Progress of Cybernetics

Volume 1

Main Papers
The Meaning of Cybernetics
Neuro- and Biocybernetics

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Proceedings of the First International Congress of Cybernetics
London, 1969

GORDON AND BREACH SCIENCE PUBLISHERS
London New York Paris

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Gordon and Breach, Science Publishers Ltd.
12 Bloomsbury Way
London W.C. 1

Editorial office for the United States of America
Gordon and Breach, Science Publishers, Inc.
150 Fifth Avenue
New York, N.Y. 10011

Editorial office for France
Gordon & Breach
7-9 rue Emile Dubois
Paris 14e

Preface

An International Congress of Cybernetics was held in London in September, 1969, the date coinciding with the twenty-first formal birthday of the new interdisciplinary science of cybernetics. This event was held under the aegis of an International Committee (I.C.C.C.) composed of eminent academics and cyberneticians from eighteen countries, and was supported by many international bodies concerned with management, labour, cybernetics, the sciences and technologies, including U.N.E.S.C.O., I.L.O., etc. The aims of the congress, which marked a milestone in the history of cybernetics and may well become the basis of a world organization, were as follows:

(1) To establish cybernetics as an interdisciplinary science on solid foundations without the spurious accretions of the last two decades.

(2) To exchange up-to-date information and meet as an international academic community.

(3) To develop more efficient liaison between various scientists on an international scale.

In accordance with the above the congress has decided to explore the possibility of establishing a World Organization of Cybernetics, under the aegis of an international agency, and a Cybernetic Foundation; the latter to finance research, publications, establishment of institutions, etc.*

The proceedings of the congress are grouped in eight parts, viz. the main papers, followed by seven sections dealing with various aspects of cybernetics; authors from eighteen countries are represented. The main section comprises eight papers contributed by the most eminent cyberneticians of our times, the subjects treated covering the whole range of the science.

Section I is concerned with the philosophy and meaning of cybernetics,

* *Note added in proof* As a result of a world-wide enquiry, a World Organisation of General Systems and Cybernetics has been established. The Chairman of Council is Professor W. Ross Ashby (U.S.A.), the Vice-Chairman is Professor Stafford Beer (U.K.), and the Director-General is Dr. J. Rose (U.K.).

are not accessible to the human brains. From there, if their conclusions prove to be accessible to our powers of comprehension, they would perhaps bring back to us answers to the cumulative and seemingly insoluble problems of modern science.

References

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CHAPTER M-2

The meaning of cybernetics in the behavioural sciences (The cybernetics of behaviour and cognition; extending the meaning of "goal")

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Summary

The paper discusses the impact of cybernetic ideas upon behavioural and cognitive studies in general but the main thesis is developed in the context of human psychology. An effort is made to trace the influence of cybernetics upon the development of psychological theories, experimental techniques and methods for modelling mental and behavioural activity. Particular emphasis is placed upon the key concept of a "goal directed" system. It is argued that this concept becomes differentiated to yield two specialised forms of system, namely "taciturn systems" and "language oriented systems"; of these, the latter are peculiarly important in connection with studies of man or attempts to control, teach, or otherwise influence human beings. As it stands, the notion of "goal directed" system is unable to adumbrate the phenomena of evolutionary development (as in open ended concept learning) and conscious experience. Problems entailing both types of phenomena are ubiquitous in the human domain and the paper considers several ways in which the connotation of goal directedness can be enlarged sufficiently to render it useful in these areas.

INTRODUCTION

For many years, there has been a fruitful interplay between the interdisplinary pursuit of cybernetic ideas (bearing this label or not) and the special departments of the life sciences. Since the early 30s, for example, anthropologists have recognised that societal homeostasis depends upon symbolic regulatory programmes manifest as rituals, conventions, and traditions. Likewise, social change is commonly understood in terms of the competitive or co-operative interaction between subsystems characterised by these symbolic structures.* Similar comments apply at the level of animal populations, where the maintenance of density, dispersion and interspecific mutualism depend upon comparable processes (see, for example, Wynne Edwards[4]). The whole of ethology is, by definition, the study of behaviours mediating control and communication; hence, cybernetics is an essential part of this science.† Moving in one direction the area of cybernetic influence extends into studies of linguistics and kinship structures.⁑ In another direction, it infiltrates biology (see, for example, Young[6]), embryology (see Waddington[7]), genetics, and developmental studies (for instance, Bonner[8]).

The crucial notion is that of a purposive or goal directed system. As the examples suggest, this concept has served very well to increase our understanding of natural processes. But the concept, as it stands, is not entirely satisfactory. The phenomena of evolution and of conscious experience are ubiquitous in all biological, social, or behavioural systems. It is far from clear that these phenomena can be explained (or even predicted and manipulated) within the existing cybernetic framework. A fundamental reappraisal of the concept "goal" is probably necessary.

Uneasiness over the adequacy of the existing framework has been expressed in various quarters; notably at the series of Wenner Gren symposia on conscious purpose and human adaptation, convened by Gregory Bateson. This is not just an academic matter. In order to control the social and ecological systems which nowadays show signs of instability or even destructive and autocatalytic degeneration, it does seem necessary to take the consciousness, self description and evaluation of these systems fully into account. Much the same theme will be developed by Stafford Beer in the

* The pioneering work is due to Bateson[1]. Recent developments along similar lines are documented in Rappaport[2] or Schwartz[3].

† This is especially obvious in the works of Lorenz, Tinbergen, and Mittelstadt.

⁑ A representative selection of papers is contained in Garvin[5].

context of government and management. Hence, the present paper will examine the theoretical issues rather than dwelling upon their practical consequences.

Before embarking on this task, I must emphasize that these comments refer to behavioural and cognitive cybernetics. They are made from the viewpoint of some one concerned with natural systems and in no way contradict Prof. Boulanger's contention that issues of consciousness, etc., are often *irrelevant*. In the previous paper Boulanger adopted the attitude of an engineer who is anxious to make purposive or intelligent artifacts. From that point of view, of course, he is absolutely right. Wearing my engineering hat, I entirely agree with him.

CYBERNETICS IN RELATION TO HUMAN PSYCHOLOGY

To be specific, I shall trace the influence of cybernetic ideas upon a single discipline (human psychology). Here, as in the general domain, the key concept is "goal directed system" and it can be usefully refined in several ways. Once again, however, the concept of "goal" must be broadened in order to deal with outstanding issues of consciousness, conceptual development and the like, which a comprehensive psychology cannot afford to neglect. After showing that the requirement for a more liberal interpretation of goal directedness arises quite naturally from the application of the concept as it stands, I shall suggest several ways in which the connotation of "goal" can be usefully extended.

History

At the moment when the word "cybernetics" first made its appearance, there existed two classes of psychological theory, each carrying its own experimental trappings. On the one hand, there was behaviourism: either a brash, almost Watsonian, behaviourism or a mellowed "functionalism done with a behaviouristic bias" (chiefly represented in this country by the Cambridge School of Applied Psychology). On the other hand, there existed a sort of mentalism, born of the Gestalt psychologies amongst others, which was pursued in a thoroughly eclectic spirit, for example, by Bartlett.

Wiener's book[9] became widely known in the early fifties. It gave a name to an ongoing way of thinking and added mathematical stamina to a body of embryonic concepts. Of course, Wiener had spoken as a pioneer before he published. But his greatest innovation was philosophical and mathematical. The psychologists had been whittling away at broader Cybernetic notions for some years. Amongst them were McCulloch[10] and Pitts in the U.S.A. and Ashby[11,12], at that time in Great Britain, who laid the foundations of that peculiarly cybernetic edifice, "the brain as a communication and control system". Working at the behavioural level, Craik[13] saw the regulatory character of human performance with enormous clarity. Finally, there was a group of psychological information theorists, centred about Hick[14], and quite closely allied in their way of thinking to physical information theorists like Cherry[15] and Gabor (at Imperial College), Mackay and Shannon.

Thereafter, cybernetic ideas became increasingly popular. Their proliferation can be followed both in the psychological literature and in the relevant sections of various interdisciplinary forums (the Macy Foundation Symposia; the London Information Theory Symposia; the Congresses of the International Association of Cybernetics; the Conferences on self-organizing systems, sponsored by ONR; the Bionics Symposia, etc.). But, at the time in question (the early 50s), these concepts made a clear philosophical impression.

Philosophical Impact

The impact of cybernetics upon human psychology was many faceted.

1) Cybernetics drew attention to the form and dynamics, i.e. the *organization* of systems, which is often of greater relevance than their physical particulars. Usefully, but more superficially, it mustered a number of mathematical techniques for talking about organisation.

2) By establishing the basic concepts of feedback and stability, cybernetic thinking resolved those teleological dilemmas that had lingered on since the vitalist–mechanist controversy of the early years of this century and gave substance to the already ubiquitous notion of "goal directedness".

(3) Within the cybernetic framework, the constituents of organization, namely *information* and *control*, acquired a status just as respectable as that already accredited to "matter" or "energy".

(4) Conversely, it became evident that no system is completely specified by its physical description *alone*. The system's informational content and its control structure must *also* be described (for example, the system "gene" is not completely specified by talking about DNA molecules; in addition, a gene entails the information encoded in the molecular configuration and the protein synthesising control loops in the context of which a gene is an hereditary unit).*

(5) As a result, the Cartesian Dualism, of which the distinction between behaviourism and mentalism is redolent, was replaced by a Systemic Monisim.

Systemic Monisim

The crux of systemic monisim is contained in the assertion that any system is a goal directed system which can be analysed into or (in context) synthesised from a collection of goal directed subsystems. The organisation of a

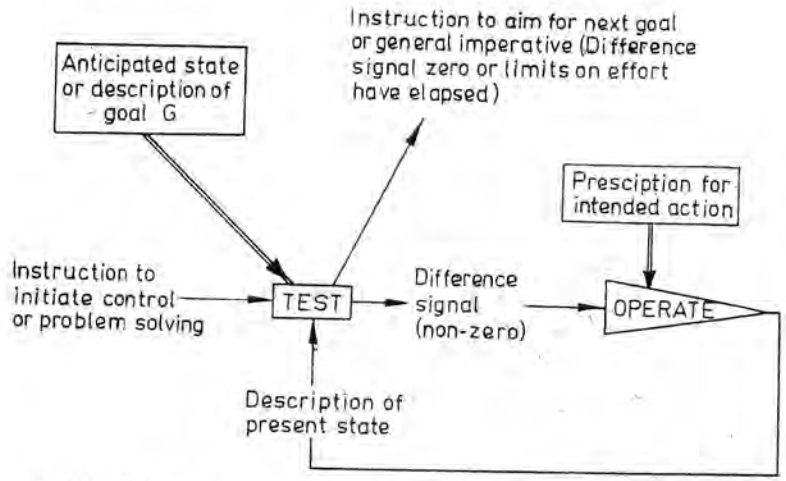

FIGURE 1 The basic goal directed system: a TOTE unit (modified)

goal directed subsystem, the basic building block, is the familiar *process* depicted in Figure 1. Notice that the organization is isomorphic with any of the following entities.

(1) A TOTE (or TEST, OPERATE, TEST, EXIT) unit, in the sense of Miller, Galanter, and Pribram[16].

* In view of later (essentially cybernetic) work in molecular biology, there is currently some doubt about hereditary units; the DNA configuration probably does not *uniquely* specify the organisation. However, the meaning of the example is clear enough.

(2) The interpretation and execution of an IF, THEN, ELSE programme segment.

(3) A properly interpreted control system.

(4) A problem solver.

(5) A game player (the equivalence of (3), (4), and (5) was mooted by Ashby and has recently been developed by Banerji)[17].

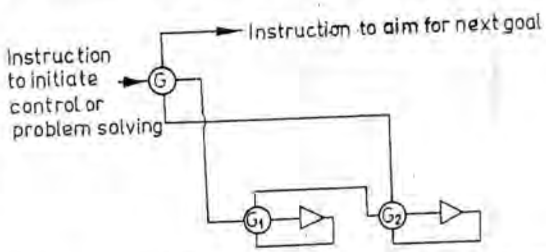

FIGURE 2 A typical decomposition of goal G: a TOTE hierarchy (modified)

(6) The execution of a state achievement command in the sense of Rescher[18].

(7) An elementary concept (regarded as a *procedure* for knowing or recognizing or doing)[19].

(8) Either the process of "abstraction" or of "completing an analogy"[20].

There are several ways of conjoining goal directed systems so that the entire system is goal directed (or, conversely, of dissecting a goal directed system into elementary units). One of them is shown in Figure 2. Here the entire system has a goal G and subgoals G_1 and G_2. In order to attain G, the uppermost unit calls for the execution of a G_1 subroutine and a G_2 subroutine, such a predictive sequence being a *plan*. Other types of composition and decomposition are discussed in a recent paper[21].

Holism and Atomism

Since it holds that composition and decomposition are universally possible, systemic monisim is a reductionist philosophy. But, in general, it is *holistic* rather than *atomistic* since, apart from a few trivial cases, the *whole* goal directed system is *more* than the sum of its goal directed parts. Further, in a sense that will be clear from the slightly unusual labelling of Figure 1, each subsystem can be said to *interpret*, to *intend*, and to *anticipate* or *expect*.

Hence, the reductionist explanations of human behaviour and mentation that feature in a cybernetic discussion are quite distinct from those (to my mind fallacious) mechanistic explanations in which man is reduced to a bag of associations and responses. To parody the position of naïve behaviourism, man is conceived *as something that reacts to stimuli*. In contrast, the cybernetic theories of psychology envisage man as *someone who interprets, intends, and anticipates*. To put it differently, a human being does not so much respond to stimuli as interpret certain states of his environment as posing *problems* which he makes an attempt to *solve*. Clearly, this point of view bridges the gap between behaviourism and cognitive psychology. A human being has the qualities ordinarily associated with mental activity; nevertheless, the human system is, in principle, reducible to elementary subsystems which have the same quality in a primitive form. Whether or not such a reductive explanation is generally *possible* is undecided at the moment; at any rate, useful explanations can be offered for certain aspects of human activity. Whether the goal directed unit is a rich enough construct to adumbrate "interpretation, intention, and anticipation" is a question to be taken up in a moment. Some disquiet on this score has been voiced already.

Cogency of the Cybernetic Approach

Since it resolves the arid conflict between behaviourism and mentalism, the cybernetic approach effects a salutory unification of the psychological field. Several theories of learning and cognition have been built up in overtly cybernetic terms; for example, in the U.S.A., the theories of Miller, Gallanter, and Pribram[16], McCulloch[10], and von Foerster[22] (or von Foerster *et al.*[23]); in the U.S.S.R., the theories of Anohkin, Amosov[24], Glushkov[25], and Napalkov and in Great Britain, my own theory[26,27]. To these should be added all theories involving cognitive and artificial intelligence models which are built up from elementary constituents with the status of information structures, for example, the models of Minsky[28], Reitman[29], Hunt *et al.*[30], Fogel *et al.*[31], George[32], Taylor[33], Uttley[34], and Young[6]. Many theories are primarily cybernetic in calibre; notably, Festinger's[35] "cognitive dissonance", Kelly's "personal constructs" and Laing's theory (see Laing *et al.*[37]) of interpersonal interaction.

Apart from this, the literature abounds with papers that are couched in behavioural terms but which are really talking about cybernetic constructs. Nowadays, when mental mechanisms are called "mediating processes" or (at a different level of discourse) are signified by "intervening variables" the author is nearly always referring to goal directed systems, programmes, and the like. The nomenclature of S.R. theory is cumbersome in this context; during a transition phase it is used by way of an apologia to classical behaviourism but is gradually being replaced by direct reference to the cybernetic entities.

Alongside this theoretical development a number of cybernetic methodologies have come into prominence. The most general of these, information theory and control theory, have already been mentioned. More specifically, the idea of a basic experimental situation is undergoing rapid change. The paradigm used to be a stimulus and response situation; now it is being equated with a game or a conversation between the subject and the experimeter (or his equipment, in some cases).

The consequences of this change in attitude extend far beyond the laboratory. They are particularly dramatic in connection with teaching, training, and computer assisted instruction, where sensible developments almost certainly rest upon the recognition that a tutorial *conversation* is the minimal, non trivial, transaction with a human being (here, incidentally, I mean conversation in the full-blooded *logical* sense; hence, "conversational interaction" with a simple computer terminal is generally insufficiently rich to qualify). These matters have been discussed extensively in other publications and I shall not dwell upon them[38-45].

Cybernetic theories and methods can be justified on psychological grounds; for example, the acquisition of either skills or concepts is most naturally described in cybernetic terms, as are the phenomena of selective attention. Empirically, cybernetic theories "work" quite well. However, the experiments of Dr. Grey Walter (which he will outline later this morning) lend a great deal of more specific support to the cybernetic contention. This work* has uncovered the physiological foundations for the goal directedness of man. Broadly, a complex of mechanisms involving the frontal cortex and certain lower regions such as the reticular formation, focus the attention upon relevant *evidence* and set up an anticipation or expectation with respect to its correlates and to properly equilibrating actions. In particular, the activity of this "expectancy" system depends upon either (1) a goal setting instruction (do so and so when something happens) or (2) an internal goal

* This is a refinement and extension of other work in the field. For particular theories in this matter, see Grey Walter[46] and Kilmer *et al.*[47] For the physiological background see Lynn[48].

orienting state. Generally speaking, a human being habituates against stimuli that are irrelevant to goals. Those which are relevant become *significant*, i.e. they pose *problems* or provide *evidence* (they do not simply "elicit responses").

It is right and reasonable to be impressed when physiology and psychology are happy bedfellows. In view of this work, there can be no serious doubt that human beings can be fruitfully represented as cybernetic systems.

DETAILED EXAMINATION OF CYBERNETIC THEORIES

Earlier in the paper I questioned the theoretical adequacy of the goal directed system as currently conceived and suggested that it is necessary to broaden our view of what such a system *is*. This calls for a more thoroughgoing appraisal of "goals" and of "cybernetic theories" in general.

Theory Building

Any theory starts off with an observer or experimenter. He has in mind a collection of abstract models with predictive capabilities. Using various criteria of relevance, he selects one of them. In order to actually make predictions, this model must be interpreted and identified with a real assembly to form a theory. The interpretation may be prescriptive and predictive, as when the model is used like a blueprint for *designing* a machine and predicting its states. On the other hand, it may be descriptive and predictive as it is when the model is used to explain and predict the behaviour of a *given* organism.

Now, in order to establish the identification and to form a predictive *theory* (indeed, in order to select one model from the set of possibilities), the observer needs to know the purpose *for* or the purpose *of* the system with which the model is identified. Lacking such a purpose, the observer would be at a loss to know what constitutes a sensible interpretation of the model or what properties of the world are relevant. In essence, of course, the purpose *for* or the purpose *of* the system is invented by the observer himself and it is stated in an observer's metalanguage for talking about the system. Thus, in the prescriptive mode, it is clear that people do not build purposeless machines. Equally, in the descriptive mode, an observer gets nowhere unless he has a systemic purpose in mind; for example, no headway was made with the explanation of amphibian vision until Lettvin, Matturana, McCulloch and Pitts* conceived the frog visual system as a machine for (with the purpose of) catching insects and avoiding predators. At that point, it became evident that the visual system consists in a set of attribute filters, evaluating properties relevant to this purpose.

In contrast, some systems have a purpose built into them; a "purpose *in*", i.e. a *goal*. Depending upon the type of observation we have in mind this may mean either (1) the models with which these systems are identified necessarily contain the mechanism of a goal directed system or (2) the system can state goals *to* the observer and accept some goals *from* him (or both). The principal cybernetic hypothesis can now be phrased as follows. *Any system with a purpose for it (any system for which a cybernetic theory can be constructed) also has a purpose in it, i.e. a goal; all systems are goal directed systems.*

Notice, in passing, the consequences of this definition. A cybernetic theory of adding machines is not just a theory of mechanical devices which have no goal. It refers directly to the *process* of addition and indirectly to the *user* of the adding machine, i.e. the mechanical device is necessarily embedded in the context which makes it meaningful.

Structural and Organizational Models

It follows from these comments that the truth of the cybernetic hypothesis cannot be decided (in respect to a particular system) at the level of the most fundamental and the simplest type of model: Ashby's "black box". However long a system identified with such a model is observed and however many experiments are carried out by varying the "black box" input, it will only be possible to say that the system behaves as *though* it is (or is not) a goal directed system. The whole concept of goal directedness depends upon the interpretation of a structural or organizational model for the system; something having enough detail to delineate the goal seeking process.†

Hence, in talking about goals, there is a tacit commitment to structural and organizational models containing a modicum of detail. At this level of

* "What the frog's eye tells the frog's brain" in *Embodiments of Mind*[10].

† This is quite clear in Ashby's work, of course. For example, in *Design for a Brain*[11] the concept of *essential variables* with limits upon their permissible values is employed to set up a goal directed system. The matter is generalized in Ashby's later work (see e.g. Ashby[48]). The present point is that structural notions, such as "essential variables" do not stem directly from the observation of a black box system. They are imported as a result of independent observations, e.g. data bearing on the nature of the animal.

discussion, still with human psychology in mind, it becomes useful to introduce a distinction between two types of goal directed system, namely *taciturn* and *language oriented* systems.* The former are systems in (roughly) the sense of general systems theory. The latter are based upon the concept of an *object language* (defined or described in the observer's metalanguage) in terms of which the system is able to accept goal statements (by programming or reprogramming) and to *describe* its current goals. The distinction "taciturn/language oriented" fundamentally entails the observer; we mean, to be strict "observed as taciturn/observed as language oriented". Nevertheless, these are features of the system, per se, which dispose us towards one mode of observation or the other.

Taciturn and Language Oriented Systems

Taciturn systems are those for which the observer asserts or discovers the goal (purpose *in*), which is thereafter equated with the purpose *for* the system in question. In contrast, language oriented systems can be asked or instructed to *adopt* goals by anyone who knows the object language and they may state and describe their own goals, using the same medium; in a very real sense these are "general purpose" systems. Ostensively, the distinction is determined by the following features.

(1) A special purpose, goal directed, computing machine (such as an autopilot) is a taciturn system. In contrast, a general purpose computer together with the compilers, interpreters, etc., required for processing statements in a programming language is a language oriented system. The programming language is the object language upon which the system is based.

Although this example is instructive, the peculiar character of general purpose computers must be kept firmly in mind throughout the discussion. In the case of a computer, an observer knows the programming language either because he has designed the machine or because he has a program-

* The basic distinction between taciturn and language oriented systems can be made in several ways of which this one is the most convenient for the present purpose. For example, Gregory[50] makes a similar spirited distinction between systems with a *deductive* capability (roughly, language oriented) and those without such a capability (roughly taciturn). Although Gregory's differentiation is elegant, and just as proper as my own, it does not fit the present framework quite so well. The caveat, *roughly*, must be taken seriously. As Figure 1 is labelled, any system with a goal (a purpose *in*) has a claim to deductive power.

ming manual written by someone who did so. In the case of a psychological system, an observer knows the programming language either because he speaks and understands it, or because of arguments involving inferences of similarity between the system and himself.

(2) A taciturn system can neither be given new goals nor can it state its goals (although an autopilot interacts with its environment, the legitimacy of calling the symbol system employed for this purpose, a "language" is suspect. Certainly it is not a language for stating new goals*). In contrast, the language oriented system is vacuous unless either it is *given* goals to aim for (by some sort of programming operation) or it already *has* goals which it is able to describe.

(3) Since a taciturn system cannot "speak" (i.e. communicate in a visual, auditory, or other symbolic modality), the notion of "mind" is irrelevant. On the other hand, within a language oriented system, it is usually possible to distinguish between a class of processes and procedures (for example, the class of programmes being executed in a general purpose computer) and the system in which these procedures are embodied (for example, the computer itself). The class of processes is an organization in the interpretative system and has the properties of *mind*, in contrast with the interpretative system itself (loosely, *brain*). Notice that the example of the general purpose computer though illuminating, is again misleading if taken too seriously. Computing systems are designed in such a way that the interpretative system, a box of logicians building bricks, is virtually independent of the organization. Brains are not like this.†

(4) In respect to a taciturn system, *information* has but one technical sense, which is developed in Prof. Ashby's paper at this congress. Briefly, information is a property of the relations existing between entries in the contingency tables which summarize the behaviours or possible behaviours of the system. It is crucial that the states so designated are defined in the observer's metalanguage and that the probability estimates, uncertainties, etc., are *observers* probability estimates, uncertainties, etc. (i.e. they are *objective*). Of course, the term information can be used in exactly the same sense with respect to the behaviour of a language oriented system. But here there is another pos-

* According to this argument, the course changing instructions delivered to an autopilot change the parameters of a given goal.

† There is, however, a fairly close relationship between brains and more complex computational systems with supervisory director programmes and resource allocation executives.

sibility as well, which is not open for the taciturn system. Clearly, the language oriented system can define a set of alternatives in terms of its own object language*; conversely, it can be *given* a set of alternatives. With respect to these it can express *subjective* or *systemic* uncertainty.

When the model for the language oriented system has been used prescriptively, as in writing an artificial intelligence programme, the observer can give an operational interpretation of subjective uncertainty and of the corresponding subjective information measure; for example, the degree of uncertainty with reference to problem P is the amount of computation required to solve P or the amount of computation which the system estimates will be needed at the moment it makes an utterance. When the model is used descriptively, an operational interpretation is not generally available and the asserted subjective uncertainties both may be and can be regarded as primitive measures. For instance, if man is a language oriented system, it is legitimate to take confidence estimates, obtained by the veridicial scoring technique of Shuford and his colleagues†, as *primitive* indices of the system state. Objective indices, which may, of course, be closely correlated with them, are, according to this point of view, indirect state descriptors.

(5) The model for a taciturn system is identified with reality (for example, in the context of an experiment) by setting up a material analogy‡ between

* To crystallize the idea of the observer's alternatives and the system's alternatives, consider a human subject as the system. If the subject is asked to respond on a five-point scale in Osgood's semantic differential test, the alternatives (words at the ends of the scale) are chosen by the observer (as a matter of fact, as a result of a prior analysis of the statistical response tendencies of a population of subjects). In contrast, the alternatives obtained and used in the Kelly grid technique are system alternatives. They are determined, in the framework of an object language, by the human subject himself. A similar point is made by Bannister and Mair[51].

† Consider an experiment in which the subject is required to respond, at the nth trial in a sequence by choosing one of M alternatives. It may be the case that the subject is uncertain about which alternative to select (in order to satisfy a goal). If so, he is required to state M numbers, $r_i(n)$ $i = 1 \cdots M$, such that $\sum_i r_i(n) = 1$. The $r_i(n)$ are interpreted as his degrees of belief in each of the alternatives presented at trial n and it is possible to score the subject over the sequence of trials as a function of the $r_i(n)$ and the alternatives he ought to have chosen. Shuford and his colleagues have introduced scoring schemes with the property that if the subject's real degrees of belief are $p_i(n)$ at the nth trial, then his mathematical expectation of score is maximized if, and only if, $r_i(n) = p_i(n)$. The same technique can be employed when the subject, rather than the experimenter, invents the alternatives. (See Shuford *et al.*[52]).

‡ For example, the sort of relationship which exists between an analogue computer model for a plant and the plant itself.

the model and the thing. Further, the observer or experimenter is solely responsible for determining and maintaining this relationship. Thus, stimulus signs are carefully delineated, responses are carefully observed, and the system is isolated from extraneous parameter variations by efforts to maintain constant and repeatable conditions. In contrast, all language oriented systems are based on models which are identified with reality in the normative framework of the object language; either the natural language of a human subject or an artificial language which he understands.* For example, the human subject is asked to participate in an experiment and he agrees to do so. Normative rules are set up which determine the nature and designation of problems, the class of solutions and so on. Above all, a goal is specified either by the subject or the experimenter. To put it succinctly, an experimental contract is established between the observer or experimenter on the one hand and the human subject on the other. The whole experiment makes sense and the model itself is identified within the framework of this contract. It follows, of course, that *both* the subject *and* the experimenter (or observer) are jointly responsible for determining and maintaining the identification.

General Statement

Theory construction in the large is a generalization of the identification or interpretation process of (5) of the preceding section (in the sense that a class of models are interpreted, not just one particular model in one particular experiment—clearly in the general case the "observer" becomes the "scientist"). Hence, we have two sorts of theory; a theory of taciturn and a theory of language oriented systems.

The theory building process is an open-ended control process in the conduct of which a cybernetic system (by definition a *control* system) is established. Hence theory building is, in one sense, "control of control". But the higher level (open-ended) control process is not formally modelled and possibly any attempt to model it would end up in a (vicious) indefinite regress.

If the cybernetic system to be established is taciturn, then the observer (scientist) is alone responsible for it. If the system is language oriented then the object language of the system is itself used as the metalanguage involved in the higher level "control of control" and the subject becomes an active participant in theory construction[53].

This is particularly obvious when we notice that the great majority of experimental contracts (preceding section, (5)) are not *really* established by one way instruction giving but are *compromise* solutions arrived at by dint of conversations about the experiment in question.

* We emphasize a point mooted earlier. The concept of language is very broad indeed. Pictograms or images are just as good a currency as words or mathematical expressions.

The Psychological Domain

Let us crystallize our attitude. *All the systems of human psychology are language oriented systems and all the models proper to human psychology are language oriented models.* This follows from the definition of a language oriented system and the discussion on pp. 25–27. To deny the assertion it would be necessary to cite a psychological experiment that does *not* depend upon an experimental contract.

As phylogenetic development proceeds, there is a tendency for the language oriented system to become apposite; it would be absurd to see primitive animals in this way but with adult man we have argued it is the only legitimate point of view. Similarly, there is an ontogenetic development beautifully illustrated by Luria's work[54]. The control function of language unfolds as a child grows up and, with it, the cogency of the language oriented system. In contrast, most functional and physiological systems are taciturn: for example, the autonomic system, simple conditioning, and non-symbolic adaptation.

At first sight, we seem to have come round a full circle and returned to a type of dualism; on the one hand there are language oriented systems ("mind" systems), on the other taciturn systems ("body" systems). But the impression is illusory. "X is a language oriented system" glosses the complete statement, "X is *observed* as a language oriented system" (and must be so viewed if the observer is a psychologist). The price to be paid for the convenience of systemic monisim is that of keeping the *observer* as an integral part of *all* observations[53,55].

With that caveat, we can often observe a human being as a psychological and a physiological system at the same instant. Grey Walter's work (see section on pp. 45–56) provides an admirable instance. On the one hand, he views the human subject as a taciturn (physiological) system. On the other, he views him psychologically, for example, in an experiment where the subject is required to entertain expectations. The psychological system is language oriented, even if the subject only "expects" clicks or light flashes. He *becomes* so, just *because* certain physiological mechanisms are brought into play.

DEPARTURES FORM THE SIMPLE PARADIGM

Let us idealize the cybernetic concept of man as it has so far been presented. An individual human being is a language oriented system (for short, an "L.O. system") occupied with one fully specified goal at once. Any change of goal is guided by a plan, in the sense of Figure 2, which determines the immediate subgoals of a still fully specified overall goal. Such a picture is isomorphic with the operation of a computer programme, the L.O. system, which is embodied in and executed by a computer called the brain.

For many purposes, the picture is a useful approximation to reality but it does not bear close scrutiny. First of all, the brain is not the passive and ductile apparatus which comes to mind at the mention of "computer". It is, indeed, a computer; but, as suggested before, it is a taciturn system in its own right with goals that are not necessarily compatible with those of the L.O. systems embodied in it. Secondly, human beings are not so single minded as the simple picture suggests. Man can often be imaged as aiming for one goal at once, especially when he is making symbolic utterances or is coupled to the observer via the string processing and push down list structures which are characteristic of immediate memory organization[56]. But he is also capable of multigoal operation. This fact opens up the possibility that man is an *evolving* L.O. system and I hypothesize that this possibility is *always* realized.* If so, the consequences are profound and roughly as follows.

An observer who sticks to the rules on p. 24 must see a human being as a system having a purpose *for* and will try to place this in correspondence with a purpose *in* or systemic goal. Now, if the observer elects to see the man as a system with *one* goal, then in certain circumstances, (by hypothesis, in *all* circumstances) the observer will be impelled to say that this goal is *underspecified*. Conversely, if he choses to see a multiplicity of goals (which, in toto, satisfy the purpose *for*) then these may be fully specified *but* the observer suffers an irreducible uncertainty over the systemic boundaries of the

* That, in a non-trivial sense, he is *always* learning. He is built with a propensity to learn[26].

individual said to *have* these goals. For, in reality, this *individual* is an evolutionary process which can be *described* (from the observer's point of view) as a self-organizing system in von Foerster's[57] sense of the phrase.

Equally if, man is defined as an L.O. system, then *he* is able to act as his *own* observer and thus to see *himself*. In that case, he (the individual human being) is in a similar position to the external observer. His evolutionary nature leads him, if questioned, to say either (a) "my goal is underspecified" (even "I have no goal")—here the integrity of the individual is taken for granted by the speaker, *or* (b) "I have a definite goal" (for example, to do running exercises for 15 min at 80 steps/min). But I might choose to aim for a different goal (e.g. writing this paper, solving a problem). Hence the boundaries of the individual are undefined. "I" am, by admission, something that is aiming for a definite goal but also something (undefined) that contemplates other possibilities so that "I" might elect to do differently. The goal, in this case, is *contingent* upon the acceptance of a normative framework, such as the experimental contract of p. 28, or the system of conventions and social mores (accepted, for example, by a devoted problem solver, clerk, or mathematician). *Contingency* arises because the human being *may* and *knows* he may disobey the norms and aim for some other goal, *or* (c) "I have a definite goal at the moment but I realize it is temporary and will give place to another". Here, the human being recognizes the temporal development of the process he *is*. Phrasing it differently, man spends much of his day in goal *setting* (or problem *posing*) rather than goal *seeking* (or problem *solving*).

In practice, the distinctions are less clearcut than (a), (b), and (c) suggest. Even the specific goals of (b) and (c) usually turn out to be underspecified to some extent, i.e. the man who describes the goal state is unable to give it a consistent ostensive definition. The ambiguity of all natural languages allows for the communication of underspecified goals. It is because of this that conversation (in a nontrivial sense) and social development in general are both possible.

We may or may not choose to call evolutionary systems "goal directed"; clearly, if they *are* goal directed at all, then they are directed towards an underspecified and generally open ended goal. Brodey and Johnson[58] have rightly pointed out the dangers of calling an individual or a society "goal directed"; the name suggests a narrowness and specificity which is counterfactual and which may encourage wrongheaded or positively harmful efforts at controlling the system in question. On the other side of the coin, these evolutionary systems are immediately related to simple goal directed systems and it may be a salutory exercise to broaden our notion of goal. One thing is certain; if we *do* use the word in connection with human affairs (and, as cyberneticians, we are prone to do so) then we should be fully aware that goal directedness is rarely, if ever, of the simple-minded sort.

DISCUSSION

The following sections discuss and develop the broader concept of goal directedness, mooted in the last section, i.e. a concept of goal setting as well as goal seeking.

Redundancy of Potential Command

McCulloch coined the phrase "redundancy of potential command" to describe the relationship existing between a set of goal directed systems which compete for dominance. It is clearly assumed that the systems in question (call them the goal directed subsystems) have a value defined on their operation; any one is built to seek an opportunity to operate and command the others and they clearly exist in such a relation to one another (or to an environment) that only one of them can command at once. Generally, the one that wins depends upon evidence from the environment (or from the aggregate of subsystems, or both); there is a tendency for command to shift from time to time in a way that favours the subsystem currently in possession of the most relevant information.*

The multi-goal systems of the last section are parallel computational systems in *this* sense; *not*, for example, in the sense that a perceptron is a parallel system.

As mentioned on p. 21, McCulloch and his colleagues have computer simulated the action of the reticular formation, which is one of the physiological mechanisms involved in directing an organization's attention. This simulation provides a lucid instance of "redundancy of potential command". The goal directed subsystems are, in this case, concerned with the potential *modes* of operation of the organism (i.e. walking, eating, etc.). They interact in the relationship indicated above and the organism as a whole is committed to one mode of activity or the other as command is shifted amongst

* The work of Mesarovic and his associates (for example, Fleming *et al.*[58]) is similar spirited. It is, however, carried out at an abstract level.

them. The selection of the currently dominant system depends upon the weight of evidence in respect to *all* of the modal computations and also upon a feedback from the cortical processes engendered by the immediate commitment. Whilst each of the goal directed subsystems has a fully specified goal (for example, "mediate eating behaviour") the goal of the system as a whole is underspecified ("general stability" or "survivial", or something of the sort).

Here, of course, we are talking about taciturn systems. But a similar picture holds good at the level of L.O. systems, which typically compete for *execution*.* For example, the perception of visual illusion figures is frequently accompanied by an oscillation between interpretative programmes†; the Necker cube, seen "infacing" at one moment and "out-facing" at the next is a clear instance of this phenomenon. Here the competing L.O. subsystems constitute a system with redundancy of potential command. But at this level, *co-operative* as well as competitive interaction becomes an obtrusive feature of the process.‡ For example, in viewing a paradoxical figure such as the "tuning fork" or the "impossible staircase", oscillation goes hand in hand with a resolution of the type proposed by von Foerster. The viewer makes an essentially self-referential statement and generates a construct

* In computational usage, a programme *is executed*; it does not of itself "compete for execution". Here the analogy with present day computation proves inadequate. The computations carried out in a brain (especially in the "working memory" to be referred to on p. 34) belong to the same class as the computations carried out in a cell. If computers were not so fashionable and cells so unfamiliar, I would have developed the argument in these terms.

To sketch what I mean, enzymes, in particular allosteric enzymes, are the most elementary goal directed systems in the cell. They operate in cyclic transformation processes which are unequivocally programmes (for example, the Krebs cycle). Some of these are protein synthesizing cycles which produce (amongst other things) fresh enzymes: for example, the well-known and unequivocally programmatic organization, "DNA message → messenger RNA; transfer RNA + amino acids → tagged amino acids; messenger RNA at ribosomal site + tagged amino acids → fresh enzymes". Here it is obvious that both simple and complex programmes have an imperative built into them; in the cellular environment they compete for execution and co-operate; in turn, they recreate or reproduce this environment. Mental organization has a similar quality and it is in *this sense* that I use the phrase "compete for execution".

† These programmes match the excitation of a sensory manifold to the expectations entertained by the subject. A similar proposal is made in Gregory[60], which also provides an elegant discussion of the field in question.

‡ "Becomes obtrusive", because, on closer examination of *all* systems with redundancy of potential command, co-operative phenomena are evident in an embryonic form.

involving a further spatial dimension in order to resolve the disparity between the rival programmes[61].* This is *co-operation* in the present sense. Two L.O. subsystems acting in concert can do more than the sum of the two acting alone and a new system is generated as a result of their interplay. If the L.O. systems are cognitive rather than perceptual programmes, then co-operative interaction is identical with Schon's[62] displacement of a concept to produce a new one (see, in particular, the example of the concept "drum", pp. 30–32).

The Individual at a Given Instant

We are now in a position to see the individual, at a given instant, not so much as a *particular* goal directed L.O. system as a collection of L.O. systems bearing (in some sense) the same name† and tied together by the relationship of enjoying redundancy of potential command with respect to an *overall* goal which will be *seen*, either by an observer or the currently dominant system, as a *contingent* or *underspecified* goal in the sense of p. 31 (a), (b), or (c).

Evolutionary Processes

An L.O. system with redundancy of potential command becomes an evolutionary system insofar as its L.O. subsystems must be embodied in a computing mechanism prior to execution, insofar as these *embodiments* are subject to decay or abrasion and insofar as there exists a reproductive or maintenance process that preserves successful subsystems or variants against decay. If so, the basic competition between the subsystems in the population becomes a competition for reproduction and survival.

I hypothesize that the brain, in particular the *functionally* (not physiologically) demarcated "working" memory mechanism, is just such a computing medium and, consequently, hold that the individual is continually evolving. It is exactly in this sense that I sometimes dub the brain (or that part of it) an "organ for reproducing concepts".

* von Foerster has studied the matter chiefly in terms of colour vision (working with Dr. Matturana) and constancy phenomena.

† Usually in the sense that the L.O. subsystems are run in the same brain. But note the previous comment, that if an observer tries to identify this class he is liable to an uncertainty about the extension of the individual. Note, also, the comments made later on the subject of conversational interaction.

Any programme being executed in working memory can address information, subroutines, and instructions which are generally lodged in the long term memory of the same brain, but which may also be written as records, in the environment. Equally well, an evolutionary process in brain A can be coupled linguistically to a process in brain B; conversational interaction often mediates exactly the same kind of co-operation as the *internal* process of conceptual displacement. Hence the evolving individual is sometimes distributed rather than localized in a single brain. Recall from p. 31, the observer's uncertainty about the boundaries of an individual.

Goal Setting

The evolutionary process generates a sequence of sets of subsystems having redundancy of potential command. As on p. 31 (a), the goals of the collection, of the whole system is necessarily underspecified. From time to time, the issue of command is temporarily resolved when an individual's goal is definite but contingent either in the sense of p. 31 (b) or (c). Looked at from a slightly different angle, the resolution process is itself part and parcel of the general evolution.

Resolution (and goal setting) occurs in several different ways.

(1) By dint of information received from the environment, which defines a new goal. In deference to Hawkins and Storm, I shall call this "eolithic intervention" (see Hawkins[63]).*

(2) By *external* co-operative interaction or conversation with some other individual.

(3) By *internal* co-operative interaction between L.O. goal directed systems seeking the same goal in different ways.

(4) By competitive interaction.

(5) A special case of (4). The language oriented individual sees his own brain (in particular the programmes run in the limbic structures) as a system

* The author recalls and develops the argument in an earlier paper by Storm. The argument is placed in the context of design, which is commonly regarded as a form of problem solving with respect to a fully specified goal. Hawkins points out that a great deal of design is quite different. The designer "has no goal" but encounters some object or method in the environment which suggests a goal; this he calls an eolith. For example, the designer may come across an oddly shaped piece of stone which suggests the goal of making a spade. In our own laboratories bits of apparatus or deeply engrained methods often set the goals for subsequent research proposals.

with goals of its own. These may or may not be consonant with the goals he currently entertains. In any case, this system ("his" computing system) "engages him in discourse".

The Correlates of Conscious Experience

"Man is a language oriented system" glosses "man is *observed* (by the psychologist) as a language oriented system", i.e. he is engaged in discourse. Insofar as the subject states or accepts goals, albeit underspecified goals, he is presumed to be aware and, in potentially communicating his awareness to the observer, to be conscious *with* him. The domain of enquiry defined as psychological on p. 29 is thus a domain of consciousness and it is pertinent to investigate the correlates of conscious experience. Notice, we are not trying to *explain* conscious experience in terms of more primitive events (for example, states of as taciturn system). According to p. 29, that would be an essay in the wrong type of reductionism. Furthermore, I believe it would be doomed to failure because observations of language oriented and taciturn systems are fundamentally different kinds of *observation* (to reiterate the point on p. 29: that does *not* mean there are two sorts of system). However, we *can* usefully set up correspondence between the appearance and even the nature of conscious experience and the operations which go on in (say) an evolutionary process. The following proposals on this score have the form "the execution of such and such a programme in working memory correlates with conscious experience".

Somewhat contrary to general belief, I contend that the human being is *unaware* of the execution of programmes with fully specified goals. He does not *know* when he is acting as an automaton. For example, he is unconscious of the execution of overlearned skills and he is unconscious of the routine and massive searches which must go on in the associative network of long-term memory. On the whole he is unaware of intellectual problem solving when the subgoals are completely specified; he becomes conscious of the process when, though the overall goal is fully specified, some of the subgoals are not, i.e. in general, he is aware of problem *posing* and the process of *constructing* problem solving procedures.

Man can be made aware of some normally unconscious processes if, when asked to describe them, he attempts the dual task of carrying out a procedure and matching an account of it to the observer's understanding (his success in actually producing a description varies widely; he is moderately competent in respect to procedures where there are subgoal points at which he *might* experience uncertainty as there usually are in intellectual tasks; he is utterly incompetent when it comes to describing how he performs an overlearned skill). In general, man becomes conscious when at least two processes are going on at once and these may or may not be internal to his brain.

For example, in skill learning (signal translation, teleprinter operation, etc.) the subject is aware of his errors insofar as (1) he has some rudimentary procedure for making a goal directed response and (2) the experimenter provides an external *co-operative* system which (as it were) does the same computation perfectly and provides the subject with knowledge of results feedback. Later in learning (with no knowledge of results feedback) subjects are conscious of *some* errors but ignorant of others. The *conscious* errors seem to be associated with the following circumstances: (a) there exist some slow but sure response programmes acquired early in learning; (b) these are lodged in long-term memory; (c) a more recent, more efficient but nevertheless more fallible procedure has been learned later for doing the same job; (d) the new procedure is applied (to achieve the goal) in parallel with the old procedure (aiming for the same goal); (e) competitive or co-operative interaction takes place insofar as a comparison is made between the "truth" (old procedure output) and the "actuality" (result of the new but fallible procedure).

Broadly speaking, man is aware of goals which he is asked to or anxious to attain but for which he does not possess the requisite goal seeking apparatus (and has to build it by a concurrent learning process). He is aware of contingent goals and, by the same token, of a mismatch between what he does and what he intends to do, between what he senses and what he expects, or between conflicting interpretations.

My conjecture is thus as follows. *The unique correlate of conscious experience is a state of a process (wholly or partly in working memory) such that (1) there exist two or more goal directed systems (usually in a relation of redundancy of potential command) and (2) these systems interact either competitively or co-operatively; in short, when they engage in discourse. Whilst the discourse in question may be internal to a single brain, it may also involve a system in the environment, in the brain of a conversation partner or in the brain of an observer.** These conditions can be satisfied by the evolution of a language oriented system.

* The interaction must be non-trivial. In conversation, for example, the sentient individual must compute what *he* believes the other individual is also computing and there

The conjecture is open to two criticisms. The first, that it says little more than "thought is subvocal speaking" is misplaced. There is no more than a superficial similarity between this dictum and the present conjecture. The second criticism, that the conjecture seems to neglect man's obvious awareness of pleasure, pain and the like can also be refuted. In fact, it would be possible to erect an entire theory of affect on the basis of discourse between programmes (L.O. systems) run in the limbic regions and those run in the neocortex (the sort of interaction mentioned on p. 35). Some recent affective psychologies come close to this stance. But the matter, though interesting, is beyond the bounds of this paper.

Predicting and Controlling Evolutionary Systems

The general *mechanism* of evolution has been computer simulated by various workers, for example, by Fogel and his colleagues[31], by Toda[64], and by myself.* Many of the more dynamic artificial intelligence programmes contain parts that are also "evolutionary". The real difficulty is modelling or representing the quasi-linguistic operation we have referred to as "setting a new goal" and this, of course, is peculiar to the embodiment and execution of an evolutionary L.O. system.

We have a limited understanding of one especially tractable situation involving an L.O. evolutionary system; namely, concept acquisition in a tutorial conversation (recall the definition of p. 20; a concept is a goal directed system). Here, the overall educational goal is fully specified in the sense that the subject (student) agrees to aim for it within the terms of an experimental contract and the whole construct is contingent upon the observance of this contract. Next, the whole of the co-operative interaction which builds up the new concept is assumed to take place via the conversational channel; it is externalized in communication between the subject and the teacher which, either in fact or in effect, is a fully specified teaching mechanism. This machine operates (1) as an external process that co-operates with the student

must be a comparison between the output from *his* model of the other individual and what the other individual says or does. The argument applies, vice versa to the other individual.

* My own work in this field is scattered through the literature, for example, Pask[65–67]. One of the most comprehensive models has been provided by Brieske[68], working at von Foerster's laboratory. Many others (notably Baricelli and Bremarman) have studied evolutionary processes in biological systems.

as he learns and (2) in the role of an observer. Whilst the subject is allowed to propose his own strategies, to set his own subgoals, etc., the acceptance of his decisions is contingent upon and is monitored by this external machinery.

Given all this, the evolutionary process of concept learning can be described by an *heterarchical* model for the subject (student). The original concept is represented by a goal hierarchy or problem solver in the sense of Figure 2; where, for example, G is at a higher level in the hierarchy than either G_1 or G_2. Learning is represented as an operation in which comparable problem solvers act upon the domain of the original problem solver (the original concept) in order to remedy its defects and to write fresh programmes. Clearly, this entails a quite different hierarchy; an hierarchy of control. For example, the original concept is a problem solver at the lowest level of *control* and the problem solvers that operate upon it reside at a higher level of *control*. Since both problem solvers may have the same organization (they need differ only in domain) and since they both have subgoals at various levels in the goal hierarchy, there is an interaction between the hierarchies and the entire model is *heterarchical*, as proposed a moment ago.*

Under these restricted conditions, it *is* possible to predict the course of evolution or learning and to control it by appropriate teaching strategies.

The trick employed is to conceive "goal setting" as higher level goal seeking (higher, that is, in the hierarchy of control). This trick is perfectly legitimate provided that the resulting model is based on the assumption that the goals "set" by the subject are *subgoals* of the *fully* specified educational goal. But the construct becomes completely invalid as soon as the subject departs from the experimental contract (which he *may* do and which he *knows* he may do).

Towards a Theory of Theory Building, i.e. a General Theory of Goal Setting

In general, the generation of new goals involves operations in which the human being becomes his own observer. In the role of observer, he sees himself as a system and defines a purpose *for* this system (in the sense of

* For an outline, see Pask[69]. The most complete statement of the theory is in Pask *et al.*[70]

the section on p. 23) which later acts as a purpose *in* the system (i.e. acts as its goal). In other words, the unconstrained goal setter (for example, "man as a scientist" in Kelly's personal construct theory or "man as an innovator" in all psychoanalytic theory) is his own theory builder (in the sense of the sections on pp. 23 and 24) and the representation of this general case calls for a formal statement of the notions contained in these sections: a theory of theory building.

No such theory exists. But some of its constituents are available, as formal tools, at the moment. The first step towards developing a theory of theories is to muster, integrate and, in some cases, sharpen these tools. The following items are the prerequisites which I, personally, have in mind.

(1) A proper logic of commands and intentions; the germ of it is available in the work of Rescher[18] and Von Wright[11] and in Kottelley's[12] intentional calculus (partly developed).

(2) A formal theory of partially co-operative interaction and conversation. This may be based on Howard's[13] theory of metagames, augmented (so far as the communication problem is concerned) by the ideas of Gorn[74].

(3) A logic of distinction to comprehend the act whereby a goal (or goal like entity) is abstracted from an amorphous flux of development. The problem was clearly stated at a philosophical level by Jung[15] in the 1920s; Spenser Brown[76] has recently solved it and provided an elegant calculus of distinctions which calls for an interpretation in the present field.

(4) A representation for essentially parallel processes. Here, the most promising candidate is Holt's occurrence theory. Within this framework, it is possible to formalize the concurrence of events and the ideas of competition and of information. The phrase "information transfer" has a meaning within occurrence theory that differs markedly from the current technical usage. "Information transfer" between occurrence systems is identical with the co-operative interaction that resolves uncertainty over an underspecified goal[77].*

(5) An axiomatic statement of the notions underlying evolutionary processes. Lars Loefgren has provided the bones of such a thing (the possibility of complete axiomatization is undecided)[78].

* Any cybernetic system, in the sense of the section in p. 24 can be represented as an occurrence system. We hypothesize that "information transfer" between goal directed systems of the evolutionary process is the unique correlate of conscious experience. The nub of the problem is, "who interprets or represents the systems in this way?".

Limitations

If a theory of theory building is fabricated, then what sort of theory will it be? As mooted earlier, a *purely* formal theory of the sort that would lead to a casual *explanation* of goal setting and conscious experience, is almost certainly unattainable. But this does not mean that no useful theory can be constructed to *adumbrate* the issues in question in the sense of predicting and controlling the behaviour of evolving, language oriented, conscious systems. The conviction that we can *adumbrate* but not *explain* these systems could be regarded as a doctrine of despair. Personally, however, I see it quite differently; as an indication of the limits and the fascinating potentialities of our discipline.

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CHAPTER M-3

The past and future of cybernetics in human development

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Summary

The contribution of cybernetics to our self-knowledge and self-control has been almost imperceptible. This is not because there has been no contribution; rather, the influence of cybernetic attitudes has been so subtle and pervasive that it has permeated the whole atmosphere of theory and technique. We must acknowledge that this atmosphere is not uniformly salubrious. In 1947 Wiener admitted that he had only a "very slight hope" that the good effects of cybernetics would "anticipate and outweigh the incidental contribution—to the concentration of power—in the hands of the most unscrupulous". Twenty-two years later we cannot honestly feel more optimistic.

In the Jewish cemetery of the ancient city of Prague, where now only the dead are Jewish, there is the grave of the Rabbi Loew. It was he who made the Golem, a magic robot which uttered prophecies; in Hebrew the word means "embryo". The myth of the Golem is in the long tradition of artificial oracles and super-human creations of human origin which were indeed the embryonic ideas which have found mature embodiment only in the last few decades—the electronic omnipotent idiots we call computers.

On the grave of the Rabbi Loew, around the lion motif on his headstone, are little twists of paper stuck in the crevices, scrawled in all languages, with pleas for help in affairs of the heart and business, in examinations and health, in war and in peace. It was not far from this cemetery that Karel Capek