So much the worse for the other aphasias, which have received considerably less attention from neurolinguists.

Aphasia in ASL

In one of the most spectacular findings of the last ten years, it has turned out that precise analogues of Broca's and Wernicke's aphasias occur in brain-damaged speakers of ASL—and parallel brain areas are affected! An ASL Broca's aphasic signs slowly and leaves out all the grammatical inflections of location and style of movement; an ASL Wernicke's aphasic signs fluently but confusingly, and shows obvious comprehension problems. Not only that: sign language aphasics can produce and comprehend pantomime despite their language deficits, and they're fine at using their hands for purposes other than language.

And not only *that*. There exist *right*-hemisphere deficits that impair one's understanding of space, typically producing a so-called *left neglect*. People with these deficits fail to see things in the left half of their visual field, fail to draw the left-hand side of pictures, and fail to dress the left-hand side of their bodies. But if they happen to be ASL speakers, they still use the left side of the space in front of them *just for the purpose of signing ASL syntax*. Another kind of right-hemisphere damage can lead to loss of the ability to produce facial expressions. But despite such damage, ASL speakers can produce the aspects of facial expression that are relevant to ASL grammar, using the very same muscles.

In each of these cases, the differential character of the deficit shows that it is not a case of motor paralysis: the muscles can still be activated. What is damaged is the part of the brain that organizes the use of the muscles into coherent actions. And it turns out that the part of the brain organizing *ASL* action is not the same as the part that organizes ordinary action.

You can see why these results are so exciting. They confirm just about all the main points we made about sign language on the basis of the functionalist approach, but now adding evidence in terms of brain damage.

1. ASL is a language, not a collection of pantomimes and facial expressions. And it is localized in the language areas of the brain, in a different place from pantomimes and facial expressions.

2. The use of space in ASL is grammatical, not just a collection of pointing gestures. And the use of space for pointing at things out in the world is localized in a different place in the brain from the grammatical use of space for ASL.
3. The grammar of ASL is, with only a few exceptions, entirely parallel to the grammar for spoken languages. And brain damage to English and ASL speakers produces parallel deficits.
4. The fact that signed and spoken grammars have similar organization shows that mental grammar is abstract—it does not have directly to do with auditory and vocal tract function. The existence of sign language aphasias shows vividly that Wernicke was wrong about the function of the language areas—they have to do with abstract *linguistic* function, not especially with the auditory–vocal channel.

All the research on aphasia, both spoken and signed, is remarkable—I can't stress enough how hard it is to work with brain-damaged subjects and to obtain reliable experimental results. Yet this research suffers from some of the same limitations as the rest of neuroscience: even if we can identify a particular deficit in function as due to damage in a particular brain area, this doesn't tell us how that brain area works. We don't know how the neurons are wired up to do what they do. Ultimately, that's what we have to understand in order to explain how language (or anything else) works in the brain.

Brain variation and plasticity

What I've said so far about the brain localization of language applies most reliably to right-handed adults who have no left-handers in their families. With other groups—children, left-handers, and right-handers with left-handed relatives—the probable severity of aphasia from damage to the "language" areas in the left hemisphere is lower, and the probable recovery from such aphasias is better.*

What's the difference? There are three possibilities: In children, etc., either (1) language is encoded more diffusely in the left hemisphere; or (2) language is encoded to some degree in the right

* Some researchers also include women among the "exceptions" to the generalizations about brain localization of language; but the evidence is less conclusive.

hemisphere as well as the left; or (3) some combination of these two. Which of these is correct, and what are the consequences for our main question of nature vs. nurture in the language capacity?

As a baseline, it is hard to believe that right-handers without left-handed relatives experience anything different in the environment from left-handers or from right-handers with left-handed relatives—at least, anything that is relevant to a difference in brain localization of language. So there is evidently some genetic input involved in these differences.

In addition, even newborns (for the most part) exhibit an asymmetry in raw size between the two hemispheres, with noticeable enlargement of the language areas on the left side. This might lead us at first to guess that hemispheric size alone is responsible for language being situated on the left. However, these asymmetries have turned up in apes as well, so they probably don't have to do entirely with language—the localization of language on the left seems to follow from more general considerations.

How much language is found in the right hemisphere? One of the best tests has been the patients mentioned earlier whose corpus callosum has been severed, so that the hemispheres cannot communicate. As a result, any task to be performed with the left hand has to be understood by the right hemisphere alone, and any verbal response based on what the left visual field has seen has to be produced by the right hemisphere alone. The linguistic capacity of the right hemisphere has turned out to be quite variable. Some of these people show virtually no verbal responsiveness in the right hemisphere, some can understand but not produce language, and some can even speak or write a few words. But at best they show hardly any capability for understanding grammatical structure, suggesting again that the left hemisphere is the seat of the language specialization.

Ah, well (says my imaginary critic), *but what about children? Don't they recover from aphasia better than adults? Doesn't this show that the brain is more adaptable than you say?*

It does show that the brains of children, who are still within the critical period, are more adaptable—but it certainly isn't *nurture* that makes them more adaptable. Rather, the loss of brain plasticity as children grow up seems to be part of the biological pattern of brain development, a factor of *nature*. Moreover, the way brain-damaged children recover is not dictated by the way they are treated. The best we can do for them is give them an environment that is rich and motivating enough to stimulate nature to take its own course. That is, proper treatment may result in better recovery, but the method of treatment doesn't itself determine which areas of the brain compensate for the damage; that too is a factor of nature.

> *But what about those children who, for some reason, have had their whole left hemisphere surgically removed? They still learn to talk.*

Children missing a left hemisphere develop language that may seem fine to a naíve observer, but under more probing examination they turn out to show some odd little deficits—for instance, an inability to do rhymes and some difficulty with tests like the ones that Broca's aphasics have trouble with (such as examples given earlier in this chapter). So the right hemisphere can take over language pretty well, but not entirely.

The hypothesis that most appeals to me at the moment is that the brain, like most of the body, is genetically coded to be essentially symmetrical, even in the language areas. However, this is overlaid genetically with relatively small asymmetries here and there between the hemispheres, which make each hemisphere slightly better than the other at performing certain tasks. In particular, the left hemisphere has a small advantage for language. In a normal brain, this advantage comes to be magnified to a full-blown asymmetry, either just because the left hemisphere learns more language, or even possibly because it actively inhibits language learning in the other hemisphere.

What happens to the right-hemisphere "language area" then? It doesn't atrophy. Rather, adjacent areas use it as extra workspace for their own specialized functions. Strikingly, just this sort of cooptation appears to take place in the congenitally deaf, who prove to have greater than normal sensitivity to certain kinds of visual inputs, especially the detection of motion in peripheral vision. It has been suggested that, in these people, the areas normally devoted to auditory processing, lacking normal input, come to be taken over by the visual system; the larger number of neurons they use for visual processing accounts for their greater sensitivity.*

In a child who is missing the left hemisphere, though, the right hemisphere's language area is not inhibited by the left, and it is the only part of the brain available to process language. As a result, it develops to its full potential as a language device, instead of being coopted for other purposes at which the right hemisphere excels. Under these conditions, it does pretty well, but not *quite* as well as the left

* These suggestions have been confirmed by animal experimentation, where it is possible to insert electrodes in the brain to investigate the sensitivities of different brain areas. In animals deprived of auditory stimuli from birth, visual inputs do indeed give rise to neural firing in the normal auditory regions of the brain.

hemisphere. For a less extreme case, left-handers perhaps have less inherent asymmetry between the hemispheres, so less inhibition of right-hemisphere language function takes place.

Of course, all this talk about hemispheres is much too crude. Language isn't spread all over the left hemisphere, it's centered in particular places. I'm going through this material anyway, because it's representative of the level at which the relation of language and the brain is often discussed. Unfortunately, it doesn't help us much with the deeper problem of exactly how the brain accomplishes language perception and production, and how mental grammar is encoded in the neurons.

Still, even at this level, we come up with a story about the brain altogether compatible with the results from the organization of adult language and from the study of language acquisition. There are brain specializations for language, especially for grammatical structure. Of course, it takes the right kind of environment for these specializations to develop properly. But consider that language develops in *this* part of the brain and not *that* one (even in signed instead of spoken language!), and that language learners extract just the right kind of stuff from the environment to construct a mental grammar. These facts strongly indicate that the role of the environment is essentially to nourish the natural development of a complex "mental organ" that is part of our genetic heritage.