Week 3 – part 1: Synapses

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:
Computational Neuroscience of Single Neurons

Week 3 – Adding Detail:
Dendrites and Synapses

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- 3.1 **Synapses**
- 3.2 **Short-term plasticity**
- 3.3 **Dendrite as a Cable**
- 3.4 **Cable equation**
- 3.5 **Compartmental Models**
  - active dendrites

Week 3 – part 1: Synapses

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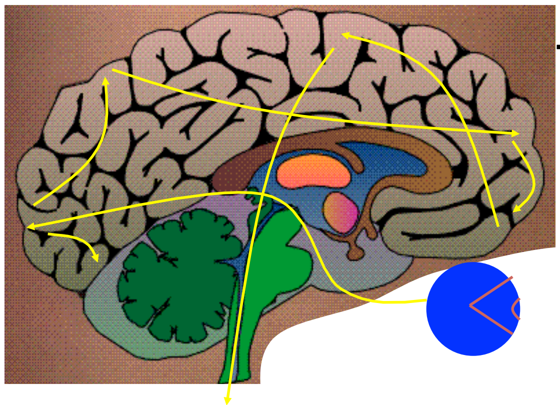
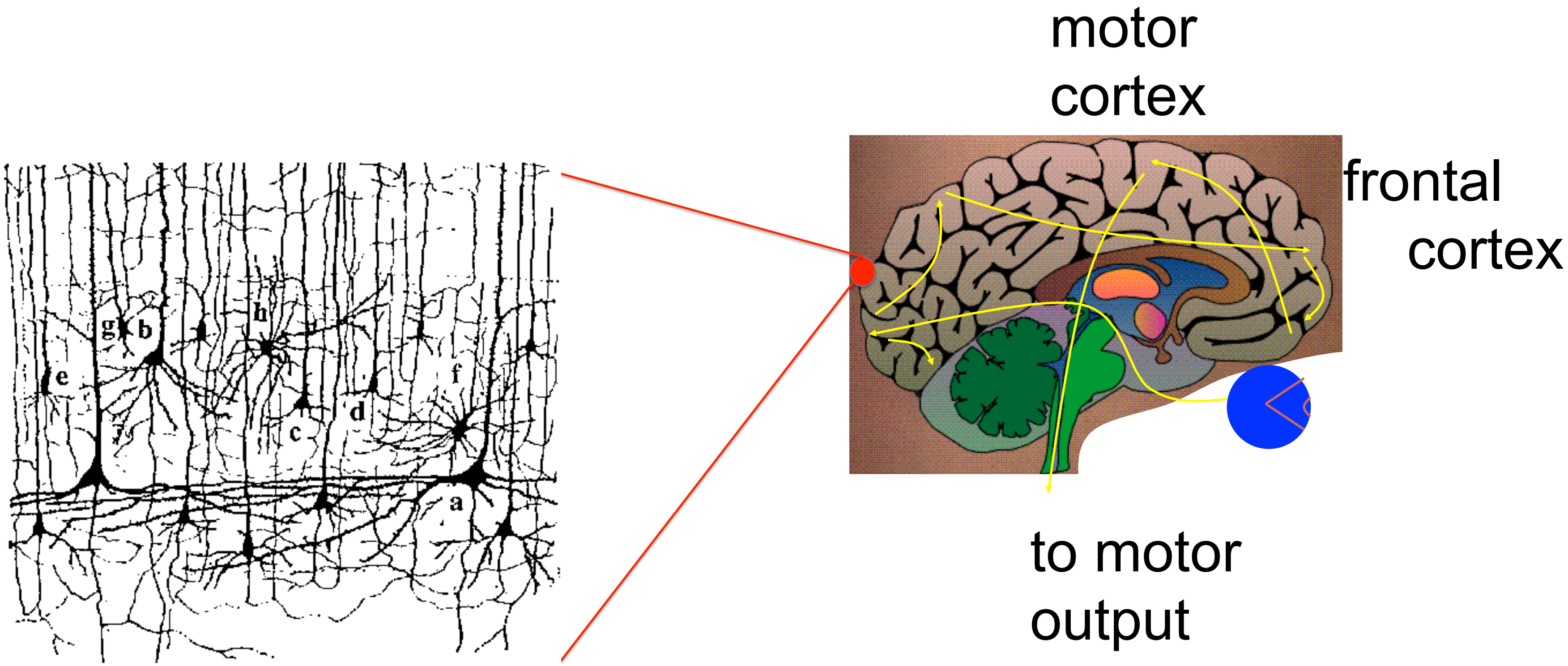
Neuronal Dynamics – 3.1. Introduction

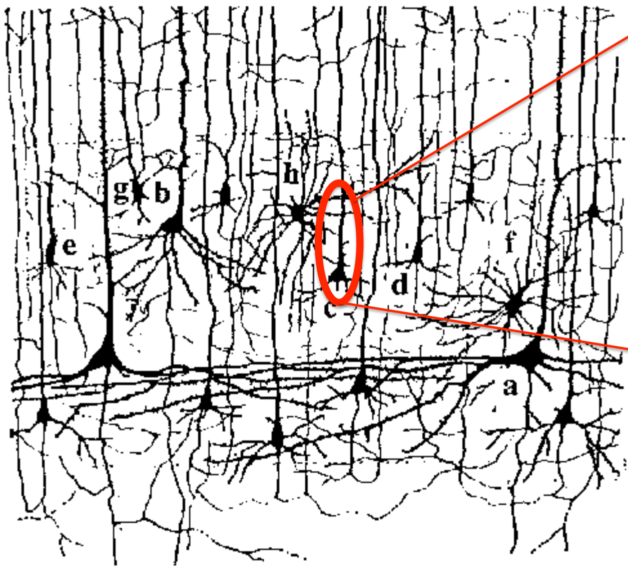


Neuronal Dynamics – 3.1. Introduction

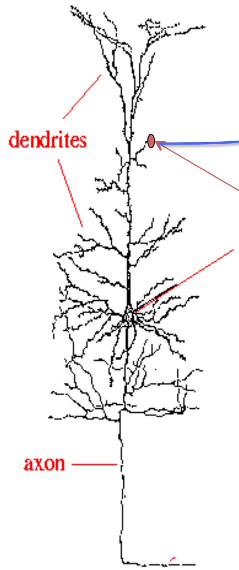


Neuronal Dynamics – 3.1 Introduction

What happens in a dendrite?



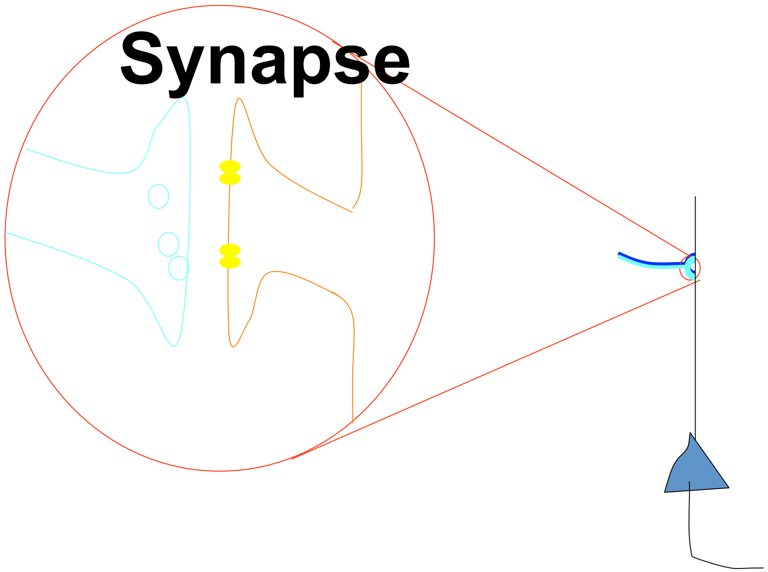
Ramon y Cajal



What happens at a synapse?

synapse

Neuronal Dynamics – 3.1 Synapses



Neuronal Dynamics – 3.1 Synapses

glutamate: Important neurotransmitter at excitatory synapses

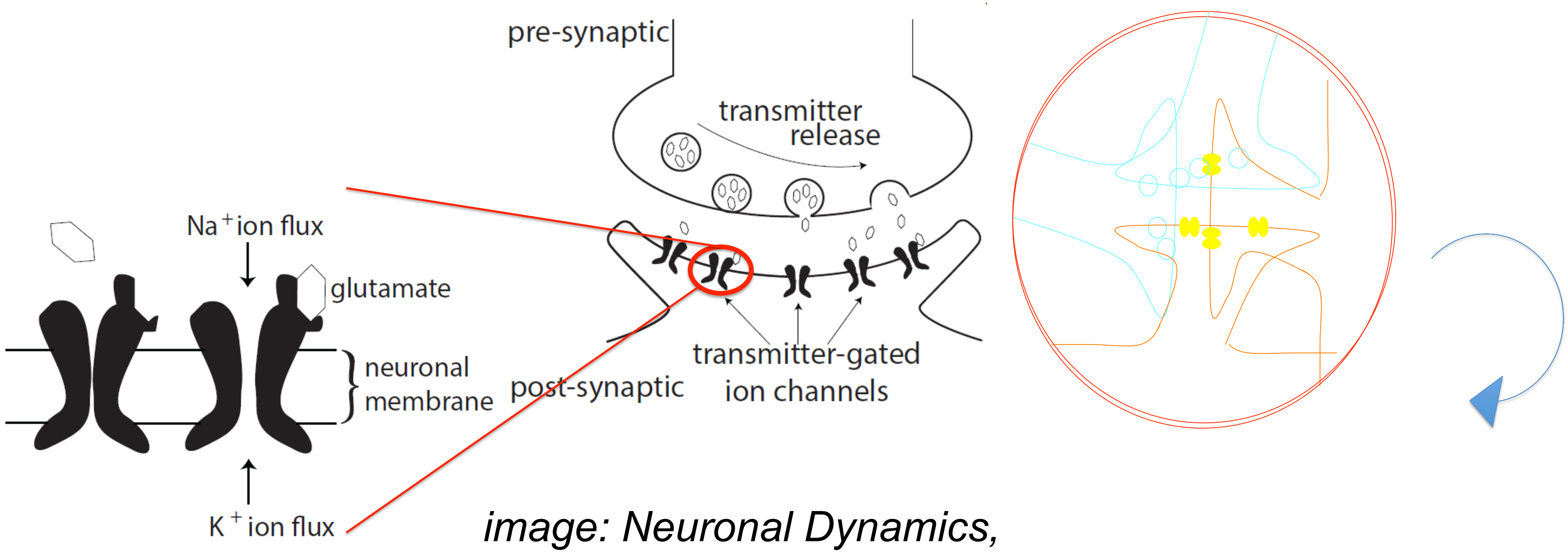


image: Neuronal Dynamics, Cambridge Univ. Press

Neuronal Dynamics – 3.1 Synapses

glutamate: Important neurotransmitter at **excitatory synapses**

-AMPA channel: rapid, calcium cannot pass if open
-NMDA channel: slow, calcium can pass, if open

(N-methyl-D-aspartate)

GABA: Important neurotransmitter at **inhibitory synapses**

(gamma-aminobutyric acid)

Channel subtypes GABA$_{\text{-A}}$ and GABA$_{\text{-B}}$

Neuronal Dynamics – 3.1 Synapse types

Model?

$$g_{syn}(t) = \quad \bar{g}_{syn} e^{-(t-t_k)/\tau} \Theta(t - t_k)$$

$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

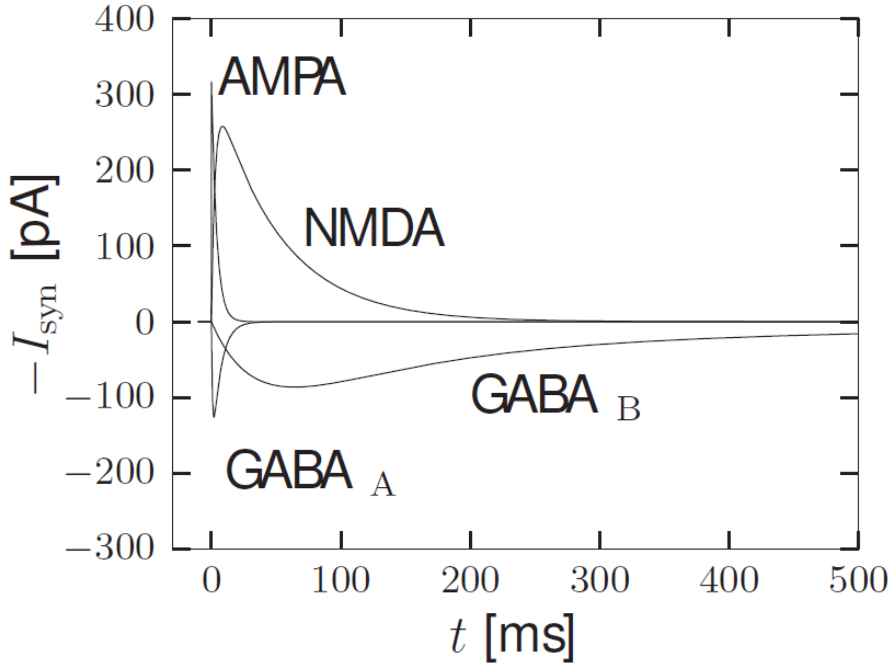
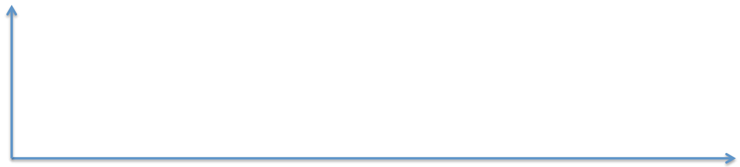


image: Neuronal Dynamics, Cambridge Univ. Press

Neuronal Dynamics – 3.1 Synapse model

Model?

$$g_{syn}(t) = \quad \bar{g}_{syn} e^{-(t-t_k)/\tau} \Theta(t - t_k)$$



$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

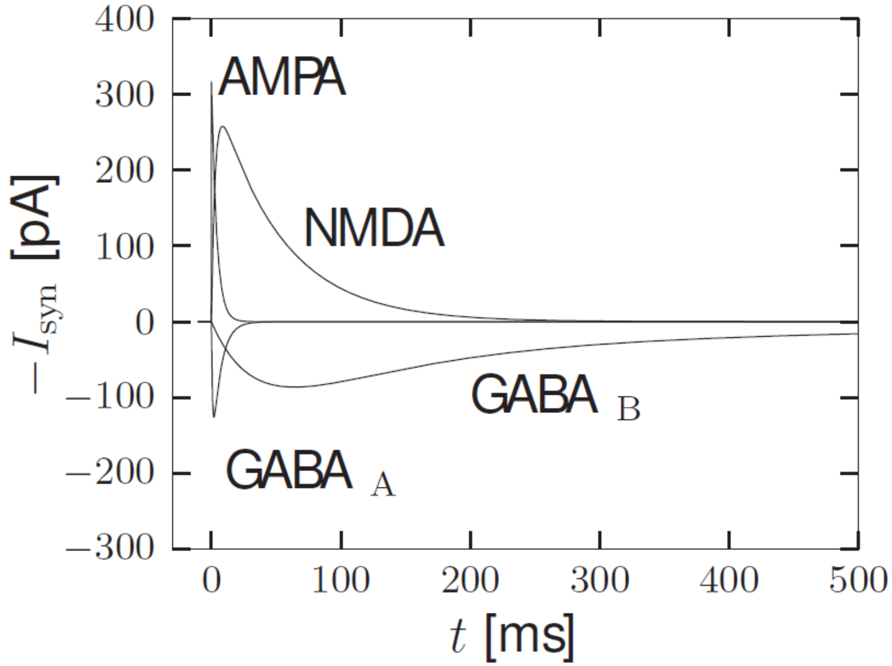
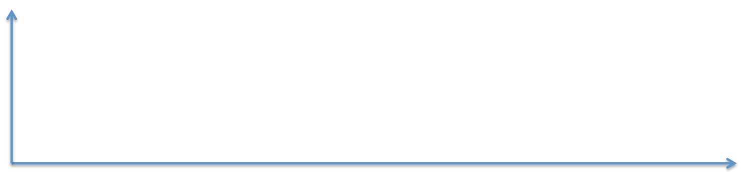


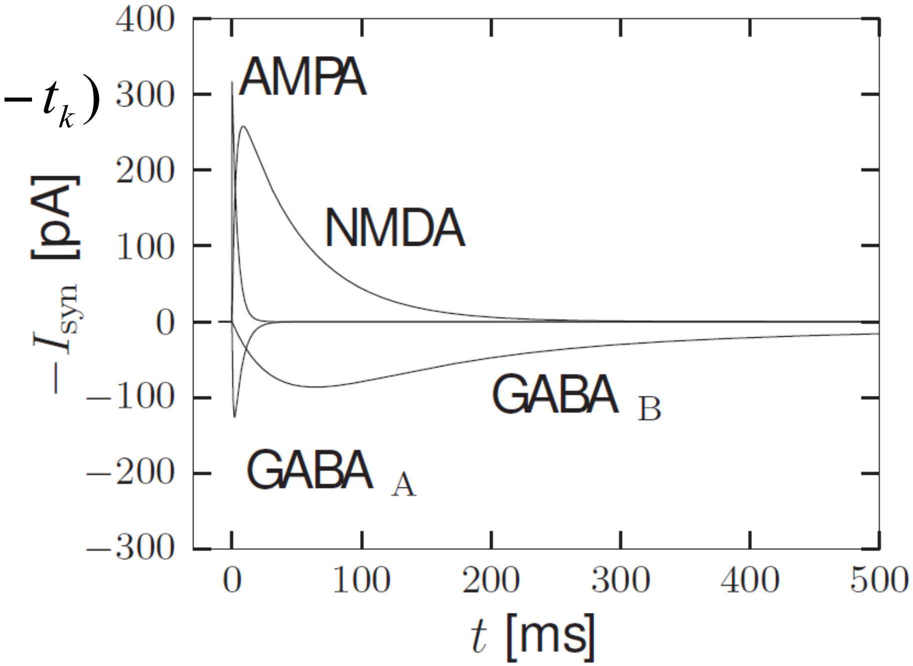
image: Neuronal Dynamics, Cambridge Univ. Press

Neuronal Dynamics – 3.1 Synapse model

Model with rise time

$$g_{syn}(t) = \sum_k \bar{g}_{syn} e^{-(t-t_k)/\tau} [1 - e^{-(t-t_k)/\tau_{rise}}] \Theta(t - t_k)$$





$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

$$C\frac{du}{dt} = -g_{Na}m^3h(u - E_{Na}) - g_K n^4 (u - E_K) - g_l(u - E_l) + I^{stim}(t)$$

image: Neuronal Dynamics, Cambridge Univ. Press

Neuronal Dynamics – 3.1 Synaptic reversal potential

glutamate: excitatory synapses

$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

$$E_{syn} \approx 0mV$$

GABA: inhibitory synapses

$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

$$E_{syn} \approx -75mV$$

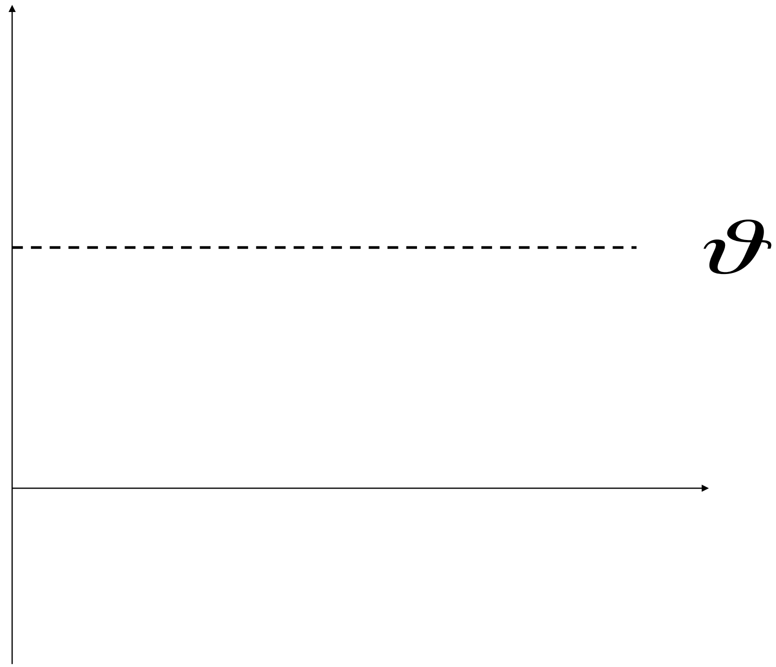
Neuronal Dynamics – 3.1 Synapses

glutamate: excitatory synapses

$$I^{stim}(t) = -I^{syn}(t)$$

$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

$$E_{syn} \approx 0mV$$

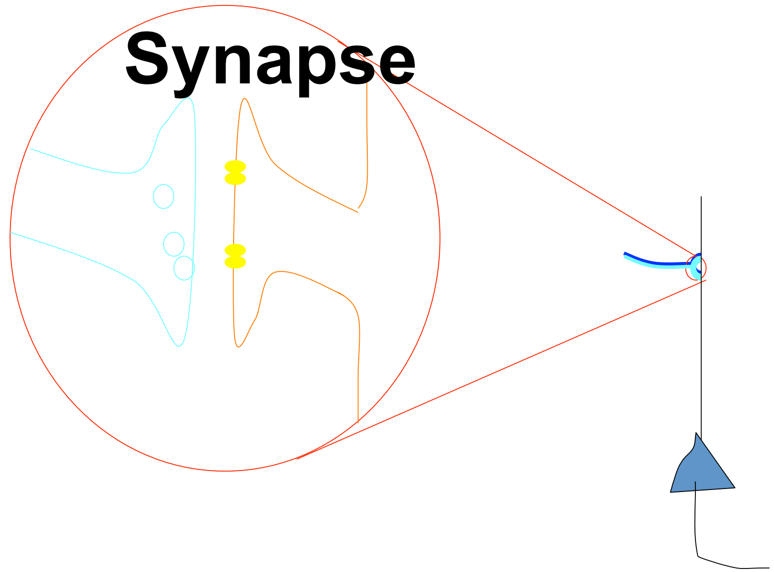


GABA: inhibitory synapses

$$-I^{syn}(t) = -g_{syn}(t)(u - E_{syn})$$

$$E_{syn} \approx -75mV$$

Neuronal Dynamics – 3.1 Synapses



Neuronal Dynamics – Quiz 3.1

Multiple answers possible!

AMPA channel

[ ] AMPA channels are activated by AMPA
[ ] If an AMPA channel is open, AMPA can pass through the channel
[ ] If an AMPA channel is open, glutamate can pass through the channel
[ ] If an AMPA channel is open, potassium can pass through the channel
[ ] The AMPA channel is a transmitter-gated ion channel
[ ] AMPA channels are often found in a synapse

Synapse types

[ ] In the subthreshold regime, excitatory synapses always depolarize the membrane, i.e., shift the membrane potential to more positive values
[ ] In the subthreshold regime, inhibitory synapses always hyperpolarize the membranel, i.e., shift the membrane potential more negative values
[ ] Excitatory synapses in cortex often contain AMPA receptors
[ ] Excitatory synapses in cortex often contain NMDA receptors