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Edited by
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BRAIN

The human brain is a complex aggregate of billions of cells working together to process stimuli, to monitor needs, and to direct behavior. Developmentally, the brain begins at the most rostral extension of the neural tube; it bends over and convolutes as it expands within the confines of the skull (cranium). The brain's expansion is disproportionate

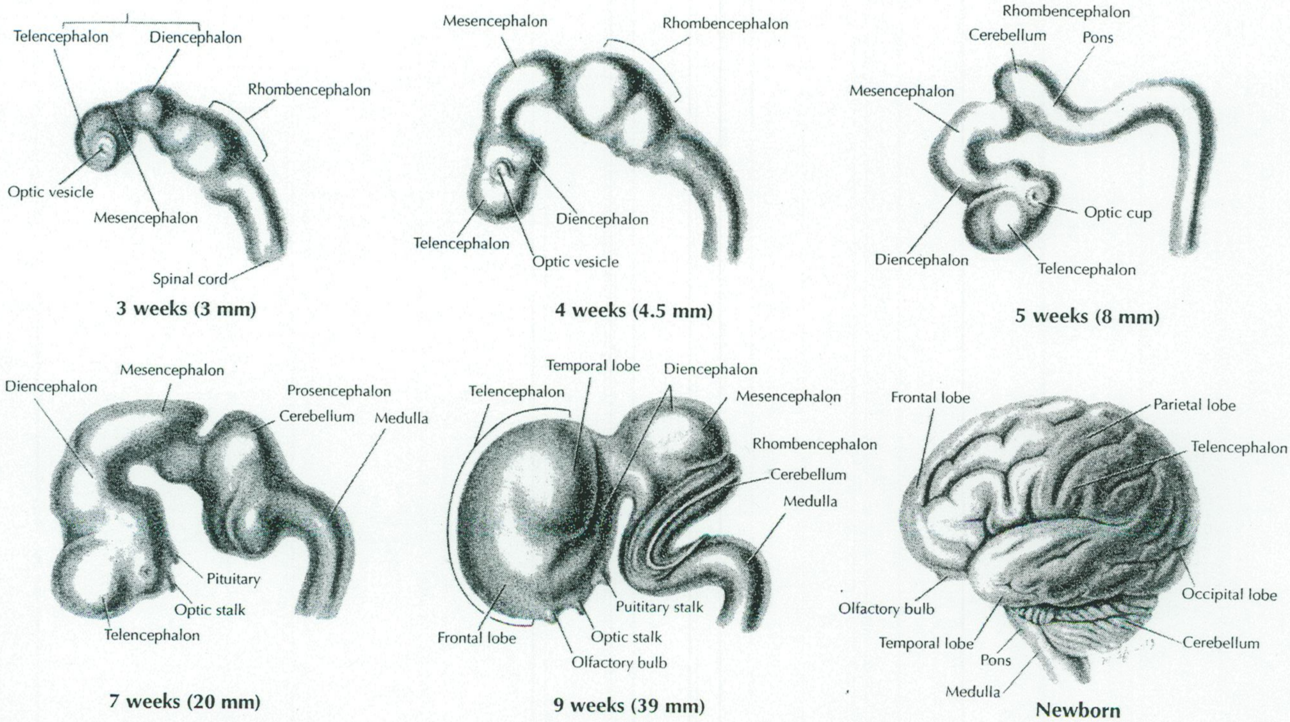

Figure 1. The development of the human brain, showing its major subdivisions.

relative to the growth of the spinal cord, the most caudal extension of the central nervous system. Figure 1 illustrates the development of the human brain, showing its major subdivisions.

There are three major sections of the brain: the prosencephalon or forebrain, the mesencephalon or midbrain, and the rhombencephalon or hindbrain. The forebrain is the largest and most expansive and is made up of two subdivisions: the telencephalon (endbrain) and the diencephalon (interbrain). Telencephalic structures account for about 75% of the weight of the entire human central nervous system. These structures include the two cerebral hemispheres that are connected by a mass of crossing of fiber tracts (called the corpus callosum). Smaller white matter bundles that form connections between the hemispheres include the anterior and posterior commissures. The surface of the hemispheres is a multicellular layer of brain tissue called the cerebral cortex, which varies in thickness from 1.5 millimeters to 4.5 millimeters. The cortex is divided into subregions according to gross neuroanatomical landmarks called sulci and gyri. The largest subregions are called lobes, of which there are four in each hemisphere: occipital, temporal, parietal, and frontal. The location of the four lobes and other major brain structures can be seen in Figures 1 and 2.

The occipital lobes have visual functions and can be divided into subregions based on the portions of visual space to which neurons contained in those subareas respond. The lateral surface of the temporal lobes is important for audition, and on the left side of the brain for understanding language. Medial regions of the temporal lobes are crucial for learning and memory functions, and ventral regions of the temporal lobes contribute to visual object recognition (including faces and words). The parietal lobes control somatosensory and visuospatial functions, and have been implicated in multimodal spatial integration, sensorimotor coordination, and more recently, in attentional switching and visual short-term memory. At the junction with the temporal lobe, the left parietal cortex is important for language comprehension. Frontal cortex is polysensory. It controls movement, and on the left side it controls language expression. The most anterior portion of the frontal lobes (prefrontal cortex) is considered to be the brain's "executive," and is important in social cognition, self-awareness, impulse control, emotional behavior, problem solving, attentional selection, and working memory.

In the cerebral hemispheres, the cortex has a laminar architecture with different neuronal cell types organized in layers. From an evolutionary standpoint, the layered cortical areas have changed in complexity across the phylogenetic scale. The most recently evolved brain areas (neocortex) typically have six defined neuronal layers, while phylogenetically older regions such as the hippocampus have fewer. In addition to neurons, the brain is composed of different types of supporting cells called neuroglia, including oligodendrocytes, microglia, and astrocytes. Oligodendrocytes are responsible for the myelination of nerve fibers (axons), which allows for faster transmission between neurons.

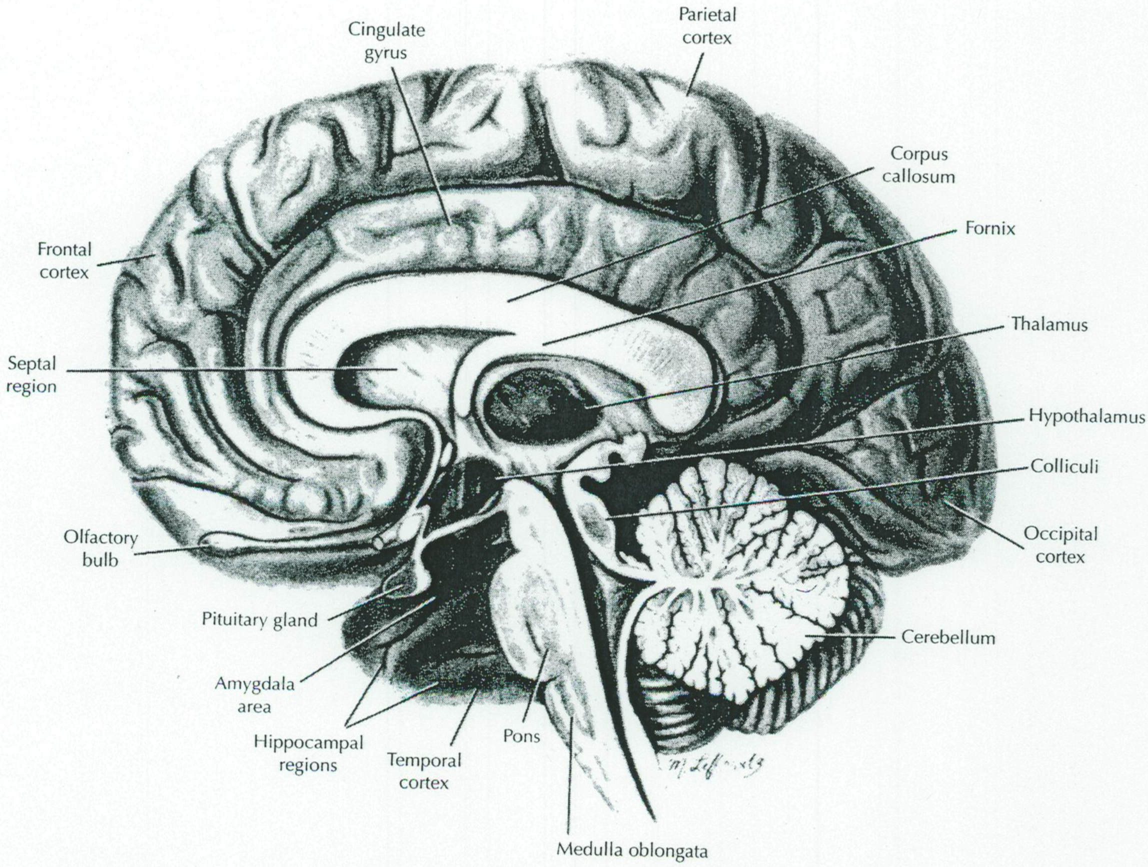

Figure 2. The location of the four lobes and other major brain structures of the adult brain.

Microglia have many functions including serving as macrophages. As such, microglia are thought to play a role in brain development following programmed cell death of neurons and to become activated following brain injury. Astrocytes, while initially thought only to provide neuronal scaffolding and to monitor homeostatis, more recently have been shown to have bidirectional signaling with neurons, demonstrating their important role in signal transmission throughout the brain (Squire et al., 2003; Allen & Barres, 2005).

Cortical nerve cell bodies collectively appear gray, thus accounting for the fact that cerebral cortex is commonly called "gray matter." Likewise, nerve fibers emanating from the cell bodies, because of their collective white appearance subcortically, have been referred to as "white matter." These fibers connect with other nerve cells that are aggregated in clusters often referred to as subcortical nuclei. In the telencephalon, these subcortical nuclei include the limbic system (including the septum, the amygdaloid complex, and the hippocampus) and nuclei of the basal ganglia (caudate, putamen, and globus pallidus). Septal and amygdala regions are intimately connected to each other and are important in emotional and motivational functions. The hippocampal region, which can be divided into the dentate gyrus, the hippocampus proper, and the subiculum, is important for memory formation and consolidation. The basal ganglia are concerned largely with various aspects of motor control, and have also been implicated in a number of other functions, including procedural learning and habit formation.

The cerebral hemispheres are attached to the diencephalon by massive fiber bundles known as the corona radiata. Major structural components present in the diencephalon include the thalamus, the subthalamus, the hypothalamus, and the epithalamus. The thalamus is the largest component of the diencephalon, and is considered a relay station for projections to cortical neurons from subcortical sensory nuclei. The subthalamus is located below the thalamus and is a way station between the thalamus and the cortex. The hypothalamus (literally, "under the thalamus") is made up of several subnuclei that play critical roles in autonomic, endocrine, and emotional regulation. The epithalamus, which contains the pineal body and the habenular complex, plays a role in endocrine function and the regulation of circadian rhythms (Nolte, 2002).

The middle section of the developing brain is called the mesencephalon or midbrain. At maturity, the mesencephalon resembles its early embryonic form more closely than do either the prosencephalon or the rhombencephalon. The mesencephalon is made up of three main parts, the tectum (containing auditory and visual relay stations called the inferior and superior colliculi), the tegmentum (containing the midbrain reticular formation that activates attention, the substantia nigra that subserves motor functions, and numerous other nuclear groups), and the crus cerebri (a descending bundle of fibers).

The third major section of the brain, part of which eventually exits into the spinal cord at the base of the skull, is the rhombencephalon or hindbrain. It is composed of two subparts, the metencephalon (consisting of the pons and cerebellum) and the myelencephalon (the medulla oblongata). The cerebellum (Latin for "little brain") is a prominent eminence containing more neurons than all other areas of the brain combined. It is subdivided into the vermis, the intermediate zones, and the cerebellar hemispheres. The cerebellum is the center for motor skills and postural adjustments, and it also is involved in certain types of cognitive and emotional activities (Schutter & van Honk, 2005; Schmahmann, 1997). The pons and medulla oblongata contain clusters of cranial nerve nuclei that connect the nerves going to and from the face and head. Because of the shape and position of the pons and medulla at the base of the brain, they often are referred to as the brain stem, although this term usually includes structures in the midbrain and lower diencephalon as well.

Embedded within the brain are four fluid-filled ventricles: two lateral ventricles (one in each hemisphere), the third ventricle, and the fourth ventricle. The lateral ventricles each reside in one of the cerebral hemispheres. The third ventricle is located near the diencephalon, and the fourth ventricle is near the pons and medulla. Cells within the lining of the ventricles produce cerebrospinal fluid (CSF), the clear liquid that fills these cavities. The CSF serves many functions in the brain, including protection from damage by providing a buffer during impact injuries, and removal of waste products from the brain. CSF is also contained within the meninges—the three protective coverings of the brain known as the dura mater, arachnoid, and pia mater.

The various components of the brain are interconnected through a very complicated network of neuronal pathways (Schmahmann & Pandya, 2006), and neurons are in continuous communication (through specialized chemicals called neurotransmitters). Nuclei within the brain seldom act autonomously. Instead, several nuclei and their fiber tracts may act together to organize and modulate complex behaviors, and through their interaction, form the basis for life. The functions subserved by these many diverse structures and systems are generally similar in all normal, healthy adults. Sensory systems regulate information coming from outside and inside the body; attentional systems not only keep us alert, but also allow us to ignore stimulus information that may be irrelevant, and to rest when we need to; motor systems regulate how we respond and move about; and emotional/motivational systems monitor drives, needs, and homeostasis. Other systems help us to learn and to remember or forget. Together, the functioning brain is essential to every aspect of life and consciousness.

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See also: **Central Nervous System; Neocortex; Primary Motor Cortex**