Generative Phonology

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Noam Chomsky and Morris Halle founded the Generative School of Phonology in the late 1950's. It's basic premises are that phonological structure reflects the linguistic competence of the individual native speaker to compute a phonetic representation for the potentially infinite number of sentences generated by the syntactic component of the grammar and that this competence can be investigated in a serious scientific fashion. The generative point of view has become dominant in the field of linguistics and has had varying degrees of influence on other cognitive sciences. This entry surveys the development of the generative approach over three fifteen-year segments and concludes with current research trajectories.

1. SPE: 1960 - 1975

The early work of Chomsky and Halle both embraces and rejects various aspects of the two major schools of American Structural Linguistics inaugurated by Edward Sapir

(1884-1942) and Leonard Bloomfield (1887-1949). Sapir's "Item and Process" model posits an abstract Phonological Representation that is converted to a Phonetic Representation by processes that delete, add, and change sounds. Sapir stressed the psychological reality of the representations and processes but did not attempt to formalize them. The Bloomfieldian School adopted an "Item and Arrangement" model with emphasis on explicit procedures of analysis. Their major research goal was to formalize a pretheoretic notion of contrast (e.g. aspiration is contrastive in Korean but not in English) as a level of representation standing between Sapir's Phonological (termed "morphophonemic") and Phonetic representations. The Bloomfieldians defined the phoneme as a class of phones (phonetic segments) in complementary distribution: e.g. in English the aspirated [p^h] of *pin* and the unaspirated [p] of *spin* are allophones of the phoneme /p/. The allophones are not derived from the phoneme by phonological processes but rather stand in a correspondence relation. For each level (phonemic and phonetic) phonotactics state the distribution of the elements composing that level: e.g. [p^h] occurs at the onset of a stressed syllable while [p] occurs elsewhere. Among the problems debated in this approach were the observation that [p^h] and [t] as well as [h] and [ŋ] are also in complementary distribution but clearly are not variants of a single phoneme. A requirement that each exponent of a phoneme has a core of defining properties (the so-called invariance criterion) was entertained. However, as noted by Bloch (1941), invariance prevents the overlapping of two phonemes on the same phone (neutralization), as in the intuitively correct phonemicization of *writer* [rajɾər] and *rider* [ra:jɾər] with a /t/ vs. /d/ contrast.

Halle (1959, 1962) and especially Chomsky (1964) subjected Bloomfieldian phonemics to a devastating critique. The former noted that Russian voicing assimilation affects both phonemes and allophones. Adherence to the phonemic level would entail splitting the unitary process into two separate rules: a morphophonemic-to-phonemic mapping that merges the phonemes /t/ and /d/ and a phonemic-to-phonetic one providing a noncontrastive voiced allophone [dᶻ] for the phoneme /c/. Chomsky observed that the phonemicization of *writer* vs. *rider* as /rajtər/ vs. /rajdər/ violates most of the proposed requirements on a valid phonemicization (invariance, linearity and biuniqueness). But the mapping follows straightforwardly from two simple ordered rules: introduction of a length distinction before voiced vs. voiceless obstruents followed by a rule replacing the dental stops with a flap.

(1)	/rajt/	/rajt+ər/	/rajd/	/rajd+ər/	Phonological Representation
	----	-------	ra:jd	ra:jdər	length rule
	----	rajɾər	----	ra:jɾər	flapping rule
	[rajt]	[rajɾər]	[ra:jd]	[ra:jɾər]	Phonetic Representation
	'write'	'writer'	'ride'	'rider'	

From examples such as these, Chomsky and Halle concluded that there simply is no phonemic level intervening between Sapir's Phonological and Phonetic Representations. Renouncing any direct representation of contrast, they shifted the goal of phonological research to the discovery of the rules that convert the Phonological to the

Phonetic Representation and to develop a general theory of their form and substance. While rejecting the phonemic level, Chomsky and Halle embraced the Bloomfieldians concern with formal statement --reflected in the adoption of Roman Jakobson's (1896-1982) theory of binary distinctive features. When phonological segments are represented as feature matrices sound change can be formalized as the modification of a feature coefficient. Features provide a measure of phonetic distance and allow a formal study of natural classes in which the plausibility of a rule is reflected in the relative simplicity of its statement. Concern for simplicity and formal statement became a cornerstone of the generative approach.

Chomsky & Halle's landmark study *Sound Pattern of English* (1968) (a.k.a. SPE) is the first systematic exposition of generative phonology. A key feature was to take seriously the notation in terms of which sounds are represented and rules are formulated. SPE's analysis of the English Vowel Shift and Velar Softening processes illustrate these points well. Alternations among [aj] ≈ [i] (*divine*, *divin-ity*), [ij] ≈ [e] (*serene*, *seren-ity*), and [ej] ≈ [æ] (*profane*, *profanity*) pervade English vocabulary. Since the short vowels of *rig**i**d*, *perpet**u**-al*, and *fin**a**l* (cf. *rigid-ity*, *perpetu-ity*, *final-ity*) are stable, the long vowel must underlie the [aj] ≈ [i], [ij] ≈ [e], [ej] ≈ [æ] alternations. But the underlying quality of the vowel is reflected in the short variant. Hence, SPE posits underlying /i:/, /e:/, and /æ:/ and two ordered rules. The first shortens the vowel before certain suffixes. Any remaining long vowels are diphthongized and then rotate their nuclei by two rules. The first interchanges high and mid /i/ and /e/ by changing [αhigh] to [-αhigh] (where α = ±). The second interchanges mid (derived from high by the first change) and low vowels by

changing [αlow] to [-αlow]. Thus, in the derivation of *divine* the high vowel switches places with the mid vowel of *serene* and then with the low vowel of *profane*.

(2)	/devi:n/	/sere:n/	/profæ:n/	Phonological Representation
	ij	ej	æj	diphthongization
	ej	ij	-------	[αhigh] -> [-αhigh]
	æj	-------	ej	[αlow] -> [-αlow]

This vowel interchange defined a new category of sound change and SPE devoted a chapter to its documentation in the historical development of English. While stunning in itself, the analysis of the Vowel Shift allowed one to make sense of a variety of consonantal changes as well. For example, /k/ is replaced by /s/ before suffixes beginning with /i/: *critic*, *critic-ism*; *medic*, *medic-ine*. But the trigger in *critic-ise* is a back vowel [aj] at the phonetic surface. However, if Velar Softening applies before Vowel Shift (to /kritik-i:z/) then the latter is not exceptional at all. On the strength of such analytic insights resting on a formally explicit methodology, SPE was universally regarded as a tremendous theoretical and descriptive advance.

The generative methodology in which systematic alternations are derived from a common underlying form by an ordered set of rules was successfully applied to such well-known languages as Russian, Japanese, French, and Spanish by Chomsky and Halle's first generation of graduate students. A critical mass of detailed analyses from the generative perspective accumulated that uncovered numerous problems and research questions--many of them still unresolved. We mention four here.

Paul Kiparsky (1968, 1971) pointed to the excessive abstractness of many analyses adhering to the generative method, raising the question of how a learner could arrive at such rules and representations in the absence of knowledge of their historical antecedents. He suggested that abstract representations are motivated by alternations and that grammars change to states in which the underlying representations can be induced by rules that state generalizations over the surface phonetic representation.

Charles Kisseberth (1970) called attention to various rules in the phonology of Yawelmani that conspire to ensure that the output does not contain three successive consonants. The language lacks roots of this structure; and when stems and suffixes are combined to create CC+C or C+CC sequences, various rules come into play that either delete one of the consonants or insert a vowel. Moreover, another rule elides a vowel in the context VC__CV; it can be understood as a more general V -> Ø process that is blocked just in case its output would violate *CCC. With its emphasis on formal connections among rules, the SPE model was unable to express the functional unity among these diverse processes. More generally, it was unclear how to formalize the notion of rules applying or blocking to satisfy a constraint.

David Stampe (1972) emphasized the importance of substantive rather than formal considerations in shaping phonological structure. He tried to make sense of two puzzles in acquisition. Languages like Catalan, Russian, and German have a process devoicing word-final obstruents. Acquisition studies fail to detect a stage where the child pronounces final [b,d,g] reflecting incomplete mastery of the rule. Rather child speech conforms to the process from the outset. More significantly, child language is rife with sound changes that lack any precedent in the mature grammar. The sound substitutions of

child phonology are thus hard to understand as immature versions of the rules of adult grammar. According to Stampe they reflect a set of innate processes that are curtailed in the process of language acquisition so that the child's output matches the ambient language. Stampe also draws a sharp distinction between such natural processes and more phonetically arbitrary rules like SPE's Vowel Shift and Velar Softening that state generalizations over limited sets of lexically related words. In his view phonological processes are what the child brings to the language while phonological rules are what the language's vocabulary brings to the child.

Finally, with its emphasis on rules of sound change, the SPE model has little to say about phonotactics--static constraints on word shape that are unsuited to rules of sound change and seem best treated as conditions on representation that outputs must respect. Kenstowicz & Kisseberth (1976) call attention to the problem that constraints on lexical shape are often duplicated by rules of sound change that can be thought of as bringing the representation in line with the constraint. This point of view was explored by Sommerstein (1974).

2. Enriched Representations: 1975-1990

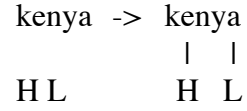
The SPE model has a simple representational format: an utterance is a string of feature matrixes punctuated by boundary symbols of various kinds to indicate stem, morpheme, word, and phrase junctures. Rules changing feature structure in a local context are ill suited to the phonology of tone, stress, and length. These suprasegmentals became the

object of intensive scrutiny that had a profound effect on how all sounds are represented and manipulated by the rules of grammar.

The tonal languages of Africa proved particularly perplexing. While phonetically expressed as a vocalic feature, a tone's phonological behavior is largely autonomous from the segmental string. For example, in Mende lexical items belong to a limited number of tonal melodies such as high (*kɔ́*, 'war', *pélɛ́* 'house', *háwámá* 'waist') or falling *mbû* 'owl, *ngílà* 'dog', *félàmà* 'junction'. The problem is to express the generalization that the falling tone is restricted to monosyllables and breaks into H+L under suffixation: cf. *mbú-mà* 'on owl'. If tone is a segmental feature analogous to [labial] or [nasal] then complicated rules are required to transform [+fall] to [+hi] followed by [-hi]. Also, in tonal languages, when a vowel elides the associated tone typically shifts to an adjacent syllable: cf. Margi *kúm-árì* 'meat' def. but *wù* 'tree', *wǎrì* def. from /wù+árì/.

Building on the work of Wil Leben, Edwin Williams and others, John Goldsmith (1976) made a significant breakthrough on this problem by proposing to represent tonal features on a separate level (tier) associated with but autonomous from the segmental tier. Conditions governing a well-formed association of tones and vowels such as one-to-one, left-to-right mapping and no unassociated tones or vowels derive the surface patterns via simple rules operating in local environments (3a). And if tones are autonomous then vowels can delete while a tone persists on its own tier and maps to an adjacent syllable to ensure maximal association (3b)

(3) a.



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        mbu    ->      mbu    ->  mbu
                         |           | \
        H L              H  L        H L

b.      wu + ari        ->      w + ari         ->      wari
          |    | |                 | \                  /|   |
          L   H L                 L  H L               LH L
```

Stress poses similar locality questions. For example, English words with final primary stress such as *T'enness'ee* invert their Weak-Strong contour when followed by a stronger stress: *T'enness'ee W''altz*. If stress is represented as a feature then the final syllable of *T'enness'ee* must be demoted in value ([1stress] -> [2stress]) while the first is raised ([2stress] -> [1stress]). One never finds [nasal] or [back] exhibiting such long-distance complementary changes. Mark Liberman (1975) and Liberman and Prince (1977) made another conceptual advance by seeing stress as the reflection of an abstract property of prominence formalized in terms of a metrical grid in which each syllable is associated with a column of marks indicating its relative prominence in the word or phrase. With the grid notation the stress inversion *T'enness'ee -> T'enness'ee* can be described by a simple rule that slides the top element of the weaker of the two clashing stresses to the next available landing site--the first syllable--to create a rhythmically more balanced contour in which two stronger stresses are separated by a weaker one.

(4)
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                *                       *
            *   *                   *   *
        *   *   *                   *   *   *
        *   *   *   *               *   *   *   *
        Tennessee Waltz     ->      Tennessee Waltz
```

Finally, while the syllable was mentioned throughout SPE's analysis of English, the notion had no formal status in the theory. Various researchers suggested that syllables could be represented by boundary symbols analogous to word junctures in order to express the frequent conjunction of preconsonantal and word-final position. Adapting insights of Kenneth Pike and Jerzy Kuryłowicz, Elizabeth Selkirk (1982) proposed that the syllable is a constituent with internal structure of onset and rhyme that organizes the individual phonemes. With the syllable given official grammatical status, rules of vocalic epenthesis (Selkirk 1981) and consonantal deletion (Steriade 1982) can be formalized as methods to achieve a parsing of segments in accord with limitations on syllable shape such as traditional grammar's sonority hierarchy.

The ideas that features appear on autosegmental tiers and that an invisible hierarchical structure underlies words and phrases proved especially fruitful. Much of the generative research of the next fifteen years involved extending and exploring the consequences of these proposals. We mention a few highlights.

Bruce Hayes (1980, 1985) analyzed the stress contours from a variety of languages with rules that group syllables into iambic (weak-strong) and trochaic (strong-weak) metrical feet in a left-to-right or right-to-left sweep of the word. Metrical stress research suggested that for restricted areas of phonology Chomsky's (1981) Principles and Parameters methodology was appropriate. Other influential studies of metrical stress include Prince (1983), Halle & Vergnaud (1987), and Dresher & Kaye (1990).

The notion of phonological features on separate tiers was extended to a variety of problems. John McCarthy (1979) suggested that the notorious root and pattern morphology of Semitic languages such as Arabic could be formalized analogous to the

behavior of tones. As illustrated in (5) derivational relations among words are marked by changes in syllabic structure rather than overt affixation: perfects have the shape CVCVC, nominals CVCC, agentives CVCCVVC, etc. If the radical consonants [drs] 'study', [ħml] 'carry' are represented on an autosegmental tier then the same principles that control tonal structure (left-to-right association, multiple linking) can describe the structure of these words.

(5)	daras-a	'he studied'	ħamal-a	'he carried'
	dars-un	'a lesson'	ħiml-un	'a load, cargo'
	darraas-un	'student'	ħammaal-un	'porter'
	daaris	'studying'	ħaamil	'carrying'

Biradicals such as [md] 'stretch' seem to spread their second consonants to fill out a CVCVC template (cf. *madad-na* 'we stretched') comparable to the extension of the L tone in the HL melody of Mende *félàmà*.

Clements & Keyser (1983) proposed extending CV representation to all languages so that a greater variety of phonological processes could be expressed in autosegmental terms. For example, long consonants and vowels can be represented as one feature matrix associated with two adjacent CV positions. With this notation changes in quantity involve the addition or deletion of CV slots. Their study demonstrates how the disparate changes of vowel shortening, consonant degemination and vowel epenthesis illustrated by the

Turkish data in (6) can be formalized as by-products of the organization of segments into CVC syllables.

(6)

accusative	nominative	ablative	
zamaan-~~i~~	zaman	zaman-dan	'time'
hiss-i	his	his-ten	'feeling'
devr-i	devir	devir-den	'transfer'

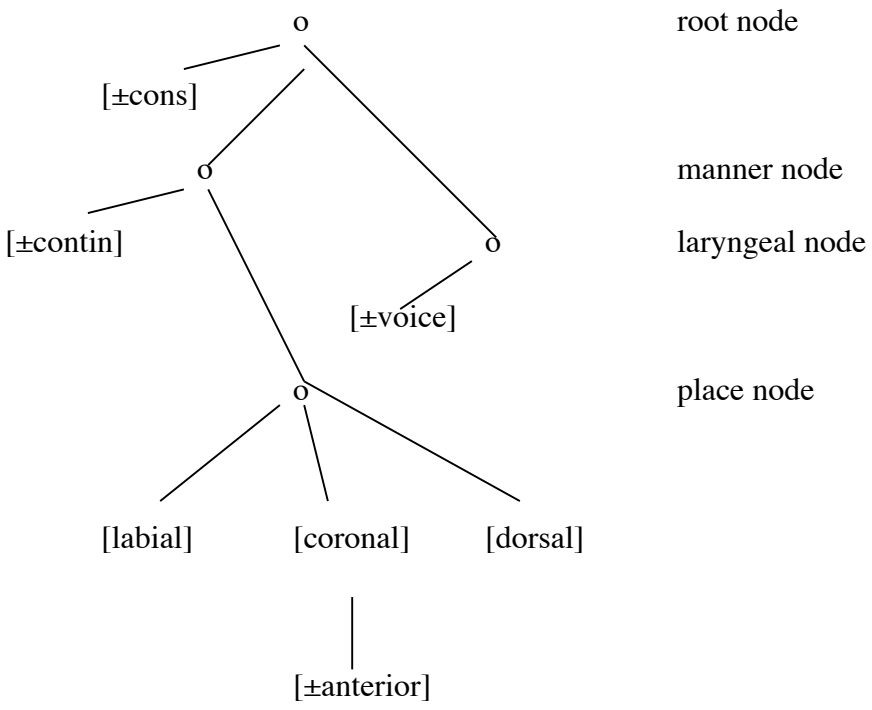
```
C V C V V C        ->    C V C V C
|  |  |  | /  |          |  |  |  |  |
z a  m  a  n             z  a  m a n

C V C C            ->    C V C
|  |  \ /                |  |  |
h i  s                   h  i  s

C V C C            ->    C V C V C
|  |  |  |               |  |  |  |  |
d e  v  r                d  e  v i  r
```

The CV tier and in particular the possibility of empty skeletal positions intervening between phonetically adjacent segments was investigated in considerable detail by researchers working under the banner of Government Phonology (see Kaye, Lowenstamm, and Vergnaud 1990). For example, where the SPE model would posit a rule deleting the medial schwa to account for the V≈Ø alternation in French *revenir* [rɛvnir] 'to come back' (cf. *revienne* 3 sg. pres. subjunctive), Government Phonology postulates an empty nucleus [rɛvønir] (Charette 1990). This approach minimizes the role of rules in favor of constraints on representations--in particular the distribution of empty

elements. The question was conceived of as parallel to the distribution of empty syntactic elements (traces) where Chomsky's (1981) notion of proper government was adapted to phonology. More generally, phonological expressions are viewed as sequences of C and V elements organized by syntactic principles based on the concept of government couched within an overarching Principles and Parameters methodology.

Building on observations by Joan Mascaró and K.P. Mohanan, George N. Clements (1984) proposed that features are organized into a hierarchical tree structure such as in (7).

(7)



This notation allows formal expression of the observation that certain features introduce sub-distinctions within the class of other features rather than partitioning the entire set of

speech sounds into two groups of comparable status like [±consonantal]. For example, the feature [±anterior] is only relevant for coronal consonants. More importantly, the feature tree allows one to formalize the observation of recurrent feature sets in assimilation rules where typically all of the subsidiary place features are spread as well. Also, some sound changes can be treated as deletion and insertion of nodes in the feature tree: e.g. debuccalization of *s* -> *h* as removal of the supraglottal place node leaving the laryngeal articulator to implement feature [continuant].

Several other lines of research were inspired by autosegmental-metrical structure. Pierrehumbert (1980) demonstrated how the intonation contours of English can be analyzed as sequences of tones analogous to the melodies found in African languages such as Mende. For example, the rising interrogative contour is composed of a L* pitch accent on the major stresssed syllable and a H% boundary tone realized at the end of the intonational phrase. Selkirk (1980, 1986) extended the prosodic hierarchy to include phonological words and phrases so that the domains of sentence-level phonological processes could be identified and investigated. McCarthy & Prince (1986) opened up the study of truncatory phenomena like hypocoristics and reduplication to formal scrutiny. Their Prosodic Morphology hypothesis states that the templates underlying such structures are not arbitrary sequences of CV slots but rather prosodic categories such as light and heavy syllables and metrical feet whose precise characterization should correspond to how these units function elsewhere in the language. For example, the truncation *Elizabeth -> Liz* minimizes the base while respecting the requirements on a freestanding English word-- a bimoraic foot. Mokilese prefixal reduplication seen in *pok-poki* 'beat', paa-*pa* 'weave', and *koo-kookɔ* 'grind coconut' converges on a heavy

syllable (CVC, CVV) while in Diyari the CV(C)CV reduplication template underlying *kanku-kanku* 'boy', *kulku-kulkuŋa* 'jump', and *tjilpa-tjilparku* 'bird sp.' consists of a disyllabic trochaic foot.

Starting with Baudouin de Courtenay in the 19th century, linguists had the impression that phonological rules fall into two broad classes that are exemplified by the English Velar Softening of *electric* ≈ *electric-ity* vs. the flapping of *write* ≈ *wri[ɾ]er*. Rules of the first type have exceptions, substitute contrastive segments, and typically apply at the juncture between morphemes. Rules like flapping tend to be automatic, may introduce allophones, and may apply morpheme internally (cf. *a[ɾ]om* vs. *a[t^{h}]omic*). In a pair of influential papers Paul Kiparsky (1982, 1985) developed a Lexical Phonology model of the grammar that formalized this intuition in an especially perspicuous way. Rules of the first type (lexical rules) are placed inside the lexicon and integrated with the morphology to apply after each rule of affixation. As such, lexical rules are inherently cyclic. Adapting Chomsky's notion of the "strict cycle", Kiparsky offered an explanation for why lexical rules normally fail to apply morpheme internally in contrast to postlexical rules, which typically introduce allophones regardless of context. While initially attractive, problems arose in extending this model to other languages necessitating complex distinctions among affixes (level-1 vs. level-2). Also the tight connection between morphological and phonological domains on which the model is based is challenged by bracketing mismatches such as *ungrammaticality* where the morphology demands the parse [un+grammatical]+ity while the phonology requires un+[grammatical+ity].

III. Constraint-Based Models: 1990-2005

As more languages were analyzed from the autosegmental and metrical perspectives, recurrent cross-linguistic patterns were discovered suggesting that a higher level of explanatory adequacy was within reach. The tension between descriptive coverage and theoretical economy came to a head with some linguists defending the latter at the cost of more elaborate representations and derivations (Jonathan Kaye's 1990 Government Phonology) while others looked to connectionist inspired modeling of "soft" universals (John Goldsmith's 1993 Harmonic Phonology), or competing principles that evaluate representations (Luigi Burzio's 1994 analysis of English metrical structure).

Alan Prince & Paul Smolensky (1993) addressed these concerns as well as the unresolved problems from the 1970's with a new model of phonological derivation (Optimality Theory) in which rules are abandoned and the explanatory burden is placed entirely on constraints of Universal Grammar. Plausible descriptive coverage is ensured by the idea that constraints conflict (echoing Stampe) and that the conflict can be resolved by a strict ranking or prioritization. OT makes it possible to formally express Kisseberth's intuition that inputs are mapped to outputs in order to satisfy a particular objective. And with its basic distinction between faithfulness and markedness constraints, OT formalizes Stampe's intuition that the radical simplifications of child speech reflect innate phonetic biases that must overcome so that the resultant adult grammar is the residue of these biases. Finally, given that OT constraints shape the output rather than the input, Kenstowicz & Kisseberth's duplication problem is resolved. Most importantly the OT model passed the basic test of pairing input with output in an explicit and workable

fashion. For these reasons OT quickly captured the attention of the generative school whose research agenda largely focused on an exploration of its implications for analysis and theory.

The OT model consists of two basic functions. GEN constructs a large (possibly infinite) pool of candidate outputs for any given input which are then EVALuated by a fixed UG set of conflicting constraints (CON) that sift through the pool of candidates to eliminate all but the correct output. Grammars differ in the ranking of the constraints, which is the major learning task in acquisition. We illustrate the OT model with the crosslinguistic treatment of word-final rising sonority clusters such as in the stem of *theatr-ic*. English *thea*[tər] inserts a schwa, Canadian French *théâ*[t] deletes the liquid, while European French *théâ*[tr] remains faithful to the input. The relevant constraints appear in (8a) and their evaluation of these candidates appears in (8b).

(8) a. Max-C: don't delete a consonant.

Dep-V: don't insert a vowel.

Sonority Sequencing: a sonority peak is a syllable peak.

b.

thea/tr/	Max-C	Dep-V	Son Seq
thea[tər]		*	
thea[t]	*		
thea[tr]			*

The grammar of English imposes the ranking Son Seq, Max-C >> Dep-V so that the faithful candidate *thea*[tr] and the truncating *thea*[t] are penalized in comparison to the winning candidate with epenthesis *thea*[tər]. These evaluations are summarized in the tableau of (9).

(9)

thea/tr/	Max-C	Son Seq	Dep-V
> thea[tər]			*
thea[t]	*!		
thea[tr]		*!	

Canadian French (cf. *théâ*[t]) demotes the ban on truncation (Son Seq, Dep-V >> Max-C) while European French (cf. *théâ*[tr]) demotes the ban on nonsyllabic sonority peaks (Dep-V, Max-C >> Son Seq).

During its initial phase, OT concentrated on recasting the basic insights of prosodic and autosegmental phonology. This research also uncovered cases of top-down and other remote effects (Berber syllabification, Hindi stress, and Malay reduplication) which are handled effortlessly by OT constraints defined over fully formed output structures but which require phonological rules to look ahead of themselves (a formal impossibility in the serial model of SPE). Other achievements include a much more nuanced and elaborated understanding of markedness (structural complexity) that has resulted in typologies with rich implicational hierarchies. The OT model also provides a

useful framework for studying phonological development from an initial state in which markedness constraints dominate faithfulness constraints and has fostered the study of learning algorithms (Tesar & Smolensky 1998).

Since the OT architecture involves a one-step mapping from input to output, it is immediately confronted by the pervasive opacity (e.g. *writer-rider*) which the original SPE handles straightforwardly with ordered rules. OT has chipped away at this problem. Some cases have been attributed to faithfulness to other members of a stem's paradigm. Other researchers have proposed intermediate stages in the input-output mapping that mirror Lexical Phonology's stem and word levels. However, a nagging and sizeable residue of examples such as Canadian English *title* [tʰʌjɾəl] (cf. *tidal* [tʰaːjɾəl]) persists as an outstanding problem (Idsardi 1998).

4. Current Trends

Constraint-based formalisms have opened up a wider range of factors that can be taken into account to model recurrent sound patterns. A lively debate has arisen over the phonetic grounding of phonological structure and more generally the relation between phonetics and phonology. Traditionally, phonology is held to deal with categorical (symbolic) distinctions and phonetics with continuous movements of articulators and associated acoustic effects. But research in the 1980's revealed systematic gradient differences between languages that provoke the question whether phonology should expand to encompass the gradient or whether the grammar includes a distinct phonetic component.

Another trend extends the data and methods for probing phonological competence. Traditionally phonologists have concentrated on the investigation of systematic generalizations in a language's inherited lexical stock with an occasional bow to supporting evidence from language games, loanwords, and speech errors. Under the banner of Laboratory Phonology (Pierrehumbert, Beckman, & Ladd 1996), linguists are adopting more experimental approaches in which subjects are tasked with learning artificial languages, judging similarity between carefully controlled stimuli, and producing tongue twisters. Computer accessible databases have made it possible to study a language's lexicon in an efficient and accurate manner. Generative phonologists are turning their attention to topics that were understudied or ignored in the classical period. We mention three.

With its concentration on rules, generative phonology abstracted away from questions of frequency--as long as an alternation or phonotactic restriction was regular it was assumed to be part of the speaker's competence. Recent research suggests that speakers have knowledge of frequency patterns in the lexicon. For example, Dutch has final devoicing. Ernestus & Baayen (2002) show that there are significant differences in the number of voiced vs. voiceless obstruents that underlie the alternation (e.g. final [p] derives from underlying /p/ for 97% of the lexicon and from /b/ for just 3%; final [x] derives from underlying /x/ 19% and from voiced /ɣ / 81%. When Dutch subjects were asked to supply the inflected form of a pseudo stem, their responses mirrored the lexical frequencies.

Anttila (2002) studied the competition between Finnish rules that shift stem-final [a] to [o] before the suffix [i] (/kana+i+ssa/ > *kanoissa* 'hen') vs. deletion in the same

context (/muna+i+ssa/ -> *munissa* 'egg'. While neither rule applies categorically, there are clear statistical differences as a function of the preceding consonant and stem vowel. Change to [o] is preferred to deletion according to the following hierarchies: stem vowel /i/ > /a,e,u/ > /o/, preceding consonant velar > dental > labial. Anttila models this orderly variability with competing OT grammars that differ in the ranking of constraints penalizing sequences of similar sounds.

The notion of contrast has been resuscitated and addressed directly in several lines of research. Flemming (2005) argues that the relative markedness of a phoneme can only be judged in relation to other segments in the system. For example, he observes that in languages contrasting front vs. back vowels front rounded /y/ and back unrounded /ɯ/ are only added to the phonemic inventory after the more peripheral vowels /i/ and /u/ are chosen. But in vertical vowel systems that do not contrast front and back, the central vowel /ɨ/ is the optimal high vowel. Recasting some of Bjorn Lindblom's ideas on vowel dispersion, Flemming models a vowel inventory in terms of competing constraints that balance articulatory effort with maximizing the number of contrasts along a phonetic dimension and maintaining sufficient phonetic distance between pairs of elements. Thus, if a language makes no contrast in the F2 dimension then minimizing articulatory effort will favor the central vowel /ɨ/. But if a contrast is introduced, then the peripheral vowels /i/ and /u/ will be chosen first on grounds of phonetic distance. More vowels such as /y/ or /ɯ/ are added at the cost of decreasing the phonetic difference between contrasting pairs.

Padgett (2002) discusses the role of contrast in motivating and restricting the scope of a Russian sound change that fronts unrounded /ɯ/ to /i/ after velars. The *ɯ -> i*

change did not occur after labials or dentals because these consonants are palatalized before /i/; fronting after /p/ would replace a more widely spaced /p'i/ vs. /pɯ/ contrast with the auditorially less optimal /p'i/ vs. /pi/. Fronting of /ɯ/ occurs after velars because an earlier sound change shifted /ki/ to /tʃi/ and so the hard-soft consonantal contrast is realized as a more perceptible dorsal-coronal one.

Based on a typological survey of contrasts in aspiration, Steriade (1999) discerns an implicational hierarchy of contexts in which a /t/ vs. /t^h/ opposition is neutralized: preobstruent > word-final > presonorant > prevocalic. The hierarchy does not align with syllable onset vs. coda position but rather with the contexts in which the principal acoustic cue to aspiration (Voice Onset Time) is optimally realized. A general Licensing by Cue format is envisioned in which phonetic perceptibility scales project corresponding ranked constraints into the OT grammar.

Blevins (2004) defends a more traditional view that synchronic grammars compute over representations in which phonetics is only reflected obliquely via distinctive features in their classificatory function. The rich phonetic grounding uncovered by studies such as Steriade's is attributed to asymmetries in actual speech samples that form the basis for induction of the grammar by the child who may misinterpret *anpa* as *ampa*, rephonologize a speaker's [ʔa] < /a/ as /ʔa/, or ground a phonological analysis in a different exemplar among a phoneme's range of permissible variants. This point of view places the study of sound change on an equal footing with synchronic structure and seriously implicates language acquisition as well. It encourages generative phonologists to open a new more integrative approach in their research

program. But despite changes in emphasis and technique, generative phonology remains committed to an explicit modeling of linguistic competence.

Bibliography

Anttila, A. (2002). 'Morphologically conditioned phonological alternations' *Natural Language & Linguistic Theory* 20, 1-42.

Blevins, J. 2004. *Evolutionary phonology*. Cambridge: Cambridge University Press.

Bloch, B. (1941). 'Phonemic overlapping' *American Speech* 16, 278-84.

Burzio, L. (1994). *Principles of English stress*. Cambridge: Cambridge University Press.

Charette, M. (1990). 'Licence to govern' Phonology 7, 233-54.

Chomsky, N. (1962). *Current issues in linguistic theory*. The Hague: Mouton.

Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht: Foris publications.

Chomsky, N. & Halle, M. (1968). *The sound pattern of English*. New York: Harper & Row.

Clements, G. N. & Keyser, S. J. (1982). *CV phonology*. Cambridge: MIT Press.

Clements, G. N. (1985). 'The geometry of phonological features' *Phonology Yearbook* 2, 225-52.

Dresher, E. & Kaye, J. (1990). 'A computational learning model for metrical phonology' *Cognition* 34, 137-94.

Ernestus, M. & Baayen, H. (2003). 'Predicting the unpredictable: interpreting neutralized segments in Dutch' *Language* 79, 5-38.

Flemming, E. 2005. Contrast and perceptual distinctness. In Hayes, B. et al (eds.) *The*

Phonetic Bases of Markedness. Cambridge University Press.

Goldsmith, J. (1976). *Autosegmental phonology*. Massachusetts Institute of Technology Ph.D. dissertation: Cambridge. [Published by Garland Press, New York, 1979]

Goldsmith, J. 1993. 'Harmonic phonology'. In Goldsmith, J. (ed.) *The last phonological rule*. Chicago: University of Chicago Press, 21-60.

Halle, M. (1959). *The sound pattern of Russian*. The Hague: Mouton.

Halle, M. (1962). 'Phonology in generative grammar' *Word* 18, 54-72.

Halle, M. & Vergnaud, J-R. (1987). *An essay on stress*. Cambridge: MIT Press.

Hayes, B. (1980) *A metrical theory of stress rules*. Massachusetts Institute of Technology Ph.D. dissertation: Cambridge. [Published by Garland Press, New York, 1985]

Hayes, B. (1985) 'Iambic and trochaic rhythm in stress rules', *Proceedings of Berkeley Linguistics Society 11. Parassession on Poetics, metrics, and prosody*. Berkeley: Berkeley Linguistic Society. 429-46.

Idsardi, W. (1998). 'Tiberian Hebrew spirantization and phonological derivations' *Linguistic Inquiry* 29, 37-73.

Kaye, J. (1990). *Phonological government*. *Phonology* 7,2 Special Issue.

Kaye, J. Lowenstamm, J. & Vergnaud, J-R. (1990) 'Constituent structure and government in phonology' *Phonology* 7, 193-232.

Kenstowicz, M. & Kisseberth, C. (1976). *Topics in phonological theory*. New York: Academic Press.

Kiparsky, P. (1968). 'How abstract is phonology?' Bloomington, Indiana: Indiana University Linguistics Club.

Kiparsky, P. (1971). 'Historical linguistics. In Dingwall, W. *A survey of linguistic*

science. College Park: University of Maryland Linguistics Program. 576-642.

Kiparsky, P. (1982). 'From cyclic phonology to lexical phonology' In van der Hulst, H. & Smith, N.(eds.) *The structure of phonological representations, part I*. Dordrecht: Foris. 131-75.

Kiparsky, P. (1985) 'Some consequences of lexical phonology' *Phonology Yearbook* 2, 85-138.

Kisseberth, C. 1970. 'On the functional unity of phonological rules' *Linguistic Inquiry* 1, 291-306.

Liberman, M. (1975). *The intonational system of English*. Massachusetts Intitute of Technology Ph.D. dissertation: Cambridge.

Liberman, M. & Prince, A. 1977. 'On stress and linguistic rhythm' *Linguistic Inquiry* 8, 249-336.

McCarthy, J. (1979). *Formal problems in Semitic phonology and morphology*. Massachusetts Intitute of Technology Ph.D. dissertation: Cambridge.[Published by Garland Press, New York, 1985]

McCarthy, J. & Prince, A. (1986/1996). *Prosodic morphology*. Report no. RuCC-TR-32. New Brunswick, NJ: Rutgers University Center for Cognitive Science. [Excerpts appear in Goldsmith J, ed. Essential readings in phonology. Oxford: Blackwell, 1999, 102-36.]

Padgett, J. (2003). 'Contrast and post-velar fronting in Russian' *Natural Language & Linguistic Theory* 21, 39-87.

Pierrehumbert, J. (1980). *The phonetics and phonology of English intonation*. Massachusetts Institute of Technology Ph.D. dissertation: Cambridge.

Pierrehumbert, J., Beckman, M. & Ladd, D. R. (1996). 'Laboratory phonology'. In *Current trends in phonology: models and methods*. Durand, J & Laks, B. (eds.) Manchester: European Studies Resarch Institute, University of Salford, 535-48.

Prince, A. (1983). 'Relating to the grid' *Linguistic Inquiry* 14, 19-100.

Prince, A. & Smolensky, P. (1993). *Optimality theory: constraint interaction in generative grammar*. Report no. RuCCS-TR-2. New Brunswick, NJ. Rutgers University Center for Cognitive Science. [Published by Blackwell: Cambridge 2004].

Selkirk, E. (1980). 'Prosodic domains in phonology: Sanskrit revisited', Aronoff, M. & Kean, M-L. (eds). *Juncture*, Saratoga, Ca.: Anma Libri, 107-29.

Selkirk, E. (1981). 'Epenthesis and degenerate syllables in Cairene Arabic' In *Theoretical issues in the grammar of Semitic languages*, Borer, H. & Aoun, J. (eds.) (*MIT Working Papers in Linguistics* 3), Cambridge: Department of Linguistics, MIT, 111-40.

Selkirk, E. (1982). 'The syllable' In van der Hulst, H. & Smith, N.(eds.) *The structure of phonological representations, part II*. Dordrecht: Foris. 337-83.

Selkirk, E. (1986). 'On derived domains in sentence phonology' *Phonology yearbook* 3, 371-405.

Sommerstein, Alan. 1974. 'On phonotactically motivated rules' *Journal of Linguistics* 10, 71-94.

Stampe, D. (1973). *A dissertation on natural phonology*. Chicago: University of Chicago Ph.D. dissertation. [Published by Garland Press, New York, 1979]

Stride, D. (1982). *Greek prosodies and the nature of syllabification*. Massachusetts Institute of Technology Ph.D. dissertation: Cambridge

Steriade, D. (1999). 'Alternatives to syllable-based accounts of consonantal phonotactics' In Fujimura, O. et al. (eds). *Proceedings of LP' 98*. Prague: Karolinum Press. Pp. 205-45.

Tesar, B. & Smolensky, P. (1998). 'Learnability in optimality theory' *Linguistic Inquiry* 29, 229-68.