PROGRESS IN BIOCYBERNETICS

VOLUME 3

EDITED BY

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PREFACE

Biocybernetics is a young science which overlaps the boundaries of many scientific disciplines. Both biology and medicine are hereby being provided with a new universal language which offers both the power of mathematics and the technical skills of the engineering sciences. Biocybernetics gives an insight into the mathematical processes underlying the organization of human beings and animals. It outlines the principals of communication and control which are common to machines and living organisms and attempts to provide a language based on the same logical foundation as that used by the organisms themselves.

In this volume, which is the third and last of a small series concerned with the medical and biological aspects of biocybernetics, a number of papers are assembled which give examples of the application of mathematics and physics to various areas of biology and medicine.

They give an indication of the wide range of topics that can contribute to this intriguing scientific discipline.

The papers are dedicated to the memory of Norbert Wiener, the father of cybernetics. He, together with the present editor, initiated the publication of this series, which was meant to be a forum for an interdisciplinary approach to medicine, biology and other related sciences.

The major part of the book consists of a stimulating review by Gordon Pask, a friend and admirer of Norbert Wiener, on the cybernetics of ethical, sociological and psychological systems. This paper admirably illustrates the true interdisciplinary approach of biocybernetics.

J. P. SCHADÉ

CONTENTS

COMMENTS ON THE CYBERNETICS OF ETHICAL, SOCIOLOGICAL AND PSYCHOLOGICAL SYSTEMS

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1.1. INTRODUCTORY COMMENTS

1.1.1. Like all Cyberneticians, I owe a gigantic intellectual debt to Wiener. In addition, so far as I am concerned, the publication of 'Cybernetics' (Wiener, 1948) had something of an emotional impact. I had dabbled amongst the varied fields of geology, biology, and in contrast, the Theatre and the important feature of each seemed to be its underlying organisation. 'Cybernetics' set a seal of respectability upon this way of thinking. Later on 'The Human Use of Human Beings' (Wiener, 1955) lent a credence and vitality to the vision behind it all.

With these remarks I hope to justify a paper that would otherwise be a shade too speculative for the occasion. It aims for a couple of objectives. In the first place it aims to counter the criticism that Cybernetics is a redundant discipline (which is only tenable if its character is oversimplified) and next, to exhibit the minimal (but all the same, rather elaborate) class of Cybernetic Models that are needed in order to pass from control techniques to the social issues dealt with in 'The Human Use of Human Beings'.

In fact an elaborate Cybernetic Model is called for fairly often in the behavioural and social sciences and I shall take the opportunity to develop several applications in connection with studies of learning and creativity in individuals and small groups of subjects that have been carried out as part of our current research programme. This work is described in the Appendix. Although the work does not apply directly to social systems, a measure of extrapolation is possible: (1) by arguing that an arbitration system, which is comprehended by the small group study, is the minimal component of a social system and (2) by assembling arbitration systems as parts of the evolutionary systems which we have computor simulated to represent learning mechanisms.

Hence my approach to the social system is, in a sense, unprofessional. I am not a sociologist, far less a political scientist. However, certain models contrived in other fields are undoubtedly applicable and a few results gleaned from experiments in these other fields can be extrapolated to yield limiting conditions upon the behaviours which are admissible if the model is accepted.

1.1.2. In 1.2.1. we review some of the difficulties encountered in the social and behavioural sciences. These are not primarily mathematical. They stem from logical or epistemological dilemmas and call for conceptual innovations which are in the province of non-trivial Cybernetics. On these grounds we aim to justify the introduction of a particular class of '*M* Models'. In 1.2.2. we emphasise the status of an *M* model in the present formulation. It is a class of logically similar descriptions providing a framework in which to fit particular and detailed cases. No attempt will be made to develop the mathematics of any special case (although this has been done, more or less effectively, for some *M* models of learning). The present paper is chiefly concerned with the *form* of a description, rather than its content.

Throughout 2.1.1. to 2.1.8. we derive the *M* model from the familiar paradigm of an hierarchically organised control mechanism (called a *C* model, in the present formulation) and the result is generalised from 2.2.1. to 2.2.8. in the first place by replacing *isomorphism* by the less precise idea of analogy and next by extending the *M* model for a pair of interacting subsystems into the *M* model for a population in which the relevant subsystems are arbitration systems. After this the paper becomes speculative. Most of 2.3.1. is concerned with a rather eclectic pursuit of the relations between the messages conveyed inside this model and the class of ethical statements and between the identified model and a social system. In 2.3.2. a specific set of rules is advanced for fabricating a social system with a number of apparently desirable properties. If the underlying definitions are generously interpreted these properties are consonant with Wiener's social requirements. The individual *M* systems discussed in the previous sections must be embedded in a social *M* system. Further, the generalised form of an individual *M* system, embedded in a social *M* system, amounts to a system of developmental psychology. Section 2.3.3. is an attempt to unify and interpret a few well known systems. Finally, 2.3.4. deals with the practical and important issues of 'immortality'. Although an individual cannot persist indefinitely it is possible to argue that some (energetically open) populations can be 'immortal' and a few epistemological consequences of this possibility are briefly considered.

1.2. PRESENT POSITION

1.2.1. There is no doubt that present-day explanations of behavioural and social phenomena are unsatisfactory. Even the broad method of explanation is undecided*. In connection with Motivation, for example, Peters (1960) has recently criticised 'all inclusive' theories. He points out that a reply to the enquiry "Why does a man do such and such" may assume a number of logically distinct forms. The enquirer may want to know the rule or habit this man obeyed or what goal he aimed to achieve. Or, more commonly, if motivation is concerned, the enquiry may be "What went amiss", or "Why did he behave in an atypical fashion" for not *all* behaviour need be motivated (to assume it is often leads to a confusion between 'motives' and 'drives') and we are most inclined to talk about motivation when some unexpected behaviour takes place. After critically reviewing the ideas about motivation that characterise a number of theoretical points of view (for example in the theories of Freud, Thorndike, Hull, Tolman and Skinner), Peters concludes that purposive action within a framework of (socially accepted) regulations is an irreducible component in motivated behaviour and that the properties of motivation cannot be deduced from any single model. In particular they can neither be deduced from a mechanistic model, however detailed it is, nor from the structure of needs that underlies most homeostatic theories of motivation and goal directed action.

Similar difficulties beset many discussions of mental phenomena. Thus Pears (1963), commenting upon a symposium concerned with determinism, believes that a 'Parallelism' or correlation between the states of a mechanistic model and the states of 'mentation' is possible in principle but admits that this may be the most deterministic representation of a mind that is achievable. For the social sciences, perhaps the most telling comments of this kind have been made by Mace (1934) and by Winch (1958).

There is no obvious way of casting these difficulties aside and the implied criticism of Cybernetics in its capacity as a unifying science contains a good deal of truth. Unless the need for a variety of descriptive expedients is discounted and there is no reason whatever to suppose that it can be discounted in a sensible fashion, there is no point in elaborating naive homeostatic devices that purport to represent the flux of mentation.

On the other hand, should we accept Peter's conception of an essentially subdivided discipline of the Mind? Manifestly there are some alternatives to this (Cybernetically speaking) repugnant possibility. We might, for example, seek 'Parallelism'. The main objection to this course is not so much its difficulty (the exercise is only possible in principle) as the rather arid character of the objective. 'Parallelism' might be intellectually satisfying but it would, in a sense, beg all of the questions. Pears makes this point in his own discussion, with particular reference to 'consciousness' which is an interesting property that would not be greatly illuminated however many correlations were achieved. The crux of the issue comes out more clearly perhaps in the social milieu. No unitary model of society would be capable of representing the hierarchies of different value hierarchies that Mace points out as essential parts in a competent description.

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* McCulloch (1965) concisely states the issues involved in a recent paper, which should be consulted.

If we aim for a *single* model the task may or may not be impossible according to taste or belief, but it will certainly be difficult. Culbertson (1963) has recently made an attempt to reduce consciousness to a unitary form but I have not yet had a chance to examine his argument. Again there is always a danger that the task may be pointless because the resulting unitary model is either incomprehensible or too cumbersome to be usefully identified in an interesting experimental situation (it may be, as Winch suggests, so much more sensible to describe some social relations poetically than mathematically that a mathematical model would be bizarre).

On the other hand, what are the possibilities if we do not insist upon a single model in the strict (and reductionist) sense?

It would be possible to resort to a model with the appearance of being unitary but which, in fact, *was* a metaphor in the sense of Ramsay (1964) or was *clothed* in metaphor, like Campbell's conception of a model in physics that can suggest ideas. The expedient we adopt is not far removed from adopting such a model, but it differs in some important respects.

The proposal is to admit that a rather elaborate logical structure is needed. Its details are probably different in different applications but its simplest manifestation will be called an 'M Model'. An 'M Model', which will be developed in 2.1.1. to 2.1.8., consists of a pair of logically distinct and differently identified components. According to one interpretation, one component represents an hierarchically organised set of linguistic constraints upon discourse and the other represents an hierarchical structure of mechanisms. Hence, an 'M Model' could contain Pears' 'Regulations' as part of its linguistic component and 'Drives' as a property of its mechanism. However, even though the 'M Model' has distinct components, a concept such as homeostasis can be applied to it directly for certain analogy relations must apply between elements in one component and subsets of elements in the other component as a result of which (in the chosen identification) discourse effects the development of a mechanism and the mechanism gives rise to discourse satisfying the linguistic constraints. (As a matter of fact, a composite model of this kind is well suited to the developmental systems of psychology.)

1.2.2. The *M* model is a canonical form of representation with two salient features. The first of these is an "hierarchy of formal metalanguages" or "a stratified linguistic structure" in which we embed descriptions of concepts and cultural constraints and intelligent communication.

Now organisms do not actually *use* formal languages. They communicate in terms of open and referentially mixed languages. But a description of their activity in these terms is ambiguous. So the hierarchy of metalanguages is introduced to avoid this ambiguity and (as in 2.2.4) to achieve a unified and simple image of the mechanism that is responsible for the communication process.

Next, the *M* model has two components, namely a mechanistic and a descriptive component. When the *M* model is experimentally *identified* (when it acts as an *M* system) these components are associated with incompletely comparable sequences of observations that (as in 2.1.4.) refer to distinct ontological classes. However, as the model is abstracted from reality the calibre of the distinction changes. When the M system is identified with a computor programme, for example, the mechanical component becomes the intensive definition of part of a formal language or, as Gorn (1962) points out, of the data processing devices that act upon it. The descriptive component becomes the extensive definition of this language. (This interpretation is pursued in 2.1.6.). At the most abstract possible level the distinction between these components is simply a distinction between the intension and the extension of relevant terms in the linguistic structure (this is the calibre of the distinction in an *M* model, devoid of an identification).

No attempt is made to particularise the *M* model but a few special cases (chiefly of learning models) have been worked out and described in the literature. Nor does this paper contain any mathematics though the bones of suitable kinds of calculus have been described by Watanabe (1962), Martin (1963) and others. The chief objective of the present discussion is to exhibit the canonical representation '*M* Model', to examine its identification with matters of fact in '*M* Systems' and to demonstrate that although more elaborate structures may be needed to describe individual 'learning' and 'mentation' no lesser construct would be sufficient.

2.1. BASIC MODELS

2.1.1. One of the broadest concepts shared between Cybernetics and Control Engineering is the idea of an ultrastable or an hierarchically organised and goal directed adaptive control mechanism (Ross Ashby, 1960; Pask, 1963e). To avoid unnecessary symbolism it will be convenient to adopt the graphical convention in Fig. 1 where adaptation is brought about by changes in the parametric coupling between the levels in the hierarchy. These changes are designed to satisfy a dispositional relation, *F*, named as a goal *F*. Thus Fig. 1 represents a single level adaptive control mechanism that interacts with its environment to bring about some condition (normally a dynamic equilibrium or stationary state) that is characterised by an invariant called *F*.

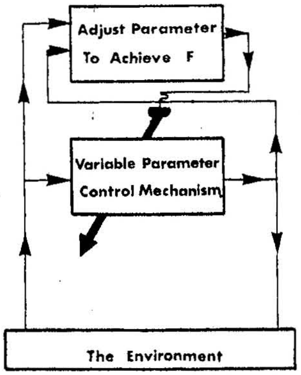


Fig. 1.

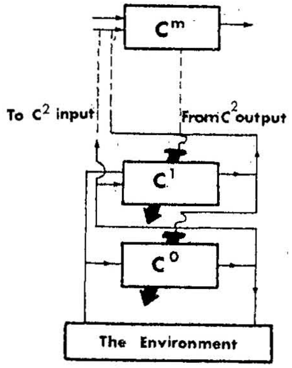


Fig. 2.

This structure is extended to an m level hierarchy in Fig. 2 and the goal F becomes an hierarchy of m subsets of subgoals. If $\Rightarrow$ is a many to one, order preserving, correspondence between levels of control and if $\Rightarrow$ is maintained by the coupling between the levels that is shown explicitly in Fig. 2, the image of Fig. 3 preserves the essential features of this m level hierarchy and represents its structure more concisely.

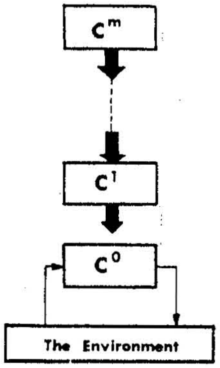


Fig. 3.

If the environment can be represented as another control mechanism (and since each stable configuration maintains an invariant subgoal characterising each level, or, since in McCulloch's (1945, 1947) and Wiener's (1948) sense the subgoals are the names for universal properties, this representation is guaranteed) then Fig. 3 becomes Fig. 4 which is the paradigm case of an interaction between n different subsystems at m different levels to produce a single control system coupled by channels of communication. Incomplete coupling between the subsystems is, however, more common in practice and is represented by deleting the connections between the subsystems at one or more levels in this hierarchy. We shall call the structure in Fig. 4 or any degenerate form of this structure a C model. It is closely related to Mesarovic's (1963) construction.

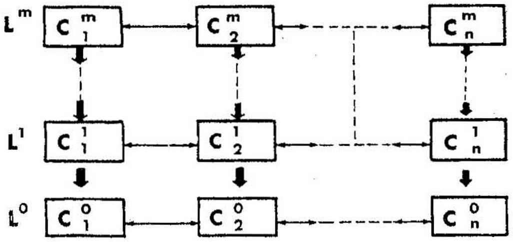


Fig. 4.

2.1.2. The C model is defined in a descriptive language, L^*, used by an observer or experimenter or a control engineer (the descriptive language L^* may be any common tongue; for example, it may be scientific English). The lowest level of interaction is often characterised by an object language L° and the higher levels of interaction *may* be characterised by *metalanguages* $L^1, L^2, \ldots\ldots L^m$, such that L^{j+1}, $j = 0, 1 \ldots\ldots m$ is capable of representing L^j. (Since all the L^j are described in L^*, this descriptive language is always a metalanguage. But the distinction between an object language L° and a metalanguage L^j is somewhat arbitrary.) The alphabet of L^j is the alphabet of signs that are used to mediate communication between the subsystems of the jth level of discourse and the syntactic constraints imposed upon language L^j are the constraints that define the channel of communication at the jth level of discourse. Occasionally it is pertinent to distinguish between languages L_i^j, $i = 1, 2, \ldots\ldots n$ at a given level, but this distinction need not be made for the present discussion. Indeed the linguistic distinction (apart from the distinction between the descriptive metalanguage L^* and a single object language for communication) is not a *necessary* feature of the C model and some *identifications* (between the C model and physical or conceptual systems) admit of a reduction of all the L^j to a single object language.

2.1.3. Within the compass of control engineering, for example, this linguistic distinction would often be pretentious. The control engineer is concerned with the extensive specification of classes of events, namely, with sets of states in a state description that is given as part and parcel of the physical situation and that entails well defined criteria of relevance. He can always provide a correspondence between physical states and communication events within the control system which is either unique or one correspondence amongst a set of equally plausible alternatives. Since only the extensive specification is required (the control engineer is *not* concerned with connotation or meaning) the hierarchy in the C model is reducible to an hierarchy in the theory of sets (in contrast, for example, to the stratification that demarcates propositions and propositional functions or propositional functions of different orders, which is most rigidly expressed in the theory of types) (Russell and Whitehead, 1927). To subsume these points, we shall say that when the C model is identified with some realistic or experimental situation and is used for the hypothesis construction or the prediction making germane to a control engineer, its stratification is *degenerate*.

2.1.4. The act of identifying the C model implies a positivistic or an operationalist or a 'Black Box' (Ross Ashby, 1957) approach to the physical or conceptual system with which it is identified. In other words the experimenter believes that all features of the system that are relevant to his enquiry can be assembled, in principle, and reduced to expressions in a single frame of reference. Now this 'Black Box' approach is amply justified for the field of control engineering simply because the relevance criteria of 2.1.3. are well defined. But certain experimental or pragmatic consequences of this fact will be important in our discussion of less restricted fields and these consequences are most conveniently introduced at this point.

Harre (1962) defines a property of sets of observations called their 'Family Continuity'. A pair, say Z_1 and Z_2, of sets of observations have a 'Family Continuity' if there is a sequence of observations, z_1 in Z_1, such that its terminal members coincide with a sequence of observations, z_2 in Z_2 (to cite a case considered by Harre Z_1 may be the set of microscopic observations of a cell and Z_2 the set of electron microscopic observations of a cell and z_1 and z_2 may each be sequences of observations of similar but decreasingly sized cellular components). The denotation of any Z is included in an ontological class. If a pair Z_1 and Z_2 have family continuity, their denotation necessarily belongs to the same ontological class, say to J_1, and if the denotation of Z_0 belongs to a different ontological class J_2 then neither Z_1 nor Z_2 has a family continuity with Z_0. For the present discussion we shall assume that ontological classes are operationally defined (introducing as an axiom that we know them as distinct because our observations are distinct). Hence, at a given state of knowledge, we exclude the possibility that if Z_3 and Z_4 have a family continuity and a denotation, like the pair Z_1 and Z_2, in J_1, then $Z_1 \cup Z_2$ does *not* have a family continuity with $Z_3 \cup Z_4$, for, at this given state of knowledge, J_1 is *known* as the denotation of a set of observations having a family continuity with the set Z_1. Later we shall give ostensive definitions of sets of observations that do and do not have family continuity and will argue that if they do not then they refer to different ontological classes.

The immediately important point is that any abstraction describing coherent events in more than one ontological class (say the coherent events in J_1 and J_2 or equivalently the events that are observed in Z_1 and Z_0) must belong to more than one universe of discourse (and, in particular, to more than one frame of reference). Consequently, since the C model is by definition an abstraction within a single frame of reference, it can only refer to a single ontological class. Conversely, if we can show that a process depends upon events in more than one ontological class or is imaged by more than one disjoint set of family continuous observations, then a C model is an insufficient representation for this process. We shall subsume these arguments by saying that a C model is only sufficient if the control system it images is *reducible*. The systems considered by a control engineer prove to be *reducible* because, in the narrowest sense, they are computing machines.

2.1.5. Whereas a control engineer constructs a control system or a control mechanism that deals with a fairly tractable environment the great majority of control systems are discovered or constructed in a very different fashion. These are control systems that solve problems and that learn and they may either be organisms or constructed artifacts. The present contention is that a learning system has a stratification which is *not*, as in 2.1.3., degenerate and that neither problem solving nor learning are *reducible* in the sense of 2.1.4. Hence a different kind of model, called an M model, is needed to represent systems that learn (or systems such that an observer is interested in their learning process).

2.1.6. Philosophers like Hamlyn (1953) have often asserted that statements about behaviour (in particular about problem solving behaviour) differ in kind from statements about mechanical change or motion. Thus a complete mechanical description of a brain would not provide a complete account of the corresponding organism's behaviour simply because motion statements and behaviour statements do not belong to the same universe of discourse, although motions and behaviours are in many ways correlated. A similar kind of distinction is made by Peters (1960) in his discussion of 'Motivation' and 'Drive'.

According to these arguments we should expect to find that any sufficient model for representing the behaviour of an organism has a dual composition or that a duality of models is necessarily involved. In our own terms a behavioural process is not reducible.

Although the duality can appear in various guises, its presence is implied by the form of even the simplest enquiries regarding 'problem solving' and 'learning' (Pask, 1961a,b; 1964a,b). In order to admit that an organism or an artifact has been (or that it is) problem solving or learning, we require it to give (or to be able to give) an account of this process in its own language. Indeed, we often insist that this account shall also be intelligible, in the sense that *it* makes use of the same concepts that *we* make use of. Let us call this facet of a reply to an enquiry on the score of problem solving or learning the *Descriptive* aspect, implying a description in the organism's ordinary tongue, of how it solves problems or learns to solve them. One convenient way to represent such a description is a computor programme, or restricting our attention to organisms with a linear language a sequential computor programme, an effective procedure or an algorithm. The *Descriptive* account of how a given organism solves a body of problems will thus be a related collection of algorithms and a specification of the alphabet upon which they act and its identification with a set of objects or events (such as stimuli and responses) that denote the problems and their solutions so far as this organism is concerned. Let us call this collection the descriptive model, A, for problem solving (the construction for learning will be considered in a moment). Since problem solving takes place at the lowest level of discourse, in L°, the descriptive problem solving model for the ith system is denoted A_i°, the index i being omitted if only a single system is concerned.

The other facet of a reply to an enquiry regarding learning or problem solving is conveniently dubbed *Mechanistic.* We accept a descriptive account of problem solving insofar as there is an analogous mechanism that underlies the process and is *responsible* for the descriptive account. The form of mechanistic model depends upon the level of the enquiry and its domain; for example, upon whether the problem solving system is a man or an artificial intelligence programme or an animal or a special purpose artifact. In each case the Mechanistic Model is denoted as B° and the required analogy with A_i° represented by $\Leftrightarrow$, is incorporated to yield $A_i^\circ \Leftrightarrow B_i^\circ$ as a minimal M model for the process.

To illustrate the A, B, distinction A_i° may be an introspective account of problem solving given by the ith subject and the corresponding mechanistic model B_i° may be a functional or even physiological model of a process in the ith subject's brain. Alternatively A_i° could be an objective account of problem solving given within the framework of a particular experiment that allows the subject to represent stages in the process. Again A_i° may be a set of programmes in an artificial intelligence system and B_i° a collection of evaluation procedures, choice rules and heuristics. Finally, in the most abstract case (which is discussed by Gorn, 1962) the model A_i° is part of the extensive definition of L° and B_i° is part of the intensive definition of L°, (so that

B_i° is the 'meaning' or the 'connotation' of A_i°) which is identified (as in Gorn's paper) with the data processing and the executive procedures that act upon L° (or in MacKay's (1959) nomenclature with a selective function).

The important points are:

(1) That A and B have certain entirely different properties. Thus it makes sense to consider the accuracy or the problem solving efficiency of A and to credit B with attention or a need for sufficient variety or with curiosity, albeit the attention or curiosity of a machine rather than an organism. But B as such cannot have problem solving accuracy nor can A as such have anything interpretable as a need or a field of attention.

(2) The experiments or observations used to investigate A and B are different in the sense that they have distinct family continuity and these models are identified with events in distinct ontological classes, in the sense of 2.1.4. Thus A is investigated by interviews or questionnaire procedures whereas B is the object of auxiliary investigations that aim to establish functional or even physiological relationships. Similar comments apply in connection with control.

(3) The models A and B are interdependent. When experimenting with an organism, for example, the object language L° is not initially *given*, as it would be in engineering. It must be *discovered*, in order to establish discourse with a system identified with A. But discovery of L° depends upon the auxilliary investigations that establish B. On the other hand, B is unrelated to problem solving unless discourse can take place with A.

(4) Thus in order to discuss solving behaviour, or merely to discuss behaviour, in the sense of Hambly, it is necessary to consider a model $A_i^\circ \Leftrightarrow B_i^\circ$ which cannot be reduced to the form C_i°. Taking up Peter's distinction (the issue of 'Motivation' and 'Drive') it is perfectly feasible to attribute 'Drive' to B alone, regardless of whether or not it is a mechanical or a peculiarly man-like drive. However, the property of a 'Motivation' could not belong to B alone nor could it belong to A alone. It might, however, be ascribed to the construct $A \Leftrightarrow B$, although the usage would be eccentric since the word is more often applied to a 'control situation' involving an interaction between a pair or more of subsystems such as $A_1 \Leftrightarrow B_1$ and $A_2 \Leftrightarrow B_2$ (this 'eccentric usage' probably *is* admissible since the single building block $A \Leftrightarrow B$ *does*, as we argue later, involve a form of 'internal stability' which we shall refer to as an 'internal analogy').

(5) It will be convenient to denote separate subsystems like individual organisms or artifacts as U_i, U_{i+1}, ... Any subsystem will involve a descriptive component A and a mechanistic component denoted as B unless it

represents the inanimate environment which is adequately depicted by C. Further, any subsystem U_i is liable to consist of several levels of description, related to several levels of discourse in L^j, L^{j+1}, ... and denoted as A_i^j, as well as several levels of mechanism denoted as B_i^j.

(6) Let v be a statement in L^j uttered by U_l and received by U_i. We shall say that U_i understands v if A_i^j can produce v, and if this production has an L^{j+1} name in the denotation of A_i^{j+1}. By definition v has a connotation F which is an attribute of B_i^j. In particular, U_i cannot understand v if either of A_i^{j+1} or A_i^j do not exist. Hence, a minimal model for representing 'understanding' is an hierarchy of the kind indicated in Fig. 5 where, for convenience, we have assumed that $j = 0$.

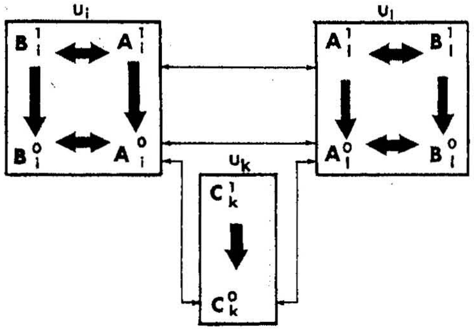


Fig. 5. U_k is environment. B_i^0 substitutes *co-operatively* for B_l^0 and B_i^1 substitutes co-operatively for B_l^1.

We have characterised 'understanding' as a condition imposed upon a participant U_i. Often, this term must be defined in terms of the discourse between a pair of participants or some property of an interaction between a system and its environment. In this case the property of being understood is attributable, by a metastatement or L^* expression concerning a body of L^1 or L° discourse, to certain L^1 or L° expressions, v. Hence, v is a concept in a fairly well accepted sense of this word. If C_k° and C_k^1 as in Fig. 5 represent the common environment of U_i and U_l it may be held that U_i understands a particular expression such as v in L^1 uttered in an instructional fashion by U_l, only if v elicits some fitting responsive activity (responsive activities like eating or moving the limbs and the sensory concommittants of these constituent motions, are assumed to constitute a subset in the denotation of L° that is common to each of A_i°, A_l°, C_k° or of A_i^1, A_l^1, C_k^1). The criterion of whether or not a given responsive activity

is defined as a metastatement in L^* (normally on evidence gleaned from auxiliary investigations concerning the B_i, for example, from investigations dealing with the conditions in which the U_i can survive).

On the other hand it may be held that U_i understands v only if this word is part of the U_i discourse and if the successive utterances v_1, v_2, ... of U_i satisfy a rule of weak inference of the kind recently advanced by Gubberina (1957). Criteria like Gubberina's rule refer in only an indirect fashion to the environment.

(7) Suppose a pair of dispositions, F_1 and F_2 of U_i which may be interpreted as drives or as stable conditions approached by processes in B_i° and as distinct goals in B_j^1. In a given environment F_1 elicits some behaviour denoted by an expression v_1 whilst F_2 elicits some behaviour denoted by a different expression v_2. Suppose that F_1 is named by an expression v_1^* whereas F_2 is named by v_2^* and that U_i understands v_1 and v_2. Finally, the environment permits either the occurrence of v_1 or v_2 and we assume a class, Π, of environments having this characteristic, the membership of Π being defined in L^*.

We shall say that U_i prefers F_1 to F_2 in conditions Π if, on receipt of an instruction (an L^1 statement limiting the possible acceptable responses of U_i to v_1 or v_2 or v_1^* or v_2^*) it is always the case that either U_i produces v_1 or U_i produces v_1^* and never produces v_2 (to verify a preference it is necessary to offer an instruction to U_i in connection with different members of Π but an F_1 to F_2 preference is usually accepted if U_i produces v_1 unless this hypothesis of preference is disconfirmed by the appearance of v_2).

(8) Suppose that U_i prefers F_1 in Π and U_{i+1} prefers F_2 in Π and that U_i interacts with U_{i+1}. We say that U_i dominates U_{i+1} if in these conditons U_i produces v_1 and U_{i+1} produces v_1 or U_i and U_{i+1} produce v_1 or U_i and U_{i+1} produce the name v_1^* and neither U_i nor U_{i+1} produce v_2. The process of achieving dominance may be referred to an L^* as an interaction of teaching or of persuasion. This definition is implicit in some of George's (1963) experiments.

(9) This definition could be erected rather precisely in terms of Harrah's (1963) model for communication in which case the understanding of the participants is guaranteed by introducing the deductive possibilities of a propositional logic into the syntactic specification of the communication language. The fact that the language system used by Harrah (or, in a different situation by George) entails our L^1 and also our L° involves only a trivial modification (we explicitly embed the logic of questions and the logic of replies in A_i°, A_i^1, and in $A_i^\circ{}_{+1}$, $A_i^1{}_{+1}$, and call the resulting model a ques-

tioner or a responder). The real price to be paid for greater elegance is a restriction upon the set of dispositions F compatible with this model, namely a restriction to rational dispositions. For many purposes this price is acceptable.

(10) If F_1 is proposed to U_i in conditions z by an L^1 assertion that recommends the adoption of v_1 for an interval $\triangle t$ and regardless of the existing U_i preference, U_i acts as though F_1 is preferred throughout this interval $\triangle t$, then we say that U_i accepts or has agreed to F_1. Thus U_i may accept or agree to rationality.

2.1.7. Whereas A_i° and B_i° remain invariant with problem solving, these models are changed by the process of learning. Insofar as concepts are acquired, certain axioms are added to the system and as a pre-requisite for discourse or control it is necessary to countenance a shift in the currently relevant level, j, of the discourse. Further, since the A_i^j can be extended indefinitely each L^j is potentially an open ended language and there is a possibility of adjoining L^{m+1} to an hierarchical structure initially terminated at L^m. Whereas for problem solving the appropriate language for interaction is an unchanging object language L° the control of a learning process involves the continual adjustment of the level of discourse so that the auxiliary investigations of 2.1.5. must be continual. Consequently the maintenance of coupling with the learning system has the logic of a 'conversation' rather than a process of communication (Pask, 1959, 1963a).

Although an hierarchical structure can be heuristically justified merely on the grounds that concepts are being learned and thus that the level of discourse is bound to change, this does not imply that the hierarchy is necessary. The 'conversation' could, for example, take place in the open ended descriptive language L*. However, a somewhat different argument is possible.

(1) At any level j the argument of 2.1.5. entails the need for $A_i^j \Leftrightarrow B_i^j$ for problem solved by U_i at the jth level of discourse.

(2) Normally $A_i^j \Leftrightarrow B_i^j$ and $A_i^{j+1} \Leftrightarrow B_i^{j+1}$ only if the same basic process is occurring at the jth level. In other words, if we assert that some process at the jth and at the $j+1$th level is analogous to 'mentation' then the term 'mentation' must imply the same thing at these different levels. Lacking this correspondence it would be necessary to postulate a distinct kind of mechanism for each level.

(3) As Minsky (1961) and Newell (1962) have pointed out, it is possible to view learning as problem solving in the domain of lower level problem solving algorithms. The 'solutions' provided by A_i^{j+1} are algorithms used by A_i^j and the activity called 'learning' in L^j is problem solving done in L^{j+1}. Thus the basic process of mentation at the jth level and at the $j+1$th level *can* be isomorphic.

(4) But this isomorphism is achieved only if the A_i^j are represented in terms of an hierarchy of metalanguages L^j. In other words the L^j are introduced so that the learning described in L^j is simply the problem solving described in L^{j+1} when mentation in L^j becomes isomorphic to mentation in L^{j+1} and the L^j are defined in order that mentation shall imply the same process. Hence a minimal model for a learning process in U_i which avoids a distinction between 'kinds' of 'mentation' and thus allows us to represent the occurrences in any physical assemblage such as a brain or an artifact on a common basis is the double hierarchy of analogous models in Fig. 6. For the case of interaction between different learning systems, the construction in Fig. 6 is developed into Fig. 7 which is the paradigm case for an M model. Fig. 7 can also be identified as an M model for the intimate dynamics of a single organism.

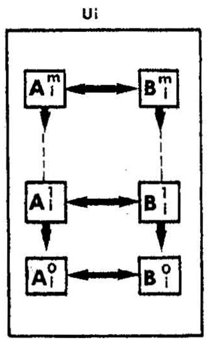


Fig. 6.

Now the construction in the latter case is unambiguous and needs no further comment but in the former case a couple of interpretations (I) and (II) are plausible due to the fact that the metalanguages L^j are conceptual languages and due to the fact that they are defined as open ended. Thus if the U_i are interpreted as distinct physical entities we may interpret a connection at the jth level, in L^j for $j > 0$, as indicating (I) a particular linguistic modality which is a physically distinct sign system or alternatively (II) as indicating the fact that L^j expressions can be denoted by words in some open ended extension of the L° alphabet when communication occurs only in L° but is capable of signifying L^j expressions. The distinction is chiefly a matter of coding and the intended choice of interpretation will either be obvious or irrelevant.

It is important to notice that an M model has a certain asymmetry due to the fact that no description of an *identified* system can be given until there is a mechanism to give it although there can perfectly well be an *identified* model of a mechanism that is incapable of describing its activity. This point is far from pedantic in connection with learning systems where we are chiefly concerned with the construction of mechanisms and descriptions.

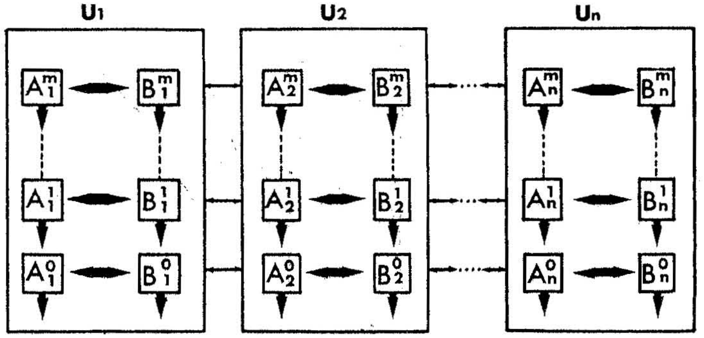


Fig. 7.

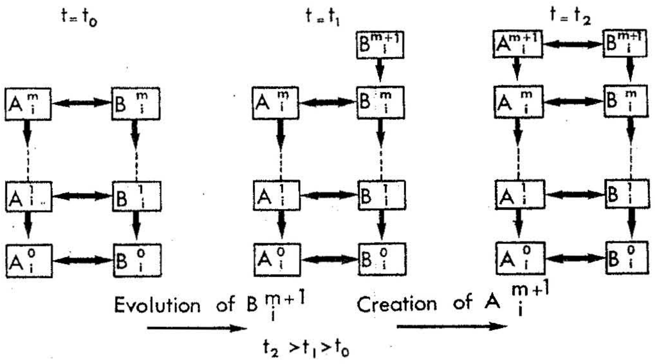


Fig. 8.

Thus it makes sense, as in Fig. 8, to postulate an identified model of a mechanism (namely the model B_i^{m+1}) for which there is, as yet, no analogous description A_i^{m+1} (the model A_i^m being the highest level descriptive model that is available). But it would not make sense to postulate an identified model A^{m+1} in the absence of a corresponding B^{m+1}.

We shall refer to the construction of A_i^{m+1} as indicated in Fig. 8 as the paradigm case for creative activity. In a sense we shall consider in detail elements that will be adjoined to any A^i as a result of learning. But whenever A_i^{i+1} is in existence, the apparatus for interpreting the adjoined component exists so that it has the calibre of some extension of a concept. According to the definition in 2.1.7. it may be understood by U_i. On the other hand, the construction of A_i^{m+1} when only A_i^m is available cannot, according to this definition, be understood by U_i and it must be comprehended by reference to experience or by using the productions of A_i^{m+1} in discourse and consequently the event of its construction has the calibre of a creative insight.

2.1.8. What form of process will give rise to an hierarchy of mechanisms, identifiable with the B_i^j, and having the property that 'mentation' or 'problem solving' in each of the analogous pairs $A_i^j \Leftrightarrow B_i^j$ is a common activity. There is probably no unique reply to this enquiry but one form of process that does fit all of the requirements is an evolutionary process, the abstract B model of which is a simulated system of evolving automata or one of the infinite automata described by Loefgren (1962) and Von Neumann (unpublished works). A suitable choice of parameter values will ensure that each of the B_i^j that evolve is a self-organising system in the sense of Beer (1962), Burks (1960), Von Foerster (1960, 1962) Bonner (1958), Mesarovic (1962), Pask and Von Foerster (1961) and Wiener (1948).

Different simulations have been used to create an hierarchy of self-organising systems by Barricelli (1963), Toda (1962) and myself (Pask, 1958, 1960a, 1962a,b) (there is a vast amount of work upon the macroscopic features of evolving populations but for the present purpose we are only concerned with those simulations that represent the microscopic activity of a population). Although we may, in fact, be imaging the evolution of stable *modes* of activity it is often convenient to use the more conceptually manipulable image of evolving *objects* that resemble animals or other organisms, since the idea that animals undergo evolution is familiar. Hence our simulation consists of a population of automata, capable of computation, reproduction, and variation of different kinds that compete for a commodity that is made available at a limited rate in their environment. This population is, rather broadly, similar to a single Von Neumann or Loefgren infinite automaton. If the rules of the simulation admit the development of communication between the automata and if the 'payoff' function (that assigns the limited commodity to the automata as a function of their activity) is superadditive (so that correlated action places automata at a selective advantage) then there is a tendency for co-operating groups of automata to form, to act as a whole, and to reproduce as a whole. Communication is established between the members of such a group as a pre-requisite for co-operative activity.

But different orders of group communicate by different orders of sign system and stable groups gain the integrity of species. In this case the various orders of sign system or communication that exist in the evolving population characterise the levels B_i^j and given that $A_i^j \Leftrightarrow B_i^j$ these communication modalities correspond to the hierarchy $L^\circ, L^1, \ldots\ldots L^m$. To say that each B_i^j is a self-organising system is equivalent to saying that each recognisable automaton, whether an individual in the original population or a group of automata that has evolved will maintain a certain finite rate of adaptation in order to survive and given $A_i^j \Leftrightarrow B_i^j$ this implies that novel problem solving programmes for A_i^j are created at a given rate in A_i^{j+1}.

We cannot claim to have expressed the conditions for securing evolution in a concise form but it is certainly possible to simulate the evolutionary component of an M model and to identify commonly occurring descriptive processes with analogous mechanistic processes. Thus 'cueing' (a descriptive process, of giving helpful information as part of a teaching procedure) is analogous in this M model to a mechanism for co-operation. In human learning, for example, it often happens that a subject is unable to solve a particular kind of problem without assistance from an instructor. But, if he is assisted for a short interval (by a 'cueing' process) he becomes able to solve the problem concerned. This transition has a pair of analogous representations within an M model of human learning. In the first place we conceive that the subject's A model at the jth level, A_i^j, does not contain an algorithm a that is needed in order to solve a given problem posed in L^j. Cueing (which represents the absent algorithm a) leads, through the application of L^j substitution rules, to the creation of a. The analogous representation images a population of automata B_i^j in which an automaton b, which is able to perform the operation a, fails to survive. The cueing procedure is analogous to the co-operative *provision* of b's until such a moment that b's can reproduce and survive on their own account in B_i^j.

Another important analogy relates the process of giving an ostensive definition of a class of operations by citing exemplars of this class and the mechanism of inducing a higher order organisation (in the biological sense) amongst the evolving entities in B. The class of operations, α_1, will be defined in A_i^{j+1} (if the operations are defined in A_i^j). The ostensive definition of α_1 consists in citing exemplars of this class denoted by L^j assertions α_0. The analogous representation images the existence in B_i^j of automata β_0 that are capable of carrying out the operations denoted by α_0 and which in aggregate are able to perform an operation β_1 that is denoted by α_1. At this stage the population B_i^j is akin to a population of cells of which β_1 (amongst many others) is a *tissue* stable (but not a *cell* stable) property. However, if the β_0 are maintained as a dominant component in B_i^j then an individual automaton may develop which is capable of reproduction and survival and which computes β_1. This automaton is a member of B_i^{j+1} and the L^j discourse has controlled its *evolution.* We comment (I) that the ostensive definition of α_1 by the α_0 in L^j could be replaced by the cueing of α_1 in L^{j+1} (analogously the L^j controlled evolution of an automaton computing β_1 could be replaced by the L^{j+1} co-operative establishment of β_1 in B_i^{j+1}). (II) That the automaton computing β_1 is not unique. The control of its evolution is a statement of a *disposition*, not a procedure. (III) That when ostensive definition occurs in the absence of A_i^{j+1} or B_i^{j+1} it amounts to the creativity of 2.1.7. and (IV) that whereas the process of cueing (or the mechanism of co-operative establishment) is responsible for building common models A_i^j amongst several U_i at a given level of discourse L^j the process of ostensive definition (or the mechanism of induction) is chiefly responsible for the development of higher levels of discourse.

2.2. CONTROL ANALOGY

2.2.1. According to Hesse (1963), an analogy involves a set of objects with properties that may either be positive or negative or neutral constituents of the analogy and a pair of relations between these objects. One relation (denoted as R) is a similarity. Positive constituents of the analogy are properties that are R similar, negative constituents of the analogy are properties that are R different, and the neutral constituents are properties that may or may not be positive constituents and the status of which awaits discovery. The other relation, denoted as F, is causal or systemic. For the present we shall define F as a dispositional relation (Pask, 1964c) commenting that a causal relation is enunciated by a condensed form of counterfactual conditional statement that, when expanded, will assert a disposition (Pap, 1962).

The paradigm case for a descriptive or explanatory form of analogy is shown in Fig. 9 and it involves the objects, a, b, d, c. When R is independent of F the associated argument is "If a (F) d, and if a (R) b and d (R) c, then b (F) c" which is a fallible but valuable component of scientific reasoning. If the relation R depends upon the existence of F (to use a case cited by Hesse if a = Father, d = Son, b = State, and if c = Citizen) then the argument associated with Fig. 9 has the form "If a (F) d, and there is some b

and some c, such that b (F) c, then if a (R) b is plausible, d (R) c is also plausible".

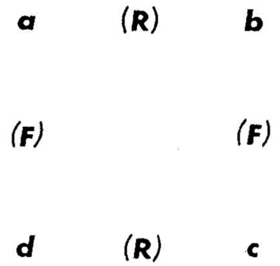


Fig. 9.

2.2.2. Apart from this descriptive or explanatory form, an argument of analogy is entailed by the concept of a control system since the control mechanism can be viewed as having a disposition F that is defined by its goal and adjusting the state of its environment or of another control mechanism until the disposition F is imposed upon the controlled assembly. Hence, a control mechanism completes an analogy, as suggested by Fig. 10. If the relation R is independent of F (as we assume in this construction) then R determines the appropriate interaction language for the control procedure.

Now this analysis is sufficient provided that the control system can be represented by a C model, when all of the analogical properties are positive or negative and none of them are neutral. But it does not adequately account for the control system that is represented by an M model wherein these restrictions do not necessarily apply.

From a slightly different point of view, a more elaborate image of the control process is needed because an M system depends upon an *internal* analogy in which $A_i^{j+1} \Rightarrow A_i^j$ and $B_i^{j+1} \Rightarrow B_i^j$ are specified by dispositions and $A_i^j \Leftrightarrow B_i^{j+1}$ and $A_i^j \Leftrightarrow B_i^j$ denote internal similarity relations. The *external* or the *control* analogy (the maintenance of F) is conditional upon the integrity of this internal analogy (hence any control process that aims to achieve F must also maintain the internal analogy).

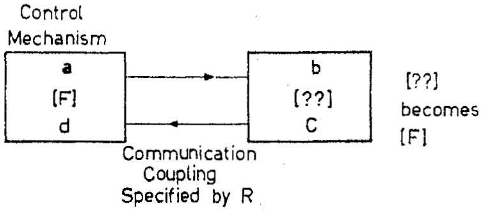


Fig. 10.

In the broadest possible interpretation, the relation $A_i^j \Leftrightarrow B_i^j$ which forms the crux of the internal analogy is an identification of a mechanism and a form of discourse. Its assertion, in the case of an organism, depends upon the observer or experimenter. MacKay (1962) calls this act a 'naming' of the organism which aptly indicates (Dewey and Bentley, 1949) its status as the result of a choice that does not only depend upon the experimental observation of an organism's behaviour. This choice to 'name' an organism depends upon evidence which comes from (at least a couple of) different ontological classes. One kind of evidence comes from the discourse of the organism (whether it shares our concepts). The other kind of evidence is gleaned from an auxiliary investigation of the fabric and the broad demeanour of the system (Pask, 1964c). We give the creature a name only if it shares our concepts in the sense that it falls in love, or it likes going to the theatre, or it aspires to fame and also if it appears to be like ourselves in the sense that it eats macaroni or it is made from protein. On the one hand, the form of these criteria points to the difference in kind between the components A and B. On the other hand it implies that no finite sequence of tests will suffice to establish $\Leftrightarrow$ since the list of relevant criterial attributes is incomplete. In other words, at least some attributes of the internal analogy are neutral and their status as positive or negative components awaits discovery. In the limiting case when all of the attributes involved in $A_i^j \Leftrightarrow B_i^j$ are determined as positive or negative constituents for all values of j the analogy becomes an isomorphism and the M model becomes a C model.

2.2.3. Suppose that U_i is a collection of self-organising systems in the sense of 2.1.8. embodied in an M model so that each B_i^j maintains a given rate of adaptive development and corresponds to some A_i^j in which a given rate of programme building is maintained. Consider the job of teaching U_i a skill characterised by F, or equivalently, of controlling the learning process in U_i so that relevant data from a training routine is assimilated.

Now the postulate that U_i is a collection of self-organising systems guarantees that learning occurs. If U_i is a man we might say that he must learn about *something*. The difficulty is, of course, to maintain his field of attention concentrated upon some *relevant* data without forcing him at one extreme into tedium or, at the other, into a situation that he finds incomprehensible. If U_i is an arbitrary system it is necessary to maintain the joint condition that an M model is applicable and that the system is coupled to the relevant environment.

We shall confine our discussion to the case of a 'structured skill' (Pask, 1963b; 1964d) which implies that the hierarchy of conceptual structures $A^* = \{A^{*j}\}$ that can be involved in the acquisition and performance of the skill are known by the instructor, that there are adequately stated criteria of proficiency (specified by a disposition F) and that the internal analogy is satisfied if for all relevant values of j, B_i^j is a self-organising system analogous to a process in A_i^j that creates relevant programmes. Finally we assume that a 'Structured Skill' is teachable.

Suppose, initially, that the internal analogy *is* maintained. In this case, the instruction of a 'structured skill' amounts to a control process of the kind depicted in Fig. 10 that aims for the goal condition of completing the external or control analogy F. When F is completed certain submodels of the finite hierarchy A^* are embedded in an hierarchy of models $A_i^\square = \{A_i^{\square j}\}$ that characterises a proficient student. The strategies employed by the instructor will be a 'cueing' procedure or 'co-operative establishment' (in the sense of 2.1.8.) whereby problem solving algorithms are adjoined to A_i^j by legal substitutions in L^j and 'ostensive definition' or 'induction' whereby classes of operation in A_i^{j+1} are related to operations in A_i^j (since A^* is defined at the outset, the creativity of 2.1.7. is not entailed in achieving the goal conditions, F).

However, all of this depends upon the assumed existence of an internal analogy, so that each model A_i^j corresponds to some analogous B_i^j. Normally we *cannot* assume that the internal analogy is satisfied unless the instructional process actively *maintains* $A_i^j \Leftrightarrow B_i^j$ for all relevant values of j. But if the skill is a structured skill then this condition is satisfied if each B_i^j is a relevant self-organising system (or a self-organising system analogous to a construction process in some part of A_i^j included by A^*).

Suppose that $i = 1$ or 2 and that U_1 represents a student and that U_2 represents an instructor. If U_1 and U_2 share a conceptual structure in a given universe of discourse (such as the data relevant to a skill), we can express the fact that a student has learned the skill, at an instant t, by the identity $A_1^\square(t) = A_2^\square(t)$ where $A_i{}^\square(t)$ is an hierarchy $A^\square = \{A^{\square j}\}$ of submodels $A^{\square j}$ that belong to A_i^j and are contained in the hierarchy $A^* = \{A^{*j}\}$. Similarly if U_1 is a student and U_2 is an instructor, then $A_1^j(t) \subseteq A_2^j(t)$ for all pertinent values of j for all t in the interval taken up by the instructional procedure. Now if the skill is a structured skill we can guarantee that all possible conceptual structures are known (and may consequently be available to an instructor) hence (I) the condition $A_1^j(t) \subseteq A_2^j(t)$ is satisfied. Next we have postulated a need to learn at a given rate. Thus in order to instruct this skill, we must ensure that each B_i^j is a self-organising system. But (II) this condition is satisfied if there is a dispositional relation between B_1^{j+1} and B_1^j for all relevant values of j such that relevant programmes are being built in A_1^j at the necessary rate by a programme building algorithm described in the L_1^{j+1} discourse between A_1^{j+1} and A_2^{j+1}. Call this relation G. From (I) the relation R between U_1 and U_2 is well defined for all relevant values of j. Hence the assertion that the skill can be instructed is tantamount to the assertion (if F is the disposition that characterise the skill) that it is possible to provide a control mechanism as in Fig. 11 that achieves and maintains the *joint* goal, F, G, (where G is the goal of maintaining a self-organising system at the relevant level of discourse).

The achievement of F is tantamount to completing a *control* analogy. The achievement of G is tantamount to completing the *internal* analogy or ensuring conditions in which the internal analogy relation $A_1^j \Leftrightarrow B_1^j$ pertains for all relevant values of j.

Since the level of discourse changes when learning occurs, the interaction between the systems U_1 and U_2 is analogous to a conversation and the system U_2 can be regarded as co-operating with U_1 by partially solving the problems that are posed by a structured skill untill U_1 can solve them alone. Because of (I) and (II) the instructor can be reduced to a C model and also completely mechanised as an adaptive teaching device. Its control procedure for maintaining the internal analogy consists in adjusting the discourse in L^j and L^{j+1} so that the disposition G is maintained and this procedure has the calibre of an auxilliary investigation in the sense of 2.1.6. The goal F of a simple C model control mechanism (equivalent, in this case, to a detailed teaching strategy) is replaced by a joint goal F, G. However, this joint goal

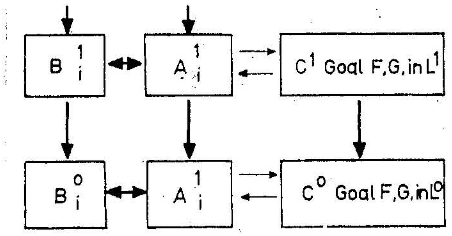


Fig. 11.

does not need to change (the control system does not need to obtain a compromise) because it is known at the outset, that a joint goal F, G, can be achieved. Hence the connotation of F, G, is irrelevant to the instruction and the teaching apparatus can be reduced to an adaptive control mechanism represented as in Fig. 11 by a C model. We shall call an interaction of this kind a *restricted* conversation and comment that restricted conversations take place when R is known, when the joint goal does not change, and when the control mechanism *dominates* the interaction and is guaranteed to achieve success.

The important point is that a restricted conversation is the minimal form of M model for representing teaching and any co-operative interaction between individuals that entails learning. It involves a special concatenation of individuals that allows for a co-operative sharing of B_i^j and B_2^j due to the existence of a common conceptual structure. It entails initial dominance of the teaching individual due to the existence of a common goal F and an initial relation $A_1^j \subseteq A_2^j$. Finally, the stipulations involving A^* that limit the restricted conversation to data that is relevant to a structured skill can be replaced by a stipulation that the conversation shall be relevant to a common environment C with which U_1 and U_2 jointly interact.

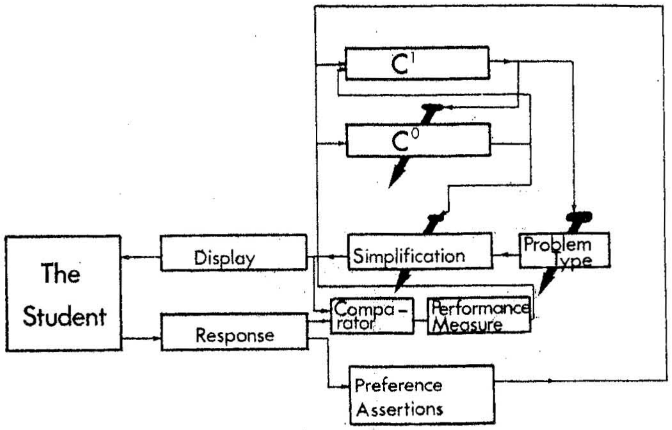


Fig. 12.

When the instructor in a restricted conversation is mechanised as an adaptive teaching machine we obtain the special case of Fig. 12 which is a minimal form of restricted conversation conducted in L° and L^1. The goal G is satisfied if $B_1^\circ \Leftrightarrow A_1^\circ \subseteq A_2^\circ \Leftrightarrow B_2^\circ$ and $B_1 \Leftrightarrow A_1^1 \subseteq A_2^1 \Leftrightarrow B_2^1$ are self-organising systems which may be rephrased as a requirement that the student's interest and attention are maintained. In the arrangement of Fig. 12 the words in L° are stimuli denoting problems of different types and different degrees of simplification and response alternatives denoting solutions. The words in L^1 denote the names of types of problems, instructional statements, and values of reinforcement (data is provided in the Appendix).

2.2.4. An unrestricted conversation between the pair of participants U_1 and U_{i+1}, in which U_i aims to persuade U_{i+1} of a certain F and in which U_{i+1} has some unspecified goal, differs from the restricted case in several ways.

(1) The relation R is undefined at the outset so that an appropriate interaction language is not initially specified. However, $A_i^j \cap A^j_{i+1}$ must be not empty for some values of j.

(2) The discourse takes place in a Mixed Language, in L^* perhaps, that mediates unstratified control in contrast to the stratified control procedure in 2.2.3. This mixed language will include connotation indicators that determine the level at which its expressions should be interpreted (and for any unrestricted conversation involving $n > 2$ participants it will also include directional indicators that define the intended recipient of messages).

In fact, a mixed language is no rarity. Computor programmes are normally expressed in a mixed programming language to mediate unstratified control but, as Gorn (1962) points out, this expedient may give rise to a 'Pragmatic Ambiguity' whereby several different levels of control expressions become confused with expressions denoting data to be processed.

(3) Although the initial goal of F is specified it may not be achievable and commonly U_i must adopt a compromise goal $F^\times$ for we cannot guarantee that U_i is initially dominant. In fact, at instants $t = 1, 2, \ldots$ there will be a sequence of goals $F(t)$ converging to an initially undefined goal of F^*.

(4) Because the relation R is unspecified the criterion of maintaining G is an inadequate canon for maintaining the internal analogy of the system. Of various possibilities that could be advanced we have so far only examined the goal of resolving the pragmatic ambiguity of the discourse with reference to the currently available specific goal $F(t)$. In this case if the disposition associated with the auxiliary goal is $G(t)$ (at an instant t) then there are convergent control procedures that maintain the current joint goal $F(t)$, $G(t)$ (and ultimately achieve F^*, G^*).

2.2.5. The *immediate* domain of discourse of A_i^j or of U_i in L^j is the collection of descriptive models that (1) represent systems that can understand the possible L^j utterances of U_i and (2) are physically related to U_i in such a way that communication is possible. Thus the immediate domain of discourse of U_i is the disjunction over j, of $\{A_i^j \cap A_l^j \cap \ldots\ldots\}$ where $U_i \Leftrightarrow U_l$.

Suppose that U_i cannot, at an instant t_0, understand an utterance v, it may become able to understand v as a result of a learning process, at some later instant $t_1 > t_0$. The *potential* domain of L^j discourse of a system U_i includes those systems which may be placed in communication with U_i and which may learn to understand the L^j utterances of U_i. Thus the potential domain of discourse of U_i is the disjunction over j, of $\{A \Leftrightarrow B_j \cap A \Leftrightarrow B_l \ldots\ldots\}$ where $U_i \Leftrightarrow U_l$ and B_i is the evolution of B_i^j.

Let us exemplify these points.

Factual operations entailing the logic of classes and relations are within the immediate domain of discourse of an 8 year old child and any contingent adult, on the assumption that this child is in its concrete operational phase in the sense of Piaget (1950, 1957). The rehearsal and manipulation of all possible hypotheses for the solution of a problem (and concepts bearing upon these abstract operations) do not form part of the immediate domain of discourse but do form part of the potential domain of discourse (on the assumption that Piaget's theory of development applies and that the adolescent will become able to understand abstract operations). Indeed, if Piaget's theory is accepted, we should be on safe ground in asserting that the adolescent can manipulate abstract hypotheses whereas the 8 year old child cannot *because* the adolescent is characterised by having a higher level of descriptive model say A_i^{m+1}. We could also argue that, at adolescence, certain expressions in A_i^m become capable of ostensively defining isomorphic expressions in A_i^{m+1}. Thus expressions of factual conservation ostensively define abstract conservation and similar comments apply to entire Piaget-like *groupings* of problem solving procedures.

However, much we aim to teach the young child to deal with other than imaginative abstractions we shall not succeed, which is a comment upon the temporal dependence of the evolutionary process that constructs the B_i. On the other hand there are plenty of adolescents who cannot perform abstract manipulations simply because they have not been taught to solve problems of the kind that involve these skills. Hence I wish to distinguish between the necessary or temporally contingent bounds of understanding (typified by the limitation upon teaching a child to manipulate rational abstractions) and an incidental bound upon understanding (typified by the adolescent who *can* be taught this skill but has not, in fact, *been* taught this skill).

Strictly we should make a more detailed analysis. The necessary bounds upon understanding are interpretable, within the M model, as an impossibility of inducing certain kinds of organisation in a population of evolving systems until after a critical change has occurred. In a detailed analysis we should consider the case when instruction may be too late or when understanding can only be achieved if the instructional discourse is closely correlated with the process of maturation, as occurs, for example, in imprinting. However, these niceties, though important, are not essential in the present discussion.

2.2.6. We are now in a position to examine one very important kind of control analogy which is closely related to the persuasive myths, allegories, and fairy stories that play such a crucial part in cultural development and social control. A cursory examination of the literature indicates that the term 'Parable' aptly describes the sort of control analogy I have in mind.

Although 'Parables' feature in nearly all of the great religions (and, for that matter, in nearly all important social and political philosophies) their use and development is most accessibly documented in connection with Christianity (and it is commonly agreed that the Christian parables are superlative). Hence I shall justify the usage of the word and illustrate its intended connotation by reference to Christian commentators alone.

The word is derived from the Hebrew 'Mashal' of which one meaning is a 'Proverb' used as a mode of instruction. The corresponding Greek word 'parabolos' carries the broader meaning of an analogy. Modern discussion of the function of the biblical parable dates back to Jullicher (1899), who discounted various allegorical interpretations that had been associated with these stories. Like a fable, a parable points out a moral or recommends some disposition conducive to a form of moral behaviour. Unlike a fable, the story of a parable involves a real and readily appreciated situation (whereas a fable normally involves mythical creatures and fantasy). A parable is part and parcel of a control procedure and its form is adjusted to specific people in the audience and a specific occasion (this point is argued and particularly emphasised by Hooke) (Jeremias, 1954). It exemplifies some principle, in fact Manson (1927) conjectures that it might be called a 'concrete universal', and in many cases the behaviour advocated by the parable ostensively defines the principle concerned. Further there is often a sense in which the audience cannot *immediately* appreciate the principle although the parable is told in the belief that at some later stage or in some later state of existence this degree of understanding will *become* available. Sweete (1920) cites the case of an organisation 'The Kingdom of God' which is exemplified in several parables by way of analogy with the organisation of a mundane kingdom.

It thus seems reasonable to say that a parable is an analogy in which R depends upon F, that is completed in a control procedure. The dominant member of the control system uses or *tells* the parable to persuade the other participants or *audience* of F or to teach them F. Hence we can distinguish between the superficially similar activities of parable telling and of coercive persuasion. In each case some dominant system, α, persuades an audience, β, to adopt a behaviour v that is symptomatic of a principle P. Now P is part of the immediate domain of discourse of α and his associates but it is *not* within the immediate domain of discourse of any β. However the audience adopt the behaviour v for *some* reason, though, by definition, they do not adopt it *because* of P, since P is incomprehensible. Let us assume they adopt v because of a concept P^* that *is* in their immediate domain of discourse and that v is also symptomatic of P^*.

Now suppose (1) that P is, or that α believes that P is, within the potential domain of discourse of β and (2) that P^* ostensively defines P so that it induces the evolution of a system able to embody P. In this case we shall say that α is telling a parable of P^* with a principle P. On the other hand if either (1) or (2) is untrue we might suspect that α is merely coercing β and inducing this audience to be meek or submissive or to adopt a particular disposition because it suits his purpose. True, α still has P in mind and the resulting behaviour pattern is still conducive to a state that is desirable if P has been accepted. But when α coerces β he does not expect to share P with β and any form of P^* that serves to promote the P desirable pattern of behaviour will be used.

The most explicit form of parable telling occurs when α is in possession of a creative insight, in the sense of 2.1.7., that β does not possess. In this case α is like U_i in the first part of Fig. 8 and is represented by an M model in which A_i^{m+1} is defined and P is named in A_i^{m+1}. Any member of the audience, say member U_k is typified by the first part of Fig. 8 in the sense that A_k^{m+1} does not exist. The effect of P^*, which can be named in the existing descriptive model A_k^m is to induce the evolution of B_k^{m+1} from B_k^m so that A_k^{m+1} can embody P. When an act of creative insight is involved in telling a parable the parable teller stands in a distinguished and special relation to the audience which closely resembles the priestly relation discussed in a somewhat different framework by C. S. Lewis (1957) (that man may be in a priestly relation to animals, is one argument in C. S. Lewis' book). In contrast, when α is acting coercively, he is related to β as an advertising agent (or an unscrupulous politician) is related to the public. Of course these relationships are not exclusive. The advertising agent or the politician may be a priest on occasion and *vice versa*.

2.2.7. Where there is a priest there may be an oracle. To consider the field of oracles and in more sober terms the field of arbitration, we need an M model in which the environment C is inhabited by an audience β and a set of systems denoted α, as in 2.2.6. It is often legitimate to assume that the rules of C are invariant and that in these conditions the members of β can meet with problems that are unsolvable within their immediate domain of discourse. Commonly enough such unsolvable problems constitute disputes between the members of β although other forms of problem (for example, how to deal with unpredictable occurrences) are admissible.

When members of β are faced with an unsolvable problem they are apt to consult an oracle. In other words, they approach some member of α for advice (rather than being approached by α) and they agree to accept the utterance of α as a solution to their problem. This approach need not be unconditional, of course. If U_1 and U_2 are disputing a particular issue they may add the conditon that the solution recommended by α shall be unbiassed or their agreement to accept the recommendation of α may be contingent upon certain boundary conditions being satisfied or certain results being achieved. However U_1 and U_2 must, to some extent, place themselves at the mercy of α. Thus an unbiassed solution can only imply a solution that favours neither U_1 nor U_2 as interpreted within the *immediate* domain of discourse of β and α can always play the trick of giving an *apparently* unbiassed solution (which will, in fact, favour one of the pair U_1 or U_2 when interpreted within the potential domain of β discourse).

An individual (or a place in which events occur and are interpreted by individuals) may qualify as an oracle on many different grounds. The replies it makes must not be absurd or completely out of keeping with the culture. But nobody seems to require predictive accuracy from an oracle and very often its recommendations are not of a kind that allow any direct test of accuracy to be made. For the most part an oracle will suggest a disposition or a procedure that should be adopted in order to solve the problem posed to it (rather than offering an outright solution) and often enough the optimum procedure is arbitrary (thus, as Ross Ashby has pointed out, it is perfectly sensible to appeal to the state of an uncoupled system; for example, the state of an animal's intestine, in order to resolve some part of a decision procedure that is nowadays resolved by a chance event). Probably the most important qualification for an oracle, and at any rate the qualification stressed in the present discussion, is the property of having insight. In other words I contend that α is distinguished as an advice giver, a prophet or the interpreter of an oracle simply because the members of α are aware that α stands in the priestly relation to β outlined in 2.2.6. This view is supported by the evidence from ethnology. Thus Fraser (1890) cites many cases in which the notion of an oracle is associated with interpreters or priests who are distinguished from the common people by a special and often trance-like state. Fraser also points out that although this special state is viewed as a kind of 'possession' by some supernatural power or deity (which constitutes the rationale of *accepting* the priest as an interpreter and the oracular occurrence as worth interpreting) the supernatural is viewed as an extension of the normal in the cultures concerned (rather than a contradiction of the normal) and consequently the state of 'possession' is viewed as an extension of *normal* awareness. Hence an individual is a member of α *because* he is like a member of β, blessed with a greater capacity for creative insight, or innovation.

In the present discussion we are not primarily concerned with classical oracles or the development of cultures. We are using the word 'oracle' to denote a fund of advisory utterances that are incompletely understood by their recipients. Hence the 'oracle' may be science and α a scientist if β is not versed in science. Equally, the oracle may be a crystal ball in a gimcrack booth and the priestly α may be a fortune teller (if β is a client). At the moment we do not aim to assess the relative value of different oracles. The emphasis is laid upon the form rather than the content of their utterances. Hence we shall avoid the temptation to dignify the scientist as a peculiarly rational priest who interprets a normative theory and the fortune teller as a priest who (according to taste) interprets a mystery or the haphazard perturbations of his brain. In fact they each have a kind of normative theory at the root of their mentation. It may be well or badly expressed. It may be more or less reliable and more or less capable of becoming public knowledge. But whatever the facts may be, when the oracle is consulted there is a magic in it so far as β is concerned and α is thus a purveyor of magic. If he tells parables he does not believe he is a magician and he does believe that one day he can share his normative theory with α, (he is honest but he is not an honest magician). If α does not tell parables he is a knave or a fraud or an honest magician (a conjuror who does tricks for the sake of these tricks).

2.2.8. We have considered the extreme cases of an oracle that utters scientific wisdom and an oracle that probably utters nonsense. At this stage we shall consider the intermediate case of an arbitration process for which Braithwaite (1955) has elegantly described the principles and arguments (the P of this case) that are used by α. We shall not use the mathematical part of Braithwaite's arbitration directly. But we shall use the fact that a stable arbitration is available and the fact that unlike other solutions it can be interpreted at many different levels of discourse, for example, in terms of algebra, in terms of symmetry, and in terms of loose but consistent concepts of equity or fairness. Because of this feature, Braithwaite's solution is rich in parables. The situation concerned is an *arbitration* between a pair of individuals (Luke and Mathew in Braithwaite's account) who live in the same house. Now Luke and Mathew are musicians, their apartments are not sound-proofed, and their opportunity for practice is limited to the same hour in the evening. However, Luke and Mathew play different instruments and have different musical tastes and the results of this, reflected in their preferences, can be represented as a *partly* competitive non-zero sum game. The possible outcomes for a single playing of this game are that one participant should sound his instrument and the other refrain, or *vice versa*, or that both should practice coincidentally, or that both should remain silent. These possibilities are shown in Fig. 13. Suppose that the arbitrator can obtain Luke's preferences for each outcome in conditions in which he is aware of Mathew's preferences and Mathew's preferences given that he is aware of Luke's. If a ratio scale of preference is constructed by comparing indifference points between a preference for a given outcome and a probabilistic combination of the alternatives, we can assign Luke's preferences to a vertical co-ordinate and locate the outcomes of Fig. 13 in the relative preference plane of Fig. 14. A choice by Luke of some independent, pure or mixed strategy and by Mathew of some independent pure or mixed strategy defines a point in the restricted part of Fig. 14 shown in Fig. 15 and a choice by one participant alone defines a line in Fig. 15. Points outside this restricted part of the plane cannot be achieved by the independent choice of pure strategies or by the independent choice of their probabilistic

		Mathew choice	
		Play	Not
Luke choice	Not	α	γ
	Play	β	δ

Fig. 13.

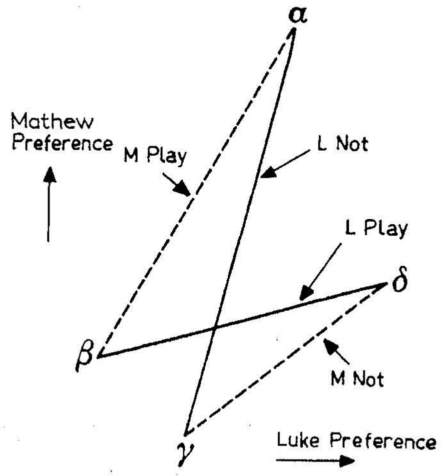


Fig. 14.

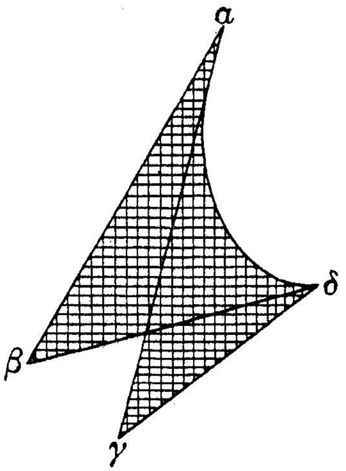


Fig. 15. Hand sketch of Braithwaite's construction. Parabola obtained by filling in *L* mixed strategies and filling in *M* mixed strategies.

combinations to select mixed strategies. These exterior points can only be achieved by correlated or co-operative selections.

Briefly, Braithwaite recommends that Luke and Mathew should be persuaded that a certain balance of advantage can be defined, given their manifest preferences, by the parabola axis in Fig. 16. To exhibit the point he asks Luke and Mathew to consider the limiting case in which they are completely avaricious (Luke does what he most prefers and Mathew does what he most prefers). The result is point *a*, which is far from optimum according to either Luke's or Mathew's point of view. Thus if the participants used Mixed Strategies (choosing a certain activity on a given percentage of evenings) it is to Luke's and to Mathew's advantage to move from point *a* to point *b* which is also on the axis of equal relative advantage but which maximises the absolute advantage obtainable for each of them. Further, this choice is safe for although it depends upon an agreement between Luke and Mathew (which might be instrumented by their agreeing to bias independent chance devices in order to achieve the point *b*) any deviation from this agreement by either participant (any deliberate neglect of the agreed selection criterion) can be countered by the other participant and the result will be a degeneration into the avaricious case. Luke's and Mathew's relative advantage would be unchanged by such a degeneration but in each case their absolute advantage would decrease. Braithwaite now points out that the relative advantage can be maintained but the *absolute* advantages of both can be further increased if Luke and Mathew agree to co-operate. In practice, if one *or* the other but not both will play their instrument on an agreed percentage of evenings such that *c* is achieved, their choice to play or not to play in this correlated fashion may be determined by consulting a common chance device, rather than the independent devices used in the

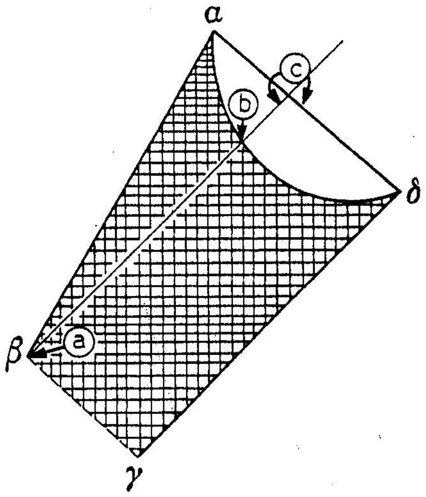


Fig. 16. Hand sketch of Braithwaite's construction.

previous recommendation. But their choices can, equivalently, be correlated by any suitable L° discourse. The crux of the matter is that communication is a pre-requisite for correlated and co-operative activity and as a final recommendation Luke and Mathew should co-operate in achieving the equitable solution of c in Fig. 16. Since this arbitrated solution is stable the participants will discover its rectitude by experience. But in order to initiate the process they are persuaded of the equity of this solution by way of an argument that involves concepts of rationality, avarice, and the symmetries and logic of the game. Broadly, this demonstration entails the normative theory of a partly competitive game.

A further property of the Luke and Mathew arbitration is that Mathew enjoys some advantage over Luke due to the relative liberality of Mathew's preferences. He would rather Luke and he played jointly than that neither of them should play. Although the relative advantage of a liberal preference is dependent upon a particular choice of values it is a very important and by no means idiosyncratic characteristic. Ross Ashby (1957) cites it, for example in connection with numerous systems and we shall use it crucially in our argument. To interpret this situation within the present framework we shall identify Luke with a system U_1 and Mathew with U_2 and their environment with a system C. The co-operative solution entails the interaction shown in Fig. 17 where the arbitrator is initially attached to the assembly of U_1, U_2 and C but is disconnected as soon as the co-operative control system is established.

Now Fig. 17 represents the least elaborate structure in terms of which it is possible to discuss an M model of arbitration or an M model of any kind of legal, social, or ethical control. This arbitration structure is a basic building block akin to the basic building block of a restricted and unrestricted conversation developed in 2.2.3. Indeed the arbitration system is derived by iterating the special concatenation of individuals that is cited in 2.2.3. (the stipulation that the discourse is relevant to a structured skill is replaced by a stipulation that the discourse is relevant to C). The condition that a structured skill is teachable is replaced by the condition that there is a stable solution for the partially competitive and partially co-operative non-zero sum interaction.

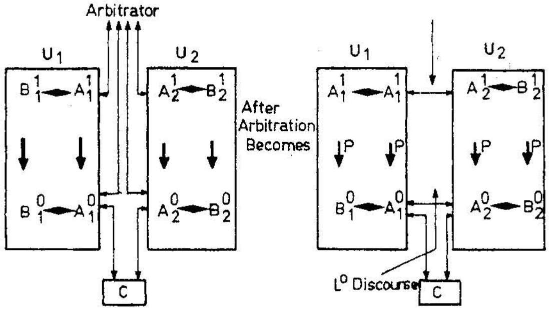


Fig. 17. Environment C determines payoff function. Ultimately, given P, there is a discourse in L^1 interpreting co-operative discourse in L^0.

Arbitration involves a sequence of conversations, namely an initial conversation, in L°, between U_1 and U_2 which is instable in C (hence an arbitrator is needed); a conversation in L° and L^1 between the arbitrator and U_1 and U_2 represented by a system (arbitrator, U_1, U_2); and finally a stable conversation induced by the arbitrator between individuals U_1 and U_2 that preserves some invariant relation denoted by an L^1 statement and derived from a normative theory of stable solutions such as Braithwaite's theory. In other words arbitration (according to this analysis) amounts to teaching U_1 and U_2 to teach one another (or to learn from one another). However, the *form* of arbitration system (arbitrator, U_1, U_2) differs according to whether the conversations involved are *restricted* conversations when Braithwaite's theory or some comparable model is ultimately accepted by U_1 and U_2 or *unrestricted* conversation when only certain properties of the theory are accepted. This distinction can be equivalently specified in terms of the *domain* of discourse of U_1 and U_2. Using the latter idiom we develop the case equivalent to a sequence of restricted conversations in (1) below and the case equivalent to a sequence of unrestricted conversations in (2) below.

(1) Suppose that the concept of the normative theory is within the immediate domain of discourse of the participants. In this case the arbitrator aims to induce in each participant a disposition P (by rational argument about the equity of the proposed solution). If he succeeds, the existence of this disposition can be expressed for U_1 and U_2 by $A_1{}^1(P)A_1{}^\circ$, $A_2{}^1(P)A_2{}^\circ$, and if the coupled system of U_1 and U_2 is stable in C then $B_1{}^1(P)B_1{}^\circ$ and $B_2{}^1(P)B_2{}^\circ$. The act of inducing P involves a restricted conversation (in the sense of 2.2.3.) between the arbitrator and U_1 and U_2. But, in the present case, induction of P is not the arbitrator's chief objective. Ultimately he aims to achieve a stable co-operative interaction in L° between U_1 and U_2 and C that preserves some relation η so that U_1 and U_2 do interact in such a fashion that $U_1\,(\eta)\,U_2$. Now the coupled system will be stable, in the absence of the arbitrator, insofar as the interaction between the participants con-

firms or substantiates P or, phrasing it differently, insofar as the L° expressions bandied about in maintaining $U_1\ (\eta)\ U_2$ ostensively define the concept of P in $A_1{}^1$ and in $A_2{}^1$. In fact we can maintain that this is so by expressing Braithwaite's argument for the stability of the arbitrated solution in terms of the preference definition in 2.1.6. in such a way that the induced disposition P implies that each participant prefers a *rational* strategy in the conditions C.

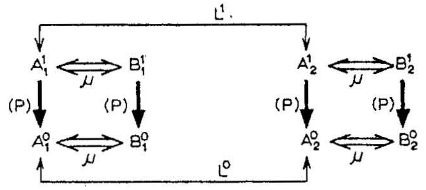


Fig. 18. The relation η between U_1 and U_2 is maintained by the L° discourse between $A_1{}^0$ and $A_2{}^0$ and the L^1 discourse between $A_1{}^1$ and $A_2{}^1$.

Assume that $U_1(\eta)U_2$ is a stable interaction in C and that the arbitrator (having acted like a catalyst) is removed. Let us call the resulting organisation a *stable* solution in M. It is characterised by Fig. 18 which exhibits the existence of a symmetry between the internal analogies $A_1 \Leftrightarrow B_1$ and $A_2 \Leftrightarrow B_2$ maintaining properties μ (as positive similarities) and the relation $U_1(\eta)U_2$ which is also an 'internal analogy' so far as the *organisation* is concerned.

(2) Suppose that the concept of the normative theory is *not* in the immediate domain of discourse of U_1 and U_2 but that it does lie in their potential domain of discourse. In this case the arbitrator may be able to use a parable P^* of P in order to achieve $U_1(\eta)U_2$, where the concept of P^* is within the immediate domain of discourse of U_1 and U_2.

In practice, the arbitrator may persuade the participants, in a restricted conversation, that they should adopt a disposition P^* that is conducive to establishing $U_1(\eta)U_2$, for example, he may appeal to their vague and irrational ideas of fairness or he may simply act as the interpreter of an oracle and assert the rectitude of $U_1(\eta)U_2$ on this authority. Although the participants cannot immediately understand the normative theory upon which the arbitrator's (or the oracles') proposal is based they can test its validity and if they do so (by deviating from $U_1(\eta)U_2$) they will discover that the recommendation is affirmed. Now if the L° expressions bandied about in maintaining $U_1(\eta)U_2$ ostensively define the concept of P^*, or, if P^* is expressed in $A_1{}^\circ$ or $A_2{}^\circ$, when these expressions are produced by a programme named by the concept of P^*, then we obtain a *stable* solution in M which is identical with Fig. 18 except that P is replaced by P^*. But $U_1(\eta)U_2$ is maintained by expressions that ostensively define not only P^* but also P. Hence, as evolution takes place in the M system, so that it becomes able to represent P, the degenerate form of Fig. 18 can be transformed into the original form of Fig. 18. Indeed, if the solution is to remain stable in an M system that evolves or matures or learns, then a structure admitting this transformation must exist.

The basic requirement is a kind of homeostasis that regulates the system so that it can withstand evolutionary changes. The most general specification of this homeostatic organisation involves a set $\{\eta_1, \eta_2, \ldots\ldots\}$ of acceptable relations between U_1 and U_2 and an associated set of dispositions $\{P_1, P_2, \ldots\ldots\ldots\}$.

We require that P_1, defined in $A_1{}^j \Leftrightarrow B_1{}^j$ and in $A_2{}^j \Leftrightarrow B_2{}^j$ gives rise to $U_1(\eta)U_2$; and that the L^j expressions used to maintain $U_1(\eta)U_2$ ostensively define the concept of P_2 in $A_1{}^{j+1} \Leftrightarrow B_1{}^{j+1}$ and $A_2{}^{j+1} \Leftrightarrow B_2{}^{j+1}$; and that P_2 gives rise to $U_1(\eta)U_2$, and so on.

It is intuitively apparent that such a homeostatic regulation depends upon relationships between the evolutionary rules that govern the development of systems in the B part of the M system and dicta governing the admissible hierarchy of constraints in the A part of the M system. The situation has not been formalised sufficiently to demonstrate the general form of these relationships but special cases are readily simulated and a number have been encountered in our learning system work. Let us call an organisation of this kind a *homeostatic* solution in M.

(3) If the concept of the normative theory is neither within the immediate domain of discourse of U_1 and U_2 nor within their potential domain of discourse then the arbitrator must either relax his objectives or introduce some kind of coercion to achieve a stable $U_1(\eta)U_2$. He could simply coerce U_1 and U_2 by interacting with them continually and, assuming dominance, by forcing them to obey his instructions. Alternatively he could introduce a modification in C that acted as a coercive *law*, for example, by altering the payoff characteristics of the environment so that other than co-operative activity became heavily penalised. Neither expedient has much interest for Luke and Mathew and it can be argued that each mode of coercion alters their problem completely. However, the idea of a coercive *law* has a wider relevance.

(4) We have, in fact, described four basically different, more or less evanescent legal constraints. Although their distinction would be unduly ponderous in a real attempt to arbitrate in the problem of Luke and Mathew they remain distinct in any *M* system, however elaborate it may be, and demarcate four important modes of control. As a conjecture they are also paradigm cases for different types of legal organisation that are widely recognised in discussions of ethics, sociology and political philosophy. These aspects of the *M* system will be developed later. For the moment we merely recapitulate the basic types.

(I) As in (3) a *dominant* system, for example, the arbitrator, may interact continually with a population and coerce it into a given mode of activity. The dominant system thus imposes a law by direct force.

(II) As in (3) an arbitrator can modify the environment c so that in view of the existing preferences a certain mode of activity is bound to occur. The arbitrator thus imposes a coercive law by indirect force.

(III) As in (1) the arbitrator acts as a catalyst and induces a *stable* solution in part of an *M* system of which the invariant feature is a *sanctioned* law. This sanctioned law is, however, *immutable* and if the *M* system evolves it may become inapplicable or ineffective. According to the form and dependence of the stable solution the associated law has the character of being morally sanctioned or being socially sanctioned, of being determined by custom or as a necessary consequence of the organisation of the *M* system as a whole. In the latter case, the whole *M* system acts as the arbitrator.

(IV) As in (2) the arbitrator acts as a catalyst and induces a *homeostatic* solution in a part of the *M* system for which any member in the class of invariants is a law. The particular form of the law is automatically adjusted if the *M* system evolves so that the definitive characteristics of this class continue to characterise the constraints imposed by the solution.

The law is a *sanctioned* law which can be characterised according to the form and dependence of the associated solution. But it imposes a dynamic rather than a static constraint upon the population concerned.

2.3. SOME IDENTIFICATIONS

Social systems

2.3.1. (1) The pragmatic side of ethics is closely related to sociology and the framework of political science. It is concerned with control and the maintenance of stable but often developing patterns of activity in a population wherein most of the members assert that they exercise and have a right to exercise 'free choice'. In this section we shall develop some basic ideas in this field and interpret a number of concepts within the framework of an *M* system. In the next section a special form of *M* system, closely related to a model that has been used for simulating a mammalian learning process, is identified with parts of the ethical structure and various consequences are discussed. Thus we are using a different *order* of identification for the *M* model by identifying it with a society with individuals rather than a brain with different components or a conversation with different participants (the case of an arbitration system considered in 2.2.8. is an important intermediate case).

The grounds for using an *M* model rather than a simpler structure (such as a communication graph or a product distribution graph) are precisely the grounds which lead us to represent learning or conversation or arbitration in this fashion. In sociology as in psychology there are competing schools of thought. All of them aim to avoid a duality of *things*. But, whereas the System theorists (Grinker, 1956; Hearn, 1958) believe that they can adequately represent social interactions by a 'Black Box' model which entails reducing the image of these interactions to a single universe of discourse, the other school of thought, typified by Mead (1934) and Burke (1950) and Duncan (1962) is apt to stress the symbolic content of social discourse and control. Consequently Duncan cannot accept a purely 'Black Box' image. The intension of the languages of social communication must be explicitly defined and this involves a duality of models. Further it is probably fair to comment that a form of 'ethical control' is introduced as one of the essential features of any adequate representation. It is not necessary to take this word 'ethical' too seriously. It could be substituted in some cases by phrases like 'value oriented' and in other cases by 'aesthetic'. But it happens that a tradition of ethical literature is available and, if we feel a System Theoretic approach is insufficient, it is useful to start from this tradition and to develop an *M* model as the least elaborate structure in which ethical systems can be adequately represented. Consequently the *M* system supplements the constructs of 'System Theory' and 'Bargaining Theory' and its introduction leads to certain unifying principles. Above all, it allows us to introduce the constraints of a language. Now, however much we may agree or disagree with the doctrine of Mead, Burke and Duncan one of their basic points, that a society is chiefly determined by its communication and that this depends upon a developing language, is certainly and vitally correct. The *M* model does not impose the correct restrictions, of course. But it provides a framework in which they can be inserted in a logically respectable fashion.

(2) In what conditions could an individual or, in particular, a participant observer, indulge in a conversation with an M system U_i and make sense of the U_i assertion, that U_i has made a 'Free Choice'? Further, what would he understand by this assertion of 'Free Choice'? To develop the point let us construe the L^j as conceptual languages characterising a population of systems U_i. We shall assume that expressions in any conceptual language, the production of a given A_i^j, are translated into L° for communication between U_i and other individuals. Suppose a choice of an action or utterance λ is made by U_i at an instant $t + \triangle t$ and consider the U_i mentation in the interval between t and $t + \triangle t$.

In the first place there is an activity in A_i^j, namely the application of programmes or algorithms and there is activity bearing upon A_i^j such as the application of substitution rules in A_i^{j+1} to yield legal substituents. Since $A_i^j \Leftrightarrow B_i^j$ for all values of j there is, of course, a correlated mechanical process going on between t and $t + \triangle t$ and there is a sense in which the activity in A_i^j is due to this analogous process B_i^j and thus is B determined. However, if a unique λ is determined by these gurgitations it is much more useful to talk about its A determination and to say that λ is a deductive consequence of the conditions at t and the logical apparatus available in the A_i^j (or, since evidence may be assessed and assimilated, possibly, in a rather weak sense, an inductive consequence). This contention is based upon the fact that (at any rate in principle) the A_i^j activity can be shared in a conversation involving U_i and another individual who (for simplicity) we shall assume to be an observer (I) able to dominate U_i and (II) superior to U_i in the sense that if A_i^j is available A_0^j is available and possibly A_0^{j+1} also.

Now, if the selection of λ at $t + \triangle t$ is uniquely determined by A_i^j and a concept available at t, we say that λ is 'psychologically determined'. The justification for the phrase 'psychologically determined' is simply that an observer could have conversed with U_i and (being another member of the same population, so that A_i^j is available) could have participated in arriving at the choice made at $t + \triangle t$ (in the simplest case this choice would still be λ, but the observer might influence U_i in some other direction).

But the mentation which takes place in the interval between t and $t + \triangle t$ may readily lead to a collection of equally legal alternatives. Hence, if we postulate that λ is selected at $t + \triangle t$ and if the 'psychologically determined' process yields only a set of equally legal alternatives, then λ is not a psychologically determined choice in A_i^j. It may be the case that λ is psychologically determined at a higher conceptual level in A_i^{j+1}. Indeed, many types of mentation resort to precisely this expedient, of changing the level at which a problem is interpreted, as a method of resolving ambiguity. Let us assume, for the moment, that this is *not* the case (in other words let us assume that λ is *not* psychologically determined in any A_i^j). If this is so then either λ is selected by B_i^1 from a set of equally legal alternatives in a fashion that U_i cannot control (which he will interpret as an 'occurrence' rather than a choice or possibly as a 'chance' selection) or, alternatively, λ is selected in a fashion that U_i can, to some extent, control but which he cannot describe.

If the λ selection is not controlled we say that the selection is 'mechanically determined'. If it *is* controlled by U_i but in a manner that U_i *cannot* completely describe it may be legitimate for U_i to call this λ selection a 'free choice', using this phrase to emphasise the volitional aspect of the process. As in our discussion of the M system some expressions in A_i^j denote dispositions which are not necessarily interpretable in A_i^{j+1}. Typically, these dispositions are named as drives and attitudes that refer to mechanisms and their properties. Although it can be argued that any disposition applied to B_i^j and named in A_i^j must ostensively define a class of operations named in A_i^{j+1} it is not necessarily the case that this class of operations exists in A_i^{j+1} or even that A_i^{j+1} is available (as we argued, in connection with creativity, in 2.1.7.). In fact, our present contention is that when U_i legitimately asserts that he has selected λ at $t + \triangle t$ as a free choice, this implies that he has adopted a disposition named in A_i^j at an instant t (perhaps as the result of a psychologically determined procedure) and that the class of operations ostensively defined by this disposition does *not* exist in A_i^{j+1} for, if it did exist, the choice of λ would be psychologically determined by a programme produced in A_i^j by invoking this class of operations at a higher conceptual level.

The amount of restriction imposed upon B_i^j by the action of adopting a particular disposition in A_i^j and the extent to which the intension of a dispositional statement can be shared between U_i and another individual appears to vary a great deal. Hence there is no hard and fast demarcation between 'free choice' and psychologically determined choice and mechanically determined choice.

At one extreme there are dispositions like 'being rational'. If U_i announces, at t, that he intends to 'be rational' the observer understands this statement completely and is able to check the subsequent U_i data processing against commonly accepted criteria of rationality. Further, if U_i adopts a rational attitude, he will restrict B_i^j so that $A_i^j \Leftrightarrow B_i^j$ is a purely deductive apparatus. Since A_i^j is identical with or forms part of A_0^j the subsequent mentation can be divided between U_i and the observer and since this observer is, by definition, able to dominate the conversation there is no need to invoke the idea of free choice on the part of U_i because any unresolved issues can be rationally decided by the dominant participant.

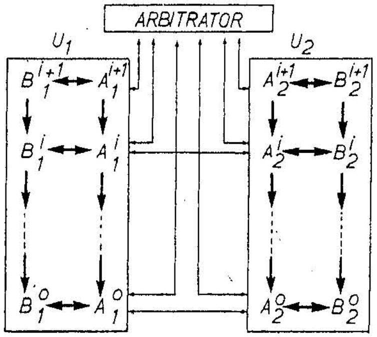
On the other hand a disposition like 'Justice' (or like the 'Fairness' of the arbitration system considered in 2.2.8.) is not so transparent. When U_i announces in A_i^j that he will adopt a 'Just' attitude this may mean that he has available, in the axiom system of A_i^{j+1}, some rules and cannons of jurisprudence or it may mean that he has a vague feeling of 'Justice' (or of 'Fairness'). In the latter case the disposition constrains B_i^j but U_i cannot describe 'justice' or adequately communicate the intension of this concept to the observer. At the most he can provide a few exemplars of 'just' and of 'unjust' decisions and if he did rehearse these the observer might infer that if psychologically undetermined situations sufficiently like these exemplars came up for resolution, then U_i would choose 'just' rather than 'unjust' alternatives. But the observer cannot claim to dominate the conversation *and* to abide by a jointly agreed interpretation of 'justice', as he could in the case of rationality, because he does not know very much about the U_i concept of 'justice' and the amount he can discover about it is limited in principle by the inability of U_i to describe the disposition concerned either for his own benefit or for the observer's benefit. Of course, the observer can dominate the conversation by teaching U_i his own concept of 'Justice' but in this case 'Justice' assumes the calibre of rationality and the choices entailing it are apt to be psychologically determined.

Finally there are curiously personal dispositions like 'merely thinking' and 'making inventions' which are distorted by any attempt to communicate the underlying concept. All that an observer can do if U_i says, at t, that "I am being inventive" and at $t+\triangle t$ that "λ was a free choice in A_i^j" is to assume "λ was a free choice in A_i^j" is a condensed form of "I did, to some extent, control the selection of λ at $t+\triangle t$ by a disposition ($z =$ Being Inventive) adopted at t, but the class of operations which might be ostensively defined by z (and which I cannot describe) is *not* a component in any A system". In particular, if A_i^m is the highest level conceptual system in U_i and A_0^m is the highest level conceptual system available to the observer, then the observer may be forced to agree that z *does* control the selection of λ, if λ ostensively defines a class of operations in A_0^{m+1}, and thus creates a rudimentary A_0^{m+1} at $t+\triangle t$. From our assumption of observer superiority it is perfectly possible for an observer to see the point of a choice made by U_i before U_i can see the point of it (hence creation of A_0^{m+1} does not entail the creation of A_i^{m+1}).

According to this analysis, free choice is associated with creative situations (in the sense of 2.1.7.) that are prefaced by announcements of a disposition that is held to control a selective *mechanism* in the *absence* of $A_i^{j+1} \Rightarrow A_i^j$ from the internal analogy relations $A_i^j \Leftrightarrow B_i^j$, $A_i^{j+1} \Leftrightarrow B_i^{j+1}$, $A_i^{j+1} \Rightarrow A_i^j$, and $B_i^{j+1} \Rightarrow B_i^j$. If the prefacing disposition is incommunicable an assertion of free choice will only make sense in the strongly asserted creativity situation of 2.1.7. for otherwise an observer has no criterion for distinguishing free choice from uncontrolled and mechanically determined selection. On the other hand, if the disposition is communicable, an observer will be uncertain whether the asserted selection was a free choice or whether it really was psychologically determined. These difficulties occur because (I) *all* selections are mechanically determined in the sense that B_i^j is responsible for the activity in A_i^j but (II) in the case of a psychologically determined selection an assertion of its mechanical determination would be *irrelevant* in the sense that this information would not help anybody to control the U_i data processing.

(3) Ethical comments about the property 'good' or about the attitude that 'good' people adopt are control statements. Stevenson (1937) deals with the issue explicitly. He points out that these comments are persuasive or emotive in character. They are uttered to evoke certain actions or to embed certain dispositions in a recipient. They are, incidentally, the 'rhetorical' statements needed to create the 'identifications' between persons and persons or persons and descriptions required by Duncan's (1962) system of sociology.

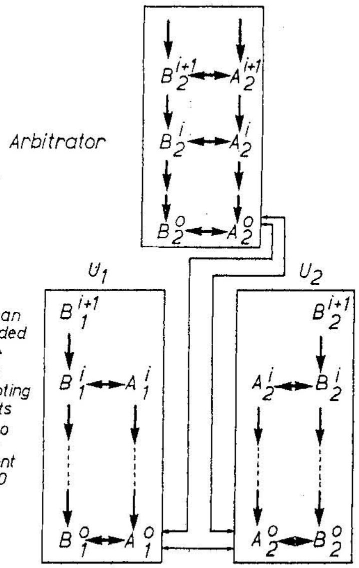
The primary situation in ethics is the resolution of a disagreement and recognition of the emotive content of the discourse reveals that most relevant disagreements involve issues of a kind that Stevenson calls disputes about interest, in contrast to disputes about belief. Whereas a difference of belief may be resolved by appealing to the evidence or the rational basis of a model, a difference of interest is resolved by altering the disposition adopted by the disagreeing participant. Of course, rational and factual data are woven into the discourse to support each point of view. But the *goal* of the system is not a proof. It is a *solution* either in the sense of an oracular dictum as in 2.2.7. or in the sense of Braithwaite's (1955) paradigm for arbitration, cited in 2.2.8. (The priest interprets the oracle and the arbitrator recommends dispositions and supports them on grounds of rationality or wisdom.) If the disagreeing participants become fused into a social organisation the solution is co-operative (again in the sense of 2.2.8.). Hence the minimal Building Block in an identified system of ethics is the arbitration system in Fig. 20.



Where the <u>highest</u> level of U_1, U_2, discourse is L^i

Fig. 19.

If L^o is an open ended language capable of denoting concepts in L^i, $i>o$ Fig. 19 is equivalent to Fig. 20



Where A_1^i and A_2^i are the <u>highest</u> level conceptual structures available in U_1 and in U_2

Fig. 20.

(4) Now ethical statements have a dual character. Shlick (1939), for example, makes a distinction between the formal attributes and the material attributes of the 'good'. Formal attributes can be classified and, acting like axioms, deductively manipulated to provide an hierarchical structure of 'norms', goal statements, and principles. Such a structure is the bedrock of a normative theory which is interpreted by the 'priest' of 2.2.7. perhaps in the guise of a law making administrator, and which leads to an arbitrator's recommendations. Normative theories differ according to the form of the bedrock. Thus there may be a unique highest 'good' according to the tenets of one theory and several according to the tenets of another. In contrast, the material attributes of the 'good' lie in the domain of psychology. They refer to properties of moral behaviour and individual valuation.

Now as Shlick points out, purely formal conceptions of ethics are somewhat arid for, at the most, they classify *what* is valued without considering *why* or *how* the valuation takes place. On the other hand a material conception of ethics tries to account for *why* things are valued and, in a generalised form, becomes a psychology of moral behaviour. But we shall argue that the control of a population, applied ethics, must entail each side of this picture.

(5) A state, in the sociological sense, exists because of a system of laws and constraints that is applied to a given population. Since I am not a political philosopher I shall take my brief from a single well-known authoritative work, by Weldon (1946), in which most of the relevant issues are discussed and a number of typical arguments and definitions are advanced. Thus, for the present purpose, 'Political Science' means chiefly the discipline considered in this work and we shall relate this conception of 'Political Science' to the Cybernetic Models we have discussed.

Weldon distinguishes between an *organic* and a *mechanistic* state. An organic state has a characterisation (a personality perhaps) of its own. It is the supremely important entity so far as its citizens are concerned. These citizens, as parts of the state, may perform differentiated functions and may be differently valued by the state. Apart from the state they have no chance of survival and no identity (it would probably be more accurate to say they have no value to the state). Typical organic states have been conceived by Plato and Aristotle and in the political philosphy of Hegel.

In contrast, a mechanistic state consists of individuals who, like the bits and pieces of engineering, have an independent existence, stability and function. Groups of these individuals decide to create the state as a machine in which they will act as components and the function of the machine is to obtain co-operative benefits that would not be available if their comportment was not subject to government.

Typical mechanistic states have been envisaged on the one hand by Hobbes (1950) and Marx (1936) and on the other by Locke (1954). So far as Hobbes is concerned, the state is brought into existence by its citizens to avoid the positively horrible state of nature which would exist in its absence (thus *any* state, even though it is a most suppressive one, is better than *none* providing it is an administratively competent state). The citizens have a kind of social contract with the state (though not in the sense advanced by Rousseau) and it is a contract enforced by their fear of nature. To Marx, on the other hand, this contract is no more than a trick played by the exploiting class upon the exploited class and unlike Hobbes (1950), Marx is an advocate of revolution, whenever the revolution is likely to be successful. But this is an 'instantaneous' interpretation of the Marxist doctrine. In general Marxism is a dynamic prescription rather than a theory of the status quo (Marx, 1936; Engels, 1925). The state develops by an interaction between its citizens and the rules of an underlying historical determinism that is incidentally couched in the language of economic theory. Thus the state develops by the replacement of one conceivable Hobbes-like form with another. Feudalism is overthrown by capitalism, capitalism is overthrown by the socialism of an urban proletariat, and this in turn by another mode of organisation.

The mechanism conceived by Locke (1952) is very different. Men could exist perfectly well in a state of nature but groups of men decide that a unified administration would be convenient. (Locke conceives of men as rational and moderately honest creatures whereas Hobbes regarded them as avaricious and irresponsible beings when left on their own, albeit imbued with a desire to be otherwise.) Locke regards the state as a Trustee working on behalf of the citizens. Its authority is limited by an agreed constitution and its decisions are made by a voting procedure (or in some other convenient and practicable fashion). One of the main conditions to be satisfied by the system is that the state does not interfere too much in the personal affairs of its citizens for according to Locke's doctrine, man needs a certain liberty or potential variety of choice and action and, in a sense, he trades off universal freedom to secure his tenure of a local freedom.

Now without in any way criticising Weldon's careful usage of the term 'organic' (he is at great pains to discuss its specialities and its defects) we should emphasise that an 'organic' state bears little relation to the Cybernetic conception of an *organism* (it neither resembles the organisation of *most* brains, or *most* animals or *most* ecological communities). True there are some organisms which do have an organisation akin to the 'organic' state. The brain of an octopus (Young, 1963) is an hierarchically organised homeostat which bears at least a superficial resemblance to the rigid whole and part pattern. The same comment applies to many insects and to animal species characterised by a transition of habitat, for example, to the frog (Lettvin *et al.*, 1959), which is in transition from an aquatic domain into the dry land environment. Finally, an ant hill is not unlike an organic state. But these are limiting cases. It is also perfectly evident that the dicta of organic state theorists lead inevitably to a limiting case organisation. Hegel may have been right in conceiving the family as the basic unit and paradigm of the state. But Hegelian dicta of the kind (I) the whole is more valuable than the part (not merely is 'more than' in the usual sense of a whole to part relation) or (II) the differentiated whole is more valuable than the less differentiated whole (regardless of the form of differentiation) guarantee that the familial state will degenerate into an ant-hill structure. The concept of synthesis is largely redundant for the development of such a state can be described as the predictable rigidification of an automaton.

My quibble over terminology is important because I hope to show that a system which *is* at any rate *more* like an organism will comprehend all of the political structures we have reviewed. Various forms of organic state are included as special and, in some conditions, undesirable limiting cases.

(6) Now a state is a description of a class of stable or metastable configurations of a system obtained by specifying a population of individuals and a set of laws. Hence it is possible to distinguish between various types of state according to the essential postulates about their citizens or according to the form of law that holds the structure together.

Thus Hobbes men were necessarily contentious and the men in a Marxist state are necessarily imbued with a sense of injustice and Locke's men are rational and libertarian. If these qualities are lacking, the drive has gone and the political model cannot be expected to work. It can be argued that the citizens of an organic state are products *of* the state but since men are known to be adaptive, their dependence is a matter of degree. Men are moulded by *any* state. It simply happens that many organic state theorists tend to hide their citizen postulates. But one suspects that Plato had a set of angels in mind and Hegel was certainly thinking about a set of Prussians.

So far as laws are concerned we have already distinguished the first four members of an hierarchy of types of law, in 2.2.8. as Type (I), (II), (III) and (IV). The hierarchy is ordered by a relation 'because of, or contingent upon'. Thus Type (I) Laws are dominance relations determining strategic advantage that are consequences of the physical structure of an animal and its environment. Type (II) Laws are coercive constraints that act because of the population and the Type (I) Laws. Type (III) Laws are stable solutions contingent upon the existing population and the Type (I) and Type (II) laws to which this population is subject and finally the homeostatic solutions characterised as the Type (IV) Laws are contingent upon Type (I), Type (II) and the Type (III) Laws (in an organic state we might replace 'contingent upon' by 'exist because of'). The hierarchy does not end with Type (IV) Laws but for the present discussion it is unnecessary to develop any further members. We comment that the difference between Type (III) and Type (II) Laws is crucial. When a Type (III) Law exists it is possible to have an arbitration system (wherein the arbitrator may, of course, also apply Type (I) and Type (II) Laws). If no Type (III) Law exists then no arbitration system is possible.

These types of Law can also be ordered by a relation that depends upon 'who can apply them'. In simple ecological communities or the natural state of political science, individuals abide by the direct force Jungle Law, of Type (I). Nature, which is not regarded as a participant, manipulates Type

(II) Laws. When individuals form herds or other co-operative aggregates there are, by definition, *some* Type (III) Laws and the Type (II) Laws (that maintain one rather than another stable solution) become enforced *by* the herd or nest or symbiotic system often through the mediacy of a social hormone or a special sign system (Lorenz, 1952; Tinbergen, 1953). At this level of social development the effect of any Type (IV) Law is exerted upon evolving species of organism and not upon the individual members of a species. No *individual* can apply any Type (III) *or* any Type (IV) Law*.

The individual ability to apply Type (III) Laws, and consequently the individual ability to act as an arbitrator, becomes potentially available when the population acquires a language capable of framing and developing concepts. In fact, this potentiality appears to exist unused (or possibly unnoticed) in natural communities, for recent experimental work by Skinner (1963), Verhave (1963) and others indicate that it can be fostered by special conditioning (when animals that do not arbitrate in their natural habitat become arbitrators in the laboratory). So far as Type (IV) Laws are concerned, they can only be applied by individuals who are capable of jointly creating concepts in conversation. The least codified form of Type (IV) Law is a cultural invariant. At a more codified level it may represent a Natural Law in the sense of D'Entrèves (1951).

The political systems we have considered are simply ethical systems which have been identified with a particular image of man and his environment. This point is conceded by many authors and it may either be taken as a definition or deduced from the methodology. In any case, if a political system is an identified ethical system as in (3) then its components will be the arbitration subsystems of Fig. 19 and Fig. 20. Hence, amongst the population there must be individuals (possibly representing institutions) who are able to arbitrate. Possibly all individuals can act as arbitrators.

All of the political systems involve each type of law but in different states a different emphasis is laid upon the application of each type of law. This distinction is chiefly reflected by differing levels of arbitration and differing roles for an arbitrator.

So far as the *level* of arbitration is concerned the normative theories used by the arbitrator in an arbitration system (or the Type (III) Laws and Type (IV) Laws they immediately engender) find application to the *whole* in an organic state whereas arbitration takes place at an *individual* level in a mechanistic state. Obviously the distinction is not hard and fast. In each case arbitration takes place at all levels. But the bias is evidenced by a more or less profusely developed individualistic or abstract Normative Theory.

So far as his *role* is concerned, the arbitrator in a pure organic state approximates the priest of 2.2.7. interpreting an oracle and a vast number of laws would exist before the state is conceived. In a mechanistic state the arbitrator justifies his normative theory and if its concept is beyond the immediate domain of discourse of his audience he uses Parables. Weldon distinguishes between mechanistic states like those conceived by Hobbes and by Marx which depend upon direct force and mechanistic states like Locke's which are governed by more rational procedures. Of course the distinction is far from absolute since all types of Law appear in all states but the basic legislature in the states of Hobbes and of Marx is introduced through Type (I) and Type (II) Laws and results in a fairly authoritarian structure. The basic legislature in Locke's state is biassed in favour of Type (III) and Type (IV) Laws that recommend *classes* of *disposition*. One result is that a coherent system of this latter kind can only be achieved by associating the laws of the state with absolute value systems outside the state. Thus D'Entrèves points out that the arbitration systems of various European civilisations have been connected with one or another absolute authority which may be divine or ideological in character or even, in the Kantian interpretation, an abstract logic relating value to imperative assertions.

(7) Various authors insist that a system of laws is distinct from a system of constraints because a law is a set of ethical statements. Hence, from the argument in (4) any law has a dual characterisation. One aspect of a law is an operational constraint upon usage or action (and this aspect is com-

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* Since this paper was written my attention has been drawn to several publications relevant to this subject. The first of these is a collection of papers by Vayda and Rappaport which demonstrate that certain ritual procedures (previously viewed as being epiphenomena of a society) act as the symbolic (descriptive or *A* component) regulatory system to maintain the *B* component goals of an adequate population density and conditions in which (for the given environment) the society exists in cooperative liaison with a partially domesticated animal community (Vayda and Rappaport, 1961).

The other publication is Wynne Edwards' work (1964) on animal dispersion. To use the present nomenclature he argues that stable animal communities involve symbolic (or *A* component) rather than physical competition for *B* component goals (in particular, in maintaining a population density that is compatible with their environmental conditions). As in the anthropological case, the symbolic interactions were previously interpreted as being epiphenomena of the organisation.

Had I been aware of this work when I wrote this paper it would have been possible to avoid certain cumbersome abstractions by reference to these specific ideas and the empirical data used to support them.

pletely specified by the written law). The other aspect is moral and is incompletely defined by the written law (the law is obeyed not only because of the operationally specified consequences of disobedience but also because it represents an individually valued intension). There is no reason to doubt the empirical validity of such a 'dual' image of a law though the meaning of its 'moral' content is obviously open to argument. For the present discussion we shall assume that the distinction between these different facets of a law is precisely the distinction we have already made between the *A* and the *B* components of an *M* model. We justify this assumption

(I) By arguing from (3) and (6) that a political system chiefly consists of arbitration subsystems.

(II) By arguing from (3) and from 2.2.8. that a minimal arbitration subsystem is an *M* system.

(III) From (3) that ethical statements are control statements and since they act upon an *M* system we infer.

(IV) That the duality evidenced in (4) implies that any such statement has an *A* and a *B* representation (in special cases this will reduce to its extensive specification and its intensive specification).

(V) If a law consists of ethical statements then it has at least this much structure (namely an *A* representation and a *B* representation). For any law that mediates control, or briefly, for any realistic law '*A* representation' $\Leftrightarrow$ '*B* representation' must be true.

As a result the set of effective laws is greatly restricted for any such law must (1) be understandable within the immediate domain of discourse of at least some arbitrator and (in mechanistic states) be within the potential domain of discourse of the relevant subset of the population *and* (2) it must satisfy conditions of a pragmatic and mechanical kind. If the *B* system is interpreted as a process in which mechanisms evolve then a law must be compatible with survival. There can be no suicidal Laws. Any Law must satisfy generalised propositions about the *B* system which have the calibre of evolutionary rules. If the *B* system is conceived as a network of intensions and values no law can contradict a generalised structure of desires and drives and motives. It must satisfy criteria of compatibility or (to conjecture slightly) it must have the essentially mechanistic property of being a moral law.

(8) Finally Weldon distinguishes between first order moral principles and second order moral principles. Again, the demarcation is not rigid but broadly second order moral principles concern the day-to-day existence of citizens, their immediate personal conduct and allegiance, their manners and their entertainment. In contrast first order moral principles are often beyond the immediate domain of discourse of a citizen but are represented, by magic or by parable, by the names of ideologies and religions, for example, by Christianity and Buddhism.

Now some disputes are *necessary* at any rate in the development of any system that evolves (where the dispute plays the part of the competitive feature of evolution, the feature that renders survival conditional upon success, or conditional upon co-operation). Moreover, we have argued that certain first order moral principles *seem* to be involved in any of the systems so far considered. In the organic state the 'highest' of these (in the sense of 'highest' in the hierarchy of a relevant normative theory) define the essence of the state. In a Locke-like state, first order moral principles are important to give the system coherence. So far as the other mechanistic states are concerned the first order moral principles appear with the chosen administration or arise from culturally or historically determinable rules. Now Weldon points out that it is first order moral principles that are prone to defeat arbitration and, partly on this account and partly because of their generality, it is first order moral principles that give rise to destructive conflicts, either conflicts between groups within a society, or between different states. People do not often get angry over second order moral principles and if they do their irritation can be moderated on rational grounds or a compromise solution can be reached without too much difficulty. But many first order moral principles seem to be diametrically opposed and particularly prone to form the matter of disputes. From this and our other postulates it is possible to deduce a number of consequences regarding the incompatibility of a pair of organic states with essentially different normative theories and the impossibility of any universal state.

Since it is obviously desirable to avoid destructive disputes it is reasonable to ask whether or not the appearances are misleading. Possibly they are. It is odd, for example, that most of the great moral issues that divided our ancestors either look to us like mildly contentious debating points or like frankly unintelligible propositions. The names persist, of course, but their connotation has changed. On the other hand, second order moral principles seem to enjoy, considerable invariance. People need to have gaiety and laughter and dancing and holiday seasons, regardless of the festival they celebrate. People need comfortable transport regardless of the state that provides it. The meaning of propositions about these matters is obviously mportant.

Now one possible interpretation of what occurs is that each generation produces a crop of names denoting very abstract concepts which are uninterpretable within the general domain of discourse but which evoke violent dispositions. Similarly a number of the names that acted in this capacity for previous generations are discarded. This process is to do with the linguistic A system and is relatively unaffected by the intensional B system although it is perfectly true that each name has a connotation, like 'Christianity' or 'Buddhism' that is intelligible in a valid sense to the elite. It does not matter very much what these statements mean, providing they are highly abstract, for the *fact*, of high abstraction appears, for some reason, to give them a high *value*. In contrast the meaning of propositions about holidays and dancing is, as we commented before, vitally important.

To reiterate my position, I do not, for a moment, contend that Christianity statements or Buddhism statements are characteristically devoid of meaning. But I do contend that the meaning of words like Christianity or Buddhism is irrelevant to their usage in the evocation of highly coloured dispositions for when they are used in this fashion they can have any meaning whatever. They are inherently ambiguous terms blessed with a high value, so that whatever they denote is also a highly valued entity.

Now words of this kind are obviously dangerous and disputes concerning them are necessarily incapable of resolution. If this analysis is valid, and it can be supported on various grounds, the disputes we are anxious to avoid come about because:

(I) There is a need, in the development of a linguistic or A system, for words that are able to evoke highly coloured dispositions.

(II) Some of the words produced for this purpose have no specific and generally interpretable connotation in the B system but *do* have a high value *because* they are abstract words.

One way to avoid the difficulties engendered by words of this kind would be to disenchant mere abstraction or to build a mechanism for the disenchantment of ambiguous but abstract terms into a social system. Another method, which we shall embed in our social M system, is to ensure that arbitration involves the use of a parable analogy rather than reference to an oracle.

Abstract model

2.3.2. (1) We shall construct an M model to represent a population U_1, $U_2 \ldots\ldots\ldots U_n$ in an environment C that consists of the various building blocks we have described. Thus any pair of individuals can be concatenated to form a restricted conversation in the sense of 2.2.3. or an unrestricted conversation in the sense of 2.2.4. (with the provision that unrestricted conversations either become restricted or terminate) and providing that the A_i^j involved satisfy the necessary conditions. Similarly any triple of individuals can become an arbitration system as in 2.2.8. (providing their A_i^j satisfy the necessary conditions) and we allow for the indefinite iteration of these structures by stipulating that any stable subsystem can be regarded as an individual. The chief requirement imposed upon this social M system is that if the B component of each individual is defined as an evolutionary process that is *not* autonomous (so that it only continues to evolve if it interacts with at least some other B components) and if each B_i^j is a self-organising system then the entire system is stable and the entire system evolves. We consider (amongst other things) the kind of constraint that is needed to ensure that individuals are *not* prevented from evolving.

This M system closely resembles the models that have been used for representing conversational interaction between individual subjects and an adaptive teaching machine and for representing the conversational interaction between a small group of subjects (Lewis, 1963a; Pask, 1962c; Pask and Lewis, 1962) (data is provided in the Appendix). In the latter case, experiments were performed to discover how a small group of people learned to carry out various roles in an inductive inference task, either individually or jointly. The experimental situation was completely mechanised and no communication was permitted except through mechanised channels of communication that connected one subject console to another. In these conditions it is possible to control the experiment by imposing a form of 'economy' upon the group. The reality of the 'economy' stems from the fact:

(I) That 'money' must be spent in order to purchase a physical connection or communication channel which is a pre-requisite for co-operative activity and

(II) That the amount of 'money' available to a given subject determines the degree of control that his preference exerts upon a periodic assignment of roles.

The entire experiment was controlled by an automaton able to sense the performance of each individual in the group and to estimate for each individual an index of learning rate or increment. This automaton was programmed to adjust the *payoff* obtained as a result of successful performance and the *cost* of purchasing a channel of communication in such a way that each participant had a positive rate of learning and, so far as possible, so that the average value of the learning rate index was maximised.

The assumption underlying this strategy was, of course, that man is a self-organising system that must learn about something (and this is one of the assumptions to be implanted in the present model). Further, the automaton controlling the experimental environment (which can be viewed as a property of the physical environment) is analogised in the present model as a vestigial form of the 'Universal Arbitrator'. The 'Universal Arbitrator' we shall introduce does, however, have many more capabilities than this simple automaton.

There are a number of other, more obvious, similarities between the experimental system and the present model as a result of which it may be legitimate to carry over some tentative conclusions from the experimental work. Of course a society is not the same thing as a small group, and the argument from group to society depends upon our assertion that a stable subsystem can be regarded as an individual. The empirical data which is introduced on the assumption that this view is accepted comes from observations of about 150 small groups in automatically controlled conditions involving approximately 500 hours experimentation. Since the control conditions in this microcosm are like the control conditions in the social *M* system we should not be too far amiss in statements about local behaviour. In particular, my contention that people do create an hierarchy of concepts in order to communicate effectively, that there is a need to learn and that the ability to learn at one level of discourse can be traded off against ability to learn at another level, stem directly from these experimental results. Some of the other assertions about the social *M* system are based upon the results of simulating evolutionary systems (of the kind briefly discussed in 2.1.8.). It is true that these simulations were intended to represent the mechanism of a learning process (in a subject's brain) and thus they are not immediately applicable to a society. However, one of the points contained in our present proposal is that social learning and individual learning are similar and inseparable, given which the evolutionary process is a useful heuristic device. We also rely upon more general conclusions about the development of stable evolutionary systems; for example, the general rule that any completely competitive pair of evolving subsystems is necessarily unstable (Hardin, 1963). Obviously a pre-requisite for any of the assertions that are made is that, in a dynamic sense of the term, the postulated structure or organisation will be stable. Finally, we shall assume for simplicity that if a pair of individuals are able to communicate, then their strategic actions interact. Hence, an individual domain of discourse is also a domain of individual strategies.

(2) In the first place let us assume that, due to the physical character of the universe, individuals exist. Each individual is minimally represented by an *M* system and as in Fig. 21 is able to communicate with at least one other individual in L°. We do not explicitly stipulate the price of maintaining the communication channel from one individual to another but comment that such a price exists. Further, any individual interacts with the physical universe *C* which represents his own fabric and the fabric of his environment. Channels of communication are created and paid for as a result of this interaction.

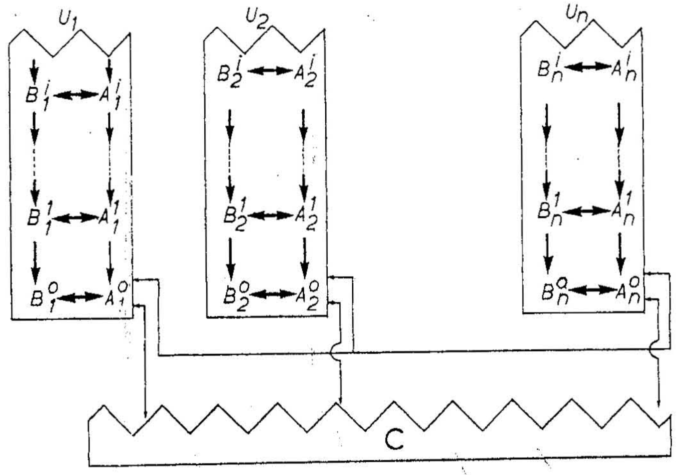

Fig. 21. L^0 is an open ended language.

An individual has temporal as well as geographical limitations. It is not difficult to show that any realised individual (roughly speaking any mechanism that is represented as a localised automaton) has a finite life span. The temporal limitation of a localised individual is a consequence of this fact (although we do not explicitly introduce a definite life span in our construction).

The process, B_i which gives rise to the hierarchy of mechanisms B_i°, $B_i^1, \ldots\ldots\ldots\ldots B_i^m$ in the ith individual, U_i, shown in Fig. 21 is evolutionary. It is restricted by the stipulation that, for $m \geqslant j$ and all j values, B_i^j is a self-organising system. Since $A_i^j \Leftrightarrow B_i^j$ we deduce that if we connect ourselves to the ith individual and indulge in a conversation then, *provided* that A_i^j is created (in other words, provided that $m \geqslant j$) but *regardless* of the level of discourse (if j is less than or equal to m) the individual U_i will learn.

It is not difficult to show, by simulation, that constraints can be applied to individuals of this kind that entail: (I) each individual must communicate with another in order to maintain a stable evolutionary process and further (II) there is an advantage to be gained from efficient communication (the Appendix contains supporting data). We shall assume that these constraints exist commenting that (I) is probably secured by a superadditive payoff function defined over the C interaction outcome states (Von Foerster, 1964) and that (II) implies that if U_i communicates with U_k and if A_i^j, $j > 0$ is available and if expressions in A_i^j are denoted by words in the alphabet of L° then the individual U_k will have to create A_k^j and to identify certain A_k^j terms with words in the alphabet of L° in order to communicate efficiently with U_i. Hence if the *advantage* of efficient communication is rendered a *necessity* then if any individual forms concepts at a higher level all individuals communicating with him are forced to attempt such a conceptualisation.

Empirically we have recognised a couple of important patterns of development in an M system namely, (1) the evolution of B_i in U_i gives rise to a widespread but low level communication to form a meta stable macrosystem and, (2) the evolution of B_i in U_i gives rise to an increasing *level* of communication with only a few individuals. Of these (2) is inherently stable for a reasonable payoff function but (if the cost of communication channels is as high as necessary to achieve the constraints we have assumed to exist) the development of (1) becomes instable. The instability is rectified by generating more efficient communication (by using L° words that denote higher level concepts). But *unless* U_i has already developed some experience in creating such concepts by dint of a local but high level interaction he may find it impossible to generate or participate in efficient systems of communication. In other words we have agreed to constrain our social M system so that any individual is associated at a given instant with an immediate domain of discourse. But also, due to the evolution of an individual, his immediate domain of discourse is likely to approach his potential domain of discourse, in the sense of increasing the number of contacted individuals, *and* in the sense of increasing the conceptual level of the communication.

Neither our experiments nor any others have involved sufficiently legar groups of subjects to admit a payoff function (or a form of C) that favours large co-operative aggregates and renders participating in extensive patterns of interaction *necessary* for the survival of any individual. However, the postulate that society exists implies such a necessity (and given that a large number of individuals is available the required constraints are perfectly obvious). Given such a system we must stipulate, as a necessary social condition for the continued evolution of the U_i that the ith potential domain of discourse is *always* greater than the ith immediate domain of discourse. Further, if this is the case any U_i has an opportunity for 'free choice' in the sense of 2.3.1.(2) and for creativity in the sense of 2.1./. If U_i represents a human being he is being 'humanly used' in Wiener's (1955) sense and we conjecture that U_i *does* represent a human being if the A_i^j are human concepts.

In addition this specification of a man satisfies the special libertarian requirements of 3.2.1.(6) and the tendency to arbitrate, which will be introduced in a moment, implies that men have a sense of injustice.

The system has a number of other properties that are worth mentioning, for example, functions like memory and the psychologically determined choices of 2.3.1.(2) are distributed about the population rather than being localised in an individual. There is also a sense in which events or utterances are multiply represented. In the first place they are represented at many levels of discourse. But also they are represented in many different individuals as states of these individuals (using 'state' in the sense of 'state' of a system) and in co-operative aggregates of individuals (as states of these aggregates).

(3) In order to satisfy the 2.3.1.(3) requirement that a social M system is built up from the arbitration subsystems of 2.2.8. it is necessary to postulate the existence of triples $\{U_i, (U_k, U_l)\}$ wherein any member can either be an individual or a co-operative aggregate of individuals.

The particular member U_i dominates the triple $\{U_i, (U_k, U_l)\}$ either because he has been asked to arbitrate by U_k and U_l or alternatively because he can enforce his arbitration upon U_k and U_l. Now we shall insist that such triples exist in the social M system and that whenever some triple is defined the dominant member, U_i, is *able* to arbitrate, in the sense of (I) below, and further, that in the sense of (II) below, it is to the advantage of U_i if he acts as an arbitrator.

(I) Suppose a discourse involving A_i^j, A_k^j, and A_l^j. Suppose that A_k^m and A_l^m are the highest conceptual models available to U_k and U_l. If A_i^{m+1} is available to U_i then U_i can arbitrate for U_k and U_l.

(II) Suppose there are outcome sets α, β, and γ in the interaction of U_j, U_k and U_l with C and one another. Of these α is an arbitrated and co-operative outcome set, β is preferred by U_k and γ by U_l in the absence of α although α would be preferred by each participant if it had occurred to them. It is worth U_i arbitrating for U_k and U_l if U_i prefers α to β or to γ.

Unfortunately, whenever dominance relations of this kind are allowed and certainly whenever they are positively encouraged, evolutionary systems are apt to reach a 'trapping state' in which one species becomes the only available arbitrator or a closely related 'trapping state' in which the arbitrated outcome has a single and often restrictive form. Since these tendencies are amply manifested in Barricelli's simulations and our own, I merely state them. But it is possible (though it is a lengthy business) to provide causal arguments that account (at various levels) for their occurrence. Whatever their cause it is evident that either 'trapping state' leads to a condition in which at least some individuals in an M system cannot evolve, which is contrary to our initial requirement. Hence, in (4) and (5) we introduce specific 'arbitration heuristics' that avoid these trapping states. The arbitration heuristics chosen for use in (4) and (5) are those that most plausibly reflect the constraints which appear to serve the same purpose in real life organisms.

(4) Any U_i may, potentially, act as an arbitrator. Insofar as this condition is satisfied the function of arbitration is distributed. But in order to ensure that the ability of a given U_i to act as an arbitrator is more than fictional it is necessary to introduce some further constraint. The chosen constraint is an arbitration heuristic that seems to apply very commonly in natural organisms and natural groups such as families. It is a stipulation that if α in (3) consists of a pair of subsets α_1 and α_2 such that the concept of α_1 ostensively defines $A_k{}^{m+1}$ or $A_l{}^{m+1}$ whereas the concept of α_2 does not ostensively define $A_k{}^{m+1}$ or $A_l{}^{m+1}$ then U_i prefers α_1 to α_2. In other words, whenever possible, U_i prefers to use a *parable* and to act as an arbitrator in Braithwaite's sense rather than acting as a priest interpreting an *oracle*.

Notice that this arbitration heuristic can either be regarded as a compensatory principle whereby the act of arbitration annuls the supremacy that allows U_i to perform as an arbitrator or alternatively as a rule for reproducing arbitration subsystems in the population.

(5) The application of (4) incidentally guarantees an increase in the level of discourse amongst the population. We now introduce a further arbitration heuristic that, once again, appears to characterise many natural organisms and natural groups and which has the incidental effect of increasing the extent of communication between the individuals in the population.

This arbitration heuristic might be dubbed a 'Tolerance Principle' or a 'Liberality Principle'. It stipulates that the arbitration carried out by U_i will ensure that if U_k has a more *liberal* preference over the outcome set, than U_l then U_k has an advantage over U_l due to his *liberality* in the sense of 2.2.8. Since the domain of discourse of an individual was assumed in 2.3.2.(1) to be coextensive with his domain of strategies the development of a communication network is also advantageous.

(6) The constraints embodied in (3), (4), and (5) are not implicit in *any* reasonable evolutionary system and *any* reasonable choice of linguistic structure. Hence they must be maintained in existence. Now these constraints could be maintained by using a 'Universal Arbitrator', a kind of umpire who looks over the shoulder of anybody acting as an arbitrator and makes certain that he does apply the prescribed arbitration heuristics as in Fig. 22

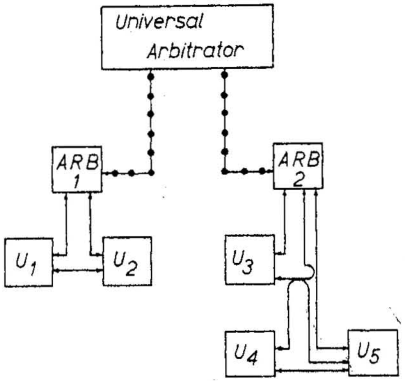

Fig. 22. Any U_i *may*, potentially, be an arbitrator. Connection -•-•-•- is established *if* U_i assumes this capacity.

The controlling automaton in the group learning experiment does something of this sort but, in many ways, the 'Universal Arbitrator' of Fig. 22 is more akin to a Supervisory Programme we have used in connection with the simulated evolutionary processes that are mentioned in 2.1.8.

In such a simulation a number of regularities appear amongst the population of automata. Thus automata show correlated motions or, as suggested in Fig. 23 wander around their environment in groups. After some experience of the system the experimenter learns the kind of regularity to expect in given conditions and he can design a supervisory programme that detects interesting regularities and does something about them. In Fig. 23 the supervisory programme detects dense regions of automata with an interior sparse region and reinforces all of the participating automata. It would, in principle, be possible to determine an initial set of parameters for the simulation that would not only give rise to the desired grouping of automata but would also provide a special form of environment that fostered this particular grouping. However, the choice of the initial parameter values is very difficult because a genuine evolutionary system not only generates automata but also generates rules that act upon the development of these automata and since the 'rules' are simply configurations in the population of automata so that they cannot readily be 'separated' out for special consideration.

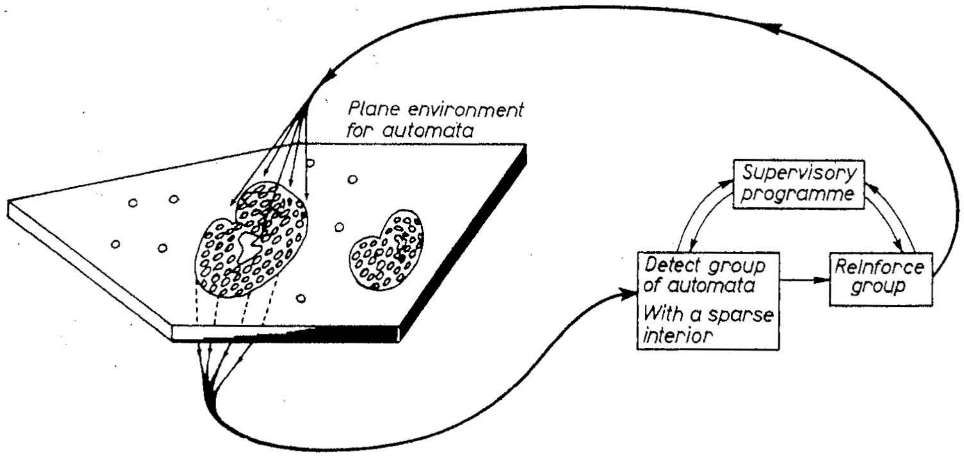

Fig. 23.

Now these comments apply with even greater cogency to an M system since, in addition to the perplexities of evolution, it is necessary to countenance the A and B interaction. The analogue for the supervisory programme is a correspondingly more elaborate structure. But just as it is easier to conceive the action of a 'Supervisory Programme' than the sequential effect of initial constraints, so it is easier to conceive the 'Universal Arbitrator' than the analogue, in an M system, for this sequential effect. The analogue is, of course, a system of laws.

(7) From 2.3.1.(7) a system of laws has a dual A and B representation and the different types of law form an hierarchy. An hierarchy of this kind is suggested in Fig. 24 but there is a very real conceptual difficulty in appreciating what a figure like this is intended to assert and I shall resort, once again, to

Type	Minimal level of arbitration	B Image of law as insensions or process		A Image or description of law	B Image of law		A Image of law
		↑		↑	↑		↑
IV	Any dominant U_i in L^β, $\beta > \alpha$	Homeostatic solution	⇔	Natural law??	Evolutionary rules	⇔	List of functors
		↑		↑	↑		↑
III	Any dominant U_i in L^α, $\alpha > 1$	Stable solution	⇔	Civil law	Classes of solutions	⇔	Sets of outcomes and values
		↑		↑	↑		↑
II	Any dominant U_i in L^1	Coercive regulations	⇔	Public School law	Classes of constraint	⇔	List of names
		↑		↑	↑		↑
I	Any dominant U_i in L^0	Direct force	⇔	Jungle law	Competitive solutions	⇔	Names of competitive situations
↑ Hierarchy of types of law	Degree of abstractions of law →	Specific cases of laws		← - - - - - - →	Abstract cases of laws		

Fig. 24.

analogy with the simpler concept of the simulated evolutionary system of 2.1.8.

At the start of a simulation we specify various attributes of the environment in which the automata of 2.1.8. will appear. Most of these are irrelevant to the initial automata. Others become relevant to co-operative groupings of automata, if and when they develop, whilst a few initially relevant attributes later become irrelevant. The hierarchy of Types of Law has this property amongst many others. Thus laws that are dependent upon and determined by stable solutions *cannot* be applied until there are active arbitration subsystems and laws that depend upon and are determined by homeostatic solutions *cannot* be applied until these arbitration subsystems evolve in a coherent fashion.

Another property common to a system of laws and a simulated evolutionary system is that many laws are dynamic. Arbitration not only applies laws to particular individuals, it also generates laws because it generates stable co-operative aggregates. We can certainly make a distinction between the extensive or A system specification of a law and other A system expressions but we cannot distinguish between the B system intension of a law and a configuration of the B system mechanism on which and through which it acts, because these are one and the same.

Any law can be stated in more or less detail by citing exemplars of its application. In Fig. 24 the most detailed assertions of laws are displaced horizontally. The *most* detailed specification reduces a law to an *indefinitely* long list of exemplars. In this case the A component of each item in the list is isomorphic with its B component.

Suppose that this array is extended indefinitely as suggested by Fig. 25. Where do we find the laws that completely replace or completely embody the Universal Arbitrator? What kinds of constraint are represented? Evidently we need the most detailed representation of the highest type of law, the upper right hand element in Fig. 25. This is a complete and Laplacian state description of the material constitution of the M system, the exhaustive specification of C. As we might have expected the Universal Arbitrator is a way of expressing the constraints of physical reality.

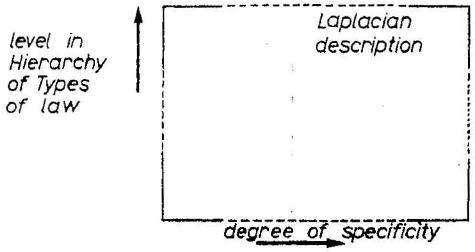

Fig. 25.

(8) The social M System we have outlined is neither maintained as a uniquely stable arrangement nor, in any sense, as an optimum social structure. So far as adequacy rather than optimality is concerned it maintains social learning and social evolution. Whether these phrases are viewed as laudatory or pejorative is a matter of taste. My chief reasons for introducing a set of constraints that resulted in an M system of this kind were that a proposed system is closely related to various other M systems about which a good deal of data can be provided and that a crass similarity appears to exist between the proposed M system and the maturational system to be considered in 2.3.3. It is certainly possible to construct special cases that have a number of interesting and, from the viewpoint of the sociological literature, unexpected properties.

(I) The social M system develops by an interaction between an evolving linguistic structure that constrains the discourse between individuals and an evolving set of mechanisms that contain the intension of expressions in the currently adopted conceptual language.

(II) It is possible to demonstrate M systems that do not become partitioned into destructively competing parts and there is no particular need for destructive dispute. We may conjecture that this is due to the bias in favour of arbitration involving the use of parable analogies that prevents the currency of abstract but ambiguous terms. It is true that a number of essential dichotomies exist, for example, the dichotomy between linguistic description and mechanism, between the extent of communication and the level of communication, the competition involved as the background for a co-operative evolutionary process and the dispute that constitutes the background for arbitration. The dynamics of these processes might be described in terms of thesis, antithesis and synthesis or in various other ways but they are all controllable by a sufficiently flexible system of evolving laws. The issue of whether or not a universal state is possible appears to depend upon whether or not a universally accepted linguistic structure is possible and this remains undecided.

(III) Attributes such as memory, choice, and arbitration are distributed rather than localised.

(IV) The concept of a developing hierarchy of different types of law is one essential component of the M system.

(V) If a class of law is represented by the set of exemplars of its application these exemplars have an isomorphic A and B image, hence the A and B distinction becomes redundant.

(VI) In this reduction the Universal Arbitrator is a complete and Laplacian state description of the system.

(VII) We claim that if the U_i are human beings then they are to a first approximation humanly used.

In this connection our arbitration heuristics act in a very elaborate fashion to achieve a condition that avoids the possibility of any 'trapping state' over a certain finite interval which it may be convenient to regard as the maximum life span for an individual. Thus it is apparent from Barricelli's work and our own work that evolutionary systems of the kind represented by the B component are liable to reach 'trapping states' in which, for example, one species of automaton dominates the population. If we now consider the set of *coupled* evolutionary systems, where the coupling is exerted between individuals through the A component, the same comment is likely to apply. However, the arbitration heuristics secure a condition in which any potential 'trapping state' in a *coupled* system, hence any joint evolutionary subsystem compatible with the linguistic constraints imposed upon the coupling, can be avoided. The legal consequence is that arbitration cannot and does not impose laws that apply indefinitely but which depend upon the immediate status quo. Hence a law that applies, say, to Jews, because they are Jews, and applies indefinitely since no individual can change the attribute of his national status is not legally possible. In fact this is a consequence of several restrictions but it depends particularly upon the requirement that arbitration is a distributed activity.

(VIII) Finally the arbitration heuristics and the definitions we have adopted lead to a reasonable interpretation of any phrase like 'Freedom of Choice'. If an individual has 'Freedom of Choice' he must make decisions about the alternatives in a domain of discourse that is as large as his evolution determines providing that his choices give rise to stability, in the dynamic sense of the term. Thus, at a practical level, we should not normally say that a University Professor was 'Free' if his choice was restricted to the domain of discourse chosen by most Bank Clerks or most labourers or most Company Directors. It is also the case that the arbitration heuristic is apt to discourage conditions in which University Professors are not 'Free'. We are, of course, adopting the Professor, falsely perhaps, as the paradigm case of an individual who is anxious to arbitrate.

*Psychological systems**

2.3.3. (1) An M model appears to be a minimal representation for any competent and comprehensive psychology of learning and maturation that deals primarily with man. There are a couple of reasons for this, namely:

(I) Significant propositions within such a system of psychology are stratified and necessarily entail some non-trivial hierarchical structure or progression and

(II) Significant propositions involve a duality of models, A type and B type, which may in some cases, be identified with 'descriptions' and 'mechanisms', in other cases with 'action' and 'effect'.

Writing $\triangle (A)$ for a change in the A_i^j and $\triangle (B)$ for any change in the B_i^j and writing $\triangle (A, B)$ for a joint or correlated change we thus contend that accounts of learning or maturation involve changes $\triangle (A, B)$ and that pure $\triangle (A)$ and pure $\triangle (B)$ are fictions in this connection. Of course the experimenter can *talk* about $\triangle (A)$ or $\triangle (B)$. But these transformations do not occur as a *result* of learning or maturation.

If we attempt to formalise Freudian psychology, for example, the least model that can be seriously considered is an M model. The stratification of (I) is an obvious concommittant of the system. So far as (II) is concerned there is a rough and ready correspondence between the mentation mechanism that is characteristic of the Id and the B model. Similarly the communicable and regular activity of the Ego is broadly identifiable with an A model. Because these correspondences *are* rough and ready and because the system is clinically oriented we may reasonably doubt the value of formalising a Freudian psychology in any fashion. My point is simply that the attempt could not be *made* within any narrower compass than an M model.

(2) As Hebb (1949), George (1961), and others have argued, a Cybernetic approach obliterates the classical dichotomy between the Gestalt and Associationist points of view. When man is regarded as a creature engaged in a control process there is always a holistic side to his activity and there is always an atomistic side and Cybernetics impels the experimenter to consider one facet or the other according to the enquiry in progress.

Undoubtedly, this approach has illuminated the field and it is most explicitly embodied in the TOTE model of Miller, Gallanter and Pribram (1960). Within this system the concept of a plan or programme is used to

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* These comments are mostly concerned with developmental psychologies, since the wider issue of cybernetics and the psychology of learning is examined in other publications in particular Pask, 1964a.

organise a hierarchical structure of TOTE units each of which represents computation of a recursive function or, in rather more concrete terms, the application of an operation and the testing of a difference, until the test reveals that the operation has removed this difference. The hierarchy in this system is an hierarchy of control. Its components can represent a 'concept' in Hovland's (1952) or in Bruner, Goodnow and Austin's (1956) sense of the word. But as it stands the model is an A model which would be masquerading as a C model if it were advanced as more than a *description* of the control structure. Now a good deal of confusion *does* arise at this point simply because a resolution into TOTE units is such a convenient representation. In fact, it represents a description of control (or it could be identified, alternatively, with a mechanism of control) but, as we have argued, there are only a few special cases (when $A \Leftrightarrow B$ becomes an isomorphism) in which a C Model adequately determines a system and consequently in which a single TOTE hierarchy is a sufficient account of mentation. Certainly Miller, Gallanter and Pribram recognise and emphasise this point when they introduce the concepts of 'heuristics' and evaluation procedures that are not parts of the TOTE hierarchy but are necessary elements in the description of learning. As we pointed out in 2.1.6. the B model affords, in one plausible interpretation, an image of the form of evaluation procedures and the selection of heuristic rules.

(3) Another distinction that is obliterated or at any rate reduced by the Cybernetic approach is the boundary that separates an individual from the society in which he develops and the physical environment in which he lives. On the one hand there is the purely notational fact that an M model representing an individual can and indeed must be embedded in some other M model (representing either the experimenter or society). On the other hand, as we argued in 2.2.2., the minimal system for experiments concerned with learning is a teaching system involving a pair of M systems (and this is far from a merely notational point). Broadly, we contend that an individual is defined in relation to a community or environment in which he is embedded so that unless the form of this association is specified the term 'individual' is functionally vacuous. Insofar as precise learning experiments are concerned, only a very limited interaction can be considered, namely the restricted conversation of 2.2.2., and insofar as we are concerned with enquiries about maturation it is necessary to consider the fashion in which the unrestricted discourse *between* individuals gives rise to the restricted conversations of *an* individual.

Let us now consider those psychologies that satisfy (1)(I) and (1)(II) and generally represent individuals that have been embedded in a social M system such as the structure considered in connection with arbitration and the discourse of ethical statements in 2.3.1. and 2.3.2. The most important systems of psychology that can be identified with such a model are those of Piaget (1962) and Vygodtsky and Luria (1961).

We shall first identify components of each system with components of an M system. Next we shall consider a few typical processes.

(4) Piaget's system of psychology is at least an M system. We shall use Flavell's (1963) commentary as the referent in our discussion.

(I) There is a unitary mentation or Basic Process and this is evolutionary (in the sense that its B modelled mechanism is evolutionary). Hence B is defined and if A is defined it is restricted as in 2.1.7.

(II) The distinction between action and effect is a distinction between an A model and a B model and if A is defined then $A_i^j \Leftrightarrow B_i^j$ for U_i.

(III) To show that the A model is defined (in the least elaborate case) consider the transition from the initially egocentric phase into the realisation that the environment exists or that there is a *problem* to solve. At this point, when the schemata are sufficiently differentiated to define an intelligible problem, the child ceases to be a creature like the point in Abbott's (1884) Flatland and becomes an individual in relation to its environment. In our nomenclature U_i is defined as an M system $A_i \Leftrightarrow B_i$ in the social M system.

(IV) From this point in development, the system postulates an ontogenetic progression through an hierarchy of stages each of which is characterised by a 'structure d'ensemble'. From the unitary mechanism postulate (or, in order to maintain the validity of this postulate) the levels in this hierarchy are non-trivially distinct as in 2.1.7. (they are associated with $L^\circ, L^1, \ldots\, L^m$).

(V) A 'schema' is a programme in some A_i^j. An *organisation* is imaged by some part of a model A_i^j and the model A_i^j is the description of a set of organisations associated with some ontogenetic state, for example, one of the 'groupings' is such a model.

(VI) Recalling that adaptation is the result of a pair of processes, namely *accommodation* and *assimilation* which jointly lead to a dynamic equilibrium or metastable condition *at* a given level, a particular adaptation at the jth level has the form $\triangle\,(A_i^j, B_i^j)$.

(VII) Accommodation is the effect of a change in B implying an analogous change in A, namely $\triangle\,(B) \rightarrow \triangle\,(A)$ and, as Piaget points out, this is an analytic concept whereas adaptation is observable.

(VIII) Similarly assimilation is an analytic concept of the form $\triangle(A) \to \triangle(B)$. Hence $\triangle(A_i^j, B_i^j,) = \triangle(A_i^j) \Leftrightarrow (B_i^j)$.

(IX) The property of schemata, namely of programmes in some $A_i^j \Leftrightarrow B_i^j$, that they 'become applied' can be inferred from the fact that the B_i^j evolve. This property is equivalent to our postulated property that a man must continually 'attend to and learn about' something. And that each B_i^j is a self-organising system.

(X) Horizontal Decalage within a level j (given that U_i is posed suitable problems α and β) is the extension of some programme in A_i^j to the domain of β when previously it was applicable only to α. Vertical Decalage is evidenced by the application of a programme a in A_i^{j+1} to a given problem previously solved in the same fashion by a programme b in A_i^j. The idea of a disposition unites these separate applications (the subject has the same disposition to solving this problem).

(XI) The assertion that levels of mentation develop is equivalent to the joint assertion that B gives rise to A and that some programmes in A_i^j ostensively define others in A_i^{j+1} through inducing dispositions in B_i^{j+1} which is the creativity of 2.1.8.

(XII) The hierarchy of Transitively ordered levels of organisation characterised by groupings and their referents (and the corresponding developmental stages, 'concrete operational' and 'hypothetical operational' and so on) are not mere abstractions (although the description of their characterisation has this calibre, as in (V)). On the contrary, each stage in development is realised in association with a corresponding level of motivation or even of effect. This much can be inferred from (X). Hence the hierarchy of A models, implicit in (V), is associated with an hierarchy of B models.

This hierarchy thus stands in the same relation to the M system of individual development, as the hierarchy of laws stands in respect to the social M system considered in 2.3.1. and in 2.3.2.

Further, without specifying the *extent* to which development depends upon the internal evolutionary process and the *extent* to which it is controlled by instruction and social interaction, it is obvious that the individual M system is embedded in a social M system. Indeed, in his recent comments upon the criticism Vygodtsky submitted on this score, Piaget agrees to a difference, if at all, of degree between his point of view and Vygodtsky's.

(5) What is gained from these identifications?

(I) We gain some insight into the logic of the system which complements the account given by Piaget. In the present nomenclature development is a process of control involving an interaction between $\triangle(A)$ and $\triangle(B)$ and the inseparability of accommodation and assimilation is a consequence of the assertion that the basic unit is a *control* procedure. Again, the broadest specification of this interaction entails the extensive description of the L^j (the set of models that *could* be described at the jth level, determined for all values of j). In fact, only a subset of this set, say a subset A^j of the extensive description of L^j, is available. The models that actually appear in U_i at a given instant or a given ontogenetic level, are A_i^j and are members of A^j. In Piaget's system, the constraints the A^j may either be inherited or social. In any case they are determined by one or more sets, Z_1 of family continuous observations in the sense of 2.1.4. and of 2.1.6.(2). Experimentally we consider the behaviours of A_i^j, B_i^j and these behaviours are apparent in another set, Z_2, of family continuous observations. But Z_1 and Z_2 are not family continuous.

(II) We gain the possibility of predicting certain features of the system independently. As in (I) above the system is chiefly presented by Piaget in terms of experiments which provide observations in the family continuous set Z_2 that assert the existence of particular A_i^j, B_i^j. However, given the A^j and given that the B_i^j are generated by a viable evolutionary process, certain predictions can be made (of the kind we considered, for a social M system, in 2.3.1. and in 2.3.2.) which turn out to be confirmed by the behavioural observations in Z_2. To avoid repetition, assume that the M system of individual development is analogous to the social M system. In this case we can infer Piaget's concept of a process whereby equilibration *at* the jth level leading to a situation that requires equilibration *at* the $j + 1$th level and predict the empirical concomittants of this process although the form of equilibrial process depends chiefly upon the A^j, its application can be iterated without limit.

(III) It is possible to relate various systems that are wholly or partially representable as M systems. Thus we shall later relate Piaget's system to Vygodtsky's and Luria's system.

(IV) Finally there is an important possibility of constructing very detailed models of restricted conversations which also have the calibre of M models. We have erected models of this kind in connection with adaptive teaching systems. Since their microstructure reflects the macrostructure of the overall M system it is feasible to derive and test rather detailed hypotheses. Since the detailed model is embedded in the overall M system this evidence confirms or denies the overall M model.

(6) Now we have argued that a macro M system like Piaget's is embedded in a social M system of the kind considered in 2.3.1. and in 2.3.2. Further the micro M system of a restricted conversation is embedded in this macro M system. There is consequently an odd but interesting continuity amongst such M systems and *one* way to exhibit it relies upon the relation '$\Leftrightarrow$' which (as we commented in 2.2.2.) can be viewed as the naming of a particular mechanism as capable of describing itself in discourse. Let us illustrate this point in embryological terms.

Suppose we *choose* to name some embryo U_i and we pursue U_i throughout his existence (performing experiments such that the relation $A_i \Leftrightarrow B_i$ allows us to apply the chosen name). My contention is that it will be possible to discover, in family continuous observations Z_1, the basis for a sequence of hierarchies A_i (1), A_i (2) . . . . and in family continuous observations Z_2, the basis for a sequence of hierarchies B_i (1), B_i (2) . . . . such that A_i (r) $\Leftrightarrow$ B_i (r) but that excepting in the limiting case Z_1 and Z_2 are not family continuous. To exemplify the point, our initial A_i (1) will be a genetic code and our B_i (1) will be the energetic mechanism of one or a few cells in the embryo U_i. Next, A_i (2) will describe a more general code, a set of hereditary *and* maternal constraints, whilst B_i (2) is the mechanism of the embryo and some parts of the placenta (this pair A_i (2) $\Leftrightarrow$ B_i (2) is what we *now* call U_i and there is family continuity between the evidence for A_i (1) and A_i (2) and family continuity between the evidence for B_i (1) and B_i (2)). At a later stage A_i (3) the code of A_i (1) becomes an hierarchy of linguistic constraints, pertinent to intra-uterine learning and already coloured by the restrictions of babyhood (upon *possible* limb movements and *possible* sensation patterns). Correspondingly B_i (3) is the hierarchy of mechanisms involved in foetal evolution. Notice that the models do not necessarily become more elaborate. But in the sense of 2.2.1. the positive analogical properties and the negative analogical properties in '$\Leftrightarrow$' are continually changing as different attributes of the physical system become relevant and others become irrelevant to U_i. The mechanism for maintaining '$\Leftrightarrow$' such that U_i exists is a change from neutral to positive or neutral to negative amongst the properties defining this analogy relation.

Finally the child U_i is born. A_i (4) is a model that refers to a language of simple signs, sensations and actions but which in an organism as structured as U_i can be held to ostensively define the language of social discourse that becomes the chief origin of relevant constraints upon the development of A_i (5).

Hence the ontogeny of U_i apart from being a development of A_i $\Leftrightarrow$ B_i, is also a journey through layers of relevance of which the latter stages (arbitrarily conceived as the transition from A_i (4) $\Leftrightarrow$ B_i (4) into A_i (5) $\Leftrightarrow$ B_i (5)) is a passage from immediate and genetic to social (and in the ordinary sense of the word) linguistic relevance. Notice, however, that each A_i (r) is an hierarchy and that insofar as A_i (r) $\Leftrightarrow$ B_i (r) can learn, a generalisation of A_i (r) is contained in some level of A_i $(r+1)$. Crudely, we might depict the process as GENERALISATION $[A_i^j(r)] \rightarrow [A_i^{j+1}(r+1) \Leftrightarrow B_i^{j+1}(r+1)]$ where the GENERALISATION operator is $B_i^j(r)$.

Manifestly this is the generalisation of self reference and a minimal application of Minsky and Selfridge's (1962) generalisation heuristic to the entire organism. There is *no* particular paradox of self reference. An organism is bound to observe itself if it learns and, like an outside observer, it is bound to change its view of those parts of the physical and linguistic world that are relevant to itself. Ultimately *the* relevant features are more or less specific organisations embedded in the social M system. An individual, in order to grow *as* an individual, grows *into* a social organisation. In this sense U_i can acquire the permanence of a social M system and, as we shall argue in 2.3.4., in this sense it can be 'immortal'.

(7) We shall consider the part of Luria's (1961) work that deals with a couple of changes that occur in the way children solve problems. One of these is the change from a simple use of speech (denoting stimulus and response terms which, for this purpose, we associate with L° and A_i°) to a more elaborate use of speech characterised by semantic content (denoting instruction terms or expressions associated with L^1 and A_i^1). The other transformation is a change from internal to external control over the development of the A_i^j and a later change back to internal control.

The experimental situation is a simple choice arrangement. The subject is asked to press a button or to select one of several buttons contingent upon visual stimuli such as the appearance of signal lamps and contingent upon verbal instructions. This work differs from superficially comparable experiments because the experimenter is primarily interested in the effect of verbal instructions and the question of their semantic content. Hence the effect of an instruction is not taken for granted.

If a child of 2 years is asked to press a button he readily does so. If he is asked to press a button after a signal lamp is illuminated, but not before, he usually fails. Either he starts pressing immediately or he does not press at all and if he does press the button he is apt to perseverate his response. Further, a verbal request to 'stop pressing' normally has the effect of making him continue the pressing action. In other words the instruction can initiate an action but it can neither terminate nor modify the action. However if the experimental situation is so contrived that the signal lamp is extinguished by the response and a child of the same age is asked to press a button 'to extinguish the lamp' then he is successful. The basic unit of behaviour is a control mechanism and the modified experimental situation provides the necessary feedback data.

At the age of 3 years the child is able to accept instructions that call for fairly elaborate selective responses conditional upon the appearance of a stimulus. However it is still the case that the assertive aspect of speech is stronger than its negating aspect. The instruction "Do not press" acts like the instruction 'Press'. Hence at this stage, words appear to be acting as stimuli denoting signs in A_i° and devoid of the semantic content that distinguishes a negation from an assertion. This point is confirmed by other experiments. In a sequential experiment there is evidence that the response is perseverated. Luria and his colleagues have also found that at this age the visual feedback can be replaced successfully by a verbal (response negating) feedback but this feedback (which acts as a reinforcement in addition to a response negating signal) must be repeated continually to achieve a satisfactory performance. By the age of 4 years the child is able to verbalise more fluently and reliably and it is possible to make him provide an *internal* signal which inhibits his own response perseveration. Initially the internally produced signal *must* be spoken aloud to prove effective. Later, however, the signal is whispered. Finally, it becomes suppressed or internalised altogether, and at this stage is a part of the internal speech considered by Vygodtsky. In conditions of overload or when the child is presented with problems that are difficult enough to prove unintelligible the various stages of development are recapitulated. The internal speech becomes whispered and possibly even spoken aloud. If the overload becomes excessive the subject begins to use spoken and internally produced reinforcement signals that act as signs in A_i° rather than signs with a semantic content applied at the A_i^1 level of discourse.

It is thus possible to empirically confirm the pair of transformations we considered at the outset. In the first place there is a change in the function of reinforcement signals from the status of signs in A_i° to A_i^1 (and there is evidence that this transformation is iterated indefinitely). But in order to achieve this change of function (which is, perhaps, the really essential feature in a learning process) there must be co-operation. The co-operative participant may be the experimenter who provides continual feedback and reinforcement or at a later stage the child may act like a surrogate experimenter by speaking the verbal reinforcement signals aloud. However, he can only act in this surrogate experimenter capacity when he has learned to use words that denote components of A_i^1 rather than A_i° as a result of social or educational interaction. Somewhat later, the feedback system elaborated by co-operative interaction is internalised or, in our nomenclature, some part of B_i^1 is created so that a stable system $A_i^1 \Leftrightarrow B_i^1$ exists in his mentation above the original system of $A_i^{\circ} \Leftrightarrow B_i^{\circ}$. There is adequate data to show that co-operative interaction is needed to guide the creativity of the child (for the production of the B_i^1 is 'creative' in the sense of 2.1.8.) but the amount of guidance necessary for development decreases as the systems at the various levels of discourse (namely the systems $A_i^{\circ} \Leftrightarrow B_i^{\circ}$ and $A_i^1 \Leftrightarrow B_i^1$) become more elaborate. The idea underlying this work on co-operation is due to Vygodtsky and we shall next consider the theoretical framework in which he embedded this and other concepts. I shall represent this framework in the nomenclature of an *M* system and refer to the original terms when ambiguity is possible.

(8) One of the basic contentions in Vygodtsky's (1962) theoretical framework is that the unit of mentation involves control and meaning. It involves control because there is a continual and normally social interaction involved in producing a feedback loop. It involves meaning because 'words' and 'thoughts' are inseparable or using our present nomenclature because each element of discourse, internal or external, has the form $A \Leftrightarrow B$ rather than *A* or *B*. This construction is valid because it does not differentiate between the location of the *B*. Thus if U_1 represents the student and if system U_2 represents the instructor and if there is enough common ground (or understanding in the sense of 2.1.6(6)) to effect instruction so that $A_1^j \Leftrightarrow A_2^j$ it will be possible to represent externalised and co-operative establishment of some feedback system by an image like $B_2^j \Leftrightarrow A_2^j \Leftrightarrow A_1^j$ (when B_2^j acts in place of the system B_1^j) and the internalised maintenance of a feedback system as $\triangle(A_1^j) \rightleftharpoons \triangle(B_1^j)$ which is implied by $A_1^j \Leftrightarrow B_1^j$. Obviously the externalised co-operation is identical with the establishment of a control analogy by a restricted conversation as in 2.2.2. and the internalised process is identical with the maintenance of an internal analogy as in 2.2.2.

But learning occurs and to comprehend this fact it is necessary to postulate (I) that the B_i^j are produced by some evolutionary or maturational process and that other members of society like U_2 are anxious to instruct U_1 (or, in the sense of 2.1.6. (1), they prefer to instruct U_1). Incidentally, if we postulate that for all values of i the B_i^j are produced by some evolutionary process, as we did in considering the social M system, then any U_2 will be anxious to instruct U_1, at some stage in his development. Next (II) we must postulate a physical and linguistic structured environment so that expressions in A_i^j ostensively define expressions in A_i^{j+1}. Unless postulate (II) is the case learning cannot occur but if (II) is the case then the combination of (I) and (II) implies that learning *must* occur. The internal interaction that maintains the internal analogy $A_i^j \Leftrightarrow B_i^j$ will embody transformations of the form $\triangle(A) \rightarrow \triangle(B)$ and other transformations of the converse form $\triangle(B) \rightarrow \triangle(A)$ (which are equivalent to the processes of assimilation and accommodation in Piaget's construction) and at least *some* of these changes will entail alterations of disposition imaged as $\triangle(A_i^j) \rightarrow \triangle(B_i^{j+1})$ and ostensive definitions which (if A_i^j is the highest level model for the relevant universe of discourse at the instant concerned) are imaged as $\triangle(A_i^j) \rightarrow \triangle(B_i^{j+1}) \rightarrow (A_i^{j+1})$, where A_i^{j+1} is created in the process. As in Piaget's system, Vygodtsky contends that the processes $\triangle(A) \rightarrow \triangle(B)$ and $\triangle(B) \rightarrow \triangle(A)$ are inseparable. Whereas Piaget conceives the minimal process as an adaptation like $\triangle(A) \rightleftharpoons \triangle(B)$, Vygodtsky conceives the minimal *unit* as $A \Leftrightarrow B$ and adjoins the postulates required to ensure that the meaning of these 'word and thought' pairs will *develop*. Although Piaget and Vygodtsky place a different emphasis upon the importance of internal and strictly maturational processes and the importance of external or co-operative processes, the difference is only one of degree (Piaget, 1957).

Some of the apparent differences between Piaget and Vygodtsky on the issue of egocentric speech (Piaget, 1962) are rendered far less poignant in terms of this M model. Thus it is a consequence of the construction that an isolated egocentric child is like the isolated point in Abotts Flatland (we made this assumption in our earlier discussion of Piaget's system) and that in order to *be* an individual the child must see himself from other points of view (the most egocentric organism is *least* able to see himself and be an individual creature). Again, the words in the metalanguages, $L^\circ, L^1 \ldots\ldots L^m$ denote concepts, albeit in some cases very crude concepts. In each system the first really important stage is demarcated by an ability to use 'words' in this 'metalinguistic' sense. Vygodtsky, reviewing the work of Kohler, Buheler, and Stern concludes that the origins of intellectual processes and verbalisation processes are independent and points out that mentation acquires a novel aspect when they are coupled, when, for example, the babbling of a child, the kind of thing described by Osgood, is coupled to the use of other than verbal processes. This event is not only important because it admits communication and thus effective co-operation. It is also important because a very effective internal organisation has been created, namely, the organisation of internal speech.

In most respects, Piaget's theory and Vygodtsky's theory have many points of similarity. Vygodtsky discovered from his experiments with test blocks that organisations are hierarchical and their acquisition is transitively ordered. In this connection Vygodtsky's nomenclature differs from the nomenclature of this paper for he uses the term 'concept' in a very specific fashion and characterises the levels of discourse in his hierarchy by the manipulation of syncratic aggregates (of objects like test blocks denoted by terms in L° or simply of the terms), by the manipulation of complexes, preconcepts and finally in the adolescent of 'concepts'. The hierarchy is conceived 'vertically' as of an increasing degree of generalisation (thus a preconcept has a greater degree of generalisation than a complex). Its 'horizontal' co-ordinate is a denotation but, as Vygodtsky points out, this co-ordinate system is only a rather convenient and oversimplified image. Scientific 'concepts' are distinguished from other 'concepts' by the existence either in the social milieu or in the language of a structural hierarchy in which they are located, for example, one of the groupings that appear in Piaget's construction. Since each element in this hierarchy has a structure $A \Leftrightarrow B$ it constitutes an hierarchical structure of laws, as in 2.2.3. analogous to or identical with those of a social M system.

Specific problem

2.3.4. (1) The human brain wears out. Further, any brain is, to some extent, isolated from any other. Hence there is a practical limitation upon the development of human knowledge, for it cannot develop indefinitely in a brain that necessarily wears out and it cannot, in the ordinary way, be transferred from one isolated brain to another with sensible efficiency.

(2) If a society of individuals brains is represented by an M system with typical components U_1 and U_2 then the difficulty is evidenced by a restriction, as in Fig. 21 to communication in L°. However, if L° is an open ended language (which it is, of course, being a language like L) then there is no *absolute* dilemma. As Vygodtsky points out (in connection with internal language) U_1 and U_2 may become more closely coupled and approximate Fig. 26 when the modality at level L° is so developed that words in the alphabet of L° denote concepts in L^j, $j \geqslant 0$, for arbitrary values of j. Indeed, as U_1 and U_2 become more closely coupled they become like a single brain

and when Fig. 21 becomes Fig. 26 the use of any language, as a communication medium *between* individual brains, becomes increasingly redundant.

(3) One practical expedient for increasing the bounds of knowledge is to institute teaching procedures 'whereby younger brains are instructed' that utilise the efficient forms of conversation in which personal languages are developed and words in L° are given a vastly informative connotation. The adaptive teaching systems (which have been considered in several other papers Pask, 1960b, c, 1962d, 1963c, 1964e; Lewis, 1963b; Lewis and Pask, 1964) aim to achieve this result by approximating the organisation of Fig. 26 rather than Fig. 21 when U_1 = The Instructor and U_2 = The Student. This idea closely parallels the educational proposals made by Vygodtsky in 1924 although the systems concerned were devised in ignorance of this work and from a somewhat different point of view.

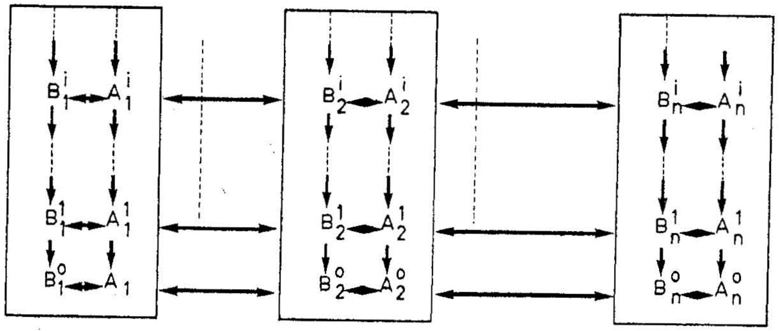

Fig. 26.

(4) Another practical expedient is concerned with man/machine symbiosis (Pask, 1963d, 1964f). Once again we aim to approximate the organisation in Fig. 26, rather than Fig. 21. In this case U_1 = An Artificial Intelligence Device and U_2 = A man using it. There is reason to believe that an Artificial Intelligence capable of developing such a genuinely symbiotic discourse can be built. (The issue is discussed in other papers, but a typical system consists of a machine that co-operates like an apprentice with a designer. Initially this machine is used as a tool. Gradually, as the conversation between it and the designer proceeds, it acquires the calibre of an assistant able to make coherent suggestions and to co-operate with the designer. Eventually the designer has exteriorised much of his mentation and the organisation in the machine is functionally indistinguishable from the organisation in his brain.)

Let us assume that this co-operative liaison can be brought to an arbitrary degree of perfection and call the process whereby mentation is exteriorised in terms of a machine organisation 'Translation into a Machine'. Empirically it is possible to achieve rather effective 'Translation into a Machine' using fairly simple machines.

(5) It is well known that no finite automaton can be immortal. However, Loefgren (Loefgren, 1962; Von Neumann, unpublished works) has shown that a certain class of infinite automata or organisations in energetically open evolutionary systems can be 'immortal' (since they repair the structural defects that occur of necessity) and can also perform useful computation (the degree of which increases as the system evolves).

(6) Let us assume that an 'immortal' automaton, in the sense of Loefgren, can be physically realised. In one way the assumption is trivial. It can be constructed in physical material without difficulty. A consideration of what happens later is not entirely trivial.

(7) Let us perform translation into a machine that consists of an 'immortal' automaton capable of computation and capable of a degree of computation that increases when this system evolves. There is nothing to prohibit translation from a number of different brains into the same 'immortal' automaton or from one automaton of the kind into another. In particular, an adequate translation will define an analogy between the 'immortal' automaton and a description of a brain or another machine. Thus the resulting system will be another M system in which the B component is the kind of evolutionary process that gives rise to an 'immortal' automaton.

(8) If this procedure is possible then there is no absolute limitation upon knowledge and the practical boundaries can, in principle, be extended indefinitely. One of the most important tasks for Cybernetics is either to show that this argument is false (in a realistic rather than a pernickety way) or to realise this procedure. (Since the really disputable part of the argument concerns the translation process, and since, in special cases, this can be shown to occur in discourse between real brains, it would be difficult to deny the essential possibility of such a realisation.) It is interesting to conjecture that there are many systems in the environment that act as immortal automata and that the interactions entailed by the translation of concepts into these systems take place 'possibly without being noticed'. If our argument

in 2.3.1. and 2.3.2. is valid a social M system can act as an immortal automaton. Perhaps a *strictly* deterministic view of the environment implies that this *must* be the case, which poses an intriguing circularity of ideas.

SUMMARY

This paper consists of a number of speculative comments chiefly motivated by the late Professor Wiener's concern to generalise the domain of Cybernetics so that this science would comprehend the control of social and psychological systems. Amongst other things any competent account of such a control process must embody some representation of ethical statements and a method for dealing with intensions. We consider a few of the difficulties involved in achieving this level of generality and conjecture that systems of this kind cannot be represented in any model less elaborate than a so called 'M model'. An attempt is made to identify the 'M model' with various systems and some broad and tentative arguments are advanced regarding the consequences of establishing such an identification.

APPENDIX

Since the empirical data concerning these systems are chiefly contained in Technical Reports by B. N. Lewis and myself, which are not always readily available, an attempt will be made to indicate its relevant features and where it can be discovered. So far as the evolutionary simulations are concerned, the data are contained in Annual Summary and Technical Reports stemming from Contract AF61(052)–640 sponsored by the Air Force Office of Scientific Research, OAR, through its European Office and conducted by System Research. It is almost impossible to condense this data and apart from citing the original documents above, we merely comment that some relevant aspects of the evolutionary simulations will soon be published.

On the other hand the relevant data concerning the paradigm adaptively controlled interaction system in 2.2.3. and the adaptively controlled group paradigm cited in 2.3.2. can be fairly readily condensed. In fact we shall extract certain items from the Annual Summary Reports 2, 3 and 4 of Contract AF61(052)–402 with System Research sponsored by the Aerospace Medical Research Laboratories, AFSC, through the European Office for Aerospace Research.

The adaptive controlled system that is cited in 2.2.3.

In practice the L° input to C° in Fig. 12 is an index ϱ of the rate at which a subject makes Correct Responses to the stimuli denoting the problems posed in the performance of a given structured skill. The L° stabilising operation carried out by C° is a variation in the degree of simplification of these problems intended to maximise the learning rate $\triangle\varrho$ (the term simplification being defined within an M model for the structured skill concerned which has been experimentally validated). If ϱ denotes an index of Correct Response percentage and if μ denotes the degree of 'simplification' (and if $\eta = \mu_{max} - \mu + 1$ is a measure of relative problem difficulty) then an adaptively stabilised teaching system for the minimal case of a skill consisting of one subskill or entailing one distinct type of problem solving activity has a behaviour of the kind shown in Fig. 27 below.

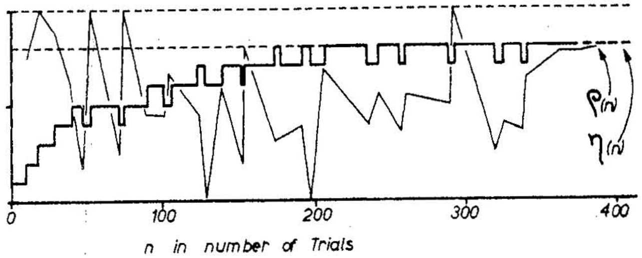

Fig. 27

When more than one problem type is involved, an adaptively stabilised teaching system has a level of L^1 stabilisation over and above the L° stabilisation that applies to each subskill or problem type separately. This level of control is mediated by C^1 in Fig. 12 and amounts to a variation in the type, labelled as i, of the problems that are to be solved by the subject.

At one extreme this variation in the i value is performed as a function of the set of estimates $\{\triangle\varrho_i\}$ calculated for each i value separately and the objective of C^1 is to maximise the mean expected value of the set of estimates $\{\triangle\varrho_i\}$. For a structured skill with a pair of subskills named $i = 1$ or 2 an adaptively stabilised teaching system exhibits the typical behaviour that is indicated in Fig. 28. At the other extreme the choice of an i value can be delegated to the student (in other words *only* the *preference* input to C^1 of Fig. 12 is utilised). In this case the system behaves in the fashion of Fig. 29.

The area between the L° stabilised values of $\eta_1(n)$ and $\eta_2(n)$ up to the nth trial in each of Fig. 29 and 28 is called λ (n) and the value of n at which the system behaves in a criterial fashion (the student achieves a given level of proficiency) is called T. Typically:

(1) T and λ (T) for 'subject choice of i' systems is greater than T and λ (T) for 'C^1 choice of i systems'.

(2) For C^1 stabilised systems A and B, if $T_A > T_B$ then $\lambda_A(T) \geqslant \lambda_B(T)$ and for $n > \frac{1}{4}T$ it is also true that $\lambda_A(n) \geqslant \lambda_B(n)$.

It can be argued that λ (n) is an inverse index of the extent to which a subject, at the nth trial, is adopting a problem solving procedure capable of comprehending problems of Type 1 *and* of Type 2 and, in terms of the M model, genuinely making L^1 choices. After, but only after, point P in Fig. 29 the subject appears to use such a higher order procedure, and consequently

TABLE I

VALUE OF T, NUMBER OF TRIALS TO REACH A CRITICAL LEVEL OF PERFORMANCE, FOR 30 SUBJECTS

Adaptive Metasystem	*Machine Choice i*	*Subject Choice i*
46	50	83
49	63	93
54	72	105
57	73	106
57	74	108
61	78	108
63	78	110
65	80	134
68	92	144
81	103	147

Using Jonckheere's Trend Test, the null hypothesis is rejected in favour of the predicted trend: T (Subject) > T (Machine) > T (Metasystem) at the 0.01% level of significance.

The subject in a metasystem and in the 'Subject Choice of i' condition is provided with an L^1 communication modality (in addition to L°) wherein he can *receive* data about properties of the system and *represent* his preference for the rehearsal of one subskill or the other. In the 'Subject Choice of i' condition his preference determines the subskill to be rehearsed. In the metasystem there is genuine L^1 *discourse* for his preference is given a weight, (or he is given a degree of *control*) that is proportional to his success in achieving the L° objectives.

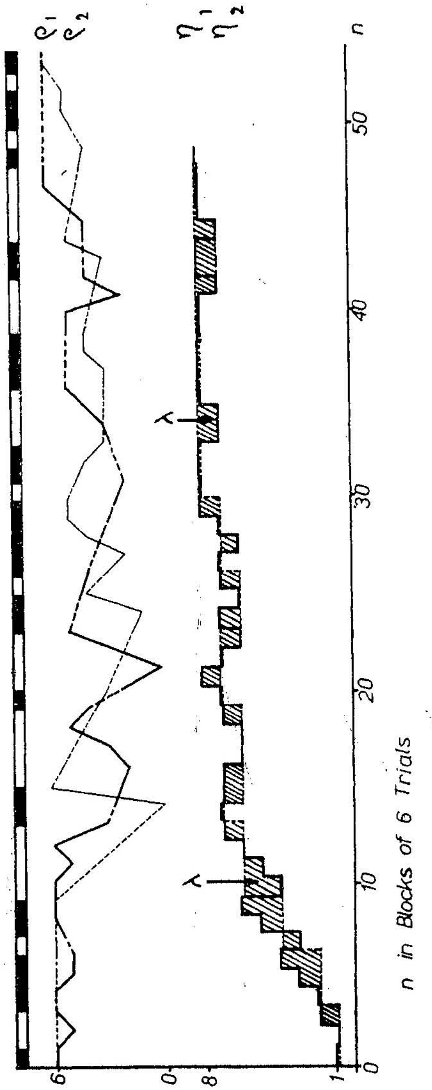

Fig. 28.

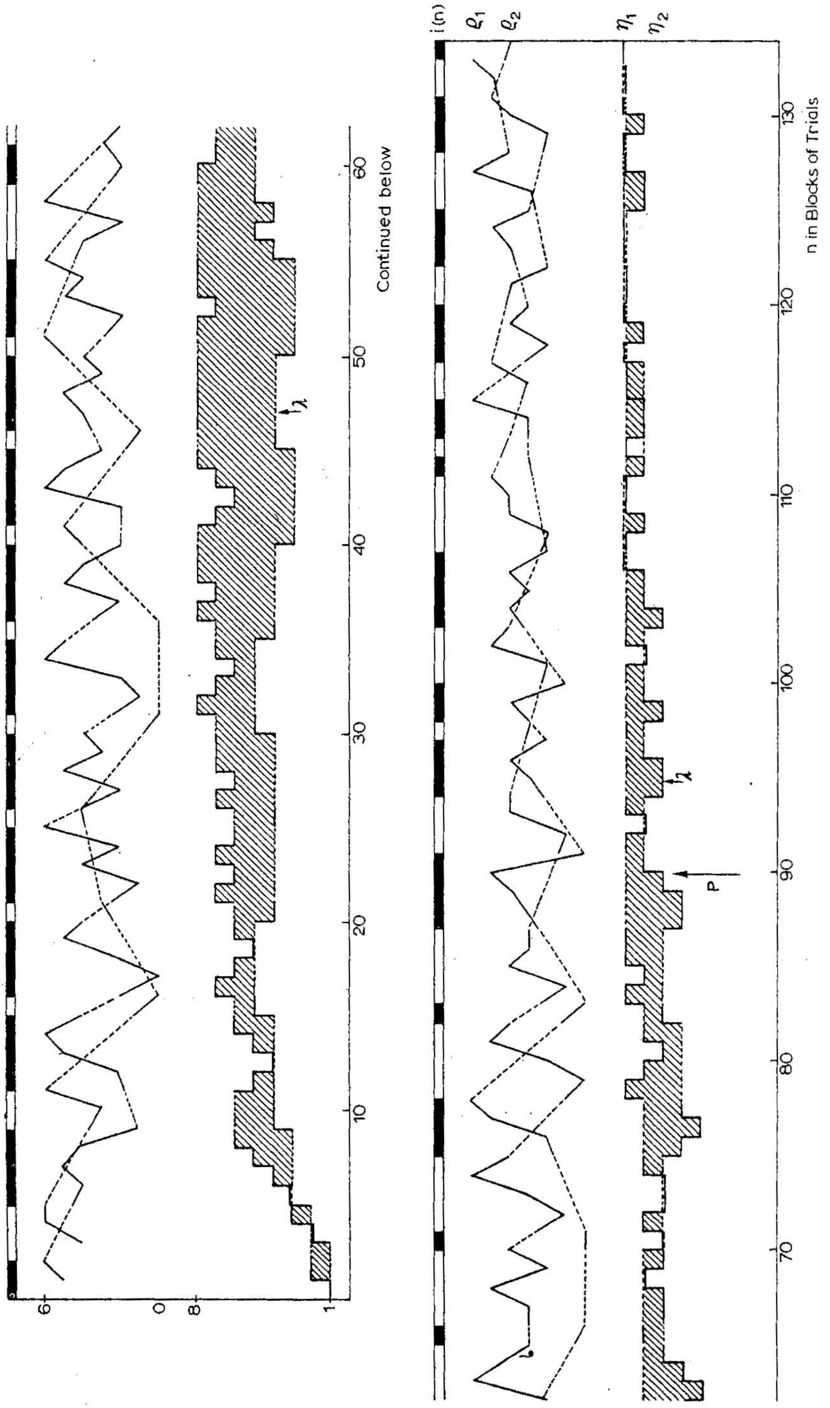

Fig. 29.

to learn in the way that he is *forced* to learn from the outset in Fig. 28. However, the evidence in Table I suggests that a C^1 Decision Rule (for choosing *i* values) that depends upon the L° data *and* the preference assertions made by a subject is more effective than a C^1 Decision Rule based upon the L° data *alone* (and certainly it is more effective than subject choice alone). Details are given as part of Table I.

The macroscopic efficacity of an adaptively controlled system

The efficacity of an hierarchically organised adaptive control mechanism as a device for maintaining the learning rate of a subject is supported by data of the kind shown in Table II. The group A of subjects learned a perceptual motor skill in conditions that were L^1 and L° stabilised by an adaptive control mechanism. The group *B* subjects learned the same perceptual motor skill in L° stabilised conditions the L^1 choice of an *i* value being determined by a

TABLE II

	T_A	T_B	T_C
	150	180	130
	170	210	140
	190	220	150
	190	230	190
	220	250	240
	220	270	290
	250	310	320
	260	330	320
	260	350	360
	270	350	390
	290	370	430
	290	370	450
	300	390	470
	310	410	490
	310	420	500
	330	430	510
	360	460	510
	380	460	530
	440	470	570
Average of T	274	343	371

Jonckheere's Trend Test applied to this data for the expected trend of $T_C > T_B > T_A$ yields a parametric value of 2.62 that confirms this hypothesis at the 0.5% level.

chance device. Finally Subjects *C* in Table II were given a plausible but conventional training routine without any adaptive control.

The adaptively controlled group system that appears in 2.3.2.

One of the main features of the adaptively controlled group learning system that is cited in 2.3.2. appears in the data of Fig. 30. The co-ordinates represent an index of the variety of behaviour with reference to an inductive inference skill and the variety of behaviour with reference to the choice of different assignments of roles to the members of a 3 person group which is performing this skill. As the skill is learned the variety of behavioural outcomes decreases and in an adaptively stabilised group there is a tendency for the variety of role assignments to increase (the members of the group experiment with different ways of doing their job). This tendency can be reversed by the introduction of misinformation (which arbitrarily increases the behavioural outcome variety).

Within the 3 person group this equivalence of variety at different levels of discourse represents the equivalence underlying the construction of the conceptual hierarchy and the evolutionary process cited in 2.3.2. Correspondingly, the observable changes are quantised and, in practice, the quantal levels shown as *A*, *B* and *C* are associated with learning about individual strategies, learning about group strategies, and learning about classes of these entities.

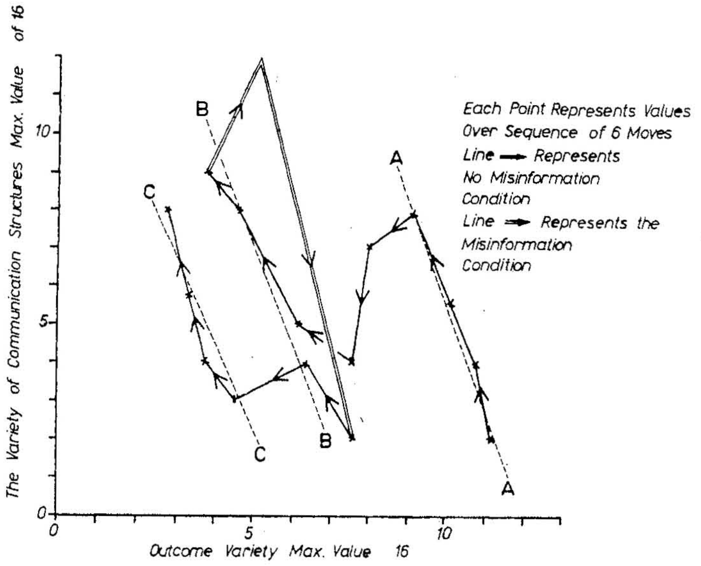

Fig. 30.

Before the statistical results from the adaptively stabilised group system can be interpreted it is necessary to introduce a couple of measures and to outline the experimental procedure. The first measure is an index of the group organisation and amounts to an index of the homogeneity of the preference for role assertions of the members of the group over a block of 45 'moves' (one 'move' consists of the solution of one problem by the group and this entails the transmission of evidential data, its reception and its analysis). This measure can be justified by a rather lengthy argument (it is not, however, ideal and it has been criticised on several different grounds). Supposing that the justification is accepted and used to determine if a group is a self-organising system, it is possible to compute a value of χ^2 which increases as the distribution of preference assertions departs from homogeneity and is thus inversely associated with the degree of organisation. In particular the group is a self-organising system as required by our argument if and only if the χ^2 measure is low in value.

The next measure is the number of 'loans' that are needed to maintain stable interaction. We have already noticed that the adaptive automaton restricts the interaction between members of the group by imposing economic constraints. Within these economic constraints, each member of the group is provided with his personal bank balance of money (increased by successful performance of the skill concerned) which must be used to purchase communication with other members of the group (and, hence, to achieve co-operative activity). The parametric constraints are adjusted by the adaptive automaton until the amount of money in each bank balance is sufficient but only sufficient to purchase communication channels that are used for fruitful co-operation.

In these conditions an individual participant can readily encounter monetary difficulties if his immediate choices are defective and, if so, he is able to ask the automaton for a unit loan of money which is paid back from his bank balance at a unit rate. The loan is not *necessarily* given when it is asked for and the automaton is arranged to give as many loans, when they are asked for, as it *needs* to do in order to maintain stable interaction. However, there is no limit upon the amount of money that can be loaned, and consequently the number of loans provided for all members of the group over a block of 45 moves is an indication of the relative amount of money that must be introduced in order to maintain stable interaction within this interval.

TABLE III

Value χ^2 First 45	*Value χ^2 Later 45*	*Loans First 45*	*Loans Later 45*
94.8	94.4	40	55
94	102	33	60
91	71.6	24	49
77.2	38.3	46	52
71.6	34.	27	64
61.2	19.6	14	24
60.3	27.1	14	21
58.3	42.7	36	57
54.	31.1	44	57
52.5	30.3	36	46
51.1	52.8	19	45
45.1	56.4	37	51
44.3	16.7	41	29
41.5	28.7	19	25
40.1	88.4	18	60
39.9	7.9	12	21
39.3	16.7	41	58
35.9	50.3	22	41
34.5	9.6	44	54
31.3	11.6	40	53
30.	44.4	20	32
28.5	23.9	23	55
25.7	32.4	40	57
25.5	15.7	19	26
25.5	23.6	19	36
24.7	34.4	21	45
23.9	18.8	24	40
22.3	57.5	39	57
20.7	16.8	40	41
18.3	15.1	20	24
17.7	6.	37	21
17.3	17.5	29	52
16.8	11.3	19	21
16.4	31.6	38	26
15.6	11.1	18	24
13.9	49.3	25	51
13.7	10.7	10	16
10.4	5.6	14	21
10.3	2.9	12	22
8.4	48.5	37	51

The experimental data displayed in Table III and in Table IV stem from 40 groups of 3 subjects each. These subjects had all previously experienced the system. The first set of 20 moves for a group is discarded. The next set of 45 moves is recorded as an *unperturbed* condition. In the next set of 45 moves misinformation is introduced in the communication channels and this set is recorded as a condition in which the group learning is *perturbed* by misinformation. Thus the experiment consists of 110 moves and occupies about 3 or 4 h. In Table III we show the data for 40 groups of subjects. In Table IV we show (1) The value of Spearman's Correlation co-efficient for the 40 pairs of results 'χ^2 value for each group in first set of 45 moves' and 'number of loans for the same group in the first set of 45 moves'. The value is not significant and it may be concluded that there is no significant correlation between the degree of organisation and the number of loans in the unperturbed condition; (2) The value of the Spearman's Correlation co-efficient for the corresponding data for the last 45 moves. In this case the value is significant at the 0.1 % level and we can infer that significantly fewer loans are needed in order to maintain a stable interaction in the conditions induced by the introduction of misinformation when the group constitutes a self-organising system as indicated by the observable degree of organisation.

TABLE IV

Spearman's Correlation Co-efficient for χ^2 First 45 and Loans First 45 moves	0.24	No Conclusion
Spearman's Correlation Co-efficient for χ^2 Later 45 and Loans Later 45 moves	0.61	Level 0.01 %
For χ^2 First moves and for Loans Later 45 moves	0.44	Level 0.1 %

Finally the correlation between the χ^2 values for the first 45 moves and the number of loans needed to maintain stable interaction over the latter 45 moves indicates enhanced stability when misinformation is introduced if the group is a self-organising system before this misinformation is introduced.

Table V refers to a control group of 20 groups of subjects which are compared with the 40 groups considered above. The control group differ in *never* having to deal with misinformation.

As we might expect from examining Fig. 30 one effect of misinformation is to increase the number of novel problem solving strategies that are learned and adopted by the group. The data in Table V shows that the control group produce, on average, 6.8 problem solving strategies in the first 45 moves and the main group 6.3. However, the control group produce an average 4.5 novel problem solving strategies in the latter 45 moves and the main group produce 6.9 problem solving strategies. We infer that this difference is due to the misinformation condition that is absent in the case of the control group of groups and that the subjects *use* this input of *variety*, to build communicable procedures, as we argued in 2.3.2.

TABLE V

	Mean Number Procedures Acquired in First 45 moves	*Mean Number Procedures Acquired in Later 45 moves*
Control Group	$A = 6.8$	$B = 4.5$
Main Group	$C = 6.3$	$D = 6.9$

Student's t for A,C, means = 0.68 with 58 $\triangleright$.*f*. no conclusion.
Student's t for B,D, means = 2.99 with 58 $\triangleright$.*f*. Level of 1%.

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REFERENCES

Abbott, E. A., (1884); *Flatland*. Oxford, Blackwell.

Barricelli, N. A., (1963); Numerical testing of evolution theories. *Acta Biotheoretica*, XVI, 10–126.

Beer, S., (1962); Toward the cybernetic factory. *Principles of Self-Organisation*. H. Von Foerster and G. W. Zopf, Editors. London, Pergamon Press (pp. 25–90).

Bonner, J. T., (1958); *The Evolution of Development*. Cambridge, University Press.

Braithwaite, R. B., (1955); *Theory of Games as a Tool for the Moral Philosopher*. Cambridge, University Press.

Bruner, J. S., Goodnow, J. J., and Austin, G. A., (1956); *A Study of Thinking*. New York, Wiley.

Burke, K., (1950); *A Rhetoric of Motives*. New York, Prentice-Hall.

Burks, A. W., (1960); Computation, behaviour, and structure in fixed and growing automata. *Self-Organising Systems*. M. C. Yovits and S. Cameron, Editors. London, Pergamon Press (pp. 282–311).

Campbell, N. R., (1920); *Physics, the Elements*. Cambridge, University Press.

Culbertson, J. T., (1963); *The Minds of Robots*. Urbana, University of Illinois Press.

D'Entreves, A. P., (1951); *Natural Law*. London, Hutchinsons.

Dewey, J., and Bentley, A. F., (1949); *Knowing and the Known*. Boston, Beacon Press.

Duncan, H. D., (1962); *Communication and Social Order*. New York, Bedminster Press.

Engels, P., (1964); *Dialectic of Nature*. London, Lawrence and Wishart.

Ferster, C. B.; Personal communication.

Flavell, J. H., (1963); *The Developmental Psychology of Jean Piaget*. New York, Van Nostrand.

Fraser, J. G., (1890); *The Golden Bough*. Cambridge, Cambridge University Press.

George, F. H., (1961); *The Brain as a Computer*. London, Pergamon Press.

George, F. H., (1963); *Pragmatic Machines. Proc. DAGK Conf.*, Karlsruhe, Neuere Ergebnisse der Kybernetik. R. Oldenburg.

Gorn, D., (1962); The treatment of ambiguity and paradox in mechanical languages. *Recursive Function Theory*. Proceedings Symposia in Pure Mathematics, Vol. 5, American Mathematical Society (pp. 201–218).

Grinker, R. R., (1956); *Toward a Unified Theory of Human Behaviour*. New York, Basic Books.

Gubberina, P., (1957); La logique de la logique et la logique du langage. *Studia Romanica Zagrebiensia*, **3**, 3–17.

Hamlyn, D. W., (1953); Behaviour. *Philosophy of Mind*. Chapell, Editor. London, Spectrum Books.

Hardin, G., (1963); The cybernetics of competition. *Perspect. Biol. Med.*, **7**, 58–84.

Harrah; D., (1963); *Communication: a Logical Model*. New York, Wiley.

Harre, R., (1962); *Theories and Things*. London, Sheed and Ward.

Hearn, G., (1958); *Theory Building in Social Work*. Toronto, University Press.

Hebb, D. O., (1949); *The Organisation of Behaviour*. New York, Wiley.

Hesse, M. B., (1963); *Models and Analogies in Science*. London, Sheed and Ward.

Hobbes, T., (1962); *Leviathan*. Glasgow, William Collins, Fontana Books.

Hovland, C. I., (1952); A communication analysis of concept learning. *Psychol. Rev.*, **59**, 461–472.

Jeremias, J., (1954); *Parables* (translated by S. C. Hooke). London, S. C. M. Press.

Jullicher, A., (1899); *Die Gleichnisreden Jesu*. Tubbingen.

Lettvin, J. Y., Matturana, H. R., and McCulloch, W. S., (1959); What the frog's eye tells the frog's brain. *I.R.E. Trans.*, **47**, 1940–1959.

Lewis, B. N., (1963a); Communication in problem solving groups. *Conference on Design Methods*. J. C. Jones and D. G. Thornley, Editors. London, Pergamon Press (pp. 169–183).

Lewis, B. N., (1963b); The rationale of adaptive teaching machines. *Mechanisation in the Classroom*. M. Goldsmith, Editor. London, Souvenir Press (pp. 85–129).

Lewis, B. N., and Pask, G., (1964); The theory and practice of adaptive teaching systems. *Teaching Machines and Programmed Instruction: Data and Directions.* R. Glaser, Editor. National Educational Association of the U.S.A. (pp. 210–266).

Lewis, C. S., (1957); *The Problem of Pain.* Oxford, Bles.

Locke, J., (1952); *Treatise of Government.* Library of liberal arts. New York, Bobbs-Merrill.

Loefgren, L., (1962); Tesselation models of self-repair. *Biological Prototypes and Synthetic Systems.* E. E. Bernard and M. R. Kare, Editors. New York, Plenum Press (pp. 342–371).

Lorenz, K., (1952); *King Solomons Ring.* London, Methuen.

Luria, A. R., (1961); *The Role of Speech in the Regulation of Normal and Abnormal Behaviour.* London, Pergamon Press.

Mace, C. A., (1934); Hierarchical organisation. *Sociol. Rev.*, **26**, 343–392.

MacKay, D. M., (1959); Operational aspects of intellect. *The Mechanisation of Thought Processes.* London, H.M.S.O.

MacKay, D. M., (1962); Comments. *Aspects of the Theory of Artificial Intelligence.* C. A. Muses, Editor. Proc. of the First International Symposium on Biosimulation, 1960.

Manson, T. E., (1927); *The Teaching of Jesus.* Cambridge, University Press.

Martin, R. W., (1963); *Intension and Decision.* New York, Prentice Hall.

Marx, K., (1936); *Capital.* New York, Modern Library.

McCulloch, W. S., (1945); A Hetrarchy of values determined by the topology of a neural network. *Bull. Math. Biophys.*, **7**, 89–93.

McCulloch, W. S., (1964); *The Embodiments of Mind.* Cambridge, M.I.T. Press.

McCulloch, W. S., and Pitts, W., (1947); How we know universals. The perception of auditory and visual forms. *Bull. Math. Biophys.*, **9**.

Mead, G. H., (1934); *Mind, Self and Society.* Chicago, University Press.

Mesarovic, M. D., (1962); On self-organisational systems. *Self-Organising Systems.* M. C. Yovits, G. T. Jacobi and G. D. Goldstein, Editors. Washington, Spartan Press (pp. 9–35).

Mesarovic, M. D., (1963); *General systems. Proc. 2nd IFAC Conference.* Basel. London, Butterworths.

Miller, G. A., Galanter, E., and Pribram, K. H., (1960); *Plans and the Structure of Behaviour.* New York, Halt.

Minsky, M., (1961); Steps towards artificial intelligence. *Proc. I.R.E.*, **49**, 8–30.

Minsky, M., and Selfridge, O. D., (1962); Random nets. *Communication Theory.* C. Cherry, Editor. London, Butterworths.

Newell, A., (1962); Learning and problem-solving. *Information Processsing.* R. Popplewell, Editor. Amsterdam, North Holland Publishing Company (pp. 407–412).

Pap, A., (1962); *Introduction to Philosophy of Science.* Chicago, Free Press of Glencoe.

Pask, G., (1958); The growth process inside the cybernetic machine. *Proceedings 2nd International Congress on Cybernetics, Namur, 1958.* Paris, Gauthier Villars.

Pask, G., (1959); Physical analogues for the growth of a concept. *The Mechanisation of Thought Processes.* London, H.M.S.O.

Pask, G., (1960a); The natural history of networks. *Self-Organising Systems.* M. C. Yovits and S. Cameron, Editors. London, Pergamon Press (pp. 232-260).

Pask, G., (1960b); Teaching machine as a control mechanism. *Trans. Soc. Instr. Technol.*, June, 1960 (pp. 72–89).

Pask, G., (1960c); Adaptive teaching with adaptive machines. *Teaching Machines and Programmed Instruction.* A. A. Lumsdaine and R. Glaser, Editors. Nat. Ed. Assoc. USA. (pp. 336–366).

Pask, G., (1961a); The cybernetics of evolutionary processes and of self-organising systems. *Proceedings 3rd Congress International Association Cybernetics, Namur, 1961.* Paris, Gauthier-Villars (pp. 27–73).

Pask, G., (1961b); *An Approach to Cybernetics.* London, Hutchinsons.

Pask, G., (1962a); The simulation of learning and decision-making behaviour. *Aspects of the Theory of Artificial Intelligence.* C. A. Muses, Editor. New York, Plenum Press (pp. 165–209).

Pask, G., (1962b); A proposed evolutionary model. *Principles of Self-Organisation.* H. Von Foerster and G. W. Zopf, Editors. London, Pergamon Press (pp. 229–253).

Pask, G., (1962c); Interaction between a group of subjects and an adaptive automaton to produce a self-organising system for decision-making. *Self-Organising Systems.* M. C. Yovits, G. T. Jacobi and G. D. Goldstein, Editors. Washington, Spartan Press (pp. 283–311).

Pask, G., (1962d); Adaptive systems and their possible application in medicine. *Proc. Med. Cybernetics.* Medicina Cibernetica. S.I.M.C. Naples (pp. 502–510).

Pask, G., (1963a); A discussion of the cybernetics of learning behaviour. *Nerve, Brain and Memory Models. Progress in Brain Research, Vol. 2.* Norbert Wiener and J. P. Schadé, Editors. Amsterdam, Elsevier (pp. 177–214).

Pask, G., (1963b); *Adaptive Teaching Systems and a Model of Learning Applicable to Systems Stabilised by an Adaptive Teaching Machine.* ASTIA Technical Report, USAF Contract AF61 (052)–402.

Pask, G., (1963c); Self-organising systems involved in human learning and performance. *Proceedings 3rd Bionics Conference, Dayton, Ohio, 1963.* In the press.

Pask, G., (1963d); The conception of a shape and the evolution of a design. *Conference on Design Methods.* J. C. Jones and D. G. Thornley, Editors. London, Pergamon Press (pp. 153–167).

Pask, G., (1963e); Learning Machines. *Survey paper at 2nd. IFAC Conference, Basle, 1963.* London, Butterworths.

Pask, G., (1964a); Man as a system that needs to learn. *Advances in Cybernetics, Vol. 1.* S. Beer, Editor. New York, Academic Press.

Pask, G., (1964b); A proposed experimental method for the behavioural sciences. *Progress in Biocybernetics, Vol. 1.* Norbert Wiener and J. P. Schadé, Editors. Amsterdam, Elsevier (pp. 171–180).

Pask, G., (1964c); The use of analogy and parable in cybernetics with emphasis upon analogies for learning and creativity. *Dialectica*, **17**, 167–201.

Pask, G., (1964d); Adaptive teaching systems. *Teaching Machines.* K. Austwick, Editor. London, Pergamon Press.

Pask, G., (1964e); Teaching as a control process. *Control*, **9**, 6–11, 69–72, 153–158, 211–216.

Pask, G., (1964f); A discussion of artificial intelligence and self-organisation. *Advances in Computers, Vol. 4.* M. Rubinoff, Editor. New York, Academic Press (pp. 110–226).

Pask, G., and Lewis, B. N., (1962); An adaptive automaton for teaching small groups. *Percept. Motor Skills*, **14**, 183–188.

Pask, G., and Von Foerster, H., (1960/1961); A predictive model for a self-organising system. *Cybernetics*, **4**, 258–300 and **1**, 44–54.

Pears, D. F., (1963); *Freedom and the Will.* London, MacMillan.

Peters, R. S., (1960); *The Concept of Motivation.* London, Routledge and Kegan Paul.

Piaget, J., (1950); *The Psychology of Intelligence.* London, Routledge and Kegan Paul.

Piaget, J., (1957); *Logic and Psychology.* New York, Basic Books.

Piaget, J., (1962); *Commentary on Vygodtsky's Thought and Language.* New York, Wiley and M.I.T. Press.

Ramsey, I. T., (1964); *Models and Mystery.* Oxford, University Press.

Rappaport, R. A., *Ritual Regulation of the Environmental Relations of the Tsombega.* To be published.

Ross Ashby, W., (1957); *Introduction to Cybernetics.* London, Chapman and Hall.

Ross Ashby, W., (1960); *Design for a Brain.* London, Chapman and Hall.

Russell, B., and Whitehead, A. N., (1927); *Principia Mathematica.* Cambridge, University Press.

Schlick, M., (1939); *Problems of Ethics.* New York, Prentice Hall.

Skinner, B. F., (1963); *Public lecture given to London University.*

Stevenson, C. L., (1937); The emotive meaning of ethical terms. *Mind.*

Swete, H. B., (1920); *Parables of the Kingdom.* London, MacMillan.

Tinbergen, N., (1953); *Social Behaviour in Animals.* London, Methuen.

Toda, M., (1962); The design of a fungus eater. *Behav. Sci.*, **7**, 164–183.

Vayda, A. P. and Rappaport, R. A., (1961); *Island Cultures. Proc. 10th Pacific Science Congress.* University of Hawai.

Verhave, T., (1963); Towards an empirical calculus for reinforcement value. *J. expt. Anal. Behav.*, **6**, 4, 525–535.

Von Foerster, H., (1960); On self-organising systems and their environments. *Self-organising Systems.* M. C. Yovits and S. Cameron, Editors. London, Pergamon Press (pp. 30–50).

Von Foerster, H., (1962); Biologic. *Biological Prototypes and Synthetic Systems.* E. E. Bernard and M. R. Kare, Editors, New York, Plenum Press (pp. 1–11).

Von Foerster, R., (1962); Structural models for functional interactions. *Information Processing in the Nervous System. Proc. I.U.P.S., 1962.* Excerpta Medica, 1964, (pp. 370–378).

Von Neumann, J.; Unpublished work.

Vygodtsky, L. S., (1962); *Thought and Language.* New York, Wiley and M.I.T. Press.

Watanabe, S., (1962); Learning process and inverse theorem. *I.R.E. Trans. Inf. Theory.* Vol. I.T. **8**, 5, 246–252.

Weldon, T. D., (1946); *States and Morals.* London, Murray.

Wiener, N., (1948); *Cybernetics.* New York, Wiley.

Wiener, N., (1955); *The Human Use of Human Beings.* London, Eyre and Spottiswoode.

Winch, P., (1958); *The Idea of a Social Science.* London, Routledge and Kegan Paul.

Wynne Edwards, C., (1964); *Animal Dispersion.* London, Oliver and Boyd.

Young, J. Z., (1964); A Model for a Brain. Oxford, University Press.

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