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## Phonology, Phonetics, and Cognition

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### PRELIMINARY REMARKS

Phonology and phonetics have emerged as independent disciplines during the twentieth century. For somebody who does not know the field of language studies, the existence of two disciplines which are so similar and yet so different, both dedicated to the study of sounds, is rather strange. At least two types of explanation are possible for this state of affairs: one consists in invoking the accidental juxtaposition of historical persons and events, the other in invoking substantive issues and research programmes. As far as the separation of phonetics and phonology is concerned, both types of

Martin Atkinson, Marianne Durand, Chantal Lyche, and Élisabeth Delais-Roussarie have helped us in the preparation of the article. If somebody should be singled out, however, it is Philip Carr, who always had time to help us sharpen our ideas about the complex interrelationship between phonology, phonetics, and cognition. Although our views are partially divergent, his own work in collaboration with Noel Burton-Roberts (Burton-Roberts and Carr 1996, 1997, Burton-Roberts, 2000, Carr 2000) provides an important and challenging approach to the subject. The reader will find an essential complement to this volume in Burton-Roberts, Carr, and Docherty (2000). Their introductory chapter provides a scholarly and insightful discussion of the issues broached here.

explanation seem to be of some importance and are often difficult to disentangle. Undeniably, some major figures and schools have shaped the field in ways that were not necessarily predictable (except in a *post hoc* manner). Simultaneously, the success of various research programmes on both sides of the new divide has led to entrenched positions. But the rise of cognitive issues has forced specialists in phonology and in the phonetic sciences to converge in spite of differences often claimed as irreducible. The temptations of autonomy and hegemony may have been historically understandable but now prevent each of these disciplines from playing a vital role in the emergence of an integrated theory of linguistic sound structure. We will attempt to support this claim by examining in turn the separation of phonetics and phonology at the beginning of the twentieth century (section 1.1), the rise of autonomous phonology (section 1.2), the cognitive reorientation taken by phonology from Jakobson to the present day (section 1.3), the parallel developments in phonetics (section 1.4), and the possibility of a new synthesis (section 1.5). While epistemological breaks can and do occur, we have emphasized throughout the deep continuities within phonology and phonetics. This should not be surprising. If linguistics is a science, the objects, methods and results of successive generations of researchers should be (at least partially) cumulative.<sup>1</sup>

## I.1. PHONOLOGY AND PHONETICS: THE PARTING OF THE WAYS

As is well known, until the 1920s, phonology and phonetics did not constitute independent disciplines and the vocabulary used to refer to subspects of the field was itself in considerable flux. The roots of the modern separation between phonology and phonetics can be traced back to the rise of synchronic linguistics and, more specifically, to the emergence of the concept of *phoneme* (or distinctive sound unit) and the correlative concept of *allophone* (realization or variant of phoneme). Clearly, the assumption that the sounds of speech might be analysable into separate, successive units of the size of the phoneme is hardly new, since all alphabetic writing systems can be argued to rest on a kind of 'phonemic intuition'. And, at many times in history, grammarians have anticipated some of the concepts and procedures which are taken to characterize modern phonology. The work of Indian

<sup>1</sup> On this point, see Durand and Laks (1996*b*), Goldsmith and Laks (2000*a*, 2000*b*), Laks (1997*b*). For exemplification, see Durand and Laks (2000), Durand and Lyche (2000).

scholars like Pāṇini in the Vedic tradition readily springs to mind in this context (cf. Allen 1953, Pinault 1989: 304–13). Nearer our own time one can think of the so-called ‘First Grammarian’, the unknown Icelandic author of the twelfth century who in the *First Grammatical Treatise* put forward a writing scheme for his language explicitly based on contrastiveness and economy of symbols (or ‘underspecification’ in a more recent terminology). As Robins (1990: 83) notes about the First Grammarian: ‘In addition to his advanced phonological theory, his discovery and demonstration procedures were quite modern. Phonemic distinctions were ascertained by controlled variation of a single segment in a constant frame along such ordered series of words as *sár, s̄or, sér, sór, s̄or, súr, s̄yr* and they were illustrated by sets of minimally different pairs of words whose difference in meaning depended on the difference of a single letter (one phoneme).’ Moreover, although many traditional grammarians spoke about the pronunciation of letters, it is clear that they were not as naive about the nature of sounds as has been claimed in many introductions to linguistics.<sup>2</sup> In classical antiquity, the term *littera* has a dual meaning: it stands for a graphical symbol and an element of voice. But this ambiguous value of *littera* did not necessarily entail that grammarians then and later were confused about the difference between these two interpretations. A particularly good example is provided by the Port-Royal grammar, Arnauld and Lancelot’s *Grammaire générale et raisonnée* (1660), where one chapter (I. 1) is devoted to the ‘Letters as sounds’ and another (I. 5) to the ‘Letters considered as characters’. Nor did this mean that letters were taken as primary and sounds as secondary. In the Port-Royal grammar, it is stated unequivocally, well before Saussure’s *Cours*, that men first expressed their thoughts in spoken words and then converted these into written symbols. Indeed, as noted by Chomsky (1968: 18), language for Arnauld and Lancelot was ‘that marvellous invention by which we construct from twenty-five or thirty sounds an infinity of expressions, which, having no resemblance in themselves to what takes place in our minds, still enable to let others know the secret of what we conceive and of all the various mental activities that we carry out’. Nor was advanced work in sound description impeded by the use of the term ‘*littera*’ to refer to the sounds of a language as shown by various classical treatises such as Hellwag’s *De formatione loquelae* (1781).<sup>3</sup>

<sup>2</sup> Thanks to the publication of a number of recent encyclopedias and histories of linguistics, we are today in a better position to assess past works on language than during the heyday of classical structuralism: see e.g. Aurox (1989, 1992, 2000).

<sup>3</sup> In fact, in Hellwag’s work, ‘*littera*’ is a unit of sound, which is opposed to ‘character’ or ‘figura’, a unit of writing. See the 1991 French edition of Hellwag (1781).

Towards the end of the nineteenth century, however, the foundations began to be laid for the establishment of a clear conceptual opposition between phonemes and their allophonic realizations. It is worth pointing out in this connection that the term ‘phoneme’ (or more precisely ‘phonème’, which was first coined by the Frenchman Dufriche-Desgenettes) did not originally have its modern sense of ‘distinctive sound unit’. For Dufriche-Desgenettes it is simply equivalent to the German ‘Sprachlaut’ and, in the writings of contemporaries such as Saussure, it simply referred to a segment of speech, a phonetic unit (cf. Anderson 1985: 38 *et passim*). In fact, Saussure called ‘phonology’ what would now be called ‘phonetics’ and the same terminology was adopted by other major sound specialists such as Grammont.<sup>4</sup> It was the Polish linguist Jan Baudoin de Courtenay who, while isolated in Kazan in central Russia, first used ‘phoneme’ in its modern sense and it is interesting to note that his definition, as we emphasize in section 1.2, was what would now be called ‘cognitive’.

The distinction made by Sweet between a ‘broad’ and a ‘narrow’ transcription is often interpreted as a clear forerunner of the distinction between phonological and phonetic levels of representation. Indeed, the new *Handbook of the International Phonetic Association* (1999: 28) tells us: ‘A connected text represented in terms of phonemes is known as a “phonemic transcription”, or, almost equivalently, a “broad transcription”. The term “broad” sometimes carries the extra implication that, as far as possible, unmodified letters of the Roman alphabet have been used . . . The term narrow transcription most commonly implies a transcription which contains details of the realisation of phonemes.’ It should, however, be realized that the contrast between two types of transcription, which has existed within the IPA tradition ever since the second part of the nineteenth century, did not mean that the opposition between two levels of representation played exactly the same role as it did later. In fact, some of the earlier members of the IPA considered that the real, scientific transcription was the narrow one and that broad transcriptions were purely for convenience. Paul Passy, the founding

<sup>4</sup> Note that in his *Mémoire* Saussure also used ‘phonème’ to refer to the *etymological* sound which is the starting point of a family of sound units. As is well known, Saussure’s terminology and positions are difficult to establish from the available sources. A full exegesis is beyond the scope of this chapter, but, for additional information, see Bouquet (1997) and the *Troisième cours de linguistique générale* (1910–11) established from Émile Constantin’s notes by Komatsu and Harris (Saussure 1993). In any case, as appropriately stressed by Anderson (1985: 56 *et passim*), the work of Baudoin and his student Kruszewski (the so-called Kazan school) presented a view of phonology which was probably more original and better articulated than that of Saussure. If one starts looking for precursors for the ‘phonemic’ principle, the list is likely to be a very long one as noted earlier in our text. For further discussion of these issues, see Laks (1997b).

father of the IPA, felt that he had to defend the distinctiveness principle and warn phoneticians against the danger of cluttering transcriptions with all sorts of arbitrary phonetic details: 'Too many signs have already been invented for varieties of sounds which have no distinctive function. This is a fatal habit which will lead us astray—as there is no reason to stop—and which will ultimately render phonetic texts illegible. *Only significant differences must be transcribed in a text*—this is a golden rule that should never be broken' (quoted in Jones 1957, our translation).

Daniel Jones, in his 1957 history of the term 'phoneme', confirms that, when he became the first teacher of phonetics at University College London, he had not yet appreciated the full importance of the concept of phoneme:

The word 'phoneme' in the sense attributed to it by Baudoin de Courtenay was first brought to my notice by L. Ščerba (one of his pupils) in 1911, who referred to the concept in his pamphlet *Court exposé de la prononciation russe* published by the IPA in that year. About two years later the theory was explained to me more fully by another of Baudoin de Courtenay's pupils, Tytus Benni of Warsaw. The immense importance of the theory then became very clear to me, especially in its relation to the construction of phonetic transcriptions, to the devising of alphabets for languages hitherto unwritten or unsuitably written, and in general to the practical teaching of foreign spoken languages. Consequently by about 1915 the theory began to find a regular place in the teaching given in the Department of Phonetics at University College.

Interestingly, and perhaps not surprisingly given the central role he assigned to transcriptions, Daniel Jones himself continued to be committed to a purely instrumental view of phonemes since for him they were just convenient abbreviations for sets of similar sounds: a phoneme is nothing but a family of speech sounds (Jones 1950: 6). But, if we stress here the emergence of the concept of phoneme, in opposition to its allophones, it is not as a convenient fictitious unit but because it was to constitute the cornerstone of the new 'structuralist' approach to language launched by the Prague School in the 1920s under the leadership of Trubetzkoy and Jakobson, not to mention the fact that it also played a central role in the North American descriptive tradition at roughly the same time. Among the tenets of the Prague movement was the idea that phonology should explicate the way significant sound differences allow for the differentiation of forms and thus emancipate 'phonetic studies from the obsession with masses of detail in which they were effectively mired as instrumental techniques of observation were refined' (Anderson 1985: 88). In this context, it may be worth remembering that, in 1928, in preparation for the First International Congress of Linguists, a set of general questions on the nature of linguistics and its methodology was devised by the organizers. To the question 'Quelles

sont les méthodes les mieux appropriées à un exposé complet et pratique d'une langue quelconque?' (What are the most appropriate methods for a complete and practical account of a given language?), Jakobson prepared a set of answers (also signed by Trubetzkoy and Karcevskij) which defended a radical reorientation of linguistic research and was enthusiastically supported by many of the participants. These answers, which became known as the Prague theses, were based on phonology (seen as quite distinct from phonetics) and took the network of phonemes of each language as central. The programme which was advocated comprised the following questions among others: What are the distinctive elements within each sound system? What recurrent features or 'correlations' can be found within such systems? What laws govern such 'correlations' across languages? Indeed, phonology, with its insistence on the fact that the object of linguistics should be the distinctive role played by phonemes and the abstract nature of their organization rather than their detailed acoustic or articulatory specifications, provided a *principium divisionis*. It allowed Trubetzkoy to distinguish those who are 'with us' and those who are not (private correspondence between Trubetzkoy and Jakobson; cited in Anderson 1985: 88).

In the United States, the difference between two levels of representation offered by sound structure and summarized as the 'emic'-'etic' distinction was equally taken as a model of linguistic research. No doubt, various researchers had different views of what phonemes were about but most of them shared the phonemic approach as a frame of reference. It is not an accident that Hockett opened *The State of the Art* (1968: 9) with the following retrospective:

Very roughly, the first part of the twentieth century saw the following major theoretical developments in our field of inquiry: (1) the confluence, with all appropriate turbulence, of the two relatively independent nineteenth century traditions, the historical-comparative and the philosophical descriptive, the practical descriptivism of missionaries and anthropologists coming in as an important tributary. (2) Serious efforts by Saussure, Sapir, and especially Bloomfield, not only to integrate the positive findings of these traditions into a single discipline but, even more, to establish that discipline with the proper degree of autonomy from other branches. (3) *The discovery and development of the phonemic principle*. (4) *Attempts, particularly during the last decade of the half-century, to put the rest of descriptive analysis ('grammar' other than phonology) on as exact and reliable a footing as we thought had been achieved for phonemics*. (our emphasis, J.D./B.L.)<sup>5</sup>

<sup>5</sup> For further discussion of the structuralists, cf. Hymes and Fought (1981), Matthews (1993). In the French context, Dosse (1991, 1993) is invaluable. With respect to phonology, Fischer-Jørgensen (1975) remains one of the essential sources.

## I.2. AUTONOMOUS PHONOLOGY

In itself, the emergence of phonology as separate from phonetics did not imply that these two disciplines should be completely separate. But the birth of phonology coincided with the emergence of linguistics as a distinct, autonomous branch of study in the Saussurean mould. Indeed, it could be said that phonology provided the best exemplification of the ‘langue’–‘parole’ dichotomy, phonemes belonging to ‘langue’ and allophones to ‘parole’. This was interpreted by some linguists as entailing a sharp separation, indeed an abyss, between linguistic form and the material substance in which it is realized. As is well known, the Danish linguist Louis Hjelmslev (1899–1965) provided the most extreme example of such a position within the framework known as *glossematics*.

In his *Prolegomena to a Theory of Language* (1953), Hjelmslev advocated a view of linguistics as seeking to establish the *immanent* structure of language in strict independence of extra-linguistic phenomena (e.g. physical, psychological, logical, or sociological). In his words, ‘The long supremacy of conventional phonetics has . . . had the effect of restricting the linguists’ conception of even a “natural” language in a way that is demonstrably unempirical, i.e. inappropriate because non-exhaustive.’ Following the analogy used by Saussure of language as a chess game which does not depend on the shape of the chessmen,<sup>6</sup> Hjelmslev saw linguistic structure as independent of the material substance in which it is actualized: thus, Hjelmslev went so far as to claim that if two consonants were systematically interchanged in the phonology of a language (e.g. /t/ and /m/ in standard German), the result would still be the same system. Even more radically, he argued that the very same linguistic system can be realized by sounds, orthography, Morse code, flag signals, or any other substance which is available. In so doing, Hjelmslev confuses two separate issues. The language faculty is indeed not inevitably linked to a particular realizational medium: while sound systems emerge naturally barring accidents, human beings can spontaneously acquire other systems such as a sign language. It does not follow that these systems should be studied in a way which treats the

<sup>6</sup> Recall the following quotes from Saussure’s *Cours*: ‘Language is a system that has its own arrangement. Comparison with chess will bring out the point . . . If I use ivory chessmen instead of wooden ones, the change has no effect on the system; but if I decrease or increase the number of chessmen, this change has profound effects on the “grammar” of the game’ and later ‘Take a knight, for instance. By itself is it an element in the game? Certainly not, for by its material make-up—outside its square and other conditions of the game—it means nothing to the player; it becomes a real, concrete element only when endowed with value and wedded to it’ (Saussure, *Course in General Linguistics*, tr. W. Baskin 1959: 22–3, 110).

expression side as lying outside the scope of linguistics.<sup>7</sup> Nor does it seem correct to assume that there is an abstract representational system for the expression plane of languages which has the very same structure whether it is realized in, say, speech or writing. Even when a relatively close correspondence exists between speech and writing in given languages, the differences are quite striking. Take, as a simple example, the fact that in English /p, t, k/ are the only phonemes allowable after /s/ in triconsonantal word-initial clusters (*splice, strain, scrape*, etc.).<sup>8</sup> Phonologists who do not exclude reference to phonetic properties have long stressed that this was not an accident and that the elements in the relevant set /p t k/ were united by common features (be they ‘voiceless plosives’ or [-sonorant, -continuant, -voiced], or statistically based acoustic features as in Coleman’s chapter, this volume). This set recurs in other contexts in the sound system of English and many other languages: it is for instance the group of segments which can be aspirated in stressed syllable initial position in English. Now, in the triconsonantal initial clusters of the spelling system of English, the letter ⟨s⟩ can be followed by ⟨c, h, p, t⟩ as in *screw, shrew, splice, strain*. While we do not doubt that letters too can be analysed in terms of distinctive graphic features, we are not aware of any natural property which brings together the set of second elements in such clusters. The generalizations to be captured with respect to these examples cannot therefore be of the same type with respect to speech and writing.<sup>9</sup>

The position of Hjelmslev was no doubt extreme. Nevertheless, it was historically part and parcel of a position which occasionally debased or downgraded phonetics and reduced it to a mere ancillary role. We have seen above that the Prague School programme was partially based on such an assumption. But the Prague School was by no means isolated. Bloomfield states: ‘the physiologic and acoustic description of acts of speech belongs to other sciences than our own’ (1926: 154). Even Pike, whose experience and status as a phonetician can hardly be doubted, said, ‘Phonetics gathers raw material. Phonemics cooks it.’ The metaphors varied but, as emphasized by Abercrombie (1991: 12), there was a phase during which the people who practised this art came to be regarded as ‘the hewers of wood and drawers of water—indispensable, perhaps, but essential menial’.

This trend of regarding phonology as substance-free has had many followers over the ages and has remained a basic tenet of various schools. Hagège (1985: 171–2), a disciple of Martinet, says:

<sup>7</sup> This issue is taken up again in section 1.3.3.1.

<sup>8</sup> Leaving rare learned examples like /sfr/ in *sphragistics*.

<sup>9</sup> On the status of writing within a theory of language, see Durand (2000a).

Thus, whereas the natural sciences create for themselves the concepts and the categories they need to describe and explain the phenomena of the physical world, linguistics, which, in this respect, is similar to other human sciences, finds these categories and these concepts already constituted within languages. An illustration of this can be found in the opposition established by structuralist linguists between phonetics and phonology. Phonetics is similar to the natural sciences in so far as its object is to establish, on articulatory or acoustic bases, the categories of sounds which can be produced by the vocal apparatus (from the lips to the larynx). Phonology, on the other hand, has for its object, within a given language, the study of phonemes, i.e. the classes of sounds already constituted within this language. (our translation, J.D./B.L.)

Such statements explain to a large extent why phoneticians, rightly convinced that the study of linguistic sound structure could not afford to neglect the physical embodiment of whatever mental acts underlie speech communication, were often tempted to reclaim the whole field for their own approach.

### 1.3. FROM PHONOLOGY TO COGNITION

#### 1.3.1. From Baudoin de Courtenay to Jakobson

While the emergence of phonology often led to a sharp separation between phonology and phonetics, on the one hand, and phonology and cognition, on the other, it should be remembered that psychological preoccupations have not been as absent from the work of phonologists as is often claimed. Thus, the originator of the term 'phoneme' in its modern sense, Baudoin de Courtenay, defended an approach which was very different from the instrumental and empiricist use of the concept of phoneme made by phoneticians like Jones. For Baudoin de Courtenay, phonemes were psychophonetic entities representing intentions and to be differentiated from the concrete objects studied by physiology or acoustics. To quote his definition:

'Phoneme' (Greek *φωνή*, *φώνημα* 'voice') is a linguistic term: a living psychological phonetic unit. So long as we are dealing with speech or hearing, which are fleeting actions, the term 'sound' is sufficient as it refers to the most simple phonatory or pronunciation unit which creates a single acoustico-phonetic impression. But if we move to the level of real language, a level which only exists in a continuous way in the mind, only as a world of representations, the notion of *sound* is not sufficient and we need another term for the psychological equivalent of sound. This is the term 'phoneme'. (our translation, J.D./B.L.; Baudoin de Courtenay 1963: i. 351)

Saussure's own work presents a very real tension between the sociological dimension and the psychological one, but the latter cannot be discarded as a mere addendum to the former. While the idea of language ('langue') as a common treasure is central to Saussure's thought, so is the description of the sign as a mental construct, the linking of a 'signified' with a 'signifier' which is an 'acoustic image'. As has now become clear, the psychological aspect of Saussure's work has been underemphasized both by Bally and Séchehaye as editors of the *Cours* and by later interpreters, or worse still, simply rejected as mistaken.<sup>10</sup> To take just one example, the French historian of linguistics Mounin (a disciple of Martinet) asks, 'What does Saussurean psychologism consist in?' His critical answer runs as follows:

First of all, in the self-confidence with which, like virtually all of his contemporaries, Saussure is a 'mentalist' (in Bloomfield's terminology), that is, assured by philosophy and introspection of knowing what goes on in the brain when man is thinking. He thus explains the facts of language by the facts of thought which are taken for granted. For instance, he assumes that 'the linguistic sign unites not a thing and a name but a concept and an acoustic image' (p. 98), therefore by means of two notions which the linguist has no handle on and understands far less than language. 'A given concept, he says, triggers in the brain a corresponding acoustic image' (p. 28). That is why he also states that 'in the last resort, everything is psychological in language' (p. 21) and that 'the linguistic sign is therefore a psychological entity' (p. 99). (our translation, J.D./B.L.; Mounin 1968: 25)

In North America, a psychological conception of phonological representations was central to Sapir's work.<sup>11</sup> To take one quote from many similar ones, 'Back of the purely objective system of sounds that is peculiar to a language and which can be arrived at only by a painstaking phonetic analysis, there is a more restricted "inner" or "ideal" system which perhaps equally unconscious to the naive speaker, can far more readily be brought to his consciousness as a finished pattern, a psychological mechanism' (Sapir 1921: 55).

The position of many of the 'structuralist' linguists, like Trubetzkoy, regarding cognitive issues is not always clear-cut and in many cases deserves to be reassessed. Did they reject a psychological analysis of the phoneme, when they did, because they did not believe in the relevance of such an approach, or because the concepts provided by psychology at the time did not seem fully adequate for a proper analysis of language, or, again, because they

<sup>10</sup> Bouquet (1997) corrects many of these questionable interpretations.

<sup>11</sup> In particular, Sapir (1933). For this reason, generative phonologists have seen their work as an extension of Sapir's work in important respects: cf. Chomsky and Halle (1968: 76, 349). For detailed discussion, see McCawley (1967).

wanted to remain neutral on issues of cognition? Bloomfield's own position in this respect is rather interesting. He first of all adopted the mentalistic approach to the psychology of language advocated by Wundt (Bloomfield 1914). Later, in 'A set of postulates for the science of language', Bloomfield (1926) offers a framework explicitly modelled on Weiss's behaviouristic paradigm for psychology, an approach he was to maintain in his subsequent work and particularly in *Language* (1933). While Chomsky's famous critique of Skinner's *Verbal Behavior* (1959) definitively demonstrated the fundamental weaknesses of classical behaviourism, Bloomfield's own approach has to be evaluated in the context of the time.

First of all, 'mentalism' was taken by Bloomfield to be a philosophical position which asserted a radical difference between mind and matter: 'The mentalistic theory, which is by far the older, and still prevails both in the popular view and among men of science, supposes that the variability of human conduct is due to the interference of some non-physical factor, a *spirit* or *will* or *mind* (Greek *psyche*, hence the term *psychology*) that is present in every human being. This spirit, according to the mentalistic view, is entirely different from material things and accordingly follows some other kind of causation or perhaps none at all' (Bloomfield 1933: 32). The numerous linguists who speak nowadays of language as a faculty of the mind/brain or stress that speakers are 'embodied' illocutionary agents would presumably not disagree with Bloomfield's distaste for radical dualism. Secondly, Bloomfield was rejecting a form of free-wheeling introspectionism which he saw as threatening the discipline, as illustrated for him by Paul's *Principles*, where statements about language are accompanied 'with a paraphrase in terms of mental processes which the speakers are supposed to have undergone' (1933: 17).<sup>12</sup> In fact, Bloomfield saw much of the psychological paraphrasing which took place in the study of language as based on western philosophical concepts and grammatical categories and he believed this was likely to inhibit the exploration of other language families. Thirdly, in some of his writings, Bloomfield also stated that linguistics could and should remain neutral as far as psychology was concerned (cf. Bloomfield 1926: 153). As he put it: 'the postulational method saves discussion, because it limits our statements to a defined terminology; in particular, it cuts us off from psychological disputes' (1926: 153 ff.) and 'Recall the difficulties and obscurities in the writings of Humboldt and Steinthal, and the psychological dispute of Paul, Wundt, Delbrueck. From our point of view, the last named was wrong in denying the

<sup>12</sup> In turn, of course, Paul's own work has to be understood as a reaction to the mystical belief of grammarians like Grimm in a Hegelian *Sprachegeist* which existed above and beyond individual speakers. Cf. Lightfoot (1999: 35–6).

value of descriptive data, but right in saying that *it is indifferent what system of psychology a linguist believes in*' (our emphasis, J.D./B.L.).

Not surprisingly Bloomfield's legacy in North America was a complex one. The post-Bloomfieldians were not as homogeneous as is often assumed, nor did they avoid being pulled in different directions like their own master. Much of the work done by the post-Bloomfieldians is better described as a form of descriptivism than a defence of behaviourism. When linguists after Bloomfield defended a 'hocus-pocus' approach, in contrast with 'God's Truth', they were indicating that they were more concerned with making progress in the description of languages of the world than with getting bogged down in debates about the mind that they saw as possibly sterile for their practical work. There had been for a long time in North America a point of view which could be summarized by the slogan: 'Leave psychology to the psychologists!' As noted by Lightfoot, this demarcation was already clearly advocated by William Dwight Whitney in the nineteenth century:

The human capacity to which the production of language is most directly due is, as has been seen, the power of intelligently, and not by blind instinct alone, adapting means to ends. This is by no means a unitary capacity; on the contrary, it is a highly composite and intricate one. But it does not belong to the linguistic student to unravel and explain . . . it falls, rather, to the student of the human mind and its powers, to the psychologist. So with all the mental capacities involved in language. (1875: 303, quoted in Lightfoot, 1999: 36)

It would of course be an overgeneralization to assert that the post-Bloomfieldians were never interested in the psychological status of their descriptions. If this were so, the following assertion by Hockett (1948: 279–80) would be incomprehensible:

The analytical process thus parallels what goes on in the nervous system of a language learner, particularly, perhaps, that of a child learning his first language. . . . The essential difference between the process in the child and the procedure of the linguist is this: the linguist has to make his analysis overtly, in communicable form, in the shape of a set of statements which can be understood by any properly trained person, who in turn can predict utterances not yet observed with the same degree of accuracy as can the original analyst. The child's 'analysis' consists on the other hand, of a mass of varying synaptic potentials in his central nervous system. The child in time comes to *behave* the language; the linguist must come to *state* it. (emphasis in the original, J.D./B.L.)

Nevertheless, it is also true that a number of post-Bloomfieldians were extremely militant in their anti-psychologism. Joos, as editor of *the* reference work of the 1950s, *Readings in Linguistics*, was to attack Sapir's students in no uncertain terms:

If their wits happen to be dimmer . . . their blunders may betray the essential irresponsibility of what has been called Sapir's 'method'. We welcome the insight of his genius, which allowed no scrap of evidence to escape at least subconscious weighing; where it is possible to check up, we normally find him right; thus we seem captious when we point out that he also said many things which are essentially uncheckable ('invulnerable') and thus not science. (Joos 1963: 25)

If there was a real turning point in phonology with respect to cognition, it was provided by Jakobson, and particularly by his theory of distinctive features. At the core of Jakobson's approach was a desire to understand the sound patterns of language within a model of communication, hence the idea that one had to start from the brain and the encoding stage of a message and move thereafter from articulation (via acoustics) to audition, and the decoding of the message by the listener. True enough, Jakobson did not provide a complete model of these stages. His prime contribution, in association with other researchers like Fant and Halle, was in the area of distinctive features. By rejecting the Saussurean assumption that the phonological system of each language imposes arbitrary distinctions on an undifferentiated speech tract and acoustic continuum, he forced phonology to renew its connections with phonetic substance and its mental representation. As is well known, for Jakobson, the distinctive features are universal (part of the human predisposition for language), they are binary (an assumption linked to hypotheses about communication and the brain), and they must have correlates in terms of both articulation and audition even though the latter takes precedence in his eyes.<sup>13</sup> Another aspect of Jakobson's work was his openness to data of all types. His speculations concerning language acquisition and breakdown provide the prime example of the difference between 'internal' and 'external' phonological evidence. While this dichotomy is untenable if conceived literally and mechanically, it offers a useful distinction between the data provided by the analysis of synchronic phonological systems, on the one hand, and the data provided, for example, by language acquisition or loss, experimental phonetics, psycholinguistics, and neurolinguistics. For Jakobson, the work of phonologists had to be properly cross- and interdisciplinary and involve links with specialists in other areas, as exemplified by the chapters in this volume. In many respects, however, Jakobson's approach remained programmatic and constrained by quite classical assumptions about language and its structure. In particular, in terms of the oscillation between 'rules' (or processes) and 'representations' which allows an interesting explanation of the historical

<sup>13</sup> For a discussion of this point and extensions, see Durand (2000b).

evolution of phonology (cf. Anderson 1985), he is definitely on the side of representations.

### 1.3.2. The Sound Pattern of English

The publication of *The Sound Pattern of English* (*SPE* hereafter) by Chomsky and Halle in 1968 is generally acknowledged as constituting a watershed in the history of modern phonology. It is customary in presenting developments in phonology to stress the profound formal changes which have taken place between, for example, structuralist models and classical generative phonology and between the latter and current non-linear models. But, in our view, a closer look at the history of our discipline shows much more continuity in depth.

To start with, the break away from previous phonemic approaches which is emphasized in early generative work (cf. e.g. Chomsky 1964, Postal 1968: 29–31) was not as radical as it may have appeared at the time. Within structural phonology, the system of phonemes was simultaneously the basis for description and explanation, as well as the target and source of synchronic and diachronic processes. And, as far as the contrast between units and processes is concerned, the former were privileged by the structuralists at the expense of the latter. On the other hand, in the wake of Jakobson's seminal work on distinctive features, generative phonologists were to stress the relevance of subphonemic units and of processes affecting them. But the divergence is less radical than it may seem. The phoneme was in fact not as defunct as appeared at first sight. For a start, in *SPE*, distinctive features were locked within unidimensional matrices which corresponded rather closely to phonemes. Secondly, in most early generative work, the representations which were the output of the phonological component were strangely similar to classical phonemic representations, even if the notion of a phonemic *level* was strongly rejected. In principle, Chomsky and Halle acknowledged the necessity of formulating all rules—including classical allophonic rules—characterizing the sound system of a language, but in practice they did not carry this out.<sup>14</sup> Indeed some influential generative phonologists such as Schane (1971) were quick to argue explicitly that the notion of phoneme remained central to generative work. Today most generative textbooks use

<sup>14</sup> See, for example, their remarks on p. 65 of *The Sound Pattern of English* where they refer in footnote 5 to Sledd (1966) 'for a discussion of very detailed phonetic rules for a Southeastern American dialect, within a general framework of the sort that we are discussing here'. Our feeling is that Sledd (1966) does not really offer a very detailed specification of low-level phonetic rules.

the term phoneme without even mentioning the acrimonious debates that took place around this concept during the 1960s.

But even if we leave the phoneme aside, it is clear that Chomsky and Halle did not reinvent the field of phonology.<sup>15</sup> At various points of *The Sound Pattern of English* (*SPE*), they are at pains to point out that their approach is by no means new but owes a great deal to the pioneering work of Sapir and Bloomfield among others (see pp. 18 n. and 76 n.). And their debt to the post-Bloomfieldians can hardly be underestimated, since it is generally agreed today that one of the basic deficiencies of the *SPE* model was its linear architecture, the idea already mentioned that phonological units (whether phonemes or boundaries) are like beads on a string—a vision very close to classical phonemics. Finally, and crucially, the range of problems that they dealt with was largely handed down by tradition. To limit ourselves to one example: in the first twenty-seven pages (pp. 330–57) of their chapter 8 ‘Principles of phonology’, they make crucial use of data and analyses associated with Grimm and Verner (pp. 340–2), Joos (pp. 342–3), Sapir (p. 344–50), Thurneysen (p. 352), Trubetzkoy (pp. 352–3), Bloomfield (via Menomini p. 356), Meinhof (p. 356), and Speiser (p. 357).

From a formal point of view, the ‘process’ approach (deriving surface forms from underlying forms through transformations) had already been used by Bloomfield in his ‘Menomini Morphophonemics’ and the *SPE* rule format, although much better articulated, can in essence be argued to go back to the rules of the neogrammarians ( $X \rightarrow Y$ /in some phonetic context). Post-Bloomfieldians like Hockett had insightfully explored the difference between an ‘item and arrangement’ description and an ‘item and process’ approach. The importance of mathematical tools for linguistic work was well understood and well exemplified by Hockett’s detailed excursus on ‘Language, Mathematics and Linguistics’ (1965). And the work of Zellig Harris provided one of the best illustrations of a transformational approach to language. What was however novel in *SPE* was the simultaneous commitment to universalism and cognition.<sup>16</sup> Whereas previous approaches saw

<sup>15</sup> For different points of view on the history of Chomskyan generative grammar, see Newmeyer (1986); Goldsmith and Huck (1995); Harris (1995). Encrevé (2000) offers a detailed criticism of the way Chomsky and Halle see their own relationship to the Bloomfieldian tradition.

<sup>16</sup> Setting aside the personal dimension to the disputes which divided American linguists, it was the general Chomskyan *Weltanschauung* (innatism, universalism, realism, etc.) and not the techniques that led Hockett (1965) to declare: ‘Chomsky’s outlook—not merely on language but also on mathematics, perhaps on everything—is so radically different from Bloomfield’s and from my own that there is, at present, no available frame of reference external to both within which they can be compared . . . let the record show that I reject that [Chomsky’s] frame of reference in almost every detail.’ Interestingly, he immediately adds: ‘The preceding

themselves as primarily descriptive and aimed at providing inventories of structures (which could converge on universal tendencies), *SPE* starts from the assumption central to Chomskyan generative grammar that the aim of linguistic theory is to establish a Universal Grammar (UG). UG will therefore provide all the formal operations and substantive units which underlie natural languages. A further assumption is that UG is made up of components (later called modules) which are interrelated but to a large extent self-contained. Thus, in the case of the phonological module, UG will specify the universal set of distinctive features from which each language draws a particular subset, it will define the way linguistically significant generalizations should be formalized (hence the stress on rule format and notational conventions), what their interrelationship is (extrinsic ordering), how many levels of representation are countenanced (two in *SPE*: phonological and phonetic), and so on. The link with cognition is seen as direct: UG is part of the innate language faculty which, barring accidents, characterizes human beings. It accounts for the ease, rapidity and uniformity of language acquisition. Thus, from the point of view of *SPE*, children will, for instance, know tacitly that the noises they hear are decomposable into segments, that these segments must be composed of distinctive features belonging to the universal inventory (and not to be rediscovered *ad hoc*), and that the distance between their phonetic percepts and stored forms is attributable to the fact that the phonological component specifies two levels of representation related by transformations.

While Chomsky and Halle repeatedly emphasize that what they put forward in *SPE* with respect to English is a competence model, they do believe that their general approach is highly relevant both for a performance model and for a model of language acquisition. The following long quotation leaves no doubt in this respect:

We might suppose, on the basis of what has been suggested so far, that a correct description of the perceptual process would be something like this. The hearer makes use of certain cues and certain expectations to determine the syntactic structure and semantic content of an utterance. Given a hypothesis as to its syntactic structure—in particular its surface structure—he uses the phonological principles that he controls to determine a phonetic shape. The hypothesis will then be accepted if it is not too radically at variance with the acoustic material, where the range of permitted discrepancy may vary widely with conditions and many individual factors. Given

declaration affects in no way my indebtedness to the transformationalists for the many specific points and procedures I have found it profitable to incorporate in my own thinking, as attested repeatedly in the present essay.' (This is part of a note added in proof 20 Aug. 1965 to Hockett's note 3, p. 156).

acceptance of such a hypothesis, what the hearer ‘hears’ is what is internally generated by the rules. That is, he will ‘hear’ the phonetic shape determined by the postulated syntactic structure and the internalised rules.

Among the internalised rules are some that are particular to the language in question and thus must have been learned; there are others that simply play a role in setting the conditions of linguistic experience. In the present case, it would be reasonable to suggest that the Compound and Nuclear Stress Rules are learned, while the principle of the transformational cycle, being well beyond the bounds of any conceivable method of ‘learning’, is one of the conditions, intrinsic to the language-acquisition system, that determines the form of the language acquired. If this assumption is correct, we would expect the principle of the transformational cycle to be a linguistic universal, that is, to be consistent with the empirical facts for all human languages, the Compound and Nuclear Stress Rules, on the other hand, might be in part language-specific. (1968: 24–5)

It should furthermore be pointed out that what made the strong link with psychology possible and provoked the epistemological break with the post-Bloomfieldians was Chomsky’s commitment to realism. Whereas many linguists had adhered to a form of conventionalism or instrumentalism, Chomsky assumes that the constructs and entities in the theories he developed are real features of the world (more precisely the mind since he has always rejected an externalist point of view). This assumption, while arguably implicit in earlier work, becomes central in *Aspects of the Theory of Syntax* where the reader is warned that the term ‘grammar’ will be used with systematic ambiguity to refer either to the linguist’s theory or to the system internalized by speaker-hearers. The realist stance is a major component of Chomskyan generative grammar and has been consistently maintained since the 1960s, as shown in sample quotations like the following: ‘A naturalistic approach to linguistic and mental aspects of the world seeks to construct intelligible explanatory theories, taking as “real” what we are led to posit in this quest, and hoping for eventual unification with the “core” natural sciences: unification not necessarily reduction’ (Chomsky 2000: 106). If one adopts this point of view, linguistics becomes not only a branch of cognitive psychology but arguably the major way of exploring the language faculty. As the following quote from Chomsky demonstrates, there is no more reason to ascribe reality to the constructs pursued in the laboratory than there is to those that are the subject of the linguist’s investigation:

To take another case, the discovery of perceptual displacement of clicks to phrase boundaries is, for now, more of a discovery about the validity of the experiment than about phrase boundaries. The reason is that evidence of other sorts about phrase boundaries—sometimes called ‘linguistic’ rather than ‘psychological’ evidence (a highly misleading terminology)—is considerably more compelling and embedded in

a much richer explanatory structure. If click experiments were found to be sufficiently reliable in identifying the entities posited in C-R [computational-representational] theories, and if their theoretical frameworks were deepened, one might rely on them in cases where 'linguistic evidence' is indecisive; possibly more as inquiry progresses. (2000: 25)

### 1.3.3. Post-*SPE* phonology

Post-*SPE* phonology is quite difficult to characterize, all the more so as we do not have the required historical distance to assess dispassionately a number of directions taken in the field. Moreover, when researchers have proposed alternatives to *SPE* assumptions, they have not always appreciated the full implications of the innovations they were putting forward. A non-trivial problem is the plethora of names which have multiplied since the 1960s and which can cover very different types of activity ranging from specific models to very general research programmes. A very incomplete and partly arbitrary list (in alphabetical order) of the types of phonology would include: articulatory phonology, autosegmental phonology, CV phonology, computational phonology, declarative phonology, dependency phonology, government phonology, harmonic phonology, laboratory phonology, lexical phonology, metrical phonology, natural phonology, natural generative phonology, non-linear phonology, radical CV phonology, tridimensional phonology. In parallel with this, we also find approaches such as moraic theory, optimality theory, theory of constraints and repair strategies, underspecification theory, and so on. We will discuss a number of these approaches under three headings: work within UG, other work, the connectionist challenge.

#### 1.3.3.1. *Approaches within UG*

It is important to realize that most of the frameworks listed above have not necessarily represented separate paradigms but have often been models of phonology differing from each other only with respect to a few assumptions. For instance, theory A might assume binary features, rule ordering, and one level of derivation, while theory B assumes binary features, no rule ordering, and two levels of derivation, and theory C assumes monovalent features, no rule ordering, and two levels of derivation. In contradistinction to theories A, B, and C, theory D might assume that there are both binary and monovalent features but no rules at all. Many of the frameworks which have emerged are characterizable in relation to *SPE* and, indeed, some textbooks published in

the 1990s have simply called themselves 'generative phonology' or 'phonology in generative grammar' to emphasize the continuity of a tradition within which they saw various developments.<sup>17</sup> One crucial aspect in which *SPE* reshaped the field is that the goal of specifying the nature of phonology within UG became a leitmotiv for researchers, even when they disagreed fairly sharply as to what the content of UG might be.

At the core of *SPE* is a commitment to a symbolic approach based on discrete mathematics and automata theory. While a number of the types of phonology listed above have remained within this paradigm, important shifts of emphasis have taken place. A good account of post-*SPE* phonology can be obtained by looking at the evolution of the field in terms of the relative weight attributed to rules and representations, a debate that stretches a long way back in the field as convincingly demonstrated by Anderson's (1985) historical account. The contribution of *SPE* was mainly in the area of rules (in the technical sense of local transformations) as a way of capturing various generalizations including invariance at the lexical level. Transformational rules made possible the positing of unique underlying forms for morphemes, even in cases where suppletive statements might have seemed warranted. These unique underlying forms were seen as quite resistant to historical change and as potentially shared by many dialects of the same language. For a number of years around the publication of *SPE* and in the decade that followed, much work was devoted to the issue of rule ordering and abstractness. This work was seen by many as having obvious implications for cognition. For instance, those working in Natural Generative Phonology (Vennemann 1973, Hooper 1976*b*) as well as others (Koutsoudas, Sanders, and Noll 1974) aimed at constructing a more realistic account of the human mind faculty by doing away with extrinsic ('stipulated') rule ordering. At some point the debate about rule ordering was felt to be counterproductive, all the more so as many of the proposed reanalyses remained very close to the standard *SPE* framework. Nevertheless, the discussions that took place around the excessive power of *SPE* (often compared with a Turing machine) had a lasting influence. Many later frameworks were constructed with the explicit aim of doing away with destructive operations (e.g. 'declarative phonology', Scobbie, Coleman, and Bird 1996, and various types of 'underspecification theory', Archangeli 1984, Anderson and Durand 1988).

Just as radical as the rejection of extrinsic rule ordering was the battle for naturalness. While the notational conventions of *SPE* and its metric of simplicity did allow an intuitively satisfying formalization of many processes,

<sup>17</sup> Cf. Kenstowicz (1994), Roca (1994).

it also failed in some fundamental respects. As Chomsky and Halle themselves acknowledged (1968: 400):

The entire discussion of English in this book suffers from a fundamental theoretical inadequacy. Although we do not know how to remedy it fully, we feel that the outlines of a solution can be checked, at least in part. The problem is that our approach to features, to rules, and to evaluation has been overly formal. Suppose, for example, that we were systematically to interchange features or to replace  $[\alpha F]$  by  $[-\alpha F]$  (where  $\alpha = +$ , and  $F$  is a feature). There is nothing in our account of linguistic theory to indicate that the result would be a description that violates certain principles governing human languages.

The solution sketched by Chomsky and Halle was the use of markedness conventions but these, in actual fact, remained external to the notation. As a result, in many different ways, phonologists began to look for ways of capturing 'naturalness' more directly within their descriptions.<sup>18</sup> One striking example was the work of Stampe (1973), who advocates a theory of phonology based on natural processes (e.g. nasalize a vowel followed by a nasal consonant in the same syllable). All these natural processes are available to a child and the learning of a language takes place, so to speak, by forgetting. Adult systems can be seen as the result of inhibiting, downgrading, or restricting natural processes (an approach not so dissimilar to optimality theory discussed below). It can however be seen that, in so far as natural processes reflect general production and perception strategies, they do not sit happily within the UG paradigm if the latter is assumed to include factors not reducible to communication. This is an issue to which we return at various points below.

Another way of capturing naturalness was via representations. Phonological representations in *SPE* were quite austere. *SPE* has occasionally been compared to Russell and Whitehead's *Principia Mathematica*, since Chomsky and Halle attempted to reconstruct phonology on the basis of a few primitives and operations. In so doing, *SPE* discarded many concepts which had been explored by earlier phoneticians and phonologists (e.g. the syllable, 'long components', or 'prosodies'). During this phase, there emerged a number of frameworks (e.g. autosegmental phonology, tridimensional phonology, metrical phonology, dependency phonology, and then feature geometries) which put forward radical revisions of standard representations by appealing to the *SPE* idea that the notation must reflect the difference between accidental facts and linguistically significant generalizations.<sup>19</sup> One of the results now taken for granted by many phonologists is multilinearity

<sup>18</sup> See the essays in Bruck, Fox, and Lagaly (1974) and Dinnsen (1980).

<sup>19</sup> Among the influential collections of articles, a special place should be reserved for van der Hulst and Smith (1982, 1988).

(the idea that representations are organized along tiers that do not coincide) and the existence of suprasegmental constituents such as the syllable.<sup>20</sup> Indeed, the syllable is pivotal to this book as demonstrated by most of the chapters in this volume.<sup>21</sup> The syllable is seen by some of the contributors as the fundamental unit from which segments and subsegmental features emerge ontogenetically and which provides the link between a physically driven system and higher-level units.

In recent years, descriptions have again focused on rules. This assertion may seem surprising in view of the fact that many current models claim to dispense with rules altogether (and in fact one famous book edited by Goldsmith (1993*b*) is entitled *The Last Phonological Rule*). The use of the term 'rule' in this context must however be clarified. Until comparatively recently, successive Chomskyan generative grammars have included two types of mechanisms, both referred to as rules historically. The first of these have been 'constituency rules' ('phrase structure rules' in syntax) and the second, transformational rules. For a very long time now, constituency rules (e.g.  $S \rightarrow NP VP$ , or  $Syllable \rightarrow Onset Rhyme$ ,  $Rhyme \rightarrow Nucleus$  (Coda)) have not been construed in procedural rewriting terms (e.g. replace the symbol Syllable by the symbols Onset and Rhyme). Rather, constituency rules are regarded as well-formedness conditions or, in a more fashionable terminology, 'constraints'. By and large, current models have not questioned the need for such descriptive devices. What, on the other hand, has been rejected by many phonologists is the use of transformational rules, which were at the core of the *SPE* approach (although one will find a spirited defence in Bromberger and Halle 1989, 1997, 2000).

There is no doubt that the use of constraints and their interrelationships has provided the central development of the last ten years. Within this development, a number of models have been in competition<sup>22</sup> such as the Theory of Constraints and Repair Strategies (Paradis 1988*a*, Paradis and Prunet 2000, this volume), Declarative Phonology (Coleman 1995, 1998*a*), and Optimality Theory.<sup>23</sup> These various models show many

<sup>20</sup> For early post-*SPE* work on the syllable, see Fudge (1969), Hooper (1972), Vennemann (1972), Anderson and Jones (1974), and Kahn (1976). For a recent, encyclopedic treatment, see van der Hulst and Ritter (1999).

<sup>21</sup> See in particular the chapters by Abry, Stefanuto, Vilain, and Laboissière; Carvalho; Dupoux and Peperkamp; Paradis and Béland; Segui and Ferrand.

<sup>22</sup> For comparisons and debates, see Durand and Laks (1996*a*), Roca (1997).

<sup>23</sup> See Prince and Smolensky (1993) and McCarthy and Prince (1993) for the two founding texts. For advanced expository discussions and further references, see Archangeli and Langendoen (1997) and Kager (1999). For an interesting application to English, see Hammond (1999).

family resemblances but also differ along a series of different dimensions. Thus, in Optimality Theory, constraints cannot construct, destroy or trigger any processes. Their role is merely to select an output form. Moreover, constraints can be violated. In Declarative Phonology, constraints cannot be violated and act as constructive processes which together define the well-formedness of output forms. In the Theory of Constraints and Repair Strategies, as in Declarative Phonology, constraints determine the validity of output forms but they can be violated, in which case they can trigger constructive or destructive processes as repair strategies. While a detailed comparison of these models would be useful, it is however the cognitive implications of post-*SPE* work which will preoccupy us here.

Many of the frameworks which have emerged since *SPE*, while formally very different from that model, have pursued the basic goals of Chomskyan generative grammar. For instance, Government Phonology as defended by Kaye, Lowenstamm, and Vergnaud (and extended by the work of Harris and Lindsey 1995, Ingleby and Brockhaus, this volume) sees work on sound structure as contributing to UG. As the following quotation shows, this approach is consonant with the Principles and Parameters approach adopted by Chomsky in syntax since the 1980s:

Our programme incorporates the view that phonology is to be regarded as a system of universal principles defining the class of human phonological systems. These principles underdetermine the class of human phonological systems. A complete phonological system consists, then, of these principles along with sets of parameter-values. Taken together, the principles and language-specific parameter settings give a complete characterisation of the phonological component. In this model, a phonological system contains no rule component.

Similarly, when launching Optimality Theory in 1993, Prince and Smolensky asserted:

The basic idea we will explore is that Universal Grammar consists largely of a set of constraints on representational well-formedness, out of which individual grammars are constructed. Departing from the usual view, we do not assume that the constraints in a grammar are mutually consistent, each true of the observable surface or of some level of representation. On the contrary: we assert that the constraints operating in a particular language are highly conflicting and make sharply contrary claims about the well-formedness of most representations. The grammar consists of the constraints together with a general means of resolving their conflict. We argue further that this conception is an essential prerequisite for a substantive theory of UG. (1993: 2)

Despite appearances, it is quite difficult to assess what stance researchers who work within the UG paradigm take vis-à-vis the status of the

phonological module within the mind/brain. For ease of description and to lighten the debate, we will divide generative linguists into religious groups.<sup>24</sup> The main groups within the UG church vis-à-vis this part of the faith are the disbelievers, the agnostics, and the faithful. There are also dissenters whose position is either critical or ambivalent. Finally, there are (as ever) other churches that we briefly examine later.

Disbelievers are rare animals. To work within Chomskyan UG but deny totally its usual psychological/biological interpretation is to live dangerously. One extreme example is that of the French linguist Milner (1982: 302–17). While accepting the realist and universalist stance of Chomskyan generative grammar, he denies the validity of a number of its basic tenets including the following (his definition E): ‘The generative linguist considers the principles which determine the class of possible grammars as a genetically determined property of the human species.’ He claims that definition E is neither logically necessary nor descriptive of a factual situation. He argues that logical necessity cannot be invoked here since other hypotheses can be envisaged: e.g. one might consider that ‘the universal principles which constrain possible grammars are not different in essence from the incest prohibition which constrains the class of possible human societies and which cannot be reasonably interpreted as a type of information which is part of the genetic code of our species’ (our translation; Milner 1982: 317). As to the factual claim, it is demonstrably false since, as Milner says provocatively, ‘there is at least one generative linguist, namely myself, who rejects (E)’. The agnostics are more widespread and provide the least challenging position from an epistemological point of view. While leaving open the question of how a grammar is instantiated in the brain, they use the concepts and hypotheses of UG as heuristic tools for describing and exploring the languages of the world. One common fate of agnostic generativists over time is to become descriptivists or to turn into formalists. The formalist orientation will be taken by those who believe that the classical goals of generative grammar are more important than the psychological dimension: i.e. the function of the grammar is to provide a fully explicit (mathematical) representation of the differences between the well-formed and the ill-formed strings of a given language. In syntax, various unification models could be taken as possible examples of this position. Within the field of sound structure, Declarative Phonology can be argued to adopt a similar position. Coleman (1995, 1998a), for instance, provides a particularly trenchant

<sup>24</sup> It is important to realize that no value judgement is being passed here. In terms of this terminology, Durand (1990, 1995) is a ‘faithful’ while Laks (1996b) is a ‘dissenter’. The same person may belong to several categories as time unfolds and occasionally at the same time in different publications. Such contradictions are not usually fatal!

example of such an approach. He argues that post-*SPE* phonologies have failed in their attempt to restrict the excessive power inherent in the *SPE* approach.

Inspired by the success of non-transformational, non-derivational syntactic theories (such as Lexical Functional Grammar and Generalized Phrase Structure Grammar) in challenging, matching and improving on transformational, derivational syntactic theory, a number of phonologists (including myself) are examining the applicability of non-derivational grammar formalisms to the phonological domain. The strategy offered by non-derivational phonology to the problem of excessive power is to drop the notion of derivation from the characterization of the surface forms of words. All rules *R* that alter representations in a way that gives rise to derivations, so that applying rule *R* before some other rule *R'* brings about a different result from applying *R* after *R'*, are to be prohibited. Such a grammar attempts to characterise the set of surface forms of utterances directly, not via representation-altering rules from lexical entries which differ from the surface. (Coleman 1995: 335)

The faithful, as far as phonology is concerned, form a complex set. There are those who, under a realist stance, take it as axiomatic that phonology is part of UG and that phonological descriptions mirror the competence system internalized by speakers. They hope that other approaches (e.g. psychological experiments) will help as we progressively sharpen our CR (computational-representational) theories but they reject the notion that psycholinguistics or neurolinguistics has any special status in helping to validate our theoretical constructs.<sup>25</sup> Let's call this group 'contemplative'.<sup>26</sup> There are also faithful, we shall call them 'working', who actually attempt to validate their CR theories by leaving the traditional field of phonological description in search of 'external' evidence and would, if they are consistent, accept that such evidence could invalidate a description that seems satisfying on theoretical

<sup>25</sup> Recall the quote by Chomsky at the end of 1.3.2.

<sup>26</sup> Within this group some even go so far as to claim that, although much remains to be learned, the competence model of the linguist is equivalent to a performance model. A recent example is provided by Bromberger and Halle (2000: 35) who assert: 'Some people may object to our way of looking at phonology on the grounds that it construes phonology as about performance not competence. If they mean that we view phonology as about processes in real time responsible for the occurrence of tokens, they are right about our view. . . . Some will object that we have loaded phonology with unwarranted assumptions. Do speakers REALLY [emphasis in the original, J.D./B.L.] retrieve morphemes from their memory, invoke rules, go through all these labours when speaking? We think they do. In fact we would like to know more about how they do it. We may be mistaken. Time will tell. But intuition will not. Clearly speakers are not aware of performing such actions. But then we perform actions like zombies (to borrow a phrase from Ned Block). That is how we learn language, recognize faces and solve most of our problems.' As far as we are aware, most phonologists are much more prudent about the 'realization' or 'implementation' issue.

grounds. One interesting example of this approach is provided by Paradis and Prunet (this volume). But the main reason we stated that the 'faithful' do not form a homogeneous set is that, setting aside the question of how the phonology can be integrated into a performance system, one can also believe in UG but deny that phonology is strictly part of the innate language faculty.

To understand, at least partially, the debate about phonology and UG, it is useful to realize the very real shift which has taken place in linguistics since the 1960s with respect to the externalization of language or, to use current terminology, with the status of the interface systems which are accessed by the language faculty. Until the 1960s, linguists adopted wholeheartedly the idea that the use of the vocal-auditory channel was a defining property of natural languages. This was the position typically adopted in structuralist introductions to language<sup>27</sup> and it was taken over in most frameworks, including generative-transformational grammar which posited three components as part of UG: semantics, syntax, and phonology (Chomsky 1965, Chomsky and Halle 1968). Until relatively recently, sign languages were not mentioned or, when they were, they were treated as systems parasitic upon speech, echoing Bloomfield's position in *Language* (1933: 39–40):

Some communities have a *gesture language* which upon occasion they use instead of speech. Such gesture languages have been observed among the lower class Neapolitans, among Trappist monks (who have made a vow of silence), among the Indians of our western plains (where tribes of different language met in commerce and war), and among groups of deaf-mutes. . . . It seems certain that these gesture languages are merely developments of ordinary language and that any and all complicated or not immediately intelligible gestures are based on the conventions of ordinary speech . . . Whatever may be the origin of the two, gesture has so long played a secondary role under the dominance of language that it has lost all trace of independent character. Tales about peoples whose language is so defective that it has to be eked out by gesture, are pure myths. (1933: 39–40)

If Bloomfield was right to criticize the idea of primitive languages based solely on gestures (and, one assumes, inarticulate cries!), it is now generally recognized that the sign languages used by deaf people have the same semiotic potential as spoken languages. In fact, some recent textbooks in English (which are good indicators of which direction the field has taken) have attempted to integrate sign languages to their overview of language (Jackendoff 1993, Fromkin and Rodman 1998). On the basis of this

<sup>27</sup> Cf. e.g. Martinet's definition of language (1960: 20) as 'an instrument of communication through which human experience can be analysed, differently in each community, in units made up of a semantic content and a phonic expression, i.e. the monemes' (our translation, J.D./B.L.).

argument and others, a number of linguists have questioned or severed the connection between the language faculty and speech. Thus John Lyons (1991: 7) points out:

On present evidence, this [i.e. the idea that the association between language and speech is innately determined, J.D./B.L.] would be a hasty conclusion to draw. In my view, it is quite possible that the language-faculty and the predisposition to vocalise are biologically independent and contingently associated in speech.

And Chomsky himself has adopted an unequivocal stance on this point:

Though highly specialised, the language faculty is not tied to specific sensory modalities, contrary to what was assumed long ago. Thus, the sign language of the deaf is structurally much like spoken language, and the course of acquisition is very similar. Large-scale sensory deficit seems to have limited effect on language acquisition. Blind children acquire language as the sighted do, even colour terms and words for visual experience like 'see' and 'look'. There are people who have achieved close to normal linguistic competence with no sensory input beyond what can be gained by placing one's hands on another person's face and throat. The analytic mechanisms of the language faculty seem to be triggered in much the same ways whether the input is auditory, visual, even tactual, and seem to be localised in the same brain areas. (1995: 16)

This whole issue is obviously highly relevant for phonology and its place within UG, on the one hand, and the nature of phonological representations within the mind/brain, on the other. Some phonologists have taken the position that phonology is not part of UG at all (Burton-Roberts and Carr 1996, 1997, Burton-Roberts 2000, Carr 2000). One simple argument given by these linguists to defend their position is that the constraints posited in most models of phonology (including optimality theory) are rooted in a range of physiological, perceptual, and general cognitive capacities which must by definition fall outside of UG. This does not mean that sound systems cannot be studied scientifically but it means that they will have properties different from those one finds in the abstract syntax that UG seeks to characterize. Others such as Durand (1995) consider that phonology is part of UG. The reasoning rests (*a*) on the 'structural analogy' between phonological, morphological, and syntactic representations, (*b*) on the classical idea that the essence of UG is to offer a *relational* system linking semantic representations/computations and a 'signology'. Saussurean signs represent the language faculty at its most basic except that they need to be enriched with a syntactic part. Since the predisposition to vocalize is universal and severely constrained by species-specific mechanisms and as a result of evolution, it is naturally accessed by the language faculty. (We are describing human beings not Martians!) In human beings suffering from a speech/hearing impairment,

it cannot be excluded that the abstract features/properties specified for phonology are recoded into an interface with a different medium.<sup>28</sup> Harry van der Hulst (1993, 2000) advocates a somewhat different position: phonology is part of UG but is concerned with the specification of something more abstract than standard phonological features, i.e. a system which underlies both speech and sign language.

This constellation of positions is extremely difficult to disentangle but many of the researchers working within the UG paradigm share the belief that a symbolic metalanguage is a good way of specifying the nature of the language faculty. Just as crucially, they often share what has been aptly called by Lindblom (1995: 464) the ‘view from syntax’. In brief, the claim about sound structure (for those who include it within UG) is that, once everything linked to the use of language (production, perception, memory, social factors, etc.) is accounted for, there will remain a large core of phenomena which belong to ‘Language *per se*’ or the innate language faculty. This faculty ‘is not reducible to features of other kinds’ and therefore ‘ought to occupy the central concern of linguists if they wish to arrive at an adequate conception of the essential and special nature of human Language’ (Anderson 1981: 495). As we shall see in the rest of this chapter, strong challenges to this assumption have appeared both within phonology and within phonetics.

### 1.3.3.2. *Other approaches*

While a number of traditional models pursued their existence after the publication of *SPE* (e.g. Martinet’s functionalist approach in France), it became increasingly difficult for phonologists not to situate themselves either in relation to *SPE* or in reaction to some post-*SPE* models symbiotically related to *SPE*. The main thrust of ‘dissident’ approaches has probably been a renewed emphasis on phonetic and general cognitive factors as opposed to the formal approach of *SPE*. As ever, there have been exceptions. A notable one is the work of James Foley (1977, 1979, *inter alia*), who adopts a point of view similar to Hjelmslev’s in that phonology is seen as totally abstract,<sup>29</sup> a science of relations rather than objects, the latter (phonetic units) being epiphenomena resulting from other fundamental notions such as relative position on abstract strength scales. This hypothesis and the analyses offered by Foley are not without their appeal, but his model, if cut off from either

<sup>28</sup> This point of view is quite different from that of Burton-Roberts and Carr and compatible with that defended by Carstairs-McCarthy (1999) who traces all asymmetric relations in language (head/complement, topic/comment, predicate/argument) to the C/V split within syllables. Extending this idea, all syntax is derivable from phonology/phonetics!

<sup>29</sup> Foley goes so far as to call the *SPE* approach ‘transformational phonetics’.

cognition or phonetic substance, can be shown to be impossible to falsify (cf. Coates 1979, Durand 1982). It seems to us that it is precisely the opposite point of view which has been dominant among the 'dissidents'.

For a number of researchers, the notion of explanatory adequacy in phonology cannot be theory internal but must rest on phonetic facts (auditory or physiological explanations) and on the nature of human communication with the constraints it imposes on signs. No more than a flavour of this type of approach can be given here. To take one example, Dressler (1981: 116 *et passim*) states that 'basic teleologies (or "functions") are assigned to each language component'. Thus, the purpose of segmental phonology lies in 'the double teleology of making language perceivable and pronounceable'. The function of natural phonological processes (e.g. the palatalization of velar consonants before [j, i, e]) is to aid or even constrain pronounceability or perceptibility by the structural change it imposes between input and output. Since this teleology can be served only by phonetic facts, the various criteria of phoneticity (plausibility, regularity, generality, phonologicalness of domains of application, etc.) can be combined as means to the same ends. More generally, following the philosopher Peirce, Dressler asserts that the more iconic a sign, the more natural it is. From this a number of consequences follow: for instance, an intrinsic allophone is favoured over a different phoneme as the output of a phonological rule. Properties which are part of UG in a generative approach and assumed to be not strictly explicable in functional terms are derived here from the semiotic nature of communication. Thus, the fact that transparency is preferred to opacity in phonological systems (cf. Kiparsky 1973) is not mysterious but the simple reflection of iconicity in language.

Another interesting type of approach refusing to sever phonology from actual performance has been that of Articulatory Phonology (Browman and Goldstein 1986, 1992). Instead of operating with classical distinctive features, Articulatory Phonology models *events* through the position of 'gestures' organized in 'tiers' within their respective subsystems in a 'gestural score'. The subsystems are the main components of speech production: i.e. the velic, glottal, and oral subsystems. The oral subsystem, to take just one example, is itself further divided into three tiers involving different coordinative structures: i.e. those controlling lip, tongue tip, and tongue body constrictions. One of the advantages of Articulatory Phonology, through the use of gestures, is the proximity of its constructs to phonetic realizations which are typically continuous and not discrete. By allowing gestures to overlap, blend, and mask one another, Articulatory Phonology offers a concrete approach, but also demonstrates that patterns of physiological activity are only indirectly reflected in the speech signal. The need for a

more concrete link with observable speech processes is indeed a strand which has been accelerating over the last decade. Thus, Coleman (this volume), after working for many years within Declarative Phonology, now advocates the abandonment of symbolic-phonological representations in favour of the hypothesis that our mental representations of the form of words are essentially phonetic. More specifically, a combination of phonetic, statistical, and semantic knowledge is sufficient in his view to explain many aspects of phonological structure. In so far as researchers, like Coleman, reject the dual view of sound structure (the idea of a phonetic component dealing with the gradient bolted onto a phonological component dealing with the discrete) and wish to devise models which directly account for performance, they must integrate facts from a variety of disciplines and be ready to abandon the sharp opposition between phonology and phonetics which has characterized the field in the past. This is precisely what has taken place with the movement known as Laboratory Phonology.

Laboratory Phonology is not a specific model with shared assumptions about a theory of language. Rather, it is a research strategy based on the cooperation of people who do not necessarily agree about phonological theory, but who believe in the need to strengthen the scientific foundations of phonology through improved methodology, explicit modelling, and cumulative results. In the words of Pierrehumbert, Beckman, and Ladd (2000: 274):

Laboratory phonologists are scientists who use laboratory methods to discover and explain the sound structure of human languages. Their philosophical stance is generally that of researchers in the mature sciences, such as biology and physics. Specifically, most laboratory phonologists have abandoned the doctrine of dualism. They view language as a phenomenon of nature, albeit a particularly complex one. Language as a cognitive system imputed to individuals is thus to be explained in terms of general facts about the physical world (such as the fact that the resonances of an acoustic tube are determined by its shape; in terms of specific capabilities of the human species that arose through evolution).

As will be obvious from the above, Laboratory Phonology is definitely not a specific model within assumptions about phonological/phonetic primitives, the nature of phonological generalizations, and the way various levels of linguistic representations are interfaced. It is a reaction to the nature of formalism defended in *SPE* and indirectly in many of the models which appeared in its wake. We saw earlier that Chomsky and Halle reacted to the limitations of the 'overly formal' route taken in their analysis of English by introducing a new type of notational device (markedness conventions). Much post-*SPE* work in phonology has been devoted to devising notations able to mirror linguistically significant generalizations. Laboratory Phonologists do

not deny the usefulness of this work. They question the assumption that work in phonology can proceed without paying attention to the nature of phonetic events and realistic models of phonetic performance. They question the modular decomposition of phonology and phonetics in which one module (phonology) is categorical and free of the gradient cumulative effects which are assumed to characterize the phonetic module uniquely (Pierrehumbert, Beckman, and Ladd 1996: 540). In a word, they defend an approach which breaks away from what they see as a traditional way of working (field work with informants and intuitions about sound structure) in favour of a more experimental, multidisciplinary paradigm.<sup>30</sup>

Laboratory Phonology offers a healthy position which is seen by some as a threat but which we are sympathetic to, as will be obvious from the selection of chapters in this book. It seems to us that the 'realist' position assumed in much Chomskyan work is open to discussion not necessarily in the letter but in the spirit with which it is applied. When we set up an account of any aspect of phonological structure, we agree with Chomsky that we do so in the hope of reaching 'truth' in that domain. In the absence of alternative accounts, the analysis proposed has to stand as 'true' and therefore in principle ascribable to the grammar internalized by speakers. But, the degree of idealization in phonological work, as in the rest of linguistics, is very high. Idealization is unavoidable and an essential component of any scientific work. It is customary in theoretical linguistics to quote approvingly work in the physical sciences to show that this is the only way to proceed. We fully understand this position. For instance, to study velocity in physics, scientists initially ignored friction. But, it should also be noted that at a later stage the scientist will reintroduce friction and such moves often lead to radical re-evaluations of previous assumptions or formalizations. Moreover, at various points in the history of science, it has not been the lack of mathematical sophistication which has impeded progress but the lack of experimentation. By this we do not mean one crucial experiment<sup>31</sup> but the cycles of conjectures and refutations involving different types of methodologies and technological innovations which have characterized modern science. We are well aware of the dangers of a naive empiricist approach, as examples can readily be found of famous scientists correcting empirical observations on the basis of

<sup>30</sup> Examples of this kind of work have been provided in the *Papers in Laboratory Phonology*, see Kingston and Beckman (1990), Docherty and Ladd (1992), Keating (1994), Connell and Arvaniti (1995), Broe and Pierrehumbert (2000).

<sup>31</sup> Thus, doubt has been expressed as to whether Galileo did perform the famous Leaning Tower experiment, see Boas (1970: 208). Boas notes the mathematical sophistication of some of the accounts of motion in the 17th century such as the Merton Rule, after the Oxford college, which gave a geometric account of accelerated motion.

their bold hypotheses. For instance, on several occasions, Newton asked Flamsteed, the first Astronomer Royal, to correct his 'data' since they clashed with his own theory and this led to a bitter personal controversy between the two men. As Lakatos (1970: 131) put it, 'One can understand the constant humiliation and slowly increasing fury of this great observer, having his data criticized and improved by a man who, on his own confession, made no observations himself.' But classical astronomy, although it has often been seen as a model for linguistic research, is not the only example one can follow. If one moves to physics, one may wonder how the idea that 'Nature abhors a vacuum' could ever have been falsified without Torricelli tubes and the kinds of experiments performed by Pascal at Clermont-Ferrand and the Puy-de-Dôme (cf. Pascal 1663).<sup>32</sup> Such a point of view will not yield a grand theory quickly but, for the practitioners of Laboratory Phonology, will contribute to the emergence of much more realistic and comprehensive models of speech production and perception in a biological perspective. What it entails however is a rejection of a strong divide between phonology and phonetics.

### 1.3.3.3. *The connectionist challenge*

In the last two decades, the greatest challenge to the cognitive approach adopted in the Chomskyan tradition (referred to as 'classical cognitivism' from now on) has arguably come from what is often referred to as 'connectionism' (Rumelhart, McClelland, et al. 1986; Elman et al. 1996). Classical cognitivism is seen by connectionists as narrowly linked to a classical approach to computation based on the division of labour between a central processor and static memory, and a digitalization of logical processes. This von Neumann architecture characterizes digital computers and finds a typical interpretation within Artificial Intelligence. Connectionism has different roots but central to its approach is the notion of analogical computation.<sup>33</sup> In this approach founded on an explicit neuronal metaphor, computation is basically energetic and dynamic. The analogical coding consists in implementing the problem to be solved in the form of energies which affect processing units which are simple but strongly interconnected: formal neurones. A neural network forms a kind of computational lattice within which possibly antagonistic energies will circulate. Ever since the seminal work of McCulloch and Pitts (1943), it has been known that the energetic

<sup>32</sup> On the new experimentalism in the philosophy of science, see Chalmers (1999: ch. 13) and the references therein.

<sup>33</sup> Contrary to what is often asserted, parallel or neuronal architectures are not a recent innovation. See for instance von Neumann (1992), who offers an explicit comparison of modes of coding (analogical/digital) and architectures (parallel/serial).

stabilization of these networks, sometimes referred to as their dynamic relaxation, allows for the analogical simulation of the calculation of logical functions and has thus been claimed to offer a first approximation to mental operations. Since the new impetus which was given to these studies in the 1980s, connectionist approaches have known extensive developments in all areas of computational and cognitive modelling. Rumelhart, McClelland et al. (1986) offer a synthesis of possible connectionist approaches to vision, reasoning, calculation, and above all language processes which, from the very beginning, have been the linchpin of cognitive modelling. In particular, they present fascinating results in the learning of irregular English verbs, the modelling of semantico-pragmatic scenarios, and the recognition of spoken words.<sup>34</sup> In phonology an original approach in the form of Dynamic Linear Models (DLMs) has been developed by Goldsmith and Larson.<sup>35</sup> DLMs are not classical connectionist models capable of implementing any function but networks specifically dedicated to phonology. Within this framework, Laks (1995, 1996*a*, 1996*b*, 1997*b*) has shown how a unilayered perceptron with bilateral inhibition such as the one represented in Fig. 1.1 is able to model accentual patterns in a wide variety of languages or to model French syllabification.<sup>36</sup>

In this network made up of six formal neurones (K1 . . . K6), the synaptic connectivity is bilateral ( $\alpha_1 \dots \alpha_6$ ,  $\beta_1 \dots \beta_6$ ). At time  $T_0$ , inputs are introduced in the form of quanta of activation for each formal neurone ( $a(K_1)T_0 \dots A(K_6)T_0$ ). The rule of dynamic relaxation for the network which leads to its stabilization at  $T$  via energy propagation through its synapses, is fixed as follows:

$$a(k_i)^{t^n} = a(k_i)^{t^0} + \alpha_i(a(k_{i-1})^{t^{n-1}}) + \beta_i(a(k_{i+1})^{t^{n-1}})$$

In connectionist approaches, a formal neurone is in fact defined as an extremely simple processor able to receive and transmit energy through its synaptic connections. The updating of the energy level of a neurone is a

<sup>34</sup> For an overview of this general approach, see Bechtel and Abrahamsen (1993). The first connectionist analyses of various morphological features of English were clearly limited and gave rise to criticisms by various linguists and psycholinguists (e.g. Prasada and Pinker 1993, and the references therein). For revisions of the connectionist treatments, see MacWhinney et al. (1989), MacWhinney and Leinbach (1991), Marchman (1993), Ling (1994), Ping and MacWhinney (1996).

<sup>35</sup> Cf. Goldsmith (1991, 1992, 1993*a*, 1993*b*, 1994), Goldsmith and Larson (1991).

<sup>36</sup> A unilayered perceptron is a simple neuromimetic structure made up of interconnected logical processors (formal neurones). The architecture is non-hierarchical (unilayered) and the connections are inhibitory. Within a level, connectivity is complete (bilateral). The network presented in the text is taken from Laks (1995). Whereas for Goldsmith  $\alpha$  and  $\beta$  are fixed for the whole network, they are variables in Laks's approach.

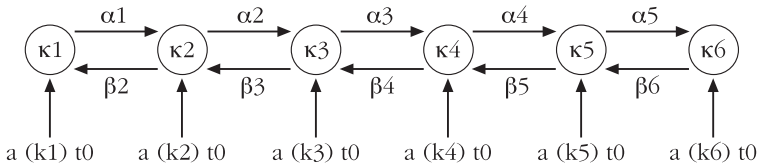


FIG. 1.1. Unilayered perceptron.

function of its inputs/outputs as well as that of its parameters of connectivity. What is usually called the ‘semantics of the network’, that is, its ability to deal with specific problems, is completely determined by its architecture and its synaptic weights. Connectivity and weights can be progressively adapted so that the network’s answer (i.e. its final state) may fit a predefined target more closely. Thus the learning process exhibits some of the properties usually considered as typical of intelligent learning: spontaneous classification and generalization, systematization, and the drawing of inferences. A network such as the one presented in Fig. 1.1 therefore implements a dynamic computation which is algebraic but not algorithmic. No rule, no rewriting symbolic rule, no predefined explicit process applies to the calculus which is strictly non-symbolic. In this cognitive approach, processes and mental states are coded and implemented without recourse to the rich symbolic lexicon linguists are familiar with (constituent, syllable, nucleus, stress) and without recourse to a more or less complex syntax based on that lexicon.<sup>37</sup> The difference between this approach and AI, and indeed all linguistic models that use a symbolic architecture, is obvious: in neuromimetic (connectionist) approaches there are no explicit symbolic representations, and calculations do not proceed through logico-syntactic manipulations. It can of course be objected that the initial coding and the external inputs reflect a representation of the problem to be dealt with, but this representation is totally or partially (according to the model) *distributed* throughout the network. No formal neurone can represent alone an element or a subpart of the representation. Rather, the representation is a function of the network as a whole.

The type of holistic approach just described has been analysed by Smolensky (1988) as *subsymbolic*. It offers a precise hypothesis as to the functioning of the mind/brain. According to this hypothesis, there is no autonomy of the mind with respect to its physiological substratum and it is seen as axiomatic that cognition takes place within dynamic systems and not within numerical computers. This is claimed to be more in agreement with the findings of neurobiology, in particular with the idea that the human brain

<sup>37</sup> For an analysis of the central role played by syntax in classical cognitivism, cf. Fodor and Pylyshyn (1987).

is defined less by the characteristics of individual neurones than by the extraordinary complexity of its architecture, the parallelism of its operations, and the vast interconnectivity of its components. This is why connectionism is often presented as a neuromimetic approach, not because the architectures it develops are necessarily fully realistic but because the principles it adopts mirror basic properties of the brain. Connectionism thus sees itself as strongly physicalist and profoundly different from the Chomskyan approach. The most advanced properties of the human mind *emerge* directly from the extraordinary complexity of the human brain. In this strictly ascending empiricist approach, there is no need for the postulation of innate functions. It is sufficient to postulate a genetic conditioning of neuronal structures. Only the physical level is truly causal.

On the basis of the notions of synaptic connectivity and synaptic plasticity, connectionism has developed a whole gamut of tools and techniques for exploring the notion of learning. Unlike Chomskyan innatism, it is claimed that learning is essentially conditioned by the repeated restructurings and reactions of an organism in response to external data plus the initial states whenever there is evidence for specialization of the brain in a particular domain (as seems plausible for phonology and phonetics). These reactions are accompanied by a continuous evaluation of the performances of the network through a process of feedback or retroactive evaluation. There is undeniably a similarity with classical behaviourism. Nevertheless, this neobehaviourism tries to integrate data collected during the last decades in psycholinguistics and does not exclude prespecification (at least in the version which seems to us defensible).

Connectionist models come in many different varieties. The most extreme varieties have often been referred to as 'eliminationist connectionist models'. Among the tenets of these approaches is the idea that the basic analytic concepts of generative and most other linguistic theories are simple artefacts which can and should be eliminated in some sense and that the dynamic numerical computations embodied in neural nets should replace all symbolic approaches. There is however a problem in adopting such a strong stance. Connectionism is neither quantitatively nor qualitatively fully realistic from a neurobiological point of view. First, the current techniques of dynamic calculations and the size, complexity, and architecture of the networks effectively manipulable are vastly inferior to the capacities of the human brain. Secondly, our knowledge of neural architectures, synaptic processes, and more generally of the neurophysiology and neurochemistry of the brain is still in its infancy, despite the very real progress which has been achieved (see Démonet et al., this volume). Thirdly, while one might disagree with the particular modular view advocated by Chomsky, and in particular the 'radical

autonomy' of syntax, it is difficult to deny that there are psycholinguistic examples (e.g. dissociations) which support specialization or a form of modularity in the present state of knowledge.<sup>38</sup> Finally, in the systemic approaches which connectionism takes as a point of departure, the quantitative complexity factors are in fact functional qualitative factors. It is often such factors which lead systems to diverge. From this angle, and in terms of complexity and therefore also of functional properties, neural networks and neuromimetic networks are within orders of magnitude which are not fully comparable. Indeed, it cannot be excluded that the typical properties of each of them might be substantially modified as sizes increase.

Our own view is that the best way to proceed is to see connectionism as allowing us to explore functional and cognitive processes in what is, in our current state of knowledge, a plausible framework from the point of view of neurobiology.<sup>39</sup> Thus, the neuromimetic metaphor is only a first approximation. We do not see connectionism as a realist model (except by fiat) but as an interesting way of simulating a number of higher cognitive processes (whether linguistic or not) such as reasoning, drawing inferences, or categorizing. The position taken by Laks (1996*a*) is that connectionism offers an intermediate level of modelling. This level seems interesting from the point of view of cognition. The reason is that, if the physical and neuronal level is ultimately the *causal* level, it is not (partially for the complexity reasons raised above) analysable or penetrable as such. This has always posed severe problems for strictly physicalist approaches. To solve them, a better strategy is to analyse neurophysiological causality and cognitive processes in general at two levels: on the one hand, the level of the concrete implementation of these processes which is solely neurophysical and, on the other hand, the description, analysis, and understanding of these same processes which are, whether we like it or not, constructed on the basis of a symbolic and discursive vocabulary and belong therefore to a quite distinct symbolic level.

#### I.4. PHONETICS: AN ALTERNATIVE PARADIGM?

As was stressed earlier on, phonetics until the twentieth century was not an autonomous discipline separate from the study of language.<sup>40</sup> Even if we

<sup>38</sup> Cf. Yamada (1990), Gopnik and Crago (1991), Smith and Tsimpli (1995).

<sup>39</sup> For a recent attempt to devise a biologically credible model of language, see Lamb (1998).

<sup>40</sup> For a thorough assessment of the historical relationship between phonology and phonetics from the perspective of a speech specialist, cf. Boë (1997).

insisted on reinterpreting past works in terms of present-day distinctions (a questionable approach), the emergence of phonetics would be seen to coincide with the beginning of the 'grammaticalization of language' in the terminology of the historian of linguistics Sylvain Auroux. But it is in the nineteenth century that phonetics reaches a form close to the modern one. First of all, it provides a tool for the description and notation of the sounds found in the languages of the world. It is not an accident if Bell's (1867) book *Visible Speech* is subtitled: *the science of universal alphabets, or self-interpreting physiological letters for the printing and writing of all languages*. It also permits a more thorough description of the dialects of each language and, fundamentally in the century which saw the birth of Darwinism, it offers a scientific account of the evolution of sounds. In the European tradition, phonetics was the discipline which allowed the Neogrammarians to break loose from orthography and build a theoretical picture of the evolution of Indo-European. In North America, phonetics provided the indispensable foundation for describing the native Amerindian languages which presented anthropologists, linguists, and missionaries with sounds usually outside the ambit of what Benjamin Lee Whorf called SAE (Standard Average European). In addition, for many centuries, the study of sounds has had an applied dimension which should not be underestimated.

One salient example of the applied role of phonetics is that of the International Phonetic Association, which from the beginning set itself very practical aims beside the description of the sound patterns of the world's languages: e.g. giving tools for devising or improving orthographic systems and helping to develop an aural-oral approach to language teaching. This practical approach has been maintained since the creation of this body in 1886 as is evident from the publication of the recent *Handbook of the International Phonetic Association* (1999). To limit ourselves to Great Britain in the twentieth century, the IPA has been linked to a rich descriptive tradition with phoneticians like Daniel Jones, then students of his such as Gimson and Abercrombie, who, in turn, trained numerous distinguished phoneticians. Their work has been in the form of advanced manuals of general phonetics (Catford 1977, Laver 1994, Ladefoged and Maddieson 1996), dictionaries (Jones 1917, Wells 1990, Roach and Hartman 1997) and pedagogical overviews of the pronunciation of various languages (e.g. for English, Jones 1956, Gimson 1962, Cruttenden 1994, Roach 2000). Because of its diverse aims, this particular strand has often steered a middle path between linguistics on the one hand and speech science on the other. A more cognitive and technical orientation has however been taken in the application of phonetics to language pathology. To help deal with a wide range of problems such as the delayed onset of language acquisition, aphasia,

or teaching the hard-of-hearing,<sup>41</sup> speech specialists have inevitably looked at both ends of the communication chain: the coding of language in the brain on the one hand and its concrete embodiment in speech patterns on the other. Such work has strongly contributed to the constitution of a multi-disciplinary programme, that of the phonetic sciences.

If one speaks of the phonetic sciences (in the plural form), it is because progress in this field of enquiry has benefited from various scientific advances in physiology, acoustics, electronics, and computing which have built on the theoretical and practical knowledge accumulated over several centuries. The groundbreaking work of physicists like Fourier and Helmholtz has made the modern developments in speech acoustics possible, in particular the theory of resonators. In the twentieth century, the development of the sound spectrograph and the combined use of techniques such as X-ray photography, then cineradiography, and more recently MRI (Magnetic Resonance Imaging)<sup>42</sup> have fulfilled the dream of 'visible speech' which had eluded the nineteenth century (except via the use of symbols). But it should not be thought that phoneticians have been passive recipients of knowledge developed in other fields. For a start, many past scholars such as Helmholtz (1867) were authentic phoneticians whose aims were indeed to explore linguistic sounds and who combined physiology and acoustics in their approach. In the twentieth century, this interdisciplinary work has been continued by specialists like Chiba and Kajiyama (1941), Fant (1960), Flanagan (1972), and their inheritors.<sup>43</sup> The birth of the phonetics laboratory took place approximately a hundred years ago and already the experimental work of specialists like Rousselot had recourse to an impressive array of techniques and machines. In its wake, modern phonetics has seen the development of essential research tools such as electro-palatography or electromyography (EMG).

Progress in phonetics during the twentieth century has been so rapid and so successful that the old dream of talking machines has been reawakened. Cordemoy's *Discours physique de la parole* (1668) was by no means putting forward a new idea when he envisaged this possibility. It is also interesting to note that the success of Vaucanson in building famous machines like his 'flautist' and his 'digesting duck' (exhibited in Paris in 1738) led some well-known contemporaries to press him to build a 'talking automaton' ('automate parlant'). As La Mettrie (1751) observed:

<sup>41</sup> It should however be noted that the teaching of the deaf was linked to an emphasis on 'oralism' which was questionable in the repressive form it often took. For sensitive discussions of this question, see Sacks (1989), Rée (1999).

<sup>42</sup> See Démonet et al. (this vol.) for the use of some of these techniques in neurolinguistics.

<sup>43</sup> e.g. Stevens (1999) and the references therein.

If Vaucanson needed more talent to make his Flautist than his Duck, he should have endeavoured even more to devise a Talker: a machine which cannot be considered as impossible, especially in the hands of this new Prometheus. (our translation, J.D./B.L.)<sup>44</sup>

Until the recent decades, however, the possibility of high-quality speech synthesis of whole utterances has not been possible and speech analysis continues to pose serious, if not insuperable, problems to specialists. One facetious version of the difficulties faced by engineers in these areas blamed the continued presence of linguists within research projects. Allegedly, every time a linguist was sacked the performance of the systems would undergo a dramatic increase! This phase was often the result of a mismatch between, on the one hand, the unrealistic hopes of engineers and their lack of appreciation of the complexity of language, and, on the other hand, the refusal by linguists to descend to the materiality of speech. At the present time, the position of many researchers in speech synthesis and analysis seems much less polarized and the need for high-level linguistic knowledge is taken for granted in a number of approaches.<sup>45</sup>

As can be seen from the many disciplines mentioned so far, one obvious problem is whether phonetics has a core around which research is organized. Ladefoged (1988), reflecting on the fact that communication engineering, physical acoustics, psychology, anatomy, physiology, linguistics, computer science, and poetry are part of the lives of phoneticians, ended up saying: ‘we are phoneticians, we the people who come to phonetic congresses, and know something about some of these diverse disciplines. None of us can know enough about all of them, which is why being a complete phonetician is an impossible task. *But every four years we can get together and pool our knowledge. This is phonetics*’ (our italics, J.D./B.L.).<sup>46</sup> But, as noted by Lindblom, while there is a sociological dimension to phonetics and while phoneticians have to learn from other disciplines, it is possible to define a research programme for phonetics. It could be defined thus:

Phoneticians seek facts and insights about how speech is produced, perceived and acquired. And about how the world’s sound patterns are related to the on-line phenomena of speaking, listening and learning. (Lindblom 1995: 462)

This view of phonetics seems to us pretty close to a consensus view of the subject. The way a number of phoneticians have interpreted this programme

<sup>44</sup> Quoted in Boë (1997: 18) who offers a worthwhile discussion of this question and further references.

<sup>45</sup> See, *inter alia*, the essays in Sagisaka, Campbell, and Higuchi (1997), Botinis (to appear).

<sup>46</sup> Quoted in Lindblom (1995: 462).

and seen it as quite different from a linguistic approach is that it emphasizes 'substance' as opposed to abstract form which is meant to be the trademark of the phonologist. Many speech specialists reject what they consider a Saussurean dogma: i.e. that 'Language' has logical priority over 'speech'. This 'substance-oriented' approach is often seen as providing a new framework for the study of language in its biological context (Liljencrants and Lindblom 1972; Lindblom 1986; Boë *et al.* 2000; Schwartz *et al.*, this volume). The description of sound systems should be based on non-phonological principles, whether listener-oriented (perceptual contrast and stability) or speaker-oriented (articulatory contrast and stability). While this is to some extent similar to some of the 'natural' approaches mentioned in 1.3.3.2 (e.g. Dressler 1981), the difference is that most of the linguistic concepts of the former are replaced here by hard constraints imposed by the physics and physiology of speech.<sup>47</sup> Because modern phonetics sees itself as dealing with the whole speech chain (from the coding of messages in the brain to utterances and back), it is at the same time cognitive and grounded in physiology and physics. It could be argued, and some distinguished phoneticians have taken that position, that such an approach makes phonology redundant.

It seems to us that this conclusion would be totally unwarranted. First of all, many of the hypotheses made about the 'physiological' dimension are themselves dependent on the work of phonologists. Lindblom's definition above mentions the world's 'sound patterns'. These 'sound patterns' are however not acoustic facts. They are, more often than not, the result of painstaking analyses by phonologists of the languages of the world. Indeed, notions such as 'opposition' and 'complementary distribution' or 'phonotactic constraint' which lie at the root of many of the databases currently used by experimental phoneticians are built on the 'phonemic' insight of early twentieth-century phonology. Secondly, when one defines principles such as perceptual or articulatory contrast as non-phonological, it is purely a matter of definition. The perception and production of contrasts can no doubt be tested in the laboratory but the basic concept of contrast cannot be divorced from its linguistic function. Thirdly, and this is a problem faced by speech synthesis/analysis, at some point hypotheses have to be made with respect to mentally represented structures. At this point, if one wants breadth of coverage (e.g. to deal with an open-ended lexicon and therefore include derivational processes and take into account the fact that language allows the construction of an indefinitely large number of utterances) it is difficult to ignore linguistics and its classical offshoot 'phonology'. One of the

<sup>47</sup> See Schwartz *et al.* (this vol.) who defend a dispersion-focalization theory of vowel production and perception.

long-standing insights of phonology (reasserted by the generative paradigm), has been that the sound systems of the world's languages are not made up of sounds qua sounds but rather show that the network of contrasts is embedded in a rich morpho-syntactic and semantic-pragmatic structure. Phonetics without phonology, and conversely phonology without phonetics, are perhaps possible but at what price?

### I.5. A NEW SYNTHESIS?

After this survey of selected aspects of the evolution of phonology and phonetics, one question can be raised: since there are undeniable signs of convergence between these two disciplines, are they likely to merge in the near future? Sociologically, a rapid merger does not seem probable. At one extreme, the fact that many phonologists teach and do research in arts faculties places constraints on the type of work they will undertake. Their students usually pursue qualifications in subjects like general linguistics, foreign languages, and English (in English-speaking countries), and they will rarely be willing or able (in terms of time or competence) to follow a highly technical literature on physiology or acoustics. The research will often be carried out in an environment which is not as rich in sophisticated equipment as that of a science faculty. Moreover, the research areas will be expected to link up with the exploration of levels of linguistic structure (e.g. morphology, syntax, semantics) which might themselves be studied by colleagues in a mode which does not favour the integration of neurobiological or phonetic analyses. Lastly, much work of a descriptive nature still has to be carried out (e.g. field work on endangered languages) which by its very nature does not favour an instrumental approach in the phonetics laboratory. At the other extreme, phoneticians who work on speech synthesis within an industrial environment (e.g. a telecom group) may have little time to worry about the ontological nature of the entities they deal with, their significance for a theory of language, or even the psychological plausibility of the techniques employed to generate high-quality signals. In addition, the publications expected of these two types of researcher, the conferences they attend, the networks within which they operate, and the external and financial recognition they receive for their work will be among the factors that will continue to divide phonologists and phoneticians.<sup>48</sup> At the same time, it

<sup>48</sup> These 'external' factors are of course part of the history of the linguistic sciences, see e.g. Chevalier (2000). Recall the quote from Ladefoged in section 1.4: 'But every four years we can get together and pool our knowledge. This is phonetics.'

seems to us likely that at the cutting edge of research the boundaries will become more and more blurred. As our understanding of the neurophysiological basis of language production and perception progresses and as our theories of language become more sophisticated, a fully integrated approach may become possible. The stratal approach still assumed by many researchers (a phonetic module dealing with the gradient bolted onto a phonology module dealing with the discrete) may well prove untenable. In the meantime, we believe that the knowledge accumulated by phonologists of the interaction of sound systems with the morphology, syntax, semantics, and pragmatics of natural languages will continue to pose a challenge to purely 'substance-based' accounts if they restrict themselves to the 'biological hardware'. What seems to us to be a thing of the past (or if one prefers a 'degenerative' research programme in the sense of Lakatos 1970) is a strident call for two totally autonomous disciplines with sharply delineated boundaries and separate research methods.