

# Phonology

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## Abstract

Phonology deals with sound structure in language. While phonetics studies the physical properties of sounds, phonology concerns their mental representations. Phonology originated with the insight that much observable phonetic detail is irrelevant or predictable in language. This led to positing *phonemes* as minimal contrastive units, each comprising a collection of *distinctive features*. Later work went beyond this focus on surface contrast and re-conceived phonology as an aspect of speakers' mental grammars. Theoretical debates have involved the interaction of phonological regularities; the relation of phonology to other components of grammar; and the use of rules versus constraints to encode phonological regularities.

Phonology is concerned with the sound structure of words and utterances, the way distinctions in sound are used to differentiate linguistic items within a language, and the ways in which the sound structure of the 'same' element varies as a function of the other sounds in its context. While both phonology and phonetics are concerned with the role of sound in natural language, they differ in that phonetics deals with the articulatory, acoustic, and perceptual properties of sounds (*see* Phonetics, Articulatory), while phonology studies the ways in which these properties are represented in the mental grammar and how the grammar manipulates these representations.

## Goals of Phonology

The study of a language's particular phonological system has a number of aspects. First, it must be able to characterize the language's *inventory*: which phonetically possible sound types occur in utterances in the language? Second, it must characterize matters of *contrast*: which of the phonetic differences that occur in the language can serve to distinguish utterances (words, sentences, etc.) from one another? Third is the matter of *contextual limitation*: even though some property P occurs in language L, are there some environments from which P is excluded? And when P is apparently a property of (some part of) some element but that element occurs in a position from which P is excluded, what other property – if any – appears in its place? Finally, and to some phonologists most importantly, there is the description of *alternation*: when the 'same' linguistic element appears in different overt forms in different environments, what systematic differences occur? What conditions govern the range of phonetically distinct forms that can count as the 'same' word, morpheme, etc.?

It should be noted that the present article is limited to the phonological systems of spoken languages and ignores manual or signed languages (*see* Sign Language). This is misleading in important respects; it has been argued that most of the basic principles of spoken language phonology characterize the organization of signed languages as well (Coulter, 1993). Just as words are composed of sounds, and sounds of component properties, signs are also composed of structured systems of more basic constituent elements. Units such as the syllable

have close parallels in signed languages. While there are clear differences that depend on modality, these are argued to be relatively superficial. A comprehensive theory of phonology as a part of the structure of natural language should take these broader issues into account.

## Some History

Prior to the early twentieth century, studies of sound in language concentrated on the ways in which sounds are made (articulatory phonetics), often confusing the letters of a language's writing system with its sounds. Toward the end of the nineteenth century, however, increasing sophistication of measurement techniques made it possible to explore a much wider range of differences among sounds, and to lay out the structure of speech in vastly greater detail. Much of what was found involved the observation that speech is continuous, such that whatever is going on at any particular moment is at least a little different from what has gone on just before and what will go on immediately afterward. A full characterization of an utterance as a physical event requires the recognition of a potentially unlimited number of distinct points in time, but it is clear that our understanding of an utterance as a *linguistic* event is hindered, rather than helped, by the recognition of this continuous character of speech. Speech normally is represented as a sequence of a small number of discrete segments, strung out in consecutive fashion like beads on a string; although such a *segmental* representation is fairly abstract, it vastly facilitates the discovery of regularity and coherence in language.

It is clear that the role of particular sound differences varies considerably from one language to another. Thus, in English, the vowel sound in the word *bad* is much longer than that in *bat* (more than half again as long), but such a difference in length is always predictable as a function of the following sound, and never serves by itself to distinguish one word from another. In Tahitian, in contrast, essentially the same difference in length is the only property distinguishing, for example, *paato* 'to pick, pluck' from *pato* 'to break out.' A theory of sound that attends only to physical properties has no way of clarifying the quite different functions these properties may have across various languages.

### Saussure and the 'Phonemic Principle'

The great Swiss linguist Saussure (1916) was the first to stress that in order to understand the role of sound in language, it is necessary to focus not (just) on the positive properties of sounds, but on their differences. He suggested that in the study of individual languages, as opposed to general phonetics, utterances should be characterized in such a way that two such representations might differ only in ways that could potentially correspond to a difference between two distinct messages in the language in question. Thus, since long and short vowels never (by themselves) distinguish two distinct utterances in English, the difference should not be indicated in that language, while for Tahitian, it must be. A representation with this property will be called *phonological*; it will obviously be specific to a particular language, and the distinctive elements that appear in it can be called the *phonemes* of that language.

While Saussure enunciated this principle quite forcefully and persuasively, he provided few specific details of just what a phonological representation should look like. There are in fact a variety of ways in which his insight could potentially be realized, and much subsequent discussion in phonology hinges on these differences of interpretation.

### The Development of Phonology as a Theory

Various individual investigators arrived at conclusions similar to Saussure's about the importance of attention to language-particular sound contrasts. One of these was the Polish linguist Baudouin de Courtenay (1972), whose work actually antedated Saussure's but attracted less attention. He developed a sophisticated view of the relation between phonetics and phonology both in individual grammars and in linguistic change. As transmitted by his later students, Baudouin's views on the nature of the phoneme constituted an important strand in thinking about language as this developed in Russian linguistics in the early years of the twentieth century. This, in turn, provided the background from which the work associated with the Linguistic Circle of Prague grew in the 1920s and 1930s.

Two of the most prominent members of the Prague Circle were Trubetzkoy (1939) and Jakobson (1941). In their studies of Slavic languages and their histories, they stressed the notion that the collection of potentially contrastive sound types in a language was not simply an inventory, but a highly structured system. This system is organized in terms of a small number of mutually orthogonal dimensions (such as voicing, stop vs continuant, nasality, etc.), each of which serves in parallel fashion as the basis of multiple contrasts. The notion that the fundamental terms of sound structure in language are these properties themselves and not (or at least not only) the complete sounds they characterize has remained an important component of most subsequent theorizing.

### American Structuralist Phonology

Early thinking about sound structure in America was dominated by the anthropological interests of Franz Boas and focused on an accurate rendering of the sound contrasts in the comparatively 'exotic' indigenous languages of the new world. Boas's student Edward Sapir, however, was concerned to place the study of language in the broader context of an understanding of the human mind and society. Therefore, he stressed (Sapir, 1925) the notion that the elements of sound

contrast in a language should be regarded as having a primarily mental reality, part of the speaker/hearer's cognitive organization rather than as external, physical events.

The rise of positivist views of science in the 1930s, and especially of behaviorist psychology, made Sapir's type of mentalism quite marginal, and replaced it with more rigorous operational procedures for investigating notions of contrast. Especially associated with the ideas of Bloomfield (1933) and later structuralists such as Harris (1951), the result was a theory of the phoneme based exclusively (at least in principle) on a set of mechanical manipulations of corpora of observed linguistic data, from which a set of contrasting minimal elements was to be derived. The central notion of this theory was a phonemic representation related to surface phonetic form in a way that would later be formulated explicitly as a condition of *bi-uniqueness*: the requirement that given either a phonetic or a phonemic representation of an utterance in a given language, that could be converted uniquely into the other (disregarding free variation) without additional information.

### Generative Phonology

The phonemic theories of American structuralists provided a way to characterize linguistic contrasts, the inventories of sound types used in a given language, and the ways in which sounds can be combined into larger structures, but other aspects of sound structure were less satisfactorily accommodated within those views. In particular, questions of the ways in which unitary meaningful elements change in shape according to their sound context (or 'allomorphy') failed to receive systematic treatment. Since any difference among sounds that could serve to contrast linguistic elements was *ipso facto* a difference between irreducibly basic terms, there was really no way to express the notion that a single item could take a variety of forms (as in the prefixes in *inefficient*, *imprecise*, *irregular*, *illegal*, etc.) except by simply listing the variants. Such a list is undoubtedly appropriate for cases such as the forms of English to be (*am*, *are*, *is*, *was*, *were*, etc.) which are unrelated to one another in form; but in many other cases, the variation is transparently systematic and a function of the sounds in the element's environment. This sort of variation was recognized by structuralist phonologists, but relegated to marginal status.

Beginning with the work of Morris Halle, a student of Jakobson, linguists began to question the centrality of surface contrasts in sound structure. The result was a new view that allowed morphophonemic regularities as well as more superficial ones to be accommodated within a phonological description. The success of this more abstract notion of sound structure in dealing with hitherto irresolvable problems in the description of stress (see Suprasegmentals) contributed greatly to its success, and the resulting theory of generative phonology as developed in the work of Halle together with Noam Chomsky rapidly became the dominant view in the field by the middle of the 1960s.

### Phonology as a System of Rules and Representations

A basic insight in the development of generative phonology was the proposal that it is not only the representation of linguistic elements in terms of basic contrasts that matters: an adequate theory must characterize what a speaker knows about

the sound system of the language, and that includes regularities of variation and alternation as well as inventories of basic elements. Combining these two aspects of phonological knowledge required the explicit recognition of a system of rules (expressions of regular patterns of contrast and variation in sound shape) in addition to the theory of representations. Developing an adequate theory of phonological rules, in turn, necessitated a notion of phonological representation that was related to surface phonetic reality in a much more complex and indirect way than the phonemic representations of structuralist linguistics. The central problems of phonological theory came to be articulated in terms of the theory of rules, their nature, and their interaction, and the underlying phonological representations that need to be posited in order to allow them to be expressed in their full generality.

### Issues in Phonological Theory

As reviewed in the section ‘Some History’ above, the problem of phonological description was originally conceived as a matter of discerning the range of contrastive sound units in a language and arranging them in a system that brings out the dimensions of their contrast. When phonology is seen as a form of knowledge, however, as generative phonologists have stressed, the sound structure of natural language takes on quite a different form and presents quite different problems. Among these are (1) the nature of underlying (‘phonological’ or ‘phonemic’) representations as well as surface (‘phonetic’) representations; (2) the ways in which phonological regularities serve to relate phonological to phonetic representation, including the interactions that may obtain among regularities; and (3) the relation between phonological form and other aspects of linguistic knowledge, such as word structure (see Morphology in Linguistics) and sentence structure. Various aspects of these questions are addressed below.

### The Abstractness of Phonological Representation

Initial reaction to the proposals associated with generative phonology centered on its abandonment of a phonemic representation based on the condition of biuniqueness. Relaxing this defining characteristic of structuralist phonemics led to phonological representations that were considerably more abstract in their relation to phonetically observable properties. The proposals of Chomsky and Halle (1968) concerning the analysis of English, for example, involved positing final ‘silent *e*’ in words like *burlesque* (phonologically /bʌrleskə/), geminate consonants in words like *confetti* (/kɒnfɛtʃi/), a distinction among /k, s, c/ such that *acquiesce* is phonologically /ækwiɛsɪs/, etc. Indeed, there were no constraints whatsoever on the relation between phonological and phonetic form, apart from the desire to set up underlying forms from which as much variation as possible in the shapes of particular morphological units could be predicted. Since much of this variation is the residue of earlier sound changes that have affected the same element in different ways in different environments, many early generative analyses resembled historical accounts of the language more than they did the knowledge of current speakers.

The perception of such apparently excessive abstractness led to proposals for constraining the operation of phonological rules in grammars, and the kinds of representation that should be posited. Kiparsky (1973), in particular, suggested a variety of conditions that would have the effect of prohibiting rules of ‘absolute neutralization’ (by which some posited phonological distinction is eliminated uniformly in surface forms, such that it never corresponds directly to a phonetic distinction) and other perceived abuses of the theory’s representational freedom. Other researchers, however, have pointed out cases where absolute neutralization does seem to be called for in the analysis of particular languages, since it allows for an explanation of the different behaviors of sets of surface-identical segments within the phonological system. The notion of *learnability* entered into this debate, with proponents of constraints on abstractness arguing that a highly abstract system is not learnable; others have argued that abstract systems are indeed learnable when there is evidence for the abstract structures in the form of alternations. The tension between a constrained universal theory versus an empirically adequate and/or elegant analysis of specific languages is apparent here as in other theoretical debates in the field. At present there is no real consensus in the field as to what, if any, constraints on abstractness should be hypothesized to exist in grammars.

### The Interaction of Phonological Regularities

In the nature of a structuralist phonemic representation, all of the regularities expressed in the grammar are mutually independent. That is, it is only necessary to know the phonemic environment of a phoneme to predict its phonetic realization, and it is only necessary to know the phonetic environment of a phonetic segment to establish its phonemic correlate. When the bi-unique relation between these levels of representation is relaxed, however, more complex possibilities arise for regularities to interact with one another.

Consider the formation of English regular plurals, for example. For the words *cat*, *dog*, *horse* (roughly (kæt), (dɒg), (hɔrs) respectively, phonetically), the corresponding plurals are *cats*, *dogs*, *horses* ((kæts), (dɒgz), (hɔrsɪz)). Assume that the phonological representations of the nouns are essentially the same as their phonetic forms, and that the regular plural ending has a single constant phonological form: /z/ for concreteness’ sake, though the point to be made is independent of this choice. Now there are two distinct regularities that are involved in determining the pronunciation of the plural ending:

- If the noun ends in a sibilant ((s, z, ʃ, ʒ, tʃ, dʒ)), a vowel (ɪ) appears between the stem and the ending.
- If the stem-final sound is voiceless, the ending is voiceless ((s)) as well.

Now consider how these principles interact in determining that the pronunciation of *horses* (phonologically /hɔrs + z/) should be (hɔrsɪz). In this case, the conditions for both of the rules above, *b* as well as *a*, are met, and we might expect both to apply, yielding (incorrect) (hɔrsɪs). The relevant observation is the following: the vowel inserted as a result of rule *a* has the effect that the stem and the ending are no longer adjacent, and so rule *b* is inapplicable. That is, the regularity

represented by rule *b* in this case presupposes that the set of clusters of consonants that will remain adjacent in surface forms (a matter that is potentially affected by applications of rule *a*) has been determined. This logical relation of presupposition between rules is generally expressed by saying that rule *a* applies 'before' rule *b*. In some cases, such rule ordering produces *opacity*, wherein the inspection of a surface form seems to show that a rule should have applied but didn't (*underapplication*) or a rule applied that should not have (*overapplication*). In the theory of rule ordering, these effects are explained by rule *b* creating the surface environment in which rule *a* would have applied if *b* had applied first (in the case of underapplication), or rule *b* eliminating the surface environment in which *a* applies, but after *a* has already applied (in the case of overapplication). Crucial to modeling such effects is the notion that the output of rule *a* is an intermediate form in the derivation, and it is to this intermediate form that rule *b* will then apply.

Much of the abstractness of early generative phonological analyses was made possible precisely by the availability of rule ordering as a descriptive device: the possibility of specifying rule interactions such as the above as an independent parameter within grammars. Although arguments for the necessity of such ordering formed an important part of the literature, and particular accounts sometimes involved apparently crucial depths of ordering as great as 12–15, some linguists felt that (as part of the general campaign to reduce abstractness in phonology) stipulated ordering relations ought not to be permitted as a descriptive device. Despite the existence of cases apparently requiring irreducible specification of relative order (e.g., dialects with the same sets of rules and underlying forms, differing in their surface forms only as a consequence of different interactions of the rules) and the fact that all proposed formulations of principles from which observed rule interactions could supposedly be predicted had obvious and well-established counterexamples, a number of linguists have persisted in their belief that 'extrinsic' rule ordering statements ought to be prohibited. This view leaves a number of kinds of empirically observed interactions unaccounted for, a problem that persists as many phonologists have turned from rules to constraints as descriptive devices.

### The Structure of Representations in Phonology

As already noted, the description of speech at either the phonetic or the phonological level as composed of a sequence of discrete segment-sized units is an abstraction from physical reality. Its justification comes not from directly observable acoustic properties of sounds, but from the extent to which it allows the analyst to uncover what is orderly and coherent in linguistic structure. By the mid-1970s, however, it had become apparent that a purely segmental organization of representations impeded the description of linguistic regularity in several respects.

One of the first of these problems to be discussed arose from the analysis of systems of tonal contrasts, common in the languages of Africa and Asia and, in fact, much of the world. Careful analysis revealed multiple ways in which tonal properties were problematic for strictly segmental models: first, what appeared to be a single tonal specification might take as its

scope more than a single segment (perhaps the vowels of several consecutive syllables, or an entire word); second, what appeared to be a single segment (a unitary short vowel, for example) might have a tonal specification involving two or even more consecutive tonal levels; and third, there was evidence for tones existing in the phonological representation of a word but not belonging to or being directly phonetically realized on any segment in that word. If it is assumed that each of the consecutive segmental units of which a representation is composed bears exactly one specification for each potentially distinctive property, and the specifications of distinct segments are independent of one another, all of these situations are anomalous.

As a result of these observations, the segmental view came to be replaced with an *autosegmental* notion of representation. On this view, specifications for each potentially distinctive property (or feature) succeed one another discretely, but an additional dimension of representation is the specification of the way these are synchronized or aligned with other properties or features. In the limiting case, where each specification for a given feature is temporally aligned with one and only one specification for each of the other features, the standard segmental picture arises; in other cases, the relations among these features are not one-to-one. Once this view was articulated, it became apparent that many properties other than those of tone were also most appropriately described in this way. Nasality, in particular, behaves similarly in many languages, and the very common phenomenon of assimilation (including vowel harmony, voicing assimilation, and assimilation in place of articulation) is often best treated as an alteration in the scope of some features rather than a change in their values.

A theory of autosegmental representations where each feature stands alone would fail to account for the fact that in many cases, groups of features act as a unit. For example, in the domain of vowel harmony, often two or more features harmonize simultaneously (e.g., the features representing backness and roundness). This observation gave rise to the notion that phonological features are not just an unordered set, but instead are organized into a hierarchical arrangement such that, for example, features of consonantal place of articulation can be manipulated by the grammar as a unit. As of the early 1990s there was some degree of consensus on specific groups of features that should be organized under distinct representational nodes in such a *feature geometry*, but with the advent of constraint-based theories, many phonologists turned to other questions and abandoned the effort to work out the full details of a universal feature geometry. At present, many questions in this area remain unresolved.

Another representational issue concerns the existence of structural units larger than the single segment, such as the syllable. Classical generative phonology, as represented by, for instance, Chomsky and Halle (1968), makes no appeal to syllables (or any other unit above the segment). This was not simply an omission, but rather a systematic claim to the effect that segmental specification could always suffice to express any phonological generalization: that is, that any observation involving syllables (of which there are many in Chomsky and Halle, 1968) could be satisfactorily reformulated in a way that dispensed with any units other than segments. The

boldness of this claim invited immediate attack, and it soon became clear that there were indeed aspects of phonological structure that required reference to syllables and other supra-segmental units. The resulting theory of the *prosodic hierarchy*, by which segments are grouped into syllables, themselves grouped together into *metrical feet*, which in turn form constituents of *phonological words* (perhaps with some additional categories, according to some writers), has become another standard assumption about phonological structure.

### Interactions between Phonology and Other Areas of Grammar

The original conception of a generative phonology was as a component of the grammar that served to map lexically specified syntactic structures onto phonetic form, a representation appropriate to serve as the instructions to the language-independent mechanisms of speech production. This picture logically entails the notion that words, phrases, and sentences are already fully assembled in the input to the phonology. This assumption, however, has proven to be problematic.

The notion that phonological properties interact with the syntactic environment in which forms occur is quite a familiar one, especially in the description of accent and intonation (see Suprasegmentals). Word formation, too, may depend in some instances on phonological properties of roots and affixes (see Morphology in Linguistics) in a way that contradicts the assumption that phonology applies strictly to the output of this part of the grammar.

The most extensively elaborated picture of how phonology interacts with the rest of grammar is presented by the theory of lexical phonology (see papers in Hargus and Kaisse, 1993 for introduction and explication). Briefly, this picture distinguishes between lexical and postlexical regularities, with the former applying in a way that interacts with word formation, and the latter applying to a representation in which fully formed words appear in their syntactic context. The lexical rules, in turn, may (depending on the language) be divided into two or more *strata*, for example, rules applying to *roots*, *stems*, or *words*. A process of word formation takes some lexical unit as its input and yields an output (affixed or otherwise altered in form), with this output then subject to appropriate phonological modification. The resultant representation may serve as the input to further *cycles* of word formation plus phonology, until a complete surface word is arrived at. Words, assembled into larger syntactic constructions, are then subject to the post-lexical rules.

While various forms of lexical phonology generally constitute the background assumption of much phonological discussion, such a view of the overall architecture of grammar has at times been rejected. In particular, constraint-based theories involving a single stage in the conversion of underlying to surface form are, in their strictest form, incompatible with the sequential, derivational character of lexical phonological description. Later work in constraint-based models recognized the need for phonology to be sensitive to the internal structure of words and has attempted to reincorporate this sensitivity into the theory in various ways.

### Rules versus Constraints in Phonological Description

Formulations of phonological regularities since the 1950s have drawn on the mechanisms of automata theory:

typically, these have been expressed as rewriting rules that map an input representation onto an output, one step at a time. In the early 1990s, however, an alternative possibility was suggested. Instead of converting inputs to outputs in several stages, with each step involving the imposition of a single regularity in the computation of a new representation, one might formulate all of the regularities as elements of a single system of constraints. If these constraints are ranked with respect to one another, it is possible to say that any particular constraint may be violated in the output, provided that such a violation is motivated by the need to avoid violating a more important (higher ranking) constraint. The resulting theory provides an architecture of grammar that is very different from that which previously dominated most of the literature in phonology. For example, the kinds of interaction among regularities treated above as matters of rule ordering can no longer be described in this way, since all of the constraints in the grammar apply (in principle) in a single, simultaneous block. Constraints can have a language-particular ranking among themselves, but this is a matter of priority, not serial ordering. Other differences have been alluded to in the discussion above.

Constraint-based theories along the lines of optimality theory (OT; Prince and Smolensky, 1993) became the most popular mode of phonological theorizing in the US in the 1990s. The earliest versions of OT were argued to be very simple, with a set of universal constraints and a parallel input-output mapping. Attempts to fit known phonological patterns into this theoretical framework posed serious problems, however. It was soon acknowledged that not all constraints can be universal; the theory needs to allow for language-specific constraints to be learned. Cases of opacity were also especially problematic, since a strictly parallel model has no way of incorporating the notion of intermediate forms that were crucial to modeling opacity in rule-based phonology. Various attempts were made to work around this problem with a series of add-ons to the original OT proposal, each of which was criticized as excessively powerful, inadequate to account for all types of opacity, and/or a rejection of the notion of parallelism that had made OT appealing to many phonologists in the first place. No consensus has been reached as to the proper treatment of opacity in constraint-based models. Another significant problem was in the failure of constraint-based theories to take the results of research in lexical phonology into account, since the original OT model was, by design, insensitive to word-internal morphological structure. Later models did incorporate word structure in various ways; for example, stratal OT is essentially OT combined with lexical phonology such that input-output mappings are still done in parallel within each level, but different levels (root, stem, word) constitute separate stages in a derivation. The state of constraint-based theories in the early 2010s appears somewhat fragmented, with some theorists pursuing models that look much more like rule-based theory in incorporating serially ordered steps in a derivation, and others positing numerically weighted constraints as opposed to strict rankings. A number of researchers reject constraint-based theories entirely, arguing against them in favor of rule-based phonology on empirical and conceptual grounds; Vaux and Nevins (2008) give an overview of this debate.

**See also:** Phonetics, Articulatory; Saussure, Ferdinand de (1857–1913); Speech Perception; Speech Production, Neural Basis of; Speech Production, Psychology of.

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