Phillips and Farmer note that the important acoustical events in speech sounds fall within a time range of a few milliseconds to a few tens of milliseconds. Speech sounds are made by rapidly moving lips, tongue, and soft palate, which produce acoustical events that can be distinguished only by a fine-grained analysis. In contrast, most environmental sounds do not contain such a fine temporal structure. The authors also note that "pure" word deafness is not absolutely pure. That is, when people with this disorder are tested carefully with recordings of a variety of environmental sounds, they have difficulty recognizing at least some of them. Although *most* environmental sounds do not contain a fine temporal structure, some do-and patients have difficulty recognizing them. For example, one patient with pure word deafness could no longer understand messages in Morse code but could still *send* messages that way.

Apparently, two types of brain injury can cause pure word deafness: disruption of auditory input to Wernicke's area or damage to Wernicke's area itself. Disruption of auditory input can be produced by bilateral damage to the primary auditory cortex, or it can be caused by damage to the white matter in the left temporal lobes that cuts axons bringing auditory information from the primary auditory cortex to Wernicke's area (Digiovanni et at., 1992; Takahashi et at., 1992). Either type of damage-disruption of auditory input or damage to Wernicke's area-disturbs the analysis of the sounds of words and hence prevents people from recognizing other people's speech. (See *Figure* 16.6.)

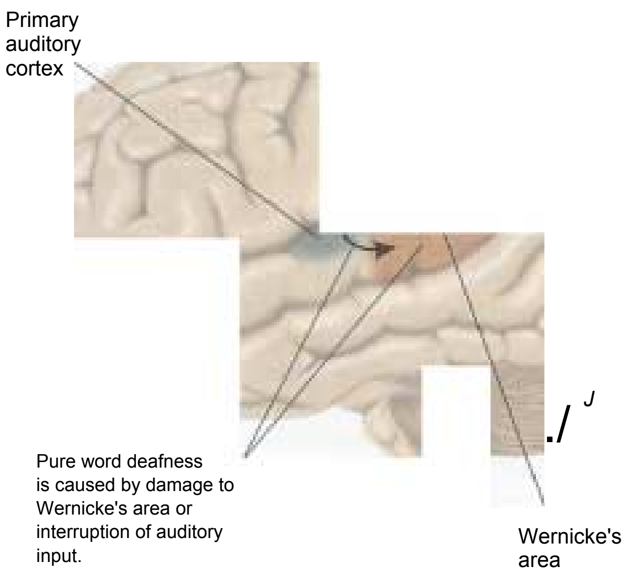

Figure 16.6
The brain damage that causes pure word deafness.

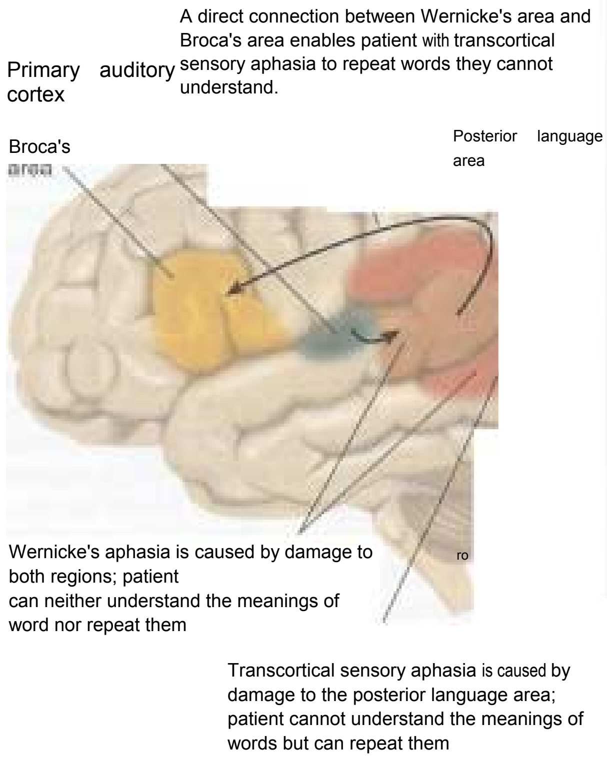

Figure 16.7
The location and interconnections of the posterior language area and an explanation of its role in transc0l1ical sensory aphasia and Wernicke's aphasia.

Comprehension: Transcortical Sensory Aphasia. The other symptoms of Wernicke's aphasia-failure to comprehend the meaning of words and inability to express thoughts in meaningful speech-appear to be produced by damage that extends beyond Wernicke's area into the re. gion that surrounds the posterior part of the lateral fissure, near the junction of the temporal, occipital, and parietal lobes. For want of a better term, I will refer to this region as the *posterior language area.* (See *Figure* 16.7.) The posterior language area appears to serve as a place for interchanging information between the auditory representation of words and the meanings of these words, stored as memo ories in the rest of the sensory association cortex.

Damage to the posterior language area alone, which isolates Wernicke's area from the rest of the posterior lan. guage area, produces a disorder known as transcortical sen. sory aphasia. (See *Figure* 16.7.) The difference between transcortical sensory aphasia and Wernicke's aphasia is that patients with this disorder *can repeat what other people say to them;* therefore, they can recognize words. However, *they cannot comprehend the meaning of what they hear and repeat; nor can they produce meaningful speech of their own.* How can these people repeat what they hear? Because the posterior language area is damaged, repetition does not involve this part of the brain. Obviously, there must be a direct connection between Wernicke's area and Broca's area that bypasses the posterior language area. (See *Figure* 16.7.)

The fact that recognition and comprehension of speech require separate brain functions is illustrated dramatically by a case reported by Geschwind, Quadfasel, and Segarra (1968). The patient sustained extensive brain damage from carbon monoxide produced by a faulty water heater. (The damage included considerably more brain tissue than occurs in most cases of transcortical sensory aphasia, but it illustrates the distinction between the recognition and comprehension of speech.) The patient spent several years in the hospital before she died, without ever saying anything meaningful on her own. She did not follow verbal commands or otherwise give signs of understanding them. However, she often repeated what was said to her. The repetition was not parrotlike; she did not imitate accents different from her own, and if someone made a grammatical error while saying something to her, she sometimes repeated correctly, without the error. She could also recite poems if someone started them. For example, when an examiner said "Roses are red, violets are blue," she continued with "Sugar is sweet and so are you." She could sing and would do so when someone started singing a song she knew. She even learned new songs from the radio while in the hospital. Remember, though, that she gave *no signs of understanding anything she heard or said.* This disorder, along with pure word deafness, clearly confirms the conclusion that *recognizing* spoken words and *comprehending* them involve different brain mechanisms.

In conclusion, transcortical sensory aphasia can be seen as Wernicke's aphasia without a repetition deficit. To put it another way, the symptoms of Wernicke's aphasia consist of those of pure word deafness plus those of transcortical sensory aphasia. (See *Figure* 16.7.)

What Is Meaning? As we have seen, Wernicke's area is involved in the analysis of speech sounds and thus in the recognition of words. Damage to the posterior language area does not disrupt people's ability to recognize words, but it does disrupt their ability to understand them or to produce meaningful speech of their own. But what, exactly, do we mean by the word *meaning?* And what types of brain mechanisms are involved?

Words refer to objects, actions, or relations in the world. Thus, the meaning of a word is defined by particular memories associated with it. For example, knowing the meaning of the word *tree* means being able to imagine the physical characteristics of trees: what they look like, what the wind sounds like blowing through their leaves, what the bark feels like, and so on. It also means knowing facts about trees: about their roots, buds, flowers, nuts, wood, and the chlorophyll in their leaves. These memories are stored not in the primary speech areas but in other parts of the brain, especially regions of the association cortex. Different categories of memories may be stored in particular regions of the brain, but they are somehow tied together, so that hearing the word *tree* activates all of them. (As we saw in Chapter 15, the hippocampal formation is involved in this process of tying related memories together.)

In thinking about the brain's verbal mechanisms involved in recognizing words and comprehending their meaning, I find that the concept of a dictionary serves as a useful analogy. Dictionaries contain entries (the words) and definitions (the meanings of the words). In the brain we have at least two types of entries: auditory and visual. That is, we can look up a word according to how it sounds or how it looks (in writing). Let us just consider just one type of entry: the sound of a word. (I will discuss reading and writing later in this chapter.) We hear a familiar word and understand its meaning. How do we do so?

First, we must recognize the sequence of sounds that constitute the word-we find the auditory entry for the word in our "dictionary." As we saw, this entry appears in Wernicke's area. Next, the memories that constitute the meaning of the word must be activated. Presumably, Wernicke's area is connected-through the posterior language area-with the neural circuits that contain these memories. (See *Figure* 16.8.)

The process works in reverse when we describe our thoughts or perceptions in words. Suppose we want to tell someone about a tree that we just planted in our yard. Thoughts about the tree (for example, a visual image of it) occur in our association cortex-the visual association cortex, in this example. Information about the activity of these circuits is sent first to the posterior language area and then to Broca's area, which causes the words to be set into a grammatical sentence and pronounced. (See *Figure* 16.8.)

What evidence do we have that meanings of words are represented by neural circuits in various regions of the association cortex? The best evidence comes from the fact that damage to particular regions of the sensory association cortex can damage particular kinds of information

transcortical sensory aphasia A speech disorder in which a person has difficulty comprehending speech and producing meaningful spontaneous speech but can repeat speech; caused by damage to the region of the brain posterior to Wernicke's area.

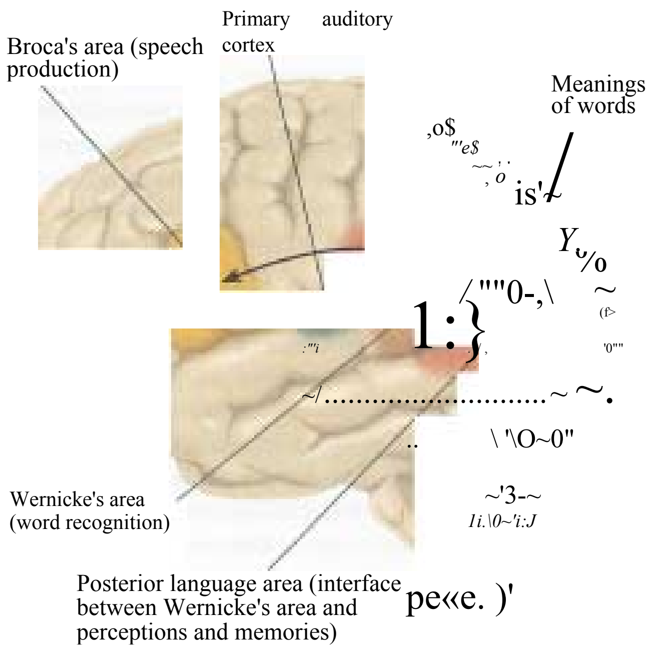

Figure 16.8
The "dictionary" in the brain. Werniche's area contains the au ditory entries of words; the meanings are contained as memories in the sensory association areas. Blach arrows represent comprehension of words-the activation of memories that correspond to a word's meaning. Red alTOWS represent translation of thoughts or perceptions into words.

and thus abolish particular kinds of meanings. For example, I met a patient who had recently had a stroke that damaged a part of her right parietal lobe that played a role in spatial perception. She was alert and intelligent and showed no signs of aphasia. However, she was confused about directions and other spatial relations. When asked to, she could point to the ceiling and the floor, but she could not say which was *over* the other. Her perception of other people appeared to be entirely normal, but she could not say whether a person's head was at the *top* or *bottom* of the body.

I wrote a set of multiple-choice questions to test her ability to use words denoting spatial relations. The results of the test indicated that she did not know the meaning of words such as *up, down,* and *under* when they referred to spatial relations, but she could use these words normally when they referred to nonspatial relations. For example, here are some of her incorrect responses when the words referred to spatial relations:

A tree's branches are *under* its roots.
The sky is *down.*
The ceiling is *under* the floor.

She made only ten correct responses on the sixteen-item test. In contrast, she got all eight items correct when the words referred to nonspatial relations like the following:

After exchanging pleasantries, they got *down* to business, He got sick and threw *up.*

Damage to part of the association cortex of the *left* pari etallobe can produce an inability to name the body parts, The disorder is called **autotopagnosia,** or "poor knowledge of one's own topography." (A better name would have been *autotopanornia,* "poor naming of one's own topogra-phy. ") People who can otherwise converse normally can-not reliably point to their elbow, knee, or cheek when asked to do so and cannot name body parts when the examiner points to them. However, they have no difficulty understanding the meaning of other words.

Other investigators have reported verbal deficits that in-clude disruption of particular categories of meaning. McCarthy and Warrington (1988) reported the case of a man with left temporal lobe damage (patient T.B.) who was un able to explain the meaning of words that denoted living things. For example, when he was asked to define the word *rhinoceros,* he said, "AnimaL can't give you any functions.' However, when he was shown a *picture* of a rhinoceros, he said, "Enormous, weighs over one ton, lives in Africa." Sim-ilarly, when asked what a *dolphin* was, he said, "a fish ora bird"; but he responded to a *picture* of a dolphin by saying. "Dolphin lives in water. . . they are trained to jump up and come out. . . In America during the war years they started to get this particular animal to go through to look into ships." Clearly, patient T.B. has not lost his knowledge of specific animals but only the ability to name them. Pre-sumably, the damage to his brain disconnected circuits involved in the recognition of words from those involved in his memories of animals. When T.B. was asked to define the meanings of words that denoted inanimate objects (such as *lighthouse* or *wheelbarrow),* he had no trouble at all.

Functional imaging studies of people without brain damage confirm these findings. Several experiments have found that perception of words and concepts from different categories activate different parts of the brain. For ex-ample, Spitzer et al. (1995) had people name pictures of items that belonged to four different categories: animals, furniture, fruit, and tools. Functional MRI scans revealed some category-specific sites of activation in the frontal and temporal lobes.

More widespread damage to the temporal and parietal lobes can cause a general loss in comprehension-and not

autotopagnosia Inability to name body parts or to identify body parts that another person names.

simply naming-presumably because of damage to re~ons of the brain that contain specific memories. For example, Damasio and Tranel (1990) studied a patient who had sustained severe damage to the temporal lobes. Besides becoming amnesic (his hippocampal formation was destroyed bilaterally), he had lost a considerable amount of specific information. For example, he recognized that a raccoon was an animal but had no idea of where it lived, what it ate, or what its name was. Hodges et al. (1992) reported several similar cases, caused by progressive degeneration of the temporal lobes. One patient was asked, 'Have you been to America?" She replied, "What's America?" When she was asked, "What is your favorite food?" she said, "Food, food, I wish I knew what that was" (p. 1786). Another patient was frightened when he found a snail in his garden and thought that a goat was a strange creature. Hodges and his colleagues suggest the term *semantic aphasia* to refer to this syndrome.

So far, most of the studies I have described have dealt with comprehension of simple concepts: spatial direction and orientation, body parts, animals, and other concrete objects. But speech also conveys abstract concepts, some of them quite subtle. What parts ofthe brain are responsible for comprehending the meaning behind proverbs such as 'People who live in glass houses shouldn't throw stones" or the moral of stories such as the one about the race between the tortoise and the hare?

Studies of brain-damaged patients suggest that comprehension of the more subtle, figurative aspects of speech involves the right hemisphere in particular (Brownell et al., 1983, 1990). Functional imaging studies confirm these observations. Bottini et al. (1994) had people listen to sentences and judge their plausibility. Some sentences were straightforward and factual. For example, "The old man has a branch as a walking stick" is plausible, whereas "The lady has a bucket as a walking stick" is not. Other sentences presented metaphors, the comprehension of which goes beyond the literal meaning of the words. For example, The old man had a head full of dead leaves" is plausible, whereas "The old man had a head full of barn doors" is not. The investigators found that judging the metaphors activated parts of the right hemisphere, while judging factual sentences did not. Nichelli et al. (1995) found that judging the moral of Aesop's fables (as opposed to judging more superficial aspects of the stories) also activated additional regions of the right hemisphere.

Repetition: Conduction Aphasia. As we saw earlier in this section, the fact that people with transcortical sensory "aphaSia can repeaCwn'a.t'tfl.~rh~an(fggeS{~lHat.lffl:re"d"a~ direct connection between Wernicke's area and Broca's

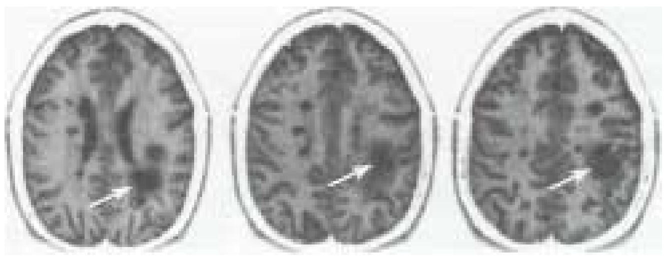

Figure 16.9
MRI scans showing subcortical damage responsible for a case of conduction aphasia. This lesion damaged the arcuate fasciculus, a fiber bundle connecting Wernicke's area and Broca's area.
(From Ameu, P.A., Rao, S.M., Hussain, M., Swanson, S.I., and Hammeke, T.A. *Neurology,* 1996,47,576-578.)

area-and there is, the arcuate fasciculus ("arch-shaped bundle"). This bundle ofaxons appears to convey information about the *sounds* of words but not their *meanings.* The best evidence for this conclusion comes from a syndrome known as conduction aphasia, which is produced by damage to the inferior parietal lobe that extends into the subcortical white matter and damages the arcuate fasciculus (Damasio and Damasio, 1980). (See *Figure* 16.9.)

Conduction aphasia is characterized by meaningful, fluent speech; relatively good comprehension; but very poor repetition. For example, the spontaneous speech of patient L.B. (observed by Margolin and Walker, 1981) was excellent; he made very few errors and had no difficulty naming objects. But let us see how patient L.B. performed when he was asked to repeat words.

Examiner: bicycle
Patient: bicycle
Examiner: hippopotamus
Patient: hippopotamus
Examiner: blaynge
Patient: I didn't get it.
Examiner: Okay, some of these won't be real words, they'll just be sounds. Blaynge.
Patient: I'm not. . .
Examiner: blanch

arcuate fasciculus A bundle ofaxons that connects Wernicke's area with Broca's area; damage causes conduction aphasia.

conduction aphasia An aphasia characterized by in ao'i1:l~Y' t(nepeafw(jf<E"rn~fai'ell~:ii'o1Ju'!'n~i' ~I'"et:!eflh and the ability to comprehend the speech of others.