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Culture Grammars

An anthropological approach to cognition may lead to theoretical models of microcultural processes.

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As more is learned about the conceptual processes underlying language and meaning, it begins to look as though any theory that can account for them will have to be a theory of culture. A new field, cognitive anthropology, may eventually develop such a theory. Cognitive anthropology has moved in recent years from a first phase that emphasized lexical structures and components to a new phase concerned with underlying processes and structures. Before suggesting how new work might lead to a theory of culture, I shall review the first, or ethnoscience, phase.

The Ethnoscience Phase

At the end of the 1950's, there was a reaction against "soft" anthropology, in which theories were often inadequately tested, if at all, and observer bias was poorly controlled. A previously obscure field, ethnoscience, underwent a metamorphosis which effected basic changes in the discipline and laid the groundwork for far-reaching changes to come. In its earliest use, ethnoscience referred to folk beliefs about natural history, as in ethnobotany or ethnozoology, or to related areas such as disease beliefs. In the new ethnoscience, native terminologies for these folk sciences were chosen for special study because their semantic organization presumably paralleled a deeper conceptual organization for the domain of interest. Studies of native taxonomies of plant names or of other word groups would hardly be expected to have gained as much visibility as they did. But the appeal of ethnoscience lay not in its subject matter, generally considered trivial, but in its semiformal approach and the fact that ethnoscience studies sometimes went beyond description to discuss elicitation techniques that minimized biases of the anthropological observer in his recording of the data (*1*). The validity criterion was seen as a major advantage of the ethnoscience approach. The question of the observer's bias, important in all fields of science, has never been so salient as in anthropology, where experience with alien cultures highlights the possibilities of misinterpretation. Anything new that claimed to minimize ethnographer bias was bound to gain attention.

As the focus in ethnoscience studies shifted from the description of native beliefs about natural history to native terminologies, an interest in semantic theory developed. It was only natural that kinship, the area of native categorization most studied by anthropologists, should fall under the influence of this new concern. Kroeber's 1909 article (*2*) analyzing kin terms by components took on new importance, showing the way for a componential approach to semantics. With these studies, the term ethnoscience was generalized to include practically any kind of intensive analysis of the way some sector of knowledge was semantically coded. Anthropologists who did such analyses came to be called "ethnoscientists." With their proclamation of a more rigorous approach to culture studies, ethnoscientists saw themselves as pioneers in an approach with great promise. The field became so messianic that its proponents often spoke of it as "the new ethnography" (*3*).

Were these claims justified? The claim for validity lies in part with the emphasis on recording verbatim the native's description of how concepts named in his vocabulary were organized in taxonomic structures. The extent to which the categories of one's ethnographic description coincided with the native vocabulary was one way of assessing the validity, or relative lack of ethnographer bias, of the categories. This strategy, however, goes back to the 16th century, when the great Franciscan anthropologist Sahagún compiled 12 volumes of Aztec texts and vocabularies. What was really innovative about ethnoscience was the analysis of the underlying semantic relations of native terms, particularly their "componential structures." Specific structures were offered as reasonable approximations of some single correct psychologically or culturally "real" structure. These claims, however, were by fiat rather than empirically demonstrated. Some investigators later relinquished the quest for cultural reality in favor of an approach in which native rituals were described and labeled by the observer without any attempt at validating the descriptive categories. In the process, the strongest feature of ethnoscience was abandoned. Other investigators assumed that there might be as many as four or five paradigms for a semantic set "floating around in a culture." Alternative paradigms for kinship terms were tested by having natives sort slips of paper with terms written on them or make similarity judgments for two or three terms at a time. The results were then run through a multidimensional scaling program. While this was indeed a test of alternative models, the models themselves and the dimensions of the scaling were, like word association norms, developed in an artificial, context-free situation.

Recently there has occurred a marked decline in interest in the ethnoscience

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approach. Some have already spoken of the demise of ethnoscience (*4*); others have denied its passing, but only by arguing that its subject matter is still under study (*5*). The best new work on native terminologies involves cross-cultural comparisons and is directed toward the discovery of cultural universals and the development of evolutionary laws—directions eschewed during the meteoric rise of ethnoscience in the 1960's (*6*). This new work is not ethnoscience as the anthropological profession has come to understand it.

The root cause of the decline of ethnoscience, and perhaps of its initial rise as well, was its emphasis on methodology as opposed to theory. New methodologies are always initially interesting. Even in the absence of theories to test, new methods may lead to the creation of interesting hypotheses. But once ethnoscientists had presented their taxonomies, word paradigms, dimensions, and eliciting techniques, nothing further was done. While valuable ecological and other studies (*7*) were made along with some of the ethnoscience work, in other cases a great deal of ethnographic field time was devoted almost entirely to having natives sort terms. The results of such sortings were at best a test of alternative partial characterizations of some modal semantic dimensions and at worst were unmotivated descriptions of a technique and its application. Few original and substantive contributions to culture theory, role theory, or even semantic theory emerged from ethnoscience studies.

Ethnoscience has nevertheless rendered a valuable service to anthropology. It has pointed many anthropologists in the direction of cognitive studies, a generally new departure. Now, as cognitive studies shake free of the ethnoscience orientation, we can expect more attention to be directed toward theoretical development.

The Current Phase

Current work in cognitive anthropology is directed toward processes as well as structures, particularly the use of rules to produce anything from simple utterances to works of art. The new work aims at greater theoretical relevance by examining evolutionary theory and universal cognitive categories underlying semantics. It is also more concerned than earlier studies with context and with procedures for learning culture. Kinship semantic studies now include distinctions relating to nonlinguistic behavior and to deviance from normative semantics occasioned by individual situational differences (*8*).

One recent approach in cognitive anthropology has led to the discovery of cultural regularities which can be described as culture grammars. "Grammar" usually means a set of syntactic rules for ordinary language. Extending the concept to nonlinguistic areas of culture brings new theoretical power to the social sciences. The notion of a culture grammar has been implicit in many anthropological writings, particularly in those of Sapir (*9*). The idea was carried further by Goodenough (*10*) and was exemplified by a system of equivalence rules which Lounsbury (*11*) offered to account for the semantics of Crow and Omaha kinship systems. However, the term "grammar" was not actually used in any of these writings to apply to nonlinguistic areas of culture. As far as I know, the first explicit application of the term "grammar" in the more extended sense was by Kluckhohn (*12*) in his lectures at Harvard during the late 1950's. Kluckhohn often spoke to his students about a "grammar of culture" as being the ultimate goal in anthropology—a goal which, once attained, would reveal a set of core culture values. In this he was influenced by Parsons (*13*), who considered values to be a fundamental part of the social system. Kluckhohn was working with an approach borrowed from linguistics in which values of different societies were compared. But his categories were imprecise and too impressionistic to lead to anything like a grammar.

The concept of grammar I wish to introduce here follows Kluckhohn in extending the term to include nonlinguistic areas of culture, but it departs from the idea of a total culture accounting or of a single infrastructure of core values. Culture is not a well integrated, holistic system but rather an orchestrated constellation of many small systems. These small systems are what I shall refer to as culture grammars. Only one of these systems, that which deals with the syntactic structure of language, has been extensively studied. As linguists now probe more deeply into semantics and presuppositional structures, they are finding that the dividing line between language and nonlinguistic knowledge is not at all a clear one. Since they are now beginning to study the pragmatic aspects lying beyond semantics and syntactics, it is not surprising to find increasing references to (nonlinguistic) culture in linguistic publications (*14*).

In its extended sense a culture grammar would consist of rules for the arrangement of cultural elements that should account for all combinations produced by the users of a culture. Any approximation to a grammar presented by a social scientist should be able to be tested and supported or weakened, if not proven false, with each new combination. Culture grammars exist for many different kinds of activities. Such grammars would include systems for organizing conceptual structures derived from speech utterances, strategies for solving problems, systems for telling stories, production procedures for iconic representations, rules of architectural and musical composition, and ritual systems.

Let us take, as an example, the subject of problem-solving. When we find African schoolchildren picking up strategies for taking IQ tests similar to the strategies used by American schoolchildren, so that both groups perform certain tasks better than do their untutored peers, we are observing the employment of culture grammars. If pieces of these grammars or surrogate heuristics are provided through some external mechanism, untutored African children can do the actual "computing" just as well as the tutored ones (*15*). If it were possible to give tests that measured this computing after the rules or "subroutines" had been made available to the child, some term other than intelligence would be needed to refer to it, since both colloquial and clinical usage of "intelligence" would refer to the availability and nature of culture grammars, rather than to the genetic capacity to learn, create, or perhaps even process such grammars.

Schwartz (*16*) appears to have something similar in mind when he speaks of "cultural heuristics." He hypothesizes that "there are a number, probably not large, of basic and powerful heuristic modes of problem construal and approaches to solutions which are variably manifest and developed in different cultures. Where these heuristics are present they may be specific to certain tasks or they may be general—in other words, available for the solution of novel problems." In his work in the Admiralty Islands and in Mexico with the Raven Progressive Mat-

rices Test (a culture *sensitive* rather than culture free test, as held by some), Schwartz found that the majority of subjects began to err consistently at the point in the test where abstractions were introduced. But those individuals in both societies who passed this point went far beyond the others. Thus the ability indexed by the Raven test was not normally distributed for these subjects. What is the reason for the secondary clustering at the high end? Schwartz suggests that the reason lies in the utilization of a heuristic, or what I would call a grammar, that generates solutions to the series of problems that could not be solved by most of their fellows. Schwartz refers to this as a "breakthrough" effect. The task of the investigator is, then, to discover the nature of the procedures and codings used in such a heuristic or grammar.

This is by no means an easy task. It now appears, however, that the discovery of culture grammars may be more feasible in limited areas of stereotyped cultural production. Two such areas are folk narrative traditions and pictorial systems.

Narrative Grammars

The idea that storytelling is either spontaneous or by rote, or a mixture of the two, has long been part of our conventional wisdom. Not long ago a third possibility was suggested by Parry and Lord (*17*) in a study of South Slavic epic songs (*18*). They concluded that good performing artists used special formulas for storytelling and with these could compose spontaneously. Studying performances by the same narrative singers in different situations, they found that the songs varied according to the mood of the audience and the occasion of the performance. Obviously, the singers had grammars for the elaboration, enrichment, and ornamentation of their songs. The use of a grammar was dramatically illustrated when Parry had an exceptional singer, Avdo Medodović, listen to a song he had not previously heard by a singer of lesser ability and then, without forewarning, asked him to repeat it. In doing so, Avdo lengthened the song many times, adding similes, finer characterization, a greater depth of feeling, and further ornamentation.

More recently, Rosenberg (*19*) showed that the sermons of fundamentalist preachers in the southern United States are composed of units or chunks which apparently follow a compositional system. While the preachers he studied sometimes used written material as guides, they soon translated or transformed it into a special form, usually a chant, and would rearrange the words and bring in special elements, parallelisms, and favorite poetic phrases. Some phrases or formulas of the chant seemed to have the purpose of giving the speaker a chance to plan his next set of verses. These Rosenberg called "stall-formulas" ("Am I right about it?" "I say unto you tonight"). He observed one case in which a preacher made a mistake about the authorship of a psalm and then corrected it in a digression of some 17 lines. The suggestion is strong that the formulas were not memorized verbatim but generated on the spot by a system or grammar the preacher carried in his head.

The evidence for grammars is clearest in cases such as these, where the cultural production is complex and must be done quickly without the chance for considered thought or slow revision. With this in mind, I examined a sample of Eskimo folktales for regularities of actions and events (*20*). By successive approximations, it was possible to arrive at an eidochronic grammar—a grammar that accounts for the sequence of event images of a narrative. In the eidochronic phenomenon, plot structure is organized into cognitive "chunks" called eidons—classes of event varieties that typically occur in a rule-governed sequence. Just as a sentence can be either simple or compound (with several clauses strung together or embedded in a variety of ways), folktale plots can be simple or complex. Several plots may be strung together in a single narrative, or a story may be told within a story. For this reason it is useful to distinguish a simple plot, analogous to the clause of a sentence, from a more complex one. A simple plot is called a move.

The actions in an Eskimo folktale move can be described as a series of responses to a single motivating event. These responses can be subdivided into actions of engagement between the protagonist and an adversary and actions which provide a resolution to the problem created in the motivating event of the story. A simple Eskimo move contains an eidon in a Motivation (M) category followed by any number of Responses (Resp); a Response consists of any number of Engagements (E) followed by a Resolution (R) as shown in the following rules, where n and m can be any number of repetitions of the Resp and E categories.

Rule 1. Move → M $Resp^n$

Rule 2. Resp → E^mR

With these two rules, we can generate such sequences as MER, MEEER, and MERER, but not MERR or MRE.

Intermediate levels of plot action are covered by other rules for the concatenation of eidons in the following categories: Value Motivation (VM), Immediate Motivation (IM), Preliminary Action (PA), Main Action (MA), Immediate Resolution (IR), and Value Resolution (VR). In the rules for these categories of eidons, linked parentheses indicate that at least one of the elements must be chosen and, if more, then in the order shown (*21*). Braces indicate that only one of the enclosed categories can appear.

Rule 3. M → $\left\{ \begin{matrix} \text{VM} \\ \text{IM} \end{matrix} \right\}$

Rule 4. E → (PA)(MA)

Rule 5. R → (IR)(VR)

An example of a rule at the eidochronic level is rule 8, which states that the Preliminary Action (PA) of the engagement can contain any one or more of the following actions, in the order given: Encounter (En), Hospitality (Hs), Challenge (Ch), and Confrontation (Cn).

Rule 8. PA → (En)(Hs)(Ch)(Cn)

If the protagonist challenges the villain and also receives hospitality from a friend or relative, the rule states that the challenge comes only after the hospitality. A challenge followed by a struggle and victory (in the MA and IR categories, respectively) may well be a universal pattern in narrative discourse, but that hospitality should precede a challenge rather than, say, follow a victory does not seem so obvious. Other more specialized actions, such as Possession (Po), where the protagonist gains possession of food or women, also follow what to us would be an unusual sequence. The rule for the occurrence of Possession places it invariably after Release (Rl) and Victory (Vc), if either or both should occur, and before Restoration (Rs), Escape (Es), Reunion (Re), and Murder (Mr), if any or all of these should occur.

Rule 10. IR → (Vc)(Rl)(Po)(Rs)(Es)(Re)(Mr)

At this stage of knowledge, it looks as though we are dealing with a set of rules that, while it is similar to a language grammar, represents the narrative action at a higher level and in a different system. So far these rules have been tested on two samples of published Eskimo folktales (*22*). The first sample was a group of 20 moves from North Alaskan Eskimo texts. The second sample consisted of 12 moves from Central Eskimo texts. These two samples contained a total of 219 primary eidons, the sequences of which, with the exception of a single eidon in one of the sequences, were successfully accounted for by the grammar's rules. In both cases all the stories published in the two sources which met the stated genre criteria were tested. One of the reasons Eskimo folktales were selected was that sufficient published and unpublished texts exist for the grammar to be tested on new samples by other investigators. Because of the impressionistic nature of many ethnographic analyses, cultural anthropology has not been noted for close replication of studies. This situation should improve as more is published on culture grammars that account for populations of data that can also be sampled by other investigators.

The basic plot of an Eskimo or any other narrative, with its sequence of narrative events and actions, constitutes the eidochronic component of a narrative grammar. In addition to the eidochronic component and the language component itself (which includes the phonetic, syntactic, and semantic aspects of the language in which the story is told), a narrative grammar has at least three other components: poetic, dramatic, and symbolic.

The poetic component consists of the choice of words, their rhythm, and similar matters connected to the language of the narration. This component is a separate system in itself and, unlike some of the other components, obviously must be analyzed in the original language. Parry and Lord's and Lord's studies (*17, 18*) of Yugoslav epic singers and Rosenberg's analysis (*19*) of spontaneous fundamentalist sermons are largely concerned with poetic formulas. Other studies of poetic structure and formulas have been made by anthropologists (*23*).

The dramatic component is made up of processes that heighten interest and focus the attention of listeners or readers on particular aspects of a narrative. Among these processes are repetition of events, contrast, and limitations on the number of characters in a scene. For example, if the protagonist is a poor man, there is often a rich man with contrasting characteristics. If the protagonist is confronted with a task, he may try and fail before finally succeeding.

The symbolic component includes metaphoric, metonymic, and synecdochic relations. These have to do with the symbolic significance of objects, characters, and, less frequently, with some of the actions of the story. While the eidochronic component is most easily discerned in folktales, the symbolic component predominates in myths. Unlike folktales, which have more of a cognitive or cerebral quality (in that their actions follow rationally out of each other in a narrative logic), myths tend toward the irrational. Myth is highly saturated with symbolism; the symbolic objects carry a maximum of meaning, not all of it coherent or synonymous. Body parts, artifacts, and common natural and cultural elements of the environment are all so much a part of an individual's world from his earliest memory that they are bound to be imbued with a rich variety of deep-seated meanings. These meanings are drawn upon during fresh metaphorical and mythic usage. The symbolic component, consisting of these more nebulous qualities, is difficult to analyze.

The interpretation of symbols in myth has recently received much attention. The work of Lévi-Strauss is perhaps the best known. This work, however, is not a grammar and is not presented in testable form. While Lévi-Strauss purports to deal with processes, his descriptions are essentially static. He himself refers to his work as "a myth about myth" (*24*), and his general writings seem to have been produced with an eye to Parisian intellectual appetites rather than to scientific canons. Thus, attempts at describing the symbolic component are still in the prescientific stage, and it may be necessary to learn more about how the eidochronic component operates in a wide variety of genres and cultures before one can know how best to work with the symbolic component that meshes with it.

It is likely that these five narrative components are not merely levels of a single hierarchical system, but entirely separate systems, each component requiring its own theoretical framework and analytical approaches. If grammars can be developed for these other components in an overall narrative grammar, they may well be quite different in character from the eidochronic rules.

Iconic Grammars

Recently an entirely new field called iconics has appeared. Iconics is devoted to the search for grammatical rules for "languages" composed of design elements such as alphabetic and numerical symbols, weaving motifs, and certain architectural features. Researchers in this new field have taken a special interest in the iconic "mistakes" people make, since such mistakes, far from being random, are highly predictable. They result from the unconscious formation of a socially "incorrect" mental grammar that has fewer special cases than the socially accepted "correct" one. Watt (*25*) has devoted his attention to such mistakes, particularly to those made by 5-year-olds as they learn the alphabet and those made by the ancient Greeks (of about 750 to 550 B.C.) as *they* learned the alphabet. The Greeks' mistakes led to evolutionary changes in the alphabet because they went uncorrected. Modern schoolchildren in many ways reenact the patterns of errors made 2700 years ago.

These natural changes that occur through the mistakes of individuals are contrasted by Watt with the kinds of conscious esthetic changes that also affect the evolution of iconic languages. The problem in many areas of culture grammar study is that the conscious changes figure much more prominently than the unconscious ones. For example, Joyce's *Ulysses* is the result of a studied craftsmanship of quite a different kind from that of Homer's *Odyssey*, which was strongly influenced by formulas and other processes similar to those described for the South Slavic epics.

The evolution of the alphabet is a result of both kinds of changes but, over the long run, primarily those of the unconscious kind. The early Greek and Etruscan predecessors of our modern alphabets were not yet frozen into the conventional forms of today. During this early period, the design elements of the alphabets changed during repeated executions and through mistaken transmissions by semiliterates. The changes that occurred resulted

from certain innate predispositions described by Watt (*25*), including a "natural" set of vertical-stroke-leftmost letters. Such a set is natural because the stroke is a base from which additions are made more easily to the right than to the left, due to the greater ease in sequencing the writing of the letters from left to right. The basic rightward direction of most writing systems is, of course, due to the preponderance of right-handed people and to a natural desire to have one's hand cover blank space rather than what one has just written. Right-handedness (and the way most writing instruments are held) is also responsible for a "markedness" (effortfulness) ranking of individual writing strokes. Leftward and upward strokes are "marked." With such a ranking, Watt has shown how the evolution of early Greek Γ into the later English C can be analyzed in terms of iconic distinctive features. He describes four distinctive features: progressive (from left to right), falling, curved, and stroke. These features are classified as marked, null-marked, or unmarked. By counting marked features as 1 and null-marked features as ½, he arrives at an elementary numerical indication of how marked a given letter is. The evolution is in the direction of less markedness (Fig. 1).

In addition to his studies of alphabets, Watt has written a grammar of Nevada cattle brands (*26*), using a sample of approximately 4000 designs. He also has provided a translation algorithm for computing the way the brands are read or renamed (their blazons) from the iconic specifications of the brands. His iconic grammar of the brand designs along with the translation rules provide a single bimodal algorithm. In this study Watt also discusses a number of questions about the nature of nonlinguistic grammars that would be relevant to any theory of culture grammars that might eventually be advanced.

Grammars in Other Areas

Other likely places to search for the elements and rules of culture grammars are in such highly stereotyped cultural behaviors as the structuring and use of belief systems, of magical practices, and of rituals. The study of belief systems has been increasing in several social science fields. It is already a major focus in cognitive anthropology (*27*). It is also an area of convergence for linguists, psychologists, and political scientists (as well as cognitive anthropologists) who are working on artificial intelligence systems (*28*). Here it is useful to distinguish between simulated and analyzed belief systems. Schank *et al.* (*29*), especially by introducing the notion of conceptual dependency in artificial intelligence programs, have demonstrated one way to schematize the underlying meaning of sentences. However, the semantic primitives used in this schematization are not derived from empirical analysis or experimental work. Drawing this distinction should by no means devalue work on artificial intelligence. On the contrary, such work is likely to have a larger place in future anthropological studies.

For example, Knaus and I have developed a computer program that produces results similar to what an Ixil-Maya Indian of Guatemala would produce in a divination ritual (*30*). The program uses Maya astrological data and personal data about the client who has requested the divination (usually a sick person seeking to discover if the sickness is caused by divine or ancestral displeasure). The program has a set of about 60 divination construction rules which, with the input of a calendrical count, can produce a small number of possible interpretations for a given situation. A final divination is selected by another set of rules from the possible interpretations. In the computer, each rule is represented as a graph-traversing program. The final result can be compared to actual divinations; if necessary, the divination rules can be modified to bring about closer agreement between the results produced by the model and those of actual case studies of divinations in a remote mountain village of Guatemala.

Although the Ixil divination simulation program can be tested with new data (just as the Eskimo narrative grammar has been), the rules and procedures of the simulation program were created on

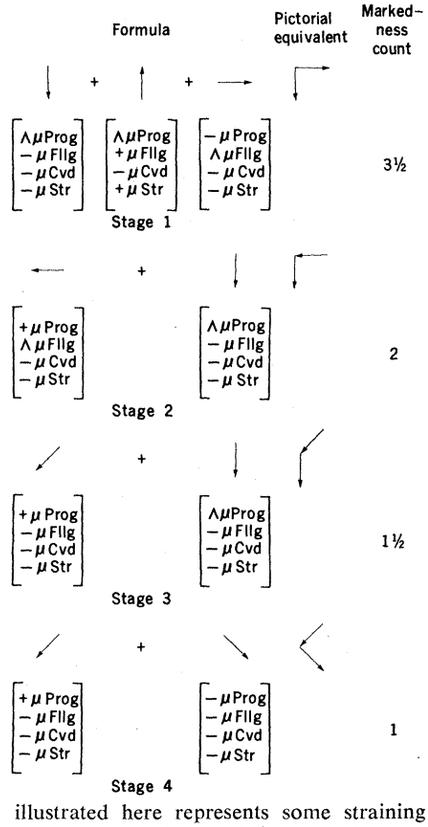

Fig. 1. How and why Γ might have evolved to C. The presentation is in terms of iconic distinctive-feature matrices, with the features Prog (Progressive, that is, for most Greek-derived alphabets from left to right); Fllg (Falling); Cvd (Curved); and Str (Stroke, that is, leaving a mark on the paper). The features' values, or coefficients, are given as $+\mu$ (marked), $-\mu$ (unmarked), and $\wedge\mu$ (null-marked—a value intermediate between + and −). These markedness values are converted (elsewhere in the iconic grammar, not shown here) to simple values of the features themselves, for example, to simply −Progressive (Not Progressive). The conversion is not so redundant as might seem to be the case from this illustration, since not every +Progressive, for example, is automatically converted to −Progressive: how marked a given stroke is depends partly on its context. The most natural iconic evolution is in the direction of less markedness. Assigning a numerical value of 1 to $+\mu$, of ½ to $\wedge\mu$, and of 0 to $-\mu$, Watt derives the "Markedness count" for each stage of evolution; the evolution towards less markedness is obvious. However, two caveats must be taken into account. First, it is really the entire system (the whole alphabet) that evolves, not just its individual members (one or two of which might actually increase in markedness); and second, the evolution illustrated here represents some straining of the facts. Given stage 1, the predicted evolution would indeed be toward stage 4, or the angular (and ultimately curved) C; but the earliest forms of the letter in question are not really so rectilinear as in stage 1, being something of a compromise between stages 1 and 3. The evidence, though, suggests that the earliest stage may still have been composed like the rectilinear stage 1 (with the illustrated stroke order), so that the evolution depicted is probably not far off the mark. If we follow this line of reasoning, the rectilinear Γ form would be a later, and somewhat artificial, development; but there is ample evidence that the Greeks did geometrize some letters. [Modified from Watt (*25*)]

an ad hoc basis. The sample of case studies was small, contextual information was sparse, and data were lacking about native thought processes that occur during divination. Thus we could only guess what the rules and codings might be and write a program that could produce results similar to those observed in the case studies.

It would be helpful if the term "grammar" were reserved for use only in two senses: (i) actual neurophysiological coding and (ii) attempts to approximate these codings. A simulation can be a helpful and important prior step but would not match cultural reality and would thus not be a grammar in either sense. Thus one could not classify as culture grammar the otherwise interesting axiomatic theory of Geoghegan (*31*) which he applies in a model of Philippine terms of personal address; Narens' mathematical approach (*32*) to adjectival relations which deals with markedness coding may come closer. Clearly we are not yet able to draw a distinction between what is a culturally real grammar (or its approximation) and what is a "black-box" model. The latter, although perhaps mathematically or computationally interesting, is capable only of generating acceptable output. The key lies not in testing the terminal string or output of a system (which is necessary but not sufficient), but in the empirical validation of the elements which the rules must work on. Everything rests on the isolation of the elements. Those who study syntactic grammars of language have had the advantage of patent elements (words) to work with. But the coding in other systems of the mind is not so readily discernible.

There are many other difficulties in discovering the elements of a culture grammar. It should be recognized that there are part-grammars, imperfectly learned grammars, and sketches of grammars in our minds. Further, full grammars may be used only partially, not as generating devices but simply as mnemonic aids, with the elements of the grammar providing a chunking procedure for narrative events. For example, in many societies, the telling of a folktale rarely shows the virtuosity of varying composition displayed by the Slavic epic singers discussed above. Grammars for the narratives of a less spontaneous group of storytellers more likely represent the collective production of stories across generations, with only unusually creative individuals at rare intervals utilizing the grammar to a fuller extent. Then one must consider that grammars can be specific to a particular individual or social group, as with the Eskimo narrative grammar (*22*), or they can be much broader in scope, as with Watt's rules (*25*) for the evolution of our alphabet, depending as they do on certain universal dispositions.

One wonders whether, in the distant future, a comprehensive theory of culture grammars might make it possible, for example, to reconstruct something like the musical grammar Mozart used and from it generate "Mozart" symphonies. Such a conjecture highlights questions about human creativity and thought. Although no computer program or grammar can exhibit anything like human intelligence, many activities previously thought unique to the human mind have now become "mechanical."

Among the problems to consider is the observation that we are more expressive of our inner selves to the extent that we do not use grammars, that we change the parameters or rules of our grammars, or that we try to build new grammars. But then we must consider that there are grammars for building grammars. In pondering these questions, we must either do away with the limitations we impose on ourselves in speaking about thought and culture as being separate or else radically change our definition of thought.

In the past, anthropologists have studied the relations between modern and primitive man and between man and animal. We must now address ourselves equally to questions about the relation between man and machine. What might be the differences between man and some future machine that can utilize the many culture grammars anthropologists may eventually describe? These questions are among the more serious ones social scientists will be dealing with in the century ahead.

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Molecular Biology of Nitrogen Fixation

Manipulation of nitrogen fixation genes may lead to increased production of high-quality protein.

K. T. Shanmugam and Raymond C. Valentine

The nitrogen in our protein foodstuffs is derived from the vast reservoir of atmospheric nitrogen by nitrogen fixation. Nitrogen-fixing organisms, such as the familiar root nodule bacteria of leguminous plants (soybeans, for example) probably account for about one-half of the total amount of nitrogen fixed annually. Large amounts of nitrogen are also fixed by chemical means, during the manufacture of nitrogenous fertilizers, for example. The great demand for these fertilizers is indicated by the more than 580 chemical fertilizer plants now in operation or under construction throughout the world, representing an investment of more than $10 billion (*1*). The manufacture of fertilizers, however, requires vast inputs of energy. Sweeney estimates that the total amount of energy required for the production of ammonium fertilizers is equivalent to 2 million (2×10^6) barrels of oil per day, worldwide (*1*). In North America, the consumption of nitrogenous fertilizers exceeded 8 million tons (metric) in 1973, more than 22 percent of the total world consumption (*2*). For corn production alone, U.S. farmers today apply nitrogenous fertilizers representing an energy input of nearly 900,000 kilocalories per acre (2,430 megacalories per hectare) (*3*). This energy input itself is almost as large as the total energy input for the 1945 corn crop.

The basic commercial process for manufacturing ammonia, which consists of catalytically reacting hydrogen with nitrogen under high pressure and temperature to form ammonia ($3H_2 + N_2 \rightleftharpoons 2NH_3$), has not changed since it was inaugurated in 1913. The dramatically rising price of petroleum as a source of hydrogen, and the many ecological and economic limitations to the heavy use of chemical fertilizers, have stimulated much interest in nitrogen fixation by microorganisms. A better understanding of the nature and manipulation of the biological system might lead to cheaper and more efficient means of producing high quality plant protein.

The only organisms known to fix nitrogen are certain bacteria that harbor the nitrogen fixation (*nif*) genes. Nitrogenase genes code for nitrogenase proteins that catalyze biological nitrogen fixation. One objective of particular significance in the application of molecular biology to the study of nitrogen fixation in bacteria is eventual "infection" of nonleguminous plants such as the cereals with *nif* genes.

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Discovery and Mapping of the Genes for Nitrogen Fixation

At Berkeley in 1971 we identified several crucial genes for nitrogen fixation which were clustered on a small segment of the chromosome of the nitrogen-fixing bacterium, *Klebsiella pneumoniae* (*4*). These genes were discovered at about the same time by Dixon and Postgate who were working in England (*5, 6*). Although the biochemistry of nitrogen fixation was not as well understood in *K. pneumoniae* as it was in other better known nitrogen-fixing bacteria, such as *Azotobacter* and some of the clostridia, we chose to work with the *Klebsiella* species because of its close genetic (evolutionary) relationship to *Escherichia coli*, which is generally acknowledged as the best understood of all living cells. We have been able to exploit the close genetic relationship between these two bacteria in a number of ways.

The finding that the bacteriophage P1 of *E. coli* would mediate the transduction of the *nif* genes (*4*) provided the foundation for studies of the molecular biology of nitrogen fixation. Transductional analysis of *K. pneumoniae* with coliphage P1 yielded several important facts; the most important was that the *nif* genes formed a cluster near the histidine operon on the *K. pneumoniae* linkage map, as shown by cotransductional mapping (*4, 7*). Most chemically induced mutations of the *nif* genes, in which the ability to synthesize nitrogenase was lost (*nif*$^-$), were found to be cotransduced with the *his* D gene (*8*) at a frequency between 30 and 80 percent. As calculated from