Tomado de http://www.answers.com/topic/central-nervous-system

Central nervous system

Definition

The central nervous system (CNS) is composed of the brain and spinal cord. The brain receives sensory information from the nerves that pass through the spinal cord, as well as other nerves such as those from sensory organs involved in sight and smell. Once received, the brain processes the sensory signals and initiates responses. The spinal cord is the principle route for the passage of sensory information to and from the brain.

Information flows to the central nervous system from the peripheral nervous system, which senses signals from the environment outside the body (sensory-somatic nervous system) and from the internal environment (autonomic nervous system). The brain's responses to incoming information flow through the spinal cord nerve network to the various effector organs and tissue regions where the target responsive action will take place.

Description

Brain

The brain is divided into three major anatomical regions, the prosencephalon (forebrain), mesencephalon (midbrain), and the rhombencephalon (hindbrain). The brain also contains a ventricular system, which consists of four ventricles (internal cavities): two lateral ventricles, a third ventricle, and a fourth ventricle. The ventricles are filled with cerebrospinal fluid and are continuous with the spinal canal. The ventricles are connected via two interventricular foramen (connecting the two lateral ventricles to the third venticle), and a cerebral aqueduct (connecting the third ventricle to the fourth ventricle).

The brain and spinal cord are covered by three layers of meninges (dura matter, arachnoid matter, and pia mater) that dip into the many folds and fissures. The meninges are three sheets or layers of connective tissue that cover all of the spinal cord and the brain. Infections of the meninges are called meningitis. Bacterial, viral, and protozoan meningitis are serious and require prompt medical attention. Between the arachnoid and the pia matter is a fluid called the cerebrospinal fluid. Bacterial infections of the cerebrospinal fluid can occur and are life-threatening.

GROSS ANATOMY OF THE BRAIN The prosencephalon is divided into the diencephalon and the telencephalon (also known as the cerebrum). The cerebrum contains the two large bilateral hemispherical cerebral cortex that are responsible for the intellectual functions and house the neural connections that integrate, personality, speech, and the interpretation of sensory data related to vision and hearing.

The midbrain, or mesencephalon region, serves as a connection between higher and lower brain functions, and contains a number of centers associated with regions that create strong drives to certain behaviors. The midbrain is involved in body movement.

The so-called pleasure center is located here, which has been implicated in the development of addictive behaviors.

The rhombencephalon, consisting of the medulla oblongata, pons, and cerebellum, is an area largely devoted to lower brain functions, including autonomic functions involved in the regulation of breathing and general body coordination. The medulla oblongata is a cone-like knot of tissue that lies between the spinal cord and the pons. A median fissure (deep, convoluted fold) separates swellings (pyramids) on the surface of the medulla. The pons (also known as the metencephalon) is located on the anterior surface of the cerebellum and is continuous with the superior portion of the medulla oblongata. The pons contains large tracts of transverse fibers that serve to connect the left and right cerebral hemispheres.

The cerebellum lies superior and posterior to the pons at the back base of the head. The cerebellum consists of left and right hemispheres connected by the vermis. Specialized tracts (peduncles) of neural tissue also connect the cerebellum with the midbrain, pons, and medulla. The surface of the cerebral hemispheres (the cortex) is highly convoluted into many folds and fissures.

The midbrain serves to connect the forebrain region to the hindbrain region. Within the midbrain a narrow aqueduct connects ventricles in the forebrain to the hindbrain. There are four distinguishable surface swellings (colliculi) on the midbrain. The midbrain also contains a highly vascularized mass of neural tissue called the red nucleus that is reddish in color (a result of the vascularization) compared to other brain structures and landmarks.

Although not visible from an exterior inspection of the brain, the diencephalon contains a dorsal thalamus (with a large posterior swelling termed the pulvinar) and a ventral hypothalamus that forms a border of the third ventricle of the brain. In this third ventral region lies a number of important structures, including the optic chiasma (the region where the ophthalmic nerves cross) and infundibulum.

Obscuring the diencephalon are the two large, well-developed, and highly convoluted cerebral hemispheres that comprise the cerebrum. The cerebrum is the largest of the regions of the brain. The corpus callosum is connected to the two large cerebral hemispheres. Within each cerebral hemisphere lies a lateral ventricle. The cerebral hemispheres run under the frontal, parietal, and occipital bones of the skull. The gray matter cortex is highly convoluted into folds (gyri) and the covering meninges dip deeply into the narrow gaps between the folds (sulci). The divisions of the superficial anatomy of the brain use the gyri and sulcias anatomical landmarks to define particular lobes of the cerebral hemispheres. As a rule, the lobes are named according to the particular bone of the skull that covers them. Accordingly, there are left and right frontal lobes, parietal lobes, an occipital lobe, and temporal lobes.

In a reversal of the pattern found within the spinal cord, the cerebral hemispheres have white matter tracts on the inside of the hemispheres and gray matter on the outside or cortex regions. Masses of gray matter that are present within the interior white matter are called basal ganglia or basal nuclei.

Spinal cord

The spinal cord is a long column of neural tissue that extends from the base of the brain, downward (inferiorly) through a canal created by the spinal vertebral foramina. The spinal cord is between 16.9 and 17.7 inches (43 and 45 centimeters) long in the average woman and man, respectively. The spinal cord usually terminates at the level of the first lumbar vertebra.

The spinal cord is enclosed and protected by the vertebra of the spinal column. There are four regions of vertebrae. Beginning at the skull and moving downward, there are the eight cervical vertebrae, 12 thoracic vertebrae, five lumbar vertebrae, five sacral vertebrae, and one set of fused coccygeal vertebra.

Along the length of the spinal cord are positioned 31 pairs of nerves. These are known as mixed spinal nerves, as they convey sensory information to the brain and response information back from the brain. Spinal nerve roots emerge from the spinal cord that lies within the spinal canal. Both dorsal and ventral roots fuse in the intervertebral foramen to create a spinal nerve.

Although there are only seven cervical vertebra, there are eight cervical nerves. Cervical nerves one through seven (C1–C7) emerge above (superior to) the corresponding cervical vertebrae. The last cervical nerve (C8) emerges below (inferior to) the last cervical vertebrae from that point downward the spinal nerves exit below the corresponding vertebrae for which they are named.

In the spinal cord of humans, the myelin-coated axons are on the surface and the axon-dendrite network is on the inside. In cross-section, the pattern of contrasting color of these regions produces an axon-dendrite shape that is reminiscent of a butterfly.

The nerves of the spinal cord correspond to the arrangement of the vertebrae. There are 31 pairs of nerves, grouped as eight cervical pairs, 12 thoracic pairs, five lumbar pairs, five sacral pairs, and one coccygeal pair. The nerves toward the top of the cord are oriented almost horizontally. Those further down are oriented on a progressively upward slanted angle toward the bottom of the cord.

Toward the bottom of the spinal cord, the spinal nerves connect with cells of the sympathetic nervous system. These cells are called pre-ganglionic and ganglionic cells. One branch of these cells is called the gray ramus communicans and the other branch is the white ramus communicans. Together they are referred to as the rami. Other rami connections lead to the pelvic area.

The bi-directional (two-way) communication network of the spinal cord allows the reflex response to occur. This type of rapid response occurs when a message from one type of nerve fiber, the sensory fiber, stimulates a muscle response directly, rather than the impulse traveling to the brain for interpretation. For example, if a hot stove burner is touched with a finger, the information travels from the finger to the spinal cord and then a response to move muscles away from the burner is sent rapidly and directly back. This response is initiated when speed is important.

Development and histology of the CNS

Both the spinal cord and the brain are made up of structures of nerve cells called neurons. The long main body extension of a neuron is called an axon. Depending on the type of nerve, the axons may be coated with a material called myelin. Both the brain and spinal cord components of the central nervous system contain bundles of cell bodies (out of which axons grow) and branched regions of nerve cells that are called dendrites. Between the axon of one cell body and the dendrite of another nerve cell is an intervening region called the synapse. In the spinal cord of humans, the myelin-coated axons are on the surface and the axon-dendrite network is on the inside. In the brain, this arrangement is reversed.

The brain begins as a swelling at the cephalic end of the neural tube that ultimately will become the spinal cord. The neural tube is continuous and contains primitive cerebrospinal fluids. Enlargements of the central cavity (neural tube lumen) in the region of the brain become the two lateral, third, and forth ventricles of the fully developed brain.

The embryonic brain is differentiated in several anatomical regions. The most cephalic region is the telencephalon. Ultimately, the telencephlon will develop the bilateral cerebral hemispheres, each containing a lateral ventricle, cortex (surface) layer of gray cells, a white matter layer, and basal nuclei. Caudal (inferior) to the telecephalon is the diencephalon that will develop the epithalamus, thalamus, and hypothalamus

Caudal to the diencephalon is the mesencephalon, the midbrain region that includes the cerebellum and pons. Within the myelencephalon region is the medulla oblongata.

Neural development inverts the gray matter and white matter relationship within the brain. The outer cortex is composed of gray matter, while the white matter (myelinated axons) lies on the interior of the developing brain.

The meninges that protect and help nourish neural tissue are formed from embryonic mesoderm that surrounds the axis established by the primitive neural tube and notochord. The cells develop many fine capillaries that supply the highly oxygen-demanding neural tissue.

Diseases and disorders of the CNS

Diseases that affect the nerves of the central nervous system include rabies, polio, and sub-acute sclerosing pan-encephalitis. Such diseases affect movement and can lead to mental incapacitation. The brain is also susceptible to disease, including toxoplasmosis and the development of empty region due to prions. Such diseases cause a wasting away of body function and mental ability. Brain damage can be so compromised as to be lethal.

Resources

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Brian Douglas Hoyle, PhD

Paul Arthur

Sci-Tech Encyclopedia:

Central nervous system

Top
Home > Library > Science > Sci-Tech Encyclopedia

That portion of the nervous system composed of the brain and spinal cord. The brain is enclosed in the skull, and the spinal cord within the spinal canal of the vertebral column. The brain and spinal cord are intimately covered by membranes called meninges and bathed in an extracellular fluid called cerebrospinal fluid. Approximately 90% of the cells of the central nervous system are glial cells which support, both physically and metabolically, the other cells, which are the nerve cells or neurons. *See also* Meninges; Neuron.

Functionally similar groups of neurons are clustered together in so-called nuclei of the central nervous system. When groups of neurons are organized in layers (called laminae) on the outer surface of the brain, the group is called a cortex, such as the cerebral cortex and cerebellar cortex. The long processes (axons) of neurons course in the central nervous system in functional groups called tracts. Since many of the axons have a layer of shiny fat (myelin) surrounding them, they appear white and are called the white matter of the central nervous system. The nuclei and cortex of the central nervous system have little myelin in them, appear gray, and are called the gray matter of the central nervous system. *See also* Brain; Nervous system (vertebrate); Spinal cord.

World of the Body:

central nervous system

Top

The central nervous system (CNS) consists of the brain (inside the skull) and spinal cord (inside the vertebral column), which derive from a single, continuous tube of neural tissue that forms at an early stage in the embryo. The head end of the tube develops into the *cerebral hemispheres*, the cerebellum, and the brain stem. The lowest part of the brain stem, the *medulla oblongata*, merges with the spinal cord at the large hole (*foramen magnum*) in the base of the skull. The spinal cord in an adult human is about 45 cm long, tapering to a cone at its lower end. It has two swellings, the *cervical* and *lumbar enlargements*, which are due to accumulations of nerve cells (*neurons*) responsible for innervating the upper and lower limbs.

Both the brain and the spinal cord are ensheathed by three protective meninges (from the Greek for 'membranes'). The outer one, the *dura mater* ('dura' because it is relatively hard and strong; 'mater' because it protects like a mother) lines the skull and the tunnel that runs through the centre of the vertebrae. The delicate, innermost *pia mater* ('pia' is Latin for soft) envelops the brain and the spinal cord closely down to the level of the upper lumbar vertebrae. Between the pia and dura is a space, particularly voluminous below where the cord itself ends. The dura is lined by the *arachnoid mater*, which is more fragile than the dura, being likened to a spider's web, the Greek origin of its name. So the space between the pia and dura, which contains cerebrospinal fluid (*CSF*), is called the *subarachnoid space*.

Twelve pairs of cranial nerves are attached to the brain, at various levels. Some, such as the olfactory and optic nerves, are purely sensory. Others, such as those supplying the muscles that move the eyeball, are motor. The tenth cranial nerve, called the 'vagus' (Latin for wanderer), carries sensory information from some of the viscera and also contains the outflow of *parasympathetic* fibres (part of the autonomic nervous system) that innervate the heart, the bronchial tree, the smooth muscle of much of the gut, and various glands.

Evolutionarily, the central nervous system is derived from the repetitive, segmented chain of nerve cells found in invertebrates, and this segmental pattern is still clear in the human spinal cord, and even in the lower parts of the brain. It is most evident in the *spinal nerves*, 31 pairs in all, that sprout from the sides of the spinal cord. Strictly, these spinal nerves are part of the peripheral nervous system, but their organization is best understood in relation to the cord itself. For each vertebra, on each side of the cord is a *dorsal root* ('dorsal' means on the top), containing sensory nerve fibres from the periphery of the body, which are destined to end in the cord or the base of the brain. The neuron cell bodies for these fibres are in swellings on the dorsal roots (*dorsal root ganglia*). There is a corresponding pair of *ventral roots* ('ventral' literally meaning on the side nearer the stomach), containing axons from motor neurons in the cord, on their way to skeletal muscles. Additional fibres leave the ventral roots in the middle levels of the cord to innervate smooth muscle (e.g. that of blood vessel walls and the gut), glands, and the heart. These are the *sympathetic* fibres and are also part of the autonomic nervous system. Just outside each vertebra, the dorsal and ventral roots unite to form a spinal nerve on each side.

If you cut a spinal cord transversely, you can see, even with the naked eye, a central, butterfly-shaped core of darker material. If such a section is examined with a microscope it becomes clear that this core consists of grey matter (grey because of a concentration of cell bodies), surrounded by columns of white matter (white because it consists largely of nerve fibres — *axons*), running up and down the cord. The dorsal part of the grey matter receives fibres of the dorsal root, relaying information about touch, temperature, pain, and also position sense. The ventral part of the grey matter contains motor neurons that send out their axons in the ventral root to reach the skeletal muscles.

Imagine what happens as nervous impulses arrive at the cord through fibres of the dorsal root. This sensory information is of several types. Firstly, it is either *somatic* (from skin, muscles, and joints) or *visceral* (from the internal organs) in origin. Secondly it may give rise to *conscious* sensation, which presupposes that the information is transmitted from the spinal cord to higher brain centres, and ultimately the cerebral cortex. Alternatively it remains *unconscious*, in which case it may be handled by brain centres such as the *cerebellum*, or it may simply feed a pathway within the spinal cord, ultimately resulting in signals passing out to cause muscle reactions (a *spinal reflex*).

Fibres concerned with touch, temperature, and pain end on nerve cell bodies in the dorsal grey matter, which in turn send axons across to the other side of the cord and then up to the brain. Many of them reach the thalamus, projecting thence to, amongst other regions, the *somatic sensory cortex* — a strip at the front edge of the parietal lobe of the cerebral hemispheres. Fibres that convey conscious position sense and fine discriminative touch also enter the cord by dorsal roots, but they behave differently in that they immediately turn upward on the same side of the cord and run all the way up through a tract of white matter called the *dorsal columns*, merely sending branches into the dorsal grey matter of the spinal cord along the way. These fibres end on groups of cells in the medulla of the brain stem, whose axons cross to the other side and run up to the thalamus, from where axons run up to the somatic sensory cortex.

The basic function of the central nervous system is to generate appropriate reactions to sensory signals, from inside or outside the body. The simplest form of such a reaction is a ‘reflex’ — an involuntary response to a sensory stimulus. The circuit of nerve cells and axons responsible is called a *reflex arc*. The simplest form of reflex arc involves an incoming fibre, which traverses the dorsal grey matter of the spinal cord to terminate at a synapse on a motor neuron in the ventral grey matter, whose axon runs out to a muscle. Since this circuit contains only one synaptic connection, it is called a *monosynaptic* reflex. The best known example is the ‘tendon jerk reflex’: when a muscle is suddenly stretched it reflexly contracts, to oppose the stretching. For instance, when the tendon just below the knee is tapped, stretching the thigh muscles to which this tendon is attached, the same muscles contract, causing the leg to kick. Such tendon jerks are tested as part of a routine neurological examination, to assess the state of synaptic connections. This very simple type of reflex arc is relatively rare, most reflexes being *complex* or *multisynaptic*. This implies that the circuit between incoming sensory fibre and motoneuron includes other nerve cells. As these may innervate several levels of the cord, or even cross to the other side, these reflexes can be much more sophisticated than simple ones. For example, burning the tip of a finger may result in reflex withdrawal of the whole upper limb.

Some reflexes, although involuntary, almost certainly involve connections running through the cerebral cortex, or through the cerebellum, which is particularly involved in the learning and execution of motor skills, especially highly automated ones whose operation does not intrude into consciousness.

As well as major ‘ascending’ pathways carrying sensory information up to the corresponding regions of the cerebral cortex, the white matter of the brain stem and spinal cord also contains many tracts of fibres running downwards. The largest of these is the *corticospinal*, or *pyramidal*, tract, which originates in large neurons in motor areas of the cerebral cortex, and descends to the lower brain stem, where most of its axons cross over and enter the spinal cord to end, without interruption, on motoneurons in the grey matter.

This brief account leaves the impression that the central nervous system is little more than a set of cables running up and down, with something akin to a telephone switchboard in between. In reality, the human central nervous system is a monstrous biological computing instrument (although many would contest the analogy with a conventional computer), which is somehow capable of capturing the *meaning* of events in the outside world, representing them in memories and as conscious experiences, and making decisions that go far beyond automatic reactions to immediate events.

— *Laurence Garey*

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That portion of the nervous system consisting of the brain and spinal cord. The portion of the nervous system beyond the brain and cord is known as the *peripheral nervous system*.

Sports Science and Medicine:

central nervous system

Top
Home > Library > Health > Sports Science and Medicine

CNS

The main mass of nervous tissue, lying between sensory receptors and effectors, which acts as an integrating centre. The CNS comprises the brain and spinal cord and consists of more than one-hundred thousand million neurones.

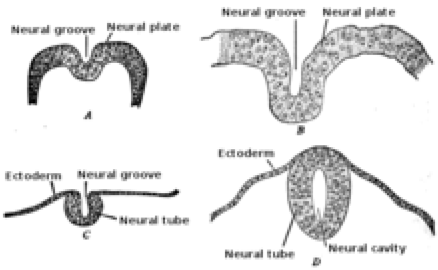
Wikipedia:

Central nervous system

Top
Home > Library > Miscellaneous > Wikipedia

The **central nervous system** (**CNS**) is the part of the nervous system that coordinates the activity of all parts of the bodies of bilaterian animals—that is, all multicellular animals except sponges and radially symmetric animals such as jellyfish. It contains the majority of the nervous system and consists of the brain and the spinal cord, as well as the retina. Together with the peripheral nervous system, it has a fundamental role in the control of behavior. The CNS is contained within the dorsal cavity, with the brain in the cranial cavity and the spinal cord in the spinal cavity. In vertebrates, the brain is protected by the skull, while the spinal cord is protected by the vertebrae, and both are enclosed in the meninges.[1]

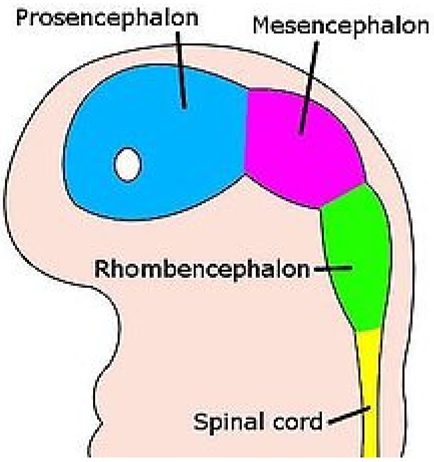
Development



Development of the neural tube
Main article: Neuroanatomy

During early development of the vertebrate embryo, a longitudinal groove on the neural plate gradually deepens as ridges on either side of the groove (the neural folds) become elevated, and ultimately meet, transforming the groove into a closed tube, the ectodermal wall of which forms the rudiment of the nervous system. This tube initially differentiates into three vesicles (pockets): the prosencephalon at the front, the mesencephalon, and, between the mesencephalon and the spinal cord, the rhombencephalon. (By six weeks in the human embryo) the prosencephalon then divides further into the telencephalon and diencephalon; and the rhombencephalon divides into the metencephalon and myelencephalon.

As the vertebrate grows, these vesicles differentiate further still. The telencephalon differentiates into, among other things, the striatum, the hippocampus and the neocortex, and its cavity becomes the first and second ventricles. Diencephalon elaborations include the subthalamus, hypothalamus, thalamus and epithalamus, and its cavity forms the third ventricle. The tectum, pretectum, cerebral peduncle and other structures develop out of the mesencephalon, and its cavity grows into the mesencephalic duct (cerebral aqueduct). The metencephalon becomes, among other things, the pons and the cerebellum, the myelencephalon forms the medulla oblongata, and their cavities develop into the fourth ventricle.



Brain regions of a 4 week old human embryo

<table>
<tr><td rowspan="6">Central nervous system</td><td rowspan="5">Brain</td><td rowspan="2">Prosencephalon</td><td>Telencephalon</td><td colspan="2">Rhinencephalon, Amygdala, Hippocampus, Neocortex, Basal ganglia, Lateral ventricles</td></tr>
<tr><td>Diencephalon</td><td colspan="2">Epithalamus, Thalamus, Hypothalamus, Subthalamus, Pituitary gland, Pineal gland, Third ventricle</td></tr>
<tr><td rowspan="3">Brain stem</td><td>Mesencephalon</td><td colspan="2">Tectum, Cerebral peduncle, Pretectum, Mesencephalic duct</td></tr>
<tr><td rowspan="2">Rhombencephalon</td><td>Metencephalon</td><td>Pons, Cerebellum</td></tr>
<tr><td>Myelencephalon</td><td>Medulla oblongata</td></tr>
<tr><td colspan="5">Spinal cord</td></tr>
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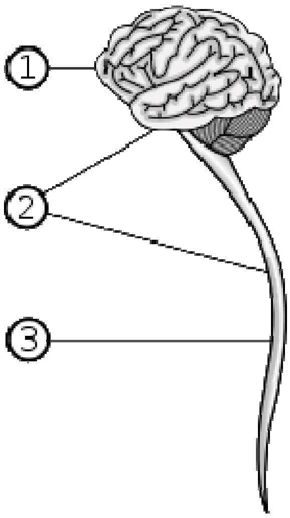
Evolution

Main article: Brain



1. Brain; **2.** Central nervous system; **3.** Spinal cord.

Planarians, members of the phylum Platyhelminthes (flatworms), have the simplest, clearly defined delineation of a nervous system into a central nervous system (CNS) and a peripheral nervous system (PNS).[2] [3] Their primitive brain, consisting of two fused anterior ganglia, and longitudinal nerve cords form the CNS; the laterally projecting nerves form the PNS. A molecular study found that more than 95% of the 116 genes involved in the nervous system of planarians, which includes genes related to the CNS, also exist in humans.[4] Like planarians, vertebrates have a distinct CNS and PNS, though more complex than those of planarians.

The basic pattern of the CNS is highly conserved throughout the different species of vertebrates and during evolution. The major trend that can be observed is towards a progressive telencephalisation: the telencephalon of reptiles is only an appendix to the large olfactory bulb, while in mammals it makes up most of the volume of the CNS. In the human brain, the telencephalon covers most of the diencephalon and the mesencephalon. Indeed, the allometric study of brain size among different species shows a striking continuity from rats to whales, and allows us to complete the knowledge about the evolution of the CNS obtained through cranial endocasts.

Mammals – which appear in the fossil record after the first fishes, amphibians, and reptiles – are the only vertebrates to possess the evolutionarily recent, outermost part of the cerebral cortex known as the neocortex.[5] The neocortex of monotremes (the duck-billed platypus and several species of spiny anteaters) and of marsupials (such as kangaroos, koalas, opossums, wombats, and Tasmanian devils) lack the convolutions - gyri and sulci - found in the neocortex of most placental mammals (eutherians).[6] Within placental mammals, the size and complexity of the neocortex increased over time. The area of the neocortex of mice is only about 1/100 that of monkeys, and that of monkeys is only about 1/10 that of humans.[5] In addition, rats lack convolutions in their neocortex (possibly also because rats are small mammals), whereas cats have a moderate degree of convolutions, and humans have quite extensive convolutions.[5]

See also: Encephalization, Archicortex

Diseases of the central nervous system

There are many central nervous system diseases, including infections of the central nervous system such as encephalitis and poliomyelitis, neurodegenerative diseases such as Alzheimer's disease and amyotrophic lateral sclerosis, autoimmune and inflammatory diseases such as multiple sclerosis or acute disseminated encephalomyelitis, and genetic disorders such as Krabbe's disease, Huntington's disease, or adrenoleukodystrophy. Lastly, cancers of the central nervous system can cause severe illness and, when malignant, can have very high mortality rates.

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