Neural Dynamics

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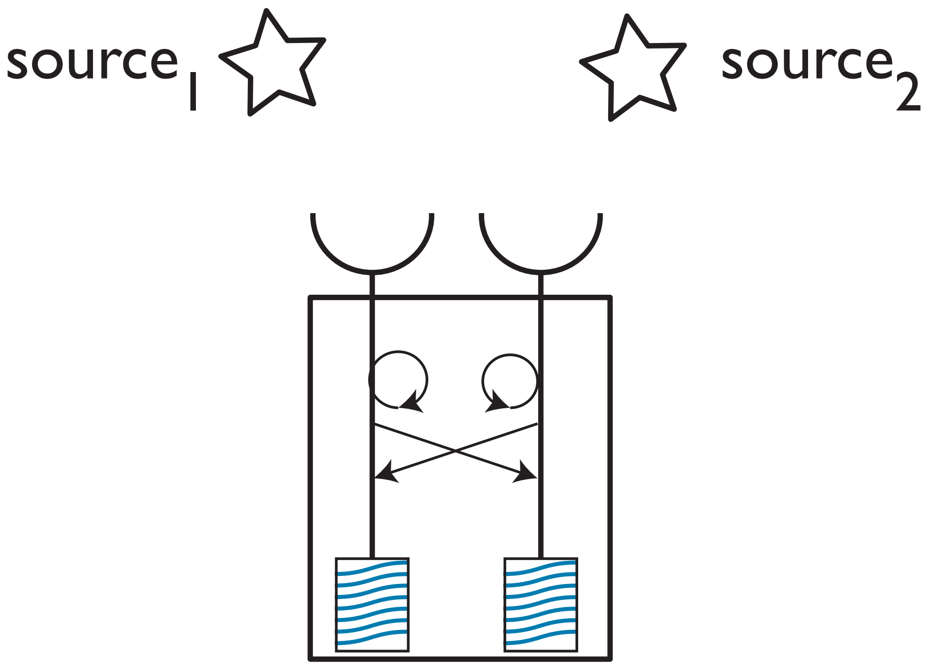
Activation

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

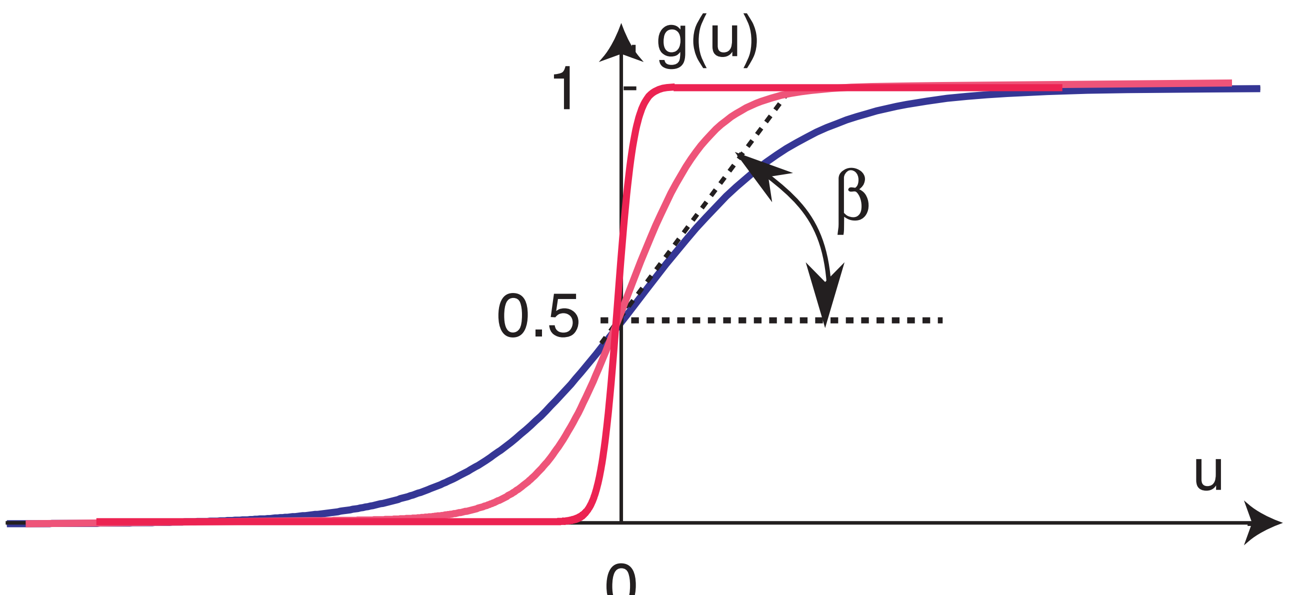


Activation

- neural state variables
  - membrane potential of neurons?
  - spiking rate?
  - ... population activation...

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



Activation

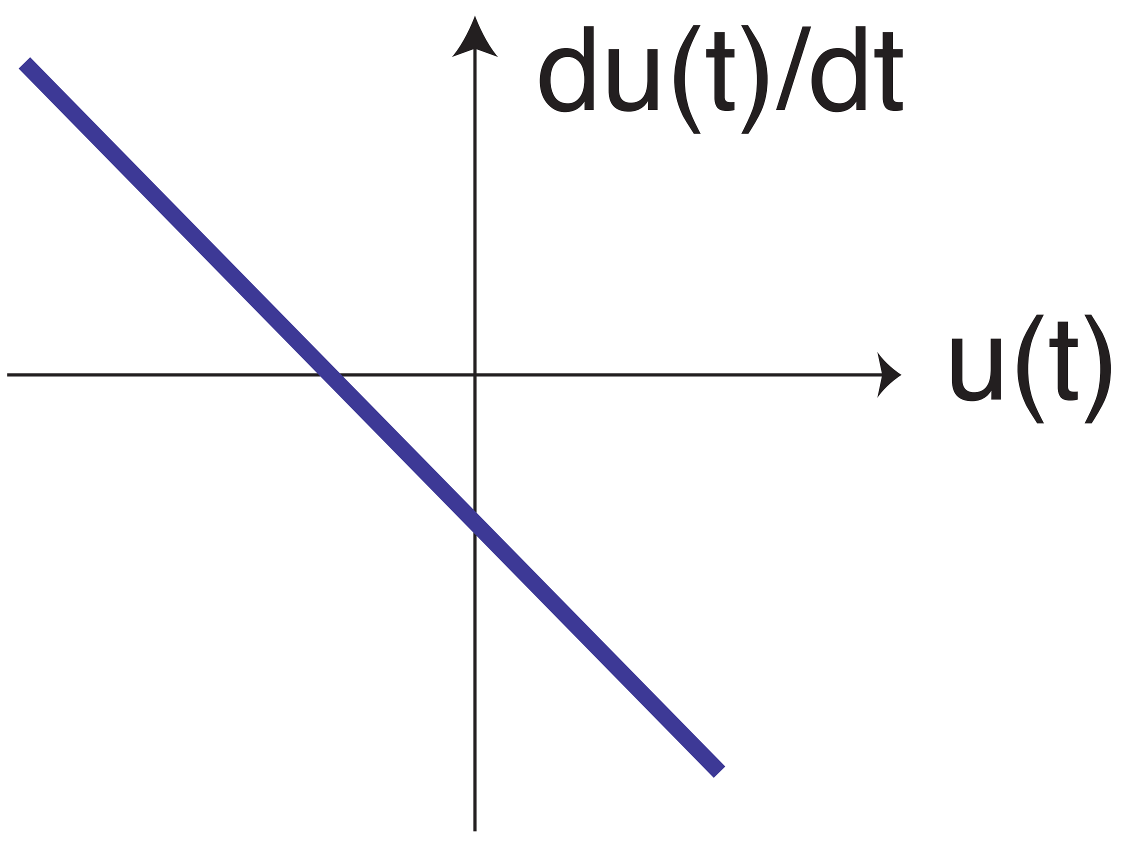
- compare to connectionist notion of activation:
  - same idea, but tied to individual neurons
- compare to abstract activation of production systems (ACT-R, SOAR)
  - different... really a function that measures how far a module is from emitting its output...
  - but related: sigmoidal function gives meaning to activation

Activation dynamics

- activation variables u(t) as time continuous functions...

$$\tau \dot{u}(t) = f(u)$$

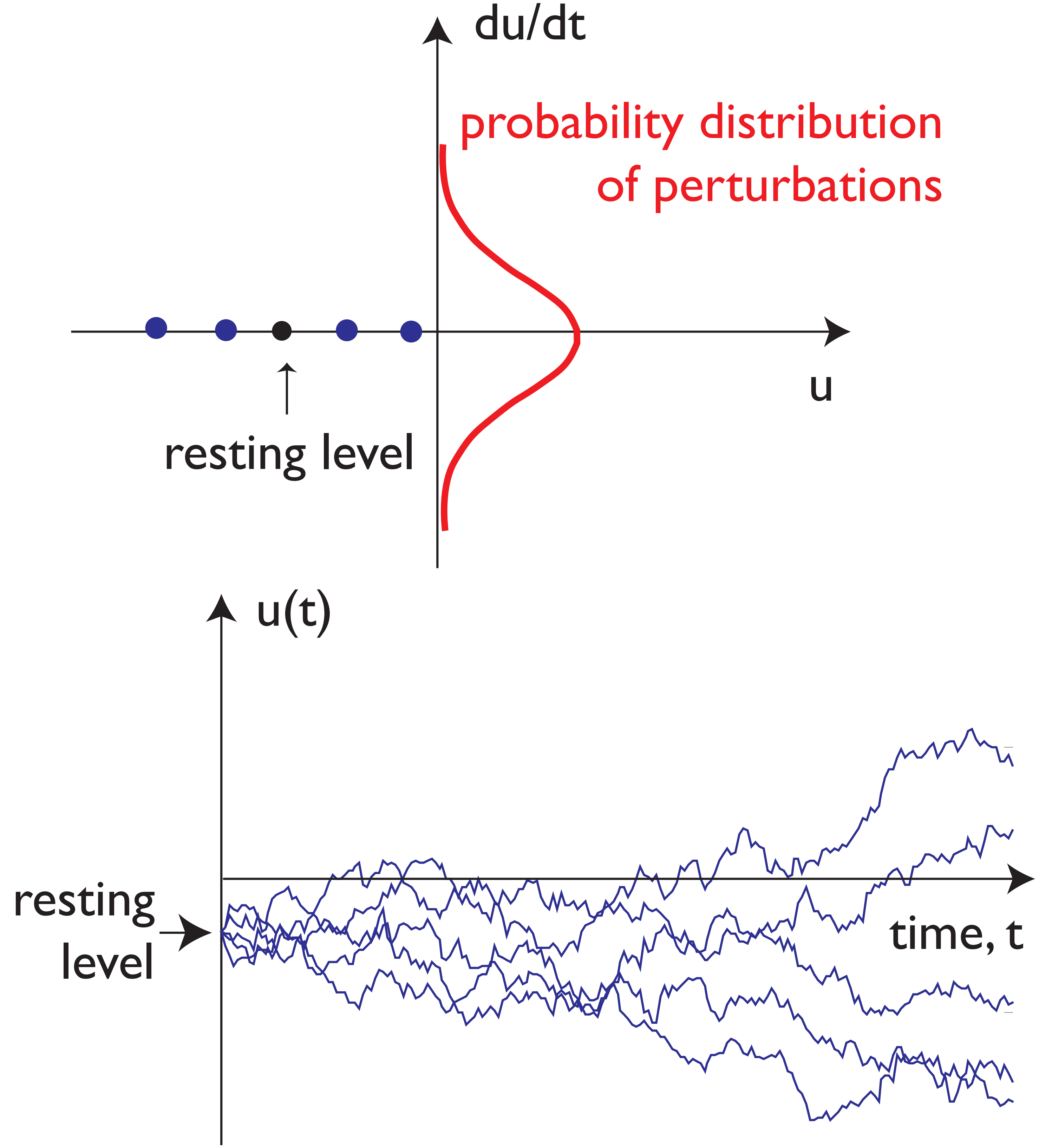
- what function f?



Activation dynamics

- start with f=0

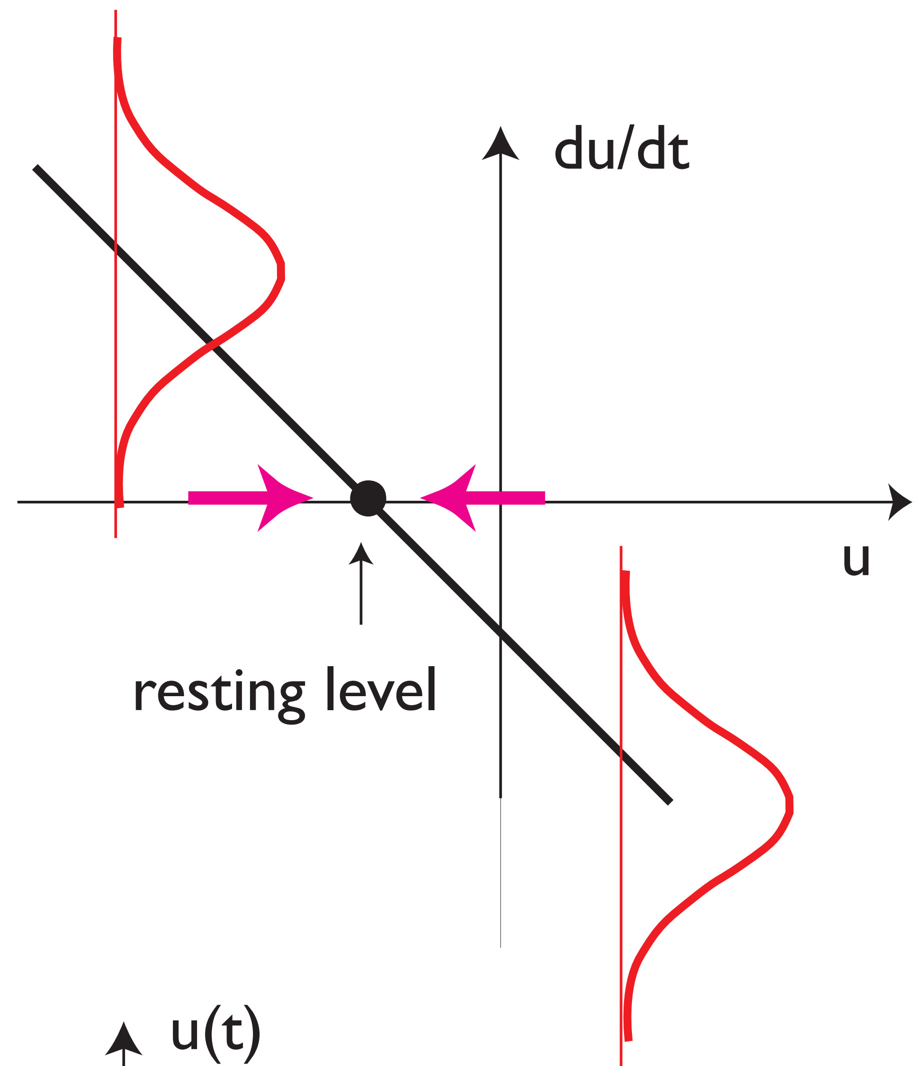
$$\tau \dot{u} = \xi_t$$

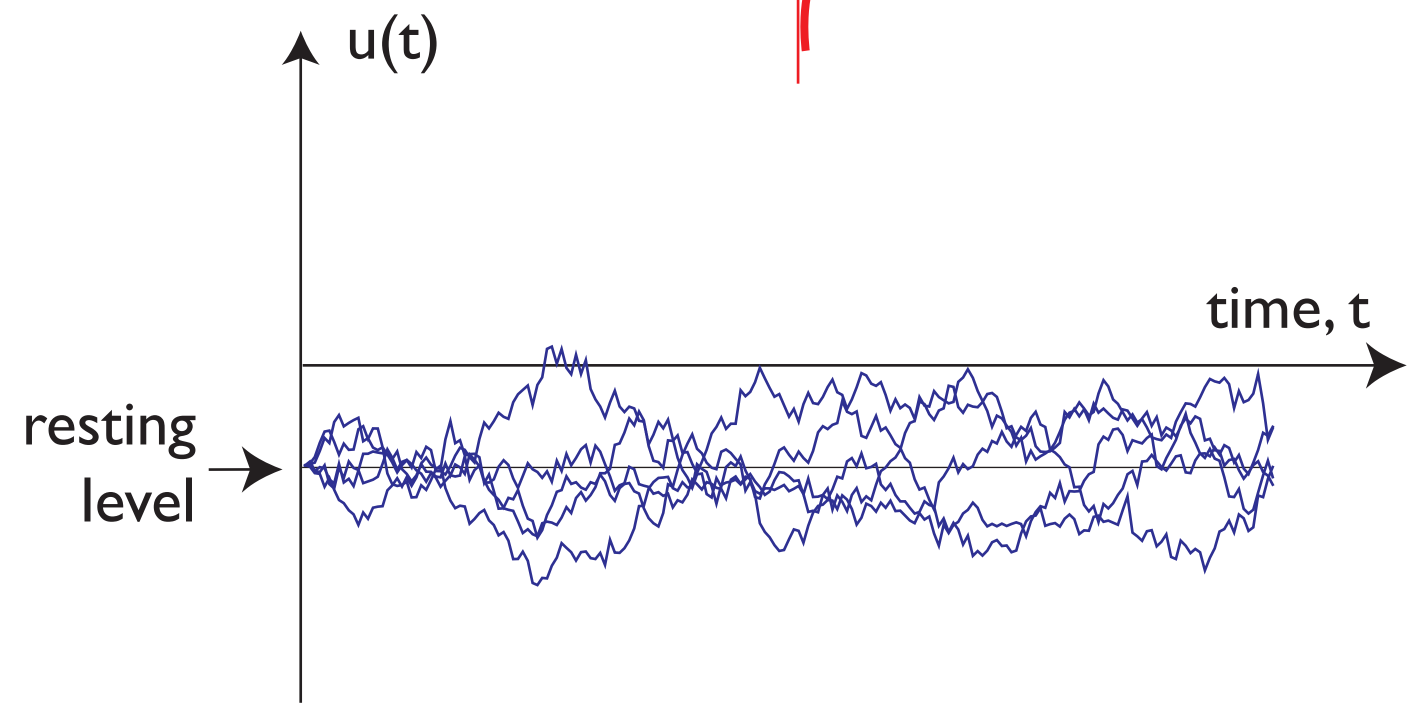


Activation dynamics

- need stabilization

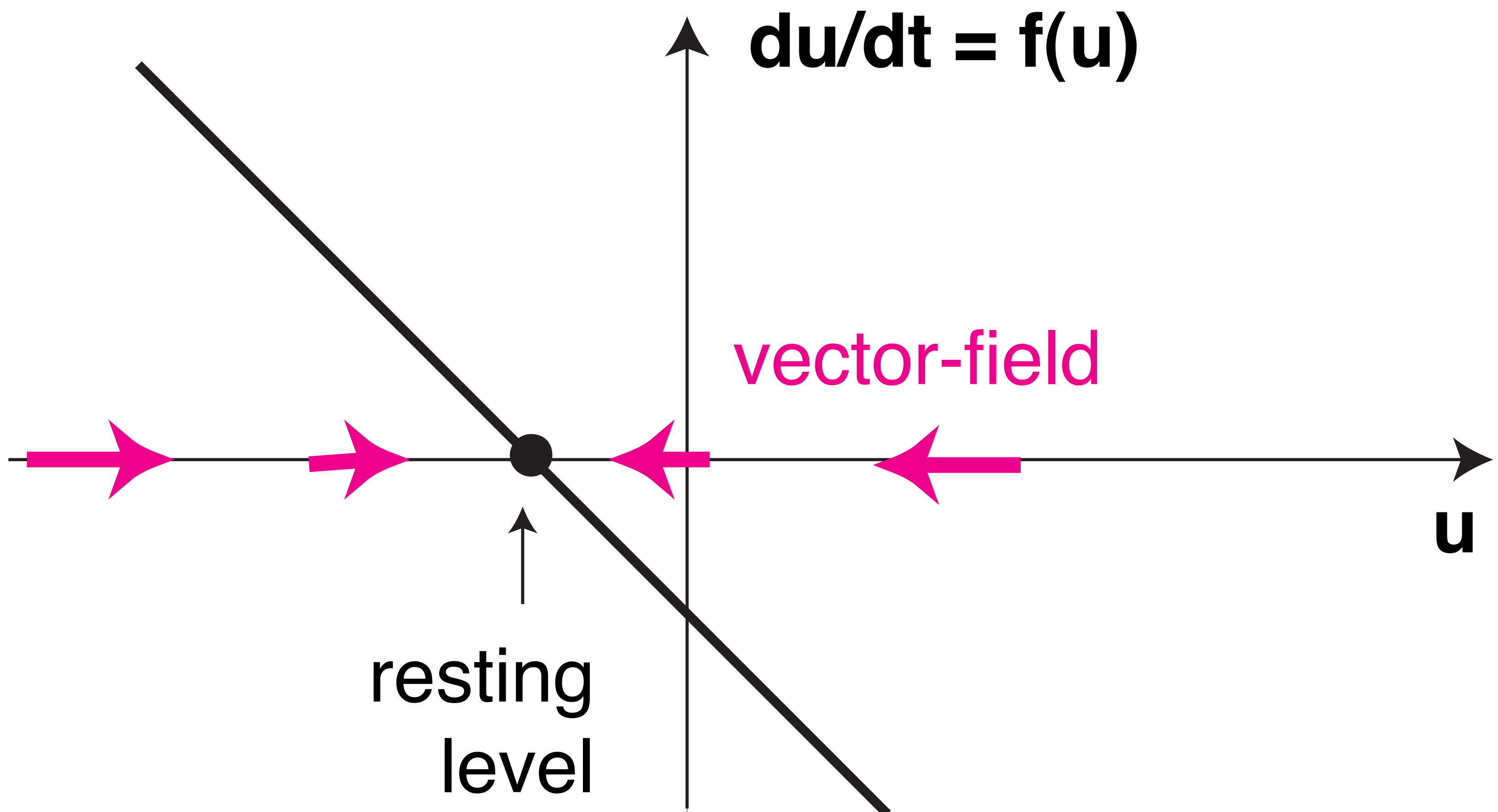
$$\tau \dot{u} = -u + h + \xi_t.$$





Neural dynamics

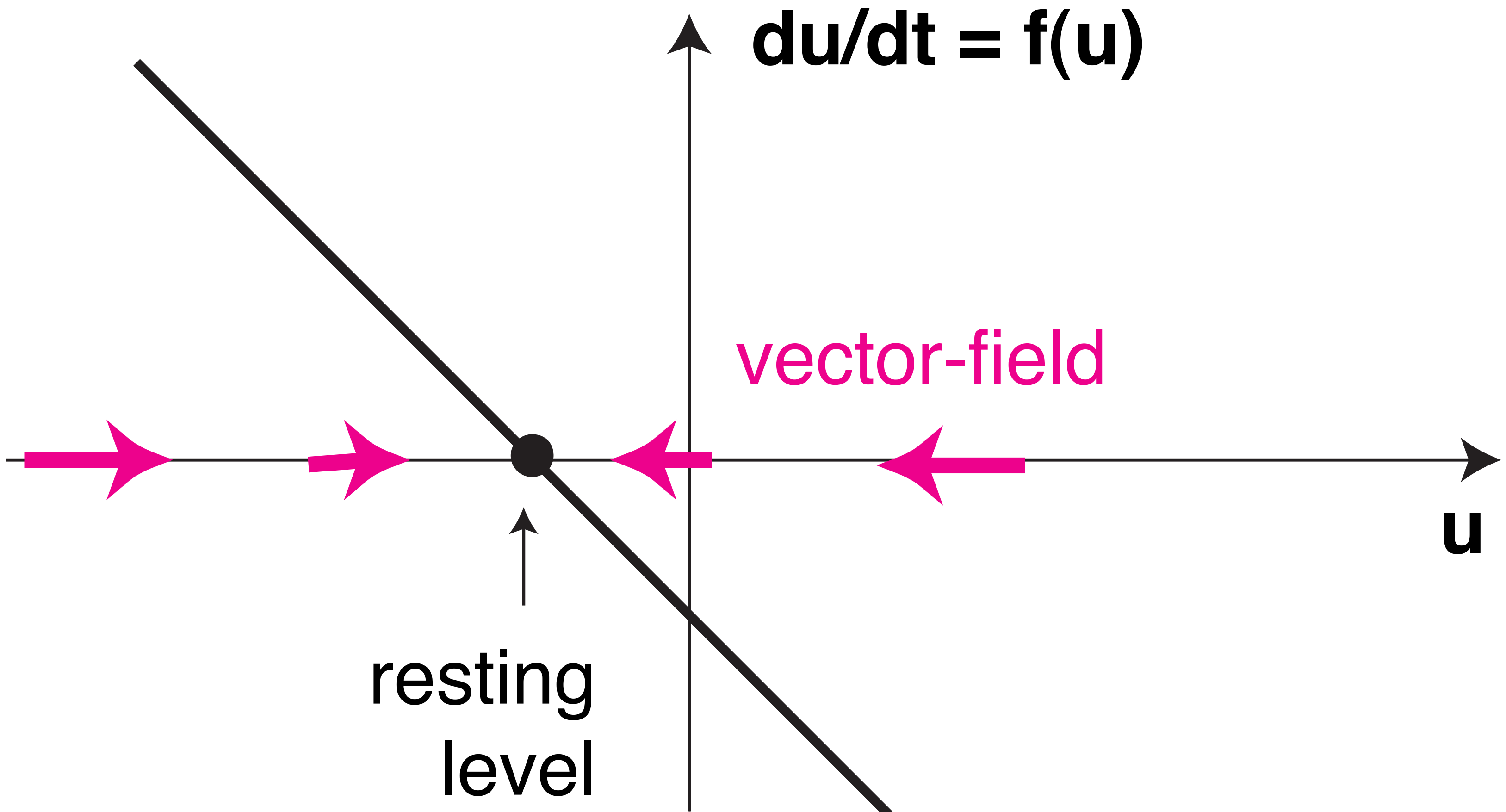
- In a dynamical system, the present predicts the future: given the initial level of activation u(0), the activation at time t: u(t) is uniquely determined



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

Neural dynamics

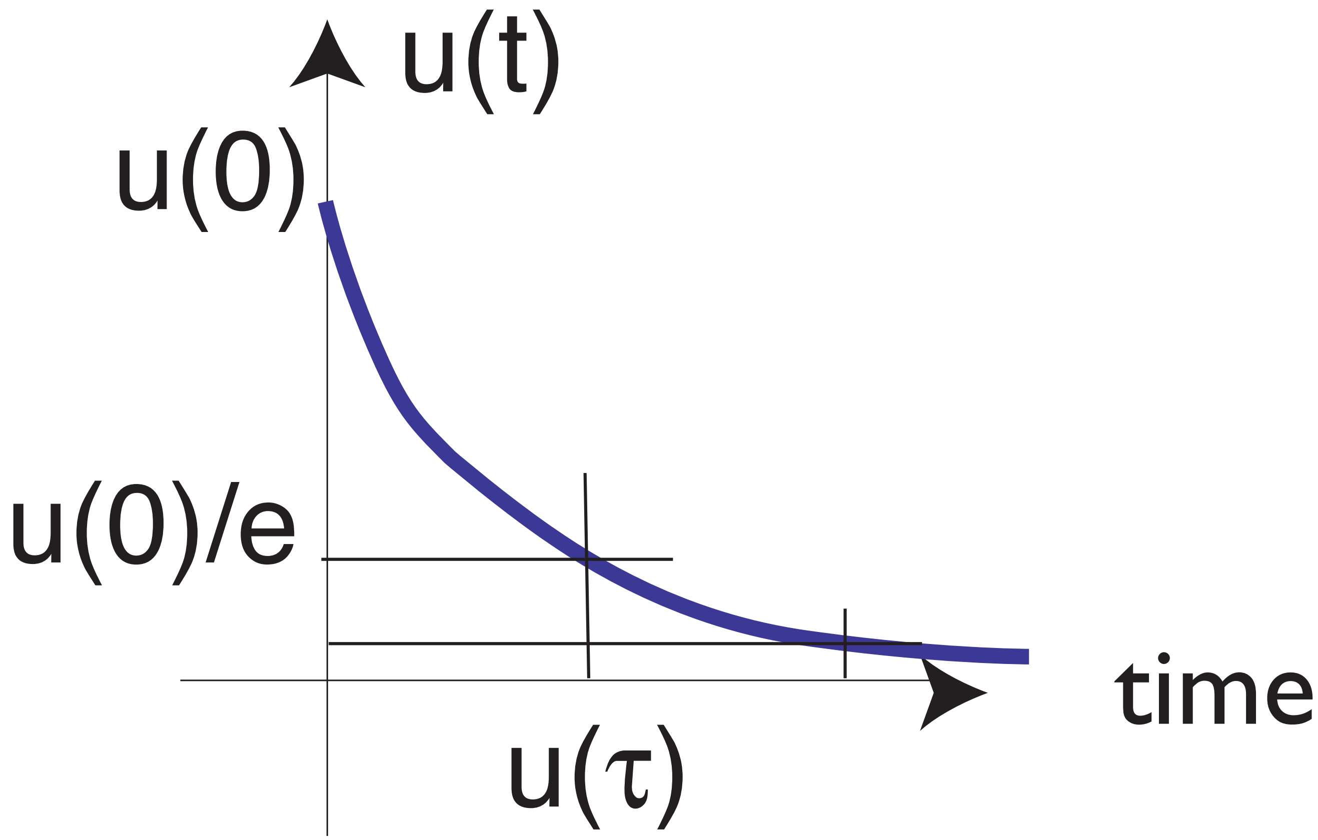
- stationary state=fixed point= constant solution
- stable fixed point: nearby solutions converge to the fixed point=attractor

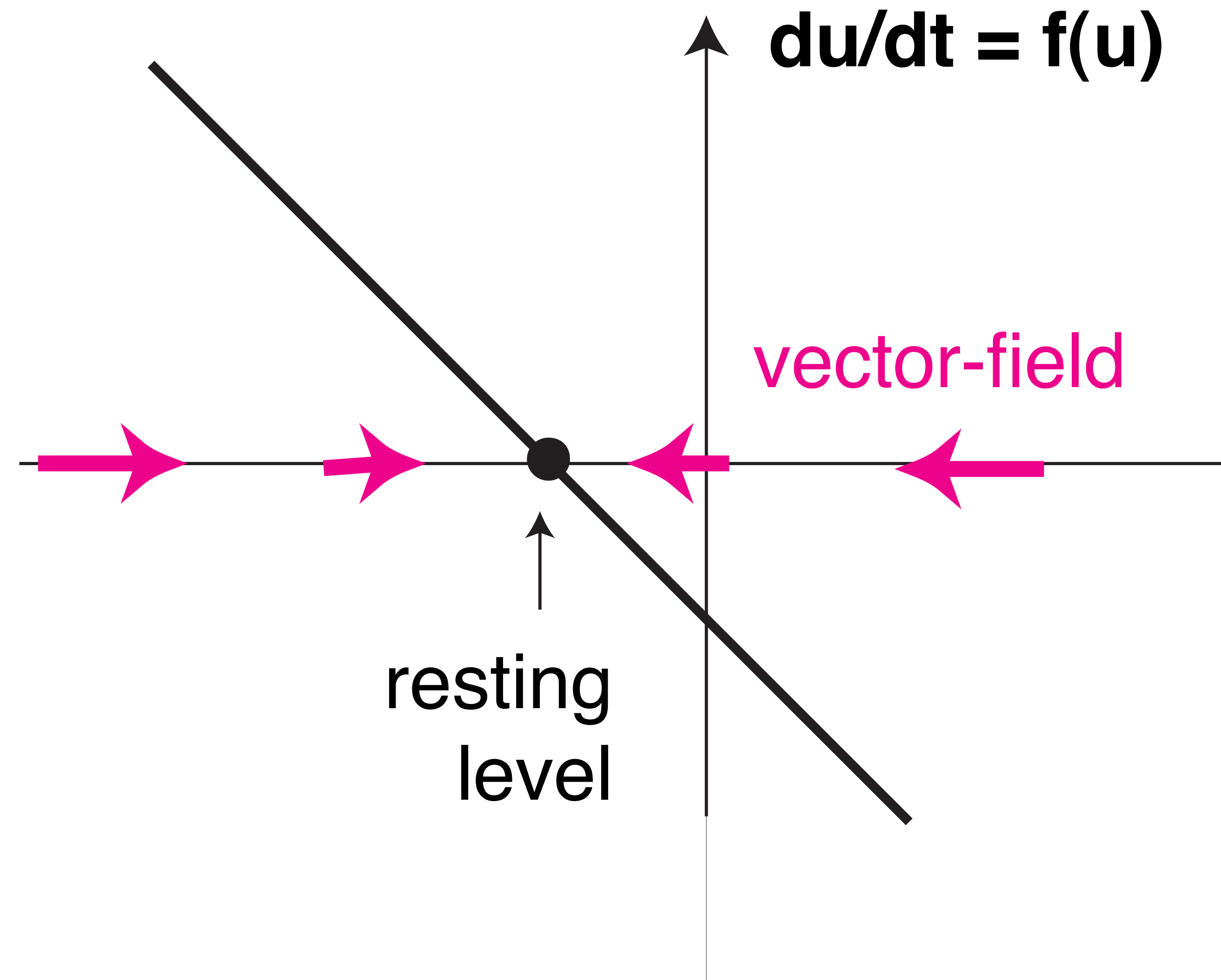


$$\frac{du(t)}{dt} = \dot{u}(t) = -u(t) + h \qquad (h < 0)$$

Neural dynamics

- exponential relaxation to fixed-point attractors
- => time scale

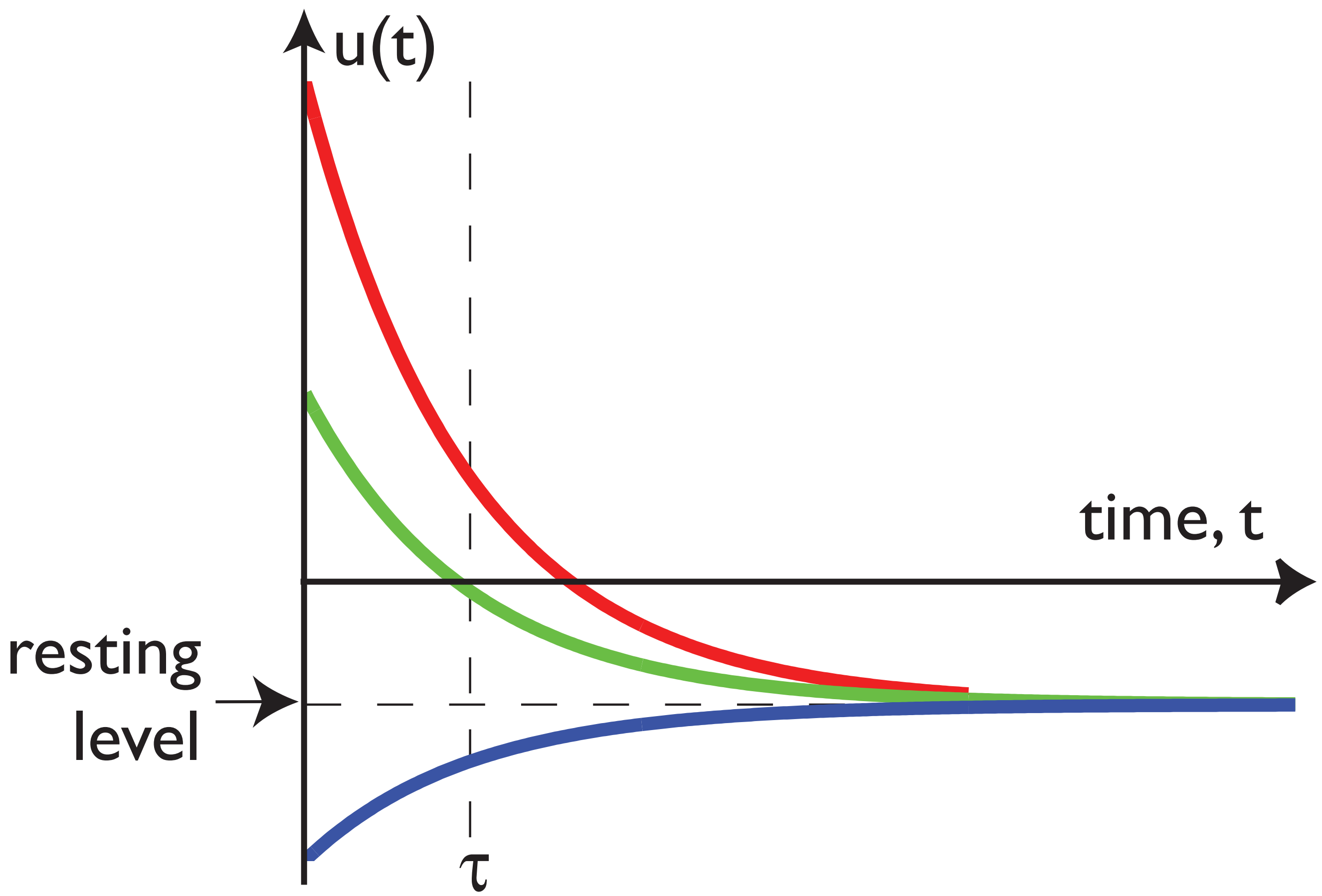


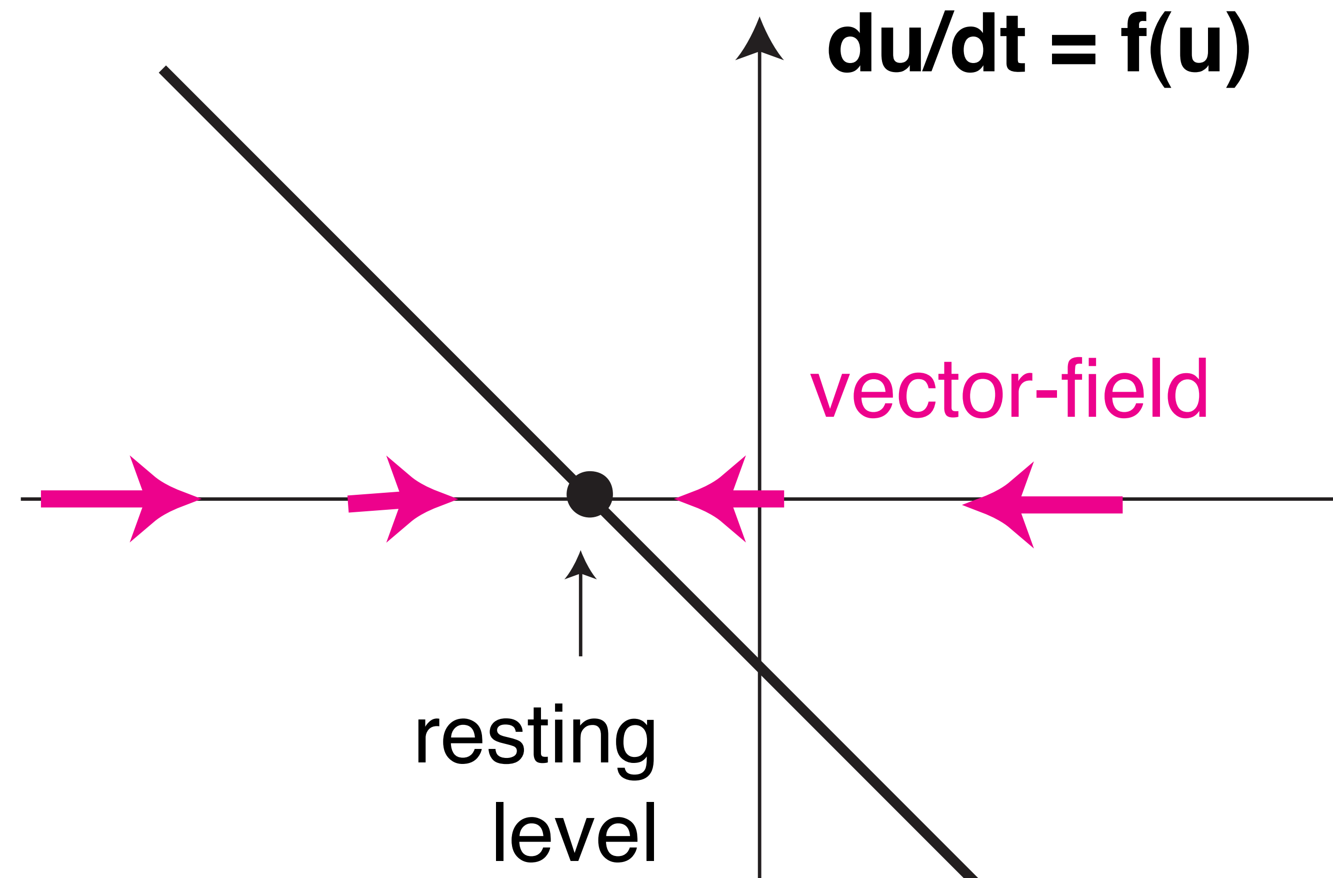


$$\tau \dot{u}(t) = -u(t) + h$$

Neural dynamics

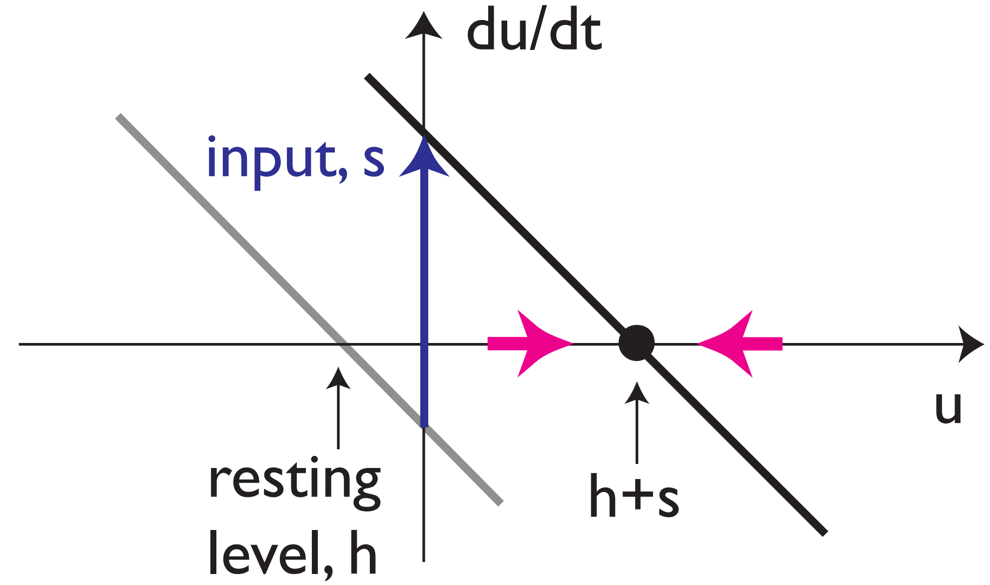
- attractor structures ensemble of solutions=flow



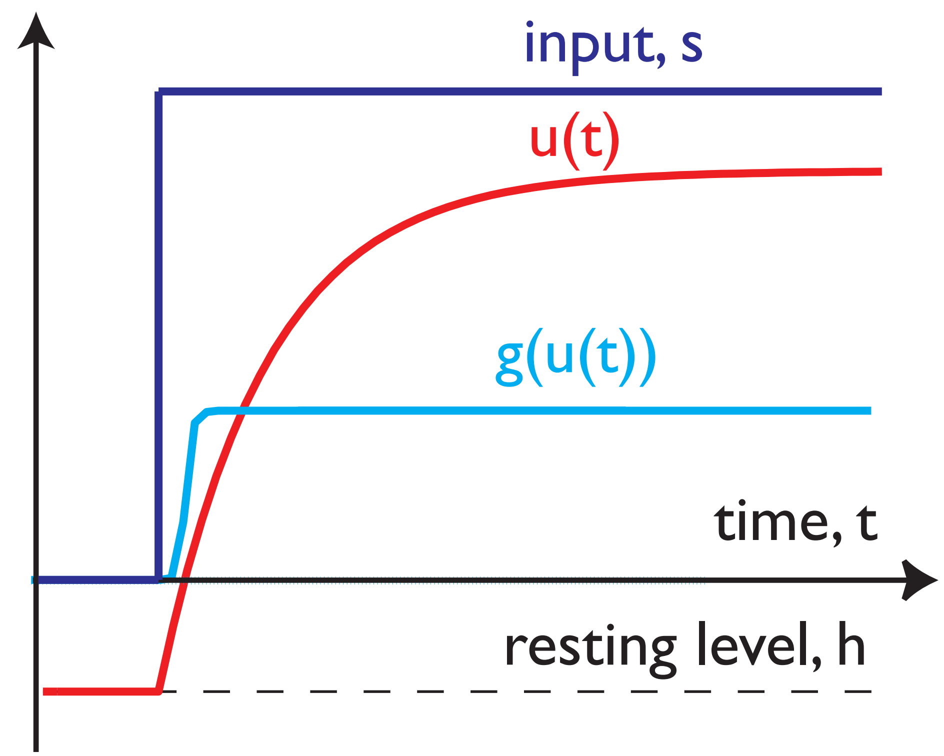


$$\tau \dot{u}(t) = -u(t) + h$$

Neuronal dynamics



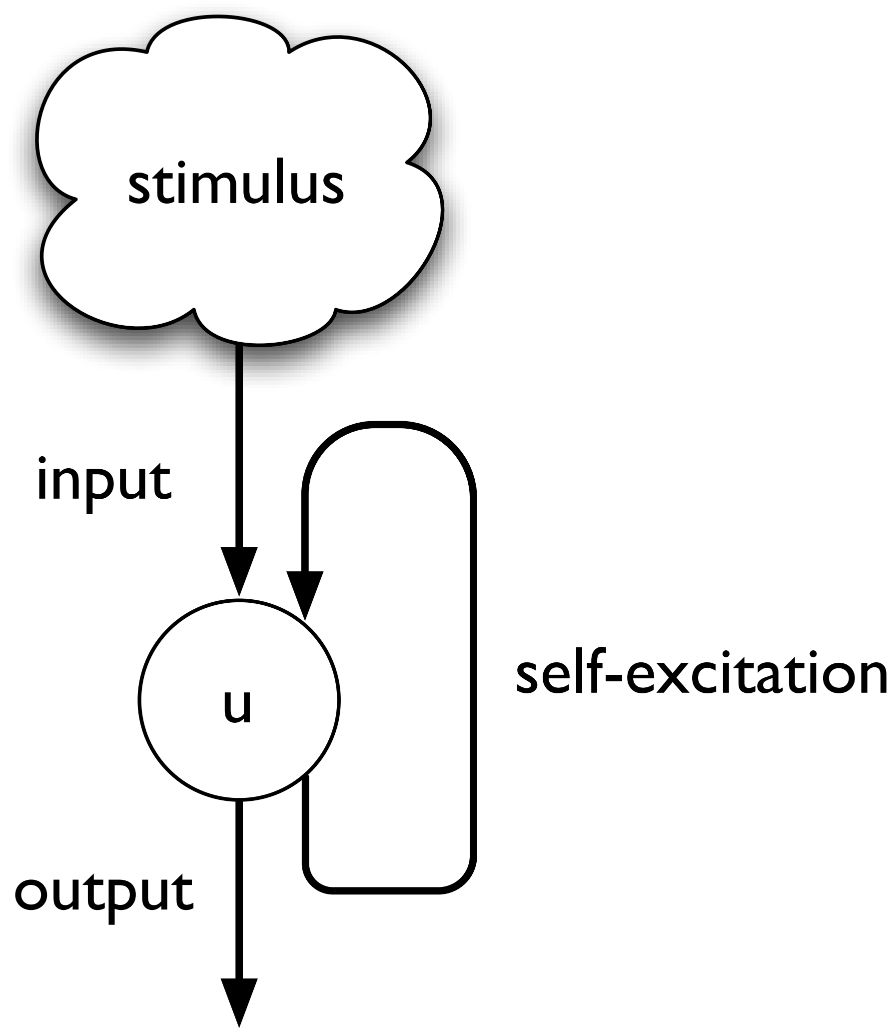
- inputs=contributions to the rate of change
  - positive: excitatory
  - negative: inhibitory
- => shifts the attractor
- activation tracks this shift (stability)

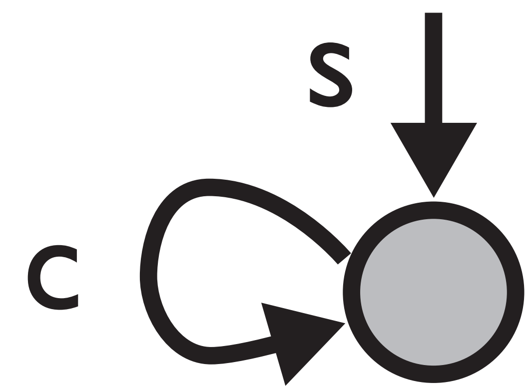


$$\tau \dot{u}(t) = -u(t) + h + \text{ inputs(t)}$$

=> simulation in live exercise session

Neuronal dynamics with self-excitation

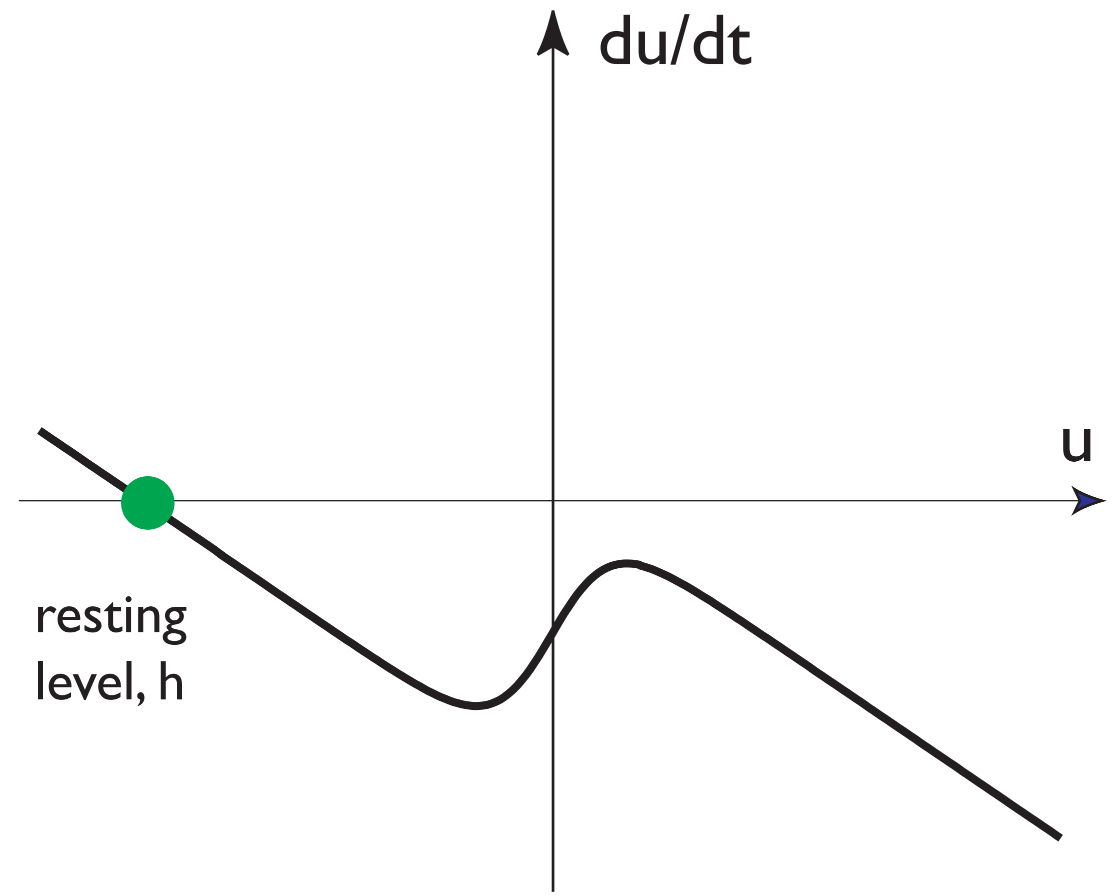




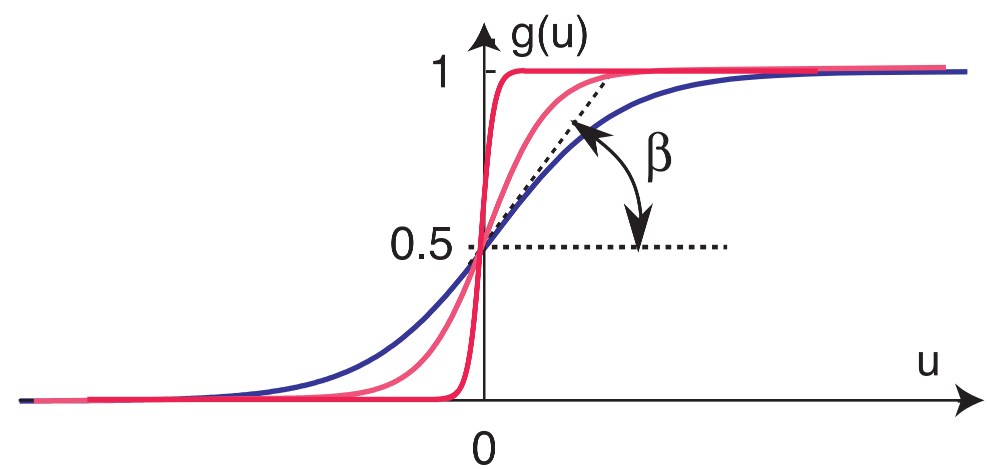
$$\tau \dot{u}(t) = -u(t) + h + s(t) + c\ g(u(t))$$

Neuronal dynamics with self-excitation

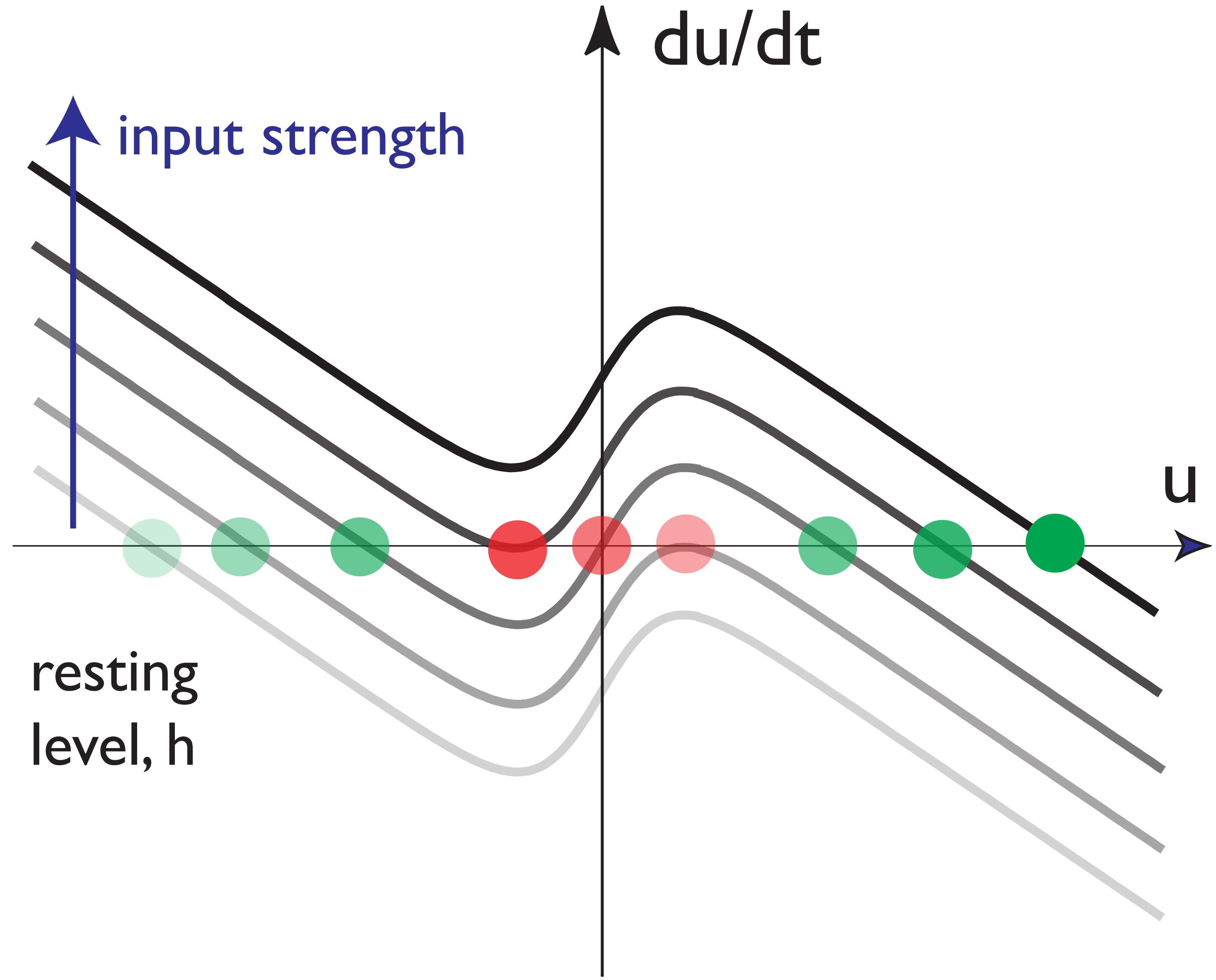
$$\tau \dot{u}(t) = -u(t) + h + s(t) + c\, g(u(t))$$



- => nonlinear dynamics!

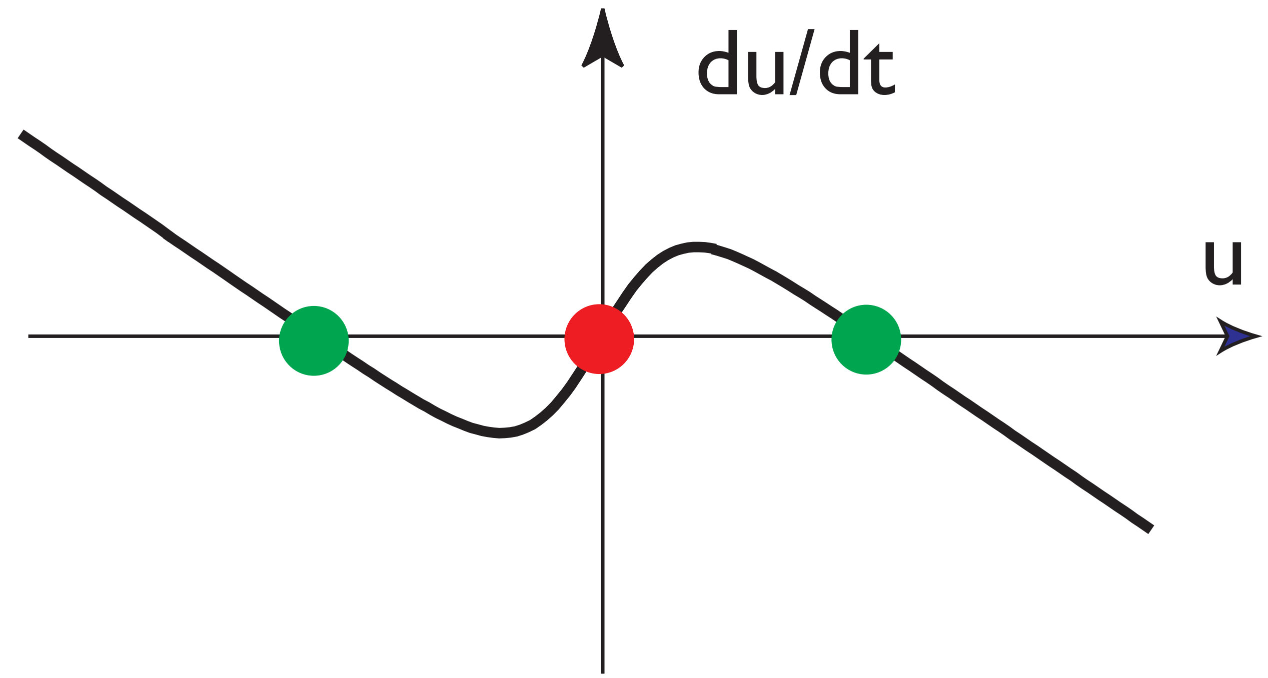


Neuronal dynamics with self-excitation

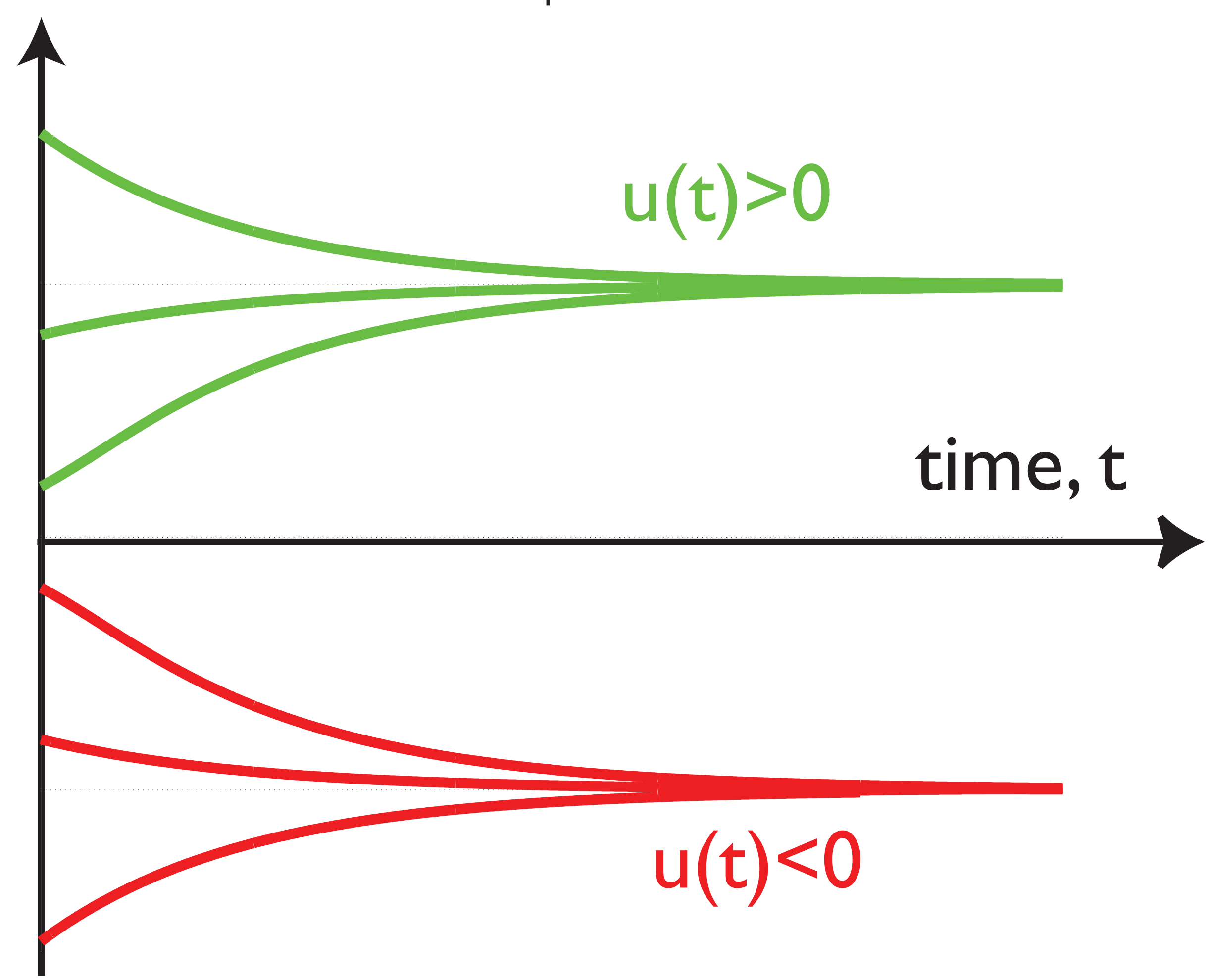


$$\tau \dot{u}(t) = -u(t) + h + s(t) + c\ g(u(t))$$

Neuronal dynamics with self-excitation



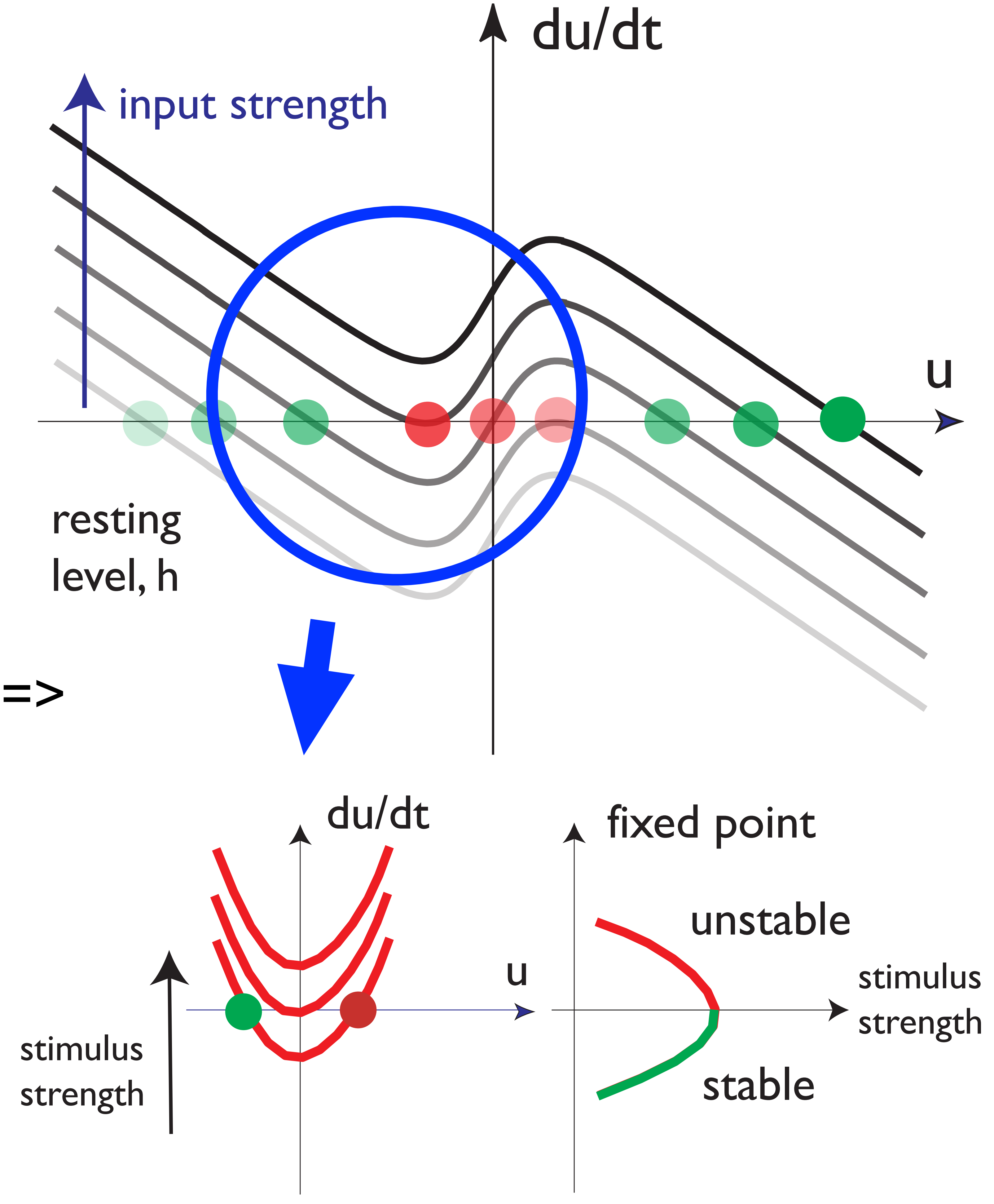
- at intermediate stimulus strength: bistable
- “on” vs “off” state



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

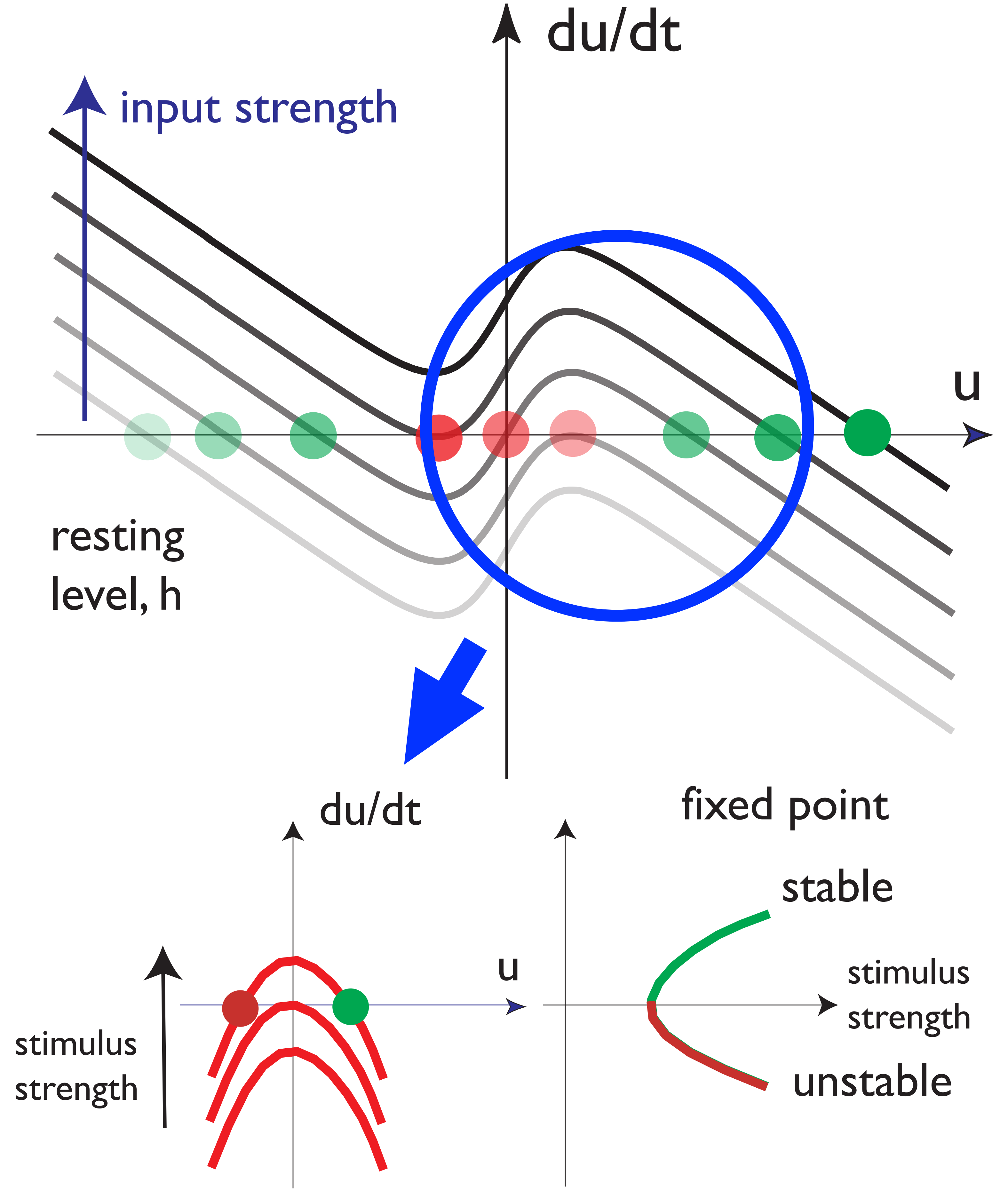
Neuronal dynamics with self-excitation

- increasing input strength => detection instability

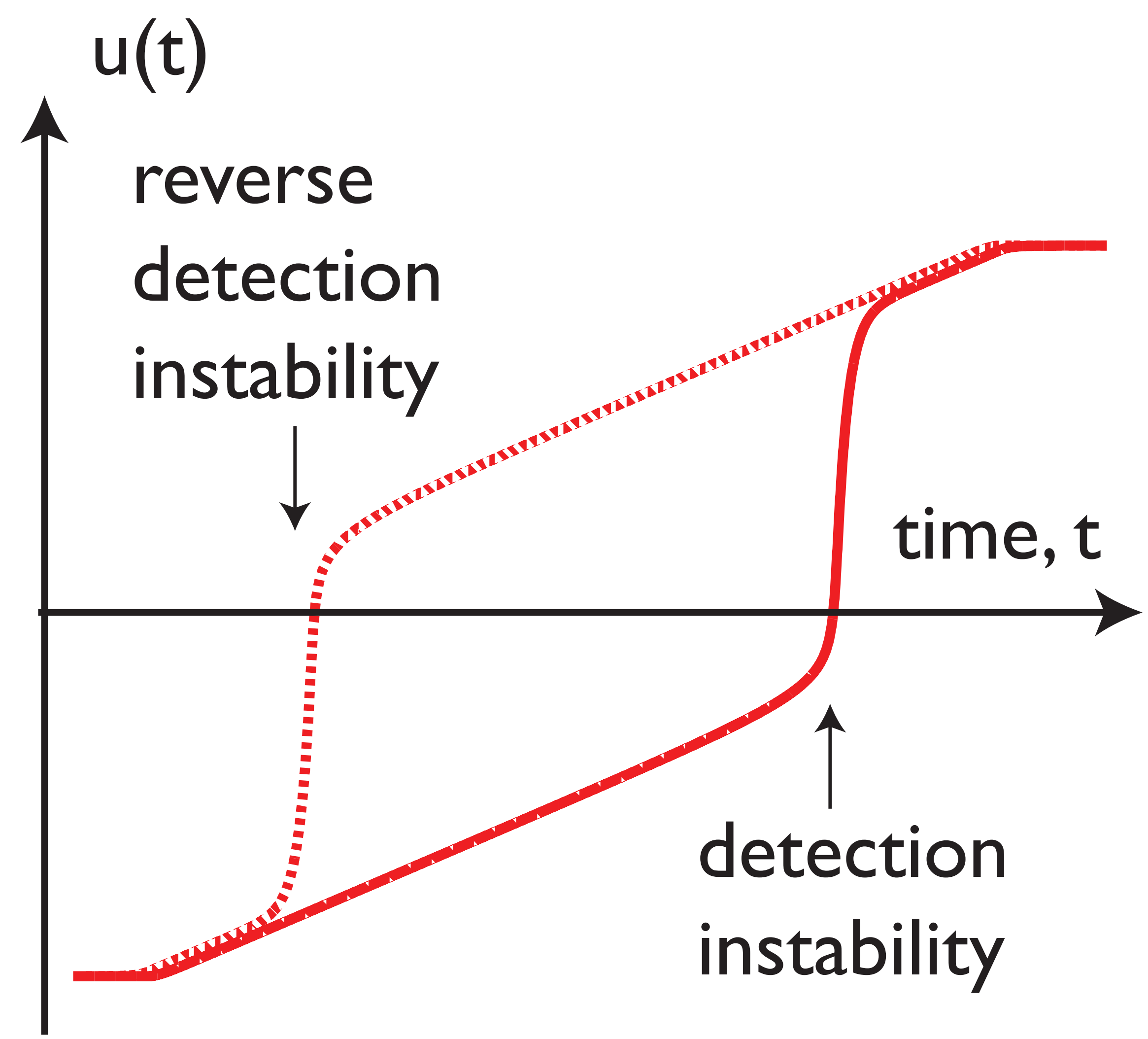


Neuronal dynamics with self-excitation

- decreasing input strength => reverse detection instability



Neuronal dynamics with self-excitation



- the detection and the reverse detection instability create discrete events out of input that changes continuously in time

- => simulation in live exercise session