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## TOWARDS A PHONOLOGICAL ALGORITHM

The ultimate goal of phonology is to uncover the mechanism whereby an indiscrete succession of sounds becomes a discrete chain of identifiable phonemes. A word falls naturally into morphemes and syllables. In the course of this double division two classes of languages emerge: those in which syllable- and morpheme-boundaries always coincide and those in which this correspondence is not obligatory. In the first case the minimal unit of segmentation is the syllable. In the second case we meet with such examples as *domus* in Latin, *reading* in English, and so on. Syllabically they are *do-mus*, *rea-ding*, morphologically *dom-us*, *read-ing*; the combined scheme is *do-m-us*, *rea-d-ing*. At the initial stage of processing the sound chain we are only able to discriminate between syllabic and phonemic languages, for /m/ in *domus* and /d/ in *reading* are phonemes, i.e. the smallest units of natural segmentation in non-syllabic languages. This is the most primitive and heuristically the earliest definition of a phoneme that a linguist can give. We will formulate the first instructions to the phonologist thus:

(1) Take any bimorphemic word (with a suffix or ending), divide it into syllables and by examining the points of morpheme- and syllable-division state the presence (resp. absence) of phonemes in the language.

In this paper we shall concern ourselves with phonemic languages.

The mainspring of further analysis is neutralization and related phenomena. Let us take the Russian form [goT]. This form is ambiguous and resolves itself into two different roots: *god-* "year" and *got-* "Goth". The fact that [goT] is the phonetic integument of only two forms proves that the distinction between *god-* and *got-* lies in one segment; if they had two different segments, the form under consideration would have resolved itself into at least four roots ( $n$  differences give  $2^n$  or sometimes  $2^n + 1$  forms): cp. the invented place-name [s·tki] ([·] designates a reduced pretonic vowel), which may equally

well represent *Sodki*, *Sadki*, *Sotki*, and *Satki* and thereby demonstrates that *sad-* and *sot-* have two points of distinction. Having found out that *god-* and *got-* constitute a minimal pair, we must localize the difference between them.

The forms of the Genitive case of the two words are *góda* and *góta*: syllabically *go-da*, *go-ta*, morphologically *god-a*, *got-a*. We cannot know how many phonemes there are in the syllable *go-*; neither do we know whether the case inflexion is monophonemic. But we may be sure that the stem-final elements of *goda*, *gota* are monophonemic (*go-d-a*, *go-t-a* as *do-m-us*, *rea-d-ing*). We have not learnt to compare phonemes, but we can compare *go-* of *go-da*, and *go-* of *go-ta*. The existence of the syllables *go*<sub>1</sub> and *go*<sub>2</sub> proves that they are able to function as independent words: otherwise their separation from the second syllables would have been impossible (cp. the English *latter* – *ladder*). But if they are words (actual or virtual: as a matter of fact /*go*/ does not exist in Russian but /*no*/, /*po*/, /*to*/, /*do*/, etc. exist), we can test their identity. If they prove to be homonyms, the difference between *goda* and *gota* is concentrated in /*d*/ – /*t*/; if they are non-homonyms, the difference lies to the left of /*d*/ – /*t*/, viz. in the vowels.<sup>1</sup> *Go*<sub>1</sub> (from *go-da*) and *go*<sub>2</sub> (from *go-ta*) are homonyms, and it follows that /*d*/ and /*t*/ are indeed different phonemes. The difference between them thus stated is the most abstract manifestation of a distinctive feature. So far it has nothing to do with phonetics; it is “a something” which keeps /*d*/ and /*t*/ apart.

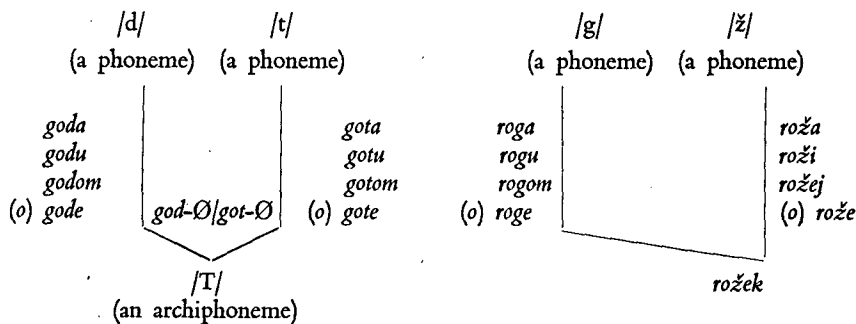
We have detected different phonemes in *go-d-a*, *go-t-a*, but we do not yet know the status of the stem-final consonant in [goT]. A chain of simple arguments will convince us that this element is not a phoneme of the same rank as /*d*/ or /*t*/.

Following the row *goda*, *godu*, *godom*, (*o*) *gode* (different oblique cases of *god-Ø*), we observe that the root is everywhere quite unambiguous. Only in the Nominative case we suddenly acquire a new meaning: [goT] is both *god-Ø* and *got-Ø*. A new meaning could not have sprung up, if one and the same phoneme went on alternating; consequently, the stem-final phonemes of *goda-godu-godom-gode* and *god-Ø* cannot be identical. On the other hand, the root of *gota-gotu-gotom-gote* is again unambiguous,

<sup>1</sup> Not in the prevocalic part, for the opposition *got* – *kot* «he – cat» could not have possibly been neutralized: all events in Russian inflexion happen at the end of the word. Also note the importance of the open syllable in *go-da*, *go-ta*: in a closed syllable we could suspect that the difference is covered by the first post-vocalic consonants.

and only in *got-Ø* we meet with an unexpected new meaning (not only *got-Ø* but also *god-Ø*). So here too the stem-final consonant of *gota-gotu*, etc. is not the same as that of *got-Ø*. The conclusion is ineluctable that [T] in [goT] does not belong either to /d/ or /t/. It is functionally a very weak element, and whatever its physical properties, it is unable to differentiate the morphemes which are distinct in all other situations. In [goT] both /d/ and /t/ must have lost the feature which otherwise prevents them from merging, and only the non-distinctive part must have remained.

The phenomenon analyzed above is alone worthy to be called neutralization. To make sure of it let us examine the root *rož-*. This is also an ambiguous root, for we have *rog-Ø* "horn" - *rožek* "little horns" (Gen., Pl.) and *rož-a* "mug" (or simply *rož-Ø* "rye"). A comparison of /ž/ and /g/ will give us a distinctive feature just as the comparison of /d/ and /t/ in *god-Ø*, *got-Ø*. But the ambiguity is present in all the cases of the word *roža* (*roža*, *roži*, *rože*, *rožei*, etc.): /ž/ does not crop up as a result of phonological weakening and is therefore a separate phoneme, as /g/. Graphically we may represent the two situations in the following way:



Our next instructions to the phonologist will be such:

(II) Examine all the monosyllabic roots of the language. Select those which are phonetically ambiguous and can be understood as the roots of two different words. Take these words and change them into dissyllabics. Find the point of syllable division in both and ascertain whether the first syllables in them are open. Only words with initial open syllables will easily lend themselves to preliminary analysis. Compare the left-hand open syllables: if they may be represented as different words, the roots under consideration have different vowels;

if the open syllables may be represented as homonyms, the difference lies in the postvocalic consonants. The opposition of the contrasting phonemes will yield the linguistic basis of the distinctive feature that keeps them apart. Study all the possible oppositions and get all the distinctive features obtainable by this method. The features will be only loosely characterized, e.g. "that which distinguishes the root-final consonant of such-and-such words and disappears before a pause". The element of the ambiguous form is not an independent phoneme if its occurrence is confined to this form. But if some root is ambiguous in all its forms and another root only in one form, we have a case of two independent phonemes crossing at a single point, so that the phonological make-up of the constantly ambiguous root remains unchanged.

When all the distinctive features have been extracted in this way, some phonemes will have become uniquely characterized as bundles of distinctive features. (It is important that at this stage a phoneme can be defined both as a minimal unit of natural segmentation and as a bundle of distinctive features, i.e. not only syntagmatically but also paradigmatically). But even these phonemes will be tied to the stem-final position. We must now learn to recognize these phonemes in other contexts, e.g. to identify /d/ in *goda* and /d/ in *dom* "house" as one and the same unit. This is the most difficult step, and nothing but a tentative solution can be proposed here. It seems that phonemes are discovered as purely linguistic entities but identified phonetically. After we have obtained the features of the type "that which distinguishes etc." (see above) we must find their physical correlates and use them as tools of further identification. Human language consists of sounds, and it could be expected that at some late moment the material implementation of phonemes would come in.

Our next instructions constitute a programme, which has already taken decades to carry out and whose termination lies in a comparatively distant future.

(III) Select the phonemes uniquely characterized as bundles of distinctive features and find their physical correlates. Use the correlates as marks whereby to recognize the phonemes in all contexts.

The Russian phonemes /d t g ž/ and some others are uniquely characterized by their distinctive features. But there are phonemes entering into few or no alternations. Thus, /b/ and /v/ never alternate in Russian,<sup>10</sup> and so the specific feature that keeps them apart defies detection. To be sure, while studying /d t g ž/ etc., we got a list of distinctive

features and later found their correlates. Therefore we can now choose some features from the general list and ascribe them to /b/ and /v/ (e.g. /b/ will be a stop and /v/ a spirant), but the arbitrariness of this procedure is apparent.

Every system of phonemes, if diagrammed, will consist of concentric circles. The nucleus contains phonemes so active that their behaviour is able to characterize them uniquely. Some phonemes are less active (e.g. /b/ and /v/ in Russian), others are (almost) non-characterizable at all (e.g. /l m n r/); in the outermost circle we shall find the English /h/ and kindred phonemes: these do not enter into any alternations and cannot be described by distinctive features. Phonemes may form a system or a list. Only the nucleus, definable through relevant features, deserves the name of system. Peripheral phonemes are juxtaposed as letters in an alphabet; they are also kept apart but their correlates must have an especially wide range of realizations.

Our next procedure resembles the previous one:

(IV) Select the phonemes whose characteristics only partly emerge from the alternations and those which are non-definable through their linguistic behaviour. Contrary to the nuclear phonemes, these must be studied as wholes, both by the linguist and by the instrumentalist. A phoneme non-analyzable into distinctive features is itself a materialized feature.

After we have identified the phonemes in all contexts each of them comes out as the invariant of some class of sounds. Hence the final definition of a phoneme: it is a minimal unit of natural segmentation in non-syllabic languages, a bundle of distinctive features, and the invariant of sounds possessing identical features.

The implications of the analysis suggested above are too far-reaching to be discussed here in detail. So only the most important of them will be enumerated.

1) Phonological research presupposes a certain amount of prosodic, morphological, and semantic data; we cannot start unless we know how to divide words into syllables and morphemes and how to distinguish homonymous forms and roots from non-homonymous ones.

2) To discover phonemes means to find their syntagmatic boundaries and to arrange them into a system. No paradigmatic procedures or procedures of identification are possible until the phonemes are separated from their neighbours.

3) Preliminary segmentation and identification concerns stem-final consonants. Later they are used as "yardsticks" to define and identify stem-initial consonants. Thus, the syntagmatic procedure comes first; then follows the paradigmatic identification of phonemes at the end of the stem, and only after that the whole string falls into discrete elements. Until the last step is made, phonology is divorced from phonetics (except what concerns syllable-division) and is a shadow of morphology.

4) Phonemes form either systems or lists, according as the language is rich or poor in inflexion.

5) A phonological algorithm starts with the function and ends up with realizations. It rejects the idea that phonology is functional phonetics and operates on the assumption that phonetics is instrumental phonology.

It is our hope that the procedures discussed in this paper can, in principle, serve the basis of an algorithm by which a chain of phonemes is generated from an indiscrete sound string. Once this algorithm becomes a reality, its programming will be almost a technical problem; we shall be able to construct an analogue of the actual speech mechanism and approach coveted goal, viz. automatic treatment of phonic substance.