Chapter 12 The Central Nervous System

Chapter Outline

Module 12.1 Overview of the Central Nervous System (Figures 12.1, 12.2, 12.3)

A. The **central nervous system (CNS)** includes the_____and _____, and is involved in movement, interpreting sensory information, maintaining homeostasis, and functions relating to the mind.

B. **Overview of CNS Functions**. The functions of the nervous system can be broken down into the following three categories:

1. _____ functions include the stimulation of a muscle cell contraction or a gland secretion. This is a function of the peripheral nervous system (PNS).
2. _____ functions, or detection of sensations within and outside the body. This also is a function of the PNS.
3. _____ functions, including decision-making processes, are an exclusive function of the CNS.

C. **Basic Structure of the Brain and Spinal Cord (Figures 12.1, 12.2)**.

1. The brain is anatomically continuous with the spinal cord. The brain resides in the cranial cavity and controls most of the body's functions.
2. What are the four divisions of the brain? (1)_____, (2) _____, (3)_____, and (4) _____ (Figure 12.1).
3. The cerebrum, the enlarged superior portion of the brain, is divided into left and right cerebral hemispheres. Summarize the responsibilities of the cerebrum: _____

   _____

   _____

   _____
4. The diencephalon, deep underneath the cerebral hemispheres, is the central core of the brain. Summarize the responsibilities of the diencephalon:

   _____

5. The cerebellum, the posterior and inferior portion of the brain, is divided into left and right hemispheres. Summarize the responsibilities of the cerebellum:

6. The brainstem connects the brain to the spinal cord. Summarize the responsibilities of the brainstem: _____

7. The spinal cord, a tubular organ enclosed within the protective vertebral cavity, blends with the inferior portion of the brainstem and ends between the first and second_____vertebrae. The central canal, filled with _____ fluid, is an internal cavity within the spinal cord that is continuous with the brain's ventricles.
8. White matter, found in both the brain and spinal cord, consists of myelinated axons (Figure 12.2). Each lobe of the cerebrum contains bundles of white matter called_____that receive input from and send output to clusters of cell bodies and dendrites in the cerebral gray matter called _____ (Figure 12.2a). Myelinated axons enable near instantaneous communication between locations.
9. Gray matter, found in both the brain and spinal cord, consists of neuron cell bodies, dendrites, and unmyelinated axons.

D. **Overview of CNS Development**. The brain and spinal cord are a tube with an enlarged end that develops in the embryo and fetus **(Figure 12.3)**.

Module 12.2 The Brain (Figures 12.4, 12.5, 12.6, 12.7, 12.8, 12.9, 12.10, 12.11, 12.12, 12.13, 12.14, 12.15, 12.16, 12.17; Table 12.1)

A. **The Cerebrum** is the structure of the brain responsible for higher mental functions **(Figures 12.4, 12.5, 12.6, 12.7, 12.8, 12.9; Table 12.1)**.

1. Gross anatomical features of the cerebrum include **sulci** (grooves), **gyri**, (ridges), and **fissures** (deep grooves) **(Figure 12.4)**.
2. The following five lobes are found in each hemisphere of the cerebrum **(Figure 12.4)**:
    a. The posterior border of the **frontal lobes**, the most anterior lobes, is called the **central sulcus**, which sits just behind the _____ **gyrus**. **What are neurons in these lobes responsible for?**

    _____

    _____

    _____

    b. The **parietal lobes**, just posterior to the frontal lobes, contain the _____ **gyrus**, which is found just posterior to the central sulcus. **What are neurons in these lobes responsible for?**

    _____

    _____

    c. The **temporal lobes** form the lateral surfaces of each cerebral hemisphere and are separated from the parietal and frontal lobes by the _____ fissure. **What are the neurons in these lobes involved in?**_____,_____, _____, and_____.

    d. The **occipital lobes** make up the posterior aspect of each cerebral hemisphere and are separated from the parietal lobe by the parieto-occipital sulcus. **What do the neurons in these lobes process?**

    _____

    e. The **insulas** are found deep underneath the lateral fissures. Neurons in these lobes are currently thought to be involved in functions related to taste and viscera (internal organs).
3. **Gray Matter**: **Cerebral Cortex**. This region is functionally the most complex part of the cortex that covers the underlying cerebral hemispheres. Most of the

cerebral cortex is **neocortex**, the most recently evolved region of the brain **(Figure 12.5)**. The neocortex is divided into the following three areas: (1) the _____, (2)_____, and (3) _____.

a. **What is the function of the primary motor cortex? _____**

b. **What are the functions of the primary sensory cortices at the first regions? _____**

4. **Gray Matter**: **Cerebral Cortex**. **Motor Cortices and Upper Motor Neurons**: most motor areas are located in the_____lobe, which contain upper motor neurons which are interneurons that connect to other neurons not skeletal muscle.
    a. Upper motor neurons of the **primary motor cortex**, involved in conscious planning of movement, are located in the precentral gyrus of the frontal lobe.
    b. Upper motor neurons of each cerebral hemisphere control motor activity of the opposite side of the body via PNS neurons called _____ motor neurons that execute the order to move.
    c. Movement requires input from many motor association areas such as the large **premotor cortex** located anterior to the primary motor cortex.
    d. The **frontal eye fields** are paired motor association areas, one on each side of the brain anterior to the_____cortex, involved in back and forth eye movements.
5. **Gray Matter**: **Cerebral Cortex**, **Sensory Cortices**: The special senses, touch, vision, hearing, smell, and taste, have a primary and a unimodal association as does the sense of equilibrium or balance. These areas are found in all the lobes of the cortex except the_____lobe.

a. **What type of somatic sensory information do the two main somatosensory areas, located in the cerebral cortex, deal with?**

_____

_____

_____

b. **Where is the primary somatosensory area (S1) located?**

_____

_____

Where is the somatosensory association cortex (S2) located?

_____

_____

c. **Where is the primary visual cortex located?** _____

What is the function of the primary visual cortex?

_____

_____

What is the function of the visual association area? _____

_____

_____

d. **Where is the primary auditory cortex located?** _____

What type of information is received by this cortex? _____

Where is this information transferred? _____

_____

_____

e. **Where is taste information processed?** _____

_____

f. **Where are the vestibular areas located?** _____

What information do these areas deal with? _____

_____

_____

g. **Where is smell information processed? _____**
Smell is the only sense that is not processed within the parietal, occipital, and/or temporal lobes.

6. **Gray Matter**: **Cerebral Cortex**. Multimodal Association Areas include the following regions of the cortex that allow us to perform complex mental functions:
   a. **Language areas** are processed in the following two areas of the cortex:_____**area**, found in the anterolateral frontal lobe, is a premotor area responsible for the ability to produce speech sounds; _____ **area** (integrative speech area), located in the temporal and parietal lobes, is responsible for the ability to understand language.
   b. The **prefrontal cortex** occupies most of the frontal lobe and communicates with the_____, other regions of cerebral gray matter, and the association areas located in other lobes. **Summarize the functions of the prefrontal cortex**:
   _____,_____, _____
   _____, and_____.
   c. The **parietal** and **temporal association areas** occupy most of their respective host lobe. **Summarize the functions of these association areas**:_____,_____,
   _____,_____, and
   _____.
7. **Gray Matter**: the **basal nuclei**, found deep within each cerebral hemisphere, contains a cluster of neuron cell bodies involved in movement. The basal nuclei includes the following regions **(Figure 12.6)**:_____,
   _____, and_____.
8. **Cerebral white matter** can be classified as one of the following three types **(Figure 12.7)**:_____fibers,_____fibers, and
   _____ fibers.

9. **Summarize a possible pathway for information transferred by the conduction of an action potential from one region of the brain to another**, shown in **Figure 12.8**: _____

_____

_____

_____

_____

10. **Structures of the Limbic System**: The **limbic system**, an important functional brain system, includes a region of the medial cerebrum called the limbic lobe, the hippocampus, the amygdala, and the pathways that connect each of these regions of gray matter with the rest of the brain. **What is the function of this system?_____**, _____,_____, and_____**(Figure 12.9)**.

B. **The Diencephalon**, found at the physical center of the brain, is composed of the following four components, each with its own nuclei that receive specific input and send output to other brain regions **(Figure 12.10)**:

1. The **thalamus** is the main entry into the cerebral cortex, which consists of two regions of gray matter of the diencephalon. The cavity of the third ventricle is found between these two regions. **(Figure 12.10a, b)**.
2. The **hypothalamus** is a collection of nuclei that sits anterior and inferior to the larger thalamus. Neurons in this region perform vital functions critical to survival including: (1)_____, (2) _____ _____, (3)_____, and (4) _____. The hypothalamus is linked to the _____ gland and secretes releasing and inhibiting_____that affect the function of the pituitary gland.
3. The **epithalamus** is superior to the thalamus but most of its bulk is an endocrine gland called the pineal gland, which secretes the hormone _____. Melatonin is involved in the sleep/wake cycle.
4. The **subthalamus**, inferior to thalamus, is functionally connected with the basal nuclei where together, they control_____.

C. The **cerebellum** makes up the posterior and inferior potion of the brain and is functionally connect with the cerebral cortex, basal nuclei, brainstem, and spinal cord. The interactions between these regions of the brain together coordinate _____ **(Figure 12.11)**.

D. **The Brainstem**, one of the oldest components of the brain, is vital to our immediate survival as its nuclei control many basic homeostatic functions such as heart rate and breathing rhythms **(Figures 12.12, 12.13, 12.14, 12.15)**.

1. The brainstem has three subdivisions: the superior_____, the middle_____, and the inferior_____.
2. The following describes the basic anatomy of the first of the three brainstem subdivision: the **midbrain**, mesencephalon, **(Figure 12.14)**: the midbrain is found inferior to the diencephalon where it surrounds the cerebral aqueduct, which connects the third and fourth ventricles **(Figure 12.14b)**. The midbrain includes the **superior** and **inferior colliculi**, **substantia nigra**, **red nucleus**, and many **cranial nerve nuclei**.
3. The **pons** is inferior to the midbrain. **Summarize the roles of the pons**: ____

   _____
4. The **medulla oblongata** is the most inferior structure of the brainstem, which is continuous with the spinal cord at the foramen magnum **(Figure 12.14c)**. The **pyramids** contain_____motor neuron fibers of the _____ tract (*pyramidal tract*), which **decussate** (crossover) within the pyramids then travel from the cerebral cortex to the spinal cord.
5. The **reticular formation** is a collection of over 100 nuclei found in the central core of the three brainstem subdivisions, making this one of the most complex regions of the brain **(Figure 12.15)**.
   a. Input is received from multiple sources including: (1) _____, (2)_____, and (3) _____.
   b. **What is the function of the central nuclei, located in the center of the reticular formation?** _____

      _____

What is the function of the nuclei surrounding the central nuclei?

_____

_____

Other nuclei are instrumental in the homeostasis of breathing and blood pressure. The lateral nuclei play a role in sensation and in the alertness and activity levels of the cerebral cortex.

Module 12.3 Protection of the Brain (Figures 12.18, 12.19, 12.20, 12.21)

A. The following three features within the protective shell of the skull provide additional shelter for the delicate brain tissue: (1)_____, (2) _____ _____(CSF), and the (3)_____.

B. **The Cranial Meninges** are composed of three protective membrane layers of mostly dense irregular collagenous tissue. The structural arrangement from superficial to deep is as follows:_____,_____, _____,_____,_____, and _____ **(Figure 12.18)**.

1. The *epidural space* is found between the inner surface of the cranial bones and the outer surface of the dura mater. This is only a potential space as the dura is normally tightly bound to the bone only allowing for the passage of blood vessels.
2. The **dura mater** or dura, the outer most superficial meninx, is a tough double-layered membrane is composed mostly of_____fibers with few elastic fibers. **Dural sinuses** are venous channels that drain___and deoxygenated blood from the brain's extensive network of veins.
3. The **subdural space**, filled with_____fluid, is found deep to the dura mater and superficial to the arachnoid mater and houses veins that drain blood from the brain.
4. The **arachnoid mater** is a thin web-like membrane composed of dense irregular collagenous tissue with some degree of elasticity **(Figure 12.14c)**. **Describe the arachnoid granulations**. _____

_____

5. The **subarachnoid space** contains the major blood vessels of the brain and is filled with_____.
6. The **pia mater** is the only meninx in physical contact with the brain tissue.

C. **The Ventricles and Cerebrospinal Fluid**. Four ventricles within the brain are linked cavities that are continuous with the central canal of the spinal cord. The ventricles and central canal are lined with_____cells and filled with _____ fluid **(Figures 12.19, 12.20)**.

1. The **right** and **left lateral ventricles**, considered the first and second ventricles, are found within their respective cerebral hemisphere **(Figure 12.19)**.
2. The **third ventricle** is a narrow cavity found between the two lobes of the diencephalon and is connected to the lateral ventricles by an opening called the_____**foramen**.
3. The **fourth ventricle**, found between the pons and cerebellum, is connected to the third ventricle by a small passageway through the midbrain called the _____ **(Figure 12.19a)**.
4. **Cerebrospinal fluid (CSF)** is a clear, colorless liquid similar in composition to blood plasma that protects the brain in the following ways:
   a. _____
   b. _____
5. **Why are the choroid plexuses significant?** _____

   Where are they located? _____
6. **Summarize the general pathway for the formation**, **circulation**, **and reabsorption of CSF (Figure 12.20)**: _____

D. **The Blood-Brain Barrier** is a protective safeguard that separates CSF and brain ECF from chemicals and disease-causing organisms sometimes found in blood plasma **(Figure 12.21)**. The blood-brain barrier consists mainly of simple squamous epithelial cells (endothelial cells) of the blood capillaries, their basal laminae, and astrocytes.

1. **What makes the barrier unique?** _____ Certain substances can pass through plasma membranes or protein channels or carriers and cross the blood-brain barrier.
2. **What is effectively prevented from cross the blood-brain barrier in any significant amount?** _____

Module 12.4 The Spinal Cord (Figures 12.22, 12.23, 12.24, 12.25)

A. The **spinal cord** is composed primarily of nervous tissue and is responsible for both relaying and processing information.

B. **Protection of the Spinal Cord**. The brain's meninges pass through the foramen magnum to provide a continuous protective covering of the spinal cord and the distal nerves at its base **(Figure 12.22)**.

1. The three **spinal meninges** include the_____mater,_____, and_____mater and are structurally similar to the brain meninges.
   What makes the spinal meninges different? _____ _____ **(Figure 12.22a)**
2. The actual or potential spaces between the spinal cord meninges are the same those found between the cranial meninges with the following features from superficial to deep **(Figure 12.22b)**:_____**space**, _____ **space**, **and**_____**space**.

C. **External Spinal Cord Anatomy**. The spinal cord extends proximally from the foramen magnum to the region between the first and second lumbar vertebrae. The following structural features can be seen on the spinal cord **(Figure 12.23)**: **posterior median sulcus**, **anterior median sulcus**, **conus medullaris**, and the **filum terminale**. **Nerve roots** that project from the spinal cord fuse together to form the spinal nerves, which carry sensory and motor impulses to and from the spinal cord.

D. **Internal Spinal Cord Anatomy**. The butterfly-shaped spinal gray matter is surrounded by tracts of white matter. The following features are seen on the cross-section of the spinal cord **(Figures 12.24, 12.25)**:

1. The **central canal**, filled with CSF and seen in the middle of the spinal cord, and is surrounded by the gray commissure.
2. Spinal gray matter makes up three distinct regions found within the spinal cord that houses neurons with specific functions and include the following **(Figure 12.24)**:
    a. The **anterior horn** (or *ventral horn*) makes up the anterior wing of gray matter and gives rise to the anterior of_____nerve roots. The neuron cell bodies found in this region are involved in somatic _____ functions, for example skeletal muscle contraction.
    b. The **posterior horn** (or dorsal horn) makes up the posterior wing of gray matter and gives rise to the posterior or_____nerve roots. The neuron cell bodies found in this region are involved in processing both incoming somatic and visceral_____information.
    c. The **lateral horn**, found only in the spinal cord between the first thoracic vertebra and the lumbar region, contains the cell bodies of neurons involved in control of the viscera via the _____ nervous system.
3. **Spinal White Matter**: **Ascending and Descending Tracts**. The white matter contains the axons of neurons that travel to and from brain, which allows the spinal cord to fulfill one of its primary functions as a relay station. White matter is organized into a general region called a_____. The

posterior funiculus, the **lateral funiculus**, and the **anterior funiculus** lie on each side of the spinal cord **(Figure 12.25)**.

4. **Ascending tracts** carry various kinds of_____information and include the major tracts such as the medial fasciculus gracilis and lateral fasciculus cuneatus in the **posterior columns**, the **spinocerebellar tracts**, and the spinothalamic tracts of the **anterolateral system (Figure 12.25a)**.
5. **Descending tracts** transmit_____information from specific regions in the brain down the spinal cord to specific regions in the body **(Figure 12.25b)**.

Module 12.5 Sensation Part I: Role of the CNS in Sensation (Figures 12.26, 12.27, 12.28)

A. Sensory stimuli are those effects that cause the senses to respond. Multiple sensory stimuli from different regions of the brain can be pulled together into a single mental picture.
   1. When the CNS has received all the different sensory inputs from various parts of the brain, it integrates them into a single **perception**. **What is perception?**

      _____
   2. Sensations can be grouped into: (1) _____ senses or (2) _____ senses.

B. **General somatic senses** pertain to_____,_____, _____,_____, and_____**(Figures 12.26, 12.27, 12.28)**.
   1. **Tactile senses** pertain to fine or discrimination touch, and include vibration, two-point discrimination, and light touch while **nondiscriminative touch** or crude touch lacks the fine spatial resolution of the tactile senses.
   2. **Sensory Pathways through the Spinal Cord to the Brain**. Two major ascending tracts in the spinal cord carry somatic sensory information to the brain: (1)_____and (2) _____. The basic pathway consists of the following:

a. A_____**-order neuron** detects the initial stimulus in the PNS. The axon of this neuron then synapses on a second-order neuron.
b. The_____**-order neuron**, an interneuron located in the posterior horn of the spinal cord or brainstem, then relays the stimulus to a third-order neuron.
c. The_____**-order neuron**, is an interneuron found in the thalamus, delivers the impulse to the cerebral cortex.

3. **Posterior columns/medial lemnsical system** includes axons of neurons that transmit tactile information about discriminative touch and axons that convey information regarding_____**(Figure 12.26)**.
4. **Anterolateral system** fibers transmit_____,_____, and nondiscriminative touch stimuli in the anterolateral spinal cord **(Figure 12.27)**.
5. **Role of the Cerebral Cortex in Sensation**, **S1**, **and somatotopy**: The thalamus relays most incoming information to the primary somatosensory cortex, or S1, in the postcentral gyrus, where each part of the body is represented by a specific region of S1, a type of organization called _____ **(Figure 12.28)**.
6. **Role of the Cerebral Cortex in Sensation**, **Processing of Touch Stimuli**: Thalamic nuclei relay touch information from the ____ tracts and posterior columns primarily to S1for conscious perception.
7. **Role of the Cerebral Cortex in Sensation**, **Processing of Pain Stimuli**: The perception of pain stimuli is called_____.

C. **Introduction to the Special Senses**. The special senses include vision, hearing (_____), taste (_____), smell (_____), and balance (_____sensation). Each special sense involves neurons that detect a stimulus and sends it to the CNS for processing and integration. The thalamus is the gateway for entry of special sensory stimuli into the cerebral cortex, which interprets the majority of this information._____is the exception to this rule.

Module 12.6 Movement Part I: Role of the CNS in Voluntary Movement (Figures 12.29, 12.30, 12.31, 12.32, 12.33)

A. Planning and coordination of voluntary movement are carried out within the CNS, and involve the motor area of the cerebral cortex, the basal nuclei, the cerebellum, and the spinal cord. The following three types of neurons are directly involved in eliciting a muscle contraction: (1)_____, (2) _____ _____, and (3)_____.

B. **Motor Pathways from the Brain through the Spinal Cord**. Axons from the cortical motor areas unite to form several white matter tracts. The largest of these tracts are the right and left corticospinal tracts and the corticonuclear tracts **(Figure 12.29)**.

C. **Role of the Brain in Voluntary Movement (Figures 12.30, 12.31, 12.32)**.

1. Even simple movements require the simultaneous firing of countless neurons as part of a selected group of actions called a **motor program**.
2. **Generalize the role of the cerebral cortex in voluntary movement**. _____

   _____

   _____
3. **Generalize the structures and role of the basal nuclei in voluntary movement**. _____

   _____

   _____ (**Figure 12.31)**
4. **Generalize the role of the cerebellum in voluntary movement**. _____

   _____

   _____

   _____ **(Figure 12.32)**

Module 12.7 Homeostasis Part I: Role of the CNS in Maintenance of Homeostasis (Figures 12.34, 12.35)

A. **Homeostasis** is defined as the maintenance of a relatively stable internal environment in the face of ever-changing conditions. Homeostatic functions include maintaining fluid, electrolyte, and acid-base balance; blood pressure; blood glucose and oxygen concentrations; biological rhythms; and body

temperature. **What are the main two systems dedicated to maintaining homeostasis?** _____

These systems work together but each has its own mechanisms for performing vital homeostatic regulation. **What two structures of the CNS are concerned directly with the maintenance of homeostasis?** _____

_____

B. **Homeostasis of Vital Functions**. Homeostasis of vital functions including heart pumping, blood pressure, and digestion is largely controlled by the **autonomic nervous system (ANS)**; a branch of the PNS that regulates the function of the body's viscera.

C. **Body Temperature and Feeding**. The hypothalamus regulates both body temperature and feeding behaviors.

D. **Sleep and Wakefulness (Figures 12.34, 12.35)**.

1. **What is sleep?** _____

_____

2. **Circadian Rhythms and the Biological "Clock"**: Human sleep follows a **circadian rhythm** where we spend a period of the cycle awake and the remainder asleep. This rhythm is controlled by the_____, which causes changes in the level of wakefulness in response to day and night cycles **(Figure 12.34)**.
3. **Brain Waves and Stages of Sleep**. The different stages of sleep can be monitored using an **electroencephalogram**, or **EEG**, which measure the electrical activity of the brain using electrodes attached to the skin **(Figure 12.35)**.

Module 12.8 Higher Mental Functions (Figures 12.36, 12.37)

A. **Cognition and Language (Figure 12.36)**.

1. **Cognition** is composed of association areas in the cerebral cortex that perform a diverse group of tasks collectively. **List some cognitive functions**. _____

_____

_____

_____

Cognitive processes are responsible for social and moral behavior, intelligence, thoughts, problem-solving skills, language, and personality.

2. **Localization of Cognitive Function**. The following areas and their functions are involved in cognition: (1)_____, (2) _____, and (3) _____.
3. **Cerebral lateralization** refers to the fact phenomenon in which many cognitive functions are unequally represented in the right and left hemispheres.
4. **Define language**. _____

_____

_____

Multiple brain regions are required for communication but the _____ area and _____ area are two critical multimodal association areas **(Figure 12.36)**.

B. **Learning and Memory**. We learn when our nervous system acquires new information that is observable as some sort of behavioral change **(Figure 12.37)**. **Memory** occurs when learned information is encoded and stored in our neural circuitry and is retrievable at will. The following are two basic types of memory are classified by the length of time in which they are stored: _____ **memory** and _____ **memory**.

C. **Emotion** involves responses mediated by the hypothalamus and the limbic system, particularly the_____.