Structure and Function in Phonology – A Systems View
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STRUCTURE AND FUNCTION IN PHONOLOGY - A SYSTEMS VIEW

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Romuald Schild of the Polish Academy of Sciences and a scholar of Stone Age prehistory of Europe has recently pointed out the increasing contemporary need for the integration of all scientific knowledge. (Schild, p. 100). Roman Jakobson has specifically emphasized that 'the relationship between linguistics and the adjacent sciences awaits an intensive examination' and notes that this idea had already been expressed by Edward Sapir in 1928. Jakobson comments that the 'problem of interrelation between the sciences of man appears to be centered upon linguistics' because of the 'unusually regular and self-contained patterning of language and to the basic role it plays in the framework of culture.' He further remarks that since linguistics is recognized as the 'most progressive and precise among the sciences of man,' it stands as a methodological model for the social disciplines. (Jakobson, pp. 25ff).

In addition to the close relationship between linguistics and such disciplines as anthropology and psychology, Jakobson notes the striking similarity between the structures of language as an informational system and the genetic code as an information-carrying system: both are based on discrete components 'which, by themselves, are devoid of inherent meaning but serve to constitute the minimal senseful units, i.e., entities endowed with their own, intrinsic meaning in the given code.' (Jakobson, p. 50). These structural similarities are attributed to the consistently hierarchical design of the respective messages as their fundamental integrative principle. Jakobson's observation is a stimulating one: if the similarities between the genetic and the linguistic codes are due to the hierarchical design of their respective messages and not to the physical structure of the messages themselves - as must be the case since the genetic code is chemically defined and the linguistic code is ultimately acoustically defined - then we must be concerned with the properties of hierarchical structure and organization as such, without reference to specific structural details of the systems we are comparing.

Although Jakobson claims that the scientific study of linguistics lies at the intersection of the physical/biological sciences on the one hand and the social sciences on the other, i.e., that linguistics serves as the interface between them, the proliferation of studies into the nature of hierarchies and complex systems has not centered specifically around linguistics. Rather, the consensus of opinion which is rapidly forming with respect to the general systems theory of hierarchical organization has by-passed linguistics and has been developing instead in the areas of subatomic and astro-physics, chemistry, biology, sociology, economics, computer science, education, and psychology. For instance, a symposium on hierarchical structures was held in November, 1968, at the Douglas Advanced Research Laboratories in Huntington Beach,

California, and included scientists from the areas of astro-physics, biology, philosophy, sociology, computer science, and education. The science of linguistics was not represented. Other examples of the lack of participation in current dialogues involving hierarchical or general systems theory by linguists can be mentioned, even though scientists in other disciplines regularly use linguistic terminology to convey their ideas. If linguistic science is to lead the way in theory and methodology for all the other sciences, we must see to it that it hurries to the head of the line and finds out where everybody is going.

Hierarchy or general systems theory concerns the questions of how complex systems are organized, the relation between structure and function of the same system, and the properties of complex systems in general. Although hierarchical organization of linguistic structures has been recognized for some time, I believe that the currently developing theories regarding the relationship of structure and function in complex systems is of immediate and fundamental importance to linguistic theory, particularly in the field of phonology.

One of the most important conclusions that general systems theory has come to is that the structure of any system cannot be derived from a knowledge of its functions nor the functions from a knowledge of its structure. A simple analogy or two should make this clear: if we confine a gas in a closed chamber, we can measure the pressure of the gas, yet the force we define as pressure is not the result of adding together the individual pressures of the gas molecules since each particle as such does not have pressure, only random motion. Again, suppose that you are caught in a traffic jam. You cannot define a traffic jam except in terms of the interactions of a number of vehicles taken as a whole; the traffic jam does not exist as a trait of the individual driver or vehicle nor of the interaction of any two vehicles such that the sum of these traits would equal the 'traffic jam.' The traffic jam is a property of the entire collection of vehicles which emerges when a particular level of vehicle interaction occurs.

The most common and concrete concept associated with hierarchical organization is the concept of discrete but interacting levels. We may conceptualize this idea by using Herbert Simon's metaphor of a set of Chinese boxes of a particular kind: 'opening any given box in a hierarchy discloses not just one new box within, but a whole small set of boxes; and opening any one of these component boxes discloses a new set in turn, but while the ordinary set of Chinese boxes is a sequence, or complete ordering, of the component boxes, a hierarchy is a partial ordering - specifically, a tree.' (Simon, p. 5). The problems associated with the levels concept include: what generates these levels? Why are the levels discrete? What separates the levels? What couples them together? In sum, what is the character of the interface between levels, how does it function, and how does hierarchical control operate between levels? We must be particularly interested in these questions since, as pointed out by Benveniste, 'a

linguistic unit may be conceived as such only insofar as one can identify it within a higher unit.' (Quoted in Jakobson, p. 51).

The problem of structure and function can be stated as one of alternate descriptions of the same phenomena, analogous to the equations of quantum physics where the position and the velocity of a particle cannot be simultaneously determined but the relationship between these two possible descriptions is expressed by the Heisenberg Uncertainty Relations. The nature of alternate descriptions can, therefore, be restated as static and dynamic descriptions of the same phenomena which are complementary.

The dynamic description of a system which is self-maintaining defines the relationships of the first-order components of that system; that is, the set of boxes we see when we open one of our Chinese boxes. The first-order components themselves, while each may contain another set of boxes, are necessarily treated as stable units. We may call this a single level of organization. The relationships of the first-order components, however, require adaptive interaction to qualify as a system. Their interactions are conservative in that their constant mutual adaptation results in an equilibrium which allows stable properties of the system as a whole to emerge. The maintenance of these stable properties allows the system to be treated as a stable unit, functioning as part of the internal mutually adapting structure of the next higher level of organization in a complex system composed of nested systems. In this way, an element can be treated as an independent integrated system at one level and simultaneously as an adaptive part of the internal structure of another system at the next higher level of organization.

If the first-order components exceed two in number, their interrelationships in terms of mutual adaptation in the context of the entire system can only be understood mathematically in terms of pairwise interactions. In fact, it has been shown that a set of differential equations representing the changes in the internal interactions of a system cannot be added together to arrive at the pattern of change in the system as a whole. That is, it can be mathematically shown that the system considered as a whole is not reducible to the simple sum of the properties and functions of its parts since the equation which describes the changes in the system as a whole is different in form from the set of equations for the changes in the internal interactions. (Laszlo, 1974, p. 212).

The description of the dynamic interactions, then, constitutes the dynamic description of a system while the description of the properties of that system taken as a whole represents the static description of the system.

To make these abstract statements clearer, let us consider the analogy of a marriage. Within a marriage the relationship of the two partners in terms of dominance may vary, depending on circumstances, but will reach a stage of relative equilibrium and we can speak of a 50-50 marriage, a 60-40 marriage, or even a 90-10 marriage. At all times the sum of the dominance percentages is equal to 100% but the properties of the marriage taken as a whole

cannot be derived from knowing the ratio of dominance. A master-slave relation such as the 90-10 marriage may be a peaceful one or an angry one but we can't predict which it will be.

The fact that we add together the relative dominance percentages to arrive at the total of 100% or unity reflects the reason for the cohesiveness of such a relationship: the mutual adaptations which result in equilibrium are undertaken in terms of a larger unit whose integrity must be maintained. If each partner did as he or she liked without reference to the other, we would not have a mutually adaptive relationship, that is, no real marriage would exist. The familiar phrase, the 'give-and-take of marriage' reflects the common understanding of this kind of internal structure of an external unity.

The static description defines the properties of the whole system in terms of which it may participate as part of the structure of the next higher level of organization. For example, our married couple may be considered by the law as a unit for tax purposes: the total income of a marriage may be taxed at a rate different from that for the total income of a single person. At this level of organization, the law ignores the internal relationships established by the marriage partners in terms of which earned more money than the other. If the law could not ignore such details of structure, it could not organize its tax system hierarchically since every income-earning individual would have to be considered simultaneously in terms of his or her financial interactions with every other individual in the system which the tax law governs.

Hierarchical organization involves two kinds of structure: internal structure or the relationships between components at a single level, and external structure or the relationships existing between levels. Hierarchical organization allows the progressive integration of many simpler systems into fewer and fewer but more and more complex systems and presupposes at every level the stability of the units which make up its nested internal systems. Such an organizational scheme allows for partial internal restructuring without destroying the entire complex system. Thus, when we have opened the lowest level of Chinese boxes, we will have a great many elements but the integration of these elements into larger and fewer sets will contribute to the stability of the system as a whole since we can decompose a box at any level into its component boxes without destroying the system.

For example, if our married couple decides to dissolve their marriage, they have in effect decomposed the marriage unit into its component parts, two individual people, which we may regard as the lowest level of organization in terms of the law. However, the dissolution of a marriage - that is, a loss of a level of organization - will not destroy the social system which the law governs since the decomposition of the marriage into its component parts affects only that subsystem, and its component parts merely descend to the next lower level and increase that level's population and their interactions.

If we must consider that a change of any component at any level of a complex system will directly affect every other component, we do not have a hierarchical complex system at all but a simple one with a great many interacting components at one level of organization. The more levels of organization within a complex system, the more stability it will have. In fact, the stability of the American political system can be attributed to the many levels of organization it contains: city, county, district, region, state, and nation.

A component of any system may simultaneously function as a component of other systems and will be constrained to adaptive interaction in those other systems. For instance, the husband of our married couple may simultaneously be a member of a professional organization, an office worker, a community leader, and a father. In all of these situations, he must make adaptations in order to maintain relationships. We will require different system descriptions for each activity that the husband engages in. This kind of simultaneous participation in a variety of separate distinguishable activities in separate distinguishable systems is characteristic of biological systems with their stratification into many levels of organization (Rosen, p. 59), and reminds us of the similarities which Jakobson and others have observed between biological and linguistic structures.

It may appear from the foregoing that I am stating the obvious and that linguistic theory has incorporated the insights of hierarchy theory, especially in the generative approach to linguistic analysis. It is certainly true that transformational grammarians propose a tree structure as a model for representing the grammatical relationships in a sentence and each bifurcation can be understood as an organizational level. However, the only structure that is considered is the external one, i.e., the relationships between levels, and does not provide for a way of understanding and representing the relationships of components which interact at the same level of organization.

Langacker has recently noted that transformational theory regards all the clauses in a tree structure as comparable in function. He has, accordingly, proposed the concept of functional stratigraphy which claims 'that the clauses or propositions of a sentential structure differ in function in a way that correlates with their relative depth of embedding, or stratigraphic layering.' (Langacker, p. 2). Langacker's proposal for a hierarchically organized semantic structure is appropriate since external descriptions can only be functional ones, not structural. (Rosen, p. 51).

Similarly in phonological theory the generativists do not allow for considering the interrelationships of elements at the same level of organization nor the possibility of systematic hierarchical structuring of the phonological component. The theory of natural classes based on the intersection of the distinctive features does form a hierarchy but only a taxonomic one since it merely postulates a system of elements held together by the inclusion relation and does not consider the aspects of dynamic interaction which

must be present by definition if a true system exists. The Chomsky/Halle approach to phonological analysis assumes a simple set of fundamental components, the distinctive features, and describes their distribution by means of phonological rules which may be read as either process statements or distribution statements. The device of the abstract underlying representation reflects the resolution of conditioned and unconditioned elements to the unconditioned member, and the ordering of the phonological rules is an attempt to combine the methodology of internal reconstruction which infers chronology in sound change with the effects of analogical restructuring, even though these two kinds of phonological change take place on entirely different bases: true sound change takes place on the basis of phonetic interactions while analogical change takes place on the basis of morphological functions.

When generative grammar was first proposed, it was assumed that a parallelism in structure existed between the syntactic component and the phonological component: each included a base or deep structure level which was related to its surface structure level by a set of ordered rules. Apparently in the interests of what was considered to be an appropriate index of simplicity, it was proposed that the number of significant linguistic levels should be reduced to two: the base or underlying level and the surface level. All intervening levels that might be created by the actions of the rules were specifically designated as linguistically insignificant. The interfaces between the semantic component, the syntactic component, the phonological component, and the phonetic component were not elegantly thought out and the difficulties of locating the division between semantics and syntax are currently of major interest. In phonology the readjustment rules which appear to function as the interface between syntax and phonology are also a source of difficulty. The most famous result of abolishing levels of organization in the phonological component was the destruction of the autonomous phoneme. Since all later phonological theories which have been proposed are derivatives of the Chomsky/Halle hypothesis, it will be useful to consider the basic assumptions of that theory.

The first basic assumption that distinctive features may be determined on the basis of acoustic and/or articulatory criteria without reference to a specific language system is equivalent to saying that the function of a particular kind of speech sound can be determined from its structure alone. This assumption contradicts the findings of every other scientific discipline, all of which agree that structure and function are incomparable and the one may not be derived or inferred from the other. In general, the error of this assumption has not caused major difficulties in analysis although a number of scholars have observed that various aspects of the distinctive feature theory are inadequate or force the writing of unnecessarily inelegant and clumsy rules. It is more likely that the distinctive feature system as proposed has instead limited the kind of phonological problems which can be solved with it. Y. R. Chao in his famous 1934 article has clearly

presented the arguments against assuming that there can be distinctive speech elements - whether phonemes or distinctive features - which can be determined independently of any specific language system.

Although generative phonology when it was first proposed seemed to offer an elegant and fruitful method for understanding and solving phonological problems, it has come under increasing attack from a number of scholars. Where the difficulty lies is not at all clear: the problem has been sought in the depth of the underlying representation, in the nature of rule ordering, in the formalism proposed, and in the nature and number of distinctive features. These difficulties indicate that the theory as a whole has a more basic flaw. Unless we can locate that flaw and remedy it, we are in danger of seeing phonology as a field of inquiry dwindle into a sterile and trivial exercise.

Chomsky and Halle's assumption that simplicity of structure, that is, reduction of levels, is equivalent to simplicity of organization is again equivalent to saying that the function of any entity can be derived from a knowledge of its structure. The device of organizing a set of components by means of ordered distribution statements is a particularly inefficient method of accounting for relationships. This was the early method employed in computer programming when it was thought to be the most economical approach to the problem of information storage and retrieval. However, it became increasingly clear that a more efficient method must be developed and computer programming is now being done on a module basis, essentially a hierarchical organization of components which can be partially decomposed and reprogrammed without having to search through the entire set of ordered instructions and having to consider the interrelations of all those instructions at one time. This new approach is called 'structured programming.' From this example, we may suspect that a far more efficient way of organizing the phonological component would be to postulate as many intermediate levels of organization as possible in order to allow for partial restructuring without endangering the system of relations as a whole and in order to ensure the greatest possible stability of the system. One of the continuing complaints, in fact, has been that generative phonology does not provide a way of accounting for the syllable and the disyllabic sequence as phonological units, both of which would represent progressively integrated intermediate levels of organization. (Grundt, Lehiste)

One way of demonstrating the need for assuming intermediate levels of organization in the phonological component would be to show that the assumption of self-maintaining subsystems with internal structure in equilibrium and external adaptation to co-occurring subsystems will allow the solution of formerly insoluble problems and can integrate and account for sound changes which were thought to be unrelated and unmotivated.

I have argued at length elsewhere (Grundt 1973, 1974, 1975a, 1975b) that open syllable lengthening in Germanic languages was

motivated by the need of a disyllabic sequence to maintain its integrity as a speech timing unit by means of compensatory internal durational adjustments: when the second vowel of the disyllabic unit was shortened and reduced, the first vowel increased in duration in proportion, thus changing the internal structure of the disyllabic sequence but allowing the maintenance of the sequence as a timing unit. In other words, the durational ratio between the vowels changed by compensatory mutual interaction of co-occurring entities at the same level of organization. At the same time the lengthening vowel considered as a unit with particular functional properties was in danger of losing its functional ability to contrast with the old long vowels in open syllables, a function required by the morphological system. But the means by which the change in durational ratio with the second vowel was implemented, that is, by the formation of a falling centering diphthong, also functioned as a means of differentiating the lengthening vowel from the old long vowels. The old long vowels, in their turn, reacted simultaneously to the lengthening vowels by mutually adapting reciprocal formation of rising diphthongs. This can be analyzed at every point as a set of pairwise interactions, each of which has two different aspects: in terms of the first change, the second change is a reaction, but in terms of the third change, the second change is an innovation; and this chain of interactions can continue until an equilibrium within a larger system is established. Also, at every point the changes can be defined in terms of both dynamic interactions and functional contrast, thus satisfying the general systems hypothesis that every system has two descriptions, a structural and a functional one. Furthermore, since the final vowels in disyllabic sequences were reduced to schwa, they thus lost their contrastive function in that position. But the morphological system required that contrast of short vowels in final position since its inflectional system was based on it. The loss of this functional ability to contrast in final position was catastrophic in English: during the Middle Ages the entire grammar changed, all inflectional morphemes except consonantal ones were lost and word order became far more rigid in compensation, thus illustrating that every higher organizational level must have stable units comprising every lower level in order to remain stable.

Another reason to suppose that the short vowels and the long vowels form related but self-maintaining subsystems within the vocalic component is the fact that, when the morphological system no longer required the old contrast of long and lengthened vowels in open syllables, they merged in the long system. However, the lengthened vowels did not merge with the long vowels to which they corresponded in former long-short alternations as in wild/wilderness, ride/riden but with those vowels which were one vowel height lower. Acoustic studies in modern Faroese and Cologne German have shown that the short vowels are not merely slightly lower and centered versions of the long vowels but actually coincide in their formant patterns with the long vowels one degree

lower: /i/ = [e], /e/ = [ɛ], /ɛ/ = [æ]. This means that the long and short vowels which had the same function in their respective systems had drastically different phonetic realities: the isofunctional members were not phonetically equivalent and, therefore, the functional and structural descriptions of the same set of formant frequencies were different.

It is clear that this analysis agrees with the general systems theory of hierarchical organization in complex systems since the changes were motivated by the need to maintain the integrity of a larger unit, they were implemented by mutually adapting interactions, the functional and phonetic descriptions of the same phenomena were different, and finally the changes can be analyzed as pairwise interactions at every point. This approach allows the motivation and interrelation on both phonetic and functional grounds of open syllable lengthening, long vowel diphthongization, and vowel height exchange. Neither the motivation nor the interrelatedness of these changes can be accounted for in generative phonological theory because that theory does not provide for intermediate levels of organization nor any means of understanding and describing the interrelations of components occurring at the same level of organization. It is obvious that, if a particular entity has a different description for its structural and its functional correlates, it cannot be described with one system of distinctive features. Such features can only describe the functional aspect. The phonetic reality of these functional features must be separately determined and specified. Historical linguists have always assumed this to be true.

The assumption of intermediate levels of organization and adaptive interrelated subsystems at each level will account for all the changes that are accounted for in generative phonological theory, will restore the autonomous phoneme to a respectable place in the hierarchy, and can account for and interrelate sound changes that have been unrelated and unmotivated before. It also demonstrates the crucial need to keep functional and structural descriptions distinct since each element has a functional and a structural description which are different and non-comparable. The ignorance of this fundamental fact is the source of all the difficulties with the generative theory: in distinctive features, in reduction of levels, and in the theory of rule ordering.

Finally, the general systems theory of hierarchical organization satisfies the scientific criteria of simplicity since the organizational principle is very simple, yet can result in ordered and highly complex systems. The principle is essentially this: in conservative self-maintaining systems, the systems functioning as wholes on one level function as parts on the higher levels, and the parts of a system on any level (with the exception of the lowest or 'basic' level) are themselves wholes on lower levels. (Laszlo, 1972a, p. 51). The interfaces between the levels are discrete because the means of forming more and more complex organizational levels are themselves discrete.

Jakobson has commented that natural languages share with biological systems the characteristics of structural regularities, dynamic equilibrium, and cohesive power. (Jakobson, p. 53). The similarities in structure are due to a common principle of organization of hierarchical complex systems, and the cohesiveness of such systems is due to the dynamic equilibriums which must be maintained at each level in order to ensure the stability of the whole. It would appear that Romuald Schild's call for the integration of all scientific knowledge can best be implemented by the use of the one principle that all current research indicates the sciences have in common: hierarchical organization of complex systems.

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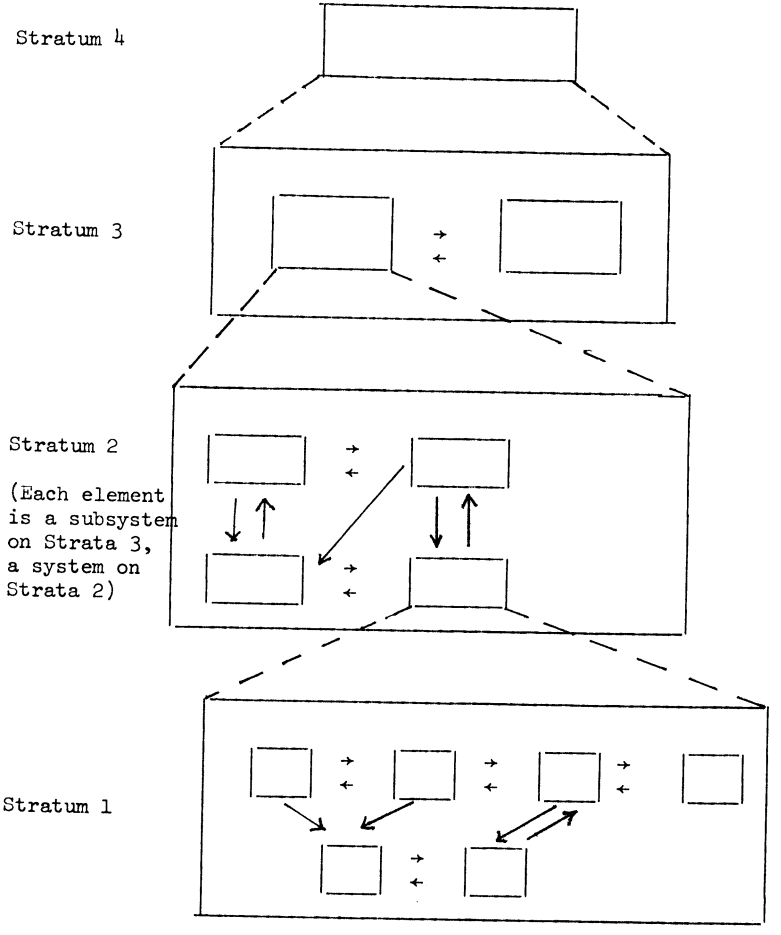
Model of a Multi-Strata (Multi-Level) System:

(Taken from: Mesarović, M. D. and D. Macko. 1969. Scientific theory of hierarchical systems. In: Hierarchical structures, Whyte, Wilson and Wilson, eds. American Elsevier Publishing Co. 29-50).



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Mesarović and Macko, p. 34. 'On any given stratum, the behavior of the corresponding systems are studied in terms of their internal operation and evolution, while the question of how these systems interact so as to form a higher stratum system is studied on that higher stratum....this object-system relationship between descriptions on various strata leads to a hierarchy of appropriate description languages. Since for each stratum there is given a different set of concepts and terms to be used for the description of the system on that stratum, there exists in general a different language.'

Germanic vowel changes: open syllable lengthening, final vowel reduction, long vowel diphthongization vowel height exchange

Stage 1 $V_1 \rightleftarrows V_2 / \#C\_\_C\_\_\#$ (stable vowel duration ratio maintained)

Stage 2 (e.g., /e/ is lengthened)

a. $V \rightarrow [ə] / \#CVC\_\_\_\#$

b. /e/ = [ɛ] → [éə] /#C__Cə#

c. /e:/ = [e:] → [ǽ]

d. /ɛ:] = [ɛ:] → [ɛ́i]

Note: 2-a is an innovation with respect to 2-b but a reaction with respect to an earlier change not considered here.

2-b is a reaction with respect to 2-a but an innovation with respect to 2-c.

2-c is a reaction with respect to 2-b but an innovation with respect to 2-d.

At 2-d it is assumed that equilibrium of the long and lengthened vowel subsystems has been established.

This analysis is supported by reflexes in the Soest dialect of Low German. (Holthausen, F. 1886. Die Soester Mundart. Diedrich Soltau's Verlag).

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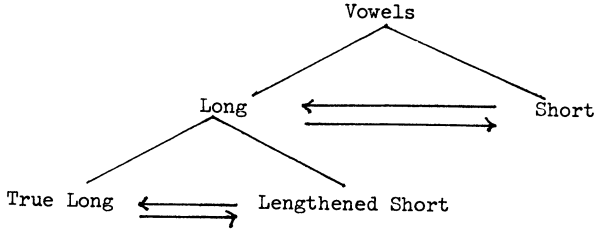
Vowel Subsystems in Soest (Westphalian) Dialect of Low German



Old long vowels:

UI	IU
ɔɛ	ɛɔ
aɛ	aɔ
ɛ:	ɔ:

Lenthened short vowels:

iə	yə	uə
ea	öa	oa
	a:	

Short vowels:

I	Y	U
ɛ		ɔ
	a	

Sources:

MLG	Soest
i:, ü:	UI
u:	IU
e:	aɛ
ɛ:, ä	ɔɛ, ɛ:
a:	ɔ:
ɔ:, ö	ɛɔ, ɔɛ
o:, ö:	aɔ, aɛ