

Antonino Pennisi
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Darwinian Biolinguistics

Theory and History of a Naturalistic
Philosophy of Language and Pragmatics

Perspectives in Pragmatics, Philosophy & Psychology

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Philosophy of Language and Pragmatics



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Antonino Pennisi and Alessandra Falzone

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Chapter 1

Introduction

A little bit of compressed air from the lungs through the narrow path of the glottis produces the voice; the many obstacles that the tongue, teeth and lips oppose this vibrant air cause the inflection and variety of sounds, each of which has its own significance. That's what reduces all great art of the word, this inestimable gift from the Creator, the main link of society (Wolfgang Von Kempelen, *Mechanismus der menschlichen sprache: nebst der Beschreibung seiner sprechenden Maschine*, 1778, 25–6).

In this book, we put forward an obvious claim, yet one which is surprisingly difficult to accept for most of those who practice the cognitive sciences as they have developed until today. This claim considers human language as a biological form of embodied species-specific intelligence based on the evolution of the overall body structure of *Homo sapiens*.

Of these structures, the brain is a fundamental part and, in order to develop articulated language, has allowed human evolution to perform a complete rewiring of respiratory, muscular and nervous physiology. It has monitored fine control of articulatory features and has functionalized them to new cognitive tasks (semantic categorization, syntax and logical representation of the world) and radical transformations of social behaviour (hyperextension and articulation of cooperation between conspecifics, pragmatic adaptability, moral normativity and aesthetics). Of all the different corporeal structures of *Homo sapiens*, the brain, however, constitutes the biologically less constrained part. In conjunction with certain trends of thought matured in the Evo-Devo, we must consider, in fact, the specific constraints of *Bauplan*, the “constraining” character of the shape of the body, which is much less flexible than the brain structure and is plastically the most adaptable organ of the whole living machine. Of course the brain is also subject to purely mechanical external constraints: it must “fill” a skull, its size varies from species to species, and from individual to individual; it is subject to the general metabolic processes, etc. Leroi-Gourhan called it, in fact, “the tenant of the rest of the body” (see Sect. 13.2). However, the brain structure may not perform any function if the mind is biologically conditioned by a body which is subjected to the same constraints which the bones or muscles are subjected to. Fortunately, as we recall Skoyles and Sagan: “our brains are set in gray matter, not in stone; their parts are predisposed but not absolutely preset for particular functions. They are built out of general-purpose

bioprocessors that, after being formed, become specialized in response to their inputs and outputs – not of preevolved, rigidly specialized processors” (2002, 26). The freedom of recabling and rewiring continuously the entire operating system of our body software, up to extreme limits, makes our brain not only a perfect Darwinian adaptation organ, but also the “organ attention to life” which Bergson considered the principle of man’s individuality and contributes to its Darwinian character.

Yet such power and freedom has a price: the brain that can adapt and coordinate, synchronize and schedule everything, which can infuse intentionality and finalize it, cannot “invent” the lowly bodily organs, its suburbs. Indeed, in a sense, from an evolutionary point of view, it is completely dependent on them. If unusual genetic mutations of the body, conforming to the laws of development and form, should in time be beneficial for the fitness of the species, the brain will certainly be able, in a short evolutionary time, to exploit and tame the possibilities, cabling, with extraordinary precision, and operating procedures. But without the slow and continuous transformation of those forms, change (that particular change) would never take place. The most important evolutionary transformations always start from modifications of the structures: the functions will follow, as well as their performative algorithms. The adaptation and control principles – specific to the brain – are opposed to those of autonomy and generation – and are typical of other structures. And this, among other things, explains what to Michael Tomasello seemed to be the biggest mystery of human evolution: the discrepancy between the cumulative cultural evolution speed, and its inexorably slow character of “normal processes of biological evolution involving genetic variation and natural selection” (1999, 2).

Current biolinguistics, almost all of Chomskyan inspiration, seems to have overlooked these at a first blush ‘paradoxical’ aspects highlighted by evolutionism and, in particular, by the recent developments of Evo-Devo. As we shall see in the chapter devoted to the historical reconstruction of the discipline, for almost all the most important manuals (Balari and Lorenzo 2013; Boeckx and Grohman 2013; Di Sciullo and Boeckx 2011; Allen 2009; Anderson and Lightfoot 2002; Jenkins 2000) biolinguistics is a contemporary science and coincides with the autonomous history of the study of the rules and underlying mental functions of language. The bio prefix is legitimized by the implicit admission, which biolinguistics scholars often leave unclarified, that mental processes should be linked to the functioning of the brain, in order to avoid falling back into an embarrassing post-Cartesian neo-dualism, or even worse, into “Plato’s problem” (evoked many times) that forces one to consider linguistic knowledge as a reminiscence of innate ideas. An underlying cerebrocentrism justifies an explicit mentalism that leaves no room for any hypothesis of embodied cognition outside the brain.

In this book, we want to argue to the contrary, that if biolinguistics must be confronted, like all other natural sciences, with the central theoretical notion of “constraint” and with its empirical correlates, it follows that its specific primary object must be just the *bodily language technology*, and in particular its most rigid and “hostile” part, that without which language would not exist: the development of phonatory organs, the structures of the hearing/voice feedback, the muscular and

respiratory structures, the genetic platform that transmits and exercises them, the maturation of neurocerebral devices that monitor it and make its physiological and social use fully functional. In this case the bodily technology is not only defined as a set of sensorimotor and conceptual interfaces (Chomsky 2005, 10), or an “extern-alization device” like the printers for PCs or brush for a painter (Bierwick and Chomsky 2016, 40 and 77; Chomsky 1982, 426). Instead, it selects in a decisive way the types of procedures that take place in the cognitive ‘black box’ and give substance to the creative activity that produces new phrases, new thoughts, new interpretations. The bodily language technology also acts as a causal pressure, not only in the phylogenetic phase (therefore in the evolutive history), but also in the ontogenetic one, therefore in the phase of cognitive development, and in the executive phase, that is, in everyday social performance of linguistics and pragmatics.

If a hypothetical Martian ethologist – but more careful than the extraterrestrial scientist evoked by Berwick and Chomsky (2016, 87) – falls on Earth to observe the behaviour of animals that inhabit it, he may start from the most macroscopic empirical finding: humans are the only animals capable of communicating through a sophisticated system based not merely on sound production but on vocal articulations. Perhaps, while retaining the same brain, they could develop systems and semiotic codes based on vision and signs, as they do sometimes in substitution of hearing and voice; or they reciprocally exchange thoughts by touching, such as the blind-deaf Helen Keller and Laura Bridgman; or, why not, create a world of olfactory representations: *but they have not done so!*

Evolution has selected the hearing-voice system, and every child is born with an innate physiological structure suitable to produce and be able to serve articulatory sounds. The Martian ethologist, before any other supposition, will have to start from this absolute truism: human bodies speak through sound waves emitted from fine modulations specific to our vocal production organs and received by our equally specialized organs of auditory reception. This is what has opened cognitive spaces unthinkable to human nature. Of course, the intentional and voluntary processes involved in speaking, as well as the complicated encoding and decoding systems of signals and their meanings, occur through cerebral processes, which would have found their routes anyway, even if we had opted for any of the other virtual communication worlds.

Bewitched for too many years by the fascinating idea of Lamarckian memory that there may be something innate, biologically inheritable that does not consist of our genetical, anatomical and physiological structures, we have enormously complicated the tasks of biolinguistics and have fueled a giant castle of speculation and philosophical novels. Maybe, there is no Universal Grammar and historical-natural languages, with their different phonological, syntactic and semantic systems, are the realization of an entire Universal Biological Structure, a neutral Bodily Language Technology which has been selected gradually over millions of years and has become irreversibly specific to the modern Homo sapiens.

Compared to this unavoidable starting point, so obvious that it has not been mentioned anywhere in the archipelago of the cognitivist hypotheses, we might provocatively state that cerebrocentrism and mentalism have hindered the biologi-

cal approach to language much more than they have favoured it. If we were, in fact, to find not just a reminder but a real comparative and scientific analysis system of the cognitive centrality of hearing-voice relationship to rebuild human cognition, we would be forced to climb to the “endless antiquities” of Vico’s memory where one would not understand or hypothesize the decisive role played by the human brain in coordinating the network of all networks: the neuro-cerebral system. We speak, of course, of the great biological Aristotelian synthesis, extremely precise and deep in the comments and reconstructions of the cognitive ontology of animals, except for one small detail: the absence of any active role of the brain. In the Darwinian biolinguistics model that we discuss here, the Aristotelian heritage will not have the value of pure historical evidence. Some of the most important works (Laspia 1997; Lo Piparo 2003) will be discussed in the first part of the book and have demonstrated the linguistic relevance of Aristotle’s ideas about language, like those of Vico and of Darwin himself, before the advent of modern neuroscience.

The book starts from a historical reconstruction of the two biolinguistic models summarized here as CBM (Chomskyan Biolinguistic Model) and DBM (Darwinian Biolinguistic Model) to which part one is devoted. In the second part, the comparison between models extends to a complete review of traditional biolinguistic issues through an evolutionary perspective and their potential influence on the global paradigm of biologically oriented cognitive science. Finally, the third part concentrates on philosophical, evolutionary and experimental principles of an extended theory of performativity as part of a pragmatic naturalistic perspective of verbal language.

Bibliographic Notes¹

Some of the ideas contained in the book have already been discussed in previous books and articles including:

- Pennisi, A. – Falzone, A., *Il prezzo del linguaggio. Evoluzione ed estinzione nelle scienze cognitive*, Il Mulino, Bologna, 2010.
- Pennisi, A., *L’errore di Platone. Biopolitica, linguaggio e diritti civili in tempo di crisi*, Il Mulino, Bologna, 2014a.
- Pennisi, A. Falzone, A., *Residuals of Intelligent Design in Contemporary Theories about Language Nature and Origins*, “Humana.Mente”, 2014, Issue 27, pp. 161–180.
- Falzone, A. *Structural Constraints on Language*, “RSL. Italian Journal of Cognitive Sciences”, Issue 2/2014, pp. 13–36.

Translations cited in the text are always drawn from the original texts located in the Bibliography. Exceptions are those texts which have not previously been translated into English. In these cases, we have translated the texts, and this is indicated in the book.

¹ Although the book is the outcome of collaborated work, Chaps. 1, 2, 3, 5, 7 and 9 (with the exception of 9.1) and Chaps. 13, 14 and 15 are attributed to Antonino Pennisi. Chapters 1, 4, 6 and 8 (with the exception of 8.1.4) Sect. 9.1 and Chaps. 10, 11, 12 and 16 (with the exception of Sect. 16.1.2) are attributed to Alessandra Falzone.

Part I

History and State of the Art

Chapter 2

Chomsky and Biolinguistics

Biolinguistics started as a specific discipline during the years in which Noam Chomsky noted the definitive failure of the applications of cybernetics to the study of language and, by publishing *Language and Mind* (1968), began to mark his biologicistic breakthrough. Turing's hypotheses (and those of other scholars involved in the first phase of AI) as applied to linguistics, in fact, clashed with the evidence that mental structures are not simply "the same" as artificial networks, whether they are established with structuralist methods of taxonomies, of skinnerian psychology, the mathematical theory of communication or that of simple automata: "what is involved is not a matter of degree of complexity but rather a quality of complexity" (Chomsky 1968, 4).

A year earlier saw the publication of *Biological foundations of language* by Eric Lenneberg (1967), a book Chomsky promoted as a point of reference for the new science, destined to establish itself in the international scene of language studies. The biolinguistic approach seemed to Chomsky the best one to establish the cognitive program in explicit and definitive opposition to the behaviorist psychology inspiring linguistic models until the mid-twentieth century. Conceiving the mind as a biological machine equipped with its own genetic program and innate domain-specific mappings could help him overcome one of the most important philosophical problems. The problematic assumption was to consider knowledge as no longer being a deposit of images and passive signs simplistically acquired by accumulation, imitation and reinforcement of the stimulus, but an active procedure of the creative mind which does not undergo categorizations and behaviors. The active and unique site of the human mind would precisely be language, that is "a specific type of mental organization, not simply a higher degree of intelligence" (Chomsky 1968, 61), "a species-specific capacity that is essentially independent of intelligence" (69), the use of which "is not automatically keyed to emotional states, and they do not pick out mind-independent objects or events in the external world" (Berwick and Chomsky 2016, 86). Additionally, it has no antecedent forms of development in other animal species constituting, from a biological standpoint, a typical case of

“emergence – the appearance of a qualitatively different phenomenon at a specific stage of complexity of organization” (Chomsky 1968, 62).

In carrying out this project – which, as we shall see, is his lifetime’s pursuit – Chomsky is confronted from the start by two basic problems which, until now, he has never been able to give a definitive or exhaustive answer to. These problems constitute, in our view, a potential conflict between his philosophy of biology and a significant part of contemporary biological theories that could legitimately inspire different biolinguistic models.

The first is of a philosophical nature and goes back to Cartesian rationalism. The rationalist inspiration always underlying Chomsky’s work, in fact, leads him to support the idea that the creative aspect of language (the ability to produce endless sentences from a finite number of elements, and to always be able to understand the new ones, regardless of the stimuli and the context) cannot be explained in mechanistic terms even if an animal or a machine “might be as fully endowed as a human with the physiological organs necessary to produce speech” (Chomsky 1968, 6). Descartes had solved the problem through a dualistic explanation. Matter and thought of the mind (spirit) are two different substances and it’s possible that one is not subject to the same restrictions as the other. But, even considering the dualist argument entirely worthy of being taken seriously, Chomsky immediately dismissed its adoption – at least explicitly – because to resort to any kind of vitalism would be completely contrary to any acceptable modern philosophy of science. The active tool of the mind was supposed to look into the very substance of which it is made: the brain. However, to safeguard the properties of “abstraction of the mind” Chomsky leaned towards the Newtonian model of gravity – an invisible principle of attraction determining the innate properties of the smallest corpuscles of matter – going so far as to see a methodological parallel “between the postulation of gravity and the postulation of a *res cogitans*” (Chomsky 1968, 6). The theory of Universal Grammar (UG) and that of innate Competence of speakers, as well as all their recent developments are treated, as we shall see later, as potential new theories of gravity, in the sense that they posit universal laws of the mind regardless of their possible implementation in the bodies of speakers with whom, in some mysterious way (that could also turn out in the end to be inaccessible to knowledge) they are connected:

it seems to me that the most hopeful approach today is to describe the phenomena of language and of mental activity as accurately as possible, to try to develop an abstract theoretical apparatus that will as far as possible account for these phenomena and reveal the principles of their organization and functioning, without attempting, for the present, to relate the postulated mental structures and processes to any physiological mechanisms or to interpret mental function in terms of ‘physical causes’ (Chomsky 1968, 12).

Without ruling out the possibility that mental processes can be related to the *res extensa* in a future unified theory of the nature of human knowledge, the current solution adopted by Chomskyan biolinguistics is to deal exclusively with abstract procedures of the mind underlying human language. In this perspective, the issue of duality, rather than being discarded, is simply evaded “opening a new chapter in the confusion of thought and language” (Loritz 1999, 9). However, there remains the problem that in this way a theory of mind, and one of the bodies in which it would

be instantiated, are segregated into watertight compartments. One also can conclude that one of the active components of the human mind can emerge from the study of *embodiment*, that *performance* is simply a mechanical execution of the algorithms of *competence* and that the latter does not play any creative cognitive role, apart from an accidental one, in the biology of language. And this, as we shall see, remains one of the unresolved problems in even the most recent developments of Chomskyan ideas in comparison with contemporary biological sciences and other competing philosophies of mind.

The second problem is epistemological and concerns the relationship with evolutionary biology and, more generally, with the philosophies of biology that appeal to Darwinism. In this case the conflict is even more obvious and insidious because Chomsky can mercilessly highlight some of the major mistakes of various Darwinian interpretations and, at times, it is difficult to distinguish between real issues and those arising from a questionable exegesis of the evolutionary method. Here we must distinguish between different stages of his thought.

In the first phase – the “Cartesian” one, which has been already discussed – Chomsky’s criticism of the evolutionary perspective is pitilessly levelled at the functionalist readings of evolutionism that do not take into account the story of the transformation of the structures but the evolution of functions. For example, Popper’s idea that human language evolved from more primitive systems (Chomsky 1968, 59 et seq.) and went through several stages, firstly from the lower ones of gesture and then to vocal gesture, and from the holistic language of emotions to articulated language. These positions appear even in the most recent theories on the origin of language (Corballis 1999 and 2002; Gentilucci and Corballis 2006; Mithen 2006; Arbib et al. 2008; Meguerditchian and Vauclair 2008, 2010; Zlatev 2008). Indeed, in some cases, scholars tried to reconstruct the evolutionary steps of the language faculty in a series of cognitive antecedents: joint attention, imitation and mentalizing abilities (Tomasello 1999; Arbib 2002, 2005, 2006, 2012; Donald 2005); the urge to cooperate socially (Tomasello 2008, 2014 and 2015); the orientation and the ability to navigate in space (Ferretti 2010, 113 et seq.; 2014, 2015); etc. Given these functionalist interpretations of Darwin, Chomsky would find it easy to point out their difficult theoretical practicability: it is not clear what relations there are between the cognitive development stages; on what basis one would track their continuity; what the mechanism by which we get from one stage to the other looks like and how it would work. In fact, according to Chomsky, in this case we are not competing between scientific perspectives based on experimental data or reconstructed events but simply facing a “metaphorical use of the term ‘language’” (Chomsky 1968, 59).

In fact, even before applying it to the term ‘language’, the functionalist theories, often implicitly, make a metaphorical use of the term ‘evolution’. It is not, in fact, possible to apply scientific methods of evolutionary biology to the study of functions. Evolutionary biology can study systematically, and with considerable profit, only the evolution of anatomy and physiology of organisms that cannot be gradual, relying on an infinite sequence of morphological transformations that are genetically hardwired. The study of the functions, on the contrary, occurs in a biological

space which is a-temporal, or in which the temporal dimension is suspended, being able to speed up or slow down suddenly with respect to variables independent from the structural constitution of the bodies. The functions, in fact, constitute a virtual projection of the possible applications of behavioral structures. This is not a behavioral determinism, in the sense that we are not obliged to hypothesize a matching two-way relationship between the structure x and the function y . It is, nevertheless, a causal relationship that remains chronologically causal: if the structures had not taken their specific constitution – one that we have elsewhere called a “bodily technology” (Pennisi 2014a, b; Falzone et al. 2014) – it would be impossible for organisms to manifest certain functions – including tout-court formal or mental technologies. Even if, analyzing them in advance, we could never say what function a certain structure would take on, we can certainly assume that the given function, that we are trying to understand the internal mechanism of, could never exist without the structure that now instantiates it. The fact remains that reconstructing the history of the transformation of the structures that, at a certain point of the process, have caused the emergence of a certain function, involves an enormous time dilation. On the contrary, measuring the time of the progress of a function starting from when the structure has potentially determined the function could well take a very short time. No one would dream of confusing the short time necessary for the establishment of the human locomotion with the long time required by musculoskeletal changes that have made stable bipedism.

As pointed out by Gould (2002, 251 et seq.), functionalist readings are partially explained by recognizing that, in connection with the concept of gradualism, Darwin himself is misleading, especially in his the *Descent of Man, and Selection in Relation to Sex* (1871) and, in particular, in the few pages dedicated to language in the context of mental faculties (see Sect. 5.3). That’s where – next to brilliant insights which we will return to later – in the Darwinian Vulgate, evolutionary hypotheses of functions, i.e. the evolution of the supposed mental abilities that would be behind the linguistic behavior, were generated. Darwin on this point seems to be a naïve philosopher rather than an authoritative biologist. His pages on language, which unfortunately are often the only ones to have inspired so many important contemporary exegetes, are pervaded by the ideological effort to demonstrate that human thought is derived from that of the other primates and that none of the mental faculties that seem unique to man actually are. The fear that one may lose the element of continuity between the animal and the human world – although that is an ethical ideal quite acceptable for a naturalistically oriented philosophy – leads Darwin to neglect the method he used for most of his works, a rigorous method based on the comparison of structures gradually evolved on the basis of modeling due to natural selection. Of course there is nothing wrong in comparing the functions into different animal species. This is still done successfully by a challenging branch of naturalist thinking: cognitive ethology. However, this is a discussion that may prove fruitful in a context of possible experimental comparisons, that is by adopting methods that do not make any use of pure speculation. The works by Michael Tomasello or Tetsuro Matsuzawa on social cognition of primates, amongst others, are now excellent examples that provide prospects for theoretical analysis

that are of tremendous interest to naturalistically oriented cognitive science. However, when the argumentative horizon becomes diachronic, especially in reconstructions of evolutionary biology, tracing functional autonomous paths runs the risk of becoming a speculative exercise, as Chomsky has been able to point out easily and repeatedly (Chomsky 1972, 1980, 1988; Hauser et al. 2014; Berwick and Chomsky 2016).

If we then conceive the study of the origins of language as the study of the transformations of the language faculty then, no doubt, criticism of Chomsky does not seem easily avoided. From this point of view, we believe that a strictly Darwinian biolinguistics should not deal in the first instance with the evolution of grammatical, syntactic or purely formal thought – that constitutes a chapter of human cultural history to be studied via the methodological tools of short chronologies and cognitive experiments – while it should confine its efforts to understanding how the systems interfacing between the vocal, acoustic, neuro-cerebral and cortical structures that regulate the functioning of language derive from the transformations of previous structures and the way they function: all steps of a very long gradual evolutionary path.

From this point of view, the second phase of Chomskyan thought, even within the framework of a rigorous basic coherence, seems to have changed little in nearly 50 years of confrontation with the biological sciences.

Even though there are many residual problems that render the two versions of contemporary biolinguistics still hardly compatible (a point which we will return to in Chap. 6), the critical assessment by Chomsky and his school of the prospects of Darwinian biolinguistics seems to focus more on *light* versions supplied by the evolutionary vulgate (evolutionary psychology, extremist adaptationism, neo-empiricism of paleoanthropology and cognitive ethology, etc.) than to the orientation of original Darwinism. In many respects, indeed since the eighties, Chomsky seems to profess a philosophy of language that does not look very different from the philosophy of biology of the latest evolutionary synthesis.

Certainly, his approach to these perspectives often highlights critical aspects that arise either when one considers unorthodox characters of the history of Darwinism such as Alfred Wallace or Thomas Henry Huxley, who had noticed inconsistencies in the hypothesis of evolution, or when one goes back to geneticists such as François Jacob, who introduced the topic of the constraints imposed by the dimension of the body on development, a theory followed by the contemporary Evo-Devo on the evolutive dimension or, finally, when one takes up evolutionary anthropologists such as Tattersal, or even eminent “revisionist” models such as Stephen Jay Gould or Stuart Alan Kauffman. In all these cases Chomsky’s criticism is not always directed at the method or the scientific spirit of evolution, but to what appears to be an evident inability to understand the nature and functions of human language (Chomsky 2005).

However Chomsky is different from many other improvised philosophers who criticize “biologism”, because no one can blame Chomsky for his scarce understanding and assessment of the contribution of the natural sciences (not only biology but also physics and chemistry) to human knowledge. He is also a skilled expert

of epistemology and philosophy of science. Finally, only few scholars in the twentieth-century can compete with him with regard to intellectual honesty in applying in practice the Popperian method of falsifiability of hypotheses. His bold defense of the principle of uniqueness of human language as a formal process of thinking must not be seen as descending from an anti-evolutionist ideological bias. Rather, as a linguist by profession, he is among the few who can boast of having an in-depth and technical knowledge of the object of his studies. Like Aristotle, Locke, Vico, Hume, and Wittgenstein, he is also a specialist who uses his philosophical expertise in the understanding of language as a form of extremely peculiar intelligence which human beings are not only capable of, but to which they are *naturalistically condemned*.

It is therefore quite obvious that this is the most important representative of the linguistic knowledge of the twentieth century and, in founding a decisive discipline such as biolinguistics as part of contemporary cognitive sciences, transfers to it the whole specific baggage of language sciences, including the irreducible conviction of the uniqueness of human language as a species-specific form of intelligence. We believe that, on this point, his contribution to the foundation of the natural sciences of language is crucial and indispensable. In the biolinguistics hypothesis we would like to propose here and which we believe is evolutionarily justifiable, one cannot neglect the formal specificity of language as “technomorphic thought” (Lorenz 1983) by which human cognition appears to us in many ways *measurably different* from that of non-human animals. Much of the criticism incessantly leveled by Chomsky to bad naturalist scholars, of the evolutionist type, who, without having specific knowledge, have adopted the dangerous hypothesis that considers language only as a tool (of thought, of communication, of symbols, of logical organization, etc.) and not a specific form of organic representation of the world (Chomsky 1968, 1975, 1980, 1993a, 2000a, 2002, 2005, 2007, 2011, 2013; Fitch et al. 2005; Hauser et al. 2002, 2014; Berwick and Chomsky 2016), can be adopted in the present work. It is not necessary (indeed it is against all evidence) to think that the biological and formal specificity of human language is anti-evolutionist (Penn et al. 2008, 121–3 and 164 et seq.).

In fact, even the hypothesis of a specific phenotype of human language as a basis for its latest biolinguistics hypothesis (Hauser et al. 2014; Berwick and Chomsky 2016), although produced as a result of the deceptive diagnosis of a substantial failure in current studies on the origin of language, now seems to admit that a theoretical evolutionary approach is licit. In this last important writing – which concludes a long research path developed gradually also by the Chomskyan school and extended to the territories of neuroscience, evolutionary genetics, ethology and cognitive paleoanthropology – Chomsky considers the Darwinian proposal an object that is “measurable” in terms of empirical and experimental investigations. And even if these have so far proven to be insufficient, one cannot say that in the future they will not reveal interpretive keys entirely worthy of being taken into account. What appears today is still a “mystery” and could gradually become a “problem”:

answering evolutionary questions is of profound interest largely because of our deep-seated curiosity about the past, about how things were, and how they have become what they are. Thanks in part to the revolution that Darwin sparked, including his ideas and methods, we now have many fine examples in which theoretical predictions about the origins and subsequent evolution of a phenotype have been described in great detail, including analyses of genomes, anatomy, and behavior. And yet some phenotypes remain poorly understood, and may remain so due to inadequate methods and impoverished evidence (Hauser et al. 2014, 8).

Chapter 3

The Last Chomsky and the Evolutionary Perspective

Initially, biolinguistics of the Chomskyan type developed an interest, albeit of a critical nature, in some aspects of evolutionism based on three key points: (1) language is a uniquely human mental faculty and one which is not manifested in any other species; (2) this faculty is primarily a formal property of the human mind, a Universal Grammar (UG) defined in terms of a species-specific cognitive process based on some unique computational operations characterizing *Homo sapiens*, that can be precisely enucleated and are powerful from the point of view of categorical, abstract and creative thought; (3) in so far as it is a formal property of the human mind, language must be thought of as a “mental organ”, and, accordingly, as: (a) an area of the brain or at least a *locus*; (b) an innate device wired in the human genotype; (c) an ontogenetic process manifesting absolute regularity in language use and learning.

Over the years this biolinguistic paradigm underwent significant changes, some of which, as we mentioned, have facilitated the development of a naturalistic research that is evolutionarily oriented, while other changes have increasingly steered research away from this framework. The basic stages of this process can be summarized in the birth of the minimalist program (Chomsky 1993b, 1995, 2002), the introduction of the distinction between “Faculty of Language in the Broad Sense” – o FL-B – and “Faculty of Language in the Narrow Sense” – o FL-N – (Hauser et al. 2002) and, finally, in the detailed definition of a specific phenotype of language (Hauser et al. 2014).

The minimalist program was established with the aim of permanently deleting all the elements that filled the gap between the descriptive adequacy and explanatory power of a linguistic theory from the study of language.

In the initial phase of linguistics, Chomsky had shown that the more you tried to develop the former, the more you weakened the latter. Any attempt to propose a specific generative rule, in fact, generated a huge amount of counterevidence and to explain them away, it was necessary to formulate a system of accessory rules that were so uneconomic from an epistemological point of view that they ran the risk of

encouraging the idea “that language variation was so free that nothing of much generality was likely to be discovered” (Chomsky 2005, 7).

In the framework of the Principles and Parameters Theory (P&P), underlying the minimalist program, the biolinguistics hypothesis acquires generality and abstractness losing specificity. From the evolutionary point of view, this epistemological shift allows greater openness when one is confronted with the cognitive abilities of non-human animals. In the more recent formulations the importance of this turning point is strongly emphasized: “so what has changed? For starters, linguistic theory has matured. Complex linguistic rule systems are now a thing of the past; they have been replaced by much simpler, hence more evolutionary plausible, approaches” (Berwick and Chomsky 2016, 2). The comparison between different species is extended to faculties that can also play a role in cognitive processes different from language and which were potentially its forerunners.

The distinction between FL-B and FL-N allows us to get closer to the evolutionary prospects. The FL-B, in fact, would include the sensory-motor system and the intentional and conceptual one. However, the FL-N would include only the recursive computational system and is the only element of the faculty of language that would remain exclusively human (but see, *contra*, Christiansen and Chater 2015; Paap and Partridge 2014). Specifically, it is responsible for generating internal representations and map them to the sensorimotor interface via the phonological system and to the conceptual and intentional interface via the semantic system.

The most recent hypothesis (Hauser et al. 2014; Berwick and Chomsky 2016) seems to finally rethink completely the evolutionary approach, re-opening issues always considered impossible (or unnecessary) to be treated satisfactorily, such as the origin of language.

It is in this new context of problems, however, that the two roads of biolinguistics (Chomskyan and Darwinian) continue to diverge, at least for now. The crucial point now seems to revolve around the unifying cognitive role of corporeality in instantiation but also the genesis of any mental process of human beings or animals. It is the boomerang effect of a difficult and unsolved relationship with dualist sirens, which, as we saw before, has weakened the “biologicistic” Platonic-Cartesian philosophy of mind by Noam Chomsky.

As a consequence of this original sin, the philosophical evolution of the Chomskyan biolinguistic paradigm has undergone ambivalent modifications during the confrontation with Darwinian perspectives. If the path from the sixties until the fulfillment of the minimalist program has opened the doors to an abstract theory of mind more oriented to understand the cognitive functions of non-human species, on the other hand it has reduced spaces for an interspecific comparison of structures. The price of raising the threshold of abstraction of the theory is a progressive reduction of its controllability at the level of structural morphology, which we believe to be the right, and probably the only realistically viable path of scientific analysis in evolutionary biology.

3.1 The Externalization Devices

The first price to pay is the progressive loss of theoretical specificity of what Chomsky calls SM (sensorimotor system) and CI (conceptual-intentional system) that, since Aristotle, have characterized the connection system relating sound to meaning (Chomsky 2005, 10). In computational biolinguistics, which initially regarded them as “peripheral organs” (Chomsky 1966, 52), i.e. morphological correlates of language, these devices could be studied independently and, indeed, “comparatively” (Chomsky 2005, 10), because they are reducible to general properties of the interface systems and to considerations of computational efficiency. In fact, they are not specific to UG: “language-independent principles” (9). Thus, they do not contribute in any way to the uniqueness of the “Faculty of Language in the Narrow sense” (FLN). Any comparative empirical study can never prove an interaction in terms of the creation of cognitive processes between the interface and abstract recursive operations of the organ of language.

In his latest formulations (Berwick and Chomsky 2016, 2), sensorimotor and conceptual interfaces, albeit with different roles, tend to appear more and more like simple *externalization devices*. They amount to structural devices, biological components associated with language, which are entirely secondary (70–71) and virtually interchangeable, allowing the internal syntax of language, the only *computational core* of the linguistic organism, to come out and materialize out of the mind. According to this hypothesis, we should, in other words, think “[the] externalization of narrow syntax, like the printer attached to a computer, rather than the computer’s CPU” (Berwick and Chomsky 2016, 9; see also pp. 72 and 108).

This recurrent and inopportune metaphor is applied to both the input/output system of learning and vocal production and to that of semantic conceptualization. It also embodies and confirms the old AI hypothesis that founded the first cognitive computationalism on the arbitrariness of symbols and theoretical delegitimization of the instantiation of software procedures in a specific hardware. For strong AI supporters (Woods, Winograd, Marcus, Hirst and many others) the nature of the symbols used, the hardware manipulating them, the bond between the symbols and their interpretation are equally insignificant (Haugeland 1985, 4 et seq.): the real problem of intelligence simulation lies in the structure of the software and in the syntactic processing rules of the symbols. It is a real revival of the Turing model:

to understand the Turing model of the brain, it was crucial to realize that it considered the physics and chemistry, including all the arguments of quantum mechanics [...], as essentially irrelevant. From his point of view, physics and chemistry were relevant only as substantiated the element that incorporated discrete elements, ‘reading’ and ‘writing’. Only the logical pattern of these ‘states’ could be really significant. The claim was that whatever a brain did, it did it by virtue of its structure as a logical system and not because it was in the head of a person, or is a spongy tissue made up of a particular type of biological cell formation (Hodges 1983, 16).

Similarly, for Chomsky, the externalization systems for vocal learning and production and the semantic-conceptual ones have nothing to do either with the

functional definition of a species-specific morphological structure or with the problems involved in the reconstruction of the evolutionary picture.

Actually, from the evolutionary viewpoint, the arguments used by Berwick and Chomsky on this point are not clear or straightforward. The statements of principle, in fact, seem entirely relevant to an orthodox Darwinian approach, but their applications are rather contradictory or, at least, ambiguous. For instance it is absolutely true that:

here is sometimes an unfortunate tendency to confuse literal evolutionary (genomic) change with historical change, two entirely distinct phenomena. (...) Confusion about these matters could be overcome by replacing the metaphoric notions ‘evolution of language’ and ‘language change’ by their more exact counterparts: *evolution of the organisms* that use language, and *change in the ways they do so*. In these more accurate terms, emergence of the language faculty involved evolution, while historical change (which continues constantly) does not (Berwick and Chomsky 2016, 83, *italics added by author*).

However, the application of these strong evolutionary principles is completely reversed when applied just to externalization devices. These would be the “key biological components associated with language” and they “have been clarified biologically and genetically” (Berwick and Chomsky 2016, 2).

One would expect, therefore, that such devices (to use the scheme proposed by Chomsky) are regulated exactly by “*evolutionary (genomic) change*” and they regard the “*evolution of organisms that use the language*”: that is “*the emergence of the language faculty (which) involved the evolution*”. Conversely changes in ways of intellectual acting, cognitive changes, right down to the grammars of historical natural languages that occupy the minds of humans, should be governed “*by the historic change*” concerning the “*changes in the ways in which (human) do*” and undoubtedly belonging to the domain of continuous historical and cultural variation.

Instead according to Chomsky, it is exactly the opposite. Biological evolution (genomics) affects only mental resources (cognitive, intellectual, computational, cultural?) and takes place through a biological sudden leap, an unexpected mutation, as we will see in (Sect. 3.3). While bodily language technology might even never have evolved:

we have no reason to suppose that solving the externalization problem involved an evolutionary change – that is, genomic change. It might simply be a problem addressed by existing cognitive processes, in different ways, and at different times. (...) If they are generally on the right track, it follows that externalization may not have evolved at all; rather, it might have been a process of problem solving using existing cognitive capacities found in other animals. Evolution in the biological sense of the term would then be restricted to the changes that yielded Merge (Berwick and Chomsky 2016, 83).

Even from the viewpoint of the general theory of language it seems that there is not a well-delineated cognitive space for externalization devices. Just as the history of evolution has produced many discoveries and inventions, so it has produced “even invention of modes of externalization (as in sign language)” (83). Combining the exhumation of computational arbitrarism and Saussurean and structuralist perspective of a general semiotics – all radically anti-biological orientations – Chomsky

loses any chance to understand the evolutionary history that has biologically selected the verbal language making it a phylogenetic structure permanently available for all mankind. A structure which is capable of evolving cognitive processes and generating historical-natural languages that produced semiotic cultures from which the different national sign languages derive. Instead – according to a completely artificial reconstruction of evolutionary processes – externalization becomes a totally relativistic and conventional system of the pure coding of signs. “Externalization – indeed – can apparently be carried out via any sensory modality – sound, sign, or touch (thankfully, smell appears to be absent from this list)” (Berwick and Chomsky 2016, 11–12). In particular, according to Chomsky, the arbitrariness of the externalization processes seems to be well demonstrated by studies in the area of language of signs in recent years according to which:

the structural properties of sign and spoken language are remarkably similar. Additionally, acquisition follows the same course in both, and neural localization seems to be similar as well. That tends to reinforce the conclusion that language is optimized for the system of thought, with mode of externalization secondary. Note further that the constraints on externalization holding for the auditory modality also appear to hold in the case of the visual modality in signed languages (Berwick and Chomsky 2016, 74–5).

It is important to note right now that the reinterpretation of the problem of signed languages plays a crucial role in defining the notion of externalization by playing down the importance of the specificity of FOXP2 gene in a general theory of the functioning and the origin of language. FOXP2 and sign languages, in fact, would be linked by the fact that even the deaf and deaf-blind with no abnormalities in FOXP2 may acquire language and have no difficulty in producing phonemes or series of marks in a serial order.

It is no coincidence, then, that the FOXP2 is involved even in the latter case concerning the externalization problems in the reconstruction of the evolutive picture. The FOXP2, in fact, is a really complex regulatory gene which is also involved, amongst other things, in controlling narrow sensorimotor processes (e.g., the production of articulate speech or manual disassembly of clock hands through small screwdrivers or tweezers) that underwent an exclusively human, final mutation, around two hundred thousand years ago. This fact can now be considered definitively acquired. It makes a difference, in the overall theoretical interpretation, to understand the sequence of evolutionary changes. The last mutation of the FOXP2 could, in fact, be regarded as the cause, or one of the causes, of the structural possibility of forming the articulatory capacity or a need to render externalization more efficient in view of the needs required by a mutation of the purely mental type. Berwick and Chomsky seem to favor the latter approach but, by also weakening the possible success of the other solution, they recognize the evolutionary legitimacy:

it is difficult to determine the causal sequence: the link between FOXP2 and high-grade serial motor coordination could be regarded as either an opportunistic pre-requisite substrate for externalization, no matter what the modality, as is common in evolutionary scenarios, or the result of selection pressure for efficient externalization ‘solutions’ after *Merge* arose. In either case, FOXP2 becomes part of a system extrinsic to core syntax/semantics (Berwick and Chomsky 2016, 77).

We will soon return to the decisive role played in Chomsky's biolinguistics by the mental operation *Merge* in the evolutionary dimension. Here it is, however, worth noting that the main interest of Chomsky's biolinguistics is entirely focused on the exclusion of externalization from any functional process decisive to the functioning of human language and/or its causal primacy in the evolution of human nature.

From this point of view, Berwick and Chomsky strongly insist on coupling the animal vocal learning and production systems with human ones. In particular, in the case of birds, the ability to emit modulated – but, in our view, not “articulated” (see below Chaps. 9 and 14) sounds – can only be seen as a “homology” which excludes immediate kinship lines. Chomsky relies on this delicate point on a “personal communication” that Michael Coen passed on to him, arguing in a yet unpublished research report, that not only all the mammals tested by him (humans, dogs, cats, seals, whales, baboons, monkeys tamarinde, mice) but also vertebrates that are not evolutionarily related (crows, finches, frogs, and others), were held to have vocal skills so far attributed to the human externalization system. Each of these species seems to present “a finite set of distinctive phonemes” (or, more accurately, ‘songemes’ – 2016, 78). In order to substantiate this very strong position against any evolutionary evidence, it is, above all, necessary to see the phonemes produced by the voice connected with the physiology of each species. In this case, Berwick and Chomsky resort to the notion of “quantum nature of vocal production” of Stevens (1972, 1989), that is to say to the purposive use of a subset of vocalizations produced by an individual species selected from a wider set of combinations of sounds. This would lead to the idea that each species is endowed with specific articulatory possibilities that are completely independent of the cognitive system. Basically all species would exhibit different ways of externalizing by means of their own sounds to a series of “internal” elaborations unconnected with the systems of I/O (vocal and conceptual-semantic) being adopted.

If the FOXP2 “is not so much part of a blueprint for internal syntax, the narrow faculty of language, and most certainly not some hypothetical ‘language gene’ (just as there are no single genes for eye color or autism) but rather part of a regulatory machinery related to externalization ” (Berwick and Chomsky 2016, 76), it remains to be seen what other tasks normally involved in language, in addition to the one typical of vocal articulation, should be attributed to variable and not exclusively human processes of externalization.

In order to tackle this issue it will be good to distinguish between problems we classify under the lexical and semantic label and those of a strictly syntactic nature, for which, as we shall see in the next section, it is not always clear whether we should place them inside or outside the core of the language faculty.

We have no doubts about lexical-semantic issues: they are regulated by externalization interfaces CI (conceptual-intentional system). The conceptual frameworks are not an exclusive human prerogative. Other primates are capable of categorizing the elements of reality external to the mind: representations of agents, actors, actions, goals, plans, number distinctions etc. These structures were “presumably recruited for language” but in human beings they are particularly rich, while the last

elements of the syntactic computation – lexical items – “appear to be uniquely human” (Berwick and Chomsky 2016, 84). Chomsky interprets this point starting from a linguistic philosophy strongly indebted to Platonic idealism, not only because he thinks that between the words-concepts and external reality there is no reference relation (in the sense of Frege’s philosophy of language or of the philosophy of Peirce, Tarski, Quine) but mostly because he believes, citing the neo-Platonist Ralph Cudworth, that “it is only by means of the ‘inward ideas’ produced by its ‘innate cognoscitive power’ that the mind is able to ‘know and understand all external individual things’” (Cudworth 1731, cit. in Berwick and Chomsky 2016, 85): the atoms of computation are reminiscences. Communication, which is not considered the main function of language, is not based on the exchange of information converging on external objects, but on the common sharing of these cognitive powers: it is an attempt to produce events in recipients seeking a common reminiscence. From a comparative point of view, human semantics offers us a world of experience different from that of other animals: whence the myth, religion, magic, philosophy, and science, too, which always remains a normative ideal, a semantic attempt to produce things with the hope that it will “pick out some real thing in the world” (86).

We will see later (Chaps. 9 and 14) how this reconstruction of conceptual externalization can be integrated – albeit not without difficulty – into a picture of evolutionary reconstruction. For the time being, we arrive at a first conclusion: all biological components of the organism of human speech that Chomsky has circumscribed in the area of externalization do not contribute to the generative processes of the faculty of language in any strict sense. Linguistic articulation and conceptualization do not contribute to its formation, but are simply arbitrary tools confined to projecting the incessant work of the internal syntax of linguistic mind to the outside world. In the last biolinguistic proposal by Chomsky, the FLN syntactic engine has relegated other properties of the UG (Universal Grammar) to externalization processes which had previously regulated the operation of transformational-generative syntax. We will see below which ones.

3.2 Computational Processes of the Linguistic Mind

First of all, reordering processes (those which in the first transformational-generative grammar were called “transformations”), definitively disappear from the domain of internal grammar, being relegated to parametric data: “ordering is restricted to externalization of internal computation to the sensorimotor system, and plays no role in the core syntax and semantics, a conclusion for which there is also accumulating biological evidence of a sort familiar to mainstream biologists” (Berwick and Chomsky 2016, 69–70. See also Chomsky 2013, 36: “order and other arrangements are a peripheral part of language, related to externalization solely at the SM interface”).

Secondly, compositionality, in addition to projection, or “labeling”, seems to be excluded from the syntactic internal processing, while the movement properties

(*Move*) are the ones that undergo the most troubled process in the evolution of Chomskyan hypothesis.

Actually it is no surprise. It has always been the case that the Chomskyan theoretical hypotheses put forward at various stages have considered surface structures as variable ways of realizing deep structures. Trace theory, which for a short period has been quite successful, especially when it was incorporated into fundamental neuroscientific studies of aphasia by Grodzinski (2000, 2006a, b), has never denied this relation of hierarchical incorporation. However in the case of Chomsky, who has been more involved in confrontation with the evolutionary hypothesis, confining the problems related to the constraints on order within the domain of externalization, has probably led to the abandonment of the centrality of one of the two central tenets of the *computational core* of language: the operation *Move*.

In the first minimalist hypothesis (Chomsky 1995) *Merge* and *Move* constitute two major operations of narrow syntax. *Merge* is a binary function of fusion endowed with recursive properties. It operates when two syntactic objects are combined to form a new syntactic unit. Its recursiveness consists of the fact that the syntactic objects can be, in their turn, products of *Merge*. A function of this kind, being able to apply to itself, starting from a finite number of elements (at least two), can give rise to an infinite series of additional merge operations, in a similar manner to what happens in the Peano axioms for natural numbers ($x = x + 1$). All representational power of language is seen to derive from this single basic computational operation:

$\text{Merge}(x, y) = [xy]$; $\text{merge}(k, [xy]) = [k[xy]]$

e.g.: (1) $\text{merge}(\text{Mario}, \text{love}) = [\text{Mario loves}]$; $\text{merge}(\text{Mario loves}, [\text{Mario loves}]) = [\text{Mario loves Mario loves}]$

Assuming you attribute recursively to x the result of k (1) – so $x = k$ (“Mario loves”) – and a second element $y = “Silvia”$, we could have as a subsequent reiterative application:

$\text{Merge}(x, y) = [xy]$; $\text{merge}(k, [xy]) = [k[xy]]$

e.g.: (2) $\text{merge}(\text{Mario loves Silvia}) = [\text{Mario loves Silvia}]$; $\text{merge}(\text{Mario loves Silvia}, [\text{Mario loves Silvia}]) = [k[\text{Mario loves Silvia}]]$

At this point k ($\text{Mario loves Silvia}$) can expand itself virtually in an indefinite way incorporating syntactic objects of all kinds (e.g. articles, prepositions, adverbs, etc.) in a linear chain. The final sentence, eventually, can become a syntactic component of other sentences that are accumulating only through the application of the recursive property.

The function *Move* has an interesting story because it cannot be rigidified in a computational flow. It manifests itself as a kind of empirical (descriptive and explanatory) emergency resulting from the fact that some syntactic objects, present in an “internal” pattern of syntax, can be “distant” from the central core, e.g. in the interrogative sentence:

(3) [w] Do you believe that Mario has doubted that Silvia has met [w]?



To incorporate *Merge* [w] in a structure (which could be, e.g., a martian, a ufo, a vampire, a zombie) one must assume a moving of [w] into the first position. This complicates the computational operation because all the syntactic structure so far produced may be parsed and, in part, reducing the economy of the potential Markovian Process *Merge* (on the controversial issue see: Uriagereka 2008, 2012). The history of the operator *Move* reflects this oscillation between the conflicting requirements of descriptive efficacy and stochastic cleaning.

Al Mutairi (2014, 39) writes: “the operation *Move* did not enjoy ontological stability within minimalism”. Repeatedly, Chomsky (1995, 2000b, 2005) warned us about the complexity and the difficult computational tractability of *Move*. In a remark dating back to 1996, the operation *Move* was defined as an “*imperfect element*”. It should be avoided for reasons of cleanliness of the software architecture, it should be considered, in short, “*a last resort* chosen when nothing else is possible” (Chomsky 2000b, 101–2. See also Boeckx 2006, 66 et seq.).

There is, however, an essential natural element in that operation, which one cannot easily give up. The dislocation operations are omnipresent in historical natural languages. A language without underlying movements is impossible not only to observe but also, perhaps, to conceive. In Chomsky 2005 reconsidering the whole question, Chomsky stresses that property of language is essential and cannot be given up, especially when he says “that property had long been regarded, by me in particular, as an ‘imperfection’ of language that has to be somehow explained, but in fact it is a virtual conceptual necessity” (2005, 12). From the point of view of the structure of natural languages, in short, “*Merge* and *Move* are two sides of the same coin” (Al Mutairi 2014, 40).

Despite this, oscillation on the theoretical status of *Move* persists. Chomsky – following an intuition formulated in 1993 that the operation MOVE should always try to build “the shortest link” to deduce a “principle of economy of derivation” (Chomsky and Lasnik 1993, 90) – at least tries to limit the damage to the cleaning of computational processes. He hypothesizes, thus, limits (delimiting the processes through phases, i.e., fixing controllable and limited points for the dislocation of elements in sentences) to the need for the extension of movements. In a paper written in 2013 (*Problems of projection*) he finally seems to reassess the status of all the fundamental properties of language in the light of the experiences pursued with the minimalist choice. The minimalist program, opening the door to a confrontation with evolutionary theories, in fact, provides a maximal effort to simplify the computational devices of language:

core properties of concern have included compositionality, order, projection (labeling), and displacement. Early work assigned the first three to phrase structure rules and the last to the transformational component. Simplification of computational procedures suggests that compositionality and displacement (along with the “copy theory”) fall together while order may be a reflex of sensorimotor externalization, conclusions that have far-reaching consequences (Chomsky 2013, 33).

By Chomsky’s own admission, what led to such a drastic simplification of the computational procedures, virtually reducing *Merge* solely to the formulation of *narrow syntax* and substantially rejecting everything else in the externalization pro-

cesses – the “strong minimalist thesis” (Berwick and Chomsky 2011, 30) – is precisely the need, which has become indispensable with the rise of the importance of the Darwinian biologicist paradigm, to explain the origin and evolution of language (Chomsky 2013, 37).

In this context, what Chomsky cannot admit is the non-existence within the evolutionary paradigm of a precise conception of language, the refusal to take into account its specific nature and its lack of distinctions with respect to “a constellation of factors that have independent functions, not an object of serious scientific inquiry in itself” (Chomsky 2013, 34; see also Berwick and Chomsky 2016, 83). Among its main targets – as we saw in the previous section – there is functionalist gradualism, neoculturalism as developed by Michael Tomasello, the variationists and all those who confuse the communicative and representational functions with the proper cognitive functions of language. Their hypotheses were “dramatic failures” to understand the nature of language: “all of these approaches share the conception of half a century ago that there is no such thing as language in any serious sense” (Chomsky 2013, 34).

In response to this kind of “linguistic negationism” (see Pennisi and Falzone 2010, 51 et seq.) Chomsky is willing to embrace a critical form of modern evolutionism like the Evo-Devo, interpreting it in a very special way and certainly not at all from orthodox point of view. The aim is the maximal possible reduction of the theoretical weight of variationism and the search for uniforming convergences at all levels, going as far as to seriously imagine that he can reasonably share the proposal that there may have been a “universal Genome that encodes all major developmental programs essential for various phyla of Metazoa that emerged at the time of the Cambrian explosion half a billion years ago” formulated by biochemist Michael Sherman, 2007 (see also Berwick and Chomsky 2016, 126). This is a species of single multicellular animal from which all the infinity of different life forms would arise, on the basis of one variation of a common *set* of genetic tools (Carroll 2005).

As we shall try to show in Chap. 9 and Sect. 13.3, what is missing in this acceptance of Evo-Devo is the more biologically substantial part, namely the detailed theory of the specific constraints of the structures that the shape and development laws determine, without any specific project, the functional evolution. For now we are interested in pointing out that it is leaning precisely towards a simplified, but clear, model of evolutionary perspective which leads Chomsky’s minimalism to the shores of the more austere simplification of the computational core of a new Universal Grammar, until eventually, only the *Merge* operation remains.

3.3 A Micromutation and in an Instant the “God-Language” appears

We have already said that *Merge* is the basic operation of *narrow syntax*. It is at the heart of language and determines inner language. As a generative mechanism, it is really simple: it combines two elements (A, B) into a third (C) and does so

recursively, that is, being able to apply again and again to an element derived from previous “mergers”. *Merge* is said to be external if A and B are already external elements, internal if A is combined with B, and B contains D with which A had already combined. That’s all!

But does the language faculty do just this and does it need such simple operations? The question admits a twofold answer. Yes, if we consider that the mental-computational component of language is the one really relevant to its definition. The rest, as we have seen, is a purely secondary process and not specific to externalization. The answer is negative, instead, if we extend its *embodiment* to the notion of language. In this case the person who produces utterances is no longer the mind but the whole organism that thinks in a certain way because his whole body (including the brain) is made in a certain way and not in another.

Whether it is considered appropriate to define the evolution of language changes depends considerably on the two different responses that we gave to the previous question. In fact, if we believe that the hallmark of language is the continuous generation of fusion procedures of syntactic elements in the mind-brain, then we have to date the origin of language at the time when this capacity was made possible, independently of the rest of structural, social and cultural evolution. If, on the contrary, we identify a consequentiality relationship between the possession of body structures capable of externalization (to stick to Chomskyan terminology) and brain structures capable of producing computational (or mental) processing of signals, then we must first establish the time required to effect the transformations of the structures and then the time in which the brain has learned to recable itself to adapt the software to the peripheral hardware. Which of the two forms of biolinguistics exists, depends on the diversity of such routes.

Chomskyan biolinguistics favors the first solution. The Darwinian form opts for the latter. Here we notice the widest gap between the two roads taken: nothing could be more different from an evolved Darwinian system than the one imagined by Chomsky. In the history of evolution he proposes, the reconstruction of the process whereby language emerges never appears to be in the least compatible with any of the assumptions of the Darwinian type:

with *Merge* available, we instantly have an unbounded system of hierarchically structured expressions. The simplest account of the ‘Great Leap Forward’ in the evolution of humans would be that the brain was rewired, perhaps by some slight mutation, to provide the operation *Merge*, at once laying a core part of the basis for what is found at that dramatic ‘moment’ of human evolution (Chomsky 2005, 11–2).

in some completely unknown way, our ancestors developed human concepts. At some time in the very recent past, perhaps about 100,000 years ago, individuals in a small group of hominids in East Africa underwent a minor biological change that provided the operation *Merge* – an operation that takes human concepts as computational atoms, and yields structured expressions that systematically interpreted by the conceptual system, provide a rich language of thought. These processes might be computationally perfect, or close to it, hence the result of physical laws independent of humans. The innovation had obvious advantages, and took over the small group. At some later stage, the internal language of thought was connected to the sensorimotor system, a complex task that can be solved in many different ways and at different times (Berwick and Chomsky 2016, 83–4).

We wanted to literally report these Chomskyan ideas about the origin of language because we were surprised by the contrast they reveal between the sumptuous richness of linguistic philosophy so far voiced and the oversimplification of evolutionary reconstruction. As already noted by Michal Tomasello, language cannot be the result of a “bizarre genetic mutation unrelated to other aspects of human cognition and social life” (1999, 94).

We would like to add here that there is no reason why an accurate and serious conception of the language faculty (which Chomsky is quite right in vindicating given the post-Darwinian oversimplification) should conflict with an equally serious and profound idea of evolution. In fact, the hypothesis of a cognitive species-specificity of human language is not at all incompatible with a strongly gradual development of evolutionary history that led to *Homo sapiens*. All the arguments that Chomskyan biolinguistics uses in favor of a hypothesis favoring a drastic evolutionary leap are due to the artificial separation he proposes between the development of the two technologies, the corporeal and mental, between structure and function, which, in fact, co-occur in the human linguistic machine. The human organism, indeed, is always one, and the fact that one adopts a scheme of convenience to distinguish the evolution of the structures from that of the functions or, in other versions of contemporary naturalism (eg. that of Tomasello 1999, 2014), biological from cultural evolution is one of the main sources of confusion in contemporary biolinguistics (Pennisi and Falzone 2014, 220, 235, 270 et seq.).

We shall go into the details of these problems in the third part of the book, but one must immediately recognize that, contrary to what many believe, Chomsky has made many steps towards an in-depth account of the reasons of modern evolutionism, often contributing to its critical revision. For example, he has placed great emphasis on the ability to take a third way between fundamentalist gradualism and Goldschmidt’s “monster”, that is an evolutionary process which should be accomplished within a single generation. The Darwinian idea, then prosecuted by Fisher in a radical way, was that evolution may not always be the result of continuous “micromutations”. Over the years, however, it has been noted, that if the evolution indeed proceeded like this, it would end up in a loss of advantages due to the stochastic nature of biological evolution, i.e. the randomness of factors and genetic drift involved in the phenomena of diffusion of mutations in a pool of genes. Here, Chomsky seems to strongly believe that this excessive tension between continuity and change, underlying continuous paradoxes, can be resolved. A “secure middle ground” (Berwick and Chomsky 2016, 36) would be the one proposed by Orr (2005) according to whom the evolutionary process would occur in waves: first we notice the innovations caused by greater impact mutations, then, in succession, we notice those of minor impact. “One can picture this kind of evolutionary change as the successively smaller rebounds of a bouncing ball, where the largest bounce comes first – a sequence of diminishing returns” (Berwick and Chomsky 2016, 36). As evidence for this process Chomsky uses paleoanthropological studies by Tattersall demonstrating that innovations (eg. lithic technologies or the use of fire) are not immediately associated with the birth of a new species of hominids, but intervene only much later. Essentially the innovations do not follow a gradual development,

and arise “independently of the functions that they will be eventually selected for” (39). This is a framework fully compatible with the idea of *exaptation*, introduced by Stephen Gould.

For those who do not adhere to the strict and systematic practice of distinguishing between the problems of structural changes (anatomical systems) from those of the function change (direct adaptation to a purpose), the temptation to immediately apply this theoretical framework to language is, of course, irresistible. And Chomsky has no reason to abstain from that. The sudden appearance of *Merge* that we first described and that would be due to a rewiring of the brain following a slight (and mysterious) mutation, presupposes that the sensorimotor externalization and conceptual apparatus came before that “*dramatic ‘moment’ of human evolution*”. This would be the case for the genetics of FOXP2 that, in human form, has existed for 200,000 years, but it is a very ancient structure and common to all vertebrates. The same applies to the lexical-conceptual dimension, but here there are not very clear positions.

It would seem, as we have already seen, that the mysterious development of human concepts, in fact, can have preceded the inception of *Merge*. Even before *narrow syntax*, therefore, cognitive categorization departed markedly from that of other primates. If this were the case, however, we should admit that the recursive leap presupposed by *Merge* enhances but does not base the cognitive revolution of *Homo sapiens*. The “human” concepts (not the forms of animal categorization) may be generated independently of a combinatorial and recursive computational procedure. But, putting things differently, what is it that caused these pre-recursive “human concepts” and these “conceptual atoms of the lexicon”? (Berwick and Chomsky 2011, 30).

Are we only dealing with vocal elements associated with meaning and of syntactic type, but not characterizable by the property of recursiveness? Or with purely mental constructs but of the holistic type? Or, again, with purely symbolical representational entities? The question is particularly delicate and insidious (see Bouchard 2013, c.I; Hurford 2014, c.II; Tallerman 2014, 208 et seq.), both from a theoretical point of view (in what sense can we speak of a pre-linguistic thought which is not based on lexical aspects?) and from the point of view of reconstructive and evolutionary biolinguistics (what is it that distinguishes human speech from that of other species if we disregard voice and articulateness and the presence of a lexicon?).

The scheme that Chomsky would like to apply is to interpret Evo-Devo in a very special way: there has always been a tool-kit for vocal and semantic learning consisting of “a (conserved) package of perhaps 100-200 or so gene specializations, no matter what the species, that can be ‘booted up’ quickly and so evolved relatively rapidly” (Berwick and Chomsky 2016, 45). Then all of a sudden, and by pure chance, there is a small brain mutation that causes *Merge* and suddenly the FLN comes into being and, with it, the immense complexity of human nature.

What we believe to be the main problem for this bold project, which is very far from the Evo-Devo contemporary philosophy, as we shall see in Sect. 13.3, is that the computational operations of the brain and the products of externalization structures are clearly kept separate. Berwick and Chomsky (2016, 2 et seq.) employs a

“divide and conquer” strategy in adopting a tripartite epistemological scheme that tackles the problem of understanding the functioning and evolution of: (1) cognitive systems (the CPU of human syntax); (2) externalization of sensorimotor systems; (3) conceptual/semantic interface systems – such a scheme loses any methodological value to become the true ontology of the FLN.

However, as was correctly noted, linguistic categorization is impossible without the lexicon and, without lexical categorization, in turn it is impossible to apply *Merge*: “the lexicon must be the critical starting point for building the syntactic engine, since without lexical items, there is nothing to merge” (Tallerman 2014, 208). It is, in fact, a unitary and indivisible process. The Chomskyan solution appears not feasible; it is completely abstract. No explanation is given of how the internal conceptual atoms could be transformed into words with the advent of *Merge*. “What kind of language, then, would occur without externalization?” (209). Furthermore, a language consisting of internal conceptual atoms could never be selected for various reasons. The most important of which is that lacking direct evolutive advantages those connected with more efficient defense and greater reproductive capacity (like the formantic deepening of the voice in the *body size exaggeration theory* by Fitch 2002 – here discussed in Sects. 9.1 and 14.2), human beings should improve fitness by optimizing social communication (e.g. requiring more cooperative attitudes, strengthening collective hunting strategies or other socially relevant activities, interactive learning processes as “shared attention” – all analyzed by Tomasello (1999, 2008, 2014 and 2015). But how can all this happen if it is an internal language that makes thought possible, although it is a thought that is not expressed and/or expressible?

The possibility of social use of any type of signs is also connected with a last crucial problem that is not resolved by the Chomskyan explanation of the origin of the FLN. This is the problem of the compatibility of the entities (in this case the internal conceptual atoms) that can be subjected to the *Merge* procedure. In a purely computational vision, a simple absolutely powerful algorithmic function, such as *Merge*, cannot process any kind of input. It is necessary to consider *a priori* the incoming data class as a set that is mathematically decidable: only this will produce lists that are recursively enumerable (Lo Piparo 1974), allowing the procedure to make any kind of infinite calculation. Are the internal conceptual atoms included in this type of data? You cannot answer this question *a priori*. If we consider pure computational processing, it is certainly possible to consider such a possibility. However, if the process involves not abstract computation, but a procedure that has adaptive value because it would allow individuals capable of exercising it to gain advantages, then it will be very difficult to imagine such a way. If, in essence, the products of the *merge* serve social communication through the production of complex entities endowed with senses – eg. expressions or phrases – then the compatibility of the entities must be ensured by the mechanism of understanding the meanings. It is in this case that the problem of compatibility arises: “it is not enough merely to have an operation list that merges items; we also need items that are able to be merged” (Tallerman 2014, 209). In the polished, but not reproducible world of the internal atoms of thought, this semantic filter can be considered secondary. But

if you try to reconstruct the concrete origin of lexical processing, then the internal rules will be performatively contracted and previously filtered by the social and externalized usage of language.

This path, being continuously in operation, makes every single combinatorial step compatible and, at the end, ensures the compatibility of the whole set of steps that will not legitimize their existence (even nonsensical sentences are “allowed” to exist) but be advantageous in their social and adaptive use.

In conclusion, therefore, any type of lexicon already implies the systematic and social use of articulated sounds emitted by specialized vocal and auditory structures and controlled by sophisticated neuromotor systems. The phonetic and lexical processes demand and imply an overall complex evolution, in which constancy of phonetic and lexical precision, allowing the categorical selection to constitute its beginning. To quote the words of Donald Loritz: “this ability to suppress irrelevant detail and place the objects and events of life into the categories we call *words* is near to the essence of cognition” (Loritz 1999, 109).

Then compared to the computational model of a Chomskyan biolinguistics that admits leaps in evolution, here a different possibility could be envisaged, a new and unexpected question: what if it was the vocal articulation and conceptual categorization that determined the fate of computational procedures? What if it was just the beginning of learning and the production, not only of discrete vocal signals, but also of signals combinable in phonological and semantic units that caused an adaptation of brain plasticity to the possibility of *narrow syntax*? And what if, in fact, the latter was not the cause but the ontogenetic and evolutionary consequence of the possibility of realizing combinatorial and recursive applications starting from structural apparatuses, slowly modified in the endless period of antiquity, and which have reached a specific degree of bodily technology?

Chapter 4

The Update of the *Biolinguistic Agenda*

In most currently held positions of the so-called “biolinguistic agenda” (Hauser and Bever 2008) researchers, both inside and outside the area of Chomskyan influence, are trying to convert theoretical positions into biological and psychological experimentation.

4.1 A Kind of Evo-Devo Account

Balari and Lorenzo, for example, are among the few linguists trying to introduce the Evo-Devo paradigm in biolinguistic issues, by stressing the importance of considering the processes of ontogenetic and phylogenetic development as the result of an interplay of “cognition and action” (Balari and Lorenzo 2014, 61). The reassessment, as part of an evolutionary theory of development, of the active component of behavior – which we redefine here as “performative” (and which we will return to in the third part of the book) – does not only concern the allocation of a “cognitive” label to events or non-intentional states or the philosophical need to avoid unintentionally falling into the dualist traps inherent in the path of Chomsky’s biolinguistics. The real issue is to figure out if the concurrent development or co-evolution of cognitive and performative factors, is a biological primacy, and if the answer to this question can really have an “impact on our understanding of what development is” (Balari and Lorenzo 2015, 61 et seq).

In particular, in biolinguistics, one would have to establish “a unified theory of biological development” (62): an objective which is not easy due to numerous diverse but convergent traditions of study which help to spread the ontogeny idea of language as a process “that simply ‘unfolds’ as the child receives the appropriate linguistic stimuli” (63). The interaction between the development of the structures and the development of learning procedures and environmental stimulation is not as naive as the ethological tradition (the concept of “instinct”), as that of ecological behavior (forced reactive processes), and as the sociobiological one (genetic

programs), but also those of evolutionary psychology and Chomskyan “platonism without pre-existence” have made us believe (Chomsky 1966, 96). Both the hypothesis that the ontogenetic development can be assimilated to the proper execution of gene expression and the hypothesis that it would derive from self-acquisition of information from the environment, and, we add, that it will turn into reminiscences, re-generations or mere reifications of the innate cognoscitive powers of the mind, are all hypotheses destined to failure.

The risk of adopting one of these assumptions is to arrive fatally at the disjunction between an organic component and a cognitive one or, at best, to a methodology that is configured as “two opposing ways of conceptualizing the language faculty, instead of as two complementary sides of it” (Balari and Lorenzo 2015, 65). On the contrary, what in this outlook may remain logically or distinct methodologically, in real biological processes are “inextricably intertwined in ways that make them crucial causal factors in each other’s development” (65). Summing up, the theoretical hypothesis of Balari and Lorenzo is that “grammars develop with the aid of a basic organic support, which in turn attains its higher degrees of complexification with the aid of the grammatical devices on the way, in what we envision as a mutually facilitating and supportive endeavor” (67).

Despite these theoretical assumptions by Balari and Lorenzo, the relationship between the performative factors of the organic base and the peripheral apparatuses of language is still unclear. They themselves recognize the original sin of all post-Chomskyan biolinguistics, that is, the almost fatal sliding from the biological to the mental side: “what started out as a quest on the evolution of language suddenly turned to the evolution of computational systems” (Balari and Lorenzo 2013, 161).

In their unified theory of language development, the organic-operative base of the language faculty is primarily made up of the functional architecture attached directly to the biological substrate of the mind and the producer of elementary computational operations. There is little doubt, however, that a fundamental role is also played by those forms of development that precede the emergence of grammatical features, in particular the articulation organs:

the development of the vocal and the auditory apparatus is an unequivocally biological process involving organogenesis but also requiring the actual fine-tuning of the organs of speech and hearing through neural development in order to gain cortical control of certain tasks related to the articulation and processing of speech sounds (Balari and Lorenzo 2015, 67)

The auditory-vocal apparatus is certainly one of the causes of cognitive development involved in language, but it is not a special feature of *Homo sapiens*. In the particular evolutionary perspective of the authors - a radical reinterpretation of Evo-Devo not far from the one adopted, or at least not rejected by Chomsky-both the computational kit and the peripheral devices of language are conceived of as general cognitive properties, that are not specific to man.

In *Computational phenotypes* of 2013, their most important book, Balari and Lorenzo, however, distance themselves from the strong core of Chomsky’s FLN: no single component of the language faculty is absent in the brains of other species.

Homologies can even be seen in connection with the key principle of all Chomskyan hypotheses: “recursion is not a human-specific feature, (...) it is not a language-specific characteristic (...) and is most probably a common feature of the brain of vertebrates” (Balari and Lorenzo 2013, 3). The biological substrate of computational operations shared at least by all vertebrates includes basic tasks such as “accessing”, “sequencing”, “storing”, “comparing” which, furthermore, are not even specific to a precise modular system such as vision or sensory-motor control. They are very general operations transcending the speciative details (5).

We are therefore in conflict, not only with the strong Chomskyan idea that language is a form of species-specific intelligence, but also with the idea that *Homo sapiens* came to this form through adaptive evolution of his biological components (Pinker and Jackendoff 2005; Jackendoff and Pinker 2005; Hauser et al. 2002; Fitch et al. 2005). It is the result of a rather bizarre, but not uncommon, path in the Evo-Devo paradigm, a path that usually leads to exasperate the (albeit strong) reasons one has in pushing the claim of the unity of *Bauplan* even at the cost of losing any ethological border between species (albeit in this way contradicting other principles of the Evo-Devo which we will return to in Sect. 13.3). This is a route that goes through the canonical steps of the theme of the rejection of “origins”, of the beginning and end of the strong evolutionary processes and the (seductive) principle of the abolition of the notion of function. These are absolutely relevant issues but subject to extreme or radical, and sometimes bizarre readings, which eventually defuse the positive epistemological potential of Evo-Devo in the context of the neo-Darwinist perspective.

In linguistic issues, an exemplary case is constituted by the interpretation of the exaptation cascade that led to the transformation of voice articulation structures. Here the perspective of the Evo-Devo has been able to show that the multiplicity of functions that have focused on specific organs and organ systems (the sub-laryngeal system: lungs, diaphragm; the supralaryngeal one: tongue, epiglottis, teeth, lips, uvula, etc.) cannot give rise to a boundary or definitively establish when the beginning and the completion of functions occurred. The paradox, however, is that these correct methodological criteria may not make use of the neutral and quite productive notion of the hierarchy of the primacy of functions, since, according to Balari and Lorenzo, the attribution of primary and secondary function “more often than not rests on subjective factors rooted in the ascriber’s system of values rather than on truly objective arguments demonstrating the primacy of some function over others” (2014, 68. See also Balari and Lorenzo 2010). This is a really radical claim that is more ideological in nature than scientific – crudely extrapolated, in Balari and Lorenzo, from the antinormative philosophies of Canguilhem (1965 and 1966), Foucault (1961 and 1974), Searle (1995) and Negri (1971) – the acceptance of which would lead to aborting any chance of building a project of cognitive evolution, or of superior functions, including language. Failing to distinguish between ancestral functions, such as breathing or eating, that are directly related to primary selection for survival and more recent and complex functions like language or the development of logical faculties, is certainly strained and useless for the purpose of a solid evolutionist view founded on biological principles.

In biolinguistics, in fact, this path has inevitably led to justly rejecting functional innatism and Platonizing ontogenesis, together with needful biological specificity of human language. A contradiction, which may even affect Chomsky's theoretical paradigm, forced us to play down the importance of the practical factors allowing the selection of language in man's evolution, a sad end of a "unique" faculty – in the words of Balari and Lorenzo:

language is an organic structure which is (very) useful but has no function. We can use it to emit warning signals in dangerous situations (like the vervet monkeys with their alarm calls) to inform others about the position of an object (as bees do with their dance), to attract and seduce the partner (such as finches with their songs), etc. The language does not seem to serve some purpose in particular. In fact, we often use it without having any real utility, as when we write or read poetry or turn complex instructions to our pets. We can also employ it in communicative situations (i.e. in contact with others) or for strictly individual and internal use (as when we try to clarify our thoughts in articulating words). Sometimes we use it in a cooperative and honest manner; other times, fraudulently and for personal gain. The language can only speak for themselves, even if you do not get any benefit, as when it accompanies our dreams. Taking all this into account we fully agree with the thesis of Chomsky that language cannot be functionally characterized by highlighting his obvious lack of specificity in a practical sense (Balari and Lorenzo 2010, 61 – Our translation from Spanish)

4.2 Contemporary Revisionism

The difficulty caused by the emancipation of the Chomskyan heritage also characterizes other major biolinguistic hypotheses that were the object of discussion in the latest contemporary debate. Certainly linguistic approaches that try to develop the theory of Universal Grammar, by investigating historical-natural languages to discover evidence of its existence, have gradually lost momentum. Conversely, there has been a development of hypotheses concerning strong biolinguistics attempting to complete the original program beyond the biological boundaries that Chomsky believed premature to overcome: anatomy, physiology, neurobiology, and genetics.

In the *Biolinguistics Manifesto* by Cedric Boeckx and Kleanthes K. Grohmann, published in 2007, there is emphasis on the need to prosecute the work by Lenneberg rather than Chomsky's work done within the minimalist program: "it is important for us to stress that biolinguistics is independent of the minimalist program. As Lenneberg's work makes clear, biolinguistic questions can be fruitfully addressed outside of a minimalist context" (Boeckx and Grohmann 2007, 3). It will be necessary, therefore, "to treat linguistics as a natural science", which has to be the object of investigation of scientists of different backgrounds, including linguists, evolutionary biologists, molecular biologists, neuroscientists, anthropologists, psychologists, computer scientists, language or speech and hearing pathologists. This program, shared by much of contemporary biolinguistics (see Di Sciullo and Boeckx, 2011, 1 et seq.) is, however, inevitably and constantly swallowed inside a

cerebrocentric computational philosophy of linguistic functions which is typical of Chomskyan scholars.

However, from this point of view, biolinguistics can only be instantiated as neurolinguistics, fulfilling the prophecy made in 1976 by the Nobel laureate neuroscientist Salvador Luria and repeatedly referred to in the Chomskyan writings and in the “Biolinguistic Research Agenda” (Di Sciullo and Boeckx 2011). According to Anderson and Lightfoot (2002, I and 18-40), human language is a “mental organ whose nature is determined by human biology. Its functional properties should be explored just as physiology explores the functional properties of physical organs”. If we can study the physical properties of the human brain, we’ll able to understand the internal organization of language. The uniqueness of human language becomes the exclusive prerogative of the brain: the attempts to teach it to other primates did not work, not because the global system of peripheral and central organs of chimpanzees and bonobos (and thus their overall cognitive profile) are different from those of human beings; what is different about the human brain is just their brains (see Chap.10).

Not everyone, however, thinks so. Aitchison (2006, 51 et seq.), for example, attributes the biological specificity of the “articulate mammal” more to the peripheral devices than to the central ones. While, according to her, there is no doubt that every single element of the vocal tract – the teeth, the lips, the tongue, the larynx, the respiratory adaptations to the muscles around the vocal tract – was selected for the production of articulated language, we can certainly not analogously suppose that this can be true of the human brain. Of course, this is not because the brain does not constitute the intentional centre of linguistic activity, but because the functions used by the latter, and, above all, the neurocerebral organic components that allow it, can be found in many other mental activities and in many other primates. They could, in short, be general properties of cognition and not language-specific properties. From this point of view, surprisingly, the human brain could share with those of other primates more things than could be shared by the vocal apparatus.

That the cerebrocentric and computationalist heritage constitutes the weak point of the Chomskyan biolinguistics hypothesis can also be seen in the contributions of one of the most authoritative authors who stressed the need to draw a bridge between minimalism and contemporary evolutionary hypotheses: Cedric Boeckx.

According to Boeckx (2011, 49), the *neo-Darwinian biolinguists* (as they are called by Givon 2002, and Marcus 2008) have appeared in the twentieth century as diametrically opposed to *Cartesian biolinguists*. The former, despite the great diversity of positions expressed by modern synthesis, all agree on the centrality of adaptation as the only source of order and complexity of biological forms. The latter, however, despite a plurality of interpretations, have the adoption of internalist explanations in common, and that they privilege the concept design and topology (the project, in short) rather than proceeding by trial and error, and they focus on function rather than on form. However, once the framework of biological complexity has expanded into the context of the evolutionary perspective, “any perceived conflict between Darwin and Chomsky – Dennett 1995 – or any need to reconcile them – Calvin and Bickerton 2000 – quickly evaporates” (Boeckx 2011, 49). The

main point of apparent agreement is “the idea that the language faculty was not shaped by adaptive demands, but by physical constraints” (50). This optimistic conclusion has become possible, according to Boeckx, only after the Chomskyan minimalist turn. Minimalism, in fact, would have allowed a rapprochement with the evolutionist perspectives because it would have reduced the inextricable complexity of biological gradualism to a simple computational mechanism that did not need to evolve (see also Fitch 2005). Given the established evolutionary recency of the language faculty – 200,000 years at most – we should, in fact, necessarily assume that there has not been enough time to build it step by step.

In the reconstruction by Boeckx – who justifies and motivates Chomsky’s choice to make a computational procedure like Merge central in the evolutionary “leap” – we see one of the central problems that have repeatedly characterized the disagreement with Darwinian biolinguistics: the confusion between the time required by changes in structures and the time required by changes in functions or even, in the case of historical-natural languages, the time required by changes in cultural modifications or trappings of functions. This is a really central question, the answer to which we shall try to address in detail in the third part of the book. For now, it suffices to note that the solution offered by Boeckx cannot but come into conflict with the reconstruction offered by Chomsky.

As we have in fact seen (in Sect. 3.3), in trying to explain the evolutionary leap through a recabling of the brain that caused Merge, Chomsky assumes that humans have begun to treat previously existing concepts as calculation atoms destined to be treated recursively. We have also seen that the nature of these pre-recursive human concepts is not at all clear (Bouchard 2013; Hurford 2014; Tallerman 2014). The bold approach taken by the biolinguistics proposal by Boeckx is that these concepts can only be lexical elements of a linguistic nature:

it is as if the lexical envelope (the edge feature) on the one hand makes the content of a concept opaque to the computational system (...) and, on the other, this concept frees from its limited (modular) combinatorial potential (...). Once lexicalized, concepts can be combined freely (via Merge) as expressions like Chomsky’s ‘*Colorless green ideas sleep furiously*’ (Boeckx 2011, 54).

In other words, *Merge* becomes a generative procedure that can adhere to the semantic and syntactic flexibility of verbal language only by failing to apply to the “calculation atoms” in the strict sense of the term, which as we have already seen (Sect. 3.3), must be able to appear like a mathematically decidable and recursively enumerable set of homogenous data. Only by getting off their computational structure, is it theoretically possible that their syntactic relations will cease to depend on the conceptual content and the semantics of “words” will cease to be linked to the reference, exactly as contemplated by the Chomskyan paradigm.

This sharp argument formulated by Boeckx as constructive criticism leveled at minimalism, or even as an attempt at complementarism, however, turns out to be a double edged sword that will have repercussions especially on the side of evolution. In fact, it can easily make two observations that are logically derived from the corollaries of Boeckx’s arguments.

The first is that if the *Merge* applies to already lexicalized content, discrete units, and, for this reason, combinable and to be recursively generated, this means that words, and then language, already existed at the time in which the fatal mental mutation *Merge* took place. The Faculty of Language – not a simple system producing signs of categorical type, nor an algorithmic system that processes homogeneous calculation atoms, but a faculty that generates precise articulated constructs endowed with semantic potential, in this case, precedes the very *Merge* operation. To quote the words by Boeckx: “the *edge feature, the catalyst for recursive Merge*, is the one key property that had to evolve” (Boeckx 2011, 54).

The second is that the lexical units that are at the “border” cannot but be constituted by articulated sounds which are also at the “border”. A word is a combination of articulated sounds, combined according to certain constraints imposed by the physiology of the vocal tract and equipped with meaning. Without the need to resort to the Prague notion of phoneme, one can, nevertheless, define the existence of a series of basic articulated sounds (syllables, that are physiologically and acoustically “licit” combinations of phones, etc.) which underlies *the mental operation of recursive combinability*. After all, it inspires the thesis of “parallel architecture” by Jackendoff, according to which combinatorial complexity arises independently in phonology syntax and semantics (Culicover and Jackendoff 2005; Jackendoff 2007). Still in the Chomskyan field, Iris Berent (2013, 5) even proposes that the fundamental innate level of language is precisely the one that combines non-meaningful sounds (vocal sounds) to make words equipped with meaning. In evolutionary terms, one could certainly conclude that without articulated sounds *Merge* could not explain the creative properties of human language.

According to Boeckx it is not important to understand how this property, that turns the phonic-conceptual continuum into discrete units, has originated: “I am silent on precisely how it evolved. It may be the result of random mutation, or an exaptation. Perhaps we will never know for sure, but it is something that is now part of our biological endowment” (Boeckx 2011, 54). What is relevant is that the combinatorial properties of discrete entities constitute the evolutionary principle from which the creative process of language originated, a process which was then developed according to itineraries of mental and cultural evolution (eg., the principle of branching, the hierarchy of logical blocks, the mapping instructions and topology of locations, etc.). In other words: “the emergence of lexical items was the sort of perfect storm that gave man his niche. Once concepts are dissociated from their conceptual sources by means of a lexical envelope, the mind truly becomes algebraic and stimulus-free” (59).

Despite its undoubtedly academic affiliation, Boeckx seems to understand that the reason why the biolinguistic hypothesis by Chomsky and his contemporary exegetes are likely to remain trapped by the computational, mentalistic and cerebrocentric schemes is that there are errors in the diagnoses in the nature of the interfaces and conceptual articulation of human language. The biological structure of the interface devices, in fact, is not a negligible detail of a computational system that relegates them to support modules of the central activity. These devices, in fact, allow the delimitation of phono-semantic “containers” by cutting out the conceptual

boundaries. The problem is that the central activity can occur only after the interface devices have been formed following the gradual and very slow evolution of anatomical structures. Once they have stabilized times and have become permanently available to the whole organism, they will allow the transmission of specific signals (and in the case of the human voice, a species-specific type of signal) to brain structures whose rewiring, and the resulting mental and computational reorganization, will make the communicative system quite functional, expressive and representational.

If, however, we were to admit that the interface devices play a decisive role in influencing the devices of mental organization and, therefore, the computational schemes derived from it, the “platonic” primacy of Universal Grammar as an ontological form of the Faculty of Language would be defeated. Yet it is a hypothesis that is evinced by Boeckx’s (2011, 57) own words: “needless to say, it is perfectly possible that our special cognitive features are the result of more basic anatomical changes”. Along these lines, we can appreciate a new specific idea of verbal intelligence that Boeckx extends to the hypotheses put forward by Mithen (1996), Fitch (2008) and the brave positions by Jackendoff (1987 and 2003).

Conferring an active and influential role to interface devices, however, amounts to questioning the innatistic conception of FLN. In the same way as in phylogenesis, the brain would have “learned” from so-called articulation and conceptual interfaces, and ontogenesis languages are learned through the innate structure of the human body’s physiological devices in its entirety and not only in its brain shrine.

This is what we will study in the second and third parts of the book.

Chapter 5

Another Biolinguistics History: From Aristotle to Darwin

In the most recent history of contemporary biolinguistics there seems to be no place for the past. Excluding Givòn (2002), all manuals or historical reconstructions in the most important contributions of recent years (Jenkins 2000; Messeri 2008; Allen 2009; Boeckx 2013a, b; Boeckx and Grohman 2007, 2013; Di Sciullo 2009; Di Sciullo and Boeckx 2011; Al-Mutairi 2014) repeat the same historiographical scheme: they start with Chomsky (1955, *Logical Structure of Linguistic Theory*), then they move on to Lenneberg's *Biological foundation of language* published in 1967, then to the conferences organized by Massimo Piattelli Palmarini in the seventies, to works by Jenkins in 2000 to Chomsky's minimalist program, until one gets to the latest works on the specific phenotype of language that combines together a diversified team including ethologists (Hauser), geneticists (Lewontin), paleoanthropologists (Tattersal). For this recent history see Di Sciullo and Boeckx (2011, 7):

biolinguistics is an important new interdisciplinary field that sets out to explore the basic properties of human language and to investigate how it matures in the individual, how it is put to use in thought and communication, what brain circuits implement it, what combination of genes supports it, and how it emerged in our species. In addressing these questions the series aims to advance our understanding of the interactions of mind and brain in the production and reception of language, to discover the components of the brain that are unique to language (especially those that also seem unique to humans), and to distinguish them from those that are shared with other cognitive domains.

In this rich and broad definition there is no awareness that for centuries this topic has been the subject of specific reflection by linguists, philosophers, physicians, neurologists, psychologists, biologists and naturalists belonging to all sorts of ideological and cultural backgrounds. In fact, the *Biolinguistic Enterprise* is centered on a single idea: language is a product exclusively generated by the computational schemes of the human mind and (perhaps) of the brain that implements them and that is, in some way, connected to it.

Expressed in these terms – certainly charged with a strong veneer of plausibility – the definition of biolinguistics is consequentially unable to consider the rich

framework prior to this official “foundation”. The awareness that there is a precise physiological relationship between the brain and the exercise of language, in fact, dates back to the early nineteenth century. If we want to date it exactly, we could mention 1861 as the year when Paul Broca broached the discovery of aphasia in *Remarques sur le siège de la faculté du langage articulé, suivies d'observation aphémie d'une (perte de la parole)*. From the reflections made by the classical Greeks through to the first half of the nineteenth century was this not a form of biolinguistics?

This is certainly a paradoxical question Chomsky himself answered throughout the second half of the twentieth century. The *philosophical problems* underlying the modern formulations were already debated in ancient times and constitute a sort of ideal inspiration for contemporary biolinguistics. For example, Plato and Descartes have themselves inspired generative linguistics: the former because he considered the “reminiscence” as the standard mode of the learned component of language in a biological framework that accepted innateness; the latter, as he provided the basics for understanding linguistic creativity and addressed the issue of the mind-body dualism behind all the paradoxes in the philosophy of mind. Platonic Idealism and Cartesian rationalism are certainly the foundation of Chomskyan mentalism and, as we'll see below, of current neurolinguistic cerebrocentrism.

There is no doubt, however, that the Platonic and Cartesian contributions constitute only an *ideal, purely philosophical context* – but no less influential – for contemporary biolinguistics. There is absolutely nothing in the Platonic and in the Cartesian work, from the point of view of biolinguistics proper, that can be regarded as a strictly scientific and still relevant element of reflection and, above all, capable of countering, revising or radically correcting the epistemological and genuinely scientific foundations of the naturalistic study of language.

The same cannot be said of many other thinkers (whether philosophers, or linguists, or cognitive scientists) of the period preceding the discovery of the relationship between brain and language. Indeed it can be said that certain purely scientific themes broached in the past have remained out of biolinguistics, which on the contrary has been increasingly dominated by mentalism and cerebrocentrism, thus impoverishing the current debate and, ultimately, the heuristic power of the new discipline. Among these issues, the following are particularly noteworthy: (a) the foundational status of the bodily technology of language in cognitive science; (b) the nature and origin of the language faculty; (c) the complicated relationship between continuity and specificity of the structures and the functions of language in relation to the evolutionary biology of animal species.

The first topic we owe to Aristotle, the second to Vico and the third to Darwin.

5.1 A Brainless Biolinguistics: Aristotle

“Everything in biology is only a footnote on Aristotle's work” John Moore (1993, 33) wrote hyperbolically. Yet in the great biological synthesis of Aristotle, strongly appreciated in science today (Berti 2004; Solinas 2015; Falcon 2005; Gothelf and

Lennox 1987; Leunissen 2010; Gotthelf 2012; Tipton 2014), with very precise and deep observations and reconstructions of animal cognitive ontology, a little disconcerting particular strikes us: the absence of any active role of the brain.

The reason is obvious. We know from the history of neuroscience (Wickens 2015, 28 et seq.; Gross 1998; Bouton 1984; Clarke and Dewhurst 1974) that the first discovery of an extensive network of nerves connecting any peripheral part to the central nervous system was intuited by the Alexandrian anatomists Herophilus and Erasistratus (250–300 BC) only after the dissection of corpses – a strict taboo in Aristotelian Greece – became permissible for a short period of time. On the basis of that small discovery, Galen (129–199 BC) came to discover the cranial nerves and the central nervous system, which he described in detail, systematically using vivisection, providing a lasting contribution, until Vesalius, of the history of brain functions and discarding Aristotle's embarrassing cardiocentric hypothesis.

Even if Galen “blushed to quote him”, when he was explaining to students Aristotle's notorious failure (Gross 1998, 19), we must explain why cardiocentrism persisted in Greek and Arabic culture and throughout the Western world for a long time (Smith 2013). To do this we must first distinguish thinkers, who had a real interest in biology, from scholars who were only interested in physiology to justify philosophical and ideological speculations.

Plato, for example, who has been called “one of the most important ideological opponents of natural science of all time” (Gross 1998, 14) thought that the brain was the only organ of reasoning (Wickens 2015, 16). He, in fact, stands at the origin of all the dualistic philosophies distinguishing, in his theory of forms, an earthly corruptible body from an entirely spiritual self (the soul). Like dualists of all time, Plato does not feel in any way obliged to explain the relationship and ways of contact between the body and mind in great detail, so he has no difficulty in placing the noblest part of the human intellect into the brain-head which “has turned out to be more sensitive and intelligent but also, in every man's case, much weaker than the body to which it is attached” (Plato TIM, 75d). In the head, however, he also placed the mouth as an externalization device: “the mouth as the entry passage for what is necessary, and as the exit for what is best”. Therefore, not only the nourishment for the body, but also the “stream of speech that flows out through the mouth, that instrument of intelligence, is the fairest and best of all streams”. (Plato, TIM, 75e).

Aristotle holds the antithetical position because, as a true biologist and coherent monist, he does not separate different substances but thinks that the visible and invisible elements of the same body are inextricably intertwined. In *De Anima*, he identifies the body and mind as a single mass of wax stamped by patterns: the wax and its imprint cannot be conceived separately in the same way in which the function of seeing cannot be separated from the organ of the eye. Each function is inseparable from what makes it possible. This view, compatible with any modern epistemological conception, greatly complicates the work of the scientist. One must no longer describe speculative assumptions that exclusively deal with their own philosophical needs, but we must reconstruct with utmost precision the way in which the visible and the invisible, structures and functions, connect in the concrete observable behavior. These rigorous scientific ethics can, of course, result in errors,

which is denied, however, by the speculative approach, being virtually unfalsifiable. Aristotle, who has provided an unparalleled description of the physiology of animals and explained the operation of a great quantity of organs in detail, now needs to explain how these are connected in a unitary body, which is more than the whole of its parts. And since this link cannot be vague and indistinct, but must be placed in the visible body, he locates it in the only network present in animal bodies known before the dissection of corpses, which is the network of blood vessels with a single afferent and efferent centre: the heart. This is why, on the basis of empirical evidence, it is pretty reasonable for Aristotle to arrive at the cardiocentric fatal error, while, on the basis of purely subjective and speculative arguments, Plato has the intuition of the centrality of the human brain.

This fatal error renders Aristotelian physiology of higher functions useless for the purpose of contemporary reconstruction. In fact, it reveals a surprising novelty. The analysis of the bodily technology of language is independent from the super-power of the invasive brain. In this way, however, it is reconstructed for the best in its most analytical ethological and comparative dimension. It is in this way that the most species-specific biological functions of the most constraining parts of the language faculty can emerge and be described in a manner still unsurpassed. In particular, we can consider the role of linguistic articulation as a function taking input from the hardware of the auditory-phonic systems to reach the logico-semantico-syntactic compositionality of more sophisticated mental procedures of human cognition. Such a role no longer relegates vocal articulation to the auxiliary position given to it by the hegemony of cerebrocentrism in contemporary cognitive science.

That, on a scientific basis, we are able to reconstruct a history of biolinguistics significantly different from the one proposed by Chomsky and his contemporary exegetes, owes much to the radical reinterpretation of Aristotelian language by Franco Lo Piparo (2003).

The former, as we have repeatedly pointed out, takes up Platonic-Cartesian epistemological models. *Plato's problem* and *Descartes' problem*, as reiterated by Boeckx (2011, 43 et seq.), are preliminaries, for Chomsky, to *Darwin's problem*. In other words, for contemporary biolinguistics, considering how language evolved biologically and investigating the relationship between language and other forms of animal cognition can only occur after one understands the relationship between innate faculties and learning processes and between the mind and the brain. The Platonic and Cartesian solutions provide an unambiguous answer: we must look within us, within our minds, to explain the outside that constitutes a reflection or a 'reminiscence'. In philosophy of mind, this solution today is called 'Internalism' and is based on an implicit *mind-body* distinction.

For Lo Piparo (2003), Aristotle's linguistic philosophy is precisely based on the disruption of this distinction that, in ancient linguistic philosophy, is embodied in the neo-Platonic opposition between *inner* and *exterior* language: "the function of the latter would be to communicate, by means of signs or symbols perceived by other bodies, the silent and wholly immaterial language that takes place in the soul" (Lo Piparo 2003, 48). In the Plotinian formulation this relationship becomes one of

close correspondence: the vocal language is *imitation* of the mental language, it is a “picture (reminiscence) of the language that resides in the soul” (48). This triumph of linguistic dualism, according Lo Piparo, is due to the “insidious misrepresentation” offered by the neo-Platonic and mentalist reading of the most important excerpt of *De Interpretatione*: “Ἐστι μὲν οὖν τὰ ἐν τῇ φωνῇ τῶν ἐν τῇ ψυχῇ παθημάτων σύμβολα, καὶ τὰ γραφόμενα τῶν ἐν τῇ φωνῇ. καὶ ὥσπερ οὐδὲ γράμματα πᾶσι τὰ αὐτά, οὐδὲ φωναὶ αἱ αὐταῖ· ὃν μέντοι ταῦτα σημεῖα πρώτων, ταῦτα πᾶσι παθήματα τῆς ψυχῆς, καὶ ὃν ταῦτα ὄμοιώματα πράγματα ἡδη ταῦτά” (Aristotle DI, 16a 3–8).

It is, of course, the most controversial excerpt of Aristotle’s work and it is impossible, here, to report the numerous philological and philosophical disputes that his translation has always provoked (see Lo Piparo 2003, 34 et seq.). According to Lo Piparo, the misrepresentation of the Aristotelian excerpt is due to two main errors:

- (a) to the identification of “τὰ ἐν τῇ φωνῇ” (literally “the things that are in the voice”) with “words” or linguistic categories/units of language (such as nouns, verbs or propositions);
- (b) to the attribution of the meaning of “affections/passions/states of mind” to the term “ἐν τῇ ψυχῇ παθημάτων”.
- (c) the translation of “σύμβολα” with the modern concepts of “symbol” or “sign”.

These highly mentalist translations seem to be all inspired by a Platonizing philosophical background that systematically de-naturalizes Aristotle’s global semantic system.

Through an in-depth philological analysis covering the whole range of Aristotle’s works, Lo Piparo shows that the “affections of the soul” are identical with “the species-specific logical and cognitive operations” of the human mind; in other words, changes or quality alterations (e.g. white and black, sweet and bitter, etc.); establishing structural or quantitative/qualitative relations between objects such as numbers, musical chords, sizes, etc.); the categorization of the properties of substances (hot, cold, dry, wet, etc.) or of physical states (liquidity of water, of different materials, etc.) or transformations of the lexis (glosses, metaphors, etc.); temporal transformations, states of thought, reminiscences of what is absent, etc. In other words, by adhering to the reconstruction of semantic fields within Aristotle’s work, the “affections of the soul” coincide with the specific forms of human reasoning, with the dynamic exercise of its ontological knowledge.

Similarly, for Aristotle, “the things that are in the voice” are not purely conceptual entities or grammatical categories, but biologically articulated expressions (i.e. segmented on the basis of typically human corporeal components) that “distinguish the species-specific human phono-semantic dimension from the inarticulate expressive phonic dimension of non-linguistic animals” (Lo Piparo 2003, 47). This conception of human vocality is the foundation, not only of the Aristotelian linguistic philosophy reconstructed by Lo Piparo, but of the possibility of conceiving a very biolinguistics alternative to the current one (which we try to sketch in this book).

Finally, the term σύμβολα has no contemporary semiotic meaning as indicates, relates, shows, etc. On the contrary, it emphasizes the differentiating character of a single entity which, as the concave and convex, is in a relation of biological complementarity. In this report, both poles interact without coordinating hierarchically (there is not a previous or following item, a primary or secondary item).

Surprisingly, the result of this first naturalistic reading anticipates many of the current contemporary biological theories: “species-specific articulations of the human voice (φωνά, γράμματα, στοιχεία) are symbols that are in a relationship of complementarity with logico-cognitive operations – themselves species-specific – of the human soul” (Lo Piparo 2003, 48).

Aristotle, in fact, seems to deeply understand the nature and principles underlying the functioning of bodily technology of human language. Unlike the artificial technology, i.e. the artifacts that are generated by man himself – as Vico will claim in his Principle of *verum-factum* – in bodily technologies, the matter already exists. It is internal to organisms and is specific to each function (Aristotle PH., 194b, 7–10), and for human language is sound. Its physics is determined by the movement of air masses, due to the vibrations of percussions which reach the organ of hearing (Aristotle DA, 419B 11–35). In modern terms we now know that the wavelength and the frequency of the sound depends on the energy and shape of the movement, while the activation of the receptive function depends on the source that filters it. In particular, we know that the vocal supralaryngeal tract, then the buccal, nasal and pharyngeal channel, act as acoustic species-specific filters for human sounds whose source is the larynx and whose energy is created by the air emitted from the lungs (Lieberman 1975).

The biology of language then sets up the physics of human sound in a specific corporeal technology. We are also indebted to Aristotle for the first complete discussion of linguistic and cognitive ethology in a purely naturalistic key. In the fourth book of *Historia animalium* (535B–536), he describes in great detail the status of the possible vocal productions and their biological functionalizations. Voice, sound and language are three different aspects of the same physical phenomenon that we first sketched. Voice can be emitted only by animals through the larynx and lungs. On the contrary, shifts of air, that is, non-speech sounds, can be produced by the hum of wings or by rubbing the “paddler” legs or elytra of insects. Fish, though voiceless, can emit some sounds by rubbing the thorny area of the gills or some internal parts of the stomach. We cannot, however, even consider “sounds” the involuntary movement of air produced by the wings of birds or by flying fish. Vice versa, whistles of dolphins can be considered voices, because the dolphin is a mammal endowed with both lungs and a trachea: however, it lacks a tongue suitable for articulation, that is, the fine filtering of sounds (Aristotle HA, 536a, 1–6).

The tongue, in fact, is one of the essential components of voice filtering procedures: “language is the articulation of voice by the tongue. Thus, the voice and larynx can emit vowel sounds; consonantal sounds are made by the tongue and the lips; and out of these language is composed” (Aristotle HA, 535a, 33). The attribution of language is primarily related to the possession of a lingual muscle capable of maximum flexibility. Birds, which also have a vocal apparatus similar to human

beings and also display a certain linguistic and even cultural biodiversity, can articulate (produce γράμματα) only if they have a wide, thin tongue (Aristotle HA, 504b and 536a).

In *De partibus animalium* (DPA, 660a et seq.) the role of the tongue in the production of articulate speech is analyzed at length. The human tongue is the most flexible, soft, large and moist of any animal species. It can produce consonants by varying these four parameters and combining them with the parameters of the modulation of the lips, teeth, palate and alveoli. The tongue can fold and move in any direction, can shrink or expand, can be raised or lowered: at the passage of the air/sound, each of these movements produces contacts with other parts of the mouth by modulating the different voice output possibilities. Conversely, almost all other mammals are unable to finely articulate the voice, mainly because they have a hard tongue that is often not flexible or thick enough. Even the relationship between the skull bones and ligaments of the tongue are decisive. The crocodile, for example, has low tongue mobility because it is attached to the jaw, i.e. the lower jaw that is reversed compared to that of other animals, and is therefore immobile.

Even human lips contribute decisively to the filtering of voice articulation. In particular their separability, softness, fullness and moisture allow the production of vowels, through their greater or smaller closure, and of many bilabial and/or explosive consonant sounds: “vocal speech consists of combinations of the letters, and most of these would be impossible to pronounce, were the lips not moist, nor the tongue such as it is. For some letters are formed by closures of the lips and others by applications of the tongue” (Aristotle DPA, 660a, 5–7). The teeth, in their turn, are essential: “in man the number and the character even of these sharp teeth have been mainly determined by the requirements of speech. For the front teeth of man contribute in many ways to the formation of letter-sounds” (661b, 15). Human teeth are also a species-specific component. The upper and lower arch, which constitute a unique barrier, meet at the top and at the bottom. Their meeting or their gradual separation, and the containment obtained through movements of the tongue, allow one to filter some of the most “difficult” consonantic voices like the consonants D, F, V, and, in some languages, the sounds SH (as in the English word “shutter”) and TH (as in “thinking”).

It is clear that for Aristotle the tongue, lips, teeth, palate, all the mouthparts, as well as the larynx, the epiglottis, the trachea, esophagus and lungs have adapted over time to the linguistic human function. This belief is made explicit in Book III of the *De partibus animalium* in which, after treating the species-specificity of the organs of articulate speech and in the framework of a general physiological principle, Aristotle describes a real anticipation of Gouldian exaptation theory:

for nature, as already said, uses the parts which are common to all animals for many special purposes, and this of her own accord. Thus the mouth has one universal function in all animals alike, namely its alimentary office; but in some, besides this, the special duty of serving as a weapon is attached to it; in others that of ministering to speech; and again in many, though not in all, the office of respiration. All these functions are thrown by nature upon one single organ, the construction of which she varies so as to suit the variations of office (Aristotle DPA, 662a, 17–25).

Corporeal technologies, therefore, determine functions through the adaptation of new structures to emerging functions, often generating huge costs to the overall balance of organisms. The most striking example is that of the epiglottis, a kind of valve alternatively opening or closing the tracheal and esophageal channels which became necessary for the development of language function as an alternative to the ineliminable nutritive function. If the epiglottis had not specialized with the use of language, one would run the risk of suffocation (Aristotle DPA, 664b–665a). Nevertheless we know that even today this risk is the fourth leading cause of death in the United States (Lieberman 2012). Analogous considerations can be made concerning the characteristically human frailty of the respiratory apparatus and the musculoskeletal system due to the structural changes determined by language and the achievement of upright posture.

Of course, Aristotle could not imagine how what is now called “natural selection” and “transfer of the phylogenetic heritage” could work. He could not, therefore, assume that there are evolutionary reasons, advantages for the species, allowing the selection of fundamental traits, in spite of undesirable and dangerous effects that they may have for particular individuals. However, even in the contemporary debate, the issue of irreversibility of structural changes and their consequent status as “biological constraint” that Aristotle strongly emphasizes, remains absolutely central. He is perhaps the only philosopher of all times who extended the notion of biological constraint even to the cognitive world by establishing an inseparable relationship between the body and the intellectual mode, in its broadest sense. In other words Aristotle is the first and perhaps the only one to claim that animals have a certain type of cognition because they have a certain body type and not just a brain. Or, to put things in a better way, one cannot have a type of cognition different from that which one’s body allows.

Now we can translate this dual constraint in purely biolinguistic terms. As we saw earlier, for Aristotle, the articulated voice, in fact, constitutes a structural constraint that is at the same time irreversible and characterizing in an exclusive way. According to Laspia (1997, 61), the notion of linguistic articulation cannot be explained except by starting from its anatomical and biological meaning. All biological constraints that we considered before regarding the shape of the buccal tract (tongue, lips, teeth, etc.) are suitable for modulating the air emitted from the lungs and conveyed through the larynx, and give rise to the articulatory dimension of the voice in the sense that each individual constraint represents a different point of articulation (“ἄρθρον” Aristotle HA, 536a, 4; “ἡ δὲ ἐν τοῖς ἄρθροις” HA: 536b, 11). The segmentation in “articuli”, literally in small pieces, in voices-letters (*γραμμάτων*), or at least as a constituent of phonemes or syllables, is the only universal biological constraint on the biological apparatus producing the human voice that can significantly affect one’s cognitive activities. This constraint is connected with the possibility of producing an infinite number of significant items, naturalistically, socially and culturally differentiated: “the voice is therefore, for Aristotle, a kind of protoplasm inextricably linking among them individual phonological entities, the matter which constitutes the full-fledged linguistic organism” (Laspia, 1997, 61).

It matters little, in this context, what, in terms of contemporary linguistics, is the type of minimal unit represented in the voice. The biological bond that characterizes human species-specificity is represented more by the articulatory activity than by the type of articulation produced. Certainly the vocal apparatus can produce articulate sounds like consonants and vowels. Rather it is just “consonants combined with vowels that form speech” (Aristotle PR, 895a, 10–11), and therefore “the syllable is (...) designed to become a lexeme, a phrase, a sentence” (Laspia 1997, 61). Of utmost importance is the fact that the articulatory capacity always follows a specific development of both ontogenetic and ethological nature. The often repeated observation by Aristotle that babies and animals cannot pronounce the γραμμάτα (articulated voices) (Aristotle PR, 895a, 14) is reflected in the modern discovery that the supralaryngeal vocal tract does not reach its lower position in the tracheal channel before the age of 2 years and, accordingly, given that it cannot assume the classic 90° angle formed by two precise channels of the same size, it is similar to that of primates (Lieberman 2012; Nishimura 2008; Nishimura et al. 2006, 2008). It is, therefore, an absolutely biological constraint that is linked to an absolutely cognitive constraint: being able to represent the world only through syllabic combinations or in any case through articulations that represent the universe of meanings, namely through the φωνὴ σημαντική. Vocal and mental articulations are complementary and coexist symbiotically “τὰ μὲν ἐν τῇ φωνῇ ἀκολουθεῖ τοῖς ἐν τῇ διανοίᾳ” (Aristotle DI, 23a, 32–33).

5.2 Vico and the Origins of the “Lingue Mutole”

If Aristotelian biolinguistics can be considered an anti-Platonic linguistic philosophy, Vico’s reconstruction of the origins of thought and language can be considered a philosophical alternative to Cartesian mentalism.

Vico’s controversy over the “conceit of the scholars and the nations” (Vico SN, 55) is a notorious reaction to the intellectual view that is attributed to the human mind and language by the “esoteric wisdom” (9) permeating Cartesian culture in the cultural environment in which Vico lived. At the same time, it can be read as a universal biologist and counter-analytic linguistic philosophy of great complexity and theoretical importance.

In a passionate letter to Gherardo degli Angioli dating back to December 1725, Vico complained that a culture based on “esoteric wisdom” had led to “a philosophy that professes to discredit all faculties of the soul that come from the body” (Vico AC: 179, Our transl. from Italian ed. Nicolini 1929). To the internalist dimension of Cartesian rationalism and its self-sufficient mentalism, he proposed a new “science of imagination” as an alternative (Verene 1981), producing inventions such as the compass and the sailing ship, the creation of paper and the press, or medical discoveries such as the circulation of the blood “that made deep changes in the physics of animated bodies and constituted a turning point in anatomy” (Vico AC: 179). The study of artificial or biological technologies should have formed the cor-

nerstone of a new philosophy, but also of a new social pedagogy, that within a few decades Antonio Genovesi would concretely have founded in the Kingdom of Naples (Pennisi 1987).

The centrality of the material and corporeal dimension in the structure and functioning of the human mind is a reflection that has deep roots in the intellectual biography of Vico. In the first *Inaugural Oration: On self knowledge* (1699), he remembered that “the acuity of the mind, to whatever degree, can penetrate all other matters, but becomes dull when considering itself” (Vico OR.I., 40). In order to understand human cognition, one should, therefore, leave aside the closed internal logico-formal processes and investigate the relationship between the body and the mind: “the human mind in the ear hears, in the eye sees, in the stomach shows anger, in the spleen laughs, in the heart discerns, and in the brain understands; but still it has no definite shrine in any part of the body” (Vico OR.I., 41). The body is not the mere seat of the soul or the container of the mind. On the contrary, it contributes to characterizing the specificity of the latter by making it a very fast device in which memory, imagination and the intellect can operate connecting mechanical and imaginative processes: capable of perceiving “res dissimillimas for sensus”; of conceiving images of things: “dum novas formas gignit et procreat”; of transforming, separating and linking images (Vico OR.I., 42 et seq.).

In the sixth *Inaugural Oration: On the proper order of studies* (1707) the *peroratio* for a naturalistic cognitive breakthrough constitutes some progress towards the epistemological core of the theory of *verum-factum*. What, according to Vico, is neglected by the Platonic-Cartesian tradition is that mathematics and metaphysics are conceived by the human mind from inner resources on the basis of preventively circumscribing the uses of its words: the shapes and numbers are signs on which men use explicit conventions (Vico OR.VI, 123 et seq.). Therefore mathematics, logic and metaphysics, as opposed to all the empirical sciences like philology, physics, medicine, mechanics, and even ethics, and theology, have knowledge but have no history. An obvious consequence is that for the historical and natural disciplines it is possible to obtain a hypothetical knowledge, while for the entirely mental sciences, one can obtain an absolute and infinite knowledge like God's. In *On the Ancient Wisdom of the Italians* (1710) Vico delves into this extraordinary faculty of the human mind that is able to reflect the divine mind and which knows everything because it contains within itself the elements out of which everything is made (“Deus omnia scit, quia itself continet elementa, ex quibus omnia componit”) (Vico, AIS: 64). This faculty is derived from a defect in the mind (“*vicium mentis*”, 66). The infinite world of shapes and numbers, which contain within itself the universe (“quem intra se universum complecteretur”, 66), in fact, still remains an underworld of empirical knowledge; empirical because the logical code to which the endless steps of the calculation could be applied – to be used – requires an imaginative-sensitive generation of terms:

quia physicus non potest res ex vero definire, hoc est rebus suam cuique natura addicere, et ex vero facere; id enim fas Dei est, nefas homini; nomina ipsa definit, et ad Dei instar ex nulla re substrata, tamquam ex nihilo res veluti creat, punctum, lineas, superficiem [...]. Atque hoc pacto, quando ei negatum est elementa rerum tenere, ex quibus res ipsae certo existant, elementa verborum sibi configit (Vico AIS, 69).

We are now faced with what in the New Science will be identified as the “primary operation of the human mind” (Vico SN, 149), which is a semantic creation and the linguistic (imaginative-material) foundation of all human knowledge. The relationship of logical dependence between logic and mathematics on the imaginative genesis of historical-natural language makes Cartesian analysis appear the most unpalatable of all sciences when it aims to extend its calculations to a universal model of human knowledge. It forgets, according to Vico, that infinite recursivity is only *nominal* (“enim vero ista genera nomine tenus sunt infinita”, AIS, 81). This is an infinity which operates only through some mental faculties and operations: lengthening, shortening, composing, adding, decreasing, computing signs (66), but not creating new ones. The genesis of all signs, including the “algebraic” ones is, on the contrary, due to the *ingenium*: the mental faculty of iconic type that notices “between distant things ties that, according to some common reason, would put them together” (Vico AC, 12); the perceptive act of similarities able to join in unities separate and different things (“in unum dissita diversa coniungendi”, Vico AIS, 117); the faculty that produces new objects of knowledge that do not show up spontaneously so as to become evident (Vico 1708, 803); the *acumen* or wit that combines and separates, in contrast to the calculation that “non tam duas lineas in angulum infra rectum coniungere, quam unam lineam producere” (Vico AIS, 123). This *ingenium* of a specifically empirical-material nature – because it acts through the senses, only operates on objects external to the mind, turns images into material objects, and gives life to mechanical things – manifests itself through more images that are always partial and never self-evident: the signs of creative thinking are always undetermined and unlimited: “sed id ipsum cogitari fateri est, quae informia esse, et fines habere nullos” (AIS, 93).

According to Vico, the “esoteric wisdom” of Cartesian culture seems to have forgotten that this great freedom characterizing the richness of semantic creation is due, in fact, to an original and archaic principle of poverty and symbolic lack of self-sufficiency:

in this way the nations formed the poetic language, composed of divine and heroic characters, later expressed in vulgar speech, and finally written in vulgar characters. It was born entirely of poverty of language and need of expression (Vico SN, 138).

The great project of a “New Science” which will be taken up by Vico’s principal work is to precisely re-read the whole story of *endless antiquities* starting from the rejection of the Cartesian method through to “esoteric wisdom”. In other words, starting from the reconstruction of an original state in which mental forms, to which we have become accustomed to over the course of a culturalization process lasting for an interminable number of centuries, are reduced to their crudest and material principles. It is the second axiom (‘*Degnità*’), of a deeply “evolutionary” orientation, of the New Science:

it is another property of the human mind that whenever men can form no idea of distant and unknown things, they judge them by what is familiar and at hand. This axiom points to the inexhaustible source of all the errors about the beginnings of humanity that have been adopted by entire nations and by all the scholars. For when the former began to take notice of them and the latter to investigate them, it was on the basis of their own enlightened, cultivated and magnificent times that they judged the origins of humanity, which must nev-

ertheless by the nature of things have been *small, crude and quite obscure*. Under this head are to be recalled two types of conceit we have mentioned above, one of the nations and the other of the scholars (Vico SN, 55).

Returning to the origins, as a naturalistic repositioning with respect to a philosophy considered too abstract and “subtle but not sharp” (SN, 151), is a constant feature of all biologicistic thought. Even if we exclude atomistic materialism, and the works of Epicurus and Empedocles, Aristotle already made the return to the origins a fundamental tenet of his *Politics*: “if we were to study things unfolding from the origin, here as elsewhere one would have a really clear view of them” (“εἰ δή τις ἔξ ἀρχῆς τὰ πράγματα φυόμενα βλέψειν, ὥσπερ ἐν τοῖς ἄλλοις, καὶ ἐν τούτοις κάλλιστ ἃν οὕτω θεωρήσειν) (Aristotle POL.I, 24–5). In this way, he considers the reproduction and conservation of species the cause of social animals, including human – the *πολιτικὸν* *ζῶον* par excellence. In *De Rerum Natura*, Lucretius elevates the reconstruction of morphological origins of human and animal life to the construction of an explicit and articulated philosophy of nature, followed many centuries later by Spinoza’s pantheism. Darwin will place the theme of the origins at the heart of the scientific revolution of evolutionary biology and today Darwinism attempts an evolutive “reduction” of any concept of modernity.

According to Vico, the reconstruction of the origins is, first of all, “glottogony” (Danesi 1993) and its evolutive “reduction” of the language faculty is a real biolinguistic program centered on the idea of the “lingue mutole”.

This expression in all of Vico’s work takes on different shades of meanings, all strongly connected within a complex linguistic philosophy. The “lingue mutole” (“the mute language of acts and objects that had natural relations to the ideas” – Vico SN, 19) are first and foremost, in the New Science, the absence of language, the lack of speaking events and the scarcity of voices, that characterize the origins of language. At this stage the bearers of mute languages are the giants of newborn gentility. The term “mute languages” then, first of all, has a *phylogenetic* value.

“Mute languages” or stages of language poverty are the context experienced by children born in the ages in which they were fully exposed to voices (“children, with very flexible fibers, born into our present plenty of words” – SN, 139). In other words, the learning of language by the individual takes us back to the primary genetic stage in which the semiotic adventure of the big giants comes to maturity. In this case the subjects availing of “mute languages” are newborns, infants and children of all ages. The expression has thus also an *ontogenetic* value.

Up until this point, we have remained within fairly traditional Western thinking, which has always seen more or less imaginative relationships between the evolution of the species and of the individual. But “mute” languages, for Vico, are the state of linguistically deprived subjects; a state that is sometimes permanent, sometimes not. The mutos, the stammerers, the aphasic – as “a good man living among us who, after a severe apoplectic stroke, utters nouns but has completely forgotten verbs”, SN, 137) – and the persons affected by Parkinson syndromes afflicted with disorders of articulatory rate (“for such perturbation quickens ideas and words rather than retards them” SN, 140). In short, all those who experience the continuous physio-psychic tension of an incessant communicative effort, instantiate the very

struggle between “poverty of language and need of expression” (SN, 138), which motivates and activates the children and the big giant of the gentility. Users of “mute languages” are, in this case, the pathological subjects and here in these situations, the expression type is *morphogenetic*.

If we were to elucidate the meaning of the term, we could say that this stage of mute languages is a permanent condition of the triple genesis of language: it plays a role in its formation, in its learning and its re-appropriation or development. It can be experienced by the species, by all its members and by a specific subset of it. Finally, it is always characterized by a struggle, by physio-psychic effort that ends with the final acquisition of a faculty not given *a priori*, but laboriously achieved through a purely performative activity: doing things that are not constrained by *a priori* knowledge.

Vico’s reasoning can result in a more difficult interpretation when the concept of “mute languages” goes beyond the limits of the genesis of communicative function to include the history of languages. In fact, in some bizarre passages of the *Scienza Nuova*, as well as in later less important writings, Vico puts forward the idea that the dumb stage of the origins may still play a crucial role in the evolution of individual historical languages. For example, in §.485 of the *Poetic logic* of the S.N:

in the returned barbarian times the nations again became mute in vulgar speech. For this reason no notice has come down to us of the Spanish, French, Italian or other languages of those times, and Greek and Latin were known only by the priests (SN, 145)

or the description of Dante’s Florence in which:

among the Italians the mute language returned, which, as we showed, existed in the first gentle nations and through which their authors – before being able to use articulated languages – had to express themselves like dumb people by actions or bodies being in a natural relationship with ideas, which at that stage had to be extremely sensitive, as the things that they wanted to signify (Vico AC, 181 – Our transl. from Italian ed. Nicolini 1929).

It would be superfluous here to report the many other passages in which he discusses the idea that “mute languages” reappear in the stages of “recurring barbarism” (see Pennisi 1987, 128 et seq.; 1993 and 1994). It will be sufficient to confine ourselves to pointing out that their historic reappearance is connected with the loss of cultural or political identification of an expressive instrument capable of activating a common sense of belonging to a nation’s language, in a set of communities or heterogeneous social strata. This expands and complicates the very meaning of “mute language”. It also concerns collectivities, society and ethnic groups, in addition to the species and classes of general and specific individuals: it is phylogeny, ontogeny, morphogenesis of language function, but also sociogenesis of specific historical-natural languages.

So this is a central concept for “mute languages”. It becomes a theoretical point of view allowing synthetic possibilities of great interest which are likely to spur us to revisit the whole biolinguistics theory produced by Vico, starting with the problems inherent in the production and reception of language, in so far as it can be considered a biologically determined cognitive function, and then proceeding with the problems inherent in the political dimension of social communication. This is a

process that makes Vico's considerations on language "a new and unique moment in the dialectics of knowledge" (Pagliaro 1961, 299).

We shall begin with the *Degnità*, that constitute the axioms of Vico's new science, a system dealing with the relationship between the origins of vocal language and its pathologies, from LVII to LX:

mutes make themselves understood by gestures or objects that have natural relations with the ideas they wish to signify. This axiom is the principle of the hie-roglyphs by which all nations spoke in the time of their first barbarism. (...) It is also the principle of the natural speech (...). This natural speech must have been succeeded by the poetic discourse of images, similes, comparisons and natural properties (Vico SN, 68–9)

mutes utter formless sounds by singing, and stammerers by singing teach their tongues to pronounce (SN, 69)

men vent great passions by breaking into song, as we observe in the most grief-stricken and the most joyful. These two axioms (supposing that the founders of the gentile nations had wandered about in the wild state of dumb beasts and that, being therefore sluggish, they were inexpressive save under the impulse of violent passions) lead to the conjecture that their first languages must have been formed in singing (SN, 69)

languages must have begun with monosyllables, for [even] in the present abundance of articulated words into which children are now born they begin with mono-syllables in spite of the fact that in them the fibers of the organ necessary to articulate speech are very flexible (SN, 69).

The glottogonic reconstruction, according to which the principle of hieroglyphics and of the "natural speech" coincide, would be demonstrated by the analysis of dumbness that forces patients to mimic objects or actions directly indicating what they want to express. This principle is called "natural" as opposed to "conventional", which Vico – mistakenly – believes to be embodied in Aristotle, which, instead, is the result of the scholastic tradition of his medieval and Renaissance commentators (see Lo Piparo 2003; *infra* §.I.4.1).

In a crucial part of the New Science, the section devoted to *Poetic logic*, it is clarified that "natural speech" is dumb because it is still comprised of "mental language" and belongs to a previous historical phase – as noted by Strabo – the consolidation of vocal and articulate language. This "natural speech", however, is not already pure reproduction or conventional duplication of reality, but a transfiguration of it, "a fantastic speech making use of physical substances" (Vico SN, 115).

The excerpt is well known and widely cited. The idealistic tradition (Croce 1911; Pagliaro 1961) correctly noticed in it the active role played by the sensory dimension in transforming stimuli from the outside world into some type of sign. There is no passive reception and sensorial perception is already interpreted. The idealistic theory of creativity may very well be reconciled with Vico's position, because even this function does not stop with the primordial era of mankind and in the presence of articulated languages: ("for when we wish to give utterance to our understanding of spiritual things, we must seek aid from our imagination to explain them and, like painters, form human images of them" – Vico SN, 115).

What does not tie in with this perspective is the fact that the "fantastic speech making use of physical substances" cannot ignore the physiology and biology of

language. That is why the pathological and the model of neonatal language learning play a crucial role in approaching the glottogonic model.

What are the features shared by the big giants, the dumbs and newborns or infants? Certainly it is the absence of abstractive intellect and the presence of strong memory, ingenuity, imagination and passion, that allow the mind to produce “animated substances”. But, before that, and above all, a shared biological obstacle is present: a physiological system that is not predisposed to articulatory phonetics. The physical dimension of sounds is, in fact, directly related to anatomical constitution. Emitting vowels only requires that the air flows out of the lungs. The consonant sounds already require vowels: thus, in human phonetic articulation, they exist only in syllabic version. This has two consequences: first, it is not possible to distinguish the consonant sounds and to pronounce them, it is indispensable to have a spoken chain whose minimal size is the monosyllable; second, to stand with each other, monosyllables must be equipped with tonal properties, and accentual metrics, that is, they must take on the status of an act of “singing” or of a “poetical verse”.

We are confronted with one of the crucial passages of *Poetic Logic* (§. 461) in which, according to the idealistic literature (Pagliaro 1961), all of Vico’s errors emerge. Here, the principal *dignità* (axioms) expressed in the section of the “Elements” are taken up:

concerning song and verse we have proposed the axiom: that since men are shown to have been originally mute, they must have uttered vowel sounds by singing, as mutes do; and later, like stammerers, they milst have uttered articulate consonantal sounds, still by singing (Vico SN, 139).

The transition from a mute mental stage to a stage of linguistic articulation does not occur through a sudden leap, but follows a precise development. Mute languages become “songs” made out of vowels; the song becomes a “monosyllable” articulated by merging with the consonants; monosyllables become articulated words. So the spondaic verse was followed by the dactyl and then by the iambic, until the stage of prose was reached and, in modern times, there was a transition from prose to writing and to printing.

Linguistic evolution traces the biological path of ontogenesis in children and the therapeutic path in patients. The dumb can circumvent their condition through the emission of successive sung vowels. In stammerers, consonants are pronounceable only in sequential association with the vowels. Even the aphasic start speaking again through repetition of serial items (one, two, three, January, February, March, etc.) or through songs. The song, then, is first of all the continuous emission of voice, and the verse is the composition of syllabic entities in rapid rhythmic succession.

Children also learn to control their voices starting from vowels: “the reason for this is that vowels are easy to form while consonants are difficult to pronounce” (Vico SN, 139), the latter will come afterwards and will lean on the vowels.

The successive song-verse at the origin of language is not determined, then, by the mental characteristics of the subjects, nor by the cultural history of people, but by biological constraints, both in terms of the physics of sound and of the physiological structure of the phonatory apparatus.

The strictly physiological principle of monosyllabism ultimately affects the whole history as well as all language structures. Therefore, it is useless to look for the meaning of the grammatical classes in logic or psychology. The diachronic sequence of pronouns-prepositions-particle-names-verbs is due to the principle of the original monosyllabism, that is the strict constraints of articulatory physiology overriding the hierarchy of communicative needs. The centuries-old practice of grammar strengthens the physiological nature of the principle, and converts it into psychic or intellectual needs. So from pronouns to verbs there is a linear progression of thought that starts from the concrete acts (nouns, pronouns and particles) to reach the abstraction of verbs that indicate motions “which involve past and future, which are measured from the indivisible present, which even philosophers find very hard to understand” (Vico SN, 137).

This continuum from concrete to abstract is, therefore, regulated by the biological laws of the articulatory production. Dumb, stuttering, aphasic individuals, children and giants proceed from mute stages to progressively articulated ones, discovering, through a tiresome mechanical sensory-motor training, the production possibilities of the phonatory system.

Baron Wolfgang von Kempelen, an eighteenth-century engineer and an expert on the theoretical debate of language disorders in the seventeenth and eighteenth centuries, has offered a radical and paradoxical version of the primacy of the physiological system for the development of languages in his huge volume dating back to 1778 and dedicated to the construction of talking machines:

a little bit of compressed air from the lungs through the narrow path of the glottis produces the voice; the many obstacles that the tongue, teeth and lips oppose this vibrant air cause the inflection and variety of sounds, each of which has its own significance. That's what reduces all great art of the word, this inestimable gift from the Creator, the main link of society (Von Kempelen 1778, 25–6).

However, Vico is not an engineer, and his is certainly not a mechanistic thought. For him, the centrality of articulatory physiology is associated with the mental activity of the mind. The “fantastic speech making use of physical substances”, as we have seen, is phonetic articulation but, at the same time, it is a fantastic transposition. And it is the term “fantastic” – with all its semantic implications – that is central in Vico's biolinguistics hypothesis on the reception-processing of language that has the same characteristics as “non-answers” of the theory of production just analyzed.

Even in this case we cannot fail to consider the “mute languages” hypothesis, because for Vico onomatopoeia is fundamental for a theory of the way language was understood at its beginning: a concept that for Pagliaro (1961, 380) constitutes a limit to freedom for the expressive potential of a human language.

The depiction of mankind after the flood gives us a first answer. The descendants of Shem, Ham, and Japheth wandered a long time in the humid forests of the post-flood period, chasing their prey and women who were “wild, unruly and shy” (Vico SN, 101). For reasons connected with the necessity of survival they were bad mothers and “abandoned their children, who in time must have come to grow up without ever hearing a human voice, much less learning any human custom, and thus descended to a state truly bestial and savage” (SN, 101).

The phylogenetic reason for onomatopoeic primacy is, thus, explained through a principle of “poverty”, the lack of exposure to the human voice. To break an endless loop – absence of reception /no production/absence of reception... – imagination is then applied to natural sounds. These are not “natural” in the sense that they are “in accord with the nature of the things it dealt with” because these things have not “nature per se” but are “fantastic speech making use of physical substances” (SN, 114). Onomatopoeia as he intends it, as Vico himself remarks, is, in this sense, very different from platonic onomatopoeia. The natural sounds, in fact, are not endowed with intrinsic properties, as in Plato’s phono-symbolism. They only constitute sensory stimuli likely to provoke responses obeying a single constraint: they necessarily have to conform to the universal logic of the mind.

We have now come to Vico’s first axiom: “because of the indefinite nature of the human mind, wherever it is lost in ignorance, man makes himself the measure of all things” (SN: 54). Thus, onomatopoeia causes responses conforming to the universal logic of the mind when, in the absence of an intrinsic property that is directly knowable (which the natural sound lacks), replaces a property derived from the similarity with what man knows of himself. Hence the metaphorical transposition of the body parts, that are the first object that man knows of himself, the poetic significance of rhetorical tropes, the principle that “no homo intelligendo fit omnia”, the equation of the true with the fact, etc, are all themes extensively analyzed in the exegesis of Vico’s thought.

What we can add here is that, in perfect contrast to the ideas by Pagliaro (1961), onomatopoeia is considered to be a fundamental principle that unleashes the strength of what he calls the mind’s first fault (“*mentis vicium*”), initially discussed, in passing, in Vico’s *On the Ancient Wisdom of the Italians* (1710). That is to say, to have the power to create all the parts by “making them again” with one’s own matter, without knowing them in advance, as in the omniscient God’s act of creation. If we excluded onomatopoeia from the fundamentals of human language, that is to say, if we excluded the fact that man started with a mute phase in which – in the absence of human voices – only natural voices could be heard, we would accidentally fall back on the idea that language is based on conventions. This idea, from Vico’s point of view, cannot but presuppose the pre-existence of the intrinsic properties of sounds and the adaptation of knowledge not to the *factum* (which pertains to the human dimension) but to the *verum* (what is true), which belongs to the divine dimension.

It is not onomatopoeia in the literal sense of the term, but the principle that solicits linguistic creation, that is, lack of exposure to the human voice, the poverty of linguistic stimuli, that explains Vico’s repeated recourse to the pathological examples (extensively studied by him, see Pennisi 1990) as early as the First New Science:

for a poverty of words naturally makes men sublime in expression, weighty in conception, and acute in understanding much in brief expression, which are the three most beautiful virtues of language (...). Next, the necessity to express themselves for communicating their ideas to others, at a time when, because of a lack of words, the spirit is wholly engaged in finding a way to express itself, makes such mute men naturally ingenious. Hence they express themselves by means of things and actions that have natural relations with the ideas they want to signify (Vico SNP, 149).

In the same way in which, then, the impossibility of big beasts to hear human voices leads to the expressive method of onomatopoeia and makes it a measure of similarity with what man recognizes as resembling himself, so deafness of the dumb triggers the natural semiotic ingenuity of hand gestures assimilating the corporeal sign to the encyclopedia of the signer. The manual language of the deaf and dumb triggers, once and for all, their language faculty and breaks the communication isolation, which is the real problem of the “mute phases” of any individual and collective history. Given the latter perspective – which is Vico’s political perspective and according to which languages are “the vehicle through which the spirit of nations is transmitted to those who learn them” (Vico AC, 200) – what socially corresponds to the lack of exposure of big giants and deaf and dumb to the human voice is the extinction of the common sense of the vernacular idioms, and hence their death:

this theory of the genesis of languages is in conformity with the principles of universal nature, by which the elements of all things, out of which they are composed and into which they are bound to be resolved, are indivisible; and also with the principles of human nature in particular, according to the axiom that ‘children, even in the present copiousness of language into which they are born, and in spite of the extreme flexibility of the fibers of their organs for articulating words, begin with monosyllables’. So much the more must we deem the first men of the nations to have done so, for their organs were extremely obdurate, and they had not yet heard a human voice. Our theory gives us, moreover, the order in which the parts of speech arose, and consequently the natural causes of syntax (Vico SN, 137).

5.3 From Darwin to Darwin

The philosophers Aristotle and Vico were markedly oriented towards a naturalistic vision of knowledge. As philosophers, their interest in language has always been primary: they knew the techniques of use as well as its nature, its characteristics and structure in great depth. They never set aside their linguistic interest, even when they studied language as a natural object. Their biolinguistics had all the characteristics of a philosophy of language capable of explaining what is now known today as, to use a technical term, “language faculty”.

Darwin was a naturalist. He had a professional interest in biology and he was an incomparable observer of animal behavior. The fact that a large part of the philosophy developing after his death, and especially the most recent part, has followed his principles does not make Darwin a philosopher, let alone a linguist. The title of this book should not be misleading: a Darwinian biolinguistics can never be a biolinguistics “technically” inspired by Darwin’s conception of language – which indeed, as we will see, looks somewhat naïve, even when he deals with the natural dimension of language. However, by the adjective “Darwinian” we refer to a biolinguistics founded on the biology of evolution and mainly on its core ideas: natural selection, biological variability and the gradualism of structural changes.

Darwin never speaks of language in the *Origin of Species* and only devotes a short chapter of a few dozen pages in his work published in *The Descent of Man and Selection in Relation to Sex* to the subject of language. This was an essay Darwin

did not intend to write – as he himself points out in the *introduction* to the volume – for two reasons. One reason was ideological opportunism (“I thought that I should thus only add to the prejudices against my views” – Darwin 1871, 1); the other was based on method, feeling that it was wrong to apply evolutionary principles to “a species taken singly”. Eliminating the comparison, as you do when you apply the method to embryological structures, anatomical, geographical distribution and geological succession, in fact, would weaken the principle of gradual reconstructive evolution, where more speculative arguments can only follow later. He concludes that it would be easier to follow the formula adopted in the *Origin of Species* where he expressed the belief “that work by this light would be thrown on the origin of man and his history” (Darwin 1871, 1).

The Descent of Man is thus characterized by the original sin of wanting to extend evolutionary analysis to a single subject. Given that the subject was the human being, it would have been inevitable to devote much space to cognitive issues and mental attitudes. So, while we can take it for granted that from the anatomical point of view, the operation would be feasible – because “all the bones in his skeleton can be compared with corresponding bones in a monkey, bat, or seal. So it is with his muscles, nerves, blood-vessels and internal viscera. The brain, the most important of all the organs, follows the same law” (1871,10) – as far as “mental powers” are concerned, comparisons are inevitably highly speculative: “no doubt the difference in this respect is enormous” (1871, 34 et seq.).

On the other hand, once one embarked on this courageous choice, it was necessary to keep to this path: avoiding questioning the structural graduality of evolution was necessary to demonstrate cognitive evolution continuity. And, in fact, this is the project Darwin carries out in the second chapter, trying to prove that humans and primates share the same senses, the same intuitions, feelings, emotions, and other mental activities such as imitation, attention, reasoning, of course all in different degrees. The main problems of these demonstrations, however, were of two kinds: one was theoretical and one was methodological.

The theoretical one is based on the very idea of how the conception of mental faculties can be considered as variables in a gradual way and, at the same time, could be considered inheritable.

He who wishes to decide whether man is the modified descendant of some pre-existing form, would probably first inquire whether man varies, however slightly, in bodily structure and in mental faculties; and if so, whether the variations are transmitted to his offspring (1871, 9).

The methodological one is based on the “technical” ability to demonstrate graduality and heritability of mental functions.

As for the theoretical problem, Darwin links it, by changing his mind throughout the various steps of his work and distinguishing what should directly depend on a biological structure shared by all animals (where in addition to the senses and memory, sometimes he includes emotions and attention, sometimes imitation and reasoning), to what now Elizabeth Spelke calls “*core knowledge*”, i.e. a core of instincts and universal behavior (trends, attitudes, tastes, habits, etc.). However, unlike *core knowledge*, according to which these belong to (genetically transmitted) innate

domains, according to Darwin, they are acquirable variables, and they may or may not become inheritable. Of course, the heritability is the most controversial issue. On this point, Darwin proves to be very cautious since the *Foundation on the origin of species*: “I wish here to consider not the probability but the possibility of complicated instincts having been acquired by the slow and long-continued selection of very slight (either congenital or produced by habit) modifications of foregoing simpler instincts” (Darwin 1844, 9). In fact, he knows well that since we are not dealing with structures (bones, muscles, tissues, etc.), but with the skills acquired, the only way that they can be transmitted to descendants is to presuppose a retroactivity of the uses of mental abilities, not of the individual, but of the whole species: which might be conducive to a variant of Lamarckism.

In the draft, dating back to 1842, the third chapter of the first part was dedicated to the variation in the instincts and mental attributes (*On variation in instincts and other mental attributes* – pp. 17–22) and considers the retroactivity of uses on structures as the only possibility: it is as if “incomprehensibly, the brain has power of transmitting intellectual operations” (Darwin 1842, 18). Instincts, in fact, would behave in the same way on survival as the corporeal organization. So selection should be conducive to modifications of the inherited habits:

every instinct must, by my theory, have been acquired gradually by slight changes (illegible) of former instinct, each change being useful to its then species (Darwin 1842, 19).

yet once granted the principle of habits, whether congenital or acquired by experience, being inherited and I can see no limit to the [amount of variation] extraordinariness of the habits thus acquired (1842, 20).

In the already mentioned essay of 1844, the third chapter now has a more precise title: *On the variation of instincts and other mental attributes under domestication and in a state of nature; on the difficulties in this subject; and on analogous difficulties with respect to corporeal structures* (pp. 112–132). Here caution is maximal and we understand that we are facing a critical point of the whole Darwinian theoretical construction. Meanwhile, the object of the discussion is restricted to the “primary mental qualities of the instincts” (Darwin 1844, 112). The transition which would ensure the gradual transformation of the instincts is then subjected to a precise analysis tending to circumscribing cases:

as the instincts of a species are fully as important to its preservation and multiplication as its corporeal structure, it is evident that if there be the slightest congenital differences in the instincts and habits, or if certain individuals during their lives are induced or compelled to vary their habits, and if such differences are in the smallest degree more favourable, under slightly modified external condition, to their preservation, such individuals must in the long run have a better chance of being preserved and of multiplying. If this be admitted, a series of small changes may, as in the case of corporeal structure, work great changes in the mental powers, habits and instincts of any species (Darwin 1844, 120).

So nesting by birds, varying widely from species to species, could indicate the “possibility” that this kind of instinct may have been acquired gradually, through the reproduction of individuals whose nests were somewhat best suited to protect the small ones under certain environmental conditions. Similarly, the “pretending to be dead” strategy in animals, including insects, would reveal that this is an instinct aris-

ing by imitation processes which only a few animals were capable of. However, the examples used never affect real-life higher intellectual functions, but only displays of behaviors which ethnologists nowadays would classify as ‘primary instincts’. Darwin then specifies a further distinction:

In considering many instincts, it is useful to endeavor to separate the faculty by which they *perform* it, and the mental power which urges to the *performance*, which is more properly called an instinct. We have an instinct to eat, we have jaws &c. to give us the faculty to do so. These faculties are often unknown to us: bats, with their eyes destroyed, can avoid strings suspended across a room, we know not at present by what faculty they do this. Thus also, with migratory birds, it is a wonderful instinct which urges them at certain times of the year to direct their course in certain directions, but it is a faculty by which they know the time and find their way (Darwin 1844, 123–4).

Having said this, however, Darwin admits that an instinct always depends on the biological structure and that its *performances* can vary culturally in many ways while remaining inextricably tied to the original ethological configuration. The instinct to eat and the bone-muscle structure set a task that can be carried out in many ways, but the way of eating has been, in the light of current knowledge, the main vehicle of biological, demographic and social development (Cunnane 2005; Ungar 2007; Stanford and Bunn 2001; Hublin and Richards 2009; Wrangham 2009). Moving or flying without bumping into an object is an instinct, but echolocation of bats today depends, as we know well, on biological biosonar equipping their structure and that of other animals such as dolphins and other toothed whales (Marler and Hamilton 1966; Busnell and Fish 1980). Migrating is a fundamental instinct of many species, but today we know that deciding how and when to do it is a biological, social and cultural process (Conradt and Roper 2003, 2005; Seeley 2009, 2010; Black 1988; Pennisi 2014a, b; Pennisi and Giallongo 2015; Cardella et al. 2013). In the case of language, the instinct to communicate can be a biological universal, but there has been a long and gradual change in the biological structures of different species to describe its possible and unpredictable phenomena and functions.

Regardless of the type of analysis used and the conclusions which one may want to derive, one thing is certain: Darwin needs to put forward a hypothesis that leaves it open for us to show that any function, even the highest, can have identifiable evolutionary precursors:

however vague and unphilosophical these conjectures may appear, they serve, I think, to show that one’s first impulse utterly to reject any theory whatever, implying a gradual acquirement of these instincts, which for ages have excited man’s admiration, may at least be delayed. Once grant that dispositions, tastes, actions or habits can be slightly modified, either by slight congenital differences (we must suppose in the brain) or by the force of external circumstances, and that such slight modifications can be rendered inheritable – a proposition which no one can reject – and it will be difficult to put any limit to the complexity and wonder of the tastes and habits which may possibly be thus acquired (Darwin 1844, 127–8).

In the final version of the *Origin of Species* (1859), the controversial issue of inheritance of instincts is juxtaposed to the crucial issue concerning the difficulties and obstacles that come in the way of the theory of natural selection. In the decisive

sixth chapter, specifically devoted to the difficulties of the theory, he identifies three dangerous observations likely to undermine the idea of natural selection. The first is the difficulty of finding forms of transition between the different phases of a selective process. The second is the one posed by the difficulty of explaining forms, as enormously complex as the eye, by using only adaptive transformations. The third is related to the topic of the inheritance of instincts (and, accordingly, of mental behavior).

On the first point, Darwin provides a clarification that does not seem to leave room for doubt. Given that “extinction and natural selection will, as we have seen, go hand in hand” (Darwin 1859, 130), the intermediate forms, precisely because they are inserted in a rapid evolutionary flow, have lasted little or very little time, and so it is very difficult to find traces of both of them in different territories and among the fossil remains.

Instead, the second and the third point are closely related and constitute a really hard tenet for the key assumptions of Darwinism. Everything is determined, in both cases, by the principle of gradualism. The changes, and therefore the evolution of the physical structures and of instincts (i.e. what among physical behaviors is closest to structure) cannot occur quickly: “*natura non facit saltum*”. By treating certain anatomical structures, the answer is more easily defensible. The classic example is the eye:

to suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree. Yet reason tells me, that if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; if further, the eye does vary ever so slightly, and the variations be inherited, which is certainly the case; and if any variation or modification in the organ be ever useful to an animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, can hardly be considered real (Darwin 1859, 140).

In the case of the eye, or any other bio-mechanical device, the perfection achieved can be observed in the transformation which it has undergone in the living proofs of natural selection, that is to say the bodies of the various related species, which can be aligned in linear chains or in trees whose nodes can be retraced in a (relatively) verifiable way. Here the process always starts with structures and forms, to arrive, through environmental changes, to the functions: it is a fully explicable story to be explained entirely *a posteriori*, however complex the end (or temporarily final) results are, albeit it cannot give rise to predictions. You can then finally understand the transition from an optical nerve simply coated with pigment to the human eye and the eye of the eagle in millions of years of “natural” evolution, in the same way as one can easily follow the simplified “artificial” process leading from a lens to the telescope in hundreds of years. Obviously, the adaptive aspect is of crucial importance in this process, but it is not always the fundamental part of explanations, as is demonstrated by the fact that there are minor organs, which are handed down and are also modified. Natural selection will only prevent the survival of harmful forms, but it is not to be taken for granted that in other physiological, environmental or

social configurations insignificant, but survived, parts of living organisms can become decisive in the evolution of a species. Furthermore, very often the modification affecting visible parts may have invisible effects on other parts and can restructure, in whole or in part, the operation of the whole organism.

In the case of complex instincts, this visibility, continuity and linearity of input from the body forms do not exist anymore, or, at least, they are much more difficult to verify. How can one explain, through gradual development, the consequences of powerful instincts resulting in the perfection of the hexagonal cells of a bee hive or the regular presence of different forms of sterile ants among ants? By answering these questions in the *Origin of Species* of 1859, Darwin does his best to try to avoid the negative consequences of the Lamarckian legacy. Although he did not completely manage to do so, he nevertheless retained a strong defensive profile.

In the reconstruction made by Gould (2002), Darwin's functionalism comes from a (moderate) but not too hidden adherence to the Lamarckian principle of the role of use and disuse of organs in the evolutionary history of animal forms. Do not forget that the core of the functionalist Lamarckian creed is the principle that "form follows function: as the order of life's history" (Gould 2002, 177). For Lamarck, one cannot question that "it is not the organs, that is to say, the nature and shape of the parts of an animal's body, that have given rise to its special habits and faculties; but it is, on the contrary, its habits, mode of life and environment that have in course of time controlled the shape of its body, the number and state of its organs and, lastly, the faculties which it possesses" (Lamarck 1809, 114). The environment does not produce any changes in the structures, but produces them indirectly by creating new needs. The needs to be satisfied create reactions in individuals and those, in the course of time, first become habits and then instincts or mental faculties. The *coup de grâce* is that these too are transmitted via the *soft inheritance of acquired characters* (Lamarck 1809, 113 et seq.), creating continuous transformations even of cognitive life.

According to Gould, Darwin was a thinker who was too sophisticated to embrace Lamarckian extremism, "although he accepted the principles of use and disuse and inheritance of acquired characters, and he awarded them a subsidiary role in his own theory" (Gould 2002, 179). However, there is no doubt that Darwin's adaptationist functionalism, outside the scope of the anatomical history, gave rise to very strong argumentative contortions in the explanation of the inheritance of the instinctual transformations. In the previously mentioned seventh chapter of the *Origin of species*, in an effort to project the gradualism of natural selection of structures in the domain of instincts, Darwin, after working out tortuous explanations, ends up admitting that "it would be the most serious error to suppose that the greater number of instincts have been acquired by habit in one generation, and then transmitted by inheritance to succeeding generations. It can be clearly shown that the most wonderful instincts with which we are acquainted, namely, those of the hive-bee and of many ants, could not possibly have been thus acquired" (Darwin 1859, 156). As evidence of this significant statement, Darwin concludes with a complex explanation – "against Lamarck's famous theory" (1859, 361) – of examples hard to reconcile with the simple transmission of acquired characters: the instinct which leads the

cuckoo to lay her eggs in other birds nests; the slave-making instinct of certain ants; and the comb-making power of the hive-bee (1859, 162 et seq.).

This prudent theoretical position promoting the rigors of natural selection without renouncing adaptive and environmental reasons, while addressing up to a minimum the influence of *soft inheritance*, therefore characterizes the *Origin of Species*. This, however, was an essay in which Darwin had never wanted to specifically deal with man and his mental faculties. Forced to do so, he must now come up with a more unconventional method and herein lies the second problem.

While there was evidence in favor of the gradual evolution of the structures, demonstrated with advanced classical instruments of zoology and comparative anatomy – which were safe after having been tested – in the case of gradual cognitive evolution tests, which are essentially constituted by pre-ethological stories of animal behavior, these were impossible to test experimentally and this can be seen throughout the work. Without detracting from the richness and charm of the tales narrated in *The Descent of Man*, which still surprise us due to the acuteness of many judgments (e.g. the one on the deliberative capacity of many animals, recently demonstrated in the scientific domain: Conradt and Roper 2003, 2005, 2010; Conradt and List 2009; Seeley 2010; Pennisi 2014a, b), one can really say that we are here in the presence of a real ethology, characterized by extremely subjective principles. Penn et al. (2008, 164) write that “his liberal use of secondhand anecdotes and anthropomorphic attributions (...) His infatuation with the mental and moral virtues of domesticated dogs (...) did not mark his finest scientific moment” especially in comparison with the rigor and effectiveness of argumentation and scientific writings on natural selection. It is Darwin himself who is acutely conscious of this and attempts to forestall possible criticism “as no classification of the mental powers has been universally accepted, I shall arrange my remarks in the order most convenient for my purpose; and will select those facts which have most struck me, with the hope that they may produce some effect on the reader” (Darwin 1871, 35).

This inherent methodological weakness becomes apparent in the chapter on language where the lack of specific knowledge and (not strictly philosophical) sources on the topic ends up foreshadowing a sort of theoretical rift between Darwin, as he appears to us in *The Descent of Man*, and the one in the *Origins of Species*, which was written nearly 20 years earlier.

Paradoxically, in the functional analysis of the language faculty, Darwin is, in fact, closer to the Cartesian and Chomskyan assumptions than to his own hypothesis about natural selection. Conversely, in the reconstructive part, he is close to Vico’s thesis, by also proposing innovative perspectives which can be applicable even today. Being a superior function, the linguistic ability, in fact, has the following characteristics:

- (a) it is an innate faculty: “for man has an instinctive tendency to speak” (Darwin 1871, 55);
- (b) it presents a species-specific morphology (“articulate language is, however, peculiar to man” the latter is not fundamental: “it is not the mere power of articulation that distinguishes man from other animals, for as everyone knows, parrots can talk” – Darwin 1871, 54);

- (c) its specific character is the result of a special type of mind: “it is his large power of connecting defined sounds with defined ideas; and this obviously depends on the development of the mental faculties” (Darwin 1871, 54).

As to its origins, however:

- (a) he takes up the idea of “imitation and modification, aided by signs and gestures, of various natural sounds, the voices of other animals, and man’s own instinctive cries” (Darwin 1871, 239);
- (b) it begins with songs, especially during the mating season, used for courtship but especially to challenge rivals in the struggle for the possession of the females: “the imitation by articulate sounds of musical cries might have given rise to words expressive of various complex emotions” (239);
- (c) it is developed through the ‘use of the vocal organs and soon becomes hereditary’: “as the voice was used more and more, the vocal organs would have been strengthened and perfected through the principle of the inherited effects of use” (239).

In connection with functional analysis of the language faculty, what is more surprising than Darwin’s homage to Cartesian rationalism is the residual persistence of an inexplicable and bizarre dualism. It is really strange, in fact, to see the father of evolutionary biology show extreme disregard for peripheral anatomy, even if little, of course, was known at the end of the nineteenth century (despite Broca’s findings). While recognizing the particular nature of articulate speech, Darwin seems to look at the lower performance of human vocality: the inarticulate voices, gestures and facial movements that human beings share with the emotional behavior of other animals. What he would like to demonstrate is that the exceptional nature of language does not depend on the articulatory system or even on the brain, but on specific mental faculties that lead to a certain way of using the organs.

Thus, according to Darwin, “the fact of the higher apes not using their vocal organs for speech, no doubt depends on their intelligence not having been sufficiently advanced” (Darwin 1871, 59). He thinks that the possession and intentional use of vocal organs in non-human primates would have been able to lead them “with long-continued practice”, (59) to articulate speech: but man remained mentally superior.

On the other hand, this opinion was normal even after the circulation of the works by Perrault (1676) and Tyson (1699), who regarded the larynx the most important organ of the vocal tract, and the similarities between the characteristics of different primates were studied. Since the larynx of the chimp looked very similar to that of human beings in an analysis in which the supralaryngeal vocal tracts did not play an important role, the idea prevailed that the organs of human and non-human primates were not so different.

Accordingly, the fact that monkeys could not speak was attributed to differences in mental power. This tradition of thought became an important point in Cartesian iatromechanics (think of the bizarre dreams by Julien Offray de la Mettrie expressed in *Man a Machine*, 1748, about the idea that monkeys could be educated) and was perpetuated until the first phase of modern zoosemiotics scholars, who tried in vain to make chimpanzees talk.

Darwin knew about Tyson and Perrault's works, probably through the writings of the physiologist Johannes Müller, who was often mentioned in his works along with Max Müller (the world-renowned linguist). And thus Darwin ended up with the usual clichés regarding the scarce importance of the vocal apparatus in all primates, including the human animal. In short, all higher mammals might have become speakers if the organs facilitating speech had been subjected to a deliberate and intensive use. It remains a mystery why even animals that have bodies and brains predisposed to specific linguistic uses (primarily some species of birds such as corvids) never activated this possibility.

In fact, it is mainly in connection with the issue that language is the greatest of the mental functions or inheritable instincts, that Darwin seems particularly indebted to the Lamarckian assumptions that we mentioned previously. Stephen Gould (2002) believes that this adaptionist temptation founded on usage is the main source of errors and contradictions in Darwin's works. It is, in an upshot, the prevalence of functionalism that ends up relegating the role of the structural constraints to a marginal position in the otherwise brilliant theory of natural selection (Gould 2002, §.4). This is a very contentious ongoing dispute that sees functional adaptation theory and the theory of constraints on forms put forward by Evo-Devo.

The constraints on forms, in fact, can be accounted for by the general Bauplan underlying the evolutionary history of all living organisms from the beginning to its development. Due to constancy and spread, some constraints stand out, mainly those related to symmetries, which explains the duplication of the organs, the number of body segments and limbs, but also the immense number of anatomical constraints related to these fundamental constraints. The constraints on form and development are higher on the hierarchy than those of natural selection, and lower in the hierarchy with respect to pure physical laws, e.g., the law of gravity and the weight of bodies. Another key feature of these constraints, which makes them different and proceeding in the opposite direction with respect to those of natural selection, is the immediate independence of functions. Normally, no purpose or adaptive function can defeat the obligations required by compliance with the forms. In a way, it is antagonistic constraints that confer evolution the characteristic of unpredictability eliminating all traces of teleology in biological inquiry, however, without making it chaotic or unexplained.

In the case of language, Darwin does not make much effort to find the connection between the evolution of the structures and the evolution of functions, of which he had also attempted to write in the '*Origin of Species*'. In other words, he does not seem to directly connect the potentiality of a peculiar anatomy with those of a peculiar function. They appear to be juxtaposed in order to avoid questioning the formal presupposition of the gradualism of any aspect of evolution. And we have to admit that, perhaps, it is this kind of task that is the most difficult to solve.

Much of the confusion generated on this point by the contemporary debate derives, in our opinion, from not being able to recognize that the typical gradualist element present in Darwin's proposal can only be applied to structures and not directly to functions. It is useless to get bogged down in speculations on the cognitive functions presupposed by language.

It is the progressive modeling of the bodies to make possible the eventual transformation of uses and behavior functions, especially those with a strong cognitive component. As we have said before, the structural constraints are higher-level than functional ones: you cannot use organs that you do not have, you cannot expect structures that do not exist to carry out new functions. But accepting this would amount to completely rejecting the charm of the Lamarckian sirens, whatever form they may have taken in the history of natural thought.

There is no doubt, however, that the weight of the theoretical ambiguity on the theme of language tormented Darwin who in the meantime was systematically reflecting on the ethology of animal communication.

A year after the first edition of *The Descent of Man*, he published *The expression of the Emotions in Man and Animals* (1872). The book recalls all the possible links between human and non-human animals related to pre-linguistic expression. The basic thesis is that the communicative uses are a universal feature that seems connected to the structural evolution of the species.

Among mammals, the default vehicle of communication is certainly the vocal apparatus: “the power of intercommunication between the members of the same community (...) is generally effected by means of the voice” (Darwin 1872, 61). “The vocal primacy is mainly due to the architecture of the respiratory system which is mechanically associated with the ability to emit vocal sounds, because respiratory organs have been specially adapted for expression” (90).

Species with different organization communicate in many ways using, in order to produce sounds, their innate biological kit: rabbits clap their feet on the ground to attract mates, porcupines vibrate spines, snakes produce jingles, insects sizzle paws on their body. Vocal communication is frequently accompanied by gestures, facial or body expressions facilitating the intentions’ intelligibility. Emotions, feelings, and other mental states, in fact, constitute cognitive pre-conditions for any type of expression. They may have played an initial role to enable increasingly complex cognitive functions, performing in different communication modalities. The role of gestures, kinetics, and proxemics constitutes the lower layer that virtually accompanies all communication practices: the *naturalistic-core* of each expression system. There is no doubt, however, that Darwin has now gained the certainty that for “the emission of sounds – with many kinds of animals, man included – the vocal organs are efficient in the highest degree as a means of expression” (1872, 83).

The evolutionary advantages of the vocality are different.

First, it allows an easier application of the principles of sexual selection, especially applied to Primates. From this point of view, Vico’s idea about sung origin of the first language, also present in *The Descent of Man*, is confirmed.

Here we add a new, more sophisticated analysis related to the technical complexity of vocal manipulation: “I have been led to infer that the progenitors of man probably uttered musical tones, before they had acquired the power of articulate speech; and that consequently, when the voice is used under any strong emotion, it tends to assume, through the principle of association, a musical character” (1872, 83).

The link between emotionality, musicality and development of vocal apparatus complexity is now seen as an inexhaustible vector of pleasure, especially for the social-species and, chiefly, for man:

the greater or less mechanical facility with which the vibrating apparatus of the human larynx passes from one state of vibration to another, may have been a primary cause of the greater or less pleasure produced by various sequences of sounds (90).

Even the pleasure derived from the vocality, then, may be correlated with the potential of “externalization” organs. This acted as a powerful incentive to use vocal organs that in modern sapiens are permanently available for phonation and technically more flexible. The hedonistic function, however ancient it may be, becomes the more refined the more the apparatus is complex. The man, in fact, “not only uses inarticulate cries, gestures, and expressions, but has invented articulate language; if, indeed, the word invented can be applied to a process, completed by innumerable steps, half-consciously made” (Darwin 1872, 60).

The vocal articulation as evolution of phonatory organs’ mechanics has nothing special, and, above all, it is not “invented”, but it results from the gradual development of the bio-psychological modifications. However, it turned out to be adapted for social communication to make its use predominant, universal (the entire human genre) and essentially irreplaceable.

Another advantage of vocality identified by Darwin is the independence of the phonatory apparatus from mind control. Or, rather, their evolutionary autonomy, which affects their functional possibilities. This is to clarify:

another obscure point, namely, whether the sounds which are produced under various states of the mind determine the shape of the mouth, or whether its shape is not determined by independent causes, and the sound thus modified (1872, 92).

It is the first time that, referring to language, Darwin seems to admit the coercive power of the body on the mind: this forced relation, in fact, is evident for all other functions within the naturalistic framework of his philosophy. This new approach is determined by the discovery of the biological limits of auditory and vocal structures supported by the Helmholtz *Théorie Physiologique de la Musique* (1868) (*On the sensations of tone as a physiological basis for the theory of music*), often cited by Darwin (1872). In the years when Darwin was meditating on the biology of animal communication, from the top of his scientific eclecticism model Helmholtz, put in close relation the anatomy of the productive and receptive apparatus (*The mechanism of the ossicles of the ear and membrana tympani*, 1869) with the structures of acoustic physics and psychology of tonal perceptual.

Essentially, Helmholtz suggests to Darwin the idea that the use of auditory-vocal organs is restricted by precise physical, physiological, and consequently psychic constraints.

Thus, eg., the vocalizations of children are determined by the compulsion to assume the physiological postures specific of mouth “from a quite distinct causes”. The mechanics of these causes escapes, by his own admission, the Darwinian competences, “but we know from the researches of Helmholtz and others that the form of the cavity of the mouth and lips determines the nature and pitch of the vowel sounds which are produced”, as Darwin himself wrote (1872, 92).

The relationship between the shape of the buccal cavity and the production of different vowels is a biological constraint as much independent from function as the body postures that indicate the surprise, disgust, anger and all universal set of primary emotions. Of course this is applied not only to humans. All species are constrained in their communication strategies by their morphological structures regardless of the quantity and quality of their cognitive encyclopedia. However, Darwin, analyzing in the descriptive chapters of the book hundreds of examples of this theoretical principle present within various species, is aware of being only at the beginning of this new path.

A big progress has been made “but the whole subject of the differences of the sounds produced under different states of the mind is so obscure, that I have succeeded in throwing hardly any light on it; and the remarks which I have made, have but little significance” (1872, 93).

Reflection elaborated in this transition book, however, affected the Darwinian linguistics deeply.

Otherwise, it would be difficult to explain the changes introduced in the second edition of *The Descent of Man* (1784) to certain essential arguments which had just been analysed: it is a crucial turning point. In fact, while the ideas of the faculty of language innateness and the substantiality of articulation for language are confirmed, the presumed human uniqueness for the mental component of language almost disappears, especially that relative to semantics understanding.

The decisive passage demonstrating this change is worthy of a comparative reading between the two editions (the differences, which we will comment on later, are in italics, the main points are in bold):

Articulate language is, however, peculiar to man; but he uses in common with the lower animals inarticulate cries to express his meaning, aided by gestures and the movements of the muscles of the face. This especially holds good with the more simple and vivid feelings, which are but little connected with our higher intelligence. Our cries of pain, fear, surprise, anger, together with their appropriate actions, and the murmur of a mother to her beloved child, are more expressive than any words. It is not the mere power of articulation that distinguishes man from other animals, for as every one knows, parrots can talk; but it is his large power of connecting definite sounds with definite ideas; and this obviously depends on the development of the mental faculties (1871, 54)

The **habitual** use of articulate language is, however, peculiar to man; but he uses, in common with the lower animals, inarticulate cries to express his meaning, aided by gestures and the movements of the muscles of the face. This especially holds good with the more simple and vivid feelings, which are but little connected with our higher intelligence. Our cries of pain, fear, surprise, anger, together with their appropriate actions, and the murmur of a mother to her beloved child are more expressive than any words. *That which distinguishes man from the lower animals is not the understanding of articulate sounds, for, as every one knows, dogs understand many words and sentences. In this respect they are at the same stage of development as infants, between the ages of ten and twelve months, who understand many words and short sentences, but cannot yet utter a single word. It is not the mere articulation which is our distinguishing character, for parrots and other birds possess this power. Nor is it the mere capacity of connecting definite sounds with definite ideas; for it is certain that some parrots, which have been taught to speak, connect unerringly words with things, and persons with events. The lower animals differ from man solely in his almost infinitely larger power of associating together the most diversified sounds and ideas; and this obviously depends on the high development of his mental powers* (1874, 85)

In the transition between the two editions it seems that Darwin has enhanced the power that the practice of spoken language may have had on the development of cognitive abilities, certainly pre-existing in other species, but totally boosted by language use. Then Darwin identified the first difference between humans and other species regarding not the mere existence of the articulated language, but its habitual use. Humans have gradually intensified this use for increasingly diverse social purposes and for needs not limited to sexuality and defence. Starting from anatomical structures inherited from other animals, man continues to set aside the inarticulate component of his vocality (and gestures) to express “the more simple and vivid feelings, which are but little connected with our higher intelligence”. However, a cognitive refinement is closely linked to the structural changes that enhance the articulatory power of voice:

as all the higher mammals possess vocal organs, constructed on the same general plan as ours, and used as a means of communication, it was obviously probable that these same organs would be still further developed if the power of communication had to be improved; and this has been effected by the aid of adjoining and well adapted parts, namely the tongue and lips (Darwin 1871, 59; 1874, 89).

The modification of cognitive configuration runs parallel to the change of organs more adapted to linguistic articulation.

In *The expression of the Emotions in Man and Animals*, Darwin has already noted that, unlike all other structures used to communicate that “has been developed or even modified exclusively for the sake of expression”, articulate language, i.e. “the vocal and other sound-producing organs, by which various expressive noises are produced, seem to form a partial exception” (1872, 356).

Now Darwin sees a biological interaction even between the expansion of spoken language practice and the brain development:

as the voice was used more and more, the vocal organs would have been strengthened and perfected through the principle of the inherited effects of use; and this would have reacted on the power of speech. But the relation between the continued use of language and the development of the brain, has no doubt been far more important (Darwin 1871, 57; 1874, 87).

Critics of Darwinian thought have largely ignored the fact that, according to this passage, the use of speech organs does not produce mental patterns that are then inherited and become evolved instincts, as in the many cases that we have previously listed. If we read this passage with an anti-Lamarckian lens (as we believe it is only right to do out of respect for the father of evolutionary biology) it indicates the power that the use of specific organs (certainly not yet all well known by Darwin) may have had on a direct evolution of the “brain” and only after, and in a mediated way, on the “mind” (which is produced from, but can not be confused with the brain).

Next to the decisive role that the habitual use of linguistic articulation has played in cognitive evolution, a second difference evident in the comparison between the first and second editions of *The Descent of Man*, is the downsizing of the mental skills related to language uniqueness, and in particular semantics and syntax. We will start with the first difference: semantic processing is *not uniquely human*.

The impact of this position lies in the idea that what distinguishes man from other animals is neither the understanding of articulate sounds or the capacity to connect sign with referent.

In other words, what we have always regarded as the highest cognitive properties of human language, that is, its ability to give meanings to specific well-defined signs in its most basic form, is virtually present in any other non-human animal.

And here, the difference between the first and second edition is also notable from the numerous empirical data that is now reported (albeit with the same anecdotal style that we already stigmatized above). Darwin considers an established fact that dogs understand many words and phrases, that parrots not only can repeat vocal sounds but also can behave consistently with the heard request; that starlings, magpies and other birds use certain vocalizations in a manner proper to contextual situations; that different kinds of monkeys always use the same songs for certain forms of courtship or to warn conspecifics of impending danger; and that one year old infants can understand words and sentences but are not able to articulate a single word (see Darwin 1874, 80 et seq.).

On the other hand, in the years between 1871 and 1874, Darwin utilizes other relevant studies appearing in zoosemiotics, in addition to those about hearing-voice biophysics by Helmholtz, already discovered in *The expression of the Emotions in Man and Animals*. In particular, decisive information are present in the *Études sur les facultes mentales des animaux comparées a celles de l'homme*, published in 1872 by J.C. Houzeau, and in the *Essays on Freethinking and Plain Speaking*, published in 1873 by Leslie Stephen. Darwin quoted Stephen (an “acute reasoner”, Darwin 1874, 78 n.2) on his opinion about nonhuman animals semantic comprehension: “a dog frames a general concept of cats or sheep, and knows the corresponding words as well as a philosopher: and the capacity to understand is as good a proof of vocal intelligence, though in an inferior degree, as the capacity to speak” (Stephen 1873, 82 – cit. in Darwin 1874, 90).

Even with syntax, albeit in a very general sense, the possibilities seem to reduce for non-human animals. In the first edition, this property is defined as “a long and complex train of thought” that requires the help of words spoken, in the same way as happens with calculations that require the use of geometric and algebraic symbols (1871, 57). In the second edition, the syntactic operations have lost the obligatory attribute of length and are only “a complex train of thought” that “is greatly facilitated by some form of language” (1874, 88). But language is not indispensable in combining thoughts. Both in the first and second editions, Darwin in fact recognizes that both deaf-blind humans (such as Laura Bridgman) and dogs would seem to be able to combine mental signs without words. In the second edition, Darwin points out that the dogs’ ability would be inferable “from the movements of dogs during their dreams” and it could be extended to all other animals (“we have, also, seen that animals are able to reason to a certain extent, manifestly without the aid of language” – 88). Therefore, it would generally be thought that neither syntax, i.e. a combinatorial cognitive operation, nor semantics are specific to language.

What would be left, then, to characterize language? Again, the answer can be derived from the crucial passage we have mentioned earlier: “the lower animals dif-

fer from man solely *in his almost infinitely larger power* of associating together the most diversified sounds and ideas". In short, a difference in vocal organs use allows a vastly wider, potentially infinite extension of those mental powers that already exist in preceding species from which we derive the physiological structures and so enabling our cognitive advancement.

From a strictly biolinguistic point of view, Seyfarth and Cheney (2010) argue that the main merit of the Darwin position on language is the definition of a method that distributes the comparison between human and other animals' vocality between three key points: production (i.e. how to articulate), use (i.e. pragmatic features, vocalizations pertinent in relation to social context) and understanding (i.e. comprehension of interlocutor vocalizations): "this three-pronged approach was essential because, whereas humans were very different from other animals in the domain of production, human and nonhuman animals seemed a bit more alike in usage and even more alike in comprehension" (2010, 92).

Agreeing with this position, we can summarize the specific Darwinian contribution to biolinguistics in the following points:

1. The origin of human language is essentially vocal, and it is derived from vocalizations of preceding animal species ("I cannot doubt that language owes its origin to the imitation and modification of various natural sounds, the voices of other animals" – Darwin 1871, 56; 1874, 87 – with some slight but significant syntactic variation between the two editions).
2. The articulated language has been selected exclusively in humans both because it is the natural-biological candidate to realize an expressive ability already existing in other animals, and also because it has allowed the preservation of a specialized use of hands (Darwin 1871, 58; 1874, 59).
3. Non-articulate vocal productions and non-verbal signs use, both shared with other animals, support vocal language for feeling and emotion expressions, even those socially selected, but they are not connected with higher-level intellectual operations (Darwin 1871, 58; 1874, 85).
4. Since only physical structures can be heritable, voice articulation increase has caused a structural change in the brains of humans (Darwin, 1871, 59; 1874, 89).
5. Continuous and totally stabilized use of articulated language in human populations has favoured a strengthening of the degree, not a change of nature, of those cognitive abilities already existing in other animals without the infinite combinatorial forms (semantic and syntactic) that allows human linguistic articulation.

In this embryonic sketch of Darwinian biolinguistics, two issues are still absent, but are still being currently debated: the problem regarding the nature of biological constraints and where these constraints exist relatively on the evolutionary timescale. A Darwinian biolinguistic has to find the answers posed by these issues.

5.4 Resistance and Resilience: The Watershed of Neuroscience

Darwin was, however, behind on the new biolinguistic trends of his time.

His knowledge of Aristotelian philosophy and Vico, and, more generally, of linguistic philosophy from ancient times until the eighteenth century encyclopedists was understandably scarce, although he considered – in the first note of the fourth edition of *The Origin of Species* – an Aristotelian excerpt (Phis., II, b8, 17–32) which he read second-hand (Solinas 2015, 1 et seq.), as the forerunner of the theory of natural selection (see Sect. 13.1).

Moreover, not even an ardent observer of animal physiology like him was able to comprehend the decisive importance of the morphological specificity of the human vocal tract: “Darwin’s ignorance on this point was something that he had in common with all contemporary scientists and which for a long time continued to hamper psychological, zoological and etiological studies” (Gensini 2014, 313).

In fact, some glimmer of hope was disseminated by the works of the great anatomists Sir Charles Bell (1824a, b; 1829) and John Bishop (1851, 1856), on the anatomy of the vocal apparatus and who had identified the crucial point of the anatomical distinction between human and non-human primates in the superior section of the vocal tract: “for articulate language an additional set of organs must be called into play, namely, the pharynx, hard and soft palate, uvula, tongue, teeth, lips, and nostrils” (Bishop 1851, 11). Bishop, moreover, seemed to show a natural propensity to project this knowledge on an evolutionary scale:

when it is considered that animals, especially those of the higher orders, are provided with a complex mechanism for the production and modification of sounds, that they are endowed with an exquisitely organized acoustic apparatus for transmitting the impression of sounds to the brain, and, lastly, that in the latter organ the nature and character of those sounds are perceived, and subjected to intellectual processes, it is reasonable to conclude that creatures so gifted were intended to employ those sounds for some beneficial purpose. The modification of the voice depends on the development of the intellect; and, accordingly, the lower we descend in the scale of animal life, the less is the power of diversifying vocal sounds. Most of the orders of mammalia are provided with mechanism capable of producing an extensive range of sounds; but the intellect even of the highest quadrupeds is not sufficiently developed, to admit of their applying these sounds for the purposes of articulate speech (Bishop 1851, 9).

However, up until the late nineteenth century, theoretical sensitivity and proper experimental methodology seem to be missing for this decisive argument and their inclusion could have solved many of Darwin’s “philosophical” problems.

In addition, Darwin seems to have missed the train of neuroscience that, during those years, began the overwhelming race that would ultimately lead to an undisputed and almost exclusive way to orient biolinguistics and modern and contemporary cognitive linguistics.

Darwin knew and often quoted Broca – who was, amongst other things, an ardent evolutionist – but only his anthropological findings, some of which had cast doubt that excessive weight had been attributed to natural selection. On the discovery of

aphasia, and Broca's fundamental essays published in 1861 and 1864, which were destined to change the history of knowledge on the relationship between brain and language, there are no specific references in Darwin's work of 1871, but only one passage full of errors and confused notions:

the intimate connection between the brain, as it is now developed in us, and the faculty of speech, is well shown by Those curious cases of brain-disease, in which speech is specially affected, as When the power to remember substantives is lost, whilst other words can be correctly used. There is no more improbability in the effects of the continued use of the vocal and mental organs being inherited, than in the case of hand-writing, Which depends partly on the structure of the hand and partly on the disposition of the mind; and hand-writing is Certainly inherited (Darwin 1871, 58).

In this passage, however, there is no reference to Broca but the Note, a work by Dr. Abercrombie of 1835 (*Inquiries Concerning the Intellectual Powers*) is cited instead. The curious thing is that despite this substantial lack of interest by Darwin in the newborn neurosciences, the reaction against his linguistic ideas is very strong and goes in the same direction as his resistance to Broca's ideas. Evolutionism and neuroscience in fact, both participated in the radical scientific breakthrough occurring in late nineteenth century culture that tended to "reduce" all processes to a physical and natural dimension. That language is localized in one part of the body (the foot of the third frontal gyrus of the left hemisphere of the brain), or that there can be a continuity between the structural apparatus (peripheral and central) of human and non-human primates, appeared, at the time, to be fierce critics of the two sides of the same coin.

This fear spread into different parts of the scientific community: neuroanatomists and physicians, linguists, philosophers are the same, basically, as they are today, but existed in an atmosphere that was not imbued with the spirit of interdisciplinary cognitive science. A precise pattern unified their anti-Darwinian reasoning and their spirit was contrary to localizationism. It was based on the following principles formulated by a physician, Frederic Bateman, a contradictory neuroscientist who was fearful but resilient, in his book with the meaningful title *Darwinism tested by language* (1877):

1. there is quality and not quantity difference between human language and that of other animals ("we possessed a difference of kind between man and the ape which Mr. Darwin professes his inability to find", Bateman 1877, 147–151; "the faculty of language establishes a difference between man and animals, not of degree only, but of kind, in fact, the very difference which Mr. Darwin has been so long in search of, and which he has hitherto failed to discover" – 178 e ss.);
2. articulate language is an attribute of all people and not of particular "races"; it is a cognitive universal (Bateman 1877, 152 et seq.);
3. the language faculty is completely immaterial and is not localized in any part of the body;

the Immateriality of the Faculty of Speech, it has been necessary to enter briefly into the much-vexed question of the Seat of Speech – the Localisation of the Faculty of Articulate Language; for, as the remarkable similarity between the brain of man and that of the ape

cannot be disputed, if the seat of human speech could be positively traced to any particular part of the brain, the Darwinian could say that although the ape could not speak, he possessed the germ of that faculty, and that in subsequent generations, by the process of evolution, the speech centre (Bateman 1877, 180).

If you think that Bateman had sent a copy of his own recent book *On Aphasia: the loss of speech, and the localization of the faculty of articulate language* (1870) – written in opposition to Broca's (1861) work and before the sharp pro Darwinian U-turn of Broca (1888) – to Darwin, immediately after the publication of the first edition of *The Descent of Man*, a clear framework can be seen to exist of how, even in a naturalistic context, there was great resistance to a materialistic biolinguistics (see Radick 2000).

Amongst linguists the strongest resistance came from Max Müller, whom Darwin considered to be his greatest source of inspiration for language facts. He completely denied the studies on comparative physiology which, as we have seen thanks to Bishop, had identified a substantial material difference in the vocal tract between human and nonhuman animals. According to Müller, the research by physiologists, acousticians and anatomists had increased, rather than dispelled, the doubts about the nature of language. This was because his real problem was with the cognitive nature of language:

there is, no doubt, in language a transition from the material to the spiritual: the raw material of language belongs to nature, but the form of language, that which really makes language, belongs to the spirit. With one foot language stands, no doubt, in the realm of nature, but with the other in the realm of the spirit; and I may here express my conviction that the Science of Language will yet enable us to withstand the extreme theories of the evolutionists, and to draw a hard and fast line between spirit and matter, between man and the brute (Muller 1881, 234).

On the other hand, it was during this period that the hypothesis was put forward about the “mould of thought” and “an attachment to thought” (Cerise 1865; Parchaphe 1865): an instrument of “externalization” as is now held by current biolinguistics and which was held by the philosopher of language William Dwight Whitney who directly inspired F. De Saussure:

the language is the instrument of thought, the machinery by which the mind works; it is the spoken means whereby thought is communicated, and it is only that; words are not mental acts, they are combinations of sounds, effects produced upon the auditory nerve by atmospheric vibrations, which are brought about by physical agencies – agencies set in operation, it is true, by acts of volition – but whose products are no more mental than are pantomimic motions voluntarily made with the fingers. Language is not thought, nor is thought language, nor is there a mysterious and indissoluble connection between the two, as there is between soul and body, so that the one cannot exist without the other. There can hardly be a greater and more pernicious error, in linguistics or in metaphysics, than the doctrine that language and thought are identical. It is, unfortunately, an error often committed, both by linguists and metaphysicians (Whitney 1867, 120 et seq.).

This trend was destined to last, hindering early formulations of neuroscientific localizationism. Scholars who professed a unitaristic approach furnished a conception that was at the same time holistic and dualist as an alternative first to the excessive enthusiasm and wild exaggeration of phrenology and then to the supporters of functional topography of the brain.

As early as 1866 John Huglings Jackson held the view that, for example, the only real loss for the aphasic patient is that of the “ability to propositionise” (1878–1879, 160) and this was contrary to both Karl Wernicke and his “centers” of verbal image, and the localizations supported by Broca’s aphasia. For Jackson, language and words are primarily psychological terms: “it is well to insist again that speech and words are psychical terms; words have of course anatomical substrata or bases as all other psychical states have. We must as carefully distinguish betwixt words and their physical bases, as we do betwixt colour and its physical basis: a psychical state is always accompanied by a physical state, but, nevertheless, the two things have distinct natures” (114).

The first revelation of this dual emphasis on linguistic knowledge is contained in one of the most controversial statements by Jackson: behind every negative phenomenon of the pathological state something positive is hiding. Studying aphasia, for example, it would seem odd to say that the production of abnormal or wrong sentences is a positive sign. However those residues of language would indicate that at least one nervous readjustment process has escaped the damage (Jackson, 1879–1880: 154–55).

The second duality is expressed in the assimilation between the automatic-voluntary nexus and simple-complex. In aphasia they do not appear to be governed by chance: the most complex skills are lost first, then the simplest ones are lost too. Complexity is controlled, simplicity is automatic. Observing the symptoms of his patients, Jackson argues that the destruction takes place primarily in the most organized brain activity pursuing aimed purposes, leaving the most humble and simple activity free to express themselves.

On this basis, the third and decisive Jacksonian duality was founded: “healthy language is of two inseparable yet distinct forms: 1) Intellectual, i.e., the power to convey propositions. 2) Emotional, i.e., the ability to exhibit states of feeling. The two are separated by disease” (Jackson 1868, 59). For Jackson, then, there is a “superior speech” and “inferior speech” directly linked to a different level of understanding, according to Jackson’s formula: *inferior speech and inferior comprehension* (Head, 1915 11 et seq.). The quantity, but especially the quality of the understanding, is related to the permanence of propositional language. This definition is independent of the type of code used. “To propositionise” is not only a spoken speech activity, but the use of signs of any expression, whether produced in speech, writing, or any other means of expression. In any kind of semiotic expression, therefore, there is a propositional component and a mechanical one. In the case of spoken language, it cannot be stated in the abstract what is considered to be propositional language or a simple automatic mechanism. A proposition for Jackson, however, is always a syntactically consistent construct (Jackson 1868, 66).

Perceptions, characterized by automatic immediacy are distinguished by their pure mental activity because they exclude the basic elements of syntactic relations, i.e. order, hierarchy, relational. A clarification by Jackson then seems to exclude that even the inhibition of simple signs of feelings can be limited to physiological aspects of the production. In aphasia not only is the external language, that is, the output, conveyed by a transmission channel (air, paper, etc.), but also the internal, mental

language is prevented from ‘propositional activities’: “loss of speech is therefore the loss of power to propositionise. It is not only loss of power to propositionise aloud (to talk), but to propositionise either internally or externally, and it may exist when the patient remains able to utter some few words” (Jackson 1878–1879, 160).

Jackson, thus, considers real language as only those organized forms of speech that testify to the unity of the individual conscious thinking. Language is a matter of high-level, essentially mental nature that has nothing to do with “the mechanical power of speech” (Bébian 1817, 13). This complex and mental high capacity that produces representational activities through language, pre-exists the very language, and would constitute a general symbolic activity that can unfold through any complex system of signs: “I think, then, that the so-called ‘faculty of language’ has no existence” (Jackson, 1866: 123). Language is based on the notion of radical arbitrariness of the sign, it does not pertain to the world of sounds, or of references and is not dependent on the phonetic or semantic dimension, but is implemented only in the world of formal and syntactic rules.

Even the unitarists of the doctrine of aphasia agree, along with the post-Darwinian exegetes, in considering the syntactic form of language as a consequence of the separation of thought and speech: “thought precedes the intellect necessarily in any sign intended to express it” (Bébian 1817, 23) or as written by the founder of the unitaristic doctrine of aphasia, the transcendentalist J. Lordat: “you can think of, combine the abstract ideas, distinguish them clearly, without having any word to express” (Lordat 1843, 142). Jackson, then, was at the top of a substantially idealistic conception of language already well underway by the early nineteenth century, and which reached full maturity with K. Goldstein and neo-Cartesian philosophy and neo-Platonic modern biolinguistics. He simply brings to the extreme the implicit mentalism of all semiotic traditions of the late nineteenth century: “in all voluntary operations (the proposition) is preconception. The operation is nascently done before it is actually done; there is a ‘dream’ of an operation as formerly doing before the operation” (Jackson 1879–1880, 168).

It is perhaps no coincidence, then, that Freud began to see in aphasia an intricate network of unconscious mechanisms that are generated in dreams or in lapses, which are at the origin of wit, condensations, camaleontisms, metaphors dreams, and that – as Jackson had pointedly noted in aphasics – preserve the integrity of the ego revealing, through an open window on the behavior, reactive activities of a psychic organism attacked by the disease, and countering everything in the black box of the mind. Nevertheless we must recognize that *On aphasia* (1891) – which was a lot more advanced than *The Interpretation of Dreams* (1900), and to *Jokes and Their Relation to the Unconscious* (1905), and the *Psychopathology of Everyday Life* (1904) – was not a reckless attack on neuroscientific hypotheses but a balanced internal critical acceptance of a clinical paradigm that would still be producing results shortly thereafter.

The real “anathema” (Lecours and Lhermitte 1979, 36) against localizationism and its variants was launched instead by Pierre Marie who was destined to become known as “the iconoclast” in the history of aphasia. The article that made him famous peremptorily stated: *La troisième circonvolution frontale gauche ne joue*

aucun rôle dans la fonction du langage, was published in “La Semaine Médicale” on May 23, 1906. The third left frontal gyrus was the area that Broca had clearly identified as the real locus responsible for aphasic manifestations. Pierre Marie wanted to show that, not only Broca’s theory, but his observations made by operating on the brain were incorrect. Based on the preserved casts of patients analyzed by Broca, Marie pointed out that damage was not only localized in Broca’s area but was spread a little everywhere and that the detected pathologies included the whole intelligence and not language in particular.

Beyond the problem of specifying the location of the damage, Pierre Marie’s subversive discourse involved the very idea that we could identify and isolate a specific language impairment, and, therefore, that aphasia was such an impairment. Aside from its careful topographic reconstructions of brain destruction, Pierre Marie’s reasoning went through a series of non-clinical arguments:

1. the inconsistency of the pragmatic theory of the centers. If the centers were to contain the images of words, one should posit an abnormal development of this center, especially among polyglots (Marie, 1922: 36). It would be more reasonable to posit a mechanism of intellectual elaboration of a restricted number of instruments of phonetic storage (ie the syllables);
2. the non-existence of “word deafness”. Clinical practice, in fact, continually showed cases of patients who were capable of emitting sounds in some conditions but not others, to “hear,” then, in an unconscious state not in a conscious one. The deficit would always be an intellectual one: “there exists in the aphasic something much more important and much more serious than the loss of the sense of the words, there’s a very sharp decline in intellectual ability in general. This notion of intellectual impairment of aphasics should dominate the doctrine of aphasia” (1922, 7).
3. if the aphasic deficit is primarily an intellectual deficit the aphasia has nothing to do with anarthric syndromes, with defects in uttering words related to the inability of vocal articulation. Anarthria does not affect the intellectual faculties of language but simply the mechanical component;
4. in language there is nothing specific (i.e. independent of intelligence) that is physiologically innate. In fact, there are close relationships between functions and organs but “the organs and functions are established and develop in a parallel manner” (Marie, 1907: 12). If it was not so, we would have to admit that all the centers (as preexisting “organs” of “functions”) have always existed. And this is clearly a falsehood, because, for example, the human species was not equipped with writing from the beginning and now even our fathers and mothers could read or write. Nor can one speak of “genetic mutation” because the written language “has had a history of elites who do not concern the species” (Marie 1922, 126). The same considerations made for the writing centers can apply to the other centers: the ear, which is not developed and does not become a “hearing organ” if it is not trained; that of reading, that should not exist at all in the vast majority of the population; and, among all, that of the word which also needs training to become language. According to Marie then, in language there are

neither facilities nor innate modules, only a form of global and unified intelligence that distinguishes humans from other animals.

Of all these varied and often extravagant forms of ideological resistance encountered in a scientific environment, Hécaen and Lantéri-Laura were about to enter the irresistible orbit of modern clinical neuroscience, by expressing this harsh judgment:

despite everything, the speech of holists, adorned with the feathers of a philosophical peacock, remained empty, and their proposals stagnated in a corner without any relationship with the empirical clinical science. In contrast, the speech of localizationists is made more precise little by little and never gives the impression of accepting this dichotomy between the setting of stable knowledge and imaginative speculation that often accompanied them (1977, 238 – Our transl from Fr.).

From an historical point of view, during the nineteenth century, biolinguistics mainly took the form of the theory of aphasia which had contributed to the decisive emancipation of neuroscience from phrenological and physiognomic speculation, damaging its image and encouraging resistance, as noted above. Certainly in biolinguistics aphasia has become intertwined with the phrenology movement, but it is not to be confused or linked with it. It can indeed be said that all the strongest neurolinguistic theses are born outside or against Gall's model.

One of Gall's faithful students, J.B. Bouillaud, is one of the leading exponents, and an initiator and main promoter of the cause of the localizationism, that moved all the threads of the academical debate between 1810 and 1860, to control and "catch", within the phrenological thesis, the rigorous scientific work of the most respected clinical scholars, particularly that of P. Broca.

Paul Broca, and with him the leading neuroscientists of the time, Rochoux, Creveilhier, Andral, Lallemand, Gerdy, Castel and, above all, Baillarger and his school, helped to circumscribe and increasingly define the role of cerebral localization in linguistic behavioral disorders, but at the same time they made an effort to precisize the clinical framework of aphasic symptomatology, without refusing to reject the topographic conjecture when it showed clinically contradictory aspects. With their work on aphasia, the localizationism model tried, for the first time, to identify the terms of cause and effect that localization involved, but at the same time revealing an internal logic to the same behavior, in their intertwining and combining in ever different ways, which could not be ascribed to a single explanation.

Whilst paying some concessions to the idealistic philosophy of language, that would still have a considerable lifespan, modern neuroscience seemed to have changed the underlying epistemological framework. The watershed that separated nineteenth century biolinguistics from that of the cognitivist century was now traced by the manifesto of the "winning" Broca:

each kind of language necessitates the play of certain organs of emission and reception. The organs of reception are at one time the ear, at another the eye, and sometimes the touch. As to the organs of emission, they are brought into play by voluntary muscles such as those of

the larynx, of the tongue, of the velum palati, of the face, of the upper limbs, etc. Every regular language, then, presupposes the integrity: 1) of a certain number of muscles, of motor nerves which supply them, and of that part of the nervous system from which these nerves arise; 2) of a certain external sensorial apparatus, of the sensitive nerve which supplies it, and of that part of the central nervous system with which this nerve is connected; 3) of that part of the brain which presides over the general faculty of language (Broca 1861, 5–6).

Part II

Towards a Darwinian Biolinguistics

Chapter 6

Comparing Two Models: CBM vs DBM

The fact that a history exists, does not mean that a theory of Darwinian biolinguistics exists. In fact, the histories of Cartesian rationalism, Platonism and Humboldtian idealism would not have been sufficient to construct the current dominant model, without a scientifically developed Chomskyan biolinguistics. It is certain that, even if in an asymmetrical position, there seems to be room for a positive antagonism between models in what will delimit the terrain of future biolinguistics. A first attempt at simplification in this direction can be made by proposing a synthesis of convergences, of possible compatibilities or of unbridgeable oppositions between models – what we shall now call the Darwinian Biolinguistic Model (DBM) and the Chomskyan Biolinguistic Model (CBM) – postponing the definition of a more precise theoretical framework – started in part one – to the following chapter.

CBM and DBM agree that there should be a privileged position for the biological dimension of language within contemporary cognitive science. This agreement is not confined to reacting to ‘linguistic negationism’ (Pennisi and Falzone 2010), which has characterized the first phase of the ascent of cognitivism, aiming to impose a real epistemological revision totally founded on the specificity of linguistic cognition within the internal mechanisms of the human mind. Unlike the “linguistic turn”, this insistence on the peculiar centrality of language within human cognition is, for both models, biologically oriented. That is to say, regardless of the interpretative differences associated with the term (which will be examined in detail) used to consider language, it is a genetically determined faculty, strongly instantiated in the human phylogenetic form and constrained by rules for development, whose study pertains to the domain of natural sciences, and it is implemented by translating the psychological into the physiological level and can be effected with experimental methods (Chomsky 1980, 101, 369, 377).

At this level of general agreements of principle – and before discussing the potential compatibilities that might emerge if the hypotheses put forward were subjected to a massive formal and substantial reformulation of the problems – we find it useful to emphasize what might be irreconcilable positions.

For DBM the following axioms of CBM are unacceptable:

1. The interface or externalization devices examined in Sect. 3.1 – that is the sensorimotor system (SM) and the intentional-conceptual one (CI) – are considered to be language-independent and to have no effects on the Narrow Faculty of Language (FLN). This principle entails a series of theoretical consequences all incompatible with DBM:
 - (a) The sensorial modality through which the externalization devices operate does not affect the cognitive function (sounds, manual signs are substantially interchangeable from a cognitive point of view). The structural properties of the languages generated by these devices are equipotent. Their acquisition processes and their cerebral localization seem to be the same;
 - (b) The genetic component which in human beings allows the detailed sensorimotor control of movements and, in particular, those aimed at the articulatory modulation of the voice, has no consequences on FLN: “FOXP2 becomes part of a system extrinsic to core syntax/semantics”;
 - (c) The systems that are responsible for learning and vocal production in other animals follow the same principles and are governed by rules similar to those operating in the human cognitive system.
2. The computational processes involved in the human linguistic mind can be confined only to MERGE (that is to the pure recursive function). The processes dependent on externalization (phonetics and lexical semantics) are not part of them; dicto for the principles underlying syntactic ordering and transformations (see Sect. 3.2).
3. The appearance of language in human evolutive history takes place by mere chance, thanks to a single mutation in mental organization (the appearance of MERGE) and is to be construed as a sudden leap (see Sect. 3.3).

Having said this, it is now possible to synthetically articulate (with a view to discuss them later) all the positions that are part of CBM that might turn out to be compatible with DBM and contribute to build up a new unitary framework for (future) biolinguistics.

Of course, this is more of a risky research project than a real possibility within our reach, since the distance between the two positions – despite appearances – is vast. Even in this case, we shall start with methodological issues, in which we predict there to be room for convergence, until we reach substantive issues where the result of coming to some areas of convergence can determine some change in biolinguistics research.

The areas within the CBM where we could find an overlap between the two models, after an attempt has been made to come to a linguistic reformulation and conceptual re-elaboration, are the following (possible re-formulations of the DBM are shown in the indented points under each main entry):

1. According to CBM, no one can seek immediate correlations between structures and mental processes, including computational functions and physiological mechanisms, in short, between physical and cognitive causes. Biolinguistics is especially pertinent at the syntactic/computational level:

- (a) in DBM the correlation of terms is to be established globally between the apparatus of the structures and the functions;
 - (b) the apparatus of the structures can be observed in several nested levels of formation and study of matter (physical sub-atomic, atomic, cellular, multi-cellular, molecular, macromolecular, biochemical, biological, anatomical, physiological, historical evolutionary levels, etc.). It is necessary to resort to lower levels when higher levels do not provide solutions or sufficient interpretations;
 - (c) the apparatus of the functions is always virtual and depends on the constraints of the structures on cognitive schemes both of mental and cultural nature. Even the study of functional systems can be nested (computational, mental, semantic, grammatical, phonological, pragmatic, cultural schemes);
 - (d) each of the nested levels of both the structures and functions require specific approaches and study methods. When one resorts to explanations that require, in any way and for any purpose, the use of lower levels, one must immediately use experimental methodologies. In the other cases, it is permissible to confine oneself to descriptive methods always making the implied logical arguments explicit;
 - (e) one can conceive of this mechanism as a shift between different resolution levels (more or less “fine-grained” in the sense of Balari and Lorenzo (2013), but also between different levels of “eidetic resolution” in the sense of phenomenology).
2. According to CBM, the complexity of a biolinguistic theory is not a matter of degree but of a quality.
- (a) in DBM, gradualism in biology only indicates the path;
 - (b) complexity, in so far as it is connected with gradualism, is an attribute of historicity applied to structures or functions;
 - (c) quality, being an attribute of the complexity of structures, is quantitatively measurable (a brain consisting of billions of neurons is qualitatively more complex than a brain consisting of millions of neurons);
 - (d) quality, being an attribute of functions, is measurable on the basis of its ecological adequacy to the environment (it is not necessarily the case that a brain consisting of billions of neurons is more suited to the environmental conditions and its changes).
3. According to CBM, language is a species-specific faculty of mental organization, essentially independent of intelligence. Its use is also independent of the context, is not connected to emotional states and does not select objects external to the mind. It has no ethological antecedents or states of evolutionary development. Its appearance can be seen as an *emergent* state (“the appearance of a qualitatively different phenomenon at specific stages of complexity of organization” – Chomsky 1968, 62).

- (a) in DBM species-specificity is a biological attribute (however, it is not necessary at all – in fact, it is against all evidence – to consider the biological and formal specificity of human language as anti-evolutionist, see Sect. 7.1);
- (b) intelligence, in so far as it is a biological property, measures the attitude of a species to solve adaptive problems posed by its environment;
- (c) in so far as they are ecological constructs, there certainly exist forms of intelligence different from the ones depending on language:
 - problem solving
 - ecological intelligence
 - social intelligence
 - ethical and aesthetic intelligence etc.
- (d) linguistic intelligence is the species-specific biological form of mental organization with which man makes use of other types of intelligence;
 - linguistic intelligence (“language *rewired* the human mind”, thesis by Bermudez 2005 and Bickerton 2009) confers a species-specific form to perception, to relationships with conspecifics, to representations, categorizations, calculations, logical analytical-deductive processes, inferential activities, ethics and aesthetic intelligence;
- (e) language, as a species-specific biological form, has precise antecedent states of development under the profile of its morphological traits:
 - the vocal tract is species-specific, but is a product of natural selection that shaped the phonatory apparatus of all forms antecedent to birds, mammals and all animals that moved out of the water;
 - the same natural history applies to the structure of the auditory system, to the bones, muscles and nerves required to implement articulated language;
 - a long history of species-specific structural transformations also applies to cerebral structures, both internal (Basal ganglia, Thalamus, Putamen, Caudate nucleus) and external (Neo-cortex);
 - taken together, the complex of articulatory, auditory, nerve, muscular structures and their cerebral coordination constitute the core of species-specific structural evolution that has made all the different functions of language possible. This set of biological specialization has determined in Homo sapiens a form of unique and irreversible cognitive specialization (from this point of view it can be correct to call it as ‘emergent trait’);
- (f) language, as a biological species-specific function (or set of functions), has also generated schemes of perception, organization and processing of information that have enhanced the formation of mental and computational models of cognitive organizations partly found in non-human antecedents, which are partially new:
 - the starting point of the biological restructuring of all forms of information processing in the human linguistic mind is the possibility of forming

informational units that are very specific, discrete and combinable either through recursive or performative procedures;

- these properties are possible because, during ontogenesis, any human child develops not only a perceptive capacity but also the ability to generate articulate sounds, through the hearing/voice synergy;
- the emission of articulated sounds, perceived as a target during the exposure to a historical-natural human language, and possible only after reaching the biological species-specific structure of the vocal tract and other morphological correlates, forms the core of any (mental/computational) procedure of the performative type;
- the performing procedures will intervene from then on whenever the cognitive structures designed for representation are engaged in activities aimed at obtaining knowledge or behaviours devoid of a certain amount of information (“dumb” mental states);

(g) The performing procedures consist of:

- a set of analogic operators that compare, in the absence of contextual identities, similarities with other contextual conditions memorized in specific libraries (analogic libraries);
- a set of exploratory operators capable of recognizing contextual clues that analyze contextual factors of any nature whatsoever;
- a set of pragmatic operators that predict the effects of any actions on the context:
 - (i) this set can predict generic actions that can be attempted or actions that can be explored;
 - (ii) generic actions constitute a library of organised solutions already tried and which have had a certain degree of success;
 - (iii) specific actions arise from changes in general ones obtained by combining generic actions of different types or trying actions never used before that could be suitable for unknown contexts;
- a set of operators or performative agents running cyclically (iii) until they find a safe but stabilized solution (approximately coming close to the purpose as much as possible, which will allow the enrichment of the library of generic actions and allows the prosecution of the activity and the one relative to the events produced).

In the following pages and in the third part of the book, we will try to explain at length this scheme of analogies, incompatibilities and potential compatibility that, at first sight, the CBM and DBM appear to exhibit.

Chapter 7

The Nature of the Species-specificity of Human Language

The starting point of a convergence of the two biolinguistic models proposed is, undoubtedly, the idea of the species-specificity of language and human linguistic cognition. Even this convergence, however, must first be clarified. We saw in Chap. 2 that Chomsky defends, first and foremost, a technical interpretation of the cognitive linguistic specificity of language. What he takes issue with – quite rightly in our view – in the evolutionist perspective, is the total absence of a theory of language, the almost “metaphorical” use of the term. To take linguistic evolutionism seriously one should at least be able to explain the specificity of syntax, the recursive nature of its procedures and its representational and cognitive power.

As noted earlier, however, the formal specificity of language intended as a form of “technomorph thinking” (Lorenz 1983), thanks to which human cognition appears to us in many ways *measurably different* from that of non-human animals, must be based on a specific fully biological sense of the term ‘species-specific’. It was the same Lorenz, in his methodological manifesto (1978), that emphasized the centrality of innate determinants in behaviour manifestations. For this purpose, for the first time, he proposed the biologically “technical” concept of *Speziesspezifität* (species-specificity), a term that has been used lately in an improper manner. Formulated in the area of ethology, it would indicate that certain organisms would be active only in combination with a particular animal or plant (think of parasites living only in certain species of animals or plants). Lorenz has borrowed this biological concept, assigning it to a higher sphere than mere chemical compatibility, that of behaviour, following laws of operation different from those of animal or plant biology. The central component of the notion of specificity that Lorenz intended to apply to animal behaviour was the element of constraints (or limits): parasites that cannot choose which plant to infest, but indeed they must attack, for their survival and reproduction, one species, show *Speziesspezifität*. So the founding father of ethology took this notion of functional constraint to apply to animal behaviour. In contemporary ethology, in fact, it is assumed that “behavior is determined largely by phylogenetic adaptations in the form of hereditary co-ordinations and

innate triggering mechanisms” (Eibl-Eibesfeldt 1967, 382): it is this biological meaning that defines the technical use of the term species-specificity.

We must not confuse the notion of species-specificity with all forms of behaviours that appear to be characteristic of a species and, in a sense, unique (Berwick and Chomsky 2016). It is not at all certain that the species-specific behaviours are the most spectacular ones. Indeed, as the species-specific behaviours are determined by the programming of genetic algorithms, they generally refer to compulsive mechanisms, actions or rhythms or mandatory phases that decisively limit the most creative adaptive strategies. Then we can call any aspect of behaviour that is regulated and permitted by the genetic endowment ‘species-specific’; these are the components which a given species cannot escape from. The natural component of behaviour lies, as well, right in the species-specific gradient that appears in an animal species: the higher the gradient, the more the behaviour of individual members is genetically determined, resulting in less flexible and less creative behaviour. It is no coincidence that on the basis of this precise epistemological definition, Lorenz (1959) has defined man as the most eurytopic animal, a true “non-specialization specialist”.

In the case of Chomskyan biolinguistics, creativity and substantial uniqueness of human language cognition is never explained on the basis of biological, cerebral or peripheral constraints. In fact, he never discusses the biological structure of the speakers. Paradoxically, in fact, he ends up sharing with his opponents the idea that language is only one type of thought, “a form of intelligence” extraneous or at least indifferent to morphological correlates with which it manifests itself in the world of surface structures. It is no coincidence that the founder of cognitive science – despite all the latest formulations we saw in Chaps. 2 and 3 – remains today largely indifferent to the neuroscientific and evolutionary perspective. Chomsky’s teaching – albeit rethought in the third millennium, stresses the need to learn to consider “human cognition as massively generative but highly constrained” (Hauser 2009, 195).

In the previous chapter, we have already seen that in order to find a philosophical point of view centered on linguistic representation but totally immersed in the perspective of biologically understood species-specific characteristics, we are forced to go back to Aristotelian linguistics. Despite the temporal distance separating the great fresco of the Aristotelian understanding from the current debate of the sciences of the mind, it is only within this global thinking on animal cognition that a realistic and feasible solution emerges. This solution hinges on the idea that human ontology coincides with the linguistic ontology of the animal-man. Man is, in fact, in a technical sense, a linguistic animal. All old and new hypotheses based on the idea that language is identified with the instrument of some primary activity (social interaction, transmission of information, the conventionality of the concepts or ideas, the vehicle of cultural artifacts etc.) appear, from this point of view, erroneous and partial: “language is not a tool but species-specific activity of natural organs” (Lo Piparo 2003, 3).

For Aristotle, *speaking is like the breath of the soul*:

the speech is not so much a bio-cognitive activity in addition to other activities that man has in common with other living beings, but rather, an activity which, starting from the moment it arises, reorganizes and makes specific all human cognitive activities, including what man shows to have in common with non-human animals: perception, imagination, memory, desire, sociality (Lo Piparo 2003: 5 – Our transl.).

Among current cognitive scientists, the scientist closest to this position is Elizabeth Spelke, best known as the author of the core-knowledge hypothesis, arguing that cognitive abilities of all animals are closely intertwined with child development and domain-specific systems of knowledge. In the same way in which baby animals show specialized perceptual systems to locate specific types of sensory information and motor systems dedicated to particular types of actions, so do cognitive systems performing specific tasks: representing material objects, navigating through space maps, numbering objects and recognizing other animals and conspecifics: “these core knowledge systems form the building blocks for uniquely human skills” (Spelke and Hauser 2004, 278).

Many years of experimental study in this area have shown that human children are equipped with a core-knowledge system similar to that of other animals, but, having reached the age of two years, they begin to exhibit such levels of ability in each of these systems to set up a real cognitive leap.

According to Spelke, that happens precisely because humans are endowed with domain-specific faculties of learning and using language:

there are no uniquely human core systems in any substantive domain of cognition, including the domain of social reasoning. Only language has uniquely human core foundations, and it serves to represent and express concepts within and across all knowledge domains. Humans' unique ability to put together distinct core representations rapidly, productively, and flexibly may reside, therefore, in our innate faculty for language (Spelke 2009, 165).

The philosophical species-specificity of language is revisited here, beginning with empirical and morpho-structural evidence. The most recent cognitive neuroscientists have speculated on the existence of modular structures of this type. Regardless of the clarification of the details of the work, there is no doubt that, in the phylogenetic structure of *Homo sapiens*, peripheral structural configurations (supralaryngeal vocal tract and auditory system) and central ones (brain areas for the understanding of language, such as Wernicke's area, and multimodal integration areas of perceptions such as Broca's area) emerge – these are probably domain-specific (see Chaps. 9 and 10).

Even if one is armed with a kind of modularity that is much weaker than current forms, functional proofs in favour of a domain-specific specificity for language seem quite strong.

The problem is how to demonstrate this.

7.1 The Cognitive Constraints of Language

An immediate consequence, and perhaps philosophically unexpected theoretical metabolization of the species-specificity of human language technology, is the implicit acceptance of the ontologically constraining nature of its physiological structure. An automatic projection of the linguistic philosophy of Aristotle, in fact, implies a reduction in margins of Lorenzian euritopicality attributable to man: “man does not choose language. From the moment he starts talking, he can no longer do without language and he cannot distance himself from it” (Lo Piparo 2003, 3).

Language, therefore, is no longer the source of unlimited creativity of the human spirit, the hallmark of his unquestioned cognitive superiority over other animal species exaggerated during the twentieth century: it is, on the contrary, a system of constraints and limits circumscribing and specializing human cognitive activity.

While in terms of the physiological structure, the constraints on language are beginning to be established with sufficient precision by different fields of neo-linguistic naturalism, which we will return to in Chaps. 8, 9, and 10, it is less clear how these constraints can be established on the cognitive level.

Antonio Damasio – one of the harshest critics of the linguistic conception of consciousness – shows, more clearly than many others, the precise awareness of the coercive nature of linguistic knowledge:

the human brain also generates an automatic verbal version of the story. I have no way of stopping that verbal translation, neither do you. Whatever plays in the nonverbal tracks of our minds is rapidly translated in words and sentences. That is in the nature of the human, languaged creature. This uninhibitible verbal translation, the fact that knowing and core self also become verbally present in our minds by the time we usually focus on them, is probably the source of the notion that consciousness might be explainable by language alone. It has been thought that consciousness occurred when, and only when, language commented on the mental situation for us. As indicated earlier, the view of consciousness required by this notion suggests that only humans with substantial mastery of the language instrument would have conscious states. Nonlanguaged animals and human babies would be just out of luck, forever unconscious (1999, 123).

If we leave aside the questionable conclusions – why should it be the case that even if the human forms of consciousness are derived from language, the forms of animal consciousness should depend on language? – few could better express the ethological condition of cognitive delimitation and species-specificity in the technical sense of the human language.

On the other hand, theoretical models of contemporary linguistics have left considerable room for these positions, proving refractory in explaining the bio-cognitive constraints of language.

For example, structuralism, which is usually credited with founding modern linguistics, although it has developed a deeper knowledge of descriptive linguistic forms already used, has never considered intercepting the binding relationship between the physiological structure and linguistic cognition in all of its forms. From this point of view, language structures, in so far as they are “semiotic”, like all other

conventional structures, are nothing more than self-sufficient cultural systems that can only be described and never explained.

It was with great merit that Chomskyan linguistics started to reflect on the specific type of cognition that is linguistic knowledge. And indeed, as we have seen, Chomsky has described language as a *sui generis* form of knowledge, but leaves the biological-structural dimension of his studies only in the background, and merely deepens knowledge of the formal properties of grammar, with its separation of the syntactic nucleus and the phonological and semantic externalization devices. In short, the basic limitation of the Chomskyan era was the autarky of his mentalism, the idea expressed in *Rules and representations*, that when we turn to the cognitive structures or physical mechanisms underlying them we are “transferring the problem from the psychological to the biological level” (1980, 369).

It is precisely this step, on the contrary, that is intricate and difficult, while remaining indispensable for a redefinition of human linguistic knowledge; it is not enough, in fact, to consider the recursion of syntactic procedures as a global response to the search for its species-specificity.

Sticking to the formal nature of these procedures, although it captures a fundamental aspect of human aspiration to cognitive precision, efficiency and methodological effectiveness, amounts to losing sight of the social purposes for which the semantic and pragmatic structures are formed: those which Tomasello would call “shared knowledge”. Finally, it clashes with the inseparable nature of phonology, semantics and syntax, which contemporary biolinguistic studies have fully demonstrated (see Sect. 4.2).

In ancient Aristotelian language (see Sect. 5.1) the theme of the inherent and inalienable syntactical character of human knowledge, on the contrary, is always combined with that of a unitary structure producing senses and cognitive algorithms: “the written dimension, species-specific articulations of the human voice, logical and cognitive operations of the human soul, which are also species-specific, are the three co-original dimensions that together produce the logos” (Lo Piparo 2003, 99).

Alphabetic writing, vocal articulation and syntactic-semantic compositionality are, in a sense, synonymous. They are the ways in which the form and content of human experience is fragmented and intertwined inextricably and inexorably.

The human condemnation to species-specificity of linguistic knowledge is not only shown in the need to articulate the unspeakable in words made up of sounds (isolable like letters) – in the “imperious impulse to find a name for things as well as for activities” (Lorenz 1973b, 378) – but also in making sure that this articulation appears not at all arbitrary and incorporates the semantic function, which a man uses in intentionally consenting exchanges with other conspecifics, and in relation to an increasingly effective pragmatic grip on non-human environment.

7.2 The Technomorphic Thought

The most convincing evidence of the first aspect of this condemnation is provided by the history of lithic technology and, more generally, the development of material culture. Up to 2.5–3 million years ago, hominids did not differ much from other primates in the use of tools. Since then, it took another million and a half years to go from Olduvaien technologies to the Acheulean ones, and yet another million to get to the Mousterian techniques. In short, in almost 3 million years, progress has been very minimal. Beginning with the Upper Paleolithic period, the landscape changes: then in a dizzyingly rapid progression, an amazing number of inventions occur which provide new ways of working with materials. Furthermore, in the last 10,000 years, we have progressed from stone to metals, from metals to written texts, from written texts to computer records.

What had not happened in almost 3 million years has taken place in the blink of an eye in evolutionary history. At the same time, the new discoveries of paleoarcheology in relation to neuroscientific knowledge (Renfrew et al. 2009) have demonstrated that the advancements in technology are connected to the emergence of the most significant form of human behaviour, that is, to language, which is intended as a symbolic capacity, and is connected to representational skills, to the theory of the mind, and to the formation of causal beliefs.

The evolution of the brain, of language and of technologies are to be identified with one specific human neural network. Read and Van der Leeuw (2008), in particular, have mapped the seven stages of cognitive differentiation of tool making established in Read's (2007) scale – from the simple use, without modification, of objects found in nature, to the full achievement of compound artefacts consisting of multiple planes, recursive-cumulative design and three-dimensionality – in relation to the short-term memory scale, and to the encephalization quotient of human and non-human primates, and confirming that it is only in the last 200,000 years, and primarily in the last 30,000 years, that the seventh stage has been reached.

Stout et al. (2009), instead, have worked to experimentally investigate the relationship between brain areas and lithic technologies. To do this, they have used people with different experiences and knowledge of the tool making technologies by measuring, through the use of the PET scan, their brain activity as they worked. Brain activity measuring was performed in relation to increasingly complex tasks reflecting the technologies, chronologically identified, from early Olduvaien to the late Acheulean. The assessments were conducted beginning with the final product that had been made: the target was typical of the Olduvaien or Acheulean industries. The experts' productions were very similar to these real models. The measured cognitive work was classified on the basis of the item matching the levels described by Read (2007) and used by Read and Van der Leeuw (2008).

These experiments have clearly shown how the neural correlates required by the various stages of lithic technologies show a close correlation with the areas of language or, to be more precise, with the complex multi-functional semi-modular unit

that focuses around that new evolutionary processor that has become known as Broca's area (see Sect. 10.4). Such a prospect had already been identified by Ambrose (2001), who has even proposed narrowing the time frame of this structural identification between technology and language to the last 12,000 years of evolutionary history. More recently, these hypotheses have also been put forward by ethologists who orbit around the Chomskyan positions: an example of generative calculation comes from the domain of handcrafts, particularly the creation and the diversity of tools. Unlike many of the most simple tools, such as the pencil, tools of animal origin are constituted by a single material, do not include more than one functional component, they are generally abandoned after the first use and are never used for functions different from the original one.

The first two characteristics reveal that, unlike human tools, the representation of tools used by animals is not combinatorial. A pencil can combine four different materials (graphite, wood, metal and rubber) to fulfil four functions (graphite to write, wood to grab the graphite, metal to join the rubber to wood, and eraser). Furthermore, each material can be used for a variety of other functions: for example, the rubber can become a component of a chewing-gum. An experiment revealed that if a child is asked what can be done with a pencil as well as writing, s/he will immediately suggest other uses for unexpected purposes, such as a stick to keep long hair collected or making a hole in a plastic cover or to attack someone by hitting him with the tip. Only humans found that the artefacts have been designed for a particular function, but, because of the multiple points of view from which they can be considered, they end up discovering many other possible functions (Hauser 2009, 193). Hauser also proposed, for the first time in the field of generative linguistics, to consider the link between the phylogenetic structures and the cognitive processes of recursive-combinatorial nature in a general framework of biological species-specific determinants that would restrict the field of possible human cultural forms:

that is, something similar to a genetic revolution must have occurred during this period (the Paleolithic), providing humans with an unprecedented set of capacities for generating novel cultural expressions in language, morality, music and technology. Specifically, at some point before or during the Paleolithic, the human brain was transformed from a system with a high degree of modularity with few interfaces to a system of modules with numerous promiscuous and combinatorially creative interfaces. This system provided a universal framework on which cultural options could be realized (Hauser 2009, 193).

Regardless of the accuracy of the chronology that will certainly locate the definitive establishment of this relationship in a broad time range, what seems significant about this data is the fact that language and technologies are cognitive phenomena that tend to coincide. In an ontological and ethological dimension of cognitive science this means, above all, that the linguistic lens by which man is forced to look at the world is one that cannot prevent him from estimating its size, shapes, structural similarities, and which forces him to make the functional relationship (in the mathematical sense of the term) with the non-human world and the surrounding environment more precise.

The imitative processes are certainly connected with the development of sociality, but human imitation is different from emulation of chimpanzees in its precise execution and in its procedural, fundamentally algorithmic, nature. This procedurality, instinctively based on a “technological” nature (Eibl-Eibesfeldt 1975, 43), is the automatic projection of linguistic species-specific cognition, not the result of social interaction with conspecifics, which is, on the contrary, affected by it.

From this point of view, the anthropocentric attempts to measure other parameters against human parameters are really incomprehensible. It is not that man is able to categorize, in articulated matrices, the phenomenal world and to connect each element of these matrices with other elements of other matrices in order to interpret it, while other primates (and, generally, other animals) are not capable of doing so. Man, on the contrary, is obliged to read the vast and rich texture of the phenomenal world only through semantico-syntactical representations and must adjust the actual resolution of these representations, losing most of the other possibilities that different animal species innately possess to represent it, and employing other types of constraints on perceptual and cognitive processes.

The theoretical point of the refunctionalization of neuro-cerebral cabling and their interaction with the peripheral organs in regionally teleonomic structures (i.e. “weak modules”) takes on, in this context, an important position to avoid assuming that, for each of these “coercive” modes of perceiving, representing and experiencing the phenomenal worlds, we must presuppose a precise structure that is dedicated adaptively. To get a different species, one should not be required to exhibit pieces of completely new parts: the emergent properties that characterize the bio-cognitive aspect of a species would result anyway by a rewiring of the set. The aversion of some evolutionary perspectives to identify any change with a genetic change, or with a structural mutation, and instead wage battle against those who always look for the domain-specific correlation within a given function (the organ of language, for example), constitute real obsessions that run the risk of jeopardizing an explanatory paradigm as effective as Darwinism.

It is true that the overall anatomical pattern of human brain structure is the same as that from which other primates are derived, but it is equally true that the combination of old and new structures available to human society has produced a morphologically new species. And, in fact, language is linked to a new physiologically teleonomic module that has to explain the articulatory/technological capacity and the written dimension in structural terms, but must not be obligatorily connected to a specific organ because of this. Similarly the supralaryngeal vocal tract indisputably allows a fine modulation of sound and specific physical articulation that other structures do not allow. However, due to this genuine evolutionary perspective, the peripheral natural correlate of technology must progressively interface with a neuro-anatomical and physiological set, otherwise it may not function well by automatically forcing humans to represent the world linguistically. Finally, language is certainly species-specific, but this does not mean it will manifest itself if the added value of social conspecificity has not been magically activated (as in the case of the *feral children* – see Pennisi 2006).

Briefly, in language it is the Lorenzian “technomorph thought”, which, as we have mentioned before, forces us to measure everything and to break up the pattern of the continuous into the constantly reorganized pattern of the discrete. Language-technology forces us towards the accumulation and reproducibility of empirical knowledge structures that are more and more complex, detailed and semantically defined.

7.3 The Bodily Technology of Language

The highest point in the development of technomorphic thought is achieved, during the entirely intellectual history of cultural evolution, when humans begin to reflect metalinguistically on their bodily technologies.

A significant example of this phenomenon is the issue of the bodily technology of language that animated speculation on language in the late seventeenth and early nineteenth century and is still very much alive in the cognitive and evolutionary studies into the species-specificity of human language. It was an issue that was then able to jeopardize the ontological foundations of Cartesian dualism and today constitutes the main antidote to a merely mentalist and cerebrocentric biolinguistics.

Jessica Riskin (2003) summed up this subversive role played by the development of corporeal technologies of language in the birth of the term *wetware* “wet, live, organic software” (“wet, living, biological”, 115). The word had already been introduced in 1988 by the mathematician Rudy Rucker in opposition to the dualistic distinction between hardware and software introduced by *computer science* since the thirties. The inventor of the term envisioned, in his scientific novel entitled, precisely, *Wetware*, that the mind and body would be connected in a unique bio-cognitive basket collecting “all (the brain’s) sparks and tastes and tangles, all its stimulus/response patterns – the whole biocybernetic software of (the) mind” (Rucker 1988, 76). Riskin considers the philosophy of wetware as being the main point of contact between the study of bodily technologies in the late eighteenth century and that of contemporary artificial life. The undisguised ambition of this philosophy is to believe that the biological and mental processes are very mechanical in nature and are therefore capable of being simulated, but are never actually reproducible.

The testing-bed for this philosophy in the eighteenth and nineteenth century was the construction of automats feigning the mechanics of human biological behaviour, and, in particular, of the verbal one. The first designers of artificial life based their projects on the imitation of natural life in structure and substance, using appropriate biological components. The resulting simulations simultaneously demonstrated the theoretical value of the project but also its empirical impossibility. Automata could approximate the schema of the mechanical structures underlying biological processes and their evolutionary foundations, but they could not reproduce reality in all its complexity. The wonderful androids produced at the end of the eighteenth century showed all this singular ambiguity: they appeared disconcerting

for their extraordinary mechanical accuracy accompanied by a hyper-realistic stereotypical performance, and for their incredible verisimilitude.

The most stinging defeat for these forerunners of AI was the demonstrated inability to build machines that could really simulate the products – simple at first sight – of the human phonatory apparatus. Although three working prototypes of talking machines were made between 1778 and 1780 – the talking heads of Abbé Mical (1778, see Chaudon-Delandine 1810), the talking machine of Baron Wolfgang von Kempelen (1778) and the vocal organ of Christian Theophilus Kratzenstein (1781) – none of these were able to even pass the test of isolating and reproducing fundamental human linguistic vocal articulation (Pennisi 2014b). The problem has not been solved even in more recent times and with more advanced mechanical technologies. As Lieberman (1975) and Lenneberg (1971) remind us, all failures in simulated body language technology depend on the unique complexity that shows the complex connections between the software and the hardware of the human machine.

The mechanistic speculation on language, therefore, gets bogged down when one comes to biological simulation: the theoretical foundations of the *wetware* may well be true, but the human machine is too complicated to be able to reduce it to an embodied simulation, that is, to a device functioning like the original. Even if we want to circumvent philosophical dualism and decide to confine ourselves to a reductionist explanation, the results are not satisfactory, perhaps the procedures can be simplified but the mental body is inimitable.

It was not until almost 50 years after the failures of the eighteenth-century engineers that it began to be understood. Beginning with Darwin, in fact, it is clear that the difficulty in penetrating the complexity of the biological machinery is due to the fact that the latter are not manufactured from scratch for a project but change slowly on the basis of states of infinite adaptive transformations induced by natural selection. This process prevents any forecast on the possible functions that these biological machines can play, erasing any finalist prospect from scientific analysis.

In contemporary thought, the Darwinian hypothesis has become prevalent within the natural sciences. For evolutionary biology, for example, it is assumed that bipedism – a species-specific characteristic of human primates – resulted from slow changes in our musculoskeletal system through small genetic mutations that favoured environmental adaptation. Similar comments could also apply in explaining the operation of a complex organ such as the eye, of the auditory system, and the endolymphatic one, of the digestive system and of the teeth: in short, for any selective transformation that has brought a certain body to speciate in a certain way by incessantly “filing” its structures until it reaches the optimal state to perform an old function in a better way or to invent a completely new one.

The explanations of linguistic evolution proceed more slowly, probably due to the dualistic residues that the cognitive function, underlying language, performs. However, it is beginning to be more and more obvious that even before being a powerful system for communication and cognitive representation of knowledge, human language is a species-specific bodily technology applied to symbolic needs. This must be interpreted in two directions: (a) language is the product of a machine

formed by slow evolution of physiological structures dedicated to primary purposes and then exapted into new uniquely human functions; (b) language produces a system of articulations of first, second and third level allowing a virtually infinite combinatorial technology based on sound units (phones, phonemes, syllables), morphology (morphemes) semantics (lexemes, words, sentences, discourses, texts) from a finite number of dedicated physiological elements.

The sense in which the term “bodily technology” is used here is very close to that outlined in the Arthur’s hypothesis (2009), as being that of a general theory of technology based on three principles:

- (1) principle of combinability which states that all technologies are combinations of existing technologies, they “are constructed or put together – combined – from components or assemblies or subsystems at hand” (2009, 42);
- (2) the principle of modularity which states that “each component of technology is itself a miniature technology (...) carrying out specific purposes” (42);
- (3) principle of naturalness, which states that “all technologies harness and exploit some effect or phenomenon, usually several” (42).

These hypotheses are certainly biologically compatible with the evolutionist perspective and with the essentially naturalistic character of the idea of technology: “technology builds itself organically from itself” (Arthur 2009, 44).

Peter Corning defines the human language as a “soft technology” (2003, 225): “The purpose of language is to facilitate social communication processes of all kinds. It evolved as an instrumental, multipurpose cultural ‘tool’ – one element in the package of anatomical and cultural adaptations that were progressively improved upon over literally millions of years”(2003, 225).

However, Corning considers language technology as a product rather than a productive activity (*the energheia* of Humboldt’s memory). According to him, the merit of human beings is to have “invented” language, that is, the means to achieve creativity and invention, literally “manufacturing” phonemes, morphemes, lexical, syntactic and semantic categorizations: “in other words, we invented inventiveness” (2003, 227). Nevertheless, although the development of writing and grammaticalization undoubtedly can be considered a decisive step for Cultural Development (Auroux 1999), the instrumental view of language revived here does not allow us to grasp the singular homology between activity and product that is species-specific, in the technical, biological sense, as we stated before.

A further step would be to not consider technology merely as a projection of our bodies to external artefacts (it is the body which produces technologies through which we build artefacts), but to incorporate the idea of technology into our very physicality: it is our own bodily technology. This further theoretical step would allow us, in fact, to reinterpret the exaptation hypothesis of language (Gould and Vrba 1982) in a new light, and avoid turning it into a superholistic fairy tale, a kind of *magic* and quite abstract readjustment: exaptation is accomplished through a series of neuro-physiological re-wiring used to manage a new function by employing specific technologies related to the possibilities inherent in the new body structure and made permanently available in the society of human primates.

In some respects, it is an idea that has always existed in the history of human thought (history of medicine, biology, mechanics, etc.), although the negative dimension of this hypothesis has never been explored completely. A technology, in a naturalistic sense, does not tell us in advance what might make a certain structure achieve a certain unpredictable stage of development during its evolution, but it certainly tells us what the technology can do. This allows us to implicitly experimentally identify, and gradually understand, the conditions favouring the establishment of a certain function which would otherwise remain unexpressed, or in the limbo of things that cannot be expressed. The idea of language being a leading technology also turns on its head, whilst not contradicting it, Chomsky's hypothesis that language is species-specific: language is "a specific type of mental organization" (1968, 62) directly dependent, however – we now add – upon its very morphological, peripheral and central technology. To be more detailed, the hypothesis advanced here is that language is species-specific in so far as it is an auditory-speech technology (*speech-making*) applied to symbolic needs that are at least as symbolic and highly specialized as manual technology (*tool-making*), with both evolving in the same brain and for the same social purposes.

More specifically, we can say that an 'auditory-speech technology' is the set of all the articulatory-auditory possibilities to which our individual and social cognition is "doomed" to achieve the fulfilment of its purposes. This auditory-speech technology – characterized by precise (peripheral-central) morphological and social correlates – has evolved over a very long time through a large amount of changes that have acted directly on the formation of structures and, at some point in their development, have indirectly become suitable to articulated language. The two criteria (direct and indirect) are not completely separable and yet today we can study the effects of these direct changes through experimentation in cognitive science and the indirect reconstructive explanation through evolutionism. In particular when 'auditory-voice technology is applied to the symbolic needs' we mean: (1) a curved vocal tract with two channels with 1:1 proportion between the horizontal oral cavity and the vertical pharyngeal cavity; (2) a set of orofacial muscles which will not hinder the vocalization order; (3) an auditory hyperspecialized cortex (Vocal Area) and an evolutionary neural processor based on categorical articulated language, i.e. Broca's area. Obviously, all of these are fully instantiated through genetic transmission mechanisms.

Chapter 8

Genetic Fundamentals

We have already noted that, for CBM, the genetic component which allows fine sensorimotor control of movement in human beings and, in particular, that which is responsible for the articulatory modulation of the voice, has no impact on the FLN. According to Chomsky, FOXP2 affects only the externalization of the functions of language. The gene could be “an opportunistic pre-requisite substrate for externalization”, or may have arisen as a solution for phonation devices after the appearance of MERGE. In any case, “FOXP2 becomes part of a system extrinsic to core syntax/semantics” (Berwick and Chomsky 2016, 77).

Chomsky excludes the possibility that FOXP2 might be considered to be the “language gene” because it seems to play no role in the mental functions performed by the syntactico-computational processes. In general, it seems that the expectation of computational biolinguistics is to find the genetic basis for a general linguistic function rather than for (peripheral and central) linguistic structures that allow the use of the spoken word.

On the contrary, DBM believes that the genetic basis on which the neurocerebral, nervous and muscular management of speaking organisms are based can only be found, provided that the complex and inherent correlation of the entire genome which regulates human organisms is considered. The functional and cultural developments that these structures perform, the products of speech and from the early cries to formal languages, however, cannot be directly explained by molecular genetics. Indirectly, genetic evolution of the structures generates individuals and selection in the gene pool causes speciation of stabilized and specialized organisms that produce historical-natural languages conforming to phonetic gradually variable grammatical, syntactical and semantical rules (from the most universal and most related to the physiological limits of articulatory-auditory modularity, to those which are more and more specific to vocabulary and pragmatics of language).

8.1 The Genetics of a Sapiens

After the extraordinary discoveries of Watson and Crick in the fifties, the comparison of human DNA with that of primates became the stronghold of the supporters of gradual evolution of all animal species, including humans. Indeed, the results of the human genome project, and satellite projects (e.g. The “Great Ape Project” or the “Human Genome Diversity Project”) applied to the genomes of other non-human animals (chimpanzees, bonobos and gorillas primarily), have filled the pages of scientific journals and newspapers, becoming standard in debates pro and against the scientific plausibility of the Darwinian theory.

For years after the mapping of the human genome and that of chimpanzees, scholars have constantly used the datum (variable and growing) to illustrate that human DNA would be equal to that of chimpanzees in 98 % of sequences. This datum would not only show the evolutionary proximity of the two species, but would constitute indisputable evidence for the fact that *Homo sapiens* is not special, because it is biologically based. Even if the DNA does not say anything “exceptional” about man, it illustrates that he is really only an animal like all the others.

Obviously this is a very naive position, and one which does not take into account the structural characteristics of DNA (the different activities of genes like operons and regulators, the complexity of the relations between the “supergenes” giving meaning to other genes and the different positions of genes that may be homologous in different animal species, etc.), or the evolutionary reasons that led to the selection of traits present in its interior.

In an essay of 2002, molecular anthropologist Marks discusses the “wild” comparison of strings of DNA that allowed science journalists to write sensational headlines about the similarity between human and chimpanzee DNA.

The anthropologist considers this comparative mode faulty and highlights that in a reality based on the universality of the replication mechanism of life, all living beings possess at least 25 % of the nitrogenous bases in common: if we compare a string of human DNA with that of a daisy the result would be a coincidence of at least 25 %, but from this we cannot deduce (as has been done in the case of chimpanzees) that we are a quarter daisy, if it makes any sense to be discussing this! (Marks 2003).

At this point, the central question in the debate on the specificity of genetic traits for humans would be: what (if any) really are the species-specific genes that are only present in a human being? Which genes in *Homo sapiens* perform species-specific functions in the Lorenzian sense of the term? Which genetic traits allow the expression of structures which are serving uniquely human functions?

The answers to these questions, as you can guess, cannot be immediate.

We will see in the next paragraphs that comparative genetic research has enabled the identification of a number of genes that are expressed in brain structures and are involved in cognitive functions (Konopka and Roberts 2016), but still their working mechanisms and interaction are not very evident. Above all, it has been well established that genes do not handle functions directly, but their action is mediated by the

morphological structures in which they are present. That gene activity is mediated, on the one hand, means that it is too “slow” (in the order of seconds) with respect to the speed execution of behaviour and cognitive activity in general (in the order of milliseconds). On the other hand, it means that gene activity effects are present on structures both during the formation of the body (embryogenesis) and during development and everyday life. Whether genes exist that control a certain “mental function” only makes sense if we bear in mind that control is always mediated by anatomical structures.

Several studies have attempted to highlight correlations between “special” aspects of human cognition and specific genes: ranging from “unlikely genes” responsible for consciousness to those sought for specific functions, such as genes for language. The survey regarding the genetic correlates of cognitive functions, however, was not based on the 2 % that differentiates human DNA from that of chimpanzees.

Or rather, in most cases, the genes that had been previously identified as correlates of complex cognitive functions were soon also traced in other animals, even those that are phylogenetically very distant from man.

8.1.1 *The FOXP2*

In recent years the FOXP2 gene has highlighted the historical genetic study of language. Dyspraxia resulting from the mutation of the FOXP2 gene, in fact, is one of the rare cases in which it was possible to identify a top-down connection between a gene and a function, that is, before the characteristics of the syndrome were described, the genetic cause had been tracked. In most cases, however, geneticists have found a bottom-up connection, that is they have identified a gene by trying to understand what it controls, by using animal models. In these cases, tracking down the specific correlation between the role of the gene and the body activities is not so simple, because often a gene controls several functions and often a single function is handled by different genes. In the case of FOXP2, however, the problem of correlation between gene activity and body structures (and their function) does not arise. It seems therefore that the FOXP2 gene is a really important one to understand not only how the structures that allow the language have evolved, but also how language is learned and used by sapiens every day.

Research on the genomics uniqueness of *Homo sapiens* is a goal which is almost unacknowledged by many geneticists and molecular biologists. Often, however, precisely because of the punctuationistic nature (Gould and Eldredge 1972) of speciation and biodiversity, the human DNA genes at least exhibit some form of similarity with those of chimpanzees. This, however, has not discouraged genetic research from identifying an element of discontinuity in the genes of different species. The genetic species-specificity of sapiens was, in fact, traced in some regulatory genes which were decisive in the process of embryogenesis. The formation of the structures of our body is entrusted precisely to these genes that are supposed to

have the task of defining the basic morphology of every member who belongs to the species.

In recent years, researchers have paid particular attention to those genes that seem to be involved in the reshaping of human brain development. Among these, the FOXP2 seems to be just one of those uniquely human genes, because it comes into play in the remodelling of the human brain and controls the uniquely human ability to articulate voice. The story of the discovery of the FOXP2 is now famous.

During the 1990s, British researchers identified the genetic sequences of an English family of Pakistani origin (the KE family). They were being studied in connection to a specific alteration in three generations of the family (Hurst et al. 1990; Lai et al. 2001). There was damage affecting FOXP2: a transcription factor of the *forkhead box P2* family, located in chromosome 7, which had resulted in half of the members of the family suffering from an orofacial dyspraxia. The deficit equally affected males and females of the family, following a typical pattern of Mendelian inheritance, from which Cecilia Lai et al. (2001) have deduced that the articulatory disorder is transmitted via an autosomal dominant monogenetic trait directly damaged by this mutation in the KE family, and such damage would be involved in the etiology of disorders related to language.

The pedigree of the KE family illustrates just that fact (Fig. 8.1).

About half of the children of affected components exhibit the disorder, while the sons of components not affected do not have such a disorder, confirming the hypothesis that it is a mutation of a dominant allele of a single gene of an autosomal chromosome (chromosome 7). As a transcription factor, FOXP2 plays a fundamental role in DNA: that of regulating the production of proteins of several genes and, during embryogenesis, of differentiating the cells that belong to the gastrointestinal tract, liver, heart, lungs and brain.

In the behavioural phenotype of affected members, described for the first time by Hurst and colleagues in 1990, the motor disorder is related to the expression and articulation of speech more than to the understanding of speech and especially to the ability to coordinate the high-speed movements necessary for the production of intelligible speech (Vargha-Khadem et al. 2005). Although the average of non-verbal IQ of affected members was lower than that of the unaffected members, affected individuals showed verbal skills close to the average population (in a case, even higher, see Hurst et al. 1990, 353). All, instead, showed severe damage to the sequence of articulatory movement pattern. No perceptual problems (auditory) or motor problems in the limbs or the movements of the individual vocal articulators (the tongue, in particular) had been detected. In addition, no neurological disorder that prevented control of swallowing or feeding early in childhood had been detected. Affected members showed no deficits in the manual praxis (Watkins et al. 2002b), perhaps because in the case of hands, the coordination movements are not as quick as those required in articulation (according to the authors, to demonstrate a manual apraxia, members of the KE family would have had to perform tasks with highly skilled motor sequences such as, for example, playing a musical instrument).

Initially, disorders exhibited by these subjects were interpreted as special cases of *SLI* (Specific Language Impairment) which involves comprehension deficits as

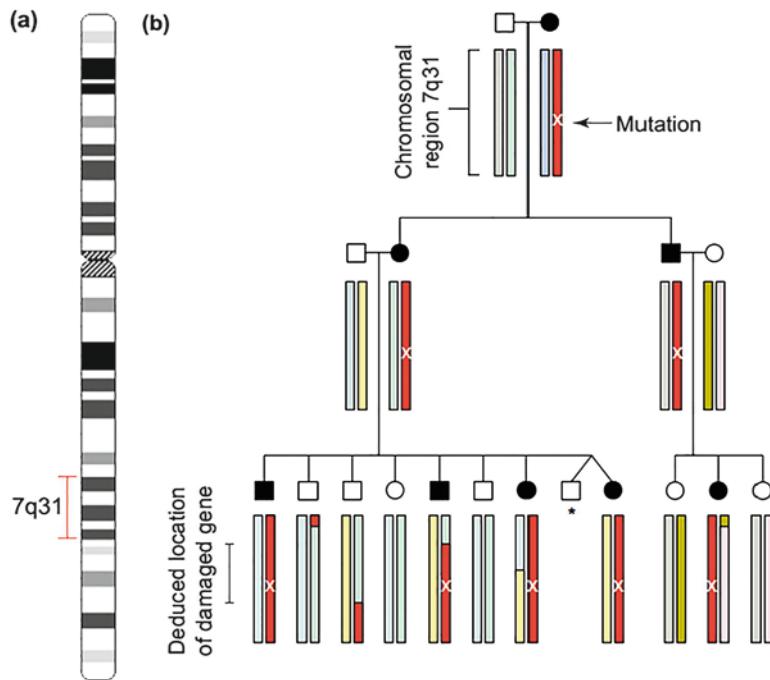


Fig. 8.1 Distribution pattern of genetic mutation of the FOXP2 in the KE family. The site of the mutation is located in the 7q31 region of chromosome 7 and is marked by a little cross. Note that the mutation occurs only on a copy of the gene, while the other is not altered. This suggests that it only takes one mutated gene for the deficit onset. The family members are so marked: males unaffected = empty square; affected males = filled square; females unaffected = empty circle; affected females = full circle (Source: Marcus and Fisher 2003)

well as deficits in the production of utterances. But the psycholinguistic tests that were administered to the KE Family clearly showed only a profound alteration of the motor articulation mechanisms of the words, while the understanding of sentences, perception and hearing comprehension was average. Furthermore, the disorder was characterized by defects in various aspects of language competence (ability to break down words into their constituent phonemes) and grammatical skills (including the production and understanding of the inflections of speech and syntactic structure). Subsequent studies by Vargha-Khadem et al. (1995, 1998) have highlighted the fact that the disorder is not limited to selective aspects of grammar (even though they are present), but causes profound difficulties in controlling complex movements during mouth-face coordination, thus preventing the normal movement needed for speech. The language used tends to be simplified, and even if the subjects are able to consciously control the position of the tongue and lips, if they are asked to do so, they are not able to manage an average sequence of articulatory movements: they make little use of impure consonants ('boon' instead of 'spoon') and often omit the first sound ('able' instead of 'table'). Generally they do not artic-

ulate the final sound well, transform polysyllabic words into bi- or mono-syllabic ones and they do not produce or understand complex sentence structures.

Several scholars who have recently returned to study the case, confirmed that the damage to members whose FOXP2 was affected show an apraxia of speech that makes their production almost incomprehensible. Although they are able to produce phonemes if produced carefully in isolation, their words, and even more noticeably, their sentences, show alterations due to omissions of phonemes, replacements, additions and phonemic distortions. These alterations in the articulation of language are caused by different dysarthric aspects, such as spastic dysarthria with characteristic low peak, accent reduction and the “voice exhaled” (or whispered). In contrast to the modal voice, in which the vocal cords vibrate and the air flow is adjusted by the resonance, in the voice exhaled or whispered the strings vibrate but are held more distant so that most of the volume of air escapes (Morgan et al. 2010).

The interpretation of the real nature of the defect has opened a debate which is still not completely solved today. For Hurst et al. (1990, 352), the disorder amounted to a “severe form of developmental verbal dyspraxia”, focusing on the profound articulation difficulties exhibited by affected individuals. Gopnik (1990) – on the basis of the characteristic errors in the production of the affected members (simplification, substitution, lack of inflectional morphemes, elimination of function words) – had gone as far as characterizing the disorder as a pathology of specific grammar skills. Indeed, the patients showed lack of verb endings and of gender markers and a decrease in number of words. Her thesis favoured the definition of FOXP as “the gene of grammar”.

This definition of FOXP2 as the “language gene” or “gene of grammar” has raised much criticism, both among geneticists, scholars of the language faculty and psycholinguists. The main cause of this criticism lies in attributing the control of a specific language function to the gene. It is just as complicated, in fact, that there is a direct influence by a gene (what is more of a transcription factor) over a cognitive function, as it is to find a single gene for hair colour or for neurodevelopmental syndromes such as autism.

It is certain that the FOXP2 gene is linked to language, but it can prove controversial when it is considered as the grammar gene. The affected members of the KE family not only show alterations in the syntactic construction of sentences (they are present, even though it is unclear if these grammatical deficits are the consequence of articulatory difficulties or they are a direct deficit caused by genetic mutation, Enard 2011), but also in the understanding of sentences and other non-linguistic academic skills (Hurst et al. 1990). If FOXP2 was “the gene of the grammar”, then the disorders of the KE family would have to relate to the precise syntactic capacity and would have to deal with a selective alteration of grammatical skills. Subsequent studies, in fact, have shown that the FOXP2 gene comes into play in the execution (and more recent studies also argue its involvement in learning, Fee and Scharff 2010; Bolhuis et al. 2010) of complex motor sequences linked to the production of articulated sounds (Vargha-Khadem et al. 2005).

What seems clear in the whole story of the KE family is that the core deficit of the disease is an orofacial dyspraxia manifested in the rapid coordination of move-

ments and high skills such as those required by the linguistic articulation. The main phenotypic marker of KE family is the evident verbal dyspraxia, probably due to the breakdown or malfunction of the network involving the ventral part of the primary motor cortex (the area of the face and tongue) and putamen (Liégeois et al. 2011).

Accordingly, it is more plausible that the FOXP2 gene is responsible for embryogenetic training and normal functioning of different structures of our body, including the basal ganglia and the formation of the cortico-subcortical connections (Tsui et al. 2013).

From the point of view of neuroimaging, the affected members of the KE family have been subjected to several methods of investigation to assess alterations in the individual brain structures and their functioning. Complex measurements were necessary, as well as the use of correlations between these measurements, to evaluate the morphometry of the brain of the KE family. As in all the disorders that involve neurodevelopment, in fact, it is virtually impossible to find a focal alteration, an alteration in a single brain centre: normally, in these cases, the anatomical differences are really subtle, and the disorder is most evident at the level of functionality of the individual areas and especially at the level of activation of the functional network. The results arising from the volumetric and functional analysis of both hemispheres showed a 25 % reduction in the caudate nucleus, a structure that belongs to the basal ganglia system, responsible for monitoring the movements of the mouth during articulation (Watkins et al. 2002a). From the functional point of view, several studies have shown the underactivation of both cortical and subcortical circuits that are related to the production of language (see Liégeois et al. 2003) and, in particular, to Broca's area and its right counterpart, the putamen (another component of the basal ganglia) and the hyperactivation of regions which are not normally involved in speech circuits (occipital, postcentral and posterior parietal regions). These brain circuits of the affected members show a greater cognitive and/or attentional effort during the production of articulated speech (Vargha-Kadhem et al. 2005).

This data, therefore, indicates that FOXP2 can be an important gene for the development of the cortical and subcortical circuits that are involved in learning, in the planning and execution (performance) of orofacial sequences and in particular articulatory ones. The FOXP2 point mutation does not, therefore, cause a language deficit, but an articulation problem.

Liégeois and associates (2011), in the wake of the findings in connection with Broca's aphasia carried out a study in which, for the first time, they performed a test of articulated production relative to non-words with members of the KE family. The purpose was to demonstrate that these individuals have an inability to use motor coordination for language sounds regardless of the fact that these sounds are connected to meaning. The purpose of the study, in essence, was to demonstrate that the deficit of the KE family is independent of the cognitive processing of meanings. The results demonstrated a clear inability of the affected members being considered to produce non-words. The authors interpreted this data, in part, by using the results of the fMRI which showed underactivation of the subcortical and cortical structures that govern phonation (in particular the Rolandic operculum, Broca's area and the

precentral gyrus). This, according to the authors, is a clear sign that the FOXP2 gene (or areas that it rules) controls the formation and functioning of brain components that are delegated to both the articulatory control (the precentral gyrus, for example, which contains the cortical representation of the tongue, lips and larynx) and the acquisition of new motor patterns: if these areas do not function, the members of the KE family do not articulate well and fail to acquire new motor patterns such as those provided by non-words.

Basically the members of the KE family have a neurodevelopmental impairment that prevents them from acquiring the necessary motor patterns necessary for the articulation of language. From the first exposure to the language the processes of learning motor patterns are impeded and, therefore, the acquisition of language skills in general is very difficult. Through this study Liégeois and colleagues demonstrate a connection between the circuit of the repetition of the non-words and the ability of the acquisition of language. This circuit is, in fact, responsible for learning new motor articulatory patterns:

our data indicate that early FOXP2-related abnormality in the cortical-subcortical articulatory network may result in an inability to form, and consequently initiate and consolidate, automatic articulatory programmes. Such dysfunction may be at the root of severe and chronic forms of childhood apraxia of speech, akin to that seen in the affected KE members, where speech output is characterized by articulatory struggle and inconsistent phonemic errors (Liégeois et al. 2011, 288).

The case of FOXP2 is emblematic because it shows how the inability to acquire new motor sequences for speech is connected with the inability to build a real linguistic competence. So a morphological and functional alteration of networks that regulate expression can produce a pathology in the articulation of language that has general repercussions on language competence.

8.1.1.1 The FOXP2 in Evolution

The discovery of the FOXP2 gene has been a very intriguing subject of study for scholars belonging to various fields, not only geneticists and linguists, but also psycholinguists and scholars of evolution.

Since the first studies, in fact, they have tried to figure out if FOXP2 was actually a uniquely human gene. The conditions for the identification of a uniquely human gene were all there: the mutation of the gene, in fact, involved specific difficulties in some components of language and, therefore, this would suggest that the gene was present only in the sapiens. In addition, a syndrome like that experienced by the KE family is extremely rare.

The KE family, along with a few other cases in the world, are the only ones to be affected by such a disorder, despite the fact that the latter is dominant. This is explained by the position in which the FOXP2 is located within the DNA: it is located in the “shrine” of the human genome, that is to say in that region that is practically unsusceptible to mutations: the gene is, in fact, preceded and followed by the two CAG and CAA codons that make it highly stable.

The FOXP2 protein also contains an extension of 40 consecutive glutamine followed by a second extension of 10 glutamine. The poliglutaminic region of the FOXP2 gene is encoded by a mixture of codons CAA and CAG. This sort of biochemical barrier guarantees the inviolability of the gene, because of the simple fact that CAG and CAA are chemically more stable DNA triplets. All this suggests that FOXP2 is fundamental to the constitution of man as being “materially” language. Actually FOXP2 regulates structures that are not directly connected with language (intestines, heart and lungs in addition to the basal ganglia), and as it regulates many structures it is present in many other species.

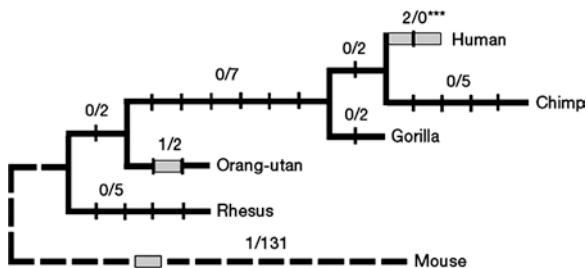
FOXP2 is not an exclusively human gene; indeed, it seems to be one of the most preserved genes among mammals (Teramitsu et al. 2004; Ferland et al. 2003). Not only is the protein encoded in chimpanzees and orangutans, but it is already present and active in mice. Recently, other molecular studies have traced forms of FOXP2 even in songbirds (Scharff and Haesler 2005). This suggests that FOXP2 is not a recent evolutionary innovation. What then does the species-specificity of this factor in man consist of? Why is it that, despite being linked with language functions, it is also present in species different from man? How is it possible that the gene, which is the basis of the articulation movements in language, which is not found in other species, is also expressed in the DNA of other animals?

Enard et al. (2002) explains this apparent contradiction with the evolution that the FOXP2 has undergone over millions of years. To do so, he compared the protein structure of FOXP2 in humans, chimpanzees, rhesus macaques, orangutan and mice. The result of this comparative genetics sheds light on a chronological reconstruction of the functions performed by the protein. The human FOXP2 contains changes in the coding of amino acids in its structure (compared to the animals) which suggests that it has been the target of positively selected mutations during human evolution. According to Enard, the first mutation of FOXP2 occurred in mice 130 million years ago, while the evolutionary lines of mice and monkeys (which, of course, contained the human one *in nuce*) separated after the second mutation of the FOXP2 gene occurred about 70 million years ago. The mutation that caused the appearance of the human evolutionary line is dated about 4,6–6,2 million years ago.

So far we have dealt with the mutagenic path of FOXP2 that allowed the differentiation of lineages from mouse to man. But by comparing human DNA with the animal one a fundamental fact was revealed: the mutations that the protein has undergone over evolution were not all the same type: while the mouse's FOXP2 has undergone several nucleotide mutations (about 130) but only one amino acid mutation, and in the monkey evolutionary line only the orangutan has undergone an amino acid mutation, the human FOXP2 is characterized by the fact that it has undergone two amino acid mutations, the first of which has allowed the differentiation of the human line from that of monkeys, the second made the protein structure as it is in modern man (Fig. 8.2).

Of fundamental importance is the recent exposure of mathematical models of intraspecific variability of the FOXP2 genomic site (Enard et al. 2002; Zhang et al. 2002): these suggest that FOXP2 is a recent target of selection, and the second amino acid mutation in humans was fixed in the population between 120,000 and

Fig. 8.2 Diagram of mutagen path of FOXP2 from mouse to man. The substitutions of amino acids are represented by grey rectangles, nucleotide substitutions by vertical bars (Source: Enard et al. 2002)



200,000 years ago (certainly not before), coinciding with the dating of the emergence of anatomically modern man.

More recent and deeper analyses of FOXP2 have revealed differences, compared to mammals and birds, just in regulatory regions that are related to language. As already stated, FOXP2 is a key regulator of the brain during embryogenesis and in particular it acts on the activation of neural cells present in the basal ganglia. From a comparative assessment of FOXP2 in other animal species an interesting fact emerges: this gene comes into play during the acquisition of specific motor patterns for intraspecific vocalizations. In some experiments, (Haesler et al. 2007; Schulz et al. 2010) Zebra Finches' FOXP2 has been *knocked-down*, and this has led to a dysfunction of the cortico-basal ganglia circuit (Enard 2011), essential for the acquisition of new vocalizations. In practice, by silencing FOXP2 you have limited the imitative ability to produce songs-targets. It is understood, in this way, that these songbirds have high levels of expression of FOXP2 in *Area X* (the *Vocal Area*) of striatum during the voice learning period and the increase of the expression would be associated with the acquisition of motor patterns different from those involved in the basic song. High levels of expression of FOXP2 produce singing stability, low levels allow voice variability. This reveals another interesting aspect of FOXP2. The gene's activity is not required to learn new motor patterns, but to make them automatic and stable. *Zebra Finches* with reduced expression of FOXP2 in *Area X* of the nucleus of the basal ganglia, present an inaccurate and inconsistent imitation comparable to the type of defect present in the KE family (Haesler et al. 2007; Schulz et al. 2010; Lai et al. 2003).

Comparative data has finally shown that the FOXP2 gene is involved in neurogenesis and in the development of cortical and subcortical organization (in particular in the white matter) during embryogenesis (Tsui et al. 2013). The expression of FOXP2 is essential for fine auditory-motor learning and cortico-striatal integration (Kurt et al. 2012). It is also interesting to note that in mice in which a humanized FOXP2 mutation was introduced, while they have not lost the ultrasonic vocalizations used as sexual lures (Hammerschmidt et al. 2015), the elongation of dendrites in the neurons of the striatum was observed, but not in other parts of the brain such as the amygdala or the cerebellum (Reimers-Kipping et al. 2011). In other words, changes have occurred only in regions connected through the cortico-basal

ganglia-circuits and the same was found in songbirds. The mice with humanized FOXP2 also showed a surprising improvement in learning and significant physiological changes in those corticostriatal circuits that are known to be involved in motor control and language (Schreiweis et al. 2014). In particular, in this recent work it has been demonstrated that “the FOXP2hum/hum mice exhibited an altered interaction between the declarative and procedural learning strategies, favouring the procedural system when both learning systems were engaged” (4). If these results are confirmed (see Chandrasekaran et al. 2015), their impact on human knowledge could be of enormous importance. In fact, we currently do not yet know anything about the role that FOXP2 plays in shaping the development of the human brain in language and speech. Similarly, we are not clear about the functional relationship between the procedural and the declarative learning strategies. An option established by the results of this research is that the efficient proceduralisation connected to the role of FOXP2 could accelerate probabilistic learning of the characteristics of articulation of language at all levels: phonetic, morphological, syntactical, semantic. In essence, FOXP2 could render more automatic the division into discrete blocks of the acoustic and motor continuum. To quote the moderate words of the authors, the merit of this research is to “prompt the intriguing speculation that the humanization of this gene imparted a facilitated ability to use procedural forms of learning and, therefore to shift rapidly from declarative to procedural forms of learning, a change that could have been important for the emergence of proficient language and speech” (Schreiweis et al. 2014, 6).

Summing up, we can say that, regardless of the type of animals in which it is present, FOXP2, amongst other complex physiological functions that it regulates, should be credited with the ability to control the precise modulation and stabilization of the executive algorithms of vocal sounds. This ability is not to be interpreted, according to DBM, as a simple strategy to ensure the efficiency of externalization interfaces in favour of an abstract hierarchically superior mental system, but as an ubiquitous feature in computational operations of every cognitive system, whether animal or human. Favouring the production, reception and the ability to articulate the acoustic-articulatory continuum (and, perhaps, more generally, the procedural continuum) in parts that are more and more discrete, it activates combinatorial computational procedures – of course always in relation to the cognitive system of the different species that possess it. It will then be left to evolutionary history to determine the specific level of complexity and functional adequacy of the different organisms that are genetically constrained. The appearance of these organisms and their evolutionary sequence suggests that the anatomy and specialized neural mechanisms that work in the production of language took place relatively late in our evolution and has certainly had important implications, not only on modern man but also on our ancestors (including the Neanderthals, from whom we separated about 500,000 years ago, and that, according to Krause et al. 2007, could present a FOXP2 gene similar to the human one).

In *Homo sapiens*, the fully human form of FOXP2 is expressed in the basal ganglia and subcortical structures known today as the seat of the motor coordina-

tion control, and also includes linguistic control (to which we return in Sect. 10.3). The basal ganglia are involved in a specific human language cortical-subcortical circuit (Vargha-Khadem et al. 2005; Ph. Lieberman 2009): damage to a part of this circuit produces a deficit whose severity depends on the extension of the lesion. They are involved in speech acquisition because they facilitate the inferences of statistical regularities in motor sequences and, in particular, in the linguistic motor sequences, which are properly combinatorial (Simon et al. 2011; Kotz and Schwartz 2010).

The difference in the FOXP2 human sequence would also explain the difference between the vocal learning capacities in humans and non human primates. Thus, it seems that the relationship between the specific morphologic structures (vocal tract) and the specialized control systems could be a good starting point for the description of functional and evolutionary features.

The evolution of FOXP2 has now been debated, both in relation to its role within language and in relation to its role in the evolution of *Homo sapiens*. Even the nature of FOXP2 control over language itself is in question. In particular, the molecular analyses suggest that it involves not only a transcription factor, but also the regulatory elements that are found around this gene (Ptak et al. 2009).

What we are sure of – and this is fully embedded in the DBM – is that the *sapiens*' body would not be “language ready” if it did not have a certain set of genes that ensured the species-specific form of *sapiens*.

If the peripheral structures, the neural control systems, neotenic brain plasticity and the cortico-subcortical organization were not ready for language, our language faculty, as a whole, could not be achieved. The morphological possibilities in DBM are not simply the *conditio sine qua non* for the appearing of the language faculty, but they are species-specific characteristics of the function. For this reason, the genes that have made us structurally and functionally *sapiens* cannot be considered marginal: the FOXP2 gene is a central piece in the evolutionary mosaic that constituted our bodily technology for language.

8.1.2 *Genes Selected to Become Humans*

The discovery of FOXP2 was considered unique: finally a gene was sequenced that could be considered responsible for biological linguistic articulation. But as we have just seen, immediately after the announcement of this discovery, several comparative studies have questioned the uniqueness of the human genetic trait, identifying similar ones (but not identical ones, and this in genetics plays a crucial role) in bonobos and chimpanzees, but also in orangutans and even in mice which are more distant in evolutionary time from men (Enard et al. 2002).

It seemed that this was a setback to the uniqueness of linguistic articulation. In fact, behind the frantic search of the evolutionary study of previous structures and

functions that are considered uniquely human, there is a totally naive notion of the relationship between structure and function, and of the selective mechanisms that maintain genic sequences or promote change, even short ones, but ones which lead to new morphological configurations.

There is no doubt, in fact, that the search for continuity in the endless evolutionary history can only make sense if guided by a comparative principle that does not flatten the individual peculiarities of the species in favour of the common *Bauplan*, which is always detectable within families and animals orders. The ingenuity of this belief conflicts with the evidence of morphological diversity and of the related functional ability that characterize each animal species, otherwise it would explain neither the evolution of forms nor biodiversity.

But then is the search that tries to track down the species-specific human genes completely vain?

The immediate answer, which is correct but not too in-depth, would be: no, it is not a vain search, because you can sequence species-specific genes for *Homo sapiens*, but maybe not ones that are unique. It is important, in fact, to emphasize that the presence of genes uniquely characterizing *Homo sapiens* does not amount to assigning, to a genetic trait, the power to realize complex cognitive functions. FOXP2 is one example of the case just described: it is not the gene of language, but the gene of linguistic articulation and this role is not directly controlled by the expression of the protein gene, but mediated by the operation of an anatomical structure, of the basal ganglia and the ancestral nuclei of the brain which coordinates movements and which, only in human beings, has control over the complex system of movements and breathing necessary to produce articulated voice. Yet, without that particular genetic trait, and without that mutation of this gene present only in human beings (in FOXP2, for example, there are two amino acid mutations unique to *Homo sapiens*), the functional possibilities of anatomical structures would be reduced.

It is in this way, then, that one obtains the genetic specificity of *Homo sapiens*. From the mid-twentieth century to present day, human-specific genes have been identified, the vast majority of them being related not only to the form and function of the brain and the bone structures of the skull and face, but also to nutrition and food possibilities in general. It is estimated that out of a total of approximately 23,000 genes in human DNA, there are probably 50–100 exclusive genes. The proportions are not such that we can assume that these genes played a decisive role in the “hominid revolution”, but they certainly helped to bring about the unlocking of genetic resources, which took hundreds of years to be set in previous species (Wainszelbaum et al. 2012).

An interesting example is the case of the regulatory genes determining the form and the arrangement of cortical structures. This is a group of homeotic genes whose gradation of activation produces the general organization of the brain from the occipital to the frontal part, but also from the deeper (and evolutionarily ancestral) part to the more superficial one: this combination of homeotic genes is specific to

Homo sapiens. These homeotic genes belong to two groups: the OTX genes (OTX1 and OTX2) and the EMX ones (EMX1 and EMX2). The first group are responsible for the fronto-occipital organization: a sort of architect gene (Boncinelli 2006) which structures, at precise times during embryonic development, the forms of the encephalus which is expressed to a greater extent in the front region and then gradually, to a lower extent, up to the cerebellum. In particular, OTX2, which is the first to be activated, determines the primary induction for the formation of the neuroectoderm, the set of cells giving rise to the neural plate from which all the tissues of the nervous system originate (Pinel 2006). OTX1, however, presides over the correct differentiation of afference nerve pathways of hearing and sight, and starts the corticogenesis. The action of these regulatory genes is sensitive to that of the other two genes, EMX1 and EMX2, which activate immediately after structuring the shape and organization of the cortex: first EMX2 and then EMX1 induce differentiation of the various types of cortical cells, producing the typically human cerebral cortex. It is easy to imagine that a single change in these genes, or in their reading, or activation timing mechanisms, can determine significant alterations in brain structure or in cell proliferation (Holland and Holland 2005; Simeone et al. 2002).

Several recent studies agree that these architect genes do not act alone but in conjunction with (or using) other genes. Oliver and colleagues (Lagutin et al. 2003) of the St. Jude Children's Research Hospital in Memphis, for example, have identified a gene (SIX3) that is responsible, not only for the typical organization and management of specific functions such as odour perception and vision, but also of more basic functions such as regulation of body temperature, respiration and sleep. This gene, therefore, is responsible for the "regionalization of the brain". So far one could argue that the genetic acquisitions described so far are so general as to cover at least the entire order of *Homo sapiens*, if not of other orders. Certainly, these genes (excluding EMX1) seem to be present in other animal species, but with different structures and loci: this, as has already been shown, changes the meaning and, in particular, the possibility of morphological and functional implementation. A regulatory gene, mutated and selected during speciation processes, can provide functional and adaptive possibilities that were not present or were silenced by the presence of other genes.

A series of mutations relating to bipedal structure and nutritive possibilities can be considered an example of this principle. To understand the terms of the debate, it is necessary to consider the molecular paleoanthropological studies that attempt to explain the transition from one species of hominid with selective environmental pressures to new genetic structures (Biondi and Rickards 2006).

The most recent molecular paleoanthropological studies, in fact, assign a central role in imputing the hominization process to those positively selected mutations that cause speciation. As is well known, often speciation processes occur by selection of minority traits in the population that seem to be either neutral or even harmful. It is a notion that is also well-established under the name of "handicap principle" (Zahavi 1975).

It seems that the process of decreasing the size of the jaw and eyebrow arch in *Homo sapiens*, a process known as gracilization, and of dispensing bone structures with chewing tasks, resulting in enlargement of the skull, has precisely followed this principle (Rotilio 2006): “the great expansion of the human brain during the long period of post-natal development, which leads to brain size three times bigger than that of the gorilla, is obtained by virtue of a handicap in mastication power to the advantage of the great elasticity of the skull”. In paleoanthropology and paleoneurology, some scholars have correlated the presence of a gene coding for a particular class of proteins that, when expressed, provide strength and speed of contraction to the muscles. This protein is myosin.

In particular, the study by Stedman et al. (2004) shows that the difference in masticatory muscles between gorillas and *Homo sapiens* is due to inactivation of a gene coding for myosin (the heavy chain of myosin MYH16). This would give a lower intrinsic contractile force to the masticatory muscles, but at the same time muscular strength is in inverse proportion to contraction speed, and this aspect is crucial for articulatory coordination and for constant modulation of vocalic range. In human speech, in fact, movements of the vocal tract’s articulators must be exactly synchronized with vibration of the vocal folds to obtain a clearly perceptible differentiation of phonemes (Hauser and Ybarra 1994; Fitch 2000). Laryngeal fibers (in particular the intrinsic laryngeal muscles) show an heterogeneous tonic myosin heavy chain (MHC) expression and this aspect confers on them a twitch contraction speed that is faster than that of fast limb muscles (Sciote et al. 2002).

An interesting aspect of the study of human gene mutations is being able to relate small, barely visible changes in DNA to macro structural and functional changes considered specific to *Homo sapiens*. Genetic variations which produce different morphologies also have an effect, for example, on the typical diet of sapiens.

The decrease of the jaw and the dental arches and the resulting reorganization in favour of the face and of the front part of the skull, and the enlargement of the cranial structure in general, in fact, was possible only because certain conditions (both morphological and ecological) simultaneously occurred. Without going into details, it is clear that one of the handicaps arising from the enlargement of the skull and brain mass is connected to an increase in energy needs: the larger the brain mass, the greater the reserves of energy it consumes.

Several studies have tried to explain the selection of this evolutionarily counter-adaptive aspect, calling into question the functional reasons such as increased cooperation and communication activities that would favour an improvement in techniques for procuring food. These explanations do not seem to answer the question of adaptability: a “handicap” taken as a brain that burns a lot of energy and requires a lot of food cannot wait for the emergence of collaborative behaviours, to be selected. These could be, if anything, a consequence of the increase in brain volume and not a cause.

Studies, according to which the genetic changes associated with the structure of the digestive tract and enzymes contained therein are the root causes of such a large brain structure do seem, however, plausible. Studies conducted into the feeding behaviour of the first *Homo sapiens* associated with the genetic analysis of fossils

have allowed us to hypothesize an adaptive advantage produced by its new nutritional option (related to the anatomical structures such as the digestive tract), that would enable it to overcome adaptive disadvantages (microprognatism, on the one hand, and increase in brain size on the other), as being the triggering of a positive feedback between nutrition and increased cognitive function quality (Rotilio 2006).

Pääbo and colleagues (Green et al. 2009) have identified a decisive difference between the DNA of Neanderthals and that of *Homo sapiens*: in the latter, in fact, there is a variation in the gene which is responsible for metabolising the lactose in sugar, providing fuel for the metabolic processes of the brain, and which is completely absent in Neanderthals. While the latter had to recover metabolic acids and polyunsaturated substances necessary for the functioning of the brain via complex intestinal and hepatic transformation processes, *Homo sapiens* could obtain them in an almost immediate way thanks to a more varied type of power supply (*sapiens* is more omnivore than Neanderthal) which is richer in constituents more likely to be immediately assimilated.

The current thinking in evolutionary genetics studies is to consider not only the genes that code proteins, but also that part of the DNA, which up until recently was considered to be “junk DNA”, and does not contain the code for protein direct production. In most cases, these parts of DNA are used to facilitate the expression of genes regulating neural functions such as neural survival, synaptogenesis and long-term potentiation. The cis-regulatory elements are often the target of mutation, possibly more often than other genes leading to morphological evolution (Carroll 2008).

In addition, the approach Evo-Devo, which we will discuss in the third part of the book, has prompted researchers to look for differences not only in the architecture of genes, but in their temporal expression and in their timing which varies among species (heterochrony). This could also explain the data about convergent genetic evolution apparently linking humans and song-learning birds. According to Pfenning et al. (2014) even though they are phylogenetically distant, both song birds and humans have similarities in the brain circuits used for control and learning of vocalizations (respectively robust nucleus of the arcopallium and human laryngeal motor cortex) and this is a consequence of one hundred genes.

Pfenning concludes:

the finding that convergent neural circuits for vocal learning are accompanied by convergent molecular changes of multiple genes in species separated by millions of years from a common ancestor indicates that brain circuits for complex traits may have limited ways in which they could have evolved from that ancestor (Pfenning et al. 2014, 1333).

So maybe the general structure of nervous connections enabling voice production is evolutionarily converged: it is no surprise that there is a convergence in the molecular expression in similar functioning cerebral areas (in fact, those cerebral networks regulate a functionally similar task, i.e. voice production).

Moreover, a convergent evolution for those structures underpinning vocal production highlights the environmental selective pressure on this communication modality. This aspect is important in defining the evolutionary value of linguistic

function and its strong connection with the sensorimotor system allowing it, despite some linguists considering that the faculty of language is independent from modality. Pfenning arrives at an interesting conclusion about brain circuit evolution, but this data does not prove that the vocal capacity for language articulation is unspecific. A pre-existing evolutionary trait, taken alone, can be only used to demonstrate the evolutionary pathway of the form, without necessarily involving the function. In fact, in this study a central aspect in the genetic characterization of tissues is not tested, that is, the timing of expression of the genes.

Some studies, in fact, have shown that more than 75 % of the genes expressed in the brain have a significantly different timing of expression in chimpanzees and humans (Somel et al. 2009), a factor conditioning synaptic density in some specific areas of the human brain like prefrontal cortex and Broca's area.

Several genes are implicated in the determination of the cortical and subcortical structures that produced the human brain architecture and some of those are involved, to a certain extent, in the language faculty (i.e. FOXP2, CNTNAP2, FOXP1, GNPTAB, GNPTG, NAGPA, cf Konopka and Roberts 2016), but they are also partially inherited from common primate ancestors. They are part of that genetic tool-kit that, however, is expressed in a species-specific temporally different manner (very quickened for some structures, very slow for others, see Somel et al. 2009).

Summing up, it can be seen that some genes prepare our body for speech articulation. It is likely that other genes favour this condition too: those that created a stable change in the structure of the vocal tract, those that allowed a fine motor control of that structure (FOXP2) and those allowing greater brain and synaptic plasticity (MEFA2A, Somel et al. 2013).

All genetic mutation should be seen in the overall genetic evolution configuration in which the relationships and connections between genes and functions are multiple and pluridirectional.

A series of mutations associated with inherited ultraspecific homologies and refunctionalizations have rendered the human DNA a mosaic (Gould 2002), a series of blocks whose meaning is defined both by the type of materials of which they are made (the stone from which are extracted) and the relationship with neighbouring blocks.

8.1.3 *Genes Lost to Become Humans*

When considering what genes are specific to *Homo sapiens*, it is necessary to identify the parts of DNA that warrant anatomical structures of highly specific functions and which are unique to *Homo sapiens*. For this reason, FOXP2 has aroused great interest, not only among linguists but, in general, among scholars of the innate components of the uniquely human cognitive functions.

The search for the genetic specificity of sapiens, however, does not only consist of morphological constraints: it appears, in fact, that differences in genetic makeup

between humans and primates can be of a negative type. It seems, that is, that the evolution of *Homo sapiens* is characterized by the loss of genes (or better of parts of genes) compared to primates. The loss (or fossilization) of a gene is an absolutely physiological mechanism of evolution. Once a gene loses its function in the case of difficulties posed by long-term environmental change, it can no longer retrieve it:

gene fossilization and loss imposes constraints on the future direction of evolution in lineages. ‘Use it or lose it’ is an absolute rule imposed by the fact that surveillance by natural selection acts only in the present –it cannot plan for the future. The downside to this rule is that if circumstances change, even over long periods of time, species that have lost particular genes will not have those genes available to adapt to new circumstances. This may be an important factor in the success or extinction of species. Keep in mind that biologists think that over 99 percent of all species that ever existed are now extinct (Carroll 2006, 266–7).

The positive selection of a deletion that prevents the expression of a regulator gene, as we have already explained, is a process that must necessarily be associated, beside a strong random component (Carroll 2006, 325), with very strong adaptive benefits, given the drastic occurrence of mutations in regulatory genes. There may also, however, be mutations in non-regulatory regions as detailed in the study conducted by Stedman described earlier, or as in the mutation of the gene coding for CMP-sialic hydroxylase acid, an enzyme that operates in the brain.

This enzyme, in other animal species, chemically prevents the manifestation of certain brain functions (Alper 2001); in *Homo sapiens*, the gene encoding has changed and this has resulted in a decrease in the expression of the enzyme with subsequent consequences on brain ability.

Haussler and colleagues (Zhu et al. 2007) have sequenced the DNA of different mammals by investigating other animals for genes that have a clear functional role, but are absent in the human DNA. These are genes whose function has been completely eliminated from the human genome, but *Homo sapiens* has benefited from this total deletion. In this research the genomes of man, mouse and dog were compared, to locate these “functional losses”. Twenty-six genes which were lost were identified: some are well-known like GULO gene, an enzyme needed to synthesize vitamin C, found in many mammals but absent in *Homo sapiens* (who is forced to take it from food). Others, however, have been added recently to the list of genetic losses. These include the ACYL3 gene, an ancestral gene previously detectable in bacteria and plants, which is needed to build up the membrane of proteins. One copy of this gene is present in all mammals with the exception of *Homo sapiens*. Without going into details, the loss of these genes could be linked to the possibility of “silencing” protein expressions by blocking some structures or functions, and also of providing material useful to “evolutionary rearrangements”, recombinations of genetic materials that often occur in the transition from one species to another.

The history of human DNA can be defined as a history of liberating constraints. The increase in encephalic size, coinciding with the expansion of the cranial cavity (see Sect. 13.2), during evolution that led to the anatomically modern *sapiens* was secured both by an increase of the existing cerebral material and by the formation of new morphological elements (produced by “genetic liberations”). The brain developed around an ancestral core (the so-called reptilian part of the anatomical and

functional model proposed by Lieberman 2001) uniting different animal species starting from the order of Reptiles, which has developed an additional layer characterized by a different cell structure. This layer – evolved in mammals and independently in birds (Domínguez Alonso et al. 2004) – would have allowed an increase in processing capability. The most recent stratum of the brain of mammals consists of the so-called neocortex that was formed during the separation from the order of reptiles 200 million years ago in conjunction with changes in auditory structures (Rowe 1996; Aboitiz et al. 2003).

The new conformation of typically cerebral mammals, however, has not been produced through mere juxtaposition of neural material: a functional reorganization has occurred allowing both the connection between old and new structures and the construction of modern functional circuits on the basis of new organizational principles (Nishikawa 1997; Karten 1997; Vallender et al. 2008), thus, increasing the ability to process information and allowing the instantiation of new cognitive functions.

8.1.4 From Individuals to Population

The point where the historical-natural languages and genetic structures of communities (not of individuals) are intertwined is the genetics of population. Although Darwin was not the founder, he is, in this case, the real father of one of the most fertile fields of modern evolutionary biology. Population genetics is indeed theoretically derived from the most ingenious Darwinian finding: what Mayr (2004, 112 et seq.) has called “populational thinking”. This notion has been little used, until now, by linguistics scholars, and exploited, instead, fully by biologists who have applied the Darwinian thought to population genetics to reconstruct the bottom layer of knowledge about the speakers of historical-natural languages (Cavalli-Sforza 1996, 2004). Populational thinking can also be very useful to contemporary biolinguistics. In fact, it resolves the tension between the variability of languages and their uses, and the aspiration to universal laws capable of explaining its nature and operation.

In its first meaning, populational thinking indicates that evolution always occurs within populations: it is the effect of the reception accorded by the environment to individual mutations, also helped by chance, which are advantageous for the individual in which they manifest themselves. Thus it allows selection to be directed not toward the idealization of the best “essences” (as in the Platonic-Cartesian paradigm) but toward processes specifically related to reproductive success. While retaining a strong margin of regularity, populational thinking is anchored to historical dynamics that really occurred, and not to ideal classes of formal perfection decided *a priori*.

In current biological terms, populational thinking coincides with the concept of a “gene pool” that has taken the place of the classification of species based on morphological characteristics, similarities or affinities of any kind. It is the set of all

alleles of the genes belonging to all individuals of a population p at a given time t . A gene pool, therefore, always contains an inherent possibility of very high variation that – associated to events caused by mutations, drift, gene flow, and by innumerable randomness factors related to the concrete realization of chromosomal transformations (for example, crossing over in meiosis) – basically makes regular but non-deterministic the reproductive process of individuals and entirely connects the affirmation of progressively adapted populations to natural selection.

From a philosophical point of view, populational thinking opens a new epistemological model to naturalism. It is no longer a typological universe of *eidos*, essences, formally defined classes treatable through reductionist formal processes that tend to be predictable, as in several physicalist paradigms, but it consists in events strongly constrained by structural trends and even more conditioned by concrete performance. If we wanted to reformulate it in biolinguistic terms, the *performance* would, thus, become the constitutive and regulatory *competence* in a model of linguistic knowledge. The linguistic genotype would become a function of populations of phenotypes.

The success of populational models applied to the reconstruction of the history of language can be considered a good example.

On 31st January 2016 at 12.00 am, there are 7102 living languages in the world distributed in more than forty variations (assuming the dialect divisions): they have been counted by www.ethnologue.com, the popular site linked to the homonymous publication, *Ethnologue. Languages of the World*, now in its eighteenth edition. This huge number of languages used by an endless number of speakers – 7,106,865,254 – is divided into seventy families: the most widely used language in the world is Chinese, with 1.197 billion speakers, while Malagasy is only spoken by 10 million inhabitants of Madagascar.

The great efforts made by reconstructive comparative linguists since the middle of the nineteenth century – based on the recognition of similarities and types of idioms – have never been able to go beyond the first few levels of affiliation among all these languages. Because of the rapidity of linguistic changes, in fact, it is almost impossible to go beyond pure hypotheses in the field of primitive glotto-chronological relations. If we were to limit ourselves only to linguistic findings, it would be impossible to accept with certainty even the monogenetic or polygenetic nature of languages. However, molecular genetics has erased any doubt – cast by paleontology – about the existence of a single human species. So in the case of comparative reconstruction of language, the study on population genetics by Luigi Luca Cavalli-Sforza's group has contributed decisively to clarify the parental lines of languages and the substantial bio-linguistic unity of the human species. If, as appears from the data collected so far, Cavalli-Sforza's (1996) theorems were true, genes and languages would have the same history, the diversification of the anthropogenic traits and the parallel branching of linguistic traits would appear as elements of surface variation of a strong biological and cultural identity of Homo

sapiens: a single ubiquitous species with a propensity for expansion and migration and to linguistic-cultural diversification.

Before attempting to explore its causes, one will need to dwell on the properties of this unique eto-ecological configuration. There is no doubt, in fact, that the main human animal zoological anomaly is the fact that although humans have been expanding rapidly everywhere, they have not found an isolated place to genetically diversify. It is, perhaps, superfluous to add that this is not a voluntary process. Population growth is the result of the adaptability of the species. However, the absolute lack of control of the phenomenon has implications of a genetically deterministic nature. The more population growth becomes uncontrollable, in fact, the more the species is stabilized by neutralizing any urge coming from random mutations that are most unlikely to be replicated in a broader population and in continuous contact in space and time. If we, then, add the complexity of human DNA, the final result will be the speciative blockage to which man seems to be doomed.

However, it is important to consider that in the human case, the genetic complexity should not be considered only in relation to absolute quantitative data (number of nucleotides or their combinability) compared to other species, but also in relation to the ratio between quantitative data and availability of compatible partners. Since its inception, human zoological typicality is, in fact, due to the close convergence between the biology of the structure and the biology of culture. The biology of the structure is the result of convergent evolution of central morphologies (neuro-brain) and peripheral ones (bone structures, muscles, nerves). The biology of culture is needed in so far as the human species is a highly migratory species that is expansive and highly communicative. The human condition is, thus, significantly representative of the unification between nature and culture embodied in the absence of any separation between one and the other.

In this respect, the analogy between genes and language, and then between the genetic and linguistic unity of the humankind, can be of great help in clarifying the underlying misconceptions on which the artificial opposition between nature and culture is always founded. For example, the fact that biological evolution is slower than the cultural one is a kind of illusion, due to the confusion between the terms spoken languages and language as function, and between historical variations and generative function of the FLN. Certainly, the language faculty has a long and gradual evolutionary history as much as that of primates. To rebuild it, one must inevitably go through the critical steps of bipedalism, growth of cranial capacity and brain changes, the descent of the larynx and the establishment of the vocal tract and, above all, exaptative processes (social uses, specific functionalization, etc.) arising at all levels from these structural changes, and by their very slow metabolism. From this point of view, it does not matter when this process exactly started and whether there are relationships of continuity or discontinuity with all previous processes converging in a set of cognitive abilities. On the other hand, both in its incubation phase and in that of its final state, this faculty has generated products: vocal articulations of varying complexity, from the first grunts to the forty thousand dialects and languages that exist today. If we call all these functional changes “languages”, biological and cultural time will coincide.

The problem would not be any different if we started from the ecological effects of the relationship between functions/structures produced by biological evolution. In this case it is certain that the cultural evolution would seem to occur very quickly: from the time when the slow transformation of the structures stabilizes into a cognitive mechanism suitable not only for the transmission but also for the formalization and maintenance of knowledge, the adaptive advantages that stem seem, in fact, to multiply dramatically. However, this acceleration is due to the maturing of those structural conditions (morphological synergies) that, although deriving from a long evolutionary path which was not aimed at cultural evolution, in fact impart to it a breakthrough that may appear as a (cognitive, technological etc.) leap.

In any case it is not possible to leave the unitary circle of nature and culture:

You can say – as Cavalli-Sforza writes – that culture is a biological device, as it depends on organs, like the hands used to make tools, the larynx to speak, ears to hear, the brain for understanding, etc. that allow us to communicate with each other, to invent and build new machines capable of fulfilling useful and special functions, to do everything that you need, you want and can do. But it is a device endowed with great flexibility that allows us to apply any useful idea we can think of, and develop solutions to the problems that arise from time to time (Cavalli-Sforza 2004, 78 – our transl. from It.).

However, resistance to this inescapable principle of developmental perspective is quite frequent. The most frequent objection is based on the type of transmission of information: “natural” information would be transmitted by genetic means while “cultural” information would be transmitted directly, a truism, which, however, restricts the term ‘nature’ to genetics and the term ‘culture’ to the social sciences. This restriction forces one to postulate a double substance: a material one (genes) and an immaterial one (ideas, knowledge, cultural capital, and so on). But could the ideas (and therefore knowledge, traditions, etc.) exist without those who have first formulated them? And could these persons formulate them in the form they have done, if they did not have an organic system (sensory-motor, brain, cognitive) organized in a specific way?

It is, therefore, an improbable ideological construction conduced to all dualistic philosophical shortcuts. In fact there is no need to consider only what is genetically transmitted as natural and everything else as cultural. Any practice that is not transmitted by inheritance is as natural as any feature transmitted from our genes to the genes of our children. These are not immaterial procedures. Both imitative processes, spontaneous or induced, and explicitly imparted education by parents or other conspecifics follow their own specific pathways and require a bodily apparatus that can produce and receive information. The proportion between the information conveyed by the phylogenetic structure and that conveyed at every ontogenetic restarting may vary to some extent from species to species, but all natural species – hence all the animal species – acquire and transmit data to their conspecifics always using specific procedures for the purpose: in biology we consider culture as being any mechanism which allows the acquisition of information from members of one’s own species through social systems that give rise to behaviours (Bonner 1980; McGrew 1992; Baumeister 2005; Shettleworth 2010).

A whale learning a different “dialect” sound from other members of its species is at the centre of a cultural mechanism for transmission of information. A macaque learning from another to wash sweet potatoes in the sea, thus cleaning them, is receiving new information through a cultural process. In the same way, a child learning to write thanks to an information sheet received from a teacher, is learning a new behaviour in a cultural way (Bisconti 2008, 27). The fact that the procedures utilized to transmit, directly or indirectly, information to one's conspecifics can change in quantity, complexity, organization, systematicity, social structures of groups etc., does not affect at all the principle of naturalness of culture: even the most complex procedures are entirely natural. Biological resources are revealed both in instructions used by chimpanzees to hunt termites through specially prepared sticks and in instructions to search the Internet to find the latest scientific papers on the spread of cancer in the industrialized areas of the planet. Of course, not all natural systems of cultural transmission reach the same degree of communicative efficiency: their technical capacity varies in relation to the volume of data to be processed, to their hierarchical structure, and the possibility of formalizing and retaining information. From this point of view there is no doubt: the culture of *Homo sapiens* is the most complex and efficient one amongst all species.

Chapter 9

Morphological Fundamentals

In the same way in which CBM tends to judge a set of specific genetic traits that make the human species experts in orofacial and manual articulation to have no influence on the cognitive core of the faculty of language, CBM does not consider even the morphological structure of the interface or externalization devices examined in Sect. 3.1 as cognitively binding. Sensorimotor (SM) and conceptual-intentional (CI) systems are considered, as we have often said, independently of the principle of language (language-independent principles) and should not affect the FLN. Consequently even the sensory modality with which the externalization devices operate (sound, manual and tactile signs are essentially interchangeable from a cognitive point of view) has no impact on the way we exercise our cognitive functions. The languages generated by sounds, hand or dactylogyc signs would all follow the same innate scheme and their acquisition processes and cerebral allocation would lead to substantial differences. The difference with non-human animals would mainly lie in the computational core of the mind, while it would not seem that the learning systems and vocal production follow principles other than those of *Homo sapiens*.

For DBM the point in question has enormous clarification power. As determined by the genetic statement, the morphology of the phonation and hearing organs, voice articulation peculiarities, hearing-voice sensory synergies, prosodic-vocalic learning systems, the ontogenetic process with which they occur and are stabilized, in short the whole of “human linguistic machine” is a species-specific device that also makes the mental performance of *Homo sapiens* specific.

Unlike the CBM, however, the ethological diversity of the linguistic species is not based on anything and does not derive from a physiological and mental void. Conversely, it derives from the slow and gradual action of natural selection that has worked for millions of years speciating common forms to different outcomes, depending not only on modification of the anatomical structures, but also on their mutual interaction, physiologically mandatory but not always functionally determined. It is not at all certain that the long path which through “chance and necessity” has led to a selective instrument endowed with such a high specificity as the

supralaryngeal vocal tract (and, more generally, all the peripheral and central apparatus of language) would then, inevitably, result in human language. Having available permanent physical structures that, emancipated from respiration and nutrition, provided a bodily technology that greatly increased the accuracy of the digital communication ability (the ability to emit and receive discrete sounds) will probably have favoured the functional exaptation to activities that we ended up defining as “linguistic”. And otherwise, as demonstrated by Fitch (2010), other non-human species have not used similar structures in the functional direction (see Sect. 9.1). It is not enough that some parts of the linguistic mosaic show analogies or similarities between different species in producing the same behavioural and cognitive outcomes. The vocal tracts are inside musculoskeletal, histological, nervous and complex structures allowing organisms to express certain kinds of social behaviour that is structurally constrained by the possibilities allowed by the phylogeny. But even within this range of possibilities, nothing is predetermined: given a certain structure, one cannot predict with absolute certainty how functional direction may extend its performative reality. Conversely, the opposite is also true: once a certain functional process starts, one cannot go back and it is really useless and idle to ask “what would happen if...”.

In the chapters that follow – dedicated to the description of “structural specialities” of the language faculty – we are, therefore, going to address a question that we believe is important for contemporary biolinguistics, but is typically systematically ignored or evaded: “Does the way speakers are made count for the purpose of defining the very nature of language?” or, in other words, “Does linguistic embodiment play a key role in a naturalistic philosophy of language?”

In our strictly Darwinian approach, one must address the debate on the issue of the biological foundations of language starting, as we have already said, from the way things have turned out to be during human evolution, from what might have been and did not happen. In other words, when we speak of “speakers” here we mean primates that communicate and build universes of representations using central and peripheral body structures suitable to modulating and de-modulating speech sounds in an exclusive way. It is irrelevant, for the perspective adopted, if some individuals of this species, affected by sensory or brain disorders, can communicate using other body structures (e.g. sign languages or tactile codes, etc.). These subjects, in fact, replace the auditory-vocal structures with other anatomical structures starting from cultures entirely founded over tens of thousands of years on the historical-natural oral languages. This is certainly a practice of “plausible” substitution, but it is not the selective choice that has unquestionably been imposed for its benefits to modern *Homo sapiens*.

Is a reconstructive speculation needed to prove this evidence? Probably not! Our phylogenetic traits and ontogenetic recapitulation in any healthy infant developed in human environments can only render any doubt superfluous: the talking animal has evolved developing default language structured as a communicative and cognitive species-specific form. Accordingly, the answer to the question we raised at the beginning should be obvious: to define the very language it matters greatly whether we know how the speakers who use it are made. The plausible, but not selected,

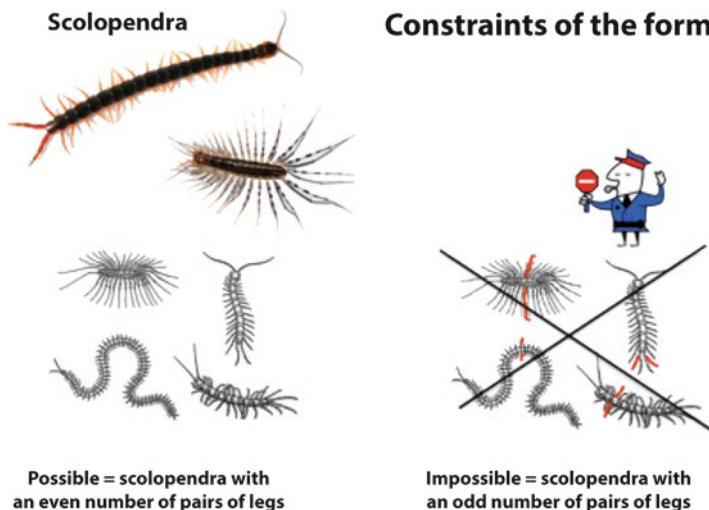


Fig. 9.1 Structural Constraints in centipedes (Source: Minelli 2007, adapted)

speakers would be those who could have used different bodies to achieve equal or at least comparable results. The possible speakers are those that have been selected to obtain major evolutionary advantages from their organic constitution. The impossible speakers are those who do not abide by the conditions and the biological constraints of the selected speakers.

As part of evolutionary biology this kind of distinction has been decisively improved through the Evo-Devo perspective. Correcting the excesses of original Darwinism, Evo-Devo made it clear that the theory of natural selection, which by its vocation requires explanatory constraints, is itself subject to constraints arising from the rules of form and development. Excluding the chimeric or virtual forms, theoretically plausible but never appeared because they were not selected, no environmental pressure could produce, for example, centipedes with an odd number of pairs of legs.

We can then discover scolopender with 22, 24, 26, P_n number of pairs of legs, but never with 23, 25, 27, O_n number of pairs of legs (Minelli 2007, 21 et seq.): see Fig. 9.1.

Centipedes, however, are not an exception: millions of transformations and millions of forms that appear to us at first sight plausible, if not possible, are actually impossible and, in fact, never realized.

One consequence of the significant epistemological primacy of the structures on the functions – or, if you will, the antagonism between the reasons of anatomy and those of functional adaptations – supported by Evo-Devo is the drastic reduction in the rate of speculation contained in the explanations of individual theoretical and reconstructive issues. Among these, the explanation of the nature of human language stands out. Without getting into complicated original reconstructions, we know that the real potential speakers are those that present some selected structural traits, because in the original balance between costs and benefits they have prevailed. For instance, the possible speakers, as we shall see in Sect. 9.1, have a supralaryng-

geal vocal tract characterized by two segments of almost equal length and positioned at a right angle: a horizontal oral cavity and a vertical pharyngeal cavity. Anatomically plausible speakers could have one of the two traits longer or shorter, or not perfectly placed at 90° to each other. This is the case, for example, in chimpanzees or human infants or other forms of earlier hominids anterior to modern sapiens. All are subjects capable of producing articulated sounds but are not able to produce the quantal vowel (i / a / u) which increases, in a decisive manner, the accuracy and robustness of the articulatory system both in production and in reception (Lieberman 2012).

Is it so important for adaptive and cognitive purposes that speakers possess an articulatory system (and also an auditory, neurocerebral, neuromotor system, etc.) that is so sophisticated? We believe that a consistent Darwinian biolinguistics viewpoint must answer Yes to this question, although, to date, we cannot record a definitive answer to this question.

Chomskyan biolinguistics, as we have clearly seen in the first part of the book, distinguished between, for example, devices internal to the mind-(brain), responsible for the computational processing of external data, and interface external devices. The structure of these “externalization” devices – which currently includes both the input-output vehicles like vocal structures (but also signs or tactile forms of one form or other), and those connected with conceptualization (hence the nature of the ideas and concepts) – remains, as in the original cognitive science, arbitrary and uninfluential on cognitive processes, making it essentially useless to study the problem of the instantiation of the functions in the structures. By contrast, the FLN is made, at present, by a single procedure: the MERGE embodying the simplest recursive architecture of the mind, which we will return to shortly. If, therefore, a biolinguist like Chomsky should answer the question that we asked ourselves, he would say that, at least for the purposes of defining the nature of language, the speakers only count in so far as we need to consider the software of their minds (brains), and not for their sophisticated articulatory system. Even when they speak of “body language” or “cognitive physiology” (Anderson and Lightfoot 2002), the Chomskyan biolinguists rely on computational rules that can serve to explain the behavior of speakers more than on the brain.

Surprisingly, even in the opposite camp of Darwinian biolinguistics, it is not always the case that a clear answer prevails in relation to the centrality of the structural constitution of the speakers in clarifying the nature of human language. Surely even the most advanced contemporary naturalism, as Darwin’s detractors and Broca did in the nineteenth century (e.g. Bateman 1868 and 1877, see Sect. 5.4), tends to relocate language and to consider it independent from the body (see Pennisi and Falzone 2010, 279 et seq.). Instead of facing the onerous task of explaining the linguistic machine in detail to understand its ethological peculiarities, it prefers to search the reasons of human uniqueness in culture, sociability, in the mind rather than in biology:

[the] most, if not all, of the species-unique cognitive skills of human beings are not due to a unique biological inheritance directly, but rather result from a variety of historical and ontogenetic processes that are set into motion by the one uniquely human, biologically inherited, cognitive capacity (...) [which] is the understanding others as intentional (or mental) agents (like the self) (Tomasello 1999, 15).

Theory of mind, culture, social relations, as well as the most disqualified linguistic theories of idealism, have been used in an attempt to avoid the Darwinian study of the structures of language. In a recent article (Pennisi and Falzone 2014) we noted that, in this respect, real residues of *Intelligent Design* exist in many naturalistic hypotheses on the origin of language. These residues contain the refusal to recognize that the gradualistic dimension typical of the Darwinian proposal can only be applied to structures and certainly not to functions. It is useless to dwell on speculations about the cognitive antecedents of language. It is the progressive modelling of the bodies that enables the eventual transformation of uses and behavioural functions, particularly those with a strong cognitive curvature. As already stated in Sect. 5.3, structural constraints are higher-level than functional ones: you cannot use organs that you have not got and you cannot allow new structures, that do not yet exist, to perform certain functions.

In the following pages, we will examine how the cognitive and evolutionary perspectives have modified, both positively and negatively, some of the most deeply held convictions about human morphological exclusivity. It should, however, be made clear right now that we will not produce a set of data in support of a reductionist idea of human cognitive abilities, nor shall we try to blindly track evolutionary precedents of anatomical structures that today substantiate complex cognitive functions. The biological perspective inaugurated recently in the analysis of human cognitive ability, contrary to the fears raised in some philosophical and humanistic fields, did not cause a trivialization of issues relating to the nature and procedures for the implementation of human cognition. Indeed, it is precisely the placement of structures and functions in the entire human organism which are subjected to undifferentiated laws of natural selection and adaptation which have resulted in a more complex picture of the differentiation of human cognition and its physiological functioning. This, also, has not led to the flattening of the interspecific differences, as described above, but, on the contrary, to a richer and less reductive assessment of human capabilities: an assessment which is finally generalized to any type of cognition, including that of animal cognition.

A clear example of the positive epistemological research introduced by the evolutionary perspective is represented by studies on central structures and language devices that bring out clearly the relationship mediated between anatomical and cognitive components in relation to the exaptation processes, a notion allowing us to completely rethink the assumptions on uniqueness and speciality of language as a whole.

9.1 The Vocal Tract and Productive Specificity

Articulated language is the result of the coordinated operation of various peripheral anatomical structures, each of which contributes to the production of the sounds typical of a language. In adult members of the human species, in particular, there exists a typical configuration of the pharyngeal channel with the larynx in a

permanently low position. The lowering of the larynx is essential for the production of the voice, since it allows one to extend the length of the oral-pharyngeal cavities. This anatomical element allows one to obtain a resonance box in which one can modulate the most pure tone emitted by the glottis before this comes out of the mouth. The sounds of human speech, in fact, are produced by the vibration of air that is emitted from the lungs and passes through the vocal tract by meeting certain anatomical obstacles with which the speaker is endowed.

The lowering of the larynx allows the sound to be filtered by more anatomical structures thereby providing a greater variation of vowel quality. In essence, it is due to this lowering of the larynx that *Homo sapiens* is capable of producing the so-called “formant frequencies”: the low position of the larynx and its inclination of about 90° with respect to that of primates determines a change in the geometry of the vocal tract, and produces a particularly advantageous proportion of about 1:1 (Lieberman and McCarthy 1999) between the length of the horizontal channel (that goes from the lips to the rear wall of the pharynx) and that of the vertical channel (that goes from the vocal slots up to the soft palate).

The immediate consequence of the increase in the size of the pharyngeal cavity and its greater mobility is that it determines the formation of a sort of dynamic filter adapted to produce vowels endowed with acoustically distinct formant frequencies (Nearey 1978; Lieberman 1984 and 1991). The shape of the larynx, together with the ability of neighbouring muscles to control its movements thereby allowing greater changeability, increases the spectrum of human articulatory possibilities (Lieberman and McCarthy 1999).

At a superficial level of analysis, it would appear, therefore, that the structure of what is now called the “vocal supralaryngeal tract” is present in *Homo sapiens* and has evidently been selected for linguistic purposes. It is precisely this anatomical feature which is unique to human beings. Based on studies conducted on both pre-sapiens hominid and non-human primates, Lieberman (1991; Lieberman and Crelin 1971) argues, for example, that man is the only living being to have a permanently low larynx. He concludes that it is the need for survival that has contributed to the lowering of the larynx. This anatomical feature, in fact, allows the sharing of a section of the passage for food and air (the pharynx). During swallowing, the breathing channel is closed by the epiglottis to prevent liquid and solid residues of mastication from ending up in the trachea, obstructing it and preventing breathing. If this operation is not effected correctly, one runs the risk of choking, a risk that would be strongly disadvantageous – and thus the human vocal tract would be negatively selectable, if there had not existed a corrective mechanism to overcome these negative effects.

According to Lieberman, the advantage is the ability to communicate verbally: in other words, lowering the larynx is an adaptation for language.

Many selectionist hypotheses about the origin of language function (Dunbar 1996; Bickerton 1990 and 2003; Deacon 1997) give a selective value to language and consider the structures which have been instantiated as adaptations for language function. But it is precisely the idea of “fit for the purpose” which has been chal-

lenged in recent years. This idea, in fact, starts from an assumption that has not always been verified from an evolutionary point of view. Darwin argued that anatomical structures are positively selected during the evolution of a species based on their adaptivity, namely the advantages and increased fitness that can be provided to members of a given group of conspecifics. This assumption, however, if it is used in a pervasive manner, is likely to become a tautological explanation: “a circular reciprocal definition of adaptation and natural selection: one defines as adaptation everything that is produced by natural selection; one defines as natural selection the mechanism that generates adaptations” (Pievani 2005, 142). And if the adaptivity is applied to functions, especially those that are cognitively complex, the picture becomes even more complicated and one is likely to fall into certain finalistic explanations when attempting to reduce all behavior and cognitive abilities of man to specific adaptations by claiming to simulate environmental contexts and functional predispositions of extinct hominids, as often happens in the formulations of evolutionary psychology (Adenzato and Meini 2006).

The role played by selective pressure on anatomical structures and some functional aspects is undeniable, but to reduce all individual structures, and functions upon which they are instantiated, to adaptive explanations, as mentioned earlier, also involves the trivialization of a scientifically founded theory, like the Darwinian one, which has never shown such levels of epistemic fundamentalism. Darwin himself considered imperfections as “evolutionary legacies” which are present in various animal species (more than perfect adaptations) and are crucial to the understanding of evolutionary processes: in fact, in the presence of adaptive compromises, the process of gradual change (that is the basis of the diversity of life forms) would be evident. The preservation of some traits that are clearly not adaptive (or neutral) within a species, in fact, is a sign of the phylogenetic heritage of previous forms and, simultaneously, is “the premise of new possible utilizations” (Pievani 2005, 143).

It is from this position that the hypothesis formulated by Fitch develops. Fitch is an evolutionary biologist involved in investigating the presence of the supralaryngeal vocal tract in other animal species. Fitch (2002) argues that the very supralaryngeal vocal tract – one of the strongholds of the specificity and uniqueness of language and articulation skills of man – is also found in other animal species that are phylogenetically distant from *Homo sapiens*, evolutionarily prior to *Homo sapiens*. According to his hypothesis, the supralaryngeal vocal tract is a manifestation of analogy (Lorenz 1978) as it plays an adaptive role in most species.

Fitch’s hypothesis is fairly well known and is based on the observation that several animal species – including the red deer (*Cervus elaphus*), dogs (*Canis familiaris*), goats (*Capra hircus*), pigs (*Sus scrofa*), tamarins (*Sanguinis oedipus*), and alligators – have been able, through muscular efforts, to obtain an anatomical structure of the supralaryngeal vocal tract which is very similar to that of the human one. Fitch’s theory would provide a better explanation for the emergence of the supralaryngeal vocal tract than the one advanced by the linguistico-evolutionary theories that illustrate the immediate advantage for the presence of several anatomical structures, including the vocal tract, for the purpose of language. According to Fitch, the

supralaryngeal vocal tract would have had an immediate function in humans: to economize the efforts to enlarge the perception of a person's size, efforts that other species fulfil by lowering the larynx to physiological limits during the production of sounds and in particular during the mating period. The lowering of the larynx increases the volume of the pharyngeal cavity (whose size is usually positively correlated with the body size of each individual) and, by providing a greater resonance chamber, allows the air to vibrate to a greater extent and, therefore, to amplify the sound, ensuring the production of formant frequencies. Fitch notes that the production of formants is not functional to the call issued, but to the perception of it by conspecifics. In essence, since there is a positive correlation between body size and the ability to emit low and defined sounds, the lowering of the larynx, with the consequent production of formants, is employed to "pretend" (obviously not intentionally) that the animal has a bigger body size. And this also applies to human beings, at least for the first forms on Earth. The adaptive value related to the production of formant frequencies, therefore, would not be detectable in articulated speech production but in the ability to be more attractive to the females of the group by pretending to enlarge their body size (*size-exaggeration theory*).

The stabilization of a structure that allows a virtuous speech production like the human one could have been positively selected during evolution by the same mechanisms and for the same functional reasons as the phonetic structures of non-human animals, but the use that *Homo sapiens* makes of the larynx today goes beyond its original purposes. It is unlikely that the descent of the human larynx is advantageous only in so far as it enlarges the body size for sexual and defensive purposes. The upgrading work mechanisms (exaptation) produced a readjustment of such a structure that, once selected positively as a consequence of some evolutionary advantage – for example, the exaggeration of their size or any other immediate advantage that has increased fitness and thereby stabilized the anatomical portion within the species – nevertheless allowed the articulation and the orderly modulation of sounds in more or less complex sequences with typically formant frequencies.

The secondary function, one that was instantiated later and not necessarily to provide immediate adaptive benefits, was that of the voice. This was an "exapted analogy", a case of co-evolution of advantageous anatomical structures and emerging possibility that, once the immediate function was stabilized, could manifest themselves having been liberated from previous evolutionary-structural constraints. Fitch's assumptions paved the way for a more plausible evolutionary perspective than the one identified by the linguistico-evolutionary theories that could not explain the time gap between the appearance of the low position of the larynx's anatomical structure in the early *Homo sapiens* (200,000–120,000 years ago) and its use for linguistic purposes (70,000 years ago). The principle according to which an immediate function has acted as a selective catalyst of the vocal tract for non-linguistic purposes, therefore, appears scientifically convincing.

However, what seems questionable is precisely the anatomical-functional comparability of the vocal tracts of different species. It is evident, in fact, that although other animal species are able to obtain a configuration similar to the one producing

human formant frequencies, such a production is bound to individual resilience in maintaining tension in the muscles and would therefore be an impediment to an increase in articulatory capacity. In response to this criticism, Fitch explained that some cases of mammals have a vocal tract characterised by a permanently low larynx (seals, koalas), which is employed, apparently, solely for reproductive purposes, which would allow a comparison to be made between the human and non-human vocal tract. The fact remains, however, that koalas, while possessing a vocal tract similar to that of humans, cannot produce an articulated voice. According to Fitch, to track the species-specific characteristics of each species and to understand the differences in productive capacity is less important than evaluating the correspondence of the anatomical structures which are being used by a given species. Therefore, research should move away from the morphological components to the nervous system that allows one to flexibly control a certain structure.

Fitch's précis highlights the incompleteness of his argument: if the anatomical structures by themselves do not inform us about the functions they could play, then the ways in which one obtains control of such structures are not necessarily binding for the presence of associated skills. They offer, at best, a possibility, a chance.

The evolution of functions, as mentioned earlier, does not follow the same adaptive times as the evolution of structures: the exaptation goes beyond the primary evolutionary reasons of structures, resulting in an overall remodelling. The decoupling of the structures from their primary functions (obviously authorized by genetic variations) provides new possibilities for new functions that, although they are not located at the bottom of the genetic flexibility of structural skills, are random and unpredictable. This does not allow us, however, to imagine that exaptation is an epiphenomenon, a kind of "magic" and quite abstract readjustment: exaptation is accomplished through a series of neural rewirings that serve to utilize the new function by using collateral structures other than the exapted one. It is a real change and as such requires altering the functions of the whole organism. A species may possess structures which are ideally suited to a function (such as the larynx in a permanently low position) but unless there is an exaptation, this function will not occur.

In this perspective, the anatomical structure in itself would not guarantee the presence of a complex function, such as language: each function can be the outcome of a rewiring of existing anatomical systems which are eventually suitable for the instantiation of a new function. It is as if the anatomical structures, initially selected for immediate adaptive purposes, were utilized by new purposes emerging from anatomical and functional reorganizations. At a peripheral level, the verbal articulation, for example, in addition to exploiting the vocal tract in the ways we described earlier, involves the reutilization of a series of structures that perform vital primary functions for the survival of the organism. Language takes advantage of the breathing mechanisms. During phonation the normal rhythm of inhalation and exhalation are, in fact, altered considerably by slowing down the expulsion of materials resulting from cellular metabolism, allowing the air to flow as slowly as possible (see Lenneberg 1967). Language also uses different muscle groups for its own purposes, including facial, pharyngeal and hyoid ones which are normally used for nutrition.

Today, the debate on how to achieve exaptive processes and especially the selective pressures that facilitate the engraftment (of a new function) at the population level is very lively. Data on laboratory studies of non-human primates, in experimental conditions, show similar cognitive abilities never seen in the natural human habitat (and which we will return to in Sect 14.1), which would seem to suggest that environmental conditions play a key role in stimulating recabling.

If, despite the presence of anatomical structures similar to those of *Homo sapiens*, different animal species do not show the same human cognitive capacity, it is likely, then, that the evolutionary history of structures has also influenced the direction of the exaptive possibilities, and that the selection pressure has not acted positively on any refunctionalizations in other animal species because they would be of little or no use in the environment in which they live. Principles of functional rearrangement constitute, therefore, a central node for the assessment of uniquely human capabilities, since they allow us to obtain an overall picture of the connections between structures and functions and of the adaptive role they play within the whole organism.

9.2 The Specificity of Auditory Perception

The human auditory perceptual system is characterized by a series of anatomical structures that humans share with phylogenetically nearby species (non-human primates) and by a certain type of organization, both at the peripheral level (in the case of the cochlea) and at the central level (the primary auditory cortex). There is no doubt, in fact, that the human auditory perceptual system is characterized by elements homologous to those of non-human primates, but it is interesting to note that these features are only present in some animal species in which vocal production is used for communicative purposes within social groups. The organization of the cortex of non-human primates that is even more complex than that of other mammals, in fact, seems to be suited to the reception of typical complex vowel sounds of oral communication.

To understand this transition for a species in which the auditory perception is secondary compared to other types of sensory perception (sight, smell, etc.), it is useful to briefly describe the conduction pathways of the human auditory signal and the related areas for the elaboration of such a stimulus at the cortical level. The primary auditory cortex, located in the superior temporal gyrus (Brodmann's areas 41 and 42) called Heschl's gyrus, receives input from the medial geniculate nucleus of the thalamus. These afferents arise from a neural circuit (auditory nerve) that starts from the cochlear nucleus and ends in the primary auditory cortex (central acoustic conduit). In common with other sensory cortices, the primary auditory cortex presents a typical tonotopical organization in which the lowest auditory frequencies are located in the rostral part (anterior part) while the higher ones are at the rear (Hudspeth 2003).

These tonotopical maps represent the entire spectrum of audible frequencies. The organization of the maps, even for this sensory cortex, is arranged in columns. The neurons of the auditory cortex have binaural characteristics, meaning that they respond to stimulation of both ears, but tend to cluster into two different types of columns, determined by the type of sensitivity of neurons of which they are composed.

Despite the fact that the auditory neurons have binaural characteristics, in fact, the summation columns respond to the stimulation of both ears (binaural response is greater than the monaural), while the columns of suppression respond to ipsilateral afferences and are instead inhibited by stimuli from the opposite ear (a monaural answer, therefore, determines a greater activation of the suppression neurons, with a dominance of afferences coming from one of the two ears). Both types of columns display a classical vertical organization that runs from the pia mater to the white matter below.

In the primary auditory cortex the brain determines the spatial position of the sound source by using the difference in time at which sound arrives at the two ears. The frequency and time are encoded by conduits arranged in parallel. In the primary auditory cortex, frequency and time are mapped along axes arranged orthogonally in order to determine the temporal sequence of isofrequent acoustic stimuli. On the basis of these time differences, the position of the sound source can be determined (Kelly and Phillips 1991).

The localization of sound is one of the main functions of the auditory systems in a large number of non-human animals. It appears, in fact, that one of the first functions of hearing, also present in humans, is the understanding of the localization of the sound source in such a manner to develop appropriate behavioural responses (Kaas 2011). Apparently, though, the source of the sound is not the only information obtainable from auditory perception: different authors (Eggermont and Wang 2011) have shown, in fact, that the cortex is involved in temporal coding tasks (which is particularly advanced in primates). On the basis of the perception of the distance from the stimulus it would be possible to evaluate the time taken to travel from it. Therefore, the auditory cortex (as a whole), would not be engaged in the trivial tasks of stimulus perception, but in processing the time-space components of the surrounding environment.

As regards interspecific comparison, it is interesting to note that the function of the auditory cortex is not the same in all animals. This is quite intuitive, since different types of sensory perception do not play the same role in all animal species. We are not surprised, therefore, by the analysis of the results obtained in the psychobiological field, from which we discover that the auditory cortex is only more specialized for auditory tasks in some animal species. To understand this analysis we can refer to studies of mice in which the removal of the auditory cortex (in both hemispheres) led to different outcomes: in fact, while in mice and cats, auditory sensory skills were almost entirely recovered 4 months after surgical removal, in primates and humans, however, the bilateral excision resulted in a total loss of hearing ability (Heffner and Heffner 1986, 1990; Harrington 2002).

This finding is significant because it highlights the differing importance that is placed on auditory perception between the class of primates and other non-human animals. In fact in primates, auditory perception is associated with a central developmental task: intraspecific communication (Kanwal and Ehret 2011). Auditory perception, therefore, would play a further role, which is critical to the high sociability of species such as primates, namely that of being able to discriminate between the biological significance of communication sounds (COO) (Petersen et al. 1978). For this reason, then, the removal of both auditory cortices in primates ensures that the ability to hear is never recovered.

According to an evolutionary principle, brain plasticity is associated with the possibility of recovery, but at the same time is characterized by the specialization of brain circuits for specific functions (see Chaps 12 and 13). In essence, in response to injury it is not to be taken for granted that the surrounding areas are able to vicariate the task executed by the injured areas, if these are used in a specific manner for particular functions, as in the case just described detailing the functionalization of the auditory cortex for intraspecific communicative purposes.

With this, we do not want to argue that other non-human animals cannot entertain intraspecific communication: it is quite clear, in fact, that communication internal to a species is the very basis for the existence and survival of a social species (from the bees upward). Instead, one needs to point out that the specialization of the auditory cortex for complex communication purposes is a unique principal characteristic of cognitive processing in primates (other species can also communicate with other senses – smell, sight and so on – but primates have an auditory sensory priority as evinced in auditory-verbal communication).

9.3 The Biological Hearing-Voice Feedback

Apparently, then, the auditory cortex of primates is specialized not only with regards to the perception of sounds and the localization of space and time but also in the encoding-decoding of communicative sounds. To corroborate these studies, Wernicke's area, which is the classically held epicentre responsible for language comprehension, is located in the secondary auditory cortex of man.

It is interesting to notice, thanks to studies on aphasia, that an injury to Wernicke's area does not involve a generic hearing impairment, but the alteration of a highly specific component, i.e. the semantics and pragmatics of language comprehension. Similarly, verbal auditory agnosia has been characterized as an inability to recognize a significant sound, while hearing is preserved at an appropriate level (Clarke et al. 2000). Conversely, the impairment of the recognition of non-verbal sounds is not necessarily associated with verbal deficits, as was evidenced in patients with non-verbal auditory agnosia, but purely with preserving verbal comprehension (Clarke et al. 1996; Fujii et al. 1990). These clinical data, along with direct neurophysiological data obtained in experiments with macaques, have led some scholars (Rauschecker 1998; Rauschecker and Tian 2000; Romanski et al. 1999; Alain et al. 2000) to assume that in the auditory cortex of primates parallel processing of diverse

sounds occurs in a ventral pathway for the recognition of information-what (a path we might call “qualitative”, i.e. the content of the sounds, the sounds of the things to which they refer) and a way back which manages the information-where (that is, spatial location, the “where”). Even more recent studies (Altmann et al. 2010), conducted through the temporal-spectral analysis of natural sounds mapped through the fMRI scan that runs from the superior temporal gyrus bilaterally within Heschl, confirm this high degree of functional specialization of the auditory cortex of primates.

Budd et al. (2003) have, on the other hand, shown that there exists in man a cito-architecturally distinct region (the lateral part of Heschl’s gyrus) which is sensitive to subtle changes in the binaural characteristics of acoustic stimuli.

All this data confirms the strong evolutionary postulate that highly specialized areas can be replaced by other areas. The circuit of language which is part of Wernicke’s area, in fact, is another example of hyper-specialization (and renovation) of the human auditory cortex. Apparently, then, not only do the central and peripheral production structures constrain our ability to produce language, but also the primary system of speech perception (hearing) would be biologically linked to the perception of highly specific stimuli (Pennisi and Falzone 2010; Pennisi 2012b, c).

Comparative studies on the auditory cortex also highlight that, despite the anatomical differences in both the auditory apparatus and the auditory cortices of different animal species, the hearing systems are constrained within their mode of perception by the characteristics of the productive apparatus: the hearing systems of the mouse are adequate for its production system, as well as those of the cat (Wang and Kadia 2001), the bat and primates (Newman and Wollberg 1973a, b; Petersen 1982; Wang et al. 1995; Tian et al. 2001; Poremba et al. 2004) or humans (Belin et al. 2000 and 2002; Fecteau et al. 2003).

It is certain, in fact, that, without going into the details of developmental timing, each of the vocal production systems of a given species needs a suitable system of perception which is adequate for the perception of the sounds produced (Kaas 2011). You could, for example, say – paraphrasing Vallortigara and Bisazza 2002 – that a bat unable to “hear” the precise location of its prey is a dead bat!

If man’s production system is based on the above-phonemic units, then its auditory system will be calibrated at least on the basis of the perception of such units. In essence, the human auditory system is not only highly specialized for the perception of the typical auditory frequency of human language (one should think of the tono-topic organization of the cochlea and the accuracy with which it allows transduction of analogically heard information into electrical signals through the auditory nerve) but is characterized at the central level precisely by the possibility to perceive sounds. For example, humans show the ability to perceive the words of a language despite production inaccuracy. In fact, according to the “cybernetic” model, i.e. a formal model of external language production for the biology of the speaker (and of the hearer), the minimum production unit would be the phoneme and the perception of words should be guaranteed by phoneme perception. So if we buy into this model,

perception should work if the brain, and in particular the auditory cortex, allow the integration of partial auditory information.

The specificity of articulated speech production, whatever the minimum articulation unit is, is guaranteed by the morphology and function of the vocal tract (which has its own evolutionary history and a typical functional adaptivity). The articulation of language, however, has adaptive value only if connected to an adequate perception and decoding system, otherwise it would not have been adopted by *Homo sapiens* (a principle dear to *Evo-Devo*). The hyper-specialization of the auditory cortex allows the flexibility of inputs to be processed and the ability to integrate them with other data (the so-called *McGurk effect*) to understand the nature of the stimulus.

This type of hearing-voice feedback, essential for children from birth, appears to be a species-specific characteristic, in a technical sense, of *Homo sapiens*: birds, in fact, contrary to the arguments in the classic comparison of ethology models from Aristotle onwards, typically have a holistic production which is not articulated, at least not in the linguistic sense of articulation, and this is determined by the possibilities offered by the biological constitution of birds. If we compare the peripheral system of birds' aural perception, we cannot in fact fail to note significant differences, not only in the structure of the ear canal and the conduction of the sounds within it (birds have a 'ear hole' often covered with hairs/receptors), but also for the precision and breadth of the range of perception.

The cochlea of birds works differently and seems to be optimized for the perception of chirps, whistles, melodic singing etc. These animals, because of the rigidity of the beak, are not generally capable of modulating the resonance frequencies of the oral cavity like humans. Their hair cells are not motile but the stereocilia have contractile microfibers which have a similar effect to the action of muscles in insects. In practice, it is not the oscillations of the basic membrane, but those of the tectorial membrane that are directly amplified (Elliot and Theunissen 2011). The production and decoding of voice signals of many non-human animals, like birds and primates, would therefore be holistic, as only human beings are capable of co-articulating sounds and decoding them and this is thanks to their highly specialized biological structures.

9.4 Interpretation of the Data

Von Uexküll was not only the inspiration for the famous pages by Wittgenstein in which it was stated that the object and subject converge in the metaphor of the single eye that looks at himself, but he is also one of the recognized founders of comparative psychology (or ethology). Ethology studies the species-specific "technique", that is, the biological conditions determining whether each species cannot be different from the way it is manifested, from the way it is. It is a science powerfully opposed to any form of anthropocentrism. Therefore, its observations are valuable when objective comparisons are made between different worlds.

The first point to note from ethological data obtained when looking at the problem of species-specific hearing is that it shows us experimentally how it is impossible to use any other model than a human model to study it. This issue, despite the progress of technology, is still present even in the cognitive sciences, since one cannot use invasive techniques on the human brain and it is completely useless to study hearing using the brains of other animals which, as we have seen, show a completely different specific “technique”.

Notice that this is only relevant to the study of hearing.

For a long time, the fields of comparative psychology and cognitive ethology today have successfully applied animal models to the study of vision. This certainly does not mean that human visual cognition is equal to that of other species: an issue already overly philosophical and now too difficult to study. However, this certainly means that human visual cognition is not species-specific in the “technical” sense.

The same cannot be said for auditory cognition.

9.4.1 Ethological Specialization of Sensory Cortices

As is widely known, the sensory cortex is a set of specialized areas dealing with receiving and processing stimuli from the sense organs. Evidently the cortical structures are innate, that is they are phylogenetically determined and so vary in shape in between different species.

The nativism of structures does not tell us, however, anything about possible functions. We have already written about the new knowledge acquired by *feral children*: children who were not imprinted from birth by their conspecifics' company would not speak and would never walk on two feet. Instead of being linguistic and bipedal animals, they will be quadrupedal and aphasic animals (Pennisi 2006).

This vindication of social instantiations on genetic structures does not, however, have anything to do with the fanciful behaviorist ideas about human nature as a tabula rasa on which it can impress any drawing as we said at the beginning. If it is in fact true that any hereditary physiological structure must be activated within social behaviors to manifest certain functions, it is also true that there can be no independent functions from inherited structures; that is, without innate structures, no specific functions can manifest themselves. In addition there is the least but in the less there is not the most.

To understand the relationship between structure and function one has to study them experimentally, see Table 9.1.

The image shows the functional possibilities associated with two types of cortex: the auditory and olfactory one. By using the experimental psychobiological studies cited (infra) in Sects. 9.2 and 9.3 it was possible to associate four possible functions with these two sensory components: spatial location, temporal location, communicative function and articulation function. Each of these functions is performed differently by different animal species and uses a different species-specific sensory component in a completely different way. For example, the spatial location is

Table 9.1 Ethological specialization of sensory cortices

	Specialization of somatosensory cortices				
	Auditory cortex				
Species	Spatial location (directions of the sound source)	Temporal localization (estimate of the time when the event occurred based on the distance of the sound)	Communicative function (decoding holistic sounds with informative value)	Articulatory function (decoding the articulated sounds with informative value)	Coefficient of specificity
Rats	0	0	0,5	0	0,5
Cats	0	0	0,5	0	0,5
Primates	1	1	1	0	3
Man	1	1	1	1	4
	Olfactory cortex				
Species	Spatial location (orientation of the basis of the smells)	Temporal localization (estimate of the time spent by the passage of conspecifics or prey/predator from the residual olfactory intensity)	Communicative function (decoding of highly specific olfactory signals for the types of information (sex, dominance, territoriality, etc.))		Coefficient of specificity
Rats	1	1	1	0	3
Cats	1	1	1	0	3
Primates	0,5	0,5	0,5	0	1,5
Man	0,25	0,25	0,25	0	0,75

mapped through the auditory perception as the direction of the sound source, while in the olfactory cortex it is mapped as the individual's orientation on the basis of odours. Similarly, the temporal location is mapped in the auditory cortex as a function of a calculation based on the distance of the sound from the time of a particular event, while it is mapped to the olfactory cortex as an estimate of the time elapsed since the passage of conspecifics or prey/predator on the basis of residual olfactory intensity.

The mapping of communicative activity takes place in a species-specific way in both cortices: in the auditory one, it signals the decoding of holistic sounds associated with informative value, while in the olfactory one, it indicates decoding of highly specific olfactory signals for the information types concerned (sex, dominance, territoriality, etc.).

A bit more complex is the mapping of the articulatory function which is accomplished only in the human auditory cortex as decoding of articulated sounds having informative value. At this stage we do not care at all whether these entities are phones, phonemes or other small units. However, we want to see how they should be considered with respect to this interplay of species-specificity of cortices and behavioural phenomena experimentally attested in any animal species.

The numerical value that has been adopted in the diagram using the studies mentioned (infra) in Sects. 9.2 and 9.3 is the result of an extremely elementary matrix (presence/absence – total/partial – from 0 to 1) that does not establish any absolute semiotic value but it simply outlines a number of possible limitations of the various species-specific *Umwelt* of various animals. For example, it is apparent from this data that primates are “hearing-centric” animals and only to a minimal extent do they use the sense of smell in the main functions we have described here; other mammals, on the contrary, as in the case of rats and cats, orient themselves in space, in time and communicate through an extensive use of the olfactory cortex and a limited use of the auditory cortex. Technically, it can be said that the studied data demonstrates that the auditory cortex is highly specialized for primates and the olfactory cortex is highly specialized for other mammals.

9.4.2 Neuroscientific Evidence in Bilateral Ablations of Auditory Cortex

In the Fig. 9.2 shown below you can see the topographical locations of the auditory cortex of the species we have previously discussed in Sects. 9.2 and 9.3, namely monkeys, men, cats and mice.

Quite independently of important issues such as size, the apparent morphological complexity or other external anatomical evidence, which we shall return to, what interests us here is the ability to isolate them in a modular way. Here, obviously, we do not want to argue as to whether the functioning of the brain is independent of the connections between the various parts and between these and the rest of the body, but there is no doubt that we are interested in a parcelled analysis of the different cortical functions. In the case of animals, it was possible to study the effects of ablation of auditory and olfactory cortices in an experimental and planned manner (see Heffner 2005, 118 et seq.). In the case of man, the data we will report is drawn from classical clinical disorders (lesion studies).

What happens when the cortical areas of mice and cats are removed? In the case of the olfactory cortex, the studies we analyzed show that these animals lose all space-time orientation ability, the ability to recognize conspecifics, and dominance and territoriality management predispositions. Cases of recovery of olfactory cortical plasticity are null or almost null. In the case in which these animals are subjected to ablation of the auditory cortex, however, obvious behavioural deficits do not

STUDIES ON THE LESIONS OF HEARING CORTEX

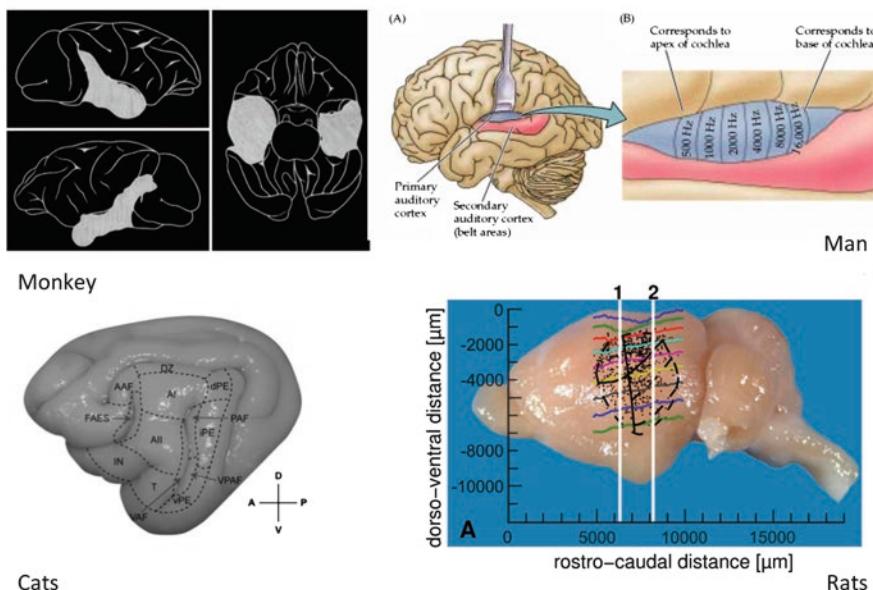


Fig. 9.2 Studies on auditory cortices ablations in monkeys, men, cats and mice, source: Pennisi 2012c

occur and functional recovery of the areas through cortical plasticity processes takes place in a period of about 4 months.

In the case of primates, the situation seems to be reversed. The damage to the olfactory cortex may be compensated thanks to a functional recovery of other cells in a short time, while the removal or pathological loss of the auditory cortex affects hearing and causes the disappearance of the associated functions described above. Above all, the most significant fact is that for the latter areas there are no chances of any recovery through recabling of adjacent neurons.

Why is it not possible to refunctionalize the auditory cortex of primates through brain plasticity mechanisms?

The real reason why it is difficult for linguists to study perception at the cortical level is the same reason why it is difficult to understand that it is impossible to functionally adapt the surrounding neurons to the functions carried out when the cortex is removed. In the absence of a detailed technical explanation which scholars still want to pursue by carrying out intensive scientific research activities – (see Winer and Schreiner 2011; Syka and Merzenich 2005), also in ethologic (Ghazanfar 2002), evolutionistic (Kaas 2011), and clinical (Kaga 2009) direction – the reason for this impossibility seems to be the biological hyper-specialization of these type of areas in an absolutely critical task for that species.

From an evolutionary point of view this hyper-specialization is a major selective advantage but also a great danger for the extinction of a species. A non-specialist structure can be replaced by other structures and can evolve environmentally (exaptation). Conversely, a highly specialized structure is something that will obstruct environmental evolution. A simple example is provided by food specializations as exhibited by the koala whose digestive tract can only metabolize the leaves of a particular type of eucalyptus which grows in restricted areas of Australia.

In short, the reason why it is impossible to rewire the surrounding neurons to the functions performed by the auditory cortex in men and to the one related to smells in mice or cats (but also in many other mammals) is that the tasks those cells have learned to carry out are so detailed, so complex and specific that it is impossible for organisms to teach the cells in the surrounding areas to perform them.

We are in the shrine of the biological species-specificity, in the heart of the *Umwelt* of the different animal species. One might even argue, from a purely evolutionary point of view, that the data provided so far is sufficient to understand the extent to which primates' cognition has departed from that of other mammals following paths different from their own. But, of course, a fact that may satisfy naturalists may be insufficient for philosophers or linguists who are interested in determining the difference between humans and other non-human primates.

First, we consider it a mistake to overlook the fact that, in general, among primates, the auditory cortex is the foundation of their cognition. Those who have read the splendid book by Jane Goodall, Frans de Waal and Stanley Greenspan on chimpanzee and bonobo communication in nature are in a position to fully appreciate the neuroscientific data. Within these cognitive worlds, a key role is played by the perception of holistic sounds, that is the full communicative functionalization of unarticulated sounds. The beautiful pages dedicated to parental care and to social dominance behaviour, conducted through the prosodic and tonal modulation associated with joint attention, give us a picture of a cognitive *Umwelt* in many respects similar to that of our ancestors. According to Mithen (2005), the transition point from these forerunners to *Homo sapiens* was the gradual emergence of an extensive use of articulate sounds (not holistic).

The point of no return between man and his whole evolutionary past is precisely the adoption of species-specific phonatory behaviours probably articulated due to the supralaryngeal mutation of the vocal tract described by Lieberman and already widely discussed. Furthermore, as we have seen before, articulatory and auditory specificity are necessarily connected.

In conclusion, all these considerations lead us to believe that the phenomena of meaning, semantics, cultural and social uses of language are the basis for the application of secondary structures which are already equipped with coding and decoding mechanisms and suitable for making sense of their species-specific signals: structures without which the human ontology could never compare with the linguistic ontology of *Homo sapiens*.

Chapter 10

Neurocerebral Fundamentals

We have seen that, according to the CBM, biolinguistics must not seek immediate correlations between structures and mental processes, including computational functions and physiological mechanisms, in short, between physical and cognitive causes. What should be central in biolinguistics is the syntactic-computational level of the linguistic mind: the one that biolinguistics has a mandate to explore.

The DBM, instead, considers it the specific task of biolinguistics to take care of relations between linguistic behaviour and the brain mainly qua an anatomical system dealing with the coordination of all the I/O data that reaches it through the central nervous systems and the peripheral body of speakers.

This does not mean adherence to a neo-phrenological vulgate, nor acceptance of a strong modularist paradigm as proposed until the early years of the twenty-first century by prominent scholars such as Jerry Fodor and many other pioneers of contemporary neuroscience. DBM considers the mapping of mental architecture, a patient experimental process of identifying infinite mediations that lead us, to use Chomsky's repeatedly mentioned phrase, to combine the psychological datum with the biological one. For this purpose, one needs a close collaboration between linguists and neuroscientists. As we shall see throughout this chapter, major neurolinguistic progress was made by combining linguistic theories with implementations of experimental protocols, usually applied to disease states. The revision of the classical theory of aphasia through the generativist hypotheses of Grodzinsky can be considered an example.

We will try to summarize here the history of these advances.

10.1 Methodological Issues

Since the first philosophical and scientific investigations, the typical human cognitive ability has been identified with verbal skills and language in general (Whitaker 1998). It is easy to explain this association: language was one of the most obvious

features distinguishing man from other animal species, and often other mental specialties were derived from it, such as thought, memory, perception, emotions and so on. The discussion of language skills had gathered momentum during the nineteenth century, particularly following the debate concerning the possibility of identifying specific portions of the brain in relation to specific skills. In the second half of the nineteenth century, in fact, there was a very heated discussion on the ways in which the brain, now recognized as an organ of the nerve pathways and consequently human behaviour management (Piccolino and Bresadola 2008), would control human intellectual activity. The encephalon studies carried out until that point in time provided information about the cellular structure and nerve conduction mode, but it was not yet clear whether the brain had control over mental activities. The controversy, as we saw in Sect. 5.4, was divided into two opposing positions: the proponents of localizationism claimed to have the ability to trace a direct correspondence between brain areas and associated functions (Gall 1798). Instead, the proponents of holism, speculated that mental life was the result not of a single area with specific skills but of the overall activity of the brain (Flourens 1825). Both positions were supported by experimental studies on the post-mortems of human beings and animals (think of Flourens' studies on birds that caused injuries in different parts of the brain as a result of trying to recover lost capacity during testing). A turning point in the debate, however, was marked by investigations conducted by Pierre Paul Broca who, for the first time, identified a correlation between a brain region, which later took his name, and a component of language function: production capacity. From that moment on, developments in the theories about the brain's control on cognitive activities, particularly in relation to language, have grown exponentially. Karl Wernicke completed the framework of the cerebral localization of language function by tracking the areas delegated to the understanding of language, and subsequent studies (see Lichtheim 1885) have validated and perfected what is now called the “classical model”.

This model, which in its most recent version was developed almost a hundred years later by Geschwind (1974), is based on the assumption that each component of language is processed by a different brain area: Broca's area would deal with linguistic production, while Wernicke's would deal with understanding. The two areas would be connected by a bundle of neurons (arcuate fasciculus) that would be responsible for conducting the information decoded in Wernicke's area to Broca's area. On the basis of this model, a nosographic framework of the various types of aphasia (the disease caused by the alteration of one of the areas of language) has been formulated, and each is characterized by the prevalence of a certain deficit in language function (Denes and Pizzamiglio 1999).

The schema provided by the classical model, therefore, required that the decoding of language, as well as its production, was handled by interconnected and specialized cortical structures. In particular, Geschwind, still on the basis of lesion studies in aphasic subjects, describes an operating model that emphasizes above all the communicative aspects of language, *a priori* excluding other functions. Language would be produced by a set of specific brain activations each of which contribute to the production of a communicative act, understood as transmission and

reception of information. In this perspective, the development of communicative input would take place according to a precise sequence of activations. For example, the decoding of auditory stimuli occurs through their processing by the primary auditory cortex in Brodmann areas 41/42 (BA 41/42), which identifies the linguistic typology of the stimulus and transmits it to the associative auditory cortex (BA 22). From here processing is transferred to Wernicke's area, in which one identifies the acoustic representation of the word heard, activates the concepts connected to it and allows the understanding of the word. At this point, via the arcuate fasciculus, the input is sent to the production area. The activation of Broca's area allows repetition of the word and determines the composition of the information regarding the pronunciation rules of the articulated sounds. This information is then sent to some components of the motor cortex (BA 4) that deal with managing articulations. A similar processing system is also used for visual language inputs: after being processed in the primary visual cortex (BA 17) and in the associative one (BA 18/19), the information is sent to the inferior parietal lobe of the angular gyrus (BA 39) in which it is subjected to a conversion from the visual mode to the acoustic one and, as a result of this conversion, it can be processed by Wernicke's area.

In the hypothesis developed by Geschwind, therefore, one can establish a biunivocal correspondence between brain areas and specific human communication skills: language comprehension would be identified with the ability to decode the message heard, and language production with the ability to program verbal articulation. The linguistic information from visual pathways would still be decoded by this circuit via a modal shift (from visual to auditory mode).

The Wernicke-Geschwind model was considered valid and maintained throughout the last century: not only does it provide a basis for the classification of nosographic neuropsychological syndromes affecting language, but also for the understanding of the physiological functioning of the mechanism of language as a communicative capacity. In fact, despite some well founded insights, several criticisms have been levelled at it due to the attention paid to the communicative component of language and for the validity of the generalizations of neuropsychological data for conditions of physiological functioning. Obviously, the two types of observations are interconnected and are essentially derived from technological advances in the field of neuroscience and from the critical review of the first version of the cognitive sciences, with particular reference to the naturalization of complex cognitive processes such as language. The strongest criticism of the classical model is derived from empirical evaluations of neuropsychological cases, the very data that had allowed the elaboration of the neurolinguistic model.

Alterations in brain function investigated in the field of neuropsychology, in fact, formed the hard core of hypotheses on the physiological functioning of neural structures. The survey conducted on people with injuries – despite unavoidable individual variations of disease produced by stroke or external traumas, whether vascular or cancer – was used as a sort of litmus test to verify the correspondence theory of brain areas and functions: if the damaged brain prevents a given activity, then it is likely that the injured region is essential for its manifestation. The idea behind the technique of clinicopathologic correlations used since the early studies of neurology

is to trace a connection between losses in behavioural manifestations in life and brain lesions detectable post mortem (Pennisi 1994).

However, the inherent limit in this technique is evident: brain damage in humans rarely has a monofactorial nature. It is normally the outcome of the interaction of multiple causes that it is difficult for the experimenter to control, like, for example, the vascular origin of a lesion, the single artery involved in trauma and the possible presence of other vessels capable of substituting the blood flow in the affected areas. Even more than the neuroanatomical and functional limitations, injuries of this type follow limits caused by the inflow of blood to the brain. The main principle of the trial – the generalizability of the results – is in part impaired by the idiosyncratic properties of lesional data: it is virtually impossible to analyse two cases with identical lesions. Nevertheless, individual case studies formed the main source of investigation within neuroscience where the variability of results is handled by crossing different data, resulting from the analysis of several people with similar brain injury and similar functional impairment, and by studying the overlap of the regions concerned: by following that combination it would be possible to trace the part of the brain which was important for the function (Purves et al. 2008).

The awareness of this individual variability in lesion studies led individual researchers, especially in the initial phase of defining the correspondences between areas and functions involved: both Broca and Wernicke were aware of the difficulties and the temerity of their generalizations, and the assumption that underlay their arguments was characterized by continuous methodological precautions.

The lesion studies leading to the formulation of the Wernicke-Geschwind model, in fact, illustrated cases characterized by the predominance of a deficient aspect of language on other competing aspects. In years of aphasia data accumulation, scholars have never positively identified a pure form, in which the symptom specificity turns out to be evident and, accordingly, one is confronted with unique cerebral involvement (Benson 1985). It is very rare to find a subject with an exclusive lesion affecting a single language area, and thus it is equally difficult to establish with certainty the correspondence between physiological and injured areas. And this is precisely because of the structure and vascularity of the brain which we have just been discussing. Therefore, neuropsychological data is, by its very nature, complicated to handle experimentally: we will see that, in recent times, the interpretation of the typical deficits in Broca's aphasia completely changed compared to the generic definition of non-fluent aphasia and has been steered in the direction of allocating superior functions to the cortical areas of language (Grodzinsky 2006a).

In addition, data from studies of patients who had undergone the surgical removal of the cortical tissue corresponding to areas of language, did not confirm the hypothesis of functional localization proposed by Geschwind: surgeries in which, for clinical reasons, all of Broca's area is removed, produced no lasting negative effects on the productive capacity (Penfield and Roberts 1959; Rasmussen and Milner 1975). After operations of this type, the subjects often had difficulties speaking, a deficit from which they soon recovered: the time necessary for recovery, of course, suggests that these deficits are probably more directly linked to the edema that is formed

at the removed region than to the removal of the Broca's area itself. Similar cases of functional recovery were also analyzed for the removal of the arcuate fasciculus (Rasmussen and Milner 1975) and Wernicke's area (Ojemann 1979).

The recovery of language skills is easier when it is only the cortical component of the linguistic regions that is damaged (Lieberman 2003). Paradoxically, cortical damage to the areas responsible for language produces deficits which are less severe than damage in subcortical areas. It is evident then, that the overall functioning of the linguistic capacity depends not only on the integrity of the so-called "areas of language", but on the correct connection between cortical and subcortical regions, the latter being responsible for both the selection and pre-processing of incoming linguistic stimuli and for the actual implementation of oro-facial movements that produce the articulatory act (see, in this regard, the work on the illustrative case of the KE family, where a very rare genetic mutation of FOXP2 – previously discussed in §. Sect. 8.1.1 – produced an alteration in the function of the basal ganglia and ancestral subcortical structures, resulting in orofacial dyspraxia, Lai et al. 2001; see Pennisi 2006; Falzone 2004, 2006).

In contemporary neuroscience, therefore, a shift has occurred in the interpretation of the locationist structure-function binomial. This combination, which was fully in accordance with the initial paradigm of cognitive science and the modularist view of mind, proved empirically inadequate. In the brain there are no independent components from which specific functions originate: complex cognitive functions, such as language, are managed by network, by connecting networks of brain epicentres whose activation contributes to the overall implementation of the cognitive task. So the research on the brain distribution of the linguistic function is no longer based – for the vast majority of research – on a logical unambiguous identification of regions specializing in language, but on a functional hypothesis in which cortical structures (that are recent from an evolutionary point of view) and subcortical ones (inherited phylogenetically in the evolutionary path that led to the current brain) represent morphological epicentres on which the function is distributed.

For reasons that follow evolutionary explanations similar to those used for peripheral morphological correlates (see Chap. 9), the human brain and neuronal connections are redundant and only one function can be handled by multiple structures, both cortical and subcortical. In recent years, on the basis of the Darwinian lessons, a hypothesis was formulated about brain structure in which the type of interconnection between cortical and subcortical structures varies in proportion to the increase in brain size (Deacon 2000; Edelman 1988): the quantitative changes – largely genetically controlled by the expression of homeotic genes – would constrain the ways in which the construction of the information useful for survival in a given environment is carried out. In this way, species-specific functions are coherently reconstructed in each species that shows variations in brain structure (Deacon 2000). It is the principle of neural wiring, according to which brain structures of phylogenetically close species can also have different regional functions and distributions, even though they have arisen from cerebral configurations present in a common ancestor.

In this regard, studies on encephalization are producing a series of significant data linking genetically determined morphological predispositions to an increase in brain plasticity, and to changes in both brain size and neural connections for the construction of species-specific functions (Fox 1999; King 2002). There is no doubt that the matter of the brain and peripheral nervous structures had a decisive impact on the realization of the typical functions of all kinds: encephalization studies, in fact, show that the quantitative increase in brain mass and changes in the type and size of cells, guide the implementation process of wiring – that is, the functional connections – typical of each species. For example, the overall changes that have produced the current anatomical and functional configuration of *Homo sapiens* allowed both the establishment of interconnections between the thalamus and the cortex that are absent in non-human primates – even if the latter possessed cortico-cortical structures like human ones (Helmuth 2001) and the reduction of an enzyme that acts in the brain (the CMP-sialic acid hydroxylase) whose presence in other animal species would indicate a chemical impediment to the manifestation of certain brain functions (Alper 2001): a central impediment, therefore, for the realization of new functions of processes (see Sects. 8.1.1 and 8.1.2).

The increase in the encephalic size during evolution that led to anatomically modern *Homo sapiens* was guaranteed both by an increase in the existing brain material and by the formation of new morphological elements (products due to the “genetic liberations” discussed in Chap. 8). The brain has thus developed around an ancestral core (the so-called “reptilian component” of the anatomical and functional model proposed by Lieberman 2001) that unites different animal species starting from the order of reptiles, and which has developed an additional layer characterized by a different cellular conformation. This layer – evolved independently in mammals and birds (Domínguez Alonso et al. 2004) – would have allowed an increase in processing capability. The most recent layer in the brains of mammals consists of the so-called “neocortex” that was presumably formed during the separation from the order of reptiles 200 million years ago in conjunction with changes in the auditory structures (Rowe 1996; Aboitiz et al. 2003). However, this new configuration typical of the brain of mammals has not been implemented through a mere juxtaposition of neural material: a functional reorganization has occurred which allowed both the connection between old and new structures and the construction of modern functional circuits on the basis of new organizational principles (Nishikawa 1997; Karten 1997), thus increasing the processing capacity of the information and allowing the instantiation of new cognitive functions.

The evolutionary reconstruction data on encephalization processes, therefore, is expanding the framework of the morphological needs related to language function: it is difficult to support the possibility that cortical areas of the brain function independently of the subcortical ones, but mostly importantly, it becomes empirically untenable to opt for a modularization view of the whole language function into sub-units that are defined and independent from an anatomical and functional point of view. Not only neuropsychological cases but also the evolutionary logic that underlies the morphological realization of the brain have called into question the plausibility of the classical neuroanatomical model of language based on a precise

correspondence between the components of language and related brain areas. We will see that the principle of modularization, valid just at the biological level (see Pennisi 2006) in the formation of new structures, can be applied, at least in its most radical formulation, only to cognitive abilities or low levels of processing: a typical example is the presence of areas of the cortex devoted to linguistic auditory processing (Johansson 2005). It is highly controversial for one to apply this principle to high-level functions, such as language, that seem to escape the pure logic of localization.

Evidently, the question concerns the difficulty in matching functional subsystems in the brain (so-called “low-level sub-units” such as dedicated sensory cortices) and logical components identified by the various linguistic theories which various experimental studies occasionally refer to (see Poeppel and Hickok 2004, for a methodological critique). Language, in fact, can be understood both as a means for the implementation of a typical communication capacity to be used by *Homo sapiens* (as interpreted in the major linguistic-evolutionary models, like Bickerton 2000, 2003; Dunbar 1996) and as a real cognitive process, that is a process by which individuals structure their knowledge of the world (Hagoort et al. 2004).

10.2 Modularisms

In recent decades, within the neuro and psycholinguistic field and the evolutionary and comparative field, the argument that language cannot merely be considered an ability to communicate, as in the model formulated by Geschwind, has gained popularity: it is considered to be a broader function that involves and co-determines the ability of every human being to produce an experience. We shall return later to the assumptions about the role that language plays in the functioning of the entire human cognitive system. At this point, it would seem expedient to stress that both neuropsychological data and evolutionary data combine to support a view of mental organization of language that is no longer based on the simplistic and reductive schemes of localizationism, but is based, instead, on a network of cortico-subcortical connections (Dronkers 2000), which probably involves areas not delegated exclusively to the linguistic function.

Language, as we have seen so far, is a function that is instantiated on anatomical structures that have an ancient evolutionary origin: the cortex is integrated with the rest of the brain which affects its functioning. An example of such a connection may be obtained from electrophysiological investigations employing event-related potentials to evaluate the change in the electrical activity of the brain during the processing of linguistic information. The event-related potentials, as is well known, involve a technique of brain activation measurement that employs the principle of the modification of the electrical potential of various areas of the brain in response to the presentation of a stimulus. Without regard for time, electrophysiological changes occur in the cortex – which includes the endogenous processing stage, and independent cognitive stimulation – and it is clear that, for the morphology of

afferent nervous systems of both auditory and visual types, the linguistic input should stimulate an initial elaboration process already at the subcortical level. The auditory inputs, for example, are processed by a specific component of the thalamus (medial geniculate nuclei) that is able to identify them as linguistic stimuli, thus sending them to the competent sensory cortex (Pinel 2006, 6.3.2).

The current trend within cognitive neuroscience is to understand language as a function instantiated on a specialized network, involving neural networks distributed mainly in the left hemisphere – but with an activation of the right hemisphere for specific skills, such as prosody and phonology (Simos et al. 1997) or during certain stages of language learning (Sabbagh 1999; Stowe and Haverkort 2003) – and in some subcortical structures (basal ganglia, see Lieberman 2006).

This new understanding of the brain distribution of the language function is not to suggest that it negates all study previously undertaken in the field of neuropsychology. Lesional data is still used but is filtered through an interpretive movement: the idea of a ‘dedicated area’ was replaced by that of “transmodal epicenter” (Mesulam 1998), which is a node of the specialized network that plays a decisive role in the implementation of the function.

In complex functions, in fact, several skills interact so that the individual can perform a particular behaviour. This often requires processing different types of data that are associated in these network nodes: it would, basically, require associative areas that together elaborate linguistic information of varying sensorial and typological nature. In this network, the regions first described as “areas of language” are central nodes that perform associative activities.

The language of the network model does not, however, reduce the competence of Broca and Wernicke linguistic areas, but rather allocates skills that are functionally less “separable” (syntax, semantics, articulation, etc.), and are more generally abstract and cognitively improved.

In the psycholinguistic area two approaches have been developed that attempt to explain how the instantiation of language is performed in the neural circuit: the neomodular approach, which is based on the idea of serial processing of various linguistic components (from the phonological to the semantic aspects), and the interactive approach, which allows for the possibility that the constituents of linguistic processing are processed in a concomitant manner, so that it would be difficult to separate them.

These two positions, in fact, represent two general trends of epistemological data interpretation within the cognitive sciences: the supporters of modularity (in various recent changes) tend to formulate hypotheses of linguistic functioning that are serial; but supporters of interactionism consider cognitive processes as a holistic process. The first position attempts to motivate functional autonomy principles, task specificity and informational content and encapsulation of the ways in which the components work within cognitive processes.

But even within this paradigm and precisely because of the results obtained from experimental linguistic processing, the modular hypothesis is no longer relevant in explaining the mind, at least not in its most rigid version (Fodor 1983): this would not constitute a refusal *in toto* of the modularist thesis, but a form of revision from

a neurophysiological point of view, based on actual evidence of neural functioning and not on theoretical speculations. In short, more recent studies are aimed at moderating the concept of a strong module that includes a processing mode for independent and automated information: it has been noticed that this wording was based on purely theoretical hypotheses that have not been confirmed by empirical research in the last 20 years.

The neuroscientific investigation, which initially was inspired over time by a strong modular paradigm has produced a large amount of data showing, however, that not even for perceptual systems (as a basic cognitive activity and historically treated as real modules, both anatomically and functionally) can one confirm a genuine informational encapsulation, a clear separation from the other components of the cognitive process, i.e. an exclusive treatment of information (Stowe et al. 2005).

The alleged perceptual modules (except, apparently, primary cortices) would communicate with other related modules during processing of sensory data. These observations led the supporters of modularity to mitigate the concept of the module: Tsimpli and Smith (1999), for example, have proposed that “quasi-modules” should replace the historically held concept. In short, a broader picture of functional structure is emerging, that looks for innate predispositions and works in continuous interaction with other structures and the learning environment (see Karmiloff-Smith 1992).

At this point, it would be natural to question the epistemological validity of a concept such as that of a weak module which resulted from the accommodation of a modular hypothesis to neuroscientific findings. This has been accepted by interactionism supporters, according to whom cognitive processes are implemented thanks to the presence of neural flows, the so-called ‘streams’ (already present, for example, at the perceptual-visual level, see Plebe 2008) and are disclosed in cortical regions whose activation allows the overall performance of the cognitive task. The entire circuit ensures the performance of the function and not the single area, and this also allows a property typical of human cognitive processes, namely flexibility, which is displayed by the ability of cortical circuits to inhibit or process signals coming from the subcortical structures, guaranteeing a hierarchy in cognitive processes crucial for the realization of a full and creative cognition (Fuster 2003). Both locations are notable points of interest when explaining how our brains perform the function of language.

As mentioned above, psycholinguistic studies employing the technique of evoked potentials have gained particular interest as the registration of such linguistic potentials which have highlighted some constants typical of the functional elaboration of language: the processing of sentence understanding is achieved, in able-bodied subjects, following a typical time course, unless there are alterations in the phonetic, morphological, syntactic and semantic type.

For both positions, such processing follows a flux of functioning that presents a subcortical-cortical-subcortical trend. It is now widely recognized, in fact, that there is subcortical structure involvement both in the process of decoding and in that of linguistic coding. What the two models disagree about is the way in which this process occurs. In particular, the proponents of modularity support an already

established functional succession in which the various components of language are processed by identified anatomical structures (Friederici and Kotz 2003), each of which is activated at different times.

The understanding of a sentence, for example, is divided into stages that go from phonological identification, to syntactic and semantic processing, until the integration of the processed meanings occurs: each stage is performed in a sequence, and then each of the stages of processing must be completed before one can go on to the next. At the basis of this hypothesis is the idea that human language is made up of autonomous sections, separate operational segments processed by regions that are activated in sequence: the four phases identified by Friederici constitute two circuits (the semantic and the syntactico-semantic circuit and the circuit responsible for integration) that are anatomically realized via the activation of subcortical and cortical networks, which have a decisive role, both in the phase of dispatching the stimuli and in the phase of integration of the processed meanings, and are assigned precisely to a subcortical structure: the basal ganglia.

The hypothesis formulated by Friederici represents an attempt to integrate current neuroscientific knowledge with the modularist thesis, although some classical principles are refuted by electrophysiological data: an example is the fact that one posits a stage of integration of the data at the end of the process of understanding a sentence (the famous activities of the P600). This would imply the need, dictated by empirical evidence, to predict a time of overall processing of the linguistic input. The proponents of interactionism argue that the neurophysiological data would be in favour of a holistic model for the understanding of sentences: the breakdown in phases proposed by Friederici would only be an explanatory grid superimposed on a single process in which syntactic and semantic processing, as well as the elaboration of pragmatic and encyclopedic information, begins and is carried out simultaneously (Hagoort and van Berkum 2007). Further investigations (Vigneau et al. 2006) corroborate the hypothesis of an architecture of the widespread language function over large networks present in the left hemisphere and not reducible solely to dedicated canonical areas.

It is evident, therefore, that the models agree on the revision of the classical Wernicke-Geschwind model by introducing the implication of subcortical structures such as the basal ganglia. In this subcortical-cortical-subcortical network, the decoding of linguistic information through an interaction of syntactic and semantic components occurs.

The two models, however, are not in agreement about when such an interaction would take place: while modularists believe that syntactic processing occurs before semantic processing, with integration occurring last, interactionists argue that the interaction is present from the start of processing, and that in any case the semantic recognition (the N400 wave), in a sense, would encompass parts of the syntactic level (as if the lexicon possessed in itself the encoding of syntactic characteristics).

The debate is currently still ongoing as several studies corroborate both positions, depending on the methodology used. Although there is no agreement on the interpretation of the ways in which linguistic processing is produced, it seems clear that the analysis of the relationship between brain structure and language function

has undergone an epistemological shift from a purely neurophysiological level – the one concerned with studies on the identification of areas delegated to language – to a neurofunctional level, in which the biological and evolutionary explanations on the structural and functional organization of the brain play a crucial role.

Establishing whether the understanding of linguistic meaning is a modularized or distributed competence, in fact, would involve understanding if, and to what extent, competence may be considered a phylogenetic derivation rewired in our species and also explaining the adaptivity of the relationship it has with other cognitive functions.

10.3 Networks for Language

The idea of the cortico-subcortical distribution of language over the past decade has become a cornerstone of the neuroscientific theories that rejected the classical model of cortical localization. In general, the second generation of cognitive science has shown, in more fields, the tendency to abandon highly simplified models, based largely on speculative assumptions, or on little experimental evidence. The network hypothesis of language, in essence, would show greater adherence to nature and to the ways in which the neuro-physiological processes involved take place.

On the other hand, as previously mentioned several times, the first studies of neuroscience have accepted the schematic version of the functioning of language offered by the Wernicke-Geschwind models for their own epistemological and methodological reasons. The research on the anatomical components that substantiate the mental processes, in fact, have debuted with a series of experiments relating to cognitive skills that today are defined as hierarchically of low level (think, for example, of studies on perception systems).

In the area of epistemology, as in the field of cognitive science, it was presupposed that it was possible to segment the activities of thought into elementary units and, ultimately, to implement its operation on structures that are not necessarily biological. When complex cognitive functions, like language, were analysed, it was considered obvious that the same explanatory paradigm was applied: modularity is an example of a simplified theoretical application to neurophysiological operations, in which no typological distinction was made between cognitive types.

The classic Wernicke and Geschwind model, with its defined correspondences between brain areas and productive or receptive language skills, provided a perfect base for the application of the modular hypothesis to higher cognitive functions. On the other hand, the tendency to reduce complex phenomena into atomic constituents was implicit in the methods of construction of a new discipline, as were the beginnings of neuroscience.

This was a methodological approach that Mayr (2004) considered a “presumption of epistemological superiority of the physical sciences” with respect to biological ones. According to the first biological approaches to the study of the natural elements, to truly understand the facts of life, they have to be broken down into

simpler units and analyzed according to the parameters of the basic sciences (chemistry and physics). Universal laws on biological phenomena could be formulated only thanks to the explanatory power of the physical sciences (power that derives from the reduction of complex phenomena to elementary entities). Obviously, the epistemological reflection in biology has led to the separation from the physical methodological explanations in the investigation of the facts related to life, with the awareness that the world of life is derived from physical and chemical components and is governed by different principles and has different characteristics (This is the so-called “principle of emergent properties,” see Mayr (2004), Boncinelli (2002) and Pennisi (2009), Pennisi and Falzone 2015).

Thus, even in the early formulations of neuroscience, one presupposed the ability to break down complex cognitive functions into simple units with the belief that one could get an elegant and powerful explanation at the same time. In fact, even in this case, the experimental evidence has led to the revision of the locationist hypothesis, especially following neurophysiological studies on lesions which highlighted the continuous anatomical and functional interconnection of regions of the brain involved in the realization of cognitive activity.

This awareness of the reductionist correspondence between a simplified model of linguistic functioning and actual neurophysiological complexity, in fact, was already present in those who had established that correspondence first. The descriptions furnished by the neuroanatomical model proposed by Broca often attribute an almost phrenological characterization of the classificatory intent of the neurologist (for a discussion, see De Bleser et al. 1993). In particular, Broca is credited with proposing an area of speech production, with a significant motor component, and identifying it as the articulatory area of language. This version – probably useful for nosographic classification, but misleading as an epistemological point of view – would, therefore, indicate, that Broca's aphasia is a motor deficit. It is a distortion or rather an extreme simplification of the French neurologist's ideas who never claimed a reduction in the production function of language to articulation skills.

During the observation of his first case (Leborgne, the famous patient *Tan* fact), Broca remarked that the deficit demonstrations did not involve alterations of the articulatory type (*Tan* was able to move the tongue when told to do so; the muscles of the larynx were intact, and the tone of voice and the ability to produce some monosyllables were normal) or alterations of the intellectual type: what was surprising, however, was his ability to make himself understood through gestures, skills that made one infer the integrity of his communication skills, with regards to understanding (Broca 1861). After the patient's death, through post-mortem examination, Broca had identified a large lesion at the front of the left hemisphere, with a focal point detectable in the posterior portion of the middle frontal gyrus from which the neuropathology would extend over the years. The autopsy also highlighted two stages of advancement of Leborgne disease that corresponded to two different symptomatic statuses: the first, in which the injury had only affected the third front convolution and a few neighboring areas and that was characterized by alterations in the linguistic faculty; the second, in which the lesion had progressed to other cerebral convolutions, the insula lobe and the ventricle of the

corpus striatum and which was characterized by the progressive paralysis of the right part of the body.

Through post-mortem examination, therefore, Broca was able to deduce that Tan's disease involved not only large regions of the cortex, but also subcortical structures: a consideration that in the classical model is completely ignored. In addition, the analysis of the residual abilities with respect to the lesion led Broca to argue that the brain region that now bears his name controlled the production of language skills, i.e. the expressive function (of a motor, but also ideational character) of language.

And, furthermore, Broca had clearly expressed in his scientific reports that the history of neuropsychological studies had a history of impure forms in which it was difficult to make a clear distinction between a production deficit and one of understanding; this statement was not only based on experimental evidence of the idiosyncrasy of brain injuries, but also on a methodological caution to understand the complexity of the linguistic function and the need for a more accurate study of brain activity and the corresponding activated functions. Neuroscientific studies had long omitted such caution and took advantage of the simplification brought by the classical model to try to achieve empirically verifiable results even in complex cognitive functions such as language.

For the reasons discussed above, neurophysiological studies on language have recently adopted Broca's conclusion that language is a cognitive process which activates subcortical structures, and it is difficult to segment it into its elementary components (at least without forcing interpretation) because there are always multiple brain activations involving areas not dedicated exclusively to language.

Based on the classical model applied to neuroscience, in fact, Broca's area has long been thought to be exclusively responsible for the generic production of language, and as such is involved in the regulation of syntactic mechanisms that come into play during the construction and understanding of sentences. The alteration produced by its damage, in fact, has been regarded as a purely syntactic deficit, characterized by agrammaticism, that is, the inability to use the rules of syntax of the specific language. In fact, this definition, both from an anatomical and functional point, has proven inadequate: not only is it the case that the functions altered in aphasic subjects with production deficiency do not manifest as pure forms of agrammaticism (they do not manifest the total loss of syntax nor of morphological and functional categories), but there are also alterations in the understanding of syntactic structures. Based on neuropsychological observations, several studies have assigned Broca's area a special role in the linguistic domain, reducible neither to articulation nor to the mere production of all syntactic mechanisms: it would be a complex functional role in the overall management of linguistic information.

This hypothesis seems to point to a specifically human cognitive task: the ability to produce and store information on syntactic roles assumed by phrasal parts within a sentence. Grodzinsky (2000), a psycholinguist supporter of this hypothesis, by using data from lesion studies, argues that the deficits in Broca's aphasic patients do not show the total loss of syntactic competence: they manage to maintain production capacity for all statements that do not present the so-called "syntactic

movement” (i.e. the effect of the changes on the surface structures of the language). The deficit, therefore, would be very small in relation to grammatical structures: it concerns only statements whose constituents have undergone one transformational shift. In essence, syntactic movement is an operation that changes the sequential order of the elements in a sentence. This assumes that the phrasal constituents have a default position reflecting the composition of the canonical sentence in which the agent of the sentence is before (to the left) and the patient of the verb of the sentence (the one who undergoes the action) is after the verb, to its right. In verbal production, however, this order is often changed, for reasons relating to both the situational context (as in the case of omission of phrasal elements which one can refer to deictically), and to the very grammatical rules (think of the transformation of the sentence from active to passive), and to the very characteristics of the verbs used (ergative or intransitive verbs that often do not require the patient's role). In these cases, according to Grodzinsky (2006a)'s hypothesis, subjects without injury to Broca's area would be able to reconstruct the meaning given that they are capable of producing a trace of the thematic (and therefore semantic) role of the element omitted or moved syntactically. Traces are representations of syntactic roles that do not contain phonetic features (and therefore are not pronounced), and which allow you to trace the semantic role of a given element of the sentence, even if it has been moved from one position to another. According to Grodzinsky (2006b), Broca's area would be responsible not for the production of language in general, but for the construction and understanding of traces. Subjects with Broca's aphasia, in fact, would be unable to track the trace produced by the transformational movement. The strategy adopted by them to assign a thematic role to the constituents of the sentence is based on the order of the linear elements of the sentence, thus attributing the role of agents to the noun phrase in front of the verb, regardless of the type of the proposed sentence.

Grodzinsky's hypothesis presents some convincing evidence, both from a theoretical and from a clinical and practical point of view. First it assigns a high functional role to Broca's area, which no longer coincides with that of the generic production area assigned by the classic model: a cognitive role of syntactico-semantic information management within processes of understanding and speech production. This new feature would exclude the pure articulation component, assigned in this model to subcortical structures (the basal ganglia), earlier than the cortex in evolutionary terms. The anarthric dysfunctions, typical manifestations of the aphasic disorder, therefore, would not be due to the involvement of Broca's area in itself, but to damage to subcortical structures – responsible in several species for motor coordination – which are said to coordinate fine orofacial movements in humans (Enard et al. 2002). In this way, Grodzinsky's hypothesis has allowed us to understand an interesting aspect for the clinical-rehabilitative practice (Grodzinsky 2000, 2006a) shifting the focus from pure recovery of articulatory motility to the reacquisition of construction procedures and syntactic decoding.

Nevertheless, this hypothesis has some problematic aspects relating to the very nature of the processes regulated by Broca's area. Several scholars of psycholinguistics have, in fact, criticized not so much the assignment of a high cognitive function to Broca's area, but more its role as the producer of traces and, therefore,

manager of transformational movements. In particular, the inquiry focused on the alleged determination by the syntactic component of semantic roles: an increasing amount of data, in fact, shows that this language processing serial vision is not supported by experimental data, not so much in connection with understanding, but more in connection with the production of utterances. The trace theory – formulated in linguistics by Chomsky to track a priority of syntactic expertise in semantics, but later abandoned – has within it an implicit confusion between syntax and semantics. The conceptual entity, in fact, would replace a syntactic position but at the same time imply a semantic role. Also, paradoxically, the allocation of the trace management function to Broca's area would push Grodzinsky's model towards the slippery slope of 1:1 correspondence between cortical areas and cognitive functions (Willems et al. 2008).

10.4 Broca's Area: A New Processor for Neural Binding

A possible solution to the impasse surrounding Grodzinsky's theory was formulated within the aforementioned interactionist theories involving early interaction of semantic and syntactic processing. In particular, the semantic component contributing to the overall understanding of a phrase and an utterance is processed concomitantly with the syntactic component. Linguistic processing, therefore, would not be characterized by tripartite architecture (sound, syntax, semantics) held together by a final integration of the three types of serial processing: integration would occur from the earliest moments of syntactic analysis (Hagoort 2003). Several studies support the possibility that lexical items co-determine syntactic relations, and that surely they intervene decisively in the case of syntactically ambiguous sentences (Tanenhaus and Trueswell 1995; Van Berkum et al. 1999; Hagoort 2003). Essentially the development of semantic elements would take place in the second phase identified by Friederici and Kotz (2003), and requires the intervention of the lexicon and the recovery of encyclopedic knowledge, which Hagoort (2005) defines as "knowledge of the world".

Knowledge about the world is the body of knowledge that we have acquired through experience and which allows us to identify the authenticity of a statement. This, in fact, requires that the subject makes, in most situations, continuous contextual references, not only within the sentence and the preceding statements, but also inside his/her prior knowledge (intended as a set of propositions or possible statements) relating to situations or similar events. Essentially, when we use language we do not simply agree on the meanings of the linguistic expressions we use, but we exchange information about the world (Hagoort et al. 2004).

Until recently, psycholinguistic studies, in fact, were based on the analysis of utterances in laboratory contexts: in everyday use, however, it is difficult to employ and decode sentences in isolation from the situational context in which we are speaking. In the vast majority of situations, our language production is continually affected by a number of more general pieces of information with respect to the

meaning of each term or the phrasal level, without implying a special effort for the speaker (Chwilla and Kolk 2005). In addition, the construction of a sentence is often modulated in its form on the basis of the situational context and previous information, taking phrasal constituents for granted. During the understanding of a sentence, for example, it is not always the case that meaning can be understood without explicit reference to common prior knowledge (in the case of indexical or elliptical sentences or even the linguistic-gestural mixed references).

The model proposed by Hagoort highlights the influence that so-called “knowledge of the world” may play in determining the meaning, and, hence, understanding, of a statement. The case may occur, for example, in which the linguistic expression has a meaning that is legitimate from a semantic point of view, but which is in conflict with our knowledge of the world. This is illustrated in the sentence “The current Pope is in favour of *de facto* unions” in which there is no semantic violation, but a portion of its meaning does not tie in with our understanding of the position that the pope, qua representative of the Church, has taken up. While the situation would be different if we read or listened to a sentence like “The Pope’s car is in favour of *de facto* unions” which reveals a semantic inconsistency because the expressed properties (being favourable to *de facto* unions) cannot be attributed to the pope’s car (inanimate object). In essence, the descriptive aspects of the object do not correspond to the semantic representations present in our memory.

Even before psycholinguistic investigations, various theories on the nature and structure of language had made a distinction between the meaning of an expression and its connection with the world, what Frege called “truth value”. This value was validated if the truth conditions were met, that is, if the meaning of the sentence coincided with the state representation of things in the world. This theoretical distinction is the basis of pragmatic theories that support the need to consider some aspects of linguistic meaning exclusively, while others support a view of meaning that is related to contextual experience: the first fall within the domain of semantics, the latter within that of pragmatics (Chomsky 1975; Sperber and Wilson 1986). According to this distinction between semantics and pragmatics, the semantic interpretation of a sentence would be separated and would precede the integration of information on pragmatic knowledge of the world.

Several surveys on the understanding of speeches and phrases (see Cook and Myers 2004), concurred about the inability to make a clear separation between semantic knowledge and knowledge of the world: neuroelectrophysiological studies (Hagoort 2005) have shown that this distinction is not acceptable. Based on the principle that different processes are instantiated on different neural circuits, such studies have shown that the development of the meanings of words and processing of meanings arising from world knowledge cannot be considered as separate processes as they are revealed concomitantly, not only from a temporal point of view (ERP), but also from an anatomical point of view. According to Hagoort, the role of integrator of the different linguistic and extra-linguistic components of language within the network would be carried out by Broca’s area, which would deal with maintaining *on-line* information as is elaborated and would make a concomitant unification of the various elements of language. In this case, it would not only be a

syntactic task but one of high order: the integration of lexical information pieces with information derived from the phrasal context and from their previous experiential knowledge (*ibid.*).

The interactionist model proposed by Hagoort also explains how new semantic concepts are acquired: the comparison with the phrasal context and, above all, with knowledge of the world would ensure the ability to insert new meanings within the speaker's language use (Hald et al. 2007). This semantic and encyclopedic production mechanism, that is, the mechanism by which we catalogue our experiences of the world, would be acquired in childhood and would be the evolutionary precursor (in the ontogenetic sense) of the typical taxonomic structure which semantic memory takes once it reaches linguistic maturity (Blewitt and Toppino 1991). The mental lexicon, then, may first be structured through mental representations of typical situations on a linguistic basis: it would construct scripts of possible scenes on the basis of expectations which are in turn structured on the basis of linguistic and experiential meaning acquired in relational contexts (Rumelhart 1980).

Broca's area, then, would be the location for the integration of semantic and syntactic information and knowledge of the world. In this way, it would represent what Jaszczolt (2009) calls "merger representations" and would allow the integration between meanings already acquired and stored in long-term memory and new ones, arising from the interaction between the subject and the world. Hagoort emphasizes that Broca's area would play this role in a functioning network that involves a larger number of facilities than those provided by the classical model: BA 47 and BA 6 (proposed as an integral part of Broca's area), the left temporal cortex (responsible for the recovery of lexical information) and the dorsolateral prefrontal cortex (which would manage the attentional control of elements). In this brain circuit, a higher and species-specific cognitive function would be generated: the constant verification of our information about the world and the production of new meanings attributed to the experiences made during the course of the speakers' lives. Broca's area, then, would play the role of a mediator and organizer of such semantic-experiential representations.

In the description of the functional role attributed to Broca's area, Hagoort wanted to emphasize its involvement in 130 tasks that are not necessarily linguistic: the fact that it plays an important role in the process of unification of the various phrasal constituents, does not confine their activities only to the linguistic domain. Broca's area would be activated, for example when searching for a hidden object (Fink et al. 2006) and during the recognition of an action (Hamzei et al. 2003).

The neurophysiological data of cortical activations collected through the use of advanced techniques for the visualization of brain activity (fMRI, PET, MEG) reported an interesting fact in that it allows us to understand both the neuroanatomical implementation of the language function and, in general, cortical distribution and selection of networks that deal with specific skills. The complex cognitive functions would not be produced by sequential areas of the brain that have dedicated and precise tasks (whatever function one takes into account), but by the continuous processing of elements that often come from different sensory inputs and require the

intervention of several skills. The execution of a type of behaviour, for example the production of a sentence to ask a question, therefore, would concurrently activate networks with specific skills but whose processing must necessarily be integrated so that it is possible to manifest this specific behaviour.

This is known as the binding problem (Hagoort 2005; Johansson 2005), i.e. the unification question of what is processed by specialized circuits. To explain how human (and also animal) cognition works, it would then not be sufficient to develop hypotheses explaining the mechanics of individual mental processes, but models would need to be found that account for the overall activity in which our mind engages, and so giving us the impression that it is a unitary process (Gazzaniga 2008). In recent years, an ever-increasing amount of data has shown that, contrary to what was suggested in the initial neuroscientific investigations, particularly at the cortical level, there occurs a multifunctional activation of different areas which were previously considered dedicated to carrying out a precise cognitive activity. And Broca's area, out of all the regions involved in higher cognitive functions, is the one area that many studies attribute to this function.

However, from the data we have so far analyzed, it is apparent that the role of Broca's area is not necessarily bound to the domain of language production and comprehension, but is more abstract. It deals with generalizing procedures allowing the subject to build abstract representations of the processed items. Once we assign this task to Broca's area, therefore, its functional significance would be compatible with many other mental activities typical of human cognition.

There has been much debate about the involvement of Broca's area in other cognitive activities (although these are primarily linguistic and cognitive-sensory-motor tasks) and the meaning attributed to such activations. Some studies, for example, argue that it is difficult to produce a unique specialization of regions in the cortex and that, therefore, the involvement of Broca's area in most cognitive tasks is due precisely to its overall function as the area responsible for generating abstractions. Other researchers, however, point out that the activation of Broca's area is dependent on the nature of the higher cognitive processes enacted, processes that require a procedural action aimed at the representation carried out by the linguistic function.

As already shown, the positions described above begin from the same starting position but arrive at substantially opposite conclusions: the first, in fact, demonstrates the generality of the epicenters of the brain networks that can perform more cognitive functions, without, however, postulating that all brain regions are functionally undifferentiated.

According to this hypothesis, the activation of Broca's area during non-linguistic tasks should be explained by considering its role as the super-area of generalization: its tasks would be essentially defined from time to time according to the network in which it is active. According to the latter position, Broca's area can be considered a producer of representations and linguistic procedures, a role that influences and codetermines the implementation of other higher functions (planning of operations, categorization of objects, storing life experiences, and so on). The difference between the two positions is represented by the very notion of language function:

while in the former case it would be a functional capacity for interpersonal communication and conveyance of verbal meanings, in the latter case it is understood as a real cognitive activity, the kind of activity allowing us to know the world around us by forming species-specific representations. Language, in short, would not only allow communication between conspecifics (indeed, this would be an accidental feature), but it would be a way for *Homo sapiens* to know, classify, interpret and act on the environment in which he lives. Obviously, while the former hypothesis sees language as a co-occurring aspect with respect to others, the latter offers a strong vision of the role that linguistic function would play within human cognition.

In recent years, network models have led to a series of data in favour of the latter hypothesis. In particular, some studies on the attention allocated during the perception of an event have shown that this can be selectively influenced by language. Papafragou et al. (2008), for example, conducted an experiment on two groups of normal subjects speaking two different languages (English and Greek) and obtained the result that there was a direct link between the modality of the verbal description typical of the languages the speakers used and the distribution of attention during the perception of an event.

The two groups were subjected to two experimental conditions: the first had to simply observe a scene, the second was instead asked to observe the scene after which they were asked to provide a pure verbal description of the same scene. The two experimental situations, therefore, demonstrated in one case pure perceptual processing, and the other perceptual processing as a function of a verbal description. To assess any change in attentional and perceptual (visual) processes, scholars employed the Eye-tracking technique, measuring the movement of the eyes with respect to relevant facts of the observed scene. In the pure perceptual condition, the eye movement of both groups was focused on typical attentional (and universal) cues, such as the shape and dimensions of the elements of the scene. In the observation condition aimed at linguistic report, however, the observed eye movements were directed to attentional cues reflecting details of the scene using verbal description, such as aspects of movement of the subjects present that coincided with the verbal typology typical of the two languages taken into account (see also Papafragou et al. 2002).

The data obtained from the survey on attention allocation conditioned by linguistic programming stressed the influence that language function can exercise on perceptive networks that are not necessarily linguistic: in essence, when the perceptual task is pushed beyond the purely visual analysis of the scene and will request an interpretation of the perceived elements, language function intervenes modifying the relevant elements in the description of a scene, thus affecting the description itself.

A model attempting to describe how the integration can take place in the language network of more areas that perform non-language functions is the one proposed by Poeppel and Hickok (2004) in which Broca's area is inserted in two popular networks (a ventral and a dorsal one) whose activation would preside respectively over auditory comprehension and auditory-motor interaction. The two circuits would be anatomically differentiated (Fig. 10.1).

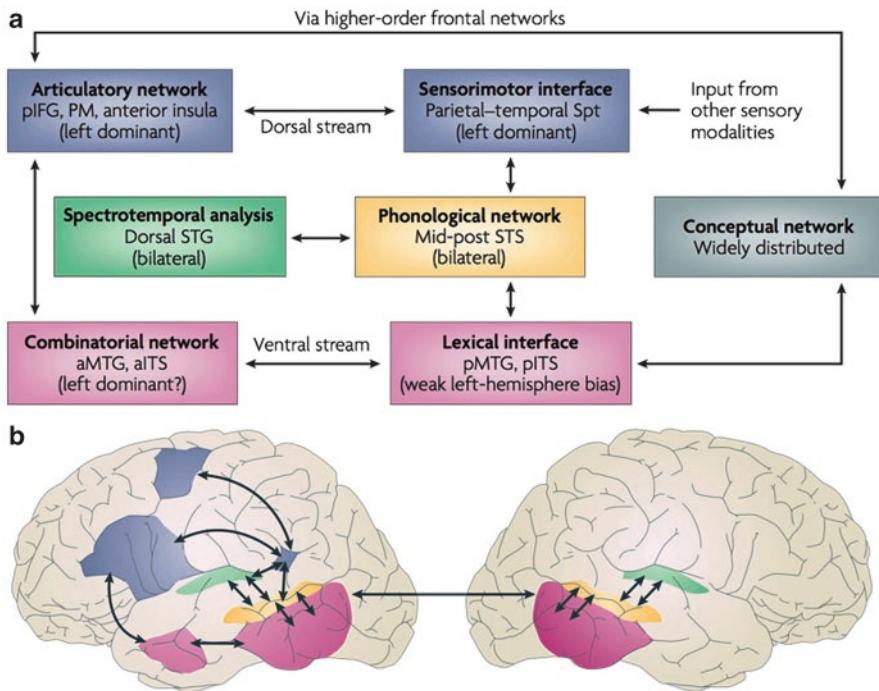


Fig. 10.1 Widespread network of language (Source: Poeppel and Hickok 2004)

The ventral pathway involves the cortical areas near the junction of the temporal, parietal and occipital areas and connects the phonological representations of sounds perceived with conceptual representations. It is in this network that the sensory information's semantic contents are defined: it contains basic areas for access to the meaning (basal language areas) which are activated because they allow the integration of polymodal semantics, i.e. the conjunction of semantic elements from different sensory systems (Marini 2008). The dorsal pathway would include, however, the inferior parietal cortex and dorsal areas responsible for auditory-motor integration by the conversion of acoustic signals into articulatory representations: it would, therefore, be an interface between the motor and sensory processes. Interestingly, in this model we can also include the language network sensory areas that do not always perform linguistic tasks: in the following paragraph, in fact, we will see that the idea of a multi-modal processing network belonging to Broca's area appears evolutionarily founded. Linguistic specificities of the spread circuit would be guaranteed by the role that is played globally by areas involved in non-linguistic tasks, specialized in the recognition of sounds and linguistic signs that flow into multimodal representations, just as in Broca's area.

10.5 Evolving Broca's Functions

Analysis of the data on the role played by Broca's area emerges from a multifunctional framework: this region seems to be activated during a series of hierarchically organized human specific tasks (e.g. syntax and the use of tools, as we shall see). The task of Broca's area, then, seems to be that of regulating hierarchical structures in different domains (Tettamanti and Weniger 2006). Different interpretations of the multifunctionality of this area have been provided. Neuroanatomical studies attribute functional flexibility to the typical cytoarchitectonic structure of BA 44/45, which would exhibit in the fourth cortical layer a structure that is both dysgranular (BA 44) and granular (BA 45) (Nishitani et al. 2005). In this neuroanatomical perspective, the structural differences constitute obvious indices of functional differences and, vice versa, functional differences require neuroanatomical differences in architecture (Bartels and Zeki 2005). But the possibility of being able to trace within the neuroanatomical characteristics the functional reasons for the instantiation of a given cognitive ability of a certain brain region is virtually null.

Instead, we prefer to consider some computational theories identifying the functional differences of brain areas, not on the basis of cytoarchitectonic characteristics, but on the basis of the variability of the stimuli: it is not the heterogeneity of brain tissue that determines the domain specificity of the cortical regions, but the way in which the functional characteristics are shaped by input (Hagoort 2006). A typical example offered by these theories to explain the way in which the cytoarchitectonic structure does not affect the type of function that is attributed to a certain region involves Broca's area.

In macaques a homologue of this area (F5) presides over motor tasks and controls orofacial movements. In humans, this area, while presenting a similar cytoarchitectonic configuration, performs a very different role (high, definitely not reducible to articulatory management). If the architectural construction of an area were to constrain the type of function that the area performs, then there should be similar tasks governed by Broca's area in humans and macaques.

To furnish an explanation based on the multifactorial nature of Broca's area it seems crucial, therefore, to make reference to an evolutionary perspective attempting to provide data to understand how a species-specific wiring is formed in that region.

The structure of the brain of *Homo sapiens*, as well as that of other animals, has been positively selected during the course of the evolutionary process leading to the current species.

It appears that the vast majority of the assumptions made on the specialties of the human brain have not taken into account the fact that it is an organ that is part of the organism, like the heart, lungs, liver, skin, and so on. The function of this controlling organ (as we shall see in Sect. 13.2. et seq.) has led many researchers to consider the brain as unconstrained by the same physico-chemical and biological forces which the rest of the body is constrained by. Although the functions connected by the brain to central coordination can justify the specificity of the nature of the con-

straints, the theory of evolution has shown that in the brain, too, structural factors are regulated by specific constraints. Obviously, the application of evolutionary principles to the brain has not immediately provided all the answers about its nature and the interspecific comparability of the homologous brain areas (Johansson 2005). The hypothesis that has emerged in recent years is based on the concept of cabling: each species, although these structures are similar to others related phylogenetically, has a specific synaptic organization that is adaptive with respect to environmental conditions. In this way the homology (anatomical-functional traits inherited phylogenetically; see Lorenz 1978) is conceivable only if we take into account the full set of structural and behavioural changes that a given species has undergone (Deacon 2004).

To give an explanation for this set of elements that contribute to the modification of the anatomical features identifying a certain species, scholars of encephalization (and evolutionary processes in general) refer to the concept of mosaic (Gould 2002): in the evolutionary path taken by a species, structures do not undergo changes of the same entity at the same time, but some of them vary in an obvious way, others in a less obvious way, others not at all, and can take on functions different from those performed before. And this process is implemented in a non-equivalent, non-symmetrical way, in all the morpho-functional components of a given organism for reasons that are related to the complex structure of DNA that would regulate structural decisive factors such as the size and shape of the brain.

As pointed out before, Broca's area is derived phylogenetically from homological precursors already found in macaques. But, based on the principle of neural wiring, it is understood that the role that it now plays in man is directly derived from the evolutionary past: each brain, even that of humans, is the result of a unique history of evolutionary modifications. In humans, these changes have resulted in an increase in brain mass and a change in the shape of the brain. That would have involved a readjustment of the neural balance, a change that is partially structural (also in the type of neurons), partially resulting from synaptic connections instantitated to handle the new functional balance (Deacon 1997). This does not imply, of course, that, for every speciation, the functional roles of structures inherited phylogenetically will be lost (or drastically modified): the basal ganglia, for example, although they have undergone progressive modifications of both quantitative and qualitative types (Smeets et al. 2000), and have maintained their basic function, namely the motor information management (planning and execution of movements) from amphibians to mammals (including humans). In *Homo sapiens*, however, they also regulate other abilities, such as the coordination of orofacial movements or switching purposes (the switch) from a cognitive task to another.

Apparently, the maintenance of homological functions occurs in a much more obvious way if the brain structures are more ancestral: there may be a functional increase, but usually if evolutionarily ancient structures were selected in previous species for the performance of a given function and recur even in the later species, then it is very likely that they maintain the functional role without preventing the assignment of new responsibilities. On the processes that allow maintenance there is no agreement (some argue that an ancestral neuroanatomical structure, if adaptive,

is maintained for reasons of evolutionary economics). What scholars agree on is that evolutionarily recent brain structures have a functional variability that is considerably higher. Broca's area is one example, as shown by paleoneurological hypotheses.

The idea at the basis of paleoneurological studies is that the implementation of cognitive functions in the genus *Homo* occurred only after the achievement of an appropriate neural configuration. Several parameters were considered decisive for the achievement of such a configuration; obviously we are dealing with indices of bone variation from which it is possible to obtain information about the likely neural structures that were contained in them. One of the first factors used as an indirect marker of cerebral changes is the increase in cranial volume. This parameter, however, considered in its absolute value, is not indicative (see infra Sect. 13.2): although growth in brain volume from Australopithecines (400–500 ml., Wood 1992) to *Homo sapiens* (1200–1700 ml., Stringer 1992) is evident by the size of the skull, it is not possible to deduce information about the specific cognitive abilities.

It is interesting, however, to note that the encephalization process reached by *Homo sapiens* has been characterized by both isometric and allometric growth: in various species of hominids it was found that, in fact, it is possible to assess not only an overall increase in brain mass (isometric increase), but also increases that are only related to certain brain components (allometric variation), especially at the cortical level (Holloway 1999). It appears, in fact, that the differences produced by the amount of brain material offer – as we shall see in the third part of the book – new possibilities of rewiring and thus new functionalization of neural structures (Gazzaniga 2008).

Studies of endocranial casts, in particular, have identified four reorganization events in the evolution of hominids (Holloway et al. 2009): (1) a reduction in the relative volume of the primary visual striate cortex (PVC, BA17), which occurred about 3.5 million years ago in australopithecines; this would have been accompanied by a relative increase in the inferior parietal lobe and temporal rear; (2) the configuration of Broca's area (BA44, 45 and 47) similar to that of *Homo sapiens*, about 1.8 million years ago; (3) the clear presence of asymmetries with *Homo rudolfensis* (KNM-ER 1470); (4) the cortical organization defining the typical pattern of modern *Homo sapiens* (from Neanderthal onwards).

Analysis of the intracranial casts also provided the opportunity to evaluate specific changes in the cortical areas in which one could appreciate shape and vascularisation because they remained etched in the intracranial cap. The cortical areas exhibiting the greatest reorganization during the transition from Neanderthals to *Homo sapiens* were the BA44, 45 and 47 areas (corresponding to the so-called "Broca's Cap") and some motor areas of the lateral prefrontal cortex (in support of a possible motor origin of language – see MacNeilage and Davis (2001) and the theorists of grounded cognition: Pulvermüller (2008) and Jeannerod (2008)).

The data obtainable from paleoneurological investigations, essentially, supported the hypothesis that the instantiation of complex cognitive functions, such as language, requires an adequate architecture and neural configuration. In the hypothesis formulated by Wilkins and Wakefield (1995), for example, allometric changes

accumulated by the *Homo habilis* onwards would have produced a typical neural configuration: the junction of the Parietal, Occipital and Temporal lobes (POT), which would include Wernicke's area. Such a neural junction would consist of a thicker bundle of hypermyelinated fibers that establishes a rapid connection between the sensory cortices in the three lobes indicated (the somatosensory, visual, and auditory ones, respectively).

According to the two researchers, the POT junction was selected because it allowed one to produce multimodal representations of sensory perceptions of the outside world through a process of integration of sensory information. In essence, visual, auditory and somatosensory data is first processed in a unimodal way in the relevant sensory cortices (for example, the visual cortex in the case of visual input) and then the association areas combine these unimodal representations with a different type of sensory information obtained from another sensory circuit (for example, somato-sensory representations). In this way, individual unimodal representations converge in pairs (auditory-visual, auditory-somatosensory and visual-somatosensory). At this point, the POT junction comes into play, through which the bimodal pairs are integrated into a single-modal representation (devoid of sensory characterizations from which it is derived). In essence, the POT junction would play the role of a super-association area that brings together all the possible sensory information related to a single element of perception.

What we now call "Broca's area" would also be inserted in the POT junction and would play, according to this hypothesis, a more general role than the one traditionally assigned to it (language production): it would be an area specialized in hierarchically structuring information in a format compatible with its temporal sequence (Wilkins 2009). Only later would Broca's area be refunctionalized for linguistic tasks: the evolutionary reason for which it was selected, however, falls outside its linguistic tasks. The role of "hierarchical-temporal organizer" of Broca's area, in fact, would not be activated only for language, but for any amodal representation of the outside world, thus determining structured semantic representations.

The neural configuration of the POT-Broca's area would, therefore, provide advantages not associated with communicative capacity but with fine manipulative abilities useful for the construction of tools (see infra Sect. 7.2): the POT junction would have guaranteed the motor-somatosensory coordination and the visual-somatosensorial feedback necessary for the manipulation of instruments. Broca's area would allow the temporal sequencing of actions to reach the final production of the object. This morphological and functional architecture would have been appropriate for the emergence of the language function: the current brain's anatomical structure is derived from selections made on raw material which was later converted into an adaptive function for that structure.

Based on the assumptions by Wilkins and Wakefield (1995), therefore, Broca's area would have not only structural but also functional evolutionary precedents which are the cognitive prerequisites for the processing of linguistic information about the outside world. Sensory perceptions, in essence, must be freed of their analog-perceptual format in order to be processed at the linguistic level. The

hierarchically structured amodal representations studied by Broca constitute the conceptual material on which the language function works.

It is clear, at this point, that the management areas of higher mental functions can be utilized in other cognitive tasks, for reasons arising from the history of adaptive selections which they underwent: language has “reutilized” the skills already selected for Broca’s area, making them an abstract ability of experiential categorization. The evolution of the multi-functionality of Broca’s area seems connected to its role as a manufacturer of high functionally conceptual representations that are linguistically based, co-determining and influencing the realization of other cognitive tasks that require procedural and semantico-encyclopedic knowledge skills.

Part III

**Extended Performativity: From Brain
Plasticity to Linguistic Pragmatics**

Chapter 11

Performance

According to what has emerged from the historical reconstruction detailed in the first part of this book and in the detailed theoretical comparison made between the CBM and the DBM in the previous part, the element hindering a unified project of contemporary biolinguistics seems to be the relationship between mental functions and body structures that are intrinsic to the language faculty.

In the CBM, this relationship is affected by two crucial distinctions that have taken various forms over the course of half a century of debate – as we saw in Chaps. 2, 3 and 4. The first distinction made is between the study of structures and the study of functions. The second distinction pertains to the field of *competence* in opposition to the field of *performance*. There are, of course, very strong links between these two distinctions: a mentalist theory that diminishes the cognitive role of body “externalizing” devices is almost obliged to consider the formalization of the computational rules of discourse, a task specific to biolinguistics, at the detriment of its “execution”. Similarly, from an evolutionary perspective, a model centred entirely on universal recursion processes can only assume a chasm between the cognitive world of human animals and that of non-human animals.

On the contrary, the DBM starts from the idea that the specificity of the human cognitive form is mainly due to biological structures that make humans capable of communicating and thinking through language. This basic principle too is subjected to two main constraints. The first constraint is that such structures are not exhausted by the specificity of the brain but in the slow natural selection of organs suitable for speech and listening to species-specific sounds. If there had not been a very slow and gradual evolution of these organs from animal forms, gradually becoming more and more differentiated, no brain evolution and no “mental leap” could have ever “invented” language. The second constraint is that the so-called cognitive abyss which has been introduced by language and has favoured an evolutionary selection suitable for human survival is not to be taken as warranting continuous adaptation. This is, first of all, because current *Homo sapiens* is just one of many species that have spread endemically across the planet: as demonstrated by Edward Wilson in *The Social Conquest of Earth* (2012), eusocial insects, rather than *Homo sapiens*,

are the real winners for the sole purpose of biological history: reproducing and spreading. And secondly, because there are many clues provided by evolutionary biology – which we will return to in the conclusion – that seem to indicate the possibility of extinction of the human species, due to the cognitive power of language (Pennisi and Falzone 2010). It is, therefore, a sort of anthropocentric bias, particularly prevalent among philosophers, linguists and, more generally, between scholars of the humanities and social sciences, that has created the legend of the sudden leap of “status” of *Homo sapiens*.

In the absence of this unexpected and sudden change of status, a genuinely Darwinian perspective, in the sense that we have described so far, should devote itself to the humble reconstruction of the differences in structural evolution that led to the biological species specificity of language – to which we have dedicated the entire second part of the book – and the clarification of the linguistic characteristics of a theory of performance that loosens its grip on a totally cerebrocentric template and formalistic biolinguistics. We have devoted the third part of the book to this purpose.

11.1 Definition, Development and Application of the Term

From an internal linguistic point of view, the technical use of the term “performance” is found, for the first time, in *Aspects of the Theory of Syntax* by Chomsky (1965). By using that term, one indicates the actual linguistic activity recorded in the production of a speaker-listener. It is used in opposition to the term “competence” that instead indicates linguistic knowledge, the grammar rules implicitly owned and internalized by the same speaker-listener. Since, at that time, Chomsky assumed that the study of linguistic theory should have the listeners-speakers of an idealized “completely homogeneous speech-community” as subjects (Chomsky 1965, 3), all possessing a perfect knowledge of their language rules and free from distractions or conditioning due to memory limitations, he believed it was impossible for performance to coincide with competence.

The argument used is that the project is determined by mental competence, by the internalized and perfect knowledge of the rules, and is systematically weakened by performance that will show “numerous false starts, deviations from rules, changes of plan in mid course, and so on” (Chomsky 1965, 3). A theory of language, worthy of that name, should single out the rules of internalized grammar and not be interested in any way in the paths used to express them. Performance is a reflection of the embodiment limits, while competence is a purely decorporealized project. In this sense, linguistic theory is mentalistic since it “is concerned with discovering a mental reality underlying actual behaviour” (Chomsky 1965, 4).

And otherwise, within the framework of the first generative grammar, the contrast *competence/**performance* was connected to another important dichotomy i.e. that which exists between *deep structure/surface structure* which expresses the idea that deep syntactic content existed in linguistic activity and that several final execu-

tive forms could be embodied in different ways. Transformational rules would serve, in fact, to explain possible different *performances* of a single mental distillation: more precisely they could always return the last metasense of each execution, due to the application of phonological and semantic components, linked to the bare syntactic structure.

As we saw in Chap. 3, some changes in Chomskyan hypotheses, over the years, have facilitated the development of naturalistic evolutionarily oriented research, while others have increasingly moved away from that, however always adhering to the same idea of how the relationship between mental components and those of the executive language work, or should work. As for minimalism, indeed, the gap between these two components widens separating them completely. In particular, competence is restricted to the unique recursive computational core i.e. MERGE, while all the executive (phonological and lexical) activity is relegated to externalization devices. All traits specifically selected by evolution for language performances, and so all the embodiment of language, is completely expelled from the FLN and considered a variable with no species specificity. For Chomsky, the executive components, the nature of the effort associated with their practice and the contribution of the intrinsic performativity of all components of language (phonic articulation, auditory forms, the “in progress” organization of grammatical forms, the proceeding of semantic and pragmatic strategies, etc.) do not play any role in the human cognitive linguistically species-specific system.

Since the original formulations by Chomsky, in linguistics, the notion of performance has undergone numerous revisions within different fields and, as a consequence, performativity theory began to attract more research which contributed to its complete redefinition.

For example, the Austinian idea of “performative acts” (Austin 1962), matured during mid-twentieth century philosophy of language, and relied on some verb classes and nouns expressing a vicarious function of the action. So saying: “I baptize you” or “I confer on you a doctorate in Cognitive Science”, I disguise behind such phrases, that are neither true or false, those acts which, just by being announced, employ a precise factual consequence: being children of the Christian community, having a socially recognized knowledge in a certain subject area, etc. Therefore, the word becomes an action.

On this linguistic path towards performativity, marked by an important critique by Derrida (1972) and levelled at Austin’s hypothesis, by the end of the century the idea that “performative power” is connected to a kind of intrinsic authoritarian nature of discourse appears to find its highest expression in the legal activity where the formulas put an end to dialogicity (Butler 1993, 1997, 1999). Therefore, the action stops procedures.

This dimension of performativity connected to the power of action has also affected significant areas of the study of social behavior, and in particular those dedicated to gender studies and sexual minorities, but not limited to cultural anthropology, social psychology and sociology (Finnegan 1969; Hymes 1973; Foster 1989; Livia and Hall 1997; Butler and Spivak 2007). These studies have dismissed the theoretical focus of performativity from its internalist value transferring it to

social networks in which the language actualizes it. The performing procedures do not depend on the psychological states of the speakers but are over-determined by cultures.

A very appropriate rapprochement between internalist and externalist values of performativity has finally occurred in the frames of the theoretical discussion on the arts and the media more and more frequently over the last 30 years, especially in the aesthetic, narratological, theatrical, photographic and cinematographic areas. Hence the “performative turn” (Robert Wilson, Jerzy Grotowski, Marina Abramovic, Richard Schechner) that led to the establishment of *performance studies*; it is focused on the redefinition of a specific heuristic space in which the expressive design is always inseparably connected to its execution (Fischer-Lichte et al. 2014; Lehmann 1999) and cannot be properly conceived separately. The “design” of a work of fiction or drama without implementing it becomes a sterile procedure and one that is impossible intellectually, in the same way in which you cannot devise a photographic image with a click, regardless of the time when the action stops, i.e. its factual implementation. These are intellectual procedures that come to light only when the action that implements them stops, stimulating the circuit of the mind that has conceived them and of the societies within which these procedures are culturally generable.

During the last 20 years, research on the performative dimension of human knowledge has been consolidated in almost all fields of current cognitive science mainly focusing on the discussion of “embodied cognition”. The framing of this subject in a series of internal subfields – the already famous 4E cognitions: embedded, embodied, enacted, extended (Rowlands 2010) – shows that, at least for the moment, the issue of performativity as embodied cognition continues to remain a common point in the relevant background and a vivid problem rather than a set of solutions.

The enactivism (enacted cognition), for example, has explored in depth the performing resources of biological organisms, their ability to develop activities, starting with motor activity and also drawing from an evolutionary perspective. According to Alva Noë, “seeing is not something that happens in us. It is not something that happens to us or in our brains. It is something we do. It is an activity of exploring the world making use of our practical familiarity with the ways in which our own movement drives and modulates our sensory encounter with the world. Seeing is a kind of skillful activity” (Noë 2009, 60).

Many studies on visual systems, and in particular those of insects, have shown this intuition. The eye of the fly, for example, was selected after following closely the characteristic zigzag motion of its flight due, probably, to its visual photoreceptor structure which is capable of providing a fast and direct response to the nervous system (Hardie 2012; Hardie and Raghu 2001; Hardie and Juusola 2015). Similarly, other sensory, auditory, olfactory and tactile repertoire are caused by “different patterns of sensorimotor interdependence. (...) Sensory modalities are really styles of exploration of the world” (Noë 2009: 61.).

The peculiarity of the activist position is its capacity to reach the most radical formulations of a performative philosophy of embodied mind: i.e., that proposing to

consider the body and its sensorimotor activities as the real constraints of cognitive activity (Menary 2006). However, in the most extreme theses such as the dynamic approach to cognition by Chemero (2009) or post-artificialist models by Brooks (1991, 2002), this trend is likely to be seen as a neo-behaviorist perspective privileging the self-organization of systems in a continuous interaction.

Even the theory of the embodied mind (embodied cognition) considers cognition as a function of biological structures. Therefore, as Shapiro tries to demonstrate (Shapiro 2004, 2011), it is possible that a different structure of the body can result in different forms of intelligence. The presence of certain anatomical features, or even large or small organizational differences in their functional mechanics which can implement performances or behaviours vital for survival or fitness of organisms, are able to determine profound cognitive, mental and, perhaps, even cultural adaptations. Even the absence, the attenuation or loss of genetically encoded traits can lead to entirely new and unexpected cognitive devices (Carroll 2006; Falzone 2014a, b; Pennisi and Falzone 2011).

The case of embedded cognition and of the extended mind is different. In these two interpretations of the paradigm of the embodied mind, the body, and, in particular, its strictly biological dimension, is less directly involved. In particular, the object of study changes: it is not so important to know how the “bodily technology” (Pennisi 2013, 2014a, 161 et seq and b; Pennisi and Parisi 2013) that allows the development of certain cognitive abilities is made, but, if anything, to understand how digital technologies, developed from certain cognitive abilities, can extend and expand the body’s powers. The mind is “immersed” (embedded cognition) in an environment in which physical, ecological and cultural agents operate in conjunction with digital devices, all of which interact and co-evolve with individual consciousness. It is also “extended” (extended cognition) to collective uses that expand far beyond the cultural dimension of the individual cognitive potential of the human mind (Rowlands 2003, 2010; Sheldrake 2003; Knappett and Malafouris 2008; Clark 2008a, b, 2016; Menary 2010; Paolucci 2011, 2012). A typical case is that of short-term memory which has been strongly influenced by digital computing advances leading to a drastic reduction in individual skills against a disproportionate increase of collective skills, or with the extraordinary prospects advanced within *artificial life* in connection with the gigantic, and no longer measurable, increase in overall network connections.

As they are sometimes incomparable to each other, all these forms and performative possibilities of the embodied mind have helped to undermine the cerebrocentric and mentalist perspective of computational neuroscience, at least under the ideological profile. In fact, a theory of the embodied mind cannot omit or forget, even for a moment, that the brain – unlike the mind – is still a body organ. What the embodied cognition theory conflicts with is the excessive power conferred by the cognitive neuroscience to a body organ (the brain) with respect to other body organs. Therefore the embodied cognition view conflicts with the ghost of dualism that still underlies – implicit and unexpressed – some neuroscientific theories, but that stands on the edge of all the naturalistic philosophies that are inspired by cognitivism.

The hypothesis we would like to explore, taking into account all these research experiences but trying to move beyond the boundaries of the theory, is that performativity is not a property limited to certain specific human skills, or to certain specific acts of language, or to accidental enrichment of creative intelligence. On the contrary, the executive and motor component of cognitive behaviour should be considered intrinsic to the physiological functioning of the mind and equipped with self-generative power.

From a Darwinian point of view this hypothesis would develop evolutionarily in close correlation with the processes of natural selection that in the human animal led, on the one hand, to the species-specificity of articulated speech and, on the other, to embodied simulation as a model of perception. Under this perspective, cognition would be a mediated form of action and not a relationship between an inner thought and behaviour taking place in the outside world. In the model of performativity that our proposal would like to develop, the action is never considered the mere externalization of a mental process, but is itself the cognitive process within the body producing it. Each species-specific body form constitutes one's own universally present way to know reality.

In this theoretical and reconstruction context, performativity can be defined as a constitutive component of cognitive processes. The material action allowing us to interact with reality is both the means by which the subject knows the surrounding world and the one through which he experiments with the possibilities of his body. This is a proposal anchored in models already shared in the philosophy of mind and language, which identifies a cognitive space that does not lie either within the individual, nor outside it. However, in the DBM, its results are constrained in a particular manner by the founding of species-specific ways through which the human body acts on the world. It is the body that over-determines the individual's cognitive ability, rather than internal abstract mental processes or solely environmental inputs.

From a philosophical point of view, this would be a new space not completely coincident with the current theories of action (the 4E's cognition) but rather, it would align itself with its deepening naturalistic tendencies. This would be a theoretical reformulation which considers the biological characteristics of the action of *Homo sapiens* and his privileged system of construction of knowledge. In this perspective, therefore, the action is not interpreted only as a relationship between the subject and the environment (enacted cognition) or as a direct product of the environment (extended cognition) but as the set of body-based cognitive ability. In short, this is one way to overcome cerebrocentrism without falling into any form of neo-behaviourism.

On the contrary, the idea proposed by classical cognitive science about action forces us to choose what takes care of the action: either the mental processes required to produce interaction with reality (the internalist perspective) or the effects by the mental processes on reality (the externalist perspective). Susan Hurley (2008) exemplifies this idea by using the metaphor of the “sandwich model”: essentially, in traditional cognitive models, the mind guarantees the “higher” role of processor of information, whereas perception is responsible for the task of transporting inputs

and the action is assigned the sole task of the performance, i.e. the output from the mind to the world.

As we have repeatedly seen in previous chapters, in biolinguistics the most prominent variant of this model can be considered to be Chomsky's hypothesis on FLN (Faculty Language in the Narrow sense) that includes only the recursive computational system. This system would generate by itself internal representations created by the Merge and Move computational operations, leaving the sensorimotor interface with the sole task of mapping them as inputs by way of the phonological system, and leaving the conceptual and intentional interface with the sole task of mapping them into outputs through the semantic system. In this way the performativity inherent in linguistic processes would become a mere "externalizing" device: a sort of "printer" of the mind ("[the] externalization of narrow syntax, like the printer attached to a computer, rather than the computer's CPU" – Berwick and Chomsky 2016, 9).

Recent literature on how human beings know external reality and perceive it by selecting different aspects of it and, primarily, how they act within external reality by exhibiting a large number of different forms of behaviour, has questioned this highly computationalist setting in which the mind coincides with a computer.

Neuroscientific and electrophysiological data, in fact, deliver a completely different framework about the role of action. In fact, the latter has not only the purpose of "implementing" a will internal to the subject, but it also allows one to learn information about the world and to build generalizable representations based on bodily technologies.

In particular, studies conducted with ERP demonstrate that this knowledge – that constitutes the wealth of both bodily and cultural experience – intervenes in the very definition of meanings. In linguistics, it was noted that ordinary conversation is not centered on the associative, semantic, or perceptive properties of the world (see McNamara and Holbrook 2003; Hutchison 2003) (for example, the fact that apples are a kind of fruit, that look like pears, are round, can be green or red and so on), but it is based mostly on events, or collocations having ordered patterns closely related to our experiences. The speaker actually uses a multitude of more general types of information and he/she extracts them without any effort from the situational context.

Even neuro-electrophysiological studies (Hagoort 2005) have shown that the distinction between processing and externalization is not acceptable. Based on the principle that different processes are located in different neural circuits, such studies have shown that the elaboration of word meanings and the processing of meanings derived from knowledge of the world cannot be considered separate processes as they are revealed concomitantly, not only from a temporal point of view, but also from that of anatomical localization (Broca's region, see the second part of this book).

Outside linguistics, the latest developments about technology interface have shown the extraordinarily located and exploratory nature of perception, highlighting that images can be physically inhabited. This process of integration becomes evident not only when subjects interact with visual devices such as pads or computers,

but also in the case of *game playing* or *augmented reality*. In related fields, another important issue is performativity mediated by machines, namely that of acting in the age of hypermediation. Studies on the extensibility of the body on artefacts demonstrate the brain's natural inclination to incorporate artificial tools. Many contemporary performers (Stelarc, Neil Harbisson) currently investigate this further horizon of possibilities.

In all these cases, action has taken on a key role in the theories that aim to describe the nature of human cognition. The explanatory presence of the acting body, in fact, is considered as constitutive for current cognitive science and so body performativity must be seen primarily as an access key to many forms of interaction occurring between individuals. The proper act and the experienced act, in short, are basic elements of any analysis of human cognition.

11.2 Performativity and Brain Plasticity

The structural foundation of the performing skills of mental and bodily types of behaviour can be identified in brain plasticity. This term, considered in its broadest biological sense, relates to the ability of cells of the nervous system to regenerate themselves and reorganize their structural and functional arrangement. This basic principle is present in the nervous systems of numerous species, from the simplest to the most complex on the so-called evolutionary ladder.

On one hand, in terms of functions, this capacity allows all the single members of a species to adapt to new environmental conditions and to change the type of behaviour required for the survival and integrity of organism. On the other hand, in terms of reconstruction, plastic processes allow the re-wiring of nervous tissues and structures for coordination. The rewiring is a central process enabling structural (histological, muscular, osseous, etc.) changes that may occur in the history of organisms so that they will evolve towards functionally efficient forms, from which species-specific advantages may be derived.

The most important aspect of plastic processes is their inseparable connection with sensorimotor systems. In particular, as we shall see later, it is not possible to change the organization of the nervous system if first a change in sensorimotor structures does not occur providing new sources of input. In the first instance, this interdependence is triggered by a one-way process, but then it is subsequently driven by the use of organs and, therefore, by the exchange of bidirectional signals that tend to favour (even without guaranteeing the outcome) instantiation of stabilized cognitive processes. Basically, the symbiosis between perception structures and neuroplasticity is the cognitive-core of any living organism.

From a biolinguistic point of view, this synergy between the inputs of sensorimotor systems and lifelong activities of specialized systems for monitoring and transforming into effective environment functional processes, is central.

It intervenes in all stages of development and use of the language faculty in the DBM, as we have previously described. Therefore, plasticity mechanisms are

present not only as part of ontogenetic modelling, but also during the rising of pragmatic and discursive competence. In direct relation with the maturation of their peripheral and central organs, human children learn to listen, categorize and, at the right time, try to pronounce the species-specific sounds of their historical and natural language until the attempts to dominate the auditory-verbal synergies are settled into a definitive cognitive verbal articulation system. Beginning from two years of age onwards, adults, in turn, are able to experience the path of creative performative uses of language, without ever exhausting it. On this path all possible extended combinations of the phonological, syntactic, semantic and pragmatic systems are made possible by the power of articulated speech converging into a single cognitive and performative device. From this perspective, the DBM can be considered the “central module” of the species-specific cognitive system of humans.

Therefore, an extended theory of performativity in which the DBM triggers itself cannot omit a detailed analysis of the two research directives on brain plasticity: namely functional and developmental directives.

Chapter 12

Functional Plasticity

The concept of the brain that the general public holds is that of a three-dimensional structure consisting of different types of neurons which, when connected together, form a dense network of connections. This network may be more or less complex and formed by a different number of neurons depending on the species being considered. Crucially, it is never the same within different species. The nervous system, in fact, is not static, but is constantly changing: from its formation until it reaches the adult stage, it undergoes noticeable changes in both the overall shape and the connections between neurons that form the basis of functional networks.

In short, the nervous system is plastic. Brain plasticity is the set of structural or functional changes in the brain which it will undergo throughout the life of the organism.

This characteristic, deriving from the cytological nature of neurons, is crucial for the role that the brain plays within the organism. As we have already said, current philosophical interpretation of neuroscientific data has assigned a functional centrality and an evolutionary “responsibility” to the brain that were often excessive. Its characteristic plasticity can be considered as one of the elements which is most useful in avoiding this error of interpretation.

If we consider that the brain is a plastic control system, not only could we shed light on the functional possibilities of the brain structure present in organisms today, but we could also make a plausible evolutionary reconstruction without any risk of cerebrocentrism. For example, reconstructions relating to the exclusive survival of *Homo sapiens* within the genus that involved qualitative leaps (such as intelligence, emergent or uniquely human cognitive functions) can be avoided. A closer look, in fact, at the plasticity of the nervous structures allows us to consider the brain as being a structure that is constrained in form, but playing a basic and stable functional role, (that is, the coordinated control of bodily functions) thereby enlarging the entire evolutionary lens from the centrality of the controller (the brain) to the centrality of the controlled (the entire body, i.e. bones, muscles, viscera, internal organs, connective tissues and obviously the nervous system).

12.1 Ontogeny and Structures of Plasticity

The brain is a plastic organ in various ways. One of its prime features is the ability to change, both in response to genetic programs (the growth of the nervous system in *Homo sapiens* is a clear example of this) and in relation to environmental demands (such as learning or structural damage).

The brain has a long path of morphological formation: it begins to form in the embryo in the womb around 3–4 weeks after fecundation. It is during this process that the architecture of the body and the brain is defined. The architecture of the nervous system, in fact, is certainly not typical of the adult *Homo sapiens*. The brain of a newborn child weighs about 350 g, a weight corresponding to 25 % of that of an adult brain (on average, 1400 g). At 2 years and 10 years old, the corresponding weights are 75 % and 95 % the weight of an adult's brain, respectively. The cerebellum, instead, does not grow exponentially but steadily increases in weight during the first 10 years of life. The spinal cord, which is part of the central nervous system, increases uniformly from birth (3 g) to adulthood (28 g). But how is the architecture of the brain defined? Why is it specific to each animal species, but can vary from individual to individual?

The formation of the nervous system is frequently studied, particularly in mammals, in relation to the growth of brain mass. Although there is substantial agreement that genetic rules determine the species-specific form of the brain, it is not so clear what determines individual variations within the same species. For example, a recent study on the growth of brain convolutions in *Homo sapiens*, that are considered to be associated with typically human cognition, has shown that the tangential expansion of the human cortex is controlled by molecular determinants, but despite that, the size, shape, location and the orientation of the folds is the result of variation in a basic mechanical instability modulated by the cerebral geometry of the fetus (Tallinen et al. 2016). What is clear, however, is that there exists a genetic program which defines the general shape of the brain: if some aspect of the program that regulates the form does not work, severe abnormalities will occur, such as microcephaly and lissencephaly (Vallee et al. 2006). It is in the training phase of the nervous system that brain plasticity manifests itself. Mechanical forces, which can exhibit individual variation, can differ from an individual to another, determining singular shape and folds.

What is evolutionary plasticity of the brain and how is it manifested in the development of the nervous system? What are the genetic mechanisms controlling it?

Brain plasticity begins in the embryo soon after the formation of the neural tube and the migration of neurons to the appropriate sites. In the embryonic stage, the neural tube begins the proliferation (i.e. production) of neural and glial cells. After a few days, these cells migrate to the appropriate sites. During migration, neurons move either radially or parallel to the neural tube, along an antero-posterior and a dorsal-ventral axis. It is at this point that brain plasticity begins: during migration and until reaching the target site, neurons are immature i.e. they are formed only by the neural body, the soma, and are devoid of the famous prolongations constituting

the input and output routes of neurons (dendrites and axons, respectively). Upon reaching the site, neurons begin to form connections with other immature cells through a process called “aggregation”. Essentially, the prolongations that arise from the neuron somas are useful in forming synapses and, consequently, in assembling the nervous system structures (Pinel 2006). So while the proliferation of neurons is soon completed, the organization of cells, the development of synapses and myelination – initiated during gestation and responsible for the formation of functional networks (i.e. brain networks responsible for cognitive functions) – will continue for long time.

Axon formation, in particular, constitutes one of the first mechanisms of brain plasticity. Through a series of intercellular communication, neurons recognize neighbouring cells and start to build ramifications of their own cell body through which they can communicate effectively with each other. These communication systems are established by specific chemical signals being released by both neighbouring cells and other cell types – the so-called glial cells – and sending chemical signals useful for the development of the axons. Essentially, this aggregation process seems to be determined by the communicative ability of cells to recognize a form of compatibility on the surface of neighbouring cells, thereby determining adhesion (Edelman 1987). It would nearly seem to appear that the axons are following chemical strips emitted by glial cells and other neurons which encourage them to grow in the right direction. And if this mechanism seems pretty trivial when considering that, within the brain, the distance between one neuron and another may be micrometric, we should consider the functional value this mechanism has in the peripheral nervous system, where the axons are bundles of very long nerve fibers, as in the case of those that control the movements of the arms or legs.

During fetal nervous system formation and during the phases of accretion, we can clearly witness the phenomena of brain plasticity, as this involves an increase in both cerebral mass and the number of neural connections, which reaches its maximum level 3 years after birth, when the peak of synaptic density occurs (Petanjek et al. 2011). For our purposes, it is important to realise that synaptic connections only become effective if they develop into functional networks, basically if they have a function to perform. For this reason, in addition to neural proliferation and synaptogenesis, another fundamental process comes into play: programmed death (apoptosis). It seems paradoxical that cell death should contribute to the efficiency of the nervous system, especially of the brain, but this is just the selection of circuits of neurons that allow a functionalization of the network. Too many connections can hinder proper cognitive development, only the right ones are useful. Then, at the cellular level, if electrical signals and neurotrophins are missing, neurons cannot be stimulated to, initially, reduce the number of connections, followed by a reduction in soma size required for non-traumatic cell death and its physiological resorption (Kandel et al. 2006).

The programmed death of neurons is associated with the formation of specialized brain circuits: for the first months after birth until adulthood, the development and branching of axons, together with apoptosis, determine brain wiring. In some areas, in fact, there is a branching and a strengthening of connections between

neurons, whereas in others a deletion of the connections takes place. On the one hand, the programmed death and, on the other, the mechanism of pruning (selection of synapses) make learning possible (Changeux 2002). According to the theory of the selection of neuronal groups (Edelman 1987), during this phase in the brain, a process similar to the activity of natural selection on organisms comes into play. The wiring of the brain is conducted by selective mechanochemical events and epigenetic factors which occur at high frequency both during the embryo-fetal stage, and after birth up until the age of three, at which point they slow down until adolescence.

This phase of strong plasticity is called the “critical” period and its duration varies depending on the type of function (Mundkur 2006). The critical period is substantially a very vigorous learning period, in which receptors acquire information from the environment, i.e. it is as if the environment is transformed into a brain activity (Maffei et al. 2010). For example, Rosenzweig and Bennet (1977) have shown how environmental enrichment influences the thickness of the cortex in rats. External information modulates the formation and the extension of the corresponding cortical areas. For certain functions, this is a critical period but this does not mean that it is not possible for other functions to continue to learn, that is, to determine changes in structure and brain function.

Among scholars of brain development, it is clear that environmental factors strongly influence the formation of brain networks, both at the level of the internal nervous system environment and of the experience of the subject. This influence is so strong that Sweatt (2013) identified a potential subfield of epigenetics dealing with the mechanisms allowing a dynamic epigenome adjustment based on the experience in neurons of so-called neuroepigenetics. This identification is justified by the fact that neurons are a particular kind of cell that do not themselves divide. Without going into the epistemological debate, the most accepted view seems to be that learning and environmental exposure both affect neuronal maps and their variation, i.e. the change of the boundaries of these maps due to cortical competition (Polley et al. 2006; Merzenich 2013).

If the environment affects brain functionalization, why is it that, in a given species, brain organization is more or less the same, despite individual microdifferences? As mentioned in the opening paragraph of the chapter, genetic programs exist that determine, not only the correct form of the nervous system but also the positioning of the correct neurons (there are several types of neurons) in the correct location.

This varied genetic program is not executed randomly, but follows a precise timing regulated by the structural genes we discussed in Sect. 8.1. In particular, architect genes (a metaphor used to refer to regulatory genes) determine the differentiation of cells. During embryogenesis, cells undergo several transformations: from the formation of the zygote until 8 days after they are totipotent, i.e. they can give birth to a progeny of cells with progressively greater degrees of differentiation. It is the process of differentiation that allows the formation of organs and tissues that give overall shape to each organism (Wagner 2014). From this stage of totipotency, cells switch to multi and pluripotency, i.e. cells that, on the one hand, exhibit a gradually

reduced “possibility” of differentiation and, on the other, exhibit a growing specialization. This is the method by which cells become tissue-specific. During this stage it is possible to detect early signs of the nervous system. The architect gene enables the specialization of cells. Some act directly on the formation of the brain, such as the OTX gene which regulates the overall structure of the brain (not only in humans), and the EMX gene which regulates the organization of convolutions and “basic formatting” of the cortical areas in relation to those specific functions which are useful for survival, i.e. those particularly related to sensory and motor skills. The EMX2 gene, in particular, controls the number of neurons in the cortex and their arrangement in the six layers of the cortex. Since the fourth layer of the cortex of the brain determines the functionality of the area, EMX2 regulates the organization in areas of the brain cortex (Mallamaci et al. 2000). In a sense, EMX2 can be regarded as the gene of the geography of the cortex as it determines “the correct positioning” of neurons in the various areas of the cortex. Some studies have shown that regulatory genes exist that control the shape of specific parts of the cortex associated with a specific function. For example, Flore et al. (2016) identified the COUP-TFI gene as being the architect of the hippocampus, a structure of the parietal lobe where the cortex takes on a convoluted shape and thins out into a dense layer of neurons, and which is responsible for both orientation ability in space and memory (Squire and Schacter 2002). The alteration of this gene produces a hippocampus with an atypical form, i.e. one with a smaller head and a tail of larger dimensions. The alteration of the hippocampus is also associated with an increase in the motor cortex but, paradoxically this increase does not produce improvements in motor coordination performance as fine as those produced by the training involved in performing motor tasks such as playing the piano. This means that, normally, the COUP-TFI gene regulates the operation of the hippocampus and therefore its alteration makes it unable to store elements in space.

The architect genes act at particular times during the body’s formation in the embryonic stage, and they also allow all the newborn of a species to possess a shape and a substantially similar development plan (Bauplan). These genes allow us to control the shape of our nervous system. It is the macroscopic structure, and not individual connections, that depend on a number of elements that are external to genetics and programming, and as such can be different even in monozygotic twins (Freund et al. 2013). In fact both neurogenesis, i.e. the formation of new neurons, and synaptogenesis, i.e. the formation of connections between neurons, are strongly influenced by environmental factors internal to the body and by external stimuli (Ernst and Frisén 2015): learning and experience favour axonal branching extensions and reinforcement of useful connections. This microscopic difference within an identical macroscopic shape of the brain has often been invoked to describe individual cognitive characteristics or differences in learning strategies and even perception.

12.2 Physiology and Pathology of Plasticity

Brain plasticity not only occurs during the formation of the nervous system but also during the entire body's lifetime. During the last 15 years, neuroscientific studies have shown that this is the mechanism by which the brain represents the sensory world both internal and external to the body.

It should be stressed that the mechanism of plasticity is an intrinsic characteristic of neural cells that enables the brain to produce cognitive memories of reality at the same time as the flexibility to produce new knowledge (Ward 2001; Merzenich et al. 2013). In a sense, this feature makes the *Homo sapiens*' brain extremely dependent on the characteristics of sensory organs and body structures that constitute the first cognitive and manipulative filter of reality.

In fact, on the one hand, the brain is able to build representations of experiences and to save them within more or less long-term memories; on the other hand, the nature of the experiences that the brain categorizes is constrained by the morphological components that only allow access to some types of sensory input (e.g. human eyes allow the brain to see only certain light frequencies, that portion of the electromagnetic spectrum that human eyes are capable to capture, from about 430 to 770 Hz).

The same ability to interact with the outside world is determined, not only by the sensorimotor coordination systems, but also by the corporeal form of each organism. While the first statement is certainly widely accepted among contemporary neuroscientists, the latter is not so obvious. The way in which the body "perceives" and "acts" can affect the organization of the brain. This knowledge has only recently been established thanks to progress made in functional cerebral techniques (Merzenich et al. 2013).

To understand how the body can affect the ways and possibilities of reality categorization (a task that pertains to the brain) it is sufficient to consider data from studies on animal models. These studies, that are now of utmost importance in the field of neuroplasticity, show that, in normal conditions, cortical visual representations in mice have a specific, balanced and columnar dominance of the two eyes in the fourth layer of the primary visual cortex (Hubel and Wiesel 1977) and that the neurons of this cortex show a specific preference for different orientations of the stimulus (Hubel and Wiesel 2005). This type of topographic representation on the cortex of the visual afferents was also found for other sensory afferents; for example, even the whiskers of mice have a specific topographic representation, vibrissae-per-vibrissae, in the sensory cortex S1 (Woolsey and Wann 1976). Studies using animal models have shown that this physiological condition of cortical representation of perceptions is not rigid, nor linked to only certain "sensitive periods". Instead, it directly depends on the sensory afferents: a change in these afferents may determine a change in the cortical representation and in its control.

An example to consider is the case of so-called animal chimera, an animal unlikely to be seen in nature. We refer here to those animals that are "manufactured" in laboratories by altering the shape of their body, adding some anatomical structures

not provided for in the DNA, but basically compatible with their morphology. These “laboratory experiments” correspond to the production of those “impossible shapes” to be discussed in Sect. 9. In fact, these chimeras are animals that the laws of the DNA have never made but are hypothetically possible. Some researchers, however, have shown that if these impossible forms ever found space in the timing of the expression of the regulator genes that produce the shape of the body, then the new morphological structures thus produced would influence brain function, even if the changes affected only sensory structures and not cerebral ones. This can be seen in the case of three-eyed frogs, that is normal two-eyed frogs onto which an embryonic third eye has been transplanted (Marcus 2004). These are normal two-eyed frogs which have a genetic program and related sensory afferent and motor efferent structures to produce two eyes, onto which an “alien” eye is added.

What happens in these “laboratory experiments”? An interesting result is that the chimeric animals develop columns of visual dominance typical of those found in many mammals. These stripes, characteristic of many mammals, for example, in mice, are not present in normal two-eyed frogs, the DNA of frogs found in nature does not “build” their brain dominance columns: the modification of the sensory structures, then, is produced during an unprecedented change in brain organization. This is a clear example of how the body represents a strong constraint for the brain, but not the contrary.

Sensory disorders, in fact, demonstrate that the brain that is not subjected to a certain type (visual or auditory, for example) of perceptive afferent, still displays at the birth the cortical structures useful to process “sensory-specific” data, and that these cortices undergo a refunctionalization when they receive no further sensory-specific impulses. In this case, the cortices are delegated to other forms of sensory processing (Kral and Sharma 2012; Merabet and Pascual-Leone 2010).

Typically the congenitally blind have a visual cortex which is functionalized for auditory purposes: this change in cortex function seems to determine the higher capacity of blind subjects to perceive environmental sounds, both for the recognition of persons, and for spatial localization (echolocation). Conversely, the auditory cortex of a congenitally deaf person is refunctionalized to visual purposes.

The brain that has no sensory afferents develops the same cortices thanks to the genetic program that constitutes its internal form: once these afferents are not present, its intrinsic plasticity allows the assignment of specific sensory cortices to other modes of perception.

That brain organization has genetic limits which establish its shape and predisposition is also evident from the results produced by laboratory studies in which the sensory afferent pathways have changed. In this case, we are not confronted with diseases, or “errors” produced by nature: the researchers have developed experiments allowing one to understand how the shape and the initial wiring of the brain were controlled genetically and how much depended on experience. To obtain this data, it was necessary to alter the afferent pathways of the brain before birth, that is “creating” animals with a genetic mutation that prevented the afferent nervous lines from reaching the cortex.

All sensory information has a specific afferent pathway, first towards the thalamus (except for the olfactory perception) and then to the specific sensory cortex. For instance, pieces of information captured by the “dark room” of the eye are transduced into the optic nerve and conducted to a contralateral nucleus of the thalamus specific to visual information and from there they are sent to the primary visual cortex (Pinel 2006). Researchers have modified mice by interrupting afferents between the thalamus and the cortex. If the signals from the thalamus were central for initial cortical formation, then the mutation would result in obvious abnormalities in the development of the cortices of mice. The mice with the mutated thalamus showed specific sensory cortices (Miyashita-Lin et al. 1999): damage to the sensory afferents would not interrupt the genetic program that structures the shape of the brain, while an extra eye would produce a new brain organization never seen before.

Re-functionalization of the cortical areas is established in a much stronger way when it occurs in early stage (i.e. at birth) and concerns perceptual systems, while the plasticity of brain circuits is highest for the cognitive activities. Essentially, plasticity is more limited in the perceptual domain than in the cognitive one. Takesian and Hensch (2013) use a clear example of the physiology of learning languages to demonstrate the difference between perceptual and cognitive plasticity in adults. The two scholars argue that the ability to hear “r” or “l” can be lost in the primary auditory cortex in Japanese natives, but the same natives are not prevented from acquiring a second language. According to these authors, plasticity in *Homo sapiens* is present throughout life, especially in the associative areas and this supports the hypothesis of a hierarchical nature of the flexibility of the functionalization of the brain. Interestingly, this type of hierarchy is also present in the brain circuitry of some primates (Condé et al. 1996).

It is also true that when the cognitive dimension directly involves perceptual afferents, it is possible to observe strict limitations in plasticity. This is evident in some neuropsychological syndromes. Brain plasticity in the adult also helps to recover some cognitive function following brain injury. It is known that patients suffering from brain damage can recover lost capacity thanks to vicariation by the brain areas surrounding the lesion that take on board the functional load of those already damaged (Denes and Pizzamiglio 1999). As is already known, this capability depends on the extent of the lesion both at the cortical and at the subcortical level. Rehabilitative possibilities of Broca’s aphasia subjects derive precisely from post-trauma plasticity.

Sometimes, though, brain plasticity is not effective, as in the case of the phantom limb syndrome, a neuro-psychological disease in which the person who has suffered amputation of a limb continues to receive painful sensory afferents from the limb that no longer exists. This mechanism is related to the phenomena of plasticity failure: the body is “tactilely” represented on the cortex in a specific way (somatotopic cortex) with a topography that does not respect the body proportions but the distribution of the receptors on derma (for example there are more receptors on the palm of our hands than on the arm). When one of the limbs is amputated, a condition could occur in which the cortical representation of that limb continues to persist, despite the fact that the limb is no longer there physically (Ramachandran et al.

1995) and there are no tangible signals from the limb. The only way to relieve the pain is to “trick” the brain with a mirror into believing that the limb is still present and synaesthetically stimulating plasticity through visual perception (Ramachandran and Rogers-Ramachandran 1996).

This data shows that brain plasticity is a feature of the brain that allows growth, learning and functional reorganization, and also makes the brain evolutionary dependent on morphological constraints.

Some researchers have attempted to explain brain plasticity by using an evolutionary point of view, arguing that in *Homo sapiens* this intrinsic characteristic of nervous cells is the result of the neotenic nature of the human brain (Bufill et al. 2011). Neoteny is a feature of some organisms which show juvenile features in adults. This retention depends on immaturity, a delay in the somatic development (Gould 1977). This delay, of course, is restricted to certain morphological structures. According to one of the most important scholars of evolutionary modern synthesis, humans are “essentially neotenic” (Gould 1977, 365). Without going into the details of the epistemological debate on neoteny, it is interesting to note that, according to Gould, neoteny allows humans (and their brain, in particular) to “escape” hyperspecialization: a functionally “immature” brain is flexible and allows one to respond even to bodily afferents that the strict laws of genetic determination have not contemplated.

The brain of *Homo sapiens*, with its characteristic convoluted shapes and its susceptibility to the plasticity of connections, is a highly performative organ, that is dependent on how morphological structures are made and is capable of producing functions by performing them. According to one of the founding fathers of the studies on brain plasticity:

changes explaining progressive performance improvements achieved via operant conditioning provided a more direct and more complete accounting for the evolution of human performance abilities, showing that the acquisition or progressive improvement of a skill or ability at any age of life was directly attributable to connectional (and other physical) remodeling (Merzenich et al. 2013, xxiii).

Chapter 13

Evolutionary Plasticity

In functional terms, the brain is a powerful biological instrument permitting continuous reorganization of the activity of organisms. An incessant activity of biological agents that move and act, that perceive and explore the world around them through a network of sensors and nerves, whose complexity of articulation is directly dependent on the species-specific structure. This activity relentlessly stimulates the rewiring of sensorimotor networks and remodeling of cognitive interactions. Our mind is the result of this close cooperation between the performative competence triggered by sensory-motor systems and the readjustment of the computational procedures of our deep brain to allow the survival and growth in the fitness of individuals and the entire species within environmental variation.

In the functional reconstruction we have so far tried to propose, performative competence describes the individual and collective behaviors that seem geared to different procedures from those originally considered by cognitive sciences. Incoming stimuli are not processed by a set of internal computing mechanisms, i.e. autonomous rules that are entirely intrinsic to innate mechanisms of thought, which always produce calculable output, except for errors or alterations of the machine procedure. Conversely, the performative inputs redetermine the rules and their countless combinations implemented by the “black box” create unexpected behaviors. This behavior should be tested in more or less extended temporal spaces by generating adaptation and fitness for the organisms. On the one hand, this mechanism starts from the “flaw” of performative competence, and proceeds in the absence of algorithms which have already been formalized and are available for application. On the other hand, it highlights the possibility of producing innovative types of behaviour: in fact, these unexpected cases “oblige” the central structure by reincorporating them within our knowledge, in new and broader coordination and control systems, creating new algorithms that could automatically produce (but it is not obvious that this will occur) new knowledge gained from exploratory activities. Essentially, it is the motor activity of our bodies that generates innovations that are ruled by our plastic brains. Change is always triggered by the bodily organs; the

brain intervenes functionally later supporting the organism to free it from the anguish of uncertainty, from the horror vacui of the inapplicability.

Of course, the brain is also part of our body, as well as the mind generated by this continuous cooperative processing. If we didn't think so, we would remain fatally trapped in the dualistic residues and the Platonism typical of CBM, discussed in detail in Chaps. 2 and 3. However, it is the biological status, the specific type of constraints which the brain obeys, that makes it functionally different in nature from other parts of organisms:

our brains are set in gray matter, not in stone; their parts are predisposed but not absolutely preset for particular functions. They are built of general-purpose bioprocessors that, after being formed, become specialized in response to their inputs and outputs – not of pre-evolved, rigidly specialized processors. There may be a protomap specifying which is to happen, yet this is easily rubbed out. Thus, neural abilities may be fated, but they are not determined (Skoyles and Sagan 2002, 26).

The structural plastic difference in cytological nature, between that part of the body we call the “brain” and all the other parts (muscular, skeletal, ligament, respiratory, digestive, integumentary system, etc.) that in symbiotic interaction determine the survival and adaptability of organisms, plays a biological decisive importance not only, as we have seen, in functional terms, but also, and perhaps most importantly, under an evolutionary profile. If the brain and, more generally, the nervous system, have to be subjected to the same slow, progressive modification of the mechanical components, organisms could not survive.

The brain's development is so fast because its loop of continuous monitoring of sensorimotor events does not allow individual strips of behaviour to be negatively affected for a long time by performing indeterminacy, to suffer the pain of insecurity or the danger of extinction without the intervention of a specific adaptation to the kind of stress that comes from activation of the modified body (by endogenous or environmentally induced mutations). The neural rewiring timing modification and the structural evolutionary modification are immeasurably different. Any slight body modification can take millions of years, it can go through thousands of intermediate stages, and it can mark a variety of overt or silent evolutionary events. But meanwhile, at every stage, it will be constantly assisted by the plasticity of the nervous systems that do not function for even a moment without continually reformatting the cognitive systems as a whole. The birth of a new species can be thought of as a discrete state of this continuous process, a stage marked by the achievement of a new and stable order of bodily and cognitive ergonomics technology. This state is not inscribed in any predictable historical process. Natural selection and random populational variation may have been modelled, for a significant time, by the mechanical components of organizations, assisted by new functions of the neuro-cerebral systems. Only when these structures, shaped by time and the environment, and by individual and socialized use, have reached a certain random or historically unpredictable combination, only when a series of organic gears, levers, wheels, cams, pistons, lubricants and whatever can support the living mechanics, will these be fitted together in a structure that allows organisms to have different interactions with the world thanks to the evolutionary plasticity of the nervous systems, then and

only then an unedited species-specific cognition will enter into competition with other species.

Considering the plasticity of neurocerebral systems to be a permanent support to the evolutionary continuum of structures until they achieve the discrete stage (i.e. speciation) that constitutes a ratchet in the life of biological organisms is a truly Darwinian theoretical starting point, since it would cover all animal species, regardless of the complexity of their cognitive systems. Similarly, it may also serve to explain the specificity, if not the functional uniqueness, of all species, not just the human one. In other words, brain plasticity could minimize what the previous articulated theories split into inefficient and consistent dichotomies (structures/functions; nature/culture; gradualism/saltation; continuous properties/emergent properties, etc.).

However, a significant price is paid for these advantages in a new philosophy of biology that is no longer based on cerebrocentric models, such as those now demanding the priority of cognitive neuroscience in the cognitivist galaxy. In fact, the brain (the nervous system, more generally) fully takes responsibility in supporting the relentless evolution of bio-mechanical structures, but, accordingly, it cannot determine the directions of development, nor be the original cause of the functions they control. Brains do not cause developmental changes but allow the establishment of them. The body-brain always comes after the body-structure.

13.1 Chrono-Logical Causalism

As we mentioned in Sect. 5.4., Darwin had read a passage in Aristotelian writings that was considered to be a precursor to his idea of natural selection, worth quoting here in full:

οὐ τούτου ἔνεκα ὦει ὅπως ἀπόληται, ἀλλὰ τοῦτο συμβέβηκεν· ὥστε τί κωλύει οὕτω καὶ τὰ μέρη ἔχειν ἐν τῇ φύσει, οἷον τοὺς ὁδόντας ἐξ ἀνάγκης ἀνατεῦται τοὺς μὲν ἐμπροσθίους ὅξεις, ἐπιτηδείους πρὸς τὸ διαιρεῖν, τοὺς δὲ γομφίους πλατεῖς καὶ χρησίμους πρὸς τὸ λεαίνειν τὴν τροφήν, ἐτεί οὐ τούτου ἔνεκα γενέσθαι, ἀλλὰ συμπεσεῖν· ὁμοίως δὲ καὶ περὶ τῶν ἄλλων μερῶν, ἐν ὅσοις δοκεῖ ὑπάρχειν τὸ ἔνεκά του. ὅπου μὲν οὖν ἄπαντα συνέβῃ ὥσπερ κάν εἰ ἔνεκά του ἐγίγνετο, ταῦτα μὲν ἐσώθη ἀπὸ τοῦ αὐτομάτου συστάντα ἐπιτηδείως· ὅσα δὲ μὴ οὔτως, ἀπόλετο καὶ ἀπόλλυται (Aristotle PH, II B, 8, 198b, 17).

why then should it not be the same with the parts in nature, e.g. that our teeth should come up of necessity – the front teeth sharp, fitted for tearing, the molars broad and useful for grinding down the food – since they did not arise for this end, but it was merely a coincident result; and so with all other parts in which we suppose that there is purpose? Wherever then all the parts came about just what they would have been if they had come be for an end, such things survived, being organized spontaneously in a fitting way; whereas those which grew otherwise perished and continue to perish (Aristotle PH, II B, 8, 198b, 17 – ed. Ross, Phys, 647).

Here Darwin admits the historical precedent of his hypothesis, but he complains about the lack of analysis undertaken on this principle by reference to the fact that teeth, too, would be formed as a consequence of a selection process and not by

chance at all. Here, actually, the “finalist” Aristotle (Solinas 2015) seems even more naturalistically close to the “functionalist” Darwin. In fact, in this passage Aristotle tends to give priority to the neutrality of the structure that has a certain random conformation. The casual conformation of the structure – through the possible options and then the continuous changes in a certain direction (in this sense the *τελός* of the front teeth is the tearing of meat whereas that of the molars is chewing in order to fragment food) – becomes a specialized part of a fully functional totality with a purpose (i.e. feeding). More generally, the naturalistic principle of the performative nature of the body structures emerges here. In particular, this performative principle is evident in the mechanical and sensorimotor structures tending towards something that solicits and generates change, without a precise pre-determination.

As we saw in Sect. 5.1, Aristotle of course moves in a epistemological horizon devoid of the “organizer reference” of the nervous system, which is erroneously replaced by the network of blood vessels and the heart. In his reconstruction of corporeal functions, the brain seems to be an organ considerably lacking in mechanical connotation to be able to perform control tasks: in the Aristotelian physiological scheme, the material of which the brain is made relegates it to the rank of blood temperature cooler. From one point of view, however, the lack of cognitive centrality of the brain allows Aristotle to explain a principle which will be decisive for the history of naturalism until modern evolutionism: the irreplaceable role of natural selection which gradually alters all mechanical structures regardless of any program, project or volition.

From this point of view, Aristotle seems to substitute the matter’s intrinsic finalism with the logical causalism of succession: that is, the evolutionary causalism of “before and after”, the irrefutably chronological sequence of states of biological life. This eradicates any possible eschatology: it is not at all certain what will evolve in a certain way, predictable because designed or functionally inevitable.

However, a certain functional outcome would not simply exist if its antecedent did not exist: in this sense the cause of a given state of affairs is always its previous state: “ἔτι ἐν ὄσοις τέλος ἔστι τι, τούτου ἔνεκα πράττεται τὸ πρότερον καὶ τὸ ἐφεξῆς” (Aristotle PH, II B, 8, 199a, 8–10) (“where a series has a completion, all the preceding steps are for the sake of that” – ed. Ross, 647) in fact “ὅμοιως γὰρ ἔχει πρὸς ἄλληλα ἐν τοῖς κατὰ τέχνην καὶ ἐν τοῖς κατὰ φύσιν τὰ ὕστερα πρὸς τὰ πρότερα” (Aristotle PH, II B, 8, 199a, 18–9) (“artificial products are for the sake of an end, so clearly also are natural products. The relation of the later to the earlier terms of the series is the same in both” – ed. Ross, 648)

So there would be no saw for cutting if there was no iron to make it, or there are no houses where one can live if there are no bricks and stones to build them (Aristotle PH, II B, 8, 200a, 10–25). Similarly, in nature, the roots of the plants grow down because there exists before them “Mother Earth” that is rich in nutrients. And so, in order to define a human being, it is essential to assume the continuity of its states which, once occurred, we can only reconstruct by describing how they are embedded within each other: “οὕτως καὶ εἰ ἄνθρωπος τοδί, ταδί· εἰ δὲ ταδί, ταδί” (Aristotle PH, II B, 8, 200b, 3–4) (“if man is this, then these; if these, then those” – ed. Ross, 651).

In naturalistic thinking, both scientific and philosophical, the principle of chronological causalism has always been a fixed point, the firm anchoring of man to his animal roots. In *De Rerum Natura*, by Lucretius – opposing the finality of the Stoics – it is claimed that functional facilities are unpredictable:

nil ideo quoniam natumst in corpore ut uti possemus, sed quod natumst id procreat usum.
 Nec fuit ante videre oculorum lumina nata nec dictis orare prius quam lingua creatast, sed
 potius longe linguae praecessit origo sermonem multoque creatae sunt prius aures quam
 sonus est auditus, et omnia denique membra ante fuere, ut opinor, eorum quam foret usus
 (DRN IV, 822–857).

(since nothing was born in the body that we might use it, but that which is born begets for itself a use : thus seeing did not exist before the eyes were born, nor the employment of speech ere the tongue was made; but rather the birth of the tongue was long anterior to language and the ears were made long before sound was heard, and all the limbs, I trow, existed before there was any employment for them : they could not therefore have grown for the purpose of being used) (DRN IV, 822–857, ed. Munro, 190).

This anti-Lamarckian *ante litteram* profession is backed up by a tight logical and biological argument that is still very current. The sharpness of the eye vision is not the result of an intelligent design, nor the locomotor apparatus, nor the human organization in the lower limbs and upper limbs respectively used to move and to produce tools, but owes something to the generosity of a God dominating nature and conditioning it: “cetera de genere hoc inter quaecumque pretantur omnia perversa praepostera sunt ratione, nil ideo quoniam natumst in corpore ut uti possemus, sed quod natumst id procreat usum” (DRN IV, 822–857) (“other explanations of like sort which men give, omnia perversa praepostera sunt ratione, one and all put effect for cause through wrongheaded reasoning”, (DRN IV, 822–857 – ed Munro, 190).

The correct relationship between the before and after, between the chrono-logical causality and unpredictable outcomes of social uses of the possible functions determines the direction of evolutionary history. As in any naturalistic philosophy, this causality is beyond the control of individual subjects and exclusively relies on the adaptation that only can avoid extinction in a regenerating alternation of life and death. In the same way, our brains can only control and direct the bodily apparatus but cannot prevent the apotheosis or the collapse of the species.

Perhaps, the philosophical voice that insisted most on these brain limitations is that of Henri Bergson, many centuries after Greek-Latin classicism. We assume that his idea about the neurocerebral apparatus is much more mechanistic than his spiritualist vitalism. In *Matière et mémoire*, the brain is considered “a kind of central telephonic exchange”, (Bergson 1896, 10) that takes care of dispatching notices, inhibiting them, fostering them, making them wait. It “adds nothing to what it receives” (10): it coordinates the stimulus and decentralizes the answers; it connects through cord and peripheral nerve excitations with central mechanisms; it directs and chooses the motor pathways. In short “the brain appears to us to be an instrument of analysis with regard to the movement received, and an instrument of selection with regard to the movement executed” (10), but in no case can it be considered an organ designed to prepare or explain a representation. Similar judgments have been confirmed, even in later writings. It is treated as a “crossroads” of vibra-

tion, a “switch” that addresses possible actions (Bergson 1911), and as an “organ of pantomime” of mental life (Bergson 1912, 58 and 1913, 92).

Despite these limitations, its continuous supervision work of motor activity and, above all, its selective role with respect to the virtual possibilities offered by the rest of the body, transform the brain into an organ of survival and adaptation. So at the same time, the brain becomes “the organ of attention of thought to life” (Bergson 1913, 93) and the organ of “racial [species] attention” (Bergson 1913, 95 and 1908, 178). *Attention to life*, for Bergson, is the ultimate subordination of mental life to practical activities, to the selective primary needs: the most important cognitive function for self-preservation.

Therefore, at the same time, thanks to its ability to select only what is essential for survival contextualized in a precise moment of time, space, and psychological and social environment, and its capability of “masking”, and ignoring everything that is extraneous to pragmatic contingency, the brain locates the existence of individuals and species, it locates them in action and focuses on behavioural opportunities.

Without this continuous liberation of organisms from what is unnecessary or even harmful in every single action, the individual would result in mental disorders, while the species would risk extinction. Bergson is among the few scholars to understand that psychopathology does not involve the violation of the logic, linguistic or abstractly rational rules (Pennisi 1998, 2001, 2012b).

In this field of study, indeed, a great follower of his has detected the presence of a form of “morbid rationalism” in the reasoning of psychotic subjects (Minkowski 1966, 1997). What makes people individually displaced, deprived of “natural evidence” (Blankenburg 1971) is the chronic loss of attention to life: such an extreme pragmatic inadequacy, such a radical decentralization from their own form of existence becomes a “failure”, and consequently a “failed existence” in the word of Binswanger (1956). If attention to individual life becomes weak, then the individual could be projected into the absence of a “continuous attention common to us all, imposed by nature” and it is precisely that “attention of the species” would lacking (Bergson 1913, 95; 1908, 178 e 1919), that attention played by the brain for preserving from biological pathology. Then, attention to life is “a present that lasts” (Bergson 1911, 909). Basically, it is the way in which the brain becomes permanently available to connect the action with sensorimotor systems, the environmental stimuli, and the cognitive understanding about the world in a stable and constant manner. Recycling their lack of functional specialization in a universal pragmatic adequacy mechanism could be the biological vocation of brain plasticity.

We can find few developments in the area of philosophical speculation (although they are highly permeated by the scientific knowledge of the time). For example, one of the pioneers of current neuroscience, Ramachandran, translates the brain’s “negative” capacity, first identified by Bergson, to obscure that which is not essential to the pragmatic behavior of selection, in a precise neurophysiological pattern. According to Ramachandran, many bizarre types of behaviour such as synesthesia, the manifestations of hysteria, phantom limbs, blind vision, spatial neglect, the extensive catalogue of expressions of autism spectrum disorders, result from the

fact that the brain is not capable of overlapping its modules: “here is a bottleneck of attention. You can only allocate your attentional resources to one thing at a time” (Ramachandran 2003, 76). The principle that “less is more” allows our brain to focus entirely on what it needs to survive. This “principle of modular isolation” (Ramachandran 2003, 55.) (or “law of [modular] isolation”, 75) would explain, at the same time, the ability to enable some autistic subjects to excel in design, numerical computation, or other modular specializations, and the logic of evolutionary selection that circumscribes and improves the behavior of the species by solely optimizing the behaviors best suited to survival, for example, protection from predators, hunting prey, foraging in general and reproduction. In either case, it is never a choice. In diseases we are forced to divert optimization towards the modules of intact behaviors because (probably) some parts of our neurocerebral system, which are normally used to control those behaviors, are somehow compromised or neutralized. In selective logic we are constrained by neurocerebral systems that are in constant contact with the environmental sensors and that hierarchize the answers on the basis of context requests. It would be a serious evolutionary disorder that would make animal brains indifferent to “attention to life”.

In carrying out this essential monitoring attentional work, under both functional and evolutionary profiles, the neurocerebral system is facing not only external enemies but also, and perhaps above all, inside antagonists: the rest of the body where “he lives”. The relationship between the bodily technology of a species and its cognitive ergonomics, that monitor and regulate it, is at the origin of all manifestation of genotypic (before) and phenotypic (after) plasticity; then it always prioritizes the relationship between the species and its cognitive ergonomics. According to Ramachandran (2003), “in the biological sphere, opportunistically abduction of a structure to induce it to perform a different function from that it was originally evolved to carry out is not the exception, but the rule”.

Recently, Pievani (2006) considered Ramachandran’s hypothesis of “the central focus of an evolutionary conception of biological plasticity”. In the DBM, this proposal would be absolutely acceptable, provided one disconnects it from any anthropocentric cerebrocentrism to which it is likely to be sometimes associated. In fact, processing power and brain plasticity are often mixed up and confused in cognitive neuroscience and philosophy of mind (Churchland 1979; Lerner 1984; Malabou 1995; Malabou and Shread 2012; Vincent and Lledo 2014; Freeman 2000; LeDoux 2002; Lynch and Granger 2008) and also in various neo-evolutionary hypotheses (Platek and Shackelford 2009, Corballis 1993). Sometimes it appears that the complexity of the human brain, consisting quantitatively of more than one hundred billion neurons that potentially give rise to a combination of mental states exceeding “the number of elementary particles in the known universe” (Ramachandran 2003, 13), should lead to its in-commensurability quality compared to the neurocerebral systems of all the other species. The human brain, however, is quite “commensurate” to any other brain, under both its quantitative and qualitative aspect, as many experimental and/or reconstructive studies have demonstrated (Allen 2009). Of course, this does not mean that sometimes human mental capacities cannot seem to us surprising, with a very popular formula being discussed in the cognitive disclo-

sure paper, “only human” (Berwick and Chomsky 2016; Hurford 2008; Gazzaniga 2008; Lieberman 1991 and 2013). However, it should not be forgotten that many other forms of ecological intelligence, or species-specific knowledge, would also surprise us and, above all, could not be explained by using the same scheme of interpretation we adopt when we measure the products of the human brain. Although this kind of consideration lies outside the scope of this book, we are interested in pointing out two principles we consider essential for a genuine Darwinian theory. The first principle is that what even appears as “unique” from an evolutionary point of view (structure, skills, abilities, behavior, etc.) must be empirically measurable. The second principle is that whatever the cognitive species-specificity we want to measure, it must always be subjected to the common constraints of all living biology. What we consider to be the main constraint is that any mental performance is always the expression of an overall structure of the organism or, more provocatively, that brains are the “tenants” of the bodies that host them.

13.2 The Brain *Tenant* of the Body

This effective expression was formulated by the founder of modern evolutionary paleoanthropology, Leroi-Gourhan (1964, 37 and 47; 1983, 25). To understand the meaning of the term, it should be noted that its creator was the first scholar to propose the idea that human lithic technology, the art of artificially modifying the matter, and more generally cognitive evolution, is the result of a complex transformation not only of the brain but of the organism as a whole. Often, Leroi-Gourhan formulated provocative paradoxes to highlight the importance of these scientific issues, as illustrated by one of his mottos: “human evolution did not begin with the brain but with the feet” (Leroi-Gourhan 1964, 229).

Leroi-Gourhan wanted to prove that many philosophical or religious theories of evolution – starting from those of the theologian Teilhard de Chardin – had started to proceed, often unintentionally, to finalistic paths with little critical spirit, and embraced the idea that evolution was characterized by a gradual increase in the size of the brain that caused an automatic development of increasingly complex cognitive faculties.

According to this hypothesis – that still exists today, see the picture (Fig. 13.1) taken from a recent essay by Chomsky and collaborators (Bolhuis et al. 2014) – evolution manifests itself firstly in the improvement of brain functional dispositions, and secondly in the resulting adaptation of mechanical dispositions: “the relations between the contained and the container” (Leroi-Gourhan 1964, 59). According to Leroi-Gourhan’s reconstruction, the flaw in this degeneration of evolutionary thought is due to the excesses of finalism, a convenient but very risky shortcut that only a rigorous analysis of the species’ mechanical consistency can avoid to derail by scientifically acceptable paths. In fact, the evolution of the neurocerebral system follows the constraints imposed by the evolution of the mechanical parts. We can image a carnivore skull with a brain the size of a nut and the rest of the skull being

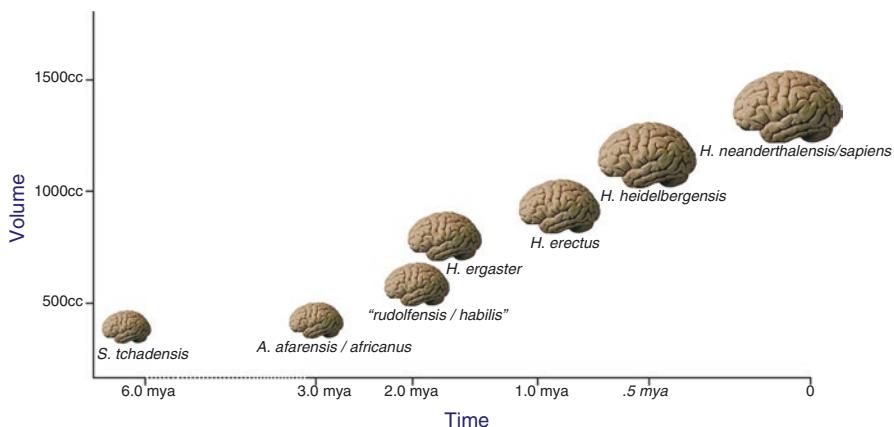


Fig. 13.1 Cognitive-brain evolution, source: Bolhuis et al. 2014

filled with bone crests and muscles, or a skull with the same shape and size as the first skull but filled with cluttered grey matter to the roof of the cranial vault. This allows us to understand the case of the evolution of hominids who can share the same bodies but not the same brain development (Leroi-Gourhan 1964, 31 et seq.).

Therefore, the teleological assumption that, as brains get bigger then cognitive abilities increase, must be subjected to a comprehensive review, as one must take into account the inseparable relationship between the structural morphology of the mechanical organs, and the specific morphology of the brain and the nervous system and that of the functional adaptations that enable the survival of the species.

It is here that the chrono-logical causalism that had secretly permeated the history of evolutionary thought, and that we have discussed above, plays an important role. This involves the renunciation of ruling cerebrocentrisms: “the ‘cerebral’ view of evolution now appears mistaken, and there would seem to be sufficient documentation to demonstrate that the brain was not the cause of developments in locomotory adaptation but their beneficiary” (Leroi-Gourhan 1964, 26). As in the Aristotelian game of “before and after”, according to Leroi-Gourhan, brain development can never be the cause of the development of the rest of the body:

although this has been at least implicitly supposed in the past, the expansive force of the brain cannot have acted as the motive force in the evolution of the skull. The number of nerve cells cannot increase before the edifice has been enlarged. Even we regard cerebral expansion and spatial improvement of the skull as a single phenomenon, we have to acknowledge that the brain ‘followed’ the general movement but did not generate it (Leroi-Gourhan 1964, 81).

From one point of view, such a clear position seems to be illustrated by Columbus’ egg. The mechanism of every evolutionary change has to be sought in the history of the changes of the mechanical structures of the body: primarily bones, muscles and all that regulates their growth and metabolic functioning. The genetic mutations that can cause these variations will be filtered by populational selection, of course, and those that will survive throughout the course of many generations will have deter-

mined a new stable genotype and, at the conclusion of a complete morphogenetic restructuring, a new species.

In the case of the human species, this complex process is pivotal to the achievement of the upright position. In fact, it causes a double “catastrophe”: firstly it frees the upper limbs establishing a new special relationship between them and the brain, and secondly, it allows the increase in skull size with subsequent development of the cortical fan. Recent studies have reported that this structural transformation also favoured the lowering of the larynx and the formation of a supralaryngeal vocal tract with two curved portions with a 1:1 length ratio (Ghazanfar and Rendall 2008). Then, starting from the feet and cascading upwards, the rest of the body was developed including the brain. However, when one considers the role of structure and brain function, there is no doubt that, under the principle of chrono-logical causality, without the revolution in bone structure, cognitive revolution would never have existed.

Therefore, far from being mere externalizing devices of computational algorithms that belong to a predestined mind, the mechanical components – but more broadly all body structures – determine the cognitive opportunities that the neuro-cerebral system has to manage in the best way possible.

Therefore, in relation to the randomness of chronological evolution, the brain evolves after the rest of the body, i.e. the brain must follow the body and be recruited for its survival. For this reason, the brain is the “tenant” of the body:

the brain, whose role as coordinator is obviously a primordial one but which functionally appears the ‘tenant’ of the rest of the body. This situation of the brain, which could be described as subordinate to the edifice as a whole, has been noted and recorded many times without its significance being wholly clarified (Leroi-Gourhan 1964, 37).

the brain, modest ‘tenant’ of the cranial cavity, plays a mechanically passive role. The apparatus that it will presently animate is there at its disposal, but its role in the evolution of forms is not immediate or direct, making itself no doubt felt in the Darwinian selection of the fittest forms but not, so far as we can see, providing any mechanical impetus. It is in this sense that I regard the development of the brain as an element incidental to evolution in general. This in no way detracts from the well-established truth of the nervous system’s evolution toward increasingly complex structures. Between the evolution of the brain and that of the body there has been a dialogue from which both sides have benefited. Evolution can of course be viewed as the triumph of the brain, but it is a triumph subordinated to certain overriding mechanical realities. In the progression of the brain and the body, at every stage the former is but a chapter in the story of the latter’s advances (Leroi-Gourhan 1964, 47).

The thinking behind this reverse order (compared to the evolutionary thought of that time) in chronological randomness is not limited to the problem of priorities of the bone structures in determining brain shape. Since the bipedal revolution and liberation of the hands, an extraordinary series of unexpected visual, postural and sensory-motor possibilities have been derived with the brain guiding a new machine capable of unexpected cognitive ability. Man’s vertical position caused revolutions in “terms of neuropsychological development; the development of the human brain was something other than just an increase in volume” (Leroi-Gourhan 1964, 19).

Take, for example, the change for hominids in their front horizontal field of view compared to that of quadrupeds, that are limited in this regard by the horizontal position of the trunk relative to the head, by the insertion of the neck muscles and by the inability to have a wide rotation of the visual axis. Or consider the changes in bodily technology applicable to extracorporeal technologies: hands capable to beat, cut, make autonomous and micrometrically controlled movements thanks to increasingly sophisticated sensorimotor rewiring: hands that can dismantle bombs, clocks, precision devices and that can use large, small and very small tools with an unthinkable accuracy. And finally, new specialized structures dedicated firstly to breathing and then to vocal production which provide greater and better control of articulated vocalizations (which we will see in detail in the following chapter).

Therefore, functions are completely redefined by the brain based on the opportunities provided by the new structure and induced by the body's live mechanics (the *Mécanique vivant*, 1983). In fact, during the evolutionary processes of any species "we observe a gradual enhancement of the brain and an improvement of the mechanical apparatus by a series of adaptations in which the brain obviously plays a role, but as a determinant of advantages in the natural selection of solutions rather than as a factor directly orienting physical adaptation" (Leroi-Gourhan 1964, 60).

Another essential aspect of the evolution of the brain is cortical structure. This is not directly dependent on the brain size but it is linked to the ability to determine behavioural functions and, therefore, functional mapping, which is better understood now than during Leroi-Gourhan's time. From the work of Penfield and Rasmussen (1950) on the mapping of the neocortex, he concludes a very pertinent fact with his assumption of interdependence between the nervous system and the musculoskeletal system. If in human primates much of the cortical surface is occupied by the areas controlling manual skills and linguistic articulation, it is evident that the bipedal revolution and the consequent settling of the entire body structure have fostered a development of the nervous system functional to technologies and word use (hence the title of his whole book *Gesture and speech*). In fact, as we will see in Sect. 14.2, most recent research has constructed a species-specific map of the human laryngeal phonation area (the larynx-phonation area) which has been derived from a migration from the homologous primate (zone 4 of the premotor cortex) to the specific human one (zone 6 of the premotor cortex).

Once this interdependence between the nervous system and other parts of the body causing evolutionary change is recognized, it is clear that increased brain size, in addition to its more complex internal structure (gyrification of the cerebral cortex, increased connectivity between functional areas of the cortex, enhanced interneurons in modulating functional connectivity, lateralization), although inherited and modified over time, represents a huge indirect step forwards in the history of hominization (Rakic 2009, García-Moreno et al. 2011, Clowry 2014). Species with "liberated" hands are the same species in which the skull is capable of containing the largest brain: "manual liberation and the reduction of stresses exerted upon the cranial dome are two terms of the same mechanical equation" (Leroi-Gourhan 1964, 60).

In general terms, the human situation is a special case of a universal law. For each species, in fact, “a cycle is established between its technical ability (its body) and its ability to organize itself (its brain)” (60), the outcome of which opens the way to an ever more effective and selective adaptation. It is then true that a quantitatively more developed brain, thanks to a bodily device which has allowed it to expand, ends up being able to develop neural and mental functions, and therefore more elaborate and complex functions, but always in relation to the limits that the type of species-specific body structure establishes. In this way – Leroi-Gourhan concludes – “the brain does control evolution, but it remains ineluctably dependent upon the possible range of selective adaptation of the body” (60).

From this theory of cognitive interdependence between the neurocerebral system and other systems of the *mécanique vivant*, Leroi-Gourhan also derives a particular interpretation of the evolution of brain plasticity that, in many ways, is comparable to that of Konrad Lorenz (1959), according to which man is the most eurytopic animal, a real “specialist in non-specialization” (see Chap. 7). According to these interpretations, what characterizes human nature is the absence of a fixed and unchanging one-to-one correspondence between organs and dedicated functions. Of course, the heart, lungs and other organs essential to survival remain bound by their vital functions. However, often many human organs lend themselves to unforeseen exaptations. For example, vocal articulation exploits breathing structures; the ability to produce artefacts and technologies exploits the upper limbs; etc. In general, “the human appears as the inheritor of creatures that escaped anatomical specialization” (Leroi-Gourhan 1964, 117–8). Teeth, hands, feet and even the human brain have avoided achieving a level of specialization similar to that of other animals that fail to use their body parts in different ways. For instance, the mammoth whose teeth had evolved into hooked fangs only suitable for defence, or the lower parts of the limbs of the ungulates, such as horses or zebras, which are ideal for moving more quickly. Or consider the metabolism of the koala which can only digest the leaves of eucalyptus or hypercarnivores who are used to high-protein diets: in these animals minimal environmental changes can create conditions which could lead to their extinction. But man remained a functionally mouldable animal: he is omnivorous, he uses limbs for running and walking but also knows how to use his hands for an astoundingly wide range of different things: scratching, tying his shoelaces, reporting, producing tools and using them with the expertise as we have already previously discussed. According to Leroi-Gourhan, all this is possible because his brain “remains capable of thinking everything and it is virtually empty at birth” (Leroi-Gourhan 1964, 228) and this allows him to become “superspecialized in the skill of generalizing” (118). A similar argument is supported by Gould (1977, 365), who imputes this brain flexibility to the neotenic nature of *Homo sapiens* (as we saw in Sect. 12.2).

Of course, as in all these hypotheses, one point remains unclear, that is the structural way through which the human brain has developed this hypercapacity of generalizing, the capacity that makes it evolutionarily flexible and adaptable to very different and highly variable environmental conditions. In a sense, to avoid answering this question, one could apply Leroi-Gourhan’s evolutionary epistemology to

the brain plasticity hypothesis: since the brain is always dependent on body mechanics, how can we explain the “mechanics” of the body that could have made the brain (and therefore human cognition) so neutral and then so powerfully flexible?

According to us, Leroi-Gourhan is not able to provide a clear answer to this question like the answer with which he attempted to reconstruct the logic of the relationship between the nervous system and live mechanics. Of course, he recognizes that the secret of brain generalization hides within language but, repeating the same Darwinian mistake, he does not realize that the physical structure of language is the key to explaining the power of the linguistic mind (1964, 86–9). Leroi-Gourhan has had the courage to claim that cognition begins from the feet and not from the head; but he has not recognized that language begins with its articulatory mechanism and not from the brain. To accomplish this last step, new knowledge and new empirical acquisitions were needed. One will need the most recent discoveries in paleontology and contemporary paleoneurology and the work of reinterpretation which the biolinguist Philip Lieberman has provided. But before acquiring this new knowledge, one needs to understand how evolutionary changes occur, another step in the reconstruction of the role of brain plasticity in human evolution.

13.3 Plasticity, Innovation and Re-Use in Evo-Devo

Is it possible to consider the attaining of an erect posture and the adoption of bipedal locomotion as a true evolutionary innovation? After reading Leroi-Gourhan’s works, it would seem easy to answer this question positively, but in the neo-evolutionary contemporary debate a new paradigm has emerged, complicating the overall epistemological framework. No one, in fact, has expressed doubts about the hypothesis that a musculoskeletal revolution can have led to the structural and cognitive changes that have marked the evolution of *Homo sapiens*. The problem that has caused the hottest controversy has more to do with a point of view than with facts. We have wondered: compared to what did those changes represent a novelty? What did they “revolutionize”? More generally, when can we speak of a real innovation in a theory of evolution like the Darwinian one in which the changes are always slow and gradual?

From this point of view, the origin of bipedalism and the origin of language (which we will return to in Chap. 14) are the most frequently studied topics amongst all the evolutionary problems. These problems constitute a real litmus test for a general evolutionary theory of innovation. They are also excellent examples of how difficult it is to clearly answer problems posed by science in which the object of study cannot be analyzed with experimental methods, but only through circumstantial surveys and speculative hypotheses.

Moreover, as repeatedly pointed out, not only by Leroi-Gourhan, but also by the most illustrious representatives of the new evolutionary synthesis such as Gould, the constant danger for the functionalist movement, which looks for an adaptationist *ad hoc* answer to any event of changes affecting the organism’s form and structure, is

when this is added to the previously described epistemological precariousness of evolutionary paleoanthropology. Just imagine that during the twentieth century no less than thirty different assumptions were evoked to explain bipedalism (Niemitz 2010). Among these assumptions there is the “Watching Out Hypothesis”— i.e. the idea that by standing on their front paws, primates would have acquired the visual advantage to overcome obstacles by more easily noticing the arrival of dangerous predators (Dart 1959; Rose 1976); the “Freeing of the Hands Hypothesis” – i.e. an ancient idea dating back to Darwin himself and then resumed by a large number of scholars during the 1950s and 60s, which details the human capacity to produce technologies, thanks to the availability of the hands; the “Throwing Hypothesis” (Kirschmann 1999; Young 2003), according to which motor control in launching weapons, stones, spears, etc. represented a major selective advantage; the “Infant Carrying Hypothesis” (Etkin 1954, Washburn 1967) which attributed the easy handling of infants by nomadic mothers to bipedalism; the “Reaching for Food Hypothesis” (Jolly 1970, Wrangham 1980, Hunt 1994) which attributed to bipedalism the greater chances of finding nourishment by being able to reach food positioned higher above the ground. This is sometimes combined with the “Carrying Food or Provisioning Hypothesis” (Hewes 1961) which emphasized the advantage of a bipedal gait in the foraging operation which is impossible without free-hands. And also various other hypotheses connecting, for example, bipedalism with better visual capacity, with the capacity of oscillation (orthograde scrambling) and being suspended on the branches of forest trees; with the ability to scavenge to find carrion to eat; with the aquatic origin of the first mammals; and with benefits for thermoregulation in the bush; etc.

This (partial) carousel of functional hypotheses – for each of which Niemitz (2010) appropriately points out an amazing amount of possible objections or real inconsistencies – is a glaring example of how dangerously speculative is the adoption of an exclusively adaptationist methodology; a methodology that is ultimately useless, just as in the case of an authentically Darwinian perspective.

If one loses sight of the principle of chrono-logical causalism, the result can only be a succession of more or less plausible hypotheses that at the same time are, of course, unprovable. It is like missing the main target linking evolutionary research to experimental research. This target involves the understanding of what has happened before in order to comprehend what has happened after. It is clear, in fact, that the apparent meaningfulness of each of the above illustrated functional hypotheses on bipedalism derives from the fact that, in any case, these hypotheses describe the consequences and not the causes, the events that came after the slow changes in the shape of the body structure and that resulted in useful behavioral adaptation and natural selection, through the possibility of reusing nervous systems that are responsible for implementing and rewiring the neuromotor and neurocerebralsystem.

The evolutionary innovation of classical theory seems cognitively blind to the dangers inherent in functionalism. According to Mayr, a pioneer of orthodox Darwinism, evolutionary innovation is simply “any newly acquired structure or property that permits the performance of a new function, which, in turn, will open a new adaptive zone” (Mayr 1963, 602, see also in 1960). More recent formulations,

derived from the adaptationist program, have considered any evolutionary improvement as an innovation on the basis of a heritable variation and a process of natural selection (Futuyma 1986; Rose and Lauder 1996). To practice this method, it is necessary simply to choose a single considered adapted trait and then to demonstrate its heritability and its relevance to the processes of natural selection. In this area of studies, more refined models have tried to measure the ratio between the quantity of micromutations and quality of innovation (West-Eberhard 2003).

Constructively criticizing these approaches, but not denying them *in toto*, Massimo Pigliucci (2008) has defined an evolutionary innovation as a “cluster concept” in the sense used by Wittgenstein (1953), which is a notion that does not allow definite boundaries but is the bearer of an actual distinguishing criterion. Innovation is hard to define, but it is easily recognizable. Its set-theoretical point can be discovered when it is possible to formulate a definition so broad so as not to confuse innovation with any change, but not so specific that it obscures or even prevents functional evidence. As well as the notion of “species”, in biology the notion of innovation must necessarily appear “fuzzy”. According to Pigliucci: “evolutionary novelties are new traits or types of behaviour, or novel combinations of previously existing traits or behaviors, arising during the evolution of a lineage, and that perform a new function within the ecology of that lineage” (Pigliucci 2008, 890). Evolutionary innovations resemble closely those constant states of physical and biological systems that complexity theory calls “attractors”. They open up the possibility of change between the start and end discrete states that always constitute “stable islands in phenotypic space” (892). The evidence of these states should not be confused, however, with the ease of its detection and with the approximated methodology used to formalize their existence. In this direction, Pigliucci considers it essential to theoretically define what evolutionary innovation is and provide a clear specification of its evolutionary history (in terms of phylogenetic events sequences), of its functional ecology within a population, of its phenotypic development, and of the type of genetic sustainability (underpinning) that made it possible.

The wisest epistemological reflection on the contemporary scene has recently attempted to achieve greater clarity on these problems by trying to formalize a precise difference between variability, change and real innovation in evolutionary processes (Newman and Müller 2005; Wagner A. 2011; Wagner G. 2014; Love 2015). The first principle inspiring these new hypotheses – matured within the framework of the Evo-Devo – is a progressive shift away from the functional dimensions of adaptation. The difficulties in defining the requirements of the *novelty* are all internal to the various structural parameters and their combinations, the different levels of analysis of form and their inextricable tangles, that are never related to the endless and “metaphysical” functional properties that they might take.

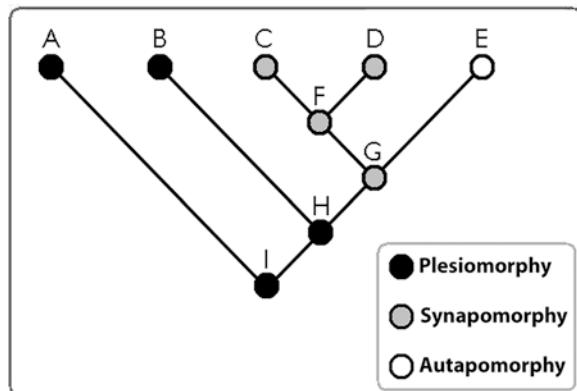
An important turning point in this debate has been the introduction of a series of purely morphological criteria. Müller and G. Wagner (1991) have criticized the adaptationist program because it has always considered the problem of innovation under a taxonomic profile and almost never “as a problem of the primary causes responsible for the generation of new anatomical structures” (230). The functionalist approach, whereby innovation is any structure allowing the adoption of a new

function, lends itself to a dual criticism. It is flawed by a principle of circularity (“new structures arise from new functions, and new functions from new structures” -1991, 231) and it would exclude all structures that are formed without a specific functional task, as in exaptations (the “Spandrels of San Marco”, Gould and Lewontin 1979). Even the assumption of the duplication of functions or organs – namely the possibility that an individual will simultaneously perform two distinct functions via the same organ (e.g., breathing and speaking) or of two separate bodies performing the same function (as in the case of gills and lungs) – proposed by Mayr (1960) to explain the transitions between a conservative and a innovative phase, even if facing an essential issue, fails to address the central question of what mechanisms have generated the new organs for the first time. More precisely, functionalism does not clarify “what precisely are the mechanical causes responsible for a specific morphological solution to a new functional and/or structural problem” (Müller and G. Wagner, 31) and it doesn’t even consider the possibility that the new structures can also arise without any change in function.

A morphological criterion for the novelty that aims to explain the generative mechanisms of morphological change must, however, confront two fundamental issues: the genetic and developmental foundations. In the first, it will be necessary to clarify the type of genetic change that makes it possible to inherit the phenotypic variation, and through what mechanisms of population genetics it can be permanently settled. This aspect of the generative problem, however, is substantially identical to that of classical mechanisms and it does not appear that it can promise revolutions in innovation theory. The latter will be essential in explaining the timing of phylogenetic changes and the speed of ontogenetic ones: in other words, the heterochrony of evolutionary processes that diagnose the primary factors of change. Heterochrony, however, can only make changes to processes already established. To identify the underlying causes of heterochronic alterations of a development process it will be essential to evaluate the hierarchical organization, the mutual interdependence and the overall equilibrium of species-specific biological systems through experimental measurements and comparative approaches.

An initial minimal definition of innovation that takes account of the critiques expressed against the functionalist approach and contributions of phylogenetic and ontogenetic developmental biology can be summarized in the simple statement that “all traits characteristic of a supraspecific taxon were a novelty at some point in the evolution of that group” (Müller and Wagner G. 1991, 236). This definition provides many advantages compared to the functional definition because it is not constrained by the innovation, by external criteria, by the shape or by general biological development, nor does it rely on a pure succession of speciation with defined borders. In fact, any morphological element can be considered a novelty not if it has specific taxonomic or functional characteristics, but if “it can become” functional inside a developmental process affecting a certain taxon. However, this initial definition is still too general, losing in perspicuity with respect to the qualitative value of the innovation. In fact, in relation to the general distinction, some morphological trait can be considered an analogy (if it performs the same function but it comes from different evolutionary structures, like the wings of birds and insects) or an homol-

Fig. 13.2 Cladistic typology of phylogenetic characters



ogy (if it is the same structure that performs several functions, like the limbs that are fins in fish, legs in mammal quadrupeds, wings in birds and arms in humans).

In fact, in a cladistic typology (Fig. 13.2), the novelty of that given trait may be measured whether it performs the role of a plesiomorphic element (i.e. a primitive character that represents an innovative evolution in common with different taxa, such as the central column of all vertebrates); or that of a synapomorphic element (i.e. a character that is new because it is derived from a previous one but shared with other taxa, such as the metabolism of carnivorous mammals); or that of an autapomorphic element (i.e. an exclusive character of each terminal taxon, such as paired and articulated segmental appendages, specific of arthropods).

Then, in order to further restrict the notion of novelty, Müller and G. Wagner tend to renovate the field of innovation. According to their position, it is not enough for innovation to coincide with an autapomorphic change because in a theory of development the autapomorphy itself could be a simple step of a permanently dynamic evolutionary scheme. For example, feathers were certainly a novelty at the time of their origin, but they are no longer so in existing birds, for which feathers are autapomorphic, anyway. For Evo-Devo, as we have repeatedly seen, the problem of innovation is not classificatory but mechanical. Hence, although very close in their outcomes, autapomorphies and innovations are not comparable in the routes and in the methods useful for identifying them (Minelli and Fusco 2005). So this different finalization of research induces Müller and G. Wagner to redefine innovation as “a structure that is neither homologous to any structure in the ancestral species nor homonomous to any other structure of the same organism” (1991, 243).

However, it is not necessarily the situation that this restricted level of innovation can explain the specificity of any case. The most radical innovations of this evolutionary history remain outside this definition, for example those that concern the *Bauplan* of phyla and classes: the origin of new body plans at the level of shape. The constitutive element of a *Bauplan* does not coincide with the resembling or the distancing itself from other forms of life, but it coincides with its overall configuration of biological species-specificity (see infra Chap. 7), its dedicated set of “constraints and opportunities” (1991, 251). It is very unlikely, therefore, that the

introduction of a single trait can change the *Bauplan* of the phyletic group, unless this very specific trait introduces very specific elements of biological and global cognitive reformatting:

only if the new character achieves an indispensable function, and becomes epigenetically integrated into the basic body design, does it become a Bauplan character. The origin of new body plans requires the origin of morphological novelties, but it also requires the integration of this new character with the other parts of the organism. In this context it is irrelevant whether integration is due to functional necessities or due to epigenetic interdependencies. What counts is that some characters acquire an indispensable biological role that causes their conservation in spite of changing adaptive pressures (Müller-Wagner G. 1991, 251).

In their study, Newman and Müller (2005) consider the idea that such a global reconfiguration of innovation theory could undermine the basic arguments of Neo-Darwinism. They propose that natural selection would retain the primacy on adaptive processes, which constitute a sort of “second stage” compared to innovation generating processes, but it would lose weight in relation to mechanical causes which trigger evolutionary processes, sometimes showing emerging mechanics. Despite the reassuring attitude of Evo-Devo representatives who consider the innovation theory to be compatible with the evolutionary synthesis, the real problem seems to be that of incorporating the notion of development which goes against both the adaptationist finalism and the gradualism of natural selection in the frameworks of neo-Darwinism. According to Newman and Müller: “a mechanistic concept of innovation could fill this void by moving beyond the neo-Darwinian focus on variation–selection dynamics which implies a pervasively gradualistic model of evolution” (2005, 499). But at what price can this mechanistic concept of innovation be acquired in the patterns of old and new Darwinism remains a problem.

According to Günter Wagner, structural changes require “a specific correction in the ontology of neo-Darwinian science” (2014, 19). In fact, the ontology of the new synthesis would focus on the implementation of the differences between organisms but ignore their underlying variational trends. If a stable distinction between change and variability is introduced, the need will arise to build a theoretical bridge between what is actually accomplished, what could be achieved and what cannot be done. Moreover, through an innovation theory, one could go beyond the limit of the genetic perspective. Wagner points out that the understanding of morphological changes is more difficult than the understanding of genetic ones. This depends on the fact that morphological characters are not inherited directly from one generation to another, as one can think, relying on the abstract scheme of genetic replication, but they must develop each time anew in the ontogenetic process. “In other words – as G. Wagner writes – a morphological character is transmitted indirectly through the transmission of the genes that control the development of the character” (2014, 2). In the long run of evolutionary history, this can lead to a loosening of the correspondence between genes and identity of character, fostering its “karst” development. The discovery of homologies can highlight this aspect and indicate new paths – on the road of “endless antiquities” – to define the way in which forms can innovate themselves in unexpected and not always functionally explainable directions.

Deepening the issues of form and exploring the dimensions that are not very well studied in evolutionary synthesis, such as molecular biology, Andreas Wagner, in an important work of synthesis (*The Origins of Evolutionary Innovations. A Theory of Transformative Change in Living Systems*, 2011), confirmed that the randomness of bodily changes and the pressure of natural selection are necessary but not sufficient to explain the mechanics of evolutionary innovation. In fact, below the macro-molecular elements (i.e. the organisms and their already functionally structured parts), there are genetic and micro-molecular reasons whose ability to change can occur independently of all functional induction factors. These basic elements for the comprehension of any innovation were set aside by Darwinism and even by a considerable proportion of twentieth century evolutionists for historical motives. Yet molecular and genetic networks actually work “together ultimately determining all observable characteristics of organisms, their phenotype” (Wagner A. 2011, 2).

So, an innovability theory should not explain individual specific facts (each as a case of *ad hoc* adapting), but it should assume the epistemological status of a falsifiable scientific theory, i.e. it should explicitly make a “small body of general principles that work together to explain a large number of empirical observations” (2). These principles still do not have to leave uncertainties about the capacity of a new phenotype to preserve existing phenotypes (it's not possible to engage in a phenotypic exploration that runs the risk of destroying life itself where the change is settled); to explain the overall unification of the biological organization of organisms (new molecular structures; new molecular expression; new combinations of both co-occur in new paths and should be explained together); and to know how to calculate the combinatorial capacity of the modules and structural macro-modules that are generated by innovation. Similarly a complete theory must take into account the role of the environment in the development of innovative needs and generate applicable technological systems models.

Therefore, a real evolutionary innovation is conceivable not only as a complex matrix of biological traits overlapping on hierarchically differentiated structural levels (i.e. genetic, micro-molecular, macromolecular, morphological levels) but also in a biological structure that is firmly unified and fully repeatable from genotype to phenotype. If an innovation theory does not explain “how exactly genotypic change maps into phenotypic change” (2011, 4), then it can be defined as being wholly unsatisfactory, immature or premature. Conversely, when the theory brings a new complex phenotype to its underlying genotype, it can also formulate deeper questions about the evolutionary development in the gene pool. Instead, hastening the adaptive explanation to the level of population genetics can cause serious errors of perspective in the innovation theory. In fact, in the light of current knowledge, it is possible to notice an asymmetry between different phenotypic definitions: “the phenotypes of population genetics are still too simple, and those of developmental biology still too complex” (2011, 5). In any case, the populational explanation cannot be separated from the analysis of the robustness of system changes that can advance or refuse the change: another structural constraint that limits the potential (abstract) virtuality of functions with all their dangerous cargo of speculative inferences.

Another interesting theme underlying the Evo-Devo theory of innovation is the relationship between novelty and reuse. As we saw above, reuse is a key point of innovation, because it can produce changes by rearranging the same structures. It is not necessary for the reuse to produce a novelty, but it could produce innovations. And if we apply reuse to the neural structure, this claim will become evident. In fact, neural reuse is one of the physiological strategies adopted by the brain in order to control the organism. Many studies have outlined how neural reuse supports cognitive functions (Anderson and Penner-Wilger 2013), and the evolutionary history of language has shed light on this matter. It is a common position among evolutionists that the language faculty does not come out of the blue, but is the outcome of a refunctionalization of a neural area previously used for other competences. According to many scholars (Dehaene 2005; Anderson and Penner-Wilger 2013), many cognitive functions have reused the neural area for installing themselves. This was possible because the brain area imposed constraints and offered opportunities for this exaptation, i.e. the neural structures allowed only certain possibilities that were exploited functionally and selected by environmental needs for new functions. According to Anderson and Penner-Wilger 2013, this reusing process “should have left detectable traces on both brain and behavior”. One sign of this process can be considered by the fact that we have gone beyond the classical modularist position, which considered the brain to be a geographic map where every single area corresponded to a single module that carried out a specific and segregated function. The evolutionary approach to neuroscience, instead, has demonstrated that this kind of position is not corroborated by the effective functioning of the brain (see infra Chap. 10) and evolutionary functionalization of the brain:

resource constraints and efficiency considerations dictate that whenever possible neural, behavioral, and environmental resources should have been reused and redeployed in support of any newly emerging cognitive capacities. Functionally isolated and dedicated neural modules just do not seem to make good design sense given the importance of efficient use of available resources, and of ongoing interactions to shaping function (Anderson and Penner-Wilger 2013, 2).

Neural reuse could account for both evolutionary brain innovation and ontogenetic implementation of neural networks, mediating between the general brain form and functionality and individual variation. Moreover, it allows researchers to identify homologies in brain development and functioning, guaranteeing continuity but at the same time allowing variations.

Chapter 14

Bio-Linguistic Plasticity and Origin of Language

As we have already discussed, performativity and neuroplasticity – functional and evolutionary – are closely linked, in terms of the biological concept of development and in terms of innovation and behavioral change. They should be considered as being the fundamental biological properties governing the organization and continuous reorganization of animal systems. If animal systems are deprived of such properties, according to the invariance and teleonomy on which they are based – as Jacques Monod's famous formula states – they would implode on themselves. In fact, the stable appearance of contemporary biology among the “ratchet” makes the inexorable nature of genetic algorithms clear to see. If there were no routes to accommodate and channel the errors of transmission, transcription and relocation of genetic code fragments within the environment and its behavioral events, it would be impossible to even imagine the dynamics of conservation and innovation of individuals and species.

Even in the Evo-Devo perspective, performativity and phenotypic plasticity of bodies provides a counterbalance for development reasons. However, in a manner that is more evident than in classical evolutionary biology, which sometimes seems to resort to the heuristic shortcut of functional modeling, in this case explanatory factors are all internal to the dynamics of the structure.

The laws of form are a coercive principle which is stronger than the principle of natural selection. In fact, structural constraints related to the symmetries, to the mechanical balance and to the conservation of *Bauplan* are beyond the contingency of individual species and are beyond the concept of species, and they derive their cogency from emerging prototypes of the “endless antiquities”. However, in this model, innovation is not conceived only as the emergence of a case to rule but as a default instance of developmental physiology. Development represents the concrete implementation of each structure's project, it unfolds in the embryonic ontogeny of individuals as a practice of organisms and evolution. Between the design of the shape and its phenotypic realization there is always the layer of events that are regulated by the development process. Natural selection, that even plays a crucial role in the developmental biology approach, arrives after the application of genetic rules.

Adaptive modeling, inexorably following chrono-logical causalism, can never be the cause of the change, it is only its decisive historical incubator.

Therefore, these considerations lead us to prefigure a model of evolutionary dynamics at multiple levels, distinct under the chrono-logical causality aspect:

1. Level of “mechanical trigger” of innovation: this is the level where “what precisely are the mechanistic causes responsible for a specific morphological solution to a new functional and/or structural problem” are explicated, using the formula by Muller and Wagner (1991, 231).
2. Level of “performative compatibility” of innovation in the context of the evolutionary development of the structure. This is the level in which, both at micro and macro-molecular stage, organisms undergo all behavioral events and conditions needed to transform the innovation into a full bodily integrated structure.
3. Level of “natural selection” applied to population genetics: this is the level at which new integrated structures are compared with functional experiments and neurocerebral map feedbacks which tests the overall bio-cognitive rebalancing useful to establishing evolutionary advantages (also of a social nature) for those subjects that are gradually selected.
4. Level of “adaptation and cultural selection”. This is the level where the functional behavior (rather than the structures) rooted in shapes stabilized by natural selection, evolves quickly, showing a high surface variability and a large capacity for environmental modification over a short time.

These four levels are independent but are also permeable, they develop during different evolutionary times and they can accumulate micro-variations which interact with each other. In particular, level (1) can be triggered by various mechanistic changes integrated into one ergonomic design that is unpredictably effective from a structural point of view. Essentially, it would be a precipitation of different favorable and gradually evolved structural configurations, giving rise to a new mechanically efficient bodily technology, completely new and ready to be exploited by different functional patterns (not necessarily related to the previous structures). Levels (2) and (3) are subjected to strict constraints because they have to ensure the conditions for transmissibility, keeping alive intermediate phenotypes (perhaps, as we saw above, ensuring duplication of functions and structures) and then allowing them to benefit from others, in the case of an increase in fitness which is prolonged in time and environment. They also move through gradualistic paths. These paths can be subjected to accelerations in relation to mutual interaction. The fourth level is separated from structural processes and from the research of functional compatibility characterizing phases 2 and 3. Moreover, it is developed in a very short time. It can be considered to be a level which is encapsulated within a structural stabilization level and a long-established functional phase. In this context, it gives rise to an intensive exploitation of cognitive testing, to a saturation of performativity and phenotypic plasticity, and to the development of extracorporeal technologies with completely unpredictable outcomes, in the sense of undetermined amplification of the adaptive processes, and also in the opposite direction of a maximization of naturalistically counter-adaptive factors. The following figure is an exemplary example of the four levels of evolutionary dynamics (Fig. 14.1):

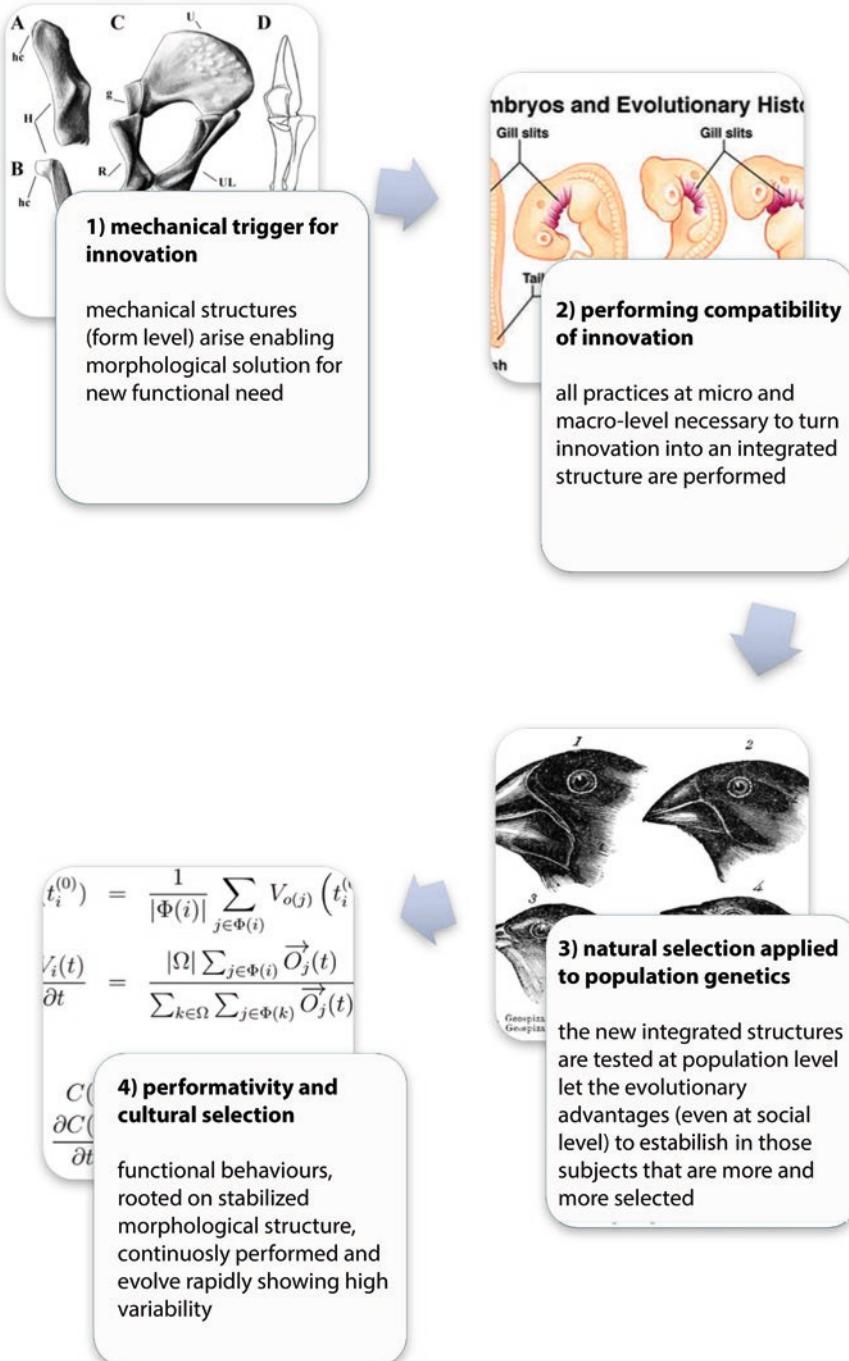


Fig. 14.1 Levels of evolutionary dynamics

In the following pages, we will try to verify this general frame of multiple levels in the case of a specific biolinguistic model such as the DBM.

14.1 The *Mechanical Trigger* and Possible Speakers

In Chap. 9 we discussed the distinction between impossible, plausible and possible speakers: that is, between those who would never have been able to be selected because they lack the properties allowing language instantiation, those who had virtually selectable characteristics but who have never been selected, and those who actually exhibited selectable and selected characters. Throughout the second part of the book we have tried to adopt a method that excludes the use of heuristic solutions, such as functionalist ones, to avoid the dangers of an exclusively adaptationist Darwinian model. Thus, we have described real speakers in their synchronicity, or as having the characteristics their structures possess today in relation to a species-specific ethological model of language. In this respect, we have given ample space to the role of genetic programs and to peripheral and central morphological foundations, documented and experimentally subjected to ongoing research in current cognitive science.

We want to intentionally match information obtained from empirical evidence and experimental research with possible speculations on the origin of linguistic phenomena. In fact, abuses of functionalist and adaptationist hypotheses have complicated, and even distorted, experimental research on the nature and function of human language as a natural fact. Remarkable examples of this speculative trend can be found in research obtained from studying the presumed gestural origins of human communication that uses deaf languages as a starting point (Wundt 1900; Paget 1930; Critchley 1975; Hewes 1973; Armstrong 1999 and Armstrong and Wilcox 2007; Armstrong et al. 1994; Kendon 2002, 2008; Corballis 2002 and 2015, 91 et seq.), or the numerous research projects centered around the so-called “preadaptations” of language (see the reviews of Christiansen and Kirby 2003a, b, 2015; Christiansen and Chater 2008a, b; MacWhinney 2008). These studies have revealed which complex hypotheses can be evoked when we do not consider the only certainty that we have relating to selected human language: the ability to emit articulated sounds that are codifiable and decodable through a system of discrete and infinitely combinable signals.

After stating the boundaries of a DBM founded on the indisputable centrality of the peripheral and central anatomical structures that speakers use to realize their communication arrangements and their mental representations of the world, it now seems to be the time to return to the question of origins, which we previously omitted, starting by using the diagram detailing the innovation levels that we believe will prevent us from adding further speculation to this debate.

The first problem we encounter along this path is the “mechanical triggering” of speech. For the moment, investigation of the problem excludes the functional approach: that is, we are not concerned about why language has arisen, but what mechanistic conditions had to manifest themselves to determine the specific human voice articulation morphology that has made an ethologically unique cognitive system possible.

In fact, there is no doubt that human language has constituted a radical innovation in cognitive evolution, in the way it is conceived. In our opinion, “human language is spectacularly unique, and spectacularly functional” (Hurford 2008, 526) but it is also spectacularly dangerous. We believe that language is not a mental technology to be adequately controlled, but it is a bodily technology that cannot be inhibited and that self-generates an infinite number of unpredictable technologies and potentially maladaptive cultural elaborations (Lorenz 1973a and 1983; Lévi-Strauss 1955; Richerson and Boyd 2005; Pagel 2009 and 2012; Pennisi and Falzone 2010; Pennisi 2014a, b).

It is not enough, then, to extol the cognitive merits of language but it is also necessary to understand its constitutive ineluctability. And to do this we have to dispose of issues which have arisen after the specific morphology of language had developed functionally and culturally, creating historical-natural languages, the evolution of syntax, sociolinguistic variability and pragmatics and everything else related to their use. From this point of view, the debate on Universal Grammar is misleading because all the formal structures of language, and their spectacular syntactic and semantic evolution, belong only to the “last mile” of the biological history of language. And it is this last “mile” that has been studied by linguists as a culturally developed form of spoken, written, and now digitized vocal articulation and of all the semiotic variants that derive from it.

On the contrary, the Cinderella of the BCM, the species-specific structure that produces and interprets articulated sounds, is the origin of the mechanical trigger from which everything begins, including recursion; this arises during the first cognitive computationalism, a “shrine” of the cognitive properties of human intellect. This is not the right time to discuss the merits and limits of this important resource of human thought, but there is no doubt that it, like all other cognitive properties that are also shown (but not only) with language, is still a consequence of a biological system capable of producing discrete, infinitely combinable signs endowed with meaning.

Of course, it is easy to witness many examples of non-verbal language capable of producing similar results. De Mauro’s (1980) *Minisemantica* reports dozens of them: for example playing cards and signalling systems for a huge amount of uses (transportation, ships, etc.) are more or less endowed with double articulation manual code signs, and symbolic, logical and gradually more and more complex mathematical codes. It can be said that if there are intentionally discrete repeatable and combinable signs, then it is possible to produce an infinite number of results with a potentially assigned meaning.

If we stop looking for the functional antecedents of language, or its cognitive “preadaptations”, we could easily recognize that the huge set of codes and combin-

able languages produced by modern *Homo sapiens* is a subset of “closed specializations” derived from the refined and exclusive use of a single *biologically natural* general code, using discrete entities, i.e. the articulated voice, that is typical of the only species able to generate it. In this context, an intrinsic Darwinian principle of biolinguistics is such that in the human cognitive system the generation of any recursively combinable element, capable of producing an infinite number of meaningful sentences is not *outside* the system, as in other derivatives codes, *but it is internal to the bodily technology of the species that produces it*. It is all about understanding how this bodily technology works and how it is formed during an endless gradual selection of body structures rather than mental forms. These latter have, by default, simply successively followed the neurophysiological arrangement of the former.

We believe that a true Darwinian method which deals with the problem of the mechanical triggering of language is mainly a problem of an anatomical nature. We do not want to know, at this first level, either the method by which we have learned to combine ideas or the method by which we have developed a new way of thinking. However, we are interested in understanding the way in which we have learned to combine more and more discrete, precise sounds by their articulatory mechanics in favour of a corresponding ability to hear, discriminating their boundaries and linking them to perceptual categorization. It is obvious that this performance experimentation has always been symbiotically assisted by the *tenant of the body*, the neuro-brain system that is responsible for the survival of the whole organism. But it is also true that, formerly, structural forms had to exist to monitor and train more specialized body parts than the slow evolution of bones, muscles, nerves, tissues and the conditions needed by natural selection for generating adaptable behaviour could provide, layer by layer, beginning with the preceding physiological stages in the bodies of more and more remote ancestors.

According to the point of view discussed in the last chapter, human language is certainly an evolutionarily autapomorphic character: it is present only in the final branch of hominine and it constitutes an irreversible event. But, linked to gradual anatomical development, “what” is exactly present in an autapomorphic manner?

Of course, it is not the generic ability to emit sound vibrations. This is a property of ancient physiological systems, dating back to the first forms of terrestrial life and probably also present in some aquatic animals. And it is not the ability to modulate sounds through some form of bodily manipulation. Many species, especially among birds and insects, are able to do so and, as we shall see, primates are able to do so too (Sect. 14.2). No other species, however, is able to use sound to generate a syllabic system with a synergistic use of a number of contoids, obtained through the modulation of expiration that is modeled plastically through the SVT (Supralaryngeal Vocal Tract) when the air encounters one or more obstacles, and vocoids that result from the final modulation of sound through the closure of the lips. In particular, no other species, and no two year old human toddler, can extend the range of vowel formant frequencies to include the quantal vowels [i], [u] and [a]: this allows us to produce reliable voice sounds, which are much less susceptible to articulatory and decoding errors (Stevens 1972; Lieberman 2008 and 2012).

We have described in detail (see Sect. 9.4.1) that this specific jewel of natural selection, because of the history and phenomenology of its specific structure, cannot be considered to be the result of an adaptation for language, at the moment of its mechanical trigger.

Primarily, this is because no language occurred, in the modern human sense, before the SVT existed. The bodily technology is able to precisely modulate the articulated voice only by starting from a certain conformation. In this conformation, the SVT is certainly a fundamental part, and we can only begin to consider the possibility of activating the faculty of language in its presence. Secondly, this is because a body is only ready to activate the faculty of language, characterized by cognitive species-specificity, when it is composed of a not inconsiderable amount of different pieces, each with its own gradual evolutionary history which are continually affected by the total anatomical aspect of the human organism and all of them being strongly interlinked. And finally, this is because the collection of all these separate pieces of human physiology, modelled by the development of forms that do not know where they are going, are able to experience many neuro-motor coordination and functional models, until some of them can lead to an opportunistic and naturalistically social environmental performance that produces effective results.

Basically, structural evolution evolves independently and randomly innovates under the laws of form and development. The body is kept constantly alive by neuro-brain coordination and develops different functional behaviors which are plausible given the environment and with states of physiological compatibility gradually being implemented. The innovative mechanical triggering of language is a random masterpiece of involuntary and forced engineering ensuring the maintenance of the functions already stabilized for survival, changing some, leaving others, until exploding in a miraculously efficient construct that was not planned or expected, despite being a foreseeable partial evolution of the old constituent parts and their previous functions.

In the case of human articulated language, a gradual evolution of the joint forms of the receptive system morphology (the auditory system) pre-exists, with the neuro-motor system continuously taking care of the ear-voice feedback with constant rewiring of the sub- and neo-cortical networks which organize it. Also many functions are related to the body as a whole, and these body parts are used at some risk to other functions. For example, the body continues to breath and eat through the same channels, despite the risk of choking, to communicate, to express primary and secondary needs and perform cognitive activities of other kinds, with or without the support of vocal organs. All this (but, at the same time, none of it) has to do with the mechanical triggering of language.

Of course, this is connected with the structures of voice and hearing that previously existed and from which it is derived; in the sense that it could not have existed if there had not been changes in the body shapes of primates and in ancestral mammals before them, etc. Likewise, it is related to the evolutionarily widespread uses of these devices: the modulation of low formants for sexual purposes (for the *exaggeration-size-theory*, see Fitch, infra Sect. 9.1, which we will investigate in detail in Sect. 14.2), the endless communication possibilities of holistic sounds

which are associated with hand gestures, or the primary uses of several distinct vocal articulations (which we will return to at the end of this chapter). And finally, it is also related to all the other activities carried out by our predecessors: mapping space, cooperating in social activities (hunting, division of labor, etc.), functionalizing and channeling emotions and facilitating the dissemination of culturally marked practices, etc.

The mechanical triggering of language – namely the achieving of a state of unexpected and very effective bodily technology in terms of the production and reception of discrete, stable, robust and permanently available signals – provides the human brain with a new cognitive ability. The ability to achieve communication and thought through a biologically rooted system of speech segmented into syllables, phonemes, uniquely identifiable discrete entities and combined without limits, opens up a totally new chapter in cognitive evolution. The functions that were performed without the use of language or with forms of pre-human language, and which continue to be performed, can sometimes greatly improve the system but at other times make it worse. But those functions that could not be performed without the use of language have to be discovered and this work represents a downhill road into which it is easy to slide. In particular, we can develop the core of neo-cognition: categorizing relationships through abstract symbols thanks to words that take the place of things, objects and ratios and which are re-embedded in the brain in another form and represented for the first time in the mind through an integrated part of the human body that “tells” them and “listens to them”. This is the species-specific intelligence discussed by Chomsky. It is not, however, triggered by a more powerful brain but by the mechanical technology of the spoken and heard word that was not initially present and that, beginning from the instance in which the spoken and heard word was present – thanks to an unforeseen set of physiological facts which combined together and become stable in an organism – has allowed the *cognitive catastrophe* of a new linguistic mind. Everything that came before language, in every sense – to paraphrase Wittgenstein – is the ladder that is thrown away after we have used it to climb on (Tractatus, 6.54).

If it is true that men and non-human primates, as has been previously demonstrated, have physiological similarities (Aiello and Dean 2002; Ankel-Simons 2007; Hopkins 2007) and similarities in the phylogenetic substrate (Marks 2003; Taylor 2009), one might think that all cognitive distances are of a mental order. In fact, according to many researchers, man is distinguishable from other primates because he is able to categorize and to do abstraction from contingent things, to locate phenomenal causality, intentionality and can recognize his conspecifics as “intentional (or mental) agents (like the self)” (Tomasello 1999, 15), to understand the semantic and syntactic structures of languages and practice its creative aspects (Chomsky) and build artefacts and technologies.

The evolutionary perspective has shown that chimpanzees, along with other animal species, demonstrate mental abilities in experimental conditions – computing, recognition of conspecifics, spatial relationships, the use of manual technology, etc. similar to human ones (Tomasello and Call 1997; Matsuzawa et al. 2006 and 2007; Biro and Matsuzawa 2001; Lonsdorf et al. 2010; Parker et al. 1994; Gòmez 2004;

Wasserman and Zentall 2006; Baber 2003; Steele et al. 2012; Bekoff et al. 2002; Hurley and Nudds 2006) – and when they are observed in their natural habitat also exhibit precise semantic decoding abilities (Thompson 1995; Cheney and Seyfarth 1997; Seyfarth and Cheney 2010; Schusterman and Kastak 2002; Kaminski et al. 2004; Tomasello and Zuberbühler 2002; Zuberbühler, 2005).

Cheney and Seyfarth (2005: 137–42 and 2015: 195 et seq.) also investigated different species of non-human primates in their natural environments, including baboons and bonobos, and observed their ability to extract complex information from sounds and confirming Premack and Woodruff's (1978) hypothesis that non-human primates have a Theory of Mind (TOM). On the other hand, the ethological limit is not an insuperable cognitive limit. Tomasello and Call (1997 and 2006) have demonstrated this, through an overwhelming amount of experimental data. In fact non-human primates taken from their natural settings and incorporated in other social contexts, are even capable of providing performance which is “humanely” relevant. The famous male bonobo Kanzi – Sue Savage-Rumbaugh's favorite student (Savage-Rumbaugh et al. 2005, 2006) – became able to understand a certain amount of human linguistic behaviour, not as a result of an explicit education condition – he had obtained poor results with his mother Matata – but “spontaneously” only after he gradually became integrated into a human community and became a stable element.

This important acquisition is attributed to Stuart G. Shanker. He noted that it was only when Kanzi and his sister Panbanisha became completely integrated into the Great Apes Trust research center in Des Moines, Iowa, that they managed to achieve the best results: “the explanation for their development lay in the language-enriched environment in which they were raised” (Greenspan and Shanker 2004: 153). This certainly comes as no surprise to us given the fact that even animals phylogenetically very distant from man, like dogs, blackbirds or parrots, but due to continuing friendship with man and sharing his domestic life, often fail to understand the pragmatic meaning of many words which they are exposed to without an intentional education. On the other hand, the most spectacular zoosemiotic linguistic performances – like those of Kanzi, Alex, Irene Peppenbergh's talking parrot, Hoover, the seal etc. – are even less relevant from a cognitive point of view because they are not derived from the social universe that ethologically belongs to their own species: in the best case, they reveal a remarkable ‘additional’ cognitive-behavioral flexibility but which is completely foreign to the genuine representative capacity of those specific individual animals.

However, in certain environmental conditions, brain structures may allow (or not prevent) the brains of non-human primates such as Kanzi to categorize, to enable intentional acts and produce mental inferences about the behavior of others, to understand the meanings of words and syntax of the languages to which they are exposed, to not only use but also to manufacture and consciously modify (i.e. following a specific intervention project) tools and lithic technologies. If we add this fact to the Chomskyan observations about the creative abilities that only man displays (e.g. syntactic recursion), this would not be sufficient to rule out that Kanzi has also repeatedly demonstrated the ability to understand sentences he has never

heard before (for further information see the website movies of Iowa Primate Learning Sanctuary, in <https://www.youtube.com/user/GreatApeTrust/videos> and in particular *Kanzi and Novel Sentences* and *Kanzi the Toolmaker*). As Philip Lieberman recently wrote: “any aspect of language that apes can master was most likely present in the common ancestor of humans and apes and was present in Neanderthals, ruling out a ‘protolanguage’ that lacked syntax” (2015, 2).

However, it remains true that even Kanzi, like no other primate, although he is capable of modulating the supralaryngeal vocal tract in non-trivial ways, cannot (and will never) articulate human words, for his vocal apparatus is not permanently suitable for language and therefore cannot consciously experience the performative function that matures with the mechanical triggering of language (see infra Sect. 10.2). Beyond the learning processes, non-human animals cannot access the linguistic mind and human animals do without the linguistic mind: humans cannot opt for language, they are forced into its cognitive formatting deriving from the biological nature of linguistic function.

In the second part of the book, we have described in detail (see Chap. 7) the compulsory component of a biological species specificity of language: a kind of obligation to categorize and to reason, starting from speech articulation, lexicalization encyclopaedia, and syntactic and semantic structuring of knowledge. Now we will try to understand the reasons why the cause of this cogency is already contained in the mechanical triggering of language. The most puzzling aspect of the phonatory system is, in fact, its extreme physio-psychic complexity, with the simultaneous ability to model all-encompassing human cognitive form in one direction. Let us now look at the basic features that make it so special.

Firstly, the necessary speed to make it work: humans are able to generate and receive from fifteen to twenty-five phonemes per second, exceeding the sound fusion threshold of the auditory system (Liberman et al. 1967, 436). An essential speed to enable the buffer of the main memory to hold a certain number of syntactically related words.

Secondly, the amount and type of physiological efforts related to its use. Talking is not an exhausting activity when compared with running, swimming or performing any other physical activity. It is, however, physiologically tiring in relation to the performing precision required. The simplest verbalization involves over a hundred different muscles, many of which are specialized in oropharyngeal motility, which does not occur in any other human activity. The monitoring of respiration is continuous and exhausting, because the duration of expiration could be dephased: almost eight times more than the default duration. The swallowing activity is solicited, so that it’s easy to fall into dangerous errors. It is, in short, a waste of attention, possible only by using an extensive range of neuromotor automatism.

Thirdly, its synergy. There is not a single piece of the articulatory system used in mechanical trigger of language that is not essential. As Aitchison (2006) has noted, human teeth are different and are arranged differently from the teeth of other animals. They also develop in height, and they form an unbroken barrier. In addition, they do not show an inclination towards the outside or the inside of the mouth and they allow the jaws to close perfectly. According to the author, this feature is cer-

tainly not a requirement for eating but to articulate a number of sounds such as S, F and V, SH, TH and many others that would otherwise be impossible to pronounce. Similar considerations apply to the human lips with their highly developed musculature which enables the small mouth to be quickly opened and closed so that explosive bilabials can be easily produced. Finally, the tongue is decisive for its muscularity, its thickness and its flexibility to allow obstructions, more or less partial, to any passage of air in the oral cavity causing the modulation of a very variable quantity of sounds. The larynx and vocal cords are located further down and are more simple in structure than those of other animals: signs of specialization aimed at letting the air flow freely through the nose and mouth without any hindrance. And finally, the lungs have become like a central control unit managing the timing and flow for breath-word alternation. In short, a collection of components, which have evolved differently, have come together to produce a perfect mechanical device.

Of great importance is the special status of verbal categorization, which is based on the mechanical processes of encoding and decoding of sounds and which we need to explain. As we have already said, the peculiarity that makes human language cognitively different is that the processing of discrete, stable, robust and permanently available signals occurs biologically, through a bodily technology. This means that the combinability of these sounds is not comparable to the formal combinability through the selection of entities in a pre-categorized series (characters, numbers, bytes, playing cards, naval signals, etc.). In the case of articulated language, a discrete class of sounds is already the result of a first performative abstraction of biological nature: by an infinite continuum, a highly variable class of sounds are combined, encountering obstacles in the last part of the SVT and a second class of equally variable sounds that result from the modulation of air from the lungs through the lips (which are more or less closed). This set is always a second order performative construct: a co-articulation of syllables or more complex combinations requiring a wetware technology that is under the control of the neuromotor profile: nothing comparable to beads-on-wire or sets of characters or alphanumeric strings, etc! As we saw in Sect. 7.3, this difficulty has always been an insuperable obstacle to any kind of mechanical or computational simulation of biological speech.

We now have to explain that way in which an absence of acoustic invariance, resulting from the fact that emitted sounds are connected in parallel with each other, can correspond to the need to perceive a single sound, which otherwise could be perceived in a unified and non-equivocal way.

In 1975, Lieberman referred to this phenomenon as the result of *a system dedicated to compressing time*, that is a process of condensation of the multiplicity into unities, a global and syncretic (non-analytical) reproduction in a single act of utterance of anatomical/physiological and neurological/cognitive processes in different time sequences and, to some extent, staggered from linear order. More particularly, the respiratory system, the muscular system, the mechanics of the articulation organs and the nervous reticulum contribute to this bio-psychic voice contraction. These four components appear to act by using mutual adaptation, implemented in real-time and consistent in dispatching the neuromotor signals necessary to com-

plete complex vocal events. Although one can listen many times to a vocal utterance, in the absence of noise acoustic perception will always be perfectly distinct. The individual sounds, however, when analyzed from a spectrographic point of view, will overlap considerably. On the other hand, it could not be otherwise, since each sound involves the activation of neuromuscular pathways which are structured differently, both in regards to the length of center-periphery conduction pathways and in the consistency of their fibrous tissues (the more dense the fibrous tissue, the longer it takes the neuroelectric pulse to cross it). It is obvious, therefore, that vocal articulation is not subjected to sequential conditioning constraints. If a sound appeared as a response to an earlier stimulus, the latter should be completed before the sound appears, in this way triggering a chain of delays that make it impossible for the unity and simultaneity of the global articulatory act.

An hypothesis initially formulated during the 1960s by Alvin Liberman et al. (1967) has tried to explain this phenomenon. This hypothesis held that we do not perceive speech sounds but “speech gestures”. The discrete perception of sound, or, in any case, its categorical identification, is made possible by the fact that we can produce articulatory postures through the movement of the vocal organs. Therefore, we are able to construct a map of sounds through the proprioception of our motor acts. According to this first hypothesis, the categorical perception, thus obtained, would form classes whose boundaries cannot be defined by sounds, but through articulatory ways: a perception that seemed, to the founders of the theory of articulatory gestures, species-specific.

Soon, however, some parts of this fascinating thesis proved to be unfounded although it was based on plausible assumptions. The categorical perception based on implicit cognition of the motor gesture was, in fact, also found to be active in newborns (Eimas et al. 1971) or in other non-human species, for example, chinchillas (Kuhl and Miller 1975) that are not articulated at all. Sound categorizations were also not the only ones with contributions from different senses: experimental studies have shown that almost all sensory perceptions discriminate categories in a trans-modal way. Finally, one last question that proved problematic for the theory of perception was how the implicit awareness of articulatory gestures is related to the heterogeneity of the very motor acts, and how this is no different from that of the lack of invariance in the emission of sounds: just as there are many ways to produce the same phoneme there are many ways to achieve the execution of any movement (e.g. playing tennis).

A more recent variation, which is fully compatible with that of articulatory gestures, but based on the specificity of the neural substrate of primates, is that of mirror neurons. According to this hypothesis, the listening perceptual constancy of speech sounds should be a spontaneously autoimitative activity of vocal movements (Iacoboni 2008). Again, different opinions have been expressed. Hickok (2014), in particular, noted that clinical trials relating to studies on the role of mirror neurons on language perception have been affected by the confusion between tasks of pure perception and tasks of phonological awareness, a skill that is vastly more complex and better connected to cultural conditioning (Morais et al. 1986).

Starting from this kind of criticism, Hickok has proposed an additional hypothesis to explain the specificity of human linguistic perception. This hypothesis, which is defined as “a two-flow processing model of language” (Hickok 2014, 109), echoes the solution suggested by Zeki and Nash (1999) in understanding visual image processing in relation to aesthetic evaluation. This involves distinguishing a dorsal and a ventral in categorical determination. The first would produce a direct encoding of acoustic type and a predictive monitoring of the motor system. The second could be considered to be a predictive coding of a cognitive and conscious type:

both streams use the same computational mechanism but for two different purposes, motor control and perceptual recognition. Because predictive coding was such an exciting discovery in the context of motor control, I think some theorists, myself included, rushed into the view that motor-generated predictions can enhance perception. I now believe that motor system and mirror neuron prediction operate squarely within the dorsal stream and play little role in perceptual recognition. But this is an empirical question. We'll have to wait and see what the data tell us (Hickok 2014, 485).

The experimental data seems to support this hypothesis; when we change the task, the results will also change. Studies testing speech perception in normal meaningful sentences, without revealing to the subjects in the experiment that it will be necessary to recognize the phonemes (or syllables), produce a negative result. Conversely, if we ask the same subjects to recognize phonemes and syllables, both in meaningful phrases and in meaningless noises, we will generally obtain a positive result. The automatic shift between the dorsal and ventral recognition is greatly aided by the selection order.

In the Hickok model it is not explicit that the selection of the aim is constrained by the bio-cognitive structure of the experimental subjects. The levels and processing circuits of the sound data vary, for example, according to the age or the species of the subjects tested. For example, it will be no surprise to learn that newborn babies can already perceive prosody and syllabic sounds already heard in the uterus (Granier-Deferre et al. 2011; Moon et al. 2013). We can also assume that subjecting infants or non-human animals to tasks involving meta-linguistic knowledge (of the morphological, semantic and syntactic type) arising from the progressive experience of performativity articulation and relating to pragmatic competence, and particularly from the explicit awareness of the structure of the language, will not provide any results. The bio-cognitive status of these individuals – that may seem obvious to the investigator – is not obvious at all if we consider the issue from the viewpoint of phylogenesis of the mechanical origin of language.

In the specific case of linguistic categorization it may be assumed, in fact, that in the mechanical triggering of language phase, where there is certainly still no morphological, syntactic and semantic system organized in a historical-natural language, the motor system has “forced” articulatory innovation towards schemes which are gradually controlled by a brain and which have not yet received the blueprint of spoken language. Experimental scientists studying motor control have named it “internal model or internal forward modelling [...]”; some call it predictive coding. Basically, after much experience with moving our bodies and recording the

(delayed) sensory feedback from those movements, the brain learns the relations between particular motor programs and how the body responds" (Hickok 2014, 473). It is an essential process to the mechanical triggering of language and it will govern the transition from one phase to another in the transition between different structures: "predictive coding via internal forward models is the key to efficient motor control and is a major computational function of the dorsal, sensorimotor stream" (474).

The evolutionary perspective based on the principle of the mechanical trigger of language helps us, then, to understand how any mechanical innovation, even before a functional specification exists, can use the direct and primary brain circuits (back) of sensorimotor control to exercise the performative primacy that, over time, will form its ventral ways allowing the combination of the initial perception control of vocal articulation with activities that are now embedded in language (predictions based on morphology, syntax, semantics and pragmatics).

A final aspect of this complex puzzle of the mechanical trigger of language and connected to the particular mode of biological production of voice categorizations that we have just explained, is the aspect that is related to how neuronal circuits connect the different parts of the brain when humans speak. Lieberman and McCarthy (2007) have returned to this point. They showed that these circuits use the putamen for neuromotor control changing "on the run" – that is, while an action report is being performed – "the direction of our thought processes based on new stimuli such as the understanding of meaning conveyed by the syntax of language" (2007, 16).

In this case, from a evolutionary perspective, we can also see a decisive breakthrough connected with the mechanical bootstrapping of speech. In most animals, in fact, these circuits regulate the motor control of the body, while in this case they also extend to the cognitive functions, to the activity of thought or thought paths. According to the authors, this kind of motorization of thought could be crucial to understanding the evolution of human language: "because it indicates that our modern brains may actually have been shaped by an enhanced capacity for speech motor control that evolved in our ancestors" (16). We will see later that this principle could also be the basis for an extended theory of performativity in linguistic pragmatics (see *infra* Sect. 15.1).

Therefore, in conclusion, the mechanical trigger of language is to be regarded as a decisive moment of purely physiological possibilities for a species that allows human beings to develop articulatory abilities which were previously impossible. That articulation option originates from a series of overall gradual structural transformations of the organism. Some of these transformations are mandatory consequences of musculoskeletal changes: the enlargement of the skull base and the cortical fan; the formation of the upper limbs for manipulation of objects; the descent of the glottis; all of these have been derived from the slow transformation that led to bipedalism.

Other transformations may also have shaped developments that are not necessarily derived from the raw form: mutations, silencing or fossilizations of genetic elements (see *Infra* Sect. 8.1); internal changes of the vocal supralaryngeal tract, of the auditory system; etc. Still others arise from the impressive work of the total

rewiring of the neuro-brain system which involved the structuring of motor coordination based on the creation of a biological perceptual categorization code for new rapid and discrete signals from an analogue continuum. Each of these structural changes have, in turn, led to further rearrangements, not all clearly understood, in sensorimotor and bio-cognitive coordination.

It is certainly too early to consider this comprehensive qualitative and quantitative framework of the elements that have contributed to mechanically trigger language as being the most important innovation of human cognitive processing. It will be the task of the sciences that form the woven fabric of contemporary Darwinism (paleoanthropology, ethology, evolutionary biology, cognitive science, amongst others) to reconstruct how the simultaneous triggering of the many components, which have then gradually developed at different times, has originated.

We do not believe that, considering the present state of knowledge, this goal can be accurately achieved. We think, however, that narrowing the surveyed items exclusively to the structural component (anatomy and physiology), many of the current difficulties can be circumvented. The confusion introduced by functionalism, the themes of pre-adaptation, and in particular the crazy idea that we can reconstruct an evolutionary history of cognition only by using the history of the brain, or by the development of the mind, and cultural products such as grammars of historical and natural languages, has so far prevented biolinguistics from being established as a naturalistic science.

On the contrary, according to the DBM we have discussed, it is the set of extenuating historical structural changes which have allowed the mechanical trigger to have an irreversible progressive form of communication, elaboration and complexification of signals, enabling the reprocessing of all existing cognitive practices, eliminating the unnecessary ones and developing new ones. The primary reason why we are different from the apes from which we derive is simply the fact that beginning a long time ago, and taking a path lasting millions of years, we have finally achieved a body that has allowed us to speak.

14.2 A Wild Ride

The creation of thousands of languages during the Upper Paleolithic period that followed the mechanical triggering of language, a complex set of closely related anatomical features which are tightly interconnected in the way that we described in the previous chapter, is defined by Philip Lieberman (2008) as “a 50,000-year wild ride”. It is one of the most recent dating obtained by subtraction of the species-specific traits of human speaker from those present in the oldest hominid species.

Those who have adopted other criteria cannot produce more precise dating. Those who consider the birth of language as being the origin of a symbolic power (Arbib 2002; Bickerton 2003 and 2014; Deacon 1997 and 2003; Davidson 2003) have the obligation to considerably backdate the starting point. The same happens to those who accept a gestural origin of language (Corballis 1999, 2002 and 2003;

Gentilucci and Corballis 2006; Mithen 2006; Arbib et al. 2008; Meguerditchian and Vauclair 2008 and 2010; Zlatev 2008) and a purely imitative origin of the gesture (Arbib 2002). The origin of the language faculty could be further back in time for those who consider it to be as the result of social cooperation (Tomasello 2008, 2014 and 2015). Those who identify language in the presence of a theory of mind (joint attention theory) are forced to choose a start date dependent on the discoveries of a theory of mind in animals considered similar to humans, mainly but not exclusively, primates (Tomasello 1999; Arbib 2005, 2006, 2012 and 2016; Donald 2005). And finally, those who consider language to arise following a sudden cerebro-mental-computing leap are forced, however, to shorten the time to an elastic range which also depends on the inclusion, or not, of lexicalization processes within the faculty of language (Berwick and Chomsky 2016; Bouchard 2013; Hurford 2014; Tallerman 2014; Boeckx 2011).

There are more significant obstacles to the dating and clarification process of linguistic phenomena if we think of language as being the continuation, albeit an enlarged one, of a certain set of cognitive properties. For example those obstacles have to be faced by those who study linguistic universals and principles of UG (Kirby 1999 and 2002; Deacon 2003), those who study semantic and conceptual complexity (Schoenemann 1999) and, more recently, the principles of the turn-taking system (Levinson, 2016). And even those who postulate a decisive role for social evolution processes (Donald 1991 and 2005; Arbib 2002; Tomasello 2003; Dunbar 1996, 1998; Dunbar and Shultz 2007), co-evolution (Deacon 1997; Ferretti 2007, 141 et seq.; 2010, 145 et seq.) or real cultural evolution (Tomasello 1999) for the origin of language.

The reason for the indubitable advantage for scholars starting from the narrow definition of human language as a system for encoding and decoding articulated voices in the sense in which it was stated in the previous chapters, is twofold. On the one hand, it can exclude all temporal phases in which speakers do not yet exist with suitable articulatory structures. On the other hand, it not need to include pre-existing cognitive skills which are not included in the definition.

Unfortunately, it is virtually impossible, due to current knowledge, to establish a well-defined line between the phases in which hominids can articulate the voice and the phases in which hominids can begin to fluently articulate the voice. It is very likely, in fact, that a clear-cut distinction has never occurred and that the mechanical triggering of language has required a number of intermediate steps occurring over a period of time and which are hardly detectable with absolute precision in the distribution of the gene pool. It is for this reason that many recent studies have proposed re-examining the age-old and confused problem of the origin of language, in the light of the “cognitive neuroscience of the voice” (Pisanski et al. 2016, 315), based on contemporary experimental research comparing speech articulation uses in humans and other animals.

According to this proposal, the obscurity of the question of the origins is caused, primarily, by the apparent absence of “an intermediate vocal communication system” (315) between the human language and the less flexible vocal repertoires of other primates, which a more defined reconstructive hypothesis may discover. The

existence, however, of a non common ability to modulate the F0 (Fundamental Frequency) and the basic formants in many primates and various other species of living mammals – as well as in many varieties of birds – could be, according to these researchers, a “living relic” – 2016, 304) of the original state. This demonstrates that the evolution of the anatomical and brain structures giving rise to human language is characterized by a gradual and fully repeatable process because it is instantiated in the bodies of the present heirs of human and non-human primates.

For a Darwinian biolinguistics, like the one we tried to outline here, this point appears to be of utmost importance. In fact, in comparison with the debate conducted during the past twenty years, there has been progress made in research concerning vocal communication in nonhuman primates and other animal species.

The idea that chimpanzees, bonobos and other zoological apes close to *Homo sapiens* exclusively express the communicative atmosphere within their social lives through visual, olfactory, tactile and kinesthetic resources, has been opposed by more recent research offering a precise empirical reconstruction of the vitality and frequency of the vocal behaviour of non-human primates, both in captivity (Lameira et al. 2013 and 2015; Hopkins et al. 2007; Taglialatela et al. 2003; Perlman-Clark 2015), and in their natural environment (Wilson et al. 2001 and 2007; Cheney and Seyfarth 1985; Laporte and Zuberbühler 2010; Crockford et al. 2012; Schel et al. 2013; Gently et al. 2014; Gamba 2014, Gamba et al. 2012).

But what does it mean to understand and to use vocalizations at these developmental levels? To answer this question, we have to face a decisive technical detail: we have to explicitly explain what exactly “speech articulation” does and we have to analyze its various meanings within the contemporary physiology of the voice. Indeed, as we have already seen – in Sect. 5.1 – use of the word “articulation” in the Aristotelian biological thought, corresponds to what we employ in ethological descriptions. However, in Sect. 9.1, we instead looked more closely at the comparison of the structural characteristics of the vocal tract in animals and humans, and insisted on anatomical species-specificity of the instruments of human phonation. In the context that we are confronted with now, it becomes essential to understand the relationship between these anatomical peculiarities, the physical principles of the voice and the ability to combine one with the other for social purposes that enlightens us on how we have been able to configure a potential evolutionary advantage for the human species.

In fact, from the point of view of the modulation of formants, we now know that not only humans, but also non-human primates and many other animal species, are able to vary the fundamental frequency (F0) and also other formants (Fitch 2000). These changes are used to mark many biological and psychological dimensions, including sex and age, the size and shape of the body, the hormone status, dominance, masculinity or femininity, and sexual and social attractiveness (Pisanski et al. 2016). We have already seen in Sect. 9.1 that the variation of F0 for low frequencies is used by red deer to simulate an increase in size for sexual purposes. The red deer strategy is still part of the so-called “honest signals” (Zahavi and Zahavi 1997; Pisanski et al. 2014), a kind of exaggeration that carries reliable information (see Falzone 2012). In some primates, however, the change in F0 for low frequencies is so marked that it completely overturns the relationship with body size.

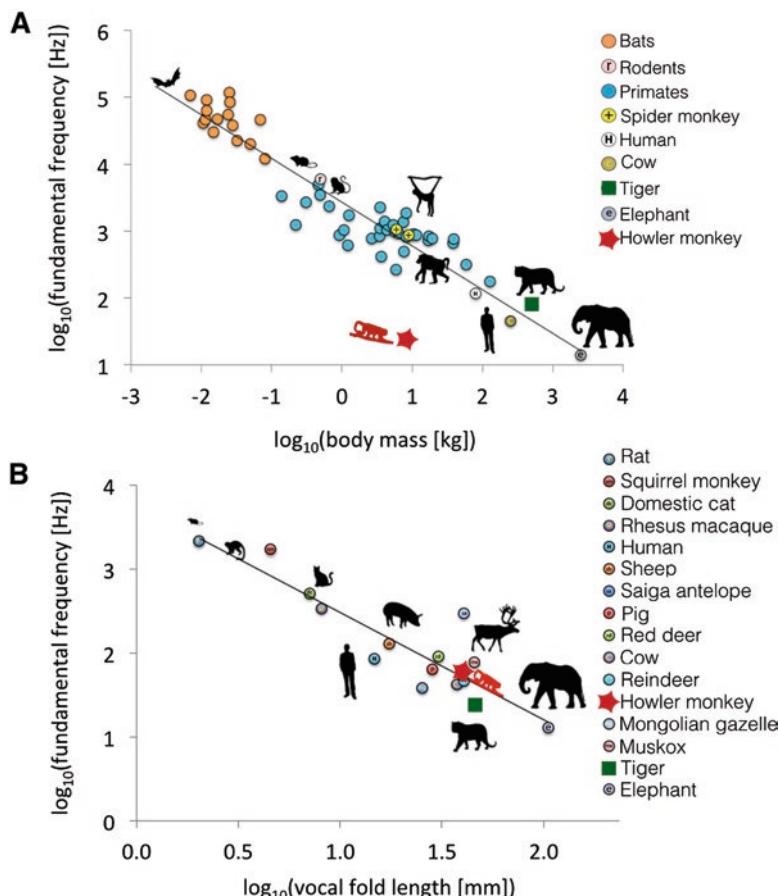


Fig. 14.2 Calls with use of low frequencies related to body weight and length of the vocal cords
(Source: Dunn et al. 2015)

The small howler monkey (*Alouatta sara* in particular, but also *Alouatta Caraya*, both weigh about 7 kg.) is capable of emitting a low intense formant, projecting a sound image analogous to that of a trumpeting elephant or a roaring tiger. The use of vocalizations to exaggerate size for sexual purposes or for defence is one of the most popular voice communication features in the entire animal world and also provides an initial approximation of the importance of the vocal dimension for a given species. Below (Fig. 14.2), depicts a chart (source: Dunn et al. 2015) illustrating the phenomenon of aligning species based on the ratios of F0/body weight and F0/length of the vocal cords.

Note that in the case of *Alouatta sara* – shown in bright red on the graph in the lower regions of the F0 – this phonic possibility is guaranteed by a hyoid bone of substantial size, as shown in the photo (Fig. 14.3 ©Jacob Dunn).

Fig. 14.3 Hyoid bone of *Alouatta sara* (Source: Jacob Dunn)



The vocal cords of this monkey are three times longer than those of a human being, despite the fact that the dimensions of its body are much smaller than those of man (about 1:10). Howler monkeys, in fact, exacerbate the cognitive function of these vocal size simulations in order to appear immensely larger than their actual size. This is used to let predators know that it would be easier to attack other mammals (a message which is similar to that produced by the gazelle's stotting when they face large felines – Zahavi and Zahavi 1997). But, above all, it serves in pre-copulatory sexual competition that occurs more with shots of exaggerated vocalizations than with real sexual displays. Dunn et al. (2015) have shown that the enormous hyoid bone of howler monkeys is inversely related to testicular size and the production of sperm. This extreme functionalization of vocalizations for sexual purposes has brought a distinct social differentiation. Males with large hyoid bones and deep roars but with smaller testicles live in small social groups comprised of a single male and its harem. In contrast, subjects with large testicles and small hyoid bones live in large groups with a maximum of five or six males and females which mate with every male in the group. These males do not have exclusive access to females, and the battle for reproduction is more oriented towards the classical “spermatic competition” (Birkhead and Møller 1998).

According to Pisanski and colleagues – that confirm and clarify Fitch's assumption (2000) – the voice exaggeration of body size “may have paved the way for more volitional forms of source and filter modulation and could have been the main driver in the evolution of vocal control” (Pisanski et al. 2016, 308). And in fact, what seems to be an abnormal use of formant modulation for social purposes in howler monkeys, should be considered a typical example of articulated voice use (in its primary “modulated” sense) that are not explicitly verbal.

Many studies have shown that these uses are also frequently seen in humans. Dimorphism in the modulation of formantic frequencies, which is very prominent in humans, has been shaped by sexual selection. Latest studies indicate that when males and females are attracted to members of the opposite sex, F0 is modulated to a range that varies from about 5 to 25 %. More specifically, it has been observed by looking at voice patterns, that many people of different sex and age, including children and teenagers, decrease the lowest formants in response to male voices and increase them in response to women voices (Cartei et al. 2012 and Cartei and Reby 2013). Typical sexual patterns (F0 low for males, higher frequencies for females) are unanimously considered attractive by the opposite sex and, in any case, are strongly marked (Feinberg 2008; O'Connor et al. 2014; Pisanski and Bryant 2016).

Even from the point of view of self-perception, the sexual characterization of formants is very strong. Male subjects that perceive themselves as being dominant produce a lower F0 when speaking to other males, while subordinate subjects raise their voice (Puts et al. 2006). Conversely, lowering of the male voice is accompanied by a minor change in vocals for the benefit of females, or the benefit of gregarious males, and in some cases the less distinctive sound is accepted by individuals with low culturalization just to exalt their manhood (Kempe et al. 2013). Both men and women can also voluntarily vary frequencies that are associated with a judgment of confidence and intelligence by increasing F0 (Hughes et al. 2010 and 2014). As the production and understanding of social signals can sometimes seem contradictory, it would appear that ignoring them comes at too high a social cost. As a result, you could choose a wrong partner (Leongómez et al. 2014), fail a job interview (Hughes et al. 2010) or fail to be considered a good political leader (Klofstad et al. 2015), etc.

According to several scholars (Fitch 2000; Cheney and Seyfarth 2005; Ackermann et al. 2014; Pisanski et al. 2016), social benefits associated with the modulation of vocalization and the perception of its indexical senses are derived from the expansion of the range of sounds that can be produced – a technique certainly used by modern *Homo sapiens*, perhaps even 50,000 years before the period hypothesized by Lieberman – which may have played a key role in the selection of articulate speech.

The production of specific vocalizations and the ability to respond in a socially appropriate and cognitively relevant way already requires a synchronized neurocerbral structure capable of speech motor control. Today, current neuroscientific knowledge allows us to hypothesize another dual-pathway model (Pisanski et al. 2016), already described in Sect. 10.3 et seq. The first path is relevant to the sensorimotor cortical systems (including the cerebellum) that directly innervate learned

vocalizations such as speech and song. The other is connected to the limbic system in the anterior cingulate cortex, is connected to the basal ganglia circuit, and is responsible for speech and unreflective motor skills of innate vocalization control (including laughter). These paths, however, are a connected network system linking, in a unitary structure, inner and archaic parts of the brain with more superficial parts, that are continuously being remodulated by “novelties”, in which the most recent evolutionary changes related to articulation skills have occurred.

These evolutionary novelties, which often appear to us as producers of “only human” behaviors, however, exploit an uncommon voice modulation, rooted in primates and socially functionalized, which only now has begun to be identified and re-evaluated in terms of cognitive continuity. As rightly written by Pisanski et al. 2016: “vocal flexibility in nonhuman primates suggests that other species have greater neuroanatomical elaboration of the direct lateral cortical motor route than previously thought or, alternatively, may be achieving flexibility with older neural structures” (314). A recent research has, in fact, begun to discover that in nonhuman primates the neo-cortex also plays a role in the articulation capacity and this could explain the presence of vocal flexibility in social uses of vocalizations. There are neurons that are activated during induced vocalization, but not in spontaneous vocalization, in the ventral premotor cortex of macaques nemestrini (Coudé et al. 2011). The ventrolateral prefrontal cortex of rhesus macaques also comes into play in learned audio-vocal interaction (Hage and Nieder 2013, 2015; Fukushima et al. 2014), and marmosets (*Callithrix jacchus*) show a clear neuronal activity in the frontal cortex during voice communication in a natural state (Miller et al. 2015).

If there cannot be any reasonable doubt in assuming that, from the point of view of the gradualistic evolution of human structures, vocal articulation is derived directly from that of non-human primates, it is, however, equally clear that these structures in *Homo sapiens* have become very specific, as we will now see by discussing recent experimental studies.

Firstly, only in *Homo sapiens*, laryngeals nuclei are directly innervated in the motor cortex (Kuypers 1958; Iwatsubo et al. 1990; Simonyan and Horwitz 2011). Rats and non-human primates have “shown there is an almost complete lack of direct connections between the various phonatory motoneuron pools” (Jürgens 2009, 1 and Fig. 1; 1987; Deacon 1989; Cunningham and Sawchenko 2000; see also the most recent review of Owren et al. 2011). It was also demonstrated that lesions, not only in areas of vocalization (Kirzinger and Jürgens 1991; Sutton et al. 1974), but also in large parts of the orofacial region of the motor cortex (Jürgens et al. 1982) have slow effects on spontaneous vocation in various non-human primates. Simonyan and Jürgens (2005a, b) infer that the laryngeal area in monkeys mainly fulfills non-voice functions.

Secondly, control of the neuroanatomical system of human voice is to be seen, as we have already described in Sect. 10.3, as a set of interconnected cortical and subcortical networks which are linked to the entire peripheral nervous system. This evolutionary innovation, with respect to a possible similar system in non-human primates, consists of a rewiring and a migration towards the dorsal layer of the upper cortex areas which are devoted to fine articulation, to enlarging of the range,

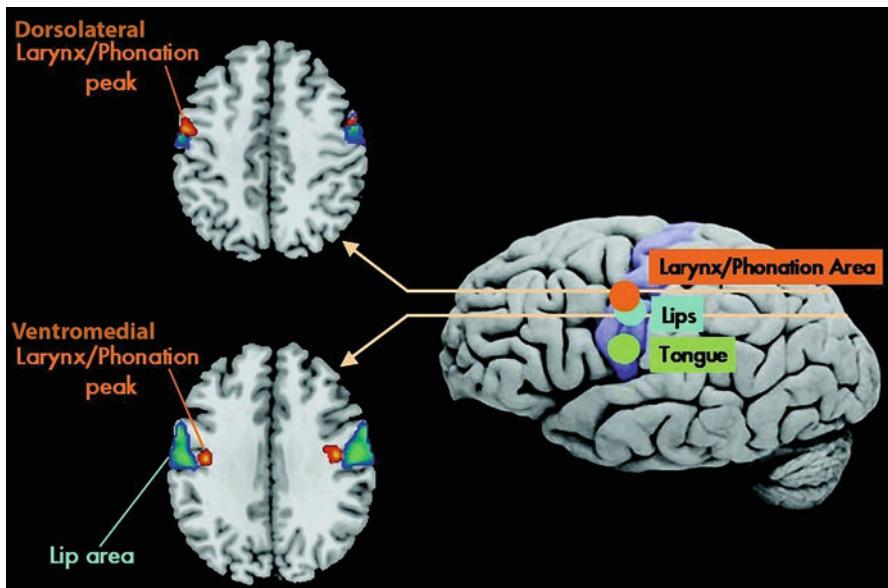


Fig. 14.4 Map of the somatotopic location of Larynx Area (Source: Brown et al. 2008, 837)

and controlling the discrete sounds of the laryngeal area specific to modern man. In particular, Brown et al. have investigated the existence of a specific cortical area responsible for the control of the intrinsic and extrinsic muscles of the larynx, demonstrating this specific somatotopic context through sophisticated brain imaging techniques. The subjects were asked to perform a series of verbal tasks to isolate articulatory components involving the opening of vowels, movements of the lips and tongue, coupled with another task that measured forced glottal stops. The results have finally been able to enrich and articulate the original mapping by Penfield and Roberts (1959) by clearly demonstrating the existence of a specific and voluntary laryngeal control area, that is a larynx/phonation area with pinpoint control of lip protrusion and vertical tongue movement: “this area is the principal vocal center of the human motor cortex” and its somatotopic location “is strikingly different from that reported in the monkey” (Brown et al. 2008, 837). It controls voice and singing, supports coordination with the respiratory system, and it is, from an evolutionary point of view, a synergy point between vocal and auditory perception production (Fig. 14.4).

Even from the point of view of perception, in fact, the specificity of a typically human *Phonation Area* clearly emerges from Brown’s experiments. During passive perception and also during perceptual discrimination of vocal production, the larynx/phonation area is always activated, and as such constitutes an absolute automatism: a highly functional voice integration system, even more functional than the manual system of mirror neurons. According to Brown: “the most evolutionarily significant sensorimotor link for the human auditory system is without question the vocal and not the manual system. This is especially so given the unique

capacity of humans among primates for vocal imitation and vocal learning” (Brown et al. 2008, 842).

From the viewpoints of ethology and evolutionary studies with neuro-stimulation techniques, scholars have never been able to identify laryngeal representations in both dogs and cats (Milojevic and Hast 1964; Simonyan and Horwitz 2011). In non-human primates it has been noted that the intrinsic and extrinsic muscles of the larynx have distinct representations inside the topographical organization (Jürgens 1974; Simonyan and Jürgens, 2002). Compared to non-human primates, cortical mapping of *Homo sapiens* appears inverted, with the CT muscle – cricothyroid muscle – in a more medial position than the TA muscle – thyroarytenoid muscle (Rödel et al. 2004). As we have seen with neuroimaging techniques applied to different types of voice tasks, the specific *Human Laryngeal Area* organization has emerged more clearly within the primary cortex (Brown et al. 2008; Loucks et al. 2007; Simonyan et al. 2009; Wilson et al. 2004), and is almost entirely located in area 4 of the premotor cortex, unlike the case of non-human primates where the homologous is located in area 6.

These important studies, recently reconfirmed (Brown et al. 2009; Belyk and Brown 2014), have specified that the somatotopy of laryngeal muscles follows a pattern that is reversed in humans, contrary to homologous somatotopic positions in monkeys. This result reinforces “the hypothesis that the larynx–phonation area is an evolutionary novelty in humans that may have migrated near the representation of the lips and tongue to facilitate coordination between phonation and articulation during speech production” (Belyk and Brown 2014, 371). In particular, this migration would allow the intentional emission of vocalization, a vocal learning based on vocal imitation, coarticulation, and speed of oscillation between voiced and voiceless sounds of language. According to Preuss (2004), it would be an evolutionary species-specific characteristic of the human brain.

Also, according to Simonyan and Horwitz, the movement of the laryngeal representation (from area 6 to area 4 of the premotor cortex) “may represent one of the major evolutionary developments in humans toward the ability to speak and vocalize voluntarily” (2011, 202). In particular, it “may have enabled the establishment of a unique direct connection between the LMC and laryngeal motoneurons of the brain stem for faster neuronal transmission and direct control over the coordinated activity of complex laryngeal, orofacial, and respiratory movements for speech production” (202). This anatomical modification would remove non-human primates from the “technical” capacity to develop an articulated, complex and voluntarily controlled vocal language.

14.3 Natural Selection, Cultural Evolution and *The Price of Language*

At whatever point of the evolutionary trajectory the departure from the corporeal technology of vocality by non-human primates occurred, the non-return moment of human cognition has to be traced back to this time. The “brain tenant of the

body” – to use Leroy-Gourhan’s words again – begins to calculate the impressive bodily transformations that will lead to bipedalism, to the reformatting of respiratory systems and to the increase of thoracic innervation. It also contributes to the descent of the larynx and the formation of a new supralaryngeal vocal tract suitable for vowel articulation 50,000 years ago, a period of time during which the exciting wild ride through the historical-natural languages takes place (Ghazanfar and Rendall 2008). The profound restructuring of the premotor cortex that we observed in the previous chapter is entirely within the evolution of modern *Homo sapiens*. It is this last act that makes the linguistic function ready for producing historical and natural languages. It is the body-body and body-brain system that, even today, regulates meaningful constraints on human vocal articulation.

What comes in between is not of decisive importance. According to the extremely restrictive reconstruction by Ph. Lieberman and R. McCarthy (2007), only after the Neanderthal was the vocal tract able to produce quantal vowels, completing the articulation possibilities as defined in contemporary man: a period of time ranging from 100,000 to 50,000 years ago. According to other scholars, however, even the bodily technology of the Neanderthal was able to produce the sounds suitable for the discrimination of the discrete thresholds that are necessary for precise and effective vocal communication (Boe et al. 1999, 2002 and 2007, contrary to Lieberman 2012). There is almost no disagreement that, from the articulatory perspective, species prior to Neanderthals were ready for language. However, we are confronted with the fact that there are extremely precise biological constraints (inclination of the channels, equivalent length, elasticity of orofacial muscles and the presence of a highly mobile tongue, etc.), and if they are not respected, the ability to produce (not individually but collectively) discrete communication systems suitable for the combination and assembly/disassembly of complex syntactic and semantic units becomes impossible.

At this point, those who opt for this thesis, advancing the theory that the nature and origin of language are still inextricably linked to a vocal bodily technology, could still wrongly date events, but the mistake will be minimal. The advantage, however, is that, once the structural demarcation criterion is established, we can focus on a more important issue than that of the dating problem: namely, what could the animal who is physiologically and brain-body suited to articulate vocal sounds do and what did he produce?

The probable answer, from the perspective adopted in this book, seems to be the following: he started to perform them without precise instructions and initially followed rules applied by a not yet functioning linguistic mind with regards to any previous types of – not even human – cognitive abilities. For example these would include perceiving contours of shapes and colours; formation of pattern recognition, categorizing, associating, distinguishing, numbering and synthesizing concepts; inferring, coordinating different inferences, drawing overall implications; focusing attention on action, trying to monitor and correct it; indicating, pointing, communicating; locating things in space, in time, mapping the area in a precise manner; monitoring and changing emotions in response to actions; recognizing conspecifics,

cooperating and undertaking joint projects; extensively practicing social learning, parental care and cultural training; etc.

This list is forcibly limited but can easily be summed up by the expression: all those things that the brains of our ancestors and of previous species did, and have always done, but not those that rely on a precise biological system in order to articulate complex operations in discrete endlessly combinable and always available cognitive body elements.

In the last fifty years, ethological studies have left no doubt that, taken individually, these activities can be found in the minds of non-human animals. It is not an unfounded hypothesis, what Elizabeth Spelke calls *core knowledge* – i.e. all the basic modules of any animal's mental shape, face recognition, spatial orientation, numbering capacity – that can pre-exist the ability for human language. But all these capabilities have evolved from earlier structural shapes and, consequently, they have certainly undergone a transformation within the adapted body. This is similar to what Spelke also argues, attributing the species-specific capacity to strengthen all the basic cognitive activities (see *infra* Chap. 7) only to the human language.

The prototypical module of artefacts categorization in a mind that evolved from an organism using language as a specific representational format – and who has another body, another brain and another cognitive organization – becomes another ability, more refined and complex. It is the same for other cognitive non-linguistic functions like mind reading or perception of mental, olfactory, tactile and kinesthetic images. Each of these functions can certainly be found in other animal species and in pre-linguistic children. When considering human subjects, the bio-linguistic device is cognitively ready, mind reading becomes a sophisticated system to predict abstract events, sensorial categorization becomes lexical and independent from stimuli, and inferential potential increases in geometrical progression articulating itself in long sequences of syntactic calculations. Evolution is not only for a single structure or a single module but for the entire organism and consequently for the species, each one having debts with the past but also credits for the future: a new and unique place in the biodiversity.

In a sense, the goal of naturalistic biolinguistics is contrary to the goal of philosophy of mind. For the former, we do not have to understand how cognitive pre-linguistic functions modulate linguistic function exercise, but we have to understand the way in which linguistic function reconverts the set of cognitive functions, as it does not have a predominantly linguistic nature in a new mental organism.

This objective is not about the idealism of the linguistic turn or computationalism. These theories do not reconstruct human linguistic mentality beginning with the body. The main emphasis for the linguistic turn is the argumentative mind and the main emphasis for computationalism is the calculating mind. These are both mental procedures which are far removed from their biology and evolutionary history.

On the contrary, a linguistically naturalized function is a focus of evolutive variability. The former is introduced, not in abstract modules, but in complex biological

organisms. Gerald Edelman's program about the third phase of cognitive sciences states:

we must incorporate biology into our theories of knowledge and language. (...) We must develop what I have called a biologically based epistemology – an account of how we know and how we are aware in light of the facts of evolution and developmental biology (Edelman 1992, 252).

Edelman was the first person to discuss the crisis within initial cognitivism at a time in which cognitivism appeared to be of great importance. Edelman believes that the reason for this crisis was as a result of “an extraordinary misconception of the nature of thought, reasoning, meaning, and of their relationship to perception has developed that threatens to undermine the whole enterprise” (228).

Edelman blames psychologists, linguists and computer scientists of the initial cognitive sciences for the adoption of a mentalist perspective that is too formalized, and for neuroscience's compromise that an “intellectual swindle” (229) both forces us “to attribute the characteristics of human mental constructions (such as logic and mathematics) to human reasoning and to the macroscopic world in which we live” – (228) and to assign semantic representations to a particular combination of syntactic organization. Natural cognitive systems have a different nature than their smaller calculistic subpart. Perception does not work with the same rules of categorization, or with Boolean and AI logics. Thought, memory and language originate from the body and from the brain. They do not operate with transcendental meanings but work with semantic negotiations developing from interactions with co-specifics and from processes of knowledge incorporation (232). For Edelman, a genuine return to Darwin means the adoption of a populational and non-essentialistic biological conception that is empirical and not platonical, and far from computationalism “which assumes that the realization of software is independent of hardware”. Therefore, not only “the mind is in the body”, but “certain dictates of the body must be followed by the mind” (239).

In this context, after the mechanical triggering of language (Sect. 14.1) and the evolutive development of structures (Sect. 14.2) from a genuinely Darwinian perspective, the remaining two chronologically successive levels have to rely on natural selection, in the sense that has been attributed to it, which we have previously discussed in Sect. 8.1.4.

In other words, there is no need to speculate about how bodily technology, necessary for language, was used. We can say that it was used in an infinite number of ways. So if we think of biolinguistics as being the DBM, we have to remove this approach from biolinguistics. Also, history and the evolution of an historical-natural language, existing mainly as cultural forms, are omitted from biolinguistics. The only feature that is universal and biologically shared in syntax, morphology, lexicon, and semantics is that they are part of the articulated voice. Also, in this case, they have to be studied by using the instrumental transformations of cultural functions of several genetic variations of *Homo sapiens*, the only human species on Earth. Historical, descriptive, comparative linguistics, sociolinguistics and more generally, cultural history have been assigned this task. Therefore, all these perspectives study the concrete forms, the products of FLN, but not the nature of the FLN itself.

On the contrary, in the case of the DBM it is important to know if (and why) the use of articulated language, i.e. the use of an extremely precise form of communication with a propositional format and an internal form of human cognition with all ensuing functions, was a selective advantage for the humans who used it in conjunction with vocalized pre-human forms, as we have seen in Sect. 14.2.

It must be stated that the answer to this matter is not obvious. We cannot be certain whether the selective expansion of language should be considered to be an incredible evolutive advantage. According to Wilson (2012), both eusocial insects and humans are conquerors of the Earth. However, there is the significant difference that the species of eusocial insects are millions of years old, whereas *Homo sapiens* is a relative newborn, being only 200,000 years old.

We have seen (Chap. 7) that if human language has its nature controlled by genetics, physiology and the neurosciences, i.e. man is a linguistic animal in a strict biological sense, then we have to ask if his consequent ability to produce cultural forms at an ever faster pace, leads towards a development or a possible premature extinction of the human species.

If this question appears offensive in the anthropocentric climate of twentieth-century culture, it can function as a stimulus for critical reflection thanks to the cognitive and natural sciences. We do not have the space here to reply with the scientific argumentations discussed in *The Price of Language* (Pennisi and Falzone 2010). However, several rules of evolutionary biology give legitimacy to the problems we can discuss in a Darwinian sense here.

The first of these rules states that no eternal species exists: every species has to become extinct, but they have different survival times on Earth. Bacteria are billions of years old. Some varieties of bivalve are hundreds of millions of years old. Coelacanth, a form of fossil fish that appeared 600 million years ago can sometimes be found in the oceans. On the other hand, there is the thylacine, a form of Australian carnivorous marsupial, and the Ethiopian lion that both only lived for some thousands of years. The duration of species survival is extremely variable. Major or minor resistance to extinction is one of the most fascinating mysteries that has emerged thanks to the evolutionary approach, but even though each species tends towards conservation, it is certain that this cannot coincide with its eternity:

It has been believed that there should be no genetic obstacle to restrict the growth of human population. More simply, the ‘immortality’ of *Homo sapiens* on earth is sometimes believed. However, each individual, which is a member of human population, is mortal. Further, each cell, which is a member of an individual, is also mortal, except tumor cells. Such mortality, as is called senescence, or apoptosis, is programmed in the human genome itself, and it seems to be a general fate of all life. Therefore, *Homo sapiens*, which is a member species on earth, may be assigned a limited lifetime as well. There is no scientific basis for us to believe the ‘immortality’ of *Homo sapiens*, except simple optimism (Kubota 2001, 299).

The second rule is known as the so-called body-size-rule or “Cope rule” – referring to the biologist who invented it in 1885 and has been confirmed by recent studies (Peters 1983; Alroy 1998; Benton 2002; Kingsolver and Pfennig 2004; Hone and Benton 2005; Smith 2007). According to this rule, large animals tend to develop and adapt to environmental conditions as quickly as they have a tendency to become

extinct. Zoological studies supporting Cope's rule allow this thesis to be best explained, making it more ambitious, because it could be claimed that extinction velocity is proportional to morphologic, social and cognitive complexity in the long term. For example, the life cycle of mammals (the most recent and complex of animals) is briefer than those of invertebrates (ten times), echinoderms (six times) and marine animals (four times).

The application of this thesis to the case of humans is worrisome. As we have tried to demonstrate in Pennisi and Falzone (2010), *Homo sapiens* seems to have reached entropic limits with regards to genetic, cognitive and social complexity. Thanks to paleontology and evolutive studies, we know that *Homo sapiens*' ancestors originated from an African lineage, and were then characterized by a shift to bipedalism, through progressive brain enlargement, the development of manual ability and sophisticated technologies, and the presence of symbolic behaviors as cultural transmission and communication forms.

In this capacity reconstruction, the evolutionary bush from which modern *sapiens* belongs is characterized by the most dizzying succession of species appearances and disappearances of the entire evolutionary history. Every attempt to "become man" involved a progressive shortening of life time: from about a million years (*Homo erectus*) to several tens of thousands of years (Neanderthal). Therefore, the zoological tree of *Homo sapiens* has been dubbed a "suicide tree". Intelligent behaviors, the extension of social organization and the existence of symbolic and religious cultures, are all cognitive aspects which belong to *Homo sapiens* which at the least could not increase survival possibilities but could decrease them. Apes that present almost the same morphological configuration as that witnessed three millions years ago, have seen passing before their eyes several more intelligent cousins that, at the same time, were less and less evolutionarily resistant.

Of course, we can say that in the case of linguistic *Homo sapiens*, this all changes because it is basically a small species and it is impossible to deduce *a priori* how long it will live based solely on a retroactive history of its predecessors. These are all logical observations, but we have to consider the ecological results of *Homo sapiens*, that are different from those of his predecessors and representing a reinforced version.

If our predecessors were extraordinary migrators with respect to other mammals, modern man has the entire world as his ecological niche. He made cold places habitable, he travelled into steppes and savannah, he climbed to the top of the highest mountains and settled in the vicinity of the sea. Basically, he cancelled the ecological notion of "geographic areal" (Gaston et al. 1998) and he therefore destroyed the limits of environmental adaptability. He then eliminated every kind of natural competition and self-limit to his capacity for expansion, so that since Pasteur's time, man does not have any real and natural enemies. Consequentially, he has distanced himself from the biological and demographic limits of death. He defeats old age and he improves his fitness, not only with the help of medicine and sciences, but with the development of a cooperative social organization. No other species has anything similar to this social cooperation. In a group of lions or chimpanzees there is no such thing as old age. An animal that is unable to take care of himself is immediately dead!

Finally, man, as in the case of other animals, transmits culture through imitative behaviors, but this culture is not directly dependent on parental care or the concrete presence of other members of the species that are cultural agents. Languages, writings and the progressive storing of memories make human knowledge as autonomous from the single subject.

As a result of articulated language, linguistic intelligence, semantics and syntax, it was possible to convert the advantages of bipedalism (a large brain and extraordinary manual skills) into technologies, values and religions. Language is a technology and a religion at the same time. Accordingly, man was able to produce the adaptive acceleration individuated in 1973 by Lorenz as the main reason behind Civilized Man's Eight Deadly Sins.

Thirty years later we can see that he was correct.

Overpopulation and demographic transitions (Pennisi 2014a, b), environmental destruction, multiplication of linguistic and cultural identities that compete with one another, ignoring aggressive behaviors which can contribute to the real danger of violence and nuclear wars, and the inability to limit the consumption of the world's natural resources are a cost that Homo sapiens pays for knowing the world through a system of symbolic and technological representation. Homo sapiens cannot choose this system because this is his biological condition and this condition characterized Homo sapiens in a social, genetic, and cognitive way.

A complicated rule of evolutionary biology exists, known as Dollo's rule, and named after the paleontologist who proposed it in 1893 (see Goldberg and Igić 2008; *but against* Diogo and Wood 2012; Galis et al. 2010). This rule is also known as a "rule of irreversibility of adaptation", according to which "the longer and more intricate the path of selective interconnected mutation processes leading to the present structure of a certain species, the less it is likely that the adaptation of such species may be reversible" (Lorenz 1983, 24-25, our translation).

Therefore summarising, Homo sapiens is the final phase of a complicated evolutionary history: a final branch that perhaps represents the highest point of mankind's social, cognitive and cerebral complexity.

The cultural, intellective and morphological events that permit the origin and development of Homo sapiens are not biologically repeatable or culturally accessible. If mankind was to become extinct, there would be no hope of a successor. Complex forms that could develop in the future would explore different possibilities with respect to those that natural selection gives mankind.

These would be non-linguistic forms of life.

Chapter 15

The Boundaries of Biolinguistics

One might say, with an epistemologically founded witty remark, that here ends the task of a possible Darwinian biolinguistics.

From an evolutionist point of view, its purpose is to satisfy the requirements proposed by the DBM detailed in Chap. 14.: individuating the level of the “mechanical trigger” of structural innovation, that is establishing the mechanical causes responsible for the origin of the FLN; reconstructing the processes leading the latter to the centre of the reorganization of the global organism; reconstructing the path followed by the restructured organism in the selective ambit of population genetics; and measuring *a posteriori* the adaptive outcome of the advantage/disadvantage of linguistic intelligence (monitoring it while it is unfolding).

From a general synchronic and theoretical point of view, the objective of DBM is exhausted in furnishing the biological coordinates within which language can develop itself as a specific form of ethological cognitive device: therefore in capturing the modalities and the constraints on its bio-mechanical functioning; in capturing the forms of reorganization of all the cognitive functions which we share with other species and in isolating others that are exclusively human; in reconstructing the specific presuppositions of the conditioning of social learning, of cultural forms and of the ecological and biopolitical intelligence of the species (Pennisi 2014a, b).

Clearly, the two perspectives are completely interdependent. The DBM is a normative framework because it connects the structure with the functions which it permits in a causal way: if we are made in a certain way, the possibilities of our cognition will constitute a finite set of probabilities of implementation.

At the same time, the DBM leaves us completely free to analyze, describe and formalize the study of the products of the functions that have been effectively activated and their purposes; therefore, the ways in which morphological, syntactic, semantic and pragmatic systems of individual languages or groups of languages function, being cultural and formally organized variables situated in a structural model that is biologically determined and, thus, universal.

From this point of view, where biolinguistics ends, other language sciences start and the latter can establish more or less close relationships with it.

First of all, we need to stress the role of cognitive linguistics, that of being more dependent on the relationship with biolinguistics because, in any case, it is concerned with an ethological comparative perspective, even if it is not yet free from the historical dimension of the evolutive component (but not from the theoretical principles of the latter).

Other language sciences that are more specifically concerned with humanistic studies are progressively freer in their relationships with biolinguistics. An example is furnished by theoretical and general linguistics that presuppose that biolinguistics is only a general background to the study of the organization of spoken and written languages. In particular, prosody has a strong nexus with prelinguistic uses of the physiology of sounds expressed holistically; articulatory, acoustic, experimental phonetics are indebted to biolinguistics as an indispensable physiological framework for the description of single systems of phonemes, which is the set of all human variations and constitute a biologically unitary collection.

Phonology cannot depart in a significant way from the constraints established by biolinguistics, not because they fail to exist but because there is a more specific historical/cultural component of systems in which the distinctivity of sounds is oriented to the comprehension and grammatical use of languages.

From this point onwards, the weight of the descriptivity of linguistic systems prevails more and more on the reason for their biological existence.

Morphology, syntax, semantics and the lexicon are, in order, more and more distant from the universality of biological laws and more dependent on historical-cultural variations which necessitate, in order to even exist, a full and detailed explanation. The grammatical descriptions of the language products, at any level, do not fit in any way with the tasks of the DBM.

At the last level of this sequence, we can place the disciplines which intend to explore the representational quality of language, and which we might call the infinitely variable eidetic granularity of the products of historical-natural languages: historical linguistics and philologies, as well as certain cultural approaches to semiotics, philosophy of language, aesthetics and literature. In these cases, linguistic analysis becomes primary in that it is not only an exclusively human product, but belongs to that minority and “less necessary elements” of human culture considered by Kant as an antidote to the biological dimension which belongs “rather to our animality, and are most opposed to our education for our higher vocation, and of making for the development of humanity” (Kant CJ, §.83:299–300).

This is a decisively anthropocentric perspective, which proceeds in the direction of Croce’s identification of aesthetics and general linguistics, which deals with linguistic forms as idiolectal facts in so far as they are historical-cultural manifestations and which, however, can be found in many contemporary approaches exalting the unrepeatability of linguistic creativity and its irreducibility to an essentially animal nature.

Of course, the epistemological sketch provided here for convenience crucially depends on the particular methodological approaches to be adopted by every individual discipline. It is certainly possible, in international scientific literature, to find grammatical and philosophical models oriented towards biolinguistics and perhaps

so-called biolinguistic models which are worlds apart from any knowledge of physiological and neuroscientific structures of language. We need, however, to accept the methodological distinction between DBM, which studies the structures of speakers and all the other models that study the products of these structures.

Structures and products certainly need different typologies of scholars. The convergence of various scholars will be much stronger, depending on how evident and explicit the causal nexus relating organisms to their products is, by uniting in a single bio-linguistic object of study what pertains to structures and what pertains to functions.

15.1 Biolinguistics of Performance

As can be seen, pragmatics does not fall within any of the sciences of language so far cited. The reason is obvious: we think that pragmatics is not (only) a real technical discipline of the sciences of language, but the constitutive dimension of a methodology that places performativity at the center of the cognitive dimension of the human mind. In other words, pragmatics is, for us, a biolinguistics of performance.

We will return to this point in Chap. 16.

For the time being, we want to note that in its enviable theoretical coherence that has lasted for over half a century, the CBM has always connected the design element of speech production – competence – with computational operations of the linguistic mind (recursive procedures from GGT to minimalism's MERGE) – and the executive element with the performance of externalization devices (see infra Chap. 11). This dualism – whatever their philosophical or functional origin – is totally rejected in the DBM as we have tried here to propose. In DBM there is not even the idea of a computational project in the production and reception of language. Its execution determines step by step the potential implementations of a biological project inherent in our genetic structure. The results of these performances are highly standardized, uniform and universal with their components being derived from the fact that all humans have the same anatomical structural, brain and corporeal configurations, whilst being very different with respect to those components that characterize the uses of language contaminated by the culture of historical and natural communities or individuals.

In DBM, performance is the default condition of language development. It is always constrained by biological structure, but from the first ontogenesis to the development of complete bio-cognitive maturity, the nature of these constraints have changed appearance, function and type of coercive force.

In the embryonic phase, performativity is in a state of immaturity. The complex and still largely unknown cerebral embryogenesis and structural mechanisms develop almost exclusively through genetic algorithms. Yet even at this stage cellular competition and neuronal selection participate in a clear manner through exchanges and communication at the macrocellular level. From Edelman (1988)

onwards, we know that the composition of different populations of cells cannot simply control morphogenesis: “the differences in position and gross shape result from the sequential (and historical) interaction of a number of different processes acting either as driving forces or as regulatory elements in shaping overall form or tissue pattern. These cellular processes are the so-called primary processes of development: cell division, cell motion, and cell death (driving force processes); and cell adhesion and differentiation (regulatory processes)” (Edelman 1988, 31).

During the fetal stage, starting from 3 months gestation, this performative participation – cell competition of “neural Darwinism” (Edelman 1987) – has invaded the neutral territories of the genetic mechanism. In-depth studies on the perception of some prosodic aspects by the fetus have been known since the 1970s (see Pennisi 1994, 261 et seq.). Then the novelty introduced by these works – initiated by J. Mehler and his team – was due mainly to the introduction, in the experimental activities, of items from natural plurisyllabic chains. Thus it was discovered that two-day old infants fail to recognize only global units of syllabic type, while at 4 months they begin to show a more detailed and analytical differentiation of consonant sounds. The real structural peculiarity of the syllable is, in fact, its musical or prosodic nature: the syllable is the bearer of the stress, it is the smallest unit in which you can already find melodic variation. Indeed, more than one unit in the (phonological, morphosyntactic, semantic) sense that normally attaches to this concept, the syllable is simply the sign of an auditory attention directed to large segments of speech. Thus, one obtains the highest level of evidence for syllabic perception, in experimental conditions, when administered in the form of items occurring within natural configurations: namely plurisyllabic sequences incorporated into events or phrasal segments. In these cases, the human voice is represented through its most significant acoustic properties: coarticulation between syllables, complete variation of stress, appearance of a contour or background intonation. These characteristics are the basis, not only of perception and phonetic recognition (of the syllable), but also of the syntactic one, in the sense that the natural prosody allows the identification of the borders of the primary constituents and the order of the words.

In line with the research of Mehler and his team, we even find studies on *motherese language*. This involves a research group who have recorded an impressive series of prosodic differences in performance when the mother shifts her attention from an adult partner to her newborn son. These changes relate mainly to a greater height of the fundamental frequency, a slowdown in the pace, exaggerated intonation, a summary of what has been called “expanded intonation contours” (Fernald and Simon 1984). This type of signal results in high perceptual salience to the infant, even a child a few days old (1984, 105). The interaction between the perception of the musical maternal language and preference of the newborn to an expansion of intonation contours, appears to be truly universal of language, both receptive and productive (Grieser and Kuhl 1988, 19). It was in fact registered both in European and Asian languages, in tonal and non-tonal languages, and there were no differences even between primiparous or multiparous mothers (Fernald and Simon 1984, 110).

From a functional point of view these studies demonstrated a number of important features that are worth discussing one by one:

1. prosody increases the redundancy of the message: while two syntactically identical sentences, but pronounced with a neutral shade, do not arouse any reaction, two syntactically different phrases, repeated through expansions of intonation contours, activate the newborn's response;
2. the exaggerations in modulation, the motherese peaks optimize the newborn care and introduce a kind of "shift" in the interlocutory game between mother and child;
3. the expansion of intonation contours strengthens affective motivations: among adults high intonation peaks and widening of the range of prosodic variation mark the most intimate behaviour;
4. the practice of motherese standardizes maternal recognition processes by the newborn;
5. the mother's prosodic patterns amplify the perceptive abilities of the newborn in anticipating the phonological, semantic and syntactic organization: in particular, the continuity of intonational blocks is the most likely to advance the idea of a sentence;
6. the exaggerated rhythmic temporality of maternal language plays a fundamental role in the formation of metric (i.e. prosodic) competence, and then in the handling of the speed best suited to language perception and production (Fernald and Simon 1984: 112).

Taken together, these observations suggest what has been called the "prosodic bootstrapping hypothesis" (Gleitmann and Wanner 1982); Morgan and Newport (1981) are organically integrated with the thesis of an auditory-musical training of a fetal nature. The point of contact between post-natal research on the characteristics of the motherese language and experiments on embryonic perception of language is represented by De Casper's works which investigate the nature of speech recognition of newborns. In the essay *Histoire de fœtus par un nouveau-né* (1990), when summarizing the experiences of many years of audio-embryological research, De Casper reveals that the pre-natal's life perceptual organization is already sensitive to the mother's voice, to the most common expressions within the mother's voice and to the nursery melodies he has already learned in utero. More recently, these pioneering studies have been confirmed experimentally beyond any reasonable doubt (DeCasper et al. 2011; Granier Deferre et al. 2011; Moon et al. 2013) and Falk (2009) have even suggested that the practice of motherese, like the maternal effort to produce communicative sensations perceived as pleasant by the newborn through the alteration of the melodic contour of nursery rhyme production, may have been the very cause of the origin of human language.

In an important and much quoted 1987 article (*Prosody and the development of comprehension*) two Cambridge psycholinguists observed that many studies on the prosodic behavior of children revealed that "children's prosodic productions appear to be more advanced than their prosodic understanding" (Cutler and Swinney 1987, 145–6). In other words, prosodic performance is systematically higher than

prosodic competence: children (aged 4–5 years) are able to cognitively use prosody more than they are able to explicitly recognize it.

Of course, prosody is learned. From what we have said before it is, indeed, the human animal's first form of auditory-vocal learning. But once having experienced the understanding of the amazing functionality of the different purposes of the melodic modulation of sounds, their use becomes a trump card in the cognitive behavioral strategies of newborns. This explains the extraordinary richness of the vocal musicality of children, perfectly harmonized to achieve their purposes.

More recently, cognitive psycholinguist Hendriks has extended the scope of this mystery with other considerations on language. In *Asymmetries between Language Production and Comprehension* (2014), she found a reversal in cognitive primacy of performance with respect to competence in the use of pronouns, and in particular of deictic elements, in the order of basic words, the decline of verbal forms, the positioning of stress on semantically and syntactically significant elements, the use of modifiers and referential constraints ("restrictive modifier") and in that of evidential morphemes: in short "Asymmetries Everywhere?" (2014, 72). Whereas the extensive literature used recordings of these phenomena in different languages (French, English, Polish, Dutch, Danish, etc.), Hendriks has seriously considered the idea that, far from reporting incidents or exceptions, "this asymmetry reflected a fundamental property of language" (2014, V).

15.2 Performative Bootstrapping in Ontogenetic Development

The ontogenesis of language fully confirms Hendriks' intuition, which, however, should be deepened and clarified. In fact, among the many explanations used for this (apparent) mystery and reflecting the linguistic ideology of different schools (generative syntacticians, structuralists, interactionists, etc.), Hendriks does not sufficiently consider the close interaction between constraints on biological development by the peripheral/central anatomic structures and the strong spurring to performative and pragmatic activity at every step of linguistic cognition.

Essentially, it is a singular dynamics of cognitive maturation that provides a synchronization and an incessant stabilization of genetic maturation processes (formation and completion of the vocal tract), of completely performative processes (action without algorithms), of pragmatic consolidation processes (Capone 2005) and, finally, of computational routinization (at the neural level). This dynamics is repeated at all historical levels of mental development, leaving to the early stages the almost complete domination of structural completion of basic routines of genetic development and, at the last stages, the infinite expansion of language's creative processes: that is the undefined structuring of very rich experiential libraries formally underlying the logic of propositional grammaticalization. In the middle, there are the partially variable processes of bio-cognitive development, the history of

which coincides with the “quantic” variability of individual subjects, and the exponential growth of the “extended mind” that is not located in a confined space, but tends to become the first cognitive and collective metaorganism of evolutionary history.

To fully implement the cognitive program of biologizing the computationalism proposed by Edelman (see Infra Sect. 14.3), therefore, the biolinguistic centrality of performance has to be considered as indispensable. If we had to define it in one general and programmatic sentence, we could say that performance is exploratory activities in the absence of known algorithms.

The brain plasticity and its ability to always follow motor skills – occurring both during the evolution and during the subject behavioral development, as we saw in Chaps. 12, 13, and 14 – allow this performative exploration activity to always act in a biologically-oriented manner, and not randomly.

At first it will be oriented by the articulation possibilities made available by an evolutionarily specialized structure such as human supralaryngeal vocal tract. However the latter does not provide, by default, the learning algorithms for historical-natural languages.

As is well known thanks to Philip Lieberman's huge works (1975, 2006; Lieberman and McCarthy 1999; see also Kent and Vorperian 1995), the classic conformation of the species-specific human vocal tract is not achieved by the child before 18–24 months of life. Until two years of age, the shape of *Homo sapiens*' vowel production organs is not dissimilar from that of other primates. This physiological state does not prevent them from producing vocalizations of various types, but it prevents several species of adult primates from producing formant variations even of considerable amplitude (see Sect. 14.2). And, in fact, human babies produce vocalizations such as cries, wails, reactive sounds of comfort or uneasiness since the early months of their life and they begin to control speech from the fifth month onwards (de Boysson-Bardies 1999). The mastery of basic vocalizations is manifested first with the cooing stage (vocalizations demonstrating that the baby is fine) and then with the babbling one, a sort of pre-linguistic vocalization mainly manifesting itself with repetitive productions and rhythmic alternations of consonants and vowels. By the common consent of all scholars, from an articulatory point of view, these kinds of vocalizations are universal and unrelated to the historical-natural mother language, while the intonation contours are already influenced by the native language from the eighth-tenth month (but on the latter timing there is no unanimity). This data seems consistent with Hendriks's observations, which have been previously presented. In fact, at this stage, prosodic performativity has almost entirely assimilated melodic development (antecedent from the point of view of physiological maturity and, therefore, of the possibility of functional use) whereas phonetic articulation is still struggling with the slow development of the vocal tract, which is not at all ready for the fine modulation of the extensive consonant setting (Vorperian and Kent 2007) and with the sex differences in the timing of the development of the anatomical region involved (Vorperian et al. 2009).

Being able to articulate clearly the sounds of the human repertoire is a hard physiological challenge due to the risks related to the use of a single channel for

different functions (phonation engages both breathing and feeding, as we have seen in Sect. 14.1). To reduce these risks, the veil and the epiglottis are very close together in infants up to two months, and the larynx is in a higher position, positioned at the level of the third cervical vertebra, thereby separating the trachea from esophagus (Zmarich 2010). When babbling starts, the larynx has already begun its descent, as well as precise physiological control of the jaw and the launch of the tongue. It is necessary to wait for the arrival of the first molars (at around 16–18 months) to allow occlusive contacts. In short, although the previous two years babbling shows all the signs of problems determined by physiological maturation, the cognitive structures that govern the categorization of auditory input have already developed, and therefore a lingual-specific development of semantic recognition and behavior-related activities is present.

From 8 to 10 months, in fact, we can note the detection of phrasal boundaries and phonotactic constraints of native language. It is also the stage at which, for the first time, the properties of pragmatic stabilization occur through understanding words in context. At 12 months, a minimum of thirty words are already recognized and understood, settling a lexicon with specific referents and with a proven pragmatic contextualization. From 16 to 20 months, this lexicon reaches at least two hundred words, but without a distinct production, i.e. phonetically organized and conforms to the native language, it is manifested with the exception of those words that require less articulatory effort (a maximum of thirty-fifty items): electively the syllabic formations constituted by vowels and bilabials, voiceless, voiced or occlusive.

From 18 months of age, when his/her cognitive activity is concentrated on producing exact articulatory movements and after great effort, often with frustrated attempts, she/he is able to repeat the auditory target continuously heard from external sources, the key step in human biolinguistics is finally accomplished. The *Homo sapiens* child, who has almost attained the human vocal anatomy, and thereby differentiating himself from other primates, can finally explore its effects on all other cognitive activities.

Achieving and overcoming this phase is perhaps the most important performance event for the human species-specific cognitive ontogenesis, as it is the voluntary and equally decisive performative event of bipedal locomotion (between 12 and 15 months of life) and for neuromotor activity which provides navigational autonomy to the human baby. Here the performing activity is expressed at its highest material level. No genetic program or mentalistic computing can suggest how the ability to produce all the sounds permitted by the vocal organs, and demanded or suggested by the native language community, has to be performed.

In the absence of innate algorithms, other than those reached when physiologic maturity arrives, the cognitive effort accomplished at this stage is so intense that Spelke and her collaborators (Spelke et al. 2013) have observed experimentally a regression of intellectual abilities, and in particular social abilities, during that period. The fulfilment of this effort that leads to a full voice articulation domain can even last months for no pathological reason. But at the end of this process, the baby's ontogenetic development will come to a *cognitive bootstrapping*: the now dominant presence of propositionality, firmly mastered by a completely emancipated articulatory performativity, which will allow the exponential increase of those

cognitive components which have been slowed down by the cognitive load connected to language learning.

Furthermore, in a short time, the definitely propositionalized cognitive activity reformats the details of other components: the visual and imaginative, inferential, logical-numeric, relational and social, aesthetic and moral components, and so on (see Part II).

The second phase of this schematic subdivision of cognitive activity in the performance biolinguistics paradigm is not, in fact, the automatic generation of syntactically correct sentences – that is, consistent with formal universal rules – but the application of the bodily technology of articulated language to the performance of significantly profitable forms, that is producing results on the real world, consisting of behavioral and emotional benefits. Hendriks' results are strongly revelatory from this point of view. Perhaps the most important property of the FLN, as sketched out in the DBM, is precisely to reverse, once it is learned, the relation between performance and competence, execution and the project. Performance is not an externalization, but an activity that builds and anticipates programs of understanding and which pragmatic stabilization will help to formalize in reusable routines, that is, in new cognitive algorithms. Learning phrasal forms and syntactic-semantic subtleties comes subsequently and quite effortlessly. Rules will be formed and reorganized pragmatically only after articulatory practice allows one to exercise, in an unbridled manner, the performative activities, which are cognitively plastic and flexible in nature. For otherwise, these always remain a testing bed for pragmatics: the success of behaviors providing advantage, or conversely the failure of behavior lacking the contact with the cognition of the world. Functional processes, acquired but species-specific, are formed from innate physiological structures.

From a neuroscientific point of view this phenomenon has been foreshadowed by Lieberman and McCarthy (2007) and Lieberman (2012, 2013) as we previously discussed in Sect. 14.1. A large amount of literature has been devoted to the investigation of this issue through both brain imaging (Monchi et al. 2001, 2006; Nagano-Saito et al. 2008), and biochemical reactions involved in the plasticity of synaptic processes (Thivierge et al. 2007; Ko et al. 2013) which have, in fact, amply demonstrated “that the caudate nucleus and the putamen are particularly important, respectively, in the planning and the execution of a self-generated novel action, whereas the subthalamic nucleus may be required when a new motor program is solicited independently of the choice of strategy” (Monchi et al. 2006, 257). Examining the biolinguistic aspects of these discoveries in depth, Lieberman and his team have shown that the neural circuits connecting different brain parts during human speech exploit the putamen for neuromotor control changing “on the run” – that is, during verbal action performance – “the direction of our thought processes based on new stimuli such as the understanding of meaning conveyed by the syntax of language” (2007: 16).

Furthermore, a similar activation of brain motor components is registered when language data are processed in the absence of grammatically well-tested algorithms, such as when a second language is learned (Klein et al. 1994), or when a subject switches from listening to informal speech to a more formal one (Abutalebi et al. 2007).

In short, the management of neurocerebral performative strategies seems to be responsible for the most dynamic processes of linguistic behavior. This kind of behaviour needs an attempt, or an active effort, that cannot be accomplished only through mechanical application of already known and stabilized rules because it requires “the execution of a self-generated action among competitive alternatives” (Lieberman 2013, 80): an activity that is prolonged virtually forever, after the first acquisition step of ontogenetic speech, moving from mechanical physiology to the physiology of thought.

This overall framework also explains why the paths of speech often follow the hesitational phenomena of breaking up, recombination, reunion, syncretism, propositional chiselling, semantic and lexical refinement: that is, all that is stigmatized by Chomsky’s idea of performance as the deposit of cognitive junk produced by externalization devices (to repeat his words: “numerous false starts, deviations from rules, changes of plan in mid course, and so on”, 1960, 530). On the contrary, the most advanced neurolinguistic research reveals the close interconnection between motor performativity and the continuous reorganization of propositional and abstract thinking: “the cortico-striatal regions that regulate language comprehension also regulate many aspects of behavior such as motor control and abstract reasoning” (Simard-Monchi et al. 2010, 1092). Evolutionarily, in fact, the performative motricity of thought could have been decisive for understanding the subsequent development of human language: “because it indicates that our modern brains may actually have been shaped by an enhanced capacity for speech motor control that evolved in our ancestors” (Lieberman and McCarthy 2007: 16).

Chapter 16

Pragmatics and Biolinguistics

As we have stated in Sect. 15.1, in this book we are considering pragmatics to be not (only) a real technical discipline of the language sciences but the constitutive dimension of a methodology placing performativity at the heart of cognitive processes in a DBM. We are not sure whether utilizing it as a naturalistic methodology might be compatible with the diverse obligations connected to the disciplinary nature of pragmatics, but we can try to avoid collisions between the two methods of analysis.

From this point of view, there are many methodological and philosophical approaches which attempt to connect pragmatics with an evolutionist model, beginning with their basic purposes.

Habermas (1979) has contrasted the “abstraction phallacy” of Carnap’s logical neo-positivism, with a theory of communicative action enhancing a pragmatic theory of language that produces a knowledge relationship between language and action, analytical processes and performative processes.

Idan and Kantorovich in *Towards an Evolutionary Pragmatics of Science* have turned this conception of pragmatics of language into an epistemological model of philosophy of science, that is antithetical to formalists who are said to ignore the “dynamical aspects of the users and of the contexts of use of theories and of scientific language” (1985, 54), stressing the importance of the path that would connect pragmatic to naturalistic conceptions to arrive at evolutionist ones. Michael Ruse has even claimed that “Darwinism suggests that in the end it is all pragmatic. We are best to go with what has worked before. However, there are no guarantees of success” (2012, 320).

In what has been called *Pragmatic evolution* (Poiani 2012), we find a manifestation of the idea that the well known absence of a planner (or designer) in evolutive history does not mean that we should be resigned to explain it by resorting to the mere notion of chance that affects all events. On the contrary, it should rely on explanatory reconstructions that depart from an established causal context of all previous states, without however being able to predict with certainty what will happen. Pragmatics, from this point of view, is the only possible laical logic of natural selection.

As for natural history, even when considering the minds of human and non-human animals, the absence of a general teleological or computational principle that contains in itself all possible logical responses to the flow of events that one can be confronted with does not mean that we are dealing with an irrational or chaotically functioning cognitive system. The rules of cognitive behaviour follow rational criteria of a local nature, that are derived from experiences that are organized and progressively ordered through performative experimentation.

Pragmatic rules stabilize and progressively formalize performative sequences that have allowed users to achieve positive results (advantages), even if it is possible that they will adopt more convenient ones in the future. However, sequences that have been stabilized, stratified and tested thanks to pragmatics constitute well structured responses that have their intrinsic attraction.

What confers a scientific (or, anyway, non arbitrary) value to both pragmatic and mental procedures as they have been delineated, is their biological anchorage. Their stories are not completely free to take place, even if they contain a great quantity of potential possibilities. We are dealing with stories that are constrained and not with arbitrary procedures. A species deriving from structural (physiological and anatomical) stratifications cannot evolve by speciating in a way that is not coherent with its past nor can it incorporate forms that are removed from its biological nature and placed into its cultural variability.

In the same way, it will not be possible for a species with a flying body to be immediately generated by the human one; in the same way, a species with an olfactory brain like that of dogs cannot be speciated from Homo Sapiens. This does not exclude the ambit of structural and functional variation which will continue to produce important gradual changes in the genic pool and in the cultural “pool” of historical-natural populations.

This is one of the most delicate points which has to be clarified. Pragmatics is intended to be a science dealing with variations in contextual contents, similar to morphology, syntax and semantics in historical-natural languages and cannot take the epistemological status of an evolutive science and will remain outside the DBM. On the other hand, the study of the biological implicatures of communicative behaviour or the methodological study of performative trajectories in relational and discursive activities are perfectly covered by a DBM as was have proposed here. Of course, both approaches have their methodological and disciplinary legitimacy and it is not to be taken for granted that they cannot interact.

However, they correspond to different epistemological needs, such as that of explaining the functioning of few universal and experimentally testable rules in the biological domain or to describe a possibly infinite quantity of *ad hoc* rules valid in specific cultural contexts that can be easily circumscribed.

Here we will consider as evolutionist a pragmatics hypothesis that satisfies the following characteristics:

- (i) It constitutes a biological explanation of human behaviour;
- (ii) It is circumscribed by precise constraints of a structural and pre-cultural nature.
- (iii) It is aimed at universal and not particular statements;

- (iv) It allows us to explain the gradual paths through which the behaviour we have to explain is instantiated;
- (v) It is able to specify the ways in which this type of behaviour is instantiated in a species-specific way.

From our point of view, any hypothesis that does not satisfy the criteria outlined here has little to do with an evolutionist hypothesis. Many hypotheses, in fact, connect only with the first point and ignore the other four. But aiming to explain only what appears as uniquely human (to use a fashionable expression), even if these explanations are fascinating and gratifying, is very far from a genuine evolutionist method.

According to our approach, the uniquely human appearances of our behaviour can only provide a starting point to the process of understanding their real nature and function, not only at their origin but also in the practice of daily uses. This should apply, in particular, to pragmatic competence which certainly covers a wider and more universal ambit than other types of linguistic competence. Therefore, we believe there are ways to define – side by side with the traditional cultural approaches – a space for discussion that explores the possibility of a naturalistic approach that is completely compatible with the Darwinian model, in the sense intended by this book and certainly likely to be integrated in the paradigm of cognitive science, which nowadays is held to be the most suitable one for the process of unification of human and natural sciences.

Having made these general clarifications, and setting aside the approaches of pragmatics (and their contents) which are beyond the interests of this book, we will try to specifically discuss, in these final sections, the possibility of technically integrating pragmatics in the DBM.

16.1 From Pragmatics to Cognitive Performativity

The interest in pragmatics in our hypothesis primarily concerns two aspects: performativity as a knowledge process (ontogenesis) and performativity as a selective process (phylogeny).

The study of the pragmatic aspects of language has a precise history and is autonomously situated in the tradition of the philosophy of language. However, in the theoretical proposal we have formulated, we will not accept a single pragmatic theory present in the contemporary philosophical-linguistic and ethno-methodological debate.

We will try to adopt, even in this case, a cognitive and biological perspective to explain how it came that linguistic action (in the motor-cognitive sense of the term) has provided, on the one hand, the evolutive trigger for the instantiation of the linguistic function and, on the other hand, the ontogenetic praxis necessary for the acquisition of language and all types of competence associated with it.

In order to do this, it is necessary to define which aspects of pragmatics have effectively acted, and continue to act, on the selection of human language. But before doing this, it is fundamental to clarify some basic concepts of classical pragmatic theories in order to avoid terminological and conceptual misunderstandings.

16.1.1 The Dichotomies of Contemporary Pragmatics

Pragmatics has been defined in different ways. Since its first definition, formulated by Morris in 1938, pragmatics has been considered to be a science which focuses on the relationship between signs and their users. The main purpose of pragmatics is the analysis of language's concrete uses in contexts. Thus, this aim is radically different from those of semantics, which clarifies the link between signs and the things to which they refer, and of syntax, which in turn examines the compositional rules of any language.

Much has changed since this first definition, in the methodological setting and in the definition itself of pragmatics' aims. As handbooks of pragmatics illustrate (Allan and Jaszczolt 2012), first of all the object has changed: Grice considered the sentence as the minimal unit of the analysis, whereas there are now "sophisticated theories" that investigate the entire speech as the unit. In this way, assertive acts are considered central in pragmatics, rather than the non assertive ones. A "pragmatic turn" has occurred (Mey 2001; Engel et al. 2016), that is a shift from the analysis of phrasal structure to the use of the sentence during the communicative interchange.

Frontier research in pragmatics deals with the conceptualization of syntax (Kempson 2012), the dynamics between semantics and pragmatics (Broggaard 2012), the study of presuppositions (Capone 2013; Macagno and Capone 2016), the truth conditions and meaning (Recanati 2012), the distinction between literal and non literal (Carston 2012) and so on.

These changes have, nevertheless, affected the general orientation of pragmatics, too. On the one hand, Anglo-American pragmatics remained inside the limits of the philosophy of ordinary language (more interested in understanding the possible formalization of linguistic uses into logics) and the comparison between pragmatics and grammar. Instead, in Europe, pragmatics began to focus on the so called micro-pragmatics, which includes societal pragmatics and topics like cross-cultural communication and its ideological implications. It is also true that some researchers tried to apply the straightforward approach of formal analysis, typical of the Anglo-American tradition, to micropragmatics, and thereby trying to integrate both these perspectives.

For example, Traugott (2012) investigates the change in linguistic uses and claims that while historical pragmatics focuses on the inner change in the individual speaker, actual interactional approaches consider speeches and genders as the relevant contextual units. Similarly, Haugh and Jaszczolt (2012) propose that conversational analysis must consider the speakers' socio-cognitive dimension, including the perception of their selves and their social roles.

According to Kecskés (2012) it is possible to find two recent perspectives in pragmatic theories: a cognitive-philosophic perspective, and an interactional-sociocultural one.

The first perspective focuses on the analysis of the expressed propositions and communicative intentions (communication is grounded on the speaker's knowledge and on the receiver's ability to recognize the speaker's intention in the context, through pragmatic inferences). The main role of pragmatics would be to explain precisely how the hearer makes these inferences about the speaker.

On the other hand, the second perspective confers greater relevance on the socio-cultural context in sentential analysis and considers it impossible to treat the speaker's intentions in a scientific way because they are ambiguous. According to these scholars, communication does not depend on the speaker's intentions (or at least the intentions are not an *a priori* mental state which constitutes communication, as claimed by the cognitive-philosophic approach), because they arise from the dynamics of meaning construction during the conversation. In this perspective the socio-cultural factors construct communication. According to Kecskes, it is possible to mediate between these approaches, by trying to show the existence of an ongoing dialectics between the speaker's *a priori* intentions and the intentions arising during the conversation. This kind of approach is defined as being socio-cognitive in nature.

It is possible to reformulate these approaches in pragmatics by distinguishing between a pragmalinguistics, which refers to the grammatical and pragmatic resources apt to display a linguistic act (that corresponds more or less with the Anglo-American philosophical approach described above), and a societal pragmatics, that is the “sociological interface of pragmatics” (Leech 1983), in other words all the social perceptions that the speakers' intentions convey during conversation.

During every conversation it is possible to ascertain the social distance between the speaker and the listener, the social power in this relationship (their rights and duties), and the degree of “obligation” present in the conversation and connected to their social roles. Strictly speaking, societal pragmatics values the appropriateness of social behaviours during conversation, and even ends up postulating about the explicit awareness derived from their pragmatic choices. Societal pragmatics is, in fact, grounded on some sociolinguistic studies that have shown how the use of a specific kind of language elicits prejudices and discriminations. The “militant” socio-cultural-interactional approach is part of societal pragmatics.

Capone (2005), reasonably aims to broaden the concept of context with respect to traditional views that see context only as a set of information which adds possible meanings to the interpretation of a phrase. He proposes the consideration of context as an experiential source, as a place to accumulate knowledge that is based on numerous conventional interactions between the meaning of phrases and certain situational configurations. These interactions affect the value of context:

I believe we may be allowed to extend this traditional view to include a new account of the way context serves to transform meaning – an account that views context as not merely adding further layers of meaning to utterance interpretation. The transformations are not realized in accordance with inferential procedures grounded in pragmatic principles, but are

based on knowledge of a number of principled and conventional interactions between utterance meaning and certain contextual and situational configurations (Capone 2005, 1360).

According to his hypothesis, at this level the process remains a kind of formalizable activity: it is possible to “translate in an algorithm” certain implicatures and thereby transforming them into linguistic-behavioral components mediated by social practices.

An example of this would be provided by the notion of pragmeme, formulated by J.L. Mey (2001). According to Mey, pragmeme are linguistic acts dependent on the interaction between linguistic and social rules. It is a situated language production whose interpretation is only possible thanks to social rules (see Capone, in press). In this sense, the concept of pragmeme constitutes a linguistic-social entity, i.e. a language production socially recognized and sensitive to the social expectations of context production.

Societal approaches to pragmatics have emphasised considerably the importance ascribed to the extralinguistic context, making it much more important than linguistic competence. Using the anthropologic approach, according to which: “meaning arises out of the interaction between language and circumstances, rather than being encapsulated in the language itself” (Hanks 1996, 266), the predominance of linguistic action upon language itself is asserted: “what is being done by the words is more important than the words themselves, which may vary endlessly” (Mey, in press)

Pragmeme, when performed in a fixed way, are automated, understandable in an implicit way and mechanically performed, would become entities almost independent from language, and are a cognitive instrument over social practice and syntactical construct:

It would be inappropriate to just call this kind of linguistic acting a ‘speech act’, as if the only faculty involved were the human voice; as I have argued elsewhere (e.g. Mey 2001: ch. 8). What we are dealing with is not a mere act of voicing (as suggested by the term ‘speech act’); rather, it is an act of performing a societal function of language use (a ‘pragmatic act’). The pragmeme captures a function from user to user, from user to the world, and vice versa; as such, it is a pragmatic function, establishing and warranting a particular pragmatic act. The pragmeme is thus the embodied realization of all the pragmatic acts (or ‘allo-practs’) that can be subsumed under it, such as the various manifestations of expressing gratitude, in much the same way as the various phonetic manifestations of /r/ may be caught under the umbrella of the same phoneme (Mey, in press).

The role of pragmatics, according to Mey, changes in a radical way: it is not to trivially investigate the linguistic context, but to reveal the socio-cultural one. The central idea of societal pragmatics is that linguistic use and socio-cultural practises are interdependent, and thus the linguistic practice produces roles and social conditions that in turn influence the language (Fetzer 2011). Language, according to Mey, cannot be separated from society, because it is society that determines the meaning of words:

the theory of pragmatic acts does not try to explain language use from the inside out, from words having their origin in a sovereign speaker and going out to an equally sovereign hearer (...). Rather, its explanatory movement is from the outside in: the focus is on the

environment in which both speaker and hearer find their affordances, such that the entire situation is brought to bear on what can be said on the situation, as well as on what is actually being said (Mey 2001, 219).

The idea that pragmatics influences the socio-cultural context in a direct and mutual way gained general consensus among scholars, so much so as to lead some scholars to propose that pragmatics (or more accurately, societal pragmatics) plays an emancipator role; it would help speakers to use words in the most adequate way, thereby bringing them to a pragmatic accuracy in communicative exchanges:

a societal pragmatics that is true to its name should at least take one (or better, several) ‘proactive step(s) in the same direction, anticipating language related social problems and planning ways to preempt them, by capitalizing on the language users’ own abilities and needs, and on the opportunities that already have been, or that will be created for them. This will include an education in practical, societally relevant language use, a use of the kind that is needed in order to have an impact in a public context (Mey 2015:38).

The same “emancipatory” principle could be applied to contexts that are not exclusively connected to the communicative meta-analysis, but to actual social usefulness, as in the case of ecologist pragmeme:

in much of the standing ecological debate, the pragmeme of ‘living with nature’ is expressed as ‘sustainability’ (of a product or process), or more generally, as ‘ecology’. The functions and operations involved here are typically adaptive: adaptation of the situation to the individual user, and conversely, the user’s adaptation to the surrounding situation (called the ‘environment’); these functions constitute the hallmark of the ecological pragmeme of adaptation. Thus, this particular function(the pragmeme of ‘living with nature’) assigns ecological ‘truth’ to our actions by uniting the responsible (sustainable) human activities under the umbrella of adaptability (Mey, in press).

16.1.2 *Explicit and Implicit Culturalist Approaches*

Summing up, we can say that what is common to almost all the hypotheses of contemporary pragmatics – with a few exceptions, which we will return to later – is that they show an explicit or implicit culturalist tendency.

Even the term “culturalism” has a varied range of meanings. In its most general sense, culturalism coincides with the tendency to reduce everything (behavior, event, practice, characteristics, etc.) to a cultural matter. In its gradually more philosophical meaning, culturalism becomes the orientation that considers culture: the (variable) way in which individuals construct their own “reality”; the system of values, beliefs, obligations, etc. that influences the actions of any individual who works in a community; the “lens” that affects every epistemological approach in the study of any social or natural phenomenon; and so on.

For many versions of “culturalism”, the notion of language and language faculties is co-essential. Language is the mirror of culture, but also *vice-versa*, culture is the mirror of language. Indeed, according to culturalists, each language constitutes the boundaries of the world of the speaker. Both in the relativist tradition (Sapir-Whorf), and in the analytical (Austin, Strawson, etc.) one, Wittgenstein’s assertion

that “the limits of my language indicate the boundaries of my world” (Tractatus, 5.6) is always precious.

One of the possible directions that linguistic culturalism could take, and, in fact, has taken with pragmatics, is to consider behavior as a set of cultural constraints. We could disambiguate phrases, expressions or discourses only if we are able to reconstruct the set of specific linguistic and extra-linguistic pieces of knowledge which are known to the speaker-hearer in that specific moment, in that specific geographical portion and social space, in that particular community, in relation to certain historical facts and to the logical, individual and collective psychological dispositions, etc.

Both Anglo-American pragmatics – that is, the cognitive-philosophical tradition, by which we have earlier defined pragmalinguistics – and European pragmatics – what we have defined as sociopragmatics or societal pragmatics – actually have the same epistemological cultural background in common, but while in the latter this background is quite explicit, in the former it often remains undefined or implied.

It seems superfluous to clarify the cultural background of sociopragmatics: we can only say that it aims to understand how social conventions could change or be changed by pragmatic choice (that are cultural themselves).

On the contrary, the cultural background of pragmalinguistics, which has a cognitive-philosophical nature, is less explicit and the epistemological requirements to which it answers have to be carefully distinguished from all others. Indeed, in this approach, some cognitive issues are undoubtedly considered: for example the presupposition that mental states are not always affected by social context but by “internal” factors of the speaker-hearer’s mind (beliefs, desires, expectation, etc.). In particular, stress is placed on the role of the intentionality of speech acts and, therefore, the disambiguation of speech is brought back to the identification of speaker intentions in producing implicatures during speech acts, and the hearer’s capacity to interpret her intentions in the correct way. In Grice’s model, face to face interaction occurs between two individuals who want to communicate. Communication is conceived “as an intentional production of effects and can be only understood within a general theory of intentional action – therefore rational” (Bianchi 2009, 14).

The degree of proximity of this pragmatic approach to a cultural paradigm depends on the way we understand cognitive intentionality. Due to time constraints, we will only consider here the two most important senses.

The first legitimate one considers the beliefs, wishes, expectations, opinions – anything that can be considered internal to an intentional mental state – of a cultural nature, or at least they should be “translated” into cultural implicatures not significantly different from those being considered by sociopragmatics.

A second legitimate sense, which is very close to computational cognitive science, is that which considers the cognitive intentionality of speech acts as an algorithmic procedure that already contains the set of all possible rules that define the discourse project. In linguistics, the founder of this position is Noam Chomsky who has fully developed this perspective by placing the explanatory focus on the syntax

and on the notion of universal grammar. Whether wrong or right, Chomsky's position has been a very strong voice in twentieth-century philosophy of language.

Apparently, pragmalinguistics seems far from this Chomskyan view. However, the most philosophical component of it, one that rightly attempts to oppose excessive cultural shattering of sociopragmatic rules, is forced, in a sense, to imagine the cognitive intentionality of speech acts as an algorithmic process of conversational rules, which would have as its object the formalization of the implicational load involved in every possible speech act. In this case – as Nerlick and Clark (1996, 7) write – “pragmatics is the framework within which syntax and semantics must be studied; semantics is subordinated to pragmatics and syntax to semantics”.

This road seems to be the most viable one for a pragmalinguistics which is rightly included in contemporary cognitive science. One, therefore, must note that just as in the current paradigm of cognitive science, there was a massive revision of Chomsky's pioneering ideas. In fact, just after the eruption of neuroscience and cognitive science in the context of evolution, computational size has had to be instantiated in the biological discipline, as we have already seen (Sect. 14.3) prefigured in Edelman's statement: “we must incorporate biology into our theories of knowledge and language. (...) We must develop what I have called a biologically based epistemology – an account of how we know and how we are aware in light of the facts of evolution and developmental biology” (1992, 252).

Contemporary research on “embodied cognition”, the extended mind, the evolutionary foundations of neuroscience, etc. now all proceed in this direction. Chomskyan biolinguistics had to make room for a theory that is beginning to take into account, to a greater extent, ethology and evolutionary hypotheses in developing a view about the nature, origin, and functioning of language. As we saw in the first part of the book, it is no coincidence that the latest Chomskyan positions have abandoned the project of a universal grammar conceived as a set of universal syntax rules, and have embraced the minimalist idea that the dimension of universality can be defined in terms of general mental and non-specific procedures (Chomsky 1995; see Al-Mutairi 2014). It is no coincidence that the Chomskyan scientific entourage has begun to seriously reflect on previously ignored natural themes such as the origin of language, comparative cognitive ethology, and the naturalistic dimension of the FLN (Hauser et al. 2002, 2014; Berwick and Chomsky, 2016).

In any case it is not to be taken for granted that the natural stopping point of the long term project based on Chomsky's ideas cannot be surpassed by pragmatics. Chomsky himself has not ruled out the possibility that pragmatics can be considered a fundamental part of the general theory of language provided that one delineate a legitimate interpretation (Chomsky 1999).

To learn from the mistakes of the first theories of computationalism and enter the new naturalistic stage of cognitive science, pragmatics should work, however, not only to prove the existence of a universal computing implicational device (*Universal Implicatures Device* – UID) but also to clarify its biological nature, procedural functioning and social necessity.

From this point of view, a pragmatic approach might be more appropriate than the syntactic one proposed by Chomsky in building a naturalistically founded model

of cognition and intentionality. Pragmatics, basically, studies adaptive behaviors, those that are selected to obtain a more immediate advantage in social competition. A pragmatically founded behavior is, by nature, an adaptive behavior. It is no coincidence that “pragmatic disorders” (Cummings 2009, 2014) include some of the most severe states of social maladjustment and interactionally disadvantaged human subjects. However, one should avoid to reduce the science of pragmatics to a detailed description of individual cases of disambiguation of linguistic-cognitive units (expressions, phrases, speeches). The descriptive dimension of a behavioral science – albeit indisputably adequate as an experimental laboratory case – has now been considered among the most successful of twentieth century scientific practices. The cognitive awareness that science uses to explain these behaviors, and not only exhibit catalogues of their culturally detected capabilities, is now part of an epistemology that goes beyond the outdated distinction between nature and culture.

The de-culturalization of the epistemological foundations of these disciplines has made important steps outside cognitivism. Even neighbouring disciplines close to pragmatics’ ethnographic approach (Garfinkel 1967; Heritage 1984; Sacks and Jefferson 1992; Mey 2006; Kecske 2012; Haugh 2012), such as cultural anthropology, have precipitated the idea that culturalism could be an obstacle to scientific knowledge of the facts. Fabietti, for example, has rebaptized the culturalist orientation as “the hoax of the culture” (2002, 51 and 25). Behind this term, in fact, there has been a tendency to amplify what differentiates humans, and reduce what unites them, to raise barriers against identification instead of increasing common substrates. So the Englishman Adam Kuper in 1999 and the Swede Unni Wikan in same year defined culture as being “a form of racism” and the Palestinian anthropologist Lila Abu-Lughod named his most renowned book: *Writing against Culture* (1991).

The recent shift from “culturalism” to “neo-culturalism” (Tomasello 1999, 2008, 2014, 2015) has traced, for the first time, an absolute discontinuity with the previous discussions on the social sciences to the affirmation of cognitive science and the new evolutionary synthesis (see Pennisi 2012a). It is based, in fact, on the legitimacy of non-human animal cultures and enlargement of cultural history in the direction of ethology and evolutionary studies: “all part – Remotti writes – from a biological view of culture as a dimension (...) that is not only human, but zoological, and thus, after all, natural; everything originates from realizing that humans are not the only cultural species, and yet a species that, more than others, did depend for its survival on culture” (Remotti 2011, VII).

16.1.3 Examples of Evolutionary Pragmatics

If we wanted to summarize what we have discussed so far, we could say that only by minimizing, or even eliminating, the thin diaphragm which, in the twentieth century, has separated nature and culture, we may open a window of opportunity for

proposing a pragmatic nature which is evolutionarily founded as the basis of this fascinating discipline.

To imagine how this could be possible we should change Nerlick and Clark's (1996, 7) aforementioned assertion: not that "pragmatics is the framework within which syntax and semantics must be studied; semantics is subordinated to pragmatics and syntax to semantics", but that "the theory of evolution is the framework within which pragmatics, semantics and syntax must be studied. Semantics is subordinated to pragmatics and syntax to semantics".

This perspective, although clearly belonging to a minority, was put forward, or even vaguely prefigured, in the proposals of some scholars of pragmatics, mainly from anthropological and psychological fields of cognitive psychology.

Sperber and Origgi (2009), for example, in the framework of Relevance Theory (Carston 2002; Sperber and Wilson 1986), have distinguished two models of communication, one traditionally used by linguists and based on code ("code model") and one typical of cognitive pragmatics which is based on contextual inferences ("inferential model"). Human evolution, according to the authors, would be characterized in a species-specific way through the interconnectedness of the two abilities that depend on both dedicated biological functions: articulated language and naïve psychology allowing us to understand the mental states of others. The interaction between linguistic and pragmatic competence would provide human communication with its "incomparable power" (see Origgi 2001; Origgi and Sperber 2000; Sperber 2000; Sperber and Wilson 2002). Language, in this theoretical context, could perform its adaptive role because, since its origins, it is acquired by a mind that is already able to attribute mental states, beliefs and interlocutors' beliefs: "in these conditions, the study of the evolution of the language faculty must be closely associated to that of the evolution of naïve psychology. Likewise, the study of the evolution of languages must systematically take into account their pragmatic dimension" (Sperber and Origgi 2009, 131).

Sperber's hypothesis, which is very similar to that expressed by Michael Tomasello until 2014, seems to grasp a fundamental aspect of the DBM: namely that pragmatics, as the world's cognitive procedure, defines a whole new cognitive device which fulfils the evolutionary history of linguistic articulation. However, more recently Tomasello, who is certainly considered to be one of the greatest experimental scientists in the field of cognition in primates, has acknowledged that shared intentionality is not exclusive to human beings, as he himself has claimed in the renowned book 'The cultural origins of human cognition' (1999):

great apes appear to know much more about others as intentional agents than previously believed, and still they do not have human-like culture or cognition. Based on much research reported here, the critical difference now seems to be that humans not only understand others as intentional agents but also put their heads together with others in acts of shared intentionality, including everything from concrete acts of collaborative problem solving to complex cultural institutions (Tomasello 2014, X).

Since 2008 (*Origins of Human Communication*) Tomasello, based on these important ethological and experimental findings, has matured his thinking and has shifted the focus of human specificity from, what Sperber calls "naïve psychology"

responsible for the understanding of intentional mental states, to a more elaborate cooperative capacity based on the intertwining of natural gestures (hand gestures, indexicality, etc.) and the pragmatics of intentional states. This idea will become the backbone of both *A Natural History of Human Thinking* (2014) and *A Natural History of Human Morality* (2015): the thinking and behavior of human morality would then be the result of a natural tendency of the collaborative purposes of the pragmatics of communication.

Wharton believes that “natural pragmatics remains an under-explored discipline” (2009, 3): that this deficiency severely damages the theoretical potential for pragmatics to be regarded as general science knowledge. A natural pragmatics, in fact, while incorporating all the cultural phenomena that can be explained, aims to clarify non-verbal communication behavior, or verbal behavior that “convey non-propositional information about mental states or attitudes” (3). These behaviors can contribute towards, not only the explanation of overt communication (the meanings of the speakers), but also to the most secret or unintentional forms of information transmission, which also retain an important social value. Similar ideas are expressed and shared by several other scholars of evolutionary or cognitive pragmatics (Weinberger 2002; Enfield 2009; Scott-Phillips 2010).

Among the most interesting examples in this area of study, the main contribution has certainly been made by Levinson in his recent essay *Turn-taking in Human Communication – Origins and Implications for Language Processing* (2016).

Turn-taking, or the acoustic, physical, linguistic, psychological and cognitive characteristics in the pragmatic alternation of the turn is considered by Levinson to be “part of the infrastructure for Universal Language” (Levinson 2016, 6). Although, in fact, cognitive sciences have neglected his study, it can lead to a deeper understanding of some of the phylogenetic and ontogenetic mechanisms of acquisition and use of language. It is also undoubtedly one of the few elements that is truly universal in language infrastructure for social, communicative and cognitive needs economy. Directly comparable studies of turn taking, in fact, tell us a significant amount about the organization ethology of the species, the ways to avoid communicative overlaps, and also the internal processing of reflected linguistic performativity – and can, therefore, be empirically observed – from its timing and division into reception phases, message processing, counterelaboration and, implementation of the response, etc. which we will return to in Sect. 16.1.3 And can also, indirectly, be “organized into short phrase or clause-like units with an overall prosodic envelope” (2016, 6). Turn-taking becomes a preferred indicator for monitoring ontogeny communicative processes. The projection of these ontogenetic mechanisms on a universal scale may also disclose “an interesting phylogenetic story in which vocal turn-taking preceded language and provided a frame for its development” (6).

Levinson’s opinion is that functional explanations of turn-taking, to which we normally confine pragmatic studies of conversation, are completely inadequate in explaining the phenomenon of three very important theoretical reasons for our DBM. The first is that, in stark contrast to the extreme variability of languages, turn-taking exhibits universality so marked and ethologically widespread as to suggest that “to a package of underlying propensities in human communication, including

the face to face character that affords the use of gesture and gaze, and the motivation and interest in other minds" (Levinson 2016, 10). The second is that for at least the first 9 months of an infant's life, turn-taking is a measurable biological support for the activity of proto-conversation (all activities such as the response to motherese language, the development of stress intonation contours and a performative understanding of patterns that we have described in Sects. 15.1 and 15.2). The third is that in reported studies amongst non-human primates one can find surprising pragmatic similarities between both *Prosimians* (Lemurs), *New World monkeys* (Marmoset, *Cercopithecus*) and *Hylobates*, in connection with voice mode, and with *Old World monkeys* (Orangutans, Gorillas, Chimpanzees and Bonobos) in connection with gestural turn-taking. Regardless of the fact that in the first case we are confronted with analogies and in second with homologies – all prove that these studies are by no means sufficient to demonstrate the absence of vocal turn-taking in Great Apes – Levinson's group suggests that "vocal turn-taking is ancestral in origin in the primate order" (Levinson 2016, 11).

This latter approach is very close to the one of pragmatic naturalistic interpretation that we would like to propose here and that is strongly supported by biological ethological and biolinguistic studies, which are all experimental in nature and recently conducted on the use of social biological mechanisms of vocal articulation by human and nonhuman primates.

It is now common knowledge that the language of human beings can be distinguished from that of other primates by its ability to produce articulate sounds. There are various forms of communication in the animal kingdom whose meanings were analyzed by ethologists as being pragmatic.

An aspect that has particularly interested scholars in pragmatics is the intentional dimension of communication and the connection between this dimension and the encoding of messages. Amongst cognitive ethologists there is no doubt that the two levels are closely intertwined: the adaptability of animal communication, in fact, is not measured in terms of logical-anthropocentric pragmatic codes, but in terms of ecological intelligence behavior: a signal which is always intentional and typically species-specific and that is encoded within the species.

Note, however, that for scholars in pragmatics the dimension of the encoding of a signal turns it from being natural to unnatural: languages are not natural but cultural codes. As described earlier, we support an evolutionary hypothesis that considers language to be a natural, biological fact, and as such is determined by functional possibilities offered by the man's body. Everything that comes from this structure is natural by definition, including language. And this approach applies not only to human linguistic communication, but also to communication in every animal species. Human linguistic communication is a specific case of animal communication which is characterized by the biology of the voice.

Verbal communication is conducted, in fact, by means of a sound wave transmitted through the air from the speaker to the hearer. At the moment of utterance, the articulated voice is the result of modification, by using a complex and variable filter, of a signal produced by the source (theory of source-filter). Phonation depends on

the origin of signal at the level of the source, while the modification of the same by the filter is called articulation.

As we have seen in different parts of this book, the entire human ability to articulate syllabic sound (consisting of consonants and vowels) of discrete nature which are combined according to phonological, morphological and syntactic rules, and which are capable of conveying meanings that are distinct enough to result in consequent actions in those who receive them, is due, primarily, to the particular conformation of the vocal supralaryngeal tract characterized by two channels in *Homo sapiens*. While other primates (stopping at the zoological relatives closer to us) are able, either spontaneously or by learning from humans in zoos or laboratories, to categorize sounds, understand their use, associate them with meanings (Thompson 1995; Cheney and Seyfarth 1997; Schusterman and Kastak 2002; Kaminski et al. 2004; Zuberbühler 2005) and even be able to understand new meanings generated by different syntactic combinations of the same words (as, for example, Kanzi in the laboratories of the “Great Apes Trust” of des Moines, Iowa), these non-human primates are not able to produce the whole range of human articulated sounds because of a different organization of their vocal tract.

Most of the recent studies referred to previously have, however, demonstrated a remarkable ability of non-human primates (and of other animal species) to modify the sound coming from the emissive source through a filter which, although not as complex and sophisticated as the human one, allows them to intentionally transmit precise social meanings, which are considered in all cases as being precise biological constraints of social behavior. A complete section of this book (Sect. 14.2) addresses this topic.

Many animal species are able to vary the fundamental frequency (F0) and many other biological and psychological dimensions, including sex and age, the size and shape of the body, hormonal condition, dominance, masculinity or femininity, and sexual and social attractiveness. Cases involving the deep vocalizations of red deer or the hugely powerful sound generated by the very small howler monkey, as we have seen, are special cases of a regular natural law that describes voice variations as being as a result of the much larger size of the animal’s body and which are required for purposes of sexuality. Man is no exception to this rule, which is made possible both by voice sexual dimorphism and by prelinguistic uses of pragmatically founded vocal style aimed at determining the success of different social practices: choose a partner, be attractive, deter adversaries and enemies, obtain favor with potential collaborators, be admired by listeners, etc. (see Sect. 14.2).

From an evolutionary point of view this basic pragmatics of the voice is certainly a bridge between human and nonhuman animals and is perhaps even more indicative and important than turn-taking. What is often overlooked is that, again, this functional pragmatic continuity is linked to a parallel and prior gradual structural continuity. Although the vast majority of non-human species uses some pragmatic function associated with the voice, in this case, a hierarchy of prelinguistic possibilities also exists. Not all neurocerebral structures suitable for voice motor control are in fact the same and equally powerful and versatile (see infra Sects. 14.2 and 15.2).

What all this experimental research in the field of ethology, neuroscience and evolution studies demonstrates is that vocalization capabilities are a strong vehicle for social conditioning of a biological but not a cultural nature. Also, use of vocal articulation at its most basic level, such as lowering of the F0 and the modulation of the formants, is, essentially, a pragmatic naturalistic indicator within which all possible top-level constraints are “collected”. The “fundamental intentions” such as sexual selection, achieving higher levels of hierarchy, adaptation to gregarious social roles, perception and self-perception of the self, the projection of (physical and social) size, etc., depend directly on the universal computing implicational device (*Universal Device Implicatures* – UID) that is not functioning as a computer, but as an archaic, and crucial, part of the biological primate brain.

16.2 Pragmatics as a Stabilization of Performative Process

Of course it could be argued that the type of work performed by this Universal computing Implicational Device (UID) is only the biological basis of cognitive pragmatics. For uses of a progressively higher level this device, by which we can explain the natural implicatures pertaining to a social dimension, loses its importance and, perhaps, is of no use. To understand the discursive meaning one must still be able to reconstruct the set of specific linguistic-textual nature implicatures (coherence, cohesion, anaphora and cataphora, connectors, the theme/rheme, the isotopy, etc.) or the set of cultural implicatures (knowledge about the world, collocations in space-time, historical events, the psychological dispositions, relativistic characterizations of the lexicon, etc.).

We can provide at least two forms of responses to this observation.

The first involves what we can synthesize at the level of organismic functioning of the brain. Unlike what one imagined in the computational cognitive science study of origins, functional modularity can never be to the detriment of the functioning of the whole organism. The brain is a body part, not the actual body. As we saw in Sect. 13.2, the brain is “the tenant of the body” (Leroi-Gourhan 1964): motor coordination always follows the body structure, thought patterns always follow motor coordinations, algorithmic procedures always follow mental schemes, and cultural behaviors are as the result of algorithms being finally stabilized. This means that the implicatures of textual or cultural nature come at the end of a huge cognitive adaptation process consisting of an indefinite amount of mediations that are always less universal and increasingly more subjective.

It is not at all certain whether this kind of endless mediation is due to scientific knowledge: to rebuild all the stabilized algorithms in the different areas of discourse is more like the work of a craftsman, an artist or a novelist than that of a modest cognitive scientist, an evolutionary biologist or a biolinguist. Also, it is not to be taken for granted that being able to formalize a gradual scale ranging from a few, certain and universal pieces of knowledge up to any number of pieces of knowledge – but only probable pieces of knowledge and exclusively applicable to

individual cases – may constitute a difficult road and one that is not without significant results. Pragmatics, in this case, would be one of the few human sciences able to escape the paralyzing epistemological dilemma posed by Carl Ginzburg at the end of the last century: “take on a weak scientific status to get to important results, or take on a strong scientific status to get to results of little relevance” (1979: 92).

The second level may be defined as that of being an unsustainable lightness of design thinking. As we have said before, in building a naturalistic approach, the cognitive pragmatician may be in an advantageous situation compared to Chomsky’s UG provided that he loses his obsession for idiolects. One should not believe that what we have called a universal device of implicature calculation (Universal Implicatures Device – UID) should take care of the rebuilding of every discursive path of intentionality in every possible speech act that can occur in conversation between any possible pair of speakers. On the contrary, the pragmatic evolutionary scholar should focus more on the few procedural rules that can generate an infinite number of products.

What are these rules? How does the universal computing implicational device function when we are exchanging phrases, speeches, texts?

Here we touch on the crux of the problem. We are trying to describe its dual representation: one based on current assumptions of traditional pragmatics and the other on a hypothetical pragmatic nature.

Although it is virtually impossible not to take into account the numerous distinctions and models of contemporary pragmatics, perhaps we could simplify things by assuming that, in the profile of implicational calculation, what unites them is the need for expressions and implicatures to co-exist in inputs. For example, Grice distinguishes between conventional and conversational implicatures.

A conventional implicature has the following form:

- He was rich but honest

In this expression the true conditional meaning does not change when compared to the first statement.

- He was wealthy and honest

However, by using the connective “but”:

- the speaker means that there is a contrast between being rich and being honest;
- there are some of those who are wealthy you can expect not to be honest

Conversely a conversational implicature can be of the following form:

A – “You will go to the party tonight?”

B – “I do not like parties”

In this exchange the deep meaning is:

- No

However, to reach this conclusion it is necessary to know a sequence of inferential steps:

- For B it is (Imp.1): “Given that I do not like them, I do not go to parties”
- For B it is (Imp.2): “Given that (habitually) I do not go to parties, I will not go to the party tonight either”

In both cases, what allows disambiguation of the meaning is the fact that expressions and implicatures are both present. Expressions and implicatures in this calculation model have the same weight, that is they are equipotent.

The price which traditional pragmatics pays is that, in the absence of these equipotent pieces of information, the calculation crashes and cannot progress. In the absence of incomplete expressions calculation will be blocked due to a lack of linguistic information. Conventional implicatures block the calculation in the absence of cultural information (to give an example, it is not to be taken for granted that in all cultures the notion is accepted that the rich cannot be honest). Conversational implicatures block the calculation because of a lack of logical or psychological information relating to the specificity of the subject (to invent an example, it is not to be taken for granted that even though I do not like parties, I could still go to the party tonight for other reasons, for example, I do not have anything better to do). In this model, implicatures of whatever nature do not have a universal or even a conventional, that is to say, a cultural value. They are specific to the conversation, and only to that. It can be likened to the case of a simple calculator operating, not with the rules of addition or subtraction but, from time to time, with the rule of the $2 + 3$, $6 + 1$, of $7 - 5$, of $99 - 0$, etc.

Is this the way that human discursivity works? Is the species-specific logic of human language based on an inferential computing system that can only proceed if all the elements of the calculation are present, whether computational units or rules of computation?

As we have seen in Sect. 15.2, the reply to these questions is certainly negative. Communicative and representational activity, whether voluntary or involuntary, at both their basic and higher, more sophisticated levels, operate for most of the time in the absence of comprehensive information – as Vico would say: in a state of *inopia linguae* (“language poverty and the need to be understood”) – Vico SN, 226. However, the intentionality of communication has a primary dimension that cannot be eliminated. All space between the intention and the realization of the sentence (or speech, or text, etc.) is covered by a cognitive performative activity which implements a linguistic project while it is executing it.

After ontogenetic bootstrapping at 18 months of age, synchronized with the completion of the articulatory physiology that will allow, even through the development of grammar, and what Chomsky (1966) has called “rule-governed creativity”, the performative continuum of linguistic cognition is increasingly being implemented more like a mental device specialized in “rule changing creativity”.

From the beginning, in the Chomskyan model, this kind of creativity has progressed – to use the apt formula detailed in previous article by D’Agostino (1981) – more and more from the status of “problems” to that of “mystery”. Chomsky

himself, answering many similar criticisms leveled by various scholars around the world (in particular Drach 1981), confirmed that the obstacle to the possibility of making the mechanisms of non-regular creativity transparent (turning them into “mystery”) depended on the incommensurability between competence and performance, and the confinement of the latter to the domain of externalization tools: the use of language through which we speak would play the same role as “brushes for painting” (Chomsky 1982, 426 et seq.), but it is not on these that creativity depends.

At the same time, however, he recognized that knowledge of recursive rules is not enough to develop a theory of language:

not only the ability to understand immediately an indefinite number of entirely new sentences, but also the ability to identify deviant sentences and, on occasion, to impose an interpretation on them (...) it is clear that a theory of language that neglects this ‘creative’ aspect of language is of only marginal interest (...) Clearly the description of intrinsic competence provided by the grammar is not to be confused with an account of actual performance (Chomsky 1982, 429).

In short, we are in a vicious circle with no chance of glimpsing solutions: just “a mystery” that Chomsky himself does not hide, but confirms during the rest of his scientific life. He is well aware that what he considers to be the mental-core of language – that is, syntactic recursion in the first phase and purely computational recursion in last phase – provides the means for a creative component. However, while it might explain its basic component, it cannot account for semantic and discursive unpredictability when “the speaker-hearer make use of language in the normal creative fashion” (Chomsky 1982, 426), that is, when it “performs”. How do we solve this crucial problem and avoid a two-sided biolinguistics which cannot become a single entity?

In the DBM, the problem is solved through the stabilizing role that pragmatics plays in the language activity, similar in function to the role played by the gradual stratification of structures in the consolidation of evolutionary change.

As provided in the synthetic schema of Sect. 7.1, the DBM does not provide a single static and central principle of ordinary language but, after learning the foundational biological function, which involves being able to communicate through accurate, articulatory discreet and combinable sounds, it initiates a dynamic, ongoing process that proceeds along endless steps of exchange between performing assets and pragmatic activities.

The performative activity produces, in the absence of known algorithms, attempts at adaptive production (selection of words, unusual syntactic-semantic pairings, production of metaphors, analogies, comparisons, naturalistic approaches, descriptions, etc.) which are integrated in the behavioral and/or dialogic situation. The hearer, who may be the same person as the speaker, engages in a similar activity on the side of understanding, which is based on hermeneutic operations permitted by already known layers of meaning, and subjecting them continuously for review and reintegration in a different cognitive framework.

The activity of pragmatic stabilization has to make sure that constructs, both produced and perceived, can be factually compatible with different types of events: strictly speaking these are logical, cognitive, social, linguistic constructs, etc.

Practically, it produces inferences and continuously tests them with respect to a certain universe of implicatures and explicatures related to a certain time, a certain space, and a certain culture, etc. The moment this stabilization becomes effective, it affects the world and others, procuring advantages in the functional specification of the entire set of events that orients general behavior, and particularly the behavior of the individual. This stabilization tends to become permanent and develops into an algorithm-based routine.

Needless to say, the terms “stabilization”, “general behavior”, “permanent”, “algorithm-based” all have regional values in that they are connected with further changes in historical time and in the geographical, cultural, environmental, situational dimension, etc. From this point of view, the products of these pragmatic stabilization activities have no universal value. However, the organizational form of these products is highly stratified, hierarchical, modularized and, therefore, constitutes the best possible reconstruction of the universe of semantic and adaptive speaker’s reference. You can, and will, obviously change, but any change will allow an overall reorganization of the whole body, in the dynamic ongoing process of linguistic cognitive activity. In this sense, as a basic cognitive activity, probably not entirely human, the performative activities and pragmatic stabilization are biological and universal functional procedures.

Ludwig Wittgenstein would have called them *Lebensformen*.

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