

The Peripheral Nervous System and Reflex Activity

Outline

The peripheral nervous system and its components:

- A. The PNS includes all neural structures outside the brain and spinal cord: sensory receptors, peripheral nerves and their associated ganglia, and efferent motor endings. (p. 486; Fig. 13.1)

PART 1: SENSORY RECEPTORS AND SENSATION

13.1 Sensory receptors are activated by changes in the internal or external environment (pp. 486–489; Table 13.1)

- A. Sensory receptors are specialized to respond to changes in their environment called stimuli. (p. 48)
 - 1. Activation of sensory receptors by a strong enough stimulus causes the production of graded potentials that trigger nerve impulses along afferent pathways to the CNS.
- B. Receptors may be classified according to the type of stimulus: (p. 486)
 - 1. Mechanoreceptors are stimulated by mechanical force, such as touch, pressure, vibration, and stretch.
 - 2. Thermoreceptors respond to changes in temperature.
 - 3. Photoreceptors detect light.
 - 4. Chemoreceptors are stimulated by chemicals, such as odorants, taste stimuli, or chemical components of body fluids.
 - 5. Nociceptors respond to painful stimuli and can stimulate some types of thermoreceptors, mechanoreceptors, or chemoreceptors.
- C. Receptors may be classified according to their location or location of stimulus: (pp. 486–487)
 - 1. Exteroceptors are located at or near the body surface and detect stimuli arising from outside the body, such as touch, pressure, pain, skin temperature receptors, and most of the special senses.
 - 2. Interoceptors, associated with internal organs and vessels, monitor chemical changes, stretch, or temperature.
 - 3. Proprioceptors are found within skeletal muscles, tendons, joints, ligaments, and connective tissue coverings of bones and muscles and relay information concerning body movements.
- D. Receptors may be classified according to their structure. (p. 487; Table 13.1)
 - 1. Simple receptors are general senses and may be nonencapsulated or encapsulated dendritic endings.
 - a. Nonencapsulated dendritic endings are free nerve endings and detect temperature, pain, itch, light touch, or are located at the base of hair follicles.
 - b. Encapsulated dendritic endings consist of a dendrite enclosed in a connective tissue capsule and detect discriminatory touch, initial, continuous, and deep pressure, and stretch of muscles, tendons, and joint capsules.

- 13.2 Receptors, ascending pathways, and cerebral cortex process sensory information (pp. 489–492; Figs. 13.2–13.3)
- A. The somatosensory system, the part of the sensory system serving the body wall and limbs, receives input from exteroceptors, proprioceptors, and interoceptors. (p. 489; Fig. 13.2)
 - B. There are three main levels of neural integration in the somatosensory system: the receptor level, circuit level, and perceptual level. (pp. 490–492; Fig. 13.3)
 1. Processing at the receptor level requires a stimulus to excite a receptor within its receptive field, causing generation of graded potentials in order for sensation to occur.
 - a. If the receptor is part of a sensory neuron, the graded potentials produced are generator potentials, that can cause the generation of action potentials on the sensory neuron.
 - b. If the receptor is a separate structure from the sensory neuron, the graded potentials produced are receptor potentials that may cause generator potentials on the sensory neuron.
 - c. Many receptors exhibit adaptation, in which a constant stimulus results in a gradual decrease in receptor sensitivity.
 2. Processing at the circuit level involves delivery of impulses along first-, second-, and third-order neurons to the appropriate region of the cerebral cortex for stimulus localization and perception.
 3. Processing at the perceptual level involves several aspects:
 - a. Perceptual detection sums input from several receptors and is the simplest level of perception.
 - b. Magnitude estimation is the ability to detect stimulus intensity through frequency coding.
 - c. Spatial discrimination allows identification of the site or pattern of stimulation through spatial discrimination.
 - d. Feature abstraction is the mechanism through which we identify complex features of a sensation.
 - e. Quality discrimination involves the ability to differentiate specific qualities of a particular sensation.
 - f. Pattern recognition is the ability to recognize a pattern in a complete scene.
 4. The perception of pain protects the body from damage and is stimulated by extremes of pressure and temperature, as well as chemicals released from damaged tissues.
 5. The pain threshold is the stimulus intensity at which we begin to perceive pain and is the same for most people, although pain tolerance is a genetically determined trait that varies from person to person.
 6. Visceral pain results from stimulation of receptors within internal organs from stimuli such as extreme stretch, ischemia, chemical irritation, and muscle spasms.
 - a. Visceral pain travels along the same fiber tracts as somatic pain impulses, giving rise to referred pain that is located in an area different from the affected area.

PART 2: TRANSMISSION LINES: NERVES AND THEIR STRUCTURE AND REPAIR

- 13.3 Nerves are cord-like bundles of axons that conduct sensory and motor impulses (pp. 492–494; Figs. 13.4–13.5)
- A. A nerve is a cord-like organ consisting of parallel bundles of peripheral axons enclosed by connective tissue wrappings. (p. 492; Fig. 13.4)
 - 1. Each axon within a nerve is surrounded by a thin layer of loose connective tissue, the endoneurium.
 - 2. A perineurium is a connective tissue wrapping that bundles groups of fibers into fascicles.
 - 3. An epineurium bundles all fascicles into a nerve.
 - B. Peripheral nerves, either cranial or spinal, are classified according to the direction in which they transmit impulses. (p. 493)
 - 1. Mixed nerves contain both sensory and motor fibers: Most nerves are mixed nerves.
 - 2. Sensory, or afferent, nerves carry impulses only toward the CNS.
 - 3. Motor, or efferent, nerves only carry impulses away from the CNS.
 - C. Ganglia are collections of neuron cell bodies associated with nerves in the PNS. (p. 493)
 - 1. Ganglia associated with afferent nerve fibers are cell bodies of sensory neurons; ganglia associated with efferent nerve fibers are mostly cell bodies of autonomic motor neurons.
 - D. Damaged CNS nerve fibers almost never regenerate, but if a PNS nerve fiber is cut or compressed, and the cell body remains intact, axons can regenerate. (pp. 493–494; Fig. 13.5)
 - 1. Schwann cells participate in regenerating PNS axons, but in the CNS, oligodendrocytes have growth-inhibiting proteins that do not support re-growth of axons.
- 13.4 There are 12 pairs of cranial nerves (pp. 494–503; Fig. 13.6; Table 13.2)
- A. There are 12 pairs of cranial nerves that originate from the brain and, with the exception of the vagus nerve, serve areas of the head and neck. (pp. 494–503; Fig. 13.6; Table 13.2)
 - 1. Olfactory nerves (cranial nerve I) detect odors.
 - 2. Optic nerves (cranial nerve II) are responsible for vision.
 - 3. Oculomotor, trochlear, and abducens nerves (cranial nerves III, IV, and VI) allow movement of the eyeball.
 - 4. Trigeminal nerves (cranial nerve V) allow sensation of the face and motor control of chewing muscles.
 - 5. Facial nerves (cranial nerve VII) allow movement of muscles creating facial expression.
 - 6. Vestibulocochlear nerves (cranial nerve VIII) are responsible for hearing and balance.
 - 7. Glossopharyngeal nerves (cranial nerve IX) control the tongue and pharynx.
 - 8. Vagus nerves (cranial nerve X) control several visceral organs.
 - 9. Accessory nerves (cranial nerve XI) have a relationship with the vagus nerves.
 - 10. Hypoglossal nerves (cranial nerve XII) innervate muscles of the tongue.
- 13.5 Thirty-one pairs of spinal nerves (pp. 503–513; Figs. 13.7–13.13; Tables 13.3–13.6)

- A. Thirty-one pairs of mixed spinal nerves arise from the spinal cord and serve the entire body except the head and neck. (pp. 503–504; Figs. 13.7–13.8)
1. Each spinal nerve connects to the spinal cord by a ventral root, containing motor fibers, and a dorsal root, containing sensory fibers.
- B. Innervation of Specific Body Regions (pp. 505–513; Figs. 13.9–13.13; Tables 13.3–13.6)
1. Rami lie distal to and are lateral branches of the spinal nerves that carry both motor and sensory fibers.
 2. The back is innervated by the dorsal rami with each ramus innervating the muscle in line with the point of origin from the spinal column.
 3. Only in the thorax are the ventral rami arranged in a simple segmental pattern corresponding to that of the dorsal rami.
 4. The cervical plexus is formed by the ventral rami of the first four cervical nerves.
 5. The brachial plexus is situated partly in the neck and partly in the axilla and gives rise to virtually all the nerves that innervate the upper limb.
 6. The sacral and lumbar plexuses overlap, and because many fibers of the lumbar plexus contribute to the sacral plexus via the lumbosacral trunk, the two plexuses are often referred to as the lumbosacral plexus.
 7. The area of skin innervated by the cutaneous branches of a single spinal nerve is called a dermatome.
 - a. Dermatomes on the trunk are relatively uniform in width, run horizontally, and are in direct line with their spinal nerves.
 - b. Dermatomes in the upper limbs are innervated by ventral rami from C₅–T₁, while dermatomes of the lower limbs are innervated by lumbar nerves (anterior surface), or sacral nerves (posterior surface).
 8. Hilton's law states that any nerve serving a muscle that produces movement at a joint also innervates the joint and the skin over the joint.

PART 3: MOTOR ENDINGS AND MOTOR ACTIVITY

- 13.6 Peripheral motor endings connect nerves to their effectors (p. 513)
- A. Peripheral motor endings are the PNS element that activates effectors by releasing neurotransmitters. (p. 513)
 - B. The terminals of the somatic motor fibers that innervate voluntary muscles form elaborate neuromuscular junctions with their effector cells and they release the neurotransmitter acetylcholine. (p. 513)
 - C. The junctions between autonomic motor endings and the visceral effectors involve varicosities and release either acetylcholine or epinephrine as their neurotransmitter. (p. 513)
- 13.7 There are three levels of motor control (pp. 513–515; Fig. 13.14)
- A. The segmental level is the lowest level on the motor control hierarchy and consists of the spinal cord circuits. (p. 514)
 1. Circuits that control locomotion or repetitive motor activity are called central pattern generators (CPGs) and consist of inhibitory and excitatory neurons that produce rhythmic or alternating movements.
 - B. The projection level has direct control of the spinal cord and acts on direct and indirect motor pathways. (p. 514)
 1. Upper motor neurons produce voluntary movement of skeletal muscles.

2. Brain stem motor nuclei help control reflex and CPG-controlled motor actions.
- C. The precommand level is made up of the cerebellum and the basal nuclei and is the highest level of the motor system hierarchy. (pp. 514–515)
 1. The cerebellum acts on motor pathways through projection areas of the brain stem, and on the motor cortex via the thalamus.
 2. The basal nuclei receive inputs from all areas of the cortex and send output to premotor and prefrontal cortices via the thalamus.

PART 4: REFLEX ACTIVITY

13.8 The reflex arc enables rapid and predictable responses (p. 515–516; Fig. 13.15)

- A. Reflexes are unlearned, rapid, predictable motor responses to a stimulus and occur over highly specific neural pathways called reflex arcs. (p. 515; Fig. 13.15)
 1. Inborn, or intrinsic, reflexes are unlearned, unpremeditated, and involuntary.
 2. Learned, or acquired, reflexes result from practice, or repetition.
- B. A reflex arc is a very specific neural path that controls reflexes and has five components: a receptor, a sensory neuron, an integration center, a motor neuron, and an effector. (p. 515)
- C. Reflexes are functionally classified as somatic, which activate skeletal muscle, or autonomic, which activate visceral effectors. (p. 515)

13.9 Spinal reflexes are somatic reflexes mediated by the spinal cord (pp. 516–522; Figs. 13.16–13.19; Focus Figure 13.1)

- A. Stretch and Tendon Reflexes (pp. 516–520; Figs. 13.16–13.18; Focus Figure 13.1)
 1. In the stretch reflex, the muscle spindle is stretched and excited by either an external stretch or an internal stretch.
 2. The tendon reflex produces muscle relaxation and lengthening in response to contraction.
- B. The Flexor and Crossed Extensor Reflexes (pp. 519–520; Fig. 13.19)
 1. The flexor, or withdrawal, reflex is initiated by a painful stimulus and causes automatic withdrawal of the threatened body part from the stimulus.
 2. The crossed-extensor reflex is a complex spinal reflex consisting of an ipsilateral withdrawal reflex and a contralateral extensor reflex.
- C. Superficial reflexes are elicited by gentle cutaneous stimulation. (p. 521)
 1. The plantar reflex is used to evaluate the proper functioning of the lower spinal cord.
 2. The abdominal reflex tests the proper function of the spinal cord and ventral rami from T₈–T₁₂.

Developmental Aspects of the Peripheral Nervous System (p. 522)

- A. The spinal nerves branch from the developing spinal cord and adjacent neural crest and exit between the forming vertebrae, ending at the adjacent muscle mass: Cranial nerves innervate muscles of the head in a similar way. (p. 522)
- B. Cutaneous nerves develop in a similar pattern: The trigeminal nerves innervate most of the face and scalp, and spinal nerves supply branches to specific dermatomes. (p. 522)

C. Sensory receptors atrophy to some degree with age, and there is a decrease in muscle tone in the face and neck; reflexes occur a bit more slowly. (p. 522)