Notes On An Epistemology For Living Things

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While in the first quarter of this century physicists and cosmologists were forced to revise the basic notions that govern the natural sciences, in the last quarter of this century biologists will force a revision of the basic notions that govern science itself. After that "first revolution" it was clear that the classical concept of an "ultimate science", that is an objective description of the world in which there are no subjects (a "subjectless universe"), contains contradictions.

To remove these one had to account for an "observer" (that is at least for one subject):

(i) Observations are not absolute but relative to an observer's point of view (i.e., his coordinate system: Einstein);

(ii) Observations affect the observed so as to obliterate the observer's hope for prediction (i.e., his uncertainty is absolute: Heisenberg).

After this, we are now in the possession of the truism that a description (of the universe) implies one who describes it (observes it). What we need now is the description of the "describer" or, in other words, we need a theory of the observer. Since to the best of available knowledge it is only living organisms which would qualify as being observers, it appears that this task falls to the biologist. But he himself is a living being, which means that in his theory he has not only to account for himself, but also for his writing this theory. This is a new state of affairs in scientific discourse for, in line with the traditional viewpoint which separates the observer from his observations, reference to this discourse was to be carefully avoided. This separation was done by no means because of eccentricity 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 abundantly 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*.

The question before us "The Unity of Man: Biological Invariants and Cultural Universals" cannot be approached in the earlier, restricted frame of mind, should the answers we may come up with be testimony of our own awareness of our own biology and culture,

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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, here 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 (in somewhat modified form) with comments in prose may facilitate reading the notes.

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

Harmless 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 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 Piaget[1] and others[2] 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.

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[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).

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 computations.[3]

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 an 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 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: $Rel^{(n)}$.

The other is to distinguish in self-referring expressions between their extrinsic and intrinsic truth values. In general such expressions do not suffer from anomalies when in the affirmative. For instance, the sentence "This sentence is true" is affirmative recursive. Its extrinsic truth-value is "true", for the hypothesis that it is "false" is refuted by the sentence. Its intrinsic truth-value can be found by applying the sentence to itself, i.e., substituting for the part "This sentence … " the whole sentence. One obtains: "This sentence is true is true" which is true, for "true true" is "true".

The situation is different for a negative recursive expression, as, for instance, "This sentence is false". No extrinsic truth-value can now be established, for the hypothesis "false" would make the sentence true, in contradiction to its pronouncement. However, its intrinsic truth-value becomes stable after two substitutions. After the first we have "This sentence is false is false". But "false false" is "true", hence we obtain "This sentence is true". A second substitution operates on an affirmative recursive expression and thus yields forever "true".

While it is known that recursive, self-referring expressions can be constructed that will intrinsically never approach a stable form (transcendental recursive expressions), in this context they will not plague us, although they may provide important clues in a behavioral analysis which is beyond this elementary discussion.

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[3]Castaneda, C.: *A Separate Reality*. Simon and Schuster, New York, (1971).

After the concepts of higher order representation 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 "organisms" 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[45] 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 comunicabilia (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.

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[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*. Faculdad de Ciencias, Universidad de Chile, Santiago, (1972).

[7]Exodus, *3*, 14.

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 inductive.[8] 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.*

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":
<div align="center">THE DISTINCT BEING THE SAME</div>
But it makes no 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":
<div align="center">THE SAME BEING DISTINCT</div>
But it makes no sense to write $x \neq x$.

3 Formalize the representations $R, S, \ldots$ regarding two sets of variables x_i and t_j $(i, j = 1, 2, 3, \ldots)$ 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:

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

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[8]Aristotle: *Metaphysics*. Volume VIII of *The Works of Aristotle*, W. D. Ross (ed., tr.), The Clarendon Press, Oxford, (1908).

3.2. The representation S of an instant t regarding the entity x_1, is distinct from the representation of this instant regarding the entity x_2:

$$S(t(x_1)) \neq S(t(x_2))$$

3.3. However, the comparative judgment ("distinct from") cannot be made without a mechanism that computes these distinctions.

3.4. Abbreviate the notation by

$$R(x_i(t_j)) \rightarrow R_{ij}$$
$$S(t_k(x_l)) \rightarrow S_{kl}$$

[where] $(i, j, k, l = 1, 2, 3, \ldots)$

4. Contemplate relations Rel_μ between the representations R and S:

$$Rel_\mu(R_{ij}, S_{kl})$$

[where] $(\mu = 1, 2, 3, \ldots)$

4.1. Call the relation which obliterates the distinction $x_i \neq x_l$ and $t_j \neq t_k$ (i.e., $i = l$; $j = k$) the "Equivalence Relation" and let it be represented by:

$$Equ(R_{ij}, S_{ji})$$

4.11. This is a representation of a relation between two representations and reads:

"The representation R of an entity x_i regarding the instant t_j is equivalent to the representation S of an instant t_j regarding the entity x_i."

4.12. A possible linguistic metaphor for the above representation of the equivalence relation between two representations is the equivalence of "thing acting" (most Indo-European languages) with "act thinging' (some African languages) (cognitive duality). For instance:

"The horse gallops" $\leftrightarrow$ "The gallop horses"

4.2. The computation of the equivalence relation 4.1 has two branches:

One computes equivalences for x only

$$Equ(R_{ij}, S_{ki}) = Obj(x_i)$$

4.211. The computations along this branch of equivalence relation are called "abstractions": *Abs*.

4.212. The results of this branch of computation are usually called "objects" (entities), and their invariance under various transformations $(t_j, t_k, \ldots)$ is indicated by giving each object a distinct but invariant label N_i ("Name"):

$$Obj(x_i) \rightarrow N_i$$

4.22. The other branch computes equivalences for t only:

$$Equ(R_{ij}, S_{jl}) \equiv Eve(t_j)$$

4.221. The computations along this branch of equivalence relation are called "memory": [illegible] .

4.222. The results of this branch of computation are usually called "events" (instants), and their invariance under various transformations $(x_i, x_l, \ldots)$ is indicated by associating with each event a distinct but invariant label T_j ("Time"):

$$Eve(t_j) \rightarrow T_j$$

4.3. This shows that the concepts "object", "event", "name', "time", "abstraction", "memory", "invariance", "change" , generate each other.

From this follows the next proposition:

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

5.1. A possible graphic metaphor for the complementarity of "object" and "event" is an orthogonal grid that is mutually supported by both (Fig. 1),
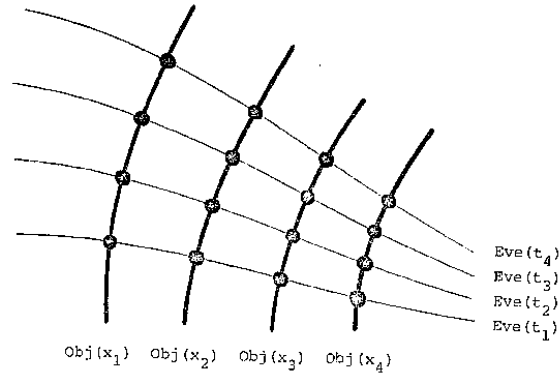

Fig. 1. *"Objects" creating "Events" and* vice versa.

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5.2. "Environment" is the representation of relations between "objects" and "events"

$$Env(Obj, Eve)$$

5.3. Since the computation of equivalence relations is not unique, the results of these computations, namely, "objects" and "events" are likewise not unique.

5.31. This explains the possibility of an arbitrary number of different, but internally consistent (language determined) taxonomies.

5.32. This explains the possibility of an arbitrary number of different, but internally consistent (culturally determined) realities.

5.4. Since the computation of equivalence relations is performed on primitive experiences, an external environment is not a necessary prerequisite of the computation of a reality.

6. Operationally, the computation $Cmp(Rel)$ of a specific relation is a representation of this relation.

$$R = Cmp(Rel)$$

6.1. A possible mathematical metaphor for the equivalence of a computation with a representation is, for instance, Wallis' computational algorithm for the infinite product:

$$2 \times \frac{2}{1} \times \frac{2}{3} \times \frac{4}{3} \times \frac{4}{5} \times \frac{6}{5} \times \frac{6}{7} \times \cdots$$

Since this is one of many possible definitions of π (3.14159...) and π is a number, we may take π as a (numerical) representation of this computation.

6.2. Call representations of computations of relations "second order representations". This is clear when such a representation is written out fully:

$$R = Cmp(Rel(R_{ij}, S_{kl}))$$

where R_{ij} and S_{kl} are, of course, "first order representations" as before (3.3).

6.21. From this notation it is clear that first order representations can be interpreted as zero-order relations (note the double indices on S and R).

6.22. From this notation it is also clear that higher order (n-th order) representations and relations can be formulated.

6.3. Call a physical mechanism that computes an n-th order representation (or an n-th order relation) an "n-th order representor" $RP^{(n)}$ (or an "n-th order relator" $RL^{(n)}$) respectively.

6.4. Call the externalized physical manifestation of the result of a computation a "terminal representation" or a "description".

6.5. One possible mechanical metaphor for relator, relation, objects, and descriptions, is a mechanical desk calculator (the relator) whose internal structure (the arrangement of wheels and pegs) is a representation of a relation commonly called "addition": Add(a,b). Given two objects, a = 5, b = 7, it computes a terminal representation (a description) of the relation between these two objects in digital, decadic form:

$$12 = Add(5,7)$$

6.51. Of course, a machine with a different internal representation (structure) of the same relation Add(a,b), may have produced a different terminal representation (description), say, in the form of prime products, of this relation between the same objects:

$$2^2 \times 3^1 = Add(5,7)$$

6.6. Another possible mechanical metaphor for taking a computation of a relation as a representation of this relation is an electronic computer and its program. The program stands for the particular relation, and it assembles the parts of the machine such that the terminal representation (print-out) of the problem under consideration complies with the desired form.

6.61. A program that computes programs is called a "meta-program". In this terminology a machine accepting meta-programs is a second-order relator.

6.7. These metaphors stress a point made earlier (5.3), namely, that the computations of representations of objects and events is not unique.

6.8. These metaphors also suggest that my nervous tissue which, for instance, computes a terminal representation in the form of the following utterance: "These are my grandmother's spectacles" neither resembles my grandmother nor her spectacles; nor is there a "trace" to be found of either (as little as there are traces of "12" in the wheels and pegs of a desk calculator, or of numbers in a program). Moreover, my utterance "These are my grandmother's spectacles" should neither be confused with my grandmother's spectacles, nor with the program that computes this utterance, nor with the representation (physical manifestation) of this program.

6.81. However, a relation between the utterance, the objects, and the algorithms computing both, is computable (see 9.4).

7. A living organism Ω is a third-order relator ($\Omega = RL^{(3)}$) which computes the rela-

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tions that maintain the organism's integrity:[9][10]

$$\Omega\{Equ[R(\Omega(Obj)), S(Eve(\Omega))]\}$$

This expression is recursive in Ω.

7.1.   An organism is its own ultimate object.

7.2.   An organism that can compute a representation of this relation is self-conscious.

7.3.   Amongst the internal representations of the computation of objects $Obj(x_i)$ within one organism Ω may be a representation $Obj(\Omega^*)$ of another organism Ω^*. Conversely, we may have in Ω^* a representation $Obj^*(\Omega)$ which computes Ω.

7.31.   Both representations are recursive in Ω, Ω^* respectively. For instance, for Ω:

$$Obj^{(n)}(\Omega^{*(n-1)}(Obj^{*(n-1)}(\Omega^{(n-2)}(Obj^{(n-2)}(\ldots\Omega^*)))))$$

7.32.   This expression is the nucleus of a theory of communication.

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

8.1.   This is so, for if a "theory" of communication were to contain primary communicabilia, it would not be a theory but a technology of communication, taking communication for granted.

8.2.   The nervous activity of one organism cannot be shared by another organism.

8.21.   This suggests that indeed nothing is (can be) "communicated".

8.3.   Since the expression in 7.31 may become cyclic (when $Obj^{(k)} = Obj^{(k-2i)}$), it is suggestive to develop a teleological theory of communication in which the stipulated goal is to keep $Obj(\Omega^*)$ invariant under perturbations by Ω^*.

8.31.   It is clear that in such a theory such questions as: "Do you see the color of this object as I see it?" become irrelevant.

8.4.   Communication is an observer's interpretation of the interaction between two organisms Ω_1, Ω_2.

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[9]Maturana, H.: "Neurophysiology of Cognition" in *Cognition: A Multiple View*, P.] Garvin (ed.), Spartan Books, New York, pp. 3–23, (1970).

[10]Maturana, H. : Biology of Cognition, BCL Report No. 9.0, Biological Computer Laboratory, Department of Electrical Engineering, University of Illinois, Urbana, 95 pp., (1970).

8.41. Let $Evs_1 \equiv Evs(\Omega_1)$, and $Evs_2 \equiv Evs(\Omega_2)$, be *sequences* of events $Eve(t_j), (j = 1, 2, 3, \ldots)$ with regard to two organisms Ω_1 and Ω_2 respectively; and let *Com* be an observer's (internal) representation of a relation between these sequences of events:

$$OB(Com(Evs_1, Evs_2))$$

8.42. Since either Ω_1 or Ω_2 or both can be observers $(\Omega_1 = OB_1; \Omega_2 = OB_2)$ the above expression can become recursive in either Ω_1 or in Ω_2 or in both.

8.43. This shows that "communication" is an (internal) representation of a relation between (an internal representation of) oneself with somebody else.

$$R(\Omega^{(n+1)}, Com(\Omega^{(n)}, \Omega^*))$$

8.44. Abbreviate this by

$$C(\Omega^{(n)}, \Omega^*)$$

8.45. In this formalism the reflexive personal pronoun "I" appears as the (indefinitely applied) recursive operator

$$Equ[\Omega^{(n+1)}C(\Omega^{(n)}, \Omega^{(n)})]$$

or in words:
   "I am the observed relation between myself and observing myself."

8.46. "I" is a relator (*and* representor) of infinite order.

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.

9.1. It is known that the presence of a perceptible agent of weak concentration may cause an organism to move toward it (approach). However, the presence of the same agent in strong concentration may cause this organism to move away from it (withdrawal).

9.11. That is "approach" and "withdrawal" are the precursors for "yes" or "no".

9.12. The two phases of elementary behavior. "approach" and "withdrawal" establish the operational origin of the two fundamental axioms of two-valued logic, namely. the "law of the excluded contradiction":

$$\overline{x \And \bar{x}}$$

in words: "not: x *and* not-x";
and the law of the excluded middle:

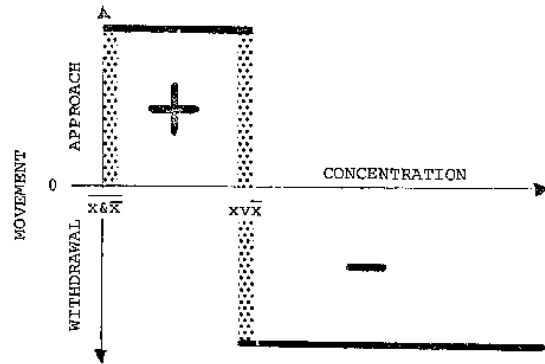$$x \vee \bar{x}$$

in words: "x *or* not-x"; (see Fig. 2).

Fig. 2. *The laws of "excluded contradiction"* $(\overline{x \& \bar{x}})$ *and of "excluded middle"* $(x \vee \bar{x})$ *in the twilight zones between no motion (M = 0) and approach (+), and between approach (+) and withdrawal (-) as a function of the concentration (C) of a perceptible agent.*

9.2. We have from Wittgenstein's *Tractatus*,[11] proposition 6.0621:

"... it is important that the signs "p" and "non-p" *can* say the same thing. For it shows that nothing in reality corresponds to the sign "non".
The occurrence of negation in a proposition is not enough to characterize its sense (non-non-p = p)."

9.21. Since nothing in the environment corresponds to negation, negation as well as all other "logical particles" (inclusion, alternation, implication, etc.) must arise within the organism itself.

9.3. Beyond being logical affirmative or negative, descriptions can be true or false.

9.31. We have from Susan Langer, *Philosophy in a New Key*:[12]

"The use of signs is the very first manifestation of mind. It arises as early in biological history as the famous 'conditioned reflex', by which a concomitant of a stimulus takes over the stimulus-function. The concomitant becomes a *sign* of the condition to which the reaction is really appropriate. This is the real beginning of mentality, for here is the birthplace of *error*, and herewith of *truth*."

9.32. Thus, not only the sense (yes or no) of descriptions but also their truth values (true or false) are coupled to movement (behavior).

9.4. Let D^* be the terminal representation made by an organism Ω^*, and let it be observed by an organism Ω; let Ω's internal representation of this description be $D(\Omega, D^*)$; and, finally let Ω's internal representation of his environment be $E(\Omega, E)$. Then we

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[11]Wittgenstein, L.: *Tractatus Logico Philosophicus*, Humanities Press, New York, (1961).
[12]Langer, S.: *Philosophy in a New Key*, New American Library, New York, (1951).

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have:

The domain of relations between D and E which are computable by Ω represents the "information" gained by Ω from watching Ω^*:

$$Inf(\Omega, D^*) \equiv Domain\{Rel_\mu(D, E)\} \quad (\mu = 1, 2, 3, \ldots, m)$$

9.41. The logarithm (of base 2) of the number m of relations Rel_μ computable by Ω (or the negative mean value of the logarithmitic probabilities of their occurrence

$$< log_2 p_i > = \sum_{i=1}^{m} p_i log_2 p_i$$

is the "amount of information, H" of the description D^* with respect to Ω:

$$H(D^*, \Omega) = log_2 m$$

(or $H(D^*, \Omega) = -\sum_{i=1}^{m} p_i log_2 p_i$)

9.42. This shows that information is a relative concept. And so is H.

9.5. We have from a paper by Jerzy Konorski:[13]

"...It is not so, as we would be inclined to think according to our introspection, that the receipt of information and its utilization are two separate processes which can be combined one with the other in any way; on the contrary, information and its utilization are inseparable constituting, as a matter of fact, one single process."

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

10.1. "Necessity" arises from the ability to make infallible deductions.

10.2. "Chance" arises from the inability to make infallible inductions.

11. The environment contains no information. The environment is as it is.

12. The environment is experienced as the residence of objects, stationary, in motion, or changing (Proposition 1).

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[13]Konorski, J.: "The Role of Central Factors in Differentiation" in *Information Processing in the Nervous System*, R. W. Gerard and J. W. Duyff (eds.), Excerpta Medica Foundation, Amsterdam, *3*, pp. 318–329, (1962).