# Medical Neuroscience | Tutorial Notes

## General principles of sensory systems

### *MAP TO NEUROSCIENCE CORE CONCEPTS*[1]

NCC1. The brain is the body's most complex organ.

NCC7. The human brain endows us with a natural curiosity to understand how the world works.

### *LEARNING OBJECTIVES*

After study of today's learning, the student will:

1. Discuss the organization of neuronal pathways in sensory and motor systems.
2. Account for the generation of action potentials in peripheral axons in response to somatic sensory stimulation.
3. Discuss factors that influence how information is coded in sensory systems.
4. Discuss the concept of the receptive field in sensory processing.

### *TUTORIAL OUTLINE*

I. Overview of sensory and motor systems

- A. neuronal pathways
    1. *series* of neurons that transmit information from one location (e.g., sensory surface) to a distant target (e.g., cerebral cortex)
    2. pathways may go in either direction; i.e., **ascending** from periphery "inwards" (e.g., towards cortex; typical of sensory pathways) or **descending** from cortex "outwards" (e.g., towards spinal cord; typical of motor pathways)
    3. nomenclature for neurons in a pathway
        - a. **first order** (primary) **neurons**
        - b. **second order** (secondary) **neurons**
        - c. **third order** (tertiary) **neurons**
- B. all major sensory and motor pathways have midline crossings (= **decussations**)
    1. although the evolutionary perspective on pathway decussations remains opaque, an important principle of brain function is that *each cerebral hemisphere receives sensory information from the opposite side of the body*
    2. therefore, each ascending (and descending) pathway must decussate

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience ) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

3. but stay tuned … in a forthcoming tutorial, you will learn that *cerebellar representation is ipsilateral!*

C. sensory transduction

1. **sensory transduction**: conversion of the physical (or chemical) energy stimulus into an electrical signal in a sensory neuron

2. in the somatic sensory system (see **Figure 9.2**[2]):

    A. application of a stimulus deforms the skin and the sensory receptors embedded within it
    B. physical deformation of receptor membranes open ions channels, and sodium ions (current) flows into receptor ending
    C. current depolarizes receptor membrane producing a **receptor** (or **generator**) **potential**

D. information coding

1. the quality of a stimulus is encoded by the identity of the activated peripheral receptor ("labeled line" coding scheme)

    a. different axonal endings respond to restricted sets of sensory stimuli

        i. selectivity is explained by:

            - morphological specializations of receptor endings

            - properties of the ionotropic channels in receptor membranes

        ii. selectivity is conveyed and preserved in parallel pathways in the CNS

2. strength of a stimulus is encoded by:

    a. the rate of action potentials in the afferent axons

    b. the temporal pattern of action potentials in afferent axons

3. **adaptation** (see **Figure 9.4**)

    a. all receptors adapt (decrease their firing rate) to the persistent presence of a stimulus

    b. some adapt slowly and display **tonic** firing patterns as long as a stimulus is present (more static qualities)

    c. others adapt rapidly and display **phasic** firing patterns (more dynamic qualities)

4. **sensory threshold** (see **Figure 9.2**)

    a. all receptors have a sensory threshold for firing action potentials

    b. in the somatic sensory system, "threshold" is the strength of mechanical deformation necessary for producing a generator potential of sufficient amplitude to elicit an action potential

        i. some receptors have a low threshold (e.g., encapsulated endings)

        ii. others have a high threshold (e.g., free nerve endings)

[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

**5.** **receptive field** (see **Figure 1.13**)

a. region of the body that when stimulated by a mechanical stress elicits a response in a sensory neuron

   i. the center of the receptive field general elicits a robust response (either a sharp increase or decrease in the firing rate of the neuron)

   ii. surrounding the center of the receptive field is a annular region (called the "surround") that antagonizes the center zone

b. receptive fields may be defined for any neuron in a sensory pathway

c. for primary neurons, receptive field size is *inversely proportional* to the density of their peripheral processes (receptors)

   i. thus, large receptive fields are created by large or diffusely distributed sensory endings

   ii. small receptive fields are created by small or spatially restricted sensory endings

d. for neurons in the cortex, receptive field size is *directly proportional* to the degree of convergence in sensory pathways

   i. thus, large receptive fields are created by a high degree of convergence as many inputs from antecedent centers converge on the dendrites of a single cortical neuron

   ii. small receptive fields are associated with minimal convergence of inputs from antecedent neural centers

e. in mechanosensation, the differential sizes of receptive fields in neurons that represents different parts of the body accounts, at least in part, for the differences in two-point discrimination along the body surface (see **Figure 9.3**)

f. in the cerebral cortex, cognitive factors (e.g., attention, stress) may modify the size and sensitivity of receptive fields

## *STUDY QUESTION*

What explains regions of high sensory acuity, such as the center of vision or the tips of the fingers?

A. large receptive fields
B. sparsely innervated sensory surfaces
C. densely innervated sensory surfaces
D. small receptive fields
E. both A & B are important for creating high sensory acuity
F. both C & D are important for creating high sensory acuity