The Central Nervous System

- **Central nervous system**
  - The brain and spinal cord
- Directional terms unique to the CNS
  - **Rostral**—toward the nose
  - **Caudal**—toward the tail

The Spinal Cord

- Figure 13.1a: The spinal cord and its nerve roots, with the bony vertebral arches removed. The dura mater and arachnoid mater are cut open and reflected laterally.
Anatomy of the Spinal Cord

Figure 13.3a

Protection of the Spinal Cord

- Protected by vertebrae, meninges, and CSF
- Meninges
  - Dura mater—a single layer surrounding spinal cord
  - Arachnoid mater—lies deep to the dura mater
  - Pia mater—innermost layer
    - Delicate layer of connective tissue
    - Extends to the coccyx
  - Denticulate ligaments—lateral extensions of pia mater

Anatomy of the Spinal Cord

Figure 13.3b
The Brain

- Performs the most complex neural functions
  - Intelligence
  - Consciousness
  - Memory
  - Sensory-motor integration
  - Involved in innervation of the head
- Brain also controls:
  - Heart rate, respiratory rate, blood pressure
  - Autonomic nervous system
  - Endocrine system
Basic Parts and Organization of the Brain

Ventricles of the Brain

The Brain Stem

Midbrain, Pons, Medulla oblongata
The Brain Stem – The Midbrain

- **Corpora quadrigemina** – the largest nuclei
  - Divided into the superior and inferior colliculi
  - **Superior colliculi** – nuclei that act in visual reflexes
  - **Inferior colliculi** – nuclei that act in reflexive response to sound

The Brain Stem – Dorsal View

The Brain Pons

Figure 13.11c

Figure 13.11b
The Brain Stem—The Pons

- Superior cerebellar peduncle
- Fourth ventricle
- Reticular formation
- Trigeminal main sensory nucleus
- Trigeminal motor nucleus
- Middle cerebellar peduncle
- Trigeminal nerve (V)
- Medial lemniscus
- Fibers of pyramidal tract

Figure 13.12b

The Brain Stem—Medulla Oblongata

- Optic tract
- Thalamus
- Hypothalamus
- Midbrain
- Pons
- Olive

Figure 13.11b

The Brain Stem—The Medulla Oblongata

- The core of the medulla contains:
  - Much of the reticular formation
    - Nuclei influence autonomic functions
  - Visceral centers of the reticular formation include:
    - Cardiac center
    - Vasomotor center
    - The medullary respiratory center
    - Centers for hiccupping, sneezing, swallowing, and coughing

16
17
18
The Cerebellum

- Located dorsal to the pons and medulla
  - Smoothes and coordinates body movements
  - Helps maintain equilibrium

The Cerebellum

- [Diagram of the cerebellum with labeled structures]

The Diencephalon

- Composed of three paired structures
  - Thalamus
  - Hypothalamus
  - Epithalamus
  - Primarily composed of gray matter
The Diencephalon and Brainstem

Figure 13.14a

- Corpus callosum
- Choroid plexus
- Thalamus (encloses third ventricle)
- Pineal gland
- Perforating commissures
- Pineal gland
- Corpus quadrigemini
- Cerebral aqueduct
- Arbor vitae (of cerebellum)
- Fourth ventricle
- Choroid plexus
- Cerebellum
- Septum pellucidum
- Interthalamic adhesion (intermediate mass of thalamus)
- Interventricular foramen
- Anterior commissure
- Hypothalamus
- Pituitary gland
- Mammillary body
- Pons
- Medulla oblongata
- Spinal cord
- Cerebral hemisphere
- Midbrain

The Diencephalon—The Thalamus

- Afferent impulses converge on the thalamus
- Synapse in at least one of its nuclei
- Is the “gateway” to the cerebral cortex
- Nuclei organize and amplify or tone down signals

The Thalamus (note nuclei)

(a) The main thalamic nuclei. (The reticular nuclei that “cap” the thalamus laterally are depicted as curving translucent structures.)
The Diencephalon—The Hypothalamus

- The master gland’s master!!
- Functions include the following
  - Control of the ANS
  - Control of emotional responses
  - Regulation of body temperature
  - Regulation of hunger and thirst sensations
  - Control of behavior
  - Regulation of sleep-wake cycles
  - Control of the endocrine system
  - Formation of memory

Nuclei of the Hypothalamus

The Diencephalon—The Epithalamus

- Forms part of the “roof” (top) of the third ventricle
- Consists of a tiny group of nuclei
- Includes the pineal gland (pineal body)
  - Secretes the hormone melatonin
  - Under influence of the hypothalamus
  - Aids in control of circadian rhythm
The Cerebral Hemispheres

(c) Lobes and sulci of the cerebrum

Figure 13.16c

The Cerebral Hemispheres

(d) Location of the insula lobe

Figure 13.16d

Lobes, sulci, and fissures of the cerebral hemispheres.

(a) Superior view

Figure 13.16a
The Cerebral Hemispheres

- Frontal section through forebrain
  - Cerebral cortex
  - Cerebral white matter
  - Deep gray matter of the cerebrum (*basal ganglia*)

The Cerebral Cortex

- **Home of our conscious mind**
- Enables us to:
  - Be aware of ourselves and our sensations
  - Initiate and control voluntary movements
  - Communicate, remember, and understand
- Composed of gray matter
  - Neuronal cell bodies, dendrites, and short axons
- Folds in cortex – triples its size
- Approximately 40% of brain’s mass
- **Brodmann areas** – 52 structurally distinct areas
Functional and Structural Areas of the Cerebral Cortex

- Motor areas
  - Primary motor cortex
  - Premotor cortex
  - Frontal eye field
  - Broca's area (outlined by dashes)

- Prefrontal cortex
  - Working memory
  - Executive area for task management
  - Working memory for object-recall tasks
  - Solving complex, multistep problems

- Frontal eye field

- Prefrontal cortex
  - Processes emotions related to personal and social interactions
  - orbitofrontal cortex

- Olfactory bulbs
- Olfactory tract
- Fornix

- The Cerebral Cortex
  - Three general kinds of functional areas
    - Sensory areas
    - Association areas
    - Motor areas
Sensory Areas—Primary Somatosensory Cortex

- Projection is *contralateral*
  - Cerebral hemispheres
    - Receive sensory input from the *opposite side of the body*
- *Sensory homunculus*
  - A body map of the sensory cortex

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Sensory Areas—Primary Somatosensory Cortex

- *Motor map in precentral gyrus*
- *Sensory map in postcentral gyrus*

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Sensory Areas—Somatosensory Association Cortex

- Lies *posterior* to the primary *somatosensory cortex*
- Integrates different sensory inputs
  - Touch
  - Pressure
- Draws upon stored memories of past sensory experiences
  - You are able to recognize keys or coins in your pocket without looking at them
Sensory Areas – Auditory Areas

- **Auditory association area**
  - Lies posterior to the primary auditory cortex
  - Located within Brodmann area 22
  - Permits evaluation of different sounds
  - Lies in the center of Wernicke’s area
  - Involved in recognizing and understanding speech

Sensory Areas – Gustatory Cortex

- Involved in the conscious awareness of **taste stimuli**
  - Corresponds to Brodmann area 43
  - Located on the “roof” of the lateral sulcus

Sensory Areas – Olfactory Cortex

- Lies on the medial aspect of the cerebrum
- Located in a region called the **piriform lobe**
- Olfactory nerves transmit impulses to the olfactory cortex
  - Provides conscious awareness of smells
Sensory Areas – Olfactory Cortex

- Part of the rhinencephalon – “nose brain”
- Includes – the piriform lobe, olfactory tract, and olfactory bulb
- Connects the brain to the limbic system
  - Explains why smells trigger emotions
- Orbitofrontal cortex
  - Involved with consciously identifying and recalling specific smells

Association Areas

- Make associations between different types of sensory information
- Associate new sensory input with memories of past experiences
- New name for association areas – higher order processing areas

Association Areas – Prefrontal Cortex

- Large region of the frontal lobe anterior to motor areas
- Performs cognitive functions
  - All aspects of thinking and perceiving
  - Remembering and recalling information
  - Also related to mood
  - Has close links to the limbic part of the forebrain
Association Areas – Prefrontal Cortex

- Functional neuroimaging techniques
  - Reveal functions of specific parts of the prefrontal cortex
- Anterior pole of frontal cortex
  - Active in solving the most complex problems

Association Areas – Prefrontal Cortex

- Functional areas located on the medial side of the frontal lobe
  - Regions near the corpus callosum
    - Involved in complex personal and social interactions
    - Involved in “mentalization”

Association Areas – General Interpretation Area

- Function is currently under investigation
- Located at the interface of:
  - The visual, auditory, and somatosensory association areas
- Newer studies show most of this region is involved in the visual processing of spatial relationships
### Association Areas – Language Area

- Surrounds the lateral sulcus in the left cerebral hemisphere
- Five parts have been identified
  - **Broca’s area** – speech production
  - **Wernicke’s area** – speech comprehension
  - **Lateral prefrontal cortex** – conceptual analysis of spoken words

### Motor Areas – Primary Motor Cortex

- **Controls motor functions**
  - Primary motor cortex (somatic motor area)
  - Located in precentral gyrus (Brodmann area 4)
- **Pyramidal cells** – large neurons of primary motor cortex
- **Corticospinal tracts** descend through brainstem and spinal cord
  - Axons signal motor neurons to control skilled movements
  - **Contralateral** – pyramidal axons cross over to opposite side of the brain

### Motor Areas

- **Specific pyramidal cells control specific areas of the body**
  - Face and hand muscles – controlled by many pyramidal cells
- **Motor homunculus** – body map of the motor cortex
- **Somatotopy** – body is represented spatially in many parts of the CNS
Motor Areas

Motor map in precentral gyrus

Figure 13.19

Motor Areas – Premotor Cortex

• Located **anterior to the precentral gyrus**
• **Controls** more complex movements
• Receives processed sensory information
  • Visual, auditory, and general somatic sensory
• **Controls voluntary actions** dependent on sensory feedback
• Involved in the **planning** of movements

Motor Areas – Frontal Eye Field

• Lies anterior to the premotor cortex
  • In Brodmann area 8
• Controls voluntary movement of the eyes
  • Especially when moving eyes to follow a moving target
Motor Areas – Broca’s Area

- Located in left cerebral hemisphere
  - In Brodmann areas 44 and 45
- Manages **speech production**
- Corresponding region in the right cerebral hemisphere
  - Controls emotional overtones to spoken words

Cerebral White Matter

- Different areas of the cerebral cortex communicate:
  - With each other
  - With the brainstem and spinal cord
- Fibers are usually myelinated and bundled into tracts

Cerebral White Matter

- Types of tracts
  - **Commissures** – composed of commissural fibers
    - Allows communication between cerebral hemispheres
    - Corpus callosum – the largest commissure
  - **Association fibers**
    - Connect different parts of the same hemisphere
  - **Projection fibers** – run vertically
    - Descend from the cerebral cortex
    - Ascend to the cortex from lower regions
Deep Gray Matter of the Cerebrum

- Consists of:
  - **Basal ganglia** – involved in motor control
  - Basal forebrain nuclei – associated with memory
  - **Claustrum** – a nucleus of unknown function
  - **Amygdala** – located in cerebrum but is considered part of the limbic system
Basal Ganglia

- Cooperate with the cerebral cortex in controlling movements
- Receive input from many cortical areas
- Evidence shows that they:
  - Start, stop, and regulate intensity of voluntary movements
  - In some way estimate the passage of time
Functional Brain Systems

- Networks of neurons functioning together
  - **The limbic system** – spread widely in the forebrain
  - **The reticular formation** – spans the brain stem

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Functional Brain Systems – The Limbic System

The “emotional brain”
- Cingulate gyrus
  - Allows us to shift between thoughts
  - Interprets pain as unpleasant
- Hippocampal formation
  - Hippocampus and the parahippocampal gyrus
Functional Brain Systems – The Reticular Formation

- Widespread connections
  - Ideal for arousal of the brain as a whole
- Reticular activating system (RAS)
  - Maintains consciousness and alertness
  - Functions in sleep and arousal from sleep

Protection of the Brain

- The brain is protected from injury by
  - The skull
  - Meninges
  - Cerebrospinal fluid
  - Blood-brain barrier
Protection of the Brain—Meninges

- Functions of meninges
  - Cover and protect the CNS
  - Enclose and protect the vessels that supply the CNS
  - Contain the cerebrospinal fluid
  - Between pia and arachnoid mater

The Dura Mater

![Diagram of the Dura Mater]

- Skin of scalp
- Periosteum
- Bone of skull
- Dura mater
- Arachnoid mater
- Pia mater
- Arachnoid villus
- Blinded vessel
- Falx cerebri (in longitudinal fissure only)

The Dura Mater

![Diagram of the Dura Mater: Midsagittal view]

- Superior sagittal sinus
- Subdural space
- Subarachnoid space
- Bone of skull
- Tentorium cerebelli
- Falx cerebri
- Falx cerebelli
- Crista galli of the ethmoid bone
- Pituitary gland

(a) Midsagittal view

Figure 13.26

Figure 13.27a
Protection of the Brain—Cerebrospinal Fluid (CSF)

- Formed in **choroid plexuses** in the brain ventricles
  - Choroid plexus is
    - Located in all four ventricles
    - Composed of **ependymal cells** and capillaries
  - Arises from blood
    - 500 ml/day

Cerebrospinal Fluid

- Fills the hollow cavities of the brain and spinal cord
- Provides a liquid cushion for the spinal cord and brain
- Other functions:
  - Nourishes brain and spinal cord
  - Removes wastes
  - Carries chemical signals between parts of the CNS
Protection of the Brain—Cerebrospinal Fluid (CSF)

- Choroid plexus of each ventricle
- CSF flows through the ventricles and into the subarachnoid space via the median and lateral apertures.
- Some CSF flows through the central canal of the spinal cord.
- CSF is absorbed into the dural venous sinuses via the arachnoid villi.

Protection of the Brain—Blood-Brain Barrier

- Prevents most blood-borne toxins from entering the brain
- Impermeable capillaries
- Not an absolute barrier
- Nutrients such as oxygen pass through
- Allows alcohol, nicotine, and anesthetics through

Ascending (Sensory) Pathways

- Conduct general somatic sensory impulses
- Chains of neurons composed of:
  - First-, second-, and third-order neurons
- Four main ascending pathways
  - Dorsal column pathway
  - Spinothalamic pathway
  - Posterior spinocerebellar pathway
  - Anterior spinocerebellar pathway
Sensory and Motor Pathways

- Most motor pathways:
  - Decussate at some point along their course
  - Consist of a chain of two or three neurons
  - Exhibit somatotopy
    - Tracts arranged according to the body region they supply
- All pathways are paired
  - One of each on each side of the body

Ascending and Descending Pathways