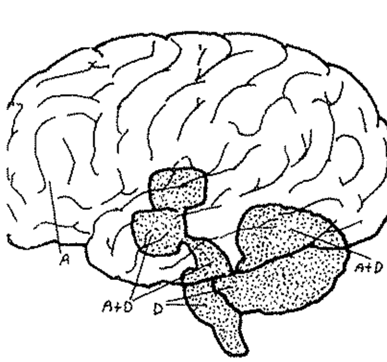
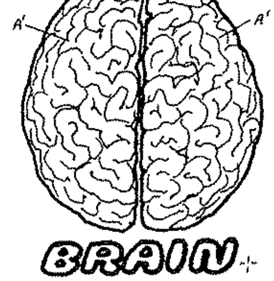


FOREBRAIN A & BRAIN STEM D

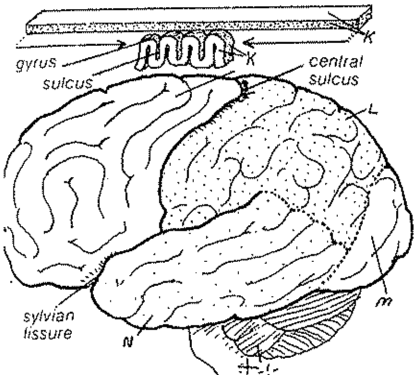
The brain may be divided into a forebrain (cerebrum), subserving higher nervous functions (perceptions, voluntary motor control, emotion, cognition, and language), and a brain stem, regulating internal bodily functions and involuntary reflexes, and also serving as a relay station for signal transmission to and from the forebrain.



BRAIN

FOREBRAIN A
CEREBRAL CORTEX A'
LIMBIC SYSTEM B
BASAL GANGLIA C

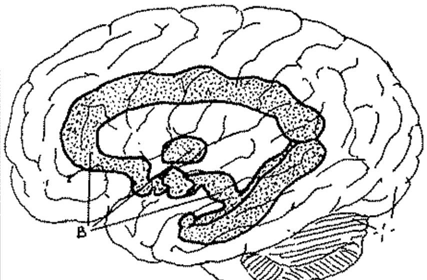
BRAIN STEM D
THALAMUS E
HYPOTHALAMUS F
MIDBRAIN G
PONS H
MEDULLA I
CEREBELLUM J



LOBES OF THE CEREBRAL CORTEX A'

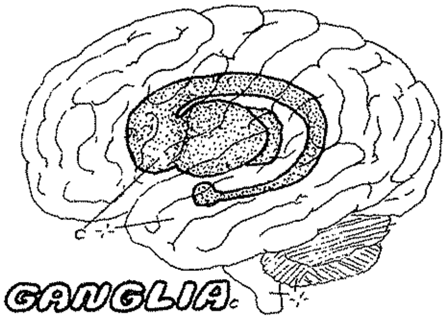
FRONTAL K
PARIETAL L
OCCIPITAL M
TEMPORAL N

The forebrain consists of two hemispheres, each divided into four major lobes — frontal, parietal, occipital, and temporal — plus the insular area (insular lobe). The lobes are covered by the cortex, a wide, thin (3–5 mm) sheet of gray matter, folded extensively to fit in the skull (hence, the convolutions — sulci and gyri). The occipital lobe performs higher visual functions; the temporal lobes house the auditory and associated language and cognitive areas; the parietal lobes perform the somatic sensory and related association functions; the frontal lobes contain the higher motor areas and those for planning and higher behavior. Deep within the lobes are the white matter (fibers), the limbic system, and basal ganglia structure of the forebrain.



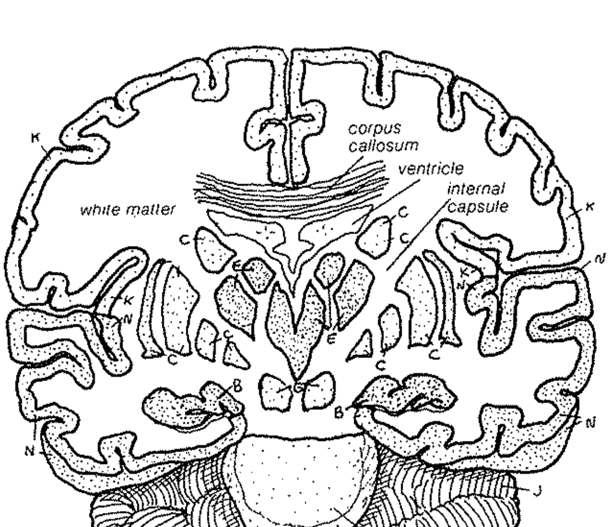
LIMBIC SYSTEM B

The forebrain's limbic system regulates and integrates expression of emotions, feelings, and drives. In lower animals, the limbic system is intimately connected with the olfactory sense. In higher animals, it is well connected with the cortex of the frontal lobes and basal ganglia. Some limbic structures (hippocampus and amygdala) are also involved in memory processing.

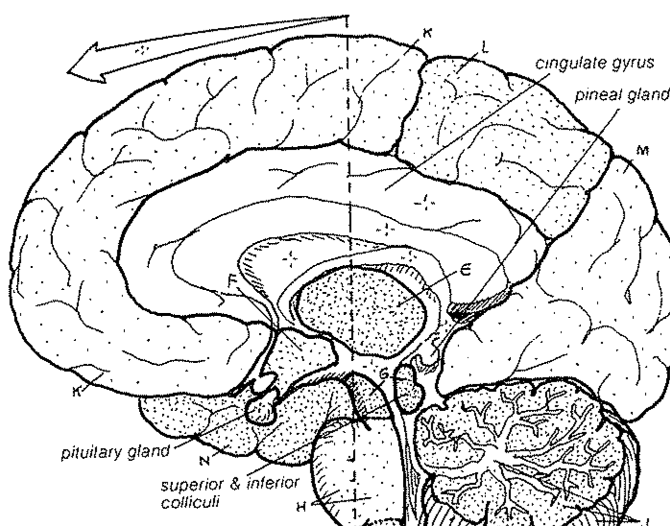


BASAL GANGLIA C

The basal ganglia structures are higher motor centers, functioning in harmony with the motor cortex. Basal ganglia lesions produce pronounced motor disorders (e.g., Parkinson's disease). In birds and lower vertebrates that lack a true cortex (neocortex), the basal ganglia are the highest motor control centers.



CORONAL SECTION



MID-SAGITTAL VIEW

To view the inner structures of the brain, either a coronal (cross) section or a sagittal section can be used. The coronal section shown (left diagram) depicts the relationship between the cortex and the underlying white matter and nerve centers (basal ganglia, thalamus). Note the corpus callosum connecting the two hemispheres. The sagittal section cuts along the medial plane, exposing the hidden medial cortical structures as well as many of the brain stem structures.

BRAIN STRUCTURES & GENERAL FUNCTIONS

Housed in the skull, the *brain* consists of all the parts of the central nervous system (CNS) above the spinal cord. The brain may be divided into two major parts—a lower *brain stem* and a higher *cerebrum (forebrain)*.

BRAIN STEM REGULATES VISCERAL FUNCTIONS & BRAIN REFLEXES

The brain stem is situated directly above the spinal cord and under the brain hemispheres and is connected to these regions with fiber pathways. The brain stem is the more ancient part of the brain and consists of the medulla, pons, and midbrain. The structure and function of the brain stem are fairly similar in the lower and higher vertebrates, particularly among mammals. Brain stem structures carry out many vital somatic, autonomic, and reflexive functions. The centers for respiration, cardiovascular, and digestive functions are in the *medulla*, the "lowest" of the brain's areas. The *pons* has inhibitory control centers for respiration and interacts with the cerebellum.

Other diffusely organized areas in the reticular core of the pons and medulla constitute the *reticular formation*, which is involved in regulation of sleep, wakefulness, and attention as well as controlling the level of excitation in the higher forebrain structures (plate 106). Somatic motor centers (nuclei) in the *midbrain* are involved in regulation of walking and posture and of reflexes for head and eye movements (plate 97). The *cerebellum*, a large motor structure involved in movement coordination, is placed in the back of the brain stem (plate 97).

The anencephalic infant—In the human infant, brain stem capacities are more mature than those of the higher forebrain regions. The role of the brain stem in behavior and body functions may be shown by observing the motor and behavioral abilities of *anencephalic* ("no brain") infants, born without a forebrain. Such infants usually do not survive for long, but during their short lives, they are capable of many behaviors. They can find the nipple and suckle milk, smile, frown, cry and make other infant sounds, and move the head and limbs in a manner similar to normal newborns.

THE FOREBRAIN REGULATES HIGHER BRAIN FUNCTIONS

The human forebrain consists of two hierarchically organized regions, a lower *diencephalon* and a higher *telencephalon*.

Hypothalamus & thalamus—The diencephalon consists of the *hypothalamus* and the *thalamus*. The hypothalamus contains numerous centers (nuclei, areas) for regulating the internal environment (homeostasis), including those for controlling body temperature, blood sugar, hunger and satiety, and sexual behavior. It controls the diurnal cycles by its biological clock and regulates the activities of the endocrine system and hormones. The *thalamus* is a complex sensory-motor relay station involved in integrating sensory signals and relaying them to the *cerebral cortex*. The thalamus also participates in motor control and in regulation of cortical excitation and attention.

Cerebral hemispheres and cortex—Situated above the diencephalic structures of hypothalamus and thalamus is the telencephalon of the forebrain. It consists of two nearly symmetrical *cerebral hemispheres*. These house the *cerebral cortex*, the *basal ganglia*, and the *limbic system*. The two hemispheres are connected by a massive bundle of fibers called the *corpus callosum*. The cerebral cortex is a network of highly organized nerve cells (gray matter) in a sheet about 5 mm thick that covers the surface of the hemispheres (cortex = bark). The neurons of the cortex are organized horizontally in six layers and vertically in functionally distinct "columns" (plates 93, 100).

The large surface area of the cortex and the need to fit this sheet within the skull produces the folds and convolutions seen in the outer brain surface (sulcus = furrow; gyrus = convolution). The cortex and the associated large mass of nerve fibers (white matter) make up the bulk of the cerebral hemispheres. In humans, the cerebral cortex is extremely well developed in both size and nerve cell organization, enabling it to be the site of the highest and most intricate analysis and integration of sensory and motor information (plate 111).

Cortical lobes—Each hemisphere (particularly its cortex) is divided into four externally visible major lobes and a large, externally hidden area, "the insula." The *frontal* lobe extends from the anterior tip of the hemisphere back to the *central sulcus* (fissure of Rolando). The posterior areas of the frontal lobe are specialized for motor functions (plate 96) and the anterior areas are involved in learning, planning, speech, and some other psychological functions (plate 111). The *occipital lobe*, located in the back of the hemisphere, carries out mainly visual functions (plate 100). The *parietal lobe* consists of the dorsal (top) and lateral areas between the frontal and occipital lobes and is specialized for somatic sensory functions (e.g., skin senses) and related association and integrative roles (plate 93). Certain areas in the parietal lobe also are very important in cognitive and intellectual processes. The *temporal lobe* comprises the hearing centers and related association areas, including some speech centers. Other areas of the temporal lobe are important in memory (plate 109). The anterior and basal areas of the temporal lobe are involved in the sense of smell and in functions related to the limbic system. A fifth major cortical area, the "insular lobe," is not visible externally and is buried deep to the lateral fissure.

The basal ganglia & the limbic system—The forebrain also houses the *basal ganglia*, a complex of mainly motor structures. In lower animals, the basal ganglia are the only higher motor structures. In humans, the basal ganglia structures work in conjunction with the motor areas of the cortex and cerebellum to plan and coordinate gross voluntary movements (plate 97). Another forebrain system is the *limbic system* or "limbic lobe." The limbic system structures—the hippocampus, the amygdala, the cingulate gyrus, and the septum—work with the hypothalamus to intimately control the expression of instinctive behavior, emotions, and drives. Also, the hippocampus and amygdala have been found to have major cognitive functions, mainly in processing of memory. Overall size and organization of the limbic system do not change significantly during the course of mammalian evolution, indicating this system's involvement with basic instinctive behaviors common to all species of mammals (plates 97, 108).

Although the motor, sensory, cognitive, and behavioral functions are fairly well localized to distinct brain areas, these regions are well connected by fiber pathways, and the brain often works as a whole. This is true for the "global functions" of the brain such as learning, memory, and consciousness.

CN: Use dark colors for B, C, E, F, and G.
1. Begin in the upper right corner by coloring the cortex of the two cerebral hemispheres (A') and the list of titles, without coloring the structures to which the titles refer. Then start with the material in the upper left corner and work your way down to the limbic system and across the basal ganglia.
2. Color both views at the bottom simultaneously. The vertical broken line in the mid-sagittal view shows the location of the coronal section.