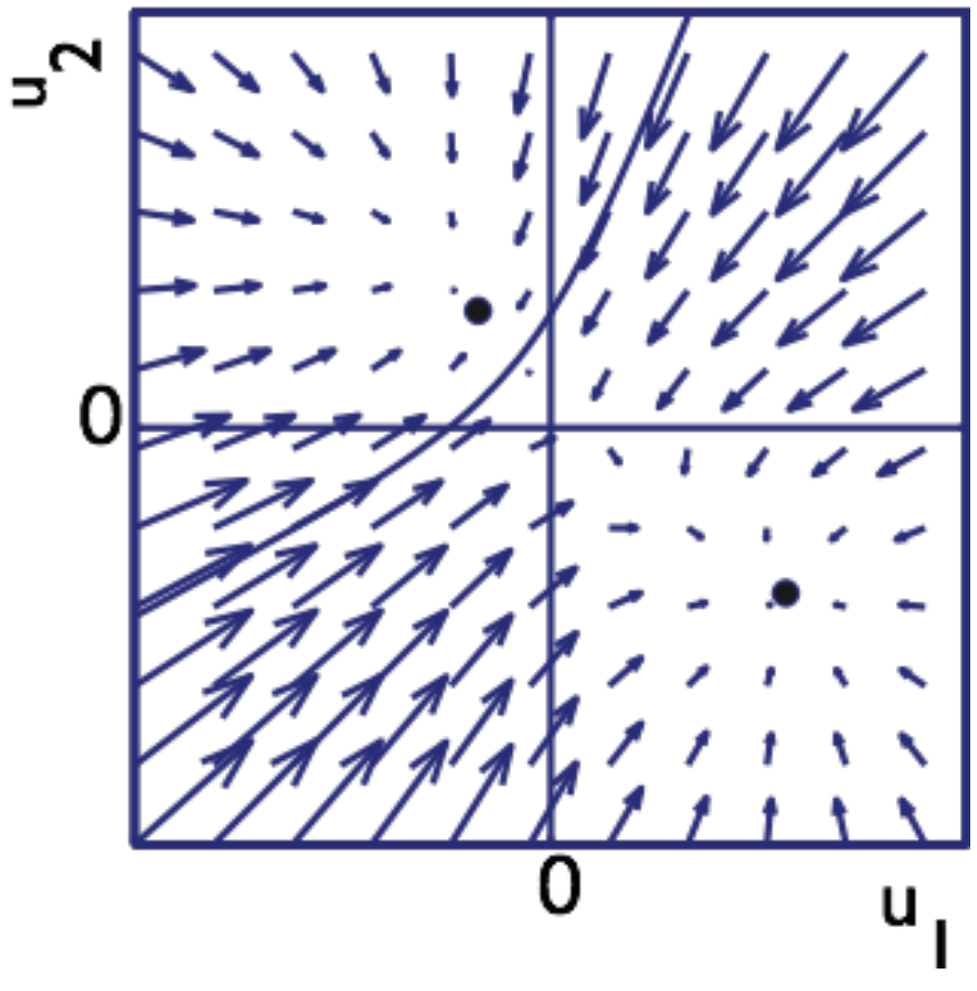
Neuronal dynamics with competition

=>biased competition

before input is presented



after input is presented



- => simulation

Outlook

- Where do activation variables come from? How does an activation variable come to "stand" for a behavior or percept ?

- How do discrete activation variables reflect continuous behaviors?

- => DFT lecture