Ch.12 – The CNS

Central Nervous System (CNS)

- CNS – composed of the brain and spinal cord

The Brain

- Composed of wrinkled, pinkish gray tissue
- Surface anatomy includes cerebral hemispheres, cerebellum, and brain stem

Basic Pattern of the Central Nervous System

- Spinal Cord
    - Central cavity surrounded by a gray matter core
    - External to which is white matter composed of myelinated fiber tracts
- Brain
    - Similar to spinal cord but with additional areas of gray matter
    - Cerebellum has gray matter in nuclei
    - Cerebrum has nuclei and additional gray matter in the cortex

Cerebral Hemispheres

- Form the superior part of the brain and make up 83% of its mass
- Contain ridges (gyri) and shallow grooves (sulci)
- Contain deep grooves called fissures
- Are separated by the longitudinal fissure
- Have three basic regions: cortex, white matter, and basal nuclei
- Five lobes: frontal, parietal, temporal, occipital, and insula

Cerebral Cortex

- The cortex – superficial gray matter; accounts for 40% of the mass of the brain
- It enables sensation, communication, memory, understanding, and voluntary movements
- Each hemisphere acts contralaterally (controls the opposite side of the body)
- Hemispheres are not equal in function
- No functional area acts alone; conscious behavior involves the entire cortex

Functional Areas of the Cerebral Cortex

- The three types of functional areas are:
    - Motor areas – control voluntary movement
    - Sensory areas – conscious awareness of sensation
    - Association areas – integrate diverse information

Motor Areas

- Primary (somatic) motor cortex
- Premotor cortex
- Broca's area
- Frontal eye field

Primary Motor Cortex

- Located in the precentral gyrus
- Composed of pyramidal cells whose axons make up the corticospinal tracts
- Allows conscious control of precise, skilled, voluntary movements
- Motor homunculus – caricature of relative amounts of cortical tissue devoted to each motor function

Premotor Cortex

- Located anterior to the precentral gyrus
- Controls learned, repetitious, or patterned motor skills

- Coordinates simultaneous or sequential actions
- Involved in the planning of movements

Broca's Area

- Broca's area
    - Located anterior to the inferior region of the premotor area
    - Present in one hemisphere (usually the left)
    - A motor speech area that directs muscles of the tongue
    - Is active as one prepares to speak

Frontal Eye Field

- Located anterior to the premotor cortex and superior to Broca's area
- Controls voluntary eye movement

Sensory Areas

- Primary somatosensory cortex
- Somatosensory association cortex
- Visual and auditory areas
- Olfactory, gustatory, and vestibular cortices

PrImary Somatosensory Cortex

- Located in the postcentral gyrus, this area:
- Receives information from the skin and skeletal muscles
- Exhibits spatial discrimination
- Somatosensory homunculus – caricature of relative amounts of cortical tissue devoted to each sensory function

Somatosensory Association Cortex

- Located posterior to the primary somatosensory cortex
- Integrates sensory information
- Forms comprehensive understanding of the stimulus
- Determines size, texture, and relationship of parts

Visual Areas

- Primary visual (striate) cortex
    - Seen on the extreme posterior tip of the occipital lobe
    - Most of it is buried in the calcarine sulcus
    - Receives visual information from the retinas
- Visual association area
    - Surrounds the primary visual cortex
    - Interprets visual stimuli (e.g., color, form, and movement)

Auditory Areas

- Primary auditory cortex
    - Located at the superior margin of the temporal lobe
    - Receives information related to pitch, rhythm, and loudness
- Auditory association area
    - Located posterior to the primary auditory cortex
    - Stores memories of sounds and permits perception of sounds
    - Wernicke's area

Association Areas

- Prefrontal cortex
- Language areas
- General (common) interpretation area
- Visceral association area

Prefrontal Cortex

- Located in the anterior portion of the frontal lobe
- Involved with intellect, cognition, recall, and personality
- Necessary for judgment, reasoning, persistence, and conscience
- Closely linked to the limbic system (emotional part of the brain)

Language Areas

- Located in a large area surrounding the left (or language-dominant) lateral sulcus
- Major parts and functions:
    - Wernicke's area – involved in sounding out unfamiliar words
    - Broca's area – speech preparation and production
    - Lateral prefrontal cortex – language comprehension and word analysis
    - Lateral and ventral temporal lobe – coordinate auditory and visual aspects of language

General (Common) Interpretation Area

- Ill-defined region including parts of the temporal, parietal, and occipital lobes
- Found in one hemisphere, usually the left
- Integrates incoming signals into a single thought
- Involved in processing spatial relationships

Visceral Association Area

- Located in the cortex of the insula
- Involved in conscious perception of visceral sensations

Lateralization of Cortical Function

- Lateralization – each hemisphere has abilities not shared with its partner
- Cerebral dominance – designates the hemisphere dominant for language
- Left hemisphere – controls language, math, and logic
- Right hemisphere – controls visual-spatial skills, emotion, and artistic skills

Cerebral White Matter

- Consists of deep myelinated fibers and their tracts
- It is responsible for communication between:
    - The cerebral cortex and lower CNS center, and areas of the cerebrum
- Types include:
    - Commissures – connect corresponding gray areas of the two hemispheres
    - Association fibers – connect different parts of the same hemisphere
    - Projection fibers – enter the hemispheres from lower brain or cord centers

Basal Nuclei

- Masses of gray matter found deep within the cortical white matter
- The corpus striatum is composed of three parts
    - Caudate nucleus
    - Lentiform nucleus – composed of the putamen and the globus pallidus
    - Fibers of internal capsule running between and through caudate and lentiform nuclei

Functions of Basal Nuclei

- Though somewhat elusive, the following are thought to be functions of basal nuclei
  - Influence muscular activity
  - Regulate attention and cognition
  - Regulate intensity of slow or stereotyped movements
  - Inhibit antagonistic and unnecessary movement

Diencephalon

- Central core of the forebrain
- Consists of three paired structures – thalamus, hypothalamus, and epithalamus
- Encloses the third ventricle

Thalamus

- Paired, egg-shaped masses that form the superolateral walls of the third ventricle
- Connected at the midline by the intermediate mass
- Contains four groups of nuclei – anterior, ventral, dorsal, and posterior
- Nuclei project and receive fibers from the cerebral cortex

Thalamic Function

- Afferent impulses from all senses converge and synapse in the thalamus
- Impulses of similar function are sorted out, edited, and relayed as a group
- All inputs ascending to the cerebral cortex pass through the thalamus
- Plays a key role in mediating sensation, motor activities, cortical arousal, learning, and memory

Hypothalamus

- Located below the thalamus, it caps the brainstem and forms the inferolateral walls of the third ventricle
- Mammillary bodies
  - Small, paired nuclei bulging anteriorly from the hypothalamus
  - Relay station for olfactory pathways
- Infundibulum – stalk of the hypothalamus; connects to the pituitary gland
  - Main visceral control center of the body

Hypothalamic Function

- Regulates blood pressure, rate and force of heartbeat, digestive tract motility, rate and depth of breathing, and many other visceral activities
- Is involved with perception of pleasure, fear, and rage
- Controls mechanisms needed to maintain normal body temperature
- Regulates feelings of hunger and satiety
- Regulates sleep and the sleep cycle

Endocrine Functions of the Hypothalamus

- Releasing hormones control secretion of hormones by the anterior pituitary
- The supraoptic and paraventricular nuclei produce ADH and oxytocin

Epithalamus

- Most dorsal portion of the diencephalon; forms roof of the third ventricle
- Pineal gland – extends from the posterior border and secretes melatonin
  - Melatonin – a hormone involved with sleep regulation, sleep-wake cycles, and mood
- Choroid plexus – a structure that secretes cerebral spinal fluid (CSF)

Brain Stem
- Consists of three regions – midbrain, pons, and medulla oblongata
- Similar to spinal cord but contains embedded nuclei
- Controls automatic behaviors necessary for survival
- Provides the pathway for tracts between higher and lower brain centers
- Associated with 10 of the 12 pairs of cranial nerves

Midbrain
- Located between the diencephalon and the pons
- Midbrain structures include:
    - Cerebral peduncles – two bulging structures that contain descending pyramidal motor tracts
    - Cerebral aqueduct – hollow tube that connects the third and fourth ventricles
    - Various nuclei

Midbrain Nuclei
- Nuclei that control cranial nerves III (oculomotor) and IV (trochlear)
- Corpora quadrigemina – four domelike protrusions of the dorsal midbrain
- Superior colliculi – visual reflex centers
- Inferior colliculi – auditory relay centers
- Substantia nigra – functionally linked to basal nuclei
- Red nucleus – largest nucleus of the reticular formation; red nuclei are relay nuclei for some descending motor pathways

Pons
- Bulging brainstem region between the midbrain and the medulla oblongata
- Forms part of the anterior wall of the fourth ventricle
- Fibers of the pons:
    - Connect higher brain centers and the spinal cord
    - Relay impulses between the motor cortex and the cerebellum
- Origin of cranial nerves V (trigeminal), VI (abducens), and VII (facial)
- Contains nuclei of the reticular formation

Medulla Oblongata
- Most inferior part of the brain stem
- Along with the pons, forms the ventral wall of the fourth ventricle
- Contains a choroid plexus on the ventral wall of the fourth ventricle
- Pyramids – two longitudinal ridges formed by corticospinal tracts
- Decussation of the pyramids – crossover points of the corticospinal tracts

Medulla Nuclei
- Inferior olivary nuclei – gray matter that relays sensory information
- Cranial nerves X, XI, and XII are associated with the medulla
- Vestibular nuclear complex – synapses that mediate and maintain equilibrium
- Ascending sensory tract nuclei, including nucleus cuneatus and nucleus gracilis
- Cardiovascular control center – adjusts force and rate of heart contraction
- Respiratory centers – control rate and depth of breathing

The Cerebellum
- Located dorsal to the pons and medulla
- Protrudes under the occipital lobes of the cerebrum
- Makes up 11% of the brain's mass
- Provides precise timing and appropriate patterns of skeletal muscle contraction

- Cerebellar activity occurs subconsciously

Cerebellar Processing

- Cerebellum receives impulses of the intent to initiate voluntary muscle contraction
- Proprioceptors and visual signals "inform" the cerebellum of the body's condition
- Cerebellar cortex calculates the best way to perform a movement
- A "blueprint" of coordinated movement is sent to the cerebral motor cortex
- Plays a role in language and problem solving
- Recognizes and predicts sequences of events

Functional Brain System

- Networks of neurons working together and spanning wide areas of the brain
- The two systems are:
    - Limbic system
    - Reticular formation

Limbic System

- Structures located on the medial aspects of cerebral hemispheres and diencephalon
- Includes the rhinencephalon, amygdala, hypothalamus, and anterior nucleus of the thalamus
- Parts especially important in emotions:
    - Amygdala – deals with anger, danger, and fear responses
    - Cingulate gyrus – plays a role in expressing emotions via gestures, and resolves mental conflict
- Puts emotional responses to odors – e.g., skunks smell bad

Limbic System: Emotion and Cognition

- The limbic system interacts with the prefrontal lobes, therefore:
    - One can react emotionally to conscious understandings
    - One is consciously aware of emotion in one's life
- Hippocampal structures – convert new information into long-term memories

Reticular Formation

- Composed of three broad columns along the length of the brain stem
    - Raphe nuclei
    - Medial (large cell) group
    - Lateral (small cell) group
- Has far-flung axonal connections with hypothalamus, thalamus, cerebellum, and spinal cord

Reticular Formation: RAS and Motor Function

- RAS – reticular activating system
    - Sends impulses to the cerebral cortex to keep it conscious and alert
    - Filters out repetitive and weak stimuli
- Motor function
    - Helps control coarse motor movements
    - Autonomic centers regulate visceral motor functions – e.g., vasomotor, cardiac, and respiratory centers

Protection of the Brain

- The brain is protected by bone, meninges, and cerebrospinal fluid
- Harmful substances are shielded from the brain by the blood-brain barrier

Meninges

- Three connective tissue membranes lie external to the CNS – dura mater, arachnoid mater, and pia mater
- Functions of the meninges
    - Cover and protect the CNS
    - Protect blood vessels and enclose venous sinuses
    - Contain cerebrospinal fluid (CSF)
    - Form partitions within the skull

Dura Mater

- Leathery, strong meninx composed of two fibrous connective tissue layers
- The two layers separate in certain areas and form dural sinuses
- Three dural septa extend inward and limit excessive movement of the brain
- Falx cerebri – fold that dips into the longitudinal fissure
- Falx cerebelli – runs along the vermis of the cerebellum
- Tentorium cerebelli – horizontal dural fold extends into the transverse fissure

Arachnoid Mater

- The middle meninx, which forms a loose brain covering
- It is separated from the dura mater by the subdural space
- Beneath the arachnoid is a wide subarachnoid space filled with CSF and large blood vessels
- Arachnoid villi protrude superiorly and permit CSF to be absorbed into venous blood

Pia Mater

- Deep meninx composed of delicate connective tissue that clings tightly to the brain

Cerebrospinal Fluid (CSF)

- Watery solution similar in composition to blood plasma
- Contains less protein and different ion concentrations than plasma
- Forms a liquid cushion that gives buoyancy to the CNS organs
- Prevents the brain from crushing under its own weight
- Protects the CNS from blows and other trauma
- Nourishes the brain and carries chemical signals throughout it

Choroid Plexuses

- Clusters of capillaries that form tissue fluid filters, which hang from the roof of each ventricle
- Have ion pumps that allow them to alter ion concentrations of the CSF
- Help cleanse CSF by removing wastes

Blood-Brain Barrier

- Protective mechanism that helps maintain a stable environment for the brain
- Bloodborne substances are separated from neurons by:
    - Continuous endothelium of capillary walls
    - Relatively thick basal lamina
    - Bulbous feet of Astrocytes
- Selective barrier that allows nutrients to pass freely
- Is ineffective against substances that can diffuse through plasma membranes
- Absent in some areas (vomiting center and the hypothalamus), allowing these areas to monitor the chemical composition of the blood
- Stress increases the ability of chemicals to pass through the blood-brain barrier

Cerebrovascular Accidents (Strokes)

- Caused when blood circulation to the brain is blocked and brain tissue dies
- Most commonly caused by blockage of a cerebral artery
- Other causes include compression of the brain by hemorrhage or edema, and atherosclerosis
- Transient ischemic attacks (TIAs) – temporary episodes of reversible cerebral ischemia
- Tissue plasminogen activator (TPA) is the only approved treatment for stroke

Degenerative Brain Disorders

- Alzheimer's disease – a progressive degenerative disease of the brain that results in dementia
- Parkinson's disease – degeneration of the dopamine-releasing neurons of the substantia nigra
- Huntington's disease – a fatal hereditary disorder caused by accumulation of the protein huntingtin that leads to degeneration of the basal nuclei