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Language

PORTRAIT: Multilingual Meltdown

K.H. was a Swiss-born architect working as a professor of architecture at a major U.S. university. Although German was his first language and he was fluent in French and Italian, his primary language had become English.

Because he had been an outstanding student, had excelled at writing, and was meticulous about his spelling and grammar, he was astonished when his mother complained that he was making spelling and grammatical errors in his letters to her, which, of course, were in German. He suspected that he must just be forgetting his German and resolved to prevent that from happening.

A few weeks later, K.H. asked a colleague to review a manuscript that he had just completed. His colleague read the manuscript and commented that K.H. must be working too hard because the manuscript was filled with errors of a kind that K.H. would not have normally made. At about the same time, K.H. noticed that the right side of his face seemed to “feel funny.” He went to a neurologist, who found a small tumor at the junction of the motor-face area and Broca’s area in the left hemisphere. (The accompanying diffusion tensor image shows the various language pathways connecting Broca’s area and Wernicke’s area within the brain.)

The tumor was benign and was removed surgically. In the first few days after the surgery, K.H. was densely aphasic: he could not talk, and he could not understand either oral or written language. Although he had been warned that aphasia was likely and that it would be temporary, he was visibly upset about his language difficulties. By the end of the first week, he could understand oral language, but his speech was still unintelligible and he could not read. By the end of the second week, he could speak German fluently but had difficulty with English, although his English was certainly understandable. He was still unable to read in any language, but he believed that he could read German and could be convinced otherwise only when he was informed that the book that he was reading was upside down. His reading and English slowly improved, but even now, years later, he has difficulty spelling in any language, and his reading is slower than would be expected for a person of his intelligence and education.

Language is one of our most precious abilities, yet most of us take it for granted, as did K.H. before his illness. We don’t realize how much depends on our ability to talk, listen, and read. We even talk to ourselves. As children, we learn language long before we can catch a ball or ride a bicycle, using words to identify and learn about the things in our environment. We use language to entertain ourselves in poetry, song, and humor. Indeed, much humor is based on nuances of language and on double entendres. Because the use of language is our most complex skill, there are many ways to approach its study. One place to start is to consider what language is.
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What Is Language?

There is no universally accepted definition of language. The word derives from *langue*, an Anglo-French word for "tongue," referring to the convention of describing language as the use of combinations of sounds for communication. But the term also includes the idea that this use of sounds is guided by rules, which, when translated into other sensory modalities, allows for equivalent communication through gestures, touches, and visual images. No other animal species uses language in the way that humans do, but many animal species have evolved forms of communication through sound, sight, touch, and olfaction.

Components of Language

Although most of us probably think of words as the meaningful units of language, linguists break language down differently (Table 19.1). They view words as consisting of fundamental language sounds called phonemes. An analysis of how phonemes are processed is called a phonological analysis.

Phonemes, in turn, are combined to form morphemes, the smallest meaningful units of words. A morpheme may be a base (*do* in *undo*), an affix (*un* in *undo* or *er* in *doer*), or an inflection (*ing* in *doing* or *s* in *girls*). Some morphemes are complete words by themselves; other morphemes must be combined to form words. A lexicon is the collection of all the words in a given language.

Words are strung together in patterns and conform to rules of grammar, also known as syntax. A key aspect of syntax is the appropriate choice of verb tenses. It is interesting that children develop syntactical skills independently of formal training, a characteristic that led the linguist Noam Chomsky to suggest that humans possess an innate brain organization for developing language.

The meaning connected to words and sentences is referred to, collectively, as semantics. Vocal intonations, the tone of voice that can modify the literal meaning of words and sentences, are collectively called prosody. Finally, stringing together sentences to form a meaningful narrative is called discourse. Although this discussion emphasizes the acoustical nature of these basic parts of

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<thead>
<tr>
<th><strong>Table 19.1 Components of a sound-based language</strong></th>
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<tbody>
<tr>
<td><strong>Phonemes</strong></td>
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<tr>
<td><strong>Morphemes</strong></td>
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<td><strong>Syntax</strong></td>
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<td><strong>Lexicon</strong></td>
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<td><strong>Semantics</strong></td>
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<td><strong>Prosody</strong></td>
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<td><strong>Discourse</strong></td>
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language, there are analogues in visual language, such as American Sign Language (ASL, or Ameslan). A morpheme in ASL, for example, would be the smallest meaningful movement.

Although the presence of words and word components is the traditional criterion by which linguists recognize language, there are other ways to describe human language. One characteristic is its use of syllables that are made up of consonants and vowels. Nonhuman species do not produce syllables, primarily because they do not produce consonants. Thus, one special thing about human language is that our mouths are capable of producing consonants and combining them with vowels to produce syllables.

The Production of Sound

Speech and language are different. Language is any system for representing and communicating ideas, whereas speech refers to a particular audible manner of communicating language. Most of us have heard talking birds such as parrots or mynahs, and we may have even heard talking seals or dolphins. We have not heard talking apes, however, and not for lack of trying.

In the 1940s, Keith and Catherine Hayes raised Vicki, a chimpanzee, as a child and made a heroic effort to get her to produce words, but she produced only four sounds, including a poor rendition of "cup," after 6 years of training. Why do our nearest animal relatives lack vocal output capabilities comparable to ours?

The basic machinery that produces sound in apes and humans is similar (Figure 19.1A). It consists of two sets of parts, one set acting as the sound source and the other set as filters. First, air exhaled from the lungs provides power to drive oscillations of the vocal folds (commonly known as the vocal cords), which

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**Figure 19.1**

The Source-Filter Theory of Vocal Production (A) Cross-sectional views of the larynx and the vocal tract in a chimpanzee and a human. (B) The formula for sound production, in which the larynx is the source of sound energy and the vocal tract filters the energy to produce the final sound output. (C) A model of how the formants of the vocal tract filter energy from the sound source to produce the final output. (After Fitch, 2000.)
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![Figure 19.1](image-url)

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are located in the larynx, or "voice box." The rate of vocal-fold oscillation (which varies from about 100 Hz in adult men to 500 Hz in small children) determines the pitch of the sound thus produced.

The acoustical energy generated then passes through the vocal tract (the pharyngeal, oral, and nasal cavities) and, finally, out through the nostrils and lips (Figure 19.1B). As this energy passes through the vocal tract, the structures there act as a series of "bandpass filters," which in the context of speech are called formants (Figure 19.1C). Formants modify the sound that is emitted, allowing specific frequencies to pass unhindered but blocking the transmission of others (review Figure 15.12). The filtering process plays a crucial role in speech. Formant characteristics are determined by the length and shape of the vocal tract and are modified rapidly during speech by the movements of the articulators (tongue, lips, soft palate, and so on).

Part of the difference between apes and ourselves lies in the part of the vocal apparatus that produces formants. The human oral cavity is longer than that of the ape, and the human larynx is situated much lower in the throat, as shown in Figure 19.1A. Starting at about 3 months of age, the human larynx begins a slow descent toward its adult position, which it reaches after 3 to 4 years. A second, shorter descent takes place in human males at puberty.

The descent of the larynx in humans was a key innovation in the evolution of speech, allowing humans to produce a much wider range of formant patterns than other mammals do. It allows the tongue to move both vertically and horizontally within the vocal tract, giving us the ability to vary the area of the oral and pharyngeal tubes independently, which adds to the variety of sounds that are easy for us to produce.

Origins of Language

The emphasis on the uniqueness of human language poses certain obstacles to understanding how language evolved. That no other species has language in the sense meant by linguists is puzzling and has led to a search for evolutionary antecedents. The search for such capacities is not a matter of idle curiosity. If we can determine which capacities were precursors of human language and why they were selected, we will have taken a giant step toward understanding how language came to be represented in our brains.

Precursors of Language

A hypothetical explanation for language is that it evolved slowly from various kinds of animal vocalizations. Perhaps it is a tribute to the imagination with which speculators approached the question of which vocalizations, in 1866, that the Linguistic Society of Paris banned future discussion of it. We will not let that ban deter us.

Gordon Hewes reviews many variants of the vocalization theory, including the pooh-pooh theory (language evolved from noises associated with strong emotion), the bow-woow theory (language evolved from noises first made to imitate natural sounds), the go-be-bo theory (language evolved from sounds made to resonate with natural sounds), and the sing-song theory (language evolved from noises made
while playing or dancing). These examples by no means exhaust the list of animal vocalization theories of language origin.

The best evidence for vocalization as a source of language origin comes from studying chimpanzees. The results of Jane Goodall's studies on the chimpanzees of Gombe in Tanzania indicate that our closest relatives have as many as 32 separate vocalizations. Goodall noted that the chimps seem to understand these calls much better than humans do, although her field assistants, the people most familiar with the chimps, can distinguish them well enough to claim that the actual number is higher than 32. Figure 19.2 illustrates the wide range of vocalizations made by free-living chimpanzees.

Jared Taftialatale and his coworkers have recorded vocalizations made by the chimp Kanzi when the chimp eats food. Recall from the portrait of Kanzi on page 29 that these investigators found that the food peels produced by Kanzi are structurally different in different contexts. This finding suggests that chimps use "chimpanzeeship," a primitive form of communication, as part of their feeding behavior.

**Language As a Recently Evolved Ability**

Let us consider the evidence that language (as used by modern humans) has a relatively recent origin. Morris Swadesh developed a list of 100 basic lexical concepts that he expected to be found in every language. These concepts included such words as "I," "two," "woman," "sun," and "green." He then calculated the rate at which these words would have changed as new dialects of language were formed. His estimates suggest a rate of change of 14% every 1000 years. When he compared the lists of words spoken in different parts of the world today, he estimated that, between 10,000 and 100,000 years ago, everyone spoke the same language.

According to Swadesh's logic, language would have had its origins at about the time when everyone spoke the same language, because diversification would have begun almost as soon as language developed. Hominids have been around for 4 million years; so how can the possibility that they were speaking much earlier than 100,000 years ago be ruled out?

Philip Lieberman studied the properties of the vocal tract that enable modern humans to make the sounds used for language. Recall that our low-placed larynx makes us unique among primates. Neither modern apos nor newborn humans have developed this characteristic and cannot produce all the sounds used in human speech.

On the basis of skull reconstructions, Lieberman suggested that Neanderthals also were unable to make the sounds necessary for modern speech. Specifically, they would not have been able to produce the vowels "a," "i," and "u." Because Neanderthals and modern humans are likely each other's closest relatives, having a common ancestor within the past 200,000 years, this inability is evidence that language developed in modern humans more recently. In

<table>
<thead>
<tr>
<th>Emotion or feeling</th>
<th>Call</th>
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<tbody>
<tr>
<td>Fear of strangeness</td>
<td>Wraaa</td>
</tr>
<tr>
<td>Puzzlement</td>
<td>Hau</td>
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<tr>
<td>Annoyance</td>
<td>Soft bark (cough)</td>
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<td>Social apprehension</td>
<td>Pant-grunt</td>
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<td>Social fear</td>
<td>Pant-bark</td>
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<td>Waa-bark</td>
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<td>Tantum scream</td>
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<td>Crying</td>
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<td>Whimper</td>
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<td>Hoo</td>
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<td>SOS scream</td>
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<td>Copulation scream (squeal)</td>
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<td>Copulation pant</td>
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<td>Laugh</td>
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<td>Pant</td>
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<td></td>
<td>Lip smack</td>
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<td>Tooth crack</td>
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<td></td>
<td>Food grunt</td>
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<td></td>
<td>Food aha call</td>
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<tr>
<td></td>
<td>Pant-foot (miscellaneous)</td>
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<tr>
<td></td>
<td>Bark</td>
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<td></td>
<td>Scream</td>
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<tr>
<td></td>
<td>Roar pant-foot</td>
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<td></td>
<td>Arrival pant-foot</td>
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<td></td>
<td>Inquiring pant-foot</td>
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<td></td>
<td>Soft grunt</td>
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<td></td>
<td>Extended grunt</td>
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<tr>
<td></td>
<td>Spontaneous pant-foot</td>
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<td></td>
<td>Nest grunt</td>
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**Figure 19.2**

**Precursors of Language**

Chimpanzee calls and the emotion or feeling with which they are most closely associated. (After Goodall, 1986. Reprinted with permission.)

**KEY**

- Call appears to be linked with one emotion only
- Call (as currently described) linked with two emotions

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opposition to this idea, X-rays of modern human skulls suggest no relation between skull morphology and larynx position.

Another argument for the recent development of language is that the ability to write and the ability to speak have a lot in common. Most notably, both require very fine movements and many movement transitions. Therefore, speech and writing could have appeared at about the same time. Alexander Marshack found that the first symbols made by humans date to about 30,000 years ago, which would be evidence that speech appeared before or at least at about this time.

What seems to link these three separate lines of evidence, making the recency hypothesis plausible, is that the first appearance of modern humans can be dated to within the past 200,000 years. The evolution of modern humans was quite sudden, and one of their adaptive strategies was language. Although the development of the vocal tract may have been crucial to human language, Peter MacNeilage argued that the critical feature of language is articulation. This characteristic can be described, basically, as what the mouth does: the mouth is usually opened once for each vocal episode, and the shape of the cavity between the lips and the vocal tract modulates the sound. Articulation is unique to humans. Furthermore, it is employed in virtually every utterance of every one of the world’s languages (with the exception of a few words consisting of a single vowel).

In human speech, the mouth alternates more or less regularly between a relatively open and a relatively closed configuration, open for vowels and closed for consonants. To MacNeilage, the question raised by this observation is not how the vocal tract changed but how the brain changed to provide the motor control of the mouth necessary for making syllables.

Speech As a Gestural Language

Some researchers suggest that primitive gestures and other body movements slowly evolved into spoken language. This theory assumes that effective hunting and farming and the maintenance of social groups required some kind of communication system and provided the impetus for language to develop.

Two lines of evidence support the gestural theory. First, gestural language and vocal language depend on similar neural systems. The cortical regions that produce mouth and hand movements are adjacent in area 4. Second, nonhuman primates can use gestures or symbols for at least rudimentary communication (see Figure 12.14).

It has long been thought that an experiment showing that gestural language and vocal language depend on the same brain structure would support the idea that gestural language evolved into vocal language. As early as 1878, John Hughlings-Jackson suggested that a natural experiment, the loss of certain sign-language abilities by people who had previously depended on sign language (specifically, ASL), would provide the appropriate evidence, and he even observed a case that seemed to indicate that sign language was disrupted by a left-hemisphere lesion, as is vocal language.

Doreen Kimura confirmed that lesions disrupting vocal speech also disrupt signing. Of 11 patients with signing disorders subsequent to brain lesions, 9 right-handers had disorders subsequent to a left-hemisphere lesion. One left-handed patient had a signing disorder subsequent to a left-hemisphere lesion,
and another left-handed patient had a signing disorder subsequent to a right-hemisphere lesion. These proportions are identical with those found for vocal patients who become aphasic (see Chapter 12). Such results strongly support the idea that some of the language systems that control vocal speech also control signing.

The idea that verbal language and sign language depend on similar neural structures is supported by Aaron Newman and his colleagues in functional magnetic resonance imaging of areas of the brain active during speech and during signing by bilingual speakers. The Newman study also compared signers who acquired sign language early in life (native signers) with those who learned sign language later in life (late signers). As is illustrated in Figure 19.3, both native and late signers show activation in the frontal and temporal lobes of the left hemisphere.

This finding confirms a left-hemisphere specialization for sign language, implicating the same left-hemisphere brain regions that are active during the use of vocal and written language. If vocal language evolved from gestures used by the ancestors of modern humans, those gestures were likely transmitted genetically rather than culturally. If so, the same gestures should still be transmitted genetically in humans and should still be found in all human groups. Our close relatives, the apes, also should use a subset of this group of gestures. The begging gesture, hand outstretched, of chimpanzees and humans could be an example of such a gesture.

A question that can be raised with respect to gestural theories is, Why was there a shift to vocalizing? There are at least two plausible explanations. First, the increasing use of tools meant that our ancestors’ hands were more frequently occupied and often could not be used for gesturing. Second, gesturing requires visual contact, but individuals picking fruit in trees or gathering food in tall grass needed to communicate about both food and predators without being able to see one another.

Multimodal Language Theory

Some theories of language view speech as more than vocal utterances. David McNeill reported that gestures accompany more than 90% of vocal utterances. Gestures thus form an integral component of language communication, suggesting not that gestures preceded vocal communication but rather that vocal-hand communication is a composite. McNeill’s view is that the neural basis of language is not simply the property of regions of the brain controlling the mouth but a property of the motor system more generally.

Other observations support this view. We may all be familiar with the cocktail-party effect. When listening to speech in a noisy environment we can “hear” what a speaker is saying much better if we can see the speakers lips. A phenomenon called the McGurk effect after its originator Harry McGurk gives another demonstration of seeing sounds. When viewers observe a speaker say one word or syl-
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Additional evidence for the multimodal origins of language comes from a study by Amy Pollick and her colleagues on the use of vocalizations and gestures in chimpanzees. They find that chimpanzees use gestures meaningfully to communicate with others and that bonobos flexibly use gestures and vocalizations in combination to communicate. These various lines of evidence suggest that speech is not simply vocal but rather multimodal in its origins and use.

Evidence for Langugelike Processes in Apses

A large number of studies have attempted to explore the multimodal hypothesis of language origins by examining gestural abilities in apes. Beatrice and Allen Gardner used a version of American Sign Language to train Washoe, a year-old chimp they brought into their home. They aimed to teach Washoe ASL hand signs for various objects or actions (called exemplars). These signing gestures, analogous to words in spoken language, consist of specific movements that begin and end in a prescribed manner in relation to the signer’s body (Figure 19.4).

The Gardners molded Washoe’s hands to form the desired shapes in the presence of exemplars of the signs, reinforcing her for correct movements. In addition, rather than using verbal language, the Gardners used ASL to communicate with each other in Washoe’s presence. Thus, Washoe was raised in an environment filled with signs. Washoe did learn to understand and to use not only nouns but also pronouns and action verbs. For example, she could sign statements such as “You go me,” meaning “Come with me.” Attempts to teach ASL to other species of great apes (gorilla, orangutan) have had similar success.

The sign-language studies have been criticized. Herbert Terrace and his colleagues analyzed more than 19,000 multisign utterances of an infant chimpanzee (Nim Chimpsky), as well as reanalyzing films of Washoe and other chimps. They claimed to have found no evidence of grammatical construction: most of the chimpanzees’ utterances were prompted by their teachers’ prior utterances and could thus be explained by nonlinguistic processes. Instead, Terrace and his coworkers were struck by the absence of creativity in the apes’ utterances and by their dependence on the prior utterances of their teachers.

Thus, they concluded, chimp language is quite unlike the advanced multiverse sequences produced by young children. In response, the Gardners have argued that Terrace used
lable while they hear a recording of a second word or syllable, they "hear" the articulated word or sound that they saw and not the word or sound that they actually heard. Or they hear a similar but different word entirely. For example, if the speaker is saying "go" but the actual sound is "de," the listener hears "jo" or perhaps the related sound "ba." The McGurk phenomenon is robust, and knowledge about it or experience with it does not make the demonstration less compelling.

Additional evidence for the multimodal origins of language comes from a study by Amy Pollick and her colleagues on the use of vocalizations and gestures in chimpanzees. They find that chimpanzees use gestures meaningfully to communicate with others and that bonobos flexibly use gestures and vocalizations in combination to communicate. These various lines of evidence suggest that speech is not simply vocal but rather multimodal in its origins and use.

Evidence for Language-like Processes in Apes

A large number of studies have attempted to explore the multimodal hypothesis of language origins by examining gestural abilities in apes. Beatrice and Allen Gardner used a version of American Sign Language to train Washoe, a year-old chimp they brought into their home. They aimed to teach Washoe ASL hand signs for various objects or actions (called exemplars). These sign-making gestures, analogous to words in spoken language, consist of specific movements that begin and end in a prescribed manner in relation to the signer's body (Figure 19.4).

The Gardners molded Washoe's hands to form the desired shapes in the presence of exemplars of the signs, reinforcing her for correct movements. In addition, rather than using verbal language, the Gardners used ASL to communicate with each other in Washoe's presence. Thus, Washoe was raised in an environment filled with signs. Washoe did learn to understand and to use not only nouns but also pronouns and action verbs. For example, she could sign statements such as "You go me," meaning "Come with me." Attempts to teach ASL to other species of great apes (gorilla, orangutan) have had similar success.

The sign-language studies have been criticized. Herbert Terrace and his colleagues analyzed more than 19,000 multigram utterances of an infant chimpanzee (Nim Chimpsky), as well as reanalyzing films of Washoe and other chimps. They claimed to have found no evidence of grammatical construction: most of the chimps' utterances were prompted by their teachers' prior utterances and could thus be explained by nonlinguistic processes. Instead, Terrace and his coworkers were struck by the absence of creativity in the apes' utterances and by their dependence on the prior utterances of their teachers.

Thus, they concluded, chimp language is quite unlike the advanced multiset sequences produced by young children. In response, the Gardners have argued that Terrace used
training methods with Nim that were inappropriate for a highly social animal such as a chimpanzee, producing stimulus-response actions in Nim rather than the social communication characterized by Washoe.

David Premack advanced the study of the language abilities of chimpanzees by teaching his chimpanzee, Sarah, to read and write with variously shaped and colored pieces of plastic, each representing a word. Premack first taught Sarah that different symbols represent different nouns, just as Washoe had been taught in sign language. Thus, for example, Sarah learned that a pink square was the symbol for banana. Sarah was then taught verbs so that she could write and read such combinations as "give apple" or "wash apple."

Her comprehension could be tested easily by "writing" messages to her (that is, by hanging up a series of symbols) and then observing her response. This procedure was followed by much more complicated tutoring in which Sarah mastered the interrogative ("Where is my banana?"), the negative, and finally the conditional (if, then). Sarah learned a fairly complicated communication system analogous in some ways to simple human language.

After studying the results of the Gardner and Premack projects, David Run-baugh launched Project Lana, which called for teaching the chimpanzee Lana to communicate by means of a keyboard programmed by a computer. The keyboard was composed of nine stimulus elements and nine primary colors, which could be combined in nearly 1800 lexigrams to form a language now known as Yerkish (Figure 19.5). Lana had simply to type out her messages on the keyboard. First, she was trained to press keys for various single incentives. Then the requirements became increasingly complex, and she was taught to compose various types of statements, such as the indicative ("Tim move into room"), the interrogative ("Tim move into room?") the imperative ("Please Tim move into room"), and the negative ("Don't Tim move into room"). Eventually, Lana was capable of composing strings of six lexigrams.

One of the weaknesses of Project Lana was its assumption that Lana was treating the lexigrams as symbols rather than as mere paired associates for certain stimuli. Indeed, some of the harshest criticisms have come from the Project Lana team itself. In their most recent project with Kanzi, they have altered the format.

As described in the Portrait at the beginning of Chapter 2, Sue Savage-Runbaugh and coworkers attempted to teach Malatta, a pygmy chimpanzee caught in the wild, the Yerkish language used with Lana. Malatta did not do well. Serendipitously, Malatta's male offspring, Kanzi, accompanied her during her language training. Even though he was not specifically trained, Kanzi learned more Yerkish and English than his mother did. Remarkably, his knowledge of English words exceeded his knowledge of the lexigrams. To facilitate his learning, his keyboard was augmented with a speech synthesizer.

When he was 6 years old, Kanzi was tested on his comprehension of multisymbol utterances. He responded correctly to 298 of 310 spoken sentences of two or more utterances. Joel Wallman concluded that Kanzi's use of lexigrams constitutes the best evidence available to date for the referential application of learned symbols by an ape.

In summary, from the study of both wild and captive apes, they clearly have a rudimentary capacity to use language. They also have a much greater predis-
position to understand language than to produce it. Anyone watching films of their performance in response to human vocal commands cannot help but be impressed by their understanding. This body of research does suggest that the basic capacity for languagelike processes was there to be selected for in the common ancestor of humans and apes.

A Theory of Language

Moira Yip argues that, in the search for communication analogous to language in nonhuman animals, researchers have not yet begun to investigate language from the point of view of its core skills. Language can be viewed as a combination of four separate abilities, to (1) categorize, (2) label categories, (3) sequence behaviors, and (4) mimic. One or another core skill underlying human language may be present in other animal species, including other apes, songbirds, and even bees. Before we review evidence of core language skills in other animals, we will describe these core skills and consider their role in human language.

Categorization

We have stressed the idea that sensory information is processed by multiple, parallel hierarchical channels. Harry Jerison suggests that, as the cortex expands and the number of channels that process parallel sensory information increases, the integration, or binding, of the information into a single reality becomes more difficult. The brain must determine which of the many different kinds of sensory information reaching the cortex correspond to a given object in the external world. In other words, it becomes necessary to categorize information (for example, to designate some qualities as belonging to plants and others as belonging to animals).

Categorizing information makes it easier not only to perceive the information but also to retrieve it later when it is needed. Most animals are likely capable of categorizing objects to some extent, and all humans have sophisticated classification systems, including informal as well as formal systems for categorizing plants and animals.

Labeling Categories

Although words are the ultimate categorizers, the use of words to label categories must be based on a preexisting perception of categories. The development of human language may have entailed a selection for a novel means of categorization that not only allowed simple sensory stimuli to be combined and grouped but also provided a way of organizing events and relations.

This system can take a concept (that is, a category) and stimulate the production of word forms about that concept; conversely, it can take words and cause the brain to evoke the concepts. Thus, a man who was once a painter but is now color-blind can know and use the words (labels) for colors, even though he can no longer perceive or imagine what the labels mean. He has, in a sense, lost his concept of color, but words can still evoke it. In contrast, certain brain-lesion patients retain their perception of color, and thus the concept, but have lost the language with which to describe it. They experience colors but cannot attach labels to them.
Sequencing Behavior
We have already considered the fact that a unique property of human language is the employment of transitional lip, mouth, and hand movements to form syllables. Left-hemisphere structures associated with language are part of a system that has a fundamental role in the ordering of vocal and hand movements such as those used in speech and signing.

Mimicry
Mimicry plays a role in language development. Athena Vouloumanos and Janet Werker find that, from birth, babies have a preference for listening to speech over other sounds. When they begin to babble, they can make the sounds used in all languages. They also copy and subsequently prefer the sounds made by adults.

By some estimates, in the formative period of development, children may add as many as 60 new words each day to their vocabularies. In our description of the organization of the motor system, we described the “mirror neurons” in a monkey’s frontal cortex that discharge both when the monkey makes a hand movement and when it observes a demonstrator make a similar hand movement (see Figure 9.11). Similar mirror neurons in the language regions of the frontal cortex are likely responsible for the mimicking of sounds and words by human children.

Core Language Skills Displayed by Nonhuman Animals
In our summary of the origins of language, we have ignored the many types of communication employed by different animal species, including birdsong, the elaborate songs and clicking of dolphins and whales, and the dances of honeybees. The preceding four-part description of some core skills underlying language allows us to see elements of some of the same skills in other animals. Language-like abilities may also be present in many different brains, even brains extremely different from our own. Irene Pepperberg’s African gray parrot Alex deserves mention. Alex could categorize, label, sequence, and mimic.

Pepperberg showed Alex a tray of four corks and asked, “How many?” Alex replied, “Four.” He could correctly apply English labels to numerous colors, shapes, and materials and to various items, made of metal, wood, plastic, or paper. He could use words to identify, request, and refuse items and to respond to questions about abstract ideas, such as the color, shape, material, relative size, and quantity of more than 100 different objects. Birds do not possess a neocortex, yet Alex was capable of forms of “thought,” “speech,” and “language.”

Two views have been expressed on why other animals including parrots can engage in rudimentary language. The first view holds that, when the brain reaches a certain level of complexity, it has the ability to perform some of the core skills of language, even without the presence of a massive neocortex with dedicated neural structures. A different view is suggested by Simon Fisher and Gary Marcus, who propose that certain genes function in such a way that their expression in neural organization facilitates the development of core abilities that underlie language.

The Snapshot on page 535 describes how genetic research on a single family lends support to the idea that a “language” gene
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The Snapshot on page 535 describes how genetic research on a single family lends support to the idea that a "language" gene
Almost half the members of three generations of the KE family are affected by a severe disorder of speech and language that is inherited as an autosomal dominant trait. The impairment, displayed by 15 of 37 family members (part A of the adjoining illustration), is best characterized as a deficit in sequencing articulation patterns, rendering speech sometimes agrammatical and often unintelligible. The impairment is orofacial and affects the production of sound sequences; it thus resembles Broca's aphasia.

Genetic analysis of the KE family identified a genetic mutation that seems to be the basis for the abnormality. The mutation affects the ability of the gene, foxhead P2, or FOXP2, to regulate the transcription of other genes. Although FOXP2 is highly conserved and plays a role in the development of many parts of the brain as well as other body organs, the gene has undergone two mutations since the human lineage separated from the ape lineage. This rapid evolution suggests that these mutations may have altered neuronal circuitry in motor regions of the brain to enable movements that contribute to human speech.

Affected and unaffected KE family members differ on neuropsychological tests. A score on a test of repetition of nonwords with complex articulation patterns successfully discriminated between the two groups. Moreover, the affected family members were impaired on verbal and performance IQ tests, including such nonverbal subtests as picture completion and picture arrangement. They were also impaired on most tests of language function. The affected members were impaired on tests of mouth movement (oral praxis), including simple movements of clicking the tongue and making sequences of movements (such as blowing up the cheeks, then licking the lips, and then smacking the lips).

When their brains were examined with MRI analysis, the affected family members were found to have significantly less gray matter in the caudate nucleus, sensorimotor cortex, inferotemporal cortex, cerebellum, and left inferior frontal cortex. These brain regions are associated with the production of facial movements necessary for language. The reduction in the volume of the caudate nucleus is particularly noteworthy, because difficulties in the use of expressive language subsequent to damage to the caudate nucleus have been reported in other studies.

Part B of the illustration charts the average volume of the caudate nucleus at different locations along its rostral-caudal extent in affected and unaffected family members. Only the head, not the tail, of the caudate nucleus was measured. The photograph shows its location. That a mutation found in the KE family mainly affects the frontal region of the brain is beginning to further understanding of how neural circuits for language develop.


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Because eyes in different species of animals are so different, the eye was once thought to have evolved a number of times. The discovery that *Pax6*, a highly conserved transcription factor, contributes to the development of all eyes across all species greatly simplified the understanding that a modification of a common substrate led to the development of different kinds of eyes.

### The Localization of Language

Current ideas about the localization of language processes come from four basic lines of inquiry: (1) anatomical studies of language, (2) studies of lesions in human patients, (3) studies of brain stimulation in awake human patients, and (4) brain-imaging studies. We consider each in turn.

#### Anatomical Areas Associated with Language

The anatomical landmarks used by researchers for describing brain regions associated with language vary considerably. Some researchers refer to sulci, others to Brodmann's areas, and still others to areas associated with syndromes, such as Broca's area and Wernicke's area. Figure 19.6 illustrates various ap-

![Figure 19.6](image)

**Figure 19.6**

*Core Language Regions of the Brain* Areas associated with language functions are shown (A) in relation to fissures and gyri, (B) in relation to Brodmann's areas, and (C) with the lateral fissure retracted to expose the insula and the medial bank of the superior temporal gyrus. (Review the photograph of the insula on page 547.)
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**Core Language Regions of the Brain**

Areas associated with language functions are shown (A) in relation to fissures and gyri, (B) in relation to Brodmann's areas, and (C) with the lateral fissure retracted to expose the insula and the medial bank of the superior temporal gyrus.

(Review the photograph of the insula on page 547.)

The temporal and frontal lobes have been pulled aside to reveal the insula.
proaches to labeling the cortical regions most frequently described as playing a core role in language:

1. Figure 19.6A shows that these regions include the inferior frontal gyrus and the superior temporal gyrus, in which Broca’s area (green) and Wernicke’s area (yellow), respectively, are located. Parts of surrounding gyri, including the ventral parts of the precentral and postcentral gyrus, the supramarginal gyrus, the angular gyrus, and the medial temporal gyrus, also are within the core language regions.

2. Figure 19.6B depicts the language areas in accord with Brodmann’s number system, in which Broca’s area is equivalent to areas 45 and 44 and Wernicke’s area is equivalent to area 22. Language regions also include parts of areas 9, 4, 3-1-2, 40, 39, and 21.

3. Figure 19.6C shows that, if the lateral fissure is opened up, a number of language-related areas can be found within it, including the insula, a large region of the neocortex lying within the dorsal bank of the lateral fissure; Heschl’s gyrus (primary auditory cortex); and parts of the superior temporal gyrus referred to as the anterior and posterior superior temporal planes (aSTP and pSTP). Together, Heschl’s gyrus, aSTP, and pSTP are sometimes referred to as the planum temporale.

This survey by no means covers all language areas. Other regions taking part in language include the dorsal part of area 6 of the motor cortex (also referred to as the supplementary motor area) that is responsible for rhythmic mouth movements to articulate sounds; parts of the thalamus, the dorsolateral parts of the caudate nucleus, and the cerebellum; visual areas (required for reading), sensory pathways, and motor pathways; and pathways connecting all these various regions. Furthermore, many regions of the right hemisphere also have roles in language.

Lesion Studies in Humans
Most discussions of the neural basis of language have centered on Broca’s area and Wernicke’s area, the historical backgrounds of which are described in Chapter 1. The early neurological model of language by Carl Wernicke, as well as its later revival by Norman Geschwind, now called the Wernicke-Geschwind model, was based entirely on lesion data (Figure 19.7). This three-part model has played a formative role in directing research and organizing research results:

1. The meaning of words is represented in Wernicke’s area. When a person listens to speech, word sounds are sent through the auditory pathways to the primary auditory cortex, Heschl’s gyrus. From there, they are relayed to Wernicke’s area, where the sense of the words is extracted.

2. To speak, word meanings must be sent over the arcuate fasciculus to Broca’s area, where morphemes are assembled.
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2. To speak, word meanings must be sent over the arcuate fasciculus to Broca's area, where morphemes are assembled.
The model proposes that Broca's area holds a representation for articulating words. Instructions for speech are sent from Broca's area to the adjacent facial area of the motor cortex; and, from there, instructions are sent to facial motor neurons in the brainstem, which relay movement commands to facial muscles.

3. Reading requires that information concerning handwritten or printed words be sent from visual areas 17, 18, and 19 to the angular gyrus (area 39) and, from there, to Wernicke's area, which reads silently or, in conjunction with Broca's area, reads out loud.

Although useful conceptually, many aspects of the Wernicke--Geschwind model have been modified by improved lesion analysis, by mapping facilitated by transcranial magnetic stimulation (TMS), and by brain-imaging studies. In the sections that follow, we'll describe the ways in which newer findings are consistent or inconsistent with the model.

Speech Zones Mapped by Electrical Stimulation

The language zones of the neocortex, particularly those pertaining to speech, were identified by Wilder Penfield and others by using intracortical stimulation during surgery. Statistical analyses of results from hundreds of patients have made the construction of a map of these regions possible (Figure 19.8). They include the classical areas of Broca and Wernicke in the left hemisphere, as well as the sensory and motor representations of the face and the supplementary speech area in both hemispheres.

Cortical stimulation produces either positive effects, meaning that stimulation elicits vocalization that is not speech but rather a sustained or interrupted vowel cry, such as "Oh," or negative effects, meaning that stimulation inhibits the ability to vocalize or to use words properly, including a variety of aphasia-like errors:

- **Total arrest of speech, or an inability to vocalize spontaneously.** This error results from stimulation throughout the shaded zones in Figure 19.8.

- **Hesitation and slurring of speech.** Hesitation results from stimulation throughout the zones shaded in Figure 19.8, whereas slurring results primarily from stimulation of the facial motor area in either hemisphere.

- **Distortion and repetition of words and syllables.** Distortion differs from slurring in that the distorted sound is an unintelligible noise rather than a word. These effects result primarily from stimulation of the classical speech zones, although occasionally from stimulation of the face area as well.

- **Confusion of numbers while counting.** For example, a patient may jump from "6" to "19" to "4," and so on. Confusion in counting results from stimulation of Broca's or Wernicke's area.

- **Inability to name despite retained ability to speak.** An example is "That is a . . . I know. That is a . . . " When the current was removed, the patient was able to name the object in the picture correctly. Another example is, "Oh, I know what it is. That is what you put in your shoes." After withdrawal of
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the stimulating electrodes, the patient immediately said "foot" (Penfield and Roberts, 1959, p. 123). Naming difficulties arise from stimulation throughout the anterior (Broca's) and posterior (Wernicke's) speech zones.

Misnaming and perseverating Misnaming may occur when the subject uses words related in sound, such as "camel" for "comb," uses synonyms, such as "cutters" for "scissors," or perseverates by using the same word twice. For example, the subject may name a picture of a bird correctly but may also call the next picture, a table, a bird. Misnaming, like other naming difficulties, occurs during stimulation of both the anterior and the posterior speech zones.

George Ojemann and his colleagues reported that, during stimulation of Broca's area, patients are unable to make voluntary facial movements and that stimulation of these same points may also disrupt phonemic discrimination and gestures, such as hand movements, associated with speech. Most reports agree that the extent of the cortical language zones as marked by stimulation varies considerably among subjects.

Speech Zones Mapped by Transcranial Magnetic Stimulation

Intracortical microstimulation has a number of drawbacks as a method for studying the neural basis of language: the procedure is performed during surgery in which the skull is removed, and the patients who are to receive surgery often have preexisting brain conditions that may lead to anomalous language organization. Transcranial magnetic stimulation is a method of exploring the organization of language in healthy subjects without invading the brain directly. The procedure is relatively easy to use, can be used repeatedly, and, when combined with MRI, can allow predetermined regions of the brain to be examined under controlled experimental conditions. TMS has drawbacks in that the stimulator produces a sound that can cue a subject to the stimulation. In addition, the stimulation must pass through the scalp, skull, and meninges and can cause muscle contractions, discomfort, and pain.

TMS has served as a source of a number of insights into the organization of language (Devlin and Watkins, 2007). TMS can interfere with neural function, producing a "virtual lesion" lasting from tens of milliseconds to as long as an hour. TMS at appropriate frequencies and intensities can prime neurons such that reaction times for behaviors dependent on the region that is stimulated are enhanced.

TMS can also be used to evaluate connections between brain regions, such as brain regions used for selecting words and brain regions used for producing sounds. For example, a movement of the lips produced by TMS to the motor cortex might be enhanced if a subject thinks of a word such as "hammer," which produces a lip movement when said. Presumably, the part of the brain thinking "hammer" is connected to the part of the brain being stimulated to produce the lip movement.

Many studies show that TMS can duplicate most of the positive and negative effects produced by intracranial stimulation, thus confirming the findings concerning the localization of language produced by electrical stimulation. For example, stimulation is much more likely to interfere with speech if applied to
the left hemisphere. It also interrupts speech without invoking facial movements when administered to Broca's area in the anterior region of the inferofrontal cortex, and it interrupts speech and invokes facial movements when administered to the the face region of the motor cortex in the posterior region of the inferofrontal cortex. In addition, muscle contractions of the hand induced by TMS delivered to the hand region of the motor cortex increase in size during speaking and reading aloud but not during silent speech and reading.

In other words, a functional connection exists between the brain's language areas and the hand region of the motor cortex during speech production. This connection may be responsible for the irrevocable use of hand gestures when a person is speaking and for the evolutionary link between vocalization and hand gestures. These results suggest that the human neural system is, indeed, similar to the mirror-neuron system identified by single-cell recording in monkeys. Hand movements produced by TMS are augmented when subjects think of or see similar hand movements, suggesting that the same brain regions that produce the movements also control the perception of the same movements by others.

TMS has been used to map specific regions of the brain, such as Broca's area. A number of brain-imaging studies suggest that the anterior region of Broca's area is implicated in semantic processing (processing the meaning of words) and the posterior region of Broca's area is implicated in phonological processing (the production of words). For example, subjects were presented word pairs on a computer screen and required to decide whether the words meant the same thing (say, "gift" and "present") or sounded the same (say, "key" and "quay"). Stimulation of the rostral region of Broca's area increased reaction times for the semantic condition but not for the phonological condition, whereas stimulation of the caudal region of Broca's area increased the reaction time for the phonological condition but not for the semantic condition.

TMS has also proved useful in studying the compensatory changes that take place after brain injury that produces aphasia. For example, in the debate concerning whether compensation is mediated by spared tissue surrounding a lesion or by the opposite intact hemisphere, several studies show that stimulation of the tissue surrounding the lesion is more disruptive to language production than is stimulation of the opposite hemisphere. This result suggests that the remaining tissue near a lesion has a much greater role in recovery than does the opposite hemisphere. In fact, TMS that suppresses the function of the opposite hemisphere has been found to improve functional recovery. Presumably, the homologous regions in the opposite hemisphere can interfere with functioning in the injured hemisphere and therefore retard recovery.

Speech Zones Mapped by Imaging

With the development of PET, fMRI, and ERP (event-related potential) procedures, cognitive psychologists have become more interested in the neural correlates of language processing.

After having used fMRI to measure brain areas implicated in language, Jeffery Binder and his colleagues reported that language-processing areas make up a remarkably large part of the brain. These researchers presented either tones or meaningful words to 30 right-handed subjects, half of whom were male and half female. Tone stimuli consisted of a number of 500- and 750-Hz pure tones pre-
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sented in sequence. The subjects pressed a button if they heard two 750-Hz tones in a sequence. Word stimuli were spoken English nouns designating animals (for example, turtle). Subjects pushed a button if an animal was native to the United States and used by humans. A rest condition consisted of no stimulus presentations.

By subtracting the activation produced by tones from the activation seen during the rest condition, the researchers identified brain regions responding to tones. By subtracting the activation produced by words from the activation produced by tones, the researchers identified brain regions responding to words. The findings are that widespread regions of the brain are activated by words, including areas in the occipital, parietal, temporal, and frontal lobes; the thalamus; and the cerebellum (Figure 19.9).

With the use of PET and a wider range of stimuli, a number of research groups have identified more-specific functions for some of these language areas (Figure 19.10). Steven Petersen's group used a variety of different conditions to identify speech regions. In one task, they passively presented words (in some cases, pseudowords or pseudosounds) either visually or aurally to a passive subject. In the next task, the subject was to repeat the word (an output task). In the final task (an association task), the subject was to suggest a use for the object named by the target word (for example, if "cake" was presented, the subject might say "eat").

![Figure 19.9](image)

**Aural Activation** Left-hemisphere brain regions activated while subjects listened to speech, as measured by fMRI. Subjects listened to spoken English nouns designating animals and were required to decide, in each case, whether the word indicated an animal that was native to the United States and used by humans. (After Binder et al., 1997.)

![Figure 19.10](image)

**Brain Areas Activated by Language Tasks** Results obtained with the use of PET to monitor blood flow were analyzed by using subtraction methods. (Part A after Posner and Raichle, 1994; part B after Wagner et al., 2001; part C after Martin et al., 1996; part D after Damasio et al., 1996.)
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The investigators monitored blood flow by using PET and analyzed their
data by using a subtraction technique (see Chapter 6). Thus, in the sensory
(reading or listening) tasks, they identified changes from baseline blood flow
by taking the difference between the activities in the two states. In the output
task, they subtracted the sensory activity, and, in the association task, they sub-
tracted the output activity.

Their results (Figure 19.10A) illustrate the involvement of many brain
regions in language and reveal some of the specific contributions of each
region:

- There was no overlap in the visual and auditory activation during the
  passive task, implying that the processing of the word forms in the two
  modalities is completely independent.

- During the speaking tasks, there was bilateral activation of the motor and
  sensory facial areas, as well as bilateral activation of the supplementary
  speech area and activation of the right cerebellum.

- For the task that required generating verbs, there was activation of the
  frontal lobe, especially the left inferior region, including Broca's area. The
  verb-generation task also activated the posterior temporal cortex, the
  anterior cingulate cortex, and the cerebellum.

Other investigators have identified still other areas that are activated, de-
pending on task demands. Anthony Wagner and colleagues presented subjects
with a single cue word and four target words. A subject's task was to indicate
which target word was most closely and globally related to the cue. Thus, the
task measured the subject's ability to retrieve meaningful information. They
found that an area in the left inferofrontal cortex just dorsal to Broca's area be-
came active during this task (Figure 19.10B).

Alex Martin and his colleagues asked subjects to name tools or animals and
subtracted activation produced by the animal brain response from the tool
brain response. They found that naming tools activates a region of the pre-
motor cortex that was also activated by imagined hand movements (Figure
19.10C). Finally, Antonio Damasio and his colleagues reported that naming
persons, animals, and tools activates specific areas in the inferotemporal lobe
(Figure 19.10D).

In summary, the results of imaging studies confirm the role of the classical
anterior and posterior speech zones in language, but they also show that other
regions are implicated. Furthermore, they suggest that the posterior speech
zone may deal largely with the analysis of auditory input. They also indicate
that Broca's area is not simply a cortical representation of the movements of
speech, as has been traditionally believed. Finally, they provide evidence that
"language" is mapped onto circuits that are ordinarily also engaged in more-
primary functions such that visual attributes of words are represented in visual
areas, auditory attributes are mapped onto auditory regions of the brain, motor
attributes are mapped onto motor regions of the brain, and so on.

That so many different regions of the brain control language raises the ques-
tion of its underlying organization. Riitta Salmelin and Jan Kujala suggest that
the brain is organized in neural webs in which nodes, representing specific
functions, are interconnected by pathways. Together, the nodes and pathways give language its more complex properties of discourse and narrative. Different nodes might represent verbs versus nouns, living versus nonliving things, animals with fur versus those without, and so on. Neural webs connect both sensory and motor representations of words. The webs are proposed to be flexible and to change as word use and meaning change, and information travels in both directions between nodes.

Some representative neural webs are illustrated in Figure 19.11. Note that, if a word contains visual content, the web includes visual areas of the brain, whereas, if it contains motor content, the web includes motor areas. Any given web will also include nodes within primary and secondary auditory areas as well as nodes within primary and secondary motor regions. We must point out that the objective of creating neural webs to represent language-related regions of the brain is not to eventually produce a wiring diagram of the brain’s neurons and their connections but rather to develop classifications that will explain how the brain produces language.

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**Disorders of Language**

In this section, we describe how neuropsychologists classify symptoms of language impairment. It is important to recognize that, whereas symptom classification was originally linked to brain regions (Broca’s aphasia and Broca’s area, for example), improved anatomical analysis suggests that such precise correlations do not exist.

Normal language depends on the complex interaction of sensory integration and symbolic association, motor skills, learned syntactical patterns, and verbal memory. Aphasia may refer to a disorder of language apparent in speech, in writing (in this case also called agraphia), or in reading (also called alexia) produced by injury to brain areas specialized for these functions. Thus, disturbances of language due to severe intellectual impairment, to loss of sensory input (especially vision and hearing), or to paralysis or incoordination of the musculature of the mouth (called anarthria) or hand (for writing) are not considered aphasic disturbances. These disorders may accompany aphasia, and they complicate its study.

Howard Goodglass and Edith Kaplan divide language disturbances into 10 basic types, which we have grouped into disorders of comprehension and disorders of production in Table 19.2. Most of these language
functions are interconnected by pathways. Together, the nodes and pathways give language its more complex properties of discourse and narrative. Different nodes might represent verbs versus nouns, living versus nonliving things, animals with fur versus those without, and so on. Neural webs connect both sensory and motor representations of words. The webs are proposed to be flexible and to change as word use and meaning change, and information travels in both directions between nodes.

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<table>
<thead>
<tr>
<th>Table 19.2 Summary of symptoms of language disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disorders of Comprehension</td>
</tr>
<tr>
<td>Poor visual comprehension</td>
</tr>
<tr>
<td>Disorders of Production</td>
</tr>
<tr>
<td>Word-finding deficit (anomia)</td>
</tr>
<tr>
<td>Unintended words or phrases (paraphasia)</td>
</tr>
<tr>
<td>Loss of grammar and syntax</td>
</tr>
<tr>
<td>Inability to repeat auditory presented material</td>
</tr>
<tr>
<td>Low verbal fluency</td>
</tr>
<tr>
<td>Inability to write (agraphia)</td>
</tr>
<tr>
<td>Loss of tone in voice (aprasodias)</td>
</tr>
</tbody>
</table>
disorders were described earlier, in our discussions of parietal-, temporal-, and frontal-lobe functions. The one exception is paraphasia, the production of unintended syllables, words, or phrases in an effort to speak. Paraphasia differs from difficulties in articulation in that sounds are correctly articulated, but they are the wrong sounds: people with paraphasia either distort the intended word (for example, “pike” instead of “pipe”) or produce a completely unintended word (for example, “my mother” instead of “my wife”).

Despite disagreement among experts concerning the number of types of aphasias, certain classification systems are widely used. The system presented in Table 19.3 groups aphasias into three broadly defined categories:

- **Fluent aphasias**, in which there is fluent speech but difficulties either in auditory verbal comprehension or in the repetition of words, phrases, or sentences spoken by others.
- **Nonfluent aphasias**, in which there are difficulties in articulating but relatively good auditory verbal comprehension.
- **Pure aphasias**, in which there are selective impairments in reading, writing, or the recognition of words.

Within each category, Table 19.3 lists numerous subtypes that are often distinguished, including Wernicke's aphasia, transcortical aphasia, conduction aphasia, anomia aphasia, and Broca's aphasia.

### Table 19.3 Definition of aphasie syndromes

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Type of Speech Production</th>
<th>Type of Language Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluent Aphasias</td>
<td>Fluent speech, without articulatory disorders</td>
<td>Neologism or anomalies, or paraphasias, poor comprehension; poor repetition</td>
</tr>
<tr>
<td>Wernicke (sensory)</td>
<td>Fluent speech, without articulatory disorders; good repetition</td>
<td>Verbal paraphasias and anomalies; poor comprehension</td>
</tr>
<tr>
<td>Transcortical (isolation syndrome)</td>
<td>Fluent, sometimes halting speech, but without articulatory disorders</td>
<td>Phonemic paraphasias and neologisms; phonemic groping; poor repetition; fairly good comprehension</td>
</tr>
<tr>
<td>Conduction</td>
<td>Fluent speech, without articulatory disorders</td>
<td>Anomia and occasional paraphasias</td>
</tr>
<tr>
<td>Anomic</td>
<td>Laborious articulation</td>
<td>Speechlessness with recurring utterances or syndrome of phonetic disintegration; poor repetition</td>
</tr>
<tr>
<td>Nonfluent Aphasias</td>
<td>Laborious articulation</td>
<td>Phonemic paraphasias with anoma; agrammatism; dysprosody</td>
</tr>
<tr>
<td>Broca (expressive), severe</td>
<td>Slight but obvious articulatory disorders</td>
<td>Uncompleted sentences and anomalies; naming better than spontaneous speech</td>
</tr>
<tr>
<td>Broca (expressive), mild</td>
<td>Marked tendency to reduction and inertia; without articulatory disorders; good repetition</td>
<td></td>
</tr>
<tr>
<td>Transcortical motor</td>
<td>Laborious articulation</td>
<td>Speechlessness with recurring utterances; poor comprehension; poor repetition</td>
</tr>
<tr>
<td>Global</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Pure&quot; Aphasias</td>
<td>Normal</td>
<td>Poor reading</td>
</tr>
<tr>
<td>Alexia without agraphia</td>
<td>Normal</td>
<td>Poor writing</td>
</tr>
<tr>
<td>Agraphia</td>
<td>Normal</td>
<td>Poor comprehension; poor repetition</td>
</tr>
<tr>
<td>Word deafness</td>
<td>Normal</td>
<td></td>
</tr>
</tbody>
</table>

Source: After Mazzocchi and Vigano, 1979.
Fluent Aphasias

Fluent aphasias are impairments related mostly to the input or reception of language. A listener who did not speak the language of a fluent aphasic would receive the impression that the subject was speaking easily and correctly.

Wernicke's aphasia, or sensory aphasia, is the inability to comprehend words or to arrange sounds into coherent speech. Alexander Luria proposes that sensory aphasia has three characteristic deficits—in classifying sounds, in producing speech, and in writing.

First, to hear and make out the sounds of speech, one must be able to qualify sounds—that is, to recognize the different sounds in the system of phonemes that are the basic units of speech in a given language. For example, in the Japanese language, the sounds "l" and "r" are not distinguished; a Japanese-speaking person hearing English cannot distinguish these sounds, because the necessary template is not in the brain. Thus, although this distinction is perfectly clear to English-speaking persons, it is not clear to native Japanese. This problem is precisely what a person with Wernicke's aphasia has in his or her own language: the inability to isolate the significant phonemic characteristics and to classify sounds into known phonemic systems. Thus, we see in Wernicke's aphasia a deficit in the categorization of sounds.

The second characteristic of Wernicke's aphasia is a defect in speech. The affected person can speak and may speak a great deal, but he or she confuses phonetic characteristics, producing what is often called word salad. The third characteristic is impairment in writing. A person who cannot discern phonemic characteristics cannot be expected to write, because he or she does not know the graphemes (pictorial or written representations of a phoneme) that combine to form a word.

Transcortical aphasia, sometimes called isolation syndrome, is curious in that people can repeat and understand words and name objects but cannot speak spontaneously or they cannot comprehend words, although they can repeat them. Comprehension could be poor because words fail to arouse associations. The production of meaningful speech could be poor because, even though the production of words is normal, words are not associated with other cognitive activities in the brain.

Conduction aphasia is a paradoxical deficit: people with this disorder can speak easily, name objects, and understand speech, but they cannot repeat words. The simplest explanation for this problem is a disconnection between the "perceptual word image" and the motor systems producing the words.

People with amnic aphasia (sometimes called amnesic aphasia) comprehend speech, produce meaningful speech, and can repeat speech, but they have great difficulty in finding the names of objects. For example, we saw a patient who, when shown a picture of a ship anchor, simply could not think of the name and finally said, "I know what it does... You use it to anchor a ship." Although he had actually used the word as a verb, he was unable to use it as a noun. Difficulties in finding nouns appear to result from damage throughout the temporal cortex (see Figure 19.10D). In contrast, verb-finding deficits are more likely to come from left frontal injuries (see Figure 19.10A).

Although the extent to which the brain differentiates between nouns and verbs may seem surprising, we can see that they have very different functions.
Nouns are categorizers. Verbs are action words that form the core of syntactic structure. It would make sense, therefore, to find that they are separated in such a way that nouns are a property of brain areas controlling recognition and classification, and verbs are a property of brain areas controlling movement.

**Nonfluent Aphasias**

In nonfluent aphasia (Broca's aphasia, or expressive aphasia), a person continues to understand speech but has to labor to produce it: the person speaks in short phrases interspersed with pauses, makes sound errors, makes repetitious errors in grammar, and frequently omits function words. Only the key words necessary for communication are used. Nevertheless, the deficit is not one of making sounds but rather of switching from one sound to another.

Nonfluent aphasia can be mild or severe. In one form, transcortical motor aphasia, repetition is good but spontaneous production of speech is labored. In global aphasia, speech is labored and comprehension is poor.

**Pure Aphasias**

The pure aphasias include alexia, an inability to read; agraphia, an inability to write; and word deafness, in which a person cannot hear or repeat words. These disorders may be quite selective. For example, a person is able to read but not write or is able to write but not read.

**The Localization of Lesions in Aphasia**

Beginning students of language are intrigued by the simplicity of the Wernicke–Geschwind model of language. In this model, Wernicke's area is associated with speech comprehension, Broca's area is associated with speech production, and the arcuate fibers that connect the two areas translate meaning into sound (see Figure 19.7). Seasoned researchers, on the other hand, are equally excited to learn that the neural organization of language is more complex than the model suggests and that, in fact, the key deficits of Wernicke's aphasia do not come from damage to Wernicke's area and the key deficits of Broca's aphasia do not come from damage to Broca's area.

Four points summarize why studying the neural basis of language is itself so complex:

1. As heretofore described, brain-imaging studies are now showing that most of the brain takes part in language in one way or another; and, indeed, it makes sense that a behavior as comprehensive and complex as language would not be the product of some small, circumscribed region of the brain.
2. Most of the patients who contribute information to the study of language have suffered strokes, usually of the middle cerebral artery (MCA). Figure 19.12A illustrates the location of this artery and its tributaries. Because stroke results from a blockage or bleeding of the artery, it is clear that all core language areas may be damaged or only smaller regions may be...
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damaged, depending on where a stroke occurs. Individual differences in the tributary pattern of the MCA add to the variation seen in stroke symptoms and outcomes. The artery supplies subcortical areas as well, including the basal ganglia, a region that includes the caudate nucleus and is important in language (Figure 19.12B).

3. Immediately following a stroke, symptoms are generally severe but, as time passes, there is considerable improvement. Thus, the symptoms cannot be easily ascribed to damage in a particular brain region.

4. Aphasias described as nonfluent (Broca's) or fluent (Wernicke's) are syndromes consisting of a number of different symptoms, each of which may have a different neural basis.

Keep these variables in mind as we consider some ideas concerning the neural basis of language.

**Cortical Components of Language**

In studying a series of stroke patients with language disorders, Nina Dronkers and her coworkers correlate different symptoms of nonfluent and fluent aphasia with specific cortical regions. Their analysis suggests that nonfluent aphasia consists of at least five kinds of symptoms: apraxia of speech (difficulty in producing sequences of speech sounds), impairment in sentence comprehension, recurring utterances, impairment in articulation of sounds, and impairment in working memory for sentences.

After using overlaying maps of brain injury to identify areas of common damage, the Dronkers team concludes that each of these impairments has a somewhat different neural basis (Figure 19.13). Their analysis also suggests that the core deficit, apraxia of speech, comes not from Broca's-area damage but from damage to the insula (see Figure 19.12B). Impairments in sentence comprehension seem to be associated with damage to the dorsal bank of the superior temporal gyrus, recurring utterances seem to stem from damage to the arcuate fasciculus, and impairments in working memory and articulation seem to be associated with damage to Broca's area.

Concerning fluent aphasia, Dronkers and her colleagues propose that most of the core difficulties, especially the lack of comprehension in speech, comes from damage to the medial temporal lobe and underlying white matter. Damage in this area not only destroys local language regions but also cuts off most of the occipital, temporal, and parietal regions from the core language region. The researchers also propose that damage to Wernicke's area does not result in the core deficits of fluent aphasia but contributes to deficits in holding sentences in memory until they can be repeated and in word rhyming. Thus, the patients appear to have impairment in the "iconic" memory for sounds but are not impaired in comprehension.
damaged, depending on where a stroke occurs. Individual differences in the tributary pattern of the MCA add to the variation seen in stroke symptoms and outcomes. The artery supplies subcortical areas as well, including the basal ganglia, a region that includes the caudate nucleus and is important in language (Figure 19.12B).

3. Immediately following a stroke, symptoms are generally severe but, as time passes, there is considerable improvement. Thus, the symptoms cannot be easily ascribed to damage in a particular brain region.

4. Aphasias described as nonfluent (Broca's) or fluent (Wernicke's) are syndromes consisting of a number of different symptoms, each of which may have a different neural basis.

Keep these variables in mind as we consider some ideas concerning the neural basis of language.

Cortical Components of Language

In studying a series of stroke patients with language disorders, Nina Dronkers and her coworkers correlate different symptoms of nonfluent and fluent aphasia with specific cortical regions. Their analysis suggests that nonfluent aphasia consists of at least five kinds of symptoms: apraxia of speech (difficulty in producing sequences of speech sounds), impairment in sentence comprehension, recurring utterances, impairment in articulation of sounds, and impairment in working memory for sentences.

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**Figure 19.13**

Proposed Relations Between Brain Regions and Symptoms of Aphasia. Note that these relations are different from those originally proposed by Wernicke and Geschwind, shown in Figure 19.7.
Subcortical Components of Language

At the same time that Broca was describing a cortical center for speech control, Hughlings-Jackson proposed that subcortical structures are critical to language. In 1866 he wrote: "I think it will be found that the nearer the disease is to the basal ganglia, the more likely is the defect of articulation to be the striking thing, and the farther off, the more likely it is to be one of mistakes of words."

The symptoms displayed by half of the members of the KE family described in the Snapshot on page 535 suggest that the basal ganglia may be important for the articulation of language. On the other hand, Alison Rowan and her colleagues used MRI and behavioral tests specifically to examine the language abilities of young patients who had suffered basal ganglia stroke. They conclude that the language deficits most likely derive from subtle damage to the neocortex.

Some of this evidence indicates that the thalamus has a role in language. Findings by George Ojemann's and Irving Cooper's research teams, in which the thalamus was electrically stimulated, indicate that the pulvinar nucleus and the lateral-posterior-lateral-central complex of the left thalamus have a role in language that is not common to other subcortical structures. Stimulation of the left ventrolateral and pulvinar nuclei of the thalamus produced speech arrest, difficulties in naming, perseveration, and reduced speed of talking. Stimulation of the thalamus has also been reported to have a positive effect on memory, because it improves later retrieval of words heard during the stimulation. As a result, some researchers have proposed that the thalamus influences language function by activating or arousing the cortex.

When the thalamus is damaged by electrical current applied for the treatment of abnormal movements, a variety of disturbances of speech and language have been found in association with lesions of the left ventrolateral thalamus or the pulvinar nucleus or both. Symptoms include postoperative dysphasia, which is usually transitory; increased verbal-response latency; decreases in voice volume; alterations in speaking rate and slurring or hesitation in speech; and impaired performance on tests of verbal IQ and memory.

Right-Hemisphere Contributions to Language

Although there is little doubt that the left hemisphere of right-handed people is dominant in language, the right hemisphere also has language abilities. The best evidence comes from studies of split-brain patients in whom the linguistic abilities of the right hemisphere have been studied systematically with the use of various techniques for lateralizing input to one hemisphere.

The results of these studies show that the right hemisphere has little or no speech but surprisingly good auditory comprehension of language, including both nouns and verbs. There is some reading ability but little writing ability in the right hemisphere. In addition, although the right hemisphere is able to recognize words (semantic processing), it has little understanding of grammatical rules and sentence structures (syntactical processing).

Complementary evidence of the right hemisphere's role in language comes from studies of people who have had the left hemisphere removed, a procedure known as hemispherectomy. If the left hemisphere is lost early in
development, the right hemisphere can acquire considerable language abilities (see Chapter 10 for details), although people with left hemispherectomies are by no means normal. Left hemispherectomy in adulthood produces severe deficits in speech but leaves surprisingly good auditory comprehension. Reading ability is limited, however, and writing is usually absent. In general, left hemispherectomy appears to leave language abilities that are reminiscent of those achieved by the right hemisphere of comissurotyotomy patients.

The effects of right-hemisphere lesions on language functions provide further indication that the right hemisphere is capable of language comprehension, especially of auditory material, even though it cannot control speech. For example, aphasia is rare after right-hemisphere lesions, even after right hemispherectomy, but more-subtle linguistic impairments are noted, including changes in vocabulary selection, in responses to complex statements with unusual syntactical construction, and in the comprehension of metaphors. In addition, right orbitofrontal lesions reduce verbal fluency and lead to deficits in the comprehension of tone of voice and in the production of emotional tone (prosody).

The differences between the functioning of the right and left hemispheres in language have been summarized in the following way. The wife of a patient with Broca's aphasia comments that her husband understands everything, even though he cannot match spoken words with their pictured representations and cannot follow two-step commands. The wife of a patient with an equivalent right-hemisphere lesion comments that her husband has difficulty following a conversation, makes irrelevant remarks, and generally seems to miss the point of what people are saying, even though he performs quite well on the same tests failed by the patient with a left-hemisphere lesion.

In reviewing the role of the right hemisphere in language, both Frank Benson and Eran Zaidel conclude that the only strictly left-hemisphere function in language is syntax (Table 19.4). This function has many components, including the production, timing, and sequencing of the movements required for speaking, as well as an understanding of the rules of grammar. The relative roles of the two hemispheres in other aspects of language comprehension remain to be ascertained.

### Table 19.4 Language activities of the two hemispheres

<table>
<thead>
<tr>
<th>Function</th>
<th>Left Hemisphere</th>
<th>Right Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestural Language</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Prosodic Language</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Rhythm</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Inflection</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Timbre</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Melody</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Semantic Language</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Word recognition</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Verbal meaning</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Concepts</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Visual meaning</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Syntactical Language</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Sequencing</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Relations</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Grammar</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

Source: After Benson, 1956.

### The Assessment of Aphasia

Since World War II, there has been widespread interest in establishing a standard systematic procedure for assessing aphasia, both to provide standardized clinical descriptions of patients and to facilitate comparison of patient populations in neuropsychological research. A number of manuals and their original references are summarized in Table 19.5.

Those in the first group are categorized as test batteries in that they contain a large number of subtests so as to systematically explore the language
Table 19.5 Summary of the major tests of aphasia

<table>
<thead>
<tr>
<th>Test</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphasia Test Batteries</td>
<td></td>
</tr>
<tr>
<td>Boston Diagnostic Aphasia Test</td>
<td>Goodglass and Kaplan, 1972</td>
</tr>
<tr>
<td>Functional communicative profile</td>
<td>Sarno, 1969</td>
</tr>
<tr>
<td>Neurosensory center comprehensive examination for aphasia</td>
<td>Spreen and Benton, 1969</td>
</tr>
<tr>
<td>Porch Index of Communicative Ability</td>
<td>Porch, 1967</td>
</tr>
<tr>
<td>Minnesota Test for Differential Diagnosis of Aphasia</td>
<td>Schuell, 1965</td>
</tr>
<tr>
<td>Wepman–Jones Language Modalities Test for Aphasia</td>
<td>Wepman and Jones, 1961</td>
</tr>
<tr>
<td>Aphasia Screening Tests</td>
<td></td>
</tr>
<tr>
<td>Conversation analysis</td>
<td>Beeke, Maxim, and Wilkinson, 2007</td>
</tr>
<tr>
<td>Halstead–Wepman Aphasia Screening Test</td>
<td>Halstead and Wepman, 1959</td>
</tr>
<tr>
<td>Token Test</td>
<td>de Renzi and Vignolo, 1962</td>
</tr>
</tbody>
</table>

capabilities of the subject. They typically include tests of (1) auditory and visual comprehension; (2) oral and written expression, including tests of repetition, reading, naming, and fluency; and (3) conversational speech.

Because test batteries have the disadvantages of being lengthy and requiring special training to administer, some brief aphasia screening tests also have been devised, including conversational analysis and some simpler formal tests. The Halstead–Wepman Aphasia Screening Test and the Token Test are often used as part of standard neuropsychological test batteries (see Chapter 28) because they are short and easy to administer and score. These tests do not take the place of the detailed aphasia test batteries, but they provide efficient means of discovering the presence of a language disorder. If a detailed description of the linguistic deficit is then desired, the more comprehensive aphasia batteries may be given.

Although theoretical models and test batteries may be useful for evaluating and classifying the status of a patient with aphasia, they are not a substitute for continued experimental analysis of language disorders. Whereas the test batteries attempt to classify patients into a number of groups, a psychobiological approach concentrates on individual differences and peculiarities and, from these differences, attempts to reconstruct the processes through which the brain produces language.

On the practical side, John Marshall notes that only about 60% of patients will fit into a classification scheme such as the one presented in Table 19.3. Similar inadequacies have been noted in the use of other classification methods. For example, most patients with a language impairment show a deficit in naming that can be elicited by having them look at pictures of objects and attempt to identify them.

Scores on standard tests often tell little about this naming impairment. A number of patients might be able to name a violin, but one patient might know only that it is a musical instrument, another that it is a stringed instrument, and still another that it is similar to a cello and not a trumpet. Some patients have highly selective naming deficits, such as being unable to name buildings or people or colors or objects found inside houses. Thus, it is inappropriate to sim-
Developmental Language Disorders

The assessment of reading disorders is becoming a special branch of the study of language for several reasons. First, it is possible to be more objective in the analysis of reading than in the analysis of writing and speaking. Additionally, there is a large pedagogical science of reading. Finally, in addition to the acquired dyslexias (impairments in reading subsequent to brain damage), cases of developmental dyslexia (failure to learn to read during development) are common and require diagnosis and remediation.

Max Coltheart argues that model building is the most objective approach to the study of reading. A model is much like an algorithm, a set of steps to follow to answer a question. Reading models are used to test reading-disabled people, both as a way of defining the impairment and as a way of testing the utility of the model.

The model-building approach views reading as being composed of a number of independent skills or subsystems, one or another of which may not be functioning in an impaired reader. The modeling approach thus differs from classical neurological approaches in two ways: (1) the latter define dyslexia according to whether it arises in conjunction with other disorders, such as dysgraphia or dysphasia, and (2) the primary intent is to correlate the impairment with the focus of brain damage.

Analyzing Acquired Dyslexia

The model-building approach can be traced to an analysis by James Hirschelwood, first published in 1900, in which he identified different types of reading disorders: (1) the inability to name letters (letter blindness), (2) the inability to read words (word blindness), and (3) the inability to read sentences (sentence blindness). Hirschelwood's taxonomy and its subsequent elaboration led to the current hypothesis that reading is composed of a number of independent abilities that may each have an independent anatomical basis.

Figure 19.14 shows a series of questions that an examiner might ask to identify the following impairments:

1. **Attentional dyslexia.** When one letter is present, letter naming is normal. When more than one letter is present, letter naming is difficult. Even if a letter is specially colored, underlined, has an arrow pointing to it, and is pointed to by the tester, it may be named incorrectly when it is not alone. The same phenomenon may occur for words when more than one word is present.
2. **Neglect.** Persons displaying this impairment may misread the first half of a word (for example, reading "whether" as "smother") or they may misread the last part of a word (for example, reading "strong" as "stroke"). This positional syndrome has received little investigation.

3. **Letter-by-letter reading.** Affected persons read words only by spelling them out to themselves (aloud or silently). When the spelling is done silently, it can be detected by the additional time required for reading long words. Frequently, an affected person can write but then has difficulty reading what was written.

4. **Deep dyslexia.** The key symptoms of this disorder are semantic errors: persons with deep dyslexia read semantically related words in place of the word that they are trying to read (for instance, "tulip" as "crocus" and "merry" as "Christmas"). Nouns are easiest for them to read, followed by adjectives and then verbs. Function words present the greatest difficulty. Those who suffer from deep dyslexia also find it easier to read concrete words rather than abstract ones and are completely unable to read nonsense words. They are also generally impaired at writing and in short-term verbal memory (digit span).

5. **Phonological dyslexia.** The one symptom of phonological dyslexia is an inability to read nonwords aloud; otherwise reading may be nearly flawless.

6. **Surface dyslexia.** The surface dyslexic cannot recognize words directly but can understand them by using letter-to-sound relations; that is, the word can be understood if it is sounded out. This reading procedure works well as long as the words are regular ones ("home," "dome"), but not if the words are irregular ("come" will be read as "comb"). Spelling is also impaired but is phonetically correct. Surface dyslexia does not develop in languages that are totally phonetic (such as Italian). Surface dyslexia is a common symptom of children who have difficulty in learning to read.

**Modeling Speech from Print**

Central to the model-building idea of reading is the dual-route theory, which proposes that reading written language is accomplished by using two distinct but interactive procedures, the lexical and nonlexical routes. Reading by the lexical route relies on the activation of orthographic (picture) or phonological (sound) representations of a whole word. The lexical route can process all familiar words, both regular and irregular, but it fails with unfamiliar words or nonwords because it lacks a representation for them.

In contrast with the whole-word retrieval procedure used by the lexical route, the nonlexical route uses a subword procedure based on sound-spelling rules. The nonlexical route can succeed with nonwords (for example, klant) and regular words that obey letter-sound rules, but it cannot succeed with irregular words that do not obey these rules (for example, winding, choir).
The application of the dual-route theory is that normal readers compute sense and sound in parallel, whereas, in the dyslexic reader, one process or the other may be absent. In deep dyslexia, a subject is unable to process for sound and reads for sense. The subject may misread the word “bird” as “butterfly,” both words referring to flying animals. In surface dyslexia, a subject is able to process for sound but not for sense. The subject might pronounce English words correctly and even read fluently but still not realize what he or she is saying. Stephen Rapcsak and his colleagues propose that the dual-route theory is effective in diagnosing both developmental and acquired dyslexia.

A model illustrating the dual-route theory is illustrated in Figure 19.15. Note that there are quite separate ways of obtaining speech from print and a still different way of producing letter names. The important feature of the dual-route approach is that it does not depend on function-anatomy relations, it can be applied to language disorders other than dyslexia, and it can lead to hypotheses concerning the anatomical organization of language.

**Summary**

**What Is Language?**
Language is a unique human ability that extends the development of multiple sensory channels. It gives us a way to organize sensory inputs by assigning tags to information, which allows us to categorize objects and, ultimately, concepts, and to speak to ourselves about our past and future. Language also includes the unique motor act of producing syllables, as well as the ability to impose grammatical rules, which dramatically increases the functional capacity of the system.

**Origins of Language**
The evolution of language does not represent the development of a single ability but rather the parallel development of multimodal processes. New investigations of language origins are directed toward understanding the component skills necessary for language and the genes that contribute to language-like processes in different animal species.

**The Localization of Language**
The various language functions take up a large part of the cortex. Some functions, such as the generation of verbs versus nouns or the understanding of visual versus auditory information, are found in precise locations. Like other cerebral functions, language seems to be organized in a series of parallel hierarchical channels that are best described as neural webs.
Disorders of Language
Traditional classifications of language disorders characterize fluent disorders, in which speech can be expressed, nonfluent disorders, in which speaking is impaired, and pure disorders, which may be quite selective. Various combinations of fluent and nonfluent types are identified, depending on the disorder.

The Localization of Lesions in Aphasia
The Wernicke–Geschwind model of left-hemisphere function still provides a simple approach to understanding deficits in speech production, but contributions of subcortical structures and the right hemisphere to language show that it is widely distributed in the brain.

References


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