22

Generative phonology

The interaction between phonology and morpho-syntax

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22.1 Introduction and scope

This chapter reports on the views that were held in the generative approach regarding the impact of morpho-syntactic information on phonology. Inquiry is restricted to this direction of conditioning. The question whether and/or how phonological information bears on morpho-syntactic computation takes a less prominent place in generative development, but was debated for example in response to Zwicky & Pullum's (1986) principle of phonology-free syntax (and morphology).[1] More recently the debate on phonologically conditioned allomorphy is another case in point.[2] These issues concern morpho-syntax and the architecture of grammar more than phonological theory itself, and will not be further addressed below.

There are two ways for morpho-syntax to bear on phonology: derivationally and representationally. The former is a genuinely generative device that was introduced by Chomsky et al. (1956: 75) and was successively known as the transformational cycle, the phonological cycle, cyclic derivation, and, more recently, as derivation by phase (in the syntactic literature, see section 22.3.5.3). Bermúdez-Otero (2011) provides an informed overview of the matter. Cyclic derivation embodies the insight that (phonological and semantic) interpretation applies successively from the most to the least embedded piece.

The other means by which morpho-syntax can influence phonology is through the insertion of a representational object into phonological structure: such a carrier of morpho-syntactic information is then processed by phonological computation. This is the traditional interface management which has been practiced (at least) since the 19th century, and is shared by structuralist and generative thinking. Carriers of extra-phonological information in phonology have been successively incarnated as juncture phonemes, boundaries (# and the like) of the type featured in Chomsky & Halle (1968) (*The Sound Pattern of English*; henceforth SPE), and the Prosodic Hierarchy, each being representative of its time. That is, carriers of morpho-syntactic information were (juncture) phonemes when phonemes were the basic units in phonological theory; they were made segments in SPE (# was supposed to be a [-segment] segment) where the basic

[1] Relevant literature includes Szymanek (1980); Ackema & Neeleman (2004); and Raffelsiefen (2015). Scheer (2011a: §412) provides an overview.

[2] See for example Mascaró (2007); Wolf (2008); Embick (2010); and Scheer (2016).

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phonological units were segments, and finally became autosegmental domains (prosodic constituency) in the early 1980s when all areas of phonology were autosegmentalized.[3]

Since the early 1980s, the two channels that transport morpho-syntactic information into phonology have each been associated with a specific theory: Lexical Phonology (and its modern offspring Stratal Optimality Theory (Stratal OT) and Derivational Optimality Theory (DOT)) on the derivational side, and Prosodic Phonology (and more recently OT versions thereof) on the representational side. A relevant question is how exactly both can or should coexist: given a phenomenon whereby phonology is influenced by morpho-syntax, is this done through the representational or the derivational channel? An influential answer was proposed by Hayes (1989b): Lexical Phonology manages pieces below the word level (i.e. the interaction with morphology),[4] while Prosodic Phonology is competent for chunks of word size and larger (i.e. the interaction with syntax).

At and above the word level, the absence of derivational management follows from an assumption that has lain at the heart of Lexical Phonology since its inception: postlexical phonology was supposed to be non-cyclic. Though the reasons for this assumption were not made explicit in the literature, it was generally adopted by the field and percolated to all modern heirs of Lexical Phonology such as Stratal OT (see section 22.3.3.1).[5]

Another relevant issue in interface theory is the question why morpho-syntactic information is made available for phonology at all, and ultimately appears in the phonetic signal. Trubetzkoy (1935: 30ff., 1936b, 1939: 241) introduced the idea that phonological effects of morpho-syntactic divisions are functional in kind. He proposed that *Grenzsignale* (demarcation signals) alert the listener in order to facilitate the parsing of the phonetic continuum. Without being helped by phonological flags, the task of identifying morphemes would be much more difficult and take much longer. Therefore some morpho-syntactic divisions leave a material trace in the signal so that they could not be missed. Trubetzkoy had many followers, structuralist and generative alike. Much of the generative literature, especially when perception-oriented, implements his functional approach in a formal framework in one way or another.[6]

A related aspect is the mapping puzzle (Scheer 2011a: §§111, 753) that has caused quite some torment to linguists working on the interface(s). They have tried to find out which particular morpho-syntactic (or semantic) configurations will be marked in the phonology (what we can call the mapping decision), and conversely, what are the particular phonological means by which the marking is implemented in the phonology (the substantive aspect of mapping). While there are natural classes of sounds, however, it does not appear

[3] In this chapter the term 'autosegmental' refers to all kinds of non-linear representations, including metrical representations.

[4] Rubach & Booij (1984) and Booij (1988) introduced prosodic constituency below the word level, however; on the possible co-existence of both derivational and representational workings below the word level, see Peperkamp (1997); Raffelsiefen (2005); and Bermúdez-Otero (2011: 2025–8).

[5] In the 1980s and later on some voices maintained the cyclic application of phonology among words: Dresher (1983), Kaisse (1985: 109–93), and McHugh (1990) are examples. In their early overview of Lexical Phonology, Kaisse & Shaw (1985: 5) write that nothing in the theory precludes postlexical cyclicity, whose existence is an empirical question. Bermúdez-Otero (2012: 33) argues on the contrary that it is the cyclic nature of phonology at the stem level that requires explanation; see Bermúdez-Otero (2018: 105–12) for a review of the evidence for cyclic application of phonology in Stratal OT.

[6] Cutler (1996) provides a review of how speech recognition is done in the psychological literature, as well as of the role that is played by signal-based models of segmentation. In phonology, relevant listener-oriented literature includes Napoli & Nespor (1979: 839); Booij (1983); Basbøll (1986); Kaye (1989); Bertinetto (1999); Loporcaro (1999); Hume & Johnson (2001); and Boersma (1998, 2005).

that there are natural classes of boundaries: both the set of relevant morpho-syntactic divisions and their phonological effects remain unpredictable.[7]

The pages below look at the history of how morpho-syntax was conceived to impact phonology through the lens of the derivational vs. representational division (following Scheer 2011a, b).

22.2 Representational management

22.2.1 Early generative phonology

In the 1950s when generative analysis was exotic in structuralist-dominated phonology, Chomsky et al. (1956) introduced what would later become cornerstones of SPE and indeed of generative phonology (significantly, in a Festschrift for Roman Jakobson).[8]

(1) a. Level Independence is eliminated
Inspired by a fieldwork perspective based on a discovery procedure that builds linguistic structure strictly bottom-up from the phonetic signal, structuralist thinking had banned any carriers of morpho-syntactic information from phonology, a principle called Level Independence (see Ladd, Chapter 17, this volume). In generative phonology, the presence of morpho-syntactic information in phonology was allowed.

b. Boundaries are placed under morpho-syntactic control
Level Independence meant that boundaries had to come in a phonological guise as juncture *phonemes*, unrelated to morpho-syntactic domains. Chomsky et al. (1956) argued that boundaries must be significant at higher levels of the grammar (see Dresher & Hall, Chapter 18, this volume).

c. Phonological domains are erected over boundaries.
This structure heralds the Prosodic Hierarchy.

d. Boundaries have no phonetic correlate.

Chomsky et al. (1956: 75) also introduce cyclic derivation, an entirely new idea in linguistic thinking. As was mentioned in the introduction, this device will be a motor in the development of generative linguistics: it incarnates into different guises over the years and in current minimalism appears as Phase Theory (see section 22.3.5.3).

A decade later, SPE set the standards for interface theory that are still valid today. Morpho-syntax talks to phonology through two channels, one procedural (cyclic derivation, which is called the Transformational Cycle in SPE), the other representational (boundaries). Structuralist junctures are now called boundaries, and boundaries are not phonemes anymore, but segments made up of features. This is because the basic phonological units in SPE are segments that are made of binary distinctive features. Like all other

[7] I do not include here the relative strength of boundaries, which does appear to be liable to cross-linguistic generalizations (see Flack 2009: 275–83; Bermúdez-Otero 2011: 2023–5, 2018: 104; and Cyran 2013).

[8] For more detail on the structuralist take, see Aronoff (1980) and Scheer (2011a: §59), as well as Ladd, Chapter 17, this volume.

segments, boundaries have a featural makeup: they are [-segment] segments (as opposed to non-boundary segments, which are [+segment]). Two more features distinguish the three distinct boundaries #, + and = that are recognized by SPE: [±word boundary (WB)] and [±formative boundary (FB)].

In SPE, morpho-syntactic structure is converted into boundaries according to a fixed and universal algorithm that works on the grounds of morpho-syntactic properties alone: # is inserted into the linear string at the beginning and at the end of each major category (i.e. nouns, verbs, and adjectives), and also on each side of higher constituents that dominate major categories, i.e. NPs, VPs, and so forth (Chomsky & Halle 1968: 12f., 366ff.).[9]

The process of translating morpho-syntactic structure into representational objects that are then inserted into phonological representations will later be called mapping (see sections 22.2.5.4 and 22.2.5.5).

22.2.2 Natural Phonology and Natural Generative Phonology

Natural Phonology (NP; Stampe 1972) and Natural Generative Phonology (NGP; Vennemann 1974a, b; Hooper 1976) are the major external challengers to SPE in the 1970s, calling for a revolution rather than engaging in an internal revision, which was Kiparsky's agenda (see section 22.3.1). In order to reduce the expressive power of the grammar, the Natural Phonologies argue for a radical reduction of the set of alternations that represent phonological activity: only a small subset of what SPE thought was phonological in fact is (natural alternations), the rest being managed in a different computational system inherited from structuralism, morpho-phonology in NGP (MP rules), rules in NP (conventionalized alternations). Like the structuralists, NP and NGP share a ban on morpho-syntactic information in truly phonological alternations (processes in NP, P-rules in NGP). Beyond these common grounds, NP and NGP have quite different workings and assumptions. Unlike NGP, NP is functional and non-generative, and space limitations preclude further discussion of it here.

In NGP (Vennemann 1974a, b; Hooper 1976), alternations are divided into two types. Those that do not suffer any exception in the entire language and exclusively appeal to phonetically retrievable information (conditions that exclude intermediate derivational stages and hence rule ordering) are called 'natural' and are granted phonological status (P-rules). The fact that phonological processes must be phonetically transparent and hence surface-true is expressed in the True Generalization Condition (Hooper 1976: 13ff.). By contrast, the statement of morpho-phonemic rules (MP-rules) requires non-phonetic information such as reference to morpho-syntactic categories, and the alternations at hand are typically riddled with exceptions.

This division enforces a corresponding split among boundaries: since #, + and the like can hardly be said to represent phonetic information (they do not have any phonetic correlate), they are banned from P-rules. However, even processes that are otherwise completely natural and qualify as a P-rule need to make reference to boundaries. This is

[9] The universal conversion algorithm of SPE is preceded by a language-particular readjustment component which modifies syntactic hierarchical structure in case it does not match the phonological result; see further section 22.2.5.4.

why Hooper (1975: 545) introduces 'phonetic boundaries': the 'syllable boundary $' and the 'pause boundary ⊠': '[b]oth of these boundaries are determined by phonetic means' (Hooper (1976: 14).

NGP also provides for boundaries that are present in MP-rules, the word (#) and the morpheme boundary (+). Given the properties of MP-rules, a prediction is thus made to the effect that these non-phonetic boundaries will never be necessary for the statement of P-rules. Devine & Stephens (1980: 71ff.) and Clayton (1981: 577ff.) demonstrate that this is not the case: many alternations in natural language are entirely regular, productive and make exclusive reference to the phonetic signal except for the fact that they crucially appeal to the word boundary.

22.2.3 Growing dissatisfaction with boundaries in the 1970s

During the 1970s, dissatisfaction and frustration were growing as boundaries were put to use. One reason was the fact that, just like on the segmental side, SPE does not impose any restrictions on the occurrence of boundaries (other than that they must coincide with a morpho-syntactic division). Parallel to the development on the segmental side where SPE was criticized for its unbounded overgeneration and lack of naturalness, this gave rise to boundary abuse and what may be called a whole boundary zoo.

Reactions against this situation were numerous, both from inside and outside of the SPE paradigm. In a first round, the general dissatisfaction with boundaries was directed specifically against the + boundary of SPE, which a number of authors sought to dispense with in the name of boundary economy (Basbøll 1981). Then the boundary zoo was targeted, as for example by Hyman (1978: 459), who reacts against 'the abuses seen in such works as Stanley (1973), where boundaries are unnecessarily proliferated.' Hyman refers to McCawley (1968: 57ff.), whose description of Japanese recognizes six different boundaries ($, #, #i, :, & and *, in order of decreasing strength), and Stanley (1969, 1973), who identifies seven different boundaries in Navaho (#, =, *, !, ", + and -, also decreasing in strength).

22.2.4 Boundaries cannot be segments

McCawley (1968: 52–8) initiated another line of attack against SPE-type boundaries: he doubts that boundaries are segments. Though McCawley agrees with Chomsky et al. (1956) and Chomsky & Halle (1968) that boundaries are not phonemes, he considers the view that they are segmental to be a hold-over from structuralist theory. Following up on Chomsky et al. (1956) (see section 22.2.1, (1c)), he proposes rather (McCawley 1968: 55) that a boundary 'gives the limits of the stretches of utterance to which certain rules apply', and are not phonological elements that are computed by phonological rules.

Pyle (1972: 524) goes further and presents a series of arguments against boundaries, designed to show that they could not possibly carry morpho-syntactic information. Were boundaries ordinary segments like /p/ or /i/, they would have to be subject to ordinary SPE rewrite rules. That is, they should be able to occur as any of the variables in the universal rule format X → Y / A__B. For instance, boundaries must be able to be epenthetic, just like

vowels and consonants, such as in a rule ø → + / A__B. This undermines the advance (1b) made by Chomsky et al. (1956) who had banned boundaries in the middle of morphemes: it is now predicted that boundaries can be inserted in this location through a phonological rule. In the same way, phonological computation should be able to transform a boundary into a regular segment (or the reverse), such as in a rule + → a / C__C. Hence, say, /dog+s/ would come out as *dogas*. This, of course, is unheard of in natural language.

Pyle was a lonesome voice at that time, though. His arguments, although conclusive (see section 22.2.6), had no bearing on further development.

22.2.5 Prosodic Phonology

22.2.5.1 Origins

Prosodic Phonology carries over the (modular) interface architecture of SPE into the autosegmental environment of the 1980s. Its genuine contribution to interface theory is thus the autosegmentalization of the carriers of morpho-syntactic information: instead of linear boundaries, an arboreal autosegmental structure (the Prosodic Hierarchy) is inserted into phonological representations.

The central idea of Liberman (1975) and Liberman & Prince (1977) is that segments are dominated by a multi-layered arboreal structure (syllables, feet, and words) which expresses rhythmic (linguistically 'musical') properties of the linear string and assigns relative prominence (strong versus weak status) to individual chunks. Based on this line of thought, Elisabeth Selkirk ([1978] 1981 and following) proposed to enrich Liberman & Prince's autosegmental arboreal interface of phonology with morpho-syntax. She thus developed a six-layered Prosodic Hierarchy where layers represent units of increasing size: the syllable, the foot, the phonological word, the phonological phrase, the intonational phrase, and the phonological utterance.

Mainstream phonology rapidly integrated Selkirk's proposals as a major contribution to the general expansion of the autosegmental idea. Her 1984 book (Selkirk 1984a), though, took a different turn under the influence of Prince's (1983) grid-only approach: autosegmental prosodic constituency was evacuated altogether in favour of the metrical grid. Nevertheless, Selkirk (1984a) is a landmark of early Prosodic Phonology, because it bridges between the linear SPE environment and the new autosegmental interface (see section 22.2.5.2). Two years later, Selkirk (1986) returned to prosodic constituency, now arguing for a 'peaceful coexistence' of the original Prosodic Hierarchy and the metrical grid (thus following Liberman & Prince 1977 and Nespor & Vogel 1982: 226, 1986).

Building on Selkirk's work but mobilizing fresh data from languages such as Italian and Greek, Marina Nespor and Irene Vogel grounded a parallel stream of inquiry. Following a number of articles (Nespor & Vogel 1979, 1982, 1983), as well as an influential article by Hayes (1989b), their 1986 book (Nespor & Vogel 1986) concentrates the insights gained and rapidly became the authoritative reference in Prosodic Phonology.

22.2.5.2 From boundaries to domains

Prosodic constituency grew out of the general dissatisfaction with boundaries (see section 22.2.3) and the new autosegmental formalism that was starting to spread through all areas

of the phonological landscape and facilitated the description of domains. Also, Prosodic Phonology made it possible to maintain the (modular) interface architecture of SPE.

The crucial difference between SPE-type boundaries and the new prosodic domains lies in the fact that domains delineate a stretch in the linear string, while SPE-type boundaries do not: they have a strictly local existence, and local action. Since Chomsky et al. (1956), domains also exist, but they are defined by a different, derivational rather than representational device: the cycle (see section 22.3). Prosodic constituency may thus be viewed as an attempt to transform a derivational into a representational device, much in line with the spirit of the time.

But recall from section 22.2.4 that there are also boundary-based domains: prosodic constituency may be merely a notational variant thereof, using the new autosegmental notation. This of course is a dangerous perspective that does not match the anti-boundary and anti-SPE self-understanding of the new approach. Hence Selkirk (1980b: 128) writes that 'the relations among boundaries that are captured in the strength hierarchy must be stipulated in the theory. They do not follow from anything inherent to the notion of boundary in the theory.' This is certainly true—but does the layering of prosodic constituents follow from anything in the theory of domains? Domains of whatever kind, boundary-based or autosegmental, exist because the related facts exist, and their size adapts to whatever is found in the data.

Although crucial, this issue did not arouse any attention, and likewise the early Prosodic Phonology literature offers surprisingly little discussion of the question why non-local domains are better than local boundaries (see Scheer 2011a: §369). It is typically mentioned that boundaries are superfluous if prosodic constituency is assumed (Selkirk ([1978] 1981: 136ff.; Booij 1983: 268), but arguments against boundaries are rare. By 1986, the question was settled: Nespor & Vogel (1986) merely state their disagreement with the linear SPE system that uses boundaries in the first sentence.

The arguments that were indeed made against boundaries on the few occasions where the transition to prosodic constituency was motivated fall into two categories: their diacritic character and the independent motivation of prosodic domains by stress, rhythm and musical properties. On the former count, Selkirk (1980b: 126ff.) reviews the arguments made by Pyle (1972) regarding the overgeneration of boundaries. Szpyra (1989: 11, 182f.) and Booij (1983: 268f., 1985b) are along the same lines. In his conclusion, Booij (1985b: 34) writes that the theory of Prosodic Phonology 'excludes the rather arbitrary use of boundaries made possible in the SPE-framework.'[10]

Selkirk's (1980b: 126ff., 1984a: 8ff.) second argument against boundaries is that domains are independently motivated by stress, rhythm, and musical aspects of speech. Boundaries, on the other hand, are unable to encode these properties. The former thus allow for a unified coverage of both interface information and stress/rhythmic/musical aspects, while the latter multiplies representational devices. The unification argument was abandoned in later work, though, which regarded rhythm as an emanation of metrical poetry and music rather than of the linguistic system (Hayes 1984: 65; Nespor 1988: 228; and all subsequent work including Nespor & Vogel 1986, 1989: 87f., and Selkirk 1986: 376).

[10] While the diacritic character of boundaries is certainly a serious argument against them, the Prosodic Phonology literature did not consider the possibility that prosodic constituents are also diacritics; see sections 22.2.5.3 and 22.2.6.

22.2.5.3 Indirect Reference versus Direct Syntax

A central tenet of Prosodic Phonology is the principle of Indirect Reference (Selkirk [1978] 1981: 131, Nespor & Vogel 1986: 37; see Scheer 2011a: §§377, 410, for a historical overview). According to Indirect Reference and in application of cognitive modularity (Fodor 1983; see Scheer 2011a: §414 for discussion), morpho-syntactic categories are invisible to the phonology. Phonological processes can only make reference to them if they are first translated into phonological vocabulary. In Prosodic Phonology, translation is done by mapping rules, whose output is the Prosodic Hierarchy, to which phonological processes then appeal.

Contrary to Prosodic Phonology, Direct Syntax, as expressed by Kaisse (1983) and Odden (1987), maintains that phonological instructions directly refer to morpho-syntactic information. That is exactly what Indirect Reference excludes. Kaisse (1990) calls attention to the redundant and diacritic character of prosodic constituency. She points out that the Direct Syntax option 'does not require the postulation of constituents that are needed only to describe the sandhi phenomena in question' (Kaisse 1990: 128).

22.2.5.4 Non-isomorphism and the conflict between Prosodic Phonology and Direct Syntax

The competition between Direct Syntax and Prosodic Phonology (e.g. Kaisse & Zwicky 1987; Inkelas & Zec 1990; Kleinhenz 1996; Nespor 1996) was decided in favour of the latter. The crucial argument that was rehearsed over and over again (e.g. Vogel & Kenesei 1990; Nespor et al. 1996; Dresher 1996: 42) is so-called non-isomorphism: the units that are relevant for the statement of phonological rules are a function of, but not isomorphic with, morpho-syntactic structure. Other factors that have been reported to play a role in the definition of phonologically relevant portions of the linear string include information structure, eurythmy, speech rate, and register. Direct Syntax could cope with these, but not with non-isomorphism, which supposes an independent mapping device. Therefore non-isomorphism was at the heart of the debate and defenders of Direct Syntax made the point that in its absence there was no reason to buy into extra representations (prosodic constituency) plus extra computation (mapping rules) which are useless if reference may be direct (Kaisse 1985: 156 note 1, 110 note 1, 1990: 128f.). That is, prosodic constituency stands and falls with non-isomorphism (see section 22.2.5.7 for further discussion).

Non-isomorphism goes back to an observation made in SPE: in some cases, the domain to which a phonological rule makes reference is not co-extensive with any morpho-syntactic domain. In other words, some phonological rules make reference to information that is absent from the syntactic surface structure. The *cat-rat-cheese* example under (2) has been famous since Chomsky & Halle (1968: 371f.) and runs through the entire Prosodic Phonology literature.

(2) a. This is [the cat that caught [the rat that stole [the cheese]]]
b. [This is the cat] [that caught the rat] [that stole the cheese]

The major syntactic divisions of the sentence under (2a) do not coincide with its intonational structure under (2b). Hence, goes the argument, whatever drives phonology to decide that the intonation is as under (2b), it is not the output of the syntactic module. Because the syntactic structure is embedded, there is no node in the syntactic tree that

uniquely dominates every intonational span of the sentence: the middle intonational chunk [that caught the rat] is not uniquely dominated by any syntactic node because its CP also dominates the further embedded chunk [that stole the cheese]. Therefore, the relevant intonational structure must be created outside of the syntax by some interface activity. In SPE, the readjustment component was devised to make morpho-syntactic structure ready for phonological use in such cases.

In Prosodic Phonology, this job (flattening the syntactic structure in our case) is done by mapping rules, which translate morpho-syntactic divisions but also add new information of their own if needed. There are two main approaches to mapping, relation-based (Nespor & Vogel 1986) and edge-based (Selkirk 1986; see Lahiri & Plank, Chapter 7, this volume). The latter holds that 'the syntax-phonology mapping can be defined simply by reference to the *ends* of syntactic constituents' (Selkirk 1986: 386; emphasis in original). Edge-based mapping pursues the goal of restricting the availability of morpho-syntactic structure that phonology can make reference to. It was adapted to OT later on and in the guise of the ALIGN constraint family has become the unquestioned standard in this theory (see section 22.2.5.6).[11]

22.2.5.5 Mapping and its location in modular no man's land

According to standard views of modularity (Fodor 1983; Coltheart 1999; Gerrans 2002; Jackendoff 2002), modules do not understand the vocabulary of other modules. Mapping is thus necessarily located in modular no man's land, somewhere after morpho-syntax but before phonology. This is what is called the interface: a mediating instance between two computational systems that does not belong to either but is able to understand the vocabularies of both. This is how Selkirk (1984a: 410f.) and Nespor & Vogel (1986: 302) conceive of Prosodic Phonology, hence the state of the art in Prosodic Phonology before it was adapted to OT.

22.2.5.6 OT: Constraint-based mapping (ALIGN)

Since there are no ordered rules in OT, translation cannot be done by mapping rules (as was the case in the 1980s) but instead must be carried out by constraints. This job is done by the ALIGN family of constraints (McCarthy & Prince 1993a; Itô & Mester 1999). The workings of ALIGN follow Selkirk's (1986) edge-based mapping (McCarthy & Prince 1993a, 2001: vii are explicit on this affiliation). Elordieta (2008) provides an informed introduction to edge-based mapping and its offspring in OT.

The move from rule- to constraint-based mapping comes with important conceptual consequences since it abandons Indirect Reference and hence modularity as conceived of in cognitive science. Instead of doing translation *before* phonology in modular no man's land (see section 22.2.5.5), mapping is now done *in* the phonology by the fundamental ALIGN constraint family. ALIGN is a piece of phonological computation and like all other constraints ranked in the constraint hierarchy. This is in overt violation of Indirect Reference, the principle saying that phonological instructions cannot make reference to

[11] More recently, the empirical reality of non-isomorphism has been called into question: Scheer (2008a, 2011a: §419f.) and Samuels (2011: 585ff.) argue that it is a mere artefact of prosodic constituency. It is to be noted that Selkirk (2011) also abandons non-isomorphism as a motivation for prosodic constituency, but no consequences were drawn from that in an OT environment where mapping is based on Direct Syntax (see section 22.2.5.7).

untranslated morpho-syntactic information. ALIGN does precisely that: it relates some morpho-syntactic item (say, a DP) with some phonological unit (say, a Prosodic Phrase) *in* the phonological computation (rather than before it begins, as was the case in pre-OT times when mapping was rule-based).

Further developments of the mapping mechanism in the context of (syntactic) Phase Theory are discussed in section 22.3.5.6 (prosodic islands).

22.2.5.7 Direct Syntax is back in OT

The replacement of mapping rules with alignment constraints obliterates a theoretically relevant distinction between Prosodic Phonology and Direct Syntax. This is because the move to OT removes the possibility of an interpretation of Prosodic Phonology in which prosodic mapping is performed outside the phonology. In this sense, constraint-based mapping through ALIGN has restored the key tenet of Direct Syntax as the standard in OT (phonological computation makes direct reference to morpho-syntactic categories). Direct Syntax is also implemented by other constraint families which freely refer to untranslated morpho-syntactic information: so-called interface constraints are a case in point, e.g. Root Faithfulness in Anttila (2009) (see also Burzio 2007). Kager (2000: 123) promotes the advantages of the fact that '[p]honological and morphological constraints are ranked together in a single hierarchy.'

It should be noted that whether or not phonology makes direct reference to morpho-syntactic categories, and hence whether or not it violates modularity, has been a relatively minor concern for OT practitioners. This may be due to OT's roots in connectionism, the Cognitive Science theory that introduced the idea of parallel computation (e.g. Rumelhart 1989, Smolensky 1987, 1988a, b; see Smolensky 2003: 385f., Smolensky & Legendre 2006). Connectionism follows a different perspective from Fodorian modularity: there are no distinct vocabularies and hence there is no interface. Nevertheless, OT is also a generative theory and modularity has been a cornerstone of the generative enterprise: the basic generative architecture, that is, the inverted T model where one computational system concatenates pieces retrieved from long term memory (morpho-syntax) and two other computational systems define the meaning (LF) and pronunciation (PF) of the result, is Chomsky's (1965: 15ff.) application of modularity to language.

Finally, recall from section 22.2.5.4 that prosodic constituency is redundant and hence useless (or, worse, unsustainable given Occam's razor) in presence of Direct Syntax: the latter can do anything the former can do without extra structure and computation. A hybrid theory like OT where both coexist therefore begs the question, and the fact that this issue is largely left undebated comes as an effect of the aforementioned little concern of OT for related issues.

22.2.6 Direct Interface: Inserting non-diacritic objects

The discussion in section 22.2.4 addressed the question what should be done once it is understood that boundaries cannot be segments (as contended by SPE). One way to go is Direct Syntax, that is, the abandonment of any translation of morpho-syntactic information into phonological objects. Another way was opened by autosegmental representations whose essence is to introduce phonological objects that are distinct from segments: syllabic

constituents, moras, x-slots, feet. Prosodic Phonology took advantage of this opportunity by transforming linear SPE-type boundaries into autosegmental structure: ω (Prosodic Word), φ (Prosodic Phrase), and so forth are phonological items, though not segments.

One thing that Prosodic Phonology did not modify was the diacritic character of the output of translation: linear diacritics were replaced by autosegmental diacritics (prosodic constituency). Carriers of morpho-syntactic information in phonology have always been diacritics, by which I mean arbitrarily chosen and interchangeable items that play no role in phonological computation outside of the interface (say, in a palatalization where no morpho-syntactic information interferes). Scheer (2008a, 2011a: §402) argues that omegas (ω) and phis (φ) are just as diacritic and irrelevant in purely phonological computation as were structuralist juncture phonemes and SPE-type boundaries.

In cognitive science, modules are defined by so-called domain specificity (Segal 1996; Gerrans 2002; Carruthers 2006): every computational domain works with a proprietary vocabulary and cannot parse or understand items that do not belong to this alphabet. Therefore intermodular communication requires translation from one vocabulary set into another. Hash-marks, phis, and the like, however, do not belong to the vocabulary of phonological computation (such as labial, occlusion, etc.). Neither, of course, do morpho-syntactic items such as DP, number, person, case, etc. It follows that Direct Syntax approaches (see section 22.2.5.3) do not qualify in a modular environment, either.

Since its earliest incarnation in the 1950s, Chomskyan linguistics and the generative architecture of grammar have applied modularity to language (Chomsky 1984, 2002: 45ff., Gardner 1985; see also section 22.2.5.3). If this setup is taken seriously, the headstone of modularity, domain specificity, cannot be circumvented. Hence, the interface must be non-diacritic in kind: there must not be any mediating diacritics between morpho-syntactic and phonological vocabulary. That is, carriers of morpho-syntactic information in phonology are (i) the output of translation, (ii) different from segments, and (iii) truly phonological objects, that is, objects which exist in phonology in the absence of morpho-syntactic conditioning. These are the properties of Direct Interface (Scheer 2012a).

Scheer (2012a: §148) argues that only syllabic space matches these requirements for the output of translation. Depending on theoretical inclination, syllabic space may incarnate as moras, x-slots, nuclei, CV units, etc. The idea that syllabic space represents morphological information was introduced by Lowenstamm (1999), who proposes that the beginning of the word materializes as an empty CV unit in phonology. Scheer (2009a, 2012a: §307) considers the initial CV from the perspective of external sandhi, concluding that it is phase- rather than word-initial.

Beyond the conceptual impossibility for modules to process alien vocabulary items, the fundamental difference between diacritics and true phonological objects is that the former do not have any effect per se (precisely because they do not have any phonological properties). That is, hash-marks and omegas sit in phonological representations, acting as sleepers: nothing happens unless a phonological instruction makes reference to them. The particular effect, then, is due to the instruction, not to the object itself. For example, there is no way to know what kind of effect the presence of a hash-mark or an omega will have: will they rather favour or disfavour consonant clusters in their vicinity? In principle they can trigger (or inhibit) any phonological process and its reverse, and they may have opposite effects in different languages. In other words, they make no predictions at all.

By contrast, if phonologically meaningful vocabulary carries morpho-syntactic information, phonological computation will react to its bare presence. This may be called the Direct Effect (Scheer 2009a, 2012a: §154, 2014b): inserting morphological information into phonological representations is not free of charge—it has consequences. Consider for example the two rules under (3).

(3) Equally probable rules?
a. V → ø / #C__CV
b. ø → V / #C__CV

Both rules are equally probable and equally natural from the point of view of a theory that uses diacritic boundaries (hash-marks, omegas, etc.): no property of the theory favours or disfavours the epenthesis into an initial cluster, or the deletion of a vowel in this context. However, every phonologist knows that (3b) is an attested phonological process, while (3a) is not on record. That is, there is no 'masochistic' language that would delete the first vowel of a word (and no other vowels), thereby creating an initial cluster. Therefore, theories that cannot discriminate between (3a) and (3b) have a problem because the critical information (word-initiality) is conveyed by a diacritic that does not make any prediction.

In contrast to this situation, the two rules may be discriminated when the extra-phonological information 'beginning of the word' comes as a real phonological object. In the environment of Strict CV (Lowenstamm 1996; Scheer 2004a) where the beginning of the word incarnates as an empty CV unit, the context of (3b) is represented as Cø-CøCV (where ø is an empty nucleus). The empty V of the CV-prefix plus the stem-internal empty nucleus form a chain of two empty nuclei, a configuration that is ruled out on more general grounds in all languages. Epenthesis is then a reaction to this sequence of empty nuclei. Note that it is only the phonological identity of the empty CV unit representing the beginning of the word (its empty nucleus) that produces the effect (epenthesis). The context of (3a), on the other hand, is represented as Cø-CVCV with only one empty nucleus. There is no reason for syncope, and removing the first stem-internal vowel would produce an illegal structure with two empty nuclei in a row. This system thus correctly predicts that (3a) does not occur.

In sum, diacritics make the empirically wrong prediction that specific morpho-syntactic divisions have arbitrary phonological effects cross-linguistically. We have just seen an example where the effect is cross-linguistically stable: either the beginning of the word has no effect on the first vowel of the stem, which happily appears as zero, just like in all other positions (as in Czech *pes* 'dog.NOM.SG' ~ *ps-a* 'dog.GEN.SG')[12] or it is unable to remain unpronounced (provoking epenthesis as in the Tiberian Hebrew imperative /ktob/ → [kəθov] 'write.IMP.2M.SG.'). But there is no language where non-initial vowels are unable to alternate with zero, while initial vowels do. In the same way, in some languages (e.g. English, French) initial clusters are restricted to #TR, where T is shorthand for obstruents, R for sonorants. In other languages (Moroccan Arabic, Czech) they are not subject to any restrictions. But there is no language where they are restricted to #RT (or to #TT or #RR). Finally, a third stable cross-linguistic effect of the beginning of the word concerns the

[12] Note that the Czech pattern is not an instantiation of (3a) since the vowel is deleted in all positions, not just word-initially; (3a) describes a pattern whereby vowels are deleted *only* in the presence of # (word-initially).

strength of word-initial consonants. In some languages word-initial consonants are especially strong. In others, they do not have any peculiar behaviour regarding strength. But there is no language where they are especially weak.

It is shown in Scheer (2004a: §87, 2009a, 2012a: §156, 2014) and Ségéral & Scheer (2008) that the three cross-linguistically stable consequences of the beginning of the word all follow when the carrier of morpho-syntactic information in phonology, here of the beginning of the word, is a truly phonological item (the initial CV) that has phonological properties. In each case, the non-occurring pattern is impossible with either the presence or the absence of the initial CV.

Irrespectively of whether it is correct to represent the beginning of the word as an empty CV unit, what the pattern shows is that Pyle (1972) was right: *ad hoc* (in my terms, diacritic) carriers of morpho-syntactic information do not qualify. Non-arbitrary and stable cross-linguistic effects cannot be due to arbitrary items devoid of any phonological characteristics.

22.3 Derivational management

22.3.1 Lexical Phonology

22.3.1.1 Origins I: Class 1 and class 2 affixes

In SPE the interface is both representational and procedural. Phonological rules can make reference to brackets, which delineate cycles, as well as to hash-marks, which are the representational means of carrying morpho-syntactic information into phonology.

Lexical Phonology makes maximal use of the procedural management of the interface, which had been introduced by Chomsky et al. (1956) but had not really been put to use since then. Kiparsky (1982a, b) condenses a number of strands (Pesetsky 1979; Rubach 1981; and see below) into what is generally held to be the initial spark of Lexical Phonology. The theory was given canonical expression in the book-length descriptions by Rubach (1984) and Mohanan (1986).

The critical discovery for the establishment of Lexical Phonology was the existence of two classes of affixes in English, and of their non-arbitrary ordering with respect to the stem. Relevant generalizations for the former insight were made by SPE (Chomsky & Halle 1968: 84ff.), for the latter by dissertations by Dorothy Siegel (MIT, 1974) and by Margaret Allen (UConn, 1978). Class 1 affixes (which are typically of Romance origin) occur closer to the stem than class 2 affixes (which typically belong to the Germanic vocabulary). That is, affixes of both classes can freely attach to stems that already contain an affix of the same class (class 1: *atom-ic$_1$-ity$_1$*, *univers-al$_1$-ity$_1$*; class 2: *atom-less$_2$-ness$_2$*, *beauty-ful$_2$-ness$_2$*, *guard-ed$_2$-ness$_2$*). In addition, class 2 affixes can hook onto a class 1 affix (*univers-al$_1$-ness$_2$*). However, Siegel (1974) observes that sequences of class 2 – class 1 affixes do not occur (**atom-less$_2$-ity$_1$*, **piti-less$_2$-ity$_1$*, **guard-ed$_2$-ity$_1$*, etc.). This is the Affix Ordering Generalization.

The morphological categorization into class 1 and class 2 items is mirrored in the phonology. There are a number of relevant effects, one of which concerns stress placement. Class 1 affixes are reputed to be stress-shifting, while class 2 affixes are stress-neutral. Classical examples are words such as *párent*, *válid*, and *átom*, which appear with right-shifted stress when occurring with a class 1 suffix (*parént-al$_1$*, *valíd-ity$_1$*, *atóm-ic$_1$*), but

conserve their stress pattern when followed by a class 2 suffix (*párent-hood*$_2$, *válid-ness*$_2$, *átom-ize*$_2$).

Siegel's (1974) Affix Ordering Generalization played an important role in the inception of Lexical Phonology, but almost immediately faced counter-evidence. This is further discussed in section 22.3.2.1.

22.3.1.2 Origins II: The abstractness debate

Lexical Phonology also has roots in the abstractness debate initiated by Kiparsky (1968a: 1968–73) and that dominated the 1970s. This origin is made explicit in Kiparsky (1982a: 34ff.). Given the overgenerating SPE mechanics, it was clear that the expressive power of the grammar needed to be constrained somehow. Restrictions on possible underlying representations (such as the (Revised) Alternation Condition, Kiparsky 1973) and on the computational component (the Strict Cycle Condition (SCC); Chomsky 1973) supplemented Chomsky's (1970) reduction of transformational power in morphology. The (Revised) Alternation Condition ('Obligatory neutralization rules apply only in derived environments' in Kiparsky's 1982b: 152 formulation) embodies the insight that phonological rules never apply inside morphemes or, conversely, that phonology only applies across morpheme boundaries. Later this condition became known as a *derived environment effect*, expressed in the phonological version of the SCC (Halle 1978, Kiparsky 1982b; see Cole 1995, Scheer 2011a: §190).[13]

The Alternation Condition is a reaction against 'absolute neutralization', a situation where all instances of a morpheme are altered by a phonological rule. An example is the SPE analysis of *ivory*, whose final vowel [i] (written *y*) is derived from underlying /j/ in order for the first vowel [aːj] to escape trisyllabic shortening (compare *line* with [aːj], but *linear* with [ɪ]). The underlying /j/ is never observed on the surface. Kiparsky argues that absolute neutralization must be disallowed on principled grounds: grammar cannot tolerate underlying forms of non-alternating morphemes which are different from their surface form. In the case of *ivory* there is an alternative analysis: trisyllabic shortening does not apply to monomorphemic strings.

On the syntactic side, Chomsky's (1970) *Remarks on Nominalization* removes the derivational morphology of words such as *reduction*, *transmission*, and *recital* from the syntax and relegates it to the lexicon. This approach is known as Lexicalism. On the phonological side of this movement towards a less permissive grammar,[14] the critical question was the attitude towards alternations that are subject to morphological conditioning. In the name of phonological realism, Natural Generative Phonology bans rules from phonology as soon as their formulation involves the slightest bit of morphology. Contrasting with this radical position, Kiparsky argued that only a certain kind of abstractness (such as absolute neutralization) needs to be done away with.

In this sense, Lexical Phonology may be viewed as an attempt to maintain as much morpho-syntax as possible in the computational device of phonology while cutting away the wildest outgrowths of SPE-induced overgeneration.

[13] For a long time, derived environment effects were a trademark of Lexical Phonology, but the SCC faced a growing amount of empirical adversity until it was ultimately abandoned by Kiparsky (1993b).

[14] On the parallel between syntactic and phonological lexicalism, see Hoekstra et al. (1980).

22.3.1.3 Inside the Lexicon: Strata/levels and interactionism

Affix classes, affix ordering, and the abstractness debate were condensed into what may be called classical Lexical Phonology. This move is described at the outset of Kiparsky (1982b). The critical innovation that enabled him to kill two birds with one stone was the idea of interspersing word formation rules with phonological rules: first you apply phonology to a piece, then you concatenate an affix, then you do some more phonology on the new string created, then you concatenate another affix, etc. This procedural scrambling of concatenation and (phonological) interpretation is called interactionism.[15]

Interactionism accounts for affix ordering by assuming the existence of several procedurally defined levels (or strata) that the morpho-phonological derivation runs through without being able to loop back (level ordering). Regarding stress placement, for example, the rule that stresses strings is placed at level 1 (after class 1 affixes have been attached to roots). Hence the root *parent* will first be concatenated with the class 1 affix *-al*, and the resulting string *parent-al* undergoes the stress placement rule which (simplifying for the sake of exposition) assigns penultimate stress. The result is *parént-al*. The root alone (when no affixes are added) also undergoes the stress rule when passing through level 1 and comes out with penultimate stress: *párent*. Class 2 affixes are concatenated at level 2, after the stress rule has applied at level 1. They thus come in too late to bear on stress assignment: the root enters level 2 stressed as *párent*, to which the class 2 affix *-hood* is added, producing *párent-hood* without any further modification.

An important consequence of this stratal architecture is the existence of multiple morpheme-specific mini-grammars: rules are assigned to a specific stratum (or level), and the set of rules that apply at a given stratum is the mini-grammar acting on the string that is returned by concatenation at this derivational stage. Hence, there is a level 1 and a level 2 phonology in English: the former is responsible for strings excluding class 2 affixes, and the latter applies to strings that include them. Morpheme-specific mini-grammars have a modern offspring in current OT, to be discussed in section 22.3.3.2.

The interspersing of concatenation and phonological interpretation (interactionism) is the way cyclic derivation incarnates in Lexical Phonology. But the theory holds that only the derivation of strings up to the word size (morphology) is cyclic: this is what is called the lexicon since words are produced here. The concatenation of larger strings (syntax) is assumed to be non-cyclic. This is what we turn to in the following section.

22.3.1.4 Outside the lexicon: Postlexical phonology

The Prague Linguistic Circle (Circle 1931) made a distinction between the phonology of words (*phonologie du mot*) and the phonology of sentences (*phonologie de la phrase*) (Booij 1997: 264n3). Rubach (1981) introduced this Praguian segregation into generative theory. Generalizing from the systematic difference between regular and surface palatalization in Polish, Rubach (1981: 18ff.) concludes that phonological rules should be split into two separate and derivationally ordered blocks: first all regular rules apply; then the output of this computation is assessed further by 'automatic' or surface-oriented rules (such as the distribution of aspiration in English, or surface palatalization in Polish).

[15] In current minimalism, interactionism is the cornerstone of Phase Theory (see section 22.3.5.3).

This is what became known as postlexical phonology, processes that apply to chunks above the word level. They are opposed to word-constructing lexical rules, which are cyclic in kind and placed inside the Lexicon. Postlexical rules are held to be non-cyclic (without argument, though; see Kiparsky 1982b: 131f.). That is, once words are concatenated by the syntax, the entire string of a full sentence constitutes one single computational domain in phonology to which postlexical rules apply. The fact that the non-cyclic nature of postlexical phonology is incompatible with current minimalist Phase Theory is further discussed in section 22.3.5.5.

22.3.1.5 Rule-triggering and rule-blocking boundaries

SPE-type boundaries could either trigger or block a phonological process. The stratal architecture of Lexical Phonology does away with rule-blocking boundaries altogether: this function is entirely taken over by the procedural management of morpho-syntactic information (Scheer 2011a: §163). This may again be illustrated by stress assignment: in SPE, class 2 affixes come with a # boundary (/#hood/), while class 1 affixes are associated to a + boundary (/+al/). The stress-assigning rule was then formulated so as to be blocked by the presence of a hash-mark: stress assignment first applies to the root /parent/ alone (returning *párent*). It then reapplies to the string /párent+al/ causing stress shift (*parént-al*). Its reapplication is blocked for /párent#hood/. None of this is needed in the stratal account (see section 22.3.1.3), where class membership is defined procedurally (the moment in the derivation when affixes are fed in), rather than representationally (# vs. +).

The stratal architecture alone cannot account for the rule-triggering pattern, though (to be discussed in section 22.3.5.1).

22.3.2 Forerunners of selective spell-out

22.3.2.1 Halle & Vergnaud (1987)

Halle & Vergnaud (1987) introduce a new idea into cycle-based interface thinking. They propose that the distinction between class 1 and class 2 affixes is not one of different action or representation, but of an action (class 1, which they call 'cyclic' affixes) against the absence thereof (class 2, 'non-cyclic'). The action taken when a class 1 affix is concatenated is the identification of this affix plus its sister in the morphological structure as a phonologically relevant domain. For example, *univers-al$_1$-ness$_2$* reaches phonology as /[[univers]-al]-ness/, where brackets indicate domains created by roots and cyclic affixes. First [únivers] is stressed; when the cyclic affix is added previously assigned stresses are erased by the Stress Erasure Convention, and stress reapplies to give [[univérs]-al]. The entire word is not a bracket-delineated domain, since it is dominated by a non-cyclic node projected by the non-cyclic class 2 affix *-ness$_2$*.

Halle & Vergnaud (1987) write that their model is a version of Lexical Phonology, except that they reject interactionism. They argue that the workings of SPE are correct and need to be restored: all concatenation occurs before all interpretation (anti-interactionism). Further, and pace their self-understanding, they dismiss all key properties of Lexical Phonology: Praguian segregation between lexical and postlexical processes, strata (which cannot exist without interactionism), and hence the management of affix class-based

phenomena by multiple mini-phonologies. As in SPE, all strings are computed by the same set of rules no matter whether they contain class 1 or class 2 affixes.[16]

Interactionism enforces the Affix Ordering Generalization (see section 22.3.1.1), which is therefore a prime target for anybody who wants to do away with interactionism: in its absence, there is no reason for affixes to observe a specific order. This is precisely Halle & Vergnaud's line of attack: they call on empirical evidence against it collected by Aronoff (1976) and Aronoff & Sridhar (1983, 1987). Examples where a class 2 affix occurs closer to the root than a class 1 affix include *develop-mént*$_2$*-al*$_1$, *organ-iz*$_2$*-át-ion*$_1$, and *patent-abíl*$_2$*-ity*$_1$. Another argument was provided by Fabb (1988), who showed that affix ordering overgenerates. It became the general consensus that affix ordering is indeed empirically unsustainable.

In the derivation of a word like *develop-mént*$_2$*-al*$_1$, on Halle & Vergnaud's analysis the root [devélop] receives a stress which is not altered by the non-cyclic inner affix, which is interpretation-neutral. Brackets are inserted again at the outer affix, which is cyclic and thus projects an interpretation-triggering node that dominates the entire word. The resulting bracketed structure is /[[develop]-mént-al]/ where stress is regularly assigned to the penultimate vowel.

Halle & Vergnaud's (1987) interface theory is taken up in Halle & Kenstowicz (1991), Halle & Matushansky (2006), and Halle & Nevins (2009), and its central piece was implemented in Government Phonology by Kaye (1995), as briefly discussed in the next section (see Scheer 2011a: §§277ff. for a more detailed comparison of these approaches). Thirteen years later, their move would be known as selective spell-out implemented by phase theory (see section 22.3.5.3): only the concatenation of a subset of the pieces engaged leaves a trace in the derivation (phonologically relevant domains are only created by some pieces). In the minimalist environment, this idea appears as the mechanism whereby only a subset of constituents of the morpho-syntactic tree trigger interpretation (phase heads).

22.3.2.2 Kaye (1995): Spell-out your sister!

Kaye (1995) calls class 1 boundaries as in *parént-al*$_1$ 'non-analytic', because they are invisible for phonological purposes; the morphologically complex item is indistinguishable from a monomorphemic string (in this case, with respect to stress assignment). Class 2 boundaries, by contrast, are 'analytic' because they alter the regular application of phonology: in *párent-hood*$_2$ the boundary causes phonology to ignore the presence of the affix. Analytic affixes portion the string into two phonologically relevant domains. Contrary to Halle & Vergnaud, on Kaye's analysis it is class 2 affixes that are interpretation-triggering (have an effect on phonology), and class 1 affixes that are interpretation-neutral.

Another innovation of Kaye's analysis is that Kaye spells out the sister of an interpretation-triggering affix, while Halle & Vergnaud spell out the mother: in a structure [X Y] where X and Y are sisters and Y is interpretation-triggering, what is spelled out is XY according to Halle & Vergnaud, but only X according to Kaye. Spelling out the sister (rather than the mother) today is known as the phase edge: when a phase head triggers

[16] There is a great risk of terminological confusion when reporting on Halle & Vergnaud's (1987) system, which uses terms such as 'strata', 'cyclic', and non-cyclic' in idiosyncratic ways. The details of Halle & Vergnaud's (1987) architecture and related terminological pitfalls are discussed in Scheer (2011a: §§234–6). The only take-home message relevant for this discussion is that there are no morpheme-specific phonologies in Halle & Vergnaud (1987): strings containing whatever kind of affixes are computed by the same set of rules.

interpretation in syntactic phase theory, only its complement (the sister of the head X^0, or spell-out domain) is interpreted. The uninterpreted portion X^0 is the phase edge (Scheer 2008b, 2011a: §§299–309).

Kaye's system thus assigns the domain structure [parent-al$_1$] (invisible affix boundary) and [[parent]-hood$_2$] (visible affix boundary): the interpretation-triggering *-hood$_2$* causes the spell-out of its sister *parent*, which is therefore made a phonological domain of its own. In Kaye's system words are always spelled out, and so constitute a phonologically relevant domain. Hence the outer brackets in the examples discussed, as well as when [parent] occurs without affixes. Penultimate stress is then assigned to every domain, which produces [párent], [parént-al] and [[párent]-hood] on the inner domain of the latter.

Kaye also introduces what he calls 'robustness': strings that have already experienced interpretation cannot be further modified. Hence stress assignment to the outer domain of [[párent]-hood] fails since [párent] was already modified in previous computation by having received stress.

Further developments regarding the workings of spell-out and the way class 1 and class 2 affixes are distinguished have occurred in Stratal OT (section 22.3.3.2) and Distributed Morphology (DM; section 22.3.4.2).

22.3.3 OT

22.3.3.1 General landscape

As was mentioned, cyclic derivation has lain at the heart of generative interface theory since Chomsky et al. (1956): it was implemented by all theories prior to OT. In its classical incarnation, however, OT must reject cyclic derivation because of the general anti-derivational orientation of the theory: computation of whatever nature must be parallel.

The intrinsically derivational character of cyclic derivation, and hence its exclusion from OT, is made explicit by Kager (1999: 277). From the late 1990s on, however, the idea that holistic parallelism is too strong a claim has gained ground: phonology proper is strictly parallel, but its interface with morpho-syntax may be derivational. This is the position of the direct heirs of Lexical Phonology, Stratal OT, and Derivational OT (DOT). More recently, phonological computation itself has been argued to be derivational by McCarthy's (2007) OT-CC, a revival of Harmonic Serialism (Prince & Smolensky 2004).

For our purposes, theories that implement morpheme-specific mini-grammars (a landmark of Lexical Phonology; see section 22.3.1.3) can be divided into two types: (i) co-phonologies (Itô & Mester 1995) and indexed constraints (Pater 2000); and (ii) Stratal OT (Kiparsky 2000; Bermúdez-Otero 2012, 2018) and DOT (Rubach 1997). The latter are the direct continuators of Lexical Phonology, although Stratal OT is explicit on the fact that not all tenets of the 1980s are taken over (see Bermúdez-Otero 2012). The former two approaches pursue a different, OT-specific, rationale.

The critical property that opposes Stratal OT/DOT on the one hand to co-phonologies / indexed constraints on the other is reranking. On the analysis of the former, mini-grammars apply in serial order, just like strata in classical Lexical Phonology did: first a string is interpreted at stratum 1/by mini-grammar 1, then it is assessed by stratum 2/mini-grammar 2. The two mini-grammars do not exist independently at any given point in time; rather, there is only one single constraint set whose content is rearranged once stratum 1

computation is completed. This operation is called reranking (of constraints in Eval); it is only reranking that makes DOT and Stratal OT derivational. On the other hand, co-phonologies and indexed constraints provide for permanently distinct mini-grammars (constraint sets) that co-exist in the same (indexed constraints) or different constraint hierarchies (co-phonologies).

22.3.3.2 Affix ordering in Stratal OT

The empirical failure of the Affix Ordering Generalization (see section 22.3.2.1) raises an obstacle for Stratal OT/DOT, whose central tenet is level ordering: how could a word such as *develop-ment*$_2$*-al*$_1$ exist? Bermúdez-Otero (2018: 120f.) proposes that lexical cycles (or strata) are defined by word formation, which is divided into a stem level (inner cycle) and a word level (outer cycle). Level ordering incarnates as the strict ordering of morphological concatenation: what is crucial for Bermúdez-Otero is that no word-level concatenation ever occurs before a stem-level operation. He thus uses morphological, rather than phonological, evidence to determine whether an affix is class 1 or class 2, and where exactly it is fed into the derivation.

On this backdrop, Bermúdez-Otero argues that *-ment*$_2$ is concatenated by a word-level operation in *devélop-ment*$_2$ since *development* may be inflected (plural: *development-s*), and only words have inflection. In *develop-ment*$_2$*-al*$_1$, however, *-ment*$_2$ is fed into the derivation by a stem-level operation—diagnosed by the fact that the intermediate string cannot be inflected for plural (**develop-ment*$_2$*-s-al*$_1$). Hence, the structure [[[develop ment]$_{\text{noun stem}}$ al]$_{\text{adj stem}}$]$_{\text{word}}$ obeys level ordering.

Phonological interpretation follows: any constituent representing a stem provokes the application of stem-level phonology to the string it dominates, and any constituent building a word triggers the application of word-level phonology. Since the entire string [develop-ment-al] is made up only of constituents representing stems, it receives stress on the penult: *developméntal*. The later application of word-level phonology does not change anything.

22.3.3.3 Output-Output correspondence

OT has given a formal expression to what has been known since the 19th century as analogy. The observation is that words are not only shaped by phonological processes that occur between an underlying (lexical) and a surface form, but also when a surface form is influenced by another surface form. In OT the the latter relationship is modelled by output-output faithfulness (OO correspondence, also called transderivational correspondence). These constraints militate against the modification of a morphologically related form, typically in an (inflectional) paradigm.[17]

For example, McCarthy (2005) observes that the participle *lightening* is pronounced trisyllabically with syllabic *n̩*: [lajtn̩ɪŋ]. On purely phonological grounds this is surprising, because the *n* could have been the onset of the following syllable; compare bisyllabic *lightning* ([lajtnɪŋ]). McCarthy proposes that the *n* is syllabic because of the influence of *lighten* [lajtn̩], where there is no vowel to its right that *n* could be the onset of. The reason

[17] Relevant literature includes Kenstowicz (1996), Benua (1997), Burzio (2000), and Downing et al. (2005); Kager (1999: 257ff.) provides a textbook introduction. Within OT, the conceptual necessity of OO-correspondence is challenged by Bermúdez-Otero (2018: 112ff.).

for this deviation from the expected workings of phonology may then be said to be OO faithfulness: there is an output-output relation between this word and the basic *lighten* that requires faithfulness. No such relation exists with the noun *lightning*, which is not a member of the verbal paradigm.

22.3.4 Distributed Morphology

22.3.4.1 General positioning

The central tenet of DM (Halle & Marantz 1993; Harley & Noyer 1999) directly impacts interface practice: DM holds that morphology and syntax are run by the same computational system (Sproat 1985). This approach excludes the existence of a lexicon in the sense of Lexical Phonology: there is no difference between the computational system that builds words from morphemes (in the lexicon) and the one that builds sentences from words (postlexically). That is, nothing can be done 'in the privacy of your lexicon' (Marantz 1997).

A corollary of this position is that there is also only one computational system for phonology: morpheme-specific mini-phonologies (strata) and the Praguian distinction between lexical and postlexical phonology are dismissed. The theory (of which Morris Halle is a co-founder) thus continues the restoration of SPE undertaken by Halle & Vergnaud (1987) (see section 22.3.2.1).

22.3.4.2 Affix class-based phenomena

A problem for DM in its initial incarnation is the inability of the theory to account for affix class-based phenomena. A ground rule in DM (Marantz 2007; Embick & Marantz 2008: 6) is that all category-defining heads (and only these, i.e. all xPs: vP, nP, aP), are phase heads: they trigger the spell-out of the complement ($[\text{x } \sqrt{}]_{\text{xP}}$ spells out $\sqrt{}$) and hence freeze the spell-out domain through the PIC (Phase Impenetrability Condition; see section 22.3.5.4). This leaves DM without an analysis for the basic stress shift triggered by class 1 affixes in English: $[[\text{n parent}]_{\text{nP}}\ \text{al}]_{\text{aP}}$ first receives stress on the complement of the nP [párent], which cannot be further modified upon the interpretation of the aP [párent al] since it is frozen by the PIC.[18] Marvin (2002: 56ff.) therefore concludes that primary (but not secondary) stress is an exception to the PIC, which does not apply to this particular phenomenon.

Embick (2010) proposes to relax the freezing pressure on derivations by modifying the spell-out mechanism: only those complements are spelled out that contain a phase head themselves. Lowenstamm (2015: 235f.) shows that this move saves stress from being frozen in the wrong place when one stress-shifting affix is present (because the root does not contain a phase head), but fails for the same reason as before when two class 1 affixes occur. In *atom-íc$_1$-ity$_1$*, stress will be incorrectly frozen on the middle xP, whose complement contains a phase head, yielding **atómi-ic$_1$-ity$_1$*.

Instead, Lowenstamm (2015) proposes that affixes are roots: class 1 affixes are root-attaching, and class 2 affixes are xP-attaching. This produces a situation where roots and all

[18] The *n* in $[\text{n parent}]_{\text{nP}}$ represets nounness. DM has lexical primitives *n*, *v*, *a* for major categories, and a root, which is lexically unspecified, becomes a noun, verb, or adjective only when it is merged with *n*, *v*, or *a*.

class 1 affixes occur below the first xP. In this area of the tree, which Lowenstamm calls the radical core, the application of phonology is not restricted since no spell-out occurs. The first spell-out takes place at the first xP that dominates the radical core and will freeze phonological matters as they are at that point in the derivation. Further affixes, all class 2, are xP-attaching and hence occur only outside of the radical core. In items such as *develop-mént$_2$-al$_1$*, Lowenstamm argues that *-ment* is not a class 2 but a class 1 affix (cf. Bermúdez-Otero 2018; section 22.3.3.2); more generally, some affixes are unspecified for class membership.[19]

22.3.5 Cyclic spell-out and no look-back devices

22.3.5.1 No look-back devices

The idea that linguistic computation cannot look back to previously interpreted strings was introduced by Chomsky (1973) under the heading of the Strict Cycle Condition. In the context of the early 1970s, this was a contribution to the attempt of constraining the generative power of the unrestricted derivational (transformational) mechanism. Ordered transformations in syntax overgenerated as much as ordered rules in phonology. Overgeneration was a serious problem for a theory aiming at explanatory adequacy, and the proposed solution was a restriction on both underlying forms (i.e. lexicalism; see section 22.3.1.2) and computation, in the form of no look-back.

During the 1970s, strict cyclicity was applied to phonology by Kean (1974) and Mascaró (1976). Mascaró is at the origin of the term *phonological cycle*, which replaces the SPE-based notion of the transformational cycle in phonological theory. His Strict Cycle Condition was adapted by Halle (1978) and Kiparsky (1982b) in order to account for derived environment effects (see section 22.3.1.2).

A competing way of implementing no look-back in Lexical Phonology is based on brackets and bracket erasure (Mohanan 1982, 1986). Recall from section 22.3.1.5 that the basic architecture of Lexical Phonology is not suited to deal with rule-triggering boundaries. Like in SPE, Mohanan holds that brackets delineate morpheme boundaries, and that the structural description of phonological rules may make direct reference to them. In English, nasal cluster simplification occurs in word-final position (*sign*) and before class 2 affixes (*sign-ing$_2$*), which in SPE is triggered by the # boundary (/sign#/, /sign#ing/). On Mohanan's (1986: 22) analysis, the two cluster-reducing contexts share the property of being morpheme-final, and the deletion rule thus makes reference to a closing bracket ']': g → ø / __ [+nasal]]. Applied at level 2, the *g* of [sign] and [[sign] [ing]] is thus deleted. It is not in level 1 *sign-ature$_1$* because of Bracket Erasure, a device specifying that internal brackets are erased at the end of each level. [[sign] [ature]] thus becomes [signature] at the end of level 1 by way of Bracket Erasure and *g* deletion cannot apply at level 2 because its environment, the closing bracket, has been destroyed.

[19] Newell (2017) shows that Lowenstamm's system runs into empirical problems when √Ps are piled up. She proposes a different account based on the idea that class membership of affixes involves a phonological distinction: class 1 affixes begin with a floating vowel, class 2 affixes do not.

22.3.5.2 Modification-inhibiting no look-back

Parallel to devices developed in Lexical Phonology, a representationally oriented way to work out no look-back was developed in the early autosegmental period of the 1980s: modification-inhibiting no look-back. The idea was that autosegmental structure that encodes stress and syllabic generalizations, namely, metrical and syllabic trees, are subject to structure preservation. That is, metrical and syllable structure that was already built on earlier cycles cannot be erased or modified (Steriade 1988a). This mechanism was known as the Free Element Condition (Prince 1985). Kaye (1995) generalizes modification-inhibiting no look-back to all areas of phonology (not just syllable and metrical structure), and its implementation is non-representational (old strings as such are concerned, rather than any specific structure). Modification-inhibiting no look-back had also a precursor in Syntax: van Riemsdijk's (1978: 160) Head Constraint.

22.3.5.3 Phase Theory

Phase Theory emerged from minimalist thinking in the early 2000s, or rather revived old ideas that were mainly developed in phonology (interactionism and selective spell-out; see section 22.3.2). Phase Theory is a cornerstone of current syntactic thinking and, if taken seriously by phonologists, impacts the workings of the interface quite significantly on the phonological side as well.

Until the late 1990s, the debate on interactionism was confined to phonology. The idea that concatenation and interpretation are interspersed then entered syntactic theory under different headings: spell-out-as-you-merge in Epstein et al. (1998), Uriagereka's (1999) multiple spell-out, and derivation by phase as in Chomsky (2000). Quite surprisingly, it appears that the relevant syntactic literature does not make reference to the phonological precedent.

Chomsky's (2000 and following) minimalist take is that the faculty of language has optimal design properties and operates with economy principles. This means, among other things, that computational complexity is unwarranted. The bias against computational complexity is assumed to have extra-linguistic causes, such as the restriction on the availability of active memory, which is an expensive cognitive resource. In a linguistic derivation, then, a whole sentence is too big and too computationally demanding to be processed in one go. If sentences are built step by step, the burden imposed on active memory by the computation of successive pieces is reduced. The interactionist come-and-go between syntax and LF/PF is thus (also) a consequence of this performance-based approach, which Chomsky first explicitly mentions in his 'Minimalist inquiries' (Chomsky 2000). Note also that derivation by phase implements the idea introduced by Halle & Vergnaud (1987) (see section 22.3.2.1): only a subset of nodes, called phase heads, trigger interpretation.

22.3.5.4 Phase Impenetrability Condition

Phase Impenetrability is the cognitive economy-born no look-back device that complements selective spell-out (i.e., derivation by phase). The economy of active memory supposes that morpho-syntactic computation is unburdened with the management of the structure of previous phases: on each pass, only the material of the current phase is subject to morpho-syntactic computation. The Phase Impenetrability Condition (PIC) transcribes this constraint on active memory (Chomsky 2001).

Phase Impenetrability is thus an old acquaintance but comes in a new guise: motivation from cognitive economy was completely absent in earlier incarnations of no look-back devices, which were exclusively based on grammar-internal considerations.

22.3.5.5 Intermodular argumentation

The existence of a single and interactionist spell-out mechanism that relates the morpho-syntactic and the phonological derivation puts pressure on both ends of the pipeline. A situation is created where syntactic theories and analyses may have direct consequences for the phonological side: Scheer (2008b, 2009b) notes that syntax can act as a referee for competing phonological theories, and vice versa. A case in point is the Lexical Phonology claim that postlexical phonology is non-cyclic (see section 22.3.1.4). If phase theory is on the right track, this must be wrong since phase heads precisely trigger the piecemeal spell-out of chunks that are bigger than words. These are then submitted to phonological computation in successive waves: that is, cyclically (D'Alessandro & Scheer 2015).

22.3.5.6 Phase-based mapping (prosodic islands)

Constraint-based mapping in OT (see section 22.2.5.6) was impacted by and adapted to syntactic phase theory. The idea is that chunks defined by the syntax as phases also grossly correspond to constituents of the Prosodic Hierarchy, which are then called prosodic islands (Dobashi 2003; Ishihara 2007).

Kratzer & Selkirk (2007) hold that spell-out domains (CP and vP on their assumption, which follows Chomsky's 2000 initial view of phase heads) correspond to major phrases on the phonological side. This is supposed to be a universal equivalence and the result of mapping. Language-specific variation in prosodic phrasing is then achieved not by the syntax-phonology mapping as before but by purely phonological 'prosodic markedness constraints, which operate to produce surface prosodic structures that are more nearly phonologically ideal' (Kratzer & Selkirk 2007: 126). This is a significant departure from a Prosodic Phonology essential: in the original theory, a great amount of language-specific variation in prosodic phrasing is implemented by language-specific mapping (see sections 22.2.5.4 and 22.2.5.5), which now becomes universal and phase driven. On the other hand, language-specific variation that was managed by mapping rules which operated in modular no man's land (see section 22.2.5.5) is now done *in* the phonology by a purely phonological mechanism.

Another property of prosodic islands is that they are always exactly isomorphic with some morpho-syntactically defined structure: they represent syntactic spell-out domains. This overthrows another fundamental tenet of Prosodic Phonology, non-isomorphism (see section 22.2.5.4) and therefore has provoked a reaction from representatives of orthodox Prosodic Phonology: Cheng & Downing (2012) insist that prosodic domains do not match spell-out domains (see also Cheng & Downing 2016).

In more recent work, Selkirk's (2011) Match Theory undoes both departures from Prosodic Phonology essentials: Match Theory returns to the edge-based logic (see section 22.2.5.4), leaving phase structure without discernible impact on mapping.

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