The Central Nervous System Outline

12.1 Folding during development determines the complex structure of the adult brain (pp. 431–435; Figs. 12.1–12.4; Table 12.1)

A. The brain and spinal cord begin as the neural tube, which rapidly differentiates into the CNS. (p. 431)

B. The neural tube develops constrictions that divide the three primary brain vesicles: the prosencephalon (forebrain), which further divides into the telencephalon, and diencephalon; the mesencephalon (midbrain); and rhombencephalon (hindbrain), which gives rise to the metenecephalon and myelencephalon. (p. 431; Fig. 12.1)

C. Since the brain grows more rapidly than the developing skull, the brain forms folds, allowing it to fit inside the space of the skull. (pp. 431–432)

D. Brain Regions and Organization (p. 432; Fig. 12.3)

1. The medical scheme of brain anatomy divides the adult brain into four parts: the cerebral hemispheres, the diencephalon, the brain stem (consisting of the midbrain, pons, and medulla oblongata), and the cerebellum.
2. The gray matter of the CNS consists of short, nonmyelinated neurons and neuron cell bodies, while the white matter consists of myelinated and nonmyelinated axons.
    a. The CNS has a central cavity surrounded by gray matter, with a layer of white matter externally.
    b. The brain stem has additional gray matter nuclei scattered within the white matter.
    c. The cerebral hemispheres and cerebellum have an outer layer of gray matter, called the cortex.

E. Ventricles (p. 432; Fig. 12.4)

1. The ventricles of the brain are continuous with one another and with the central canal of the spinal cord.
    a. The ventricles are lined with ependymal cells and are filled with cerebrospinal fluid.
    b. There are four ventricles in the brain: paired lateral ventricles deep within each cerebral hemisphere, a third ventricle within the diencephalons, and a fourth ventricle within the hindbrain.
    c. There are several openings connecting the ventricles: The third ventricle communicates with the lateral ventricles via two interventricular foramina, the fourth ventricle is connected with the third ventricle through the cerebral aqueduct, and lateral and median apertures connect the fourth ventricle to the subarachnoid space.

12.2 The cerebral hemispheres consist of cortex, white matter, and the basal nuclei (pp. 435–443; Figs. 12.5–12.10; Table 12.1)

A. The cerebral hemispheres form the superior part of the brain and are characterized by ridges and grooves called gyri and sulci. (p. 435; Table 12.1)

1. The cerebral hemispheres are separated along the midline by the longitudinal fissure and are separated from the cerebellum along the transverse cerebral fissure.

2. The five lobes of the cerebral hemispheres separated by specific sulci are frontal, parietal, temporal, occipital, and insula.
    a. The central sulcus separates the frontal and parietal lobes.
    b. The precentral gyrus lies anterior to the central sulcus, while the postcentral gyrus lies posterior to the central sulcus.
    c. The parieto-occipital sulcus separates the parietal lobe from the occipital lobe.
    d. The lateral sulcus separates the temporal lobe from the parietal and frontal lobes.
    e. The insula forms part of the floor of the lateral sulcus and is covered by the temporal, parietal, and frontal lobes.
    f. Each cerebral hemisphere has three regions: the superficial cortex of gray matter, internal white matter, and areas of gray matter deep within the white matter, the basal nuclei.

B. The cerebral cortex is the location of the conscious mind, allowing us to communicate, remember, and understand, and comprises about 40% of the total brain mass. (pp. 435–440; Figs. 12.6–12.8; Table 12.1)
1. The cerebral cortex has three kinds of functional areas: motor areas, sensory areas, and association areas.
2. Each hemisphere has contralateral control over sensory and motor functions, meaning that each hemisphere controls the opposite side of the body.
3. The hemispheres exhibit lateralization of function, meaning that there is specialization of one side of the brain for certain functions.
4. Motor areas of the cortex are found in the posterior part of the frontal lobes and control voluntary movement.
    a. The primary motor cortex allows conscious control of skilled voluntary movement of skeletal muscles.
    b. The premotor cortex is the region controlling learned motor skills.
    c. Broca's area is a motor speech area that controls muscles involved in speech production.
    d. The frontal eye field controls eye movement.
5. There are several sensory areas of the cerebral cortex that occur in the parietal, temporal, and occipital lobes.
    a. The primary somatosensory cortex allows spatial discrimination and the ability to detect the location of stimulation.
    b. The somatosensory association cortex integrates sensory information and produces an understanding of the stimulus being felt.
    c. The primary visual cortex and visual association area allow reception and interpretation of visual stimuli.
    d. The primary auditory cortex and auditory association area allow detection of the properties and contextual recognition of sound.
    e. The vestibular cortex is responsible for conscious awareness of balance.
    f. The olfactory cortex allows detection of odors.
    g. The gustatory cortex allows perception of taste stimuli.
    h. The visceral sensory areas are involved in conscious awareness of visceral sensation.

6. Multimodal association areas are not connected to any specific sensory cortex, but are highly interconnected areas throughout the cerebral cortex.
   a. The anterior association area, or prefrontal cortex, is involved with intellect, cognition, recall, and personality and is closely linked to the limbic system.
   b. The posterior association area aids in recognition of patterns and faces, as well as understanding of written and spoken language, and includes Wernicke's area.
   c. The limbic association area deals with emotion surrounding situations and includes the cingulate gyrus, parahippocampal gyrus, and hippocampus.
7. There is lateralization of cortical functioning, in which each cerebral hemisphere has unique control over abilities not shared by the other half.
   a. Often, the left hemisphere dominates language abilities, math, and logic, and the right hemisphere dominates visual-spatial skills, intuition, emotion, and artistic and musical skills; however, both sides of the brain are involved in all skills.
8. Cerebral white matter is responsible for communication between cerebral areas and the cerebral cortex and lower CNS centers.
   a. Association fibers are tracts of cerebral white matter that run horizontally, connecting different parts of the same hemisphere.
   b. Commissural fibers run horizontally and connect corresponding areas of gray matter in the two hemispheres, allowing the hemispheres to function together as a whole (includes the corpus callosum).
   c. Projection fibers run vertically, and connect the cerebral cortex to the lower brain or cord centers, tying together the rest of the nervous system to the body's receptors and effectors.

C. Basal nuclei consist of a group of subcortical nuclei that have overlapping motor control with the cerebellum that regulate cognition and emotion. (pp. 440–443; Figs. 12.9–12.10)

12.3 The diencephalon includes the thalamus, hypothalamus, and epithalamus (pp. 443–448; Figs. 12.11–12.13; Table 12.1).

A. The thalamus plays a key role in mediating sensation, motor activities, cortical arousal, learning, and memory. (p. 444; Fig. 12.11; Table 12.1)
B. The hypothalamus is the control center of the body, regulating ANS activity, initiating physical responses to emotions, and regulating body temperature, food intake, water balance, thirst, sleep-wake cycles, and endocrine function. (pp. 444–446; Figs. 12.11–12.13; Table 12.1)
C. The epithalamus includes the pineal gland, which secretes melatonin, and regulates the sleep-wake cycle. (p. 446; Figs. 12.11, 12.13; Table 12.1)

12.4 The brain stem consists of the midbrain, pons, and medulla oblongata (pp. 447–450; Figs. 12.14–12.15; Table 12.1).

A. One set of midbrain structures are the cerebral peduncles, which contain pyramidal (corticospinal) motor tracts that descend toward the spinal cord. (p. 447; Fig. 12.14; Table 12.1)
B. Also within the midbrain are the corpora quadrigemina, which control visual and auditory startle behaviors, the substantia nigra, part of the basal nuclei,

and the red nucleus, that act as relays in some of the descending motor pathways controlling limb flexion. (pp. 447–448, Fig. 12.14; Table 12.1)

C. The pons contains fiber tracts that complete conduction pathways between the brain and spinal cord, as well as giving rise to some cranial nerves, and contains some important nuclei, including one that helps control breathing. (p. 448; Figs. 12.14–12.15; Table 12.1)

D. The medulla oblongata is the location of the pyramids, which act as crossover points for corticospinal motor tracts, resulting in the contralateral control of voluntary movements, as well as housing some ascending sensory tracts, and several visceral motor nuclei controlling vital functions such as cardiac and respiratory rate. (pp. 448–450; Figs.12.14–12.15; Table 12.1)

12.5 The cerebellum adjusts motor output, ensuring coordination and balance (pp. 450–452; Fig. 12.16; Table 12.1)

A. The cerebellum processes inputs from several structures and coordinates skeletal muscle contraction to produce smooth movement. (p. 450; Table 12.1)

B. There are two cerebellar hemispheres consisting of three lobes each: (p. 450; Fig. 12.16; Table 12.1)

1. Anterior and posterior lobes coordinate body movements, and the flocculonodular lobes adjust posture to maintain balance.
2. Three paired fiber tracts, the cerebellar peduncles, communicate between the
cerebellum and the brain stem.

C. Cerebellar processing follows a functional scheme in which the frontal cortex communicates the intent to initiate voluntary movement to the cerebellum, the cerebellum collects input concerning balance and tension in muscles and ligaments, and the best way to coordinate muscle activity is relayed back to the cerebral cortex. (pp. 451–452)

D. The cerebellum may also play a role in thinking, language, and emotion. (p. 452)

12.6 Functional brain systems span multiple brain structures (pp. 452–454; Figs. 12.17–12.18; Table 12.1).

A. The limbic system is involved with emotions and is extensively connected throughout the brain, allowing it to integrate and respond to a wide variety of environmental stimuli. (pp. 452–453; Fig. 12.17; Table 12.1)

B. The reticular formation extends through the brain stem, keeping the cortex alert via the reticular activating system and dampening familiar, repetitive, or weak sensory inputs. (pp. 453–454; Fig. 12.18; Table 12.1)

12.7 The interconnected structures of the brain allow higher mental functions (pp. 453–460; Figs. 12.19–12.21)

A. The ability to both speak and understand language is produced through coordination of several brain areas, notably Broca's area and Wernicke's area (pp. 455–456).

B. Memory is the storage and retrieval of information, and there are different kinds of memory: declarative (fact-based), procedural (skills), motor, and emotional. (pp. 456–457; Fig. 12.19)

1. Declarative memory has two stages: short-term memory, and long-term memory.

a. Short-term memory (STM), or working memory, allows the memorization of a few units of information for a short period of time.
b. Long-term memory (LTM) allows the memorization of potentially limitless amounts of information for very long periods.
c. Transfer of information from short-term to long-term memory can be affected by emotional state, rehearsal, association of new information with old, or the automatic formation of memory while concentrating on something else.
d. Memory consolidation involves communication between brain areas, allowing memories to become permanent.

C. Brain Wave Patterns and the EEG (pp. 457–458; Fig. 12.20)
1. Normal brain function results from continuous electrical activity of neurons and can be recorded with an electroencephalogram, or EEG.
2. Patterns of electrical activity are called brain waves and fall into four types:
a. Alpha waves are regular, rhythmic, low-amplitude, synchronous waves that indicate calm wakefulness.
b. Beta waves have a higher frequency than alpha waves and are less regular, usually occurring when the brain is mentally focused.
c. Theta waves are irregular waves that are not common when awake, but may occur when concentrating.
d. Delta waves are high-amplitude waves seen during deep sleep, but indicate brain damage if observed in awake adults.
3. An absence of brain waves defines brain death.

D. Consciousness can be clinically defined on a continuum that measures behavior in response to stimuli and ranges through several stages: alertness, drowsiness or lethargy, stupor, and coma (p. 458).
1. Consciousness involves simultaneous activity of large areas of the cerebral cortex, is superimposed on other types of neural activity, and is totally interconnected throughout the brain.

E. Sleep and Sleep-Wake Cycles (pp. 458–460; Fig. 12.21)
1. Sleep is a state of partial unconsciousness from which a person can be aroused and has two major types that alternate through the sleep cycle: non–rapid eye movement (NREM) and rapid eye movement (REM).
a. Non–rapid eye movement (NREM) sleep has four stages, which are characterized by progressively slower frequency but higher-amplitude EEG waves.
b. After reaching NREM stage 4, an abrupt change in brain waves occurs, indicating the onset of rapid eye movement (REM) sleep.
c. Eyes move rapidly under the eyelids during REM sleep, skeletal muscles are inhibited, and most dreaming occurs during this stage.
2. Sleep patterns are regulated by the hypothalamus, which inhibits, regulates, and then arouses the RAS.
3. NREM sleep is considered restorative, and REM sleep allows the brain to analyze events or eliminate meaningless information.

12.8 The brain is protected by bone, meninges, cerebrospinal fluid, and the blood–brain barrier (pp. 460–464; Figs. 12.22–12.25)

A. Meninges are three connective tissue membranes that cover and protect the CNS, protect blood vessels and enclose venous sinuses, contain cerebrospinal fluid, and partition the brain (pp. 460–461; Figs. 12.22–12.23).
   1. The dura mater is the most durable, outermost covering that extends inward in certain areas to limit movement of the brain within the cranium.
   2. The arachnoid mater is the middle meninx that forms a loose brain covering.
   3. The pia mater is the innermost layer that clings tightly to the brain.

B. Cerebrospinal Fluid (pp. 461–463; Figs. 12.24–12.25)
   1. Cerebrospinal fluid (CSF) is the fluid found within the ventricles of the brain and surrounding the brain and spinal cord.
   2. CSF gives buoyancy to the brain, protects the brain and spinal cord from impact
      damage, and is a delivery medium for nutrients and chemical signals.

C. The blood–brain barrier is a mechanism that helps maintain a protective environment for the brain (pp. 463–464).
   1. Nutrients, essential amino acids, and some electrolytes are allowed to pass into cerebrospinal fluid, but metabolic wastes, proteins, toxins, and drugs are excluded.
   2. Lipid-soluble molecules easily cross the blood–brain barrier.

12.9 Brain injuries and disorders have devastating consequences (pp. 464–466; Fig. 12.26)

A. Traumatic head injuries can lead to brain injuries of varying severity: concussion, contusion, and subdural or subarachnoid hemorrhage. (p. 464)

B. Cerebrovascular accidents (CVAs), or strokes, occur when blood supply to the brain is blocked, resulting in tissue death. (p. 464)

C. Alzheimer's disease is a progressive degenerative disease that ultimately leads to dementia. (pp. 464–465; Fig. 12.26)

D. Parkinson's disease results from deterioration of dopamine-secreting neurons of the substantia nigra and leads to a loss in coordination of movement and a persistent tremor. (p. 465)

E. Huntington's disease is a fatal hereditary disorder that results from deterioration of the basal nuclei and cerebral cortex. (p. 465)

12.10 The spinal cord is a reflex center and conduction pathway (pp. 466–473; Figs. 12.27–12.32; Tables 12.2–12.3)

A. Gross Anatomy and Protection (pp. 466–468; Figs. 12.27–12.28)
   1. The spinal cord extends from the foramen magnum of the skull to the level of the first or second lumbar vertebra and provides a two-way conduction pathway to and from the brain and serves as a major reflex center.
   2. Fibrous extensions of the pia mater anchor the spinal cord to the vertebral column and coccyx, preventing excessive movement of the cord.
   3. The spinal cord has 31 pairs of spinal nerves along its length that define the segments of the cord.
   4. There are cervical and lumbar enlargements for the nerves that serve the limbs and a collection of nerve roots (cauda equina) that travel through the vertebral column to their intervertebral foramina.

B. Spinal Cord Cross-Sectional Anatomy (pp. 468–470; Figs. 12.29–12.31)

1. The ventral median fissure and dorsal median sulcus divide the spinal cord into two halves: A cerebrospinal fluid–filled central canal runs the length of the spinal cord at its center.
2. The gray matter of the cord is at the core; the white matter surrounds it on the outside.
   a. The gray matter resembles a butterfly in cross section: the dorsal horns contain interneurons; the ventral horns consist mostly of cell bodies of somatic motor neurons.
   b. In the thoracic and superior lumbar regions, there are also paired lateral horns that extend laterally between the dorsal and ventral horns, and contain cell bodies of autonomic motor neurons.
3. Ventral roots exit the spinal cord carrying axons of motor neurons, and fuse with dorsal roots entering the spinal cord from peripheral receptors just beyond the spinal cord to form spinal nerves.
4. The white matter of the spinal cord allows communication between the cord and brain.

C. Spinal Cord Trauma and Disorders (pp. 470–471)
1. Any localized damage to the spinal cord or its roots leads to paralysis (loss of motor function) or paresthesias (loss of sensory function).
   a. Severe damage to the ventral root or ventral horn results in flaccid paralysis, since nerve impulses are not transmitted to the skeletal muscles.
   b. When upper motor neurons of the primary motor cortex are damaged, spastic paralysis occurs, in which voluntary control over skeletal muscle is lost.
   c. If damage to the spinal cord occurs between T_1 and L_1, lower limbs are affected, resulting in paraplesia, but if the damage occurs in the cervical region, all four limbs are affected, resulting in quadriplegia.
2. Poliomyelitis results from destruction of ventral horn motor neurons by the poliovirus.
3. Amyotrophic lateral sclerosis (ALS), or Lou Gehrig's disease, is a neuromuscular condition that involves progressive destruction of ventral horn motor neurons and fibers of the pyramidal tracts.

12.11 Neuronal pathways carry sensory and motor information to and from the brain (pp. 472–476; Figs. 12.32–12.33; Tables 12.2–12.3)

A. All major spinal tracts are part of paired multineuron pathways that mostly cross from one side to the other, consist of a chain of two or three neurons, and exhibit somatotopy. (p. 472)

B. Ascending pathways conduct sensory impulses upward through a chain of three neurons. (p. 472; Fig. 12.32; Table 12.2))
1. Nonspecific ascending pathways receive input from many different types of sensory receptors, and make multiple synapses in the brain.
2. Specific ascending pathways mediate precise input from a single type of sensory receptor.
3. Spinocerebellar tracts convey information about muscle and tendon stretch to the cerebellum.

C. Descending pathways involve two neurons: upper motor neurons and lower motor neurons. (p. 472–473; Fig. 12.33; Table 12.3)

1. The direct, or pyramidal, system regulates fast, finely controlled or skilled movements.
2. The indirect, or extrapyramidal, system regulates muscles that maintain posture and balance and control coarse limb movements and head, neck, and eye movements involved in tracking visual objects.

Developmental Aspects of the Central Nervous System (pp. 477–479; Figs. 12.34–12.36)

A. Between three and four weeks in embryonic development, the ectoderm thickens and folds, forming the neural tube, which gives rise to the CNS, and neural crest cells, which give rise to some ganglionic neurons. (p. 477; Fig. 12.34)
B. By six weeks into development, each side of the neural tube has formed two clusters that will give rise to interneurons, motor neurons, and white and gray matter of the spinal cord, while neural crest cells residing along side the spinal cord will become sensory neurons. (p. 475; Figs. 12.33–12.34)
C. Gender-specific areas of the brain and spinal cord develop depending on the presence or absence of testosterone. (p. 478)
D. Growth and maturation of the nervous system continue throughout childhood and largely reflect development of myelination, which progresses in a superior-to-inferior direction. (p. 478)
E. Age brings some cognitive decline, but losses are not significant until the seventh decade of life. (p. 478)