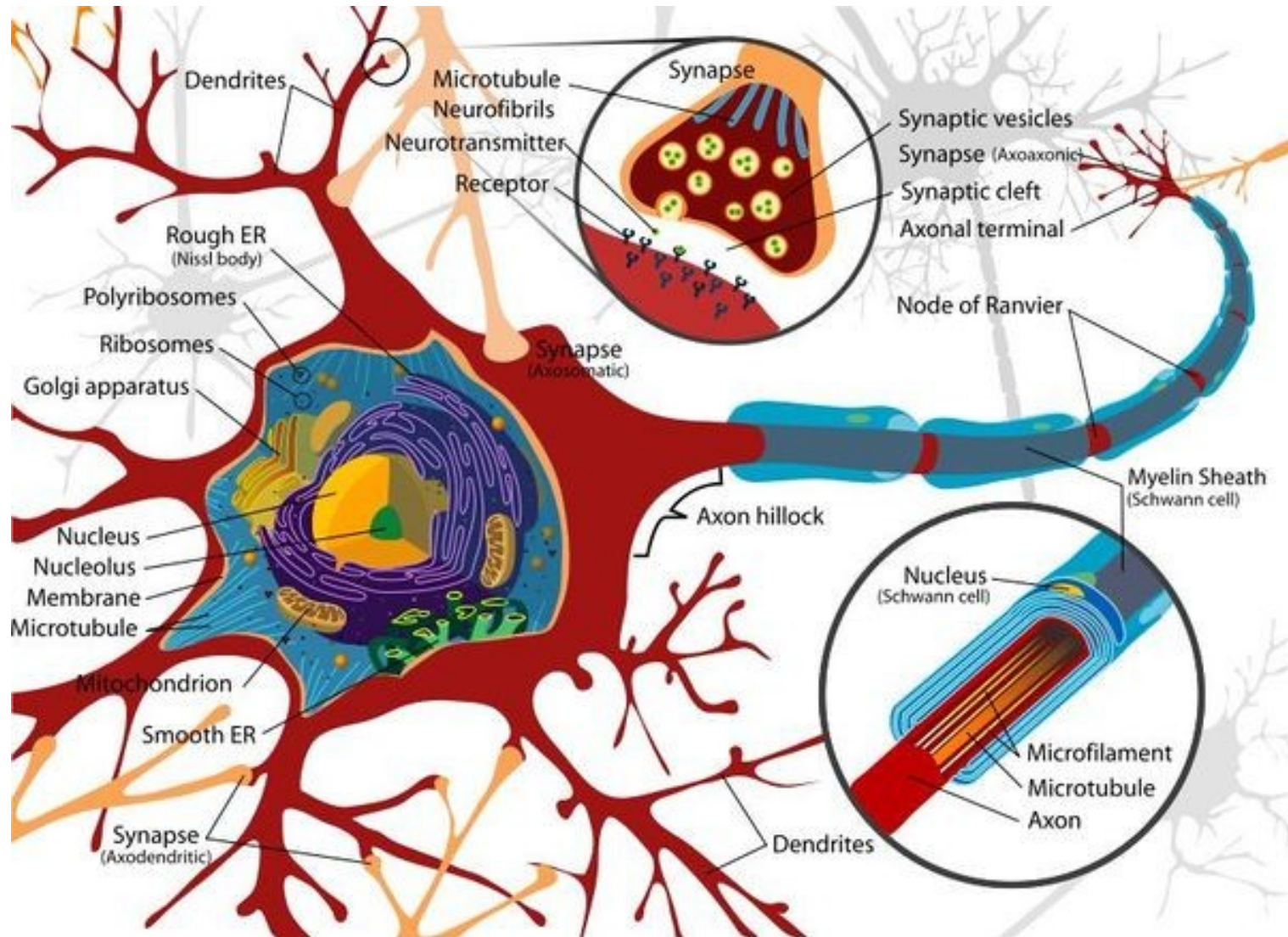


Neurons: biology & models

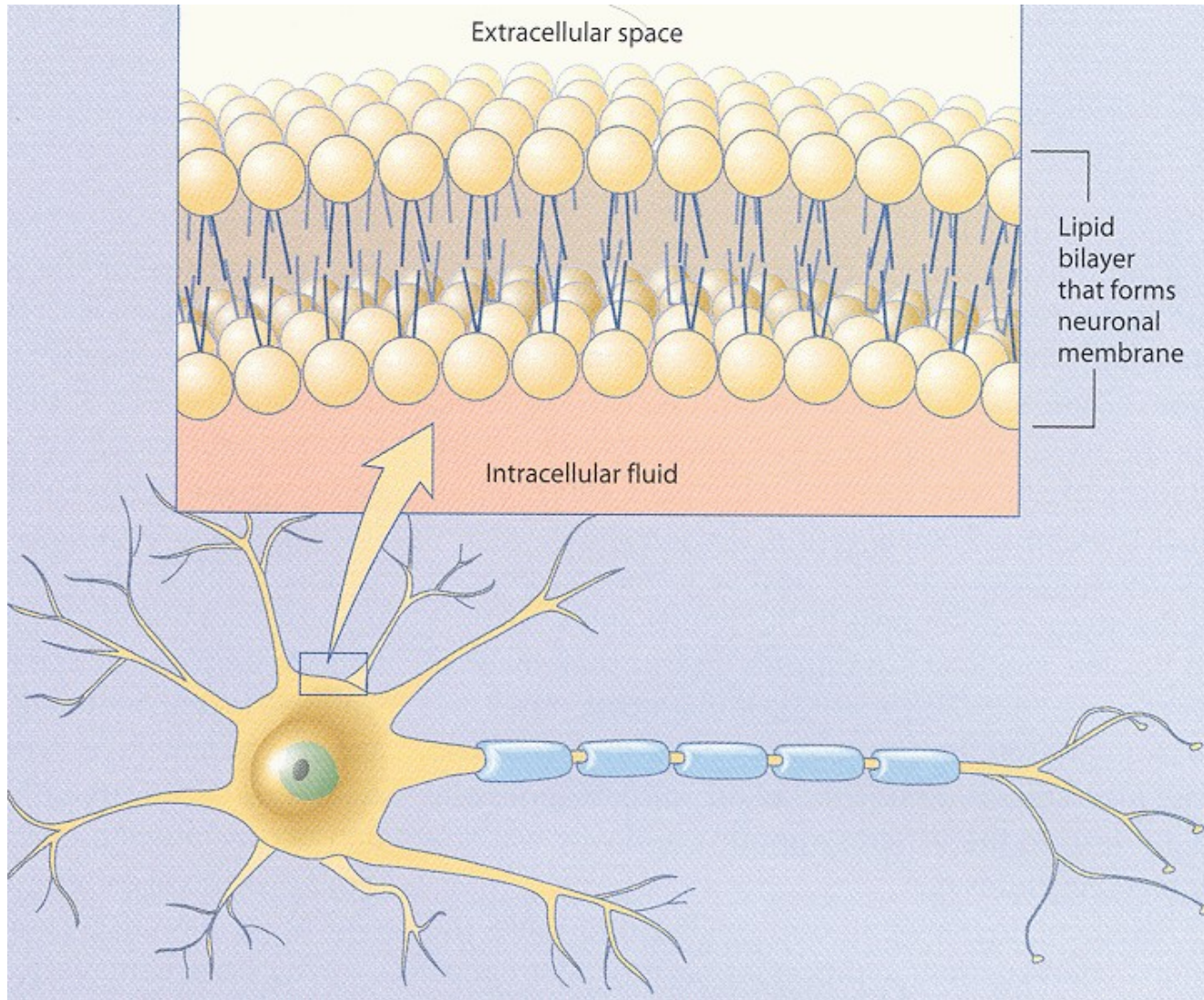


Informatics in cognitive science
NAIL087
Ján Antolík
MFF UK, 2019

The key components



Neural membrane



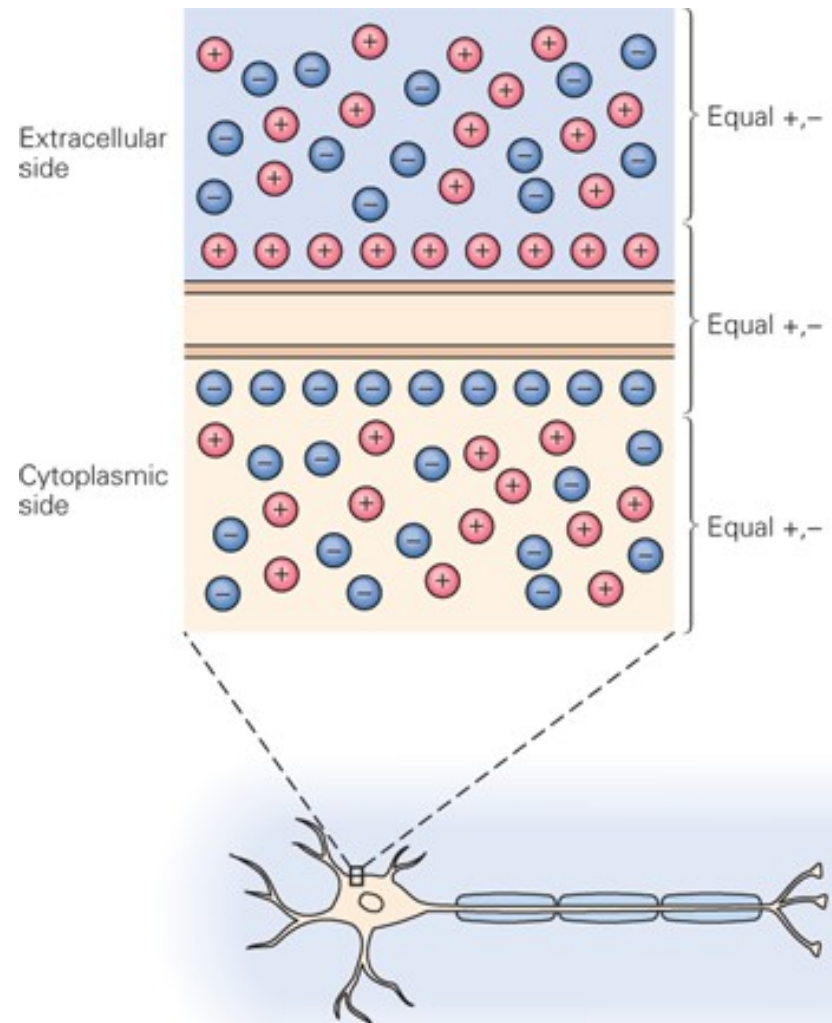
Little recap



**How does equilibrium
membrane potential come
about?**

Membrane potential summary

- Equilibrium potential
 - single ion
 - concentration gradient
 - remains constant
 - difference of charge
 - permeability
- Membrane potential
 - Equilibrium potential across all ions
- Changes in permeability for individual ions change membrane potential



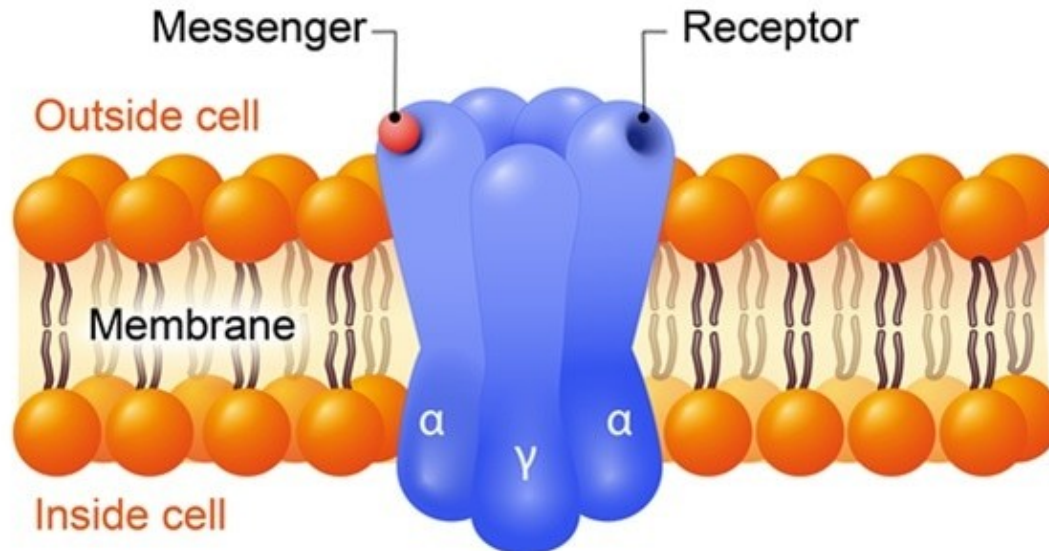
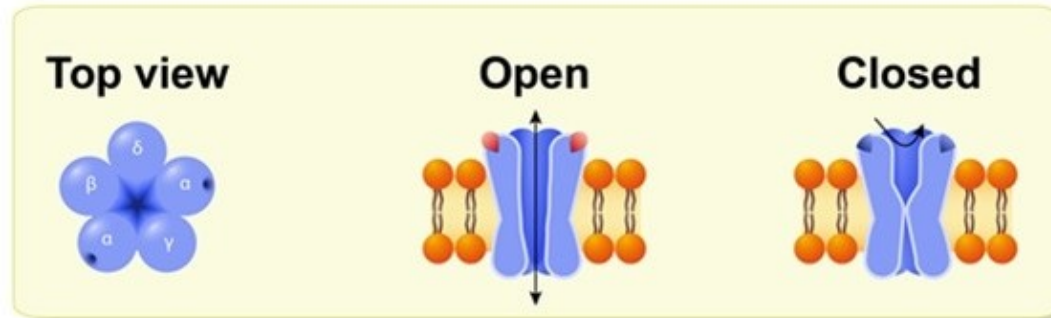
Little recap



How do neurons change their permeability?

Membrane Channels

ION CHANNEL



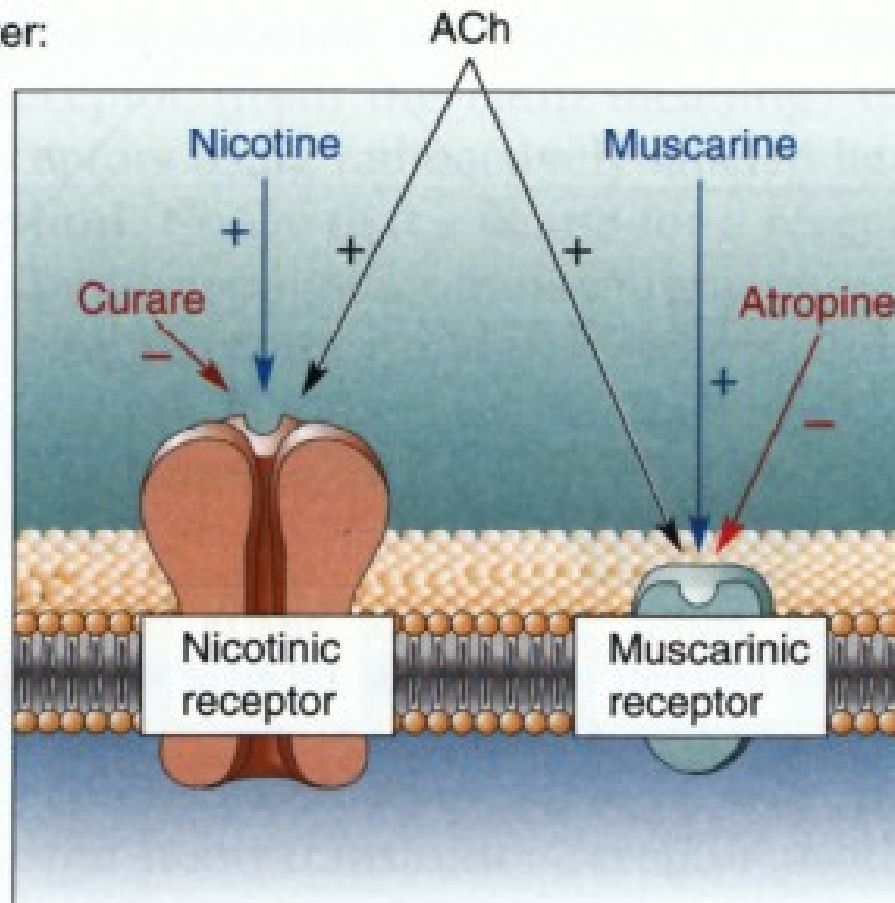
Neurotransmitters

Neurotransmitter:

Agonists:

Antagonists:

Receptors:



TODAY

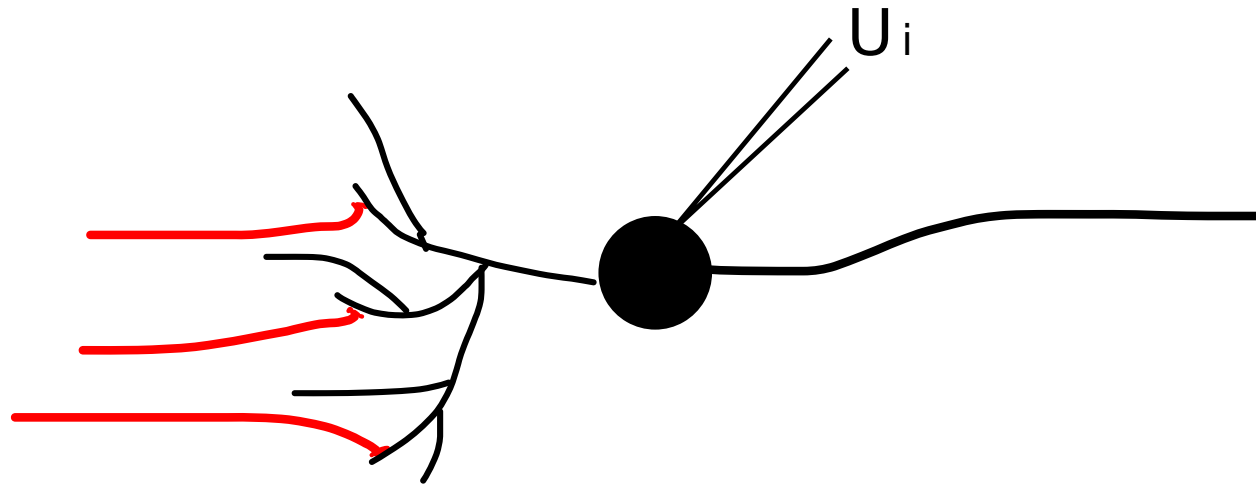
**How to abstract everything we
learned last time?**

Where to start?

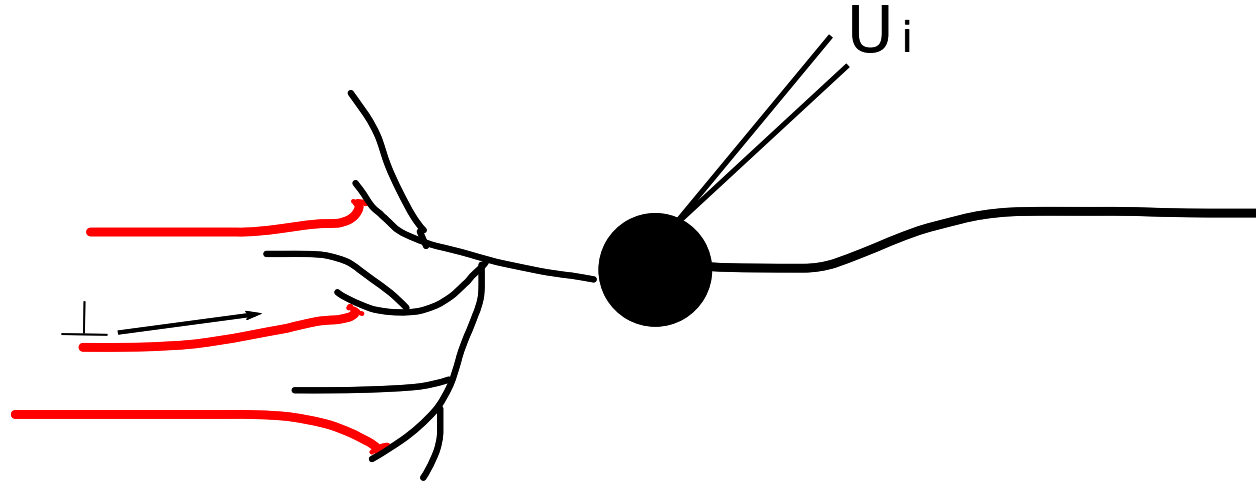


What would be the key aspects of the neuron behavior to replicate?

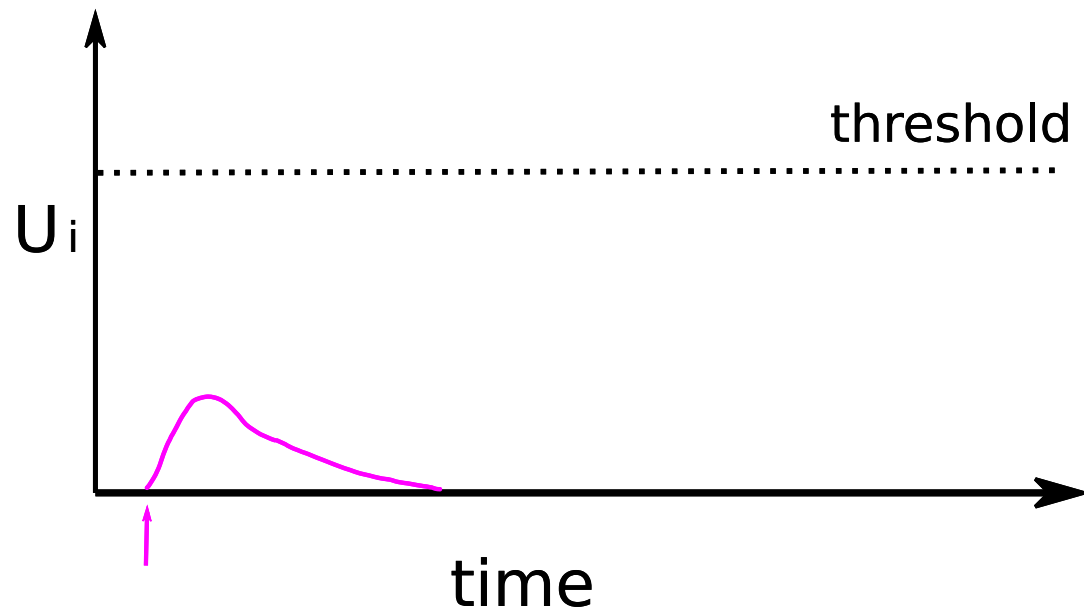
Leaky integrate & fire



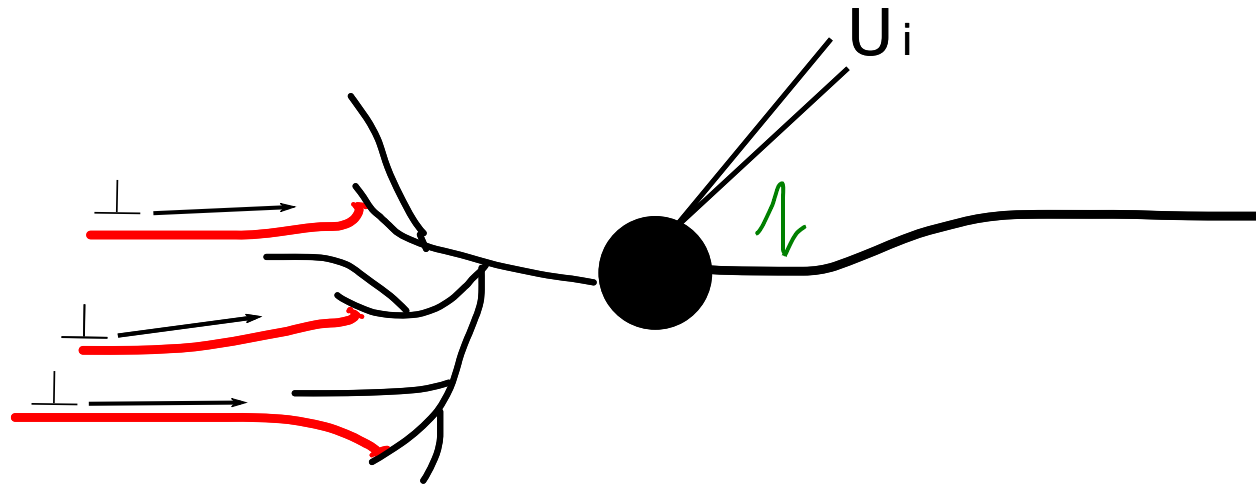
Leaky integrate & fire



Single spike coming via
excitatory synapse will
induce a single Excitatory
Post Synaptic Potential
(EPSP)

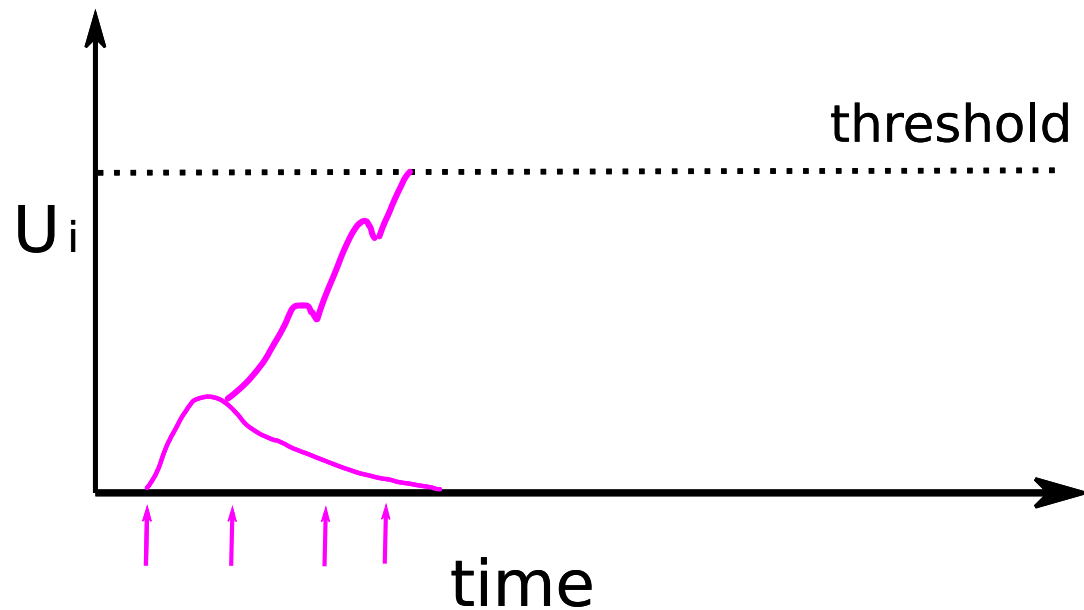


Leaky integrate & fire

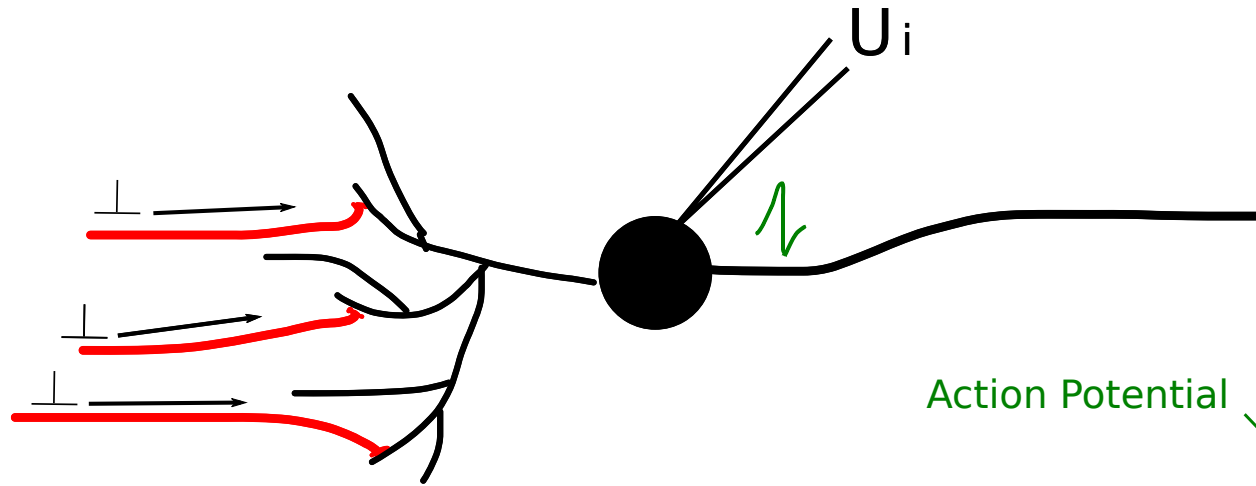


Multiple EPSPs sum up until they reach threshold.

In reality non-linearly.

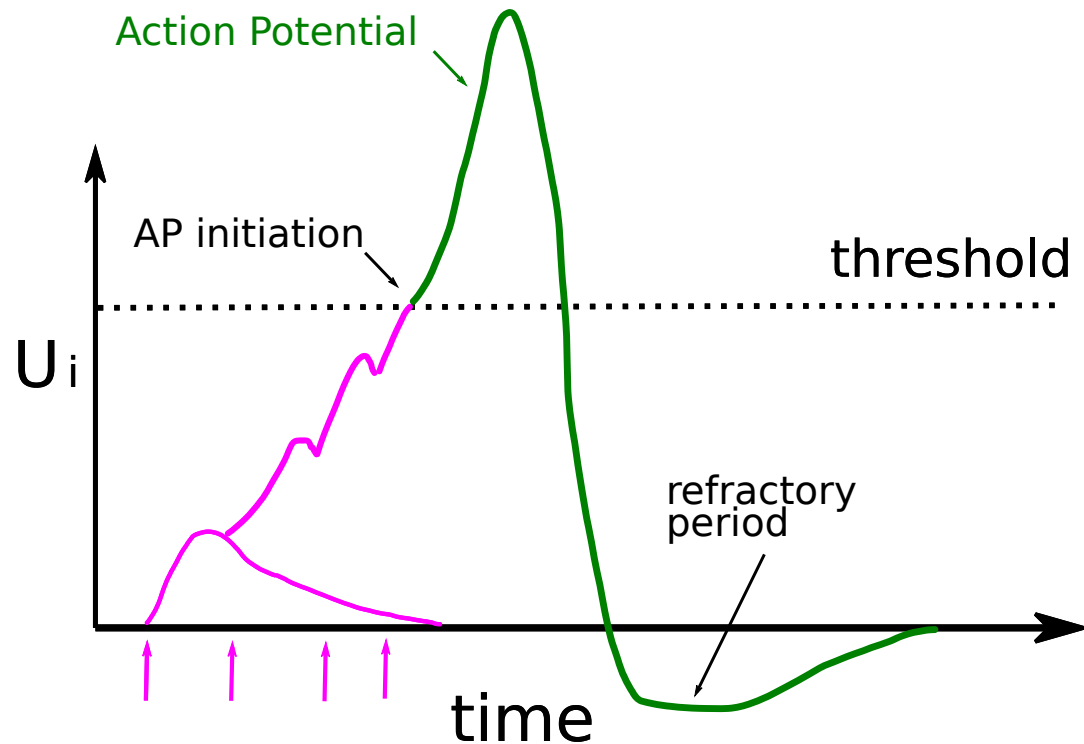


Leaky integrate & fire

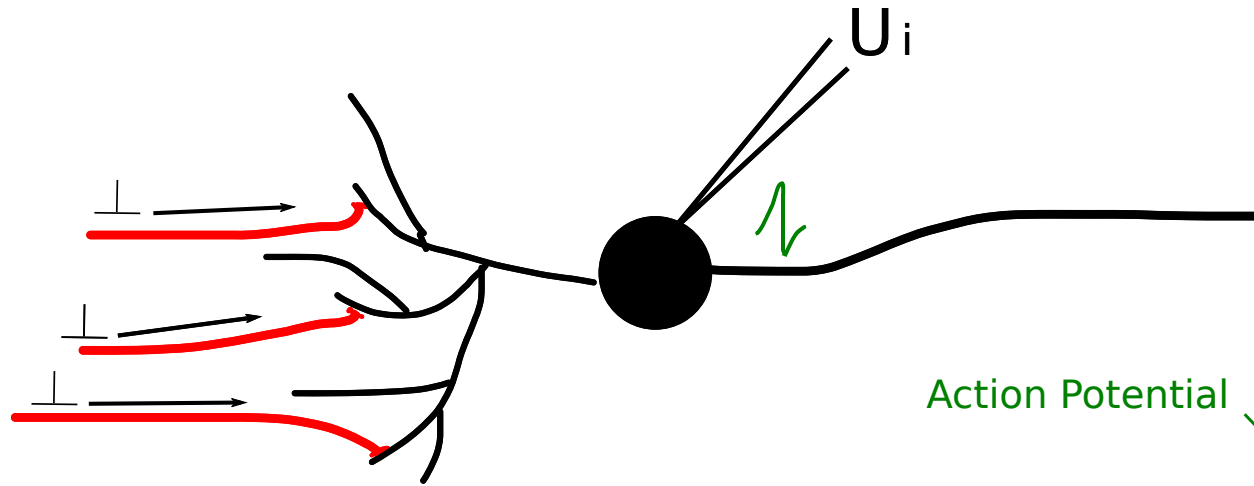


Upon reaching threshold a stereotypical process starts:

- membrane potential rapidly reaches $\sim 40\text{mV}$.
- membrane potential rapidly hyperpolarizes below resting membrane potential.
- resting membrane potential gets slowly restored



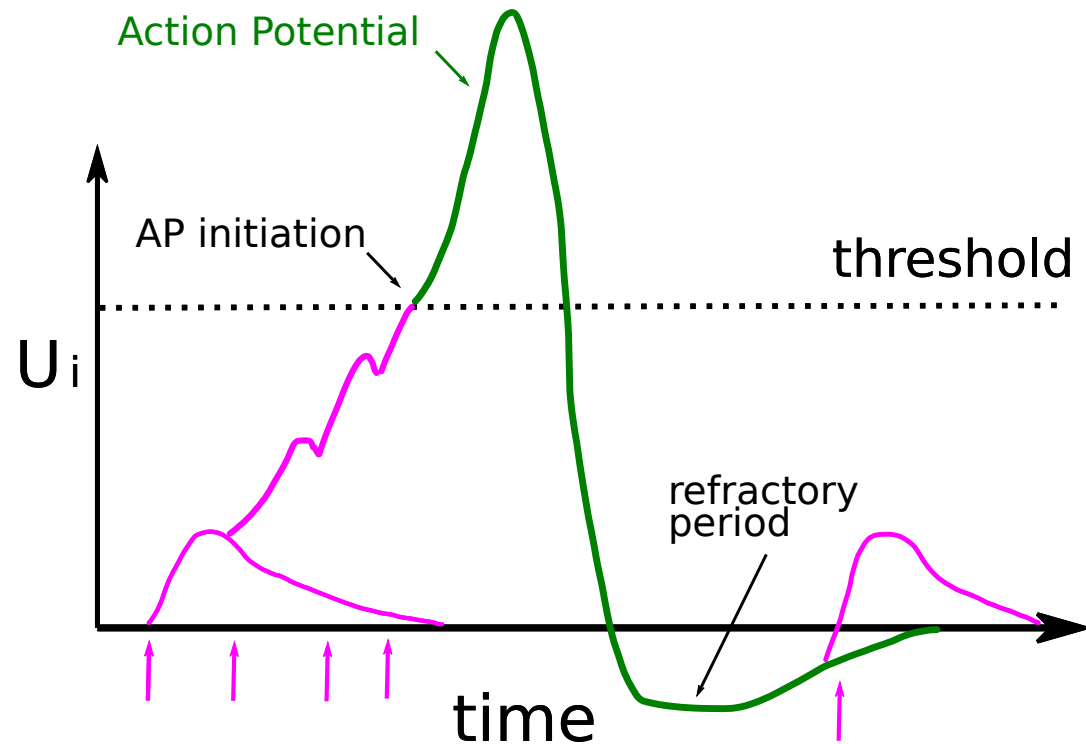
Leaky integrate & fire



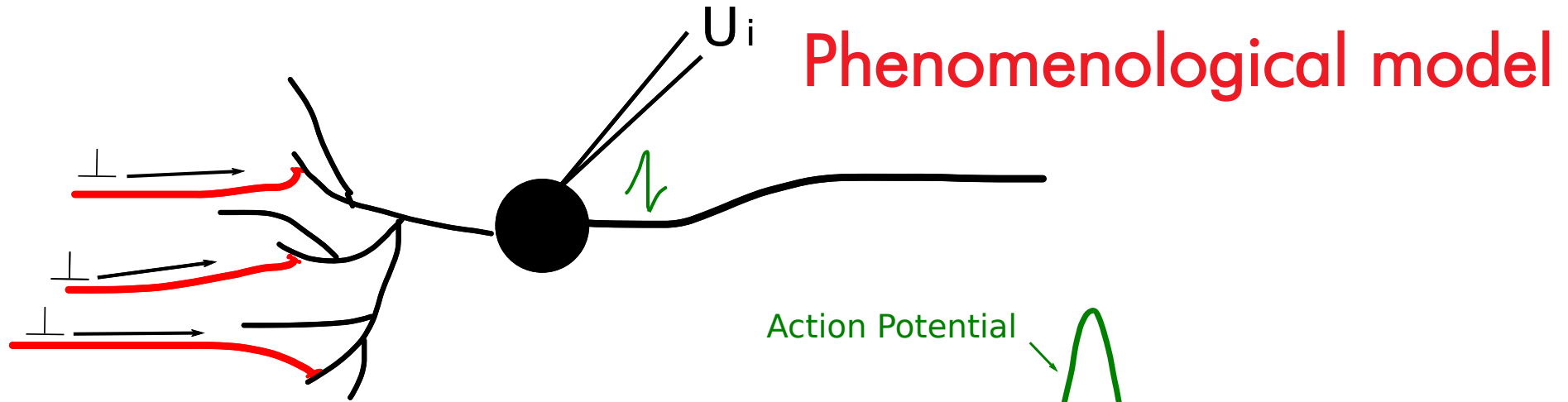
The integration of EPSP can start at any time.

Refractory period only means, it will start from lower membrane potential.

It thus means it is less likely for neuron to reach threshold in this period.



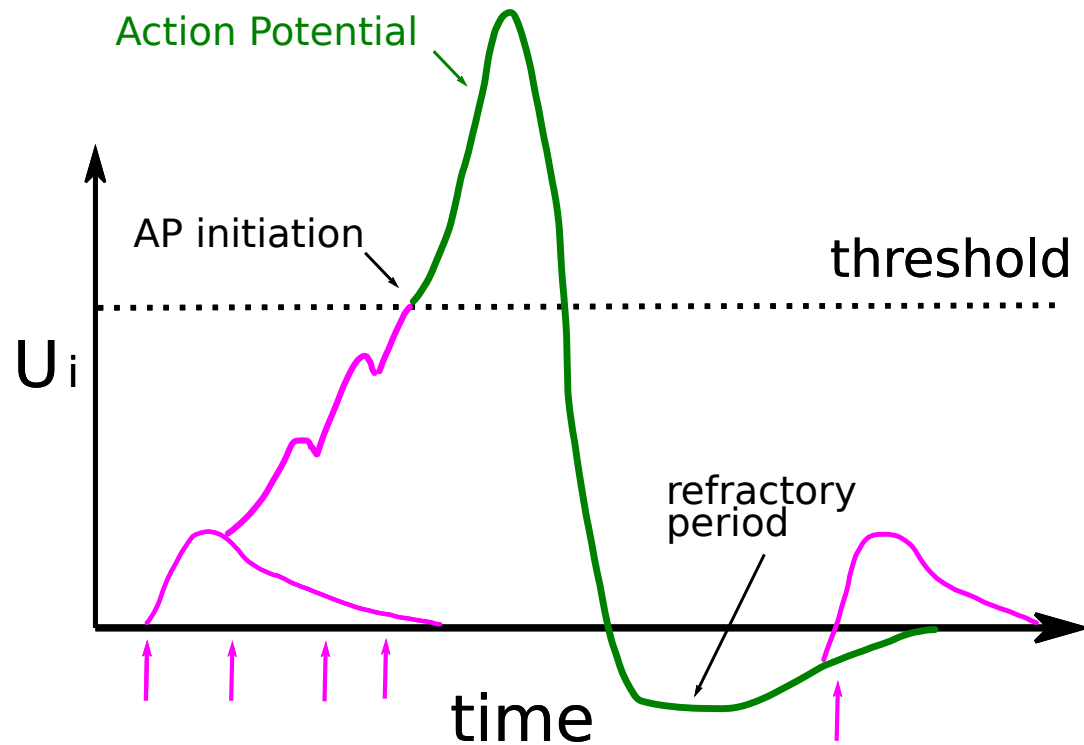
Leaky integrate & fire



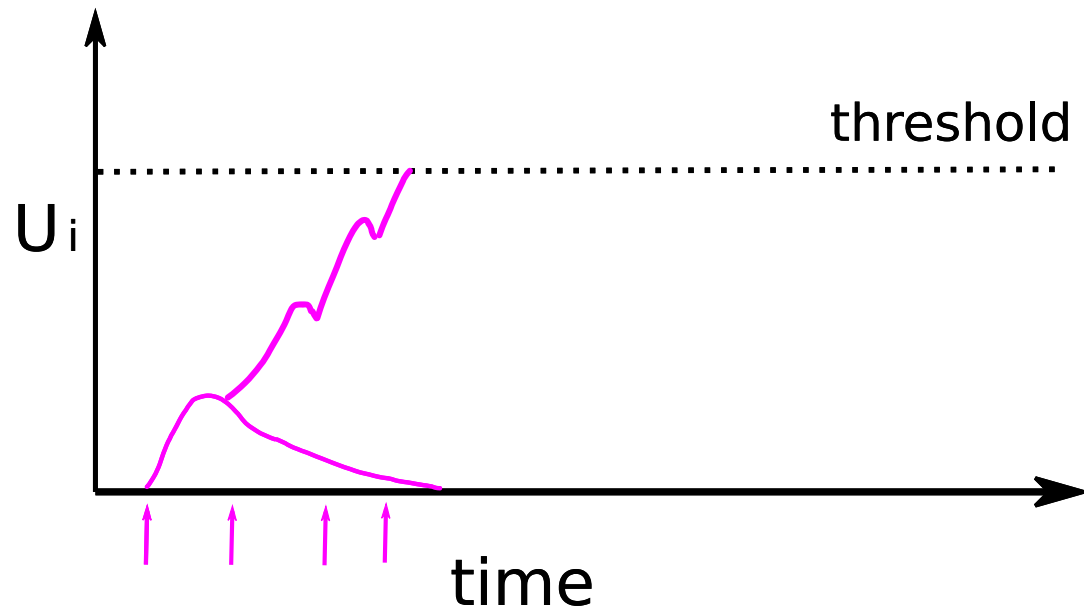
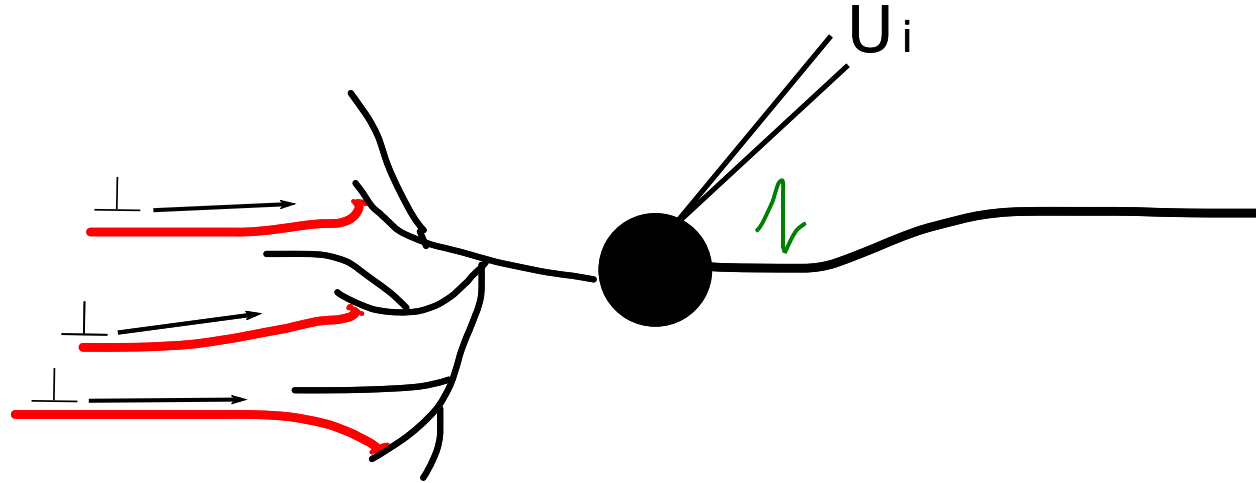
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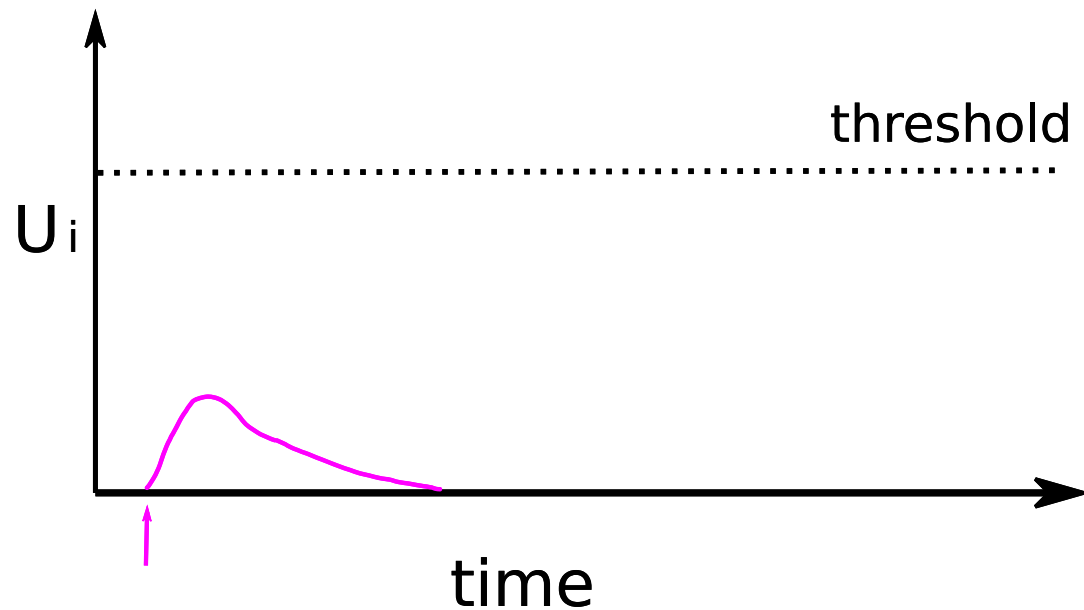
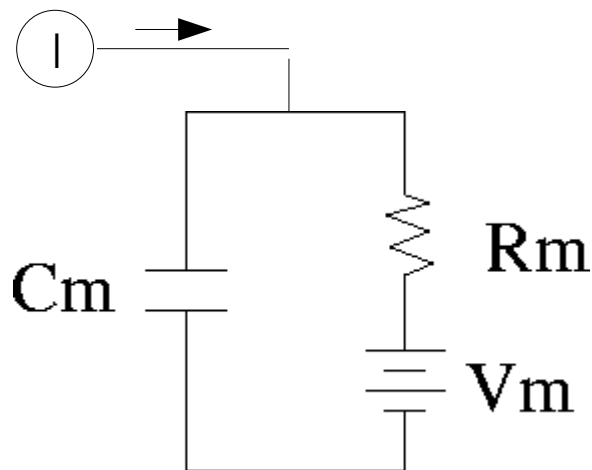
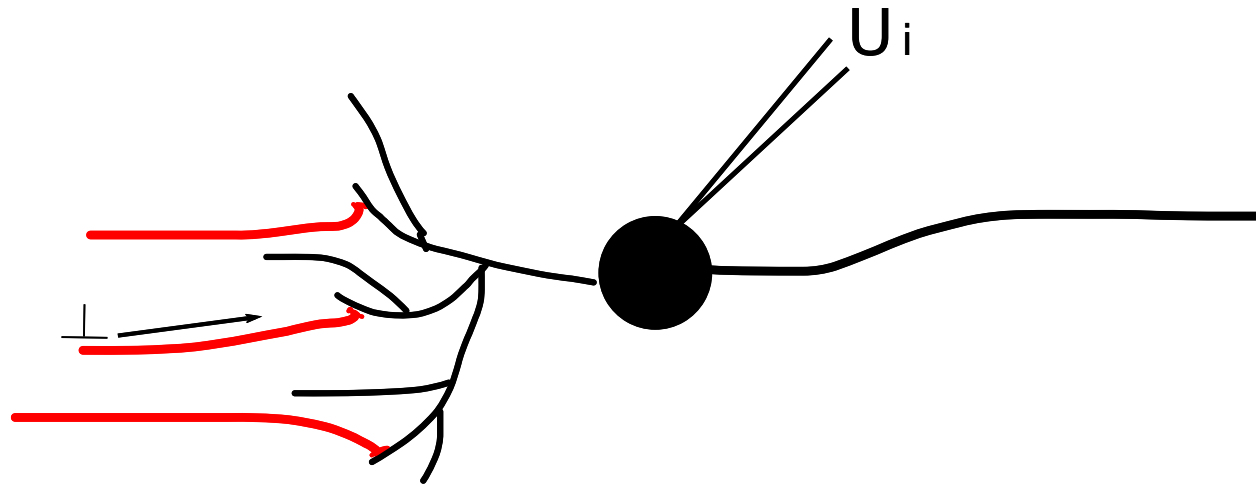
It thus means it is less likely for neuron to reach threshold in this period.



Let's first formalise what happens in passive membrane (sub-threshold)



Leaky integrate & fire



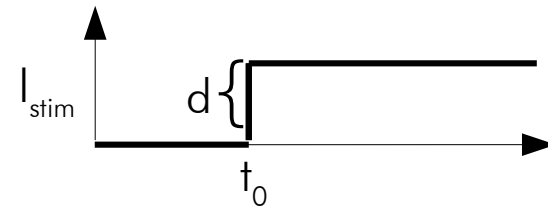
Let's put it into equations:
PASSIVE MEMBRANE

Blackboard time

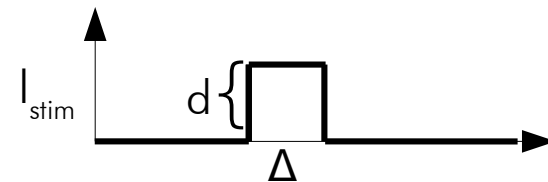
Question

What will be the evolution of membrane potential (U) to

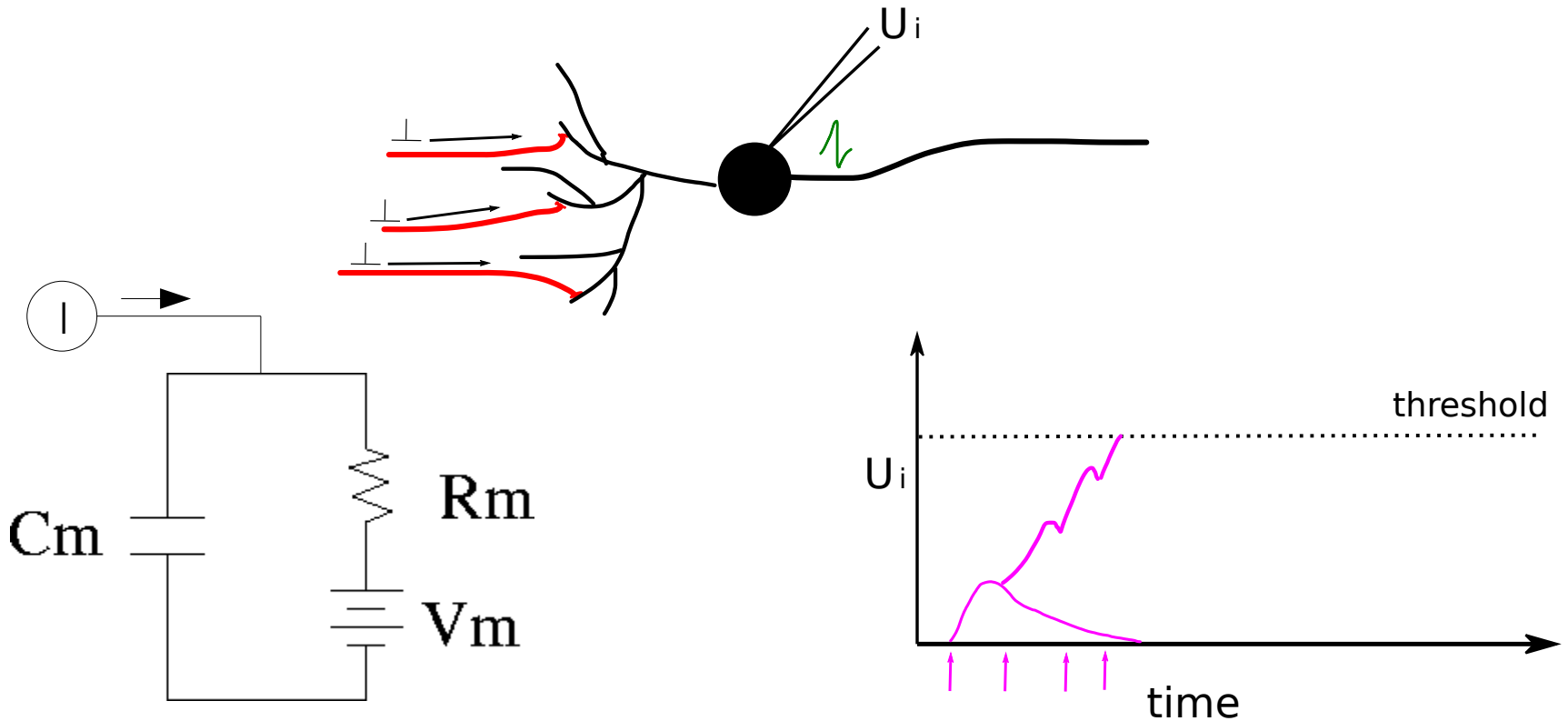
1. step current



2. pulse current



Leaky integrate & fire

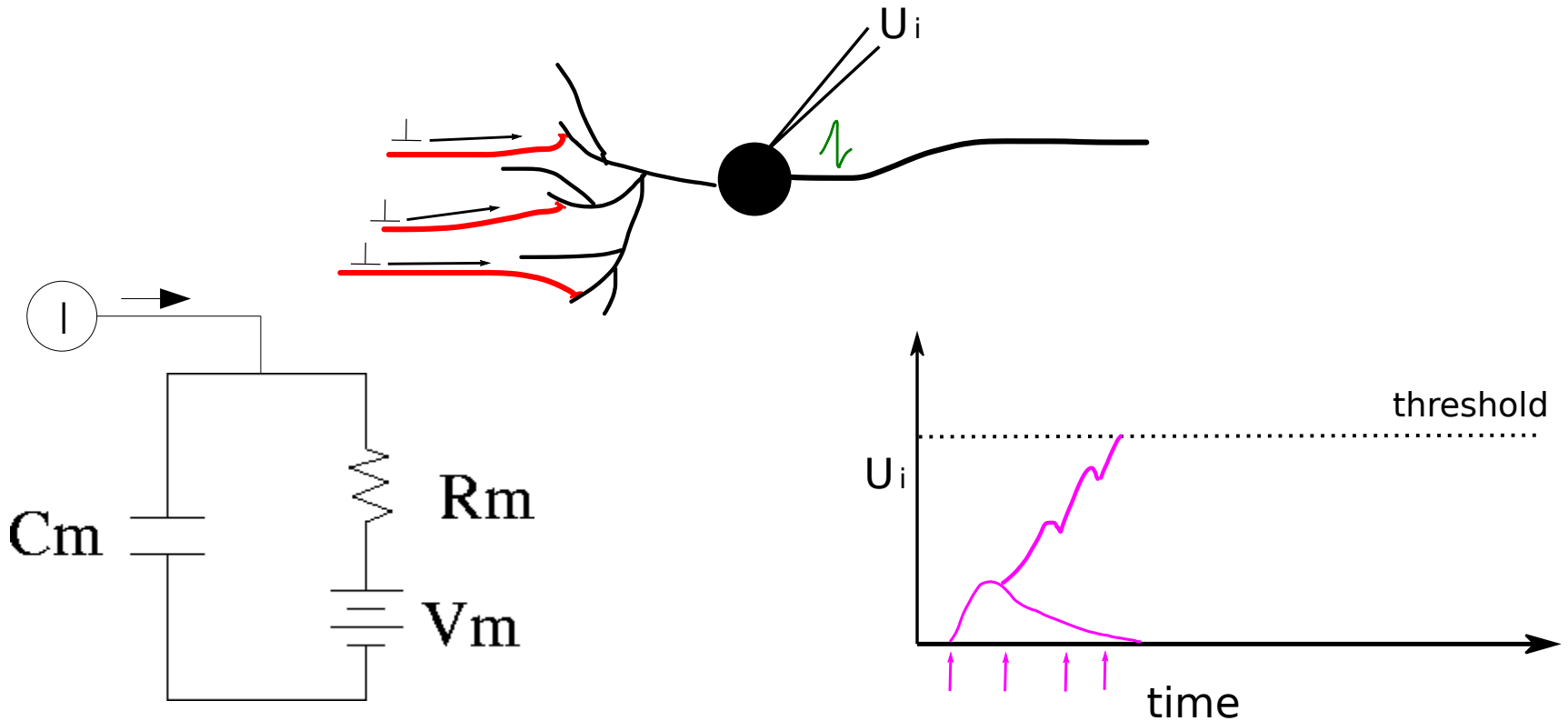


$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

Response to step and pulse current

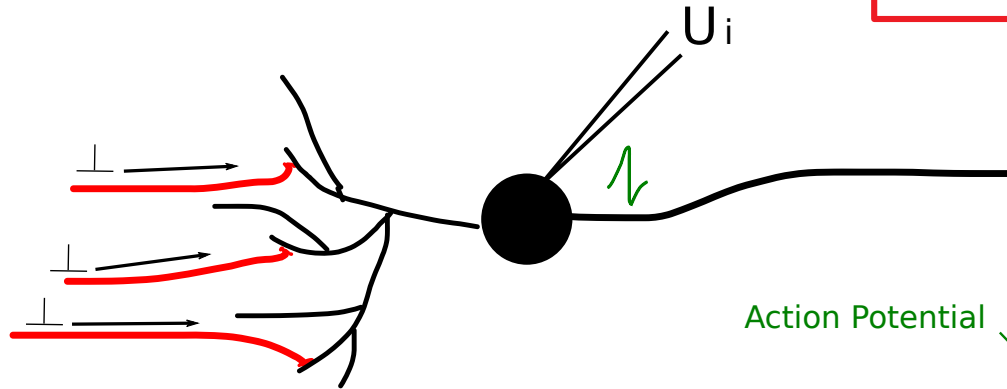
Blackboard time

Leaky integrate & fire

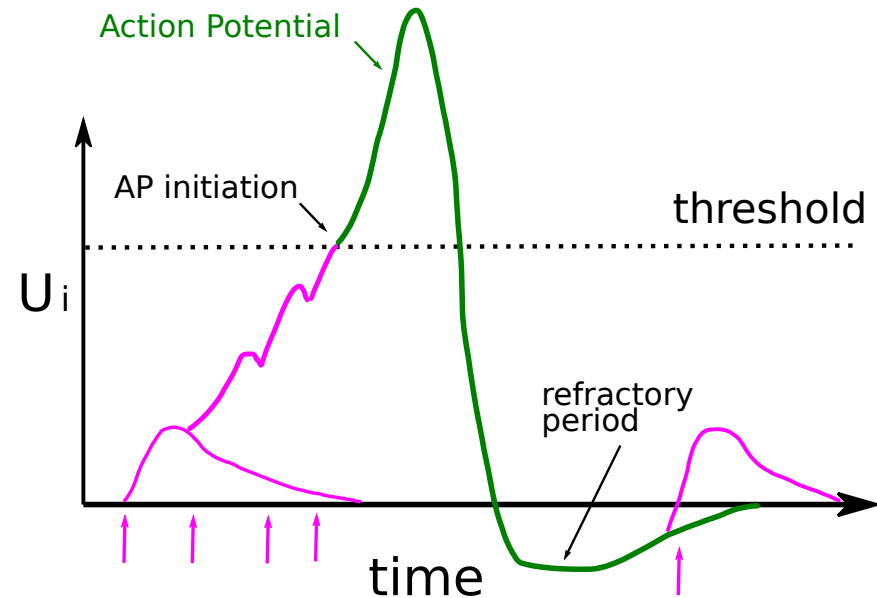


$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$

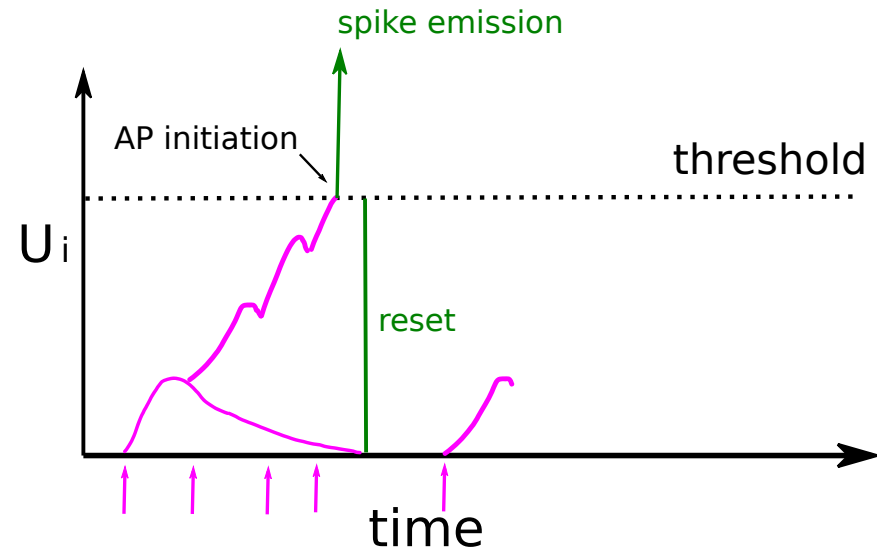
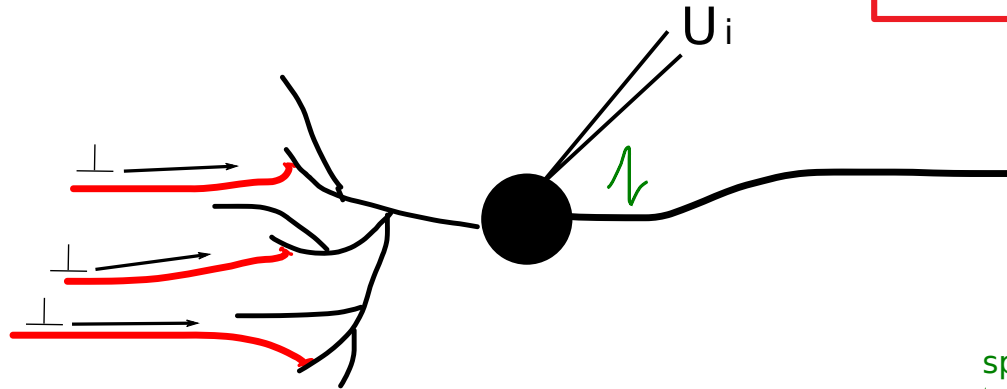
Leaky integrate & fire



$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$



Leaky integrate & fire



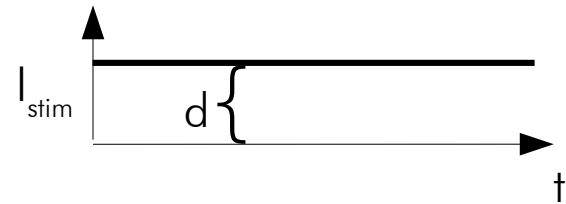
$$\tau \cdot \frac{d}{dt} u = -(u - u_{rest}) + RI(t)$$
$$u_i(t) = \mathcal{G} \Rightarrow \text{Fire+reset}$$

**What have we ignored in
this model?**



Question

1. What will be response to constant current



2. what is minimal d for a spike?