

## CHAPTER 16

### LECTURE OUTLINE

#### I. INTRODUCTION

- A. The components of the brain interact to receive sensory input, integrate and store the information, and transmit motor responses.
- B. To accomplish the primary functions of the nervous system there are neural pathways to transmit impulses from receptors to the circuitry of the brain, which manipulates the circuitry to form directives that are transmitted via neural pathways to effectors as a response.

#### II. SENSATION

- A. Sensation is a conscious or unconscious awareness of external or internal stimuli. Perception is the conscious awareness and interpretation of sensations.

##### B. Sensory Modalities

- 1. Sensory Modality is the property by which one sensation is distinguished from another.
- 2. In general, a given sensory neuron carries only one modality.
- 3. The classes of sensory modalities are general senses and special senses.
  - a. The general senses include both somatic and visceral senses, which provide information about conditions within internal organs.
  - b. The special senses include the modalities of smell, taste, vision, hearing, and equilibrium.

##### C. The Process of Sensation

- 1. For a sensation to arise, four events must occur, these are stimulation, transduction, conduction, and translation.
  - a. A stimulus, or change in the environment, capable of initiating a nerve impulse by the nervous system must be present.
  - b. A sensory receptor or sense organ must pick up the stimulus and transduce (convert) it to a nerve impulse by way of a generator potential.
  - c. The impulse(s) must be conducted along a neural pathway from the receptor or sense organ to the brain.
  - d. A region of the brain or spinal cord must translate the impulse into a sensation.

##### D. Sensory Receptors

1. Types of Sensory Receptors (Figures 16.1a)
2. On a microscopic level, sensory receptors are free nerve endings, encapsulated nerve endings at the dendrites of first-order sensory neurons, or separate cells that synapse with first order sensory neurons (Figure 15.1).
3. When stimulated the dendrites of free nerve endings, encapsulate nerve endings, and the receptive part of olfactory receptors produce generator potentials.
  - a. The specialized cells that act as receptors for the special senses of vision, hearing, equilibrium, and taste produce receptor potentials in response to stimuli.
4. Generator and receptor potentials are graded, local potentials; generator potentials trigger action potentials, whereas receptor potentials do not.
5. According to location, receptors are classified as exteroceptors, interoceptors (visceroceptors), and proprioceptors.
6. On the basis of type of stimulus detected, receptors are classified as mechanoreceptors, thermoreceptors, nociceptors, photoreceptors, chemoreceptors, and osmoreceptors.
7. Table 16.1 summarizes the classification of sensory receptors.

#### **E. Adaptation in Sensory Receptors**

1. A characteristic of many sensations is adaptation, i.e., a change in sensitivity (usually a decrease) to a long-lasting stimulus.
2. Receptors vary in how they adapt
  - a. Rapid adaptor
  - b. Slow adaptors
3. The receptors involved are important in signaling information regarding steady states of the body.

### **III. SOMATIC SENSATIONS** (Receptors for somatic sensation are summarized in Table 16.1)

#### **A. Tactile Sensations**

1. Tactile sensations are touch, pressure, and vibration plus itch and tickle.
  - a. Tactile receptors include corpuscles of touch (Meissner's corpuscles), hair root plexuses, type I (Merkel's discs) and type II cutaneous (Ruffini's corpuscles) mechanoreceptors, lamellated (Pacinian) corpuscles, and free nerve endings (Figure 16.2).

#### **2. Touch**

- a. Crude touch refers to the ability to perceive that something has simply touched the skin; fine touch provides specific information about a touch sensation such as location, shape, size, and texture of the source of stimulation.
- b. Receptors for touch include corpuscles of touch (Meissner's corpuscles) and hair root plexuses; these are rapidly adapting receptors.
- c. Type I cutaneous mechanoreceptors (tactile or Merkel discs) and type II cutaneous mechanoreceptors (end organs of Ruffini) are slowly adapting receptors for touch (Figure 16.2).
- d. Pressure
  - 1) Pressure sensations generally result from stimulation of tactile receptors in deeper tissues and are longer lasting and have less variation in intensity than touch sensations; pressure is a sustained sensation that is felt over a larger area than touch.
  - 2) Receptors for pressure are type II cutaneous mechanoreceptors and lamellated (Pacinian) corpuscles.
    - i. Like corpuscles of touch, lamellated corpuscles adapt rapidly.
- e. Vibration
  - 1) Vibration sensations result from rapidly repetitive sensory signals from tactile receptors; the receptors for vibration sensations are corpuscles of touch and lamellated corpuscles, which detect low-frequency and high-frequency vibrations, respectively.
- f. Itch
  - 1) Itch and tickle receptors are free nerve endings.
- g. Tickle
  - 1) Tickle is the only sensation that you may not elicit on yourself.
- h. Phantom pain is the sensations of pain in a limb that has been amputated.

**(Clinical Connection)**

**B. Thermal Sensations**

- 1. Thermoreceptors are free nerve endings.
- 2. Separate thermoreceptors respond to hot and cold stimuli.

**C. Pain Sensations**

1. Pain is a vital sensation because it provides us with information about tissue-damaging stimuli and with signs that may be used for diagnosis of disease or injury.
2. Pain receptors (nociceptors) are free endings that are located in nearly every body tissue; adaptation is slight if it occurs at all.
3. Types of pain
  - a. Two kinds of pain are recognized in the parietal lobe of the cortex: somatic (superficial and deep) and visceral; visceral pain, unlike somatic pain, is usually felt in or just under the skin that overlies the stimulated organ – the pain may also be felt in a surface area far from the stimulated organ in a phenomenon known as referred pain (Figure 16.3).
4. Localization of Pain
  - a. Fast pain is very precisely localized
  - b. Slow pain usually appears over a larger area
  - c. Referred pain (Figure 16.3)
5. Analgesic drugs block pain sensations (Clinical Connection).

#### **D. Proprioceptive Sensations**

1. Receptors located in skeletal muscles, in tendons, in and around joints, and in the internal ear convey nerve impulses related to muscle tone, movement of body parts, and body position. This awareness of the activities of muscles, tendons, and joints and of balance or equilibrium is provided by the proprioceptive or kinesthetic sense.
2. **Muscle spindles:**
  - a. proprioceptors in skeletal muscles that monitor changes in the length of skeletal muscles and participate in stretch reflexes
  - b. muscle spindle consists of several slowly adapting sensory nerve endings that wrap around 3 to 10 specialized muscle fibers, called intrafusal muscle fibers
  - c. The main function of muscle spindles is to measure muscle length (figure 16.4)
3. **Tendon Organs**
  - a. located at the junction of a tendon and a muscle
  - b. protect tendons and their associated muscles from damage due to excessive tension
4. **Joint Kinesthetic receptors**
  - a. respond to acceleration and deceleration of joints during movement
  - b. (Table 16.2).

#### IV. SOMATIC SENSORY PATHWAYS

- A. Somatic sensory pathways relay information from somatic receptors to the primary somatosensory area in the cerebral cortex.
  - 1. The pathways consist of first-order, second-order, and third-order neurons.
  - 2. Axon collaterals of somatic sensory neurons simultaneously carry signals into the cerebellum and the reticular formation of the brain stem.
- B. Posterior Column-Medial Lemniscus Pathway to the Cortex
  - 1. The nerve impulses for conscious proprioception and most tactile sensations ascend to the cortex along a common pathway formed by three-neuron sets (Figure 16.5).
  - 2. Impulses conducted along this pathway are concerned with discriminative touch, stereognosis, proprioception, and vibratory sensations.
- C. Anterolateral Pathways to the Cortex
  - 1. The anterolateral or spinothalamic pathways carry mainly pain and temperature impulses (Figure 16.6).
  - 2. They also relay the sensations of tickle and itch and some tactile impulses.
- D. Trigeminothalamic Sensory Pathways to the Cortex
  - 1. The trigeminothalamic pathways carry mainly tactile sensations, pain and temperature impulses from the face (Figure 16.7).
  - 2. They relay the sensations to the somatosensory area via the same side thalamus.
- E. Mapping the Primary Somatosensory Area
  - 1. Specific areas of the cerebral cortex receive somatic sensory input from particular parts of the body and other areas of the cerebral cortex provide output instructions for movement of particular parts of the body (Figure 15.5)
  - 2. Precise location of somatic sensations occurs at the primary somatosensory area (Figure 16.8a).
- F. Somatic Sensory Pathways to the Cerebellum
  - 1. The posterior spinocerebellar and the anterior spinocerebellar tracts are the major routes whereby proprioceptive impulses reach the cerebellum.
  - 2. The cuneocerebellar and rostral spinocerebellar tracts convey impulses from proprioceptors of the trunk and upper limbs.
- G. Table 16.3 summarizes the major sensory tracts in the spinal cord and pathways in the brain.
- H. Tertiary syphilis causes a progressive degeneration of the posterior portions of the spinal cord resulting in lost somatic sensations and proprioception failure. (**Clinical Connection**)

## V. SOMATIC MOTOR PATHWAYS

- A. Lower motor neurons extend from the brain stem or spinal cord to skeletal muscles.
- B. Four distinct neurons participate in control of movement by providing input to lower motor neurons (Figure 16.9).
- C. Local circuit neurons are located close to lower motor neuron cell bodies in the brain stem and spinal cord.
  - 1. Local circuit neurons and lower motor neurons receive input from upper motor neurons.
  - 2. Neurons of the basal ganglia provide input to upper motor neurons.
  - 3. Cerebellar neurons also control activity of upper motor neurons.
- D. Organization of Upper Motor Neuron Pathways
  - 1. The primary motor area in the precentral gyrus of the frontal lobe is a major control region for voluntary movements (Figure 16.8)
  - 2. Direct, or pyramidal, motor pathways provide input to lower motor neurons from the cortex (Figure 16.9)
  - 3. Indirect motor pathways provide input to lower motor neurons from motor centers in the brain stem (Figure 16.9)
- E. Direct motor pathways .
  - 1. The various tracts of the pyramidal system convey impulses from the cerebral cortex that result in precise muscular movements.
  - 2. The direct pathways include the corticospinal tracts (Figure 16.10) and corticobulbar tracts (Figure 16.11).
  - 3. The corticospinal tracts promote voluntary movements of the limbs and trunks (Figure 16.10)
  - 4. The corticobulbar tracts are tracts that promote voluntary movements of the head (Figure 16.11)
  - 5. Damage or disease of lower motor neurons produces flaccid paralysis of muscles on the same side of the body. Injury or disease of upper motor neurons results in spastic paralysis of muscles on the opposite side of the body. (Clinical Connection)
  - 6. Amyotrophic Lateral Sclerosis (ALS) is a disease that attacks motor areas of the cerebral cortex, axons of upper motor neurons and cell bodies of lower motor neurons. It causes progressive muscle weakness (**Clinical Connection**).
- F. Indirect Motor Pathways

1. Indirect or extrapyramidal pathways include all somatic motor tracts other than the direct (corticospinal and corticobulbar) tracts.
  - a. Indirect pathways involve the motor cortex, basal ganglia, thalamus, cerebellum, reticular formation, and nuclei in the brain stem (Table 16.4).
  - b. Major indirect tracts are the rubrospinal, tectospinal, vestibulospinal, and reticulospinal tracts.
  - c. Table 16.4 summarizes the major motor tracts, their functions, and pathways in the brain.

#### G. Roles of the Basal Ganglia

1. The basal ganglia help program habitual or automatic sequences and set an appropriate level of muscle tone.
2. They also selectively inhibit other motor neuron circuits that are intrinsically active or excitatory.
3. Impairment of the basal ganglia results in uncontrollable, abnormal body movements, often accompanied by muscle rigidity and tremors. A number of diseases, including Parkinson disease, Huntington disease, Tourette syndrome basal ganglia disorders **(Clinical Connection)**.

#### H. Modulation of Movement by the Cerebellum

1. The cerebellum is active in both learning and performing rapid, coordinated, highly skilled movements and in maintaining proper posture and equilibrium.
2. The four aspects of cerebellar function are monitoring intent for movement, monitoring actual movement, comparing intent with actual performance, and sending out corrective signals (Figure 16.12)

## VI. INTEGRATIVE FUNCTIONS OF THE CEREBRUM

- A. The integrative functions include sleep and wakefulness, memory, and emotional responses (discussed in Chapter 14).

#### B. Wakefulness and Sleep

1. Reticular Activating System (RAS)
2. Sleep and wakefulness are integrative functions that are controlled by the reticular activating system.
3. Arousal, or awakening from a sleep, involves increased activity of the RAS.
  - a. Once the RAS is activated, the cerebral cortex is also activated and arousal occurs.

- b. The result is a state of wakefulness called consciousness.
- 4. Sleep
  - a. During sleep, a state of altered consciousness or partial unconsciousness from which an individual can be aroused by different stimuli, activity in the RAS is very low.
  - b. Normal sleep consists of two types: non-rapid eye movement sleep (NREM) and rapid eye movement sleep (REM).
    - 1) Non-rapid eye movement or slow wave sleep consists of four stages, each of which gradually merges into the next. Each stage has been identified by EEG recordings .
    - 2) Most dreaming occurs during rapid eye movement sleep.
  - c. **Clinical Connection:** Sleep disorders, insomnia, sleep apnea, narcolepsy and hypocretin.

### C. Learning and Memory

1. Learning is the ability to acquire new knowledge or skills through instruction or experience. Memory is the process by which that knowledge is retained over time.
2. For an experience to become part of memory, it must produce persistent functional changes that represent the experience in the brain.
3. The capability for change with learning is called plasticity.
4. Memory is the ability to recall thought and is generally classified into two kinds based on how long the memory persists: short-term and long-term memory.
5. A memory trace in the brain is called an engram (a change in the brain that represents the experience).
  - a. Short-term memory lasts only seconds or hours and is the ability to recall bits of information; it is related to electrical and chemical events.
  - b. Long-term memory lasts from days to years and is related to anatomical and biochemical changes at synapses.
  - c. Loss of memory is called amnesia (**Clinical Connection**)

## VII. DISORDERS: HOMEOSTATIC IMBALANCES

- A. Parkinson's disease is a progressive degeneration of CNS neurons of the basal nuclei region due to unknown causes that decreases dopamine neurotransmitter production.
  1. This condition produces motor coordination problems of involuntary tremor and/or rigidity.

2. Motor performance can be described as bradykinesia (slow) and hypokinesia (limited).
3. Limited treatment is provided with L-dopa, a precursor to dopamine, or through acetylcholine inhibitors.

**VIII. MEDICAL TERMINOLOGY** - Alert students to the medical terminology associated with the sensory, motor and integrative systems.