Neuronal Dynamics - 1.1. Neurons and Synapses/Overview

Neuronal Dynamics:
Computational Neuroscience
of Single Neurons

Week 1 – neurons and mathematics:
a first simple neuron model

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Neuronal Dynamics - 1.1. Neurons and Synapses/Overview

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motor
cortex

frontal
cortex

visual
cortex
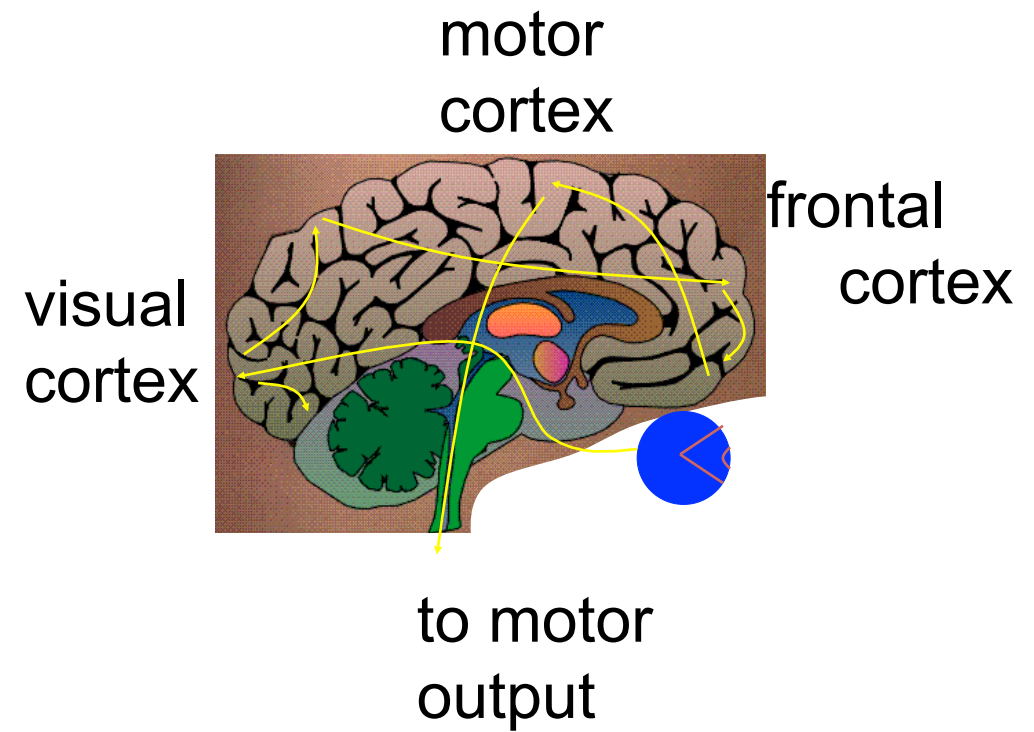
to motor
output

Neuronal Dynamics – 1.1. Neurons and Synapses/Overview

10 000 neurons
3 km wires

1mm
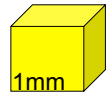
motor
cortex

frontal
cortex

to motor
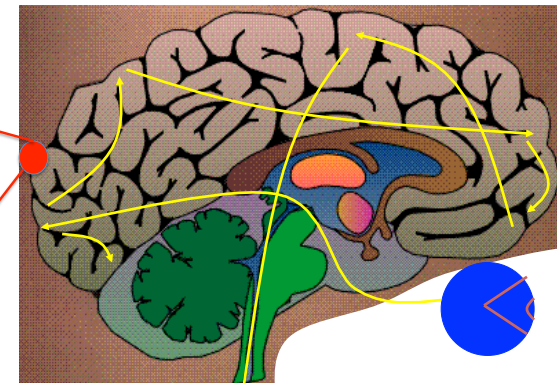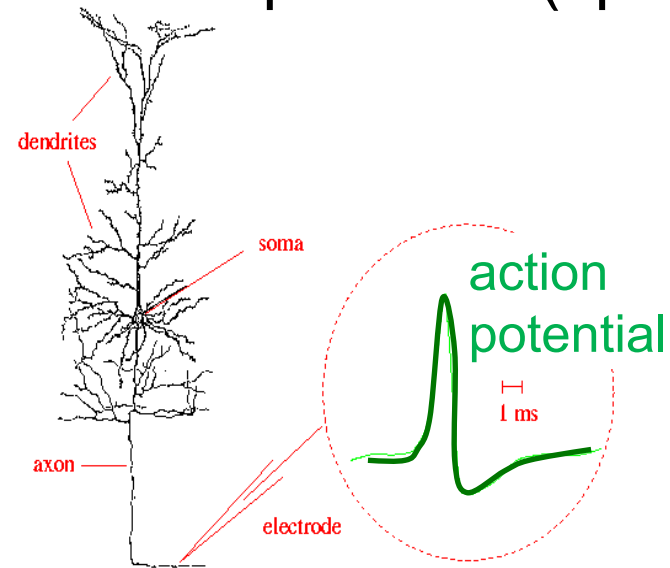output

Neuronal Dynamics – 1.1. Neurons and Synapses/Overview

1mm — 10 000 neurons
3 km wires

Ramon y Cajal

Signal:
action potential (spike)

dendrites

soma

action potential

1 ms

axon

electrode

Neuronal Dynamics – 1.1. Neurons and Synapses/Overview

Hodgkin-Huxley type models:
Biophysics, molecules, ions
(week 2)

Signal:
action potential (spike)

-70mV

Na^+

K^+

Ca^{2+}

Ions/proteins

dendrites

soma

electrode

action
potential

1 ms
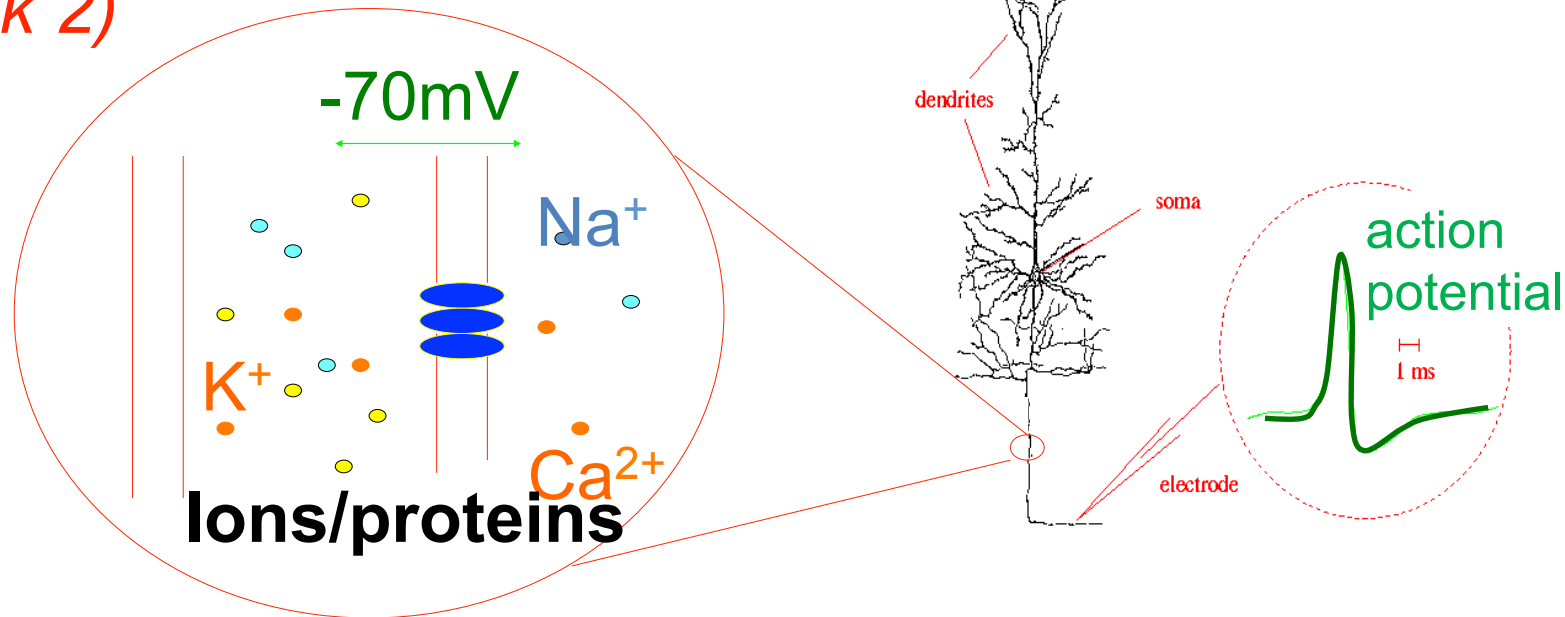
Neuronal Dynamics – 1.1. Neurons and Synapses/Overview

Signal:
action potential (spike)

dendrites

soma

axon

electrode

action potential

1 ms
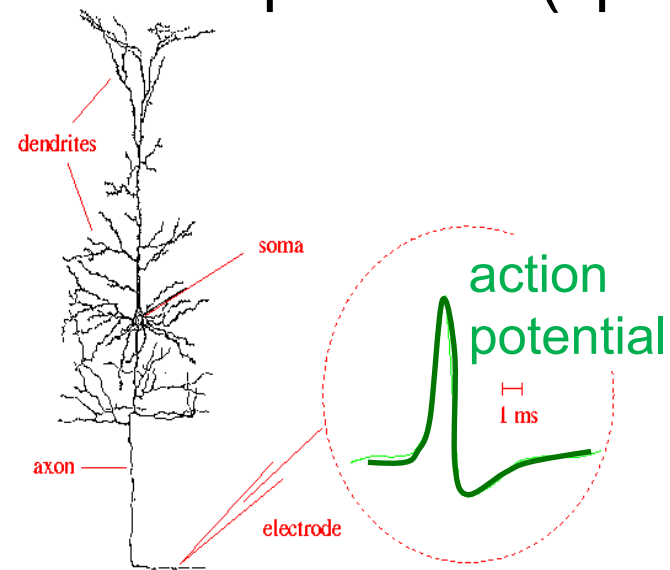
Integrate-and-fire models:
Formal/phenomenological

(week 1 and week 6+7)

Spike emission

synapse

Spike reception

u

ϑ

t

Postsynaptic
potential

-spikes are events
-triggered at threshold
-spike/reset/refractoriness
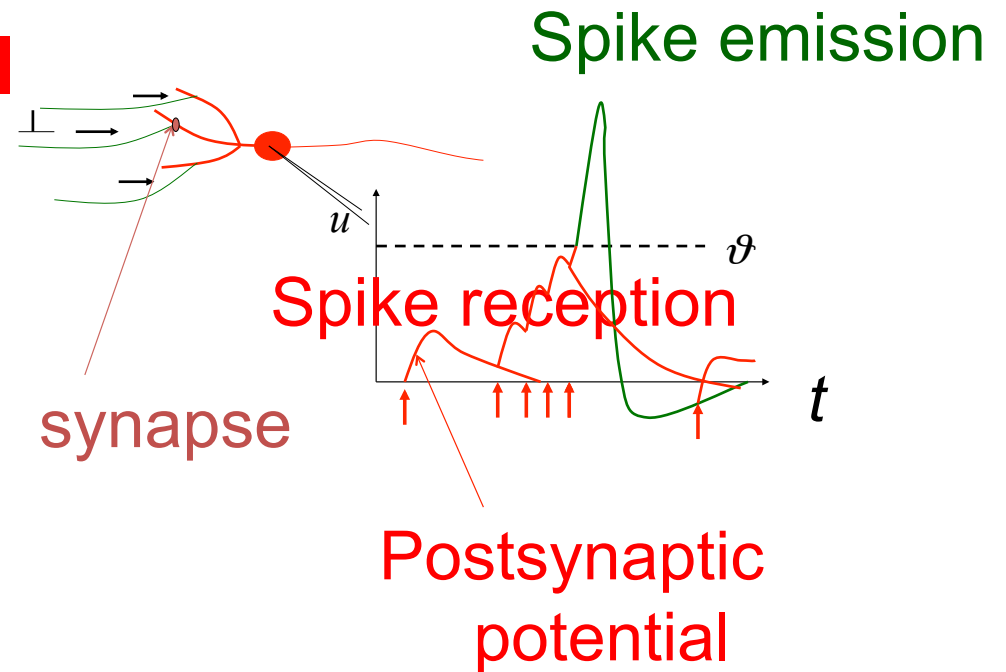
Noise and variability in integrate-and-fire models

j

i

u_i
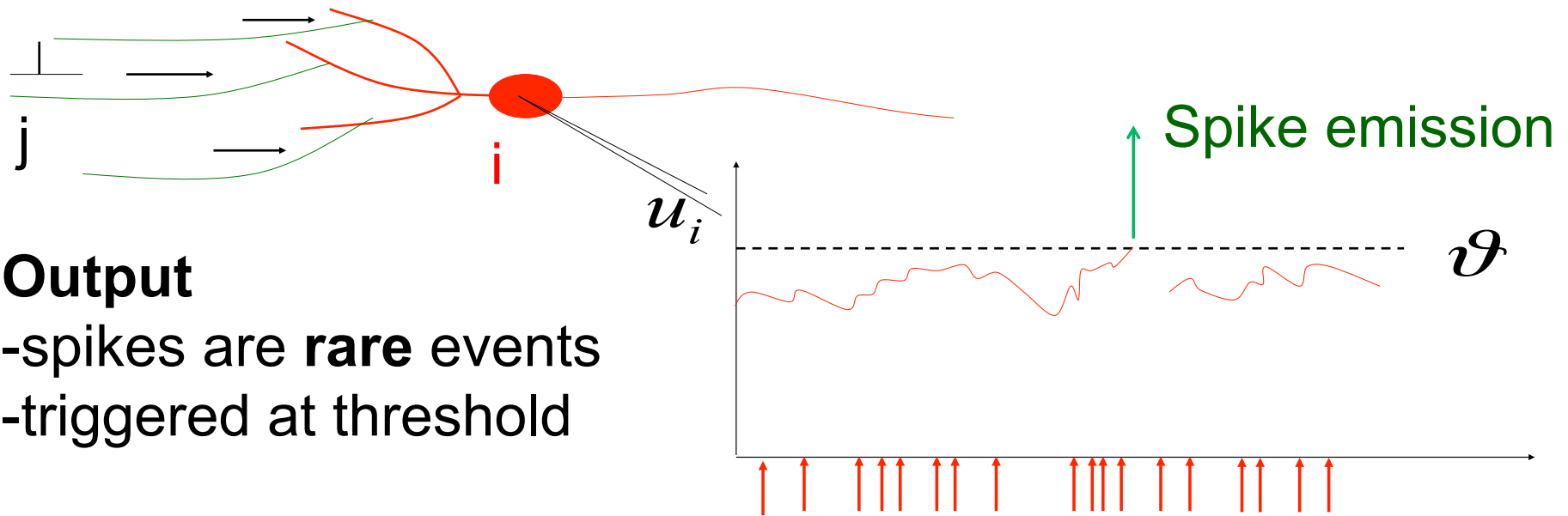
Output
-spikes are **rare** events
-triggered at threshold

Subthreshold regime:
-trajectory of potential shows fluctuations

Spike emission

ϑ

Random spike arrival

Neuronal Dynamics – membrane potential fluctuations

Spontaneous activity *in vivo*

What is noise?

What is the neural code?

(week 5+6)

electrode
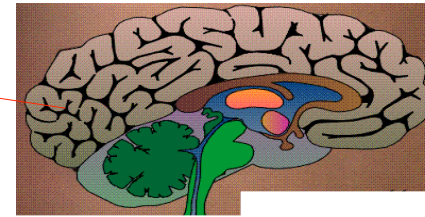
Brain

awake mouse, cortex, freely whisking,

Crochet et al., 2011

Fig. 7.1: Spontaneous activity *in vivo*. Sample of a voltage trace (whole-cell recording) of a cortical neuron when the animal receives no experimental stimulation. The neuron is from layer 2/3 of C2 cortical column, a region of the cortex associated to whisker movement. The recording corresponds to a period of time where the mouse is awake and freely whisking. Data courtesy of Sylvain Crochet and Carl Petersen (Crochet et al.,

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Week 1: **A first simple neuron model/ neurons and mathematics**

Week 2: **Hodgkin-Huxley models and biophysical modeling**

Week 3: **Two-dimensional models and phase plane analysis**

Week 4: **Two-dimensional models Dendrites**

Week 5: **Variability of spike trains and the neural code**

Week 6: **Noise models, noisy neurons and coding**

Week 7: **Estimating neuron models for coding and decoding**

Neuronal Dynamics – Exercises 1.1

Take 3 minutes NOW!

Multiple answers possible!

Neuronal Dynamics – Exercises 1.1

A cortical neuron sends out signals which are called:
   [ ] action potentials
   [ ] spikes
   [ ] postsynaptic potential

The dendrite is a part of the neuron
   [ ] where synapses are located
   [ ] which collects signals from other
      neurons
   [ ] along which spikes are sent to other
      neurons

In an integrate-and-fire model, when the voltage hits the threshold:
   [ ] the neuron fires a spike
   [ ] the neuron can enter a state of
      refractoriness
   [ ] the voltage is reset
   [ ] the neuron explodes

In vivo, a typical cortical neuron exhibits
   [ ] rare output spikes
   [ ] regular firing activity
   [ ] a fluctuating membrane potential

Multiple answers possible!