How the Brain Evolved Language

Donald Loritz

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This book is dedicated to my family
and
to the memory of
Walter A. Cook, S.J.

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In the late 1970s and 1980s, there was little appreciation of neural networks. During these years I must thank in particular Jan Robbins, Walter Cook, and Sam Sara for supporting me on little more than simple faith. By the late 1980s, however, neural networks had become more widely respected, and with the help of Bernard Comrie, Charles Ferguson, Winfred Lehmann, and Betty Wallace Robinett, and the support of my colleagues, I succeeded in securing tenure and setting aside some time to think heretically about how language could possibly work without a computational homunculus.

For such sense as the following pages might make, I am indebted also to Allen Alderman, Kathy Broussard, Craig Chaudron, Dick Chen, Brad Cupp, Lisa Harper, Beatriz Juacaba, Jee Eun Kim, Elena Koutsomitopoulou, Bernard Kripkee, Mark Lewellen, Lise Menn, Afsar Parhizgar, Lisette Ramirez, Bill Rose, and Elaine Shea for their insights and support. I fear I have not yet achieved the rigorous standards my teachers have set, but the time has come to collect my attempts at explaining language so that better minds might bring them to fruition.

December 1998 D. L.

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CONTENTS

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• ONE •

Lought and Thanguage

A baby wildebeest, born on the Serengeti, learns to walk and run in a matter of minutes. The precocious wildebeest is marvelously adapted. But once a wildebeest can outrun a lion, its adaptation is largely done. Humans must adapt, too, but they must continue to adapt, first to mother, then to brother, then to teacher, then to work, then to him, then to her, then to babies, and so it goes. The world to which humans must adapt is a world of words: his word, her word, my word, your word, word of mouth, word of honor, word of scripture, word of law, the adaptive word.

A baby wildebeest, born on the Serengeti, learns to walk and run in a matter of minutes, but it takes two full years before a baby human makes a word, learns to talk. And it is another ten years before the human child learns to talk back. Even then, it is an immature criterion that would claim the teenager has mastered language. Human beings' fascination with language persists as long as their fascination with life. How does a baby learn language? How does one talk to a teenager—or, for that matter, to a parent? What do words mean? Or, since *I* know what *I* mean, what do *your* words mean? And what do *you* think *my* words mean? Does she think I'm a nerd? Does he think I'm a bimbo? Will my boss think I'm disloyal if I don't say *yes*? How can I adapt?

Where Is Language?

One doesn't have to be a philosopher to ask such questions, and in fact, it may be better if one is not. The celebrated learned men of history never concerned themselves much about the learning of language. (After all, teaching children language is women's work!) Thus absolved of responsibility for explaining language in its most human terms, the wise men of history were freed to conflate and confuse thought and language as they pleased.

This is not to deny that down through the ages many amusing books have been written on the topic of language. For example, in 1962 the philosopher J. L. Austin published a book exploring the question *Is the King of France bald?* (Since there is no longer a King of France, Austin concluded the question is neither true nor false, but simply *void.*) By and large however, previous philosophers of thought and language have simply been ignorant of one important modern fact: *thought happens in the brain!*

Aristotle, to pick one particularly influential example, thought that the main function of the brain was to cool the blood.[1] In hindsight, the ancients' ignorance of the brain and its function was quite understandable. Locked up in its bony carapace, the brain, which resisted exposure to the warrior's sword, resisted as well the anatomist's scalpel. And even when the ancients noticed there was a brain beneath all that bone, they couldn't see it *do* anything. It didn't beat or breathe or bend. What ancient could have imagined that the brain created ideas with the same electrical forces as Zeus's thunderbolts? Real knowledge, Aristotle thought, was lodged in the *heart,* and even today, when we know something well, we say we "know it by heart." So we can understand as well the ancients' belief that knowledge was mysteriously dissolved in the blood.

Finally, 2,000 years after Aristotle, Harvey showed that the heart pumped blood through the body, circulating nourishment to the organs of the body. Knowledge had to be somewhere else. But the microscope had not yet been invented, and when the seventeenth-century eye looked at the brain, the first feature it noted was that the brain, like the heart, had several connected, fluid-filled chambers, called *ventricles.* (In Figure 1.1, a *horizontal section* of the brain exposes the main, lateral ventricles.) To seventeenth-century philosophers, the meaning was obvious: the brain was just another pump. Following Galen and Harvey, Descartes thought it pumped an animating fluid (*animus*) through the nerves, thereby causing muscles to move. He specifically thought that the pineal gland at the base of the ventricles was a kind of master valve, which controlled hydraulic pressure in the system. To Descartes, this brain-pump was just so much more plumbing. Hydraulically moving the muscles was important, but it was just machinery; it could have nothing very much to do with thought. For Descartes, thought happened somewhere else. Thought happened in the *mind,* not in the brain.

But where was the mind? For Descartes, language, mind, and thought were all essentially the same thing. Descartes would have asserted that it makes no more sense to ask *Where is the mind?* than it does to ask *Where is language?* or *Where is algebra?* Such questions, to use Austin's term, were simply void. Language, thought, and mind were abstract sets of formal relations. They could relate things in places to other things in other places, but they were not themselves in some place. For Descartes, thought and language, mind and meaning, algebra and geometry, were all essentially the same sort of thing, which is to say they weren't really *things* at all.

In the seventeenth century this dualism of mechanics and mind, of things-in-the-world and things-not-in-the-world, had a confirming parallel in the Church's natural-supernatural dualism of life and afterlife. In a sense, Descartes

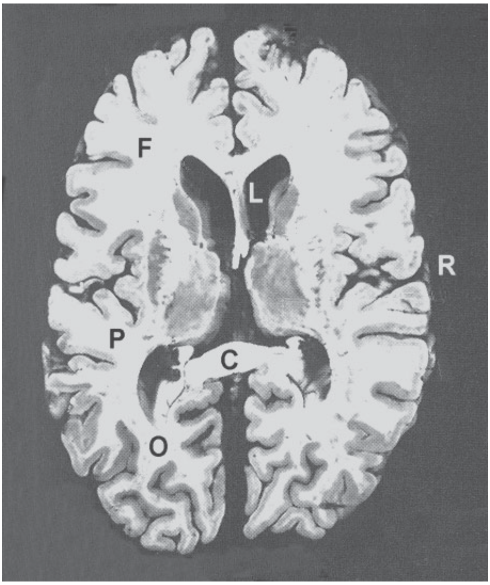

Figure 1.1. Horizontal section of the cerebrum. The (lateral) ventricles are exposed. Occipital lobe (O), parietal lobe (P), frontal lobe (F), lateral ventricle (L), corpus callosum (C), fissure of Rolando (R). (Kirkwood 1995, 15. Reprinted by permission of Churchill Livingstone.)

extended the conception of the supernatural to include not only angels but also algebra, algorithms, and language. These otherworldly entities had a truth that, to Descartes, was obviously true, a priori, before and independent of any empirical experience. One could only find this truth by doubting empirical, in-the-world experience and by believing in a priori, not-in-the-world truths, truths like the existence of God.

But how could you or I, mere mortals both, know in the mind that even we ourselves exist, let alone so sublime a being as God? Was there a less presumptuous a priori truth from which we could deduce these larger Truths? Perhaps the most famous "rationalist" deduction of this sort was Descartes's proof of his own existence:

cogito ergo sum (1.1)

think-I therefore exist-I

"I think therefore I am."

Unfortunately, as Nietzsche later observed, Descartes's "proof" turns out to be uselessly circular: in Latin, the *-o* on *cogito* and the form *sum* itself both indicate first-person *I*. Consequently, as the literal gloss of 1.1 emphasizes, the premise *I think* presupposes the conclusion *I am*. To illustrate this point, consider 1.2 and 1.3 (here and elsewhere a * means "something seems wrong with this sentence"):

*You think therefore I am. (1.2)

or

*Thought exists therefore I am. (1.3)

Without its presuppositions, Descartes's proof fails utterly. In Descartes's defense, we should perhaps consider the context of his times. The Reformation had put reason at odds with God, and Descartes had a larger agenda than to vainly prove his own existence. But the proof is still false. Even a genius cannot deduce truth from faulty premises.

Tabula Rasa

Well before Nietzsche, many philosophers objected to Descartes's dualistic method. Descartes's contemporary Francis Bacon strenuously objected to Descartes's introspective method. Francis Bacon (and, coincidentally, 400 years earlier, Roger Bacon) espoused a rather distinctively English empiricism. Unlike Descartes's dualism, this empiricism was a triadism that divided the universe into Soul, Mind, and Matter. Leaving the supernatural aspects of Soul to God, empiricism proceeded to focus on the material aspects of Matter. But neither Bacon was a rigorous scientist by modern standards. (In what was apparently his first and only scientific experiment, Francis Bacon stuffed a chicken with snow to see if the snow would inhibit decay. The only reported result was that Bacon caught cold and died.) The relationship of Mind to Soul and Matter was little advanced by their methods. It wasn't until a hundred years after Descartes that empiricism found a clear voice in the philosophy of John Locke. For Locke, Mind was just a blank slate, an erased tablet of Matter, a tabula rasa. Experience wrote upon the tablet, thus creating Mind. Of course rationalists objected that this explained no more than *cogito ergo sum.* If, as the empiricists would have it, there was such a tablet, then where was it? Where was Mind? And if this tablet were writ upon in language, then where was language? Void questions all! So rationalism survived until 1849, when Claude Minié invented the conical bullet.

Before 1849, bullets were musket balls. Musket balls had a frustrating habit of curving unpredictably in flight, so prior to 1849, opposing armies would line themselves up, shoulder to shoulder, in order to give the opposing team a reasonable chance. Even then, when a musket ball did happen to score, it tended to shatter the skull, causing massive damage to the brain beneath. Minié's conical bullet, on the other hand, flew true. Even better, it was frequently able to create a surgically clean hole in the skull and a nice, focused wound (a *focal lesion*) in the underlying brain tissue.

As a result of this technological advance, a young doctor in France, Pierre Paul Broca, obtained a sizable cohort of war casualties whose brain lesions disturbed their ability to speak but otherwise left the patients' minds and behaviors remarkably intact. In 1861, Broca presented the discovery that such *aphasia* occurred almost exclusively when injury was sustained to a relatively limited area of the left half of the brain. Several years later a Viennese doctor, Karl Wernicke, discovered that injuries to another region on the left side of the brain caused a second kind of aphasia. Whereas "Broca's aphasics" had difficulty speaking but relatively little difficulty comprehending language, "Wernicke's aphasics" had no difficulty speaking but great difficulty comprehending. *Where is language?* had seemed a void question, but suddenly—and quite unexpectedly—it had an answer.

Where Language Is

Language was in the brain! This finding, utterly implausible to the ancients, was supported by copious and irrefutable evidence: spoken output was generated in Broca's area, and heard input was processed in Wernicke's area. The scientific community instantly and earnestly undertook the study of the brain.

It was no longer the seventeenth century. Leeuwenhoek had long since invented the microscope, and within a generation of Broca, scientists had trained it on the brain. In 1873, Camillo Golgi discovered that chromium-silver salts would selectively stain brain cells, thus making them clearly visible under the microscope. Using Golgi's staining method, Santiago Ramón y Cajal charted the microstructure of the brain in encyclopedic detail, and by the dawn of the twentieth century, it had become an established scientific fact that mind was brain. And since brain was made up of white matter and gray matter, mind was matter. Rationalism was dead.

For their discovery of the brain's previously invisible structure, Golgi and Ramón y Cajal were awarded the 1906 Nobel Prize.[2] Their work also engaged them in a famous debate. Ramón y Cajal believed each cell was a separate cell, wholly bounded by its cell membrane and unconnected to its neighbors, but his microscopes weren't powerful enough to prove it. On the other hand, Galvani had long before shown that electricity made a dissected frog's leg twitch. It could therefore be readily inferred that there was electrical communication among nerve cells. But how could electrical impulses be transmitted if the wires weren't connected? Golgi maintained that the myriad cells of the nervous system must form a continuous network.

In the early 1900s many more researchers joined in this debate. Using ever-more-powerful microscopes, they took ever-closer looks at nerve cells. In the end, Sherrington, Adrian, Dale, Loewi, and others proved that Ramón y Cajal was right, earning in the process Nobel Prizes for their efforts. Neurons were discrete cells separated by a synaptic gap. This gap was small, but it was big enough to electrically insulate each cell from the next. So how did neurons pass their messages across the synapse? They passed their electric messages using chemicals, called *neurotransmitters.* Doubt of the world and belief in truth were now clearly behaviors of the brain:

> Thus, both doubt and belief have positive effects upon us, though very different ones. Belief does not make us act at once, but puts us into such a condition that we shall behave in a certain way, when the occasion arises. Doubt has not the least effect of this sort, but stimulates us to action until it is destroyed. This reminds us of the irritation of a nerve and the reflex action produced thereby; while for the analogue of belief, in the nervous system, we must look to what are called nervous associations—for example, to that habit of the nerves in consequence of which the smell of a peach will make the mouth water. (Peirce 1877:9)

Never Mind the Mind

But Peirce was ahead of his time. Twenty years later, in America, Peirce's "pragmatic" perspective developed into behaviorism. Behaviorism came in many flavors, but one lineage descended from Peirce to Dewey to Thorndike to Watson to Lashley. In the formulation of John B. Watson, behavior could be observed and scientifically reduced to a series of *stimulus-response* events, "habits of the nerves," occurring along a chain of neurons. Mind was just an unobservable and useless abstraction. All of creation, from the lowliest animal to the highest form of social organization (then widely believed to be either the assembly line or the Prussian army), could be pragmatically analyzed solely in terms of stimulus-response chains of command. Behaviorism, in the social form of totalitarianism, promised a well-regulated society in which every animal want could be provided by eliciting strict, learned, obedient responses to the stimuli of an all-powerful, all-loving dictator.

Predictably, this utopian vision was especially popular among the ruling and managerial classes, who had never worked on an assembly line or directly experienced the new, improved, conical bullet. Many, following Herbert Spencer (1862) and later "social Darwinists," envisioned themselves to be "supermen," a new species which had evolved through natural selection to a point "beyond good and evil" (Nietzsche 1883). However, after World War II and the likes of Hitler and Stalin, this utopian vision began to lose some of its appeal, even among the controlling classes. In his 1948 utopian novel *Walden Two,* the celebrated Harvard behaviorist B. F. Skinner attempted to dissociate behaviorism from these infamous European practitioners. As Skinner spun the story, everyone—more or less regardless of race, creed, color, or, for that matter, genetics—could be educated to perfection through the application of "programmed learning." In programmed learning, students were methodically rewarded for correct answers and punished for incorrect answers. In this way, it was believed that good habits would be efficiently "learned" and bad habits would be efficiently "extinguished."

In the United States, however, there was a new class of university students: World War II veterans whose college tuition was paid as a war benefit. These students and vocal, war-hero labor union leaders let it be known that they did not consider *any* chain of command to be utopian. Whether on the front line, the assembly line, or the school registration line, they did not want to be programmed! By the mid-1950s, opposition to Skinner had become widespread, but it was inchoate. Behaviorism had been politically refuted by the European experiment with totalitarianism, but Skinner's scientific authority as a Harvard professor was still unassailable, and there were no viable alternatives to his psychological theories.

In 1957, amid mounting popular disdain for behaviorism, Skinner published a scholarly book, *Verbal Behavior*. In it, he sought to show that behaviorism had developed far enough beyond the study of lab rat behavior to undertake the explanation of human language. In 1959, two years after the publication of *Verbal Behavior*, Noam Chomsky, a young linguist at the Massachusetts Institute of Technology, published a disdainful review of it in the journal *Language*. Not only did Chomsky find Skinner's analyses of language naïve, but he found them to be proof of the vacuity of behaviorism in general.

Skinner didn't reply directly to Chomsky's review, but he did write another book, *Beyond Freedom and Dignity*, to which Chomsky also gave a bad review. These reviews of Skinner and behaviorism made Chomsky an instant, popular champion of freedom and dignity, opening a new chapter in the confusion of thought and language.

Finite Mind, Infinite Language

Reaching back to rationalism for support, the thrust of Chomsky's argument was that language was not a "thing" like a stimulus or a response, a punishment or a reward. Language was a unique—and uniquely human—module of mind. Thus, twentieth-century *generative grammar* became grafted onto a Cartesian dualism. The resulting generative philosophy has depended heavily on what I call the "generative deduction," the basic form of which may be given as follows:

(1a) The human brain is finite, but
(1b) an infinity of sentences exists,
(1c) which can be generated by rule,

proving language is infinite. Nevertheless,

(2a) normal human children acquire language quickly and effortlessly,
(2b) even though no one teaches language to young children,
(2c) and only human children so acquire language.

Therefore,

(3) language is innate. It is not so much learned as it is "acquired."

The premises of the generative deduction have come under attack from many quarters, but it has not yet been refuted. Consider, for example, Jackendoff's 1994 witty defense of premise 1. First, Jackendoff opens the dictionary at random and generates a large number of sentences by a simple rule:

> A numeral is not a numbskull.
> A numbskull is not a nun.
> A nun is not a nunnery.
>
> . . .
>
> These are all completely absurd, but they are sentences of English nevertheless. There will be something like $10^4 \times 10^4$ of them = 10^8. Now let's put pairs of these sentences together with *since*, like this:
>
> . . .
>
> Since a numeral is not a numbskull, a numbskull is not a nun.
>
> . . .
>
> Since a numeral is not a numbskull, a numbskull is not a nunnery.
>
> . . .
>
> And so on it goes, giving us $10^8 \times 10^8 = 10^{16}$ absolutely ridiculous sentences. Given that there are on the order of ten billion (10^{10}) neurons in the entire human brain, this divides out to 10^6 sentences per neuron. Thus it would be impossible for us to store them all in our brains. (Jackendoff, 1994:21)

Although 10^{16} does not quite qualify as mathematical infinity, it certainly seems infinite for human purposes. This infinity of language was at the nub of Chomsky's arguments against Skinner in 1959, and premise 1 of the generative deduction has stood unrefuted and irrefutable until the present day.

For the past forty years, a variety of biologists, psychologists, teachers, and child-language researchers have contested premise 2, arguing that children *are taught* language and do in fact *learn* in the process. But premise 1 forms the basis for a strong logical defense of premise 2. Chomsky has introduced that defense with a different quotation from Peirce:

> You cannot seriously think that every little chicken that is hatched has to rummage through all possible theories until it lights upon the good idea of picking up something and eating it. On the contrary, you think that the chicken has an innate idea of doing this; that is to say, that it can think of this, but has no faculty of thinking anything else. . . . But if you are going to think every poor chicken endowed with an innate tendency towards a positive truth, why should you think to man alone this gift is denied? (Peirce, quoted in Chomsky 1972, 92)

Peirce called the ability to come up with new theories *abduction,* a logico-cognitive process which he believed was more important than either of the logical processes of induction or deduction. Chomsky asked essentially the same question of children and language: one cannot seriously think every little child that is born has to rummage through all possible grammatical theories until it lights upon the one right way of making words into sentences. Language could not be learned unless every child was endowed with an innate tendency toward a correct, universal grammar.

Following Chomsky's suggestions, researchers undertook a series of mathematical analyses, collectively referred to as "learnability theory," to investigate the conditions under which language could be learnable (Gold 1965, 1967; Hamburger and Wexler 1975; Wexler and Culicover 1980; see Pinker 1984, 1989, for approachable reviews). The gist of their argument was the following. If you say *potayto* and I say *potahto,* how is a child to learn which one to say? This argument becomes more convincing as one considers, not just the 5,000 or 10,000 words that a child might memorize, but also the fact that the child knows how to transform these words à la Jackendoff into an infinite number of sentences (premise 1 again). Chomsky's seminal example was the "passive transformation," as of 1.4 into 1.5:

John saw her. (1.4)

She was seen by John. (1.5)

Instead of 1.5, why doesn't a child ever say 1.6*,

*Saw by John was she. (1.6)

or any of the other 118+ possible permutations of 1.5? "Because the child never hears those other 118+ permutations," you may say. But the child has likely never heard the exact permutation which is 1.5, either. Nevertheless, every child has learned to produce passive sentences like 1.5 by the age of six or so (premise 2a).

"Well, the child doesn't memorize rote sentences," you reply. "He remembers patterns." But exactly how *does* he remember patterns? No one in his right mind sits down and teaches a child of four that "to transform an active sentence pattern into a passive sentence pattern, one positionally exchanges the subject and direct object, prefaces the subject with the word *by*, appropriately changes the grammatical case of the moved subject and direct object, precedes the main verb with the tensed auxiliary of *be*, agreeing in number and person with the new subject, and replaces the main verb by its past participle."

You might instead argue that the child learns language patterns by *imitating* adult speech, and this was in fact the explanation proposed by behaviorists. Unfortunately, child-language researchers quickly found that children don't imitate adult speech. Consider the following, oft-quoted transcript from McNeill 1966:

Child Nobody don't like me.
Mother No, say "Nobody likes me."
Child Nobody don't like me.
Mother No, say "Nobody likes me."

Child	Nobody don't like me.
Mother	No, say "Nobody likes me."
Child	Nobody don't like me.
Mother	No, say "Nobody likes me."
Child	Nobody don't like me.
Mother	No, say "Nobody likes me."
Child	Nobody don't like me.
Mother	No, say "Nobody likes me."
Child	Nobody don't like me.
Mother	No, say "Nobody likes me."
Child	Nobody don't like me.
Mother	Now listen carefully. Say "Nobody likes me."
Child	Oh, nobody don't likes me.

To maintain that language is "learned," it appears one needs a better theory of learning than imitation.

Although generative philosophy has demonstrated the failure of behaviorism to most observers, it has not been without its critics. For example, the claim that language is rule-based (premise 1c) extends back to the foundations of modern linguistics in the eighteenth century, but for forty years, nonlinguists have objected that language cannot be rule-governed, because *semantics*, the meaning system of language, is not rule-governed. After all, what rule could definitively tell you what I mean when I say *I love you*? But semantics has little to do with the generative deduction. Chomsky has argued that "such understanding as we have of [language] does not seem to be enhanced by invoking thoughts that we grasp, public pronunciations or meanings, common languages that we partially know, or a relation of reference between words and things" (1993, 25), and as Jackendoff's *A nun is not a nunnery* illustrates, sentences can be grammatical even if they are meaningless. That is, leaving meaning aside, how is one even to explain *syntax*, if not as acquired through the agency of an innate, rule-governed system?

Recently, many cognitive psychologists have attacked premise 1c by demonstrating that pattern-based neural networks can exhibit linguistic behaviors similar to that of rule-based systems (Rumelhart and McClelland 1986a). But to date these demonstrations have been more semantic than syntactic. Also, the fact that rulelike behavior can be elicited from an artificial neural network does not preclude the possibility that the brain functions at some other, more interesting level like a rule-based digital computer.

My discomfort with the generative deduction originated with premise 2a, that children learn language "effortlessly." To be sure, childhood in middle-class America in the latter half of the twentieth century has been mostly child's play, but even privileged children display the temper tantrums of the "terrible twos," and these are nothing so much as results of the child's frequently frustrated *efforts* at communication. Nor do mommies and au pairs find the terrible twos "effortless." Nevertheless, the claim that toddlers learn language effortlessly seems never to have been challenged directly, and I am unaware that generative philosophers have ever independently proposed an objective measure of child effort. The problem, no doubt, is that *effort* is an intrinsically subjective, "nonscientific" concept. Society devalues child labor because no one pays children a salary, and no one hears children complain—no one except mommies and au pairs, that is, but "scientific" society doesn't pay *them* salaries, either.

"Hard science" often tries to distance itself from such social issues, but when the object of scientific inquiry is language, it is hard to maintain distance. As a kind of compromise, sociolinguists (Ferguson and Slobin 1973) and "functionalists" (Bates and MacWhinney 1982; MacWhinney 1987a) have attacked premise 2b by redefining learning away from the narrow terms of behaviorism into more general terms of interaction in the social environment. We learn that the sky is blue, that birds fly, and that ice is slippery from the physical environment without a teacher, but no one claims *this* knowledge is innate. Sociolinguistic functionalism argues that we learn language from the social environment in much the same way. But how *do* we learn that birds fly and ice is slippery? Generative philosophers have justifiably objected that this sort of learning (*a*) is not itself well understood and so (*b*) barely begins to address deeper problems like how we understand the sentence *I don't think penguins can fly*.

Finally, biologists have often attacked premise 2c, the human uniqueness of language, citing dancing bees and signing apes as evidence of the evolution and learning of language in other species. Nevertheless, not even the proudest trainer invites his animals to cocktail parties. Whatever their language, animals' language is still a far cry from human language.

Although locally convincing, none of these attacks has proved generally fatal to the generative deduction, much less added up to a viable alternative theory of thought or language. Taken together, though, they indicate that something is amiss with the generative deduction. Forty years after first postulating that children have an innate "language acquisition device," generative philosophers have as yet been unable to find its place in human biology, and generative theory has found itself increasingly at odds with the rest of science and society. Chomsky himself has become defensive, asserting that "no one knows anything about the brain" (Chomsky 1988, 755), and asking,

> how can a system such as human language arise in the mind/brain, or for that matter, in the organic world, in which one seems not to find systems with anything like the basic properties of human language? That problem has sometimes been posed as a crisis for the cognitive sciences. The concerns are appropriate, but their locus is misplaced; they are a problem for biology and the brain sciences, which, as currently understood, do not provide any basis for what appear to be fairly well-established conclusions about language. (Chomsky 1994, 1)

The preceding is neither a crisis for biology nor a crisis for linguistics; it is a crisis for Science. The assertion that no one knows anything about the brain may have been defensible in 1936, when Turing initiated "the study of cognitive activity from an abstract point of view, divorced in principle from both biological and phenomenological foundations" (Pylyshyn 1979). It may also