Introduction to Neuroinformatics **HS 2018**

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Lecture 2

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This course provides an introduction to the functional properties of neurons. Particularly, the description of membrane electrical properties (action potentials, channels), neuronal anatomy, synaptic structures, and neuronal networks. The lectures covers different topics and depending on your background some parts will seem easy, whereas some others will be more difficult. Due to this fact every exercise is preceded by a brief description of the topic and should contain all the information that you require to understand the problem. The exercises are not meant to match closely the teaching schedule as you may expect, but rather as a complement and we will give you the opportunity to address directly some of the questions that will arise during this course.

This exercise sheet is aimed at giving you a taste of what is going to come in this course. Many of the expressions here have not been discussed in the lecture so far, but they are topics of future lectures.

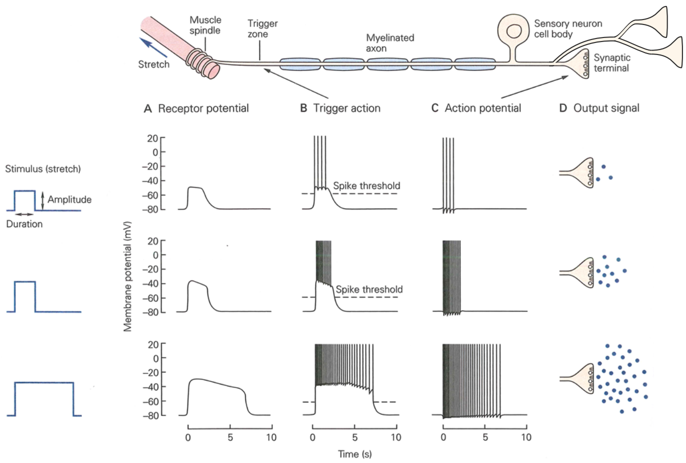
Exercise 2.1: All-or-none vs. graded (digital vs. analog)

Illustrated below are the signals observed in the different parts of a sensory neuron responding to muscle stretch, a mechanical process involved in the knee jerk reflex (*figure adapted from* ***Principles of Neural Science****, 5th edition, Kandel et al*).

- **The stimulus:** On the leftmost panels you can see the three different stimuli to the neuron under consideration (stimulus strength as a function of time). As mentioned, for this particular neuron the stimulus is a stretch of the muscle it is attached to.
  (a) What could be the use of having stretch receptors in our muscles?
  (b) What other types of stimuli can you think of for other types of sensory neurons?

- **A Receptive component: The receptor potential:** At the receptive surface of a sensory neuron certain proteins (ion channels) are responsive to certain aspects of the sensory stimulus and regulate the flow of ions across the biophysical membrane of the neuron. A flow of ions across the membrane results in a change of the potential associated with the membrane (*'receptor potential'*) as depicted in the panels in the second column from the left for each stimulus.
  (c) What happens to the receptor potential if you double the amplitude of the stimulus?
  (d) What happens to the receptor potential if you double its duration?
  (e) Is the receptor potential an analog (graded) or a digital (all-or-none) signal?

- **B Summing or integrative component: The trigger zone:** Now look at the panels in the third column from the left. If the membrane potential exceeds a certain voltage threshold at the trigger zone, action potentials (spikes) are generated, which propagate along the axon. We will learn in detail how this spike generation works in terms of membrane properties in later lectures.
  (f) How is the signal transformed? How is the information about the stimulus amplitude (stretch) encoded in the axon?
  (g) What would happen if you reduce the amplitude of the stimulus to a tenth of the original strength?
  (h) Sketch the firing frequency (the number of spikes in a given interval of time) as a function of stimulus amplitude. Does the line you drew intersect the origin? Why or why not?



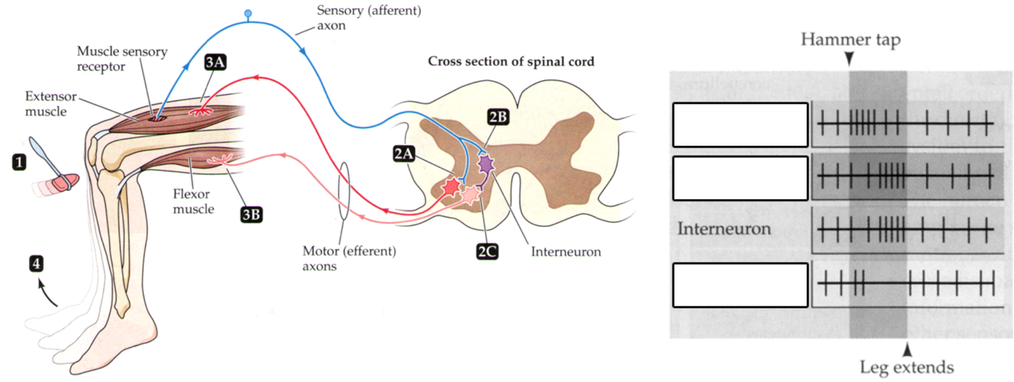
- **C Long-range signaling component: The axon:** In the axon the only signal you see is the train of action potentials (the graded receptor potential decays due to the distance: passive propagation). All action potentials are propagated faithfully along the axon.
  (i) Is the action potential a graded or an all-or-none mechanism?

- **D Secretory component: The synaptic terminal:** When the signal arrives at the synaptic terminal the electrical signal is transformed into a chemical one through release of neurotransmitter molecules which are represented by the blue dots in the figure. Therefore, neurotransmitter release is the output signal.
  (j) How does the amount of transmitter released depend on the number of spikes?
  (k) How does it depend on the initial sensory stimulus?
  (l) Is this signal analog or digital?

- **Summary A-D: the whole system:** Now look at the whole system from stimulus to synaptic terminal, considering also the stages in between.
  (m) What kind of computation/operation does it perform?
  (n) Why does it make sense to use analog and digital signals in the different stages?

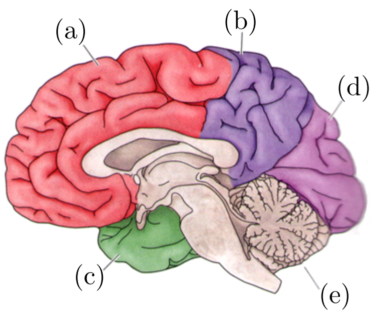
Exercise 2.2: The monosynaptic stretch reflex circuit

The stretch reflex is the monosynaptic reflex arc that occurs involuntarily when a muscle is stretched. It is also called knee-jerk reaction. On the left side, you see the circuit of the monosynaptic reflex arc and on the right the activity patterns of the involved neurons when a hammer is tapped on the knee. Fill in the gaps. (*figure adapted from Neuroscience, 5th edition, Purves* et al.)



Exercise 2.3: The four lobes of the cerebral hemispheres

Midsagittal view of the human brain. The four lobes of the cerebral hemispheres are seen from their medial surface. Label them correctly. What is the remaining structure (e)? (*figure adapted from* ***Neuroscience****, 5th edition, Purves et al.*)



Exercise 2.4: Terminologies in basic neurobiology

- Describe: association cortex, central nervous system (CNS), cerebral cortex, corpus callosum, cortex, gray matter, gyrus, limbic system, neocortex, peripheral nervous system (PNS), spinal cord, white matter.

- Describe: action potential, afferent, axon, dendrite, efferent, interneuron, synapse, neurotransmitter, excitatory neuron, inhibitory neuron, soma.