Variation and Selection in Language Change*

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When one hears the word "evolution", one typically thinks of biological change, especially these days when much is being written to honor the memory of Charles Darwin, who died a century ago. Yet in a recent article by a leading biologist, we find an enthusiastic acknowledgment of evolutionary work done in another field: on language. I quote from Lewis Thomas (1981):

> "Long before the time when the biologists, led by Darwin and Wallace, were constructing the tree of evolution and the origin of species, the linguists were hard at work on the evolution of language. After beginning in 1786 with Sir William Jones and his inspired hunch that the remarkable similaries among Sanskrit, Greek and Latin meant, in his words, that these three languages must 'have sprung from some common source, which, perhaps, no longer exists,' the new science of comparative grammar took off in 1816 with Franz Bopp's classic work···—a piece of work equivalent in its scope and in its power to explain, to the best of nineteenth century biology. The common Indo-European ancestry of English, Germanic, Slavic, Greek, Latin, Baltic, Indic, Iranian, Hittite, and Anatolian tongues, and the meticulous scholarship connecting them, was a tour de force for research—science at its best, and social science at that."[1]

Historians of linguistics will tell us that the Indo-European hypothesis, in

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1. I am indebted to Hsin-I. Hsieh for this quote.

its various forms, was already in the literature perhaps a century before Jones delivered the famous lecture on his "hunch", much as traces of Darwin and Wallace could be found in their precursors. Nonetheless, no one disputes that in the works of Jones, Bopp, and several other scholars of the early nineteenth century, linguistics first emerged as a systematic discipline.

Language evolution has always fascinated thinkers in many areas. Charles Lyell, whose work in geology helped shape Darwin's ideas, devoted a chapter on the similarities between languages and species in his book, The Geological Evidences of the Antiquity of Man. Darwin himself was deeply curious about language. He and his wife kept a notebook on the linguistic development of their children, with entries spanning from 1839 to 1856. [2]

In chapter 3 of his Descent of Man, he remarked that "the formation of different languages and of distinct species···are curiously parallel," and went on to enumerate some of these parallels in these words:

> "We find in distinct languages striking homologies due to community of descent, and analogies due to similar process of formation. The manner in which certain letters or sounds change when others change is very like correlated growth. We have in both cases the reduplication of parts, the effects of long-continued use, and so forth. ···We see variability in every tongue, and new words are continually cropping up, but as there is a limit to the powers of the memory, single words, like whole languages, gradually become extinct. ···The survival or preservation of certain favored words in the struggle for existence is natural selection."

This parallelism is echoed by Lewis Thomas in his book, The Lives of a Cell, who added some comparisons with modern genetics. "Some mixed words are dominated by one parent while the other is recessive. The way a word is used this year is its phenotype, but it has a deeply seated, immutable meaning, often hidden, which is the genotype."

2. I thank Edward S. Reed for calling my attention to the Darwins's Notebook. It is currently in the Darwin Archives of the Cambridge University Library.

Wallace also thought much about language evolution. In fact, his observation that "the lowest savages" possessed languages "not in any way inferior to that of the higher races" led him to have increasing reservations about the applicability of biological evolution to human intellect, and to a parting of the ways between himself and Darwin. The (apparently) equal complexity of all human languages and their great distance from animal communication systems were also noted by the linguist Max Muller, who challenged Darwin's theories in several public lectures, entitled Mr. Darwin's Philosophy of Language.

There were linguists, however, who quickly saw the pertinence of Darwin's ideas and applied them in a rather literal way to their own endeavors. The best known work is by August Schleicher, who wrote in the form of an open letter to his neighbor, the biologist Ernst Haeckel, who first drew Schleicher's attention to Darwin's Origin. This work published in Weimar was immediately translated into English with the title, Darwinism tested by the Science of Language, 1869.

Schleicher's monograph was to have a great influence on the development of linguistic thought in its literal application of biological concepts and vocabulary. Thus today we speak of languages living and dying, parent languages and sister languages, genetic relations, and so on. Today, languages are typically shown to be related by tree diagrams, much as Schleicher advocated over a century ago. Such diagrams are completely appropriate for the classification of biological species where the transmission of traits is strictly vertical, i. e., from parent to offspring. Language transmission, however, often proceeds along other paths (from peer to peer, from teacher to pupil, etc.), and the tree diagram needs to be supplemented in major ways if we are to understand language relations accurately.

Once the conceptual foundations were laid for language evolution, questions naturally arose as to the exact mechanisms whereby language changes. The realization came early that it is the change in the phonetic shape of words that is frequently responsible, directly or indirectly, for the whole-sale restructuring of languages. English is now clearly very different in its structure from its sister

languages in the West Germanic group, and these differences came about largely through the phonetic reduction of inflectional endings.

Another reason for the concentration of effort on sounds is that each language has a small inventory of just a few dozen sound categories. As sounds change from one category to another, they tend to follow a surprisingly small set of recurrent patterns, regardless of the time or the language in which the change is taking place. These patterns are ultimately due to our biological equipment for the production and perception of speech, in terms of some principle of least effort.

We can see such a principle at work in other linguistic systems as well. This is nicely captured in an example provided by Klima and Bellugi from American Sign Language (1979):

> "When deaf researchers in our laboratory needed to refer to a videotape recorder, for which there was no regular ASL sign, they used the index fingers of both hands moving counterclockwise (as the reels do) to indicate the tape moving from one reel to another. Within a short period of time, however, some of the realism of the representation was lost. The neologism is now made with the index fingers describing circles that both move inward, no longer mimicking the way the reels actually move; the modification makes this representation more like other ASL signs."

The sign change here from parellel movement to mirror-image movement is presumably due to the less effort involved in the latter movement. Given the symmetric structure of the arms and the hands, it is easier for the brain to send the same motor commands to both sides of the body, resulting in the latter movement. Numerous similar cases can be offered from sound change. What is remarkable about this sign example is that it is found in a symbol system of a different modality, and that, in contrast to sound change, the investigators were able to note exactly how long it took for one movement to change to the other. Continued comparative research into the evolutionary patterns of sign and sound will surely increase our understanding of human language in a fundamental

way.

Let us now return to sound change, where the major thrust of research on language evolution has taken place over the past two centuries. The most explicit hypothesis on how sound change comes about was proposed by a group of linguists working in Europe in the 1870's, who called themselves the neogrammarians. The neogrammarian hypothesis has essentially two parts: lexical regularity and phonetic gradualness. I will now examine this hypothesis in greater detail.

Assume that a language L has a hundred words that are pronounced with an initial sound X at the beginning of some time span. A change is regular if at the end of the time span all one hundred words, or however many of them that remain in L, are pronounced with an initial Y sound. The length of the time span will vary according to the particular sound change; it could be a decade or two, or over many centuries. In this respect sound change is not unlike biological speciation, which may happen within a few millenia or across hundreds of millions of years, depending on the organism in question.

The assumption of lexical regularity was more or less implicit in the work of the early 19th century reconstructions. After all, if a German word such as "zehn", which begins with a ts- sound, is reconstructed to begin with a t- sound, much as in the cognate English word "ten", then it is natural to expect that other similar words which now have ts- also had t- as well. Indeed, we do find such a correspondence between German "zu, zwangzig, zwei, Zahn, Zeit", etc. and English "to, twenty, two, tooth, tide." Without such expectations, the task of reconstruction that Lewis Thomas praised so highly would have been a morass of details from which few generalizations could be drawn.

So the contribution of the neogrammarians here was to make the assumption explicit and absolute. They especially emphasized the "exceptionlessness" of this part of their hypothesis, and this emphasis gave rise to much controvery. For as the data base for language change broadened over the decades, it became increasingly obvious that although sound changes tend to be regular they often are not absolutely so.

The other part of the neogrammarian hypothesis is a suggestion on how such absolute regularity may come about—through phonetic gradualness. All the one hundred words of our hypothetical language would change in synchrony with each other, but in small phonetic increments. Such a picture of sound change would, of course, always yield the kind of absolute regularity of change that the neogrammarians championed.

Although all the X words are marching in locked step with each other toward the Y pronunciations, the steps are imperceptibly small. So small, in fact, that Charles Hockett, writing in 1958, sees no reason that they will ever be detectable "by direct observation." If this were really the case, linguists would never be able to study language change except by historical inference. Fortunately, however, phonetic gradualness is not the complete story, and methods are being developed to directly observe language change in progress.

I will not repeat the various arguments that have been offered recently to show that certain difficulties arise when we try to apply gradualism to all types of sound change (see Wang, 1969). It is of interest, however, to note that there are conceptual parallels between the phonetic gradualism that the neogrammarians proposed and the phyletic gradualism that Darwin assumed. Both ideas have to do with the evolution of objects across time, and both posit a continuum of unattested intermediate states.

And now, a century later, the faith that there lies buried somewhere a whole chain of missing links waiting to be unearthed has all but dissipated in organic evolution. Instead, biologists are questioning the basis of phyletic gradualism, and are proposing scenarios of punctuated equilibria and revamping their time-tables (Gould and Eldredge).

The linguistic analog to the missing links would be all sorts of intermediate vowels and consonants, say, something halfway between a /b/ and a /d/, or intermediate between a /k/ and a /s/. Similarly, these sounds have not been attested, even though hundreds of languages have been analyzed and our techniques of acoustic measurement are more than adequate for the phonetic requirements.

How then DOES language change? The solution lies in an insight biology gained many decades ago: that change comes through discrete variation. Once we understand the variation in language as seeds for change, then we can see change in progress everywhere. A large number of words in every language have two or more variants. Sometimes it is possible to predict which variant will occur from its context. For instance, the word "sane" is pronounced with one vowel when it is used as an adjective, but it has a different vowel when it takes on a suffix and becomes a noun, i. e., "sanity". Here we say the variation is conditioned. On the other hand, the word "room" may be pronounced with the vowel of "pool" or that of "pull". For many speakers, this variation is not conditioned.

To the ear of the trained linguist, this type of variation, both conditioned and unconditioned, is abundantly observable in all living languages. Not all variations will result in a permanent change in the language, but only a very small subset of these. In many cases, the traditional variants will remain. But with every new generation, a few new variants will become the accepted norm, selected by the social forces of prestige, education, or by the phonetic forces of production and perception.

The mechanism pictured now is quite different from that the neogrammarians advocated. To go back to our example of the hundred words with the X pronunciation, the change may very well start with a handful of words with a variant pronunciation with Y. From generation to generation, more and more words will acquire the Y pronunciation, sometimes with variation and sometimes without. If the change is indeed a regular one, then at the end of the time span all the words would be pronounced with Y.

However, there is no assurance within this scenario that the change WOULD be regular. In fact, it could very well happen that the words that led the change into Y may have taken another step and changed into Z pronunciations before the lagging words caught up to the Y pronunciation. Or, it could be that some

of the words have other variant pronunciations than Y, and changed into something else completely different instead. The mechanism I have described here as another route via which language change may take place is called lexical diffusion. It is illustrated in Figure 1.

Stages / Words	u	v	c
W_1			$\bar{W}_1$
W_2		$W_2 \sim \bar{W}_2$	
W_3		$W_3 \sim \bar{W}_3$	
W_4	W_4		
W_5	W_5		

Figure 1: The three stages of lexical diffusion, from unchanged to variation to changed. Taken from Wang, 1979.

The three stages that lexical diffusion goes through are shown in the three columns of Figure 1. They are labeled U for unchanged, V for variation, and C for changed. The W's stand for individual words in the X pronunciation, and the barred W's for words in the Y pronunciation. In contrast to the neogrammarian assumption of phonetic gradualism, which virtually guarantees absolute regularity of outcome, a change via lexical diffusion may or may not be regular. Instead of an article of faith, regularity is really a question that needs to be investigated empirically and, whenever possible, quantitatively.

Actually, the lack of regularity did not escape altogether the attention of the neogrammarians themselves. Hermann Paul observed (p. 80), for example, that whereas the great majority of German words underwent the sound change of t to ts or s, in Middle Franconian there are exceptions. Specifically, the residue includes dat, wat, dit, it, allet, plus one noun, one preposition, and the past tense and past participial forms of certain weak verbs[3]. Apparently, there was not perfect consistency between the neogrammarians' doctrine and their actual

3. My appreciation to Ilse Lehiste for this example.

practice, as Hoenigswald has astutely noted (p. 181).

Over the past dozen years, research on lexical diffusion has been done on many diverse languages, from common ones like English and German, to less familiar ones like Telugu and Nitinat (partly anthologized in Wang, 1977). These languages are spoken in very different cultural contexts and have markedly varied structures; yet cases of lexical diffusion have been reported for all of them. It is clear by now that the the neogrammarian mechanism of sound change must be complemented by lexical diffusion as well as by other mechanisms, as judiciously reviewed by William Labov in his presidential address to the Linguistic Society of America, Resolving the neogrammarian controversy (1981).

Given the reality of lexical diffusion, a whole series of interesting new questions arise. In the process of diffusion across the lexicon, some words will lead the change while others will lag behind. Is there any principle that determines which words will be leaders and which ones laggers? A pessimistic view is that expressed by Vogt, who sees the diffusion process as resulting from an interplay of factors so complex that "most often the choice will appear as being due to pure chance."

But a hypothesis was already put forth by Hugo Schuchardt in 1885, in his classic article titled on phonetic laws, against the neogrammarians. "Very rarely used words remain behind," he wrote, "very frequently used words take the lead; therefore exceptions to the phonetic laws come from both sides." In other words, the relative frequency of a word determines its schedule in lexical diffusion.

An early effort to apply this frequency hypothesis was that by Scherer, who tried to explain why certain Indo-European words were exceptional to a set of correspondences known as Grimm's Law. But his attempt was made over a century ago on ancient languages for which it is virtually impossible to get reliable frequency data. For lack of such data, he was reduced to some unrealistic speculations. The overall effort was quite futile, as was noted by the neogrammarian Karl Verner.

Over the last several decades, however, lists of relative frequencies are becoming increasingly available, and it is now possible to put the frequency hypothesis to a quantitative test. I will now turn to some interesting experiments which have been just completed, and report some of their results. Specifically, I will discuss two cases of change in the recent history of English: first, diatone formation, and then, /u/-shortening. These cases have much to tell us concerning how language change actually operates via lexical diffusion.

Modern English has numerous pairs of disyllabic words related one to the other in the following way. In a form like "convict", the noun is pronouced with stress on the first syllable whereas in the verb the stress is on the second syllable. Let us refer to such pairs of homographic words as diatones.

A historical investigation into the formation of diatones by Donald Sherman reveals that this is a process that began in the latter part of the 16th century. In the majority of cases, the original form had stress on the second syllable. In these cases, the change involves the retraction of the stress to the first syllable in the pronunciation of the noun.

In a dictionary compiled by Peter Levins, published in 1570, only three diatones are listed; they are "outlaw, rebel, record". Twelve years later, Mulcaster's dictionary shows that five more came into the language. Tracing the diffusion process through several dozen dictionaries of this sort, up till the Shorter Oxford English Dictionary of 1934, Sherman was able to construct its chronological profile. This is shown in Figure 2.

As the figure clearly shows, the change is accelerating in its tempo, adding to the class of diatones with increasing frequency. The Shorter Oxford Dictionary of 1934 shows 150 diatones. It also contains 215 homographic noun-verb pairs, such as "consent, reply, account, delay" etc., where the stress is indicated only on the second syllable. These pairs, according to Sherman, are the likeliest candidates for the formation of more diatones.

Here we have then a suitable body of data against which we can test the frequency hypothesis. Given two groups of forms, i.e., 215 pre-diatones and

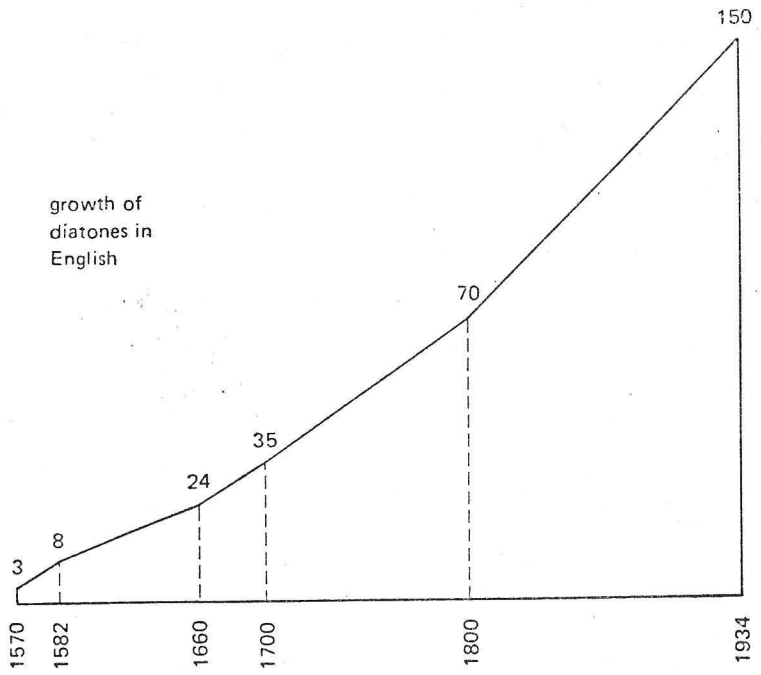

Figure 2: The chronological profile of diatone formation in English. Based on Sherman, 1975.

150 diatones, or, 215 unchanged forms and 150 changed forms, are these two groups separated in terms of the relative frequencies of their members? In work yet unpublished, Betty Phillips addressed herself to this question, basing her figures on the 1971 American Heritage Word Frequency Book, edited by John Carroll.

As a first approximation to this problem, we constructed a table with three columns, where the first column gives the relative frequencies of the words in ascending order. When a word is unchanged, we can list it in the second column; and if it is changed, we can list it in the third column. If the frequency hypothesis is an effective sieve, then the words in each column should cluster tightly together.

In the table we constructed for all the diatones, however, no such picture emerged. Instead of the clustering that the frequency hypothesis would predict, there is in fact a random mixing of the two groups of words. Portrayed in this

fashion, word frequency is not a good indicator for sound change.

But Phillips noted that phonetics must be taken into consideration as well, especially the structure of the first syllable onto which the stress retracts. If the first syllable is sup-, for example, then the word is always in the unchanged group, i. e., the stress does not retract, as in "supply, support," etc. Conversely, if the syllable is per-, then the word is always changed, as in "permit, perfume," etc. Taking these for cue, she divided the words into subgroups according to the first syllable.

000. 1133		CONVICT
000. 6516		COMPRESS
002. 5129		CONSERVE
005. 9361	CONSENT	
010. 9077		CONCERT
014. 067		CONCRETE
014. 3565		CONTRACT
016. 82	CONCERN	
019. 6599		CONTENT
022. 787		CONTRAST
026. 2759	COMMAND	
077. 509	COMPARE	
095. 7737	CONTROL	

Figure 3: Diatones with con-.

Figure 3 shows the distribution of the subgroup that begins with the syllable con-. It is seen that with two exceptions, the words in each column do cluster according to frequency. Figure 4 shows the distribution of the subgroup that begins with schwa. A similar picture is found in the other dozen or so subgroups as well. The division is never perfect, but the tendency is clearly there. For each of these subgroups, Phillips compared the average relative frequency of the unchanged forms with that of the changed forms. In each case, the average of the former is greater than that of the latter. Word frequency is a useful indicator

000. 0107	AFFRONT	
000. 2770		AFFIX
000. 3825	ATTIRE	
000. 4028	ASSENT	
001. 0052	ABUSE	
001. 4100	ASSIGN	
001. 5342		ANNEX
001. 6220	ACCORD	
002. 4004	ASSAULT	
002. 5444		ALLY
003. 1677		ALLOY
003. 4136	ARREST	
005. 1637	AWARD	
007. 7926	ARRAY	
011. 344	APPEAL	
014. 556		ADDRESS
016. 495	ALARM	
019. 153	APPROACH	
019. 6257	ADVANCE	
024. 405	ATTEMPT	
029. 7974		AFFECT
036. 505	ACCOUNT	
043. 4879	ATTACK	
105. 7694	AMOUNT	

Figure 4: Diatones beginning with Schwa.

then in the lexical diffusion of diatones. But the correlation seems to go in the opposite direction from that envisioned by Schuchardt. That is, in this particular case, the leaders are the low frequency words and the laggers are the high frequency ones.

The other case I will now consider has to do with the development of a vowel of Early Modern English that Shakespeare probably pronounced with a long /u/. This is based on an investigation in progress by Mieko Ogura. She collected a list of a hundred some such words with the vowel occurring in comparable environments, namely in monosyllables ending in a single consonant. For her frequency figures she also uses the American Heritage Word Frequency Book, after consulting several other sources. Information regarding the pronunciation of these words is based on a variety of grammars and pronunciation dictionaries, dating back again to the 16th century.

One new item of information that is available in this study but absent from the diatone study is the group of words that show variation in their present pronunciation of this vowel. These include "groom, soot, roof, hoop, soon", etc., which for many speakers of American English can be pronouced either with a long /u/ as in "pool" or a short /u/ as in "pull". Here the scenario of change accords more closely to that depicted in Figure 1. Another feature about u-shortening which makes it different from the diatone data seen earlier is that some of the words in the changed column, i.e., the fourth column, have changed one more step from short /u/ to an unrounded central vowel. These words include "blood, flood, glove." For many people, the word "good" is undergoing this change right now, varying between the short /u/ and the central vowel.

Once again in a composite table which includes all the relevant words, the effects of frequency on the sound change are obscured. Upon closer examination, however, the subregularities do emerge. One has to do with the loss of the distinction between the long /u/ and the short /u/ before the consonant /r/ in all words. Another subregularity is the shortening in almost all the words that end with /k/. (An exception is the slang word "kook", which has been used since ca. 1961, according to Partridge's dictionary.)

But again if we divide the words according to the relevant phonetic environment, (in this case it is the final consonant), a tendency to change according to

word frequency begins to show itself. Figure 5 shows the distribution of the -d words; here no variation words are recorded. Figure 6 shows the -m words; this appears to be a conservative group where none has reached the changed stage. They are not as conservative as the -s words and the -z words, however, where all have remained unchanged. Figure 7 shows the -t words and the 3 stages of the change they are undergoing. In these figures, the words in each column tend to cluster together due to the proximity of their frequencies.

0002. 4554	brood	
0020. 8485		flood
0028. 3360	mood	
0106. 6296		blood
0145. 9439		wood
0215. 7500		stood
0470. 2823	food	
1014. 6809		good

Figure 5: u-shortening in -d words.

000. 2417	womb	
001. 0161	zoom	
001. 2873	doom	
002. 0009		groom
003. 8791	gloom	
005. 5663	loom	
009. 3252	boom	
010. 8083	bloom	
012. 3313		broom
051. 1080	whom	
328. 6094		room

Figure 6: u-shortening in -m words.

000. 2500	scoot		
000. 8000	loot		
001. 1624	hoot		
001. 5975	toot		
001. 8513		soot	
005. 6262	boot		
034. 3580	shoot		
059. 0547		root	
158. 6421			foot

Figure 7: u- shortening in -t words.

It is interesting to note in connection with the -d words that vowel shortening started earliest with this subgroup. "Blood, flood, good" were shortened as early as the 16th century. Yet there still are words in this subgroup which lag behind, i. e., "brood, mood, food". In contrast, the -k words started their shortening somewhat later. By now, however, with the exceptions of the word "spook", which exhibits variation (according to Kenyon and Knott), and the slang "kook", the change in this subgroup is complete. It is clear that these two subgroups of words changed at different rates.

In the literature on rates of linguistic change, an S-curve has been occasionally proposed as a model. That is, a change is viewed as starting out slow, picking up speed in mid-stream, and tapering off toward the end. This may be explained in part by the observation made above contrasting the -d words and the -k words. Although the -d words were the first to change, the -k words actually changed faster once they got started. This diffusion across more and more subgroups may be responsible for the acceleration that one sees in the S-curve, as Labov observed earlier in his investigations of sound changes in New York City (1972).

In considering these two case studies, diatone formation and u-shortening, we see that word frequency appears to play a role in determing the leaders and the laggers in the diffusion process. Even though the correlation is far from

perfect in the results achieved so far, it is clear that the scheduling of words for change is not "due to pure chance," as Vogt had feared.

The most striking difference between the two sets of results, however, is that in the diatone study the high frequency words lag behind in the change whereas in the vowel shortening they are the leaders. This difference is surely significant, and may be attributable to any of several factors. In the formation of diatones, for instance, the change involves a grammatical distinction, that between noun and verb. In the u-shortening, no grammatical distinction is involved. The diatone change is one of suprasegmental features, whereas the u-shortening is one of segmental features. Other factors can be mentioned as well. But until additional data becomes available on more types of change in diverse languages, so that a correlation can be observed on a larger sample, it is difficult to explain this intriguing discovery.

So the conjecture Schuchardt made, almost a century ago, tells only half the story. It is true that "very rarely used words remain behind," but only in certain types of change. His insight that word frequency is a relevant determinant of change is certainly correct; the effect of frequency can be seen most clearly when we divide the words into subgroups where differences of phonetic environment are properly factored out.

In recent years various psycholinguistic findings have been made on the effect of frequency on such memory functions as word recognition and recall. An especially interesting study just completed by Seidenberg has to do with reading Chinese and English words. He finds that for both languages, in spite of the basic difference in the writing systems, it is only the low frequency words that get facilitated when they contain more direct phonetic cues. In the light of these various psycholinguistic findings, it is not surprising that word frequency should play a significant role in language change as well.

Both of the studies discussed above deal with change in a given set of words within one speech community. For my last topic I would like to turn to an investigation of the relations between words and spatial distances. This work was

suggested to me by Luca Cavalli-Sforza, a geneticist at Stanford. It represents our collaborative effort.

A good amount of work has been done in recent years in relating distance of separation and the genetic similarity among peoples, as measured from blood samples. Typically, the relations turn out to be quite lawful, and appear as straight lines on a graph where genetic similarity is plotted on a logarithmic scale against distance plotted on a linear scale. The slope and intercept of the line varies from region to region, depending on such factors as topography and the density of communication. This work on isolation by distance has been reviewed in the recent book by Cavalli-Sforza and Feldman (1981). Figure 8 is taken from that book.

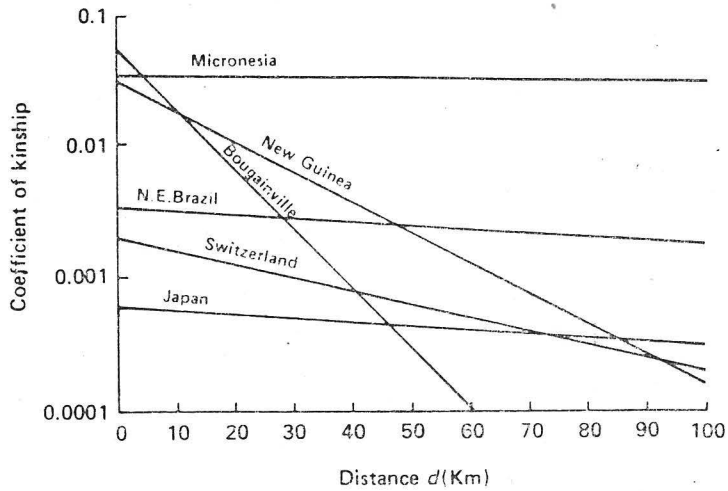

Figure 8: The relation between distance distance and genetic similarity in different areas of the world. Taken from Cavalli-Sforza and Feldman, 1981, p. 164.

In these biological studies, the gene is taken to be the basic unit. Since a particular gene may be manifested by several possible alleles, the extent to which two communities manifest common alleles can be taken to be an index of their genetic similarity. The counterpart to the gene: allele distinction in language would be that between concept and word. The concept "10" corresponds to a

gene, while the English word "ten" and the German word "zehn" correspond to the allele. In this case it is the same "allele", since the two forms trace back to the same word. On the other hand, English "glove" and German "Handschuh" do not trace back to the same word; they are different "alleles". Analogous to the biological case, it is clear that the extent to which two communities share common words can be taken to be an index of their linguistic similarity.

We applied the methods of isolation by distance to some Chinese data provided by C. C. Cheng. Using the report prepared by Beijing University, HANYU FANGYAN CIHUI, Cheng has computed the lexical correlation coefficients among 18 major Chinese dialects (1981). We plotted the logarithms of these coefficients along the ordinate. Along the abscissa we plotted the geographical distance between all pairs of the 18 dialect sites, i. e. $(18\times17)/2$ or 153 distance numbers.

Unlike the biological studies, the resulting graph on these Chinese data turns out to show no orderliness of distribution whatever. Evidently, the very long history of intermingling as well as the complex topography of China have obscured whatever lawful relations that may have existed between lexical similarity and geographical distance in the development of these dialects.

What is needed is a test case where the cultural and topographical conditions are more promising for the isolation by distance method. Such a case was found among a chain of West Caroline Islands in Micronesia. Here our data come from an unpublished dissertation by E. Quackenbush (1968). Following the same procedure as the Chinese case, the graph which resulted from the Micronesian data exhibits a high degree of lawfulness between lexical similarity and geographical distance. This graph is shown in Figure 9, taken from Cavalli-Sforza and Feldman (1981).

In this paper, my purpose has been to discuss the one area of language evolution where linguists have achieved the most significant results over the last 200 years, namely, the area of sound change. Starting from the hypothesis of genetic relations among the Indo-European languages, put forth by William Jones

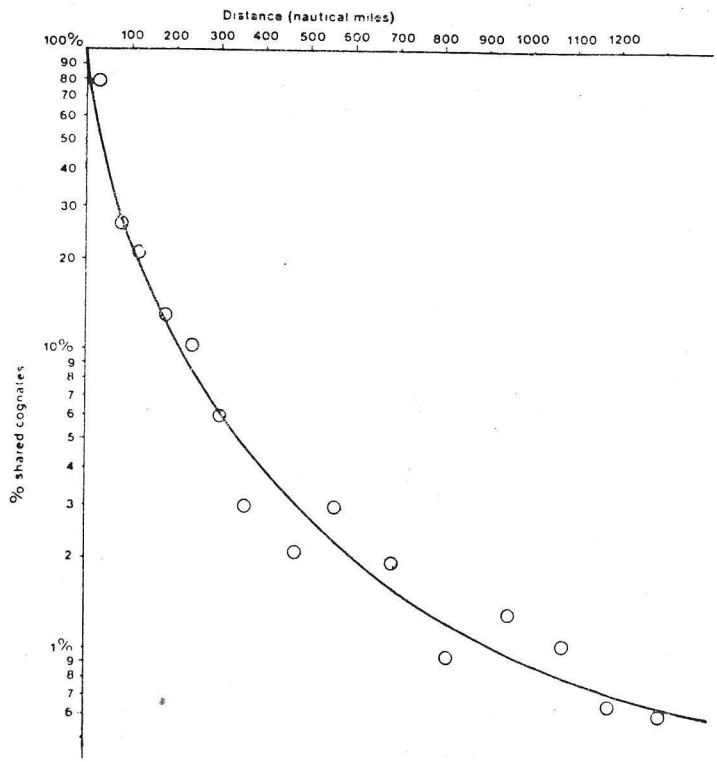

Figure 9: The relation between distance and lexical similarity in Micronesia. Taken from Cavalli-Sforza and Feldman, 1981, p. 169.

in 1786, there has been an intertwining of biological and linguistic thought. The tree diagrams that Schleicher drew for language families were explicitly acknowledged to be an application of Darwin's theory. The kind of phonetic gradualism that the neogrammarians hypothesized is similar to the phyletic gradualism that is presently questioned in paleobiology.

The awareness of parallels between biological and linguistic evolution is useful, if only heuristically, even though we know that there are fundamental differences in their respective modes of transmission—genes exclusively vertically, language horizontally and obliquely as well. I find it helpful to think of lexical diffusion as reflecting the interaction of variation and selection, parallel to that operating in the change of organisms. Furthermore, the more stable selective forces are the

biological ones, namely the constraints that are imposed by our organs of cognition, production and perception.

Overlaid on the biology are the more random cultural forces of selection. These include the social dynamics of groups, the contact of peoples in migrations, etc., which also significantly influence language evolution. The frequency of the word aspirin clearly depends on the rate of headaches in a speech community rather than on factors internal to the language itself, and this rate may fluctuate widely from year to year. Yet we have seen from the studies in lexical diffusion that there is a certain degree of lawfulness between word frequency and the diffusion process as it operates across several centuries. And from the study on the Micronesian islands, we have seen that there is a certain degree of lawfulness in the sharing of words as a function of distance between the communities.

There are many areas of language evolution that I have not discussed, including one which has drawn much interdisciplinary interest in the last several years. This is the area of language macrohistory, which addresses itself to questions of the earliest stages in the emergence of human language, as it diverged from other systems of animal communication (see Wang, 1982).

In very broad outline, hominids achieved bipedal gait some 4 million years ago. They started making tools some 2 million years ago, and the rapid growth in brain size also started about then. Controlled use of fire dates back at least a half million years, and consistent right handedness perhaps a quarter million years. The pace of cultural evolution quickened especially in the last 100,000 years, from organized hunting, to long distance migrations, to cave art, to flower burial, ···, down to the invention of agriculture and the founding of the first cities.

Arguments can be advanced to link the emergence of language to any or all of the above, but none of these arguments is decisive. What we see instead is evidence for a gradual, gradient and cumulative evolution in communicative ability that is symbiotic with the growth in culture: each dependent on the other and each enriching the other.

One useful landmark along this path of language macrohistory is the shift from attributing signal value to long term acoustical parameters, such as pitch and loudness contours, voice quality, rhythm, etc., to short term parameters, such as complex frequency spectra. Typically, the former signals require several seconds for their transmission whereas the latter require centiseconds. In linguistic terminology, the shift is from a phonology that is primarily suprasegmental to one that is primarily segmental, composed of consonants and vowels. With this shift, language achieved a duality of patterning, i.e., an elaborate set of arbitrary signals can be constructed from the short term parameters to accommodate a rapidly increasing set of messages. This feature of duality of patterning is the most powerful and the most distinctive aspect of human language (Pulleyblank, 1981).

A fundamental issue in this area of language macrohistory concerns whether there are special adaptations in our central and peripheral systems which are exclusive to language. Here the tie into biological methods is obvious, as we probe the shape of the throat and the structure of the brain for these adaptations. Recent results from this area of research suggest that humans have exceptionally acute capacities for the resolution of fine temporal and spectral patterns, and that these capacities are important prerequisites to the effective use of spoken and written language (Schwartz and Tallal, 1980). The development of an extremely finely tuned "time keeping mechanism in the left hemisphere" (Tzeng et al, 1983) is the most critical prerequisite for the shift from suprasegmental to segmental phonology. This shift, in turn, is the single most significant landmark for the emergence of language.

Another area in the investigation of language evolution has to do with ontogeny. Language is perpetuated because children learn it. Yet this learning takes place primarily at an age when the learner's biological equipment is very different from that of the adult models. Furthermore, it is also an age when change in the shape and structure of this equipment is occurring at a dramatically fast pace. It has long been remarked that this generational discontinuity must

play an important role in language evolution. But we are very far from an exact understanding of this role.

From the vocalizations of the early hominids to the babbling of infant in his modern crib, language is constantly evolving. It is unlikely that evolution at such greatly different time scales is always implemented by the same mechanisms (Wang, 1978). More probably, the kind of studies I have described today pertain most to the evolutionary scale that historical linguistics has traditionally worked on, changes that take place over decades and centuries. However, it is clear that a deep knowledge of language evolution can only come once we see how these three scales of diachrony connect one into the other.

Toward achieving this knowledge, insights and methods from linguistics and from biology will probably continue to cross-fertilize to the mutual benefit of these disciplines, as they have in past centuries. Such a symbiosis is to be expected, given the hypothesis that "all evolutionary processes are basically similar, whichever the objects that evolve" (Cavalli-Sforza, 1975, p. 91).

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