STROKE

Louis R. Caplan, MD

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Stroke

By
Louis R. Caplan, MD

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Preface

"Knowledge is power."

Francis Bacon

Medical care in the twenty-first century has become more complex than at any time in the past. Insurance companies and those who pay for medical care, hospitals, and doctors have created many rules that complicate entry into the medical system and sometimes make it difficult for patients to receive the medical care they need and deserve. Patients and their loved ones face more barriers and hassles than in the past.

Good medical care requires an effective partnership between doctors and patients and their loved ones. In order for individuals to become good consumers and to press for the best medical care, they need to understand the functions of their bodies and the diseases and risks for diseases they are likely to develop as they age. The Internet, and publications aimed at patients and potential patients have greatly proliferated. The public has been deluged with information. Some of the information is too complicated to be easily understood, some of the information is wrong, and some media communications are motivated by marketing strategies aimed at getting people to buy a medicine or to undergo a procedure.

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The quote at the beginning of this chapter was written by Eric Hodgins, the author of the popular best seller *Mr. Blandings Builds His Dream House.* In Hodgins's later book, *Episode: Report on the Accident Inside My Skull,* he describes exactly what it felt like to be suddenly deprived of speech and the movement of his right limbs. He changed from a highly functioning human being in one moment to a helpless, dumb invalid, "a case," in the next instant. Imagine an articulate author dependent for his livelihood on his use of language becoming totally unable to speak or write.

THE COMPLEXITY OF STROKE

Stroke is a complicated condition having many different causes and very different effects on individuals. Loss of function may be temporary or permanent, slight or devastating. Some functions may improve, while others do not. Readers will better understand stroke, as explained in this book, by following the stories of the four stroke patients referred to throughout the book. Their symptoms, stroke risk factors, the causes of their strokes, their evaluations and treatments, and the effects that their strokes had on themselves and their families and environment will be described. The four patients are:

Robert H., a 68-year-old retired engineer who lives with his wife. His three children are married and are

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stroke research gets much less funding than heart disease, cancer, diabetes, and AIDS. Figure 1-1 shows the relative spending on research for these diseases in 1994 and 1996.

Although strokes are much more common in people over 65, and many people believe that strokes only happen to old folks, strokes can occur at any age, including infancy, childhood, adolescence, and early adulthood. During the last 35 years, I have taken care of over 200 patients who have had strokes before their 40th birthday. There are now several medical books devoted entirely to discussions of strokes in the young. Stroke can happen to anyone. Stroke can happen to you!

STROKES IN HISTORY

The history of the world has undoubtedly been greatly affected by stroke. Many important leaders in science, art, medicine, and politics have had their productivity cut prematurely short by stroke. Louis Pasteur, the great French scientist whose discoveries led to the vaccines that prevent smallpox, had a stroke at age 46 that caused left-sided paralysis. In spite of this stroke, he continued to make important advances until additional strokes further impaired his ability to function at age 65. Marcello Malpighi, one of the first individuals to describe the biologic characteristics of the small blood vessels and capillaries, and who wrote

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ened artery with a wall that is ballooned outward. The artery breaks, spilling blood instantly into the spinal fluid that circulates around the brain and spinal cord. The sudden release of blood under high pressure increases the pressure inside the skull and causes severe, sudden-onset headache, often with vomiting. The sudden increase in pressure causes a lapse in brain function, and the patient may stare, drop to his knees, or become confused and unable to remember anything.

Most often, the symptoms in patients with subarachnoid hemorrhage relate to a general decrease in brain function, because usually there is no bleeding into one part of the brain. The decreased function is caused by increased pressure within the skull. In contrast, in patients with intracerebral hemorrhages, the hematoma is localized and causes loss of function related to the area damaged by the local blood collection. For example, if the bleeding occurs into the left cerebral hemisphere, the patient often has weakness and loss of feeling in the right limbs and a loss of normal speech, whereas a hemorrhage into the cerebellum will cause dizziness and a loss of balance.

Tom M., who was introduced in Chapter 1, had an intracerebral hemorrhage into his left cerebellum. Recall that he suddenly became dizzy, staggered, and vomited. He became unable to walk. The cerebellum is specialized for balance, equilibrium, and coordina-

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red clot broke off and moved into his head, causing his stroke.

Several conditions promote and accelerate the development of atherosclerotic plaques, including hypertension, especially if not well controlled, cigarette smoking, high blood cholesterol levels (elevated low density lipoproteins [LDL] and low high density lipoproteins [HDL]), and diabetes, especially if not well controlled. These factors will be discussed in relation to the prevention of stroke in the next chapter.

Hypertension

Hypertension is the single most important risk for brain ischemia and brain hemorrhage.

High blood pressure (hypertension) leads to wear and tear on arteries. Picture again a plumbing situation in which the water pressure is quite high. The pipes and the walls of the pipes might become thinned and rusted with time. Similarly, high blood pressure in the body accelerates the development of atherosclerotic changes in the large arteries of the neck and head. Plaque development is more severe and occurs earlier in life than when blood pressure is normal. Hypertension also leads to thickening of the walls of small arteries within the brain. This thickening

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is understood. The heart is the center of the circulatory system; it pumps blood continuously to the various vital body organs, including the brain. The heart is divided after birth into two quite separate circulatory systems, one supplying blood to the lungs (pulmonary circulation), and one supplying the brain and the rest of the body (systemic circulation). Each side of the heart has two chambers: an upper chamber called the *atrium.* and a lower chamber called the *ventricle.* Blood returns from the veins of the body into the right side of the heart and enters into its upper chamber, the right atrium. The various body organs have used up the oxygen in this blood, so the returning venous blood is blue. The blood then passes through a valve (called the *tricuspid valve.* because it has three cusps) that lies between the right atrium and the lower muscular chamber, the right ventricle. The right ventricle pumps the blood through a different valve, the *pulmonic valve.* into the main *pulmonary arteries.* which supply the lungs.

The blood is then reinfused with oxygen in the lungs. When it returns to the heart through the pulmonary veins, it is bright pink or red, indicating high oxygen content. The oxygenated blood returning to the heart from the lungs goes into the left side of the heart. It enters the left upper chamber (the left atrium), and then passes

valves, causing *mitral insufficiency* and *mitral stenosis. Aortic stenosis* and *aortic insufficiency* are also common. Some children are born with abnormal heart valves. Aging can also lead to degenerative changes within the valves. One relatively common valve condition that is especially frequent in women is called *mitral valve prolapse.* This means that portions of the mitral valve go backward into the atrium instead of entirely going into the left ventricle. Mucoid material can be deposited within the mitral valve and cause this abnormal functioning. Heart valves can also be damaged by infection. This is usually termed *bacterial endocarditis.* Valve diseases can lead to discharge of a number of different types of particles into the blood stream: white and red blood clots, and pieces of calcium, bacteria, and fibers that collect along the valve. Poorly functioning valves sometimes need to be replaced surgically. Clots can form on artificial valves and become a source of embolism.

Congenital Heart Disease

Some heart problems are congenital.

Some heart problems are congenital, meaning that the defects are present at birth and continue. Some people have holes between their left and right atria or ventricles. These are referred to as *atrial* or

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that occur during and just after pregnancy can also promote excessive blood clotting.

Some blood proteins *(antithrombin III. protein C.* and *protein S)* inhibit the blood from clotting when they are present in normal amounts. When there is a deficiency of one of these substances, usually from birth, then blood clotting will be excessive. There will be an increased tendency for the blood to clot when other blood clotting proteins are excessive; for example, *factors VII. VIII.* or *XII.* Thrombi can develop within blood vessels that have plaques, within apparently normal small blood vessels, and within the veins that drain the brain.

CONDITIONS THAT CAUSE BRAIN AND SUBARACHNOID HEMORRHAGE

Hypertension

Hypertension is the most significant risk factor for bleeding within the brain. Sudden increases in blood pressure severely stress small arteries within the brain and can cause them to break, resulting in hemorrhage into brain substance. Chronic, poorly controlled hypertension also produces wearing down of the walls of the small arteries so that small outpouchings *(microaneurysms)* develop. These outpouchings are not visible grossly, but are seen only through a microscope. The walls of the outpouchings are thin and can break,

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is illustrated in Figure 3-7. Most often they appear like small lakes of blood located within the brain. When they bleed, the hemorrhage is usually contained within the capsule in the brain substance.

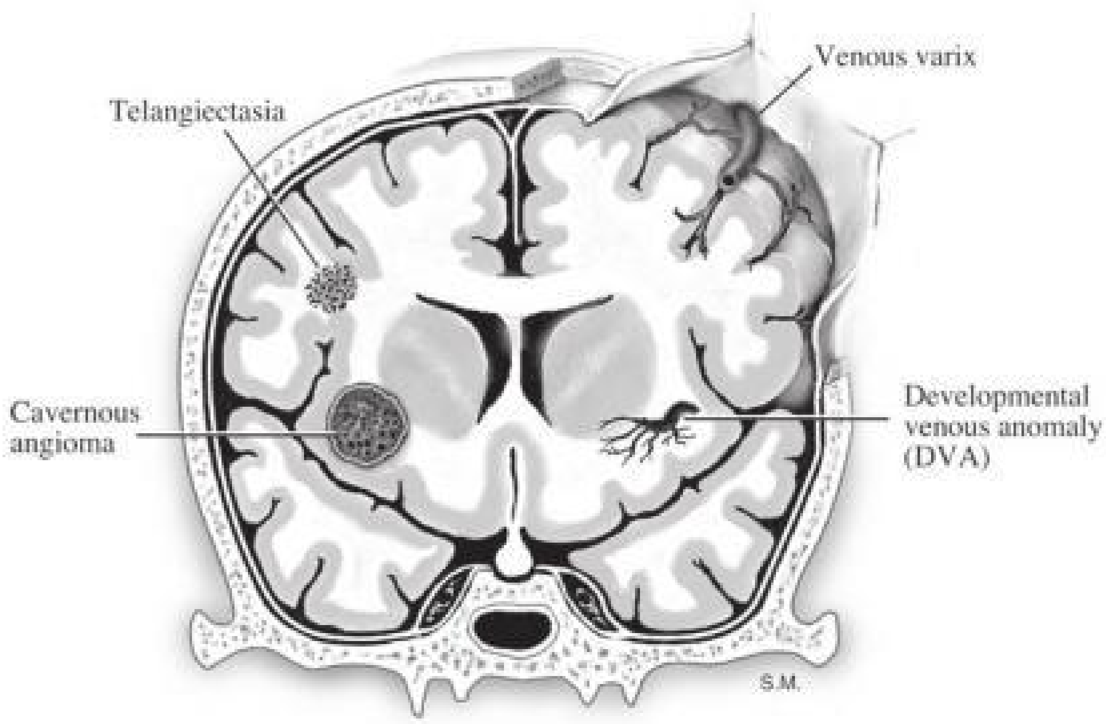

Figure 3-7: Cross section of the brain containing a cavernous angioma, developmental venous anomaly, telangiectasis, and a venous varix.

Venous angiomas (usually called *developmental venous anomalies* [DVAs]) are the most common type of vascular malformation found in the brain by modern brain imaging and after death. There is a deficiency of draining veins in children born with DVA, so that some of the remaining veins must drain a larger portion of brain than is customary (Figure 3-7). DVAs are probably not an important cause of brain hemorrhage, but they do predispose to epileptic seizures.

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Table 4-3 Medications Used to Control Diabetes

tolbutamide (Orinase®)

chlorpropamide (Diabinese®)

glyburide (Micronase®)

glipizide (Glucatrol®)

repaglinide (Prandin®)

metformin (Glucophage®)

acarbose (Precose®)

miglitol (Glyset®)

pioglitazone (Actos®)

troglitazone (Rezulin®)

rosiglitazone (Avandia®)

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increased frequency of miscarriage, stroke, leg vein clotting, and migraine.

Comments on Diet

Health is not determined only by what you eat. Nevertheless, many individuals are intensely focused on dietary intake as the way to prevent the development of disease. Research on the relationship between the intake of various food substances and disease is particularly difficult. In order to show that a given food substance either prevents or contributes to the development of a given medical condition, researchers want everything else to remain the same, including the intake of all other foods, genetics, behavior, and other diseases. The only variable should be the food substance being tested. Unfortunately, in real life there are many other variables, and they cannot always be controlled.

Health is not determined only by what you eat.

The American Heart Association and other medical organizations agree on the following nutritional recommendations to help prevent vascular disease:

- Do not overeat
- Limit salt intake

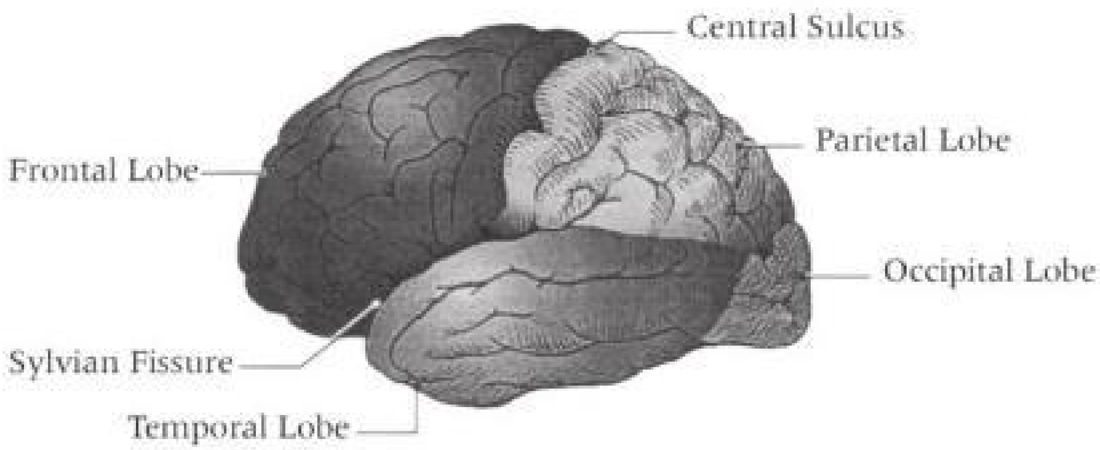

Figure 5-1: View of the cerebrum from the left side.

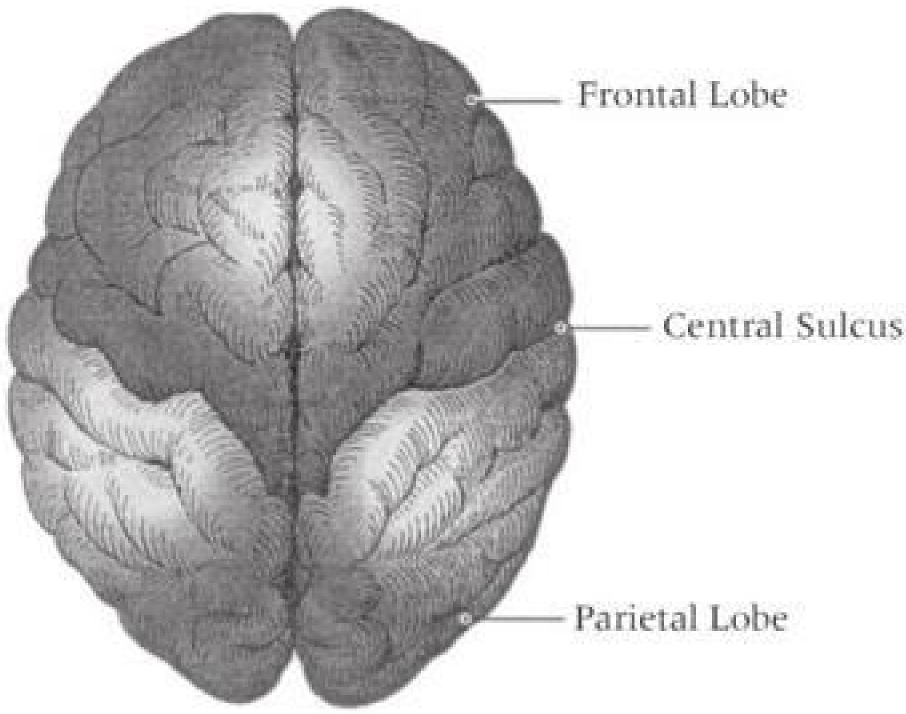

Figure 5-2: View of the cerebral hemispheres from the top.

brum, which covers them in the same way a cap hovers over the rest of a mushroom.

The surface of the cerebral and cerebellar hemispheres of the brain is made up of folded raised strips of brain tissue called *gyri.* There are valleys or clefts called *sulci* between the gyri. A black line is drawn on Figure 5-1 along the *central sulcus.* The frontal lobe lies in front of the central sulcus; the *parietal lobe. temporal lobe.* and *occipital lobe* lie behind the central sulcus. These names are derived from common terms for the

Cerebellum literally means "little cerebrum," or "little brain." It resembles a small walnut attached to the brainstem far back in the head below and behind the cerebrum, which dwarfs the cerebellum in size. The cerebellum helps coordinate all body movements, including those of the limbs, eyes, and mouth.

Internal Appearance and Composition

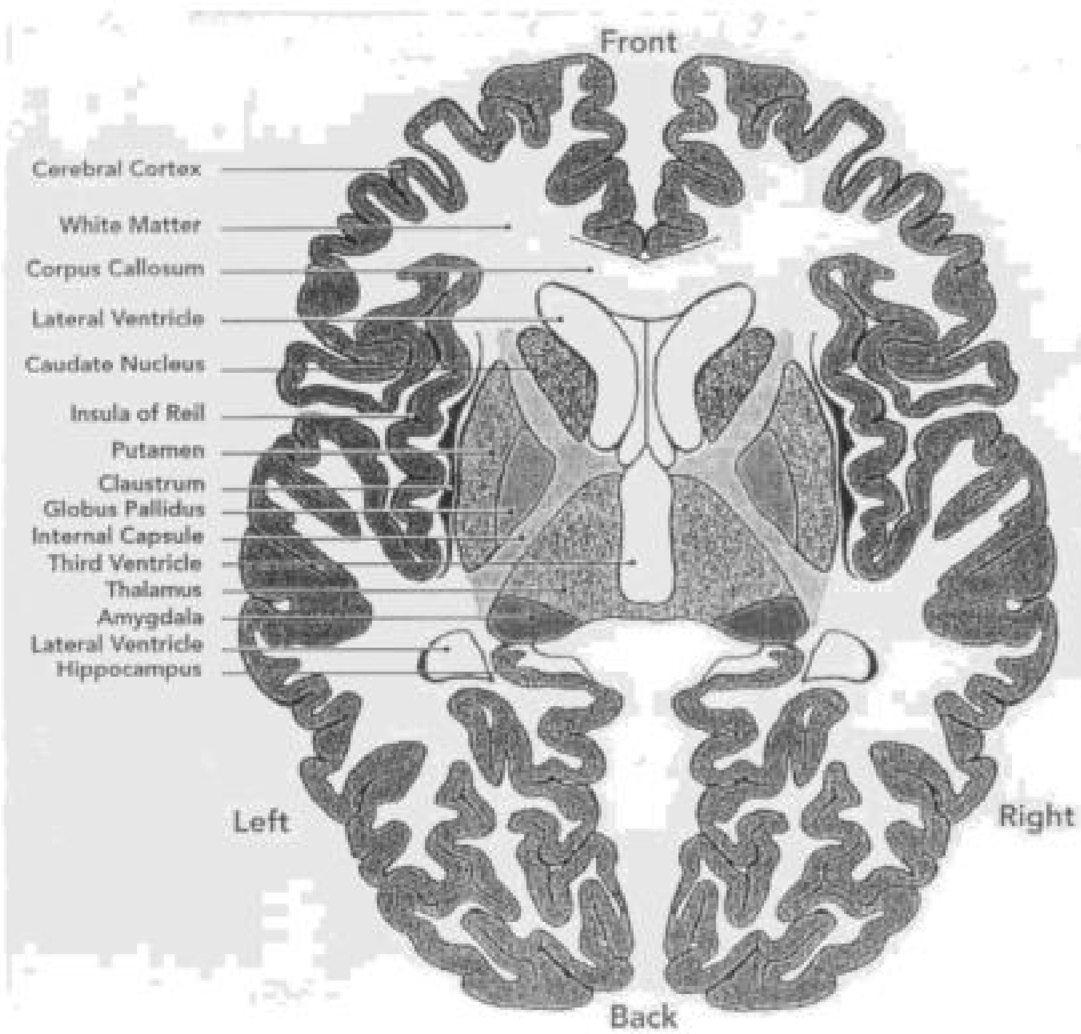

Figure 5-4: A cut section of the cerebrum.

Figure 5-4 shows a cut section of the brain. The *cerebral cortex* is the gray ribbon on the very periphery of the section. Many of the nerve cells that relate

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only be reached through the village by three different roads (the *superior. middle.* and *inferior cerebellar peduncles*), which attach to the brainstem in its lower (medulla), middle (pons), and upper (midbrain) portions. The cerebellum coordinates eye, neck, tongue, and body movements; it intimately relates to the *vestibular system* in the brainstem. The peripheral receptors for the vestibular system are located within the inner ear. They relate to a series of canals that are shaped similar to tires. Movement of the head and neck send the water in these canals in motion and tell the individual precise information about movement and the relation of the head to space. (This type of information about motion and localization in space is absolutely critical for birds and fish.) Humans get this type of information from a number of inputs, including the vestibular system, vision, and joint position sense. Information goes from the inner ears in the vestibular nerves to the vestibular nuclei located within the brainstem tegmentum. The information then goes to the nuclei that control eye movements so that your eyes move with your head, allowing you to continue to focus while running, swimming, or turning. It also goes to the cerebellum to help coordinate walking and use of the limbs. The cerebellum sends information to the cerebrum and the spinal cord nerve cells by way of the brainstem.

Alertness is maintained by a series of small neurons (called the *reticular activating system*) located on each side, near the middle of the brainstem tegmentum. These nerve cells send messages through the thalamus to each side of the cerebrum in order to maintain alertness and an energized state. Coma develops if the *reticular activating system* on both sides of the brainstem is injured. This system, along with other nuclei located in the upper brainstem, also control the sleep – wake cycle.

BRAIN FUNCTIONS

Most organs, such as the liver, lungs, and skin, are relatively homogeneous: One part of these organs looks and works the same as another. This is not the case in the brain. The structures and functions of the brain are quite well localized, and the various brain regions look and function differently. For example, moving a limb, feeling something in a hand, seeing, talking, reading, smelling, walking, hearing, and many other key bodily functions are all localized to very different but characteristic brain regions. To make things even more complex, the sides of the body, and even the functions of the individual limbs, are controlled from different localizations within the brain. The left side of the brain generally controls activities of the right arm and leg; it is involved in the perception and analysis of various stimuli (feeling, sound, and visual objects), which are presented to the right side of the body and the right side of space outside of the body. The right side of the brain controls the same functions on the left side of the body. Many psychologic and general medical problems show general symptoms of brain dysfunction, including feeling depressed, tired, sleepy, confused, and generally weak. The most common disorder affecting a local region of the brain is stroke.

The most common disorder affecting a local region of the brain is stroke.

MOTOR FUNCTIONS (MOVEMENT, STRENGTH, COORDINATION, AND WALKING)

In general, the parts of the brain in front of the central sulcus (the frontal lobes) are mostly related to *action* and *movement.* the so-called *motor functions.* The areas behind the central sulcus are more involved with sensory input. Figure 5-6A, B and 5-7A are diagrams of the efferent motor pathway, which originates from the primary motor cortex primarily localized to the *precentral gyrus.* The efferent pathway from the motor cortex neurons is called the *cortico-spinal* or *pyramidal tract.* This tract descends within the white matter under the cortex (called the *centrum semi-ovale*) into the white matter near the deep gray nuclei (called the *corona radiata*). The tract next courses through the front portion of the *internal* *capsule.* a white matter tract with a single, nearly 45-degree bend between various basal gray nuclei. This tract then descends within the basal portion of the brainstem. Fibers within the pyramidal tract will leave the main path to synapse with the various nuclei within the brainstem that control movements of the eyes, face, jaw, and tongue. The pyramidal tract then descends into the spinal cord to synapse on motor neurons within the anterior horns of the spinal cord, which innervate the muscles of the trunk and limbs. Fibers that influence voluntary movement of the upper limbs leave the tract in the upper neck (cervical portion of the spinal cord); fibers that influence the lower limbs leave the tract in the lower back (lumbar region). Some fibers within this descending motor tract go all the way to the lower end of the spinal cord (sacral or tail region) and synapse with the nerve cells that help control the pelvic and genital muscles, which relate to urination, defecation, and sexual function. Figure 5-8 shows the spinal cord and the location of the motor and sensory tracts within the spinal cord. Damage to the motor cortex or this pathway at any point leads to loss of voluntary motor control of any parts below the interruption. When the pyramidal tract or the fibers leading into it are interrupted, individuals will not be able to move their arm, hand, and leg at will. (The parts of the motor system are labeled on Figure 5-6B.)

spinal cord. These neurons send information about touch, pain, heat, cold, pressure, and the location of the limbs in space, toward the brain. They also send information locally to the motor nerve cells so that automatic reactions (reflexes), such as limb withdrawal, can occur without the need for the information to pass through the brain. The tracts for pain and temperature sensation *(spino-thalamic tracts)* cross to the opposite side of the spinal cord and then ascend toward a very large, centrally located structure called the *thalamus..* which sits on top of the brainstem and at the foot of the cerebral hemispheres, and serves as the main way station or relay for sensory input to the brain. Sensors specialized for motion and the position of joints and limbs send information through a different pathway. The sensory ganglia send information in a tract in the back portion of the spinal cord called the *posterior columns.* These fibers cross in the brainstem and form a tract called the *medial lemniscus.* which also travels to the sensory nuclei in the thalamus. Fibers from these two systems both synapse in nuclei in the lateral parts of the thalamus. The sensory information is then transmitted from the thalamic nuclei to a somatosensory area in the parietal lobe located in and around the post-central gyrus. When the information reaches the brain, the individual becomes aware of sensory input and changes on the opposite side of their body. (Figure 5-7B shows the pathways for transmission of sensory information.)

> The visual and auditory systems relay important information to the conscious brain in a similar pattern.

The visual and auditory systems relay important information to the conscious brain in a similar pattern. In each, information is first perceived in peripheral receptor nerve cells in the eye *(retina)* and inner ear *(cochlea).* Information then goes through the brain toward special nuclei in the thalamus; it is then relayed to specialized regions in the brain. The information from each eye travels through the *optic nerve* behind the eye. The fibers conveying information about visual stimuli coming from the outside parts of vision are called *temporal fields* because they are close to the temple. They travel in the inner portions of each optic nerve. The fibers conveying visual data about the inner portions of the visual fields are called *nasal fields* because they are close to the nose. They travel in the outer portions of each optic nerve. The inner fibers in each optic nerve then cross in an X-shaped structure near the pituitary gland called the *optic chiasm.* As you can see in Figure 5-10, this crossing realigns the visual fibers so that visual information related to the right side of vision in each eye is now grouped in a fiber bundle that travels at the base of the left side of the brain, called the *optic tract.* This tract contains information from the right temporal visual field and the left nasal field; that is, if you drew a line directly in the middle of your vision, everything

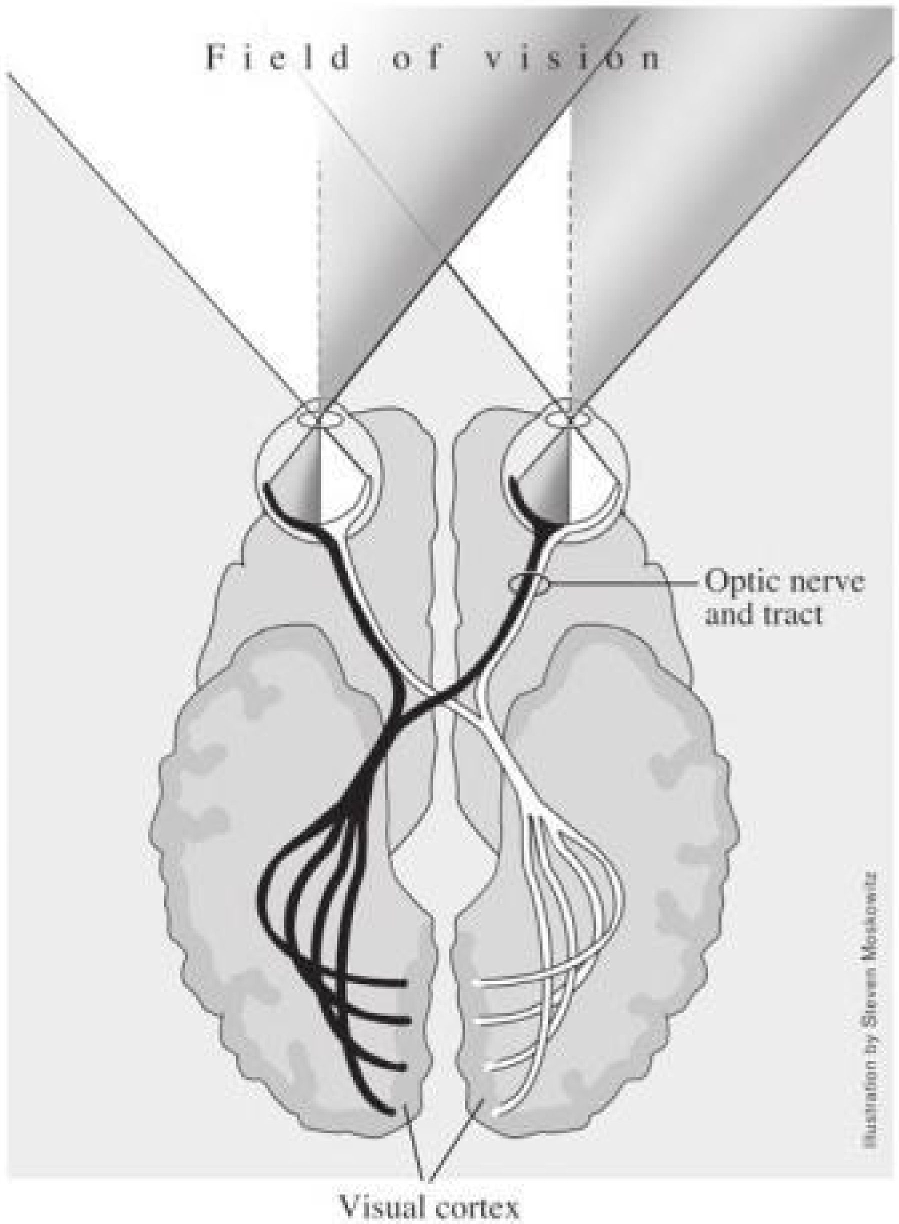

Figure 5-10: The visual pathways.

that is on the right would be contained in the left optic tract. Similarly, the right optic tract contains information from all the visual stimuli on your left (the left temporal field and right nasal field). Each optic tract synapses in a specialized visual nucleus in the back and lateral portion of the thalamus on each side, called the *lateral geniculate bodies.* In turn, fibers travel on each side within the back part of the brain in the visual radiations (called the *geniculo-calcarine tracts*) to end up in the visual cortex in the occipital lobe. The left visual cortex receives visual information from the right side of visual space, and the right visual *(striate)* cortex receives information from left visual space. The concept that the brain is organized in relation to the sides of visual space is very difficult for laypersons to grasp because they tend to think of vision solely in relation to the individual eyes. As can be seen from Figure 5–10, an abnormality in the right eye or right optic nerve will lead to loss of vision in that eye. In contrast, an abnormality in the right optic tract, right lateral geniculate body, right visual radiations, or right visual cortex will lead to vision loss in the left side of visual space.

Sound input is received by nerve cells in the inner ear, and then travels within the *auditory nerves* to nuclei located in the lateral portion of the brainstem (pons) on each side. These nuclei are appropriately named the *auditory nuclei.* Information is then relayed through a number of brainstem nuclei, finally arriving at specialized nuclei on each side of the thalamus called the *medial geniculate bodies.* which lie near but inside of the specialized visual nuclei. From here, the information is relayed to specialized hearing cortex in each temporal lobe, called *Heschl's gyri* after the individual who discovered their functions. The right temporal lobe receives information from the left side of auditory space; the left temporal lobe subserves right auditory space. Similar to the visual system, if an abnormality develops in the left ear or left auditory nerve, you will have difficulty hearing sounds exposed to the left ear. An injury to the left medial geniculate body or left temporal lobe involves all sound coming from the right side of auditory space, irrespective of which ear hears the sounds.

The thalamus also connects to regions of the cerebral cortex on each side, which have specialized abilities for memory, language, visual-spatial, and other cognitive and behavioral functions. These connections are organized as circuits in which there is reciprocal connectivity between the thalami, basal ganglia, substantia nigra, and the different regions of the cerebral cortex.

LANGUAGE AND SPEECH

Language is extremely important for daily communication. The ability to use written language, to read and write, separates humans from all other species. Speech consists of two different components: language and the mechanical movements of the mouth lips and tongue that allow humans to articulate language. The language functions are primarily localized to a region surrounding the large fissure that separates the frontal and temporal lobes on the outer surface of the brain (the *sylvian fissure*) in the so-called dominant hemisphere of the brain. The hemisphere that is dominant for speech is nearly always the left cerebral hemisphere in right-handed individuals and in 80% of left-handers. People who are left-handed are more likely to have speech functions in each hemisphere.

Written language is mostly localized to a region surrounding the angular gyrus within the inferior back portion of the parietal lobe within the dominant cerebral hemisphere. Strokes and other causes of damage to this region cause individuals to become functionally illiterate. They are no longer able to read, write, and spell correctly. The inability to read and write is usually referred to as *alexia with agraphia.* Comprehension and repetition of spoken speech, and the use of wrong words depends on whether the injury also involves the temporal lobe.

MEMORY

Memory storage functions are thought to be localized into a region called the *Papez circuit.* so-named after James W. Papez, the American anatomist who first identified it. The structures within this circuit are mostly located in the medial parts of the temporal lobes on both sides and the medial portion of the thalamus and a structure called the *fornix.* a fiber band that connects the temporal lobe and the thalamus. Several key nuclear structures within the temporal lobes, called the *hippocampi* and the *amygdaloid nuclei.* play an important role in the retention of memories. The hippocampi are shaped similar to sea horses and are located adjacent to the temporal horns of the lateral ventricles of the brain. The amygdaloid nuclei are adjacent to the hippocampi and are almond-shaped. Some of the structures that play a role in memory functions are in the frontal lobes. The most important of these are the *cingulate gyri.* which are located just above the *corpus callosum* on both sides of the brain. Figure 5-11 shows the hippocampus and its location.

The ability to retain information is enhanced if a person consciously tries to retain the material.

Memory functions can be divided into four parts: registration, reinforcement, storage, and retrieval. A person must be attentive and interested in being able to later recall certain information in order to initially register and retain it in their brain. If you are thinking about something else or daydreaming while being told something, you will not recall it later. The ability to retain information is enhanced if a person consciously tries to retain the material. This is done by repeating the information or by associating it with something else to reinforce it. For example, a person might recall a name such as *Blaire* because it resembles their sister's name *Claire.* or because it rhymes with *fair.* Once it is reinforced and repeated, it is probably stored within structures in the Papez circuit for later retrieval. (Figure 5-11)

The left temporal lobe and thalamus are specialized for word and language memories; the right temporal lobe and thalamus are specialized for visual memories.

Memory and language are two functions that organize and integrate the sensory and perceptual functions of the brain. Having discussed these two integrative functions and some of the various forms of perception, including vision, hearing, feeling, and motor function, the following briefly discusses general patterns of cerebral hemisphere functions.

One important theme of the cerebral functions is the interrelationship between motor and sensory functions. Using vision as an example, suppose you see a picture of a scene. Most observers first *see* a key element within the scene. This is done within the *striate visual cortex* within the *occipital lobes.* This initial visual information generates questions that the viewer tries to answer by looking further at the picture. Eye movement searches are generated by the frontal lobe gaze centers. This looking induces further input of visual information, which, in turn, raises further questions and stimulates more looking. Gradually, the viewer gets more and more information from the picture. This process of exploration, a motor behavior called "looking" in the visual sphere, and a perceptual activity referred to as "seeing" in the visual sphere together result in acquiring maximum information.

The information acquired by an individual depends on their intelligence and experience.

The information acquired by an individual depends on their level of interest, intelligence, and experience. Referring to the memory zones within the temporal lobes and thalami and the language area in the left *perisylvian* areas supports the interpretation of visual information and the ability to name the various things seen. Similarly, if you are blindfolded and something is placed in your hand, you will feel it and generate possibilities regarding the nature of the object. You will touch and explore the object in order to discover its nature and its name. This tactile perception takes place in the somatosensory area within the postcentral gyrus of the parietal lobe opposite to the hand in which the object was placed. The manual movements of exploration are generated in the hand and arm area of the precentral gyrus in the opposite frontal lobe. Similarly, hearing a tune being played on a piano occurs in the lateral portion of the temporal lobes. An individual will try to listen or "tune into" certain aspects of the music. This tuning is probably a frontal lobe function. Of course, as in seeing, accurate identification of the nature of the object to be felt or the music being played depends heavily on the previous experience of the individual. If they have never heard the tune or felt the object, they will not be able to identify it correctly.

Another important theme is the circuitry between perceptual regions (located behind the central sulcus) and language and memory regions. For example, suppose someone shows you a familiar coffee mug. You first *see* the cup with your eyes and your visual cortex. Transmission of the visual data to your language area in the left cerebral hemisphere will probably result in generation of the word name *mug* or *cup.* Transmission of the information to your visual memory area in the right medial temporal lobes and then the left medial temporal lobe enables you to *remember* that this particular cup was given to you as a present by your office staff and that you use the mug for coffee each morning at work. Activation of your taste regions in the temporal lobes reinforces that coffee is the only substance placed in this mug. The tactile zones in your parietal lobes might result in your recalling the feeling of the mug in your hands in the morning and that the mug is made of clay. Relay of information between the various sensory areas, the motor exploration areas, memory, and language have let you characterize the nature of that particular object.

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CHAPTER 6

What Are the Arteries and Veins that Supply the Brain?

> "All the veins and arteries proceed from the heart, and the farther away they are from the heart the thinner they become and they are divided into more minute ramifications."
>
> *Leonardo da Vinci*

Just as a plumber needs to know what pipes connect to a malfunctioning sink and how those pipes carry water from the water source to the sink, doctors must try to identify the blood vessels that are blocked or leaking. Identifying the location and nature of the problem in the heart and blood vessels is important in order to choose the appropriate treatment.

Figure 6-1 shows the neck arteries that branch out from the aorta. The two main arteries are called the *carotid arteries;* they are located on each side of the front of the neck. The *common carotid arteries* are branches that arise low in the neck. On the right side, the *innominate artery* is the first large branch to come from the aorta. The innominate artery branches into the right *subclavian artery* (literally, the artery that goes under the clavicle) to supply the right arm and the right common carotid artery, which ascends on the right side of the neck. The left common carotid artery is the second major branch coming from the aorta. It ascends towards the head on the left side of the neck. The third branch from the aorta is the left subclavian artery, which supplies the left arm with blood.

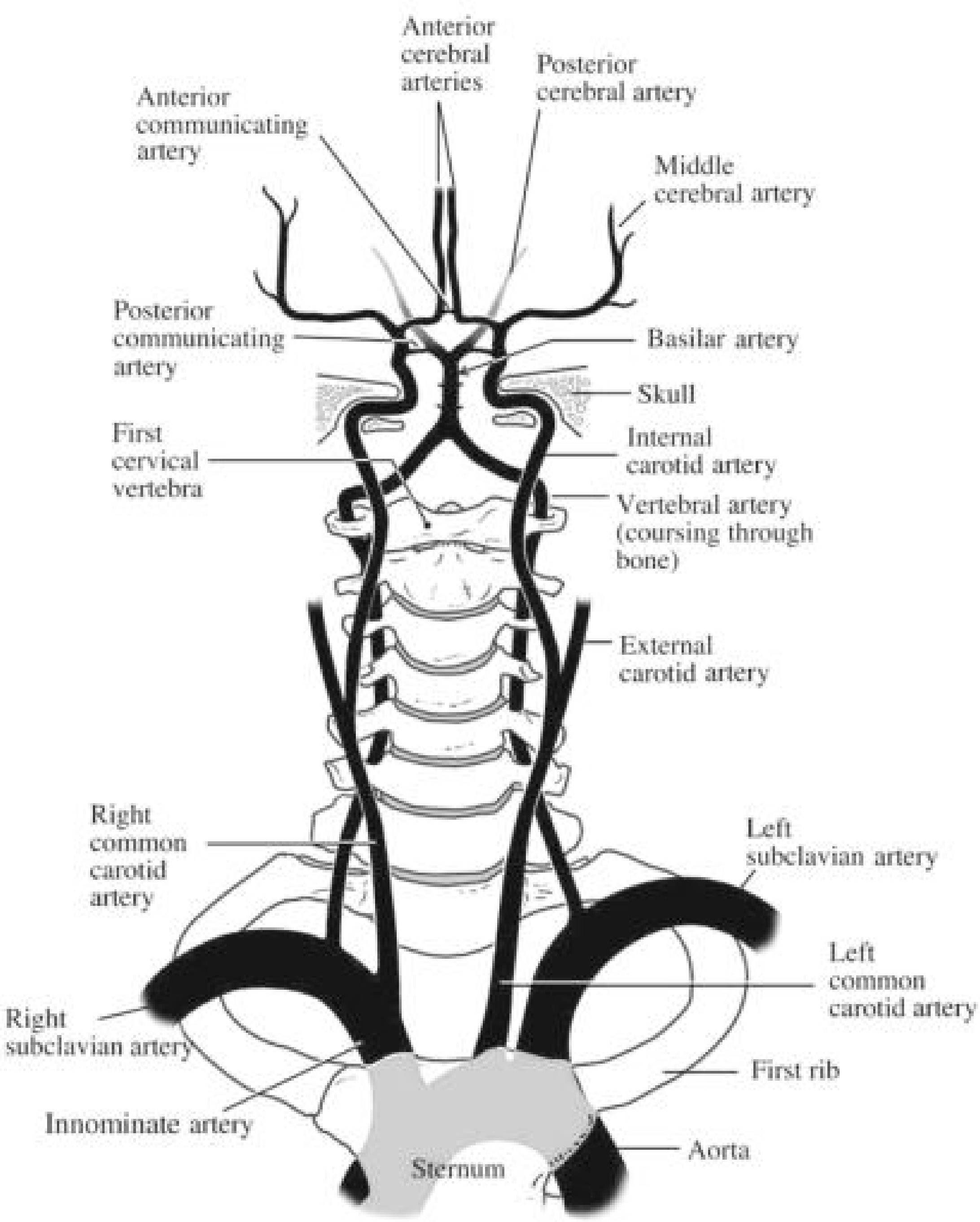

Figure 6-1: Arteries located in the neck.

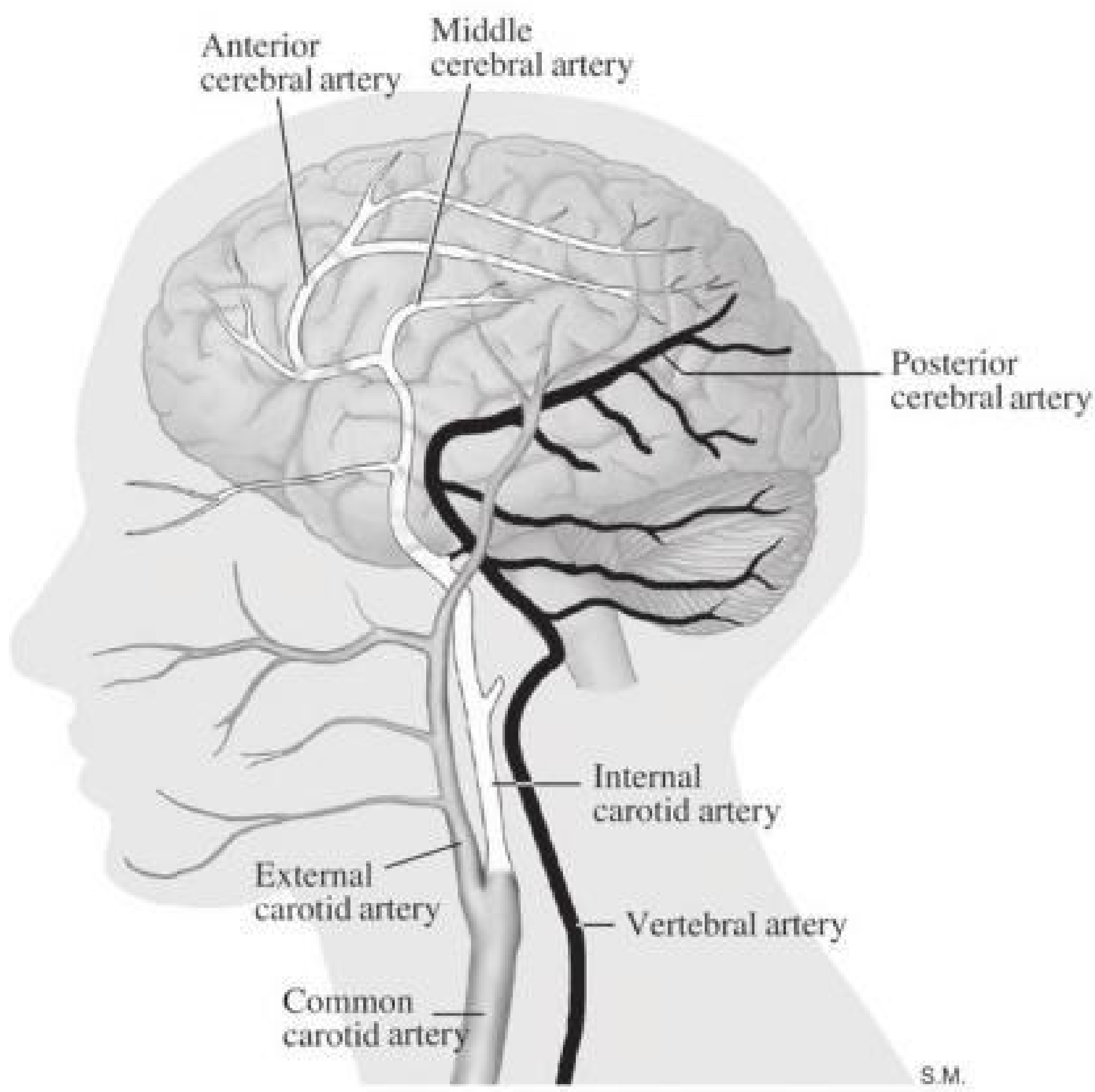

Figure 6-2: Arteries of the neck and head viewed from the left side.

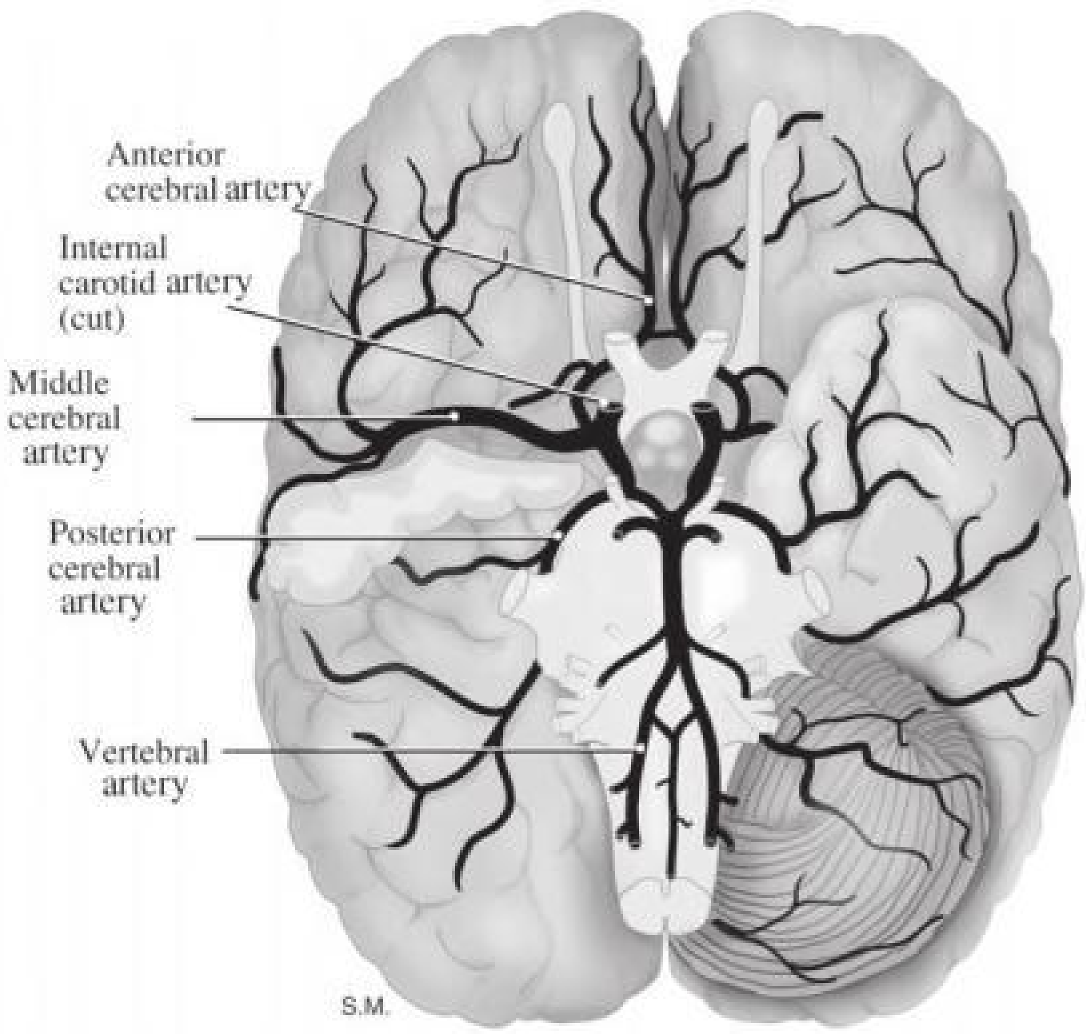

Figure 6-3: Vertebral and basilar artery branching within the skull.

The two *vertebral arteries* that ascend towards the brain in the back of the neck on each side nourish the parts of the brain not supplied by the internal carotid arteries. The paired *vertebral arteries* branch off from the arteries to the arms (the subclavian arteries), and pass through holes in the vertebral bodies. They eventually enter into the back of the brain through a large hole located at the point where the neck vertebrae meet the skull (the *foramen magnum*). The two vertebral arteries supply the medulla oblongata and the back undersurface of the cerebellum on each side, and then join to form the *basilar artery.* a midline blood vessel that supplies the brainstem above the medulla oblongata on both sides. The basilar artery gives off branches near its termination that supply the upper surface of the cerebellum on both sides. The basilar artery divides at a midbrain level and gives branches to the thalami and the temporal and occipital lobes of the cerebral hemispheres on each side. The end large artery branches of the basilar artery are called the *posterior cerebral arteries.* Figure 6-3 shows the supply of the vertebral and basilar arteries to the brain.

Veins are located deep within the brain and on its surface. These veins drain into large venous structures, the *dural sinuses.* located within layers of the dura mater. Blood drains into large neck veins from the sinuses, and from there into the heart. The largest neck veins are called the *jugular veins.* Fluid cannot

CHAPTER 7

What Are the Different Symptoms of Stroke? What Abnormalities Do Doctors Look for and Find in Stroke Patients?

"Listen. Listen to your patient. He is giving you the diagnosis."

Dr. Rene Laennec

"History and the physical examination provide the essential basic facts for diagnosis."

Dr. A.M. Harvey

The timing of treatment is critical.

Good medical care involves full interaction and cooperation between patients and doctors. Of course, doctors cannot treat someone unless the person comes to the doctor with their symptoms. Symptoms

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condition that affected the lateral part of her brain on the left side.

Tom M. leaned to the left when he attempted to sit or stand. He could not walk. He lurched in a drunken fashion to his left side when he attempted to walk. His left arm and hand were quite clumsy when attempting to reach for an object. These findings reinforced the idea that his left cerebellum was not functioning normally.

Having determined the nature of the patient's symptoms and the abnormalities found on examination, the doctor is in a position to order images and laboratory tests to better pinpoint any abnormalities in the brain and in the blood, heart, and blood vessels that supply the brain.

MAKING IMAGES OF THE BRAIN

There are two general types of brain imaging tests: *computed tomography* (CT) and *magnetic resonance imaging* (MRI). CT uses ordinary X-rays and computers to make images of thin slices through different levels of the brain. Each slice contains a picture of the brain structures present at that level. MRI uses magnetic energy to create images of the brain. Both tests are safe and painless. Each requires the patient to place their head into a machine, and with MRI, much of the body may also be enclosed. Patients must remain completely immobile so the machines are able to make clear, high-quality images. People who are claustrophobic may have difficulty holding still while they are in the machine. The MRI machine is also noisy.

MRI produces images of different sections of the brain and generates them at different angles. Cuts are taken from the top to the bottom (coronal), along the long axis of the brain (axial), and from side to side (sagittal). Doctors sometimes order an intravenous injection of a substance that adds contrast to the images in order to obtain more detail on the brain image. In CT this is usually an iodine-containing substance. Gadolinium is the chemical used for contrast enhancement during MRI. Occasionally, patients have an allergic response to these

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MAKING IMAGES OF THE BLOOD VESSELS AND DETERMINING BLOOD FLOW

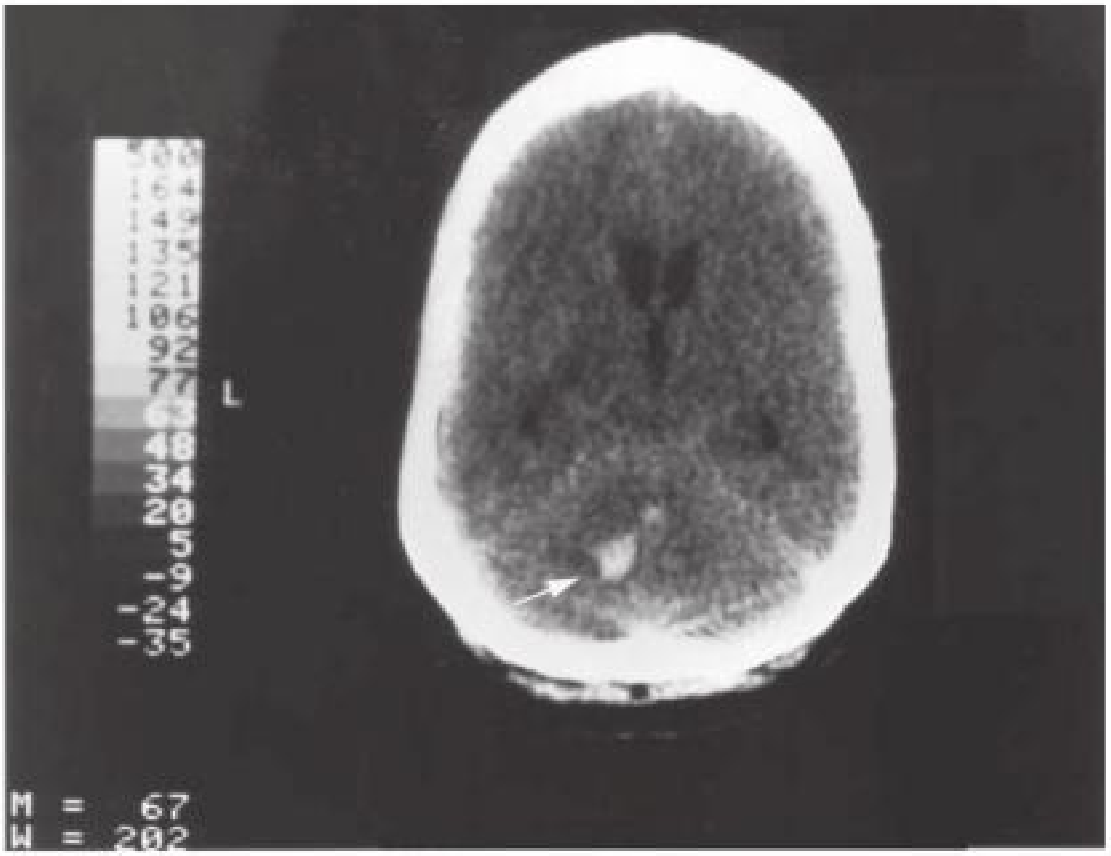

Figure 8-3: CT scan of Tom M. showing a left cerebellar hemorrhage. The hemorrhage appears white (white arrow points to the hemorrhage).

> After identifying stroke-related abnormalities in the brain, doctors test the arteries that supply the injured brain.

After identifying stroke-related abnormalities in the brain, doctors test the arteries that supply the injured brain. Pictures of the arteries *(angiograms)* can be created using a CT scanner. *CT angiograms* (CTAs) are made by injecting an iodine-containing dye into an arm vein and then taking pictures rapidly as the dye goes through the arteries and veins in the brain. *Magnetic resonance angiograms* (MRAs) can be made without injecting dye, by changing the settings on the MRI machine to capture vascular images instead of brain images. MRA can be performed at the same time as MRI; examinations using CTA can be done at the same time as CT. Figures 8-5 and 8-6 show examples of CTA and MRA images. (Figure 8-4 & 8-5))

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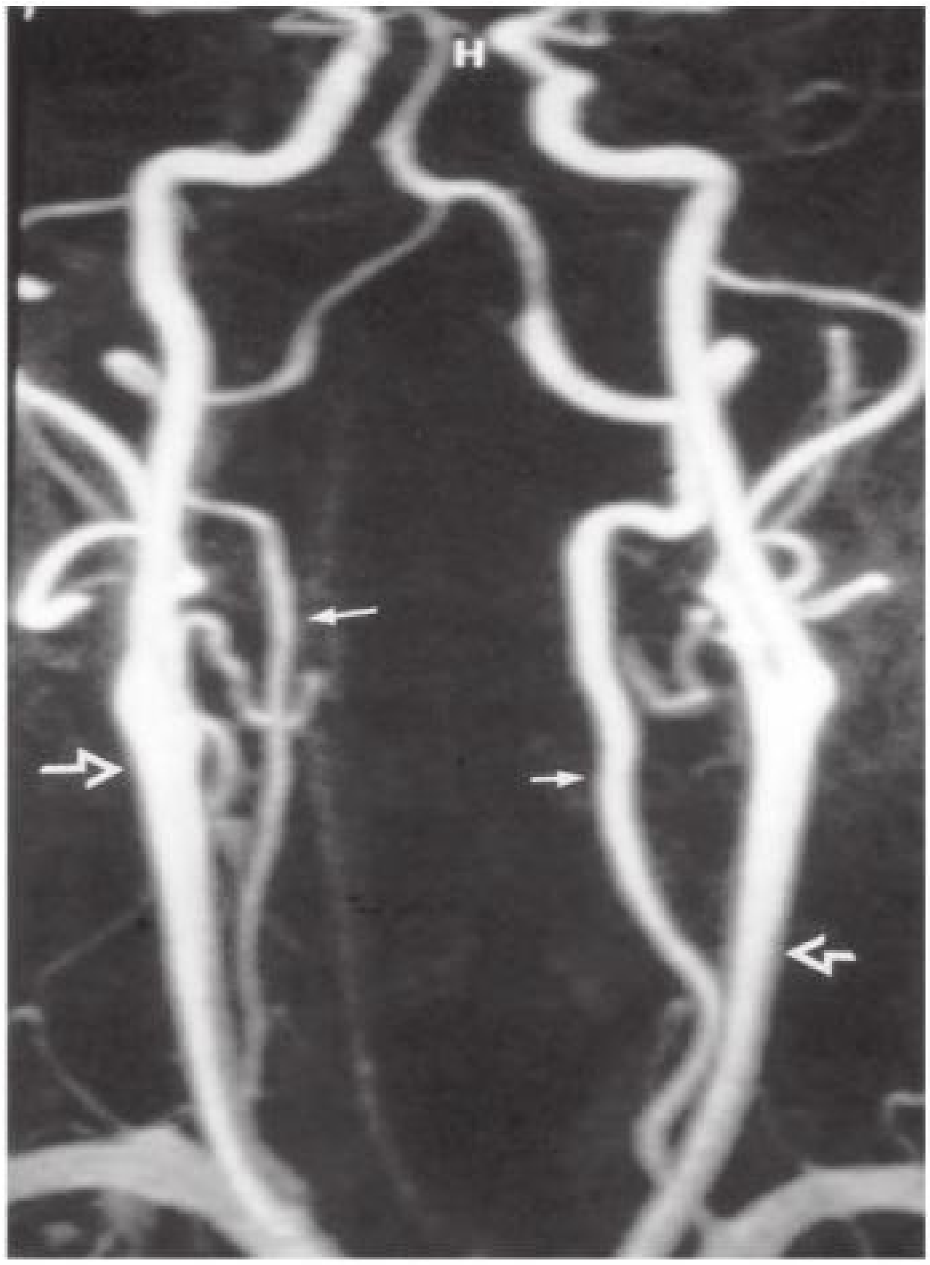

Figure 8-6: MRA showing all of the arteries that branch from the aorta going to the brain. The two open arrowheads on the outside of the arteries point to the carotid arteries. The two smaller white arrows on the inside point to the vertebral arteries.

Duplex ultrasound scans of the neck create images and sound curves of the carotid and vertebral arteries in the neck. Figure 8-7A shows an example of an ultrasound examination of one carotid artery. Some laboratories use *transcranial* ultrasound (TCD) to examine blood flow in the arteries inside of the head. This technique is illustrated in Figure 8-7B. Using this technique, small probes are placed over the eyes, back of the neck, and temples. These are places where the skull is absent or thin. Blood flow velocities in the various arteries within the skull are also checked for narrowing, occlusion, or abnormally increased or decreased blood flow. When an artery in the neck is narrowed or blocked, TCD of the main branches of that artery in the head can reflect the impact of the neck disease on blood flow to the threatened region of the brain.

Single photon emission computed tomography (SPECT) is used to estimate blood flow to a region. After a chemical tagged with a radionuclide is injected into a vein, the brain is scanned with a special machine that detects the distribution of the injected substance. This helps identify relative blood flow to various parts of the brain, but, unlike MRA, CTA, and ultrasound, SPECT does not give images or direct information about the state of the supplying arteries. All of these brain and vascular imaging tests are quite safe and can be performed quickly either inside or outside the hospital.

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gram showed a region of impaired contraction where he had had a myocardial infarct.

STUDYING THE ELECTRICAL ACTIVITY OF THE BRAIN

Doctors can record and study the electrical activity of the brain by placing small electrodes over the scalp. This test is called an *electroencephalogram* (EEG), and it is often used to distinguish between a transient ischemic attack (TIA) and a seizure arising from increased brain activity. Patients with seizures may have temporary interruptions in functioning that can be difficult to distinguish from TIAs without an EEG. Strokes can occasionally cause injuries that induce abnormal electrical discharge, causing patients to develop seizures.

BLOOD TESTS

Blood tests are routinely performed in patients who have had a stroke, or who are suspected of having a TIA or a stroke. The different types of blood tests are listed in Table 8-1. Of course, not all of these tests will be ordered for every patient.

> Blood tests are routinely performed in patients who have had a stroke.

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