Language and the Aphasias

Language is the Ability to Encode Ideas Into Signals and Must Be Distinguished From Thought, Literacy, and Correct Usage

Language Has a Universal Design
- Complex Language Develops Spontaneously in Children
- Languages Are Learned and the Capacity to Learn Language Is Innate
- Other Animals Appear to Lack Homologs of Human Language, but Language May Nonetheless Have Evolved by Darwinian Natural Selection

The Study of Aphasia Led to the Discovery of Critical Brain Areas Related to Language
- Broca Aphasia Results From a Large Frontal Lobe Lesion
- People With Broca Aphasia Have Trouble Understanding Grammatically Complex Sentences
- Wernicke Aphasia Results From Damage to Left Temporal Lobe Structures
- Conduction Aphasia Results From Damage to Structures That Interact With Major Language Areas of the Brain
- Transcortical Motor and Sensory Aphasia Result From Damage to Areas Near Broca’s and Wernicke’s Areas
- Global Aphasia Is a Combination of Broca, Wernicke, and Conduction Aphasia

Beyond the Classic Language Areas: Other Brain Areas Are Important for Language
- The Right Cerebral Hemisphere Is Important for Prosody and Pragmatics
- Alexia and Agraphia Are Acquired Disorders of Reading and Writing
- Developmental Dyslexia Is a Difficulty in Learning to Read
- An Overall View

Language is the Remarkable System that allows people to communicate an unlimited combination of ideas using a highly structured stream of sounds (or, in signed languages, of manual and facial gestures). Language is the most accessible part of the mind, and for millennia it has been a central concern of scholars in many disciplines. Intensive scientific investigation by linguists and psycholinguists in the past 40 years has revealed that all languages are based on remarkably similar design principles and that language emerges spontaneously in all normal children in all societies. Language thus appears to be a species-wide adaptation, and, as we shall see, is supported by neural circuitry of considerable complexity.

Language is the Ability to Encode Ideas Into Signals and Must Be Distinguished From Thought, Literacy, and Correct Usage

The word language is used in many ways, and in undertaking a scientific investigation of language it is useful to distinguish the core faculty of language itself from other abilities that are often lumped with it.

First, language is often said to be inextricable from thinking, but in fact the two should be distinguished. Thinking is the ability to have ideas and to infer new ideas from old ones; language is the ability to encode ideas into signals for communication to someone else. Language, the code by which we transmit ideas, is different from ideas themselves. People do not think only in the words and sentences of their language; thinking can occur in the absence of language. Infants, nonhuman primates, aphasic individuals, and normal adult
humans think when they use visual images, abstract concepts and propositions, and other nonlinguistic forms of thought. Moreover, language is too ambiguous and sketchy to express the totality of a person's knowledge.

Second, language should be distinguished from reading and writing. Written language is a recent invention in human history and must be explicitly taught, with uneven results. Finally, mastery of language is not the same as mastery of the prescriptive rules of "correct" usage spelled out by teachers and style manuals. These rules specify differences between standard and nonstandard dialects of a language (eg, isn't vs ain't) and the conventions of written prose. The scientific study of language is descriptive. It is concerned with how people do talk, not how they ought to talk. Thus, for linguists, "grammar" refers to the rules that allow people to connect thoughts in sentences, both when speaking and understanding.

Language Has a Universal Design

All human cultures have language, and everywhere people use it creatively to convey new ideas. How do they do it?

The design of language is based on two components: words and grammar. A word is an arbitrary association between a sound and a meaning. For example, English speakers use the word cat (as opposed to chat, dog, or hickety) to refer to a certain animal, not because the word has any natural connection with this animal but simply because it is a shared convention used by a community of speakers who have all, at some time in their lives, memorized the connection between that sound and that meaning. By age 6, children comprehend about 13,000 words, and high school graduates have mastered at least 60,000. This means that children connect a new sound and meaning about every 90 waking minutes. The connection is bidirectional: Children merely have to hear a word to use it themselves; they do not need molding or feedback.

Words in the huge open-class (or content) vocabulary refer to a vast number of concepts, such as objects, states, events, motions, qualities, people, paths, and places, and include nouns, verbs, adjectives, adverbs, and some prepositions. Words in the much smaller closed-class (or grammatical) vocabulary have a more restricted set of meanings related to time, logic, and the relationships among the content words. They are used primarily to define a sentence's structure and include articles, auxiliaries, prefixes and suffixes, particles, and prepositions not included in the open class.

Grammar is the system that specifies how vocabulary units can be combined into words, phrases, and sentences, and how the meaning of a combination can be determined by the meanings of the units and the way they are arranged. It allows us to distinguish, for example, between Man bites dog and Dog bites man, using the positions of the words man and dog with respect to bites. Because grammar is based on a set of rules for assembling words into new combinations, rather than on the storage and recall of fixed word sequences, the number of sentences a language speaker can produce and understand is vast. The number of possibilities grows exponentially with the length of the sentence; there are on the order of 10^20 grammatically meaningful sentences of 20 words or fewer. Indeed, the number of possible sentences is in principle infinite, because one can embed one sentence inside another without limit: I think that he thinks that she thinks that . . .

Grammar has three main components: morphology, syntax, and phonology. Morphology refers to the rules for combining words and affixes into larger words, as in ten + able + istry or bite + s. In many languages morphology plays a crucial role in conveying who did what to whom. Nouns are marked with suffixes that help indicate whether the noun is the agent, the affected party, or some other kind of participant in the event or state, and verbs are marked with suffixes that pin down various properties of those participants (such as person, number, and gender). Old English relied heavily on these devices, and modern English has vestiges of them in pronoun case (I versus me, he versus him) and subject-verb agreement (He dawdles versus They dawdle).

Syntax consists of rules for combining words into phrases and sentences and determining relations among words. These rules do not simply order words in a linear string. At heart, syntax involves three principles. First, sequences of words are grouped into phrases, which are grouped into larger phrases, and so on, defining a tree-like phrase structure. For example, in Animal Crackers Groucho Marx said, "I once shot an elephant in my pajamas. How he got into my pajamas I never know." The joke stems from the fact that two phrase structures are possible for the same sequence of words: "[I shot [an elephant] in my pajamas], and [I shot [an elephant in my pajamas]]."

Second, the verb determines how the meanings of the words in a phrase structure are to be integrated into a cohesive proposition. A person's "mental dictionary entry" for a word includes not just its sound, meaning and grammatical category (noun, verb, adjective, preposition) but also a grammatical subcategory. Familiar examples of subcategories for verbs are those for transitive and intransitive verbs. A transitive verb requires an object.
jet (eg, we say Maria devoured the pizza, never just Maria devoured), while an intransitive verb does not have an object (eg, we say Maria dined, not Maria dined the pizza). The subcategory of a verb specifies the semantic roles of its arguments, the different participants in the action or state expressed by the verb. For example, in the sentences Man fears dog and Man frightens dog, man has a different role despite the fact that the word occupies the same position in both phrases. The word fear specifies “the subject is the experiencer, the object is the cause,” whereas frighten specifies “the subject is the cause, the object is the experiencer.” To understand either of these sentences, one must distinguish between the subject and the object; they can be identified by their positions in phrase structure, their case endings, or both.

The third syntactic principle is that two phrases in a sentence are sometimes linked so that they refer to the same entity in the world, a phenomenon called anaphora. For example, in Sheila washed herself the words Sheila and herself are understood to refer to the same person. Sometimes the process of anaphora links a word to a structural gap later in the sentence that provides a clue to the role of the word in the sentence. In the sentence Which man did the dog bite, the semantic role of which man (the man who was bitten) is determined not by the position of that phrase at the beginning of the sentence but by the empty object position after the word bite. That is, the position for the object is left empty and is not expressed overtly in the speaker’s utterance. This phenomenon motivated Noam Chomsky to distinguish between the deep structure and the surface structure of a sentence. In the deep structure every phrase is in its proper position (for example, which man would follow bite). However, a movement rule or transformation can move a phrase to another position (such as the beginning of the sentence), leaving behind a gap (or trace). The resulting structure of the sentence is called the surface structure.

The third subsystem of grammar, phonology, consists of rules combining sounds into a consistent pattern in the language. For example, we recognize that blicket may be an English word, whereas nggat probably is not. But unlike syntax and morphology, phonology does not assign a meaning to the elements it combines. Sound elements of phonemes, such as t and i, and their articulatory components, such as voicing and use of the tongue tip, do not themselves have meanings, nor does their arrangement correspond to some meaningful relation among entities. (There is nothing in the ordering of d, o, and g that predicts how the meaning of dog differs from the meaning of god.) The rules of phonology, then, are merely a way of taking a small set of basic articulatory gestures and using them to form a vast set of possible words, each with an arbitrary meaning that must be memorized. Phonology also embraces prosody: patterns of intonation, stress, and timing that span entire phrases and sentences. Prosody can have a grammatical role—for example, in distinguishing words (blackboard versus black board)—as well as a broader communicative function, differentiating questions from statements, supplying emphasis, indicating sarcasm, and expressing emotion.

Using grammar and lexicon alone does not allow one to produce or comprehend a sentence. Grammar and lexicon are merely codes, or protocols, that establish a relationship between meanings and signals for a given language. To produce a sentence one must choose words and use grammatical rules to encode ideas and intentions (that is, the message) and generate a set of articulatory commands to the motor system. To comprehend a sentence one must coordinate the sensory information that comes in through the auditory system (or the visual system in signing and reading) with the grammar and lexicon and send information about the resulting interpretation (the message) to the systems underlying memory and reasoning. Using language, then, requires complex patterns of information flow involving many parts of the brain.

Complex Language Develops Spontaneously in Children

According to Darwin, “Man has an instinctive tendency to speak, as we see in the babble of our young children; while no child has an instinctive tendency to brew, bake, or write.” In the first year of life children work on sounds. They begin to make language-like sounds at 5–7 months, babble in well-formed syllables at 7–8 months, and gibber in sentence-like streams by the first year. In their first few months, they can discriminate speech sounds, including ones that are not used in their parents’ language and that their parents do not normally discriminate (for example, Japanese babies can discriminate /r/ and /l/). By 10 months they discriminate phonemes much as their parents do. This tuning of speech perception to the specific ambient language precedes the first words, so it must be based on the infant performing sophisticated acoustic analyses, rather than on the infant correlating the sounds of words with their meanings.

A child’s first words are spoken around the time of his or her first birthday, and the rate of word learning increases suddenly around age 18 months, which is also the age at which children first string words into combinations such as More outside and Allgone doggie. Children at age 2 begin to speak in rich phrase structures and
master the grammatical vocabulary of their language (articles, prepositions, etc). By age 3, children use grammatical words correctly most of the time, use most of the constructions of the spoken language appropriately, and in general become fluent and expressive conversational partners. Although children make many errors, their errors occur in a minority of the words they use and are highly systematic. Indeed, this fact confirms what we might have guessed from the fact that children are so fluent and creative: children must be engaging in sophisticated grammatical analysis of their parents' speech rather than merely imitating them.

Take, for example, this error of a 3-year-old: Mommy, why did he dis it appear? First, it shows that children do not merely record stretches of sound but are hyperalert for word boundaries. This child misanalyzed disappear as dis appear. Second, this error shows that children work to classify words in grammatical categories. The child's newly extracted appear is being used not as the verb an adult uses but as a unit of speech that the child has hypothesized from the context, namely, a particle (examples of particles are the second words in blow away and take apart). Third, it shows how children look for grammatical subcategories that determine the interaction between words and grammar. The child creatively converted an intransitive verb meaning "vanish" to a transitive verb meaning "cause to vanish," in conformity with a widespread pattern in English grammar: The ice melted/She melted the ice; The ball bounced/She bounced the ball, and so on.

Several kinds of evidence have been adduced to support Chomsky's hypothesis. First, there are the gross facts of the distribution of language across the species. People in technologically primitive cultures, helpless year-olds, and poorly educated adults in our culture all master complex grammar when they first acquire language, and they do so without special training sequences or feedback. Indeed, when children in a social environment are deprived of a bona fide language, they create one of their own; this is how the sign languages of the deaf arise. Similarly, in the eighteenth and nineteenth centuries, slave children living on plantations and children in other mixed-culture societies who were exposed to crude pidgin languages (choppy strings of words) used by their parents developed full-fledged languages, called creoles, from the pidgin languages. In all these cases the languages children master or create follow the universal design of language described earlier in this chapter.

In addition, language and more general intelligence are dissociated from one another in several kinds of pathological conditions. Children with a heritable syndrome called specific language impairment can have high intelligence, intact hearing, and normal social skills but have long-lasting difficulty in speaking and understanding according to the grammatical rules of their language. Conversely, children with certain kinds of mental retardation can express their confabulated or childlike thoughts in fluent, perfectly grammatical language and score at normal levels on tests of comprehension of complex sentences. These dissociations, in which complex language abilities are preserved despite compromised intelligence, can appear in people who have hydrocephalus caused by spina bifida and in people with Williams syndrome, a form of retardation associated with a defective stretch of chromosome 7.

Finally, grammar has a partly quirkily design that cuts across the categories underlying concepts and reasoning. Consider the statements It is raining and Pat's running. Both "it" and "Pat" have the same grammatical function; both words serve as subjects of the sentence and both can be interchanged with the verb to form a question (Is it raining? Is Pat running?) despite the fact that "it" is a grammatical placeholder without cognitive content. Though the sentence The child seems to be sleepy can be shortened to The child seems sleepy, the nearly identical sentence The child seems to be sleeping cannot be shortened to The child seems sleeping. Subtleties such as these which emerge in all speakers without specially tailored training sequences or systematic feedback, are consequences of the design of grammar; they cannot be predicted from principles governing what makes sense or what is easy or difficult to understand.
In sum, children seem to acquire language using abilities that are more specific than general intelligence but not so specific as the capacity to speak a given language—English, Japanese, and so on. What, then, is innate? Presumably, it is some kind of neural system that analyzes communicative signals from other people, not as arbitrary sequences of sound or behavior but according to the design of language. By following this design a child learns a lexicon of bidirectional arbitrary pairings of sound and meaning and several kinds of grammatical rules. One kind assembles phonological elements into words; other kinds assemble words into bigger words, phrases, and sentences according to the principles of phrase structure, grammatical categories and subcategories, case and agreement, anaphora, long-distance dependencies, and movement transformations. Presumably all these abilities come from adaptations of the human brain that arose in the course of human evolution.

Other Animals Appear to Lack Homologs of Human Language, but Language May Nonetheless Have Evolved by Darwinian Natural Selection

One might think that if language evolved by gradual Darwinian natural selection it must have a precursor in other animals. But the natural communication systems of nonhuman animals are strikingly unlike human language. They are based on one of three designs: a finite repertoire of calls (e.g., one to warn of predators, one to announce a claim to territory), a continuous analog signal that registers the magnitude of some condition (e.g., the distance a bee dances signals the distance of a food source), or sequences of randomly ordered responses that serve as variations on a theme (as in birdsong). There is no hint of the discrete, infinite combinatorial system of meaningful elements seen in human language.

Some animals can be trained to mimic certain aspects of human language in artificial settings. In several famous and controversial demonstrations, chimpanzees and gorillas have been taught to use some hand signs based on American Sign Language (though never its grammar), manipulate colored switches or tokens, and carry out some simple spoken commands. Parrots and dolphins have also learned to recognize or produce ordered sequences of sounds or other signals. Such studies have taught us much about the cognitive categories of nonhuman species, but the relevance of these animal behaviors to human language is questionable.

It is not a matter of whether one wants to call the trained artificial systems "language." This is not a scientific question, but a matter of definition—how far are we willing to stretch the meaning of the word language? The scientific question, and the only one relevant to whether these trained behaviors can serve as an animal model for language, is whether the abilities are homologous to human language—whether the two cognitive systems show the same basic organization owing to descent from a single system in a common ancestor. For example, biologists do not debate whether the wing-like structures of gliding rodents (flying squirrels) may be called "genuine wings" or something else (an uninformative question of definition). These structures are not homologous to the wings of bats because they have a different anatomical plan reflecting a different evolutionary history. Bat wings are modifications of the hands of a common mammalian ancestor; the wings of a flying squirrel are modifications of its rib cage. The two structures are merely similar in function, or analogues, but not homologous.

Though artificial signaling systems taught to animals have some analogies to human language (e.g., they are used in communication and sometimes involve combining basic signals), it seems unlikely that they are homologous. Chimpanzees require extensive teaching contrived by another species (humans) to acquire rudimentary abilities, mostly limited to a small number of signs, strung together in repetitive, quasi-random sequences, used with the intent of requesting food or tickling. The core design of human language—particularly the formation of words, phrases, and sentences according to a single plan that supports both production and comprehension—fails to emerge as the chumps interact with each other and, as far as we know, it cannot be taught to them.

All this contrasts sharply with human children, who learn thousands of words spontaneously; combine them in novel structured sequences in which every word has a role; respect the word order, case marking, and agreement of the adult language; use sentences for a variety of nonutilitarian purposes, such as commenting on interesting objects; and creatively interpret the grammatical complexity of the input they receive (reflected in their systematic errors or in their creation of novel sign languages and creoles).

Nevertheless, this lack of homology does not cast doubt on a Darwinian, gradualist account of language evolution. Humans did not evolve directly from chimpanzees. Both evolved from a common ancestor, probably around 6-8 million years ago. This time span leaves about 300,000 generations in which language could have evolved gradually in the lineage leading to humans after it split off from the lineage leading to chimpanzees. Presumably language evolved in the human lineage because of two related adaptations in our ances-
The Study of Aphasia Led to the Discovery of Critical Brain Areas Related to Language

The lack of a homolog to language in other species precludes the attempt to model language in animals, and understanding of the neural basis of language must be pieced together from other sources. By far the most important source has been the study of language disorders known as aphasia, which are caused by focal brain lesions that result, most frequently, from stroke or head injury.

The early study of the aphasias paved the way for a number of important discoveries on the neural basis of language processing. First, it suggested that in a way
ity of individuals language depends principally on left hemisphere rather than on right hemisphere structures. All but a few right-handed individuals have left cerebral dominance for language, and so do most left-handed individuals. All told, about 96% of people depend on the left hemisphere for language processing related to grammar, the lexicon, phonemic assembly, and phonetic production. Even languages such as American Sign Language, which rely on visuomotor signs rather than auditory speech signs, depend primarily on the left hemisphere. Second, the early study of aphasia revealed that damage to each of two cortical areas, one in the lateral frontal region, the other in the posterior superior temporal lobe, was associated with a major and linguistically different profile of language impairment. The two cortical areas are Broca’s area and Wernicke’s area (Figure 59-1).

These findings allowed neurologists to develop a model of language that has become known as the Wernicke-Geschwind model. The earliest version of this model had the following components. First, two areas of the brain, Wernicke’s and Broca’s, were assumed to have the burden of processing the acoustic images of words and the articulation of speech, respectively. Second, the arcuate fasciculus was thought to be a unidirectional pathway that brought information from Wernicke’s area to Broca’s area. Third, both Wernicke’s and Broca’s areas were presumed to interact with the modular association areas. After a spoken word was processed in the auditory pathways and the auditory signals reached Wernicke’s area, the word’s meaning was evoked when brain structures beyond Wernicke’s area were activated.

Similarly, nonverbal meanings were converted into acoustic images in Wernicke’s area and turned into vocalizations after such images were transferred by the arcuate fasciculus into Broca’s area. Finally, reading and writing ability both depended on Wernicke’s and Broca’s areas, which, in the case of reading, received visual input from left visual cortices and, in the case of writing, could produce motor output from Exner’s area (in the premotor region above Broca’s area).

This general model formed the basis for a useful classification of the aphasias (Table 59-1) and provided a framework for the investigation of the neural basis of language processes. However, several decades of new lesion studies and research in psycholinguistics and experimental neuropsychology have shown that the general model has important limitations. In particular, much progress has come from the advent of new methodologies, including positron emission tomography (PET), functional magnetic resonance imaging (fMRI), event-related electrical potentials (ERP), and the direct recording of electrical potentials from the exposed cerebral cortex of patients undergoing surgery for the management of intractable epilepsy. Each of these techniques has contributed to a better definition of the areas important for the performance of language tasks.

As a result of these advances, it now is apparent that the roles of Wernicke’s and Broca’s areas are not as clear as they first appeared. Similarly, the arcuate fasciculus is now appreciated to be a bidirectional system that joins a broad expanse of sensory cortices with prefrontal and premotor cortices. Finally, a variety of other regions in the left hemisphere, both cortical and subcortical, have been found to be critically involved in language processing. These include higher-order association cortices in the left frontal, temporal, and parietal regions, which seem to be involved in mediating between concepts and language; selected cortex in the left insular region thought to be related to speech articulation; and prefrontal and cingulate areas that implement executive control and mediation of necessary memory and attentional processes. The processing of language requires a large network of interacting brain areas.

The modern framework that has emerged from this work suggests that three large systems interact closely in language perception and production. One system is formed by the language areas of Broca and Wernicke, selected areas of insular cortex, and the basal ganglia. Together, these structures constitute a language implementation system. The implementation system analyzes incoming auditory signals so as to activate conceptual knowledge and also ensures phonemic and grammatical construction as well as articulatory control. This implementation system is surrounded by a second system, the mediational system, made up of numerous separate regions in the temporal, parietal, and frontal association cortices (Figure 59-1). The mediational regions act as third-party brokers between the implementation system and a third system, the conceptual system, a collection of regions distributed throughout the remainder of higher-order association cortices, which support conceptual knowledge.

**Broca Aphasia Results From a Large Frontal Lobe Lesion**

Broca aphasia is not a single entity. True persisting Broca aphasia is a syndrome resulting from damage to Broca’s area (the inferior left frontal gyrus, which contains Brodmann’s areas 44 and 45); surrounding frontal fields (the external aspect of Brodmann’s area 6, and areas 39, 10, and 46); the underlying white matter, insula, and basal ganglia (Figure 59-2); and a small portion of the anterior superior temporal gyrus. The patient’s speech is labored and slow, articulation is impaired, and the melodic intonation of normal speech is lacking (Table 59-2). Yet patients have considerable success at verbal
<table>
<thead>
<tr>
<th>Type of aphasia</th>
<th>Speech</th>
<th>Comprehension</th>
<th>Capacity for Repetition</th>
<th>Other Signs</th>
<th>Region Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca’s</td>
<td>Nonfluent, effortful</td>
<td>Largely preserved for single words and grammatically simple sentences</td>
<td>Impaired</td>
<td>Right hemiparesis (arm &gt; leg); patient aware of defect and may be depressed</td>
<td>Left posterior frontal cortex and underlying structures</td>
</tr>
<tr>
<td>Wernicke’s</td>
<td>Fluent, abundant, well articulated, melodic</td>
<td>Impaired</td>
<td>Impaired</td>
<td>No motor signs; patient may be anxious, agitated, euphoric, or paranoid</td>
<td>Left posterior, superior, and middle temporal cortex</td>
</tr>
<tr>
<td>Conduction</td>
<td>Fluent with some articulatory defects</td>
<td>Intact or largely preserved</td>
<td>Impaired</td>
<td>Often none; patient may have cortical sensory loss or weakness in right arm</td>
<td>Left superior temporal and supramarginal gyrí</td>
</tr>
<tr>
<td>Global</td>
<td>Scant, nonfluent</td>
<td>Impaired</td>
<td>Impaired</td>
<td>Right hemiplegia</td>
<td>Massive left perisylvian lesion</td>
</tr>
<tr>
<td>Transcortical Motor</td>
<td>Nonfluent, explosive</td>
<td>Intact or largely preserved</td>
<td>Intact or largely preserved</td>
<td>Sometimes right-sided weakness</td>
<td>Anterior or superior to Broca’s area</td>
</tr>
<tr>
<td>Transcortical Sensory</td>
<td>Fluent; scant</td>
<td>Impaired</td>
<td>Intact or largely preserved</td>
<td>No motor signs</td>
<td>Posterior or inferior to Wernicke’s area</td>
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</tbody>
</table>
communication even when their words are difficult to understand because the selection of words, especially nouns, is often correct. Verbs, as well as grammatical words such as conjunctions, are less well selected and may be missing altogether. Another major sign of Broca aphasia is a defect in the ability to repeat complex sentences spoken by the examiner. In general, patients with Broca aphasia appear to comprehend the words and sentences they hear, but the comprehension is only partial, as we shall see below.

When damage is restricted to Broca's area alone, or to its subjacent white matter, a condition now known as Broca area aphasia, the patient develops a milder and transient aphasia rather than true Broca aphasia.

People With Broca Aphasia Have Trouble Understanding Grammatically Complex Sentences

Broca aphasia was initially thought to be a deficit of production only, because most patients give the impression of understanding casual speech. Modern psycholinguistic studies have shown that people who have Broca aphasia comprehend sentences whose meaning can be pieced together from the individual meanings of content words and prior knowledge of how the world works. For example, these patients can understand The apple that the boy is eating is red. Boys eat apples, but apples do not eat boys; apples are red, but boys are not. But they cannot comprehend sentences in which meaning depends on complex grammar. They cannot understand The boy that the girl is chasing is tall.

Aphasic patients can understand the first sentence, as well as much casual conversation in general, based on vocabulary and general knowledge, without exercising grammatical abilities. But they have difficulty with the second sentence because either boys or girls can be tall and either one can chase the other. The only way to understand the second sentence is to recover its phrase structure, look up the lexical entry of chase to find the positions of the chaser and the person being chased, and link the gap after chasing to the boy. People with Broca aphasia are tripped up by this demand, showing that their aphasia is not just a disorder of speech output but embraces deficits in syntactic processing.

Is Broca aphasia, then, a deficit of grammar, implying that Broca's area is the center for grammar? Not really. First, the speech of patients with Broca aphasia is not altogether devoid of grammatical structure. Their speech retains the phrase order of their particular language (eg, subject-verb-object in English, subject-object-verb in Turkish). Moreover, although grammatical suffixes such as -ed, -ing, and -s are often omitted in the speech of English-speaking aphasic patients, suffixes may be preserved in the speech of aphasic patients speaking other languages in which suffixes are obligatory to conform with the phonological structure of words. Second, people with Broca aphasia often can make surprisingly fine grammatical judgments, discriminating the grammatical and ungrammatical versions of sentences such as the following:

John was finally kissed by Louise.
John was finally kissed Louise.
I want you to go to the store now.
I want you will go to the store now.

For a sentence to be grammatically well formed, it needs certain functional morphemes—the smallest meaningful unit of a word. The ability of patients to recognize that a sentence needs these morphemes—combined with an inability to analyze those morphemes when understanding complex sentences—has been called the "syntax-there-but-not-there" paradox.

A possible resolution is that the major syntactic difficulty in Broca aphasia is linking up elements in different parts of the sentence that must refer to the same entity (anaphora and gap-filling). In John was finally kissed by
<table>
<thead>
<tr>
<th>Type of aphasia</th>
<th>Spontaneous speech</th>
<th>Auditory comprehension</th>
<th>Repetition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca</td>
<td>Stimulus (Western Aphasia Battery picnic picture): What do you see in this picture?</td>
<td>“Yea, but, ah, notes an’, ah . . . an’, ah . . . I don’ know.”</td>
<td>“Elated.”</td>
</tr>
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<td></td>
<td>“O, yea. Det’s a boy an’ a girl . . . an’ . . . a . . . car . . . house . . . light po’ (pole). Dog an’ a . . . boat. ‘N det’s a . . . mm . . . a . . . cofee, an’ reading. Det’s a . . . mm . . . a . . . det’s a boy . . . fishin’.”</td>
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<td></td>
<td>(Elapsed time: 1 min 30 s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wernicke</td>
<td>“Ah, yes, it’s, ah . . . several things. It’s a girl . . . uncurl . . . on a boat. A dog . . . ’S is another dog . . . uh-oh . . . long’s . . . on a boat. The lady, it’s a young lady. An’ a man a They were eatin’. ’S be place there. This . . . a tree! A boat. No, this is a . . . It’s a house. Over in here . . . a cake. An’ it’s, it’s a lot of water. Ah, all right. I think I mentioned about that boat. I noticed a boat being there. I did mention that before . . . Several things down, different things down . . . a bat . . . a cake . . . you have a . . .”</td>
<td>“Well, I jus’ lost a lot a time”</td>
<td>“/l/ . . . no . . . In a br’”</td>
</tr>
<tr>
<td></td>
<td>(Elapsed time: 1 min 20 s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduction</td>
<td>“Kay. I see a guy readin’ a book. See a women / ka . . . he . . . pourin’ drink or somethin’. An’ they’re sittin’ under a tree. An’ there’s a . . . car behind that an’ then there’s a house behind th’ car. An’ on the other side, the guy’s flyn’ a / fait . . . fait /kite). See a dog there an’ a guy down on the bank. See a flag blowin’ in the wind. Bunch of /hi . . . a . . . trees in behind. An a sailboat on th’ river, river . . . lake. ’N guess that’s about all . . . ‘Basket there.”</td>
<td>“T: see if I can’t talk straight, where I can have . . . not havin’trouble to say words an’ sentences.”</td>
<td>“The baker was . . . What was that last word?”</td>
</tr>
<tr>
<td></td>
<td>(Elapsed time: 1 min 5 s)</td>
<td></td>
<td>“(Let me repeat it: The pa’ cook was elated.”)</td>
</tr>
<tr>
<td>Global</td>
<td>(Grunt)</td>
<td>(Gesturing)</td>
<td>(No response)</td>
</tr>
</tbody>
</table>
Figure 59-3 Wernicke aphasia. Left: A three-dimensional magnetic resonance imaging (MRI) reconstruction of a lesion in a patient with Wernicke aphasia. The infarction affected a large area of temporal lobe cortex as well as underlying white matter. Large, deep lesions are typically seen in severe cases. Right: Coronal section of the same brain taken along the plane defined by the blue slab. The brain is viewed from the front, with the left hemisphere on the right half of the image. The infarct is visible in black.

Louise, the failure to link John to the empty object position after was kissed would make the sentence incomprehensible. The aphasic person is able to detect the ungrammaticality of John was finally kissed Louise by simply noting that a passive verb (was kissed) appears illicitly with a direct object. This recognition does not depend on linking a gap with its filler. Indeed, people who have Broca aphasia cannot recognize that a sentence is ungrammatical if the ungrammaticality comes from an incorrect linkage between two separated elements in a sentence. That is, they are poor at discriminating between sentences such as the following pairs:

The woman is outside, isn’t she?
The woman is outside, isn’t it?

The girl fixed herself a sandwich.
The girl fixed themselves a sandwich.

Linking two elements (filler to gap, or antecedent to pronoun) requires keeping the first element in one’s working memory (Chapters 19 and 62) until the second is encountered and the two can be joined. This suggests that Broca’s area and associated regions may participate in the verbal short-term memory required for sentence comprehension. Recent functional brain imaging studies using PET show that the level of activation in a subregion of Broca’s area increases when a subject has to understand a sentence in which there is a long gap in the middle compared with the level when the subject must understand similar sentences with shorter gaps in the middle.

The idea that Broca’s area is related to short-term working memory fits with other findings. Working memory is thought to have a phonological loop consisting of a transient memory store for phonological information and a rehearsal process—a covert articulatory process in which commands are sent to the vocal tract muscles but not carried out—which repeatedly refreshes the memory. Broca’s area may participate in the rehearsal component of the loop, something that accords with the well-documented role of Broca’s area in articulation.

The structures usually damaged in true Broca aphasia and in Broca area aphasia may be part of a neural network involved in both the assembly of phonemes into words and the assembly of words into sentences. This network is thought to be concerned with relational aspects of language, which include the grammatical structure of sentences and the proper use of grammatical vocabulary and verbs. The other cortical components of the network are located in external areas of the left frontal cortex (Brodman’s areas 47, 46, and 9), the left parietal cortex (areas 40, and 39), and sensorimotor areas above the sylvian fissure between Broca’s and Wernicke’s areas (the lower sector of areas 3, 1, 2, and 4) and the insula.

Wernicke Aphasia Results From Damage to Left Temporal Lobe Structures

Wernicke aphasia is usually caused by damage to the posterior sector of the left auditory association cortex (Brodman’s area 22), although in severe and persisting cases there is involvement of the middle temporal gyrus and deep white matter (Figure 59-3). The speech of patients with Wernicke aphasia is effortless, melodic, and produced at a normal rate and is thus quite unlike that of patients with true Broca aphasia. The content, however, is often unintelligible because of frequent errors in the choice of words and phonemes, the individual sound units that make up morphemes (Table 59-2).

Patients with Wernicke aphasia often shift the order of individual sounds and sound clusters and add or subtract them to a word in a manner that distorts the intended phonemic plan. These errors are called phonemic paraphasias (paraphasia) refers to any substitution of an erroneous phoneme or entire word for the intended, cor-
rect one). When phoneme shifts occur frequently and close together, words become unintelligible and constitute neologisms. Even when words are put together with the proper individual sounds, patients with Wernicke aphasia have great difficulty selecting words that accurately represent their intended meaning (known as a *verbal* or *semantic paraphasia*). For example, a patient may say *headman* for *president*.

These patients also have difficulty comprehending sentences uttered by others. Although this deficit is suggested by the Wernicke-Geschwind model, Wernicke's area is no longer seen as the center of auditory comprehension. The modern view is that Wernicke's area is part of a processor of speech sounds that associates the sounds with concepts. This processing involves, in addition to Wernicke's area, the many parts of the brain that subserve grammar, attention, social knowledge, and knowledge of the concepts corresponding to the meanings of the words in the sentences.

**Conduction Aphasia Results From Damage to Structures That Interact With Major Language Areas of the Brain**

Patients with *conduction aphasia* comprehend simple sentences and produce intelligible speech but, like those with Broca and Wernicke aphasia, they cannot repeat sentences verbatim, cannot assemble phonemes effectively (and thus produce many phonemic paraphasias), and cannot easily name pictures and objects (the task called *confrontation naming*). Speech production and auditory comprehension are less compromised in conduction aphasia than in the other two major aphasia (Table 59-2).

Persistent conduction aphasia is caused by damage to the left superior temporal gyrus and the inferior parietal lobe (Brodman's areas 39 and 40). The damage may extend to the left primary auditory cortex (Brodman's areas 41 and 42), the insula, and the underlying white matter. There is no evidence that conduction aphasia is caused by a simple interruption or disconnection of the arcuate fasciculus alone, although the damage does destroy feed-forward and feedback projections that interconnect temporal, parietal, insular, and frontal cortices. This connectional system seems to be part of the network required to assemble phonemes into words and coordinate speech articulation.

Even though the exact anatomical correlates of conduction aphasia are being revised and the mechanism of the defect now appears not to be as proposed in the Wernicke-Geschwind model, Wernicke correctly predicted the main signs of the syndrome. This is a testimony to the considerable power of the early clinical observations in aphasia.

**Transcortical Motor and Sensory Aphasias Result From Damage to Areas Near Broca's and Wernicke's Areas**

The Wernicke-Geschwind model predicts that aphasia can be caused by damage not only to components of the language system but also to areas and pathways that connect those components to the rest of the brain. Patients with transcortical motor aphasia speak fluently but they can repeat even very long sentences. According to the Wernicke-Geschwind model, the aphasia is caused by a disconnection of the language areas from those that initiate and control spontaneous speech. Repetition is preserved because the connection to Wernicke's area is intact.

The aphasia has been linked to damage to the left dorsolateral frontal area, a patch of association cortex anterior and superior to Broca's area, although there may be substantial damage to Broca's area itself. Dorsolateral frontal cortex is involved in the allocation of attention and the maintenance of higher executive abilities, including the selection of words. For example, part of the area is activated in PET studies when subjects have to produce the names of actions associated with particular objects (e.g., saying *kick* in response to *hit*). Damage to this area leaves patients unable to perform such a task, although they can produce words in ordinary conversation.

The aphasia can also be caused by damage to the left supplementary motor area, located high in the frontal lobe, directly in front of the primary motor cortex and buried medially between the hemispheres. Electrical stimulation of the area in nonaphasic surgery patients causes the patients to make involuntary vocalizations or be unable to speak, and neuroimaging studies have shown this area to be activated in tasks of speech production. Thus the supplementary motor area appears to contribute to the initiation of speech whereas the dorsolateral frontal regions contribute to ongoing control, particularly when the task is difficult.

People with transcortical sensory aphasia have fluent speech with impaired comprehension, and they also have great trouble naming things. This aphasia differs from Wernicke aphasia in the same way that transcortical motor aphasia differs from Broca aphasia: repetition is spared. In fact, patients with transcortical sensory aphasia may repeat and even make grammatical corrections in phrases and sentences they do not understand, and they can repeat words in foreign languages. The aphasia thus appears to be a deficit in semantic retrieval with syntactic and phonological abilities still relatively intact.

Transcortical motor and sensory aphasias are believed to be caused by damage outside of the perisylvian area, in particular, outside the superior temporal and...
inferior parietal lobes, which explains the sparing of repetition skills. Transcortical aphasias are thus the complement of conduction aphasia, behaviorally and anatomically. Transcortical sensory aphasia itself appears to be caused by damage to parts of the junction of the temporal, parietal, and occipital lobes, which connect the perisylvian language areas with the parts of the brain underlying word meaning.

Global Aphasia Is a Combination of Broca, Wernicke, and Conduction Aphasias

Global aphasics have completely lost the ability to comprehend language, formulate speech, and repeat sentences, thus combining the features of Broca, Wernicke, and conduction aphasias. Speech is reduced to a few words at best. The same word may be used repeatedly, appropriately or not, in a vain attempt to communicate an idea. However, other abilities may be preserved: nondeliberate (“automatic”) speech such as stock expletives (used appropriately and with normal phonemic, phonetic, and inflectional structures), routines such as counting or reciting the days of the week, and the ability to sing previously learned melodies and their lyrics. Auditory comprehension is limited to a few words and idiomatic expressions.

Classic global aphasia is accompanied by weakness in the right side of the face and paralysis of the right limbs and is caused by damage in the anterior language region and the basal ganglia and insula (as in Broca’s area), the superior temporal gyrus (as in conduction aphasia), and the posterior language regions (as in Wernicke aphasia). So much damage can only be caused by a large infarct in the region supplied by the middle cerebral artery.

Beyond the Classic Language Areas: Other Brain Areas Are Important for Language

The anatomical correlates of the classical aphasias comprise only a restricted map of language-related areas in the brain. The past decade of research on aphasia has uncovered numerous other language-related centers in the cerebral cortex and in subcortical structures. Some are located in the left temporal region.

For example, until recently the anterior temporal and inferotemporal cortices, in either the left or the right
hemisphere, had not been associated with language. Recent studies reveal that damage to left temporal cortices (Brodman’s areas 21, 20, and 38) causes severe and pure naming defects—impairments of word retrieval without any accompanying grammatical, phonemic, or phonetic difficulty. When the damage is confined to the left temporal pole (Brodman’s area 38) the patient has difficulty recalling the names of unique places and persons but not names for common things. When the lesions involve the left midtemporal sector (areas 21 and 20) the patient has difficulty recalling both unique and common names. Finally, damage to the left posterior inferotemporal sector causes a deficit in recalling words for particular types of items—tools and utensils—but not words for natural things or unique entities. Recall of words for actions or spatial relationships is not compromised.

These findings suggest that the left temporal cortices contain neural systems that access words denoting various categories of things but not words denoting the actions of the things or their relationships to other entities. Localization of a brain region that mediates word-finding for classes of things has been inferred from two types of studies: examination of patients with lesions in their brain from stroke, head injuries, herpetic encephalitis, and degenerative processes such as Alzheimer disease and Pick disease, and functional imaging studies of normal individuals and electrical stimulation of these same temporal cortices during surgical interventions (Figure 59-4).

Another area not included in the classical model is a small section of the insula, the island of cortex buried deep inside the cerebral hemispheres (Figure 59-5). Recent evidence suggests that this area is important for planning or coordinating the articulatory movements necessary for speech. Patients who have lesions in this area have difficulty pronouncing phonemes in their proper order; they usually produce combinations of sounds that are very close to the target word. These patients have no difficulty in perceiving speech sounds or recognizing their own errors and do not have trouble in finding the word, only in producing it. This area is also damaged in patients with true Broca aphasia and accounts for much of their articulatory deficits.

The frontal cortices in the mesial surface of the left hemisphere, which includes the supplementary motor area and the anterior cingulate region (also known as Brodman’s area 24), play an important role in the initiation and maintenance of speech. They are also important to attention and emotion and thus can influence many higher functions. Damage to these areas does not cause an aphasia in the proper sense but impairs the initiation of movement (akinesia) and causes mutism, the complete absence of speech. Mutism is a rarity in aphasic patients and is seen only during the very early stages of the condition. Patients with akinesia and mutism fail to communicate by words, gestures, or facial expression. They have an impairment of the drive to communicate, rather than aphasia.

The Right Cerebral Hemisphere Is Important for Prosody and Pragmatics

In almost all right-handers, and in a smaller majority of left-handers, linguistic abilities—phonology, the lexicon, and grammar—are concentrated in the left hemisphere. This conclusion is supported by numerous studies of patients with brain lesions and studies of electrical and metabolic activity in the cerebral hemispheres of normal people. In “split-brain” patients, whose corpus callosum has been sectioned to control epilepsy, the right hemisphere occasionally has rudimentary abilities to comprehend or read words, but syntactic abilities are poor, and in many cases the right hemisphere has no lexical or grammatical abilities at all.

Nonetheless, the right cerebral hemisphere does play a role in language. In particular, it is important for communicative and emotional prosody (stress, intonation, and intonation). Patients with right anterior lesions may produce inappropriate intonation in their speech, but with right posterior lesions have difficulty interpreting the emotional tone of others’ speech. In addition, the right hemisphere plays a role in the pragmatics of language. Patients with damage in the right hemisphere have difficulty incorporating sentences into a coherent narrative or conversation and using appropriate language in particular social settings. They often do not understand jokes. These impairments make it difficult for patients with right hemisphere damage to function effectively in social situations, and these patients are sometimes shunned because of their odd behavior.

When adults with severe neurological disease have the entire left hemisphere removed, they suffer a permanent and catastrophic loss of language. In contrast, when the left hemisphere of an infant is removed, the child learns to speak fluently. Adults do not have the plasticity of function, and this age difference is consistent with other findings that suggest there is a critical period for language development in childhood. Children can acquire several languages perfectly, whereas most adults who take up a new language are saddled with a foreign accent and permanent grammatical errors. When children are deprived of language input because their parents are deaf or deprived, they can catch up fully if exposed to language before puberty, but they are strikingly inept if the first exposure comes later.
Despite the remarkable ability of the right hemisphere to take on responsibility for language in young children, it appears to be less suited for the task than the left hemisphere. One study of a small number of children in whom one hemisphere had been removed revealed that the children with only a right hemisphere were impaired in language (and other aspects of intellectual functioning), compared with children who had only a left hemisphere (these children were less impaired overall). Like people with Broca aphasia, children with only a right hemisphere comprehend most sentences in conversation but have trouble interpreting more complex constructions, such as sentences in the passive voice. A child with only a left hemisphere, in contrast, has no difficulty even with complex sentences.

Alexia and Agraphia Are Acquired Disorders of Reading and Writing

Certain brain lesions in adults can cause alexia (also known as word blindness), a disruption of the ability to read, or agraphia, a disruption of the ability to write. The two disorders may appear combined or separately, and they may or may not be associated with aphasia, depending on the site of the causative lesion. Reading emerged only recently in history (less than 5000 years ago), and universal literacy is even more recent (less than a century ago). Therefore, pure alexia without aphasia cannot be attributed to impairment of a special “reading system” in the brain but must be caused by a disconnection between the visual and language systems.

Because vision is bilateral and language is lateralized, pure alexia results from disruptions in the transfer of visual information to the language areas of the left hemisphere. In 1892 the French neurologist Jules Dejerine studied an intelligent and highly articulate man who had recently lost the ability to read, even though he could spell, understand words spelled to him, copy written words, and recognize words after writing the individual letters. The patient could not see color in his right visual field, but his vision was otherwise intact in both visual fields. Postmortem examination revealed damage in a critical area of the left occipital region that
Figure 59-6 Areas of significant change in activity, indexed by perfusion, when subjects performed two language tests. The activated areas are superimposed on a lateral projection of the dominant left hemisphere with the frontal lobe to the left. The two pictures on the left are the results from normal subjects and the pictures on the right demonstrate results from patients with developmental dyslexia.

Memory task: The upper two images demonstrate activity associated with remembering short lists of letters. In the normal subject an extensive area involving the inferior left frontal cortex, the superior temporal cortex, and the inferior parietal cortex is activated. In dyslexic patients only the inferior parietal and superior temporal cortex are activated.

Rhyming task: During a rhyming task (lower images) that engages inner speech almost exclusively without taxing phonological memory, the inferior frontal and superior temporal cortex are activated in normal subjects, but only the inferior frontal cortex is activated in dyslexic subjects. Thus, dyslexic patients are able to activate each component of the verbal working memory system separately, but, unlike normal subjects, integrated activity between the precentral and postcentral structures appears defective. (Courtesy of R. Frackowiak.)

disrupted the transfer of visually related signals from both the left and right visual cortices to language areas in the left hemisphere. The postmortem examination also revealed some damage to the splenium, the posterior portion of the corpus callosum that interconnects left and right visual association cortices. This lesion is no longer believed to be involved in pure alexia, however. When the splenium is cut for surgical reasons without damaging visual cortices, the patient can read words normally in the right visual field but not those in the left.

PET studies have shown that reading words and word-like shapes selectively activates extrastriate left cortical areas anterior to the visual cortex. This suggests that the processing of word shapes, like other complex visual qualities, requires that general region.

Developmental Dyslexia Is a Difficulty in Learning to Read

A more prevalent form of reading disorder is seen in children who have difficulty in learning to read and spell despite normal eyesight and hearing, adequate educational and normal IQ. This syndrome, called developmental dyslexia, has been estimated to affect between 10 and 20% of the population. As mentioned earlier, reading is a complex and historically recent skill, and it is unlikely that
there is a well-defined system in the brain dedicated to it. Many disorders of visual and language processing could disrupt reading, and dyslexia is probably a condition with several possible causes rather than a single syndrome.

Most children with dyslexia have not developed phonological awareness: the ability to attend to individual sounds, particularly phonemes, in the continuous speech wave and to associate them with letters. However, they understand other communicative symbols—such as traffic signs or words—that have a unique visual appearance, such as the Coca Cola trademark. Indeed, studies in the United States have shown that some dyslexic children can learn to read English when entire words are represented by single characters rather than a sequence of characters.

Defects in visual processing can also lead to developmental dyslexia. Similarities between dyslexia and alexia caused by stroke suggest that developmental dyslexia might sometimes result from abnormalities in connections between visual and language areas.

Some dyslexic children also exhibit a tendency to read words backward (e.g., confusing saw and was) and have difficulty distinguishing letters that are mirror images of each other—such as b and d—both in reading and writing. These errors, together with the disproportionately number of left-handers among dyslexics, suggest that dyslexia might involve a deficit in the development of hemispheric specialization. In fact, in dyslexic males, unlike in normal males, the left planum temporale is not much larger than the right one, and it shows cytoarchitectonic abnormalities, including an incomplete segregation of cell layers and clusters of inappropriately connected neurons. Thus the migration of neurons to the left temporal cortex during development may have been slowed in some dyslexic patients.

Another possible problem in dyslexia is an inability to process transient sensory input quickly. The normally rapid conduction in the magnocellular pathway of the visual system (Chapter 27) is below average in people with dyslexia, whereas conduction in the parvocellular pathway is normal. In particular, dyslexic patients have difficulty processing fast, high-contrast, visual stimuli. A plausible anatomical correlate of this disorder is seen in some dyslexic patients examined at autopsy: the cells in the magnocellular layers of the lateral geniculate nucleus are abnormally small compared to parvocellular layers and compared to magnocellular layers in control subjects. A similar defect is sometimes evident in the fast-conducting component of the auditory pathways (Chapter 30).

In addition to these processing impairments, patients who have developmental difficulties with reading can have other neuropsychological deficits (Figure 59–6). Such linkages must be considered tentative, however, until there is finer delineation of the disorders currently lumped together as dyslexia.

**An Overall View**

The study of language processing in the brain has come a long way in a century, but the challenges to understanding it are formidable. Great progress has been made since Broca’s and Wernicke’s seminal discoveries, and that progress has brought a more complete understanding of linguistic processes and an appreciation of the complex ways in which they interconnect with systems for perception, motor control, conceptual knowledge, and attention.

Several developments offer the hope of even greater progress in the near future. Improvements in anatomical imaging will allow more precise and consistent delineation of lesions that affect specific features of language ability, and greater involvement by linguists and experimental psychologists will allow more precise and consistent delineation of the deficits in functioning.

Measurement of brain activity in normal subjects, using PET, functional MRI, and magnetoencephalography (MEG), will become more important in the next few years as the spatial and temporal resolution of these techniques improves and the most sophisticated experimental paradigms and linguistic analyses are systematically applied. Neurosurgical candidates, whose brain functions must be mapped by stimulation during surgery or recording from implanted electrode grids that remain in the skull during everyday activities, will be an important source of fine-grained information, especially if the language tasks administered to them are carefully constructed to isolate functions.

Progress in the understanding of language is important for the advancement of fundamental neuroscience and indispensable for the treatment of patients with aphasia, which is by far the most frequent impairment of higher function caused by stroke and head injury. The astonishing feat of language is too complex to be understood with the tools of any single academic or medical specialty, but as several disciplines come together to study the underlying neural processes, we can expect significant breakthroughs.
Selected Readings


References


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