

excentricity or folly, for under certain circumstances inclusion of the observer in his descriptions may lead to paradoxes, to wit the utterance “I am a liar.”

In the meantime however, it has become clear that this narrow restriction not only creates the ethical problems associated with scientific activity, but also cripples the study of life in full context from molecular to social organizations. Life cannot be studied *in vitro*, one has to explore it *in vivo*.

In contradistinction to the classical problem of scientific inquiry that postulates first a description-invariant “objective world” (as if there were such a thing) and then attempts to write its description, now we are challenged to develop a description-invariant “subjective world,” that is a world which includes the observer: *This is the problem.*

However, in accord with the classic tradition of scientific inquiry which perpetually asks “How?” rather than “What?,” this task calls for an epistemology of “How do we know?” rather than “What do we know?”

The following notes on an epistemology of living things address themselves to the “How?” They may serve as a magnifying glass through which this problem becomes better visible.

II. Introduction

The twelve propositions labeled 1, 2, 3, . . . 12, of the following 80 Notes are intended to give a minimal framework for the context within which the various concepts that will be discussed are to acquire their meaning. Since Proposition Number 12 refers directly back to Number 1, Notes can be read in a circle. However, comments, justifications, and explanations, which apply to these propositions follow them with decimal labels (e.g., “5.423”) the last digit (“3”) referring to a proposition labeled with digits before the last digit (“5.42”), etc. (e.g., “5.42” refers to “5.4,” etc.).

Although Notes may be entered at any place, and completed by going through the circle, it appeared advisable to cut the circle between propositions “11” and “1,” and present the notes in linear sequence beginning with Proposition 1.

Since the formalism that will be used may for some appear to obscure more than it reveals, a preview of the twelve propositions* with comments in prose may facilitate reading the notes.

*1. The environment is experienced as the residence of objects, stationary, in motion, or changing.***

Obvious as this proposition may look at first glance, on second thought one may wonder about the meaning of a “changing object.” Do we mean the

* In somewhat modified form.

** Propositions appear in italics.

change of appearance of the same object as when a cube is rotated, or a person turns around, and we take it to be the same object (cube, person, etc.); or when we see a tree growing, or meet an old schoolmate after a decade or two, are they different, are they the same, or are they different in one way and the same in another? Or when Circe changes men into beasts, or when a friend suffers a severe stroke, in these metamorphoses, what is invariant, what does change? Who says that these were the same persons or objects?

From studies by Piaget¹ and others² we know that “object constancy” is one of many cognitive skills that are acquired in early childhood and hence are subject to linguistic and thus cultural bias.

Consequently, in order to make sense of terms like “biological invariants,” “cultural universals,” etc., the logical properties of “invariance” and “change” have first to be established.

As the notes proceed it will become apparent that these properties are those of descriptions (representations) rather than those of objects. In fact, as will be seen, “objects” do owe their existence to the properties of representations.

To this end the next four propositions are developed.

2. *The logical properties of “invariance” and “change” are those of representations. If this is ignored, paradoxes arise.*

Two paradoxes that arise when the concepts “invariance” and “change” are defined in a contextual vacuum are cited, indicating the need for a formalization of representations.

3. *Formalize representations R, S , regarding two sets of variables $\{x\}$ and $\{t\}$, tentatively called “entities” and “instants” respectively.*

Here the difficulty of beginning to talk about something which only later makes sense so that one can begin talking about it, is pre-empted by “tentatively,” giving two sets of as yet undefined variables highly meaningful names, viz, “entities” and “instants,” which only later will be justified.

This apparent deviation from rigor has been made as a concession to lucidity. Striking the meaningful labels from these variables does not change the argument.

Developed under this proposition are expressions for representations that can be compared. This circumvents the apparent difficulty to compare an apple with itself before and after it is peeled. However, little difficulties are encountered by comparing the peeled apple as it is *seen now* with the unpeeled apple as it is *remembered* to have been before.

With the concept “comparison,” however an operation (“computation”) on representations is introduced, which requires a more detailed analysis. This is done in the next proposition. From here on the term “computation” will be consistently applied to all operations (not necessarily numerical) that transform, modify, re-arrange, order, etc., either symbols (in the

“abstract” sense) or their physical manifestations (in the “concrete” sense). This is done to enforce a feeling for the realizability of these operations in the structural and functional organization of either grown nervous tissue or else constructed machines.

4. *Contemplate relations, “Rel,” between representations, R, and S.*

However, immediately a highly specific relation is considered, viz, an “Equivalence Relation” between two representations. Due to the structural properties of representations, the computations necessary to confirm or deny equivalence of representations are not trivial. In fact, by keeping track of the computational pathways for establishing equivalence, “objects” and “events” emerge as *consequences* of branches of computation which are identified as the processes of abstraction and memorization.

5. *Objects and events are not primitive experiences. Objects and events are representations of relations.*

Since “objects” and “events” are not primary experiences and thus cannot claim to have absolute (objective) status, their interrelations, the “environment,” is a purely personal affair, whose constraints are anatomical or cultural factors. Moreover, the postulate of an “external (objective) reality” disappears to give way to a reality that is determined by modes of internal computations³.

6. *Operationally, the computation of a specific relation is a representation of this relation.*

Two steps of crucial importance to the whole argument forwarded in these notes are made here at the same time. One is to take a computation for a representation; the second is to introduce here for the first time “recursions.” By recursion is meant that on one occasion or another a function is substituted for its own argument. In the above Proposition 6 this is provided for by taking the computation of a relation between *representations* again as a representation.

While taking a computation for a representation of a relation may not cause conceptual difficulties (the punched card of a computer program which controls the calculations of a desired relation may serve as a adequate metaphor), the adoption of recursive expressions appears to open the door for all kinds of logical mischief.

However, there are means to avoid such pitfalls. One, e.g., is to devise a notation that keeps track of the order of representations, e.g., “the representation of a representation of a representation” may be considered as a third order representation, $R^{(3)}$. The same applies to relations of higher order, n: $Rel^{(n)}$.

After the concepts of higher order representations and relations have been introduced, their physical manifestations are defined. Since representation and relations are computations, their manifestations are “special purpose computers” called “representors” and “relators” respectively. The

distinction of levels of computation is maintained by referring to such structures as n-th order representors (relators). With these concepts the possibility of introducing “organism” is now open.

7. A living organism is a third order relator which computes the relations that maintain the organism's integrity.

The full force of recursive expressions is now applied to a recursive definition of living organisms first proposed by H. R. Maturana^{4,5} and further developed by him and F. Varela in their concept of “autopoiesis”⁶.

As a direct consequence of the formalism and the concepts which were developed in earlier propositions it is now possible to account for an interaction between the internal representation of an organism of himself with one of another organism. This gives rise to a theory of communication based on a purely connotative “language.” The surprising property of such a theory is now described in the eighth proposition.

8. A Formalism necessary and sufficient for a theory of communication must not contain primary symbols representing communicabilia (e.g., symbols, words, messages, etc.).

Outrageous as this proposition may look at first glance, on second thought however it may appear obvious that a theory of communication is guilty of circular definitions if it assumes communicabilia in order to prove communication.

The calculus of recursive expressions circumvents this difficulty, and the power of such expressions is exemplified by the (indefinitely recursive) reflexive personal pronoun “I.” Of course the semantic magic of such infinite recursions has been known for some time, to wit the utterance “I am who I am”⁷.

9. Terminal representations (descriptions) made by an organism are manifest in its movements; consequently the logical structure of descriptions arises from the logical structure of movements.

The two fundamental aspects of the logical structure of descriptions, namely their sense (affirmation or negation), and their truth value (true or false), are shown to reside in the logical structure of movement: approach and withdrawal regarding the former aspect, and functioning or dysfunctioning of the conditioned reflex regarding the latter.

It is now possible to develop an exact definition for the concept of “information” associated with an utterance. “Information” is a relative concept that assumes meaning only when related to the cognitive structure of the observer of this utterance (the “recipient”).

10. The information associated with a description depends on an observer's ability to draw inferences from this description.

Classical logic distinguishes two forms of inference: deductive and inductive⁸. While it is in principle possible to make infallible deductive inferences

(“necessity”), it is in principle impossible to make infallible inductive inferences (“chance”). Consequently, chance and necessity are concepts that do not apply to the world, but to our attempts to create (a description of) it.

11. *The environment contains no information; the environment is as it is.*

12. *Go back to Proposition Number 1.*

References

1. Piaget, J.: *The Construction of Reality in the Child*. Basic Books, New York, (1954).
2. Witz, K. and J. Easley: *Cognitive Deep Structure and Science Education in Final Report*, Analysis of Cognitive Behavior in Children; Curriculum Laboratory, University of Illinois, Urbana, (1972).
3. Castaneda, C.: *A Separate Reality*. Simon and Schuster, New York, (1971).
4. Maturana, H.: *Neurophysiology of Cognition in Cognition: A Multiple View*, P. Garvin (ed.), Spartan Books, New York, pp. 3–23, (1970).
5. Maturana, H.: *Biology of Cognition*, BCL Report No. 9.0, Biological Computer Laboratory, Department of Electrical Engineering, University of Illinois, Urbana, 95 pp., (1970).
6. Maturana, H. and F. Varela: *Autopoiesis*. Facultad de Ciencias, Universidad de Chile, Santiago, (1972).
7. Exodus, 3, 14.
8. Aristotle: *Metaphysica*. Volume VIII of *The Works of Aristotle*, W. D. Ross (ed., tr.). The Clarendon Press, Oxford, (1908).

III. Notes

1. *The environment is experienced as the residence of objects, stationary, in motion, or changing.*

1.1 “Change” presupposes invariance, and “invariance” change.

2. *The logical properties of “invariance” and “change” are those of representations. If this is ignored paradoxes arise.*

2.1 The paradox of “invariance:”

THE DISTINCT BEING THE SAME

But it makes not sense to write $x_1 = x_2$ (why the indices?).

And $x = x$ says something about “=” but nothing about x .

2.2 The paradox of “change:”

THE SAME BEING DISTINCT

But it makes no sense to write $x \neq x$.

3. *Formalize the representations R, S, . . . regarding two sets of variables x_i and t_j ($i, j = 1, 2, 3 \dots$), tentatively called “entities” and “instants” respectively.*

3.1 The representation R of an entity x regarding the instant t_1 is distinct from the representation of this entity regarding the instant t_2 :

$$R(x(t_1)) \neq R(x(t_2))$$