

anterior columns. Each of the columns contains a number of fiber tracts made up of axons with the same destination and function. Tracts conducting sensory impulses to the brain are *sensory*, or *afferent, tracts*. Those carrying impulses from the brain to skeletal muscles are *motor*, or *efferent, tracts*. All tracts in the posterior columns are ascending tracts that carry sensory input to the brain. The lateral and anterior tracts contain both ascending and descending (motor) tracts.

Homeostatic Imbalance

If the spinal cord is transected (cut crosswise) or crushed, *spastic paralysis* results. The affected muscles stay healthy because they are still stimulated by spinal reflex arcs, and movement of those muscles does occur. However, movements are involuntary and not controllable, and this can be as much of a problem as complete lack of mobility. In addition, because the spinal cord carries both sensory and motor impulses, a loss of feeling or sensory input occurs in the body areas below the point of cord destruction. Physicians often use a pin to see if a person can feel pain after spinal cord injury—to find out if regeneration is occurring. Pain is a hopeful sign in such cases. If the spinal cord injury occurs high in the cord, so that all four limbs are affected, the individual is a *quadriplegic* (kwod"rī-ple'jik). If only the legs are paralyzed, the individual is a *paraplegic* (par"ā-ple'jik). ▲

Peripheral Nervous System

The **peripheral nervous system (PNS)** consists of nerves and scattered groups of neuronal cell bodies (ganglia) found outside the CNS. One type of ganglion has already been considered—the dorsal root ganglion of the spinal cord. Others will be covered in the discussion of the autonomic nervous system. Here, we will concern ourselves only with nerves.

Structure of a Nerve

A **nerve** is a bundle of neuron fibers found outside the CNS. Within a nerve, neuron fibers, or processes, are wrapped in protective connective tissue coverings. Each fiber is surrounded by a delicate connective tissue sheath, an **endoneurium** (en"do-nu're-um). Groups of fibers are bound by a coarser connective tissue wrapping, the **perineurium** (per"ī-nu're-um), to form fiber bundles, or **fascicles**. Finally, all the fascicles are bound together by a tough fibrous sheath, the **epineurium**, to form the cordlike nerve (Figure 7.20).

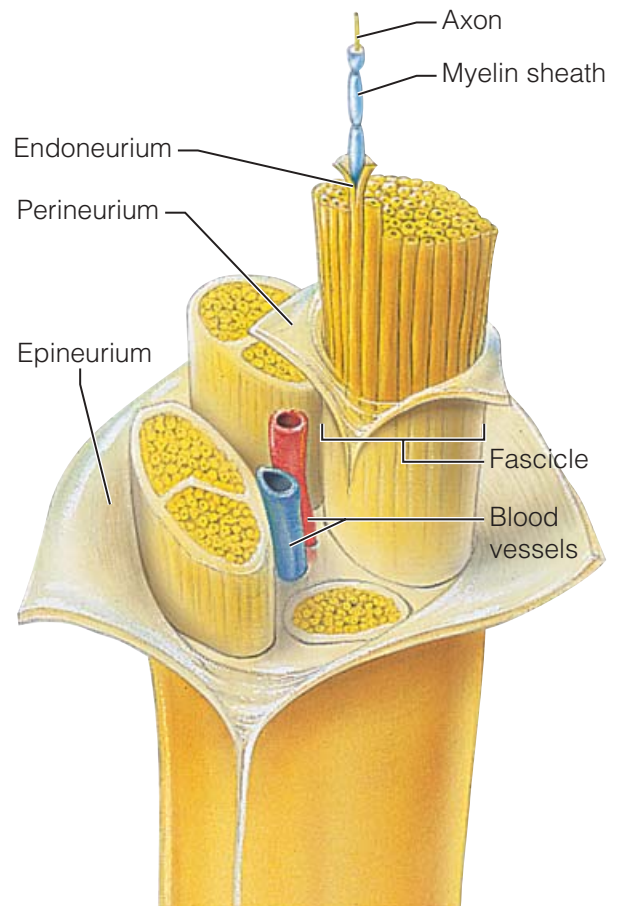


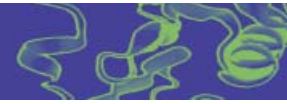
FIGURE 7.20 Structure of a nerve. Three-dimensional view of a portion of a nerve, showing its connective tissue wrappings.

Like neurons, nerves are classified according to the direction in which they transmit impulses. Nerves carrying both sensory and motor fibers are called **mixed nerves**; all spinal nerves are mixed nerves. Nerves that carry impulses toward the CNS only are called **sensory**, or **afferent, nerves**, whereas those that carry only motor fibers are **motor**, or **efferent, nerves**.

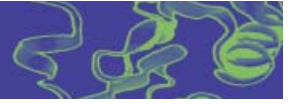
Cranial Nerves

The 12 pairs of **cranial nerves** primarily serve the head and neck. Only one pair (the vagus nerves) extends to the thoracic and abdominal cavities.

The cranial nerves are numbered in order, and in most cases their names reveal the most important structures they control. The cranial nerves are described by name, number, course, and major function in Table 7.1. The last column

**TABLE 7.1** The Cranial Nerves

Name/Number	Origin/Course	Function	Test
I. Olfactory	Fibers arise from olfactory receptors in the nasal mucosa and synapse with the olfactory bulbs (which, in turn, send fibers to the olfactory cortex)	Purely sensory; carries impulses for the sense of smell	Subject is asked to sniff and identify aromatic substances, such as oil of cloves or vanilla
II. Optic	Fibers arise from the retina of the eye and form the optic nerve. The two optic nerves form the optic chiasma by partial crossover of fibers; the fibers continue to the optic cortex as the optic tracts	Purely sensory; carries impulses for vision	Vision and visual field are tested with an eye chart and by testing the point at which the subject first sees an object (finger) moving into the visual field; eye interior is viewed with an ophthalmoscope
III. Oculomotor	Fibers run from the midbrain to the eye	Supplies motor fibers to four of the six muscles (superior, inferior, and medial rectus, and inferior oblique) that direct the eyeball; to the eyelid; and to the internal eye muscles controlling lens shape and pupil size	Pupils are examined for size, shape, and size equality; pupillary reflex is tested with a penlight (pupils should constrict when illuminated); eye convergence is tested, as is the ability to follow moving objects
IV. Trochlear	Fibers run from the midbrain to the eye	Supplies motor fibers for one external eye muscle (superior oblique)	Tested in common with cranial nerve III for the ability to follow moving objects
V. Trigeminal	Fibers emerge from the pons and form three divisions that run to the face	Conducts sensory impulses from the skin of the face and mucosa of the nose and mouth; also contains motor fibers that activate the chewing muscles	Sensations of pain, touch, and temperature are tested with a safety pin and hot and cold objects; corneal reflex tested with a wisp of cotton; motor branch tested by asking the subject to open mouth against resistance and move jaw from side to side
VI. Abducens	Fibers leave the pons and run to the eye	Supplies motor fibers to the lateral rectus muscle, which rolls the eye laterally	Tested in common with cranial nerve III for the ability to move each eye laterally

TABLE 7.1 (continued)

Name/Number	Origin/Course	Function	Test
VII. Facial	Fibers leave the pons and run to the face	Activates the muscles of facial expression and the lacrimal and salivary glands; carries sensory impulses from the taste buds of anterior tongue	Anterior two-thirds of tongue is tested for ability to taste sweet, salty, sour, and bitter substances; subject is asked to close eyes, smile, whistle, etc.; tearing is tested with ammonia fumes
VIII. Vestibulocochlear	Fibers run from the equilibrium and hearing receptors of the inner ear to the brain stem	Purely sensory; vestibular branch transmits impulses for the sense of balance, and cochlear branch transmits impulses for the sense of hearing	Hearing is checked by air and bone conduction, using a tuning fork
IX. Glossopharyngeal	Fibers emerge from the medulla and run to the throat	Supplies motor fibers to the pharynx (throat) that promote swallowing and saliva production; carries sensory impulses from taste buds of the posterior tongue and from pressure receptors of the carotid artery	Gag and swallowing reflexes are checked; subject is asked to speak and cough; posterior tongue may be tested for taste
X. Vagus	Fibers emerge from the medulla and descend into the thorax and abdominal cavity	Fibers carry sensory impulses from and motor impulses to the pharynx, larynx, and the abdominal and thoracic viscera; most motor fibers are parasympathetic fibers that promote digestive activity and help regulate heart activity	Tested in common with cranial nerve IX, since they both serve muscles of the throat
XI. Accessory	Fibers arise from the medulla and superior spinal cord and travel to muscles of the neck and back	Mostly motor fibers that activate the sternocleidomastoid and trapezius muscles	Sternocleidomastoid and trapezius muscles are checked for strength by asking the subject to rotate head and shrug shoulders against resistance
XII. Hypoglossal	Fibers run from the medulla to the tongue	Motor fibers control tongue movements; sensory fibers carry impulses from the tongue	Subject is asked to stick out tongue, and any position abnormalities are noted

Q If you can't shrug your right shoulder, what cranial nerve is involved?

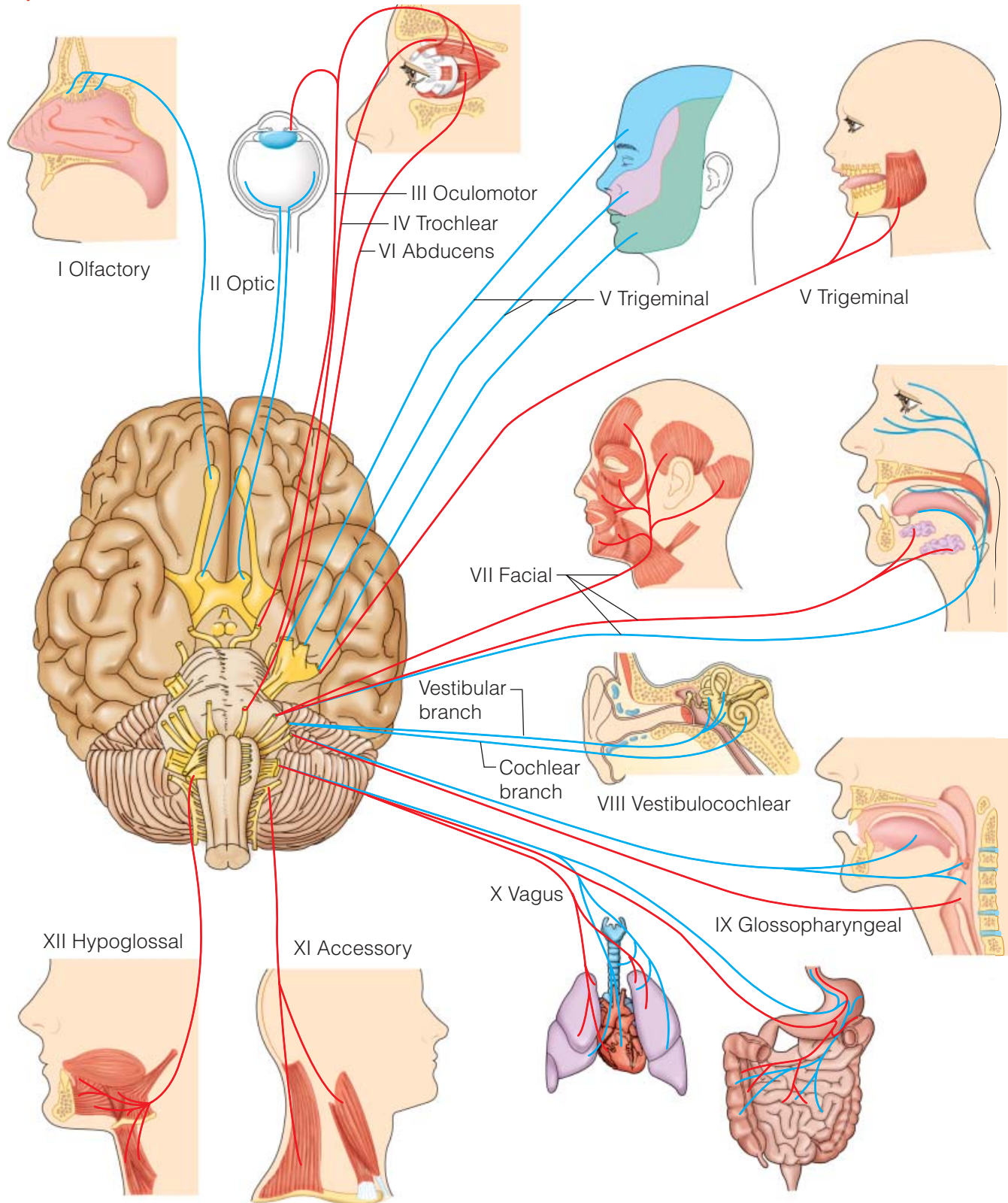


FIGURE 7.21 Distribution of cranial nerves. Sensory nerves are shown in blue, motor nerves in red. Although cranial nerves III, IV, and VI have sensory fibers, these are not shown because the sensory fibers account for only minor parts of these nerves.

A

Left member of cranial nerve XI.

of the table describes how cranial nerves are tested, which is an important part of any neurologic examination. You do not need to memorize these tests, but this information may help you understand cranial nerve function. As you read through the table, also look at Figure 7.21, which shows the location of the cranial nerves on the brain's anterior surface.

Most cranial nerves are mixed nerves; however, three pairs, the optic, olfactory, and vestibulocochlear (ves-tib"u-lo-kok'le-ar) nerves, are purely sensory in function. (The older name for the vestibulocochlear nerve is *acoustic nerve*, a name that reveals its role in hearing but not in equilibrium.) I give my students the following little saying as a memory jog to help them remember the cranial nerves in order; perhaps it will help you, too. The first letter of each word in the saying (and both letters of "ah") is the first letter of the cranial nerve to be remembered: "**O**h, **o**h, **o**h, **t**o **t**ouch **a**nd **f**eel **v**ery **g**ood **v**elvet, **a**h."

Spinal Nerves and Nerve Plexuses

The 31 pairs of human **spinal nerves** are formed by the combination of the ventral and dorsal roots of the spinal cord. Although each of the cranial nerves issuing from the brain is named specifically, the spinal nerves are named for the region of the cord from which they arise. Figure 7.22 shows how the nerves are named in this scheme.

Almost immediately after being formed, each spinal nerve divides into **dorsal** and **ventral rami** (ra'mi), making each spinal nerve only about ½ inch long. The rami, like the spinal nerves, contain both motor and sensory fibers. Thus, damage to a spinal nerve or either of its rami results both in loss of sensation and flaccid paralysis of the area of the body served. The smaller dorsal rami serve the skin and muscles of the posterior body trunk. The ventral rami of spinal nerves T₁ through T₁₂ form the *intercostal nerves*, which supply the muscles between the ribs and the skin and muscles of the anterior and lateral trunk. The ventral rami of all other spinal nerves form complex networks of nerves called **plexuses**, which serve the motor and sensory needs of the limbs. The four nerve plexuses are

described in Table 7.2; three of the four plexuses are shown in Figure 7.23.

Autonomic Nervous System

The **autonomic nervous system (ANS)** is the motor subdivision of the PNS that controls body activities automatically. It is composed of a special group of neurons that regulate cardiac muscle (the heart), smooth muscles (found in the walls of the visceral organs and blood vessels), and glands. Although all body systems contribute to homeostasis, the relative stability of our internal environment depends largely on the workings of the ANS. At every moment, signals flood from the visceral organs into the CNS, and the autonomic nerves make adjustments as necessary to best support body activities. For example, blood flow may be shunted to more "needy" areas, heart and breathing rate may be speeded up or slowed down, blood pressure may be adjusted, and stomach secretions may be increased or decreased. Most of this fine-tuning occurs without our awareness or attention—few of us realize when our pupils dilate or our arteries constrict—hence the ANS is also called the **involuntary nervous system**.

Somatic and Autonomic Nervous Systems Compared

Our previous discussions of motor nerves have focused on the activity of the somatic nervous system, the motor subdivision that controls our skeletal muscles. So, before plunging into a description of autonomic nervous system anatomy, we will take the time to point out some important differences between the somatic and autonomic divisions.

Besides differences in their effector organs and in the neurotransmitters released, the patterns of their motor pathways differ. In the somatic division, the cell bodies of the motor neurons are inside the CNS, and their axons (in spinal nerves) extend all the way to the skeletal muscles they serve. The autonomic nervous system, however, has a chain of *two* motor neurons. The first motor neuron of each pair is in the brain or spinal cord. Its axon, the **preganglionic axon** (literally, the "axon before the ganglion"), leaves the CNS to synapse with the second motor neuron in a ganglion outside the CNS. The axon of this neuron, the