Chapter 13 The Peripheral Nervous System

Chapter Outline

Module 13.1 Overview of the Peripheral Nervous System (Figures 13.1, 13.2)

A. The **peripheral nervous system (PNS)** links the CNS to the body and to the external environment.

1. The PNS detects _____ stimuli and delivers the information to the CNS as sensory input.
2. The CNS processes the input and transmits the impulse through the PNS to _____ cells and _____ as motor output.

B. **Divisions of the PNS**: the PNS is classified functionally into the following two divisions, which are further subdivided by anatomically by the types of structures they innervate **(Figure 13.1)**:

1. The **sensory division** consists of sensory (afferent) neurons that detect and transmit sensory stimuli to the CNS and has the following two anatomical subdivisions: somatic sensory and visceral sensory **(Figure 13.1a)**.
    a. **Summarize the function of the somatic sensory division**. _____
    _____
    _____
    b. **Summarize the function of the visceral sensory division**. _____
    _____
    _____
2. The **motor division** consists of motor (efferent) neurons that carry out motor functions of the nervous system and has the following subdivisions based on the organs that the neurons contact **(Figure 13.1b)**:
    a. **Generalize the function of the somatic motor division**. _____
    _____
    _____
    _____
    b. **Generalize the function of the visceral motor division (autonomic motor nervous system, ANS)**. _____

c. **What is the sympathetic nervous system of the ANS (fight or flight division) involved in?** _____

d. **What is the parasympathetic system of the ANS (rest and digest division) involved in?** _____

C. **Overview of Peripheral Nerves and Associated Ganglia (Figure 13.2)**

1. **Peripheral nerves**, the main organs of the PNS, consist of the axons of many neurons bound together by connective tissue.
    a. Nerves of the PNS contact, or **innervate**, the majority of structures in the body.
    b. **What do mixed nerves contain?** _____
    c. **Sensory nerves** contain only_____neurons, while **motor nerves** contain mostly motor neurons and some _____ neurons involved in muscle stretch and tension.
2. Spinal nerves and cranial nerves are classified according to their location. **Spinal nerves** originate from the spinal cord and innervate structures below the head and neck. The following anatomical structures are associated with this group of nerves **(Figure 13.2a)**:
    a. Two collections of axons connect the PNS with the spinal cord's gray matter: the **anterior root** consists of_____neurons from the anterior horn, and the **posterior root** consists of _____ neurons from the posterior horn.
    b. These roots fuse to form the spinal nerve just lateral to the posterior root ganglion. All of the_____pairs of spinal nerves are mixed nerves.

3. **Cranial nerves** attach to the brain and mostly innervate structures in the head and neck. These nerves are not formed by the fusion of sensory and motor roots, which allows for purely sensory, mixed, and mostly motor nerves.
4. The following structures are associated with spinal nerves **(Figure 13.2c)**:
    a. **What is the function of the epineurium?** _____

    b. **What is the function of the perineurium and its relationship to fascicles?** _____

    c. **What is the function of the endoneurium?** _____

D. **Functional Overview of the PNS**: the functions of the PNS are integrated with those of the CNS**.**
1. Sensory neurons detect stimuli at sensory receptors after which the following events occur:
    a. _____

    b. _____

2. The motor response is initiated by commands from the motor areas of the cerebral cortex which leads to the following events:
    a. _____

    b. _____

Module 13.2 The Cranial Nerves (Figure 13.3; Tables 13.1, 13.2, 13.3)

A. **The Sensory Cranial Nerves**: the following three cranial nerves contain axons of only sensory neurons: the_____(CN I),_____(CN II), and

_____ (CN VIII) nerves **(Table 13.1)**. See table 13.1 for the location and function of these nerves.

B. **The Motor Cranial Nerves**: the following five cranial nerves contain primarily axons of motor neurons with their associated sensory axons responsible for proprioception: the_____(CN III),_____(CN IV), _____ (CN VI),_____(CN XI), and _____ (CN XII) nerves **(Table 13.2)**. See table 13.2 for the location and function of these nerves.

C. **The Mixed Cranial Nerves**: the following four cranial nerves contain axons of both sensory and motor neurons: the_____(CN V), _____ (CN VII),_____(CN IX), and _____ (CN X) nerves **(Table 13.3)**. See table 13.3 for the location and function of these nerves.

Module 13.3 The Spinal Nerves (Figures 13.4 – 13.10)

C. **Structure of Spinal Nerves and Spinal Nerve Plexuses**: spinal nerves are formed by the fusion of anterior and posterior roots. The_____pairs of spinal nerves can cluster to form networks or plexuses. The following are structural features associated with these nerves **(Figures 13.4, 13.5)**:

1. The spinal nerve is short and divides into the following two mixed nerves, which both carry both somatic motor and sensory information **(Figure 13.4)**:
    a. The **posterior ramus** travels to the_____side of the body.
    b. The **anterior ramus** travels to the_____side of the body, or to an upper or lower limb.
2. Thirty-one pairs of spinal nerves consist of_____pairs of cervical nerves, _____ pairs of thoracic nerves,_____pairs each of lumbar and sacral nerves, and one pair of coccygeal nerves **(Figure 13.5)**.
3. The anterior rami of the cervical, lumbar, and sacral spinal nerves each merge to form complicated networks of nerves called **nerve_____**.

D. **Cervical Plexuses**: the right and left cervical plexuses are found deep in the _____ lateral to the 1st through 4th cervical vertebrae, which includes nerves roots C1–C5 **(Figure 13.6)**.

1. The plexus consists of anterior rami of C1–C5 and a small contribution from the hypoglossal nerve (cranial nerve XII).
2. **What do the branches of this plexus serve?** _____

   _____

   _____

   _____
3. The **phrenic nerve** is a major motor branch of C4 with contributions from C3 and C5 (3-4-5 to stay alive), which innervates the _____

E. **Brachial Plexuses**: the right and left brachial plexuses are lateral to the 5th cervical through the 1st thoracic vertebrae and provide motor and sensory innervation to the_____limbs, which includes nerve roots from C1–T1 **(Figure 13.7)**.

1. The brachial plexus begins with the formation of large nerve **trunks**.
2. Each trunk splits into an anterior and a posterior division that becomes the **cords** of the plexus **(Figure 13.7a)**.
3. The following are the five major nerves of the brachial plexus **(Figure 13.7b)**:
   a. The **axillary nerve** is a branch of the posterior cord. **What does this nerve innervate?** _____

      _____
   b. The **radial nerve** is the continuation of the posterior cord as it descends in the posterior arm. **What does this nerve innervate?**

      _____

      _____

      _____
   c. The **musculocutaneous nerve** is the continuation of the lateral cord. **What does this nerve innervate?** _____

      _____

d. The **median nerve** is derived from the fusion of the lateral and medial cords and travels down the middle of the arm and forearm. **What does this nerve innervate?** _____

_____

_____

e. The **ulnar nerve** is the continuation of the medial cord as it travels near the elbow where it enters the forearm. **What does this nerve innervate?** _____

_____

_____

F. **Thoracic Spinal Nerves** do not form plexuses except T1. **What does each posterior ramus innervate?** _____
Where does each anterior ramus travel? _____

_____

G. **Lumbar Plexuses**: the left and right lumbar plexuses are derived from the anterior rami of L1–L5, which are anterior to the vertebrae embedded deep within the psoas muscle. **What do branches from this plexus innervate?**

_____

_____ **(Figure 13.8)**

1. The anterior division's largest member is the _____ **nerve**, which enters the thigh from the pelvis via the obturator foramen. **What do branches of this nerve innervate?** _____

_____

2. The posterior division's largest member, the _____ **nerve**, is the largest branch of the lumbar plexus. This nerve travel from the psoas, through the pelvis and under the inguinal ligament to enter the thigh. **What does this nerve innervate?** _____

_____

H. **Sacral Plexuses**: the right and left sacral plexuses are formed from the anterior rami of spinal nerves L4–S4. **What do nerve branches from this plexus**

innervate? _____

_____ **(Figure 13.9)**.

1. The _____ **nerve**, the longest and largest nerve in the body, contains axons from both the anterior and posterior divisions of the sacral plexus **(Figure 13.9a)**. The nerve travels through the greater sciatic notch in the pelvis into the thigh, passing between the greater trochanter and the ischial tuberosity. **What does this nerve innervate?** _____

   _____

2. The **tibial nerve**, the larger branch of the sciatic nerve, contains axons from the anterior division of the sacral plexus **(Figure 13.9b)**. **What do the branches of this nerve innervate?** _____

   _____

   _____

   Smaller nerve branches serve the posterior and lateral skin of the leg as well as the skin and muscles of the foot.

3. The smaller **common fibular nerve** (common peroneal) is made up of axons from the posterior division of the sacral plexus. **What does this nerve and its branches innervate?** _____

   _____

   _____

   _____

I. **Summary of the Distribution of Spinal Nerve Branches** is shown in figure 13.4 **(Figure 13.4)**.

   1. **Figure 13.4a** summarizes the cutaneous distribution of the spinal plexuses, indicating the areas of the skin from which these nerves carry sensory information.
   2. **Figure 13.4b** illustrates the motor distribution of these plexuses, showing which groups of muscles these nerves carry motor signals.

Module 13.4 Sensation Part II: Role of the PNS is Sensation (Figures 13.11–13.16)

D. **From PNS to CNS**: **Sensory Reception and Sensory Receptors**. Stimuli are first detected by sensory neurons that transmit impulses to the CNS. From that

point, the stimulus is transmitted by sensory neurons to the CNS where the stimulus is integrated and interpreted by CNS neurons **(Figure 13.11)**.

1. **Summarize sensory transduction**. _____

   _____

   _____

   a. **The basic mechanism of transduction and the way in which sensory receptors respond to stimuli is as follows (Figure 13.11)**:

      _____

      _____ → _____

      _____

      _____

      _____ → _____

      _____ → _____

      _____

      _____

   b. **Rapidly adapting receptors** respond rapidly with high intensity to stimuli but stop sending signals after a certain time period, called _____. These receptors detect the initiation of stimuli but ignore ongoing stimuli.

   c. **Slowly adapting receptors** respond to stimuli with constant action potentials that don't diminish over time.

2. **Classification of sensory receptors**: s**ensory receptors** exist in many forms; some called **encapsulated nerve endings** are surrounded by specialized supportive cells while others, called **free nerve endings**, lack supportive cells.

3. **Classification of sensory receptors**: sensory receptors can be sorted into the following classifications by the location of stimuli they detect.

   a. **Discuss where exteroceptors are located and what they detect**.

      _____

      _____

b. **Discuss where interoceptors are located and what they detect**.

_____

_____

4. **Classification of sensory receptors**: the following comprehensive classification sorts sensory receptors into five classes based on the type of stimuli that causes them to depolarize and generate a receptor potential:
    a. **Mechanoreceptors** are encapsulated either interoceptors or exteroceptors found in the musculoskeletal system, skin, and in many other organs. **What causes mechanoreceptors to depolarize?**

    _____

    _____

    _____

    b. **Thermoreceptors** are exteroceptors, most of which are slowly adapting receptors. **What causes thermoreceptors to depolarize?**

    _____

    _____

    Separate receptors detect hot and cold.

    c. **Chemoreceptors** can be either interoceptors or exteroceptors that are capable of binding to specific chemicals that, once bound, generate a receptor potential as sodium ion channels open. **What causes chemoreceptors to depolarize?** _____

    _____

    d. **Photoreceptors** are special sensory exteroceptors found only in the eye. **What causes photoreceptors to depolarize?** _____

    e. **Nociceptors** are usually slowly adapting exteroceptors. **What causes nociceptors to depolarize?** _____

5. **Classification of sensory receptors**: the following summarize the six classes of mechanoreceptors **(Figure 13.12)**:
    a. **Merkel cell fibers** consist of a slowly adapting nerve ending surrounded by a capsule of Merkel cells found in the epidermal ridges of the integumentary system. These receptors are found primarily in

the skin of the hands, especially the fingertips, where receptor potentials are generated by mechanically gated ion channels. **What do these receptors detect?** _____

_____

b. **Tactile corpuscles** (Meissner corpuscles) found in the dermal papillae are rapidly adapting tactile exteroceptors. **What do these receptors detect?** _____

_____

c. **Ruffini endings** (bulbous corpuscles) are spindle-shaped, slowly adapting receptors found in the dermis, hypodermis, and ligaments. **What do these receptors detect?** _____

d. **Lamellated corpuscles** (Pacinian corpuscles) have a layered onion-shaped appearance. These rapidly adapting receptors are found deep within the dermis. **What do these receptors detect?** _____

_____

_____

e. **Hair follicle receptors** are free nerve endings surrounding the base of hair follicles found in thin skin, not on the palms and soles. **What do these receptors detect?** _____

_____

f. **Proprioceptors** are found in the musculoskeletal system. **What do these receptors detect?** _____

_____

E. **Sensory Neurons**: the structure and function of somatic sensory neurons and the areas of skin that these serve, called receptive fields, are found below **(Figures 13.13, 13.14)**:

1. **Structure of sensory neurons**. Somatic sensory neurons are pseudounipolar neurons with the following three main components **(Figure 13.13)**:

   a. The_____is located in the posterior root (or dorsal root) ganglion, just lateral to the spinal cord. Cell bodies of cranial nerves are found in cranial nerve ganglia located in the head and neck.

b. The peripheral process of the neuron is a long_____that transmits action potentials from the source of the stimulus (a receptor) to the neuron's central process.

c. The central process exits the cell body and travels through the posterior root to enter the spinal cord at the posterior horn or the brainstem for cranial nerves where they deliver their action potentials.

2. **Classification of sensory neurons**: sensory neurons are classified by the following two factors that determine the speed with which their peripheral axons conduct action potentials: the diameter of the axon and the thickness of its myelin sheath.

   a. Large diameter axons with thick myelin sheaths conduct the _____ impulses. **What types of axons fall into this category?** _____

   _____

   _____

   _____

   b. Small diameter axons with little myelin transmit action potentials the _____. **What types of axons fall into this category?**

   _____

   _____

3. **Receptive fields** are the areas served by a particular neuron. The more branches a neuron possesses the larger that neuron's receptive field **(Figure 13.14)**.

   a. Body regions whose primary function is sensing the environment contain many neurons with smaller receptive fields. **Provide an example of a body region with a small receptive field**: _____.

   b. Body regions that are not as involved in sensing the environment have fewer neurons with larger receptive fields. **Provide an example of a body region with a large receptive field**: _____

c. **Two-point discrimination threshold** is a method for measuring the relative size of receptive fields **(Figure 13.14b)**

F. **Dermatomes and Referred Pain (Figures 13.15)**

1. Skin can be divided into different segments called **dermatomes** based on the spinal nerve that supplies the region with somatic sensation.
    a. Dermatomes can be combined to assemble a dermatome map that represents all (except the first cervical spinal nerve) of the sensory pathways to different parts of the body **(Figure 13.15a)**.
    b. **Why are dermatome maps used clinically?** _____

2. **Referred pain** is a phenomenon whereby pain that originates in an organ is perceived as cutaneous pain. **Why does referred pain occur?** _____

Module 13.5 Movement Part II: Role of the PNS in Movement (Figure 13.17)

D. **From CNS to PNS**: **Motor Output**. The muscular and nervous systems are inextricably linked to one another. Skeletal muscle fibers are voluntary and contract only when stimulated to do so by a somatic motor neuron.

1. **Upper motor neurons** in the primary_____cortex of the cerebrum make the decision to move and initiate that movement but they are not in contact with the muscle fiber itself.
2. **Lower motor neurons** receive messages from the upper _____ neurons, which are in contact with skeletal muscle fibers. These neurons release a neurotransmitter,_____, onto muscle fibers to initiate contraction.

E. **The Role of Lower Motor Neurons**

1. Lower motor neurons are multipolar neurons whose cell bodies are found in either (1)_____or (2) _____ _____, both regions of the CNS. The axons of these neurons are found in the PNS.

2. Groups of lower motor neurons that innervate the same muscle, called _____, are found clustered in the anterior horn of the spinal cord.

Module 13.6 Reflex Arcs: Integration of Sensory and Motor Functions (Figures 13.18–13.21)

A. **Reflex Arcs** occur in a three-step sequence of events that involve programmed, automatic responses to stimuli called **reflexes**. Reflex arcs are usually _____ feedback loops that are protective**.** Reflexes begin with a _____ stimulus and finish with a rapid_____response. Neural integration occurs in the CNS, at the spinal cord or brainstem, between the sensory stimulus and motor response.

B. **The Role of Stretch Receptors in Skeletal Muscles**: mechanoreceptors with muscles and tendons monitor muscle length and the force of contraction and communicate this information to the spinal cord, cerebellum, and the cerebral cortex **(Figure 13.18)**.

1. **Muscle spindles**, or **extrafusal muscle fibers**, are tapered structures found scattered among regular contractile muscle fibers **(Figure 13.18a)**.
2. **Golgi tendon organs** are mechanoreceptors located within tendons near the muscle-tendon junction that have the following features **(Figure 13.18b)**:
    a. Golgi tendon organs monitor the_____generated by a muscle contraction.
    b. These mechanoreceptors consist of an encapsulated bundle of collagen fibers attached to about 20 extrafusal muscle fibers.
    c. Each Golgi tendon organ contains a single somatic sensory axon that fires more rapidly as greater tension is generated with each contraction. The information is sent to the CNS.

C. **Types of Reflexes**: reflexes can be classified by at least two criteria, **first**:

_____

_____

second: _____

_____ **(Figures 13.19, 13.20)**

1. The simplest reflex arcs, called _____ **reflexes**, involve only a single synapse with the spinal cord between a sensory and motor neuron**.** More complicated types of reflex arcs, called _____ **reflexes**, involve multiple synapses.
2. The **simple stretch reflex** is the body's reflexive response to stretching of the muscle to shorten it back to within its "set" optimal length. The patellar, or knee-jerk reflex, and the jaw-jerk reflex are examples. **Describe the steps involved in a simple stretch reflex in a spinal nerve (Figure 13.19)**:

   _____

   _____

   _____

   _____

   _____

   _____

3. **Golgi tendon reflexes** are polysynaptic reflexes that protect muscles and tendons from damage. This reflex causes muscle _____, the opposite of the simple stretch reflex action.
4. **Flexion (withdrawal) and crossed-extension spinal reflexes (Figure 13.20)**:
   a. The **flexion**, or **withdrawal reflex**, involves rapidly conducting nociceptive afferents and multiple synapses in the spinal cord. **What is the result of this reflex? _____ _____ (Figure 13.20a)**
   b. The **crossed-extension reflex** occurs simultaneously on the opposite side of the body to balance and postural support while the other limb is withdrawn from a painful stimulus **(Figure 13.20b)**.
5. **Cranial nerve reflexes** are polysynaptic reflex arcs that involve cranial nerves. The following are two of the more important cranial reflexes:
   a. The **gag reflex** is triggered when visceral sensory nerve endings of the _____ nerve in the posterior throat are stimulated.

b. The **corneal blink reflex** is triggered when a stimulus, reaches the somatic sensory receptors of the trigeminal nerve in the thin outer covering of the eye (cornea); something contacts the eye leading to a blink response.

D. **Sensory and Motor Neuron Disorders**: disorders that impact the sensory and motor neurons of the PNS are collectively called peripheral neuropathies. Homeostasis requires the proper functioning of both sensory and motor neurons **(Figure 13.21)**.