The Organization and Functions of the Nervous System

Chapter Outline

The Central Nervous System
  The Forebrain

APPLICATION: The Case of Phineas Gage
  The Midbrain and Hindbrain
  The Spinal Cord
  Protecting the Central Nervous System

CONCEPT CHECK

The Peripheral Nervous System
  The Cranial Nerves
  The Autonomic Nervous System

CONCEPT CHECK

Development and Change in the Nervous System
  The Stages of Development
  How Experience Modifies the Nervous System
  Damage and Recovery in the Central Nervous System

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IN THE NEWS: Nuclear Testing Reveals Adult Neurogenesis in Humans

APPLICATION: Mending the Brain with Computer Chips

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Learning Objectives

After reading this chapter, you should be able to answer the following questions.

1. What are the major functions of each of the cerebral hemispheres?
2. What are the locations and major functions of the thalamus, hypothalamus, midbrain, hindbrain, and cerebellum?
3. Describe the structure and function of the spinal cord.
4. What features of the central nervous system protect it?
5. What structures make up the peripheral nervous system, and what are their functions?
6. What happens in the nervous system during each of the stages of neural development?
7. How does the nervous system change in response to experience?
8. What are the barriers to recovery from damage in the nervous system? What new techniques are being developed to overcome some of these barriers?

The Central Nervous System

Summary and Guided Review

After studying this section in the text, fill in the blanks of the following summary.

The central nervous system (CNS) is composed of the ______________________ (1) and the ______________________ ______________________ (2). In the CNS a bundle of axons is called a(n) ______________________ (3) and a group of cell bodies is known as a(n) ______________________ (4). In the peripheral nervous system (PNS), an axon bundle is called a(n) ______________________ (5) and a group of cell bodies is referred to as a(n) ______________________ (6). Early in development, the CNS begins as a hollow tube and quickly differentiates into a spinal cord and three brain areas, the ______________________ (7) (which in humans becomes the largest area), the ______________________ (8), and the ______________________ (9).

The forebrain contains two ______________________ (10) hemispheres, the ______________________ (11) that receives sensory information, and the underlying ______________________ (12). The hemispheres are separated by the longitudinal ______________________ (13). For the most part, each hemisphere receives information from and controls movement in the ______________________ (14) side of the body. The outer layer of the cerebral hemispheres, the ______________________ (15), is wrinkled in appearance and contains many ______________________ (16) (ridges) and ______________________ (17) (grooves). The surface is composed mostly of cell ______________________ (18), which accounts for its gray appearance. Its convoluted structure allows for greater ______________________ (19) area and more efficient connections for axons. The interior of the cortex, composed mostly of axons, appears ______________________ (20). Furthermore, the cortex is arranged in six ______________________ (21) in most areas. The layers are organized in ______________________ (22) that run perpendicular to the cortical surface area; these provide a vertical unity to the layers and are considered the primary ______________________ (23) processing unit in the cortex.

Among humans, having a larger brain is not usually an indication of superior ______________________ (24). In comparing different species, the overall size of the brain is in proportion to the body, with larger animals having larger brains. The intelligence of a species appears to be more related to the ______________________ (25) of the brain rather than its size. Among the most intelligent species, the cortex is ______________________ (26) in proportion to other brain areas. The nervous system itself is arranged in a(n) ______________________ (27), with complexity in structure and in the behaviors controlled increasing from the spinal cord up to the cortex.
Each hemisphere is divided into four lobes, and each lobe contributes to somewhat different functions. One function that the ______________________ (28) lobes are involved in is movement, as well as some of the most complex human capabilities. Different parts of the body are mapped onto areas of the ______________________ (29), the location of the primary motor cortex, in the form of a(n) ______________________ (30), such that the parts of the body that are capable of fine motor movements (such as the fingers) are represented by a larger portion of the brain. The primary motor cortex also works with neighboring ______________________ (31) motor areas and subcortical structures such as the ______________________ ______________________ (32) in the control of movement. ______________________ (33) area, another frontal lobe structure, is involved in ______________________ production and grammar.

The ______________________ (35) cortex, which is the anterior portion of the frontal lobe and the largest area of the human brain, contributes to a number of cognitive functions. Damage to this area can lead to many types of problems, including an inability to plan or organize actions, learn from experience, control impulsive behavior, or make decisions. It is also believed to be involved in mental illnesses such as schizophrenia and ______________________ (36). In the 1940s and 1950s, it was common practice to “disconnect” the prefrontal cortex from the rest of the brain through a procedure known as a(n) ______________________ (37). Over 40,000 of these were performed in the United States on people with mental illnesses of various types. The success of this procedure was limited, and it eventually fell into disfavor, especially when effective ______________________ (38) treatments become available in the 1950s. The importance of the frontal lobes was clearly demonstrated in the case of ______________________ ______________________ (39) who suffered specific deficits as a result of an accident in which a dynamite tamping iron pierced his skull and brain.

The parietal lobe contains the postcentral gyrus, which includes the ______________________ (40) cortex, onto which the body senses are projected. This area is structured to represent the body in much the same way as the primary motor cortex. The parietal lobe ______________________ (41) provide further processing of sensory information, integrating several different types of sensory input. A person with damage to this area may experience ______________________ (42), a condition in which objects, people, and activity on the side opposite the damage are ignored.

The ______________________ (43) lobe contains the auditory cortex and (on the left hemisphere) ______________________ (44) area, which is involved in language comprehension and production. Visual identification of objects is carried out in the ______________________ (45) temporal cortex; people with damage to this area have difficulty recognizing objects by sight, including familiar people. People have reported experiencing specific events or memories when parts of the temporal cortex have been stimulated during brain surgery. Most of this brain stimulation research was conducted by the neurosurgeon ______________________ (46).

The entire occipital lobe is devoted to the sense of ______________________ (47). The primary projection area is organized like a map of the retina (the back part of the eye). The remainder of the occipital cortical areas process different components of images, such as color, form, and movement.

Other major structures of the forebrain include the ______________________ (48), which serves as a relay station for sensory information, and the ______________________ (49), which is important in emotions and motivated behavior. The hypothalamus controls the ______________________ (50) or master gland, which in turn controls all other glands in the body. Bodily cycles such as sleep are controlled in part by the ______________________ (51) gland.

One way in which the hemispheres communicate with each other is via structures such as the corpus ______________________ (52), which is found at the bottom of the longitudinal
fissure. In cases of severe epilepsy, the corpus callosum may be surgically disconnected. People who have had this procedure can lead normal lives, but they show to a certain extent that the two hemispheres have different functions, the left hemisphere being more involved in ______________________ (53) and the right in ______________________ (54) tasks and recognizing faces. Fluid-filled cavities called ______________________ (55) are located in the brain. They contain ______________________ (56) fluid, which transports nutrients to and wastes away from the CNS.

The midbrain contains several important structures. The superior and inferior ______________________ (57) are involved in eye movements and locating sounds, respectively. The midbrain also contains areas involved in movement; degeneration of cells in the ______________________ (58) is implicated in Parkinson’s disease. The ventral ______________________ (59) area plays a role in reward. The tube-shaped midbrain and hindbrain make up the brainstem (60). The hindbrain includes the ______________________ (61), which is involved in vital functions such as respiration and keeping the heart beating, and the ______________________ (62), which is involved in sleep and arousal. The ______________________ (63) formation is a collection of nuclei running through the core of the midbrain and hindbrain. On the back of the brain stem is the ______________________ (64), which physically resembles the cerebral cortex and is essential in a number of motor and cognitive activities.

The spinal cord communicates between the brain and the body; it contains ______________________ (65), which are motor programs for repetitive behaviors such as walking, and is responsible for certain reflexive behaviors. The spinal cord contains ascending ______________________ (66) tracts, which enter the spinal cord through the ______________________ (67) roots, and descending ______________________ (68) tracts, which exit the spinal cord through the ______________________ (69) roots. Some of the sensory neurons form connections directly or indirectly with motor neurons, which allow for spinal ______________________ (70).

The CNS is protected in a number of ways. It is covered by the ______________________ (71) (three-layered membrane), and the ______________________ (72) fluid cushions the brain. Harmful substances are prevented from entering the brain by the ______________________ (73) barrier. The cells making up the walls of many of the ______________________ (74) serving the brain are tightly joined, which keeps many substances from passing through them. One area of the brain that is not protected in this way is the area ______________________ (75); when toxins are detected here, vomiting occurs.

Short Answer and Essay Questions

Answer the following questions.

1. What is a major advantage of the convoluted structure of the cerebral cortex?
2. Why is brain size alone not a good indication of intelligence of different species of animals (e.g., humans and elephants)? What is a better indication?
3. How are the primary motor and somatosensory cortices organized in relation to the body areas they receive information from or send information to? What determines how much space on the cortex is devoted to a particular area of the body?
4. What is the condition known as neglect? What is the likely cause of it?
5. Identify three of the many functions of the temporal lobe.
6. Name three areas in the midbrain and hindbrain that are involved in motor function.

7. Why is the blood-brain barrier important? Explain how the structure of the blood-brain barrier helps keep some harmful substances out of the brain. Why is it advantageous that the area postrema NOT be protected by the barrier?

The Peripheral Nervous System

Summary and Guided Review

After studying this section in the text, fill in the blanks of the following summary.

The peripheral nervous system (PNS) is composed of spinal and __________________ (76) nerves; it can be divided into the __________________ (77) nervous system, which is involved in the control of movement and carries sensory information to the CNS, and the autonomic nervous system (ANS), which is involved in the control of __________________ (78) and glands. Two of these are sometimes considered part of the brain: the __________________ (79) nerve, which carries information about smell, and the __________________ (80) nerve, which carries information about vision.

The ANS has two divisions: the __________________ (81), which mobilizes bodily resources, and the __________________ (82), which helps to restore energy. The sympathetic nervous system is highly coordinated due to the sympathetic __________________ (83). Most of the affected organs are stimulated together when this system is activated. In general, the two branches of the ANS have opposite effects on organs. For example, sympathetic activation __________________ (84) heart rate, while parasympathetic activation __________________ (85) it. However, both branches are active at the same time, but one may have a stronger effect at one time than the other.

Short Answer and Essay Questions

Answer the following questions.

8. From the information provided in Figure 3.19, which cranial nerves appear to be involved in eye movement? Which are probably involved in speaking?

9. Why is the sympathetic nervous system able to act in a more coordinated fashion than the parasympathetic? What advantage is there for the coordinated action of the sympathetic nervous system?

Development and Change in the Nervous System

Summary and Guided Review

After studying this section in the text, fill in the blanks of the following summary.

Once the neural tube has formed, the nervous system develops in stages. During the first stage, __________________ (86), new neurons are formed at a high rate in the ______________ (87) zone of the neural tube. In the second stage, the new neurons migrate toward the outer layers of the tube with the support of __________________
glial cells. During this time, the neurons have the potential to become many different types of neurons. The next stage is ______________________ ______________________ (89) formation, during which axons find their way to target cells and form synapses with them. The chemical environment of the developing nervous system is detected by ______________________ ______________________ (90) on the ends of the axons; they are attracted to certain locations and repelled from others by the chemicals. The genes ______________________ (91) 1 and 3 are involved in getting neurons to their final destination. The nervous system produces many more neurons than it needs, and during the next stage of development, ______________________ ______________________ (92), synapses are eliminated and neurons die, leaving only those that are functional and useful. A neuron is more likely to survive this stage if it fires at the same time as its neighbors, in part because postsynaptic neurons release ______________________ (93) that enhance the development of presynaptic neurons. Circuit pruning may occur before birth, even in the absence of environmental input. In the visual system, for example, waves of activity sweep through the ______________________ (94), strengthening the connections that have been formed. As synapses are formed, most neurons lose ______________________ (95), or the ability to undergo modification, while others remain flexible throughout the life span.

During the formation of the nervous system, disruption of development can have serious consequences. For example, periventricular ______________________ (96), a genetic disorder, produces a smooth cortex, which usually results in severe epilepsy and mental retardation. Prenatal exposure to _________________ (97) consumed by the mother may result in neurons migrating to the wrong place or failing to become appropriately organized. Babies with fetal alcohol syndrome often have small and malformed ______________________ (98) and are mentally impaired. Ionizing _________________ (99) is another environmental agent that can interfere with proliferation and migration, particularly if the mother is exposed between the 8th and 15th week of pregnancy. The nervous system is not considered fully mature until _________________ (100) is complete, which happens sometime in late ______________________ (101) or adulthood. This process begins with the lower areas of the brain, and the last areas to mature are the ______________________ (102) lobes.

Throughout the life span, the nervous system may undergo ______________________ (103) in response to experience. Through this process, some synapses may be lost while new ones are formed, and areas of the brain devoted to specific functions may actually expand. Reorganization can even violate the doctrine of specific ______________________ (104), which states that input to a particular sensory area will always result in the same type of sensation. In the blind, for example, some of the visual cortex may be taken over by the _________________ (105) system, so the visual cortex actually participates in reading Braille. Sometimes reorganization can have detrimental effects, such as when a limb is amputated and the somatosensory neurons from nearby body parts take over the part of the cortex that was devoted to the missing limb; this is thought to be responsible for _________________ (106) pain that amputees sometimes experience. Experiments with cats have revealed that if an animal sees only vertical stripes during early development, it will not be able later to detect objects that are oriented _________________ (107).

Recovery from damage in the nervous system is limited. Although in some species, such as ______________________ (108), damaged neurons easily regenerate, this is not true in all animals. In mammals, regeneration involving the regrowth of a severed _________________ (109) occurs in the ______________________ (110) nervous system with the help of myelin. In the CNS, however, regrowth is unlikely because of the chemical environment, scar tissue, and the presence of glial and ______________________ (111) cells. Also, in most parts of the nervous system, new cells are not produced once proliferation ends. However, new cell production, or ______________________ (112), is seen in the hippocampus.
and the olfactory bulb, as well as at other sites when disease-related damage occurs. It may be possible to enhance regeneration as a treatment for brain damage.

Many people who suffer brain damage do recover some of the functions lost initially from the damage through the process of ______________________ (113), in which healthy neurons take over the connections that were lost due to the damage. Reorganization may also occur, such as in the case of ______________________ (114) (language impairment). Occasionally, researchers encounter a person who suffers from profound structural damage but who shows no apparent behavioral impairment. Examples from the text include cases of periventricular heterotopia, which has been discussed previously, and ______________________ (115), a condition in which blockage of cerebrospinal fluid can lead to severe retardation if untreated. These cases demonstrate that the nervous system is capable of compensating for even extensive damage, although the processes involved are not understood.

There are some other promising forms of therapy that may result in repairing CNS damage, including spinal cord injury and brain damage. One promising molecule, when given to rats with induced stroke, blocks glutamate-induced ______________________ (116), reducing the area of brain damage by 40%. Embryonic ______________________ (117) cells are pluripotent and may be used in the mature brain to replace cells damaged by injury or disease.

Short Answer and Essay Questions

Answer the following questions.

10. During neural development, axons often have to grow over extensive distances, and sometimes across hemispheres, in order to reach their target postsynaptic cells. How is this accomplished? Include in your answer the roles of growth cones and the Robo1 and Robo3 genes.

11. It is clear that the nervous system starts out with a lot more neurons than it needs. Why do you think it is advantageous for the nervous system to have so many neurons to start with, if many of them are only going to be lost? Keep in mind that the environment an animal encounters is at least somewhat unpredictable.

12. Maria was exposed to high levels of ionizing radiation during her 32nd week of pregnancy. She is concerned that this will have profound negative effects on her fetus, particularly its nervous system. What would you tell her?

13. What is syndactyly? How does surgical correction of syndactyly and the resulting changes in the brain demonstrate neural reorganization?

14. Describe some ways in which the CNS can compensate at the level of the synapse for the loss of neurons in specific locations.

15. Describe some possible treatments that may be used in the future to correct brain and spinal cord injuries.

Post-test

Use these multiple-choice questions to check your understanding of the chapter.

1. A ___ is the name for a bundle of neurons in the PNS.
   a. nerve
   b. tract
   c. nucleus
   d. ganglion
2. The spinal cord is part of the ___ nervous system.
   a. central
   b. autonomic
   c. peripheral
   d. sympathetic

3. Which of the following is the largest division of the mature CNS in humans?
   a. forebrain
   b. midbrain
   c. hindbrain
   d. spinal cord

4. The space separating the cerebral hemispheres is called the
   a. lateral fissure.
   b. corpus callosum.
   c. central sulcus.
   d. longitudinal fissure.

5. The surface of the cortex appears gray because it is composed mostly of
   a. unmyelinated axons.
   b. unmyelinated cell bodies.
   c. myelinated axons.
   d. myelinated cell bodies.

6. In the cortex, a ridge is called a
   a. fissure.
   b. gyrus.
   c. tract.
   d. sulcus.

7. What is the name of the 19th-century European anatomist who argued that because women have smaller brains than men, they are less intelligent?
   a. Penfield
   b. Ramón y Cajal
   c. Bischoff
   d. Sperry

8. Animal species that are the MOST intelligent tend to have
   a. bigger brains overall.
   b. more convolutions on the cortex.
   c. a proportionately larger forebrain.
   d. b and c

9. The directional term *anterior* means
   a. in front of.
   b. behind.
   c. above.
   d. below.

10. The brain area controlling fine motor movement is located on the
    a. prefrontal cortex.
    b. precentral gyrus.
    c. postcentral gyrus.
    d. central sulcus.
11. The area of the motor cortex devoted to which of the following body areas is probably the smallest?
   a. lips
   b. tongue
   c. thumb
   d. thigh

12. Damage to the prefrontal cortex is LEAST likely to result in problems with
   a. decision making.
   b. planning.
   c. speech comprehension.
   d. impulse.

13. Who among the following was a proponent of lobotomies as a treatment for mental illness?
   a. Penfield
   b. Gage
   c. Freeman
   d. Bischoff

14. The somatosensory cortex is located in the ___ lobe.
   a. frontal
   b. occipital
   c. temporal
   d. parietal

15. Identifying objects by touch is a function of the
   a. somatosensory cortex.
   b. parietal association cortex.
   c. visual cortex.
   d. inferior temporal cortex.

16. Modern computer studies of the skull of Phineas Gage have revealed the extent of damage to the
   a. frontal lobes.
   b. corpus callosum.
   c. parietal lobes.
   d. brain stem.

17. Which of the following is NOT a function of the temporal lobes?
   a. processing auditory information
   b. language comprehension
   c. fine motor control
   d. visual identification of objects

18. Electrical stimulation of the association areas of the temporal lobe may result in the patient experiencing
   a. intense pain.
   b. buzzing sounds.
   c. bright lights.
   d. vivid memories.

19. The occipital lobe processes ___ information.
   a. visual
   b. auditory
20. The thalamus receives information from all of the sensory systems EXCEPT the system for
   a. vision.
   b. hearing.
   c. smell.
   d. taste.

21. The hypothalamus is located ___ the thalamus.
   a. above
   b. below
   c. behind
   d. in front of

22. The ___ is the body’s “master” endocrine gland.
   a. pituitary
   b. pineal
   c. hypothalamus
   d. pons

23. The sleep-inducing hormone melatonin is released by the
   a. pituitary gland.
   b. pineal gland.
   c. hypothalamus.
   d. pons.

24. Which statement regarding the corpus callosum is FALSE?
   a. It consists of neuron tracts connecting the two hemispheres.
   b. It is the only place in the brain where information crosses from one side to the other.
   c. It may be severed in order to help control epileptic seizures.
   d. It allows the left side of the brain to share information with the right.

25. Which of the following structures is NOT part of the brain stem?
   a. lateral ventricle
   b. midbrain
   c. pons
   d. medulla

26. All of the following structures are located in the midbrain EXCEPT the
   a. superior colliculi.
   b. ventral tegmental area.
   c. pons.
   d. substantia nigra.

27. Heart rate and breathing are controlled by the
   a. pons.
   b. cerebellum.
   c. superior colliculi.
   d. medulla.

28. A person with damage to the cerebellum may
   a. be blind.
   b. be unable to recognize familiar objects.
c. be insensitive to pain.
d. have problems with movement.

29. The cerebrospinal fluid protects the brain in all of the following ways EXCEPT that it doesn’t
   a. provide nourishment to brain cells.
   b. cushion the brain.
   c. remove waste products from the CNS.
   d. prevent toxins from entering the CNS.

30. The skeletal muscles are MOST directly controlled by the ___ nervous system.
   a. autonomic
   b. somatic
   c. sympathetic
   d. central

31. Which of the following cranial nerves is sometimes considered part of the CNS rather than the PNS?
   a. oculomotor
   b. auditory
   c. vagus
   d. optic

32. Which of the following is more a result of parasympathetic than sympathetic activation?
   a. increased digestive activity
   b. increased heart rate
   c. increased blood pressure
   d. increased respiration

33. The stage of neural development in which axons grow toward their target connections is called
   a. proliferation.
   b. migration.
   c. circuit formation.
   d. circuit pruning.

34. Cell proliferation occurs
   a. in the innermost layer of the neural tube.
   b. in the outermost layers of the neural tube.
   c. throughout the neural tube.
   d. in the location of a neuron’s final destination.

35. Cells that form a scaffold for neural migration are called
   a. astrocytes.
   b. radial glial cells.
   c. myelin cells.
   d. ladder cells.

36. During the first three weeks after birth, the neurons in a monkey’s corpus callosum
   a. triple in number.
   b. increase by about 8 million.
   c. decrease by about 8 million.
   d. undergo very little change.
37. Neural plasticity is retained to the greatest extent in adulthood in which of the following brain areas?
   a. primary visual cortex
   b. somatosensory cortex
   c. primary motor cortex
   d. association cortex

38. Which of the following is NOT a result of fetal exposure to alcohol?
   a. improper migration of cells
   b. failure of cells to form myelin
   c. small brain size
   d. mental retardation

39. Which of the following brain areas is among the last to undergo myelination?
   a. frontal cortex
   b. occipital cortex
   c. spinal nerves
   d. medulla

40. Which of the following is NOT an example of brain reorganization?
   a. larger area of the somatosensory cortex devoted to the index finger in people who read Braille
   b. the occipital cortex of people blind from birth responding to somatosensory information
   c. phantom limb pain following amputation of a leg
   d. regrowth of a severed spinal motor neuron

41. Regeneration is LEAST likely to occur in the
   a. CNS of a frog.
   b. PNS of a frog.
   c. CNS of a mammal.
   d. PNS of a mammal.

42. In the adult mammal, neurogenesis is MOST likely to occur in the
   a. spinal cord.
   b. medulla.
   c. hippocampus.
   d. hypothalamus.

43. Which of the following is NOT true of hydrocephalus?
   a. It results from a blockage of the cerebrospinal fluid.
   b. It can be treated using a drainage shunt.
   c. Even without treatment, individuals usually have normal intelligence.
   d. It affects the development of the CNS.

44. Which of the following is NOT a problem following stroke?
   a. edema
   b. abnormal protein deposits
   c. excitotosis
   d. paralysis

45. Which of the following is FALSE regarding traumatic brain injury? It
   a. can produce Alzheimer-like effects even in young brains.
   b. includes concussion as one of its mild forms.
   c. requires a severe blow, due to the brain’s cushioning.
   d. can be minimized by 3 weeks of rest.
## Answers

**Guided Review**

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72. cerebrospinal 99. radiation
73. blood-brain 100. myelination
74. capillaries 101. adolescence
75. postrema 102. frontal
76. cranial 103. reorganization
77. somatic 104. nerve energies
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83. ganglion chains 110. peripheral
84. increases 111. immune
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86. proliferation 113. compensation
87. ventricular 114. aphasia
88. radial 115. hydrocephalus
89. circuit formation 116. excitotoxicity
90. growth cones 117. stem
91. Robo

Short Answer and Essay Questions

1. One advantage is that it increases the surface area of the brain without increasing its size a great deal. This means more cortex can be packed into a small area.

2. If we compare between species, brain size is more related to body size than intelligence; the largest animals tend to have the largest brains. A good way of representing the connection between brain and intelligence is its complexity, particularly the degree to which the forebrain is developed. Humans’ forebrains are larger and more extensively convoluted than apes’ brains, which are larger and more convoluted than monkeys’ brains, etc.
3. These areas of the brain are organized like maps of the body. Sensory neurons from adjacent areas of the body project to adjacent areas of the somatosensory cortex, and neurons from adjacent parts of the motor cortex control movement in adjacent areas of the body. Areas of the body that are either especially sensitive (because they contain a lot of sensory receptors) or capable of fine motor movement are represented by a larger area of the cortex than areas that are less sensitive or not involved in fine motor movement. For example, the fingers are represented to a greater extent in both cortices than is the back.

4. This is usually the result of damage to the association cortex in the parietal lobe. It occurs because this part of the brain is involved in various spatial tasks, such as being able to tell where things are in the environment and being able to locate one’s own body in space. Persons who suffer damage to this area in the right hemisphere may not pay attention to things on the left side of the body; such an individual may not even recognize that an arm or leg belongs to her or him.

5. The temporal lobes are where auditory information is initially processed and most of language comprehension occurs; the lobes also contain auditory and visual association areas responsible for tasks such as recognition of faces and other visual objects.

6. Three areas with a role in motor function in the midbrain and hindbrain are the substantia nigra, the cerebellum, and the reticular formation.

7. The main route for toxins and other substances to get into organs is through the bloodstream. The brain is especially vulnerable (because most adult CNS neurons do not replicate), so it is especially important to keep toxins out of the brain. In many parts of the brain, the capillaries are structured to do just that. The cells that make up the capillary walls are tightly packed together, so that very few substances can pass through them without going through special channels, and the special channels are selective in what they allow through. However, not all brain areas are protected in this manner. In the area postrema, toxins can get in, and it is actually beneficial that they do in some cases. If a toxin is detected in this area, it triggers the vomiting response, and if the source of the toxin is in the stomach, it will be removed from the body.

8. Cranial nerves III (oculomotor), IV (trochlear), and VI (abducens) control eye movement. Cranial nerves X (vagus) and XII (hypoglossal) are probably involved in speech.

9. The sympathetic nervous system consists of components of several of the spinal nerves serving various internal organs. The activity of its neurons is coordinated because many of them are interconnected within the sympathetic ganglion chain just outside the spinal cord, which allows for a coordinated response. No such structure exists in the parasympathetic division. The advantage of the coordination of the sympathetic division is that it provides a mobilization of most of the body’s resources in times of stress.

10. First of all, axons contain a growth cone, which is used to find the correct pathway. The cone is sensitive to the external chemical environment, and it is attracted to certain places and repelled from others. The sensitivity of the growth cone to different chemicals can also change over time as the axon grows into different areas. The Robo1 gene produces a chemical that repels axons; so when it is active, axons do not grow across the midline of the brain. Activation of the Robo3 gene leads to axons being attracted across the midline. Once it is deactivated, the axon is no longer attracted to the midline and continues to grow in that side of the brain.

11. By initially overproducing neurons, the nervous system allows for streamlining (elimination of unused and retention of used connections) to eliminate errors in circuit formation. The alternative to overproduction would be more precise circuit formation, which would require complex chemical and genetic codes. In addition, this strategy allows for adaptation to
varied environmental conditions that could not be predicted in advance. An example of such selection occurred in the experiment in which kittens were reared with only horizontal or only vertical stripes.

12. While there may be some detrimental effects, they would probably be worse if she had been exposed earlier, between 8 and 15 weeks of gestation, because that is when proliferation and migration of neurons are occurring at high rates.

13. Syndactyly is a condition in which the fingers are connected by a web of tissue, are of limited usefulness, and are mapped onto overlapping areas of the somatosensory cortex. Within a week following surgical separation, patients’ brains showed dramatic changes in that the separated fingers were now represented in distinct locations on the somatosensory cortex.

14. Healthy presynaptic neurons can form new terminals to create replacement connections. Postsynaptic cells can create new receptors to compensate for reduced presynaptic input. And “silent” collaterals, terminals that were inactive, may become active almost immediately following injury.

15. One possibility is introducing new neurons, either from fetal cells or stem cells. The other possibilities involve manipulating the environment of the mature CNS so that it does not inhibit axon regeneration. These mechanisms include providing the nervous system with substances that can promote neural growth, inhibit those substances that inhibit neural growth, serve as scaffolds for developing axons, and/or block the immune response that may be harmful to developing axons. Use of glial and stem cells from the person’s own olfactory mucosa may also be helpful in restoration or improvement in function.

Post-test