OBJECTIVES

- List the elements of the central and peripheral divisions of the nervous system.
- Discuss the difference between the sensory and motor portions of the nervous system, and name the two divisions of the motor portion.
- Recognize the terms that describe the development of the human brain, and discuss the relationships between the terms.
- As directed by your instructor, identify the bold terms associated with the cerebral hemispheres, diencephalon, brain stem, and cerebellum on a dissected human brain, brain model, or appropriate image, and state their functions.
- State the differences among gyri, fissures, and sulci.
- Describe the composition of gray matter and white matter in the nervous system.
- Name and describe the three meninges that cover the brain, state their functions, and locate the falx cerebri, falx cerebelli, and tentorium cerebelli.
- Discuss the formation, circulation, and drainage of cerebrospinal fluid.
- Identify the cranial nerves by number and name on a model or image, stating the origin and function of each.
- Identify at least four key anatomical differences between the human brain and sheep brain.

PRE-LAB QUIZ

1. Circle the correct underlined term. The central nervous system / peripheral nervous system consists of the brain and spinal cord.

2. Circle the correct underlined term. The most superior portion of the brain includes the cerebral hemispheres / brain stem.

3. Circle True or False. Deep grooves within the cerebral hemispheres are known as gyri.

4. On the ventral surface of the brain, you can observe the optic nerves and chiasma, the pituitary gland, and the mammillary bodies. These externally visible structures form the floor of the:
   a. brain stem  
   b. diencephalon  
   c. frontal lobe  
   d. occipital lobe

5. Circle the correct underlined term. The inferior region of the brain stem, the medulla oblongata / cerebellum houses many vital autonomic centers involved in the control of heart rate, respiratory rhythm, and blood pressure.

6. Directly under the occipital lobe of the cerebrum is a large cauliflower-like structure known as the:
   a. brain stem  
   b. cerebellum  
   c. diencephalon

Text continues on next page.
When viewed alongside all Earth’s animals, humans are indeed unique, and the key to our uniqueness is found in the brain. Each of us is a reflection of our brain’s experience. If all past sensory input could mysteriously and suddenly be “erased,” we would be unable to walk, talk, or communicate in any manner. Spontaneous movement would occur, as in a fetus, but no voluntary integrated function of any type would be possible. Clearly we would cease to be the same individuals.

For convenience, the nervous system is considered in terms of two principal divisions: the central nervous system and the peripheral nervous system. The central nervous system (CNS) consists of the brain and spinal cord, which primarily interpret incoming sensory information and issue instructions based on that information and on past experience. The peripheral nervous system (PNS) consists of the cranial and spinal nerves, ganglia, and sensory receptors.

The PNS has two major subdivisions: the sensory portion, which consists of nerve fibers that conduct impulses from sensory receptors toward the CNS, and the motor portion, which contains nerve fibers that conduct impulses away from the CNS. The motor arm, in turn, consists of the somatic division (sometimes called the voluntary system), which controls the skeletal muscles, and the other subdivision, the autonomic nervous system (ANS), which controls smooth and cardiac muscles and glands.

This exercise focuses on the brain (CNS) and cranial nerves (PNS) because of their close anatomical relationship.

### The Human Brain

During embryonic development of all vertebrates, the CNS first makes its appearance as a simple tubelike structure, the neural tube, that extends down the dorsal median plane. By the fourth week, the human brain begins to form as an expansion of the anterior or rostral end of the neural tube (the end toward the head). Shortly thereafter, constrictions appear, dividing the developing brain into three major regions—forebrain, midbrain, and hindbrain (Figure 14.1). The remainder of the neural tube becomes the spinal cord.

The central canal of the neural tube, which remains continuous throughout the brain and cord, enlarges in four regions of the brain, forming chambers called ventricles (see Figure 14.8a and b, page 265).

####_identifying External Brain Structures

Identify external brain structures using the figures cited. Also use a model of the human brain and other learning aids as they are mentioned.

Generally, the brain is studied in terms of four major regions: the cerebral hemispheres, diencephalon, brain stem, and cerebellum.

### Cerebral Hemispheres

The cerebral hemispheres are the most superior portion of the brain (Figure 14.2). Their entire surface is thrown into elevated ridges of tissue called gyri that are separated by shallow grooves called sulci or deeper grooves called fissures. Many of the fissures and gyri are important anatomical landmarks.

The cerebral hemispheres are divided by a single deep fissure, the longitudinal fissure. The central sulcus divides the frontal lobe from the parietal lobe, and the lateral sulcus separates the temporal lobe from the parietal lobe. The parieto-occipital sulcus on the medial surface of each hemisphere divides the occipital lobe from the parietal lobe. The sulcus is not visible externally. Notice that these cerebral hemisphere lobes are named for the cranial bones that lie over them. A fifth lobe of each cerebral hemisphere, the insula, is buried deep within the lateral sulcus and is covered by portions of the temporal, parietal, and frontal lobes.

Some important functional areas of the cerebral hemispheres have also been located (Figure 14.2d).

The cell bodies of cerebral neurons involved in these functions are found only in the outermost gray matter of the cerebrum, the area called the cerebral cortex. Most of the balance of cerebral tissue—the deeper cerebral white matter—is composed of myelinated fibers bundled into tracts carrying impulses to or from the cortex. Some of the functional areas are summarized in Table 14.1.

Using a model of the human brain (and a preserved human brain, if available), identify the areas and structures of the cerebral hemispheres described above.

Then continue using the model and preserved brain along with the figures as you read about other structures.

### Diencephalon

The diencephalon is embryologically part of the forebrain, along with the cerebral hemispheres. See Figure 17.1, page 308.
Figure 14.1 Embryonic development of the human brain. (a) The neural tube becomes subdivided into (b) the primary brain vesicles, which subsequently form (c) the secondary brain vesicles, which differentiate into (d) the adult brain structures. (e) The adult structures derived from the neural canal.

Figure 14.2 External structure (lobes and fissures) of the cerebral hemispheres. (a) Left lateral view of the brain. (b) Superior view. (c) Photograph of the superior aspect of the human brain.
Figure 14.2 (continued) External structure (lobes and fissures) of the cerebral hemispheres. (d) Functional areas of the left cerebral cortex. The olfactory cortex, which is deep within the temporal lobe on the medial hemispheric surface, is not identified here.

Turn the brain model so the ventral surface of the brain can be viewed. Starting superiorly (and using Figure 14.3 as a guide), identify the externally visible structures that mark the position of the floor of the diencephalon. These are the olfactory bulbs (synapse point of cranial nerve I) and tracts, optic nerves (cranial nerve II), optic chiasm (where the medial fibers of the optic nerves cross over), optic tracts, pituitary gland, and mammillary bodies.

**Brain Stem**
Continue to identify the brain stem structures—the cerebral peduncles (fiber tracts in the midbrain connecting the pons

<table>
<thead>
<tr>
<th>Table 14.1</th>
<th>Important Functional Areas of the Cerebral Cortex</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional sensory areas</strong></td>
<td><strong>Location</strong></td>
</tr>
<tr>
<td>Primary somatosensory cortex</td>
<td>Postcentral gyrus of the parietal lobe</td>
</tr>
<tr>
<td>Primary visual cortex</td>
<td>Occipital lobe</td>
</tr>
<tr>
<td>Primary auditory cortex</td>
<td>Temporal lobe in the gyrus bordering the lateral sulcus</td>
</tr>
<tr>
<td>Olfactory cortex</td>
<td>Medial surface of the temporal lobe, in a region called the uncus</td>
</tr>
<tr>
<td><strong>Functional motor areas</strong></td>
<td><strong>Location</strong></td>
</tr>
<tr>
<td>Primary motor cortex</td>
<td>Precentral gyrus of the frontal lobe</td>
</tr>
<tr>
<td>Broca’s area</td>
<td>At the base of the precentral gyrus of the frontal lobe just above the superior sulcus, in only one hemisphere</td>
</tr>
</tbody>
</table>
below with the cerebrum above), the pons, and the medulla oblongata. Pons means “bridge,” and the pons consists primarily of motor and sensory fiber tracts connecting the brain with lower CNS centers. The lowest brain stem region, the medulla oblongata, often shortened to just medulla, is also composed primarily of fiber tracts. You can see the decussation of pyramids, a crossover point for the major motor tracts (pyramidal tracts) descending from the motor areas of the cerebrum to the spinal cord, on the medulla’s surface. The medulla also houses many vital autonomic centers involved in the control of heart rate, respiratory rhythm, and blood pressure as well as involuntary centers involved in vomiting, and swallowing.

Cerebellum

1. Turn the brain model so you can see the dorsal aspect. Identify the large cauliflower-shaped cerebellum, which projects dorsally from under the occipital lobe of the cerebrum. Notice that, like the cerebrum, the cerebellum has two major hemispheres and a convoluted surface (see Figure 14.6). It also has an outer cortex made up of gray matter with an inner region of white matter.

2. Remove the cerebellum to view the corpora quadrigemina (Figure 14.4), located on the posterior aspect of the midbrain, a brain stem structure. The two superior prominences are the superior colliculi (visual reflex centers); the two smaller inferior prominences are the inferior colliculi (auditory reflex centers).

**Activity 2**

**Identifying Internal Brain Structures**

The deeper structures of the brain have also been well mapped. As the internal brain areas are described, identify them on the figures cited. Also, use the brain model as indicated to help you in this study.

**Cerebral Hemispheres**

1. Take the brain model apart so you can see a medial view of the internal brain structures (see Figure 14.4). Observe the model closely to see the extent of the outer cortex (gray matter), which contains the cell bodies of cerebral neurons. The pyramidal cells of the cerebral motor cortex (Exercise 13 and Figure 13.5) are representative of the neurons seen in the precentral gyrus.

2. Observe the deeper area of white matter, which is made up of fiber tracts. The fiber tracts found in the cerebral hemisphere white matter are called association tracts if they connect two portions of the same hemisphere, projection tracts if they run between the cerebral cortex and lower brain structures or spinal cord, and commissures if they run from one hemisphere to another. Observe the large corpus callosum,
Figure 14.4 Diencephalon and brain stem structures as seen in a median section of the brain. (a) Photograph. (b) Diagram.
the major commissure connecting the cerebral hemispheres. The corpus callosum arches above the structures of the diencephalon and roofs over the lateral ventricles. Notice also the *fornix*, a bandlike fiber tract concerned with olfaction as well as limbic system functions, and the membranous *septum pellucidum*, which separates the lateral ventricles of the cerebral hemispheres.

3. In addition to the gray matter of the cerebral cortex, there are several clusters of neuron cell bodies called *nuclei* buried deep within the white matter of the cerebral hemispheres. One important group of cerebral nuclei, called the *basal nuclei*, or *basal ganglia*, flank the lateral and third ventricles. You can see these nuclei if you have an appropriate dissectible model or a coronally or cross-sectional human brain slice. Otherwise, the figure (*Figure 14.5*) will suffice.

The basal nuclei are involved in regulating voluntary motor activities. The most important of them are the *caudate nucleus*, the *putamen*, and *globus pallidus*.

The *corona radiata*, a spray of projection fibers coursing down from the precentral (motor) gyrus, combines with sensory fibers traveling to the primary somatosensory cortex to form a broad band of fibrous material called the *internal capsule*. The internal capsule passes between the thalamus and the basal nuclei and through the caudate and putamen, giving them a striped appearance. Hence they are called the *striatum*, or “striped” body (*Figure 14.5a*).

4. Examine the relationship of the lateral ventricles and corpus callosum to the thalamus and third ventricle—from the cross-sectional viewpoint (*Figure 14.5b*).

### Diencephalon

1. The major internal structures of the diencephalon are the thalamus, hypothalamus, and epithalamus (see *Figure 14.4*). The *thalamus* consists of two large lobes of gray matter that laterally enclose the narrow third ventricle of the brain. A slender stalk of thalamic tissue, the *interthalamic adhesion*, or *intermediate mass*, connects the two thalamic lobes and bridges the ventricle. The thalamus is a major integrating and relay station for sensory impulses passing upward to the cortical sensory areas for localization and interpretation.

2. The *hypothalamus* makes up the floor and the inferolateral walls of the third ventricle. It is an important autonomic center involved in regulating body temperature, water balance, and fat and carbohydrate metabolism as well as many other activities and drives (sex, hunger, thirst). Locate again the pituitary gland, which hangs from the anterior floor of the hypothalamus by a slender stalk, the *infundibulum*. The pituitary rests in the hypophyseal fossa of the sella turcica of the sphenoid bone.

3. The *epithalamus* forms the roof of the third ventricle and is the most dorsal portion of the diencephalon. Important structures in the epithalamus are the *pineal gland* and the choroid plexus of the third ventricle.

### Brain Stem

1. Now trace the short midbrain from the mammillary bodies to the rounded pons below. (Continue to refer to *Figure 14.4*) The *cerebral aqueduct* is a slender canal traveling through the midbrain; it connects the third ventricle to the fourth ventricle. The cerebral peduncles and the rounded corpora quadrigemina make up the midbrain tissue anterior and posterior (respectively) to the cerebral aqueduct.

2. Locate the hindbrain structures. Trace the rounded pons to the medulla oblongata below, and identify the fourth ventricle posterior to these structures. Attempt to identify the single median aperture and the two lateral apertures, three openings found in the walls of the fourth ventricle. These apertures serve as passageways for cerebrospinal fluid to circulate into the subarachnoid space from the fourth ventricle.

### Cerebellum

Examine the cerebellum. Notice that it is composed of two lateral hemispheres, each with three lobes *(anterior, posterior; and a deep flocculonodular)* connected by a midline lobe called the *vermis* (*Figure 14.6*). As in the cerebral hemispheres, the cerebellum has an outer cortical area of gray matter and an inner area of white matter. The treelike branching of the cerebellar white matter is referred to as the *arbor vitae*, or “tree of life.” The cerebellum controls the unconscious coordination of skeletal muscle activity along with balance and equilibrium.

### Vegetative State (VS)

We appreciate the thalamus more when we look at what happens when it is damaged. This is the problem that afflicts patients trapped in a vegetative state. A vegetative state (VS) is described as a disorder of consciousness that lasts more than 4 weeks in which the patient has lost awareness of self and environment. Unlike coma patients, who cannot be awakened, VS patients can be aroused—they display wakefulness without awareness. The vegetative state is clinical loss of cerebral cortex function with unaffected brain stem function. In many cases, there is no structural damage to the cerebral cortex, but its function is lost because the relay of signals to the cortex—the thalamus—is not working.

*The historical term for these nuclei, *basal ganglia*, is misleading because ganglia are PNS structures. Although technically not the correct anatomical term, “basal ganglia” is included here because it is widely used in clinical settings.*
Figure 14.5 Basal nuclei. (a) Three-dimensional view of the basal nuclei showing their positions within the cerebrum. Globus pallidus lies medial and deep to the putamen. (b) A transverse section of the cerebrum and diencephalon showing the relationship of the basal nuclei to the thalamus and the lateral and third ventricles.
Meninges of the Brain

The brain and spinal cord are covered and protected by three connective tissue membranes called meninges (Figure 14.7). The outermost meninx is the leathery dura mater, a double-layered membrane. One of its layers (the periosteal layer) is attached to the inner surface of the skull, forming the periosteum. The other layer (the meningeal layer) forms the outermost brain covering and is continuous with the dura mater of the spinal cord.

The dural layers are fused together except in three places where the inner membrane extends inward to form a septum that secures the brain to structures inside the cranial cavity. One such extension, the falx cerebri, dips into the longitudinal fissure between the cerebral hemispheres to attach to the crista galli of the ethmoid bone of the skull (Figure 14.7a). The cavity created at this point is the large superior sagittal sinus, which collects blood draining from the brain tissue. The falx cerebelli, separating the two cerebellar hemispheres, and the tentorium cerebelli, separating the cerebrum from the cerebellum below, are two other important inward folds of the inner dural membrane.

The middle meninx, the weblike arachnoid mater, underlies the dura mater and is partially separated from it by the subdural space. Threadlike projections bridge the subarachnoid space to attach the arachnoid to the innermost meninx, the pia mater. The delicate pia mater is highly vascular and clings tenaciously to the surface of the brain, following its gyri.

The subarachnoid space is filled with cerebrospinal fluid. Specialized projections of the arachnoid tissue called arachnoid granulations, or arachnoid villi, protrude through the dura mater. These granulations allow the cerebrospinal fluid to drain back into the venous circulation via the superior sagittal sinus and other dural venous sinuses.

Meningitis, inflammation of the meninges, is a serious threat to the brain because of the intimate association between the brain and meninges. Should infection spread to the neural tissue of the brain itself, life-threatening encephalitis may occur. Meningitis is often diagnosed by taking a sample of cerebrospinal fluid (via a lumbar puncture) from the subarachnoid space.

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Cerebrospinal Fluid

The cerebrospinal fluid (CSF), much like plasma in composition, is continually formed by the choroid plexuses, small capillary knots hanging from the roof of the ventricles of the brain. The cerebrospinal fluid in and around the brain forms a watery cushion that protects the delicate brain tissue against blows to the head.

Within the brain, the cerebrospinal fluid circulates from the two lateral ventricles (in the cerebral hemispheres) into the third ventricle via the interventricular foramina, and then through the cerebral aqueduct of the midbrain into the fourth ventricle (Figure 14.8). CSF enters the subarachnoid space through the three foramina in the walls of the fourth ventricle. There it bathes the outer surfaces of the brain and spinal cord. The fluid returns to the blood in the dural venous sinuses via the arachnoid granulations.

Ordinarily, cerebrospinal fluid forms and drains at a constant rate. However, under certain conditions—for example, obstructed drainage or circulation resulting from tumors or anatomical deviations—cerebrospinal fluid accumulates and exerts increasing pressure on the brain which, uncorrected, causes neurological damage in adults. In infants, hydrocephalus (literally, “water on the brain”) is indicated by a gradually enlarging head. The infant’s skull is still flexible and contains fontanelles, so it can expand to accommodate the increasing size of the brain.
Exercise 14

Cranial Nerves

The cranial nerves (Figure 14.9) are part of the peripheral nervous system and not part of the brain proper, but they are most appropriately identified while studying brain anatomy. The 12 pairs of cranial nerves primarily serve the head and neck. Only one pair, the vagus nerves, extends into the thoracic and abdominal cavities. All but the first two pairs (olfactory and optic nerves) arise from the brain stem and pass through foramina in the base of the skull to reach their destination.

The cranial nerves are numbered consecutively, and in most cases their names reflect the major structures they control. The cranial nerves are described by name, number (Roman numeral), origin, course, and function in Table 14.2. You should memorize this information. A mnemonic device that might be helpful for remembering the cranial nerves in order is “On Occasion, Our Trusty Truck Acts Funny—Very Good Vehicle AnyHow.” The first letter of each word and the “a” and “h” of the final word “anyhow” will remind you of the first letter of each cranial nerve name.

Text continues on page 269.
Figure 14.8 Location and circulatory pattern of cerebrospinal fluid. (a, b) Brain ventricles. Regions of the large lateral ventricles are the anterior horn, posterior horn, and inferior horn. (c) Cerebrospinal fluid (CSF) flows from the lateral ventricles, through the interventricular foramina into the third ventricle, and then into the fourth ventricle via the cerebral aqueduct. Most of the CSF circulates in the subarachnoid space and returns to the dural venous sinuses via the arachnoid granulations.
### The Cranial Nerves (see Figure 14.9)

<table>
<thead>
<tr>
<th>Number and name</th>
<th>Origin and course</th>
<th>Function*</th>
<th>Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Olfactory</td>
<td>Fibers arise from olfactory epithelium and run through cribriform foramina of ethmoid bone to synapse in olfactory bulbs.</td>
<td>Purely sensory—carries afferent impulses associated with sense of smell.</td>
<td>Person is asked to sniff aromatic substances, such as oil of cloves and vanilla, and to identify each.</td>
</tr>
<tr>
<td>II. Optic</td>
<td>Fibers arise from retina of eye and pass through optic canal of the sphenoid bone. Fibers partially cross over at the optic chiasma and continue on to the thalamus as the optic tracts. Final fibers of this pathway travel from the thalamus to the primary visual cortex as the optic radiation.</td>
<td>Purely sensory—carries afferent impulses associated with vision.</td>
<td>Vision and visual field are determined with eye chart and by testing the point at which the person first sees an object (finger) moving into the visual field. Fundus of eye viewed with ophthalmoscope to detect papilledema (swelling of optic disc, the point at which optic nerve leaves the eye) and to observe blood vessels.</td>
</tr>
<tr>
<td>III. Oculomotor</td>
<td>Fibers emerge from ventral midbrain and course ventrally to enter the orbit. They exit from skull via superior orbital fissure.</td>
<td>Primarily motor—somatic motor fibers to inferior oblique and superior, inferior, and medial rectus muscles, which direct eyeball, and to levator palpebrae muscles of the superior eyelid; parasympathetic fibers to iris and smooth muscle controlling lens shape and pupil size.</td>
<td>Pupils are examined for size, shape, and equality. Pupillary reflex is tested with penlight (pupils should constrict when illuminated). Convergence for near vision is tested, as is subject’s ability to follow objects with the eyes.</td>
</tr>
<tr>
<td>IV. Trochlear</td>
<td>Fibers emerge from midbrain and exit from skull via superior orbital fissure.</td>
<td>Primarily motor—provides somatic motor fibers to superior oblique muscle that moves the eyeball.</td>
<td>Tested in common with cranial nerve III.</td>
</tr>
<tr>
<td>V. Trigeminal</td>
<td>Fibers run from face to pons and form three divisions, which exit separately from skull: mandibular division fibers pass through foramen ovale in sphenoid bone, maxillary division fibers pass via foramen rotundum in sphenoid bone, and ophthalmic division fibers pass through superior orbital fissure of sphenoid bone.</td>
<td>Mixed—major sensory nerve of face; conducts sensory impulses from skin of face and anterior scalp, from mucosae of mouth and nose, and from surface of eyes; mandibular division also contains motor fibers that innervate muscles of mastication and muscles of floor of mouth.</td>
<td>Sensations of pain, touch, and temperature are tested with safety pin and hot and cold probes. Corneal reflex tested with wisp of cotton. Motor branch assessed by asking person to clench the teeth, open mouth against resistance, and move jaw side to side.</td>
</tr>
<tr>
<td>VI. Abducens</td>
<td>Fibers leave inferior region of pons and exit from skull via superior orbital fissure.</td>
<td>Primarily motor—carries somatic motor fibers to lateral rectus muscle that abducts the eyeball.</td>
<td>Tested in common with cranial nerve III.</td>
</tr>
</tbody>
</table>

*Does not include sensory impulses from proprioceptors.
<table>
<thead>
<tr>
<th>Number and name</th>
<th>Origin and course</th>
<th>Function*</th>
<th>Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII. Facial</td>
<td>Fibers leave pons and travel through temporal bone via internal acoustic meatus, exiting via stylomastoid foramen to reach the face.</td>
<td>Mixed—supplies somatic motor fibers to muscles of facial expression and the posterior belly of the digastric muscle; supplies parasympathetic motor fibers to lacrimal and salivary glands; carries sensory fibers from taste receptors of anterior portion of tongue.</td>
<td>Anterior two-thirds of tongue is tested for ability to taste sweet (sugar), salty, sour (vinegar), and bitter (quinine) substances. Symmetry of face is checked. Subject is asked to close eyes, smile, whistle, and so on. Tearing is assessed with ammonia fumes.</td>
</tr>
<tr>
<td>VIII. Vestibulocochlear</td>
<td>Fibers run from inner ear equilibrium and hearing apparatus, housed in temporal bone, through internal acoustic meatus to enter pons.</td>
<td>Mostly sensory—vestibular branch transmits impulses associated with sense of equilibrium from vestibular apparatus and semicircular canals; cochlear branch transmits impulses associated with hearing from cochlea. Small motor component adjusts the sensitivity of sensory receptors.</td>
<td>Hearing is checked by air and bone conduction using tuning fork.</td>
</tr>
<tr>
<td>IX. Glossopharyngeal</td>
<td>Fibers emerge from medulla and leave skull via jugular foramen to run to throat.</td>
<td>Mixed—somatic motor fibers serve pharyngeal muscles, and parasympathetic motor fibers serve salivary glands; sensory fibers carry impulses from pharynx, tonsils, posterior tongue (taste buds), and pressure receptors of carotid artery.</td>
<td>A tongue depressor is used to check the position of the uvula. Gag and swallowing reflexes are checked. Subject is asked to speak and cough. Posterior third of tongue may be tested for taste.</td>
</tr>
<tr>
<td>X. Vagus</td>
<td>Fibers emerge from medulla and pass through jugular foramen and descend through neck region into thorax and abdomen.</td>
<td>Mixed—fibers carry somatic motor impulses to pharynx and larynx and sensory fibers from same structures; very large portion is composed of parasympathetic motor fibers, which supply heart and smooth muscles of abdominal visceral organs; transmits sensory impulses from viscera.</td>
<td>As for cranial nerve IX (IX and X are tested in common, because they both innervate muscles of throat and mouth).</td>
</tr>
<tr>
<td>XI. Accessory</td>
<td>Fibers arise from medulla and superior aspect of spinal cord and travel through jugular foramen to reach muscles of neck and back.</td>
<td>Mixed (but primarily motor in function)—provides somatic motor fibers to sternocleidomastoid and trapezius muscles.</td>
<td>Sternocleidomastoid and trapezius muscles are checked for strength by asking person to rotate head and shoulders against resistance.</td>
</tr>
<tr>
<td>XII. Hypoglossal</td>
<td>Fibers arise from medulla and exit from skull via hypoglossal canal to travel to tongue.</td>
<td>Mixed (but primarily motor in function)—carries somatic motor fibers to muscles of tongue.</td>
<td>Person is asked to protrude and retract tongue. Any deviations in position are noted.</td>
</tr>
</tbody>
</table>

*Does not include sensory impulses from proprioceptors.
Figure 14.9 Ventral aspect of the human brain, showing the cranial nerves. (See also Figure 14.3.)
Most cranial nerves are mixed nerves (containing both motor and sensory fibers). But close scrutiny of the table (Table 14.2) will reveal that three pairs of cranial nerves (optic, olfactory, and vestibulocochlear) are primarily or exclusively sensory in function.

**Activity 3**

**Identifying and Testing the Cranial Nerves**

1. Observe the anterior surface of the brain model to identify the cranial nerves (Figure 14.9). Notice that the first (olfactory) cranial nerves are not visible on the model because they consist only of short axons that run from the nasal mucosa through the cribriform foramina of the ethmoid bone. (However, the synapse points of the first cranial nerves, the olfactory bulbs, are visible on the model.)

2. Testing cranial nerves is an important part of any neurological examination. (See the last column of Table 14.2 for techniques you can use for such tests.) The results may help you understand cranial nerve function, especially as it pertains to some aspects of brain function.

3. Several cranial nerve ganglia are named in the accompanying chart. Using your textbook or another appropriate reference, fill in the **Activity 3 chart** by naming the cranial nerve the ganglion is associated with and stating the ganglion’s location.

<table>
<thead>
<tr>
<th>Cranial nerve ganglion</th>
<th>Cranial nerve</th>
<th>Site of ganglion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigeminal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geniculate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spiral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vestibular</td>
<td></td>
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</tr>
</tbody>
</table>

**Dissection**

**The Sheep Brain**

The sheep brain is enough like the human brain to warrant comparison. Obtain a sheep brain, disposable gloves, dissecting tray, and instruments, and bring them to your laboratory bench.
Figure 14.11 Intact sheep brain. (a) Photograph of ventral view. (b) Diagram of ventral view.
Gross Anatomy of the Brain and Cranial Nerves

1. Identify the cerebral peduncles on the ventral aspect of the midbrain, just posterior to the mammillary body of the hypothalamus. The cerebral peduncles are fiber tracts connecting the cerebrum and medulla oblongata. Identify the large oculomotor nerves (III), which arise from the ventral midbrain surface, and the tiny trochlear nerves (IV), which can be seen at the junction of the midbrain and pons. Both of these cranial nerves provide motor fibers to extrinsic muscles of the eyeball.

2. Move posteriorly from the midbrain to identify first the pons and then the medulla oblongata, structures composed primarily of ascending and descending fiber tracts.

3. Return to the junction of the pons and midbrain, and proceed posteriorly to identify the following cranial nerves, all arising from the pons. Check them off as you locate them. (Figure 14.11b):
   - Trigeminal nerves (V), which are involved in chewing and sensations of the head and face.
   - Abducens nerves (VI), which abduct the eye (and thus work in conjunction with cranial nerves III and IV).
   - Facial nerves (VII), large nerves involved in taste sensation, gland function (salivary and lacrimal glands), and facial expression.

Ventral Structures

Turn the brain so that its ventral surface is uppermost. (Figure 14.11a and b show the important features of the ventral surface of the brain.)

1. Look for the clublike olfactory bulbs anteriorly, on the inferior surface of the frontal lobes of the cerebral hemispheres. Axons of olfactory neurons run from the nasal mucosa through the cribriform foramina of the ethmoid bone to synapse with the olfactory bulbs.

How does the size of these olfactory bulbs compare with those of humans?

Is the sense of smell more important for protection and foraging in sheep or in humans?

2. The optic nerve (II) carries sensory impulses from the retina of the eye. Thus this cranial nerve is involved in the sense of vision. Identify the optic nerves, optic chiasma, and optic tracts.

3. Posterior to the optic chiasma, two structures protrude from the ventral aspect of the hypothalamus—the infundibulum (stalk of the pituitary gland) immediately posterior to the optic chiasma and the mammillary body. Notice that the sheep’s mammillary body is a single rounded eminence. In humans it is a double structure.

4. Identify the cerebral peduncles on the ventral aspect of the midbrain, just posterior to the mammillary body of the hypothalamus. The cerebral peduncles are fiber tracts connecting the cerebrum and medulla oblongata. Identify the large oculomotor nerves (III), which arise from the ventral midbrain surface, and the tiny trochlear nerves (IV), which can be seen at the junction of the midbrain and pons. Both of these cranial nerves provide motor fibers to extrinsic muscles of the eyeball.

5. Move posteriorly from the midbrain to identify first the pons and then the medulla oblongata, structures composed primarily of ascending and descending fiber tracts.

6. Return to the junction of the pons and midbrain, and proceed posteriorly to identify the following cranial nerves, all arising from the pons. Check them off as you locate them. (Figure 14.11b):
   - Trigeminal nerves (V), which are involved in chewing and sensations of the head and face.
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   - Facial nerves (VII), large nerves involved in taste sensation, gland function (salivary and lacrimal glands), and facial expression.
Exercise 14

7. Continue posteriorly to identify:
   - Vestibulocochlear nerves (VIII), mostly sensory nerves that are involved with hearing and equilibrium.
   - Glossopharyngeal nerves (IX), which contain motor fibers innervating throat structures and sensory fibers transmitting taste stimuli (in conjunction with cranial nerve VII).
   - Vagus nerves (X), often called “wanderers,” which serve many organs of the head, thorax, and abdominal cavity.
   - Accessory nerves (XI), which serve muscles of the neck, larynx, and shoulder; notice that the accessory nerves arise from both the medulla and the spinal cord.
   - Hypoglossal nerves (XII), which stimulate tongue and neck muscles.

   It is likely that some of the cranial nerves will have been broken off during brain removal. If so, observe sheep brains of other students to identify those missing from your specimen, using your check marks as a guide.

**Dorsal Structures**

1. Refer to Figure 14.11c as a guide in identifying the following structures. Re-identify the now exposed cerebral hemispheres. How does the depth of the fissures in the sheep’s cerebral hemispheres compare to that in the human brain?

2. Examine the cerebellum. Notice that in contrast to the human cerebellum, it is not divided longitudinally and that its fissures are oriented differently. What dural fold (falx cerebri or falx cerebelli) is missing that is present in humans?

3. Locate the three pairs of cerebellar peduncles, fiber tracts that connect the cerebellum to other brain structures, by lifting the cerebellum dorsally away from the brain stem. The most posterior pair, the inferior cerebellar peduncles, connect the cerebellum to the medulla. The middle cerebellar peduncles attach the cerebellum to the pons, and the superior cerebellar peduncles run from the cerebellum to the midbrain.

4. To expose the dorsal surface of the midbrain, gently separate the cerebrum and cerebellum (Figure 14.12). Identify the corpora quadrigemina, which appear as four rounded prominences on the dorsal midbrain surface.

   What is the function of the corpora quadrigemina?

   Also locate the pineal gland, which appears as a small oval protrusion in the midline just anterior to the corpora quadrigemina.

**Internal Structures**

1. The internal structure of the brain can be examined only after further dissection. Place the brain ventral side down on the dissecting tray, and make a cut completely through it in a superior-to-inferior direction. Cut through the longitudinal fissure, corpus callosum, and midline of the cerebellum. Refer to Figure 14.13 as you work.

2. The thin nervous tissue membrane immediately ventral to the corpus callosum that separates the lateral ventricles is the septum pellucidum. Pierce this membrane, and probe the lateral ventricle cavity. The fiber tract ventral to the septum pellucidum and anterior to the third ventricle is the fornix.

   How does the relative size of the fornix in this brain compare with the human fornix?

   Why do you suppose this is so? (Hint: What is the function of this band of fibers?)

3. Identify the thalamus, which forms the walls of the third ventricle and is located posterior and ventral to the fornix. The interthalamic adhesion spanning the ventricular cavity appears as an oval protrusion of the thalamic wall.
4. The hypothalamus forms the floor of the third ventricle. Identify the optic chiasma, infundibulum, and mammillary body on its exterior surface. The pineal gland is just beneath the junction of the corpus callosum and fornix.

5. Locate the midbrain by identifying the corpora quadrigemina that form its dorsal roof. Follow the cerebral aqueduct through the midbrain tissue to the fourth ventricle. Identify the cerebral peduncles, which form its anterior walls.

6. Identify the pons and medulla oblongata, which lie anterior to the fourth ventricle. The medulla continues into the spinal cord without any obvious anatomical change, but the point at which the fourth ventricle narrows to a small canal is generally accepted as the beginning of the spinal cord.

7. Identify the cerebellum posterior to the fourth ventricle. Notice its internal treelike arrangement of white matter, the arbor vitae.

8. If time allows, obtain another sheep brain, and section it along the frontal plane so that the cut passes through the infundibulum. Compare your specimen to the photograph (Figure 14.14), and attempt to identify all the structures shown in the figure.

9. Ask your instructor whether you should save a small portion of spinal cord from your brain specimen for the spinal cord studies (Exercise 15). Otherwise, dispose of all the organic debris in the appropriate laboratory containers, and clean the laboratory bench, the dissection instruments, and the tray before leaving the laboratory.
Figure 14.14 Frontal section of a sheep brain. Major structures include the thalamus, hypothalamus, and lateral and third ventricles.

**GROUP CHALLENGE**

**Odd (Cranial) Nerve Out**

The following boxes each contain four cranial nerves. One of the listed nerves does not share a characteristic with the other three. Working in groups of three, discuss the characteristics of the four cranial nerves in each set. On a separate piece of paper, one student will record the characteristics for each nerve for the group. For each set of four nerves, discuss the possible candidates for the “odd nerve” and which characteristic it lacks, based upon your notes. Once you have come to a consensus within your group, circle the cranial nerve that doesn’t belong with the others, and explain why it is singled out. What characteristic is missing? Sometimes there may be multiple reasons why the cranial nerve doesn’t belong with the others.

<table>
<thead>
<tr>
<th>1. Which is the “odd” nerve?</th>
<th>Why is it the odd one out?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optic nerve (II)</td>
<td></td>
</tr>
<tr>
<td>Oculomotor nerve (III)</td>
<td></td>
</tr>
<tr>
<td>Olfactory nerve (I)</td>
<td></td>
</tr>
<tr>
<td>Vestibulocochlear nerve (VIII)</td>
<td></td>
</tr>
<tr>
<td>2. Which is the “odd” nerve?</td>
<td>Why is it the odd one out?</td>
</tr>
<tr>
<td>Oculomotor nerve (III)</td>
<td></td>
</tr>
<tr>
<td>Trochlear nerve (IV)</td>
<td></td>
</tr>
<tr>
<td>Abducens nerve (VI)</td>
<td></td>
</tr>
<tr>
<td>Hypoglossal nerve (XII)</td>
<td></td>
</tr>
<tr>
<td>3. Which is the “odd” nerve?</td>
<td>Why is it the odd one out?</td>
</tr>
<tr>
<td>Facial nerve (VII)</td>
<td></td>
</tr>
<tr>
<td>Hypoglossal nerve (XII)</td>
<td></td>
</tr>
<tr>
<td>Trigeminal nerve (V)</td>
<td></td>
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<tr>
<td>Glossopharyngeal nerve (IX)</td>
<td></td>
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</tbody>
</table>
The Human Brain

1. Match the letters on the diagram of the human brain (right lateral view) to the appropriate terms listed on the left.

   ______  1. frontal lobe
   ______  2. parietal lobe
   ______  3. temporal lobe
   ______  4. precentral gyrus
   ______  5. parieto-occipital sulcus
   ______  6. postcentral gyrus
   ______  7. lateral sulcus
   ______  8. central sulcus
   ______  9. cerebellum
   ______ 10. medulla
   ______ 11. occipital lobe
   ______ 12. pons

2. In which of the cerebral lobes would the following functional areas be found?

   primary auditory cortex: ____________________________
   primary motor cortex: ________________________________
   primary somatosensory cortex: ________________________
   olfactory cortex: ___________________ 
   primary visual cortex: ______________________________
   Broca’s area: ____________________________

3. Which of the following structures are not part of the brain stem? (Circle the appropriate response or responses.)

   cerebral hemispheres  pons  midbrain  cerebellum  medulla oblongata  diencephalon
4. Complete the following statements by writing the proper word or phrase on the corresponding blanks on the right.

A(n) _______ is an elevated ridge of cerebral tissue. The convolutions seen in the cerebrum are important because they increase the _______. Gray matter is composed of _______. White matter is composed of _______. A fiber tract that provides for communication between different parts of the same cerebral hemisphere is called a(n) _______ tract, whereas one that carries impulses from the cerebrum to lower CNS areas is called a(n) _______ tract. The caudate nucleus, putamen, and globus pallidus are collectively called the _______.

1. __________
2. __________
3. __________
4. __________
5. __________
6. __________
7. __________

5. Identify the structures on the following medial view of the human brain by matching the numbered areas to the proper terms in the list.

   a. anterior commissure  
   b. cerebellum  
   c. cerebral aqueduct  
   d. cerebral peduncle  
   e. choroid plexus  
   f. corpora quadrigemina  
   g. corpus callosum  
   h. fornix  
   i. fourth ventricle  
   j. hypothalamus  
   k. interthalamic adhesion  
   l. mammillary bodies  
   m. medulla oblongata  
   n. optic chiasma  
   o. pineal gland  
   p. pituitary gland  
   q. pons  
   r. septum pellucidum  
   s. thalamus
6. Using the letters in front of the terms from question 5, match the appropriate structures with the descriptions given below. (Not all terms will be used.)

_______  1. site of regulation of body temperature and water balance; most important autonomic center
_______  2. site where medial fibers of the optic nerve cross
_______  3. located in the midbrain; contains reflex centers for vision and hearing
_______  4. responsible for regulation of posture and coordination of complex muscular movements
_______  5. important synapse site for afferent fibers traveling to the primary somatosensory cortex
_______  6. contains autonomic centers regulating blood pressure, heart rate, and respiratory rhythm, as well as coughing, sneezing, and swallowing centers
_______  7. large commissure connecting the cerebral hemispheres
_______  8. fiber tract involved with olfaction
_______  9. connects the third and fourth ventricles
_______  10. encloses the third ventricle

7. Embryologically, the brain arises from the rostral end of a tubelike structure that quickly becomes divided into three major regions. Groups of structures that develop from the embryonic brain are listed below. Designate the embryonic origin of each group as the hindbrain, midbrain, or forebrain.

___________________  1. the diencephalon, including the thalamus, optic chiasma, and hypothalamus
___________________  2. the medulla oblongata, pons, and cerebellum
___________________  3. the cerebral hemispheres

8. What is the function of the basal nuclei? ____________________________________________________________

9. What is the striatum, and how is it related to the fibers of the internal capsule? ____________________________

10. A brain hemorrhage within the region of the right internal capsule results in paralysis of the left side of the body.
    Explain why the left side (rather than the right side) is affected. ________________________________________

11. Explain why trauma to the brain stem is often much more dangerous than trauma to the frontal lobes.
12. Explain how patients in a vegetative state can have no damage to their cerebral cortex and yet lack awareness of their environment.

13. Patients in a vegetative state will often reflexively respond to visual and auditory stimuli. Where in the brain are the centers for these reflexes located?

Explain how this phenomenon relates to the unaffected parts of their brain involved in sensory input.

Meninges of the Brain

14. Identify the meningeal (or associated) structures described below:

1. outermost meninx covering the brain; composed of tough fibrous connective tissue
2. innermost meninx covering the brain; delicate and highly vascular
3. structures instrumental in returning cerebrospinal fluid to the venous blood in the dural venous sinuses
4. structure that produces the cerebrospinal fluid
5. middle meninx; like a cobweb in structure
6. its outer layer forms the periosteum of the skull
7. a dural fold that attaches the cerebrum to the crista galli of the skull
8. a dural fold separating the cerebrum from the cerebellum

Cerebrospinal Fluid

15. Label on the accompanying diagram the structures involved with circulation of cerebrospinal fluid.
Add arrows to the figure on p. 278 to indicate the flow of cerebrospinal fluid from its formation in the lateral ventricles to the site of its exit from the fourth ventricle. Then fill in the blanks in the following paragraph.

Cerebrospinal fluid flows from the fourth ventricle into the central canal of the spinal cord and the 1 space surrounding the brain and spinal cord. From this space it drains through the 2 into the 3.

1. ____________________________
2. ____________________________
3. ____________________________

**Cranial Nerves**

16. Using the terms below, correctly identify all structures indicated by leader lines on the diagram.

a. abducens nerve (VI)  j. longitudinal fissure  s. pituitary gland
b. accessory nerve (XI)  k. mammillary body  t. pons
c. cerebellum  l. medulla oblongata  u. spinal cord
d. cerebral peduncle  m. oculomotor nerve (III)  v. temporal lobe of cerebral hemisphere
e. decussation of the pyramids  n. olfactory bulb  w. trigeminal nerve (V)
f. facial nerve (VII)  o. olfactory tract  x. trochlear nerve (IV)
g. frontal lobe of cerebral hemisphere  p. optic chiasma  y. vagus nerve (X)
h. glossopharyngeal nerve (IX)  q. optic nerve  z. vestibulocochlear nerve (VIII)
i. hypoglossal nerve (XII)  r. optic tract
17. Provide the name and number of the cranial nerves involved in each of the following activities, sensations, or disorders.

1. rotating the head
2. smelling a flower
3. raising the eyelids; constricting the pupils of the eye
4. slowing the heart; increasing the motility of the digestive tract
5. involved in Bell’s palsy (facial paralysis)
6. chewing food
7. listening to music; seasickness
8. secreting saliva; tasting well-seasoned food
9. involved in “rolling” the eyes (three nerves—provide numbers only)
10. feeling a toothache
11. reading the newspaper
12. primarily sensory in function (three nerves—provide numbers only)

**Dissection of the Sheep Brain**

18. Describe the firmness and texture of the sheep brain tissue as observed when you cut into it. _________________________

___________________________________________________________________________________________________

Given that formalin hardens all tissue, what conclusions might you draw about the firmness and texture of living brain tissue?
___________________________________________________________________________________________________

19. When comparing human and sheep brains, you observed some profound differences between them. Record your observations in the chart below.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Human</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olfactory bulb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pons-medulla relationship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of cranial nerve III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mammillary body</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corpus callosum</td>
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<tr>
<td>Interthalamic adhesion</td>
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<tr>
<td>Relative size of superior and inferior colliculi</td>
<td></td>
<td></td>
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<tr>
<td>Pineal gland</td>
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