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Introducing the volume

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The *Handbook of Biolinguistics* is intended to be, first and foremost, an illustration of the range, and explanatory power, of interdisciplinarity afforded in the domain of cognition, and more specifically, linguistics, when the nature of human language is approached from a biological perspective. This biological perspective has roots that go back to the birth of modern science and natural philosophy, and it has been emphasized in modern times by Noam Chomsky, Eric Lenneberg, Morris Halle, and many others since.

Biolinguistics takes as its focus of inquiry the remarkable ability, present in all children barring severe pathologies, to develop a grammatical system ("linguistic competence") that is both amazingly plastic (if it were not, we would not witness the linguistic variation we find among human languages) and surprisingly constrained (so many logically possible rules do not appear to be part of any human language). Although the environment in which the child grows up certainly plays a role in triggering the use of this capacity for language, it is equally obvious that the human child must be biologically equipped in a way distinct from other species if we are to explain how humans turn some of the noise around them into news.

Some sixty years ago, when they were still graduate students, Chomsky and Lenneberg decided to find out what the biological foundations of the human linguistic capacities were, and in so doing created the field of biolinguistics. As should be obvious, biolinguistics is a supremely interdisciplinary enterprise, requiring insights from many fields and collaboration among many researchers from vastly different backgrounds. This, of course, comes with its own challenges. It is all too easy for a researcher focusing on a particular problem to not only lose sight of the big picture, but also to be unable to keep track of recent developments in allied disciplines that may shed light on the particular problem at hand.

We are very fortunate to write at a time when the interdisciplinarity that is characteristic of the field of biolinguistics is making a comeback at the

forefront of many studies in the language sciences, so much so that we felt it was the right time to not only launch a new journal that strives for a rapprochement among disciplines, the open-access *Biolinguistics* (www.biolinguistics.eu), but also to provide students and experts alike with a representative sample of some of the best and most influential works in biolinguistics today. Hence this handbook.

In the mid 1970s, Salvador Luria singled out the field of biolinguistics in an AAAS keynote address as a very promising avenue for both biologists and linguists. Luria felt that the time was ripe for the two disciplines to be confronted with each other's results. Developments in genetics, developmental biology, computer science, neuroscience, experimental psychology, and theoretical linguistics in the intervening years have vastly expanded the range of results to take into account and, we think, have raised the prospects of genuine convergence – an opinion that we hope the reader of this handbook will share.

Needless to say, preparing a handbook of such a complex and varied field-in-the-making as biolinguistics is no easy task. We were confronted with difficult choices as to what to include, and we are painfully aware of the fact that some may feel that their favorite areas of study were not given pride of place in the pages that follow. We have tried to be as comprehensive as possible while remaining within reasonable size limits. Being theoretical linguists by training we decided not to make theoretical debates – as fascinating as we find them – the focus of our handbook. When it comes to theoretical assumptions, the reader will find an unusually pluralist perspective in the chapters that make up this volume. Although we personally favor certain theoretical commitments, we did not feel that it was right to be dogmatic about them in a handbook like this one. Instead, we decided to organize the handbook along several research questions that Eric Lenneberg placed at the heart of his 1967 *Biological Foundations of Language*: language development, language evolution, and the relation between mind and brain. These form the core axes of this volume.

In addition, we wanted to offer a historical and conceptual overview of the field, to help the reader relate current findings to long-standing questions. This is the purpose of the early chapters of this handbook, which includes contributions by Lyle Jenkins (the author of the first comprehensive overview of the range of questions at the heart of biolinguistics, Jenkins 2000), Massimo Piattelli-Palmarini (the person who gave the name "biolinguistics" its modern meaning and one of the strongest advocates of interdisciplinarity in the field), and James McGilvray (an expert on the philosophical foundations of modern linguistics and cognitive science).

Part I of the handbook addresses central issues in the domain of language development, many of which were introduced by Eric Lenneberg: the range of evidence in favor of a "language instinct" (Tsimpli), the

existence of a critical period for language acquisition (Meisel), the issue of maturation in the context of language acquisition (Wexler), and the impact of language on other cognitive systems (e.g., as seen in the domain of bilingualism; Hernandez, Martin, Sebastián-Galles, and Costa). Part I also reviews influential proposals on how the child may use the input to figure out the properties of the language to be acquired (Millotte, Cauvet, Brusini, and Christophe on the "prosodic bootstrapping" hypothesis), and the range of options ("parameters") that biology seems to make available to the child during the course of language acquisition (Pearl and Lidz).

Part II focuses on the interplay between mind, brain, and behavior. It deals with the nature of theoretically informed experiments (Sprouse and Almeida), working memory and language processing (Wagers and McElree), modularity (Marcus and Rabaglia, and Rabagliati), language deficits (Benítez-Burraco), and pathologies (Friedmann, Biran, and Dotan). It also provides overviews of what we currently know about how basic properties of core domains of linguistic inquiry, i.e. syntax (Schlesewsky and Bornkessel-Schlesewsky), semantics (Pylkkänen, Brennan, and Bemis), morphology (Bornkessel-Schlesewsky and Schlesewsky), and phonology (Monahan, Lau, and Idsardi), may be implemented in the brain. Finally, it traces the fate of Broca's area and its use in relating mind and brain (Hickok).

Finally, Part III of the handbook focuses on a range of issues relevant to the study of language evolution: the cognitive capacities of non-human primates (Zuberbühler), the abilities of non-human vocal learners (Okanoya), the potential use of fossil records to shed light on the evolution of language (Balari, Benítez-Burraco, Longa, and Lorenzo), the possible role of natural selection (Bickerton), and the insights from computational modeling in the context of language evolution (Kirby).

It goes without saying that entire volumes could well be devoted to each of the topics covered in this handbook. Accordingly, readers are asked to take the contributions that follow as solid points of departure to explore the literature. Inevitably, our contributors have emphasized certain aspects (be they theoretical assumptions, experimental results, etc.) at the cost of others, but taken as a whole we hope that the volume offers a comprehensive overview of the fruitfulness of interdisciplinarity, and of the promises of the field of biolinguistics.

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Biolinguistics: A historical perspective

Lyle Jenkins

2.1 Introduction

In what follows I present a historical sketch of what has become called *biolinguistics*, the study of the biology of language. My intention is to provide the reader of this handbook with enough of the history of the field to provide the context in which the questions discussed here arose and hopefully to illuminate their subsequent development. I provide sources for additional reading. However, in some cases my selections are meant only to be illustrative. I am not attempting a comprehensive overview here and put aside questions of priority.

Biolinguistics, as the study of the biology of language, poses exactly the same kinds of questions as in other areas of biology; e.g., questions about form/function, ontogeny, and phylogeny (Chomsky 1976; Chomsky and Lasnik 1993).

1. What is knowledge of language?
2. How does language develop in the child?
3. How does language evolve in the species?

The shift in viewpoint from structural linguistics to the modern biolinguistic viewpoint of language (as described by a *generative grammar*) as part of an innate language faculty was marked by the circulation of a draft of Noam Chomsky's *Logical Structure of Linguistic Theory* in 1955 (Chomsky 1955/1975).

At the same time Eric Lenneberg investigated many of the areas to be explored in biolinguistics in the decades that followed, including the genetics of language acquisition and of language disorders (dyslexia, specific language disabilities), language of deaf children, "wolf children," the critical period, twin studies, family pedigrees, aphasia, and evolution of language. This work culminated in Lenneberg's *Biological Foundations of Language* to which Chomsky contributed a chapter entitled "The formal

nature of language" (Lenneberg 1967); for an analysis of the connections between Lenneberg's work and modern biolinguistics, see Boeckx and Longa (2011).

This was followed by an interdisciplinary meeting on language and biology at Dedham, Massachusetts, in 1974, sponsored by the Royaumont Center for a Science of Man. This meeting, organized by Massimo Piattelli-Palmarini, brought together researchers in linguistics and biology to discuss language and the brain, as recommended by Chomsky and the biologist and Nobel Laureate Salvador Luria. The report for this meeting referred to the topics discussed by the term "biolinguistics" (Piattelli-Palmarini 1974). After the Dedham meeting, the MIT Work Group in the Biology of Language was formed (1975–76) with the support of the Alfred P. Sloan foundation and MIT (Walker 1978).

The Royaumont Center also developed a "Communication and Cognition" project under the sponsorship of Luria and Chomsky with the assistance of others (for additional details, see Jenkins (2000)). This project, also organized by Piattelli-Palmarini, held a conference on "Ontogenetic and Phylogenetic Models of Cognitive Development" at Royaumont Abbey near Paris in October, 1975. There were discussions of many topics bearing on the biology of language at this conference which was attended by Chomsky, Piaget, and many biologists, including Jean-Pierre Changeux, François Jacob, and Jacques Monod, among others (Piattelli-Palmarini 1980); for a retrospective see also Piattelli-Palmarini (1994). Concurrently, Paris had become an important center internationally for the study of generative grammar.

In 1976 another conference, this one with a focus on evolution of language, Origins and Evolution of Language and Speech was organized by the New York Academy of Sciences. Chomsky was a speaker at that conference and one of the conference organizers, Stevan Harnad, noted in his introductory remarks that "the revolution of linguistics due to Noam Chomsky has provided a very different idea of what the nature of the 'target' for the evolutionary process might actually be."

At the same time there was a great deal of work underway on brain and language, including neurology of language and evolution of language; e.g. Geschwind and Galaburda's work on cerebral dominance and asymmetry (Geschwind and Galaburda 1984, 1987), Le May and Geschwind's work on the morphological asymmetries of the brains and skulls of non-human primates (LeMay and Geschwind 1975), to mention only a few examples. Nor was work on evolution of lateralization limited to the language areas; consider, e.g., Denenberg and colleagues' work on functional asymmetries in the rat (Denenberg 1981) as well as the numerous asymmetries in lower organisms documented by Corballis and Morgan (Corballis and Morgan 1978; Morgan and Corballis 1978).

The conference on Maturational Factors in Cognitive Development and the Biology of Language was held in 1978. One can get a flavor of the

discussions taking place among linguists and neurologists at that time in the discussion between Chomsky and the neurologist Norman Geschwind about a number of questions concerning evolution of language; among others, about the cerebral asymmetries in the great apes, auditory tasks in the left temporal lobe of the monkey, asymmetry for emotional behavior in the brain, the recognition of species-specific cries in the left hemisphere of Japanese monkeys, male–female differences in left–right asymmetry for areas involved in bird song, and so on (Caplan and Chomsky 1980).

Much of the work in these areas was soon forgotten and an attempt was made to rewrite history, at least in the media. In 1998, when Gannon and colleagues reported their findings of an asymmetry in the left planum temporale area of chimpanzee brains (Gannon *et al.* 1998), this was heralded in the press as "challenging cherished notions of how language evolved in humans and why apes cannot talk" (*New York Times*). However, left–right asymmetries in non-human primates, including the planum temporale area, had been long known (see e.g. Cunningham 1892; Fischer 1921; Yeni-Komshian and Benson 1976). The German magazine *Der Spiegel* claimed that until the study of Gannon *et al.*, it had been thought that the left and right sides of the brains of non-human primates were absolutely equal, although this had been shown twenty years earlier not to be the case by the study of Beheim-Schwarzbach (1975), who had compared the temporal regions in humans, chimpanzee, and the orangutan.

In 1977 GLOW (Generative Linguistics in the Old World) was founded by Henk van Riemsdijk and colleagues in the Netherlands, and it rapidly became vital to the development of biolinguistics throughout Europe and around the world. GLOW organizes an annual conference, periodic summer schools, and publishes a newsletter (http://glow.uit.no, with a link to Facebook), all of which have greatly helped to promote generative grammar. In recent years a sister organization was founded in Asia, GLOW (Asia). The annual conference in 2010 was hosted in Beijing (www.blcu.edu.cn/CLT/glow/glowasia8.html).

In 1979 the Linguistics Society of America held its first Summer Institute abroad at the Joint Linguistic Society of America and Summer Linguistics Institute at the University of Salzburg, Austria, with the theme of "Linguistics and Biology," which included courses, seminars, and other presentations as well as discussions on linguistics and biology of language, including neurology and the evolution of language. Also around this time there were many fruitful contacts between the ethologist and evolutionary biologist, Konrad Lorenz and his colleagues in Austria and at the Max Planck Institute in Germany and generative linguists at the University of Vienna and Salzburg. In 1976 Lorenz and his colleagues participated in a symposium on language and biology at the Salzburg Summer School of Linguistics.

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 (Jenkins 2000). Topics ranged over theoretical linguistics, molecular biology, learning disorders, neurobiology of animal communication, neurolinguistics, brain lateralization, neural plasticity and critical periods, aphasia, dyslexia, critical period in vision, dreams, computational linguistics, pre-linguistic speech perception in infants, chromosomal language disability, and evolution of language. Maxam and Jenkins also founded the Biolinguistics Institute in Cambridge, Massachusetts, dedicated to the promotion of interdisciplinary research into the biology of language.

Recently, there have been a number of conferences and publications sponsored by the International Biolinguistics Network (Di Sciullo 2010) (see below).

2.2 Questions in biolinguistics

Note that the three questions about biology of language above are interrelated in a particular way. The question of how language develops in the child (2) depends on understanding what the properties of the language system are, the answer to the question about what knowledge of language is (1). And the third question about how language evolved in the species, depends crucially on the answers to the first two questions. In practice, one only has partial answers to all three questions, so that it becomes necessary to study all the questions in parallel, constantly revising the answers as new empirical data becomes available.

Consider question (2) for the moment. How does language develop or "grow" in the child? This process is often visualized as the "language acquisition device" (LAD) (Chomsky 1965), which maps experience to a particular language (English, Japanese, etc.). The problem for biolinguistics is to determine what is in the box; that is, to discover what mechanisms one must assume that the child brings to language in order to map experience ("primary linguistic data") to a particular language.

Language "grows" from an initial state, proceeds through a series of intermediate states and then attains a final state in the adult. Here the initial state corresponds to the genetic endowment and the final state corresponds to English, Japanese, etc. The linguist's characterization of the initial state is termed *universal grammar* (UG) and that of the final state, *grammar*.

The answers to questions (1)–(3) have in turn stimulated investigation into the deeper "why" question; i.e. why are the principles of language what they are? – the basis for the "minimalist" program (Chomsky 1995b). The answers to all of these questions will provide insight into the "unification problem"; i.e. how the study of language can be integrated with the rest of the natural sciences (Chomsky 1994).

In studying any of these questions, one must keep in mind that properties of an acquired language result from an interaction of three factors (Chomsky 2005):

(a) genetic endowment
(b) environment and
(c) principles not specific to the faculty of language.

A conceptual breakthrough was achieved with the development of the principles and parameters approach to language acquisition (Chomsky 1981a; see additional references there). Here genetic endowment provided universal principles (UG), which were parameterized, with environment providing particular values for each parameter; e.g., head-initial or head-final. Then a particular language, like English, can be regarded as a collection of parametric choices for the grammar, in addition to a list of vocabulary items, which must (in part) be learned. This provided a resolution for the acquisition paradox; i.e. that it seemed that "languages could differ from each other without limit and in unpredictable ways," as the structural linguist Martin Joos put it (Joos 1957), and at the same time, the universal format for language needed to be highly restricted to account for the ease and speed of acquisition as well as for poverty-of-stimulus considerations (Chomsky 2009). Chomsky noted that the Nobel Laureate François Jacob was posing similar questions in the area of molecular biology, asking, "what accounts for the difference between a butterfly and a lion, a chicken and a fly, or a worm and a whale." Jacob concluded that it wasn't biochemical innovation, but new regulatory circuits (Jacob 1978). Chomsky remarked that "in a system that is sufficiently intricate in structure, small changes at particular points can lead to substantial differences in outcome" and that the principles and parameters approach had the right properties to account for acquisition from this perspective (Chomsky 1980/2005).

The "cartographic project," has focused inquiry on syntactic configurations (including phrases with such syntactic elements as complementizer, tense, inflection, determiner, etc.) to map out the fine-structure of the areas around these elements, uncovering additional invariant structural properties of language (Cinque 1999, 2002; Rizzi 2004; Belletti 2004; Cinque and Rizzi 2010 and references there). Much research has also focused on the nature of parameters; e.g., their locus in the lexicon, in particular, as properties of functional elements, macroparameters vs. microparameters (Cinque and Kayne 2005), parameters and (non)pronunciation (Kayne 2010), etc.

Chomsky has suggested that principles of efficient computation, such as minimal search are principles that might not be specific to the faculty of language (c) and provide part of the answer to the question of "why" language is like it is (Chomsky 2009). Another source of principles might be dynamical system constraints such as symmetry breaking

(Jenkins 2000, 2011). A third might be probabilistic or stochastic constraints. Similar "why" questions can be asked about any biological system – viruses, bacterial cell division, protein folding, sunflowers, bumblebees, falling cats, wiring of circuits in nervous systems, etc.

These design properties may be non-domain specific or non-species specific. (Here, of course, biological design is meant, not the "intelligent design" of creationism.) For example, properties of human language might (or might not) turn out to be specific to language, or may be operative in other cognitive domains, such as mathematics, vision, etc. Other properties might (or might not) be shown to be specific to humans or might be found in other non-human species as well (Hauser, Chomsky, and Fitch 2002). To answer such questions, one needs in-depth studies of other cognitive domains (Boeckx 2009), such as mathematics (Dehaene *et al.* 2006) and cross-species comparative work (Christiansen and Kirby 2003a; Fitch 2010).

The questions above, including the study of the three factors, must be posed in any biolinguistic approach to biology (see Di Sciullo *et al.* 2010; Di Sciullo and Boeckx 2011). Moreover, they have been studied since the earliest days of modern biolinguistics and are currently under investigation in the *minimalist program* (*Minimalism*) (and its predecessors) (Chomsky 1995b; Boeckx 2006, 2008, 2011). For some other perspectives on biolinguistics, see Larson, Déprez, and Yamakido (2010).

2.3 Current research

Research into biolinguistics since the early 1950s has drawn on many kinds of evidence: theoretical linguistics (including universal and comparative grammar, syntax, semantics, morphology, phonology, and articulatory and acoustic phonetics; language acquisition and perception; language change (Radford, Atkinson, Britain, Clahsen, and Spencer 2009; Hogan 2011), sign language (Brentari 2010), language contact (Hickey 2010), linguistic savants (Smith and Tsimpli 1995; Smith *et al.* 2011); genetic language disorders (Marcus and Fisher 2003; Fisher and Marcus 2006) and agrammatism (Grodzinsky and Amunts 2006); neurology of language, including expressive and receptive aphasias, imaging and the electrical activity of the brain (Stemmer and Whitaker 2008); studies of split brain patients (Gazzaniga 2005), comparative ethology and evolution (Christiansen and Kirby 2003a); mathematical modeling and dynamical systems (Nowak, Komarova, and Niyogi 2002; Niyogi 2006), language and mathematics (Dehaene *et al.* 2007), etc.

In recent years there have been a number of conferences, workshops and summer schools focused on the biolinguistic perspective. In 2001 Henk van Riemsdijk and Riny Huybregts organized a stimulating interdisciplinary conference on *The Genetics of Language* at Tilburg University,

The Netherlands, to bring together researchers from many areas of biolinguistics (Jenkins 2004). More recently there was a conference *Biolinguistics: Acquisition and Language Evolution* (University of York, UK, July 2–4, 2008) and a course *Of Minds and Language: A Conversation with Noam Chomsky*, 2006, 25th Anniversary of the European Summer Courses of the Basque Country (Piattelli-Palmarini, Uriagereka, and Salaburu 2009). There was also a workshop on *Advances in Biolinguistics*, held at the 44th Annual Meeting of the Societas Linguistica Europaea (September 10–11, 2011).

In addition, every two years a conference focused on issues of evolution, the International Conference on the Evolution of Language (EvoLang) has been held at various locations (Edinburgh, London, Paris, Cambridge, MA, Leipzig, Rome, Barcelona, Utrecht); for coverage of EvoLang 8 at Utrecht, see Balter (2010). EvoLang 9 was held at Kyoto (March 13–16, 2012, http://kyoto.evolang.org). More information on previous conferences is available on the conference websites archived at www.ling.ed.ac.uk/evolang.

Another important development for biolinguistics was the founding by Cedric Boeckx and Kleanthes K. Grohmann of the *Biolinguistics* journal, a peer-reviewed interactive online journal devoted to articles, interviews, and editorials on current issues in biolinguistics (www.biolinguistics.eu) (Boeckx and Grohmann 2007). Since the journal was established in 2007, the subscribed base has grown to over 2,500 readers.

In addition to the journal, information on current conferences and other news items of interest to biolinguists may be found on the *Biolinguistics* blog (http://biolingblog.blogspot.com, @biolinguistics on Twitter), set up by the journal editors and maintained by Bridget Samuels, Hiroki Narita, and Txuss Martin. In addition, a Biolinguistics Workshop (in conjunction with the Special Interest Group (SIG) on Biolinguistics of the Linguistic Society of America) was organized at the 2012 LSA Annual Meeting (Portland, January 5–8). This SIG is coordinated by Kleanthes K. Grohmann and Bridget Samuels. Additional information relevant to biolinguistics, as well as for topics outside of biology and language, may be found on the LINGUIST List (http://linguistlist.org).

In addition, the *International Biolinguistics Network* (IBN) was organized by Anna Maria Di Sciullo and colleagues to encourage collaboration between groups doing research on biolinguistics. The IBN (www.biolinguistics.uqam.ca/) provides information on ongoing projects, conferences, and links to other resources in biolinguistics (Di Sciullo 2010). Several conferences have been arranged under the auspices of the IBN: the *Biolinguistics Network Inaugural Conference*, University of Arizona, Tucson (February 22–24, 2008) and *The Language Design*, University of Quebec at Montreal (May 27–29, 2010). Two other conferences were held earlier: *Biolinguistic Investigations*, Santo Domingo, Dominican Republic (February 23–25, 2007) and *Biolinguistics: Language Evolution and Variation*, University of Venice (June 2–4, 2007) (Di Sciullo *et al.* 2010; Di Sciullo and Boeckx 2011).