Chapter 15

Feeling Jumpy: The Nervous System

In This Chapter

- Breaking down the structure of nerves
- Centering with the central nervous system
- Branching out with the peripheral nervous system
- Taking a hands-off approach to the autonomic nervous system
- Examining the senses

Throughout this book, you look at the human body from head to toe, exploring how it collects and distributes the molecules it needs to grow and thrive, how it reproduces itself, and even how it gets rid of life's nastier byproducts. In this chapter, however, you look at the living computer that choreographs the whole show, the one system that contributes the most to making us who we are as humans.

The nervous system is the communications network that goes into nearly every part of the body, enervating your muscles, pricking your pain sensors, and letting you reach beyond yourself into the larger world. More than 80 major nerves make up this intricate network, and each nerve contains somewhere around 1 million *neurons* (individual nerve cells). It's through this complex network that you respond both to external and internal stimuli, demonstrating a characteristic called *irritability* (the capacity to respond to stimuli, not the tendency to yell at annoying people).

There are three functional types of cells in the nervous system: *receptor cells* that receive a stimulus (sensing); *conductor cells* that transmit impulses (integrating); and *effector cells*, or motor neurons, which bring about a response such as contracting a muscle. Put another way, there are three functions of the human nervous system as a whole: *orientation,* or the ability to generate nerve impulses in response to changes in the external and internal environments (this also can be referred to as *perception*); *coordination,* or the ability to receive, sort, and direct those signals to channels for response (this also can be referred to as *integration*); and *conceptual thought,* or the capacity to record, store, and relate information received and to form plans for future reactions to environmental change (which includes specific *action*).

In this chapter, you get a feel for how the nervous system is put together. You practice identifying the parts and functions of nerves and the brain itself as well as the structure and activities of the Big Three parts of the whole nervous system: the central, the peripheral, and the autonomic systems. In addition, we touch on the sensory organs that bring information into the human body.

Building from Basics: Neurons, Nerves, Impulses, Synapses

Before trying to study the system as a whole, it's best to break it down into building blocks first.

Neurons

The basic unit that makes up nerve tissue is the *neuron* (also called a *nerve cell*). Its properties include that marvelous *irritability* that we speak of in the chapter introduction as well as *conductivity,* otherwise known as the ability to transmit a *nerve impulse.*

The central part of a neuron is the *cell body*, or *soma*, that contains a large nucleus with one or more nucleoli, mitochondria, Golgi apparatus, numerous ribosomes, and *Nissl bodies* that are associated with conduction of a nerve impulse. (See Chapter 2 for an overview of a cell's primary parts.) Extending from the cell body are threads of cytoplasm, or cytoplasmic projections, containing specialized fibrils, or *neurofibrillae.* Two types of cytoplasmic projections play a role in neurons: *Dendrites* conduct impulses to the cell body while *axons* (nerve fibers) usually conduct impulses away from the cell body (see Figure 15-1). Each neuron has only one axon; however, each axon can have many branches called *axon collaterals*, enabling communication with many target cells. The point of attachment on the soma is called the *axon hillock.* In addition, each neuron may have one dendrite, several dendrites, or none at all.

There are three types of neurons, as follows:

- **Motor neurons,** or *efferent neurons,* transmit messages from the brain and spinal cord to effector organs, including muscles and glands, triggering them to respond. Motor neurons are classified structurally as *multipolar* because they're star-shaped cells with a single large axon and numerous dendrites.
- **Sensory neurons,** or *afferent neurons,* are triggered by physical stimuli, such as light, and pass the impulses on to the brain and spinal cord. Sensory fibers have special structures called receptors, or end organs, where the stimulus is propagated. Sensory neurons can be classified structurally as either *monopolar* or *bipolar.* Monopolar neurons have a single *process* (a projection or outgrowth of tissue) that divides shortly after leaving the cell body; one branch conveys impulses from sense organs while the other branch carries impulses to the central nervous system. Bipolar neurons have two processes — one dendrite and one axon.
- **Association neurons** (also called *internuncial neurons, interneurons,* or *intercalated neurons*) are triggered by sensory neurons and relay messages between neurons within the brain and spinal cord. Interneurons, like motor neurons, are classified structurally as multipolar.

TIP

Here are a couple of handy memory devices: Afferent connections arrive, and efferent connections exit. Dendrites deliver impulses while axons send them away.

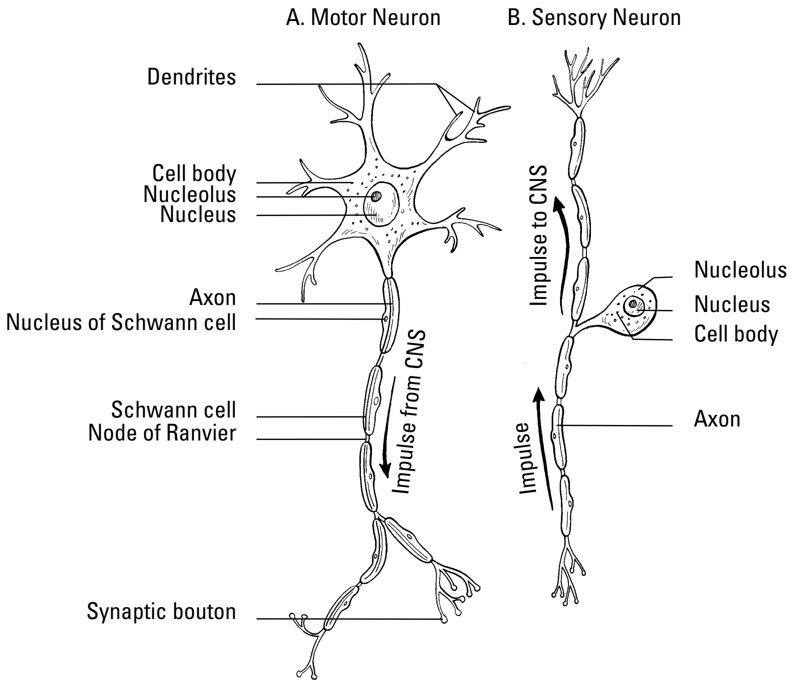

Figure 15-1: The motor neuron on the left and sensory neuron on the right show the cell structures and the paths of impulses.

Nerves

Whereas neurons are the basic unit of the nervous system, *nerves* are the cable-like bundles of axons that weave together the peripheral nervous system. There are three types of nerves:

- **Afferent nerves** are composed of sensory nerve fibers (axons) grouped together to carry impulses from receptors to the central nervous system.
- **Efferent nerves** are composed of motor nerve fibers carrying impulses from the central nervous system to effector organs, such as muscles or glands.
- **Mixed nerves** are composed of both afferent and efferent nerve fibers.

The diameter of individual axons (nerve fibers) tends to be microscopically small — many are no more than a micron, or one-millionth of a meter. But these same axons extend to lengths of 1 millimeter and up. The longest axons in the human body run from the base of the spine to the big toe of each foot, meaning that these single-cell fibers may be 1 meter or more in length.

Each axon is swathed in *myelin,* a white fatty material made up of concentric layers of *Schwann cells* in peripheral nerves. *Oligodendrocytes* in the central nervous system are also associated with myelinated nerve fibers. The result is a structure referred to as a *myelin sheath.* Gaps in the sheath called *nodes of Ranvier* give the underlying nerve fiber access to extracellular fluid, to speed up propagation of the nerve impulse. *Nonmyelinated nerve fibers* lie within body organs and therefore don't need protective myelin sheaths to help them transmit impulses. Many peripheral nerve cell fibers also are protected by a *neurilemmal sheath,* a membrane that surrounds both the nerve fiber and its myelin sheath.

From the inside out, nerves are composed of the following:

- **Axon:** The impulse-conducting process of a neuron
- **Myelin sheath:** An insulating envelope that protects the nerve fiber and facilitates transmission of nerve impulses
- **Neurolemma (or neurilemma):** A thin membrane present in many peripheral nerves that surrounds the nerve fiber and the myelin sheath
- **Endoneurium:** Loose, or *areolar,* connective tissue surrounding individual fibers
- **Fasciculi:** Bundles of fibers within a nerve
- **Perineurium:** The same kind of connective tissue as endoneurium; surrounds a bundle of fibers
- **Epineurium:** The same kind of connective tissue as endoneurium and perineurium; surrounds several bundles of fibers

There also is a class of cells called *neuroglia,* or simply *glia,* that act as the supportive cells of the nervous system, providing neurons with nutrients and otherwise protecting them. Glia include oligodendrocytes that support the myelin sheath within the central nervous system; star-shaped cells called *astrocytes* that both support nerve tissue and contribute to repairs when needed; and *microgliacytes*, cells that remove dead or dying parts of tissue (this type of cell is called a *phagocyte,* which literally translates from the Greek words for “cell that eats”).

Impulses

Neuron membranes are *semi-permeable* (meaning that certain small molecules like ions can move in and out but larger molecules can’t), and they’re *electrically polarized* (meaning that positively charged ions called *cations* rest around the outside membrane surface while negatively charged ions called *anions* line the inner surface; you can find more about ions in Chapter 1).

A neuron that isn’t busy transmitting an impulse is said to be at its *resting potential.* But the *nerve impulse theory,* or *membrane theory,* says that things switch around when a stimulus — a nerve impulse, or *action potential* — moves along the neuron. A stimulus changes the specific permeability of the fiber membrane and causes a depolarization due to a reshuffling of the cations and anions. This change spreads along the nerve fiber and constitutes the nerve impulse. It’s called an *all-or-none response* because each neuron has a specific threshold of excitation. Once that threshold is exceeded, the nerve fiber responds with a fixed impulse. After depolarization, repolarization occurs followed by a refractory period, during which no further impulses occur, even if the stimuli’s intensity increases.

REMEMBER

Intensity of sensation, however, depends on the frequency with which one nerve impulse follows another and the rate at which the impulse travels. That rate is determined by the diameter of the impacted fiber and tends to be more rapid in large nerve fibers. It’s also more rapid in myelinated fibers than nonmyelinated fibers. The cytoplasm of the axon or nerve fiber is electrically conductive and the myelin decreases the capacitance to prevent charge leakage through the membrane. Depolarization at one node of Ranvier is sufficient to trigger regeneration of the voltage at the next node. Therefore, in myelinated nerve fibers the action potential does not move as a wave but recurs at successive nodes, traveling faster than in nonmyelinated fibers. This is referred to as saltatory conduction (from the Latin word *saltare,* which means “to hop or leap”).

Synapses

Neurons don't touch, which means that when a nerve impulse reaches the end of a neuron, it needs to cross a gap to the next neuron or to the gland or muscle cell for which the message is intended. That gap is called a *synapse,* or *synaptic cleft.* An electric synapse — generally found in organs and glial cells — uses channels known as *gap junctions* to permit direct transmission of signals between neurons. But in other parts of the body, chemical changes occur to let the impulse make the leap. The end branches of an axon each form a terminal knob or bulb called a *bouton terminal* (that first word's pronounced *boo-taw*), beyond which there is a space between it and the next nerve pathway. When an impulse reaches the bouton terminal, the following happens:

1. ***Synaptic vesicles* in the knob release a transmitter called *acetylcholine* that flows across the gap and increases the permeability of the next cell membrane in the chain.**
2. **An enzyme called *cholinesterase* breaks the transmitter down into *acetyl* and *choline,* which then diffuse back across the gap.**
3. **An enzyme called *choline acetylase* in the synaptic vesicles reunites the acetyl and choline, prepping the bouton terminal to do its job again when the next impulse rolls through.**

Nervous about getting all this right? Try some practice questions:

1.–5. Match the term to its description.

1. _____ Irritability

2. _____ Conductivity

3. _____ Orientation

4. _____ Coordination

5. _____ Conceptual thought

a. Tissue's ability to respond to stimulation

b. Ability to receive impulses and direct them to channels for favorable response

c. Sense organs' capacity to generate nerve impulse to stimulation

d. Spreading of the nerve impulse

e. Capacity to record, store, and relate information to be used to determine future action

6. The brain and spinal cord are called the

a. Central nervous system

b. Visceral afferent system

c. Autonomic nervous system

d. Peripheral nervous system

7. The functional unit of the nervous system is the

a. Axon

b. Nephron

c. Dendron

d. Neuron

8. The terminal structure of the cytoplasmic projection of the neuron *cannot* be a(n)

a. Node of Ranvier

b. End organ

c. Effector

d. End bulb

e. Receptor

9. The afferent fiber that carries impulses to a neuron's cell body is called a

a. Nissl body

b. Neuron

c. Dendrite

d. Axon

e. Mitochondria

10. The membrane surrounding the axon (nerve fiber) is the

a. Sarcolemma

b. Neurilemma

c. Perineurium

d. Epineurium

11.–15. Match the term to its description.

11. _____ Astrocytes

12. _____ Microgliacytes

13. _____ Oligodendrocytes

14. _____ Axons

15. _____ Dendrites

a. Cytoplasmic projections carrying impulses to the cell body

b. Cells that form and preserve myelin sheaths

c. Cytoplasmic projections carrying impulses from the cell body

d. Cells that are phagocytic

e. Cells that contribute to the repair process of the central nervous system

16. The neuroglia cells are important as

a. Sensory tissue

b. Supporting tissue

c. Irritable tissue

d. Conducting tissue

17. Axons tend to consist of

a. Single processes

b. Several synapses

c. Multiple processes

d. None of the above

e. Both a and c

18. A synapse between neurons is best described as the

a. Transmission of a continuous impulse

b. Transmission of an electrical impulse

c. Transmission of an impulse through a chemical and physical change

d. Transmission of an impulse through a physical change

e. Transmission of an impulse through a chemical change

19.–23. Match the term to its description.

19. _____ Endoneurium

20. _____ Neurilemma

21. _____ Schwann cell

22. _____ Node of Ranvier

23. _____ Myelin sheath

a. Fatty layer around an axon fiber

b. Outer thin membrane around an axon fiber

c. Cell in the sheath of an axon

d. Depression in the sheath around a fiber

e. Connective tissue surrounding individual fibers in a nerve

24.–28. Match the term to its description.

24. _____ All-or-none response

25. _____ Cation

26. _____ Anion

27. _____ Polarization

28. _____ Depolarization

a. Impermeability of cell membrane

b. Negatively charged ion on the inner surface of the cell membrane

c. Threshold of excitation determines ability to respond

d. Positively charged ion on the outer surface of the cell membrane

e. Reshuffling of cell membrane ions; permeability of cell membrane

29.–33. Match the term to its description.

29. _____ Cholinesterase

30. _____ Choline acetylase

31. _____ Terminal bulb

32. _____ Acetylcholine

33. _____ Synapse

a. Excitatory chemical necessary for continual nerve pathway

b. Enzyme for breakdown of excitatory chemical

c. Enzyme for reformation of excitatory chemical

d. Space between neurons

e. Contains storage vesicles for excitatory chemical

Minding the Central Nervous System and the Brain

Together, the brain and spinal cord make up the central nervous system. The spinal cord, which forms very early in the embryonic spinal canal, extends down into the tail portion of the vertebral column. But because bone grows much faster than nerve tissue, the end of the cord soon is too short to extend into the lowest reaches of the spinal canal. In an adult, the 18-inch spinal cord ends between the first and second lumbar vertebrae, roughly where the last ribs attach. Its tapered end is called the *conus medullaris.* The cord continues as separate strands below that point and is referred to as the *cauda equina* (horse tail). A thread of fibrous tissue called the *filum terminale* extends to the base of the *coccyx* (tailbone) and is attached by the coccygeal ligament.

Spinal cord

An oval-shaped cylinder with two deep grooves running its length at the back and the front, the spinal cord doesn't fill the spinal cavity by itself. Also packed inside are the *meninges,* cerebrospinal fluid, a cushion of fat, and various blood vessels.

Three membranes called *meninges* envelop the central nervous system, separating it from the bony cavities. The *dura mater,* the outer layer, is the hardest, toughest, and most fibrous layer and is composed of white collagenous and yellow elastic fibers. The *arachnoid,* or middle membrane, forms a web-like layer just inside the dura mater. The *pia mater,* a thin inner membrane, lies close along the surface of the central nervous system. The pia mater and arachnoid may adhere to each other and are considered as one, called *pia-arachnoid.*

There are spaces or cavities between the pia mater and the arachnoid where major regions join, for instance where the medulla oblongata and the cerebellum join. These sub-arachnoid spaces are called *cisterna*. Spaces or cavities between the arachnoid layer and the dura mater layer are referred to as *subdural*.

Two types of solid material make up the inside of the cord, which you can see in Figure 15-2: *gray matter* (which is indeed grayish in color) containing unmyelinated neurons, dendrites, cell bodies, and neuroglia; and *white matter,* so-called because of the whitish tint of its myelinated nerve fibers. At the cord's midsection is a small *central canal* surrounded first by gray matter in the shape of the letter H and then by white matter, which fills in the areas around the H pattern. The legs of the H are called anterior, posterior, and lateral *horns* of gray matter, or *gray columns.*

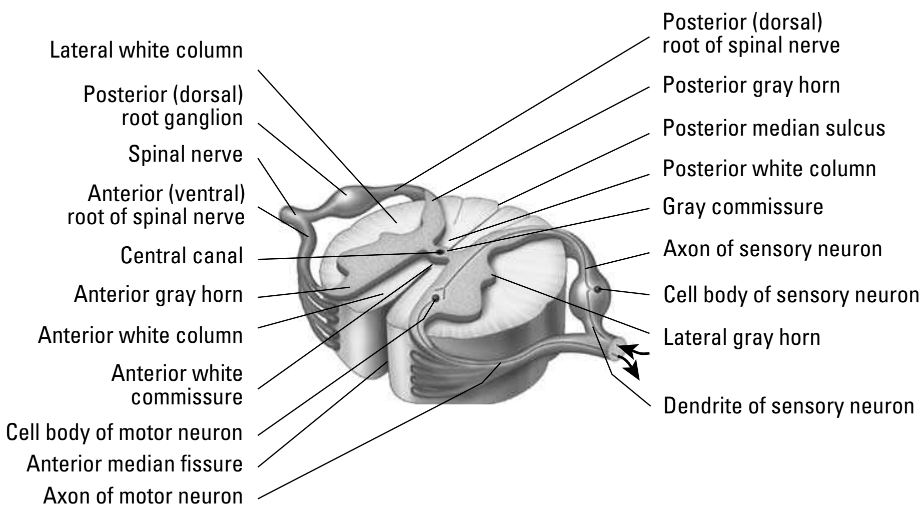

Illustration by Imagineering Media Services Inc.

Figure 15-2: A cross-section of the spinal cord, showing spinal nerve connections.

The white matter consists of thousands of myelinated nerve fibers arranged in three *funiculi* (columns) on each side of the spinal cord that convey information up and down the cord's tracts. Ascending afferent (sensory) nerve tracts carry impulses to the brain; descending efferent (motor) nerve tracts carry impulses from the brain. Each tract is named according to its origin and the joint of synapse, such as the corticospinal and spinothalmic tracts.

Thirty-one pairs of spinal nerves arise from the sides of the spinal cord and leave the cord through the *intervertebral foramina* (spaces) to form the peripheral nervous system, which we discuss in the later section "Taking Side Streets: The Peripheral Nervous System."

Brain

One of the largest organs in the adult human body, the brain tips the scales at 3 pounds and packs roughly 100 billion neurons (yes, that's billion with a "b") and 900 billion supporting neuroglia cells. In this section, we review six major divisions of the brain from the bottom up (see Figure 15-3): *medulla oblongata, pons, midbrain, cerebellum, diencephalon,* and *cerebrum.*

Medulla oblongata

The spinal cord meets the brain at the *medulla oblongata,* or *brainstem,* just below the right and left cerebellar hemispheres of the brain. In fact, the medulla oblongata is continuous with the spinal cord at its base (inferiorly) and back (dorsally) and located anteriorly and superiorly to the pons. All the afferent and efferent tracts of the cord can be found in the brainstem as part of two bulges of white matter forming an area referred to as the *pyramids.* Many of the tracts cross from one side to the other at the pyramids, which explains why the right side of the brain controls the left side of the body and vice versa.

Along with the pons, the medulla oblongata also forms a network of gray and white matter called the *reticular formation,* the upper part of the so-called *extrapyramidal pathway.* With its capacity to arouse the brain to wakefulness, it keeps the brain alert, directs messages in the form of impulses, monitors stimuli entering the sense receptors (accepting some and rejecting others it deems to be irrelevant), refines body movements, and effects higher mental processes such as attention, introspection, and reasoning. Although the cortex of the cerebrum is the actual powerhouse of thought, it must be stimulated into action by signals from the reticular formation.

Nerve cells in the brainstem are grouped together to form nerve centers (nuclei) that control bodily functions, including cardiac activities, and respiration as well as reflex activities such as sneezing, coughing, vomiting, and alimentary tract movements. The medulla oblongata affects these reactions through the vagus, also referred to as cranial nerve X or the 10th cranial nerve. Three other cranial nerves also originate from this area: the 9th (IX) or glossopharyngeal, 11th (XI) or accessory, and 12th (XII) or hypoglossal.

Pons

The *pons* (literally "bridge") does exactly as its name implies: It connects the cerebellum through a structure called the middle peduncle, the cerebrum by the superior peduncle, and the medulla oblongata by the inferior peduncle. It also unites the cerebellar hemispheres, coordinates muscles on both sides of the body, controls facial muscles (including those used to chew), and regulates the first stage of respiration. Oh, and it contains the nuclei for the following cranial nerves: the 5th (V) or trigeminal, the 6th (VI) or abducens, 7th (VII) or facial, and 8th (VIII) or vestibulocochlear.

Midbrain

Between the pons and the diencephalon lies the *mesencephalon,* or *midbrain.* It contains the *corpora quadrigemina,* which correlates optical and tactile impulses as well as regulates muscle tone, body posture, and equilibrium through reflex centers in the *superior colliculus.* The *inferior colliculus* contains auditory reflex centers and is believed to be responsible for the detection of musical pitch. The midbrain contains the *cerebral aqueduct,* which connects the third ventricle of the *thalamus* with the fourth ventricle of the medulla oblongata (see the section “Ventricles” later in this chapter for more). The mesencephalon contains nuclei for the 3rd (III) or oculomotor cranial nerve and the 4th (IV) or trochlear cranial nerve. The red nucleus that contains *fibers* of the *rubrospinal tract,* a motor tract that acts as a relay station for impulses from the cerebellum and higher brain centers, also lies within the midbrain, constituting the superior cerebellar peduncle.

Cerebellum

The *cerebellum* also is known as the *little brain* or *small brain.* The second-largest division of the brain, it’s just above and overhangs the medulla oblongata and lies just beneath the rear portion of the cerebrum. Inside, the cerebellum resembles a tree called the *arbor vitae,* or “tree of life.” A central body called the *vermis* connects the two lateral masses called the *cerebellar hemispheres* and assists in motor coordination and refinement of muscular movement, aiding equilibrium and muscle tone. The cerebellar cortex or gray matter contains Purkinje neurons with pear-shaped cell bodies, a multitude of dendrites, and a single axon. It sends impulses to the white matter of the cerebellum and to other deeper nuclei in the cerebellum, and then to the brainstem. The cerebellar cortex has parallel ridges called the folia cerebelli, which are separated by deep sulci.

Diencephalon

The *diencephalon,* a region between the mesencephalon and the cerebrum, contains separate brain structures called the *thalamus, epithalamus, subthalamus,* and *hypothalamus.* The region where the two sides of the thalami come in contact and join forces is called the *intermediate mass*. The thalamus is a primitive receptive center through which the sensory impulses travel on their way to the cerebral cortex. Here, nerve fibers from the spinal cord and lower parts of the brain synapse with neurons leading to the sensory areas of the cortex of the cerebrum. The thalamus is the great integrating center of the brain with the ability to correlate the impulses from tactile, pain, olfactory, and gustatory (taste) senses with motor reactions.

The epithalamus contains the *choroid plexus,* a vascular structure that produces spinal fluid. The pineal body and olfactory centers also lie within the epithalamus, which forms the roof of the third ventricle. The *subthalamus* is located below the thalamus and regulates the muscles of emotional expression.

The *hypothalamus* contains the centers for sexual reflexes; body temperature; water, carbohydrate, and fat metabolism; and emotions that affect the heartbeat and blood pressure. It also has the *optic chiasm* (connecting the optic nerves to the optic tract), the posterior lobe of the pituitary gland, and a funnel-shaped region called the *infundibulum* that forms the stalk of the pituitary gland.

Cerebrum

The *cerebrum,* or forebrain, is often called the *true brain.* It has two cerebral hemispheres — the right and the left. A thin outer layer of gray matter called the *cerebral cortex* features folds or convolutions called *gyri;* furrows and grooves are referred to as *sulci,* and deeper grooves are called *fissures.* A longitudinal fissure separates the cerebrum. The transverse fissure separates the cerebrum and the cerebellum. Each hemisphere has a set of controls for sensory and motor activities of the body. Interestingly, it’s not just right-side/left-side controls that are reversed in the cerebrum; the upper areas of the cerebral cortex control the lower body activities while the lower areas of the cortex control upper-body activities in a reversal called “little man upside down.”

Commissural fibers, a tract of nerves running from one side of the brain to the other, coordinate activities between the right and left hemispheres. The *corpus callosum* physically unites the two hemispheres and is the largest and densest mass of commissural fibers. A smaller mass called the *fornix* also plays a role.

Different functional areas of the cerebral cortex are divided into lobes:

- **Frontal lobe:** The seat of intelligence, memory, and idea association
- **Parietal lobe:** Functions in the sensations of temperature, touch, and sense of position and movement as well as the perception of size, shape, and weight
- **Temporal lobe:** Is responsible for perception and correlation of acoustical stimuli
- **Occipital lobe:** Handles visual perception

Medulla

The medulla, the region interior to the cortex, is composed of white matter that consists of three groups of fibers. *Projection fibers* carry impulses afferently from the brain stem to the cortex and efferently from the cortex to the lower parts of the central nervous system. *Association fibers* originate in the cortical cells and carry impulses to the other areas of the cortex on the same hemisphere. *Commissural fibers* connect the two cerebral hemispheres.

Ventricles

The brain's four *ventricles* are cavities and canals filled with cerebrospinal fluid. Two lateral ventricles are separated by the *septum pellucidum.* The lateral ventricles communicate with the third ventricle through the *foramen of Monro.* The third ventricle is connected by the *cerebral aqueduct* to the fourth ventricle, which is continuous with the central canal of the spinal cord and contains openings to the meninges. The fourth ventricle has openings that allow fluid to enter into the subarachnoid spaces.

Lining the ventricles is a thin layer of epithelial cells known as *ependyma,* or the *ependymal layer.* Along with a network of capillaries from the pia mater, the ependyma and capillaries form the *choroid plexus,* which is the source of cerebrospinal fluid. The choroid plexus of each lateral ventricle produces the greatest amount of fluid. Fluid formed by the choroid plexus filters out by *osmosis* (refer to Chapter 2) and circulates through the ventricles. Fluid is returned to the blood through the *arachnoid villi,* finger-like projections of the *arachnoid meninx,* which absorbs the fluid.

Twelve pairs of cranial nerves connect to the central nervous system via the brain (as opposed to the 31 pairs that connect via the spinal cord). Cranial nerves are identified by Roman numerals I through XII, and memorizing them is a classic test of anatomical knowledge. Check out Table 15-1 for a listing of all the nerves, and then read on for a memory tool.

Table 15-1 Cranial Nerves

Number	*Name*	*Type*	*Function*
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Mixed nerve	Eyeball muscles
IV	Trochlear	Mixed nerve	Eyeball muscles

(continued)

Table 15-1 *(continued)*

Number	***Name***	***Type***	***Function***
V	Trigeminal	Tri means "three," so the three types of trigeminal nerves are 1) Opthalmic nerve: sensory nerve; skin and mucous membranes of face and head; 2) Maxillary nerve: mixed nerve; mastication; 3) Mandibular nerve: mixed nerve; mastication	Skin; mastication (chewing)
VI	Abducens	Mixed nerve	Eye movements
VII	Facial	Mixed nerve	Facial expression; salivary secretion; taste
VIII	Vestibulocochlear	Sensory	Auditory nerve for hearing and equilibrium
IX	Glossopharyngeal	Mixed nerve	Taste; swallowing muscles of pharynx
X	Vagus	Mixed nerve	Controls most internal organs (viscera) from head and neck to transverse colon
XI	Accessory	Mixed nerve	Swallowing and phonation
XII	Hypoglossal	Motor nerve	Tongue movements

The first letters of each of these nerve names, in order, are OOOTTAFVGVAH. That's a mouthful, but students have come up with a number of memory tools to remember them. Our favorite is: Old Opera Organs Trill Terrific Arias For Various Grand Victories About History.

Put your knowledge of the central nervous system to the test:

EXAMPLE

Q. The meninges' functions are primarily

a. Immunological

b. Supportive

c. Protective

d. Both a and b

e. Both b and c

A. The correct answer is supportive and protective. Yes, meninges have two functions.

34. The cerebrum consists of two major halves called

- **a.** Cerebellar hemispheres
- **b.** Cerebral spheres
- **c.** Cerebellar spheres
- **d.** Cerebral hemispheres

35. The cerebrum is divided into two major halves by the

- **a.** Lateral fissure
- **b.** Transverse fissure
- **c.** Longitudinal fissure
- **d.** Fissure of Sylvius
- **e.** Central sulcus

36. In the cerebrum, the

- **a.** Right side tends to control the left side of the body and vice versa
- **b.** Upper area controls lower-body activity
- **c.** Lower area controls upper-body activity
- **d.** None of the above are correct
- **e.** A, b, and c are correct

37. The functions of the occipital lobe of the cerebrum pertain principally to

- **a.** Visual activity
- **b.** Autonomic control
- **c.** Associative reasoning
- **d.** Motor coordination
- **e.** Auditory control

38. The cerebellum functions primarily as a center of

- **a.** Visual activity
- **b.** Associative reasoning
- **c.** Auditory activity
- **d.** Autonomic coordination
- **e.** Motor control

39.–43. Match the term to its description.

39. _____ White matter

40. _____ Reticular formation

41. _____ Funiculus

42. _____ Dorsal root ganglion

43. _____ Gray matter

a. Has the capacity to arouse the brain to wakefulness

b. Myelinated fibers

c. Bundles of nerve fibers arranged in tracts

d. Collection of cell bodies outside of the central nervous system

e. Unmyelinated fibers, cell bodies, and neuroglia

44.-48. Match the term to its description.

44. _____ Pons

45. _____ Cerebellum

46. _____ Medulla oblongata

47. _____ Cerebrum

48. _____ Mesencephalon

a. Bridge connecting the medulla oblongata and cerebellum

b. Contains the centers that control cardiac, respiratory, and vasomotor functions

c. Contains the corpora quadrigemina and nuclei for the oculomotor and trochlear nerves

d. Controls motor coordination and refinement of muscular movement

e. Controls sensory and motor activity of the body

49. The largest quantity of cerebrospinal fluid originates from the

a. Foramen of Monro

b. Arachnoid villi

c. Lateral ventricle

d. Optic chiasm

e. Foramen of Luschka

50. The part of the brain that contains the thalamus, pituitary gland, and the optic chiasm is the

a. Diencephalon

b. Mesencephalon

c. Myelencephalon

d. Telencephalon

e. Metencephalon

51.–62. Use the terms that follow to identify the parts of the brain shown in Figure 15-3.

a. Pons

b. Thalamus

c. Cerebellum

d. Corpus callosum

e. Third ventricle

f. Hypothalamus

g. Cerebrum

h. Cerebral aqueduct

i. Midbrain

j. Pituitary gland

k. Medulla oblongata

l. Fourth ventricle

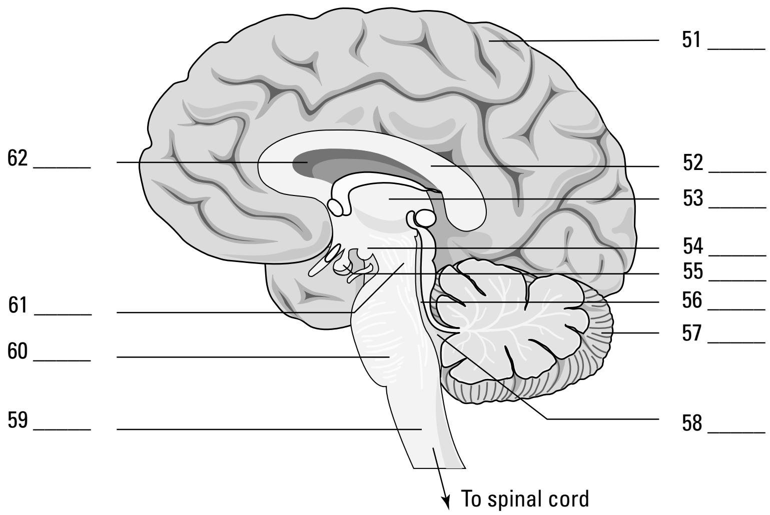

Figure 15-3: Sagittal view of the brain.

Taking Side Streets: The Peripheral Nervous System

The peripheral nervous system is the network that carries information to and from the spinal cord. Among its key structures are 31 pairs of spinal nerves (see Figure 15-4), each originating in a segment of the spinal cord called a *neuromere.* Eight of the spinal nerve pairs are *cervical* (having to do with the neck), 12 are *thoracic* (relating to the chest, or thorax), five are *lumbar* (between the lowest ribs and the pelvis), five are *sacral* (the posterior section of the pelvis), and one is *coccygeal* (relating to the tailbone). Spinal nerves connect with the spinal cord by two bundles of nerve fibers, or *roots.* The *dorsal root* contains afferent fibers that carry sensory information from receptors to the central nervous system. The cell bodies of these sensory neurons lie outside the spinal cord in a bulging area called the *dorsal root ganglion* (refer to the cross-section of the spinal cord in Figure 15-2). A second bundle, the *ventral root,* contains efferent motor fibers with cell bodies that lie inside the spinal cord. In each spinal nerve, the two roots join outside the spinal cord to form what's called a *mixed spinal nerve.*

Spinal reflexes, or *reflex arcs,* occur when a sensory neuron transmits a "danger" signal — like a sensation of burning heat — through the dorsal root ganglion. An internuncial neuron (or association neuron) in the spinal cord passes along the signal to a motor neuron (or efferent fiber) that stimulates a muscle, which immediately pulls the burning body part away from heat (see Figure 15-5).

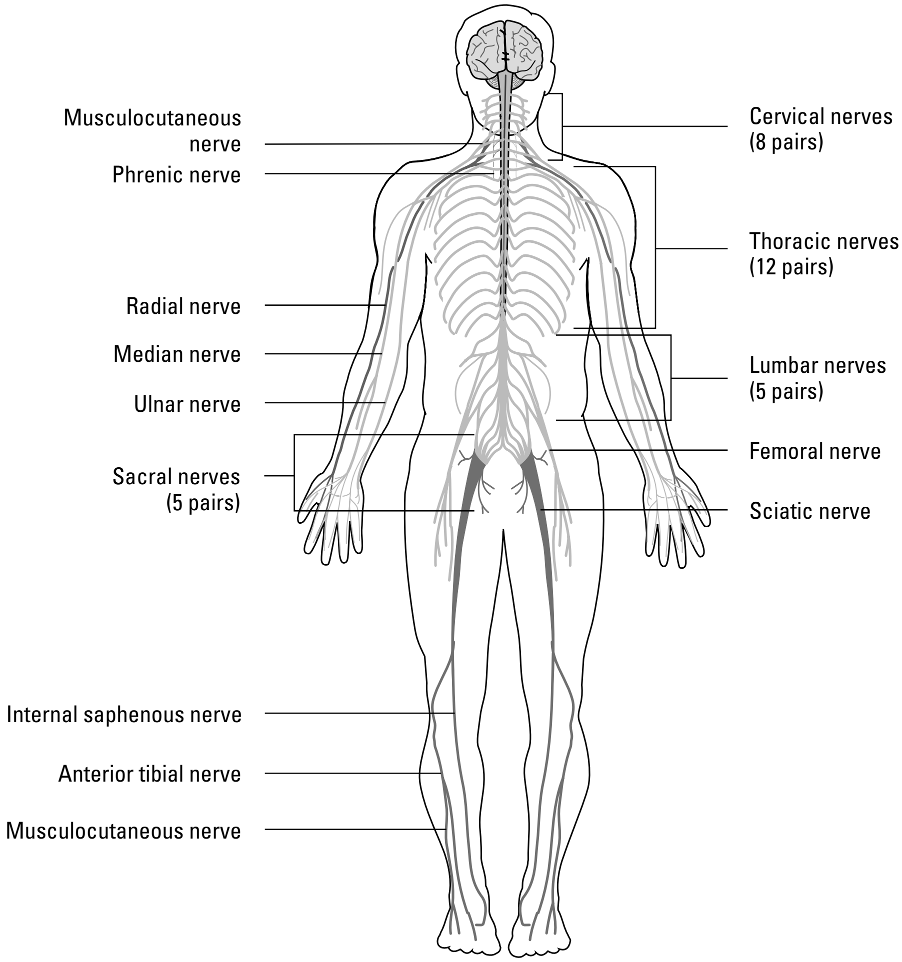

Figure 15-4: The spinal nerves plus branching plexus nerves.

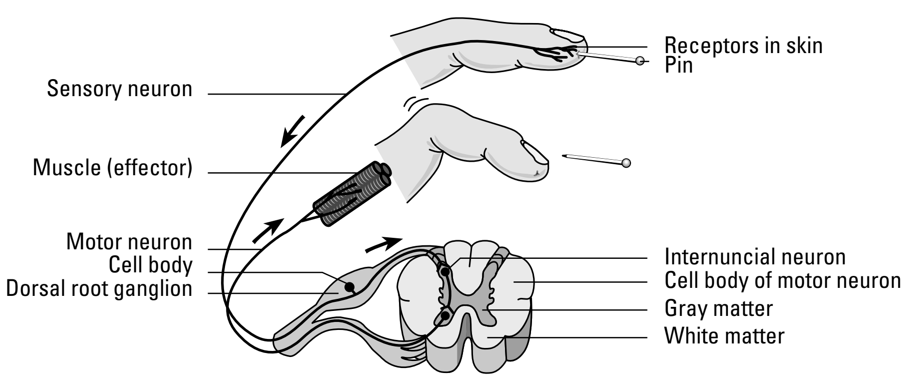

Figure 15-5: A reflex arc — responding to pain.

After a spinal nerve leaves the spinal column, it divides into two small branches. The posterior, or *dorsal ramus,* goes along the back of the body to supply a specific segment of the skin, bones, joints, and longitudinal muscles of the back. The ventral, or *anterior ramus,* is larger than the dorsal ramus and supplies the anterior and lateral regions of the trunk and limbs.

Groups of spinal nerves interconnect to form an extensive network called a *plexus* (Latin for "braid"), each of which connects through the anterior ramus, including the cervical plexus of the neck, brachial plexus of the arms, and lumbosacral plexus of the lower back (including the body's largest nerve, the *sciatic nerve*). However, there's no plexus in the thoracic area. Instead, the anterior ramus directly supplies the intercostal muscles (literally "between the ribs") and the skin of the region.

63. The network of nerves formed by the ventral branch of the spinal nerve is a

a. Pedicle

b. Papilla

c. Plexus

d. Plica

e. Phallus

64. How many spinal nerves are there?

a. 61

b. 31 pairs

c. 13 pairs

d. 1

e. 12

65. Which spinal nerve area does not form a plexus?

a. Cervical

b. Lumbar

c. Sacral

d. Thoracic

Keep Breathing: The Autonomic Nervous System

Just as the name implies, the autonomic nervous system functions automatically. Divided into the *sympathetic* and *parasympathetic* systems, it activates the involuntary smooth and cardiac muscles and glands to serve such vital systems that function automatically as the digestive tract, circulatory system, respiratory, urinary, and endocrine systems. Autonomic functions are under the control of the hypothalamus, cerebral cortex, and medulla oblongata. The sympathetic system, which is responsible for the body's involuntary fight-or-flight response to stress, is defined by the autonomic fibers that exit the thoracic and lumbar segments of the spinal cord. The parasympathetic system is defined by the autonomic fibers that either exit the brainstem via the cranial nerves or exit the sacral segments of the spinal cord.

REMEMBER

The sympathetic and parasympathetic systems oppose each other in function, helping to maintain *homeostasis,* or balanced activity in the body systems. Yet, often the sympathetic and parasympathetic systems work in concert. The sympathetic system dilates the eye's pupil, but the parasympathetic system contracts it again. The sympathetic system quickens and strengthens the heart while the parasympathetic slows the heart's action. The sympathetic system contracts blood vessels in the skin so more blood goes to muscles for a fight-or-flight reaction to stress, and the parasympathetic system dilates the blood vessels when the stress concludes.

As shown in Figure 15-6, a pair of sympathetic trunks lies to the right and left of the spinal cord and is composed of a series of ganglia that form nodular cords extending from the base of the skull to the front of the coccyx (tailbone). Sympathetic nerves originate as a short preganglionic neuron with its cell body inside the lateral horn of the gray matter of the spinal cord from the first thoracic to the third lumbar. Axons of these nerves then pass through the ventral root of the spinal nerve, leaving it through a branch of the spinal nerve called the *white rami* (named for their white myelin sheaths), which connect to one of the two chains of ganglia in the trunks. Within these hubs, synapses distribute the nerves to various parts of the body.

The parasympathetic system is referred to as a craniosacral system because its ganglia originate in the medulla oblongata (brainstem), mesencephalon, and the sacral portion of the spinal nerves, sending out impulses through the following cranial nerves: the oculomotor III, the facial VII, glossopharyngeal IX, and the vagus X. Parasympathetic nerves consist of long preganglionic fibers that synapse in a terminal ganglion near or within the organ or tissue that's being innervated. Generally speaking, the parasympathetic system acts in opposition to the sympathetic system.

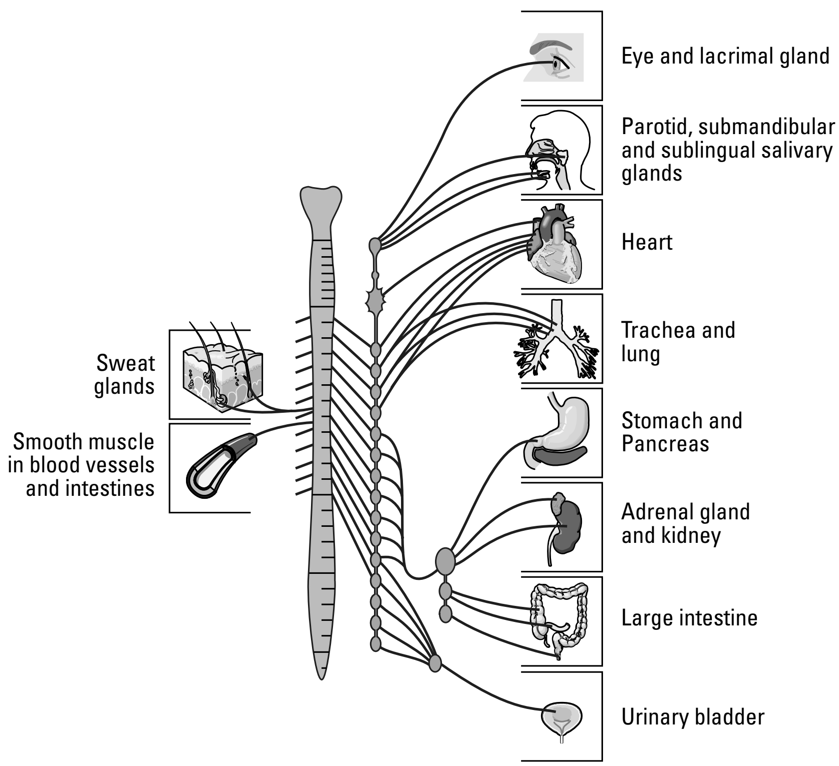

Figure 15-6: The sympathetic nervous system.

See whether any of the following practice questions touch a nerve:

66. The autonomic nervous system

a. Innervates involuntary body functions

b. Responds only at times of emotional stress

c. Is composed only of sensory neurons

d. Is separate anatomically and functionally from the cranial nerves

67. Which of the following statements is true about the autonomic nervous system?

a. It has two parts: the parasympathetic that controls all normal functions, and the sympathetic that carries out the same functions.

b. It's the nervous system that controls all reflexes.

c. It doesn't function when the body's under stress.

d. It has two divisions that are antagonistic to each other, meaning that one counteracts the effects of the other one.

e. It controls the contractions of the skeletal, smooth, and cardiac muscle tissue.

68. The divisions of the autonomic nervous system are

a. Sympathetic and peripheral

b. Somatic and peripheral

c. Parasympathetic and peripheral

d. Sympathetic and parasympathetic

69. Which part of the autonomic nervous system can be called a craniosacral system?

a. Ganglia

b. Sympathetic trunks

c. Parasympathetic system

d. Medulla oblongata

Coming To Your Senses

The nervous system must have some way to perceive its environment in order to generate appropriate responses. That's where the senses come in. *Sense receptors* are those numerous organs that respond to stimuli — like increased temperature, bitter tastes, and sharp points — by generating a nerve impulse. While there are millions of *general sense receptors* found throughout the body that can convey touch, pain, and physical contact, there are far fewer of the *special sense receptors* — those located in the head — that really bring meaning to your world.

Sense receptors are classified by the stimuli they receive, as follows:

- **Exteroceptors:** Receive stimuli from the external environment. These are sensory nerve terminals, such as those in the skin and mucous membranes, that are stimulated by the immediate external environment.
- **Interoceptors:** Receive stimuli from the internal environment. These can be any of the sensory nerve terminals located in and transmitting impulses from the viscera.
- **Proprioceptors:** Part of the "true" internal environment. They're sensory nerve terminals chiefly found in muscles, joints, and tendons that give information concerning movements and position of the body.
- **Teleceptors:** Sensory nerve terminals stimulated by emanations from distant objects. They exist in the eyes, ears, and nose.

Eyes

Although there are many romantic notions about eyes, the truth is that an eyeball is simply a hollow sphere bounded by a trilayer wall and filled with a gelatinous fluid called, oddly enough, *vitreous humor* (see Figure 15-7). The outer fibrous coat is made up of the *sclera* in back and the *cornea* in front. The sclera provides mechanical support, protection, and a base for attachment of eye muscles, and it assists in the focusing process. The cornea covers the anterior with a clear window.

An intermediate, or vascular, coat called the *uvea* provides blood and lymphatic fluids to the eye, regulates light, and also secretes and reabsorbs *aqueous humor,* a thin watery liquid that fills the anterior chamber of the eyeball in front of the iris. A pigmented coat has three layers: the *iris,* containing blood vessels, pigment cells, and smooth muscle fibers to control the pupil's diameter; the *ciliary body,* which is attached to the periphery of the iris; and the *choroid,* a thin, dark brown, vascular layer lining most of the sclera on the back and sides of the eye. The choroid contains arteries, veins, and capillaries that supply the *retina* with nutrients, and it also contains pigment cells to absorb light and prevent reflection and blurring. An *optic nerve* enters at the back (posterior) of each eye.

The *retina* is part of an internal nervous layer that connects with the optic nerve. The nervous tissue layers along the inner back of the eye contain *rods* and *cones* (types of neurons that analyze visual input). The rods are dim light receptors whereas the cones detect bright light and construct form, structure, and color. The retina has an *optic disc,* which is essentially a blind spot incapable of producing an image.

REMEMBER

The crystalline lens consists of concentric layers of protein. It's *biconcave* in shape, bulging outward. Located behind the pupil and iris, the lens is held in place by ligaments attached to the ciliary muscles. When the ciliary muscles contract, the shape of the lens changes, altering the visual focus. This process of *accommodation* allows the eye to see objects both at a distance and close up.

The *palpebrae* (eyelids) extend from the edges of the eye orbit, into which roughly five-sixths of the eyeball is recessed. Eyelids come together at medial and lateral angles of the eye that are called the *canthi.* In the medial angle of the eye is a pink region called the *caruncula,* or *caruncle.* The caruncula contains sebaceous glands and sudoriferous (sweat) glands. A mucous membrane called the *conjunctiva* covers the inner surface of each eyelid and the anterior surface of the eye. Up top and to the side of the orbital cavities are lacrimal glands that secrete tears that are carried through a series of lacrimal ducts to the conjunctiva of the upper eyelid. Ultimately, secretions drain from the eyes through the nasolacrimal ducts.

Ears

Human ears — otherwise called *vestibulocochlear* organs — are more than just organs of hearing. They also serve as organs of equilibrium, or balance. Here are the three divisions of the ear:

- The *external ear* includes the *auricle,* or *pinna,* which is the folded, rounded appendage made of cartilage and skin. Extending into the skull is the *ear canal,* or *external auditory meatus,* a short passage through the temporal bone ending at the *tympanic membrane,* or *eardrum.* Sebaceous glands near the external opening and *ceruminous* glands in the upper wall produce the brownish substance known as earwax, or *cerumen.*

- The *middle ear* is a small, usually air-filled cavity in the skull that's lined with mucous membrane. It communicates through the *Eustachian tube* with the pharynx. The Eustachian tube keeps air pressure equal on both sides of the eardrum (tympanic membrane), equalizing pressure in the middle ear with atmospheric pressure from outside. Three small bones called *auditory ossicles* occupy the middle ear, deriving their names from their shapes: the *malleus* (hammer), the *incus* (anvil), and the *stapes* (stirrup).
- The *internal ear* is the most complex structure of the entire organ because it's where vibrations are translated. It's composed of a group of interconnected canals or channels called the *cochlea.* Within the cochlea are three canals separated from each other by thin membranes; two of the canals — the *vestibular* and the *tympanic* — are bony chambers filled with a *perilymph fluid*, and the third canal — the *cochlear* canal — is a membranous chamber filled with *endolymph.* The cochlear canal lies between the vestibular and tympanic canals and contains the *organ of Corti,* a spiral-shaped organ made up of cells with projecting hairs that transmit auditory impulses.

The process of hearing a sound follows these basic steps:

1. **Sound waves travel through the auditory canal, striking the eardrum and making it vibrate and setting the three ossicle bones into motion.**
2. **The stapes at the end of the chain strikes against the oval window of the vestibular canal, translating the motion into the perilymph fluid in the vestibular and tympanic canals of the cochlea.**
3. **The vibrating fluid begins moving the basilar membrane that separates the two canals, stimulating the endolymph fluid in the membranous area of the cochlea.**
4. **The stimulated endolymph fluid in turn stimulates the hair cells of the organ of Corti, which transmit the impulses to the brain over the auditory nerve**.

That's the hearing part of your ears. Equilibrium requires that some additional parts come into play. Three semicircular canals, each with an *ampulla* (or small, dilated portion) at each end, lie at right angles to each other. The *ampullae* connect to a fluid-filled sac called a *utricle,* which in turn connects to another fluid-filled sac called a *saccule.* Both sacs contain regions called *maculae* that are lined with sensitive hairs and contain concretions (solid masses) of calcium carbonate called *otoliths* (or *otoconia*). When linear acceleration pulls at them, the otoliths press on the hair cells and initiate an impulse to the brain through basal sensory nerve fibers. When the head changes position, it causes a change in the direction of force on the hairs. Movement of the hairs stimulates dendrites of the *vestibulocochlear nerve* (the eighth cranial nerve) to carry impulses to the brain.

EXAMPLE

Q. The most sensitive region of the retina producing the greatest visual acuity is the

a. Blind spot

b. Cornea

c. Fovea centralis

d. Macula lutea

e. Lens

A. The correct answer is fovea centralis. It's loaded with light-sensitive cones.

70.–83. Use the terms that follow to identify the internal structures of the eye shown in Figure 15-7.

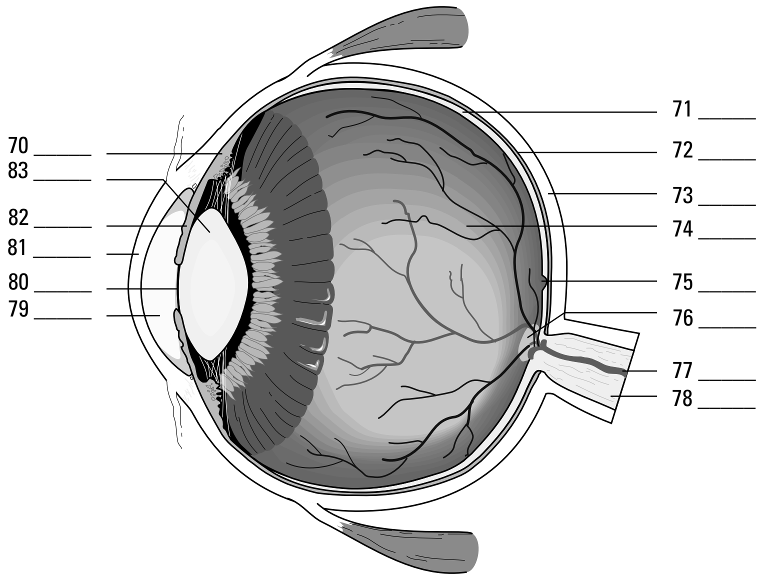

Figure 15-7: The internal structures of the eye.

a. Blind spot

b. Pupil

c. Optic nerve

d. Retina

e. Cornea

f. Sclera

g. Ciliary body

h. Fovea centralis

i. Lens

j. Anterior cavity (aqueous humor)

k. Choroid

l. Blood vessels

m. Iris

n. Posterior cavity (vitreous humor)

84. The area of the eyeball that contains cells that are sensitive to light is the

a. Cornea

b. Retina

c. Sclera

d. Lens

e. Optic nerve

85. Which of the following structures is not part of the eyeball?

a. Optic nerve

b. Iris

c. Cornea

d. Pupil

e. Ciliary body

86. The accommodation (focusing) of the eye is accomplished by the

a. Sphincter of the pupil

b. Contraction of the iris

c. Action of the ciliary muscles

d. Dilator of the pupil

e. Contraction of the pupil

87. The structure in the eye that responds to the ciliary muscles during focusing is the

a. Pupil

b. Lens

c. Retina

d. Iris

e. Choroid

88. The middle ear is separated from the external ear by the

a. Tympanic membrane

b. Round window

c. The organ of Corti

d. Oval window

e. Cochlea

89. The structure that contains the receptor cells for the perception of sound is the

a. Tympanic membrane

b. Semicircular canals

c. Mastoid air cells

d. Organ of Corti

e. Middle ear cavity

90. The fluid in the membranous canal of the cochlea is called

a. Aqueous humor

b. Plasma

c. Endolymph

d. Perilymph

e. Vitreous humor

91. Equilibrium is maintained by receptors in the

a. Cochlea

b. Utricle and saccule

c. Tympanic membrane

d. Organ of Corti

e. Middle ear cavity

92. The small bone in the ear that strikes against the oval window of the vestibular canal, setting into motion the perilymph fluid in the vestibular and tympanic canals of the cochlea, is the

a. Incus

b. Hammer

c. Malleus

d. Anvil

e. Stapes

93.–105. Use the terms that follow to identify the structures of the ear shown in Figure 15-8.

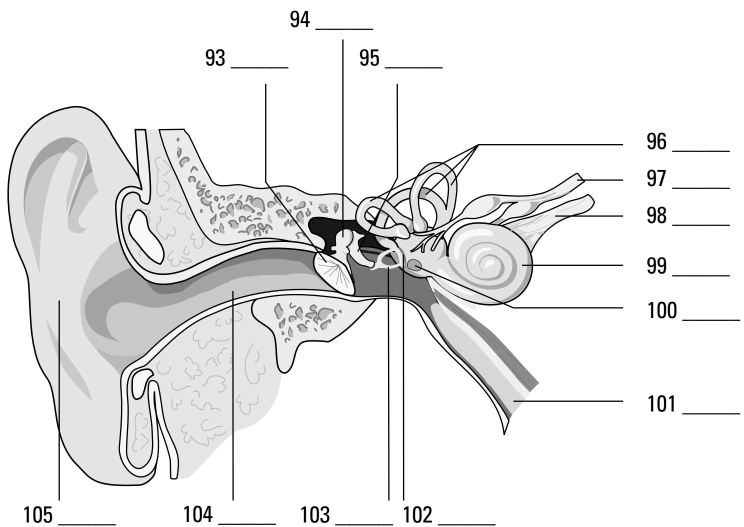

Figure 15-8: The anatomy of the ear.

a. Oval window

b. Semicircular canals

c. Cochlea

d. Pinna

e. Malleus

f. Cochlear nerve

g. Stapes

h. Incus

i. Round window

j. Auditory canal

k. Tympanic membrane

l. Vestibular nerve

m. Auditory tube

Answers to Questions on the Nervous System

The following are answer to the practice questions presented in this chapter.

1 Irritability: **a. Tissue's ability to respond to stimulation**

2 Conductivity: **d. Spreading of the nerve impulse**

3 Orientation: **c. Sense organs' capacity to generate nerve impulse to stimulation**

4 Coordination: **b. Ability to receive impulses and direct them to channels for favorable response**

5 Conceptual thought: **e. Capacity to record, store, and relate information to be used to determine future action**

6 The brain and spinal cord are called the **a. central nervous system.** They're at the *center* of everything.

7 The functional unit of the nervous system is the **d. neuron.** Some of the other answer options are *parts* of a neuron, but the neuron is the central unit.

8 The terminal structure of the cytoplasmic projection of the neuron *cannot* be a(n) **a. node of Ranvier.** The nodes of Ranvier are gaps along the myelin sheath, so one of them can't be found at the end of the line.

9 The afferent fiber that carries impulses to a neuron's cell body is called a **c. dendrite.** Dendrites carry impulses to the neurons; axons carry them away.

10 The membrane surrounding the axon (nerve fiber) is the **b. neurilemma.** When present, this fiber actually wraps around the myelin sheath, so it's always on the outside.

11 Astrocytes: **e. Cells that contribute to the repair process of the central nervous system**

12 Microgliacytes: **d. Cells that are phagocytic**

13 Oligodendrocytes: **b. Cells that form and preserve myelin sheaths**

14 Axons: **c. Cytoplasmic projections carrying impulses from the cell body**

15 Dendrites: **a. Cytoplasmic projections carrying impulses to the cell body**

16 The neuroglia cells are important as **b. supporting tissue.** They nourish and protect neurons.

17 Axons tend to consist of **a. single processes.** A neuron may have one, many, or no dendrites, but it always has a single axon.

18 A synapse between neurons is best described as the **e. transmission of an impulse through a chemical change.** With all that acetylcholine and cholinesterase floating around, it must be a chemical transmission.

19 Endoneurium: **e. Connective tissue surrounding individual fibers in a nerve**

20 Neurilemma: **b. Outer thin membrane around an axon fiber**

21 Schwann cell: **c. Cell in the sheath of an axon**

22 Node of Ranvier: **d. Depression in the sheath around a fiber**

23 Myelin sheath: **a. Fatty layer around an axon fiber**

24 All-or-none response: **c. Threshold of excitation determines ability to respond**

25 Cation: **d. Positively charged ion on the outer surface of the cell membrane**

26 Anion: **b. Negatively charged ion on the inner surface of the cell membrane**

27 Polarization: **a. Impermeability of cell membrane**

28 Depolarization: **e. Reshuffling of cell membrane ions; permeability of cell membrane**

29 Cholinesterase: **b. Enzyme for breakdown of excitatory chemical**

30 Choline acetylase: **c. Enzyme for reformation of excitatory chemical**

31 Terminal bulb: **e. Contains storage vesicles for excitatory chemical**

32 Acetylcholine: **a. Excitatory chemical necessary for continual nerve pathway**

33 Synapse: **d. Space between neurons**

34 The cerebrum consists of two major halves called **d. cerebral hemispheres.** Cerebrum = cerebral, and two halves = hemispheres.

35 The cerebrum is divided into two major halves by the **c. longitudinal fissure.** Longitudinal is the most likely position for an equal division.

36 In the cerebrum, the **e. a, b, and c are correct (right side tends to control the left side of the body and vice versa, upper area controls lower-body activity, and lower area controls upper-body activity).** Right = left, and up = down. Clear as mud?

37 The functions of the occipital lobe of the cerebrum pertain principally to **a. visual activity.** To remember, use the word "occipital" to bring to mind the word "optic," which of course is related to visual activity.

38 The cerebellum functions primarily as a center of **e. motor control.**

39 White matter: **b. Myelinated fibers**

40 Reticular formation: **a. Has the capacity to arouse the brain to wakefulness**

41 Funiculus: **c. Bundles of nerve fibers arranged in tracts**

42 Dorsal root ganglion: **d. Collection of cell bodies outside of the central nervous system**

43 Gray matter: **e. Unmyelinated fibers, cell bodies, and neuroglia**

44 Pons: **a. Bridge connecting the medulla oblongata and cerebellum**

45 Cerebellum: **d. Controls motor coordination and refinement of muscular movement**

46 Medulla oblongata: **b. Contains the centers that control cardiac, respiratory, and vasomotor functions**

47 Cerebrum: **e. Controls sensory and motor activity of the body**

48 Mesencephalon: **c. Contains the corpora quadrigemina and nuclei for the oculomotor and trochlear nerves**

49 The largest quantity of cerebrospinal fluid originates from the **c. lateral ventricle.** This one requires rote memorization — sorry!

50 The part of the brain that contains the thalamus, pituitary gland, and the optic chiasm is the **a. diencephalon.** Think of it as the home of the thalamus, and you can't go wrong.

51–62 Following is how Figure 15-3, the brain, should be labeled.

51. **g. Cerebrum**; 52. **d. Corpus callosum**; 53. **b. Thalamus**; 54. **f. Hypothalamus**; 55. **j. Pituitary gland**; 56. **h. Cerebral aqueduct**; 57. **c. Cerebellum**; 58. **l. Fourth ventricle**; 59. **k. Medulla oblongata**; 60. **a. Pons**; 61. **i. Midbrain**; 62. **e. Third ventricle**

63 The network of nerves formed by the ventral branch of the spinal nerve is a **c. plexus.** The word stems from the Latin for "braid," which makes sense for a network.

64 How many spinal nerves are there? **b. 31 pairs.** Count them: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral — plus 1 tailbone (coccygeal).

65 Which spinal nerve area does not form a plexus? **d. Thoracic**

66 The autonomic nervous system **a. innervates involuntary body functions.** It's the only answer option with a sense of automation.

67 Which of the following statements is true about the autonomic nervous system? **d. It has two divisions that are antagonistic to each other, meaning that one counteracts the effects of the other one.** As a result, the body achieves homeostasis.

68 The divisions of the autonomic nervous system are **d. sympathetic and parasympathetic.** They work against each other in order to help the body maintain balance.

69 Which part of the autonomic nervous system can be called a craniosacral system? **c. Parasympathetic system.** It originates in both the brainstem and the sacral region.

70–83 Following is how Figure 15-7, the internal structures of the eye, should be labeled.

70. **g. Ciliary body**; 71. **d. Retina**; 72. **k. Choroid**; 73. **f. Sclera**; 74. **n. Posterior cavity (vitreous humor)**; 75. **h. Fovea centralis**; 76. **a. Blind spot**; 77. **l. Blood vessels**; 78. **c. Optic nerve**; 79. **j. Anterior cavity (aqueous humor)**; 80. **b. Pupil**; 81. **e. Cornea**; 82. **m. Iris**; 83. **i. Lens**

84 The area of the eyeball that contains cells that are sensitive to light is the **b. retina.** It's at the back of the eyeball.

85 Which of the following structures is not part of the eyeball? **a. Optic nerve.** This nerve carries the visual signals to the brain.

86 The accommodation (focusing) of the eye is accomplished by the **c. action of the ciliary muscles.** They reshape the lens by contracting and relaxing as needed to bring things into focus.

87 The structure in the eye that responds to the ciliary muscles during focusing is the **b. lens.** Refer to the explanation for the preceding question.

88 The middle ear is separated from the external ear by the **a. tympanic membrane.** Otherwise known as the eardrum, this membrane sometimes bursts or tears as a result of infection or trauma.

89 The structure that contains the receptor cells for the perception of sound is the **d. organ of Corti.** Hairs in this structure are what ultimately send the signal down the auditory nerve.

90 The fluid in the membranous canal of the cochlea is called **c. endolymph.** Don't forget that the prefix *endo*– means "within."

91 Equilibrium is maintained by receptors in the **b. utricle and saccule.** These little endolymph-filled sacs have hairs and chunks of calcium carbonate that detect changes in gravitational forces.

92 The small bone in the ear that strikes against the oval window of the vestibular canal, setting into motion the perilymph fluid in the vestibular and tympanic canals of the cochlea, is the **e. stapes.** That's the only bone that actually touches the window. The other two carry the signal down the chain to the stapes.

93–105 Following is how Figure 15-8, the structures of the ear, should be labeled.

93. **k. Tympanic membrane**; 94. **e. Malleus**; 95. **h. Incus**; 96. **b. Semicircular canals**; 97. **l. Vestibular nerve**; 98. **f. Cochlear nerve**; 99. **c. Cochlea**; 100. **i. Round window**; 101. **m. Auditory tube**; 102. **a. Oval window**; 103. **g. Stapes**; 104. **j. Auditory canal**; 105. **d. Pinna**