Asst: Nicoletta Risi, Raphaela Kreiser, Ioana Calangiu {nicoletta, rakrei, calangiu}@ini.uzh.ch

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

(a) To make sure that the CNS 'knows' about the tension in the muscle. This is important for stability: in the case of an involuntary stretch of the muscle, it must contract. This is exactly what happens in the stretch reflex as described in exercise 2 (the sensory neuron we look at in this exercise is the blue one in exercise 2).

(b) Light, temperature, pressure, vibration, smell, taste, endolymph motion, etc. All of these different modalities are perceived with different sensors. Note: Most receptor potentials are depolarizing (excitatory), but interestingly, a receptor potential can also be hyperpolarizing (inhibitory) as in the retina.

(c) The response (receptor potential) also increases (roughly doubles up to a ceiling).

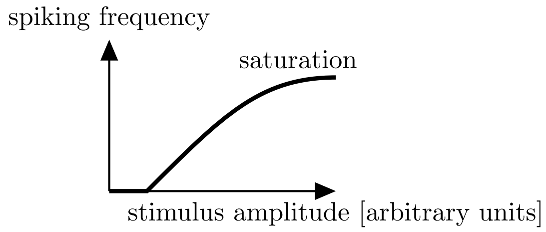
(d) The receptor potential also doubles its duration.

(e) The receptor potential is a graded signal (analog).

(f) If the receptor potentials are large enough, it exceeds the threshold for the generation of an action potential (spike). The firing rate of spikes codes for the intensity of the stimulus.

(g) You may be under the **threshold**, and in this case no response spike would be elicited. Thus, it is a thresholded response.

(h) No, it does not intersect the origin, because the stimulus must elicit a potential change above a certain threshold to trigger a spike.



(i) The action potential is an all-or-none mechanism: it is an event that, once started, proceeds by itself to completion; if not started, a substantially different thing happens. So, stimuli below threshold do not produce a signal, and stimuli above threshold produce all signals of the (same) amplitude. Therefore it is a digital signal. However, the intensity of the stimulus is coded by the frequency (1/time between 2 spikes), which is graded. So, the action potentials are all-or-none, but their frequency is graded. Note: In the figure you can also see spike frequency adaptation, but this is not discussed here.

(j) The incoming spikes trigger the release of vesicles containing the neurotransmitter. The frequency of action potentials determines exactly how much neurotransmitter is released by the cell.

(k) The more intense the stimulus, the more frequent spikes are, and the more vesicles are released.

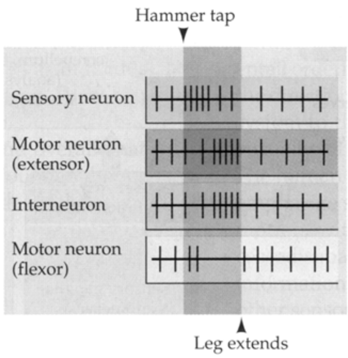
(l) The output signal (neurotransmitter release) is again a graded signal (the more intense the stimulus is, the more neurotransmitter is released). (However, as we will see, neurotransmitter release is quantal, so you could also consider neurotransmitter as digital: number of released vesicles.)

(m) The whole system maps the mechanical stimulus onto an amount of released neurotransmitter with a 'digital' stage in between. Therefore, the process can be seen as an analog (receptor potential) – digital (action potential) – analog (transmitter release) conversion.

(n) An analog sensor is more sensitive, can more easily be adaptative. In contrast, transmission over large distances is better with a periodically regenerated digital signal.

Note: The discussed neuron is a sensory neuron and has a 'pseudounipolar morphology'. This is a particular cell type and does not represent the most frequent morphology of CNS neurons. Most neurons in the CNS have an unmyelinated dendrite with many branches as input structure and as an output structure an axon which also branches and which can be myelinated. In these cells, the trigger zone is the initial segment of the axon, where it branches off from the soma. There, the density of voltage-sensitive Na^+-channels is highest and therefore the threshold for generating an action potential is lowest. At the end of the branches of the axon there are many synapses.

Solution 2.2: The monosynaptic stretch reflex circuit



Note: In this circuit, the interneuron makes *feedforward* inhibition. Feedforward inhibition is inhibition at a subsequent site in the pathway, whereas feedback inhibition is inhibition at a previous site in the pathway. The sense of feedback inhibition is to dampen the activity within the stimulated pathway to prevent it from exceeding a certain critical level. If you want to see how *feedback* inhibition works in the spinal cord, check for *'Renshaw inhibition'*.

Solution 2.3: The four lobes of the cerebral hemispheres

(a) Frontal lobe
(b) Parietal lobe
(c) Temporal lobe
(d) Occipital lobe

And the remaining structure is (e) Cerebellum.

Solution 4: Some expressions in basic neurobiology

Taken from glossary of Purves *et al.* Neuroscience, Sinauer, fifth edition:

association cortex:
Defined by exclusion as those neocortical regions that are not involved in primary sensory or motor processing.

central nervous system (CNS):
The brain and spinal cord of vertebrates (by analogy, the central nerve cord and ganglia of invertebrates).

cerebral cortex:
The superficial gray matter of the cerebral hemispheres.

corpus callosum:
The large midline fiber bundle that connects the cortices of the two cerebral hemispheres.

cortex:
The superficial mantle of gray matter (a sheet-like array of nerve cells) covering the cerebral hemispheres and cerebellum, where most of the neurons in the brain are located.

gray matter:
General term that describes regions of the central nervous system rich in neuronal cell bodies and neuropil; includes the cerebral and cerebellar cortices, the nuclei of the brain, and the central portion of the spinal cord.

gyrus:
The ridges of the infolded cerebral cortex (the valleys between these ridges are called sulci).

limbic system:
Term that refers to those cortical and subcortical structures concerned with the emotions; the most prominent components are the cingulate gyrus, the hippocampus, and the amygdala.

neocortex:
The six-layered cortex that forms the surface of most of the cerebral hemispheres.

peripheral nervous system (PNS):
All nerves and neurons that lie outside the brain and spinal cord.

spinal cord:
The portion of the central nervous system that extends from the lower end of the brainstem (the medulla) to the cauda equina.

white matter:
A general term that refers to large axon tracts in the brain and spinal cord; the phrase derives from the fact that axonal tracts have a whitish cast when viewed in the freshly cut material.

action potential:
The electrical signal conducted along axons (or muscle fibers) by which information is conveyed from one place to another in the nervous system.

afferent:
A neuron or axon that conducts action potentials from the periphery toward the central nervous system.

axon:
The neuronal process that carries the action potential from the nerve cell body to a target.

dendrite:
A neuronal process arising from the nerve cell body that receives synaptic input.

efferent:
A neuron or axon that conducts information away from the central nervous system toward the periphery.

interneuron:
Technically, a neuron in the pathway between primary sensory and primary effector neurons; more generally, a neuron whose relatively short axons branch locally to innervate other neurons. Also known as local circuit neuron.

synapse:
Specialized terminal between two neurons that is responsible for transmitting information across the two two neurons, either chemically or electrically.

neurotransmitter:
Substance released by synaptic terminals for the purpose of transmitting information from one cell (the presynaptic cell) to another (the postsynaptic cell).

excitatory neuron:
A neuron that excites its post-synaptic neuron thus increasing the chances of action potentials in the post-synaptic cell.

inhibitory neuron:
A neuron that inhibits its post-synaptic neuron thus reducing the chances of action potentials in the post-synaptic cell.

soma:
The cell body of a neuron.