Introduction

A BRIEF CHRONOLOGY

Chomsky has posed what we consider to be the central questions for the study of language and biology (*biolinguistics*[1]):[2]

(1) What constitutes knowledge of language?
(2) How is this knowledge acquired?
(3) How is this knowledge put to use?
(4) What are the relevant brain mechanisms?
(5) How does this knowledge evolve (in the species)?

Chomsky asks "how can we integrate answers to these questions within the existing natural sciences, perhaps by modifying them?" (Chomsky, 1991a:6). This more general question is part of what he has referred to as the *unification problem*, a topic to which we return below (Chomsky, 1994a:37,80).

The discussion of the questions (1)–(5) above within the tradition of generative grammar began in the early 1950s: "At least in a rudimentary form, these questions were beginning to be the topic of lively discussion in the early 1950s, primarily among a few graduate students. In Cambridge, I would mention particularly Eric Lenneberg and Morris Halle, and also Yehoshua Bar-Hillel" (Chomsky, 1991a:6).

The period between the mid-1950s and the present is sometimes referred to as the "cognitive revolution." However, Chomsky has observed that contemporary work might be more properly viewed as a "renewal" of the "classical concerns" of the seventeenth and eighteenth centuries (Chomsky, 1997a). This earlier period of the study of mind, which includes as a central element the Cartesian theory of body and

[1] Our usage of the term "biolinguistics" derives from a report on an interdisciplinary meeting on language and biology, attended by Salvador Luria and Noam Chomsky, among others, that was held in 1974 under the sponsorship of the Royaumont Center for a Science of Man (Piattelli-Palmarini, 1974). The earliest use of the term "biolinguistics" with which I am familiar is from Clarence L. Meader and John H. Muyskens, *Handbook of Biolinguistics,* (1950, Toledo: H. C. Weller). It is also used by John Locke in more recent work (Locke, 1993). [2] See, for example, Chomsky and Lasnik, 1993.

mind, might then be called the "first cognitive revolution" (Chomsky, 1994a:35). There are, in addition, many antecedents to modern-day studies of language and mind, both before and after this period. To reflect this fact, Chomsky often refers to the first question – what constitutes knowledge of language? – as *Humboldt's problem*, to the second question – how is knowledge of language acquired? – as a special case of *Plato's problem*, and to the third question – how is knowledge of language put to use? – as *Descartes' problem*, to highlight the fact that the modern study of these problems has a long and rich historical tradition.[3] In what follows we will be primarily focusing on a part of the "second cognitive revolution," the modern study of biolinguistics; i.e., on work going back to the early 1950s.

In the spring of 1955, the first version of *The Logical Structure of Linguistic Theory* was completed, duplicated, and circulated, although a version of the manuscript was not published until 20 years later (Chomsky, 1975a). In the introduction to that version, Chomsky notes:

> LSLT [*The Logical Structure of Linguistic Theory*] is an attempt to develop a theory of transformational generative grammar. The "realist interpretation" of linguistic theory is assumed throughout, and it is argued that the competence attained by the normal speaker-hearer is represented by a transformational generative grammar, which determines the representation of each sentence on the levels of phrase structure and transformational structure (*inter alia*). These representations are then employed in the use and understanding of language, and provide the basis for the more general theory of language that will be concerned with meaning and reference, the conditions of appropriate use of language, how sentences are understood, performance in concrete social situations, and in general, the exercise of linguistic competence in thought and communication. The principles of this theory specify the schematism brought to bear by the child in language acquisition. They define the linguistic universals that constitute "the essence of language" (as distinct from accidental properties or properties determined by the exigencies of language use), and thus can be taken as one fundamental element in the characterization of the innate "language faculty." (Chomsky, 1975a:45)

Thus the basis for the study of biolinguistics, specifically for questions (1) knowledge of language (= competence), (2) acquisition of language, and (3) use of language, are laid out in LSLT. And once we have asked questions (1)–(3), questions (4) brain mechanisms, and (5) evolution, are automatically implied; see the discussion below of Lenneberg's work

[3] Chomsky has extensively documented the historical antecedents to modern discussions of language and mind (e.g., in the works of Plato, Descartes, Hume, Humboldt, and many others in the rationalist, empiricist, and romantic traditions). For some of this discussion, see *Cartesian Linguistics* (Chomsky, 1966). Much of this work was largely forgotten or ignored in the fields of structural linguistics and psychological behaviorism, to the detriment of studies on language.

along those lines. It is observed that the general theory in LSLT is "to be understood as a psychological theory that attempts to characterize the innate human 'language faculty.'" Here and below "psychological theory" and "biological theory" can be used interchangeably. As Chomsky put it during an interview in 1968, linguistics "is really a theoretical biology, if you like, a theoretical psychology" (Sklar, 1968:217). However, this seminal work, which set the stage for future work in biolinguistics, was promptly turned down for publication and only parts of it were published; e.g., some of the material was integrated into the much better known *Syntactic Structures*:

> After the revisions described were completed, I submitted parts of the manuscript to the Technology Press of MIT for consideration for potential publication. It was rejected, with the not unreasonable observation that an unknown author taking a rather unconventional approach should submit articles based on this material to professional journals before planning to publish such a comprehensive and detailed manuscript as a book. This was no easy matter, however. The one article I had submitted on this material to a linguistics journal had been rejected, virtually by return mail. I had lectured on some of this material at several universities, but as far as I could determine, there was little interest in these topics among professional linguists. (Chomsky, 1975a:3)

In the interview "The Birth of Generative Grammar," Chomsky talks about his "close friend Eric Lenneberg, who at that time was beginning his extremely interesting studies in the biology of language, working along rather similar lines" (Chomsky, 1979:133). This work was to culminate with Lenneberg's *Biological Foundations of Language* (Lenneberg, 1967), to which Chomsky contributed a chapter entitled "The Formal Nature of Language." Lenneberg anticipated many themes of the coming decades: genetics of language acquisition, genetics of language disorders (dyslexia, specific language disabilities), language of deaf children, "wolf children," critical period, twin studies, family pedigrees, aphasia[4] and language, evolution of language, etc.

What Chomsky realized early on was that linguistics could now suggest core internal properties of the language faculty, that in turn posed important questions for biology. These properties were discussed in various settings, as, e.g., the language acquisition device (LAD) and universal grammar (UG). It has taken quite a while for it to sink in that the syntactic computations of the language faculty are the biological evidence.[5]

[4] Aphasia is the loss of language due to brain disease or injury.

[5] A residue of the older attitude towards linguistics has been expressed most recently by the psychologist Steven Pinker, who dismisses Chomsky's arguments as "abstruse formalisms" (Pinker, 1994a:24). Like the scientists of Mendel's time, Pinker fails to comprehend that abstract computations are evidence on a par with any other kind of biological evidence.

Mendel was misunderstood for similar reasons; as the biologist George Beadle and author Muriel Beadle note, "There was no evidence for Mendel's hypothesis other than his computations and his wildly unconventional application of algebra to botany made it difficult for his listeners to understand that these computations *were* the evidence" (Beadle and Beadle, 1979:68).

Although the basic ideas of biolinguistics found a great deal of resistance in the academic fields of linguistics, philosophy, and in some areas of the cognitive sciences, by the early 1970s the results concerning the biological nature of generative grammar had been easily assimilated and well received by many geneticists and molecular biologists, who offered a number of speculations on biology and language with specific reference to generative grammar. For example, Monod stated that, given reasonable biological assumptions, it is not at all surprising that "the linguistic capacity revealed in the course of the brain's epigenetic development is today part of 'human nature', itself defined within the genome in the radically different language of the genetic code" (Monod, 1974:129).

Monod's colleague, Jacob also found this idea plausible: "According to modern linguistics, there is a basic grammar common to all languages; this uniformity would reflect a framework imposed by heredity on the organization of the brain . . . Many traits of human nature must be inserted in the framework established by the twenty-three pairs of chromosomes that make up the common inheritance of man" (Jacob, 1976:322).

And in his discussion of "modern linguistic analysis," Luria wrote: "To the biologist it makes eminent sense to think that, as for language structures, so also for logical structures, there exist in the brain network some patterns of connections that are genetically determined and have been selected by evolution as effective instruments for dealing with the events of life" (Luria, 1973:141).

The immunologist Niels Jerne commented as follows in his Nobel Prize address:[6]

> It seems a miracle that young children easily learn the language of any environment into which they are born. The generative approach to grammar, pioneered by Chomsky, argues that this is only explicable if certain deep, universal features of this competence are innate characteristics of the human brain. Biologically speaking, this hypothesis of an inheritable capability to learn any language means that it must somehow be encoded in the DNA of our chromosomes. Should this hypothesis one day be verified, then linguistics would become a branch of biology. (Jerne, 1985:1059)

[6] See chapter 3 for a discussion of Jerne's ideas on selection and instruction.

Unification, whether in physics, linguistics, or any other science, has many cross-disciplinary connections. One such connection that Chomsky introduced into the linguistic discussion was work from the field of animal behavior or, as it was more commonly called in Europe, ethology. In a 1959 review of B. F. Skinner's *Verbal Behavior*, Chomsky introduces ideas and lines of arguments from genetics, (comparative) ethology, and biology in general, alongside a number of other kinds of arguments, in critiquing Skinner's "functional analysis" of verbal behavior, which was based on such behaviorist notions as stimulus, reinforcement, and deprivation (Chomsky, 1959).[7] Chomsky draws on the work of Lorenz, Tinbergen, Thorpe, Jaynes, and others. For example, he argues that learning, whether of bird song or human language, can be unrewarded; i.e., it need not proceed by means of "differential reinforcement":

> Imprinting is the most striking evidence for the innate disposition of the animal to learn in a certain direction and to react appropriately to patterns and objects of certain restricted types, often only long after the original learning has taken place. It is, consequently, unrewarded learning, though the resulting patterns of behavior may be refined through reinforcement. Acquisition of the typical songs of song birds is, in some cases, a type of imprinting. Thorpe reports studies that show "that some characteristics of the normal song have been learned in the earliest youth, before the bird itself is able to produce any kind of full song." (Chomsky, 1964:561–62)

Chomsky concludes that any learning theory must account for the fact that children acquire grammars with "remarkable rapidity" and "to a large extent independently of intelligence," suggesting that "human beings are somehow specially designed to do this, with data-handling or 'hypothesis-formulating' ability" (p. 577), noting that these abilities are rooted in man's biological nature:

> There is nothing essentially mysterious about this. Complex innate behavior patterns and innate "tendencies to learn in specific ways" have been carefully studied in lower organisms. Many psychologists have been inclined to believe that such biological structure will not have an important effect on acquisition of complex behavior in higher organisms, but I have not been able to find any serious justification for this attitude. (Chomsky, 1964:577, n. 48)

In the reprint of the review of Skinner, Chomsky annotates a footnote about Tinbergen and Schiller to drive home further the importance of biological analysis: "Lenneberg . . . presents a very interesting discussion of the part that biological structure may play in the acquisition of language, and the dangers in neglecting this possibility" (Chomsky, 1964:564).

[7] Citations are given from the version reprinted in 1964 (Chomsky, 1964).

As a further example, we can take Chomsky's discussion of the role of "primary linguistic data" in the process of language acquisition, where it can assume multiple roles; e.g., it can "determine to which of the possible languages . . . the language learner is being exposed" or it can simply "set the language-acquisition device into operation" (Chomsky, 1965:33). He remarks that "this distinction is quite familiar outside of the domain of language acquisition" in other areas of contemporary biology:

> For example, Richard Held has shown in numerous experiments that under certain circumstances reafferent stimulation (that is, stimulation resulting from voluntary activity) is a prerequisite to the development of a concept of visual space, although it may not determine the character of this concept . . . or, to take one of innumerable examples from studies of animal learning, it has been observed . . . that depth perception in lambs is considerably facilitated by mother–neonate contact, although again there is no reason to suppose that the nature of the lamb's "theory of visual space" depends on this contact. (Chomsky, 1965:33–34)

Chomsky has introduced a number of intriguing proposals and ideas bearing on the evolutionary basis of human language into the linguistic discussion throughout the years, often in connection with particular linguistic models. For example, in a presentation of the background assumptions underlying what was later called the "standard theory," Chomsky makes remarks about "principles of neural organization" and "physical law," which have been echoed in much of his later work (see chapter 5):

> However, there is surely no reason today for taking seriously a position that attributes a complex human achievement [language or other kinds of knowledge] entirely to months (or at most years) of experience, rather than to millions of years of evolution or to principles of neural organization that may be even more deeply grounded in physical law. (Chomsky, 1965:59)

At around the same time (1966), Chomsky noted the striking conceptual resemblance between the idea that universal grammatical principles determine "the class of possible languages" and Goethe's theory of Urform, as exemplified, e.g., by the Urpflanze:

> Thus, the Urform is a kind of generative principle that determines the class of physically possible organisms; and, in elaborating this notion, Goethe tried to formulate principles of coherence and unity which characterize this class and which can be identified as a constant and unvarying factor beneath all the superficial modifications determined by variation in environmental conditions. (Chomsky, 1966:24)

The idea of the Urpflanze has resurfaced in interesting ways in work in developmental biology. We will explore the idea there that similar kinds of generative principles may be involved in the mental domain; i.e., in the

development and evolution of human language. Thus the Urform idea ties in in interesting ways with other threads of Chomsky's ideas on evolution of language.

The question of "language design" has also been one of the central areas of interest in modern generative grammar. For example, in 1977, Chomsky and Lasnik proposed a (perceptual) filter to account for the contrast between the grammatical "That he left is surprising" and the ungrammatical "*He left is surprising" and concluded:

> The first question to ask is whether the filter (20) is a true universal (that is, a principle of UG), or whether it is specific to the language under analysis. Suppose that [filter] (20) belongs to UG. Then it need not be learned, just as universal phonetics need not be learned; it is part of the genetically-determined language faculty. The functional explanation then holds, if at all, at the level of evolution of the species. (Chomsky and Lasnik, 1977:436–37)

We will return to this question in chapter 5.

Chomsky noted that although one must abstract away from genetic variation in universal grammar in the initial stages of study, he also emphasized the potential relevance of studies of genetic variation of the language faculty; see chapter 4 for further discussion.

> At the same time, it would come as no surprise to discover that there is some genetic variation [of the language faculty], and if this could be discovered, it might lead to new and possibly revealing ways to study the intrinsic nature of the language faculty. It has occasionally been observed, for example, that unusually late onset of language use seems to run in families, and one might find other aspects of language use or structure that are subject to a degree of variability – a discovery that might be significant for therapy as well as for research into language. (Chomsky, 1978:312)[8]

Around 1978, Chomsky noted that the logic behind what later came to be known as the "principles-and-parameters" approach to language acquisition was "rather similar" to the problem of biological speciation, as discussed by the molecular biologist François Jacob. Jacob had written that

> it was not biochemical innovation that caused diversification of organisms . . . What accounts for the difference between a butterfly and a lion, a chicken and a fly, or a worm and a whale is not their chemical components, but varying distributions of these components . . . specialization and diversification called only for different utilization of the same structural information . . . It is thanks to complex regulatory circuits, which either unleash or restrain the various biochemical activities of the organism, that the genetic program is implemented. [In related organisms, mammals for example], the diversification and specialization . . . are the result of mutations which altered the organism's regulatory circuits more than its

[8] Slightly amended version reprinted in Otero, 1988:233–50.

chemical structures. The minor modification of redistributing the structures in time and space is enough to profoundly change the shape, performance, and behavior of the final product. (Jacob, 1978; cited from Chomsky, 1980c:67)

Chomsky noted that the principles-and-parameters model of language acquisition had some of the same properties: "In a system that is sufficiently intricate in structure, small changes at particular points can lead to substantial differences in outcome. In the case of growth of organs, mental organs in our case, small changes in parameters left open in the general schematism can lead to what appear to be very different systems" (Chomsky, 1980c:67).

Jacob's remarks represent a concrete picture of the idea of Goethe's Urform, as Chomsky put it (see above), the "generative principle that determines the class of physically possible organisms."Thus one can envision that the ontogenetic principles-and-parameters model might someday find its place in a phylogenetic principles-and-parameters theory of language evolution. This theory of evolution would provide an "explanatory" account of the "descriptive" theory of language acquisition, in much the same way that an account of language acquisition provides an explanatory account for the properties of language.[9] We will return in chapter 5 to related ideas in developmental and evolutionary biology.

The program encompassed by these concerns came to be known in some circles as "biolinguistics." Under the sponsorship of The Royaumont Center for a Science of Man (with funding from the Volkswagen Foundation), and organized by Piattelli-Palmarini, an interdisciplinary meeting on language and biology was held at Endicott House, Dedham, Massachusetts in May 1974.[10] This meeting was part of a pilot project of the Royaumont Center entitled "Animal Communication and Human Communication" and was set up to explore among other topics "relations between brain structure and language, first recommended as a subject for enquiry by Salvador E. Luria and Noam Chomsky." Luria, Chomsky and participants from the fields of biology, neurophysiology, ethology, linguistics, psychology, psycholinguistics, philosophy, social psychology, biophysics, and mathematics met to discuss the possibilities of collaboration on a variety of proposed topics:

If certain areas of the brain, found to be highly correlated with specific language functions, are destroyed, is the ability to carry out the other language functions hampered? Can the region of lesion be circumvented? If so, what are the consequences to cortical or cerebral functioning (i.e. if a left hemispheral lesion occurs

[9] See Chomsky for a discussion of the technical notions of descriptive adequacy and explanatory adequacy (Chomsky, 1965).
[10] See Piattelli-Palmarini, 1974.

in the Temporal Gyrus (phonetic discrimination), the Superior Temporal Gyrus (phonetic production and semantic configurations), Supramarginal Gyrus and Angular Gyrus (syntactic and semantic configurations), etc.? What feedback effects are observed in adjacent cortical areas?

Do certain linguistic functions seem to be dominant with respect to one another? With respect to non-linguistic functions and vice-versa? If they are impeded by lesion, do they reroute to another area of the cortex which then suppresses its normal correlative function? Suppression? Mutual facilitation? In phonological production and reception? Semantic orientation? Syntactic composition and decomposition?

Why does syntax appear to obey structure-dependent rules of organization (computation) rather than intrinsically simpler structure-independent orderings?

The above topics and others concerning the biological foundations of language which are proposed for further investigation are referred to in the report on the meeting by the term "biolinguistics." [11]

After the Dedham meeting the Royaumont Center developed a project entitled "Communication and Cognition," under the sponsorship of Luria and Chomsky with the assistance of Jean-Pierre Changeux, Jacques Mehler, Klaus Scherer, Antoine Danchin, and Jean Petitot.[12] The last stage of this project was a conference on "Ontogenetic and Phylogenetic Models of Cognitive Development" at Royaumont Abbey near Paris in October 1975.[13] This conference was attended by many biologists, including Jean-Pierre Changeux, François Jacob, Jacques Monod, and others. Also subsequent to the Dedham meeting an MIT Work Group in the Biology of Language was formed during the period from July 1975 to August 1976, with the support of grants from the Alfred P. Sloan Foundation and from MIT on the basis of a proposal submitted by Noam Chomsky, Susan Carey-Block, and Salvador E. Luria (Walker, 1978).

In 1976 Konrad Lorenz and his colleagues traveled to Salzburg to participate with linguists in a symposium on language and biology at the Salzburg Summer School of Linguistics. In addition, Lorenz's colleague Otto Koenig hosted a series of meetings on sign (semiotics) and language with the Department of Linguistics of the University of Vienna at the Wilhelminenberg research station. And, finally, the Linguistics Society of America Summer Institute in 1979 in Salzburg was devoted to the topic of "Linguistics and Biology."

The influences of ethology on the study of language in the 1950s

[11] This report makes reference to "the study group on biolinguistics already active at M.I.T" (p. com.2).

[12] *Activities Report from February 18, 1975 (date of the last meeting of the Board of Directors) to November, 1976*, Part II, Centre Royaumont Pour une Science de l'Homme, Paris.

[13] Piattelli-Palmarini has thoroughly documented the conference and also presented a retrospective on the conference nearly twenty years later (Piattelli-Palmarini, 1980; Piattelli-Palmarini, 1994).

discussed above now came full circle. Lorenz introduced arguments from linguistics into the field of human ethology (Eibl-Eibesfeldt, 1970):

> A strong support for human ethology has come from the unexpected area of linguistic studies; Noam Chomsky and his school have demonstrated that the structure of logical thought – which is identical to that of syntactic language – is anchored in a genetic program. The child does not learn to talk; the child learns only the vocabulary of the particular language of the cultural tradition into which it happens to be born.[14] (Lorenz, 1981:11)

In 1980 The Harvard Medical School Biolinguistics Group was formed under the sponsorship of Allan Maxam's Laboratory of Molecular Biology to provide an interdisciplinary forum for researchers interested in the biological foundations of language. Over the years topics ranged over theoretical linguistics, molecular biology, learning disorders, neurobiology of animal communication, neurolinguistics, brain lateralization, neural plasticity and critical periods, aphasia, dyslexia, vision, dreams, computational linguistics, pre-linguistic speech perception in infants, chromosomal language disability, and evolution of language.[15]

At around this time a set of experiments was designed to explore the language areas of the brain at the molecular level. Norman Geschwind and Albert Galaburda were to carry out the neurological part of the collaboration. The experiments were to be conducted at Allan Maxam's Laboratory for Molecular Biology at the Harvard Medical School. Noam Chomsky agreed to write the introduction to the proposal, but pointed out to me that time wouldn't permit him to actually be in the laboratory doing the experiments (not that he had been expected to). It was, on paper at least, the first cross-disciplinary collaboration between neurologists with an interest in the language areas, molecular biologists, and linguists. An attempt was made to get funding from the field of linguistics, but the proposal was neither written nor submitted, since no one would agree to even look at it.[16] Norman's subsequent tragically premature death was a further blow to the project.

By the first half of the 1980s, the "appropriate" subject material had swung full circle. There were now new buzzwords in academia and indus-

[14] This is a more elegant way of saying that the locus of cross-linguistic variation is in the lexicon, in terms of one variant of the principles-and-parameters model (discussed in chapter 3).

[15] For discussion of the application of linguistic and computational techniques to molecular biology, see Collado-Vides, Magasanik, and Smith, 1996.

[16] In the late 1980s, the peer review panel of a prominent federal scientific agency turned down a modest request for funding for biolinguistics in part on the grounds that it had not been shown that the relationship between linguistics and biology was more than an "analogy."