Chapter seven

THE PHONETIC FRAMEWORK

1. *Phonetic representation*

1.1. PHONETIC TRANSCRIPTION AND THE SPEECH SIGNAL

The phonological component expresses the relationship between the surface structure of a sentence and its physical actualization insofar as this relationship is determined by grammatical rule, in the very general sense which we will elucidate below. The surface structure may be represented as a string of formatives, properly bracketed with labeled brackets (see Chapter One, Section 5). Given the surface structure of a sentence, the phonological rules of the language interact with certain universal phonetic constraints to derive all grammatically determined facts about the production and perception of this sentence. These facts are embodied in the "phonetic transcription." Therefore, as P. Postal has remarked, this transcription represents:

> the derivative knowledge a speaker has about the pronunciation by virtue of his knowledge of the superficial syntactic structure of the sentence, the lexical items or formatives it contains and the rules of phonology . . . The phonetic transcription . . . is the most gross and superficial aspect of linguistic structure . . . It is the most important but far from the only parameter determining the actual acoustic shape of the tokens of the sentence.

Our conception thus differs from an alternative view that the phonetic transcription is primarily a device for recording facts observed in actual utterances. That the latter view is not tenable, in any very strict sense, has been known at least since mechanical and electrical recordings of utterances have revealed that even the most skillful transcriber is unable to note certain aspects of the signal, while commonly recording in his transcriptions items for which there seems to be no direct warrant in the physical record. But even if the phonetic transcription were as faithful a record of speech as one could desire, there is still some question whether such a record would be of much interest to linguists, who are primarily concerned with the structure of language rather than with the acoustics and physiology of speech. It is because of this question that many structural linguists have felt that phonetics has very little to offer them and have therefore assigned to it a secondary, peripheral role.[1]

[1] As an illustration of this lack of interest in phonetics we may cite the numerous articles on phonological subjects that have appeared in the last thirty years in journals such as the *International Journal of American Linguistics* in which information concerning the phonetic properties of the phonemes of a language is often restricted to a simple listing of alphabetic symbols.
See also comments in Chomsky (1964, page 69n and pages 76 f).

These problems do not arise when phonetic transcription is understood in the terms outlined above, that is, not as a direct record of the speech signal, but rather as a representation of what the speaker of a language takes to be the phonetic properties of an utterance, given his hypothesis as to its surface structure and his knowledge of the rules of the phonological component. Since in this view phonetics is concerned with grammatically determined aspects of the signal, there can be no question about the relevance of phonetics to the study of language. Moreover, since the phonetic transcription, in this sense, represents the speaker-hearer's interpretation rather than directly observable properties of the signal, the existence of certain discrepancies between the transcription and the signal can be understood. Thus it is no longer a problem that the transcription is composed of discrete symbols whereas the signal is quasi-continuous, or that the transcription provides information only about some properties of the signal and not about others, or, finally, that physically identical signals may have distinct phonetic transcriptions. Clearly, a person's interpretation of a particular speech event is not determined merely by the physical properties constituting the event. A person will normally not be aware of many properties manifest in the signal, and, at the same time, his interpretation may involve elements which have no direct physical correlates,[2] since what is perceived depends not only on the physical constitution of the signal but also on the hearer's knowledge of the language as well as on a host of extragrammatical factors.

Implicit in this approach is the view that speech perception is an active process, a process in which the physical stimulus that strikes the hearer's ear is utilized to form hypotheses about the deep structure of the sentence. Given the deep structure and the rules of the grammar, all other representations of the sentence can be derived, including in particular the phonetic transcription, which is the terminal representation generated by the grammar.[3] These derived representations are used by the speaker to check his hypothesis against the external stimulus, which provides the data that stand in the most direct (though not necessarily a point-by-point) relationship with the phonetic transcription. Since the hypotheses made in speech perception are highly specific—that is, we understand our interlocutor to have said a particular sentence—they are highly improbable. Consequently even crude agreement between the external stimulus and the internally generated hypothesis suffices to confirm the latter. In other words the dependence of perception on properties physically present in the signal is less than total. What is more, there are many extragrammatical factors that determine how close a fit between data and hypothesis is required for confirmation.

In the phonetic transcription an utterance is represented as a sequence of discrete units, each of which is a complex of phonetic features such as voicing, nasality, tongue height, etc. The phonetic transcription can therefore be taken to be a two-dimensional matrix in which the columns stand for consecutive units and the rows stand for different features. At this level of representation each feature is to be thought of as a scale. A particular entry in the matrix, then, indicates the position of the unit in question on the given scale. The total set of features is identical with the set of phonetic properties that can in principle

[2] In fact, we do not wish to exclude the possibility that under certain conditions distinctions that might be implied by the phonological rules of the language may not actually be realizable. This seems particularly to be true in the case of the different degrees of stress predicted by the stress subordination rules discussed in Chapter Three.

[3] It is not necessarily the case that each deep structure determines a single phonetic representation; if the grammar contains optional rules or analyses, a given deep structure can underlie two or more phonetic transcriptions.

be controlled in speech; they represent the phonetic capabilities of man and, we would assume, are therefore the same for all languages.

As already noted, phonetic transcriptions consistently disregard many overt physical properties of speech. Among these are phonetic effects that are not locatable in particular segments but rather extend over entire utterances, such as the voice pitch and quality of the speaker and also such socially determined aspects of speech as the normal rate of utterance and what has been called by some writers the "articulation base":

> the system of characteristic articulatory movements of a given language that confer upon it its general phonetic aspect; in French the mobility of the lips and forward position of the tongue (Marouzeau, 1943, p. 38).

In addition, phonetic transcriptions omit properties of the signal that are supplied by universal rules. These properties include, for example, the different articulatory gestures and various coarticulation effects—the transition between a vowel and an adjacent consonant, the adjustments in the vocal tract shape made in anticipation of subsequent motions, etc.

1.2. PHONETIC AND PHONOLOGICAL REPRESENTATION

As mentioned above, the phonetic transcription is related by the rules of the phonological component to a string of formatives with labeled bracketing which represents the surface syntactic structure of the sentence. We will now examine in some detail the manner in which these formatives are represented in a linguistic description. Many of the formatives are lexical items, the "roots" or "stems" of traditional grammar. A grammar must include a list of these items, for part of a speaker's knowledge of his language consists of knowing the lexical items of the language. It is by virtue of this knowledge that the native speaker is able to distinguish an utterance in normal English from an utterance such as Carnap's "Pirots karulized elatically" or from Carroll's jabberwocky, which conform to all rules of English but are made up of items that happen not to be included in the lexicon of the language.

The representations of the individual items in the lexicon must incorporate the knowledge which makes it possible for the speaker to utilize each lexical item in grammatically correct sentences. This includes certain syntactic information which the speaker must have. For example, he must know that a particular item is a noun and that it belongs to a large number of intersecting categories such as "animate" or "inanimate," "human" or "nonhuman," "feminine" or "masculine." Since the only question of interest here is whether or not a given item belongs to the category in question, it is natural to represent this information by means of a binary notation: *cow*, for example, would be specified as [+animate, −human, +feminine]. In addition to these syntactic features, each lexical entry must contain specified features which determine the phonetic form of the item in all contexts. We shall call these the "phonological features." The phonological features cannot be chosen arbitrarily, for the phonological component would then have to include a huge number of ad hoc rules of the type

$$[+A, -B, -C, +D] \rightarrow [\text{h\'{ʌ}t}]$$
$$[-A, -B, -C, +D] \rightarrow [\text{r\'{ʌ}t}]$$
$$[-A, +B, -C, +D] \rightarrow [\text{əl\'{i}ps}]$$

Moreover, if we represented lexical items by means of an arbitrary feature notation, we would be effectively prevented from expressing in the grammar the crucial fact that items which have similar phonetic shapes are subject to many of the same rules.

We might consider overcoming these difficulties by representing each lexical item in its phonetic representation. However, this solution is not open to us either, for a lexical item frequently has several phonetic shapes, depending on the context in which the item appears. If we chose to represent each lexical item by the set of its phonetic representations, we would be treating all phonetic variations as exceptions and would, in principle, be unable to express within our grammar the phonetic regularities and general phonological processes that determine phonetic form. If, on the other hand, we chose to allow only a single phonetic representation for each item, then we would have to provide some rationale for our selection. Furthermore, it is easily shown that many of the most general and deep-seated phonological processes cannot be formulated as rules that directly relate phonetic representations; rather, these processes presuppose underlying abstract forms.

We therefore can represent lexical items neither in phonetic transcription nor in an arbitrary notation totally unrelated to the elements of the phonetic transcription. What is needed is a representation that falls between these two extremes. Accordingly we propose that each item in the lexicon be represented as a two-dimensional matrix in which the columns stand for the successive units and the rows are labeled by the names of the individual phonetic features. We specifically allow the rules of the grammar to alter the matrix, by deleting or adding columns (units), by changing the specifications assigned to particular rows (features) in particular columns, or by interchanging the positions of columns. Consequently, the matrix that constitutes the phonetic transcription may differ quite radically from the representation that appeared in the lexicon. There is, however, a cost attached to such alterations, for they require the postulation of rules in the phonological component. Such rules are unnecessary in cases where the lexical representation can be accepted as the phonetic representation. In general, the more abstract the lexical representation, the greater will be the number and complexity of the phonological rules required to map it into a phonetic transcription. We therefore postulate abstract lexical entries only where this cost is more than compensated for by greater overall simplification—for example, in cases where the combination of abstract lexical entries and a set of rules permits the formulation of phonological processes of great generality that would otherwise be inexpressible.

Thus, lexical representations and a system of phonological rules are chosen in such a way as to maximize a certain property that we may call the " value " of the grammar, a property that is sometimes called " simplicity." As has been emphasized repeatedly in the literature, the concept of " simplicity " or " value " is an empirical one. There is some correct answer to the question of how lexical items are represented and what the phonological rules are. A particular notion of " value " or " simplicity " will lead to an assumption about lexical items and phonological rules which is either right or wrong, and therefore the validity of the notion must be determined on empirical grounds, exactly as in the case of every other concept of linguistic theory. It may be difficult to obtain crucial empirical evidence bearing on proposed definitions of " simplicity," but this cannot obscure the fact that it is an empirical concept that is involved, and that one can no more employ a priori arguments in determining how " value " should be defined than in determining how to define " set of distinctive features " or " grammatical transformation " or any other concept of linguistic theory.

A specific proposal as to the definition of " value " will make certain assumptions as to what constitutes a linguistically significant generalization, as to what constitutes a " regularity " of the sort that a child will use as a way of organizing the data he is confronted with in the course of language acquisition. The child is presented with certain data; he arrives at a specific grammar, with a specific representation of lexical items and a certain system of phonological rules. The relation between data and grammar is, we naturally assume, language-independent: there is no basis for supposing that individuals differ genetically in their ability to learn one rather than another natural language. Consequently, the relationship is determined by a principle of universal grammar. Specifically, the definition of "value" or "simplicity" must be part of universal grammar, and a specific proposal will be right or wrong as it does or does not play its part in accounting for the actually existing relation between data and grammar.

Summarizing, we postulate a set of lexical matrices and a system of phonological rules which jointly maximize value, in some sense which will be defined. Phonological representation in terms of lexical matrices (as modified through readjustment rules—see Chapter One, Section 5.1, and Chapter Eight, Section 6.5) is abstract in the sense that the phonological representation is not necessarily a submatrix of the phonetic representation. We do not, in other words, impose the conditions of linearity and invariance (see Chomsky, 1964) on the relation between phonological and phonetic representation. The indirectness of this relation must be purchased at the cost of adding rules to the grammar. Given a definition of "value," we can therefore say that the facts of pronunciation induce the representation of items in the lexicon.[4]

Notice that the phonetic features appear in lexical entries as abstract classificatory markers with a status rather similar to that of the classificatory features that assign formatives to such categories as "noun," "verb," "transitive." Like the latter, the phonological features indicate whether or not a given lexical item belongs to a given category. In the case of the phonological matrices, these categories have the meaning "begins with a voiced stop," "contains a vowel," "ends with a strident nonback obstruent," and so on. In view of the fact that phonological features are classificatory devices, they are binary, as are all other classificatory features in the lexicon, for the natural way of indicating whether or not an item belongs to a particular category is by means of binary features. This does not mean that the phonetic features into which the phonological features are mapped must also be binary. In fact, the phonetic features are physical scales and may thus assume numerous coefficients, as determined by the rules of the phonological component. However, this fact clearly has no bearing on the binary structure of the phonological features, which, as noted, are abstract but not arbitrary categorial markers.[5]

As already noted, the phonetic representation can be thought of formally as a two-dimensional matrix in which the columns stand for consecutive units and the rows stand for individual phonetic features. The phonetic features can be characterized as physical scales describing independently controllable aspects of the speech event, such as vocalicness, nasality, voicing, glottalization. There are, therefore, as many phonetic features as there are aspects under partially independent control. It is in this sense that the totality of phonetic features can be said to represent the speech-producing capabilities of the human vocal apparatus. We shall say that the phonetic representations of two units are distinct if they differ in the coefficient assigned to at least one feature; phonetic representations of sequences of units are distinct if they contain distinct units or if they differ in the number or order of units.

At the level of phonetic representation, utterances are comparable across languages; it thus makes sense to ask whether the phonetic representation of an utterance of language L_1 is distinct from a phonetic representation of an utterance of a different language L_2. For

[4] For additional discussion see Chapter Four, Section 2.

[5] Failure to differentiate sharply between abstract phonological features and concrete phonetic scales has been one of the main reasons for the protracted and essentially fruitless debate concerning the binary character of the Jakobsonian distinctive features.

example, an utterance containing an apical dental stop must have a different phonetic representation from an utterance that is identical except for containing a laminal dental stop in place of the apical dental stop. The representation must differ since the distinction is determined in part by language-specific rules; it is not a case of universal free variation. An interesting example of cross-language contrasts that require a special phonetic feature is provided by the labiovelar consonants found in many African languages. In some languages, such as Yoruba, these consonants are produced with a special clicklike suction, whereas in other languages, such as Late, they are produced without this suction (Ladefoged, 1964, p. 9). Since clicklike suction is clearly an independently controllable aspect of the speech event, the data just cited establish suction as a separate phonetic feature, regardless of the fact that apparently in no language are there contrasting pairs of utterances that differ solely in this feature.

The situation is not always straightforward, however. Since phonetic features are scales which may in principle assume numerous discrete coefficients, the question may arise, under certain circumstances, whether a certain phonetic contrast is to be represented by means of a new phonetic feature or by increasing the number of coefficients that some already extant phonetic feature may be allowed to assume. The latter solution may appear especially attractive in cases where a slight redefinition of some phonetic feature would readily accommodate the proposed solution.

To summarize, the features have a phonetic function and a classificatory function. In their phonetic function, they are scales that admit a fixed number of values, and they relate to independently controllable aspects of the speech event or independent elements of perceptual representation. In their classificatory function they admit only two coefficients, and they fall together with other categories that specify the idiosyncratic properties of lexical items. The only condition that we have so far imposed on the features in their lexical, classificatory function is that lexical representations be chosen in such a way as to maximize the " value " of the lexicon and grammar, where the notion " value " is still to be defined precisely, though its general properties are clear. Apart from this, the representation of a lexical item as a feature complex may be perfectly abstract.

In a later discussion (see Chapter Nine), we will consider significantly heavier conditions on lexical representation. There we will turn to the question of " plausible phonological rules " and, more generally, to ways in which a particular feature may or may not function in the lexicon and in the phonology. These considerations will differentiate features from one another with respect to the role that they can play in the system of rules and in lexical representation. At that point in the development of our theory, considerations beyond maximization of value will enter into the determination of lexical representations.

2. *The phonetic features*

In the remainder of this chapter we attempt to sketch the universal set of phonetic features. Our aim is to cover every inherent phonetic feature regardless of whether it plays a role in the phonetics of English. We are well aware of the many gaps in our knowledge that make the success of this undertaking somewhat problematical, but we feel that general phonetics has been neglected for so long that agreement on even the most elementary propositions of phonetic theory cannot be taken for granted at present.

In the succeeding pages we shall list the individual features that together represent the phonetic capabilities of man. Each feature is a physical scale defined by two points, which are designated by antonymous adjectives: high-nonhigh, voiced-nonvoiced (voiceless), tense-nontense (lax). We shall describe the articulatory correlate of every feature and illustrate the feature by citing examples of its occurrence in different languages of the world. We shall speak of the acoustical and perceptual correlates of a feature only occasionally, not because we regard these aspects as either less interesting or less important, but rather because such discussions would make this section, which is itself a digression from the main theme of our book, much too long. We shall consider the phonetic features under the headings given below. (The numbers in parentheses refer to the section in which the feature is discussed.)

- Major class features (3)
  - Sonorant (3.1)
  - Vocalic (3.2)
  - Consonantal (3.3)
- Cavity features (4)
  - Coronal (4.1.1)
  - Anterior (4.1.2)
  - Tongue-body features (4.2)
    - High
    - Low
    - Back
  - Round (4.3)
  - Distributed (4.4)
  - Covered (4.5)
  - Glottal constrictions (4.6)
  - Secondary apertures (4.7)
    - Nasal (4.7.1)
    - Lateral (4.7.2)
- Manner of articulation features (5)
  - Continuant (5.1)
  - Release features: instantaneous and delayed (5.2)
    - Primary release (5.2.1)
    - Secondary release (5.2.2)
  - Supplementary movements (5.3)
    - Suction (5.3.1)
      - Velaric suction (clicks)
      - Implosion
    - Pressure (5.3.2)
      - Velaric pressure
      - Ejectives
  - Tense (5.4)
- Source features (6)
  - Heightened subglottal pressure (6.1)
  - Voice (6.2)
  - Strident (6.3)

Prosodic features (7)
- Stress
- Pitch
  - High
  - Low
  - Elevated
  - Rising
  - Falling
  - Concave
- Length

This subdivision of features is made primarily for purposes of exposition and has little theoretical basis at present. It seems likely, however, that ultimately the features themselves will be seen to be organized in a hierarchical structure which may resemble the structure that we have imposed on them for purely expository reasons.

2.1. THE NEUTRAL POSITION

In most X-ray motion pictures of speech, it can readily be observed that just prior to speaking the subject positions his vocal tract in a certain characteristic manner. We shall call this configuration the "neutral position" and shall describe some of the ways in which it differs from the configuration of the vocal tract during quiet breathing. In the latter state the velum is lowered, thereby allowing air to pass through the nose; in the neutral position, on the other hand, the velum is raised, and the air flow through the nose is shut off. The body of the tongue, which in quiet breathing lies in a relaxed state on the floor of the mouth, is raised in the neutral position to about the level that it occupies in the articulation of the English vowel [e] in the word *bed;* but the blade of the tongue remains in about the same position as in quiet breathing.[6] Since speech is generally produced on exhalation, the air pressure in the lungs just prior to speaking must be higher than the atmospheric pressure. During quiet breathing, the vocal cords must be widely spread apart since practically no sound is emitted. On the other hand, there is good reason to believe that prior to speaking the subject normally narrows his glottis and positions his vocal cords so that in the neutral position they will vibrate spontaneously in response to the normal, unimpeded air flow. Since this spontaneous vocal cord vibration has been almost totally ignored in the literature, we digress here in order to examine it in somewhat greater detail.

2.2. VOCAL CORD VIBRATION—SPONTANEOUS AND OTHERWISE

The two major factors controlling vocal cord vibration are the difference in air pressure below and above the glottis and the configuration of the vocal cords themselves—their tension, shape, and relative position. The subglottal pressure is that maintained in the trachea by the respiratory muscles. In the absence of a significant constriction in the oral cavity, the supraglottal pressure will be about equal to atmospheric pressure and will, of course, be lower than the subglottal pressure. If, on the other hand, there are significant constrictions in the oral cavity, the supraglottal pressure will rise above the atmospheric pressure since the air being exhaled from the lungs will not be allowed to flow out freely. Part or all of this air will be trapped in the supraglottal cavity, building up the pressure there and thus reducing the

[6] We follow here Bell, Sweet, D. Jones and other phoneticians in drawing a distinction between the body and the blade of the tongue. See D. Jones (1956, p. 15): ". . . the part which normally lies opposite the teeth ridge is called the *blade*. The extremity of the tongue is called the *tip* or *point*, and is included in the blade." An almost identical description is given by Westermann and Ward (1933, p. 17).

pressure difference below and above the glottis. This is of importance to us here since, all other things being equal, this pressure difference determines the rate at which the air will flow from the lungs through the glottis, and it is the flow rate which determines whether or not the glottis will vibrate.

In order to initiate vocal cord vibration, it is not necessary that the glottis be totally closed. If the velocity of the air flow through the glottis is high enough, it may reduce the pressure inside the glottis opening (the Bernoulli effect) to the point where the pressure is insufficient to prevent the elastic tissue forces from pulling the vocal cords together and closing the glottis. As soon as the glottis is closed, the subglottal pressure begins to build up and ultimately becomes large enough to overcome the elastic tissue forces pulling the glottis shut. At this point the glottis is opened, and air flows through it again. The air flow is subsequently cut off again since it once more produces a critical pressure drop inside the glottis opening. Obviously the Bernoulli effect can take place only if the vocal cords are appropriately positioned. If they are spread too far apart, as they are in quiet breathing, the pressure drop inside the glottis will not be great enough to pull the vocal cords together and thus initiate vibration.

We have already postulated that in the neutral position the vocal cords are placed so as to vibrate spontaneously in response to the unimpeded air flow. It is, however, a well-known fact that vocal cord vibrations also occur when there is a radical constriction, or even total closure, in the oral cavity. Although direct observations have not as yet been made, there is reason to suppose that the positioning of the vocal cords and their manner of vibration in the presence of a significant constriction in the oral cavity differ in important ways from the position and vibration observed during unimpeded air flow. It thus appears that voicing in obstruents is a rather different matter from that observed in sonorants.

Theoretical investigations by Halle and Stevens (1967) have shown that for sounds with low first formants—i.e., for sounds other than vowels—periodic vocal cord vibrations can be maintained only if the width of the glottal pulse is increased by lengthening the open phase during each glottal vibration over that normally found in vowels and/or if the damping of the first formant is substantially increased by creating a larger average glottal opening. The increased glottal opening would also help to maintain the vibration in the face of the reduced pressure drop across the glottis resulting from the buildup of pressure behind the consonantal constriction in the supraglottal cavity.

Certain well-known observations seem to support the theoretical conclusion that nonspontaneous voicing involves quite different adjustments than does spontaneous voicing. Thus, the air flow in voiced obstruents is noticeably faster than that in sonorants (vowels, glides, liquids, nasals). This fact is readily explained on the assumption that the average glottal opening is larger in obstruents than in vowels. Moreover, studies now in progress indicate that at least in the production of some voiced obstruents, the glottis is partially open during the phonation period. Finally, the very common lengthening of vowels before voiced obstruents can be explained on the grounds that it requires time to shift from the glottis configuration appropriate for vowels to that appropriate for obstruents.

3. *Major class features*

Reduced to the most rudimentary terms, the behavior of the vocal tract in speech can be described as an alternation of closing and opening. During the closed phase the flow of air from the lungs is either impeded or stopped, and pressure is built up in the vocal tract; during the open phase the air flows out freely. This skeleton of speech production provides the basis for the major class features, that is, the features that subdivide speech sounds into vowels, consonants, obstruents, sonorants, glides, and liquids. Each of the three major class features —sonorant, vocalic, consonantal—focuses on a different aspect of the open-versus-closed phase.

3.1. SONORANT—NONSONORANT (OBSTRUENT)

Sonorants are sounds produced with a vocal tract cavity configuration in which spontaneous voicing is possible; obstruents are produced with a cavity configuration that makes spontaneous voicing impossible.

As we noted above, spontaneous voicing may be suppressed by narrowing the air passage to a point where the rate of flow is reduced below the critical value needed for the Bernoulli effect to take place. Constrictions more radical than those found in the glides [y] and [w] will have this result. Hence sounds formed with more radical constrictions than the glides, i.e., stops, fricatives, and affricates, are nonsonorant, whereas vowels, glides, nasal consonants, and liquids are sonorant.

In this connection it should be observed that there appear to be differences in the degree of constriction with which [l]- and [r]-sounds are produced. In the better known cases these sounds are produced with a very moderate degree of constriction and are therefore clearly sonorants. There are, however, liquids which are produced with a quite radical constriction and which have to be regarded as obstruents. Such is the case, apparently, in Chipewyan, in certain Caucasian languages, and in those languages with strident liquids, such as the Czech [ř].

3.2. VOCALIC—NONVOCALIC

Vocalic sounds are produced with an *oral* cavity in which the most radical constriction does not exceed that found in the high vowels [i] and [u] and with vocal cords that are positioned so as to allow spontaneous voicing; in producing nonvocalic sounds one or both of these conditions are not satisfied.

Vocalic sounds, therefore, are the voiced vowels and liquids, whereas glides, nasal consonants, and obstruents, as well as voiceless vowels and liquids, are nonvocalic.[7]

3.3. CONSONANTAL—NONCONSONANTAL

Consonantal sounds are produced with a radical obstruction in the midsagittal region of the vocal tract; nonconsonantal sounds are produced without such an obstruction.

It is essential to note that the obstruction must be at least as narrow as that found in the fricative consonants and must, moreover, be located in the midsagittal region of the cavity. This feature, therefore, distinguishes liquids and consonants, both nasal and nonnasal, from glides and vowels. It has been observed by Sievers (1901) that an essential characteristic of vowels is their "dorsal articulation"; that is, vowels commonly are produced with the blade of the tongue some distance from the roof of the mouth. When the blade of the tongue is raised close enough to the roof of the mouth to produce the requisite obstruction, the result is a true consonant or a liquid. Thus an [l]-sound is produced when the tip of the tongue touches the roof of the mouth, thereby blocking the midsagittal region of the vocal tract. In the case of the common lingual [r]-sounds, the raised tongue narrows the passage sufficiently to produce a

[7] Recent work indicates that in place of "vocalicness" the phonetic framework should contain a feature of "syllabicity"—see Chapter Eight, pages 353–55.

consonantal obstruction even if it does not make complete contact with the roof of the mouth. The uvular [R] is produced in a quite similar fashion, but in this case the lowered uvula rather than the raised tongue forms the obstruction in the midsagittal region of the vocal tract.

The presence of an obstruction in the midsagittal region is not necessarily accompanied by sufficient closure of the entire passage to suppress spontaneous voicing. The liquids are therefore consonantal sonorants. In producing the consonantal nonsonorants (obstruents), the passage is narrowed to a point where spontaneous vocal cord vibration is impossible; among the latter types of sounds are the plosives, affricates, and fricatives. On the other hand, not every sound produced with a raised tongue tip is consonantal. The so-called retroflex vowels are formed with a raised tongue tip, which, however, is not close enough to the palate to constitute a consonantal obstruction. These vowels are thus nonconsonantal.

The major class features therefore define the categories of speech sounds shown in Table 1.

TABLE 1. *The major class features*

	sonorant	consonantal	vocalic
voiced vowels	+	−	+
voiceless vowels	+	−	−
glides (I): *w*, *y*	+	−	−
glides (II): *h*, ʔ	+	−	−
liquids	+	+	+
nasal consonants	+	+	−
nonnasal consonants	−	+	−

4. *Cavity features*

4.1. PRIMARY STRICTURES

There are several ways in which primary strictures have been treated in the phonetic literature. The most widely known approach, that of the International Phonetic Alphabet, utilizes different features to characterize the strictures in vowels and in consonants. Vowel strictures are described with the help of the features "front-back" and "high-low," whereas consonantal strictures are characterized by means of a single multivalued parameter that refers to the location of the constriction. The disadvantage of this method is that it fails to bring out the obvious parallels between vocalic and consonantal strictures. Thus, the difference between palatal and velar consonants clearly parallels that between front and back vowels, for in both cases there are the same differences in the position of the body of the tongue. There is, however, no mechanism in the IPA framework to capture this and similar facts.

One of the many contributions of R. Jakobson is a phonetic framework in which many of these parallels are properly captured. As is well known, the salient characteristic of the Jakobsonian framework is that the same three features—"gravity," "compactness," and "diffuseness"—are used to describe the primary strictures in both vowels and consonants. This complete identification of vowel and consonant features seems in retrospect to have been too radical a solution, for reasons that we briefly outline below. We have therefore made a number of changes in the framework, in particular, with regard to the primary cavity features. The revised framework is quite likely to appear to depart from the earlier framework much more radically than it in fact does. This deceptive impression is the result of the unfortunate need to change terminology once again and replace the by now reasonably familiar terms "compact," "diffuse," and "grave" in part by totally new terms, in part by terms that are a return to the status quo ante. We discuss the relationship between the two frameworks in Section 4.2.1.

4.1.1. CORONAL—NONCORONAL

Coronal sounds are produced with the blade of the tongue raised from its neutral position; noncoronal sounds are produced with the blade of the tongue in the neutral position.[8]

The phonetic classification effected by this feature is all but self-evident. The so-called dental, alveolar, and palato-alveolar consonants are coronal, as are the liquids articulated with the blade of the tongue. The uvular [R] and the consonants articulated with the lips or with the body of the tongue are noncoronal. The glides [y] and [w] are noncoronal. Finally, the so-called retroflex vowels which are found in some languages of India—e.g., Badaga (H. L. Gleason, personal communication)—as well as in many English dialects in the position before [r] are coronal. Nonretroflex vowels are, of course, noncoronal.

4.1.2. ANTERIOR—NONANTERIOR

Anterior sounds are produced with an obstruction that is located in front of the palato-alveolar region of the mouth; nonanterior sounds are produced without such an obstruction. The palato-alveolar region is that where the ordinary English [š] is produced.

It follows from the proposed characterization that vowels, which are formed without constrictions in the oral cavity, are always nonanterior. Consonants and liquids are anterior when they are formed with an obstruction that is located farther forward than the obstruction for [š]. The consonants that in traditional terminology are described as palato-alveolar, retroflex, palatal, velar, uvular, or pharyngeal are therefore nonanterior, whereas labials, dentals, and alveolars are anterior.

4.2. FEATURES RELATING TO THE BODY OF THE TONGUE: HIGH—NONHIGH, LOW—NONLOW, BACK—NONBACK

The three features "high," "low," "back" characterize the placement of the body of the tongue. Recall that in the neutral position the body of the tongue was assumed to be raised and fronted, approximating the configuration found in the vowel [e] in English *bed*. In characterizing these three features, we shall be concerned with the various displacements of the tongue body from the neutral position.

HIGH–NONHIGH. High sounds are produced by raising the body of the tongue above the level that it occupies in the neutral position; nonhigh sounds are produced without such a raising of the tongue body.

[8] The term "coronal" is used here in the sense of the German *Vorderzungenlaut* and the Russian *peredne-jazyčnyj*. Sievers (1901) distinguished two types of linguo-palatal sounds with nonlateral articulation:

"(1) Coronale Articulation: die Articulation wird durch den vorderen Zungensaum bewirkt, welcher sich als eine mehr oder weniger scharfe Kante dem Gaumen entgegenstellt . . .

(2) Dorsale Articulation: die nothwendigen Engen bez. Verschluesse werden durch Emporheben eines Theiles des Zungenrueckens . . . zum Gaumen gebildet" (p. 59).

In much the same way the term is defined by Broch (1911): "Wird die charakteristische Enge oder der Verschluss durch den Vorderrand der Zunge gebildet, wobei sich ihre Oberflaeche gewoehnlich auf einer groesseren oder kleineren Strecke als konkav bezeichnen laesst, so wird die Artikulation koronal genannt" (pp. 11 f.)

We differ somewhat from Sievers and Broch in that we regard as coronal all types of sounds formed with the blade of the tongue; Sievers and Broch did not use this term when speaking of sounds formed with the flat part of the blade (Sweet's "laminal"). (See note 6.) The latter distinction is handled in the present framework with the help of the feature "distributed" (see Section 4.4 of this chapter).

LOW–NONLOW. Low sounds are produced by lowering the body of the tongue below the level that it occupies in the neutral position; nonlow sounds are produced without such a lowering of the body of the tongue.

BACK–NONBACK. Back sounds are produced by retracting the body of the tongue from the neutral position; nonback sounds are produced without such a retraction from the neutral position.

The characterization of the vowels in terms of the three features above is quite straightforward and differs little from that found in most traditional phonetics books. We must observe only that the phonetic characterization of "low" and "high" rules out sounds that are $\begin{bmatrix} +\text{low} \\ +\text{high} \end{bmatrix}$, for it is impossible to raise the body of the tongue above the neutral position and simultaneously lower it below that level.

The characterization of the consonants in terms of these same features is equally straightforward, though perhaps somewhat unfamiliar. Consider first the consonants where the primary constriction is formed with the body of the tongue, in other words, those that are both noncoronal and nonanterior: the palatals, velars, uvulars, and pharyngeals. These four "points of articulation" are readily captured with the help of the three features under discussion, as shown in Table 2.

TABLE 2.

	palatals	velars	uvulars	pharyngeals
high	+	+	−	−
low	−	−	−	+
back	−	+	+	+

The absence of nonhigh nonback consonants is a direct consequence of the fact that the body of the tongue can form a constriction only if it is high or back.

While no language known to us has all four types of consonants in Table 2, there are quite a number of languages in which three of the four classes are attested. Serer, a West African language, has palatal, velar, and uvular voiceless stops.[9] Ubykh, a Caucasian language, distinguishes pharyngeal, uvular, velar, and perhaps also palatal obstruents (Vogt, 1963; Allen, 1964). In Ubykh, as in many other languages, such as Gilyak (see Zinder and Matusevič, 1937; Halle, 1957), the difference between velar and uvular points of articulation is paralleled by the difference between nonstrident and strident. This, however, is by no means universal. For instance, the spectrographic evidence published by Ladefoged (1964, p. 22) shows that in Serer the velar and uvular stops are both nonstrident plosives. Distinctions among palatal, velar, and uvular obstruents are also found in Chinook (Boas, 1911) and are mentioned by Trubetzkoy (1958, p. 122) as attested in certain Nilotic languages (Herero, Nuer, Dinka).

We must now inquire into the role that the features "high," "low," and "back" play in the remaining class of consonants, which in terms of the present framework are anterior and/or coronal. We observe that the three features may be used in a natural manner to characterize subsidiary consonantal articulations such as palatalization, velarization, and pharyngealization. These subsidiary articulations consist in the superimposition of vowel-like

[9] The following contrasting forms are cited by Ladefoged (1964, p. 46; see also pp. 21–22): [$k_1$it] "gift," [kid] "eyes," [qos] "leg," where the symbol k_1 represents the voiceless palatal stop equivalent to the IPA *c*.

articulations on the basic consonantal articulation. In palatalization the superimposed subsidiary articulation is [i]-like; in velarization, [ɨ]-like; and in pharyngealization, [a]-like. The most straightforward procedure is, therefore, to express these superimposed vowel-like articulations with the help of the features "high," "low," and "back," which are used to characterize the same articulations when they appear in the vowels. We shall say that palatalized consonants are high and nonback; velarized consonants are high and back; the pharyngealized consonants (e.g., the Arabic "emphatic" consonants) are low and back. On the other hand, consonants neutral with respect to palatalization, velarization, and pharyngealization are $\begin{bmatrix} -\text{high} \\ -\text{back} \end{bmatrix}$, since such configurations lack a constriction formed by the body of the tongue. Incidentally, it is not clear what role the feature "low" plays in such configurations since we do not know of any language with uvularized dentals or labials. If such consonants exist, however, they will be characterized in terms of our framework as nonhigh, nonlow, and back.

The palato-alveolars differ from the labial and dental consonants in that they are redundantly [+high]. In place of the four-way contrast found in the labials and dentals, the palato-alveolars, therefore, exhibit only a two-way contrast of palatalized ([−back]) and velarized ([+back]). The phonetic contrast can be seen very clearly in the X-ray tracings given by Fant (1960) of the two [š] sounds of standard Russian.

Table 3 (p. 307) gives the feature composition of the most important classes of speech sounds.

4.2.1. ON THE RELATIONSHIP BETWEEN THE FEATURES "DIFFUSENESS," "COMPACTNESS," AND "GRAVITY" AND THE FEATURES OF THE PRECEDING SECTIONS

The features discussed in the preceding sections are basically revised versions of "diffuseness," "compactness," and "gravity," which are well known from earlier presentations of the distinctive feature framework where they served to characterize the main articulatory configurations in the vowels as well as the consonants. As more and more languages were described within this framework, it became increasingly clear that there was a need for modification along the lines discussed in the preceding section. In this section we shall examine some of the problems that arose within the earlier framework and outline the way in which these problems are overcome by the revised features presented above. This question has recently been examined also by McCawley (1967a).

The revisions proposed in the last few pages have the following main effects:

(1) Features specifying the position of the body of the tongue are now the same for vowels and consonants.
(2) In the characterization of vowel articulations, the features "high," "low," "back" correspond to the earlier "diffuse," "compact," and "grave," respectively. In consonants, the same three revised features correspond to palatalization, velarization, and pharyngealization in the manner discussed above.
(3) The feature "anterior" mirrors precisely the feature "diffuse" in consonants.
(4) The feature "coronal" corresponds most closely to the feature "grave" in consonants but with opposite value. Except for the palatals ([k_1], etc.), consonants that were classified as nongrave in the earlier framework are coronal in the revised framework, whereas those that were classified as grave are noncoronal. The palatals, which in the earlier framework were nongrave, are noncoronal.

We recall that in the earlier framework the feature "diffuse" was used to characterize

TABLE 3. *Feature composition of the primary classes of speech sounds*

	anterior	coronal	high	low	back
CONSONANTS					
labials	+	−	−	−	−
dentals	+	+	−	−	−
palato-alveolars	−	+	+	−	−
(does not exist)	−	−	−	−	−
palatalized labials	+	−	+	−	−
palatalized dentals	+	+	+	−	−
palatals	−	−	+	−	−
velarized labials	+	−	+	−	+
velarized dentals	+	+	+	−	+
velarized palato-alveolars	−	+	+	−	+
velars	−	−	+	−	+
(?) uvularized labials	+	−	−	−	+
(?) uvularized dentals	+	+	−	−	+
uvulars	−	−	−	−	+
pharyngealized labials	+	−	−	+	+
pharyngealized dentals	+	+	−	+	+
pharyngeals	−	−	−	+	+
VOWELS (nonretroflex)					
high front	−	−	+	−	−
high back	−	−	+	−	+
mid front	−	−	−	−	−
mid back	−	−	−	−	+
low front	−	−	−	+	−
low back	−	−	−	+	+
GLIDES					
y	−	−	+	−	−
w	−	−	+	−	+
h,ʔ	−	−	−	+	−
LIQUIDS					
dental	+	+	−	−	−
palatal	−	−	+	−	−
uvular	−	−	−	−	+
palato-alveolar	−	+	+	−	−

both the distinction between high and nonhigh vowels and that between what we have called anterior and nonanterior consonants. As a result the articulatory and acoustical characterization of the feature became quite complex and rather implausible. (See, for example, the discussion of diffuseness in Halle (1964).)

A further consequence of the same fact was the need to characterize palatalization, velarization, and pharyngealization by means of independent features. This, in turn, failed to explain why these subsidiary articulations are not found with consonants that are formed with the body of the tongue, i.e., consonants that are noncoronal and nonanterior in the present framework. In the former framework this was a mere accident; in the revised framework the gap is structurally motivated, as shown in Section 4.2. It is worthy of note that rounding (labialization), which is also a subsidiary articulation, is not subject to similar restrictions. All classes of consonants, including labials, may be rounded.

A related inadequacy of the former framework is that it provided no explanation for the fact that palatalization, velarization, and pharyngealization are mutually exclusive. In the revised framework the co-occurrence of these articulations is a logical impossibility since a given sound cannot be back and nonback. In the former framework, on the other hand, this is no more than a coincidence.

The former framework, furthermore, did not bring out the fact that palatalization and velarization characteristically occur before front and back vowels, respectively; the connection between palatalization and front vowels and between velarization and back vowels was no more motivated than a connection between glottalization or voicing and front vowels. In the revised framework, on the other hand, palatalization and velarization are obvious cases of regressive assimilation.

The earlier framework failed to account for the appearance of palatal, in place of velar, consonants in precisely the same environments where other classes of consonants undergo palatalization. (Recall that palatalization preserves the point of articulation, whereas the change of velar to palatal constitutes a change in the point of articulation.) In the revised framework these two superficially distinct processes are shown to be a result of the same change, that is, [+back] to [−back]. A parallel argument can be given for the treatment of velarization and pharyngealization in the two frameworks.

The earlier framework made it impossible in principle to distinguish velar from uvular or pharyngeal consonants by means of their points of articulation. Such distinctions instead had to be made by the use of some subsidiary feature such as "stridency." There are, however, languages (Serer, for example—see p. 305 and note 9) in which velar and uvular consonants do not differ in any such subsidiary feature and which therefore could not be accounted for. This shortcoming is easily taken care of in the revised framework, in which the different points of articulation in velar, uvular, and pharyngeal consonants are specified with the help of the features "high," "low," and "back."

4.2.2. DEGREES OF NARROWING IN THE VOCAL TRACT

In our discussion of the features up to this point, we have spoken at length about the location of strictures in the vocal tract but we have said nothing about differences in the degree of narrowing that can readily be observed in the strictures found in different sounds. This omission has been due to the tacit assumption that the degree of narrowing is determinable from other features of a particular sound. This approach is perfectly familiar in phonetics; for example, no phonetics book does more than remark that in rounded vowels the degree of lip narrowing is most radical for high vowels and least radical for low vowels. While degree of narrowing never functions as the sole cue for differentiating two otherwise identical utterances, it is not true that in all languages the degree of narrowing involved in a particular sound is always predictable from universal phonetic principles. This becomes quite clear if we examine velarized consonants, which appear in various languages with radically different degrees of velar constriction.

In Russian a moderate narrowing in the velar region is present in the articulation of the so-called "hard" consonants, where concomitant with velarization we find a certain degree of lip rounding.[10]

Velarization with more radical narrowing has been reported by C. M. Doke (1931) as occurring in Shona:

> Velarization is brought about by an abnormal raising of the back of the tongue towards the soft palate (velum), instead of the usual slight raising effected in

[10] See Broch (1911, pp. 224 ff.) and X-ray pictures in Fant (1960, pp. 140, 163, 170, 186).

> pronouncing the velar semivowel *w* . . . The extent to which the tongue is raised differs with the dialects. If the back of the tongue is so far raised as to effect contact with the velum, the velarization will appear as *k*, *g*, or ŋ . . . Similarly if the raising of the tongue is not so great, corresponding fricative sounds will replace the explosives . . . (p. 109).

Similar phenomena have been noted by Ladefoged (1964) in West African languages. Velarization in which there is complete closure in the velar region was found in Effutu and Nkonya (pp. 51–54). Kom, moreover,

> has the velarized forms *bγ*, *dγ* which are clearly sequences from the auditory point of view; but equally the articulatory gestures overlap, in that the velar stricture is formed during the stop closure. In this language there are strong grounds for saying that this is a kind of additive component or secondary articulation . . . (p. 31).

The most striking instance of extreme velarization is that of the Bushman and Hottentot clicks, all of which are produced with complete closure at the velum.[11] The clicks, however, differ from other velarized consonants in that in addition to complete closure they involve a special suction mechanism. The clicks will therefore be discussed when we deal with suction mechanisms in Section 5.3.1.

We know of no languages that exhibit parallel variations in degree of narrowing concomitant with palatalization or pharyngealization, but, as will be shown in the next section, parallel variations are found with the feature of "rounding."

4.3. ROUNDED—NONROUNDED

Rounded sounds are produced with a narrowing of the lip orifice; nonrounded sounds are produced without such a narrowing.

All classes of sounds may manifest rounding. In glides and nonlow vowels, rounding is commonly correlated with the feature "back": sounds that are back are also round, those that are nonback are nonround. This association is not obligatory, however, and there are many instances where the features "round" and "back" combine freely. Turkish, for example, has all of the four possible feature combinations contrasting among its high vowels, as shown in Table 4.

TABLE 4. *Turkish high vowels*

	i	ɨ	ü	u
back	−	+	−	+
round	−	−	+	+

French distinguishes three glides phonetically: nonround nonback [y], as in *les yeux*, "the eyes"; round back [w], as in *les oiseaux*, "the birds"; and round nonback [ẅ], as in *tuer*, "to kill."

In consonants, rounding, which is usually designated by the term "labialization," is

[11] In our analysis of the clicks as instances of extreme velarization, we follow a suggestion made by Trubetzkoy (1958, p. 129). We differ from Trubetzkoy, however, in postulating a special feature (suction) to account for the peculiar release of these secondary constrictions.

not uncommon, especially in velars. Labialized velars are found, for example, in Southern Paiute (Sapir, 1930), Chippewyan (Li, 1946), and Navaho (Hoijer, 1945). Labialized dentals and palato-alveolars are found in certain West African languages, such as Effutu, Gã, and Krachi (Ladefoged, 1964). Finally, contrasting labialized and nonlabialized labials are attested in Kutep (Ladefoged, 1964) and in certain Caucasian languages such as Ubykh (Vogt, 1963).

Labialization combines quite commonly with velarization, but we do not know of any examples where these two features act independently in a given phonological system. On the other hand, there appear to be a number of languages where labialization and palatalization function independently. Trubetzkoy (1939) notes that in Dungan Chinese rounding may be distinctive for dental continuants and affricates that are $\begin{bmatrix} +\text{high} \\ -\text{back} \end{bmatrix}$, i.e., palatalized, as well as those that are not. Similar observations have been made in Kashmiri (Jakobson, Fant, and Halle, 1963, p. 35), and in certain West African languages such as Twi and Late (see Ladefoged (1964), plate 9, which reproduces excellent records made of a "labialized and palatalized pre-palatal affricate" (p. 20)).

The degree of rounding is always determinable from other features. In the vowels and glides it is correlated with the maximum degree of constriction in the oral cavity. Glides and high vowels have most rounding; low vowels, least.

There are parallel variations in the degree of rounding in consonants. These vary from a degree that is equivalent to that of the glides to complete closure. Thus, we find rounded consonants with a moderate degree of lip constriction in such languages as Chipewyan (Li, 1946), Hausa (Ladefoged, 1964, p. 64), and Rutulian (Trubetzkoy, 1958, p. 125), whereas in languages such as Ewe and Kpelle we find rounded consonants implemented with complete closure at the lips. The latter are the consonants that are commonly represented orthographically as *kp* and *gb*.[12]

In addition to rounded consonants with moderate constriction and those with total closure, there appear to be consonants of this type which involve an intermediate degree of labial constriction. Thus, Ladefoged (1964) reports that Kom:

> has a labiodental fricative which seems to be superimposable on other articulations. The sounds observed in this language include k^f, g^v, j^v . . . A similar secondary articulation also occurs in Kutep; but in this language labiodentalization occurs only after fricatives (including those in affricates) and is in complementary distribution with labialization, which occurs after stops and nasals (p. 31).[13]

A parallel instance of different degrees of rounding being contextually distributed may be cited from Margi, a language spoken in Nigeria. In this language moderate degrees of rounding occur with noncoronal consonants (labials and velars), and extreme degrees of

[12] In some African languages—e.g., Effutu, Nkonya (as noted by Ladefoged, 1964, pp. 51–54)—these symbols represent, rather, velarized labials. There are, moreover, different ways in which the secondary closure is released in these sounds, as discussed in Section 5.2.

[13] Quite similar facts are reported by Doke (1931) for Shona: "Labialized alveolar fricatives and affricates occur in all Shona dialects . . . In several of the Manyinka dialects and in Tavara, the lip rounding of these sounds is so extreme that the explosive element in the affricates has an acoustic bias towards *p* . . . In Northern Tavara the lip contact in the affricates is complete with many speakers, and the resultant forms are actually [pş] and [bz̧] . . . " (p. 47).

rounding with coronal (dental and palato-alveolar) consonants.[14] This language is interesting also because of the fact that the extreme degree of rounding is superimposed on dentals and palatal consonants, whereas in most other languages extreme rounding (i.e., total lip closure) is a feature of velars. In addition, in Temne (Ladefoged, 1964, p. 47), a voiceless plosive with a moderate degree of rounding, [k^w], is paired with a voiced plosive with extreme rounding, [g^b], the degree of rounding being dependent on voicing.

In sum, in consonants there are at least three phonetically different degrees of rounding. It appears, however, that the particular degree of rounding that obtains in each instance can be determined by the phonological rules of the language so that it is sufficient to indicate in the lexicon whether the given segment is or is not rounded.

An interesting question arises with regard to the labiovelars. We may ask whether these are labials with extreme velarization or velars with extreme rounding, or, in feature terms, whether they should be represented as (1) or as (2):

$$(1) \qquad \begin{bmatrix} +\text{anterior} \\ -\text{coronal} \\ +\text{back} \\ +\text{high} \end{bmatrix}$$

$$(2) \qquad \begin{bmatrix} -\text{anterior} \\ -\text{coronal} \\ +\text{back} \\ +\text{high} \\ +\text{round} \end{bmatrix}$$

We cannot determine this by direct phonetic observation since these two feature configurations seem to result in the same articulatory gesture. Sometimes, however, it is possible to make a decision between such configurations on the basis of the facts of the language. In Nupe (N. V. Smith, personal communication) round (labialized) labials are distinguished from nonround labials; e.g., [p^w] is distinct from [p]. In addition Nupe has two types of labiovelars, rounded and unrounded. The existence of both types immediately resolves the question as to how they are to be represented. We must regard them as labials with extreme velarization (i.e., as having the feature configuration (1)), which may or may not also be rounded. The reason is that if we chose to represent one of the two labiovelars with the feature configuration (2), we should then be unable to represent its phonetic cognate with the same set of features (except for rounding).

Incidentally, in Nupe there is the further interesting fact that all obstruents palatalize before front vowels. Velars become palatals, and the labials become palatalized, that is, show the characteristic [i]-like transition to the adjacent vowel. The labiovelars show the same type of [i]-like transition as the labials. This fact further supports the decision to regard labiovelars as labials with extreme velarization.

[14] See Hoffmann (1963, pp. 27–29). In his list of phonemes Hoffmann also cites a number of dental consonants with superimposed rounding of a moderate degree, which he symbolizes by di- and tri-graphs ending with the letter *w: sw*, *tw*, *tlw*. Hoffmann believes that these are in contrast with dentals with labial closure. A good many of the examples quoted, however, seem to be instances of a plain dental being followed by the suffix /wa/ and hence are not really relevant. For example, *swá*, "to shut (without locking)," is given on page 149 as *s(ú)wá* and compared with the stem *sų́*, "to contract (disease)"; *tlwá*, "to cut in two (with knife)," is derived on page 148 from *tlá*, "to cut (with knife)."

4.4. DISTRIBUTED—NONDISTRIBUTED

The features "anterior" and "coronal" provide for a four-way classification of consonants corresponding to the four main points of articulation: labial, dental, palato-alveolar, and post-alveolar (palatal, velar, uvular, pharyngeal). We have seen (Section 4.2) that in the fourth class—i.e., in the $\begin{bmatrix}-\text{anterior}\\-\text{coronal}\end{bmatrix}$ consonants—additional points of articulation are provided for by the features "back," "high," and "low." The same is not true of the other classes of consonants, where these three features instead account for supplementary articulations such as palatalization, velarization, and pharyngealization. Thus we have in effect recognized three points of articulation in the pre-palatal region. The question that must now be considered is how the proposed framework will treat various languages that appear to distinguish more than these three points of articulation.

There are quite a number of languages with the obstruent system in (3):

(3) p t̪ t ʈ k_1

where t̪ represents a dental, *t* an alveolar, ʈ a retroflex, and k_1 a palato-alveolar plosive. Such systems have been reported for Aranta (K. Hale, personal communication), Araucanian (Echeverría and Contreras, 1965), Madurese (A. M. Stevens, 1965), Toda (Emeneau, 1957), and many other languages. In at least some of these languages (Araucanian and Aranta, for instance), these distinctions must be directly represented in the lexicon since they function as the sole distinguishing mark among items belonging to identical grammatical categories. We must, therefore, add a feature to the framework, and the next problem to consider is the phonetic nature of this feature. At first sight it may appear that in each of the three "points of articulation" so far established we must recognize a forward and back region. This, however, does not reflect all the facts since in most cases the subsidiary differences in point of articulation are also accompanied by characteristic differences in the length of the zone of contact. The length of a constriction along the direction of the air flow has obvious acoustical consequences, and it would be highly plausible that these should be controlled by a special feature, which we shall call "distributed."

Distributed sounds are produced with a constriction that extends for a considerable distance along the direction of the air flow; nondistributed sounds are produced with a constriction that extends only for a short distance in this direction.

The distinction that we are trying to capture here has by no means gone unrecognized in the past. Phonetics books traditionally distinguish apical from laminal and retroflex from nonretroflex consonants.[15] As a first approximation (to be further refined below), we class the former as [−distributed] and the latter as [+distributed].

In postulating the feature "distributed," we are in effect claiming that subsidiary differences in points of articulation are in all cases describable with the help of low-level phonetic rules, rules which, like the stress rules of English, assign numerical values to the different features. This is by no means an empty claim. It would be controverted if, for example, a given language were shown to have dental and alveolar consonants which both had apical articulations. This question has been investigated by Ladefoged (1964, pp. 19 f. and

[15] Zwicky (1965) has argued convincingly that in Sanskrit the retroflex *ṣ* is [−anterior] ([+compact] in the framework used by Zwicky), like the palato-alveolar *ç*, and not [+anterior] like the dental *s*. This view was apparently shared by Whitney (1941), who comments: "This very near relationship of *ṣ* and *ç* is attested by this euphonic treatment which is to a considerable extent the same."

passim), with results that are of great interest. In what we may term the denti-alveolar region, Ladefoged distinguishes three areas: (1) teeth and teeth-ridge; (2) front of teeth-ridge; (3) back of teeth-ridge. In each of these areas Ladefoged finds consonants produced with and without a distributed constriction. In Table 5 we summarize the relevant data given by Ladefoged.

TABLE 5.

	teeth and teeth-ridge	front of teeth-ridge	back of teeth-ridge
Twi		apical	laminal
Ewe	laminal		apical
Temne	apical	laminal (affricated)	
Isoko	laminal (affricated)	apical	

It is immediately clear from the table above that no single language has more than two consonants in the denti-alveolar region, of which one is apical and the other laminal. The simplest situation is that in Twi, where we have the common contrast between alveolar and palato-alveolar consonants (in our terms, anterior and nonanterior consonants). This solution is in accord with Ladefoged's comment that "it was only an arbitrary decision to symbolize the pre-palatal position by a symbol indicating a retracted alveolar rather than an advanced palatal" (p. 19).

The situation is equally simple in Ewe, where dental consonants contrast with retroflex consonants. In our terms the former would be characterized as $\begin{bmatrix}+\text{anterior}\\+\text{distributed}\end{bmatrix}$; the latter as $\begin{bmatrix}-\text{anterior}\\-\text{distributed}\end{bmatrix}$. Ladefoged notes that the Ewe retroflex consonant "sounds slightly different from the retroflex stop found in Indian languages such as Hindi" (p. 18). If this difference is systematic, it would clearly have to be reflected in the grammars of these languages. It is, however, quite sufficient to note that the point of contact between the tongue and the roof of the mouth is somewhat more advanced in one language than the other. This fact would presumably be reflected in low-level phonetic rules that assign numerical values to the different features. The existence of a systematic phonetic difference does not, therefore, in itself constitute a necessary and sufficient condition for postulating an additional point of articulation.

In both Temne and Isoko we find a contrast between distributed and nondistributed anterior consonants. In Temne the nondistributed consonant is articulated at the teeth, whereas the distributed consonant is articulated somewhat farther back. In Isoko the situation is the reverse: the distributed consonant is articulated in the front part of the dental region and the nondistributed consonant is articulated farther back. In both cases the facts can be readily accounted for by low-level phonetic rules, provided that the distinction between [+distributed] and [−distributed] is given.

We noted above that the difference characterized by distributed versus nondistributed does not correspond precisely to the distinction between laminal and apical. The relevant distinction is not between articulations made with parts of the tongue other than the apex and those made with the apex, but rather between sounds made with long constrictions and those made with short constrictions. The dividing line between nondistributed and distributed articulations seems to us to be best exemplified by the articulatory distinction between the Polish "hard" and "soft" dentals. Wierzchowska (1965) describes this difference in the following terms:

> The contact made by the tongue with the roof of the mouth in articulating [the "soft" dentals—NC/MH] ć ʒ́ as well as ś ź is considerably wider than the contact made in the hard c ʒ s z. The closure in the forward portion of the region of contact includes in the case of ć ʒ́ the teeth ridge and extends to the forward part of the hard palate . . . The groove in ś ź is longer than in the hard consonants c ʒ s z extending not only across the teeth ridge but also across the forward part of the hard palate . . . [The groove] is formed by a part of the tongue that is farther back than that used in the case of the hard consonants . . .

The excellent illustrations (palatograms, linguograms, and X-ray tracings) contained in the book appear to indicate that the critical difference in the length of the stricture is in the vicinity of 1.5 cm. It is this longer stricture that accounts for the striking hushing quality that is observed in the Polish "soft" dentals.[16]

Finally a word must be said about the distinction between labials and labiodentals. As these fit rather naturally under the proposed distinction, we shall assume that labials are [+distributed], labiodentals are [−distributed]. The fact that there are other feature distinctions between these two classes of sounds makes this distinction in the length of stricture somewhat peripheral, though no less real.

Since phonetic features induce categorizations of segments, one expects these categorizations to be reflected in the phonological rules. This has clearly been the case with all features that have been discussed so far. Since it is, however, less obvious with regard to the feature "distributed," an example is called for here. The feature "distributed" provides a natural characterization of the alternation between the dental and retroflex consonants that are found in Sanskrit. If it is assumed, as is usual, that the Sanskrit dentals are [−distributed], then the alternation can be characterized by the following rule:[17]

$$(4) \qquad \begin{bmatrix} -\text{distributed} \\ +\text{coronal} \end{bmatrix} \rightarrow [-\text{anterior}] \ / \begin{bmatrix} -\text{anterior} \\ -\text{low} \end{bmatrix} \_\_\_$$

4.5. COVERED—NONCOVERED

In many West African languages there is vowel harmony in terms of a feature that has been variously described as "tenseness" (Ladefoged, 1964), "heightening" (Welmers, 1946), "brightness" (Sapir, 1931). The X-ray tracings published by Ladefoged (1964, p. 38) clearly show that in one set of these vowels the pharynx is more constricted than in the other and that the constriction in the pharynx is accompanied by a noticeable elevation of the larynx. We venture to suggest that this difference corresponds to the difference between the vocal tract positions in open and covered singing. The particular dull quality associated with covered voice production appears not to be present in all cases. Sapir (1931) observed it in Gweabo, and Berry (1957) mentions it for Twi, but other observers, including Ladefoged (1964), have

[16] In Russian the "soft" [s,] lacks this hushing quality. It is also formed with a much shorter stricture. (See the X-ray tracing in Fant (1960, p. 172), where the length of the stricture is 1 cm.) The Russian sound is therefore to be regarded as [−distributed].

[17] We assume here that the [r] in Sanskrit, as in English, is [−anterior] and that all vowels are universally [−anterior]. The feature [−low] in the rule excludes the environment after the vowel [a].

failed to notice it. In view of the uncertain status of our data, the proposed description of this feature must be taken as tentative (but see Stewart (1967) for recent strong supporting evidence).

We shall assume that covered sounds are produced with a pharynx in which the walls are narrowed and tensed and the larynx raised; uncovered sounds are produced without a special narrowing and tensing in the pharynx.

As far as we know, this feature is restricted to vowels and is found primarily in the West African languages exhibiting vowel harmony. It is possible, however, that it has a wider utilization. For example, the two rounded front vowels of Swedish represented as [y] and [ʉ] may perhaps differ in that the latter is covered whereas the former is not. The X-ray tracings published by Fant (1959) lend some plausibility to this suggestion.

4.6. GLOTTAL CONSTRICTIONS

Glottal constrictions are formed by narrowing the glottal aperture beyond its neutral position. Such constrictions may accompany many different types of supraglottal articulatory configurations. Included among the sounds with glottal constriction are both the implosives and the ejectives, as well as certain types of clicks. Since phonetically the most interesting factor is the manner in which the glottal closure is released and the motion of the glottis that may precede the release, we shall discuss these different types of glottalized sounds in Section 5.2, which deals with release features.

Glottal constrictions are commonly of an extreme degree, i.e., they involve total closure. There are, however, instances where glottal constrictions of lesser degree occur. Thus, for instance, in the dialect of Korean described by Kim (1965), the tense glottalized stops represented by Kim as *p* t* k** have glottal constriction, but not glottal closure, for otherwise it would be impossible to account for the buildup of oral pressure during the stop phase that was observed by Kim. That the vocal cords are, on the other hand, not wide open is shown by the timing of the voicing onset in the adjacent vowel. This begins in these stops as soon as the primary stop closure is released, whereas in the stops without glottal constriction the onset of voicing is delayed. (For further discussion of this point, see Section 6.2.) It follows from the preceding that in sounds produced with glottal constriction voicing can occur only after the glottal constriction has been released.

Several African and Caucasian languages exhibit the so-called laryngealized or "creaky" voice (Knarrstimme), which seems to be an instance of glottal constriction. This phenomenon has been described by Ladefoged (1964):

> In this state of the glottis there is a great deal of tension in the intrinsic laryngeal musculature, and the vocal cords no longer vibrate as a whole. The ligamental and arytenoid parts of the vocal cords vibrate separately . . . Laryngealized voicing often occurs during an implosive consonant . . . [but] need not occur in implosive consonants; and equally it [laryngealized voicing—NC/MH] can occur without the downward movement of the larynx which must by definition be present in an implosive. We can, therefore, separate out two kinds of glottalized consonants: what we are here calling voiced implosives (as in Igbo and Kalabari), in which there is always a downward movement of the glottis—and there may or may not be laryngealized voicing; and what we are here calling laryngealized consonants (as in Hausa), in which there is always a particular mode of vibration of the vocal cords—and there may or may not be a lowering of the larynx (p. 16).

In describing the actual production of one of these sounds, Ladefoged noted:

> The vocal cords were apparently tightly closed for at least 30 msec in between the two syllables . . . then, when they did start vibrating, there were four glottal pulses irregularly spaced in a little under 20 msec; these pulses were followed by a gap of almost 17 msec; the next pulse was the first of a series recurring at regular intervals of about 12 msec. During some of the 17 msec before the regular vibrations began the vocal cords must have been held together; I have no criteria for deciding whether the vocal cords were together for long enough for this part of the sequence to be called a glottal stop. It is often not possible to make an absolute distinction between laryngealization and glottal closure . . . (pp. 16–17).[18]

4.7. SECONDARY APERTURES

4.7.1. NASAL—NONNASAL

Nasal sounds are produced with a lowered velum which allows the air to escape through the nose; nonnasal sounds are produced with a raised velum so that the air from the lungs can escape only through the mouth.

The most common type of nasal sounds are the anterior nasal consonants [m] and [n], where nasalization is superimposed upon a plosive articulation, i.e., on that of [b] and [d], respectively. These are found in the overwhelming majority of languages. Less common are the nonanterior nasals [ɲ] and [ŋ]. Nasal consonants of other types are quite uncommon. Ladefoged (1964, p. 24) reports that Tiv has nasal affricates which contrast with both nasal and nonnasal plosives. We do not know of any certain examples of nasal continuants such as a nasal [z] or [v]. Nasal vowels are, of course, quite common. In the best known cases, such as in the Romance and Slavic languages, however, the nasality of vowels is contextually determined and would not appear in the representation of items in the lexicon.

In Yoruba, Nupe, and other African languages, nasality can be superimposed on glide as well as liquid articulation; i.e., the language exhibits nasal cognates of the nonnasal [y], [w], [r]. These, however, are contextual variants of the nonnasal phonemes. (See Ladefoged, 1964, p. 23). The superimposition of nasality on the lateral [l] is phonetically attested in modern French in such words as *branlant*, "shaking," where [l] appears between two nasal vowels. Nasalized [r] is attested phonetically in Yoruba (Siertsema, 1958).

Nasal sounds are normally voiced because the open nasal passage does not permit sufficient pressure buildup inside the vocal tract to inhibit spontaneous vocal cord vibration. There are rare instances of contrast between voiced and voiceless nasals. (See Westermann and Ward, 1933, p. 65).

PRENASALIZED CONSONANTS. In many rather widely scattered languages of Africa there are prenasalized consonants, which contrast with both voiced plosives and the familiar type of nasal consonant. Ladefoged (1964) reports the existence of prenasalized consonants in Serer, Fula, Mende, Sherbro, Tiv, Kutep, and Margi among the West African languages. They occur also in other parts of Africa; e.g., in Kikuyu[19] and in Xhosa (McLaren, 1955).

[18] All but the first of the durations in the above quotation have been reduced by us by a factor of 10 to conform to the facts as shown in Ladefoged's oscillogram on which the passage is an extended comment (Plate 1B).

[19] L. E. Armstrong (1940). In Kikuyu prenasalized consonants do not occur initially in verbal stems (note 2, p. 40). On the other hand, there are hardly any nasals of the familiar type in initial position in noun stems. The noun stems beginning with a prenasalized labial, a large number of which are listed in the glossary of Armstrong (1940), appear in almost every case to consist of a special nasal prefix plus stem.

Phonetically, prenasalized consonants differ from the more familiar type of nasal consonant in that the velum, which is lowered during the period of oral occlusion, is raised prior to the release of the oral occlusion, whereas in the more common type of nasal consonant the velum is raised simultaneously with or after the release of the oral occlusion. It would appear, therefore, that phonetically we have to recognize a feature that governs the timing of different movements within the limits of a single segment. As an alternative to this, it has been suggested to us by R. Carter that the difference between prenasalized and ordinary nasal consonants might be regarded as an instance of instantaneous versus delayed release (see Section 5.2). This suggestion appeals to us but we are at present unable to provide serious arguments in its favor.[20]

4.7.2. LATERAL—NONLATERAL

This feature is restricted to coronal consonantal sounds. Lateral sounds are produced by lowering the mid section of the tongue at both sides or at only one side, thereby allowing the air to flow out of the mouth in the vicinity of the molar teeth; in nonlateral sounds no such side passage is open. Laterality is compatible both with vocalic (liquid) and nonvocalic sounds, the difference being that in the vocalic lateral (liquid) the passage is wider and less obstructed than in the nonvocalic lateral. Among the lateral nonvocalic sounds we have continuants opposed to affricates, whereas there does not seem to be any such subdivision among the vocalic laterals. A good example of the nonvocalic affricates is provided by Chipewyan (Li, 1946), where a lateral series exactly parallels the different manners of articulation found in nonlateral series. Thus, nonlateral series such as (5) are paralleled by lateral series such as (6).

(5) t d t'
č ǰ č' š ž

(6) tł dł tł' ł l[21]

Of the laterals only the vocalic [l] occurs with any frequency among the languages of the world. Nonvocalic laterals, which often are strident, are found in various widely scattered areas of the globe: the Caucasus, Africa, and among the languages native to the American continent.[22]

5. *Manner of articulation features*

5.1. CONTINUANT—NONCONTINUANT (STOP)

In the production of continuant sounds, the primary constriction in the vowel tract is not narrowed to the point where the air flow past the constriction is blocked; in stops the air flow through the mouth is effectively blocked.

Among the stops are the plosives (nasal as well as oral), the affricates, and the glottal

[20] J. D. McCawley (personal communication) has suggested that prenasalized consonants be regarded as obstruent nasals, as opposed to the familiar types of nasals which are sonorant.

[21] *t'* represents a glottalized *t*, and ł a voiceless *l*.

[22] For the Caucasian languages, see Trubetzkoy (1922); for African languages, Ladefoged (1964); and for instances of laterality in American Indian languages, Li (1946).

stops, as well as various types of sounds with closure not only at the point of primary constriction but also at supplementary constrictions, including clicks, other doubly articulated plosives (labiovelars), and implosive and ejective stops.

The status of the liquids with regard to this feature requires some comment. The fricative varieties of [r] do not represent any particular difficulty; they are clearly continuant. The trilled [r] is more difficult, for here there is interruption of the air stream during at least part of the duration of the sound. The vibrations of the tongue tip, however, are produced by the drop in pressure which occurs inside the passage between the tip of the tongue and palate when the air flows rapidly through it (Bernoulli effect). The trill is thus a secondary effect of narrowing the cavity without actually blocking the flow of air. Consequently there is good reason to view the trilled [r] as a continuant rather than as a stop. The distinction between the tap [r] and the trilled [r] is produced by a difference in subglottal pressure: the trilled [r] is produced with heightened subglottal pressure; the tap [r], without it. (See also Section 6.1.)

It may be noted parenthetically that the tap [r] may be produced by a different mechanism than the so-called "tongue flap" [D] which greatly resembles the tap [r]. Whereas the latter is the result of the aerodynamic mechanism just described, it is quite possible that the tongue flap [D] is produced by essentially the same muscular activity that is found in the dental stop articulation, except that in the case of the tongue flap the movement is executed with great rapidity and without tension.

The characterization of the liquid [l] in terms of the continuant-noncontinuant scale is even more complicated. If the defining characteristic of the stop is taken (as above) as total blockage of air flow, then [l] must be viewed as a continuant and must be distinguished from [r] by the feature of "laterality." If, on the other hand, the defining characteristic of stops is taken to be blockage of air flow *past the primary stricture*, then [1] must be included among the stops. The phonological behavior of [1] in some languages supports somewhat the latter interpretation. As noted above (Section 4.7.2), in Chipewyan the lateral series parallels the nonlateral series if [1] is regarded as a continuant. Moreover, continuants (including [l]) are subject to voicing alternations which do not affect noncontinuants (Li, 1946). On the other hand, there are other facts in different languages which suggest that [l] is best regarded as a noncontinuant (with the definition of the feature adjusted accordingly). Thus, for instance, in certain dialects of English spoken in Scotland, diphthongs are lax before noncontinuants and tense before continuants (Lloyd, 1908). Thus there is [r'ʌjd] but [r'ajz]. The liquids [l] and [r] pattern in parallel fashion, the former with the noncontinuants and the latter with the continuants: [t'ʌjl] but [t'ajr].

5.2. RELEASE FEATURES: INSTANTANEOUS RELEASE—DELAYED RELEASE[23]

These features affect only sounds produced with closure in the vocal tract. There are basically two ways in which a closure in the vocal tract may be released, either instantaneously as in the plosives or with a delay as in the affricates. During the delayed release, turbulence is generated in the vocal tract so that the release phase of affricates is acoustically quite similar to the cognate fricative. The instantaneous release is normally accompanied by much less or no turbulence.

Though restricted to sounds produced with a closure, the release is of significance

[23] These terms have been suggested to us by R. Carter.

not only for closures at the primary stricture but also for closures at the secondary stricture. Our phonetic framework must therefore contain two release features.

5.2.1. RELEASE OF PRIMARY CLOSURES

As already noted the release feature of the primary constriction distinguishes the affricates from the plosives: plosives such as English [p b t d k g] are produced with an abrupt release; affricates such as English [č ǰ] are produced with a delayed release. Quite similar to the gesture involved in the production of these fairly common affricates is the gesture that produces the lateral affricates found in the Athabaskan languages of North America (Li, 1946; Hoijer, 1945), and in some Caucasian languages (Trubetzkoy, 1922). The closure in these sounds is commonly produced by contact between the blade of the tongue and the dental or palatal region of the mouth. During the delayed release of this closure, the sides of the tongue, but not its tip, are lowered, thereby allowing the air to flow sideways across the molar teeth. As stated above, the lateral affricate differs from other laterals in that it requires complete closure (which is then followed by a lateral release); in the other laterals, the lateral aperture is open all through the articulation of the sound.

5.2.2. RELEASE OF SECONDARY CLOSURES

The chief examples of the role played by the release of secondary closures are provided by the clicks. Clicks are formed with two or even three simultaneous closures. In the terms of the framework developed here, clicks are noncontinuants with extreme velarization, i.e., $\begin{bmatrix} +\text{high} \\ +\text{back} \end{bmatrix}$. They may or may not be glottalized. In this section our attention will be focused on the release mechanisms, and we shall therefore touch only in passing upon such major aspects of the clicks as the suction produced by the backward movement of the secondary closure or the order in which the different closures are released. These matters are discussed more fully in Section 5.3.

Our discussion is based primarily on the detailed description of clicks given in D. M. Beach (1938). Beach views the articulation of a click as composed of two separate parts, an "influx" and an "efflux." Under the term "influx" he subsumes the features that are relevant for the primary constriction; all other click features are subsumed under the heading "efflux." Beach finds that in Hottentot there are four types of influx: (1) the dental affricative ʇ, (2) the denti-alveolar implosive ǂ, (3) the lateral affricative ʖ, (4) the alveolar implosive type C. As the palatograms in Beach clearly show, the first two are dentals and the latter are "post-alveolar" or "palato-alveolar" (p. 81). In the terms developed here, all clicks are [+coronal]; the former two are [+anterior], the latter two [−anterior]. Each of the pairs has one member which is plosive and one member which is affricative. In our terms we characterize the former as being formed with an instantaneous release, and the latter as being formed with a delayed release. In the nonanterior clicks the delayed release is lateral rather than frontal.[24] We summarize the preceding discussion in Table 6 (p. 320).

[24] "The principal difference between ʇ and ǂ is not in the *place* but rather in the manner of influx. ʇ is affricative, whereas ǂ is plosive, in other words, the lowering of the tip and blade of the tongue is sudden for ǂ, but more gradual for ʇ. Doke . . . uses the term *instantaneous* and *drawn out* for *plosive* and *affricative*, respectively" (Beach, 1938, p. 77). "Although there is very little difference in tongue-position between C and ʖ there are two other very great differences. In the first place, C is "frontal," whereas ʖ is lateral. For C the tip of the tongue is lowered first, while for ʖ the release is made at the side (or sides) of the tongue. And in the second place C is implosive ("instantaneous"), whereas ʖ is affricative" (ibid., p. 80).

Each of these four classes of influx is paired with some efflux to produce a particular click. The number of different effluxes differs somewhat from dialect to dialect. We shall discuss here the Korana dialect which has the largest number of effluxes—six. These are, according to Beach, (1) nasal symbolized by *N*, (2) "weak unvoiced velar plosive" symbolized by *k*, (3) "strong unvoiced velar affricative" symbolized by *kxh*, (4) "glottal plosive"

TABLE 6.

	ʇ	ǂ	ʖ	ʗ
anterior	+	+	−	−
coronal	+	+	+	+
delayed primary release	+	−	+	−
lateral	−	−	+	−

symbolized by ʔ, (5) "glottal fricative" symbolized by *h*, (6) "velar glottalic affricative" symbolized by *kx*. Since each of the four influxes discussed in the preceding paragraph can be combined with each of these six types of efflux, there are twenty-four different clicks in Korana. (Nama, the other Hottentot dialect discussed by Beach, lacks the "velar glottalic affricative efflux" and hence has only twenty distinct clicks.) We must now characterize the features of the different effluxes.

Of the six effluxes, the one termed nasal by Beach presents no serious difficulty.

> In clicks containing this type of efflux the [nasal—NC/MH] efflux commences during the lingual occlusion before either the prevelar or velar release has been made. The prevelar influx then occurs, followed by a silent release of the velar closure. The nasal efflux continues throughout both of these releases, and to a lesser extent throughout the following vowel (p. 87).

This evidently is a click with nasalization, whereas the other five types of click are nonnasal.

Of the remaining five clicks, two are of the velar "affricative" type, whereas the others —and also the nasal type—have a "plosive" or "silent" velar release. The velar affricative release is described by Beach as being somewhat more gradual than the velar plosive release "so that an affricate . . . is heard instead of a pure plosive" (p. 85). It is clear that we are dealing with sounds differing in the manner of release of the secondary closure. The two affricative types have a delayed release of the secondary closure; all other types have instantaneous release. The two types with affricative secondary releases are further subdivided into an aspirated and a glottalized type. The aspirated type of efflux shall be classified as being produced with heightened subglottal pressure (aspiration), but without glottal constriction, whereas the glottalized type of efflux is produced with glottal constriction and presumably without heightened subglottal pressure. This type of efflux is described by Beach as being

> made by making two airtight chambers, an outer or mouth-chamber formed by placing the rim of the tongue . . . in the position for making the required influx, and an inner pharynx-chamber having as its boundaries the velar closure and the closed glottis. Suction is created in the outer or mouth-chamber by lowering the "front" of the tongue (still keeping the rim in contact with the roof of the mouth), and pressure is created in the inner or pharynx-chamber by raising the larynx (p. 232).

The glottalized type of efflux is marked, therefore, not only by glottal closure but also by an upward movement of the larynx which is the main characteristic of glottalized or ejective sounds. (See Section 5.3.2.)

Thus, of the three nonnasal types with plosive efflux, one is aspirated and the other two are nonaspirated. Of the latter, one is made with glottal closure, but apparently without movement of the larynx, and the other is made without glottal closure. We have been unable to determine the role, if any, that is played by tenseness in the production of clicks.

The feature characterization of the six types of efflux given above are summarized in Table 7.

TABLE 7.

	N	*k*	*kxh*	ˀ	*h*	*kx*ˀ
nasal	+	−	−	−	−	−
delayed release of secondary closure	−	−	+	−	−	+
glottal (tertiary) closure	−	−	−	+	−	+
heightened subglottal pressure	−	−	+	−	+	−
movement of glottal closure	n	n	n	−	n	+

n = not applicable

The click system of Xhosa, perhaps the best known of the click languages, is somewhat different from that of Hottentot. Of the four different types of influx found in Hottentot, Xhosa has only three, lacking the dental plosive types. Each of the three influxes may be produced with or without nasalization. Both nasal and nonnasal clicks may be aspirated or unaspirated. The unaspirated nonnasal clicks are, in turn, subdivided into voiced and voiceless. It appears, thus, that the release of the secondary closure plays no role in Xhosa; all secondary closures have an instantaneous release. The parallelism between voicing in Xhosa and glottal closure in Hottentot is found in many nonclick languages.

5.2.3. COMMENTS ON THE RELEASE FEATURES

COMMENT 1. We have seen that each closure in the vocal tract may be released instantaneously or with a delay. There are, however, important restrictions on the release features. Only sounds produced with closure can have different types of release. Ladefoged (1964) describes a labiodental flap (in Margi) which consists in effect of a labiodental fricative terminating in an instantaneous release. This sound, however, occurs only in "ideophones," e.g., in utterances such as *bə́v*^{b}*ú*, "describing sudden appearance and flight," *hév*^{b}*áwù*, "describing escape of an animal," *kév*^{b}*áhù*, "describing intruding into a place" (Hoffmann, 1963, pp. 25 f.), which occupy a clearly marginal position in the phonological system.

It appears that there are no clicks formed with laryngeal voice. In view of this we propose the following general restriction: in a sound formed with all three of the possible types of closure, only the primary and secondary can have both types of release while the tertiary closure must be released instantaneously.

COMMENT 2. In Jakobson, Fant, and Halle (1963), the difference between plosives and affricates was characterized by means of the feature "stridency." Plosives were characterized as nonstrident stops, affricates as strident stops. Thus no allowance was made for the existence of nonstrident affricates. Such sounds do, however, exist; for example, in the American Indian language Chipewyan, there are contrasting dental strident and nonstrident affricates (Li, 1946). The device for characterizing these differences is already available. Since the manner of release is clearly relevant for the secondary and tertiary closure, there is little reason not to extend it to include the primary closures, as was done above. In this way we can fill the gap just noted: plosives are stops with instantaneous (primary) releases, affricates are stops with delayed releases. The feature "stridency" can then be used to distinguish strident from nonstrident affricates. Stops with instantaneous releases are universally nonstrident.

5.3. *SUPPLEMENTARY MOVEMENTS*

In sounds formed with two simultaneous closures, such as the clicks, the labiovelars, or the glottalized sounds, there may be movements of the velar or glottal closures during the period of closure. If these movements are in a direction toward the lungs, the volume of the space between the two closures is increased and the pressure inside that space decreases. As a result, when the primary closure is released there will be a suction effect produced and air will flow into the mouth. If, on the other hand, the movement of the constriction is in a direction away from the lungs, the volume between the two closures will be reduced and the air pressure inside the cavity will increase.

These two opposite motions underlie the phonetic properties "suction" and "pressure," respectively. In the case of both suction and pressure we find that they can be produced by motions either of the velar or of the glottal closure. In fact, there are sounds (e.g., the imploded labiovelars observed by Ladefoged (1964, p. 9) in Idoma and Bini) where both closures move during the articulation of a single sound.

5.3.1. SUCTION

It must be noted that the velar closure that produces suction need not necessarily be a secondary closure but may also be a primary closure. In the Hottentot or Xhosa clicks, the velar closure is secondary, since, as we have seen, it combines with different primary articulations. In the labiovelar suction stops of such languages as Kpelle, on the other hand, the closure at the velum is primary and the closure at the lips secondary (rounding). The velar nature of the sound in question is clearly indicated by the fact that a preceding nasal, which always assimilates to the primary point of articulation of the following stop, is velar before labiovelars as well as before velars (Welmers, 1962).

CLICKS AND IMPLOSIVES. Since suction is produced by a downward movement of velar or glottal closures, it is necessary from a phonetic point of view to postulate two distinct suction features, one (the "click" feature) is associated with velar closure and the other (the "implosion" feature) with glottal closure. As noted above, the clicks have primary constrictions in the dental and alveolar region, but there are also clicklike sounds which have a labial closure. Moreover, there appear to be labiovelar suction sounds with glottal implosion. In his discussion of the African labiovelars, Ladefoged notes:

> These sounds are formed in at least three different ways . . . The first type occurs in many Guang languages (Late, Anum). It consists of simply the simultaneous articulation of *k* and *p* or *g* and *b*, superimposed on a pulmonic airstream. [In the terms of the preceding discussion, these are sounds without suction and glottal closure—NC/MH.] The second type, which is found in

> Yoruba, Ibibio, and many other languages, is more complicated. After the two closures have been made, there is a downward movement of the jaw, and a backward movement of the point of contact of the back of the tongue and the soft palate; these movements cause a lowering of the pressure in the mouth. Thus from the point of view of the release of the closure at the lips, there is an ingressive velaric airstream. But there is still a high pressure behind the velar closure owing to the outgoing air from the lungs . . . This combination of a velaric and pulmonic airstream mechanism has been described very accurately by Siertsema . . . who concluded that Yoruba $\widehat{kp}$ 'is implosive at the lips, "explosive" at the back.' [These sounds, then, are produced with suction at the velar closure, but, like the first type of labiovelar, without glottal closure—NC/MH.] . . . In the third type of $\widehat{kp}$, which is found in Idoma and sometimes in Bini, all three airstream mechanisms are involved. After the two closures have been made there is a backward movement of the tongue . . . and during the latter part of the sound there is also a downward movement of the vibrating glottis . . .[25] [This type of labiovelar is produced with closures at the velum and the glottis, and with suction movements at both closures—NC/MH.]

An interesting side effect of the lowering of the glottis in the implosives is that it is usually accompanied by vocal cord vibration. This vibration is the direct consequence of the drop in supraglottal pressure and the rise in subglottal pressure which result from the increase in the supraglottal volume and the decrease in the subglottal volume that are produced by the lowering of the glottis.

5.3.2. PRESSURE

Like suction motions, pressure motions can be executed by the velar or by the glottal closure. We must therefore postulate two pressure features, a "velar pressure" feature and a "glottal pressure" feature. We shall refer to the latter by its traditional name "ejection," in view of its greater familiarity.

VELAR PRESSURE. The existence of velaric pressure stops, which is occasionally mentioned in the literature (see Heffner, 1950), could not be substantiated.

EJECTION. Ejection is produced by an upward movement of the glottal closure. Ejective consonants have been described in languages all over the globe—in India, in the Caucasus, and in American Indian languages.[26] It has also been observed that ejectives and implosives differ in the effect on the transition of the second formant in the adjacent vowel. Ejectives have a transition with a somewhat higher termination frequency than the corresponding nonejectives, and resemble palatalized consonants in this respect; in the implosives (as in rounded or velarized consonants), the termination frequency is somewhat lower. This is a direct consequence of the fact that in the ejectives the glottis is raised above its normal position and is therefore being lowered during part of the vowel articulation, whereas in the implosives, at the beginning of the vowel articulation the glottis is lower than its normal position and moves upward. As a result, after the ejectives there is a lengthening and after

[25] Ladefoged (1964, p. 9). See also Beach's description of clicks with a "velar glottalic affricative efflux" on page 320. Note the close similarity between this type of click and Ladefoged's third type of labiovelar.

[26] On ejectives in the languages of India, see citations in Trubetzkoy (1958, pp. 146–150), where ejection is designated by the term *Rekursion*. On ejectives in the Caucasian languages, see Trubetzkoy (1931) and, more recently, Kuipers (1960). On ejectives in American Indian languages, see Sapir (1949b). In the West African languages surveyed by Ladefoged (1964), ejectives were found only in Hausa (p. 5).

implosives a shortening of the vocal tract, which is directly translated into a falling or rising, respectively, transition in the second formant of the adjacent vowel.[27]

5.3.3. ORDER OF RELEASES IN SOUNDS WITH MULTIPLE CLOSURES

The order of release of the different closures is governed by a simple rule. In sounds without supplementary motions, the releases are simultaneous. In sounds produced with supplementary motions, closures are released in the order of increasing distance from the lips. The reason for this ordering is that only in this manner will clear auditory effects be produced, for acoustic effects produced inside the vocal tract will be effectively suppressed if the vocal tract is closed.

5.4. TENSE—NONTENSE (LAX)

The feature "tenseness" specifies the manner in which the entire articulatory gesture of a given sound is executed by the supraglottal musculature. Tense sounds are produced with a deliberate, accurate, maximally distinct gesture that involves considerable muscular effort; nontense sounds are produced rapidly and somewhat indistinctly. In tense sounds, both vowels and consonants, the period during which the articulatory organs maintain the appropriate configuration is relatively long, while in nontense sounds the entire gesture is executed in a somewhat superficial manner.[28]

Dealing first with vowels, we find examples of tense versus nontense sounds in modern German, for instance, where this feature plays a differentiating role in pairs such as *ihre*, "her," versus *irre*, "err"; *Huhne*, "chicken," versus *Hunne*, "Hun"; *Düne*, "dune," versus *dünne*, "thin"; *wen*, "whom," versus *wenn*, "if"; *wohne*, "reside," versus *Wonne*, "joy"; *Haken*, "hook," versus *hacken*, "hack."

One of the differences between tense and lax vowels is that the former are executed with a greater deviation from the neutral or rest position of the vocal tract than are the latter. It has been observed, for instance, that the tongue constriction in tense [i] is narrower than that in lax [i]. This difference in tongue height is superficially rather similar to that observed between high [i] and nonhigh [e]. The mechanism involved, however, is quite different in the two cases, a fact which was already well known to Sievers (1901), who explicitly warned against confusing the two:

> Man hüte sich auch davor, die Begriffe "gespannt" (oder "eng") und "ungespannt" (oder "weit") mit denen zu verwechseln, welche die althergebrachten Ausdrücke "geschlossen" und "offen" bezeichnen sollen. Diese Letzteren wollen nur aussagen dass ein Vocal geringere oder grössere Mundweite habe als

[27] Sonagrams of implosives which show these transitions clearly can be found in Ladefoged (1964, Plate 4B). Note also the comment of Trubetzkoy (1931): "Was die Verkürzung des Resonanzraumes des Mundes betrifft, so geschieht sie in den ostkaukasischen Sprachen mit aktivheller Eigentonauffassung (*positive transition*) nicht durch die gewöhnliche Palatalisierung, d.h., Vorschiebung der Zungenmasse nach vorne, wie in vielen Sprachen der Welt, sondern durch die Verschiebung des Kehlkopfes nach oben" (pp. 10–11); as well as the observation of Ladefoged (1964) that in Igbo, at least, implosives are "velarized as well as usually involving lowering of the glottis" (p. 6), i.e., they exhibit secondary movements that bring about a negative transition in the adjacent vowel.

[28] This difference was well brought out in one of the earliest phonological studies, Winteler (1876): "... diejenigen Artikulationen, welche Lenes [lax—NC/MH] erzeugen, [werden] in demselben Augenblicke wieder aufgegeben . . . in welchem sie ihre Kulmination erreicht haben. . . . Bei der Bildung der Fortes [tense—NC/MH] verharren die Sprachwerkzeuge fühlbar in ihrer Kulminationsstellung . . ." (p. 27).

ein anderer, aber ohne alle Rücksicht auf die Verschiedenheit der Articulationsweise, welche die Differenzen der Mundweite im einzelnen Fall hervorruft, speciell also ohne alle Rücksicht darauf ob die specifische Mundweite auf grössere oder geringere Erhebung oder auf grösserer oder geringerer Spannung der Zunge beruht . . . (p. 100).

The greater articulatory effort in the tense vowels is further manifested by their greater distinctiveness and the markedly longer duration during which the articulatory configuration remains stationary. This fact has been documented by the detailed studies of X-ray motion pictures of speech conducted by Perkell (1965), who comments that:

the pharynx width remains relatively stable throughout the tense vowels whereas there is a change in this width during the lax vowels. . . . It is as though the tongue shape in the lower pharynx is relatively unconstrained during a lax vowel, and is free to be influenced by the adjacent phonetic segment. For a tense vowel, on the other hand, the tongue position and shape in this region are rather precisely defined.

Turning now to consonants, we note that the differences between tense and lax consonants also involve a greater versus a lesser articulatory effort and duration. The greater effort is produced by greater muscular tension in the muscles controlling the shape of the vocal tract. Evidence supporting this comes primarily from X-ray studies and from observations on the onset of voicing in vowels following a stop consonant. It is obvious that voicing can occur only if two conditions are met: the vocal cords must be in a position that will admit voicing, and there must be a flow of air through the glottis. When a stop is produced and the oral cavity is blocked while the vocal cords are in the appropriate configuration for voicing, pressure will build up in the cavity and will very rapidly—within about 20 msecs, under normal conditions—increase to the point where it is approximately equal to the subglottal pressure. This will halt the flow of air through the glottis, thereby making further vocal vibrations impossible. Under these conditions there is only one way in which the pressure buildup inside the vocal tract can be slowed down and voicing allowed to take place during the closure phase of a stop, that is, by allowing the vocal tract to expand. If the walls of the tract are rigid as a result of muscular tension, this expansion of the cavity volume cannot take place, and, therefore, tense stops will not show any voicing during the closure phase. If, on the other hand, the walls of the cavity are lax, the vocal tract can expand and voicing can occur even during the closure phase. In fact, X-ray motion picture studies conducted by Perkell (1965) show precisely this behavior.

In analyzing the behavior of the pharynx in the nonsense words [hət′ɛ] and [həd′ɛ] as spoken by American subjects, Perkell found that during the period of closure there was a significant increase in the pharynx width when the nontense [d] was articulated but not when the tense [t] was articulated. This increase in pharynx volume in the nontense obstruent was also accompanied by the presence of voicing during the period of oral closure, which, however, died off toward the end of the stop gap. Perkell commented:

The tense vocal-tract configuration for /t/ would imply a rigid vocal-wall, which would not expand to permit the increase in volume needed for a voiced stop. Presumably a similar tense configuration exists for the voiceless unaspirated stop consonants occurring in certain languages . . . For such stop configurations an instruction to the larynx musculature to assume a configuration appropriate for voicing would not result in vocal-cord vibration until the release of the stop, whereas a lax vocal-tract configuration would permit a limited amount of air to pass through the glottis, with consequent glottal vibration.[29]

6. *Source features*

6.1. HEIGHTENED SUBGLOTTAL PRESSURE

In discussions concerning tenseness it is usually observed that tense sounds are produced with greater subglottal pressure and that this fact accounts for the well-known presence of aspiration in the tense voiceless stops of many languages. Since, however, the tenseness of the supraglottal muscles is evidently controlled by a different mechanism than is tenseness in the subglottal cavities, these two properties cannot be combined into a single phonetic feature. Instead we must set up in addition to tenseness a feature of "heightened subglottal pressure."

It must further be noted that heightened subglottal pressure may be used in the production of a speech sound without involving tenseness (in the supraglottal musculature). This is the situation in the aspirated voiced stops of languages such as Hindi, where, according to Lisker and Abramson (1964), voicing commonly occurs during the period of oral closure. As explained in the preceding section, this is possible only when the vocal tract is allowed to expand during the stop closure; but this expansion *cannot* occur if the supraglottal musculature is tense. We shall say, therefore, that the voiced aspirated stops of Hindi are produced without tenseness but with heightened subglottal pressure.[30]

Heightened subglottal pressure is a necessary but not a sufficient condition for aspiration. Aspiration requires, in addition, that there be no constriction at the glottis. If there is a glottal constriction, aspiration will not occur. Stops of this type—produced with (supraglottal) tension, heightened subglottal pressure, and glottal constriction—are found in Korean, for example, where they constitute the third class of stops, in addition to the heavily aspirated tense stops produced without glottal constriction and the slightly aspirated stops produced with no heightened subglottal pressure and no glottal constriction. (For pressure measurements see Kim (1965).)

6.2. VOICED—NONVOICED (VOICELESS)

In order for the vocal cords to vibrate, it is necessary that air flow through them. If the air flow is of sufficient magnitude, voicing will set in, provided only that the vocal cords not

[29] The fact that the supraglottal vocal tract musculature is under greater tension in sounds such as the English [p t k] in initial position would provide a straightforward explanation for the observation made by Lisker (1963, p. 382) that "the rate of pressure build-up is significantly slower for voiced stops than for voiceless." The lesser rigidity of the walls in the "voiced" stops (which are nontense) would allow the cavity to expand after the buccal closure is made. This increase in volume would result in a slowing down of the pressure buildup inside the cavity. Since the volume would remain more or less fixed in the "voiceless" stops, which are tense, the pressure buildup after buccal closure would be more rapid in these consonants.

[30] The question of how this obvious relationship should be expressed in the phonetic framework is of great importance. It has been suggested that there be set up a hyper-feature of "strength of articulation" under which tenseness, heightened subglottal pressure, and, perhaps, certain phonetic features would be subsumed as special cases. While certain facts such as the treatment of Spanish consonants in different contexts (see J. Harris, 1967) make this suggestion quite attractive, we have not adopted it here as it conflicts with our conception of phonetic features as directly related to particular articulatory mechanisms. Instead we have chosen to reflect the interrelatedness among these different features with the help of marking rules (see Chapter Nine).

be held as widely apart as they are in breathing or in whispering. As has been demonstrated in the various high-speed motion pictures of the vocal cords, glottal closure or a constriction of the glottis is not required for voicing; it is necessary only that the glottis not be wide open. On the other hand, vocal cord vibration will also result when the glottis is constricted, as long as there is an air flow of sufficient magnitude or the vocal cords are not held so tight as to prevent vibrating, as they are in the case of sounds produced with glottal constrictions.

In Section 2.1 it was suggested that when the vocal tract is in its neutral speech position, the vocal cords are placed in a configuration that will cause them to vibrate if air flows through them. The vocal cords may also be spread farther apart than in the neutral position, in which case voicing will not occur. We shall restrict the term "nonvoiced" or "voiceless" to sounds produced with a glottal opening that is so wide that it prevents vocal vibration if air flows through the opening. This widening of the glottis is a sufficient condition to suppress vocal cord vibration, but, as suggested in the discussion above, it is not a necessary condition. It should be noted that the narrowing of the glottis in voiced sounds can be quite moderate and may never attain complete closure.

Our understanding of the mechanism of voicing has recently been advanced by the investigations of Lisker and Abramson (1964) of the onset time of vocal cord vibrations in the following vowel relative to the moment of release of the stop closure. We do not share Lisker and Abramson's view that it is the timing of the onset of vocal cord vibrations that is being controlled in implementing the various feature complexes that in the phonetic literature have often been subsumed under the term "voicing." The data on the onset of vocal vibration that have been gathered by Lisker and Abramson can be readily accounted for in terms of the present framework. It is to such an account that the remainder of this section is devoted.

From their measurements Lisker and Abramson conclude that the onset times of vocal vibrations fall into three distinct categories:

(1) onset of voicing precedes stop release
(2) onset of voicing substantially coincides with stop release
(3) onset of voicing lags after stop release

In an investigation of onset times of voice after Korean stops, Kim (1965) has found, moreover, that at least for Korean there are two distinct types of lag, a short lag and a considerable lag. In particular, he found that for the glottalized stop, voice onset occurred 12 msecs after the stop release (substantial coincidence); for the weakly aspirated stops, it was 35 msec (moderate lag); and for the heavily aspirated stops, it was 93 msec (considerable lag). (The cited values are mean values for about 800 sample words.) Re-examination of the Lisker and Abramson data shows such a moderate lag to be present at least after the velar stops of Korean, and also, somewhat less convincingly, after the labials and dentals; in addition, the unaspirated velar stops of Cantonese and English also show a short lag. We now have, therefore, four distinct categories:

(1) onset of voicing precedes stop release
(2) onset of voicing substantially coincides with stop release
(3) onset of voicing lags moderately after stop release
(4) onset of voicing lags considerably after stop release

To account for these facts we have at our disposal four phonetic features: voicing, tenseness, glottal constriction, and subglottal pressure. The simplest case to deal with is case (1)—the stops with voicing lead. All these must be produced with vocal cords in voicing position and without tenseness. The aspirated stops will, moreover, have high subglottal pressure and no glottal constriction. The unaspirated voiced stops will be produced with normal subglottal pressure; the data do not allow us to draw conclusions about glottal constriction, but we suspect that none is present. Next in complexity is case (4)—the sounds with greatly delayed voicing onset. These are all produced with vocal cords *not* in voicing position and hence without glottal constriction but with tenseness and marked subglottal pressure. The sounds of case (3)—those with slight or no aspiration and moderate delay of voicing onset—are produced with vocal cords not in voicing position, normal or low muscular tension in the vocal tract, and low or moderate subglottal pressure. It is significant that, as noted by Lisker and Abramson, it is precisely this category of stops in Korean that is "voiced through" in intervocalic position, rather than the stops with simultaneous voicing onset, which at first sight might seem more reasonable candidates. Observe, however, that it is the former rather than the latter type of stop that is produced without strong muscular tension in the vocal tract. In order for a stop to be "voiced through," it is necessary that the cavity be allowed to expand during the period of stop closure. Consequently one should expect the Korean lax stops to be "voiced through" rather than the tense stop with glottal constriction. Finally, there is case (2), the category where the onset of voicing substantially coincides with the stop release. These sounds are produced with a glottis that either is in the voicing position or has

TABLE 8.

	Voicing leads	Voicing coincides substantially	Voicing lags moderately	Voicing lags considerably
tense	No	Yes, if glottal constriction	No	Yes
voice	Yes	Yes	No	No
heightened subglottal pressure	Yes, if aspirated No, if unaspirated	Either	No	Yes
glottal constriction	No	Yes, if heightened subglottal pressure; otherwise, optional	No	No
Examples in Lisker and Abramson (1964) and Kim (1965)[a]	Dutch Spanish Tamil English[b] Thai Eastern Armenian Hindi Marathi[c]	Dutch Spanish Hungarian English Cantonese Korean Thai Eastern Armenian Hindi Marathi	 Korean	 English Cantonese Korean Thai E. Armenian Hindi Marathi

[a] When the name of a language appears in a particular column, this indicates that in the cited studies the language was found to have had stops of this type in contrast with stops of some other type. Thus, Dutch was found by Lisker and Abramson to have stops with voice onsets that precede the release as well as stops where the voice onset coincides with the release.

[b] Almost all instances of stops with voicing onset preceding stop release came from a single speaker, who, however, lacked stops where the voicing onset coincided with the release. All other speakers used the second type of stop almost exclusively. (See Lisker and Abramson, 1964, pp. 395–97.)

[c] Hindi and Marathi have two distinct types of stops in which voicing onset leads the stop release; these two types are distinguished by the presence or absence of aspiration.

a constriction. They may or may not be produced with heightened subglottal pressure. If they are produced with heightened pressure, they will be tense and may or may not have a glottal constriction.

We summarize this discussion in Table 8.

6.3. STRIDENT—NONSTRIDENT

Strident sounds are marked acoustically by greater noisiness than their nonstrident counterparts. When the air stream passes over a surface, a certain amount of turbulence will be generated depending upon the nature of the surface, the rate of flow, and the angle of incidence. A rougher surface, a faster rate of flow, and an angle of incidence closer to ninety degrees will all contribute to greater stridency. Stridency is a feature restricted to obstruent continuants and affricates. Plosives and sonorants are nonstrident.

Examples of nonstrident versus strident sounds are bilabial versus labiodental continuants in Ewe: *éɸá*, "he polished," *éfá*, "he was cold"; *ɛ̀βɛ̀*, "the Ewe language," *ɛ̀vɛ̀*, "two" (Ladefoged, 1964, p. 53); interdental versus alveolar continuants in English: [θin], "thin," [sin], "sin"; post-alveolar versus palatal continuants in German: [liçt], "light," [lišt], "extinguishes"; interdental versus dental affricates in Chipewyan: *tθɛ*, "stone," *tsá*, "beaver."

Strident liquids, which are nonvocalic (see Section 3.1) are found, for example, in Czech *řada*, "row," versus *rada*, "council," in which strident and nonstrident [r] contrast; in Bura and Margi we find contrasts of strident and nonstrident [l] (Ladefoged, 1964).

7. Prosodic features

Our investigations of these features have not progressed to a point where a discussion in print would be useful. Some recent work by W. S-Y. Wang seems to us promising. For a report of some early results, see Wang (1967).