

The Peripheral Nervous System

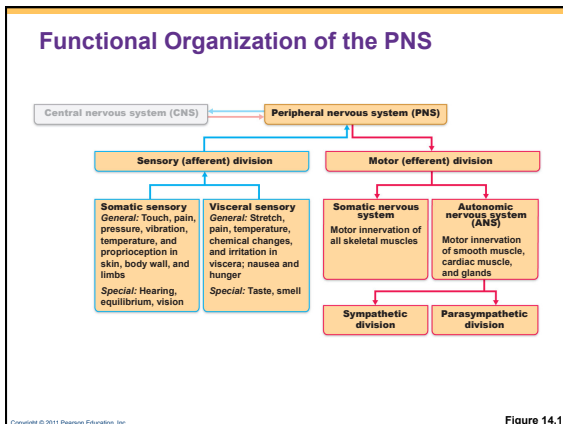
- The PNS
 - Is the nervous system outside the brain and spinal cord
 - Provides vital links to the body and outside world
 - Nerves allow the CNS to receive information and initiate action

The Peripheral Nervous System

- The PNS is functionally divided into **sensory** and **motor** divisions
 - Sensory inputs and motor outputs are subdivided into
 - Somatic and visceral
 - General and special
 - Nerves allow the CNS to receive information and initiate action

Organization of the Peripheral Nervous System

- General **visceral motor part** of the PNS is known as the Autonomic nervous system (ANS)
 - ANS has two divisions
 - **Parasympathetic** (non-stress “rest & digest”)
 - **Sympathetic** (stress responder “fight, flight, or fight”)



Basic Structural Components of the PNS

- **Sensory receptors**—pick up stimuli from inside or outside the body
- **Nerves and ganglia**
 - **Nerves**—bundles of peripheral axons
 - **Ganglia**—clusters of peripheral neuronal cell bodies
- **Motor endings**—axon terminals of motor neurons
 - Innervate effectors (muscle fibers and glands)

Peripheral Sensory Receptors

- Structures that pick up sensory stimuli
 - Initiate signals in sensory axons
- (This section on sensory reception to be covered with Chapter 16)

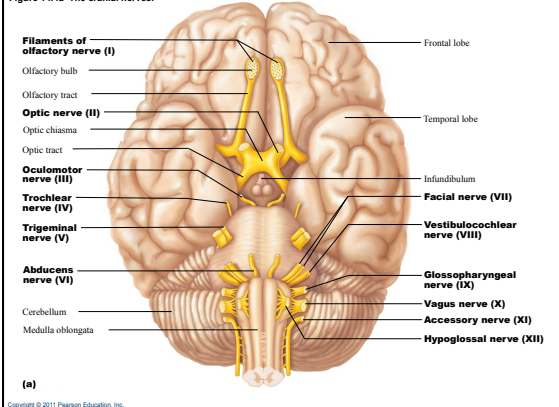
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Cranial Nerves

- Attach to the brain and pass through specific foramina of the skull
- Numbered from I to XII
- Cranial nerves I and II attach to the forebrain
 - All others attach to the brain stem
- Primarily serve head and neck structures
 - The **vagus nerve (X)** is the only cranial nerve that extends into the abdomen

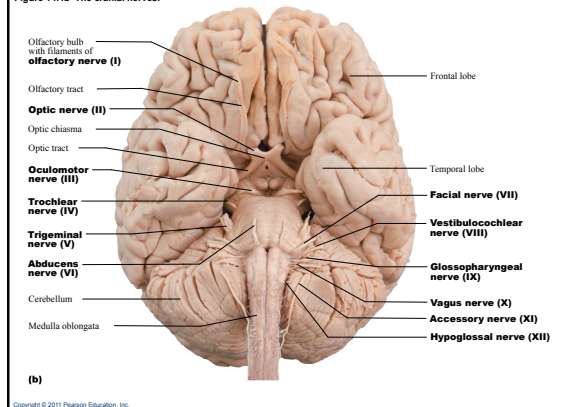
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Figure 14.4a The cranial nerves.



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Figure 14.4b The cranial nerves.



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The Cranial Nerves

Cranial nerves	Sensory function		Motor function	
	Somatic sensory (SS)	Visceral sensory (VS)	Somatic motor (SM)	Visceral motor: parasympathetic (VM)
I Olfactory		Smell		
II Optic	Vision			
III Oculomotor			SM	VM
IV Trochlear			SM	
V Trigeminal	General		SM	
VI Abducens			SM	

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Figure 14.4b (1 of 2)

The Cranial Nerves

Cranial nerves	Sensory function		Motor function	
	Somatic sensory (SS)	Visceral sensory (VS)	Somatic motor (SM)	Visceral motor: parasympathetic (VM)
VII Facial	General	General; taste	SM	VM
VIII Vestibulocochlear		Hearing; equilibrium	Some	
IX Glossopharyngeal	General	General; taste	SM	VM
X Vagus	General	General; taste	SM	VM
XI Accessory			SM	
XII Hypoglossal			SM	

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Figure 14.4b (2 of 2)

I Olfactory Nerves

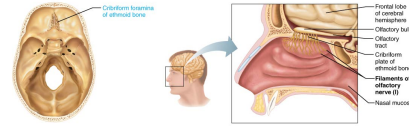
- Special visceral sensory—sense of smell
- Olfactory receptor cells located in olfactory epithelium of nasal cavity
- Pass through the cribriform foramina of the ethmoid bone

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Table 14.2 Cranial Nerves (1 of 18)

Table 14.2 Cranial Nerves

CN I OLFACTORY (ol-fak'te-nē) NERVES



Sensory function	Special visceral sensory, sense of smell.
Origin	Olfactory receptor cells (bipolar neurons) in the olfactory epithelium of the nasal cavity.
Pathway	Pass through the cribriform foramina of the ethmoid bone to synapse in the olfactory bulb. Fibers of olfactory bulb neurons extend posteriorly beneath the frontal lobe as the olfactory tract. Terminate in the primary olfactory cortex of the cerebrum. (See also Figure 14.3, p. 471.)
CLINICAL APPLICATION	Anosmia Fracture of the ethmoid bone or lesions of olfactory fibers may result in partial or total loss of smell, a condition known as anosmia (an-oh'see-ah).

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II The Optic Nerves

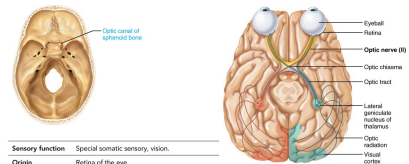
- Special somatic sensory—vision
- Originate on the retina of the eye
- Pass through the optic canals of the sphenoid bone

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Table 14.2 Cranial Nerves (2 of 18)

Table 14.2 Cranial Nerves (continued)

CN II OPTIC NERVES



Sensory function	Special somatic sensory, vision.
Origin	Retina of the eye.
Pathway	Pass through the optic canal of the sphenoid bone. Optic nerves converge to form the optic chiasm (ok'see-ah'zee-ah), where fibers partially cross over, then continue as the optic tracts to synapse in the thalamus. Thalamus projects to and terminates in the primary visual cortex in the occipital lobe. (See also Figure 14.14, p. 524.)
CLINICAL APPLICATION	Optic Nerve Damage Damage to an optic nerve results in blindness in the eye served by the nerve; damage to the visual pathway distal to the optic chiasm results in partial visual losses; visual defects are called scotomata (skoh'toh-mah).

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III The Oculomotor Nerves

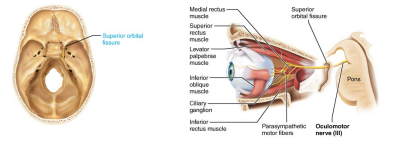
- Somatic motor function—innervates four of the extrinsic eye muscles
 - Superior rectus, medial rectus, inferior rectus, inferior oblique
- Visceral motor function
 - Constricts pupil
 - Controls shape of lens
- Pass through the superior orbital fissure

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Table 14.2 Cranial Nerves (3 of 18)

Table 14.2 Cranial Nerves (continued)

CN III OCULOMOTOR (ok'yuh-loh-moh'ter) NERVES



Somatic motor function	Innervates four extrinsic eye muscles that direct the eyeball: superior rectus, medial rectus, inferior rectus, inferior oblique muscles. Innervate levator palpebrae superioris muscle that elevates the upper eyelid (p. 492). Afferent proprioceptive fibers return from the extrinsic eye muscles.
Visceral motor function (Parasympathetic)	Afferent proprioceptive fibers return from the extrinsic eye muscles. Ciliary muscle controls lens shape.
Origin	Oculomotor nuclei in the ventral midbrain.
Pathway	Pass through the superior orbital fissure to enter the orbit. Parasympathetic fibers from the brain stem synapse with postganglionic neurons in the ciliary ganglion that innervate the iris and ciliary muscle.
CLINICAL APPLICATION	Oculomotor Nerve Palsy Because the actions of the two extrinsic eye muscles not served by cranial nerve III are unopposed, the eye cannot be moved up or inward, and at rest the eye turns laterally (external strabismus [strah-bid'ee-zhm]). The upper eyelid droops (ptosis), and the person has double vision.

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IV The Trochlear Nerves

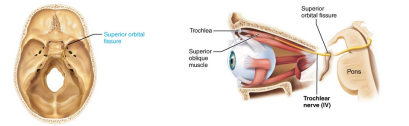
- Somatic motor function—innervate the **superior oblique muscle** (an extrinsic eye muscle)
- Pass ventrally and laterally around midbrain
 - Pass through superior orbital fissure

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Table 14.2 Cranial Nerves (4 of 18)

Table 14.2 Cranial Nerves (continued)

CN IV TROCHLEAR (trok'le-er) NERVES



Somatic motor function	Innervate the superior oblique muscle . This muscle passes through a ligamentous pulley at the roof of the orbit, the trochlea, from which its name is derived. Affected proprioceptor fibers return from the superior oblique.
Origin	Trochlear nuclei in the dorsal midbrain
Pathway	Pass ventrally around the midbrain, pass through the superior orbital fissure to enter the orbit.
CLINICAL APPLICATION	Trochlear Nerve Damage Damage to a trochlear nerve results in double vision and reduced ability to rotate the eye inferiorlaterally.

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V The Trigeminal Nerves

- Largest of the cranial nerves
 - Has three divisions
 - Ophthalmic division (V_1)
 - Maxillary division (V_2)
 - Mandibular division (V_3)
- Cell bodies of sensory neurons located in the trigeminal ganglion
- Mandibular division contains motor fibers that innervate the chewing muscles

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V The Trigeminal Nerves

- Pathways of divisions
 - V_1 – Superior orbital fissure
 - V_2 – Foramen rotundum
 - V_3 – Foramen ovale; mandibular foramen

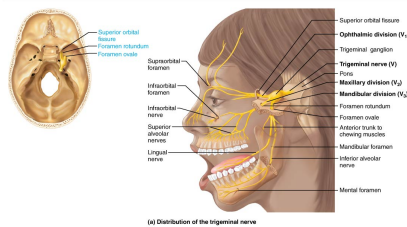
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Table 14.2 Cranial Nerves (5 of 18)

Table 14.2 Cranial Nerves (continued)

CN V TRIGEMINAL NERVES

The large trigeminal nerve forms three divisions (trigeminal = threefold): ophthalmic (V_1), maxillary (V_2), and mandibular (V_3) divisions. This mixed nerve is the general somatic sensory nerve of the face for touch, temperature, and pain. The mandibular division supplies somatic motor innervation to the chewing muscles. Details on the next page.

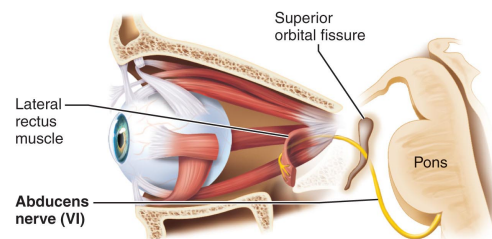


(a) Distribution of the trigeminal nerve

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VI The Abducens Nerves

- Abducts the eyeball—innervates lateral rectus muscle



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Table 14.2 (6 of 12)

VI The Abducens Nerves

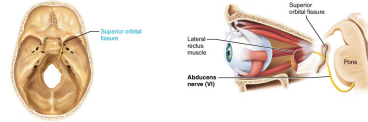
- Somatic motor function
 - Innervates **lateral rectus** muscle—abducts the eye
- Pass through the superior orbital fissure

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Table 14.2 Cranial Nerves (8 of 18)

Table 14.2 Cranial Nerves (continued)

CN VI ABDUCENS (ab-duh'sens) NERVES



Somatic motor function	Innervate the lateral rectus muscle . This muscle abducts the eye. Different proprioceptive fibers return from the lateral rectus.
Origin	Abducens nuclei in the inferior pons.
Pathway	Pass through the superior orbital fissure to enter the orbit.
CLINICAL APPLICATION	Abducens Nerve Palsy In abducens nerve palsy, the eye cannot be moved laterally; at rest, affected eyeball turns medially (internal strabismus).

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VII The Facial Nerves

- Sensory function
 - Special visceral sensory from taste buds on anterior two-thirds of tongue
- Somatic motor function
 - Five branches—innervate facial muscles
- Visceral motor function
 - Innervation of lacrimal glands, submandibular and sublingual salivary glands

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VII The Facial Nerves

- Visceral motor function
 - Innervation of lacrimal glands, submandibular and sublingual salivary glands
- Pathway
 - Enter temporal bone through the internal acoustic meatus

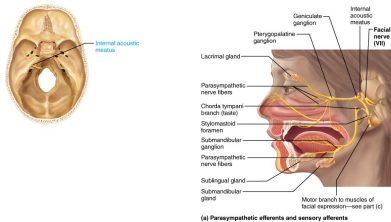
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Table 14.2 Cranial Nerves (9 of 18)

Table 14.2 Cranial Nerves (continued)

CN VII FACIAL NERVES

A mixed nerve. Chief somatic motor nerve to the facial muscles; parasympathetic innervation to glands; special sensory taste from the tongue. Details on the next page.



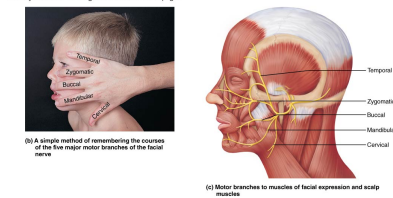
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Table 14.2 Cranial Nerves (10 of 18)

Table 14.2 Cranial Nerves (continued)

CN VII FACIAL NERVES (continued)

A mixed nerve. Chief somatic motor nerve to the facial muscles; parasympathetic innervation to glands; special sensory taste from the tongue. Details on the next page.



(b) A simple method of remembering the courses of the five major motor branches of the facial nerve.

(c) Motor branches to muscles of facial expression and scalp muscles.

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VIII The Vestibulocochlear Nerves

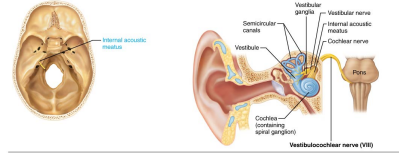
- Sensory nerve of hearing and equilibrium
 - Vestibular branch—special somatic sensory: equilibrium
 - Cochlear branch—special somatic sensory: hearing
- Pathway
 - From inner ear cavity, fibers pass through the internal acoustic meatus

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Table 14.2 Cranial Nerves (12 of 18)

Table 14.2 Cranial Nerves (continued)

CN VIII VESTIBULOCOCHLEAR (ves-tib"u-lo-ko-k'le-er) NERVES



Sensory function Vestibular branch: Special somatic sensory, equilibrium.
Cochlear branch: Special somatic sensory, hearing.
Small motor component adjusts the sensitivity of the sensory receptors

Origin Sensory receptors in the inner ear for hearing (within the cochlea) and for equilibrium (within the semicircular canals and vestibule)

Pathway From the inner ear cavity within the temporal bone, fibers pass through the internal acoustic meatus, merge to form the vestibulocochlear nerve and enter the brain stem at the pons.
Sensory nerve cell bodies for vestibular branch located in vestibular ganglia (see Figure 16.18, p. 510); for the cochlear branch, in the spiral ganglia within the cochlea. (See Figure 16.19, p. 511.)

CLINICAL APPLICATION Vestibulocochlear Nerve Damage Lesions of cochlear nerve or cochlear receptors result in deaf or severe deafness; lesions of vestibular division produces dizziness, rapid involuntary eye movements, loss of balance, nausea, and vomiting.

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IX The Glossopharyngeal Nerves

- Sensory function
 - Special visceral sensory from taste buds on posterior one-third of tongue
 - General visceral sensory
 - Posterior one-third of tongue
 - Pharyngeal mucosa
 - Chemoreceptors in carotid body
 - Baroreceptors of carotid sinus

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IX The Glossopharyngeal Nerves

- Somatic motor function
 - Elevate pharynx during swallowing
- Visceral motor function
 - Innervate the parotid salivary gland
- Pathway
 - Fibers pass through the jugular foramen

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IX The Glossopharyngeal Nerves

- Innervates structures of the tongue (taste) and pharynx

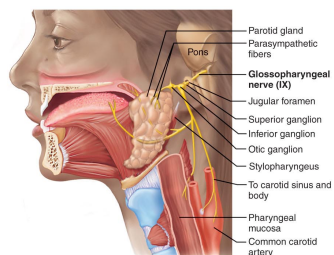


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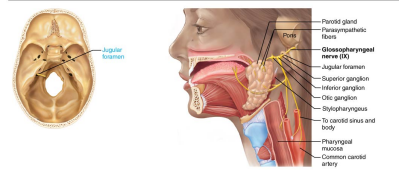
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Table 14.2 Cranial Nerves (continued)

CN IX GLOSSOPHARYNGEAL (gl'o-far-'nir-'je-ah) NERVES

Mixed nerve innervating the tongue (general and special sensory), the pharynx, and the parotid salivary gland.



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X The Vagus Nerves

- Sensory functions
 - General visceral sensory from thoracic and abdominal viscera
 - Special visceral sensory—taste buds on epiglottis
- Somatic motor functions
 - Skeletal muscles of the pharynx and larynx

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X The Vagus Nerves

- Visceral motor functions
 - Parasympathetic innervation to
 - Heart
 - Lungs
 - Abdominal viscera
- Pathway
 - Fibers exit through the jugular foramen

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X The Vagus Nerves

- A mixed sensory and motor nerve
- “Wanders” into thorax and abdomen
- Parasympathetic innervation of organs

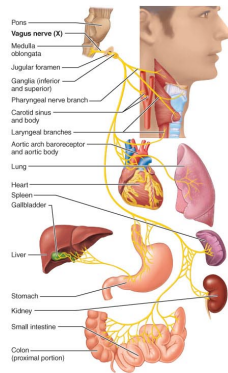


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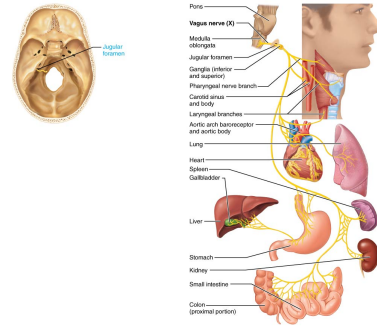
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Table 14.2 Cranial Nerves (15 of 18)

Table 14.2 Cranial Nerves (continued)

CN X VAGUS (va'gus) NERVES

Mixed nerves; major function is parasympathetic innervation to the thoracic and abdominal viscera.



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XI The Accessory Nerves

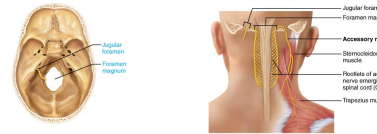
- Somatic motor function
 - Innervates trapezius and sternocleidomastoid
- Formed from ventral rootlets of C₁–C₅
 - Do not arise from the brain stem
- Spinal rootlets merge to form this nerve
 - Pass into skull through foramen magnum
 - Exit skull through the jugular foramen

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Table 14.2 Cranial Nerves (17 of 18)

Table 14.2 Cranial Nerves (continued)

CN XI ACCESSORY NERVES



Somatic motor function: Innervates the trapezius and sternocleidomastoid muscles that move the head and neck.
Afferent proprioceptor fibers return from these muscles.

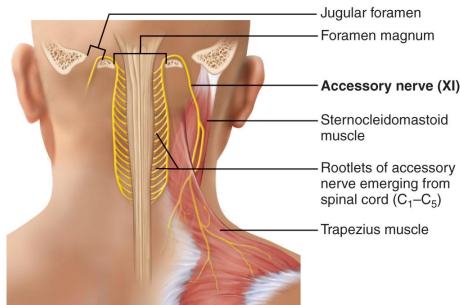
Origin: Formed from ventral rootlets arising from C₁–C₅ of the spinal cord. Long considered to have both a cranial and spinal portion, the cranial rootlets have been shown to be part of the vagus nerves.

Pathway: Upon emerging from the spinal cord, spinal rootlets merge to form the accessory nerves, pass into the skull through the foramen magnum, and then exit the skull through the jugular foramen.

CLINICAL APPLICATION: Damage to accessory nerves injury to the spinal root of one accessory nerve causes the head to turn toward the side of the injury as result of sternocleidomastoid muscle paralysis. Shrugging of that shoulder (side of trapezius muscle) becomes difficult.

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XI The Accessory Nerves



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XII The Hypoglossal Nerves

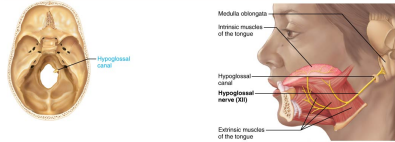
- Somatic motor function
 - Innervate the tongue muscles
- Exit the skull through hypoglossal canal

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Table 14.2 Cranial Nerves (18 of 18)

Table 14.2 Cranial Nerves (continued)

CN XII HYPOGLOSSAL NERVES



Somatic motor function Innervate the intrinsic and extrinsic muscles of the tongue. Aid tongue movements during feeding, swallowing, and speech.
 Afferent proprioceptor fibers return from these muscles.

Origin Arise from a series of roots from on the ventral medulla oblongata.

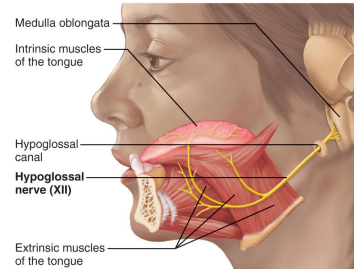
Pathway Exit the skull through the hypoglossal canal and travel to the tongue.

CLINICAL APPLICATION Hypoglossal Nerve Damage Damage to hypoglossal nerves causes difficulties in speech and swallowing. If both nerves are impaired, the person cannot protrude the tongue. If only one side is affected, the tongue deviates (turns) toward affected side. Eventually the parotid gland begins to atrophy.

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XII The Hypoglossal Nerves

- Runs inferior to the tongue
 - Innervates the tongue muscles



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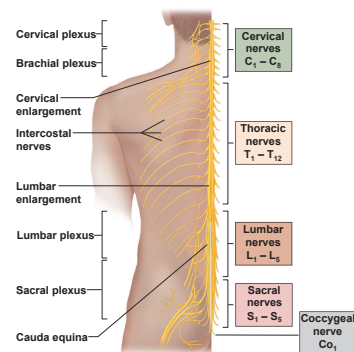
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Spinal Nerves

- 31 pairs—contain thousands of nerve fibers
- Connect to the spinal cord
- Named for point of issue from the spinal cord
 - 8 pairs of cervical nerves (C₁–C₈)
 - 12 pairs of thoracic nerves (T₁–T₁₂)
 - 5 pairs of lumbar nerves (L₁–L₅)
 - 5 pairs of sacral nerves (S₁–S₅)
 - 1 pair of coccygeal nerves (Co₁)

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Spinal Nerves Posterior View



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Figure 14.5

Spinal Nerves

- Connect to the spinal cord by the dorsal root and ventral root
 - **Dorsal root**—contains sensory fibers
 - Cell bodies—located in the dorsal root ganglion
 - **Ventral root**—contains motor fibers arising from anterior gray column

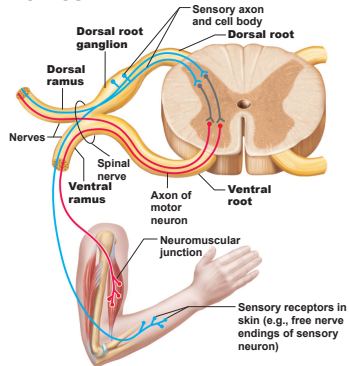
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Spinal Nerves

- Branch into **dorsal ramus** and **ventral ramus**
 - **Dorsal** and **ventral rami** contain sensory *and* motor fibers
- **Rami communicantes** connect to the base of the ventral ramus
 - Lead to the **sympathetic chain ganglia**

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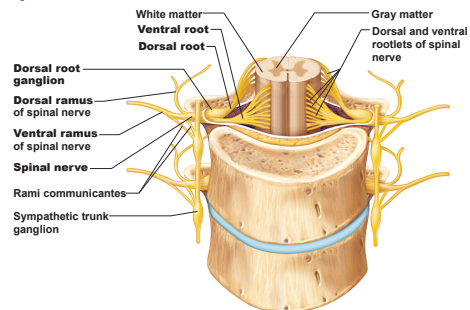
Spinal Nerves



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Figure 14.6

Spinal Nerves



(a) Anterior view showing spinal cord, associated nerves, and vertebrae. The dorsal and ventral roots arise medially as rootlets and join laterally to form the spinal nerve.

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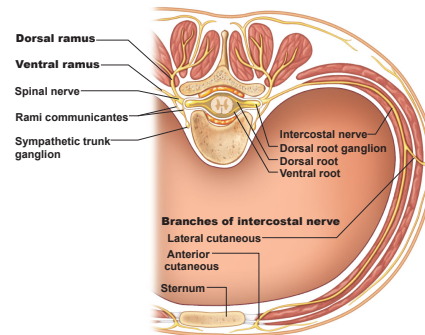
Figure 14.7a

Innervation of the Back

- **Dorsal rami**
 - Innervate back muscles
 - Follow a neat, segmented pattern
 - Innervate a horizontal strip of muscle and skin
 - In line with emergence point from the vertebral column

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Innervation of the Back



(b) Cross section of thorax showing the main roots and branches of a spinal nerve.

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Figure 14.7b

Innervation of the Anterior Thoracic and Abdominal Wall

- Thoracic region
 - **Ventral rami** arranged in simple, segmented pattern
 - **Intercostal nerves**—supply intercostal muscles, skin, and abdominal wall
 - Each gives off **lateral** and **anterior cutaneous branches**

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Introduction to Nerve Plexuses

- **Nerve plexus**—a network of nerves
- **Ventral rami** of all spinal nerves (except T₂–T₁₂) branch and join with one another to form nerve plexuses
 - These plexuses occur in cervical, brachial, lumbar, and sacral regions
 - Primarily serve the limbs
 - Fibers from ventral rami crisscross -- so each muscle in limb receives its nerve supply from more than one spinal nerve

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The Cervical Plexus

- Buried deep in the neck
 - Under the **sternocleidomastoid muscle**
- Formed by ventral rami of first four cervical nerves (cn 1–4)
- Most are cutaneous nerves
- Some innervate muscles of the anterior neck
- **Phrenic nerve** — the most important nerve of the cervical plexus

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The Cervical Plexus

- **Phrenic nerve**
 - The most important nerve of the cervical plexus
 - Formed from fibers from C₃, C₄, and C₅
 - Innervates the diaphragm

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The Cervical Plexus

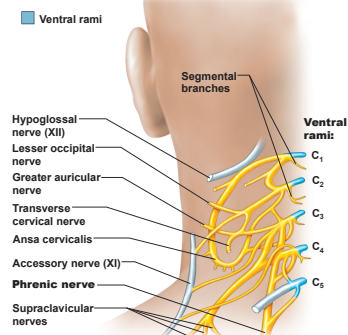


Figure 14.8

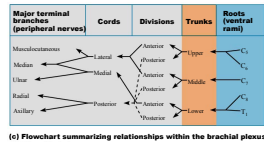
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The Brachial Plexus and Innervation of the Upper Limb

- Brachial plexus lies in the neck and axilla
- Formed by ventral rami of C₅–C₈
- Cords give rise to main nerves of the upper limb

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Figure 14.9c The brachial plexus, anterior view.



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Nerves from the Lateral and Medial Cords

- **Musculocutaneous**—main branch of the lateral cord
 - Innervates the biceps brachii and brachialis
- **Median**—originates from both lateral and medial cords
 - Innervates anterior forearm muscles and lateral palm

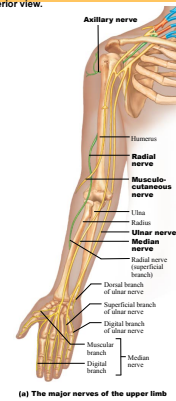
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Nerves from the Lateral and Medial Cords

- **Ulnar**—branches from the medial cord
 - Innervates intrinsic hand muscles and skin of the medial hand

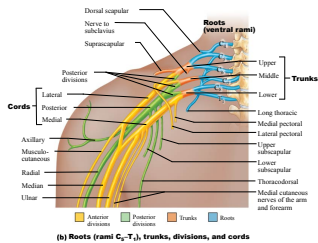
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Figure 14.9a The brachial plexus, anterior view.



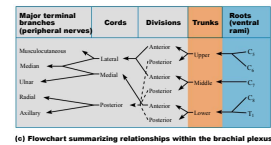
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Figure 14.9b The brachial plexus, anterior view.



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Figure 14.9c The brachial plexus, anterior view.



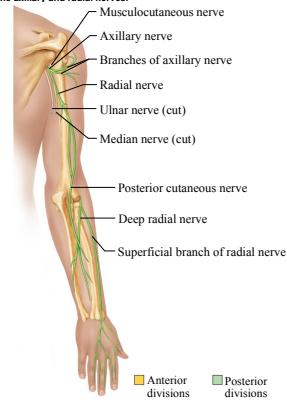
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Nerves from the Posterior Cord

- **Radial**—continuation of the posterior cord
 - Largest branch of the brachial plexus
 - Innervates muscles of the posterior upper limb
- **Axillary**
 - Innervates the deltoid and teres minor

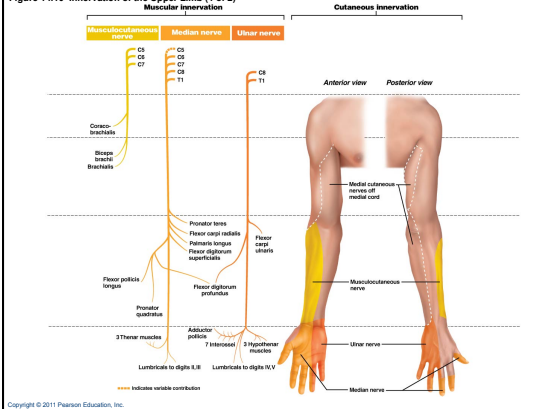
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Figure 14.11 Course of the axillary and radial nerves.



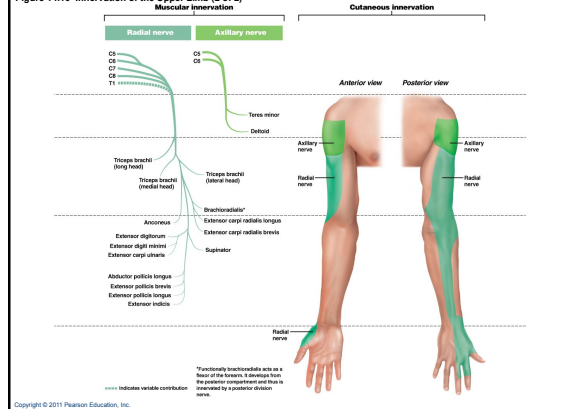
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Figure 14.10 Innervation of the Upper Limb (1 of 2)



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Figure 14.10 Innervation of the Upper Limb (2 of 2)



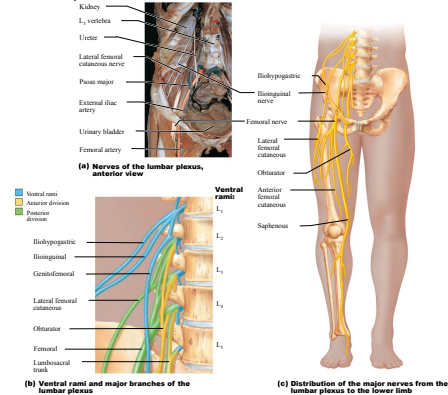
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The Lumbar Plexus and Innervation of the Lower Limb

- **Lumbar plexus**
 - Arises from L₁ to L₄
 - Smaller branches innervate the posterior abdominal wall and psoas muscle
 - Main branches innervate the anterior thigh
 - **Femoral nerve**—innervates anterior thigh muscles
 - **Obturator nerve**—innervates adductor muscles

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Figure 14.12 The lumbar plexus.



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The Sacral Plexus

- Arises from spinal nerves L₄–S₄
- Caudal to the lumbar plexus
- Often considered with the lumbar plexus
 - **Lumbosacral plexus**

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Innervation of the Lower Limb

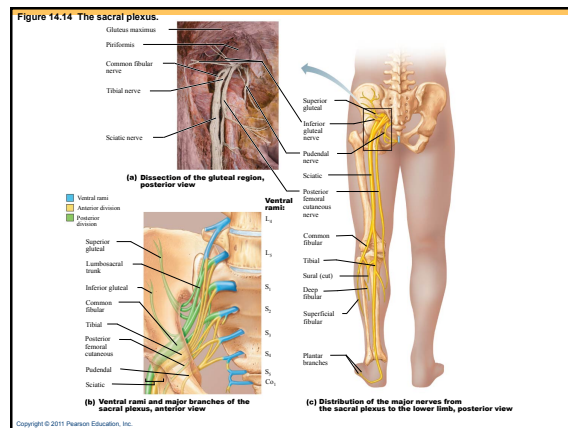
- **Sciatic nerve**—the largest nerve of the sacral plexus
 - Actually two nerves in one sheath
 - **Tibial nerve**—innervates most of the posterior lower limb
 - **Common fibular (peroneal) nerve**—innervates muscles of the anterolateral leg

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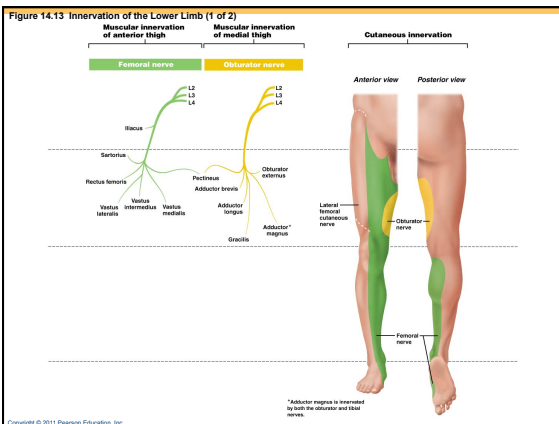
Innervation of the Lower Limb

- Superior and inferior gluteal nerves
 - Innervate the gluteal muscles
- Pudendal nerve
 - Innervates muscles of the perineum

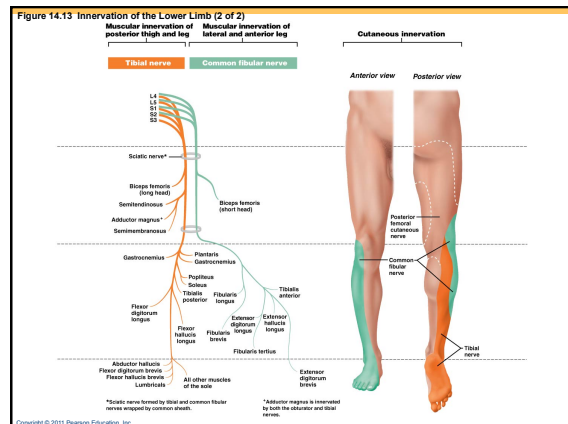
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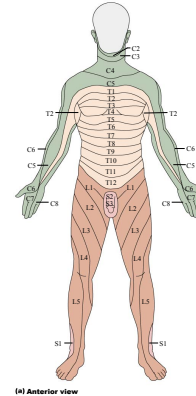
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Innervation of the Skin: Dermatomes

- **Dermatome**—an area of skin
 - Innervated by cutaneous branches/dorsal root of a single spinal nerve
- Upper limb
 - Skin is supplied by nerves of the **brachial plexus**
- Lower limb
 - Lumbar nerves—**anterior surface**
 - Sacral nerves—**posterior surface**

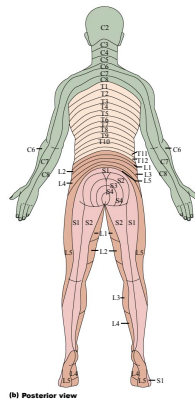
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Figure 14.15a Map of dermatomes.



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Figure 14.15b Map of dermatomes.



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Disorders of the PNS

- **Shingles (herpes zoster)**
 - Viral infection
 - Stems from childhood chicken pox
 - Often brought on by stress
 - Mostly experienced by people over 50

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Disorders of the PNS

- **Migraine headache**
 - Relates to sensory innervation of cerebral arteries
 - Arteries dilate and compress and irritate sensory nerve endings

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Disorders of the PNS

- **Peripheral neuropathy**
 - Pathological condition of peripheral nerves
 - Symptoms of sensory nerve involvement
 - Paresthesia, pain, burning, loss of sensation
 - Symptoms of motor nerve involvement
 - Muscle weakness and paralysis
 - Causes:
 - Trauma, repetitive use
 - Systemic disorders—HIV, diabetes, vitamin B deficiency

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The PNS Throughout Life

- **Spinal nerves** form late in week 4
- Each of the 31 pairs of spinal nerves:
 - Sends motor fibers to an individual myotome
 - Sends sensory fibers to the overlying band of skin
- During week 5, nerves reach the organs they innervate

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The PNS Throughout Life

- Embryonic muscles migrate to new locations
 - Some skin dermatomes become displaced
 - Muscles and skin always retain their original nerve supply

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