Polytypy in Folk Biological Taxonomies

William H. Geoghegan

polytypy in folk biological taxonomies[1]

WILLIAM H. GEOGHEGAN—*University of California, Berkeley*

introduction

Polytypy is a biological concept that refers to the systematic internal diversity of plant and animal taxa. A convenient index of the degree of polytypy within a given taxon is its *size*: that is, the number of distinct subtaxa into which it is immediately divisible, pursuant to the consistent application of standardized classification procedures. Because of the relationship between the size of biological genera and such phenomena as their "evolutionary age," their geographical dispersion, and so forth, polytypy has received considerable attention in systematic biology. Until quite recently, however, the corresponding phenomenon of polytypy in *folk* taxonomies has attracted little more than passing interest from those concerned with principles of folk biological classification. I would like to suggest here that polytypy does in fact have a great deal of potential relevance to many of the developing theoretical concerns in ethnobiology and that a better understanding of the form that it takes in folk biological taxonomies will be useful both in the analysis and interpretation of single systems and for comparative ethnobiological studies.

The distribution of polytypic diversity among biological genera—that is, the distribution of genera by number of immediately included species—can be approximated by a relatively simple mathematical function that has been understood in biology for many years. Taking at face value the contention of Berlin and his associates that folk classification accurately reflects objective, natural groupings of biological individuals (Berlin 1972; Berlin, Breedlove, and Raven 1973, 1974), we should not be surprised to find this same function characterizing the distribution of polytypy among *folk* biological genera as well. I will shortly present data indicating that such is in fact the case with folk taxonomies. While this lends support to the idea that folk systems of classification are

The mathematical relationship between the size of biological genera (the number of included species, or polytypy) and their relative frequency has been well understood for over fifty years. It is argued here that a similar mathematical relationship should hold for the distribution of polytypy within folk biological taxonomies, but with the overall degree, or tendency toward polytypy subject to influence by cultural factors (salience, agricultural practices, etc.). This is demonstrated with data from several different folk taxonomies. The findings support the contention that folk systems of biological nomenclature accurately reflect natural biological diversity, and that they are able to do this despite the strong influence of cultural factors. The data also provide indirect support for some of Berlin's suggestions concerning the temporal development of folk taxonomic systems.

based upon the recognition of objective morphological groupings in nature, there is also much evidence to suggest that this recognition is tempered by cultural factors: especially by the cultural significance assigned to particular groupings of folk genera. Berlin and his collaborators, for example, have pointed out that the proportion of polytypic taxa within significance classes of Tzeltal botanical genera declines with decreasing cultural significance (Berlin, et al. 1974). The same appears to be true for Aguaruna botanical genera (Berlin n.d.). Conklin's Hanunóo study (1954) suggests yet another instance of the phenomenon. Data presented later in this discussion, however, show that while cultural significance does affect the amount of, or tendency toward polytypy within a given set of folk biological genera, it does not affect the type of statistical distribution involved. This suggests that while cultural significance in some manner determines the degree of polytypy, the occurrence and magnitude of systematic morphological discontinuities internal to folk generic taxa determine its distribution. My aim in the present discussion is to point out how this might take place: to propose a formal mechanism, more or less cognitive in nature, that establishes the necessary linkage between cultural significance and polytypy and does so in a manner consistent with the theoretical and mathematical requirements of the observed distribution of polytypy within folk and scientific taxonomies.

Let me first describe and discuss very briefly the mathematical form of the polytypy distribution and then turn to the question of cultural significance and its effects. I would also like to comment upon several illustrative examples drawn from recent ethno-biological studies.

the statistical distribution of polytypy

A common index of systematic diversity within a given biological taxon is the number of distinct, coordinate subtaxa into which it is systematically subdivided. It follows that the distribution of systematic diversity throughout a set of biological taxa, all of the same rank, can thus be represented by the distribution of these taxa according to size: that is, by the number of subtaxa into which each is immediately divided. Owing largely to the work of Yule (1924) and those who stimulated his interest in the mathematics of evolutionary theory, the statistical form of this distribution and its mathematical derivation have been well understood for the last fifty years or so. Its most complete and accurate expression is cumbersome to use in practice, but Yule derived an approximation that turns out to be quite satisfactory for most empiricial applications.[2] Yule's derivation was originally intended only to characterize the distribution of biological genera by size, but it is equally applicable to the distribution of families by number of included genera, the distribution of species by number of included varieties, and so on.

Yule's approximation, which I have rewritten here in a form more suitable for present purposes, can be stated as follows:

$$f_n = f_1 n^{-k} \tag{1}$$

where f_n is the proportion of genera of size n (having n species), f_1 is the proportion of monotypic genera, and k is a constant (about which more will be said shortly). Equation (1) has the form of a straight line under a logarithmic transformation. That is:

$$\log f_n = \log f_1 - k \log n \tag{2}$$

Equations (1) and (2) can be expressed in terms of frequencies rather than proportions. If F_n is taken as the number of genera with n species, and F_1 as the number of monotypic genera, we have:

$$F_n = F_1 n^{-k}$$ (3)

$$\log F_n = \log F_1 - k \log n$$ (4)

A body of data representing the empirical distribution of polytypy for a given set of genera, under the logarithmic transformation, should therefore approximate a straight line with slope equal to $-k$. Parameter estimation can be carried out in a straightforward manner by calculating the coefficients of the straight line that best fits the logarithmically transformed data.

In Yule's derivation, the constant factor that I have represented as k is given as

$$k = 1 + \frac{1}{\rho}$$ (5)

where ρ is taken to be the ratio of two probabilities, s and g, that refer to the respective likelihoods of specific and generic "mutations," so-called, occurring within some fixed interval of time. More precisely, Yule took s to represent the likelihood that any given genus within the set under consideration would develop a new *species* within an interval of time Δt; while g was taken to be likelihood of a new *genus* developing within the set during an interval of similar length. Thus, we have

$$\rho = \frac{s}{g}$$ (6)

and hence

$$k = 1 + \frac{g}{s}$$ (7)

These are the only *biological* parameters in Yule's derivation, and it is their ratio that determines the values of ρ and k, and hence the shape of the entire distribution.

Through a chain of reasoning that I will only summarize at this point, it can be argued that equations (1) through (4) should also characterize the distribution of polytypy within certain equivalence classes of *folk* biological genera: specifically, in the distribution of such genera by the number of immediately included folk species. There are several conditions that must be met, or at least approximated, if this extension of Yule's derivation is to be valid. First of all, the folk genera upon which the distribution is defined must be more or less equivalent to one another in terms of cultural significance. Second, the set of folk biological principles underlying the subdivision of these genera into systematically recognized folk species should be based primarily upon morphological characteristics of the plants or animals involved; and these principles should be consistent in their application across the set of genera as a whole.[3] In general, these conditions (and hence the applicability of Yule's derivation) will be approximated only in significance classes of genera subsumed under a single unique beginner (e.g., the set of cultivated plant genera in a given botanical taxonomy), and only if it is morphological characteristics, consistently applied, upon which the folk systematization of such a class in based.

Given the above conditions, the distribution of polytypy within a particular significance class also depends upon a pair of "mutational probabilities," G and S, defined

for *folk* genera and species, respectively. We will take G to represent the likelihood, for some specified interval Δt of time, of the occurrence of a biological or cultural event (or events) sufficient to produce a distinct grouping of biological individuals having the present status of a culturally recognized folk genus. Similarly, S is taken to denote the likelihood, within an interval of length Δt, of any given folk genus in the set undergoing a biological or cultural change that produces a stable grouping of individuals presently acceptable to the culture as a folk specific taxon. Rephrasing equations (6) and (7) in terms of the above, we have:

$$\rho = \frac{S}{G} \tag{8}$$

$$k = 1 + \frac{G}{S}$$

I should point out that it is unnecessary to know the actual numerical values of S and G, since it is only their ratio that is relevant to the shape of the polytypy distribution.

In order to provide a brief illustration of some of the points made so far, I have included in Figure 1 the frequency distribution of polytypy among the 342 Tzeltal folk zoological genera described in Hunn's recent study (Hunn 1973:160). The vertical axis corresponds to the logarithm of frequencies F_n, and the horizontal axis gives $\log n$. The best-fit straight line approximation to the data is also shown, and it should be apparent that the fit to the actual distribution is quite good ($r^2 = .98$ for $F_1 = 256.4$ and $k = 2.783$). From the best-fit value of k (2.783), we determine the value of ρ to be 0.561. These values are quite typical of those found for folk taxonomies in general.

Up to this point, I have said nothing about how cultural factors might affect the distribution of polytypy in folk taxonomies. It is to this topic that I now want to turn. If we consider for a moment the nature of the so-called "mutational probabilities" employed in Yule's original derivation, as well as in its extension to folk systems of classification, it should be clear that they refer to much more than just the likelihood of particular sorts of biological or genetic events taking place during the evolutionary
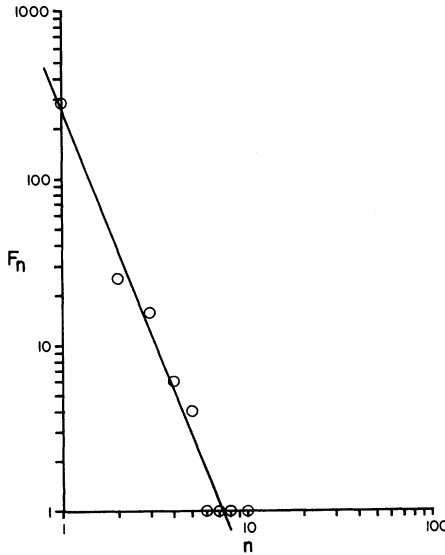

Figure 1. Distribution of polytypy in the Tzeltal folk zoological taxonomy.

development of plants and animals. They are also inextricably bound to the criteria used by the taxonomist himself to decide whether or not the systematic morphological contrast between two sets of plants or animals is of sufficient magnitude to allow their classification as different species of the same genus. These "mutational probabilities," and hence the distribution of polytypy within a given set of folk or biological genera, are in reality complex functions of both the likelihood of certain biological events taking place *and* the magnitude of systematic morphological differences that must exist between two natural groupings before the taxonomist will recognize them terminologically as distinct species.[4] Both of these factors, moreover, are subject to cultural influence. Agricultural practices, for example, can increase the likelihood and hence the rate of varietal formation within an intensively cultivated species, through a process of artificial (rather than natural) selection and through the careful separation of varietal stocks. And the significance assigned by a culture to particular sets of folk taxa can influence the conditions under which that culture is willing to accept variation within a given taxon as sufficient for the formation and labeling of new subtaxa. It is the latter type of cultural influence that is of particular concern to us here, and I would like to consider its taxonomic implications in some detail.

the effect of cultural significance on polytypy

A large body of data has been amassed recently in support of the notion that folk biological classification is highly responsive to the objective regularities of natural biological diversity. This is not to say, however, that all systematic diversity need be recognized taxonomically, nor that the response need be the same across different taxonomic levels. Quite to the contrary, available evidence indicates that the nature of this response to diversity, and the degree to which it can be influenced by cultural factors, differ substantially between taxa of folk generic and folk specific ranks. Recent work by Bulmer and his associates (Bulmer and Tyler 1968; Bulmer and Menzies 1972, 1973), Berlin and his collaborators (Berlin 1972; Berlin, et al. 1973, 1974), Hunn (1973), and others has strongly suggested that the taxonomic status of folk genera is much more a matter of panhuman psychological factors (perception, recognition routines, etc.) than of variable cultural factors and that the groupings thus recognized are sufficiently "obvious" and fundamentally "real" to human perception that cultural significance can have relatively little effect on their taxonomic status. Such natural groupings are so basic, Berlin (1972) has contended, that they are the first folk taxa to be given stable linguistic recognition in the historical development of any folk biological taxonomy.

The situation is quite different in the case of folk specific taxa. They seem to have a different psychological status, with regard to both their "primitiveness" as semantic concepts (Berlin 1972) and the mental routines used in their perception and recognition (Hunn 1973). They postdate generic taxa with respect to the time of their incorporation into taxonomies (Berlin 1972); they are named by more complex lexical constructions (Berlin, et al. 1973); and, most importantly for us, their incorporation into a folk taxonomy seems to be highly sensitive to factors of cultural significance (Berlin, et al. 1973). These differences between folk generic and folk specific taxa have important implications for the mechanism by which cultural significance affects the distribution of polytypy within folk taxonomies. Consider the implications of equation (9); that is,

$$k = 1 + \frac{G}{S} \qquad (9)$$

where G and S are, once again, the "mutational probabilities" defined for folk genera and folk species, respectively. In any given folk biological taxonomy we would expect, according to the argument just presented, that the value of G would be relatively stable across subsets of folk genera differing from one another only in cultural significance. We would anticipate some variation in G according to biological factors—across different biological families, for example—but so long as these factors do not correlate too strongly with cultural significance, we should expect the value of G to remain fairly constant across significance classes drawn from a single taxonomy.[5] The value of S, on the other hand, should be much less stable across such classes. Its value should be relatively high for the class of most significant folk genera, and it will decrease as we move through classes of declining cultural salience. The argument in support of this assertion can be stated briefly as follows.

Let us assume—quite reasonably, I think—that there is a strong *inverse* relationship between the cultural importance of any given folk genus and the magnitude (or "obviousness") of systematic internal discontinuities prerequisite to its division into stable, linguistically recognized folk specifics. On the whole, human interaction with unimportant folk genera will be relatively infrequent and nonintensive, with only casual attention normally being paid them by human actors. Under these circumstances, systematic variation of only the most obvious sort, easily perceived under conditions of casual observation, would be given formal taxonomic recognition. For the more important folk genera, interaction with and treatment by human beings would be at a higher rate and generally more intensive, with greater attention being paid on the average to individuals of such taxa when encountered. Less obvious discontinuities within the genus would have a greater chance of being consistently noticed; and there would be an increased likelihood for such potential dividing lines to be pertinent to cultural concerns (acquisition techniques, desirability, etc.), and hence to be the objects of deliberate inspection. Among culturally important folk genera, therefore, we should expect not only the glaringly obvious sort of internal diversity to be recognized taxonomically, but also morphological characteristics that are much harder to perceive under casual inspection. For the culturally important folk genus, therefore, in contrast to one of less significance, a greater proportion of the existing internal diversity would generally be available for use in subdividing the genus into folk species. This, in turn, implies a higher value of S for genera of high cultural significance than for those of less cultural importance.

How does this affect the distribution of polytypy within a folk taxonomy? Referring once again to equation (9), I have argued that the value of G should remain relatively stable across significance classes of folk genera; while S will vary across such classes, taking high values for sets of important folk genera and lower values for sets of less significant taxa. This implies that the ratio of G to S that appears in equation (9), and hence the value of k, should be *lower* for the important genera than for the unimportant ones. Finally, since the degree of polytypy is inversely related to k, we should expect the tendency toward polytypy within different significance classes of folk genera to vary directly with the cultural importance of the taxa included in each such class.

examples and discussion

I would like to turn now to a consideration of data drawn from two ethnobotanical studies for which detailed information on cultural significance is available. These include the Tzeltal ethnobotany project carried out by Berlin and his associates (Berlin, et al. 1974) and Berlin's Aguaruna study (Berlin n.d. and personal communication).

Berlin originally divided the 471 Tzeltal botanical genera into four significance classes: (1) "cultivated," (2) "protected" (plants not actively cultivated, but protected from destruction), (3) "significant" (unprotected plants having some recognized utility), and (4) "unimportant" (those having no culturally defined uses at all). He divided the 592 Aguaruna plant genera into three significance classes (Berlin n.d.): "cultivated," "significant," and "unimportant," with the class of "significant" plants corresponding to a combination of Tzeltal "protected" and "significant" (Berlin, personal communication). For the purposes of this analysis, I have grouped together the Tzeltal "protected" and "significant" classes so as to get a more direct comparison with the Aguaruna data.

Plots of the frequency distributions of folk genera by size are given for each of these significance classes, grouped by culture, in Figures 2 through 7. Also shown are the straight line approximations giving the best fit to each of the distributions. Table 1 represents the values of k and ρ computed from these approximations.[6]
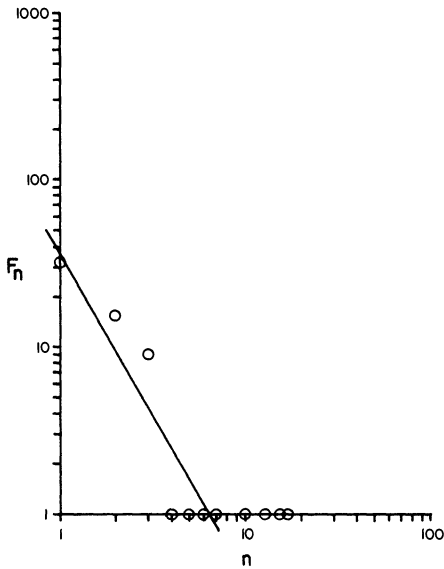

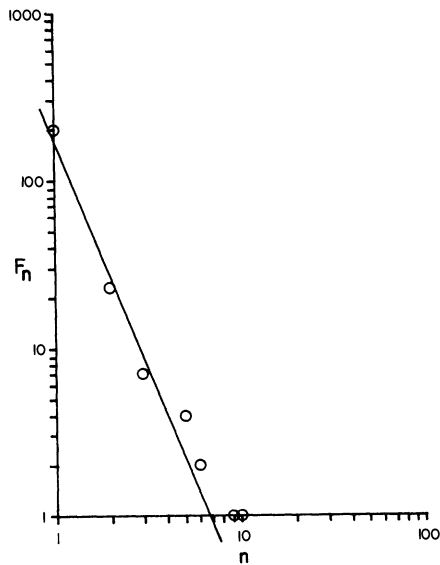Figure 2. Tzeltal cultivated plants.   Figure 3. Tzeltal protected and significant plants.

The information given in Table 1 and the distribution plots evidence a strong relationship between polytypy and cultural significance for the Aguaruna and Tzeltal botanical taxonomies. In scientific taxonomies, for example, the value of k always lies between 1.0 and 2.0, owing to the fact that s is invariably greater than g. This upper limit of 2.0 for k does not hold in the case of folk taxonomies because S is allowed to vary with cultural significance and may take on a value less than G. Nevertheless, experience suggests that values of k will stay within the range of about 1.3 to 5.0 (with ρ ranging from about .25 to 3.0); and from this standpoint the variation in k and ρ shown in Table 1 is quite remarkable. This is especially true of the Aguaruna materials, where k varies from a low of about 1.9 for cultivated plants, to a high of about 4.3 for the class of unimportant plants. (Keep in mind that k varies inversely with cultural significance.)

To illustrate the type of comparative problem to which such data and indices might be relevant, let us consider more closely the differences between the figures for Tzeltal and Aguaruna folk botanies. At both ends of the scale—for both important and unimportant plants—the Aguaruna values are more extreme than those for the Tzeltal. That is, the
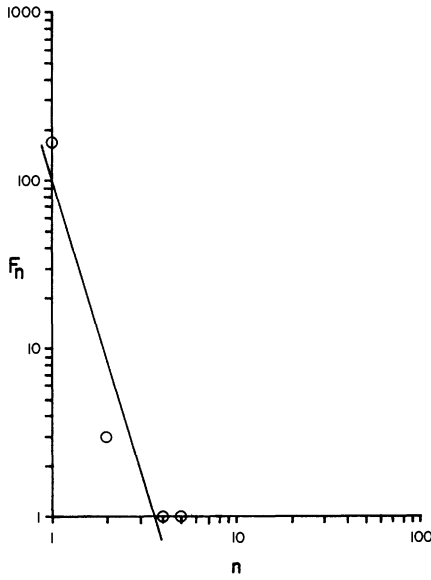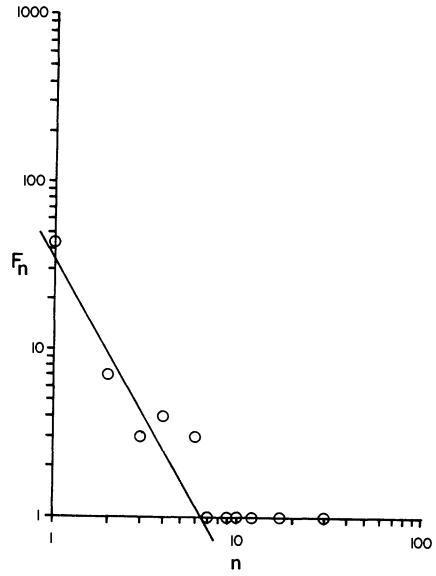
Figure 4. Tzeltal unimportant plants.

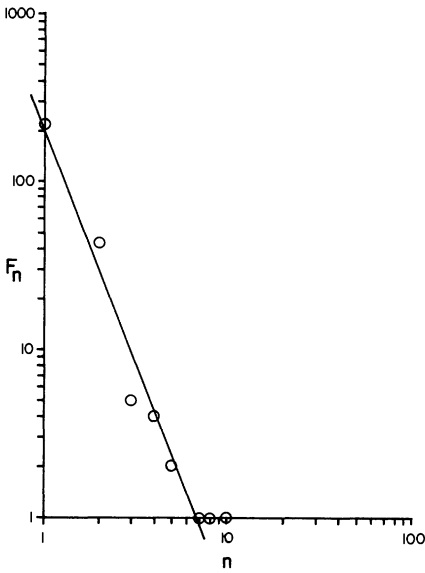Figure 5. Aguaruna cultivated plants.

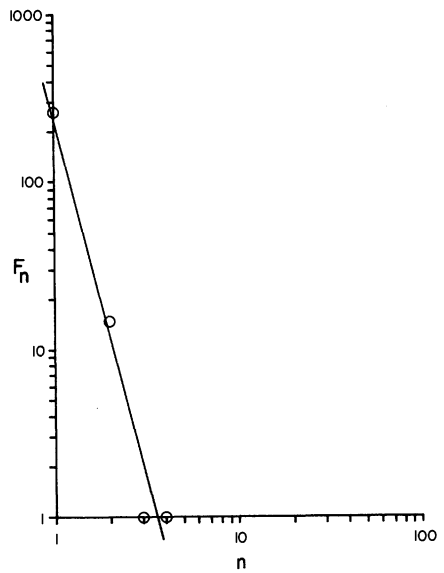
Figure 6. Aguaruna significant plants.

Figure 7. Aguaruna unimportant plants.

Aguaruna cultigens tend to be much more highly polytypic than Tzeltal cultigens, and the category of unimportant plants shows less polytypy among the Aguaruna than among the Tzeltal.

Why this might be the case I can only speculate, although it might be explicable in part by Berlin's ideas concerning the historical growth of ethnobotanical nomenclature (Berlin 1972). If his suggestions about the developmental sequence are correct, then we should expect that at some relatively early stage in the development of a given taxonomy

Table 1. Coefficients of polytypy by significance class.

		Aguaruna	Tzeltal*
Cultivated	k	1.873	1.956
	ρ	1.145	1.047
Significant	k	2.800	2.663
	ρ	.556	.601
Unimportant	k	4.325	3.817
	ρ	.301	.355

*Tzeltal significance classes "protected" and "significant" have been merged under the heading "significant."

the set of folk genera will be essentially complete, but with very little subdivision into folk specifics: i.e., a nearly full set of folk genera with very low polytypy. As times goes on, we would expect the level of polytypy in the taxonomy as a whole to increase, but—and here is where I embellish Berlin's argument—with polytypic elaboration taking place much more rapidly among the most important folk genera, especially among the cultigens. A newly developed varietal among the cultivated plants, for example, might be accorded taxonomic status as a folk species almost as soon as it was recognized as worth the effort of continued horticultural (or agricultural) maintenance. And thus a period of rapid horticultural (or agricultural) expansion within a society might well be accompanied by correspondingly rapid taxonomic elaboration, or polytypy, among the cultivated folk genera. Such a process would account for the observed differences between the Tzeltal and Aguaruna plant taxonomies, so long as we were willing to accept the possibility that the Tzeltal taxonomy might be somewhat further along in its development. This is suggested by the fact that the Aguaruna taxonomy, despite a richer botanical setting (Berlin, personal communication), shows a lower degree of polytypy in both significance classes of noncultivated plants.

In regard to the cultivated plants, on the other hand, it should be noted that the Aguaruna have only thirty-seven generic cultigens compared to sixty-three for the Tzeltal, indicative perhaps of the recency of intensive horticulture among the Aguaruna, relative to the length of time that agriculture has been practiced among the Tzeltal. The degree of polytypy among the most intensively cultivated plants is about the same in both taxonomies. The Tzeltal maintain a large number of plants, however, that are cultivated only on an incidental and casual basis, and without the intensive treatment reserved for their more important crops. Such is not the case with the Aguaruna. The presence of these less important (and less polytypic) cultigens among the Tzeltal—or their relative absence among the Aguaruna—produces a lower degree of polytypy for the Tzeltal cultivated plants as a whole. With time, we might expect something similar to occur among the Aguaruna: that is, the acquisition of nonintensively treated cultigens, with an overall decrease in the level of polytypy for the set of cultivated folk genera. At the same time, we could anticipate a general increase in the degree of polytypy for the lower ranked significance classes.

This argument finds some support from the unusual distribution of polytypy in

Ndumba plant taxonomy (Hays n.d. and personal communication). In Figure 8 we see a distribution characterized by a very large number of monotypic folk genera (333 in all) and a small number of polytypic genera that show an extremely high degree of polytypy. Considering only the polytypic genera, and without regard to any possible division into significance classes, we find a value of 1.428 for k, and a value of 2.338 for ρ, figures more extreme than those obtained for the highly important Aguaruna cultigens. The Ndumba distribution is odd in several ways. The excessively high number of monotypic genera could be taken as pointing to the taxonomy being in a relatively early stage of development compared to the others we have been considering. If the majority of the polytypic genera are of high cultural significance (e.g., cultigens), then I would take these data as supporting my earlier extension of Berlin's arguments concerning the growth of folk taxonomies: namely, that the subdivision of folk generics into specific taxa during the early development of a taxonomy takes place most rapidly among the folk genera of greatest importance, and relatively slowly among those of lesser significance. At an early stage of taxonomic development, we would expect to find something very close to what we see for the Ndumba data: a disproportionately high number of monotypic folk genera and a relatively small number of polytypic taxa, but with the latter displaying a high degree of polytypy. I might also point out that the curvature so obvious in the graph of Figure 8 is a characteristic of distributions where biological diversification is comparatively recent (Yule 1924).[7] This is not to suggest that New Guinean plants of the region inhabited by the Ndumba have only recently begun evolving. This is patently not the case. But agriculture can effect the *rate* at which new biological varietals (normally corresponding to folk species among the cultigens) are created or otherwise introduced to the culture. The recent onset of intensive horticulture could have produced a sharp, culturally induced increase in the probability (S) of folk species formation within the relevant set of plants. In time, this would produce a distribution mathematically similar to what we observe for the genera of recent biological families: that is, a rapid, nonlinear drop-off in frequency (log F_n) with increasing size—just the sort of thing that can be seen in Figure 8. This would stem from the lack of sufficient time for a large number of highly polytypic folk genera to be developed.
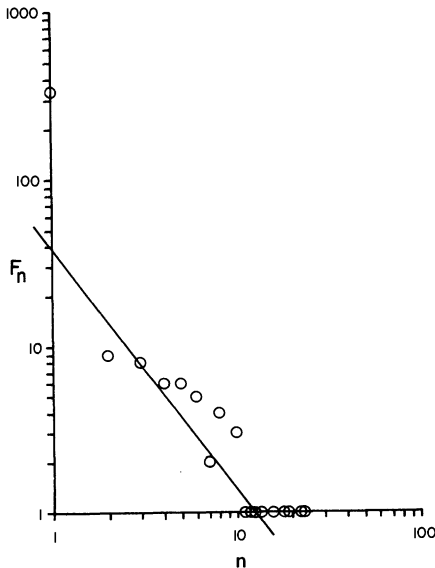

Figure 8. Distribution of polytypy in the Ndumba plant taxonomy.

Hays (personal communication) has, in fact, pointed out that horticulture among the Ndumba is a fairly recent phenomenon, on the order of perhaps 200 years or so; that they are relatively recent immigrants into the highlands where they now reside (an area botanically distinct from their homeland); and that polytypic folk genera within the Ndumba taxonomy are predominantly of high cultural significance. This information tends to confirm the conclusions that I would draw from an inspection of the frequency distribution alone. It also suggests that analyses of polytypy in folk biological taxonomies might fruitfully be applied in assessing the chronological age of agricultural or horticultural systems. Before this could become a realistic possibility, however, more research and a great deal of additional comparative data would be needed.

notes

[1] An earlier version of this paper was presented during the symposium, Folk Systems of Biological Classification, 72nd Annual Meeting of the American Anthropological Association, New Orleans, 1973. I have benefited from helpful criticisms by Brent Berlin, James Boster, Terence Hays, Chad McDaniel, and others, none of whom should be held responsible for any errors of omission or commission that may be apparent in the paper. I owe special thanks to Terence Hays for providing me with the excellent data on Ndumba plant taxonomy that figures so prominently in the latter part of the discussion.

[2] The bilogarithmic form of this approximation had been known for a number of years prior to Yule's work, but it had not been given a formal derivation. It was brought to Yule's attention by his colleague, J. D. Willis (Yule 1924), and has occasionally been referred to as the "Willis distribution."

[3] Both of these conditions, incidentally, are implicit within Yule's own derivation, which would be rendered invalid if the "scientific" taxonomist were to investigate certain genera in much greater detail than others (a violation of the "equal significance" provision), or if he were to be grossly inconsistent in his use of morphological criteria in the systematization of a given family of genera.

[4] A similar conclusion was reached by Herdan (1960) in his discussion of Yule's derivation. He went further, however, and redefined the "mutational probability" as the likelihood of a *taxonomist* (rather than Nature) splitting a taxon during some time interval Δt. This effectively eliminated any direct consideration of actual biological diversity.

[5] There may be a slight correlation between the significance of a given folk genus and the rank of the biological taxon (or taxa) to which it corresponds. Completely insignificant plant genera, for example, may show a higher rate of correspondence to botanical genera than would be the case with important cultigens, where we would expect extremely high correspondence with botanical species. Even so, I would expect the effects of cultural significance on G to be of much lower magnitude than its effects on the value of S. And since it is the ratio of G to S that determines the distribution, rather than the actual values of these probabilities, the influence of cultural significance on polytypy would still follow the pattern suggested here.

[6] The values of k were computed statistically by determining the coefficients of the straight lines providing the best fit to logarithmically transformed data (equations 2 and 4). A smoothing procedure similar to the one used by Yule (1924) was utilized to correct for the presence of null entries (i.e., when $f_n = 0$). The constant p was derived from the computed value of k (equation 5). All calculations were carried out on a Hewlett-Packard 9805A statistics calculator, preprogrammed for linear regression analysis.

[7] The linear relationship of equation (4) is approached only in the limit, as the age of the set of genera under consideration increases. In the case of relatively recent biological families, for example, there has not been sufficient time for the development of the larger genera, and we observe a more rapid than expected fall-off in the frequency of genera with increasing size. As the age of the family increases, a linear relationship between $\log F_n$ and $\log n$ is more closely approximated. A full mathematical treatment of this is given in Yule (1924).

references cited

Berlin, Brent
    1972 Speculations on The Growth of Ethnobotanical Nomenclature. Language in Society 1:51-86.
    n.d. Implications of Aguaruna Jivaro Phytosystematics for General Principles of Folk Biological Classification. Paper presented at the 72nd Annual Meeting of the American Anthropological Association, New Orleans, 1973.

Berlin, Brent, Dennis E. Breedlove, and Peter H. Raven
    1973 General Principles of Classification and Nomenclature in Folk Biology. American Anthropologist 75:214-242.
    1974 Principles of Tzeltal Plant Classification: An Introduction to the Botanical Ethnography of a Mayan Speaking People of Highland Chiapas. New York: Academic Press.
Bulmer, Ralph, and Michael Tyler
    1968 Karam Classification of Frogs. Journal of the Polynesian Society 77:333-385.
Bulmer, Ralph, and J. I. Menzies
    1972 Karam Classification of Marsupials and Rodents. Part I. Journal of the Polynesian Society 81:472-499.
    1973 Karam Classification of Marsupials and Rodents. Part II. Journal of the Polynesian Society 82:86-107.
Conklin, Harold C.
    1954 The Relation of Hanunoo to the Plant World. Unpublished Ph.D. dissertation. Yale University.
Hays, Terence E.
    n.d. A Method for Deriving Covert Categories with Nonliterate Informants. Paper presented at the 72nd Annual Meeting of the American Anthropological Association, New Orleans, 1973.
Herdan, Gustav
    1960 Type-Token Mathematics. Janua Linguarum Series Major IV. 'S-Gravenhage: Mouton.
Hunn, Eugene Stuart
    1973 Tzeltal Folk Zoology: The Classification of Discontinuities in Nature. Unpublished Ph.D. dissertation. University of California, Berkeley.
Yule, G. Udny
    1924 A Mathematical Theory of Evolution, Based on the Conclusions of Dr. J. D. Willis, F. R. S. Philosophical Transactions of the Royal Society of London (Series B) 213:21-87.