Chapter 13

Brain and Cranial Nerves

Olfactory bulb (olfactory nerves [I]) enter bulbs
Optic nerve (II)
Oculomotor nerve (III)
Trigeminal nerve (V)
Abducens nerve (VI)
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Hypoglossal nerve (XII)
Accessory nerve (XI)
Brain and Cranial Nerves

- **Brain**
  - Part of CNS contained in cranial cavity
  - Control center for many of body’s functions
  - Much like a complex computer but more
  - Parts of the brain
    - **Brainstem**: connects spinal cord to brain; integration of reflexes necessary for survival
    - **Cerebellum**: involved in control of locomotion, balance, posture
    - **Diencephalon**: thalamus, subthalamus, epithalamus, hypothalamus
    - **Cerebrum**: conscious thought, control

- **Cranial nerves**: part of PNS arise directly from brain. Two pairs arise from cerebrum; ten pairs arise from brainstem

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Sagittal Section of Brain
**Table 13.1** Divisions and Functions of the Brain

<table>
<thead>
<tr>
<th>Division</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brainstem</strong></td>
<td>Connects the spinal cord to the cerebrum; several important functions (see below); location of cranial nerve nuclei.</td>
</tr>
<tr>
<td>Medulla oblongata</td>
<td>Pathway for ascending and descending nerve tracts; center for several important reflexes (e.g., heart rate, breathing, swallowing, vomiting)</td>
</tr>
<tr>
<td>Pons</td>
<td>Contains ascending and descending nerve tracts; relay between cerebrum and cerebellum; reflex centers</td>
</tr>
<tr>
<td>Midbrain</td>
<td>Contains ascending and descending nerve tracts; visual reflex center; part of auditory pathway</td>
</tr>
<tr>
<td>Reticular formation</td>
<td>Scattered throughout brainstem; controls cyclic activities such as the sleep-wake cycle</td>
</tr>
<tr>
<td><strong>Cerebellum</strong></td>
<td>Control of muscle movement and tone; balance regulates extent of intentional movement; involved in learning motor skills</td>
</tr>
<tr>
<td><strong>Diencophalon</strong></td>
<td></td>
</tr>
<tr>
<td>Thalamus</td>
<td>Major sensory relay center; influences motor and movement</td>
</tr>
<tr>
<td>Subthalamus</td>
<td>Contains nerve tracts and nuclei</td>
</tr>
<tr>
<td>Epithalamus</td>
<td>Contains nuclei responding to olfactory stimulation and contains pineal body</td>
</tr>
<tr>
<td>Hypothalamus</td>
<td>Major control center for maintaining homeostasis and regulating endocrine functions</td>
</tr>
<tr>
<td><strong>Cerebrum</strong></td>
<td>Conscious perception, thought, and conscious motor activity; can exercise most other systems</td>
</tr>
<tr>
<td><strong>Basal nuclei</strong></td>
<td>Control of muscle activity and posture; largely inhibit unintentional movement when at rest</td>
</tr>
<tr>
<td><strong>Limbic system</strong></td>
<td>Autonomic response to smell, emotion, mood, and other such functions</td>
</tr>
</tbody>
</table>

**Brainstem and Diencephalon**
Brainstem: **Medulla Oblongata**

- Most inferior part
- Continuous with spinal cord; has both ascending and descending nerve tracts
- Discrete nuclei in internal gray matter
- Regulates: heart rate, blood vessel diameter, respiration, swallowing, vomiting, hiccupping, coughing, and sneezing
- **Pyramids**: descending nerve tracts on the anterior surface. Inferiorly fibers decussate; thus each half of the brain controls the opposite half of the body
- **Olives**: rounded; protrude from anterior surface. Nuclei within help regulate balance, coordination, modulation of sound from inner ear
- Nuclei of cranial nerves V, IX-XII

Brainstem: **Pons**

- Superior to the medulla oblongata
- Fiber tracts: ascending and descending
- Nuclei
  - **Pontine**: anterior portion, relay between cerebrum and cerebellum
  - For cranial nerves V-IX: posterior portion
  - Sleep center
  - Respiratory center coordinates with center in medulla
Brainstem: Midbrain

- Also called mesencephalon
- Small and superior to pons
- Nuclei
  - Of cranial nerves III-V
  - Tectum: four nuclei that form mounds on dorsal surface of midbrain.
    Corpora quadrigemina
    - Each separate part is a colliculus
    - Two superior colliculi involved in visual reflexes; receive information from inferior colliculi, eyes, skin, cerebrum
    - Two inferior colliculi involved in hearing
  - Red nuclei of tegmentum: aid in unconscious regulation and coordination of motor activities
  - Substantia nigra: pigmented with melanin; interconnected with basal nuclei of the cerebrum
- Tracts
  - Tegmentum: ascending tracts such as spinal and medial lemniscus from spinal cord to brain
  - Descending: cerebral peduncles from cerebrum through brainstem to spinal cord

Oblique Section Through Midbrain

![Oblique Section Through Midbrain](image)
Reticular Formation

• Group of nuclei scattered throughout brainstem
• Controls cyclic activities such as sleep-wake cycle

Cerebellum

• Attached to brainstem posterior to pons
• **Cerebellar peduncles**: fiber tracts that communicate with other parts of brain
  – **Superior**: to midbrain
  – **Middle**: to pons
  – **Inferior**: to medulla oblongata
• Gray cortex and nuclei with white matter (tracts) between
• Cortex folded in ridges called **folia**; white matter resembles a tree (**arbor vitae**)
Purkinje Cells in Cerebral Cortex

- Purkinje cells: largest in CNS. Receive 200,000 synapses, are inhibitory, only cerebellar cortex neurons sending axons to cerebellar nuclei
- Cortex has $10^{12}$ neurons; more than cerebral cortex

Cerebellar Functions

- **Flocculonodular lobe**: balance and eye movements
- **Vermis** and medial portion of hemispheres: posture, locomotion, fine motor coordination leading to smooth, flowing movements
- **Lateral hemispheres**, major portion: works with cerebrum to plan, practice, learn complex movements
Diencephalon

- Located between brainstem and cerebrum
- Components: thalamus, subthalamus, epithalamus, hypothalamus

Thalamus

- Two lateral portions connected by the intermediate mass
- Surrounded by third ventricle
- Sensory information from spinal cord synapses here before projecting to cerebrum
  - Medial geniculate nucleus: auditory information
  - Lateral geniculate nucleus: visual information
  - Ventral posterior nucleus: most other types sensory information
- Motor function: ventral anterior and ventral lateral nuclei
- Mood modification: anterior and medial nuclei connected to limbic system
- Emotion regulation: lateral dorsal nucleus
- Sensory integration: lateral posterior and pulvinar nuclei
Subthalamus

- Involved in controlling motor function
- Contains subthalamic nuclei, parts of red nuclei and substantia nigra.
- Several ascending and descending nerve tracts

Epithalamus

- Pineal gland: (hypothetically) causes sleepiness, helps regulate biological clock, may play a role in onset of puberty
- Habenular nucleus: emotional and visceral responses to odors
Hypothalamus

- Most inferior portion of diencephalon
- **Mammillary bodies**: bulges on ventral surface; olfactory reflexes and emotional responses to odors
- **Infundibulum**: stalk extending from floor; connects hypothalamus to posterior pituitary gland. Controls endocrine system.
- Receives input from viscera, taste receptors, limbic system, nipples, external genitalia, prefrontal cortex
- Efferent fibers to brainstem, spinal cord (autonomic system), through infundibulum to posterior pituitary, and to cranial nerves controlling swallowing and shivering
- Important in regulation of mood, emotion, sexual pleasure, satiation, rage, and fear

<table>
<thead>
<tr>
<th>Table 13.2 Hypothalamic Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Autonomic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Temporal cortex</td>
</tr>
<tr>
<td>Metabolic control</td>
</tr>
<tr>
<td>Regulation of food and water intake</td>
</tr>
<tr>
<td>Emotions</td>
</tr>
<tr>
<td>Regulation of the sleep–wake cycle</td>
</tr>
<tr>
<td>Sexual development and behavior</td>
</tr>
</tbody>
</table>

13-20
Cerebrum

- Largest portion of brain
- Composed of right and left hemispheres each of which has the following lobes: frontal, parietal, occipital, temporal, insula
- Sulci and Fissures
  - Longitudinal fissure: separates the two hemispheres
  - Lateral fissure: separates temporal lobe from frontal and parietal lobes
  - Central sulcus: separates frontal and parietal lobes
- Cortex: outer surface
  - Gyri are folds
  - Sulci are depressions
- Medulla: center
- Nuclei: gray matter within the medulla

Cerebrum, cont.

- Central sulcus: between the precentral gyrus (primary motor cortex) and postcentral gyrus (primary somatic sensory cortex)
- Frontal lobe: voluntary motor function, motivation, aggression, sense of smell, mood
- Parietal lobe: reception and evaluation of sensory information except smell, hearing, and vision
- Occipital lobe: reception and integration of visual input
- Temporal lobe: reception and evaluation for smell and hearing; memory, abstract thought, judgment. Insula is within.
Cerebral Medulla

- White matter between the cortex and nuclei
- **Association fibers**: connections within the same hemisphere
- **Commissural fibers**: connect one hemisphere to the other
- **Projection fibers**: tracts between the cerebrum and other parts of the brain and spinal cord

Basal Nuclei (Basal Ganglia)

- Found in the cerebrum, diencephalon, and midbrain
- Motor function control
- The nuclei in the cerebrum (caudate and lentiform) are called the **corpus striatum**
Limbic System

- Part of cerebrum and diencephalon
- Basic survival functions such as memory, reproduction, nutrition
- Emotions
- In cerebrum: cingulate gyrus and hippocampus
- Various nuclei of the thalamus
- Part of the basal nuclei, hypothalamus, olfactory cortex, fornix

Meninges

- Connective tissue membranes
  - Dura mater: superficial
  - Arachnoid mater
  - Pia mater: bound tightly to brain
- Spaces
  - Subdural: serous fluid
  - Subarachnoid: CSF
Dura Mater

- Superficial, tightly bound to internal periosteum except:
  - **Falx cerebri** in longitudinal fissure between the two cerebral hemispheres
  - **Tentorium cerebelli** between Cerebellum and cerebrum
  - **Falx cerebelli** between the two cerebellar hemispheres.
  - Venous sinuses form at the bases of the three folds.

Arachnoid Mater; Subdural Space

- Thin, wispy layer
- Subdural space: between dura and arachnoid; only a small amount of serous fluid within
Pia Mater and Subarachnoid Space

- **Pia mater**: thin, delicate C.T. membrane closely adhered to brain; follows external contours.
- **Subarachnoid space**: contains web-like strands of arachnoid, blood vessels, and cerebrospinal fluid.

Ventricles

- **Lateral ventricles**: within cerebral hemispheres; separated by septa pellucida
- **Third ventricle**: within diencephalon
- **Interventricular foramina**: join lateral ventricles with third
- **Fourth ventricle**: associated with pons and medulla oblongata. Connected to third ventricle by the **cerebral aqueduct**, continuous with the spinal cord, and connected to the subarachnoid space by the **lateral and medial apertures**
Cerebrospinal Fluid (CSF)

- Similar to serum, but most protein removed
- Bathes brain and spinal cord
- Protective cushion around CNS
- Choroid plexuses produce CSF which fills ventricles and other parts of brain and spinal cord
  - Composed of ependymal cells, their support tissue, and associated blood vessels
  - Blood-cerebrospinal fluid barrier
    - Endothelial cells of capillaries attached by tight junctions
    - Substances do not pass between cells
    - Substances must pass through cells
    - Makes the barrier very selective

Flow of CSF
Brain Blood Supply

• Brain
  – Requires a tremendous amount of blood
  – Receives 15-20% of blood pumped by heart
  – Interruption can cause unconsciousness and irreversible brain damage
  – High metabolic rate; dependent upon constant supply of oxygen and glucose
  – Receives blood through arteries: internal carotids and vertebral arteries. The vertebral arteries join to form the basilar artery. Carotids plus basilar form the cerebral arterial circle (Circle of Willis).

• Blood-brain barrier
  – Capillary endothelial cells along with astrocytes and basement membrane
  – To be considered when developing drugs

Arteries of the Brain
Blood-Brain Barrier

- Endothelial cells (lining all capillaries) have tight junctions between them.
- Astrocytes have foot processes that influence capillary permeability.
- Basement membrane of endothelium.
- These three taken together:
  - Lipid-soluble substances pass through by diffusion: nicotine, ethanol, heroin
  - Water soluble substances move through by mediated transport: amino acids, glucose.

Cranial Nerves

- Indicated by
  - Roman numerals I-XII from anterior to posterior
  - Names
- May have one or more of three functions
  - Sensory (special or general)
  - Somatic motor: control of skeletal muscles
  - Parasympathetic (regulation of glands, smooth muscles, cardiac muscle)
### Table 13.4 Functional Organization of the Cranial Nerves

<table>
<thead>
<tr>
<th>Nerve Function</th>
<th>Cranial Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>I  Olfactory</td>
</tr>
<tr>
<td></td>
<td>II  Optic</td>
</tr>
<tr>
<td></td>
<td>VIII  Vestibulocochlear</td>
</tr>
<tr>
<td>Somatic motor and sensory</td>
<td>IV  Trochlear</td>
</tr>
<tr>
<td></td>
<td>VI  Abducent</td>
</tr>
<tr>
<td></td>
<td>XI  Accessory</td>
</tr>
<tr>
<td></td>
<td>XII  Hypoglossal</td>
</tr>
<tr>
<td>Somatic motor and parasympathetic</td>
<td>V  Trigeminal</td>
</tr>
<tr>
<td>Somatic motor, sensory, and parasympathetic</td>
<td>III  Oculomotor</td>
</tr>
<tr>
<td></td>
<td>VII  Facial</td>
</tr>
<tr>
<td></td>
<td>IX  Glossopharyngeal</td>
</tr>
<tr>
<td></td>
<td>X  Vagus</td>
</tr>
</tbody>
</table>

### Table 13.5 Cranial Nerves and Their Functions

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I  Olfactory</td>
<td>Cribriform plate</td>
<td>Sensory, special sense of smell</td>
</tr>
</tbody>
</table>

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### Table 13.5 Cranial Nerves and Their Functions

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. Optic</td>
<td>Optic foramen</td>
<td>Sensory</td>
</tr>
<tr>
<td></td>
<td>Eyeball</td>
<td>Special sense of vision</td>
</tr>
</tbody>
</table>

![Brain Diagram]

**Notes:**
*Motor and parasympathetic.

Motor to eye muscles (superior, medial, and inferior rectus; inferior oblique and upper eyelid (levator palpebrae superioris)).

Proprioception from those muscles.

Parasympathetic to the sphincter of the pupil (causing constriction) and the ciliary muscle of the lens (causing accommodation).

*Note: All nerves exit through the skull.

*Proprioception is a sensory function, not a motor function; however, motor nerves to muscles also contain some proprioceptive fibers.

Note these muscles. Because proprioception in the eye sensory information carried by some cranial nerves, these nerves still are considered "motor."
<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI. Abducens (abduces)</td>
<td>Superior orbital fissure</td>
<td>Motor to one eye muscle (lateral rectus)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proprioceptive from that muscle</td>
</tr>
</tbody>
</table>

**Table 13.5 continued**

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII. Facial</td>
<td>Internal acoustic meatus, stylomastoid foramen</td>
<td>Sensory, motor, and parasympathetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sense of taste from anterior two-thirds of tongue, sensory for nerve of external ear and palate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor to muscles of facial expression, tensor (posterior belly of digastric, stylohyoid, and mylohyoid muscles)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proprioceptive from these muscles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parasympathetic to salivary and sublingual salivary glands, lacrimal gland, and glands of the nasal cavity and palate</td>
</tr>
</tbody>
</table>

**Diagram**: Arteries and cranial nerves (including labels for facial nerve and major foramina).
<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII: Vestibulocochlear</td>
<td>Internal auditory meatus</td>
<td>Sensory: Special senses of hearing and balance</td>
</tr>
<tr>
<td></td>
<td>Vestibular ganglion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vestibular nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vestibulocochlear nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cochlear nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spiral ganglion of cochlea</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX: Glossopharyngeal</td>
<td>Regular foramen</td>
<td>Sensory, motor, and parasympathetic: Sensory from posterior third of tongue, taste from tongue, palatine tonsil, posterior third of tongue, middle ear, carotid sinus and carotid body, Motor to pharyngeal muscle (stylopharyngeus), Proprioceptive from that muscle, Parasympathetic to parotid salivary gland and the glands of the posterior third of tongue</td>
</tr>
<tr>
<td></td>
<td>Superior and inferior ganglia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To parotid gland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glossopharyngeal nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To stylopharyngeal muscle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To palatine tonsil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To carotid body and carotid sinus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To posterior third of tongue for taste and general sensation</td>
<td></td>
</tr>
</tbody>
</table>
Table 13.5 continued

<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Foramen or Fissure*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>XI: Accessory</td>
<td>Accessory foramen</td>
<td>Motor to sternocleidomastoid and trapezius</td>
</tr>
<tr>
<td></td>
<td>Sternohyoid foramen</td>
<td>Motor to sternocleidomastoid and trapezius</td>
</tr>
<tr>
<td></td>
<td>Spinal roots of accessory nerve</td>
<td>Accessory nerve</td>
</tr>
</tbody>
</table>

* Foramen or fissure names may vary depending on the region of the body.

Sensory, motor, and parasympathetic
- Sensory from inferior pharynx, larynx, thoracic and abdominal organs, sense of taste from posterior tongue
- Motor to soft palate, pharynx, intrinsic laryngeal muscles (voice production), and all extrinsic tongue muscle (salivation/tongue) 
- Parasympathetic to thoracic and abdominal viscera
Cranial Nerve Reflexes

- **X (Vagus):** reflexes having to do with heart rate, blood pressure, and respiration
- **Reflexes involving both cranial nerves and brainstem:**
  - Turning the eyes toward sudden noise, touch on skin, flash of light
  - Eyes tracking a moving object.
  - Reflex using VIII, V, and VII to contract muscles associated with middle ear that protect ear ossicles
  - Chewing reactions to textures of food, movement of tongue pushing food under tooth-row and out of harm's way