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Representation, Comprehension and Communication of Sets: the Role of Number* (Part I.)

(Sect. 1–6.1)

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Examines the cognitive and other factors which tend in practice to limit the number of elements distinguished in a set, particularly for sets fundamental to social science and policy formation, such as: human needs, values, principles, problems. It is argued that the number of elements so distinguished influences significantly both the relationships perceived between the elements and the qualitative characteristics manifested by them, irrespective of the content of the set. Such effects are important in the case of the more abstract sets for which the ambiguity of verbal descriptors creates considerable problems of comprehension and communication, especially when the set of elements is used as the basis for the elaboration of a group of cooperating institutions. The representation of such sets in traditional symbol systems and in modern 2 and 3-dimensional forms, is reviewed both as a source of constraints on set formulation and as a guide to the formulation and comprehension of the more complex sets through which the problems of society can be better contained. (Author)

1. Introduction

There is a widespread tendency to formulate insights, proposals or principles in point form, namely as made up of a specific number of items usually presented as a list. Such items will be considered here as the elements of the set which they collectively constitute in any particular case.

This paper is therefore concerned with problems relating to the representation and comprehension of such sets – whether the elements in any given case are *basic*: human *needs*, human *values, principles, concepts, problems*, human *rights*, human *responsibilities* or components of a policy.

The paper explores the possibility that (irrespective of the nature of the elements in any such case) there may be different kinds of constraints on the distinctions and relationships between the elements, depending upon the total number of elements in the set. Clearly, the total number of elements in the set also affects the manner in which the set can be represented, communicated and comprehended.

Briefly, therefore, the paper argues that consensus on a 5-element set of human needs (or a 5-point programme) for example, implies certain kinds of distinctions and relationships between the 5 elements, depending solely on the number (e.g. in contrast with a 3-element or 10-element set). These may not have been met in a given case because the elements are either (a) inappropriately defined, or (b) appropriate to a 4-element or 6-element set (with the consequence that there are elements in excess or missing from the set). Inadequacies of this kind are of importance in themselves but also affect the representation and communicability of the set, and ultimately its role and viability in the psycho-social domain.

2. Context

1. The following argument applies only to cases where the elements are conceived as making up a *complete set*. It does not apply when the elements have been selected (possibly as a sample) from a larger set. Where the elements are selected on a priority basis, as being the "most important", the argument only applies when this may be interpreted as implying most "fundamental" or "basic"[1]. Ideally the argument should also apply to any numbered list of points in an argument. But, since numbers are usually allocated for convenience to provide a simple structure to a sequence of paragraphs (and only indirectly related to the concepts developed), this is seldom the case. It should however apply wherever the author(s) declare that: "The following points apply", provided "*including* the following points" is not used or implied. The list of points should therefore have been elaborated through a "struggle" to get the best "fit" – a struggle which may have required much more than superficial reflection over a short period of time[2].

2. The sets under consideration contain elements which are essential to the ordering of an equilibrium state or an evolving process (expecially in the psychosocial domain). As such each element is different and has a special part to play. Each complements the others and all are conceived as essential (e.g. in the case of human values or needs). There is a desire that such sets should be well-formed or well-ordered, even if some degree of "fuzziness" must be tolerated as the content is clarified through research and debate.

3. The elements in such sets should be equally distinct from one another or else the question arises whether two or more similar elements should not be redefined as one. This said, however, two cases must be distinguished:
– the set itself may well be made up of sub-sets whose elements have characteristics in common
– some elements may be more directly related to others whilst still being distinct from them.
Any ambiguity implied here should be resolved by the form in which the set is represented (see below; also in Part II).

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3. Constraints on number of elements in a set

1. There is an implicit assumption that authors are free to include as many elements in a set (of the above kind) as they wish. In fact, 1-element and 2-element sets are seldom of interest to scholars, although there is a tendency reinforced by public policy considerations to identify 1-element sets (e.g. *the* fundamental value, need, problem, principle, etc.). At the other extreme, 1000-element sets are considered unacceptable, as are 100-element, or even 20-element, sets. The implication here would be that the authors have not made an adequate attempt to regroup the elements in the light of common characteristics. An apparent exception is the matrix, but even here the number of columns or rows becomes unacceptable (for other than special cases) in excess of 20, for example. In fact, the probability of encountering a set with a given number of elements seems to decrease rapidly when the number exceeds about 10. It would be interesting to see whether a survey[3] would show any relation to the isotope abundance curve (see Fig. 1) in which the peaks are approximately congruent with the atoms of highest structural stability[4].

2. Authors are therefore constrained, irrespective of the nature of the set, to reduce the number of elements to something in the region of 10. Each such element, however, may in turn be considered as a (sub)set within which a similar number of elements is admissable. In this way, any number of elements can ultimately be incorporated. This coding procedure is considered legitimate because it facilitates comprehension. The consequences of such a procedure have not been examined – and yet *it is this very procedure which produces the sets of values, principles, problems, needs, concepts, policy elements, etc. in terms of which attempts are made to order social processes and resolve their problems.*

3. The objectivity by which elements are selected on the basis of scientific criteria for inclusion in a set is therefore strongly affected by constraints on the ability of the author/observer to comprehend the set as a whole and to render it comprehensible to others. As Christopher Alexander notes (ref.(2), p.5) it has been shown

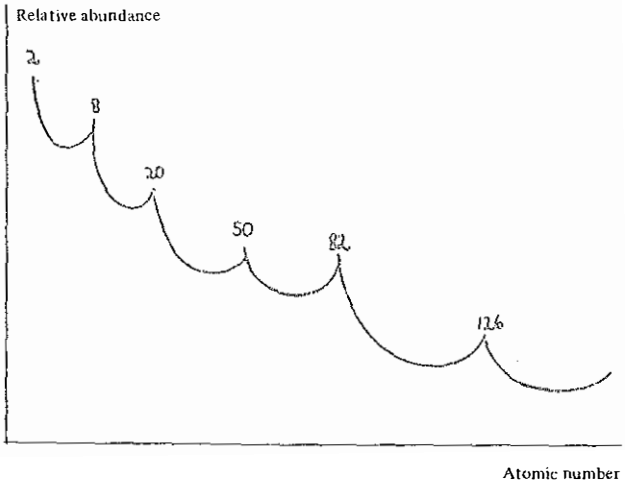

Fig. 1: Indication of progressive decrease in relative abundance of isotopes of increasing atomic number

that there are bounds to man's cognitive and creative capacity. There are limits to the difficulty of a laboratory problem which he can solve (3); to the number of issues he can consider simultaneously (4) (5)[5]; to the complexity of a decision he can consider wisely[6]. In commenting on relevance judgements in priority determination, a Unesco document notes "The number of positions on the scale (of relevance) can be at most 6 or 7, the maximum number of different positions among which the human mind can meaningfully discriminate". (6)

4. This constraint is also reflected in the "embodiment" of such sets in social organization, namely in the limits on the size of an effective committee, on the one hand, or on any small encounter/therapy group, on the other (7). The limit to the number of subordinate bodies which a body can effectively control is of the same kind, particularly as evidenced by the number of divisions reporting to a coordinating or presidential office. Antony Jay has explored many organizational examples of such limits[7]. Note that such organizational sub-division is carried out and limited irrespective of the complexity or diversity of the operations or problems with which the body as a whole has to deal.

5. The constraint is also "embodied" in the category sub-division of the thesauri which govern the manner by which information is obtained from libraries and information systems. Note again that this is so irrespective of the complexity or diversity of the subjects recorded in such systems.

6. The constraint may also be noted in the sets of "key" or "fundamental" problems, values, needs, etc. which are identified as the basis for action programmes. Such a breakdown lends itself readily to institutional embodiment or reinforces institutional structures which already reflect (and are therefore unthreatened) by this structuring. The predilection for sets of 10 key problems is noted by the editors of the Yearbook of World Problems and Human Potential (ref. (19), see especially Appendix 3). An excellent example is Unesco's own exercise to identify the major world problems with which it is concerned. It found 12 and condensed them under 10 objectives in its Medium-Term Plan 1977–1982 (Paris, Unesco, 1977, 19 C/4). Another excellent example is the Assessment of Future National and International Problem Areas (Washington, National Science Foundation, 1977, NSF/STP76-02573). This carries an illustration, reproduced here as Fig. 2, which shows admirably the nature of the process. The document concentrates on the 6 problems which emerge from this filtering procedure. (It is perhaps naive to ask what attention will be given to the 994 problems excluded by this procedure.)[8]

7. Such is the prevalence of this constraint that it is of interest to identify the conditions under which it is exceeded and the consequences of doing so for the communicability and viability of the set[9].

8. Another aspect of the constraint on the number of elements in a set emerges from recent explorations into the psychophysical significance of number as the common ordering factor of psyche and matter (9). Since this raises the question of the nature of the observer's relation to the observed, this is discussed separately below.

4. Representation of sets: Introductory comment

Herbert Simon notes: "An early step toward understanding any set of phenomena is to learn what kinds of things there are in the set – to develop a taxonomy. The step has not yet been taken with respect to representations. We have only a sketchy and incomplete knowledge of the different ways in which problems can be represented and much less knowledge of the significance of their differences." ((5) p. 78)

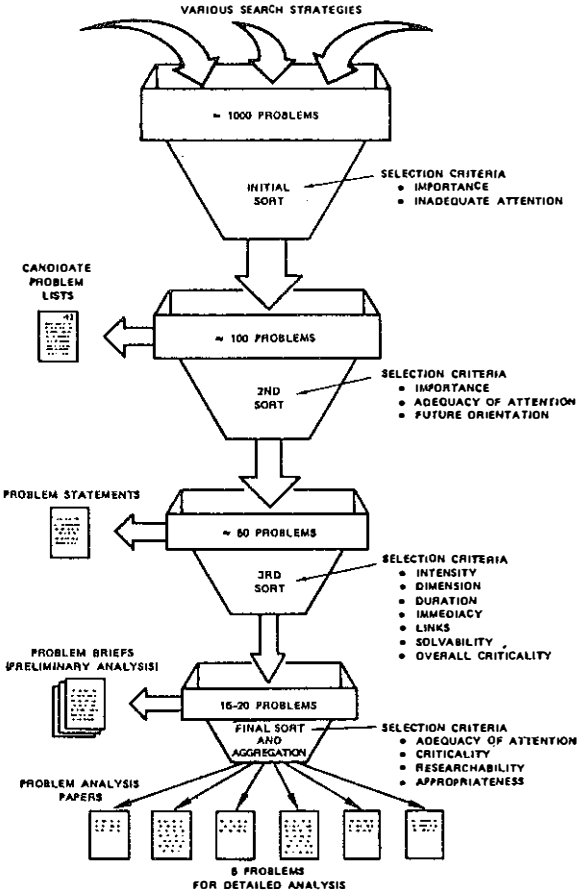

Fig. 2: Illustration of the project approach of the "Assessment of Future National and International Problems". (Reproduced from a document of that title, published by the National Science Foundation, Washington DC, 1977.)

The problem of representation is generally considered to be of little interest compared with the subject matter of the representation and is seldom a matter of scholarly concern[10]. One reason derives from the prevalence of evidence that the physical and social environment is hierarchically ordered (10)[11]. Now hierarchical structures are those in which the interactions amongst the subsets are weak in comparison with interactions between the elements within the set. They are therefore referred to as "nearly decomposable" and as such the high-frequency dynamics within subsets are distinguished from the low-frequency dynamics between subsets. Herbert Simon relates this property to the comprehensibility of such systems: "The fact, then, that many complex systems have a nearly decomposable, hierarchic structure is a major facilitating factor enabling us to understand, to describe, and even to "see" such systems and their parts" ((5), p. 108). And clearly once it is assumed that the subsets can be represented individually, or separately in relation to the set and to each other, representation is merely a question of a hierarchy of "maps". Each can be made as detailed as necessary and can be comprehended separately.

It may be argued, however, despite the apparent ease of this approach, that widespread understanding of the many systems within which man functions (or with which he interacts) remains elusive. Indeed complaints about "increasing complexity" are now common. And studies of psycho-social systems have not produced insights to make them more manageable, in fact such systems appear to have become less manageable whilst such studies are produced.

There are three weaknesses in the conventional stress on the prevalence of hierarchical ordering. Herbert Simon follows the previously cited remark with: "Or perhaps the proposition should be put the other way round. If there are important systems in the world that are complex without being hierarchic, they may to a considerable extent escape our observation and our understanding." ((5), p. 108). Such systems, possibly exerting a "field effect" or based on non-hierarchically ordered networks may indeed be at the root of our difficulties. It is interesting that the 1970s has witnessed a rapidly burgeoning interest in networks of all kinds and a suspicion of hierarchically coordinated social structures (13). The relationship between sub-sets of different hierarchies is recognized as being increasingly critical (e.g. in environmental systems). The problem of representing such complex patterns of relationship to facilitate comprehension has not been resolved[12].

A second weakness derives from lack of clarity on the nature of the set of which the hierarchical set under consideration is a sub-set – namely the super-ordinate set. Each discipline is responsible for its own hierarchical sets, none is responsible for the super-ordinate set (and the interactions between its sub-sets). This relates back to the first weakness. There is little understanding of what happens at the "top" of hierarchies and especially "above" them[13].

A third weakness derives from lack of clarity on the relation of the person creating or observing the set – to that set. Some aspects of this question are discussed separately below. It is particularly important where one or more such sets are expected to order the comprehension of the individual who therefore has the problem of "juggling" them into a suitable configuration in relation to his own psychic ordering[14]. This raises the question of the iconicity of any representation which is discussed below.

In discussing the description of complexity, Herbert Simon makes a basic distinction between state descriptions and process descriptions[15]. "These two modes of apprehending structures are the warp and weft of our experience. Pictures, blueprints, most diagrams and chemical structural formulas are state descriptions. Recipes, differential equations, and equations for chemical reactions are process descriptions. The former character-

ize the world as sensed; they provide the criteria for identifying objects, often by modeling the objects themselves. The latter characterize the world as acted upon; they provide the means for producing or generating objects having the desired characteristics. ... Given a desired state of affairs and an existing state of affairs, the task of an adaptive organism is to find the difference between these two states and then to find the correlating process that will erase the difference. Thus, problem solving requires continual translation between the state and process descriptions of the same complex reality." ((5), p. 111–112).

Some of the ways of representing sets are discussed below.

5. Representation of sets: review of types

1. *Lists:* As implied above, the most favoured way of presenting a set is in the form of a list of items or points. Such lists may be unstructured or else items may be grouped into subsets. No other aid is provided for the comprehension of the set. It is assumed that any normal mind will be able to grasp the content in a satisfactory manner. Such lists do not identify the nature of the relations between the elements of the set (other than by what is implied by grouping into subsets).

2. *Thesauri:* As mentioned above, when there are many elements these are classified, with the aid of thesauri, into subsets at various depths within a thesaurus structure. Again little is provided to aid comprehension, the assumption being that a person knows which element is required and that the structure of the whole is of little importance. (There are a number of competing thesauri prepared by institutions – themselves competing for resources.)

3. *Tables/Matrices:* The degree of order of a set becomes clearer when it is presented in the form of a table, of which there are various kinds (e.g. the periodic table of chemical elements). These blur into matrices as a more general form of tabular presentation, which may be multi-dimensional. But here again the mind has difficulty in comprehending the whole, although it may distinguish the parts. There is a limit to the tolerance for complex tables or matrices in policy-making circles, for example, and they are seldom suitable for media-oriented presentations.

4. *Diagrams:* As the variety of relationships between the elements of a set is recognized to be of importance a diagrammatic form of presentation may be used – even if it means sacrificing the precision of a matrix presentation. There are many kinds of diagrams (14), from the simplistic to the full detail of a system flow chart. But again the simplistic can only serve momentarily to introduce the set, they cannot carry the detail which a highly ordered set demands; whilst the overall significance of the detailed charts eludes the grasp of most minds[16]. It is also interesting to note that there are constraints on the representation of such diagrams on paper due to the limited acceptability of lines crossing each other, multiple line coding, or the use of many colours.

5. *Yantras/Mandalas:* One form of diagram of special interest, because of its deliberate orientation ofward the observer, is the "yantra" (or "mandala", in its circular form). These have been used extensively in Eastern cultures to integrate many hierarchic levels of information detail concerning the universe in a form designed to be both comprehensible and to have a profound impact on the attentive observer. Indeed special practices have been developed for their preparation and use[17]. Significant in the light of the weaknesses connected with hierarchical representations noted above, is the fact that here hierarchies are bound together within a common framework with detailed elements on the outer edge of the diagram and the super-ordinate sets linking into a common centre – the focal point for the observer[18] through whose awareness (once refined) the disparate sets of experience are integrated. The challenge to the observer is to penetrate into and structure his awareness through the diagram. It is especially noteworthy that diagrams of this type contain a high degree of symmetry, as well as colour coding and symbols of various kinds. (These are in part designed to "trigger" the conditions required of the senses and awareness in order for the "programme" to work.) The symmetry features are of course constrained by the planar representation.

6. *Other techniques:* The paragraphs above would seem to mark out the current ability to represent sets, given the number of elements, the degree of their ordering, and the erosion of comprehensibility as the combination number/degree of order increases in complexity.

There are a number of other techniques of communicating the content of a set. Some are discussed in (16), but they tend to suffer from the defect of being unable to represent the set in a form which can be easily reproduced and which lends itself to detailed examination and review. It is also appropriate to note here that many authors do not summarize their insights as a set of points or insights and may well consider such a representation as damaging to the nature of the insights they seek to communicate. Indeed the pre-logical biases, identified by W. T. Jones (17)[19] against such a representation may in certain cases constitute an ultimate constraint on clearly distinguishing the elements in a set.

7. *Three-dimensional constructs*

7.1 As noted above, diagrams in 2-dimensions are extensively used to represent sets. It is however very rare to see 3-dimensional representations of sets, partly for the obvious reason that it is difficult to see the internal structure of such representations. And, despite the considerably increased facility it offers, 3-dimensional representation creates a barrier to the linear verbal description so essential to the verbal and textual expression on which much research and decision-making is based[20]. However there are techniques for handling the representation of sets in 3-dimensions, of which the most sophisticated are the graphic terminals used in computer-aided design ((19) Appendix 6). But it is interesting that, despite much attention to hierarchical ordering in organic and inorganic systems composed of 3-dimensional entities, it is in terms of a 2-dimensional representation that such hierarchies are studied[21].

This is so even though the champion of the hierarchical perspective, Lancelot L. Whyte, specifically notes that "the real need is for a systematic and exhaustive survey of the types of three-dimensional spatial ordering which characterize the more important levels in both realms" (ref. (10), p. 13). He also remarks that "Where

a system is 'sufficiently ordered' and 'sufficiently nearly stationary' (terms to be clarified) three-dimensional *geometrical* relations (i.e. lengths or angles) may play a fundamental role. . . It is conceivable, in principle, that under certain conditions everything is derivable from angles. It seems that theory may sometimes pass rather easily from central geometrical hierarchical models to the heterogeneous properties of static, stationary, or near-equilibrium systems, thus opening the way towards a physics of hierarchy" (ref. (10), p. 11). The equivalence in properties between physical and social systems has been repeatedly noted (20).

7.2 A further justification for moving to 3-dimensions is that it increases the *iconicity* of the representation, namely the degree of isomorphism between the structure of the reality represented and the structure of the representation. Where this is high, comprehension is considerably facilitated – which is why architects communicate new concepts to clients via models and not plans.

7.3 The question now arises as to what relation the cognitive elements of the set bear to their representation. This argument is based on the assumption that in the case of the fundamental elements under consideration, there is a strong configurational component to their comprehension as nested concepts. Many of the arguments in support of (and against) this assumption have been developed by Rudolf Arnheim (21), who states, moreover: "The aesthetic element is present in all visual accounts attempted by human beings. In scientific diagrams it makes for such necessary qualities as order, clarity, correspondence of meaning and form, dynamic expression of forces, etc. The value of visual representation is no longer contested by anybody. What we need to acknowledge is that *perceptual and pictorial shapes are not only translations of thought products but the very flesh and blood of thinking itself*. . ." ((21), p. 134). And also: "In the perception of shape lie the beginnings of concept formation." (21,p. 27). He defines "shape" to include 3-dimensional forms, though most of his examples are based on 2-dimensional shapes, especially sketches and diagrams. He does, however, imply that a third dimension (depth) enters into perception, when appropriate (as with pictures). It may therefore be concluded that under certain conditions man thinks in terms of 3-dimensional constructs, whether or not he also thinks in terms of words or 2-dimensional shapes.

7.4 In moving to 3-dimensions a highly significant constraint emerges. In 2-dimensions there is, conventionally[22], a certain freedom in that the planar surface may be extended and divided at will (within the limits of line and colour coding noted above). Whereas, in 3-dimensions, what are known as packing constraints become much more significant (23). The ways in which subsets can be nested within sets may then be severely limited.

The question is then whether such geometric constraints on representation bear any relationship to constraints on the interrelationship between subsets or their elements as concepts in the human mind. On a hypothetical 2-dimensional system flow chart, one can well imagine over 50 input/output lines drawn to a particular process box. There appears to be no restriction (although there must be electro-mechanical and computing limits to their control). But at the conceptual level, the number would be unacceptable (in terms of the constraints noted earlier) and the process box would have to be divided into smaller units. A process box with 50 input/output lines would not be a useful guide to thinking about the system. It is as though each such unit could only have one of a small range of "valencies", to borrow a chemical term (24).

Now in 3-dimensional representations the permissable valencies emerge from the manner in which the sub-components can be packed in contact together (e.g. packing small spheres into a larger one). In fact this is also true in 2-dimensions (e.g. packing small circles into a larger one), but at this level the number of relationships (i.e. points of contact) is more limited than with 3-dimensions. It can of course be argued that in many cases such a representation is adequate to the complexity represented. The search for improved tools is however stimulated by the failure of the existing ones to improve collective, operational understanding of the social condition; the assumption of adequacy may not in fact correspond to the complexity of the environment.

The 2-dimensional model is not rich enough to reflect a 3-dimensional reality adequately (or with the compact elegance and symmetry that one may suspect comprehension of complexity demands). But it may also be argued that a 3-dimensional model is equally inadequate at reflecting higher dimensional realities. However there is little to suggest that man tends to think *in* 4 or more dimensions, even if some can think *about* them and represent their results in mathematical terms[23]. To be comprehensible and widely so (in order to be of relevence to social change), "it seems safe to say that only what is accessible to the perceptual imagination at least in principle, can be expected to be open to human understanding" ((21), p. 293). Hence the value of exploring the conceptual significance of 3-dimensional representation as opposed to other forms.

7.5 The point by Whyte cited above "that under certain conditions everything is derivable from angles" has recently been explored independently in a book by Arthur M. Young. He argues "a whole object or situation is divided into aspects (or, to use Aristotle's word, causes) and that these aspects have an angular relationship to one another" ((25), p. XV). He asks: "Is my opening statement, 'All meaning is an angle', too abstract? Not if one accepts my allegation that meaning is in general a kind of relationship" ((25), p. XV). Despite his unique understanding of 3-dimensions (as the inventor of the Bell helicopter), he only applies his approach to 2-dimensional cases. In a second book (26), published simultaneously, he explores related matters basing them on a 3-dimensional concept – but he does not link this explicitly to the angular concept of meaning.

7.6 For an extensive exploration of the meaning associated with the geometry of 3 dimensions, it is necessary to turn to R. Buckminster Fuller (see note 4). His preoccupation, despite the subtitle of his book, is however with the architectural and concrete material implications of his work (of which one application is the geodesic dome which he invented). Nevertheless, in his work especially, and in that of others, stimulated by it[24] lie the basis for many generalizations in support of the argument here. In particular, as with Whyte and Young, he is also sensitive to the general significance of angle[25].

This is essential to his basic argument that the focal points for energy events in any system are linked into a closed pattern of relationships which can be effectively represented by an appropriate polyhedron ((1), p.95 and 655). "All the interrelationships of system foci are conceptually represented by vectors. A system is a closed configuration of vectors. It is a pattern of forces constituting a geometrical integrity that returns upon itself in a plurality of directions." ((1), p. 97). No reason is given why this should not apply to a system of conceptual elements constituting the kind of ordered set of interest here.

An attempt by a biologist has in fact been made to use the geometry of the 3-dimensional biological cell structure as a cubic framework in terms of which concepts may be ordered and interrelated (29). This has been extensively developed (using large-scale 3-dimensional models) as an experiential learning tool. Another very interesting approach (30), again using a cubic framework, has been considerably developed – from a model originating in the data-processing industry (31) – in order to provide a way of structuring and representing ideas. Many points relevant to the argument here are discussed, as well as the transition from 2 to 3-dimensions. Whilst interesting and valuable as exercises, these raise further points discussed below.

8. *Mathematical notations and N-dimensional representations:* Much that is of interest with regard to sets and their elements is expressed and represented in mathematical notation which is meaningful to very few (including this writer!). This is the case with the highly relevant argument of Spencer Brown (18). It is also true of the very relevant insights of René Thom who leaves most social scientists, and policy makers behind at his point of departure: "We therefore endeavor in the program outlined here to free our intuition from three-dimensional experience and to use much more general, richer, dynamical concepts, which will in fact be independent of the configuration spaces. In particular, the dimension of the space and the number of degrees of freedom of the local system are quite arbitrary – in fact the universal model of the process is embedded in an infinite-dimensional space." ((32), p. 6). He does however support the geometric representation argued above: "I should like to have convinced my readers that geometrical models are of some value in almost every domain of human thought. Mathematicians will deplore abandoning familiar precise quantitative models in favor of the necessarily more vague qualitative models of functional topology; but they should be reassured that quantitative models still have a good future, even though they are satisfactory only for systems depending on a few parameters." ((32), p. 324). However rich the resultant insights, it is their significance and representation in 3 dimensions which is fundamental to their value for the comprehension and ordering of social processes.

6. Involvement of the observer/creator of the set

1. Whenever it is convenient, there is a widespread tendency to avoid consideration of the impact of those involved on research or on the policy-making process in which they participate. Researchers correct for bias in experiments and aim for reproducible results. Efforts are made to balance the interests represented at policy meetings. Consequently, when sets of basic values, problems, concepts, or principles are generated by either, they are conceived to be objective. The relationship between any such objectively determined category sets and the thinking processes of those involved (or on whom those categories are subsequently "inflicted") is not open to rational discussion in the same arenas and may well be perceived both as impolite and threatening. And yet it is recognized that:

> "The categories in terms of which we group the events of the world around us are constructions or inventions. The class of prime numbers, animal species, the huge range of colours dumped into the category "blue", squares and circles: all of these are inventions and not "discoveries". They do not "exist" in the environment. The objects of the environment provide the cues or features on which our groupings may be based, but they provide cues that could serve for many groupings other than the ones we make. We select and utilize certain cues rather than others." (Jerome S. Bruner et al., (33), p. 232.)

And again:

> "Nowadays we concede that the purpose of science is to invent workable descriptions of the universe. Workable by whom? By us. We invent logical systems such as logic and mathematics whose terms are used to denote discriminable aspects of nature and with these systems we formulate descriptions of the world as we see it and according to our convenience. We work in this fashion because there is no other way for us to work." (S S Stevens, (34), p. 93.)

In justifying their own work, Bruner et al. argue:

> "Two consequences immediately become apparent. . . The characteristic forms of coding, if you will, now become a dependent variable worthy of study in their own right. It now becomes a matter of interest to inquire what affects the formation of equivalent classes or systems of equivalence coding. The second consequence is that one is now more tempted to ask about systematic individual and cultural difference in categorizing behavior." ((33), p. 8).

This point was however made in 1956. Both in the research on which they report and in subsequent research, it would appear that the focus has been on categorization in the case of "laboratory problem" sets which are essentially trivial in comparison with the sets of *fundamental* concepts which are elaborated *consciously* in the course of research (or policy-formulation). The former are laboratory exercises requiring minutes or hours, the latter involve much reflection and a protracted "struggle" for the best "fit", possibly over a period of many months or years. In particular, to give the kind of "uncomfortable" example that is required, the research has *not* been applied to the sets and categories selected by those undertaking research in this very area, as an aid to explaining the differences of opinion which give rise to non-rational behavioural dynamics between the various schools of thought affected. Only "pointed", self-reflexive research of this kind, on the formulators of sets which are fundamental to social policy, can help to clarify the basis for the opposition between policies which tends to fragment society into hostile camps.

Notes:

1 Further attention should be given to 0-element sets and their significance.

2 Obtaining a "good fit" is essentially a problem of design and indeed in his influential book on the subject, Christopher Alexander (ref. 2) devotes several chapters to the question. *Deciding on the boundaries of a set and distinguishing itselements is a problem of design* as Alexander would see it (as is

the problem of elaborating a suitable representation, particularly when the relationships between the elements are taken into account). He notes:

"The ultimate object of design is form . . . every design problem begins with an effort to achieve fitness between two entities: the form in question and its context. The form is the solution to the problem; the context defines the problem. In other words, when we speak of design, the real object of discussion is not the form alone, but the ensemble comprising the form and its context. Good fit is a desired property of this ensemble which relates to some particular division of the ensemble into form and context." (p. 15–16)

And also:

"What does make design a problem in real world cases is that we are trying to make a diagram of forces whose field we do not understand. Understanding the field of the context and inventing a form to fit it are really two aspects of the same process. It is because the context is obscure that we cannot give a direct, fully coherent criterion for the fit we are trying to achieve; and it is also its obscurity which makes the task of shaping a well-fitting form at all problematic. . . I should like to recommend that we always expect to see the process of achieving good fit between two entities as a negative process of neutralizing the incongruities, or irritants, or forces, which cause misfit." (p. 21–24)

3 It would be a simple matter to select, from papers of a wide range of disciplines or administrative activities, lists of "basic points" made (possibly with sub-point coding if any). Irrespective of content, the number of points should follow a pattern which could suggest interesting lines for future research. A rich source of popular material is *The Book of Lists*, edited by David Wallachinsky, et al. (New York, William Morrow, 1977) from information supplied for *The People's Almanac*. It contains 377 lists on all topics. Even if biased toward a particular format (of the Almanac) or to conform with the style of earlier lists, the results are still indicative. (*1–10* items per list, 54.6%; *11–20*, 35.0%; *21–30*, 7.2%; *31–40*, 1.3%; *41–50*, 0.5%; *51–60*, 0.5%; *61–70*, 0.3%; *71–80*, 0%; *81–90*, 0%; *91–100*, 0.3%; *100+*, 0.5%. With *10* items, 39.3%; *15*, 8.0%; *20*, 6.4%). A new edition is in production.

4 For a comment on the *general structural* significance of the peaks in the curve, see ref (1), p. 604–607.

5 Herbert Simon (ref. (5), p. 39–40) notes that such constraints can now be less plausibly explained by a single parameter and that under certain circumstances the value falls from 7 to 2 (on which point see the peaks in the curve of Fig. 1). It appears that it is *short-term* memory which can only handle information by chunks of 7. This constraint does not apply to long-term memory. However this does not change the fact that the sets under discussion usually contain about 7 chunks or less – possibly because access to such sets and their representations is necessarily via short-term memory.

6 Alex Bavelas and Howard Permutter, classified work done at the Center for International Studies, MIT, quoted in "The relation of knowledge to action", by Max Millikan (see (40) p. 164).

7 Antony Jay, in (8), identifies size limitations for organizations: "ten group" of 3–12 (work group, project group, task force); "camp" of 20–60 (work group plus those dependent upon their activity or servicing their requirements); "tribe" of 300–1000 (identity group, mutual recognition); "kingdom" of 5,000–60,000 (administrative, social, cultural or military coherence); "empire" of 100,000+. It would be interesting to explore the change in the nature of government once the number of ministries and cabinet ministers exceeds the critical number for small groups (see (7)) and the usual constraints on span of control.

8 In the light of the NSF exercise, it will be interesting to note the organization of the results of the exercise launched in 1978 by the US Office of Technology Assessment "on the identification of major long-range problems and opportunities facing American society".

9 An intergovernmental meeting may give rise to a many-pointed declaration as the basis for a programme of action. This is then progressively condensed into a programme grouped under a number of headings within the number constraint noted. (Consider the evolution of the UN Environment Programme from 1972, for example.) Where an action programme does not emerge, the number of points remains unconstrained by the limit, particularly in legalistic declarations of principles such as the Universal Declaration of Human Rights (31 articles). But even here, such a declaration would be unacceptable if it had 131 articles, so a new constraint may be in operation.

10 From which arises the whole problem of communication with the non-scholar and between scholars of different disciplines.

11 Magoroh Maruyama has consistently argued that the hierarchical orientation is only one of four culturally determined epistemological standpoints and is characteristic of the following cultures: European (and American), Islamic, Hindu, Japanese, Yamato, Kwekiutl, for example (see (11) and (12)).

12 "It appears that the attention paid hitherto in exact science to increasing precision of analysis into smaller and smaller parts needs now to be supplemented by a method capable of representing the processes of complex systems composed of many parts. But there is no sign as yet of a simple comprehensive method of describing the changing form or structure of a complex of relationships." (ref. (37), p237)

13 This point is discussed in further detail in a later section.

14 Problems also arise when creation of the set is expected to improve the status and prestige of the producer at the expense of others – who may have produced their own or may thereby be challenged into doing so. Such dynamics cannot be discussed rationally in the same arena as for the content.

15 Note that this "basic distinction" constitutes a 2-element set which is subject to many of the points made in this paper.

16 An interesting example is the single sheet chart of the biochemical metabolic pathways in living systems: see (15).

17 "The neophyte can . . . grasp this unstable universe of powers which are both within and without. For him the symbol is like a magical and irresistible admission into this formless and tumultuous tangle of forces. With the symbol he grasps, dominates and dissolves it. Through the symbol he gives form to the infinite possibilities lying in the depths of his subconscious, to inexpressed fears, to primordial impulses, to age-old passions." (See (38), p. 22.)

18 Although it is very seldom done, any conventional hierarchical structure (e.g. an organization chart of a corporation) can be curved into a circle with the superordinate element at the centre.

19 Jones discusses seven pre-logical axes of bias and their application to scholarly debates in the arts and in the sciences. (17)

20 "The main difficulty in translating from the written to the verbal form comes from the fact that in mathematical writing we are free to mark the two dimensions of the plane, whereas in speech we can mark only the one dimension of time" (ref. (21), p. 92). And in conventional text, where subscripts and superscripts are not permitted, writing becomes as restricted as speech.

21 "Any aggregate that is neither completely ordered nor completely disordered must have hierarchical aspects, but the perception of the levels of the hierarchy requires the recognition of a two-dimensional surface to define each three-dimensional unit in accordance with Euler's Law" (ref. (10), p. 81).

22 Of special interest in the 2-dimensional case, is the situation when line coding is not permitted and ways have to be found to fit shapes together. The book by Critchlow (22) explores the variety of regular patterns which result. These patterns can be important when any attempt is made to represent sets and their subsets by nested areas.

23 "If a fourth spatial dimension cannot be visualized, it is probably because geometry is concerned with relations that can use perceptual and physical space as a convenient image up to the third dimension, but no further. Beyond that limit, geometrical calculations – just as any other multidimensional calculations, such as factor analysis in psychology – must be content with fragmentary visualization, if any. This also means probably putting up with pieces of understanding rather than obtaining a true grasp of the

whole." (ref. (21), p. 292.) Note that in ref. (39) it is argued that higher dimensions can be suitably visualized.

24 See ref. (22) and (23).

25 "When man employs nature's basic designing tools, he needs only generalized angles and special-case frequencies to describe any and all omnidirectional patterning experience subjectively conceived or objectively realized. For how many cycles of relative-experience timing shall we go in each angular direction before we change the angle of direction of any unique system-describing operation?" ((1), p. 248–9).

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