Peripheral Nervous System (PNS)

- All neural structures outside the brain
  - Sensory receptors
  - Peripheral nerves and associated ganglia
  - Motor neuron endings
  - Pathway between CNS and outlying structures
  - 12 pairs of cranial nerves
  - 31 pairs of spinal nerves
Cranial Nerves

- 12 pairs of nerves
  - Associated with the brain
- Most are mixed in function
  - Only 2 pairs are purely sensory
- Each nerve is identified by
  - Number (I through XII)
  - Name

“On occasion, our trusty truck acts funny—very good vehicle anyhow”
### Cranial nerves I – VI

<table>
<thead>
<tr>
<th>Cranial nerves</th>
<th>Sensory function</th>
<th>Motor function</th>
<th>PS* fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Olfactory</td>
<td>Yes (smell)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>II Optic</td>
<td>Yes (vision)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>III Oculomotor</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>IV Trochlear</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>V Trigeminal</td>
<td>Yes (general sensation)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>VI Abducens</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

### Cranial nerves VII – XII

<table>
<thead>
<tr>
<th>Cranial nerves</th>
<th>Sensory function</th>
<th>Motor function</th>
<th>PS* fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII Facial</td>
<td>Yes (taste)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VIII Vestibulocochlear</td>
<td>Yes (hearing and balance)</td>
<td>Some</td>
<td>No</td>
</tr>
<tr>
<td>IX Glossopharyngeal</td>
<td>Yes (taste)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>X Vagus</td>
<td>Yes (taste)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>XI Accessory</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>XII Hypoglossal</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*PS = parasympathetic*
Table 13.2  Cranial Nerves

1 The Olfactory Nerves (ol-fak’to-re)

**Origin and course:** Olfactory nerve fibers arise from olfactory receptor cells located in olfactory epithelium of nasal cavity and pass through cribriform plate of ethmoid bone to synapse in olfactory bulb. Fibers of olfactory bulb neurons extend posteriorly as olfactory tract, which runs beneath frontal lobe to enter cerebral hemispheres and terminates in primary olfactory cortex. See also Figure 15.21.

**Function:** Purely sensory; carry afferent impulses for sense of smell.

**Clinical testing:** Person is asked to sniff aromatic substances, such as oil of cloves and vanilla, and to identify each.

**Homeostatic imbalance:** Fracture of ethmoid bone or lesions of olfactory fibers may result in partial or total loss of smell, a condition known as anosmia (an-oz’mé-ah).
### TABLE 13.2 Cranial Nerves (continued)

#### II The Optic Nerves

**Origin and course:** Fibers arise from retina of eye to form optic nerve, which passes through optic canal of orbit. The optic nerves converge to form the optic chiasma (ki-az’mah) where fibers partially cross over, continue on as optic tracts, enter thalamus, and synapse there. Thalamic fibers run (as the optic radiation) to occipital (visual) cortex, where visual interpretation occurs. See also Figure 15.19.

**Function:** Purely sensory; carry afferent impulses for vision.

**Clinical testing:** Vision and visual field are determined with eye chart and by testing the point at which the person first sees an object (finger) moving into the visual field. Fundus of eye viewed with ophthalmoscope to detect papilledema (swelling of optic disc, the site where the optic nerve leaves the eyeball), as well as for routine examination of the optic disc and retinal blood vessels.

**Homeostatic imbalance:** Damage to optic nerve results in blindness in eye served by nerve; damage to visual pathway beyond the optic chiasma results in partial visual losses; visual defects are called anopsias (ah-nop’se-ahz).
TABLE 13.2 Cranial Nerves (continued)

III The Oculomotor Nerves (ok”u-lo-mo’tor)

**Origin and course:** Fibers extend from ventral midbrain (near its junction with pons) and pass through bony orbit, via superior orbital fissure, to eye.

**Function:** Chiefly motor nerves (oculomotor = motor to the eye); contain a few proprioceptive afferents. Each nerve includes the following:

- Somatic motor fibers to four of the six extrinsic eye muscles (inferior oblique and superior, inferior, and medial rectus muscles) that help direct eyeball, and to levator palpebrae superioris muscle, which raises upper eyelid.

- Parasympathetic (autonomic) motor fibers to sphincter pupillae (circular muscles of iris), which cause pupil to constrict, and to ciliary muscle, controlling lens shape for visual focusing. Some parasympathetic cell bodies are in the ciliary ganglia.

- Sensory (proprioceptor) afferents, which run from same four extrinsic eye muscles to midbrain.

**Clinical testing:** Pupils are examined for size, shape, and equality. Pupillary reflex is tested with penlight (pupils should constrict when illuminated). Convergence for near vision is tested, as is subject’s ability to follow objects with the eyes.

**Homeostatic imbalance:** In oculomotor nerve paralysis, eye cannot be moved up, down, or inward, and at rest, eye rotates laterally [external strabismus (strah-biz’mus)] because the actions of the two extrinsic eye muscles not served by cranial nerves III are unopposed; upper eyelid droops (ptosis), and the person has double vision and trouble focusing on close objects.
**TABLE 13.2 Cranial Nerves (continued)**

**IV The Trochlear Nerves (trokˈle-ər)**

**Origin and course:** Fibers emerge from dorsal midbrain and course ventrally around midbrain to enter orbit through superior orbital fissure along with oculomotor nerves.

**Function:** Primarily motor nerves; supply somatic motor fibers to (and carry proprioceptor fibers from) one of the extrinsic eye muscles, the superior oblique muscle.

**Clinical testing:** Tested in common with cranial nerve III.

**Homeostatic imbalance:** Trauma to, or paralysis of, a trochlear nerve results in double vision and reduced ability to rotate eye inferolaterally.
Table 13.2 Cranial Nerves (continued)

V The Trigeminal Nerves

**Homeostatic imbalance:** Trigeminal neuralgia (nu-ral’je-ah), or tic douloureux (tik doo’loo-ruh; tic = twitch, douloureux = painful), caused by inflammation of trigeminal nerve, is widely considered to produce most excruciating pain known; the stabbing pain lasts for a few seconds to a minute, but it can be relentless, occurring a hundred times a day. Usually provoked by some sensory stimulus, such as brushing teeth or even a passing breeze hitting the face. It is thought to be caused by compression of the trigeminal nerve by a loop of artery or vein close to its exit from the brain stem. Analgesics and carbamazepine (an anticonvulsant) are only partially effective. In severe cases, surgery relieves the agony—either by moving the compressing vessel or by destroying the nerve. Nerve destruction results in loss of sensation on that side of face.

(a) Distribution of the trigeminal nerve

(b) Distribution of sensory fibers of each division

(c) Motor branches of the mandibular division (V₃)
TABLE 13.2  Cranial Nerves (continued)

VI The Abducens Nerves (ab-du’senz)

**Origin and course:** Fibers leave inferior pons and enter orbit via superior orbital fissure to run to eye.

**Function:** Primarily motor; supply somatic motor fibers to lateral rectus muscle, an extrinsic muscle of the eye; convey proprioceptor impulses from same muscle to brain.

**Clinical testing:** Tested in common with cranial nerve III.

**Homeostatic imbalance:** In abducens nerve paralysis, eye cannot be moved laterally; at rest, affected eyeball rotates medially (internal strabismus).
### Cranial Nerves (continued)

#### VII The Facial Nerves

- **Facial nerve (VII)**
  - Geniculate ganglion
  - Pterygopalatine ganglion
  - Internal acoustic meatus
  - Motor branch to muscles of facial expression

- **Parasympathetic efferents and sensory afferents**
  - Lacrimal gland
  - Parasympathetic nerve fibers
  - Chorda tympani branch (taste)
  - Stylomastoid foramen
  - Submandibular ganglion
  - Parasympathetic nerve fibers
  - Sublingual gland
  - Submandibular gland
  - Motor branch to muscles of facial expression

- **Motor branches to muscles of facial expression and scalp muscles (see pp. 329–331)**
  - Temporal
  - Zygomatic
  - Buccal
  - Mandibular
  - Cervical

- **A simple method of remembering the courses of the five major motor branches of the facial nerve**

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### TABLE 13.2 Cranial Nerves (continued)

#### VII The Facial Nerves

**Origin and course:** Fibers issue from pons, just lateral to abducens nerves (see Figure 13.5), enter temporal bone via *internal acoustic meatus*, and run within bone (and through inner ear cavity) before emerging through *stylo mastoid foramen*; nerve then courses to lateral aspect of face.

**Function:** Mixed nerves that are the chief motor nerves of face; have five major branches: temporal, zygomatic, buccal, mandibular, and cervical (see c).

- Convey motor impulses to skeletal muscles of face (muscles of facial expression), except for chewing muscles served by trigeminal nerves, and transmit proprioceptor impulses from same muscles to pons (see b).
- Transmit parasympathetic (autonomic) motor impulses to lacrimal (tear) glands, nasal and palatine glands, and submandibular and sublingual salivary glands. Some of the cell bodies of these parasympathetic motor neurons are in *pterygoplatine* (ter'eh-go-pal'ah-tīn) and *submandibular ganglia* on the trigeminal nerve (see a).
- Convey sensory impulses from taste buds of anterior two-thirds of tongue; cell bodies of these sensory neurons are in *geniculate ganglion* (see a).

**Clinical testing:** Anterior two-thirds of tongue is tested for ability to taste sweet (sugar), salty, sour (vinegar), and bitter (quinine) substances. Symmetry of face is checked. Subject is asked to close eyes, smile, whistle, and so on. Tearing is assessed with ammonia fumes.

**Homeostatic imbalance:** *Bell’s palsy*, characterized by paralysis of facial muscles on affected side and partial loss of taste sensation, may develop rapidly (often overnight). Most often caused by herpes simplex 1 viral infection, which causes swelling and inflammation of facial nerve. Lower eyelids droop, corner of mouth sags (making it difficult to eat or speak normally), tears drip continuously from eye and eye cannot be completely closed (conversely, dry-eye syndrome may occur). Condition may disappear spontaneously without treatment.
Table 13.2 Cranial Nerves (continued)

VIII The Vestibulocochlear Nerves (ves-tib"u-lo-kok"le-ar)

**Origin and course:** Fibers arise from hearing and equilibrium apparatus located within inner ear of temporal bone and pass through internal acoustic meatus to enter brain stem at pons-medulla border. Afferent fibers from hearing receptors in cochlea form the **cochlear division**; those from equilibrium receptors in semicircular canals and vestibule form the **vestibular division** (vestibular nerve); the two divisions merge to form vestibulocochlear nerve. See also Figure 15.27.

**Function:** Mostly sensory. Vestibular branch transmits afferent impulses for sense of equilibrium, and sensory nerve cell bodies are located in **vestibular ganglia**. Cochlear branch transmits afferent impulses for sense of hearing, and sensory nerve cell bodies are located in **spiral ganglion** within cochlea. Small motor component adjusts the sensitivity of sensory receptors. See also Figure 15.28c.

**Clinical testing:** Hearing is checked by air and bone conduction using tuning fork.

**Homeostatic imbalance:** Lesions of cochlear nerve or cochlear receptors result in central or nerve deafness, whereas damage to vestibular division produces dizziness, rapid involuntary eye movements, loss of balance, nausea, and vomiting.

Table 13.2
IX The Glossopharyngeal Nerves (glos'ō-fah-rin'je-al)

**Origin and course:** Fibers emerge from medulla and leave skull via jugular foramen to run to throat.

**Function:** Mixed nerves that innervate part of tongue and pharynx. Provide somatic motor fibers to, and carry proprioceptor fibers from, a superior pharyngeal muscle called the stylopharyngeus, which elevates the pharynx in swallowing. Provide parasympathetic motor fibers to parotid salivary glands (some of the nerve cell bodies of these parasympathetic motor neurons are located in otic ganglion).

Sensory fibers conduct taste and general sensory (touch, pressure, pain) impulses from pharynx and posterior tongue, from chemoreceptors in the carotid body (which monitor O₂ and CO₂ levels in the blood and help regulate respiratory rate and depth), and from baroreceptors of carotid sinus (which monitor blood pressure). Sensory neuron cell bodies are located in superior and inferior ganglia.

**Clinical testing:** Position of the uvula is checked. Gag and swallowing reflexes are checked. Subject is asked to speak and cough. Posterior third of tongue may be tested for taste.

**Homeostatic imbalance:** Injury or inflammation of glossopharyngeal nerves impairs swallowing and taste.
**Cranial Nerves (continued)**

**X The Vagus Nerves (va’gus)**

**Origin and course:** The only cranial nerves to extend beyond head and neck region. Fibers emerge from medulla, pass through skull via jugular foramen, and descend through neck region into thorax and abdomen. See also Figure 14.4.

**Function:** Mixed nerves; nearly all motor fibers are parasympathetic efferents, except those serving skeletal muscles of pharynx and larynx (involved in swallowing). Parasympathetic motor fibers supply heart, lungs, and abdominal viscera and are involved in regulation of heart rate, breathing, and digestive system activity. Transmit sensory impulses from thoracic and abdominal viscera, from the aortic arch baroreceptors (for blood pressure) and the carotid and aortic bodies (chemoreceptors for respiration), and taste buds of posterior tongue and pharynx. Carry proprioceptor fibers from muscles of larynx and pharynx.

**Clinical testing:** As for cranial nerve IX (IX and X are tested in common, since they both innervate muscles of throat and mouth).

**Homeostatic imbalance:** Since nearly all muscles of the larynx ("voice box") are innervated by laryngeal branches of the vagus, vagal nerve paralysis can lead to hoarseness or loss of voice; other symptoms are difficulty swallowing and impaired digestive system motility. Total destruction of both vagus nerves is incompatible with life, because these parasympathetic nerves are crucial in maintaining normal state of visceral organ activity; without their influence, the activity of the sympathetic nerves, which mobilize and accelerate vital body processes (and shut down digestion), would be unopposed.

<table>
<thead>
<tr>
<th>Vagus nerve (X)</th>
<th>Medulla oblongata</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jugular foramen</td>
<td>Ganglia (interior</td>
</tr>
<tr>
<td></td>
<td>and superior)</td>
</tr>
<tr>
<td>Pharyngeal nerve</td>
<td>Carotid sinus</td>
</tr>
<tr>
<td>branch</td>
<td>and body</td>
</tr>
<tr>
<td>Laryngeal branches</td>
<td>Aortic arch baroreceptor and aortic body</td>
</tr>
<tr>
<td>Lung</td>
<td>Heart</td>
</tr>
<tr>
<td>Spleen</td>
<td>Gallbladder</td>
</tr>
<tr>
<td>Liver</td>
<td>Stomach</td>
</tr>
<tr>
<td>Kidney</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Colon (proximal portion)</td>
<td></td>
</tr>
</tbody>
</table>
Table 13.2 Cranial Nerves (continued)

XI The Accessory Nerves

Origin and course: Unique in that they are formed from ventral rootlets that emerge from the spinal cord, not the brain stem. These rootlets arise from superior region (C_{1}–C_{3}) of spinal cord, pass upward along spinal cord, and enter the skull as the accessory nerves via foramen magnum. The accessory nerves exit from skull through jugular foramen together with the vagus nerves, and supply two large neck muscles. Until recently, it was thought that the accessory nerves also received a contribution from cranial rootlets, but it has now been determined that in almost all people, these cranial rootlets are instead part of the vagus nerves. This raises an interesting question: Should the accessory nerves still be considered cranial nerves? Some anatomists say “yes” because they pass through the cranium. Others say “no” because they don’t arise from the brain. Stay tuned!

Function: Mixed nerves, but primarily motor in function. Supply motor fibers to trapezius and sternocleidomastoid muscles, which together move head and neck, and convey proprioceptor impulses from same muscles.

Clinical testing: Sternocleidomastoid and trapezius muscles are checked for strength by asking person to rotate head and shrug shoulders against resistance.

Homeostatic imbalance: Injury to the spinal root of one accessory nerve causes head to turn toward injury side as result of sternocleidomastoid muscle paralysis; shrugging of that shoulder (role of trapezius muscle) becomes difficult.
TABLE 13.2  Cranial Nerves (continued)

XII  The Hypoglossal Nerves (hi’po-glos’al)

**Origin and course:** As their name implies (hypo = below; glossal = tongue), hypoglossal nerves mainly serve the tongue. Fibers arise by a series of roots from medulla and exit from skull via hypoglossal canal to travel to tongue. See also Figure 13.5.

**Function:** Mixed nerves, but primarily motor in function. Carry somatic motor fibers to intrinsic and extrinsic muscles of tongue, and proprioceptor fibers from same muscles to brain stem. Hypoglossal nerve control allows not only food mixing and manipulation by tongue during chewing, but also tongue movements that contribute to swallowing and speech.

**Clinical testing:** Person is asked to protrude and retract tongue. Any deviations in position are noted.

---

Homeostatic imbalance: Damage to hypoglossal nerves causes difficulties in speech and swallowing. If both nerves are impaired, the person cannot protrude tongue. If only one side is affected, tongue deviates (points) toward affected side; eventually paralyzed side begins to atrophy.
Activity

- Complete Cranial Nerve Chart
Spinal Nerves

- 31 pairs of mixed nerves named according to their point of issue from the spinal cord
  - 8 cervical (C₁–C₈)
  - 12 thoracic (T₁–T₁₂)
  - 5 Lumbar (L₁–L₅)
  - 5 Sacral (S₁–S₅)
  - 1 Coccygeal (C₀)
Cervical plexus

Brachial plexus

Cervical enlargement

Intercostal nerves

Lumbar enlargement

Lumbar plexus

Sacral plexus

Cauda equina

Cervical nerves
\( C_1 - C_8 \)

Thoracic nerves
\( T_1 - T_{12} \)

Lumbar nerves
\( L_1 - L_5 \)

Sacral nerves
\( S_1 - S_5 \)

Coccygeal nerve \( Co_1 \)
Spinal Nerve Organization

- Spinal nerve connects to the spinal cord via two roots
  - Ventral roots
    - Contain motor (efferent) fibers from the ventral horn motor neurons
    - Fibers innervate skeletal muscles
  - Dorsal roots
    - Contain sensory (afferent) fibers from sensory neurons in the dorsal root ganglia
    - Conduct impulses from peripheral receptors
Spinal Nerve Organization

- Dorsal and ventral roots unite to form spinal nerves
  - Emerge from vertebral column via the intervertebral foramina
Spinal Nerve Organization

- **Rami**
  - Each spinal nerve branches into mixed rami
    - Dorsal ramus
    - Ventral ramus
      - Rami communicantes (autonomic pathways) join to the ventral rami in the thoracic region
    - Meningeal branch
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.
Spinal Nerve Organization

- **Dorsal ramus**
  - **Innervates**
    - Deep back muscles
    - Posterior surface of trunk

- **Ventral ramus**
  - **Innervates**
    - Superficial back muscles
    - Limbs
    - Lateral and anterior surfaces of trunk
(b) Cross section of thorax showing the main roots and branches of a spinal nerve.
Distribution of Spinal Nerves

- **Dermatome**
  - Area of skin innervated by the cutaneous branches of a single spinal nerve
  - All spinal nerves except C₁ participate in dermatomes
  - Most dermatomes overlap
Plexuses

- All ventral rami form interlacing nerve networks
  - 4 plexuses
    - Cervical, brachial, lumbar, and sacral
- Exception: ventral rami of $T_2 - T_{12}$
  - Do not form a plexus
  - Form intercostal nerves
Figure 13.6

- Cervical plexus
- Brachial plexus
- Cervical enlargement
- Intercostal nerves
- Lumbar enlargement
- Lumbar plexus
- Sacral plexus
- Cauda equina
- Cervical nerves $C_1 - C_8$
- Thoracic nerves $T_1 - T_{12}$
- Lumbar nerves $L_1 - L_5$
- Sacral nerves $S_1 - S_5$
- Coccygeal nerve $C_{o1}$
Plexuses

- **Cervical plexus**
  - Formed by ventral rami of C₁–C₄
  - Innervates skin & muscles of the neck, ear, back of head, and shoulders

- **Phrenic nerve**
  - Major motor and sensory nerve of the diaphragm
    - Receives fibers from C₃–C₅
Hypoglossal nerve (XII)
Lesser occipital nerve
Greater auricular nerve
Transverse cervical nerve
Ansa cervicalis
Accessory nerve (XI)
Phrenic nerve
Supraclavicular nerves
Plexuses

- Brachial plexus
  - Formed by ventral rami of C₄–T₁
  - Gives rise to the nerves that innervate the upper limb
    - Median
    - Ulnar
    - Axillary
    - Radial
    - Musculocutaneous
(a) Roots (rami C₅ – T₁), trunks, divisions, and cords
(c) The major nerves of the upper limb

- Median nerve
- Musculocutaneous nerve
- Radial nerve
- Humerus
- Ulna
- Radius
- Ulnar nerve
- Radial nerve (superficial branch)
  - Dorsal branch of ulnar nerve
  - Superficial branch of ulnar nerve
  - Digital branch of ulnar nerve
- Muscular branch
- Digital branch
- Axillary nerve
- Anterior divisions
- Posterior divisions
- Trunks
- Roots
Injuries

Radial Nerve

Ulnar Nerve

Carpal Tunnel Syndrome

wrist drop from crutch pressure

Area of pain and numbness

Median nerve

Transverse carpal ligament

Claw hand of the first and second finger
Plexuses

- **Lumbar plexus**
  - Arises from L₁–L₅ (some T₁₂)
  - Innervates thigh, abdominal wall, external genitalia, leg & foot
    - **Femoral nerve**
      - Innervates quadriceps, skin of anterior thigh & medial surface of leg
    - **Obturator nerve**
      - Passes through obturator foramen
      - Innervates adductor muscles
Figure 13.10

(a) Ventral rami and major branches of the lumbar plexus

(b) Distribution of the major nerves from the lumbar plexus to the lower limb

Ventral rami:
- L1: Iliohypogastric
- L2: Ilioinguinal
- L3: Femoral
- L4: Lateral femoral cutaneous
- L5: Obturator

Additional nerves:
- Genitofemoral
- Saphenous
- Anterior femoral cutaneous
Plexuses

- **Sacral plexus**
  - Arises from $L_4 - S_4$
  - Serves the buttock, lower limb, pelvic structures & perineum
    - Sciatic nerve
      - Longest and thickest nerve of the body
  - Innervates
    - Muscles of the leg and foot
    - Skin on the leg and foot
Superior gluteal
Lumbosacral trunk
Inferior gluteal
Common fibular
Tibial
Posterior femoral cutaneous
Pudendal
Sciatic

Ventral rami and major branches of the sacral plexus
(b) Distribution of the major nerves from the sacral plexus to the lower limb