

Sets and Fuzzy Sets: Variations in Category Formation

SETS AND FUZZY SETS: VARIATIONS IN CATEGORY FORMATION

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ABSTRACT

The emergence of fuzzy set theories calls into question the fundamental structures of category formation, and the implicit biases anthropologists bring with them when, given their scientific approach, they seek to sort data in terms of well formed sets. The discovery that categories can be formed in several ways, with different structural characteristics, has significant implications for many areas of anthropological thought, including cognitive anthropology, analyses of social structures, linguistics and ethnoscience. This paper presents a preliminary taxonomy of sets on the basis of their structures and suggests some of the implications of this diversity for sociocultural analyses by contrasting American and Indian world views on the basis of their use of sets.

(fuzzy sets, categories, world view, India)

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The analysis of categories, both social and cultural, has been a key method of anthropological investigation throughout much of its history. Studies of kinship terms (Morgan 1871), color categories (Rivers 1901; Berlin and Kay 1969), folk classifications (Malinowski 1922; Evans-Pritchard 1937), linguistic structures (Sapir 1949), and, more recently of componential domains (Goodenough 1956), lexical/semantic relations (Greenberg 1963; Fraake 1964; Werner 1972), social boundaries (Barth 1969) and cognitive categories (Leach 1961 ; Douglas 1966 ; Turner 1964) have all investigated relationships between categories. Implicit in many of these studies seems to be the assumption that there is only one way to form categories and one system of logic to relate them, namely that of modern set theory. Sets in this theory are "well defined" - that is, they have clear boundaries.

The formulation of fuzzy set theory by Zadeh (1965), and its subsequent elaboration in terms of fuzzy relations, fuzzy logic, fuzzy topology, fuzzy composition, fuzzy events and fuzzy models by Kaufmann (1975) and others challenges this earlier assumption and raises both conceptual and ethnographic questions. How many ways can categories be formed, and how do the structures by which categories are formed affect the relationships between them. And what implications do variations in the structures of sets have for ethnoscience, linguistics and studies of social groups? Do different cultures use different types of sets in creating their worlds, and what biases in terms of category formation does the ethnographer bring with him or her into the field?

TWO DIMENSIONS OF CATEGORY FORMATION

As we have noted Zadeh introduced the distinction between well formed and fuzzy sets. A second distinction should be made, namely between intrinsically and extrinsically defined sets.

Well Defined and Fuzzy Sets

The essential difference between well defined and fuzzy sets has to do with their boundaries. Well formed sets are characterized by clear boundaries. Elements are either inside or outside the set.¹ The result is the law of the excluded middle. Things cannot be partly in and partly out of the set at the same time.

Well defined taxonomies based on such sets are made up of categories that a) do not overlap, and b) exhaust the domain. The result is a tidy, well ordered world. Moreover, as the philosopher of science Charles Peirce observed long before the mathematical formulation of fuzzy set theory (1955:371, original 1893) logic within such a system allows for only one conclusion to be drawn from any given set of premises.² The result, he adds, is a strong sense of the certitude of knowledge (1955:356).

Fuzzy sets, on the other hand, have unsharp boundaries. Membership in a set may vary by degrees from fully in to fully out. For example, the colors in a spectrum range from "fully red" to "partly red", "slightly red" and "not red".³ Because there are degrees of inclusion in a set, there is no law of the excluded middle. Things are arranged along continuums rather than divided into discrete opposing categories, and a member may be partly A and partly not-A at the same time. In taxonomies based on fuzzy sets an element may belong to two categories at the same time. For example, in

in terms of well formed sets, Americans can be divided on the basis of their ethnicity into "whites", "blacks" and so on. In fuzzy set terms, an American may be one quarter (or eighth or sixteenth) white and the rest black, or one quarter black and the rest white (figure 1). A person who is one eighth black and seven-eighths white would be seen as almost white, rather than as black (an "octroon") in American slave days. Moreover, in the logic of relative or fuzzy terms, more than one valid conclusion can be drawn from the same set of premises (cf. Peirce 1955:371).

Regarding the relationship between sets as cognitive categories, whether well formed or fuzzy, and the external world, Zadeh writes (Kaufmann 1975:ix):

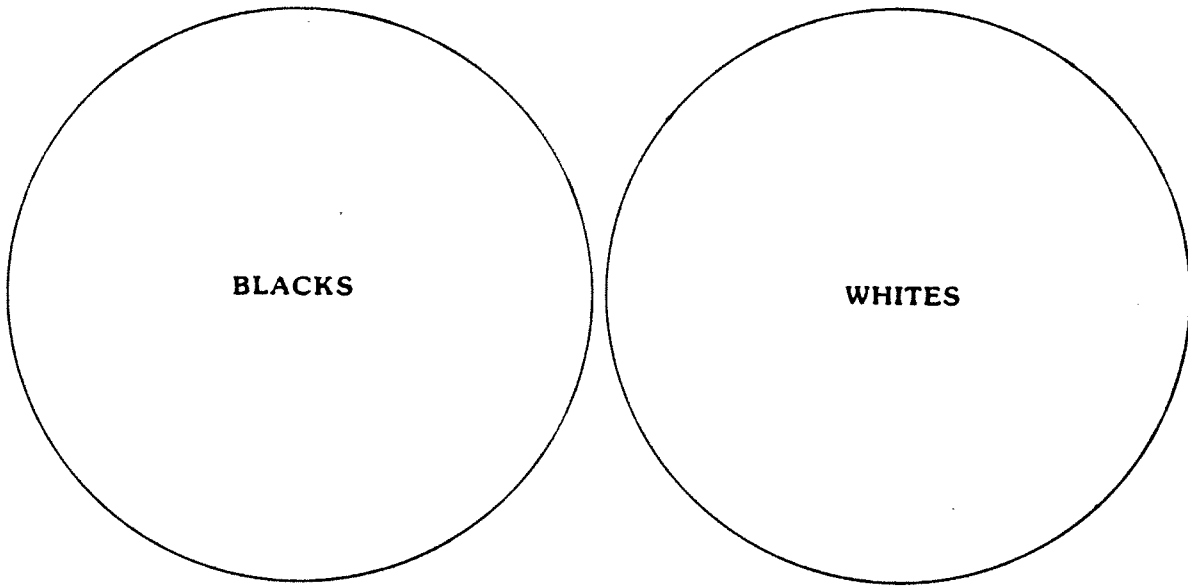
The theory of fuzzy subsets is, in effect, a step toward a rapprochement between the precision of classical mathematics and the pervasive imprecision of the real world - a rapprochement born of the incessant human quest for a better understanding of mental processes and cognition. . . . We have been slow in coming to the realization that much perhaps most, of human cognition and interaction with the outside world involves constructs which are not sets in the classical sense, but rather "fuzzy sets" (or subsets). . . . Indeed, it may be argued that much of the logic of human reasoning is not the classical two-valued or even multivalued logic but a logic with fuzzy truths, fuzzy connectives, and fuzzy rules of inferences. . . . In our quest for precision, we have attempted to fit the real world to mathematical models that make no provision for fuzziness. We have tried to describe the laws governing the behavior of humans, both singly and in groups, in mathematical terms similar to those employed in the analysis of inanimate systems. This, in my view, has been and will continue to be a misdirected effort, comparable to our long-forgotten searches for the perpetuum mobile and the philosopher's stone.

Peirce probably would have disagreed with the phrase "imprecision of the real world" for in his doctrine of synechism he held that the real world itself is characterized by continuity and that it is our human knowledge of it that is imprecise and fallible, in part because we must force it into a limited number of categories of our own making (1955:354-360).

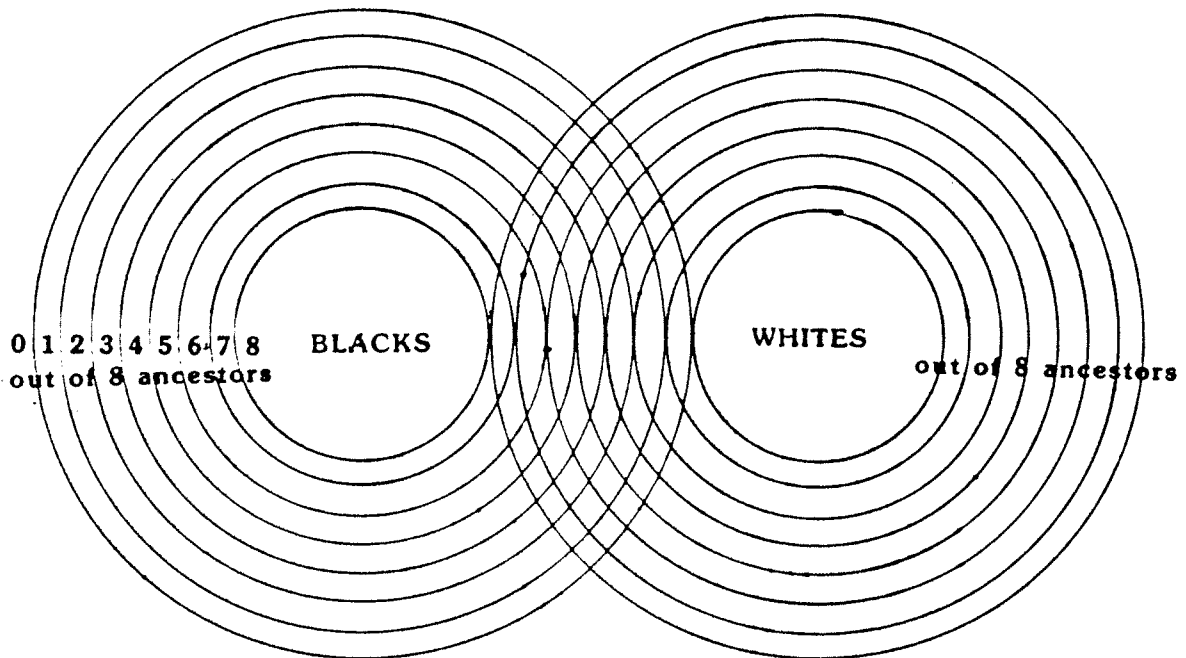
FIGURE 1

Perception of Ethnic Groups in Well Formed and Fuzzy Set Terms

In Well Formed Sets:



In Fuzzy Sets:



Intrinsically and Extrinsically Defined Sets

A second distinction can be made between sets defined on the basis of the intrinsic characteristics of the members, and sets defined on the basis of the relationships members have to external reference systems. For example, a woman is a "female" on the basis of what she is, but a "daughter" on the basis of her relationship to someone else - her "mother". This distinction should not be confused with Saussure's observation that all categories are defined by their place within a cognitive system (1966).

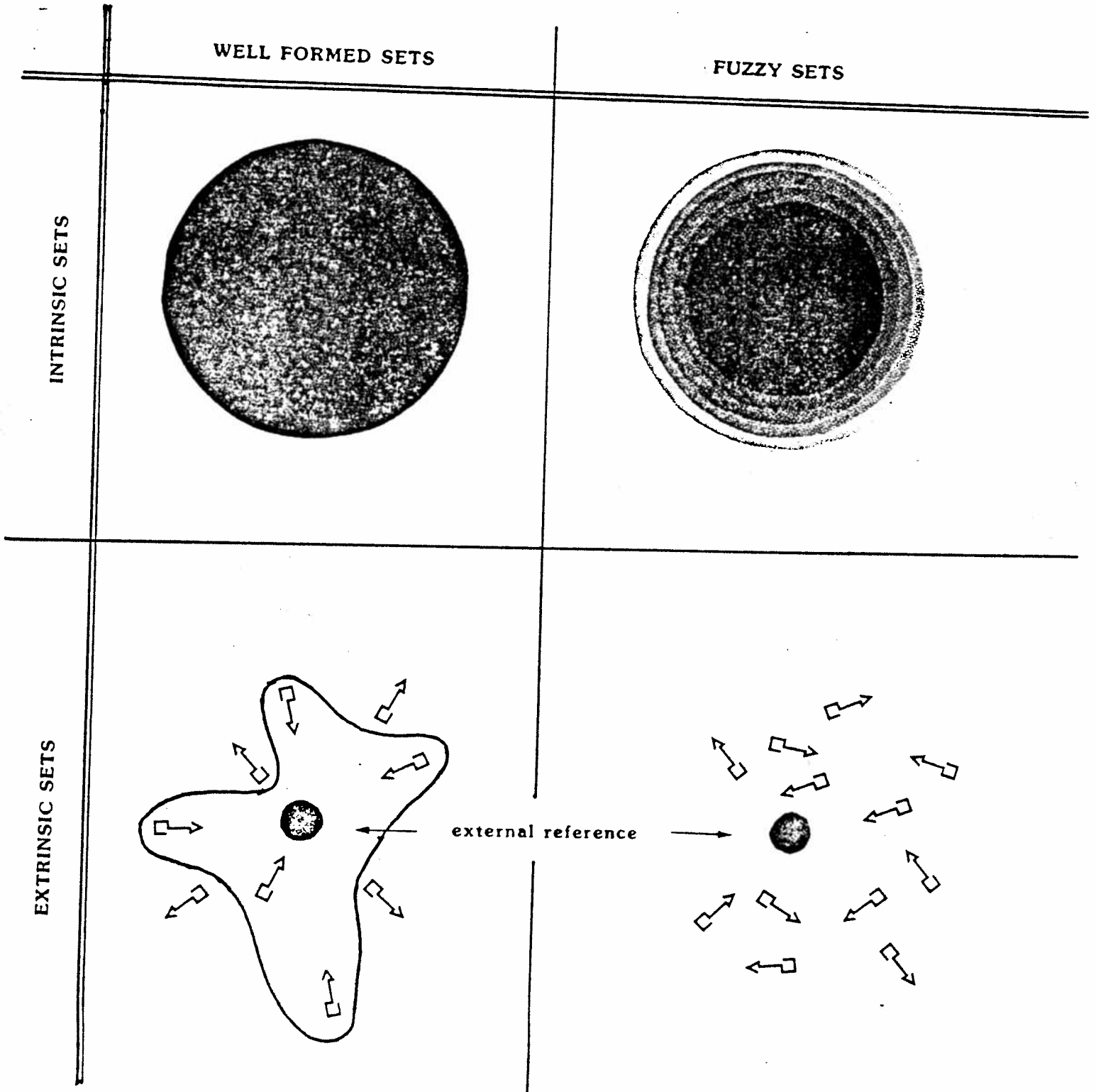
Many, if not most English nouns are based on intrinsic definitions. For instance, a "dog" is defined as "a highly variable carnivorous domesticated mammal" (Webster 1961:246). So too is the definition of the scientific equivalent, canis familiaris.

The word "north", on the other hand, is defined as "in the direction of the north terrestrial pole" (Webster 1961:575). The external reference here is a point, the north pole. Similarly, the term "forty-five degrees and zero minutes north" refers to a set of points, but their reference is the equator. In music the term "mi" is defined with regard to "do" where ever do is set, and the term "third" to the relationship between two notes. In social organization, most roles such as "teacher," "father," and "disciple" are defined in extrinsic terms.

A TYPOLOGY OF CATEGORY FORMATION

Combining these two dimensions, we have a simple cross-break that can serve as a taxonomy of set formation (figure 2). Each type of set has certain basic structural characteristics that influence the way reality is perceived when viewed through sets of that type.

FIGURE 2
A Typology of Sets



Intrinsic - Well Defined Sets

Sets defined on the basis of the intrinsic characteristics of their members, and marked by clear boundaries order reality in several ways:

a. The central focus has to do with the essence of things - with what they are. The definitive characteristics are stated in terms of the intrinsic qualities of things.

b. The set has a clear boundary. In fact, it is the boundary that structurally creates the category. Consequently boundary maintenance is essential, for if the boundary ceases to exist, the set no longer exists.

c. Members within a set are seen as essentially uniform in character. Because they must have all of the defining characteristics, and because these characteristics can only be present or absent, members of a set are the same, at least in matters related to the formation of the set. For example, in this way of thinking there may be small dogs and big ones, black ones and white, but all are one hundred percent "dog". An animal cannot be half dog and half cat at the same time. If it were, it would, in fact, be seen as another kind of creature.

d. So far we have viewed the set statically. Seen dynamically, the only changes that can take place in elements without altering the structures of the sets themselves is for elements to move from outside to inside the set or vice versa. A dog ceases to be a dog when its life and body are destroyed. Moreover, there is a sharp disjunction at the point of change. The dog is not seen as gradually becoming less dog in the process.

Several types of social organization are based on intrinsic - well formed sets. For example, clubs in the west such as Girl Scouts and formal chess clubs are based on common interests and have well defined boundaries based on membership lists and dues. Male associations that

require initiation rites for entry are also of this type. So too are labor unions. Social classes, to the extent they have clear boundaries are intrinsic-well formed sets. "Kind" in the case of class has to do with what people are intrinsically - with their values, wealth, life styles and tastes.

Examples of intrinsic-well formed sets in the area of western culture are scientific taxonomies of animals and plants, and different religions. For many in the west, religious affiliation is defined in terms of orthodoxy (what one believes) and/or orthopraxy (how one acts), and is exclusive (one cannot belong to two religions at the same time).

Extrinsic - Well Defined Sets

Structural characteristics of this type of set are:

a. Membership is defined on the basis of relationships things have to other things, or to an external center or frame of reference. The focus is on relationships.

b. As in the case of intrinsic - well formed sets, there is a clear boundary setting off the set based on the presence or absence of the definitive relationships.

c. Members within a set are seen as essentially uniform in character - they are all equally members of the set. However, because extrinsic-well formed sets are defined on the basis of the relationships elements have to something other rather than on their intrinsic characteristics, the sets are affected by the nature of the other. The external reference may be a single point. For example, the Moonies" are followers of Rev. Moon. Or the external reference may be a larger matrix or grid such as an ordinal or interval number scale in which a number of well formed sets are organized

into a single relational system. An example of this is "temperature" which Webster's Dictionary defines (1965:908) as the "degree of hotness or coldness measured on a definite scale."

On another level, relational scales may be seen as relative or absolute, depending upon how the reference system is perceived. For example, "32° Centigrade" (if are using an interval scale) refers to a degree of hotness measured in terms of a relative scale where 0° C is arbitrarily set at the temperature of water at the point of freezing. "32° Kelvin," however, is measured in terms of a scale seen as absolute for 0° K is defined as a molecular state in which there is no motion at all. No lower temperature is possible.

d. Viewed dynamically, things may move into or out of extrinsic-well formed sets depending upon whether the relationship is formed or broken. The transition is abrupt.

However, because relational sets are linked to external reference systems, change takes on a more complex character. Other factors such as quality, directionality and reciprocity of relationships enter the picture. A room that is 32° C may become 33° C or 31° C. In either case it is no longer 32° but now directionality of change becomes important.

Several types of social organization are relationally defined and clearly bounded. One case is a band of disciples following a guru, where membership is marked by clear initiation rites. Such was the case with Jim Jones. Another is "tribe", again where the boundary is well defined. In tribes "consciousness of kind" is defined in terms of the web of kinship relationships that link people together because they share the same "blood." A third case is citizenship in nations where dual citizenship is not allowed. A citizen is defined in terms of relationships to a certain piece of land.

In the area of culture, an example of extrinsic-well formed sets is the western musical scale, do, re, me, fa and so on. Each note is clearly set off from the others and intermediate pitches are excluded. Moreover, notes other than "do" are defined by their relationship to it. As we have already seen, other cultural instances of clearly defined relational categories are ordinal and interval scales.

Intrinsic - Fuzzy Sets

Intrinsic-fuzzy sets share some characteristics with intrinsic-well formed sets, but differ from them primarily in terms of their boundaries.

a. Like the latter, intrinsic-fuzzy sets are defined on the basis of the intrinsic characteristics of the members.

b. Unlike them, intrinsic-fuzzy sets have fuzzy boundaries. Things may vary in the degrees to which they are members of a set, and elements may belong to two or more sets at the same time. There is no law of the excluded middle. The result is a second algebra and fuzzy propositional logic that are significantly different from comperable systems formed on the basis of well formed sets.

c. Because things vary in the extent to which they are members of a set, they are not uniform or equal. In other words, variations are hierarchies are recognized within a fuzzy set.

d. The only change possible within the structure of such sets is the movement from out to in or vice versa. But this transition may be made gradually and by degrees. A seed becomes a tree by a process rather than by an instantaneous transformation.

Social groups that are intrinsic-fuzzy sets include some forms of crowds, mobs and friendship cliques. Also social classes with no sharp boundaries.

Cultural instances of intrinsic-fuzzy sets are many words in ordinary language (Hintikka 1973; Lear 1977). For example, some things are clearly "chairs" and others are not, but many things fall in between. Many adjectives in English have fuzzy boundaries. This is reflected in their comparative forms such as "sweet," "sweeter," "sweetest." Folk sports such as back yard games of volleyball or sandlot baseball are often characterized by fuzzy boundaries and fuzzy rules.

Extrinsic - Fuzzy Sets

Extrinsic-fuzzy sets combine the extrinsic characteristics of well defined extrinsic sets and the fuzzy boundaries of intrinsic fuzzy sets.

a. They are defined by the relationship of members to some external system of reference.

b. They have fuzzy boundaries. Things may vary in the degree to which they are related to the external system. Consequently they operate by the logic of fuzzy algebra. There is no law of the excluded middle.

c. Because there are degrees of inclusion in the set, differences are recognized between members in the fuzzy set.

d. Change is viewed as a process rather than as a disjunctive transformation. Moreover, secondary variables such as nature and reciprocity of relationships become part of the structure of the set.

Social groups that fit this type of set include kindreds, spectator audiences in public squares, pilgrims, royal classes and darbars. The latter are royal audiences in which the Indian raja presides over matters of state surrounded by a hierarchy of participants ranging from noblemen to professional advocates, supplicants and general public.

Cultural examples include ratio number scales such as those used in the west to measure time and space, political allegiances and Hindu religious practices in which a devotee may worship a number of gods at the same time.

SETS AND CULTURAL DIFFERENCES

Do cultures differ in the types of sets they use to order their worlds? Systematic ethnographic analysis of specific cultures is needed before a clear answer can be given. However, some tentative hypotheses can be drawn from a rough comparison of Indian and American cultures.

Both cultures make use of all four types of sets in their social and cultural systems. As we have seen instances of each can be found in the American setting. Similar cases can be pointed out in India. On the other hand, these two cultures seem to differ in the ways they use different types of sets, particularly in forming the most fundamental categories used to create their worlds.

American culture places great emphasis on well defined categories. Positive value is placed on roads marked by curbs and well marked lanes; on edged lawns uniformly planted with one kind of grass; on rooms with clear borders and moldings separating walls, doors, ceilings and floors; on silverware trays to keep forks, spoons and knives apart; and on well ordered desks in the office. Schools, churches and other associations are concerned with membership lists. Bureaucracies work towards separation of statuses into uniform, standardized job descriptions with well defined role relationships between them (Berger 1974). And stores use fixed prices.

In many ways Indian culture makes use of fuzzy sets. Roads, particularly in the countryside, have fuzzy boundaries. The central portion may be

paved but on either side there are gravel and dirt shoulders used by carts, animals and pedestrians. Outside these are regions of decreasing navigability used when necessary. There is little effort to keep traffic on the roadways segregated into uniform categories. Trucks, cars, cycles, rickshaws, carts, animals and pedestrians compete for the use of the same space (Hiebert 1976). The basis for economic exchange is bargaining in which relationships and variable prices play key roles.

A number of specific contrasts illustrate the different types of sets the two cultures use in similar settings. The first has to do with legal decision making. Western legislatures, courts and juries have well defined memberships. Consequently decisions can be made on the basis of voting. In a traditional Indian panchayat there is no clear membership. Those recognized as senior elders sit in the center surrounded by lesser elders and bystanders. All participate in the discussions, but the words of the senior elders carry greater weight. Voting in such a situation has little meaning and decisions are based on a consensus dominated by the elders.

A second contrast is musical scales. The well tempered scale of the West is made up of twelve semi-tones. These are extrinsic-well formed sets related to the key of C which is set at 454 cycles per second. Notations are made on staves that depict a limited number of clearly differentiated notes; and many instruments such as pianos and organs can only play these notes. There is some room for vibratos and, in more modern music, for slides but the basic structure calls for clearly bounded notes.

Indian music is based on 22 microtonal intervals (shrutis) that acquire their pitch and emotional qualities as soon as the keynote (shadja) to which they are all related is fixed. There is no standard keynote, no fixed scale.

While each note constitutes a definite set of sounds, variations in pitch are recognized in each of them. The result, as Ranade points out (1960:40) is that European scholars have treated Indian music as uncritical or primitive. The problem is that western musicians have been unable to think in terms of fuzzy sets. The artistic style of an Indian musician lies in part in his ability to use gamakas or the dynamic shading of pitches. Parshvadeva, a medieval authority, defines gamaka thus:

When in a song a note peeps over from the region of its own legitimate shrutis a shade into the region of its (higher or lower) neighbours a gamaka is there (Ranade 1960:42).

Both Ranade (1960) and Shukla (1960) point out that the player uses this shading of pitch not only to maintain a subjective sense of pitch (for as the volume of a sound increases, its pitch seems to rise), but also to add color and feeling to the note by bringing it into the range of adjacent notes and thereby producing a contrast with the unheard note. Consequently, the glide becomes the hallmark of Indian music. Ratanjankar notes (1960:55)

An Indian musician, vocalist or instrumentalist, will never produce his 'sa' straight on its pitch. He will always start it on the 'ni' or 'pa' of the mandra saptak, or on the ga or ri of the madhya saptak and glide in an expressive way to the proper pitch of 'sa'. Every note is linked up with its precedent and subsequent notes. . . Individual notes have no meaning in Indian music. . .

A third illustration is religion. Westerners tend to see religions as mutually exclusive. A person may be a Jew, Christian, Muslim or Hindu, but not more than one at a time. In Hinduism, a person may participate in the worship of several different gods without contradiction. It is not uncommon for Hindus to stop at the shrine of a Muslim saint to offer incense and coconuts. It is the exclusivity of Islam and Christianity that is the greatest offense to Hindu thought. In philosophy, it may be the differences

between well formed and fuzzy sets that underlie the western emphasis on exclusivity and the law of the excluded middle, and Indian inclusivity with its "both/and" approach to reality.

Another contrast must be presented as a tentative hypothesis at best, namely the predominant nature of nouns and adjectives in the languages of the two cultures. For example, an American in a shop may ask for a "ripe banana." The noun, or essential word, is banana - an intrinsic, well formed set. "Ripe," on the other hand, is a fuzzy set for there are degrees of ripeness. In South India, a Telugu speaker asks for a "banana ripe." The essential term here is "ripe" (pandu). "Banana" (arati) here is the adjective. One can simply ask for a ripe, for ripes can be eaten without cooking. To the question, what kind of ripe, one may respond, an apple ripe, an orange ripe or a banana ripe.

A final contrast is more difficult to analyse, that between class and caste as forms of social organization and hierarchy. In the western social system, the unit of ranking is the class, or group of people sharing similar wealth, values and life styles. The basic unit of rank in Indian society is the jati, or genus of human beings. People belong to a jati because they are linked to one another by certain biological and substance ties (cf. Marriott and Inden 1965). The extrinsic nature of jati is illustrated further by the fact that castes are not seen as a series of independent groups that happen to coexist in the same area. They are castes only because they are complementary members of a single unitary society.

The question of boundaries is more difficult. Western analysts have not reached a consensus either on the number of classes or on the

nature of the boundaries between them. A strong case can be made, however, that classes are more comparable to varnas than to jatis, for both classes and varnas provide the broad societal categories that determine social hierarchies. Jatis, on the other hand, are more comparable to western associations in that both are made up of social groups formed within these broader hierarchies (cf. Hsu 1963). An Indian acquires status by belonging to a jati that has a certain rank within the varna system. An American acquires status by joining associations such as clubs, churches, neighborhoods and institutions (such as universities) that have certain ranks within the class system. Viewed this way, it is interesting that western associations strive for clear membership boundaries. Jatis have fuzzy boundaries. As Dumont points out (1970) there are degrees of purity within each caste. Moreover, jati boundaries are blurred by hypergamy, and by miscegenation between castes. Little research has been done on the latter, but a study in one village has shown that mixed caste offspring (kaltri) are fairly common and occupy a marginal status on the edges of different castes (Hiebert 1971). Finally, as Kaufmann points out (1975:7-8), hierarchy and dominance are fundamental to fuzzy set relationships. On the other hand, uniformity and equality are characteristic of well formed sets. It may well be that here lie the deep roots of the west's idealization of egalitarianism, and of India's stress on hierarchy.

CONCLUSIONS

Current explorations into the ways humans create sets and categories provide us with a better understanding of their basic structural differences. The implications for analytical approaches such as social structure, ethnoscience, linguistics and symbolic analysis may, in the end, be of great significance.

But of equal importance is the fact that these studies make us aware of structural biases which, so far, have been largely implicit in western thought, and consequently in anthropology. Science has sought for ever greater precision in definitions, and has, in recent years, drawn heavily from boolean mathematics and logic in which, as Alfred de Musset notes, "it is necessary that a door be open or closed." The danger is that we seek in our studies an exactness of categories that may not exist either in nature or in the cultures we examine.

NOTES

1. In mathematical terms, $X:X = 0,1$. In other words, all elements have a score of either zero or one. No intermediate scores are allowed.
2. Peirce uses the terms "non-relative" and "relative" for what appears to be essentially the same distinction. This can be seen also in his discussion of the statistical nature of scientific observations, and in his discussion of synechism or the doctrine of the continuity of all things (cf. 1955:150-227, and 339-360).
3. Mathematically, $X:X = 0 \rightarrow 1$. All intermediate states between zero and one are possible. In order to discuss fuzzy sets in precise mathematical terms, the word "fuzzy subsets" is used, for then fuzzy sets are thought of as an infinite set of sets ranging from zero to one.

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