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NERVOUS SYSTEM

The nervous system consists of the brain, spinal cord, sensory organs, and all of the nerves that connect these organs with the rest of the body. Together, these organs are responsible for the control of the body and communication among its parts. The brain and spinal cord form the control center known as the central nervous system (CNS), where information is evaluated and decisions made. The sensory nerves and sense organs of the peripheral nervous system (PNS) monitor conditions inside and outside of the body and send this information to the CNS. Efferent nerves in the PNS carry signals from the control center to the muscles, glands, and organs to regulate their functions.

Nervous System Anatomy

Nervous Tissue

The majority of the nervous system is tissue made up of two classes of cells: neurons and neuroglia.

Neurons: Neurons, also known as nerve cells, communicate within the body by transmitting electrochemical signals. Neurons look quite different from other cells in the body due to the many long cellular processes that extend from their central cell body. The cell body is the roughly round part of a neuron that contains the nucleus, mitochondria, and most of the cellular organelles. Small tree-like structures called dendrites extend from the cell body to pick up stimuli from the environment, other neurons, or sensory receptor cells. Long transmitting processes called axons extend from the cell body to send signals onward to other neurons or effector cells in the body.

There are 3 basic classes of neurons: afferent neurons, efferent neurons, and interneurons.

Afferent neurons: Also known as sensory neurons, afferent neurons transmit sensory signals to the central nervous system from receptors in the body.

Efferent neurons: Also known as motor neurons, efferent neurons transmit signals from the central nervous system to effectors in the body such as muscles and glands.

Interneurons: Interneurons form complex networks within the central nervous system to integrate the information received from afferent neurons and to direct the function of the body through efferent neurons.

Neuroglia: Neuroglia, also known as glial cells, act as the “helper” cells of the nervous system. Each neuron in the body is surrounded by anywhere from 6 to 60 neuroglia that protect, feed, and insulate the neuron. Because neurons are extremely specialized cells that are essential to body function and almost never reproduce, neuroglia are vital to maintaining a functional nervous system.

Brain

The brain, a soft, wrinkled organ that weighs about 3 pounds, is located inside the cranial cavity, where the bones of the skull surround and protect it. The approximately 100 billion neurons of the brain form the main control center of the body. The brain and spinal cord together form the central nervous system (CNS), where information is processed and responses originate. The brain, the seat of higher mental functions such as consciousness, memory, planning, and voluntary actions, also controls lower body functions such as the maintenance of respiration, heart rate, blood pressure, and digestion.

Spinal Cord

The spinal cord is a long, thin mass of bundled neurons that carries information through the vertebral cavity of the spine beginning at the medulla oblongata of the brain on its superior end and continuing inferiorly to the lumbar region of the spine. In the lumbar region, the spinal cord separates into a bundle of individual nerves called the cauda equina (due to its resemblance to a horse’s tail) that continues inferiorly to the sacrum and coccyx. The white matter of the spinal cord functions as the main conduit of nerve signals to the body from the brain. The grey matter of the spinal cord integrates reflexes to stimuli.

Nerves

Nerves are bundles of axons in the peripheral nervous system (PNS) that act as information highways to carry signals between the brain and spinal cord and the rest of the body. Each axon is wrapped in a connective tissue sheath called the endo-neurium. Individual axons of the nerve are bundled into groups of axons called fascicles, wrapped in a sheath of connective tissue called the perineurium. Finally, many fascicles are wrapped together in another layer of connective tissue called the epineurium to form a whole nerve. The wrapping of nerves with connective tissue helps to protect the axons and to increase the speed of their communication within the body.

Afferent, Efferent, and Mixed Nerves: Some of the nerves in the body are specialized for carrying information in only one direction, similar to a one-way street. Nerves that carry information from sensory receptors to the central nervous system only are called afferent nerves. Other neurons, known as efferent nerves, carry signals only from the central nervous system to effectors such as muscles and glands. Finally, some nerves are mixed nerves that contain both afferent and efferent axons. Mixed nerves function like 2-way streets where afferent axons act as lanes heading toward the central nervous system and efferent axons act as lanes heading away from the central nervous system.

Cranial Nerves: Extending from the inferior side of the brain are 12 pairs of cranial nerves. Each cranial nerve pair is identified by a Roman numeral 1 to 12 based upon its location along the anterior-posterior axis of the brain. Each nerve also has a descriptive name (e.g. olfactory, optic, etc.) that identifies its function or location. The cranial nerves provide a direct connection to the brain for the special sense organs, muscles of the head, neck, and shoulders, the heart, and the GI tract.

Spinal Nerves: Extending from the left and right sides of the spinal cord are 31 pairs of spinal nerves. The spinal nerves are mixed nerves that carry both sensory and motor signals between the spinal cord and specific regions of the body. The 31 spinal nerves are split into 5 groups named for the 5 regions of the vertebral column. Thus, there are 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, 5 pairs of sacral nerves, and 1 pair of coccygeal nerves. Each spinal nerve exits from the spinal cord through the intervertebral foramen between a pair of vertebrae or between the C1 vertebra and the occipital bone of the skull.

Meninges

The meninges are the protective coverings of the central nervous system (CNS). They consist of three layers: the dura mater, arachnoid mater, and pia mater.

Dura mater: The dura mater, which means “tough mother,” is the thickest, toughest, and most superficial layer of meninges. Made of dense irregular connective tissue, it contains many tough collagen fibers and blood vessels. Dura mater protects the CNS from external damage, contains the cerebrospinal fluid that surrounds the CNS, and provides blood to the nervous tissue of the CNS.

Arachnoid mater: The arachnoid mater, which means “spider-like mother,” is much thinner and more delicate than the dura mater. It lines the inside of the dura mater and contains many thin fibers that connect it to the underlying pia mater. These fibers cross a fluid-filled space called the subarachnoid space between the arachnoid mater and the pia mater.

Pia mater: The pia mater, which means “tender mother,” is a thin and delicate layer of tissue that rests on the outside of the brain and spinal cord. Containing many blood vessels that feed the nervous tissue of the CNS, the pia mater penetrates into the valleys of the sulci and fissures of the brain as it covers the entire surface of the CNS.

Cerebrospinal Fluid(CSF)

The space surrounding the organs of the CNS is filled with a clear fluid known as cerebrospinal fluid (CSF). CSF is formed from blood plasma by special structures called choroid plexuses. The choroid plexuses contain many capillaries lined with epithelial tissue that filters blood plasma and allows the filtered fluid to enter the space around the brain.

Newly created CSF flows through the inside of the brain in hollow spaces called ventricles and through a small cavity in the middle of the spinal cord called the central canal. CSF also flows through the subarachnoid space around the outside of the brain and spinal cord. CSF is constantly produced at the choroid plexuses and is reabsorbed into the bloodstream at structures called arachnoid villi.

Cerebrospinal fluid provides several vital functions to the central nervous system:

CSF absorbs shocks between the brain and skull and between the spinal cord and vertebrae. This shock absorption protects the CNS from blows or sudden changes in velocity, such as during a car accident.

The brain and spinal cord float within the CSF, reducing their apparent weight through buoyancy. The brain is a very large but soft organ that requires a high volume of blood to function effectively. The reduced weight in cerebrospinal fluid allows the blood vessels of the brain to remain open and helps protect the nervous tissue from becoming crushed under its own weight.

CSF helps to maintain chemical homeostasis within the central nervous system. It contains ions, nutrients, oxygen, and albumins that support the chemical and osmotic balance of nervous tissue. CSF also removes waste products that form as byproducts of cellular metabolism within nervous tissue.

Sense Organs

All of the bodies' many sense organs are components of the nervous system. What are known as the special senses—vision, taste, smell, hearing, and balance—are all detected by specialized organs such as the eyes, taste buds, and olfactory epithelium. Sensory receptors for the general senses like touch, temperature, and pain are found throughout most of the body. All of the sensory receptors of the body are connected to afferent neurons that carry their sensory information to the CNS to be processed and integrated.

Nervous System Physiology

Functions of the Nervous System

The nervous system has 3 main functions: sensory, integration, and motor.

Sensory: The sensory function of the nervous system involves collecting information from sensory receptors that monitor the body's internal and external conditions. These signals are then passed on to the central nervous system (CNS) for further processing by afferent neurons (and nerves).

Integration: The process of integration is the processing of the many sensory signals that are passed into the CNS at any given time. These signals are evaluated, compared, used for decision making, discarded or committed to memory as deemed appropriate. Integration takes place in the gray matter of the brain and spinal cord and is performed by interneurons. Many interneurons work together to form complex networks that provide this processing power.

Motor: Once the networks of interneurons in the CNS evaluate sensory information and decide on an action, they stimulate efferent neurons. Efferent neurons (also called motor neurons) carry signals from the gray matter of the CNS through the nerves of the peripheral nervous system to effector cells. The effector may be smooth, cardiac, or skeletal muscle tissue or glandular tissue. The effector then releases a hormone or moves a part of the body to respond to the stimulus.

Divisions of the Nervous System

Central Nervous System

The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control center of the body by providing its processing, memory, and regulation systems. The CNS takes in all of the conscious and subconscious sensory information from the body's sensory receptors to stay aware of the body's internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body's homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.

Peripheral Nervous System

The peripheral nervous system (PNS) includes all of the parts of the nervous system outside of the brain and spinal cord. These parts include all of the cranial and spinal nerves, ganglia, and sensory receptors.

Somatic Nervous System

The somatic nervous system (SNS) is a division of the PNS that includes all of the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.

Autonomic Nervous System

The autonomic nervous system (ANS) is a division of the PNS that includes all of the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue.

There are 2 divisions of the autonomic nervous system in the body: the sympathetic and parasympathetic divisions.

Sympathetic: The sympathetic division forms the body's "fight or flight" response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.

Parasympathetic: The parasympathetic division forms the body's "rest and digest" response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

Enteric Nervous System

The enteric nervous system (ENS) is the division of the ANS that is responsible for regulating digestion and the function of the digestive organs. The ENS receives signals from the central nervous system through both the sympathetic and parasympathetic divisions of the autonomic nervous system to help regulate its functions. However, the ENS mostly works independently of the CNS and continues to function without any outside input. For this reason, the ENS is often called the “brain of the gut” or the body’s “second brain.” The ENS is an immense system—almost as many neurons exist in the ENS as in the spinal cord.

Action Potentials

Neurons function through the generation and propagation of electrochemical signals known as action potentials (APs). An AP is created by the movement of sodium and potassium ions through the membrane of neurons.

Resting Potential: At rest, neurons maintain a concentration of sodium ions outside of the cell and potassium ions inside of the cell. This concentration is maintained by the sodium-potassium pump of the cell membrane which pumps 3 sodium ions out of the cell for every 2 potassium ions that are pumped into the cell. The ion concentration results in a resting electrical potential of -70 millivolts (mV), which means that the inside of the cell has a negative charge compared to its surroundings.

Threshold Potential: If a stimulus permits enough positive ions to enter a region of the cell to cause it to reach -55 mV, that region of the cell will open its voltage-gated sodium channels and allow sodium ions to diffuse into the cell. -55 mV is the threshold potential for neurons as this is the “trigger” voltage that they must reach to cross the threshold into forming an action potential.

Depolarization: Sodium carries a positive charge that causes the cell to become depolarized (positively charged) compared to its normal negative charge. The voltage for depolarization of all neurons is +30 mV. The depolarization of the cell is the AP that is transmitted by the neuron as a nerve signal. The positive ions spread into neighboring regions of the cell, initiating a new AP in those regions as they reach -55 mV. The AP continues to spread down the cell membrane of the neuron until it reaches the end of an axon.

Repolarization: After the depolarization voltage of +30 mV is reached, voltage-gated potassium ion channels open, allowing positive potassium ions to diffuse out of the cell. The loss of potassium along with the pumping of sodium ions back out of the cell through the sodium-potassium pump restores the cell to the -55 mV resting potential. At this point the neuron is ready to start a new action potential.

Synapses

A synapse is the junction between a neuron and another cell. Synapses may form between 2 neurons or between a neuron and an effector cell. There are two types of synapses found in the body: chemical synapses and electrical synapses.

Chemical synapses: At the end of a neuron’s axon is an enlarged region of the axon known as the axon terminal. The axon terminal is separated from the next cell by a small gap known as the synaptic cleft. When an AP reaches the axon terminal, it opens voltage-gated calcium ion channels. Calcium ions cause vesicles containing chemicals known as neurotransmitters (NT) to release their contents by exocytosis into the synaptic cleft. The NT molecules cross the synaptic cleft and bind to receptor molecules on the cell, forming a synapse with the neuron. These receptor molecules open ion channels that may either stimulate the receptor cell to form a new action potential or may inhibit the cell from forming an action potential when stimulated by another neuron.

Electrical synapses: Electrical synapses are formed when 2 neurons are connected by small holes called gap junctions. The gap junctions allow electric current to pass from one neuron to the other, so that an AP in one cell is passed directly on to the other cell through the synapse.

Myelination

The axons of many neurons are covered by a coating of insulation known as myelin to increase the speed of nerve conduction throughout the body.

Myelin is formed by 2 types of glial cells: Schwann cells in the PNS and oligodendrocytes in the CNS.

In both cases, the glial cells wrap their plasma membrane around the axon many times to form a thick covering of lipids. The development of these myelin sheaths is known as myelination.

Myelination speeds up the movement of APs in the axon by reducing the number of APs that must form for a signal to reach the end of an axon. The myelination process begins speeding up nerve conduction in fetal development and continues into early adulthood.

Myelinated axons appear white due to the presence of lipids and form the white matter of the inner brain and outer spinal cord. White matter is specialized for carrying information quickly through the brain and spinal cord.

The gray matter of the brain and spinal cord are the unmyelinated integration centers where information is processed.

Reflexes

Reflexes are fast, involuntary responses to stimuli. The most well known reflex is the patellar reflex, which is checked when a physicians taps on a patient’s knee during a physical examination. Reflexes are integrated in the gray matter of the spinal cord or in the brain stem. Reflexes allow the body to respond to stimuli very quickly by sending responses to effectors before the nerve signals reach the conscious parts of the brain. This explains why people will often pull their hands away from a hot object before they realize they are in pain.

Functions of the Cranial Nerves

Each of the 12 cranial nerves has a specific function within the nervous system.

The olfactory nerve (I) carries scent information to the brain from the olfactory epithelium in the roof of the nasal cavity.

The optic nerve (II) carries visual information from the eyes to the brain.

Oculomotor, trochlear, and abducens nerves (III, IV, and VI) all work together to allow the brain to control the movement and focus of the eyes. The trigeminal nerve (V) carries sensations from the face and innervates the muscles of mastication.

The facial nerve (VII) innervates the muscles of the face to make facial expressions and carries taste information from the anterior 2/3 of the tongue.

The vestibulocochlear nerve (VIII) conducts auditory and balance information from the ears to the brain.

The glossopharyngeal nerve (IX) carries taste information from the posterior 1/3 of the tongue and assists in swallowing.

The vagus nerve (X), sometimes called the wandering nerve due to the fact that it innervates many different areas, "wanders" through the head, neck, and torso. It carries information about the condition of the vital organs to the brain, delivers motor signals to control speech and delivers parasympathetic signals to many organs.

The accessory nerve (XI) controls the movements of the shoulders and neck.

The hypoglossal nerve (XII) moves the tongue for speech and swallowing.

Sensory Physiology

All sensory receptors can be classified by their structure and by the type of stimulus that they detect. Structurally, there are 3 classes of sensory receptors: free nerve endings, encapsulated nerve endings, and specialized cells. Free nerve endings are simply free dendrites at the end of a neuron that extend into a tissue. Pain, heat, and cold are all sensed through free nerve endings. An encapsulated nerve ending is a free nerve ending wrapped in a round capsule of connective tissue. When the capsule is deformed by touch or pressure, the neuron is stimulated to send signals to the CNS. Specialized cells detect stimuli from the 5 special senses: vision, hearing, balance, smell, and taste. Each of the special senses has its own unique sensory cells—such as rods and cones in the retina to detect light for the sense of vision.

Functionally, there are 6 major classes of receptors: mechanoreceptors, nociceptors, photoreceptors, chemoreceptors, osmoreceptors, and thermoreceptors.

Mechanoreceptors: Mechanoreceptors are sensitive to mechanical stimuli like touch, pressure, vibration, and blood pressure.

Nociceptors: Nociceptors respond to stimuli such as extreme heat, cold, or tissue damage by sending pain signals to the CNS.

Photoreceptors: Photoreceptors in the retina detect light to provide the sense of vision.

Chemoreceptors: Chemoreceptors detect chemicals in the bloodstream and provide the senses of taste and smell.

Osmoreceptors: Osmoreceptors monitor the osmolarity of the blood to determine the body's hydration levels.

Thermoreceptors: Thermoreceptors detect temperatures inside the body and in its surroundings.

1. Lobes of the Brain

Although the minor wrinkles are unique in each brain, several major wrinkles and folds are common to all brains. These folds form a set of four lobes in each hemisphere. Each lobe tends to specialize for certain functions.

Frontal Lobes: At the front of the brain are the frontal lobes, and the part lying just behind the forehead is called the prefrontal cortex. Often called the executive control center, these lobes deal with planning and thinking.

They comprise the rational and executive control center of the brain, monitoring higher-order thinking, directing problem solving, and regulating the excesses of the emotional system.

The frontal lobe also contains our self-will area—what some might call our personality. Trauma to the frontal lobe can cause dramatic—and sometimes permanent—behavior and personality changes.

Because most of the working memory is located here, it is the area where focus occurs (Geday & Gjedde, 2009; Smith & Jonides, 1999). The frontal lobe matures slowly. MRI studies of post-adolescents reveal that the frontal lobe continues to mature into early adulthood.

Thus, the capability of the frontal lobe to control the excesses of the emotional system is not fully operational during adolescence (Dosenbach et al., 2010; Goldberg, 2001). This is one important reason why adolescents are more likely than adults to submit to their emotions and resort to high-risk behavior.

Temporal Lobes: Above the ears rest the temporal lobes, which deal with sound, music, face and object recognition, and some parts of long-term memory. They also house the speech centers, although this is usually on the left side only.

Occipital Lobes: At the back are the paired occipital lobes, which are used almost exclusively for visual processing.

Parietal Lobes: Near the top are the parietal lobes, which deal mainly with spatial orientation,

calculation, and certain types of recognition.

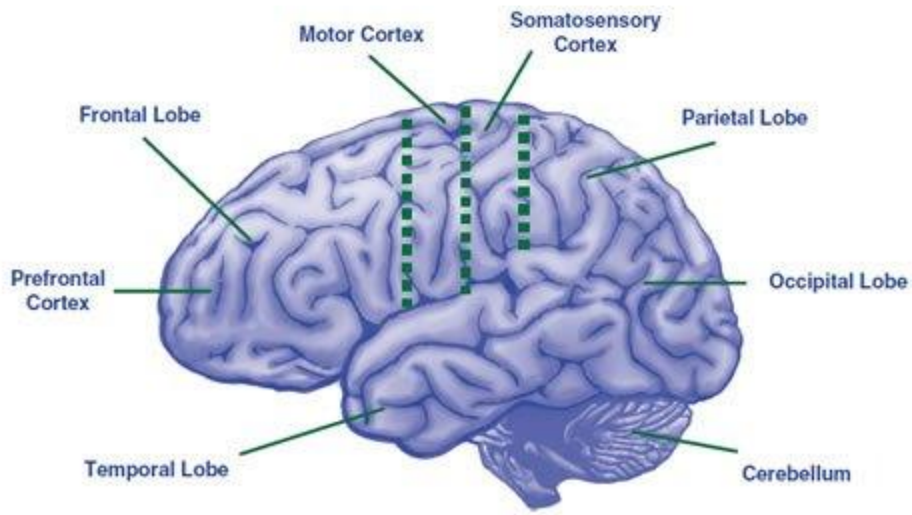

Figure 1.1 The major exterior regions of the brain.

2. Motor Cortex and Somatosensory Cortex

Between the parietal and frontal lobes are two bands across the top of the brain from ear to ear. The band closer to the front is the motor cortex. This strip controls body movement and, as we will learn later, works with the cerebellum to coordinate the learning of motor skills. Just behind the motor cortex, at the beginning of the parietal lobe, is the somatosensory cortex, which processes touch signals received from various parts of the body.

3. Brain Stem

The brain stem is the oldest and deepest area of the brain. It is often referred to as the reptilian brain because it resembles the entire brain of a reptile. Of the 12 body nerves that go to the brain, 11 end in the brain stem (the olfactory nerve—for smell—goes directly to the limbic system, an evolutionary artifact). Here is where vital body functions, such as heartbeat, respiration, body tem¬perature, and digestion, are monitored and controlled. The brain stem also houses the reticular activating system (RAS), responsible for the brain’s alertness.

4. The Limbic System

Nestled above the brain stem and below the cerebrum lies a collection of structures commonly referred to as the limbic system and sometimes called the old mammalian brain. Many researchers now caution that viewing the limbic system as a separate functional entity is outdated because all of its components interact with many other areas of the brain.

Most of the structures in the limbic system are duplicated in each hemisphere of the brain. These structures carry out a number of different functions including the generation of emotions and processing emotional memories. Its placement between the cerebrum and the brain stem permits the interplay of emotion and reason.

Four parts of the limbic system are important to learning and memory. They include the following:

The Thalamus: All incoming sensory information (except smell) goes first to the thalamus (Greek for "inner chamber"). From here it is directed to other parts of the brain for additional processing. The cerebrum and the cerebellum also send signals to the thalamus, thus involving it in many cognitive activities, including memory.

The Hypothalamus: Nestled just below the thalamus is the hypothalamus. While the thalamus monitors information coming in from the outside, the hypothalamus monitors the internal systems to maintain the normal state of the body (called homeostasis). By controlling the release of a variety of hormones, it moderates numerous body functions, including sleep, body temperature, food intake, and liquid intake. If body systems slip out of balance, it is difficult for the individual to concentrate on cognitive processing of curriculum material.

The Hippocampus: Located near the base of the limbic area is the hippocampus (the Greek word for "sea horse," because of its shape). It plays a major role in consolidating learning and in converting information from working memory via electrical signals to the long-term storage regions, a process that may take days to months. It constantly checks information relayed to working memory and com-pares it to stored experiences. This process is essential for the creation of meaning.

Its role was first revealed by patients whose hippocampus was damaged or removed because of disease. These patients could remember everything that happened before the operation, but not afterward. If they were introduced to you today, you would be a stranger to them tomorrow. Because they can remember information for only a few minutes, they can read the same article repeatedly and believe on each occasion that it is the first time they have read it. Brain scans have confirmed the role of the hippocampus in permanent memory storage. Alzheimer's disease progressively destroys neurons in the hippocampus, resulting in memory loss.

Recent studies of brain-damaged patients have revealed that although the hippocampus plays an important role in the recall of facts, objects, and places, it does not seem to play much of a role in the recall of long-term personal memories (Lieberman, 2005). One surprising revelation in recent years is that the hippocampus has the capability to produce new neurons—a process called neurogenesis—into adulthood (Balu & Lucki, 2009). Furthermore, there is research evidence that this form of neurogenesis has a significant impact on learning and memory (Deng, Aimone, & Gage, 2010; Neves, Cooke, & Bliss, 2008). Studies also reveal that neurogenesis can be strengthened by diet (Kitamura, Mishina, & Sugiyama, 2006) and exercise (Pereira et al., 2007) and weakened by prolonged sleep loss (Meerlo, Mistlberger, Jacobs, Heller, & McGinty, 2009).

The Amygdala: Attached to the end of the hippocampus is the amygdala (Greek for "almond"). This structure plays an important role in emotions, especially fear. It regulates the individual's interactions with the environment that can affect survival, such as whether to attack, escape, mate, or eat.

Because of its proximity to the hippocampus and its activity on PET scans, researchers believe that the amygdala encodes an emotional message, if one is present, whenever a memory is tagged for long-term storage. It is not known at this time whether the emotional memories themselves are actually stored in the amygdala. One possibility is that the emotional component of a memory is stored in the amygdala while other cognitive components (names, dates, etc.) are stored elsewhere (Squire & Kandel, 1999). The emotional component is recalled whenever the memory is recalled. This explains why people recalling a strong emotional memory will often experience those emotions again. The interactions between the amygdala and the hippocampus ensure that we remember for a long time those events that are important and emotional.

Teachers, of course, hope that their students will permanently remember what was taught. Therefore, it is intriguing to realize that the two structures in the brain mainly responsible for long-term remembering are located in the emotional area of the brain.

5. Cerebrum

A soft, jellylike mass, the cerebrum is the largest area, representing nearly 80 percent of the brain by weight. Its surface is pale gray, wrinkled, and marked by deep furrows called fissures and shallow ones called sulci (singular, sulcus). Raised folds are called gyri (singular, gyrus). One large sulcus runs from front to back and divides the cerebrum into two halves, called the cerebral hemispheres. For some still unexplained reason, the nerves from the left side of the body cross over to the right hemisphere, and those from the right side of the body cross to the left hemisphere. The two hemispheres are connected by a thick cable of more than 200 million nerve fibers called the corpus callosum (Latin for “large body”). The hemispheres use this bridge to communicate with each other and coordinate activities.

The hemispheres are covered by a thin but tough laminated cortex (meaning “tree bark”), rich in cells, that is about one tenth of an inch thick and, because of its folds, has a surface area of about two square feet. That is about the size of a large dinner napkin. The cortex is composed of six layers of cells meshed in about 10,000 miles of connecting fibers per cubic inch! Here is where most of the action takes place. Thinking, memory, speech, and muscular movement are controlled by areas in the cerebrum. The cortex is often referred to as the brain’s gray matter.

The neurons in the thin cortex form columns whose branches extend through the cortical layer into a dense web below known as the white matter. Here, neurons connect with each other to form vast arrays of neural networks that carry out specific functions.

6. Cerebellum

The cerebellum (Latin for “little brain”) is a two-hemisphere structure located just below the rear part of the cerebrum, right behind the brain stem. Representing about 11 percent of the brain’s weight, it is a deeply folded and highly organized structure containing more neurons than all of the rest of the brain put together. The surface area of the entire cerebellum is about the same as that of one of the cerebral hemispheres.

This area coordinates movement. Because the cerebellum monitors impulses from nerve endings in the muscles, it is important in the performance and timing of complex motor tasks. It modifies and coordinates commands to swing a golf club, smooth a dancer's footsteps, and allow a hand to bring a cup to the lips without spilling its contents. The cerebellum may also store the memory of automated movements, such as touch-typing and tying a shoelace. Through such automation, performance can be improved as the sequences of movements can be made with greater speed, greater accuracy, and less effort. The cerebellum also is known to be involved in the mental rehearsal of motor tasks, which also can improve performance and make it more skilled. A person whose cerebellum is damaged slows down and simplifies movement, and would have difficulty with finely tuned motion, such as catching a ball or completing a handshake.

Recent studies indicate that the role of the cerebellum has been underestimated. Researchers now believe that it also acts as a support structure in cognitive processing by coordinating and fine-tuning our thoughts, emotions, senses (especially touch), and memories. Because the cerebellum is connected also to regions of the brain that perform mental and sensory tasks, it can perform these skills automatically, without conscious attention to detail. This allows the conscious part of the brain the freedom to attend to other mental activities, thus enlarging its cognitive scope. Such enlargement of human capabilities is attributable in no small part to the cerebellum and its contribution to the automation of numerous mental activities.

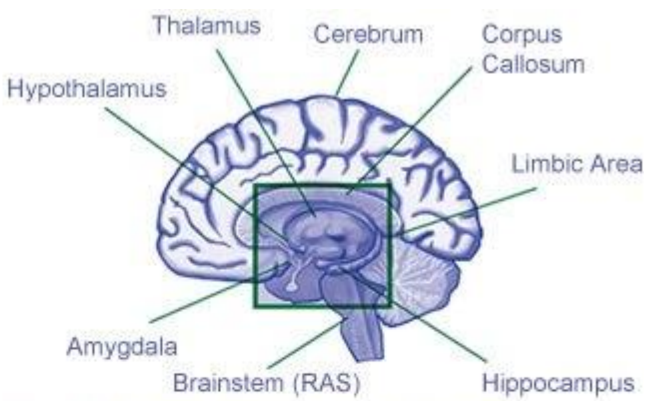

Figure 1.2 A cross section of the human brain

QUICK VIEW OF LIMBIC SYSTEM:-

Hippocampus: This portion of the brain is used for learning memory, specifically converting temporary memories into permanent memories which can be stored within the brain. The hippocampus also helps people analyze and remember spatial relationships, allowing for accurate movements. This portion of the brain is located in the cerebral hemisphere.

Hypothalamus:The hypothalamus region of the brain controls mood, thirst, hunger and temperature. It also contains glands which control the hormonal processes throughout the body.

Thalamus:The Thalamus is located in the center of the brain. It helps to control the attention span, sensing pain and monitors input that moves in and out of the brain to keep track of the sensations the body is feeling.

Brain Stem

All basic life functions originate in the brain stem, including heartbeat, blood pressure and breathing. In humans, this area contains the medulla, midbrain and pons. This is commonly referred to as the simplest part of the brain, as most creatures on the evolutionary scale have some form of brain creation that resembles the brain stem. The brain stem consists of midbrain, pons and medulla.

Midbrain:The midbrain, also known as the mesencephalon is made up of the tegmentum and tectum. These parts of the brain help regulate body movement, vision and hearing. The anterior portion of the midbrain contains the cerebral peduncle which contains the axons that transfer messages from the cerebral cortex down the brain stem, which allows voluntary motor function to take place.

Pons: This portion of the metencephalon is located in the hindbrain, and links to the cerebellum to help with posture and movement. It interprets information that is used in sensory analysis or motor control. The pons also creates the level of consciousness necessary for sleep.

Medulla: The medulla or medulla oblongata is an essential portion of the brain stem which maintains vital body functions such as the heart rate and breathing.

THE AUTONOMIC NERVOUS SYSTEM

Anatomical Structure of the System

The nervous system comprises the brain and various types of nerves, including afferent nerves (from the Latin, ad = towards; ferro = I carry), which carry sensory impulses from all parts of the body to the brain and efferent nerves (ex = from; ferro = I carry) through which "messages" are conducted from the brain to the muscles and all of the organs of the body.

The somatic part of the nervous system has sensory components which convey sensations from the eyes, the nose and other sensory organs to the brain (mainly the cerebral cortex) where most of the impulses reach our awareness, and motor components transmitting impulses to the skeletal muscles in the limbs and trunk permitting voluntary control of movements.

The autonomic nervous system conveys sensory impulses from the blood vessels, the heart and all of the organs in the chest, abdomen and pelvis through nerves to other parts of the brain (mainly the medulla, pons and hypothalamus).

These impulses often do not reach our consciousness, but elicit largely automatic or reflex responses through the efferent autonomic nerves, thereby eliciting appropriate reactions of the heart, the vascular system, and all the organs of the body to variations in environmental temperature, posture, food intake, stressful experiences and other changes to which all individuals are exposed.

There are two major components of the autonomic nervous system, the sympathetic and the parasympathetic systems. The afferent nerves subserving both systems convey impulses from sensory organs, muscles, the circulatory system and all the organs of the body to the controlling centers in the medulla, pons and hypothalamus.

From these centers efferent impulses are conveyed to all parts of the body by the parasympathetic and sympathetic nerves. The impulses of the parasympathetic system reach the organs of the body through the cranial nerves # 3, 7, 9, & 10, and some sacral nerves to the eyes, the gastrointestinal system, and other organs.

The sympathetic nerves reach their end-organs through more devious pathways down the spinal cord to clusters of sympathetic nerve bodies (ganglia) alongside the spine where the messages are relayed to other nerve bodies (or neurons) that travel to a large extent with the blood vessels to all parts of the body.

Through these nervous pathways, the autonomic nerves convey stimuli resulting in largely unconscious, reflex, bodily adjustments such as in the size of the pupil, the digestive functions of the stomach and intestines, the rate and depth of respiration and dilatation or constriction of the blood vessels.

Transmission of Autonomic Stimuli

Like other nerves, those of the autonomic nervous system convey their messages to the appropriate end organs (blood vessels, viscera, etc.) by releasing transmitter substances to which the receptors of the target cells are responsive.

The most important of these transmitters in the autonomic nervous system are acetylcholine and norepinephrine. In the parasympathetic system, acetylcholine is responsible for most of these transmissions between the afferent and efferent nerves of the system and between the efferent nerve endings and the cells or organs that they subserve.

Acetylcholine also serves to transmit nerve-to-nerve messages in the afferent nerves and the brain centers of the sympathetic nervous system.

However, the final transmission of messages from the sympathetic nerves to the end-organs or cells that they innervate is conveyed by the release of norepinephrine (noradrenaline) with at least one important exception, namely the sympathetically conveyed stimulus to the sweat glands which is transmitted by acetylcholine.

A stimulus to contraction of the blood vessels is required in order to maintain the blood pressure when we arise from bed in the morning, so as to prevent fainting from excessive pooling of blood in the lower body.

This stimulus is conveyed by norepinephrine release within the walls of the blood vessels from the nerve endings of the sympathetic nerves that innervate each blood vessel.

Functions of the Autonomic Nervous System

(a) The Parasympathetic System

When a stimulus arises in an organ, such as a bright light shone into the eyes, the message is conducted through sensory fibers to the midbrain to give rise to an appropriate stimulus that travels through the parasympathetic fibers of the oculomotor (third cranial) nerves to the pupils, resulting in automatic contraction of the pupillary muscles to constrict the aperture and so reduce the amount of light reaching the sensory cells in the retinae of the eyes.

Similarly, the stimuli associated with the entry of food into the stomach are conveyed by afferent fibers of the vagus nerve to the command station or nucleus of the vagus in the brain whence messages are automatically conveyed through efferent fibers of the vagus back to the stomach.

These stimulate the secretion of gastric juices and peristaltic contractions of the stomach to mix the food with the secreted digestive juices and gradually to convey the gastric contents into the intestines where a similar process is initiated through essentially the same parasympathetic nerve pathways.

Fortunately, emptying of the rectum and of the urinary bladder is not entirely automatic but is subject to parasympathetic impulses that are voluntarily controlled.

Thus, filling of the urinary bladder with urine stimulates stretch-sensitive receptors in the wall of the bladder whence the message is conveyed to the midbrain where the stimulus to bladder contraction and opening of the sphincters is voluntarily initiated to allow the discharge of the contained urine.

Similarly the very complex requirements of giving birth to a baby are initiated by stimuli to dilatation of the cervix, and involuntary contractions of the uterine musculature with delivery of the fetus assisted by voluntary contraction of the abdominal muscles.

(b) The Sympathetic Nervous System

The sympathetic nervous system is even more automatic and only exceptionally susceptible to any voluntary control. When the environmental temperature is raised on a hot summers day, the increased temperature initiates several automatic responses.

Thermal receptors convey stimuli to sympathetic control centers of the brain from which inhibitory messages travel along the sympathetic nerves to the blood vessels of the skin resulting in dilatation of the cutaneous blood vessels, thereby greatly increasing the flow of blood to the surface of the body from where heat is lost by radiation from the surface of the body. Dilatation of the blood vessels in this way tends to lower the blood pressure and to promote oozing or transudation of the fluid from the capillaries which may result in swelling of the dependent limbs.

Thus, fine adjustments in sympathetic control of vascular contraction and "tone" are required to prevent excessive vascular dilatation and undue reduction in blood pressure. Otherwise, this might result in severe gravitational pooling of blood in the lower limbs thereby reducing blood flow to the brain and causing fainting spells, to which individuals with impaired sympathetic nervous functions are very susceptible.

The sympathetic nervous system responds to environmental heat in another important way. The rise in body temperature is sensed by the hypothalamic center from which stimuli emanate via sympathetic nerves to the sweat glands, resulting in appropriate sweating.

This serves to cool the body by the loss of heat resulting from evaporation of the sweat, aided by a cool breeze. The only really voluntary input that we have to facilitate cooling in a warm environment is to get into a pool, a cold shower, or an air-conditioned room! We cannot voluntarily influence the dilatation of our blood vessels or the adequacy of our sweating in response to heat in other ways.

Control of the rate and strength of cardiac contractions is also under the predominant control of the sympathetic nervous system.

Thus, a fall in blood pressure resulting from traumatic injury causing blood loss is sensed by pressure-sensitive parts of the arteries called baroreceptors. Evidence of reduced arterial distension is sensed by these baroreceptors and conveyed by the parasympathetic (mainly the glossopharyngeal) nerves to the cardiovascular control center in the medulla, called the nucleus tractus solitarii.

From these nuclei sympathetic stimuli conveyed by the cardiac nerves cause acceleration of the heart rate, probably complemented by simultaneous reduction in the parasympathetic stimuli via the vagus nerves which slow the heart rate.

Although pain, anxiety, fear and injuries or blood loss would involuntarily increase the sympathetic stimulation to cardiac acceleration, most of us are unable to influence either this effect or the consequences of blood loss per se on cardiac acceleration.

(c) The Adrenal Medulla

The central part of the adrenal glands (the adrenal medulla) contains a collection of sympathetic nerve cells specialized in at least two important respects.

Because of their proximity to the adrenal cortex which surrounds the medulla and secretes hydrocortisone (or cortisol), the neurons of the medulla are able to synthesize not only norepinephrine but also, by attaching a methyl group to this compound, epinephrine (or adrenaline).

The adrenal medulla is the only source of more than trivial amounts of epinephrine that enters the blood stream. The second aspect of specialization of the adrenal medulla is in its responses, via the sympathetic efferent nerves that reach it, to specific types of stimuli that have little or no effect on the rest of the autonomic nervous system.

Thus, whereas changing from recumbency to the upright posture activates mainly the sympathetic neurons of the blood vessels where norepinephrine is released with resulting elevation mainly of plasma norepinephrine levels, a fall in blood sugar induced by an injection or excessive release of insulin causes a predominant increase in plasma epinephrine, the concentration of which may rise to 3 or 4 times the concomitant level of plasma norepinephrine. Situations such as emotional excitement, fear, apprehension, psychic distress, panic reactions, sexual activity and fight-or-flight stimuli probably activate many parts of the sympathetic nervous systems including the adrenal medullae.

It is evident, therefore, that while we are not constantly aware of the activity of the autonomic nervous system as we are of unusual sensory and motor events, the normal functioning of the autonomic nervous system day and night, from heart-beat to heart-beat, plays a largely unconscious but vital role in our livelihood.

It is not surprising, therefore, that autonomic abnormalities, though they are usually more difficult to recognize than a severe pain, a sensory loss or paralysis of a limb, may be even more important in impairing the quality and even jeopardizing the continuation of life.

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