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Genetic epistemology, constructivism, and arealism : knowledge for self-organization of the physico-cognitive whole

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**Genetic epistemology, constructivism, and arealism: Knowledge
for self-organization of the physico-cognitive whole**

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San Jose State University, 1991

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GENETIC EPISTEMOLOGY, CONSTRUCTIVISM, AND AREALISM:
KNOWLEDGE FOR SELF-ORGANIZATION
OF THE PHYSICO-COGNITIVE WHOLE

A Thesis

Presented to

The Faculty of the Department of Anthropology and
Cybernetic Systems
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In partial Fulfillment
of the Requirements for the Degree
Master of Science

By

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ABSTRACT

GENETIC EPISTEMOLOGY, CONSTRUCTIVISM, AND AREALISM: KNOWLEDGE FOR SELF-ORGANIZATION OF THE PHYSICO-COGNITIVE WHOLE

By Jeffrey E. Dooley

Questions focused upon the source, nature, acquisition and use of human knowledge have remained unclarified by philosophers, while, at the same time, scientific inquiry has grown more complex, and more in need of epistemological support. A naturalistic epistemological approach is adopted in order to warrant the scientific study of knowledge. An examination of Piaget's inquiry into the source, nature, development and use of knowledge reveals that his model of knowledge-organization is cybernetic and autopoietic. Moreover, Piaget presents a model of cognition which is a reflection and extension of self-conserving biological organization, and it is subordinate to the auto-conservation of the organization of the physico-cognitive whole. A constructivist definition of knowledge implies an epistemic shift away from passive reflection of ontological fact and toward active regulation of phenomenal regularities. It implies a benign, epistemic skepticism which avoids ontological skepticism. It is neither antirealism nor realism, but an instance of arealism.

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This essay began at the top of a tree in Berkeley in 1979, but it was poorly conceived, and I shortly abandoned it before a clear research focus was ever defined. Borrowing a phrase of Larry Laudan's, I would like to express my gratitude to Dr. William Reckmeyer for remembering that I needed to write this essay, even when I was sure that I did not. I would like to express additional appreciation to Dr. William Shaw and Mr. William Powers, who served as most careful readers and who offered indefinitely many critical and clarifying suggestions along the way. I also owe a debt of gratitude to Dr. Ernst von Glasersfeld who offered tremendously helpful commentary on some early drafts. Finally, to my wife, Lynn and daughter, Johanna, I would like to express my deep appreciation for their common sense, critical feedback and good-humored support along the way.

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CHAPTER I

SCIENCE, KNOWLEDGE, AND SYSTEMS

So, Theaetetus, neither perception, nor true belief, nor the addition of an 'account' to true belief can be knowledge. - Socrates

Plato, Theaetetus (210 a,b)

Introduction

As humans facing problems of increasing complexity, we require new ways of problem approach, definition, and resolution. These challenges require new kinds of knowledge. Yet "knowledge" appears ever more elusive. This chapter offers a statement of this problem and introduces the major themes developed in this essay through which I seek its clarification.

Much of the knowledge we require about complex phenomena has to do with the behavior of apparent organizations of things, and not just separate things themselves. At the very least, such study requires new language, language which deals with our perception of apparent complex wholes and their interactions. Therefore, some basic terms of such language are clarified in this chapter according to current systems science application relevant to this inquiry.

Science, Complexity, and Subjective Knowledge

Knowledge arises in experience. But what is the relation of knowledge to experience? Do we know experiences or do we know facts? If it is facts we know, what is a fact and how do we get to know it? Is our knowledge genuine or is it merely, perhaps mistaken, belief? Finally, why do we know what we know?

Attempts to answer such questions have dotted the written record of human thought for thousands of years. A most sensible outcome of such inquiry may have been the advice Socrates gave Theaetetus at the conclusion of their dialog: if what constitutes knowledge continues to elude you, at least you will be "gentler and more agreeable to your companions, having the good sense not to fancy you know what you do not know."¹

Despite the failures of philosophers and scientists to satisfy our curiosity about knowledge and the human faculties by which we come to have it, we continue to amass and use knowledge to bring about desired outcomes throughout the course of our everyday affairs. Although clarification of our fundamental questions about the nature, source, and function of knowledge may have largely eluded us, our everyday affairs have grown more complex. Ironically, it

¹Plato, *Collected Dialogues*, ed. Edith Hamilton and Huntington Cairns, (Princeton: Princeton University Press, 1973), p. 919.

may be this very complexity which gives us the clues we may need if we are to progress in our understanding of human knowledge.

Out of interest in complexity has grown the study of systems. As the study of organized aggregates comprising perceived, unified wholes, the study of systems has paralleled a revolt against objective knowledge in psychology, biology, neurophysiology, social science, and philosophy.² As such it has fostered a subjective explanation of the content of knowledge which exacerbates

²For Psychology, see Jean Piaget, *The Origins of Intelligence in Children*, (New York: International Universities Press, 1952); Piaget, *Genetic Epistemology*, (New York: Norton, 1970); Piaget, *Biology and Knowledge*, (Chicago: University of Chicago Press, 1971); and Piaget, *The Construction of Reality in the Child*, (New York: Ballantine, 1971). For Biology, see Humberto Maturana and Francisco Varela, *Autopoiesis and Cognition: The Realization of the Living*, Dordrecht: Reidel, 1980). For Neurophysiology, see Warren McCulloch and Walter Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity," *Modern Systems Research for the Behavioral Scientist*, ed. Walter Buckley, (Chicago: Aldine, 1968). For Social Science, see Peter Berger and Thomas Luckmann, *The Social Construction of Reality*, (New York: Doubleday, 1966). For Philosophy, see Norwood R. Hanson, *Patterns of Discovery*, (Cambridge: Cambridge University Press, 1958); Paul Feyerabend, "Explanation, Reduction, and Empiricism," *Scientific Explanation, Space, and Time*, ed. Herbert Feigl and Grover Maxwell, (Minneapolis: University of Minnesota Press, 1966); Thomas Kuhn, *The Structure of Scientific Revolutions*, (Chicago: University of Chicago Press, 1962); and Wilfrid Sellars, "Empiricism and the Philosophy of Mind," *The Foundations of Science and the Concepts of Psychology and Psychoanalysis*, ed. Herbert Feigl and Michael Scriven, (Minneapolis: University of Minnesota Press, 1956).

epistemological, methodological, and ontological difficulties already apparent in the physical sciences.³

These difficulties, which have nagged at the physical sciences over the objectivity of observation and the evidential equivalence of conflicting theories, have occasioned the reconsideration of epistemological and methodological norms governing scientific practice in general.⁴

At the same time, the technical challenge of dealing with problems of increased complexity has paralleled the emergence of new theoretical tools such as statistical theory of information, automata theory, cybernetics, and game theory for which the epistemological and methodological problems of the physical sciences appear more grave than

³See: Piaget, *The Construction of Reality in the Child*; Piaget, *Biology and Knowledge*; John Richards and Ernst von Glasersfeld, "The Control of Perception and the Construction of Reality," *Dialectica* 33, no. 1 (1979): 37-58; and William Powers, *Behavior: The Control of Perception*, (Chicago: Aldine, 1973).

⁴For objectivity of observation, see Pierre Duhem, *The Aim and Structure of Physical Theory*, (Princeton: Princeton University Press, 1954); Hanson, *Patterns of Discovery*; Feyerabend, "Explanation, Reduction, and Empiricism"; and Kuhn, *The Structure of Scientific Revolutions*. For evidential equivalence of conflicting theories, see Duhem, *The Aim and Structure of Physical Theory*; W. V. Quine, "On Empirically Equivalent Systems of the World," *Erkenntnis* 9, no. 3 (November 1975): 313-328; and Larry Laudan, "Demystifying Underdetermination," *Scientific Theories*, ed. C. Wade Savage, (Minneapolis: University of Minnesota Press, 1990). For norms, see Laudan, *Science and Values*, (Berkeley: University of California Press, 1984).

ever.⁵ A result of this epistemic confusion, according to LeMoigne, is that "the theories which we need the most to confirm and justify our practical interventions are the very same which lack scientific justification."⁶

Meanwhile, philosophers have increasingly questioned the validity of the empiricist thesis that knowledge derives exclusively from experience. They have, instead, proclaimed that some subjective classification or organization of perception is required of the subject for knowledge to be possible at all.⁷ On the other hand, naturalists such as Dewey, Quine, Giere, and Laudan have attacked any notion of a priori epistemic norms, accepting the inevitable circularity in the use of contingent knowledge to evaluate contingent knowledge as a virtue and not a vice.⁸

⁵See: Mario Bunge, *The Myth of Simplicity*, (Englewood Cliffs, N. J.: Prentice Hall, 1963); Bunge, "The GST Challenge to the Classical Philosophies of Science," *International Journal of General Systems* 4 (1977): 29-37; and William Reckmeyer, "The Emerging Systems Paradigm: An Historical Perspective" (Ph.D. diss., American University, 1982).

⁶Jean Louis Le Moigne, "Towards New Epistemological Foundations for Information Systems," *Systems Research* 2, no. 3 (1985): 249.

⁷See: Grover Maxwell, "Induction and Empiricism: A Bayesian Frequentist Alternative," *Induction, Probability, and Confirmation*, (Minneapolis: University of Minnesota Press, 1975); Quine, "Natural Kinds," *Ontological Relativity and Other Essays*, (New York: Columbia University Press, 1969); and Paul Churchland, "On the Nature of Theories," *A Neurocomputational Perspective*, (Cambridge: MIT Press, 1989).

⁸See: John Dewey, *Logic: the Theory of Inquiry*, (New York: Holt, 1938); Quine, "Two Dogmas of Empiricism," *From a Logical Point of View*, (Cambridge: Harvard University Press, 1953); Ronald Giere, "Philosophy of Science Naturalized,"

Finally, philosophers of science have renewed an historic debate over the issue of whether there is an external, structured reality for science to discover or whether science can proceed without such an assumption. This issue, the empiricism-realism debate has called into question a fundamental aim of traditional science: that it explain phenomena by reflecting an accurate account of nature's deep structure.⁹

Clearly, we need to clarify the meaning and scope that we attribute to human and scientific knowledge, along with the justificatory norms by which theory is approved for practice. Our need to know how to deal with complexity requires a reassessment of what it means to know anything at all.

Biology, Knowledge, and Constructivism

If we are to accept the judgment of philosophers like Hanson, Feyerabend, and Kuhn that perceptual objectivity is unattainable, accepting also the judgment of Maxwell that strict empiricism makes the fact of knowledge inexplicable,

Philosophy of Science 52, no. 3 (September 1985): 331-356; and Laudan, *Science and Values*.

⁹For Empiricism, see Bas van Fraassen, *The Scientific Image*, (Oxford: Oxford University Press, 1980). For Realism, see Hilary Putnam, "What is Mathematical Truth?" *Mathematics Matter and Method*, (Cambridge: Cambridge University Press, 1975). For the debate, see Jarrett Leplin, ed., *Scientific Realism*, (Berkeley: University of California Press, 1984); and Paul Churchland and Clifford Hooker, ed., *Images of Science*, (Chicago: University of Chicago Press, 1985).

then we are forced to consider some account of the source, nature and aim of knowledge that is intimately connected with human cognitive apparatus.¹⁰

In this essay, I examine accounts of knowledge that are the result of descriptive study of how knowledge has been observed to be accumulated and used by humans. The core of this research is found in Piaget's genetic account for the accumulation, application, and scope of human knowledge, developed through his study of the cognitive development of children. If, in the course of this study, certain normative guidelines are suggested, this is done in the naturalistic spirit that the practice of science is the best laboratory for determining what is to constitute scientific practice.

A case is argued that Piaget's structuralism, combined with his inferences from observations of the cognitive development of children, marks the establishment of an epistemological watershed which breaks dramatically from traditional definitions and aims of knowledge.¹¹ He has concluded that human knowledge is the active construction of reality into stable, organized structures of perception and

¹⁰Maxwell, "Induction and Empiricism: A Bayesian Frequentist Alternative," 119.

¹¹von Glasersfeld, "Radical Constructivism and Piaget's Concept of Knowledge," *The Impact of Piagetian Theory*, ed. Frank Murray, (Baltimore: University Park Press, 1979), p. 109.

thought--a position that has come to be known as constructivism.¹²

Piaget's constructivism, as interpreted by von Glasersfeld, carries drastic implications for epistemology, methodology, and ontology. These implications, largely developed by von Glasersfeld and Maturana, are examined in light of the cybernetic model adopted by Piaget for explaining the incremental line of equilibrium which he believes forms the trajectory of development of human cognition. This examination is aided by further clarifications in control-theory modeling in living neural-networks.¹³

Among the philosophical implications of a constructivist-cybernetic model of knowledge is an epistemic shift of knowledge-focus away from traditional attempts to discover or mirror nature's deep structure. This shift emphasizes the cognitive processes of recognizing, classifying and controlling regularities arising in experience--regularities which, under Piaget's influence, are considered the phenomenal products of human cognition, requiring no additional reference to ontological fact. At

¹²See: von Glasersfeld, "Radical Constructivism and Piaget's Concept of Knowledge"; von Glasersfeld, "An Introduction to Radical Constructivism," *The Invented Reality*, ed. Paul Watzlawick, (New York: Norton, 1984).

¹³Powers, *Behavior: The Control of Perception*; and McCulloch and Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity."

the same time, ontology, as the study of what there is, is stripped of any epistemic relevance in terms of knowledge of an external reality independent of our cognitive relations. These implications call for the adoption of an epistemic skepticism. This attitude avoids ontological skepticism by declaring piecemeal ontological commitments irrelevant, and by acknowledging the interactive reality of constructed experience, which is the only reality available, according to this view. The manner in which cognitive agents manipulate experience through the exercise of knowledge is seen as the operation of a cybernetic control system, on multiple recursive levels.

Piaget's equilibrating model of knowledge appears, in addition, to exhibit organizational closure and structural plasticity in a manner similar to the self-referring model of living (physical) organization called "autopoiesis" by Maturana and Varela.¹⁴ Piaget's self-referring model of cognitive structures forms the basis of a conjecture that the organization and function of knowledge is an extension and elaboration of the organization and function of the biological system. On Piaget's account, biological and cognitive structures form a physico-cognitive totality that

¹⁴Maturana and Varela, *Autopoiesis and Cognition*, 78-79. Thanks to William Powers and William Reckmeyer for pointing out that the notion of "organizational closure" is controversial among systems theorists, not all of whom agree on its usefulness or epistemic accessibility.

has its own organization, which is an extension of the structure and functioning of the bio-cognitive organization on a higher recursive level. In short, a context for the development, relevance, and application of knowledge is drawn which suggests that the *format* and *content* of knowledge is to be fundamentally subordinate to the satisfaction of the biological (and cognitive) viability needs of the organism and not for the discovery of independent reality.

It is important to emphasize that a liberal interpretation of the epistemic implications of autopoiesis, following Varela, is adopted here.¹⁵ According to this interpretation, the closed organization defined by autopoiesis is necessary but perhaps not sufficient for the explanation of living phenomena (including cognitive structures). Instead, in a more relaxed naturalistic atmosphere of inquiry, explanations beyond mere contiguous chemical transforms are allowed epistemic consideration, explanations which may make use of symbolic constructs not operationally relevant to the stark phenomenology of autopoiesis itself.

Finally, parallels between the constructivist position implied by Piaget and developed by von Glasersfeld will be

¹⁵Varela, "Describing the Logic of the Living," *Autopoiesis: A theory of Living Organization*, ed. Milan Zeleny, (New York: Elsevier, 1981)

compared with the constructive empiricism of Bas van Fraassen. The two positions appear epistemically and methodologically indistinguishable. This clarification of the empiricist position in the empiricism-realism debate within philosophy of science, in combination with a flight among some realists from literal *truth-of-reference* to *explanatory adequacy* as an aim of science, provides a startling perspective. It suggests that all of the positions in the debate appear to have converged upon a similar, pragmatic methodology. Realists require further that theories must provide *metaphors* at least suggestive of nature's truth. This requirement for some kind of ontological commitment by the realists, however, is argued to be epistemically irrelevant in light of the clarified constructivist position. This irrelevance becomes apparent when the exercise of human knowledge, on the strength of some neurocomputational facts, is modeled as the output of a control system. Based on this view I argue that there is *no epistemic problem* in the abandonment of ontological reference to an external world. From this it becomes apparent that the constructivist position is neither realism nor antirealism, hence, the designation *arealism*.

No claim is made here about the way things are or might be in absolute fact. The point-of-view represented here is reflected as a possible source of models; its value is

intended to consist in its logical consistency, rationality, and pragmatic utility. As Quine remarks,

. . .it is meaningless, I suggest, to inquire into the absolute correctness of a conceptual scheme as a mirror of reality. Our standard for appraising basic changes of conceptual scheme must be, not a realistic standard of correspondence to reality, but a pragmatic standard.¹⁶

In view of Quine's call for pragmatic norms of concept and theory-evaluation, let us now consider some concepts of systems science and cybernetics which may, as models, prove pragmatically useful.

Concepts of System and Organization

In this section concepts of system and organization are examined and clarified. These include *the observer, system, organism-environment and structural-coupling, homeostasis, organization, and boundary*.

1. *The observer*. In view of the declared subjective character of these concepts, it is important to make explicit the role of the observer who makes these conceptual distinctions. Without an observer to distinguish a system from its environment, no differentiation of a system or relations holding between it and any larger domain may be made. When a distinction of a system is made, it is made by an observer.

¹⁶W. V. Quine, "Identity, Ostension, and Hypostasis," *From A Logical Point of View*, (Cambridge: Harvard University Press, 1953), p. 79.

The identification of cognitive constructs such as systems as the linguistic products of an observer is not new. Ashby, in 1962, wrote that the "theory of organization will be concerned with properties that are not intrinsic to the thing but are relational between observer and thing."¹⁷

Piaget, too, was concerned with distinguishing models of things from the things themselves, and he was careful to separate epistemological domains of distinctions and of things. He observes that

it is impossible to compare these theories or general attitudes about life and knowledge. . . without also analyzing the notions and explanations that are used in doing so--in other words, without formulating an epistemology of the kinds of knowledge which belong to the biologist qua biologist and not to the organism qua subject.¹⁸

The deepest and most extensive treatment of the observer is to be found in Maturana. He has declared all linguistic distinctions about things to be the constructed models of an observer, not copies of independent entities. He writes:

The observer is a human being, that is, a living system, and whatever applies to living systems applies also to him. . . For an observer an entity is an entity when he can describe it. To describe it is to enumerate the actual or potential interactions and relations of the described entity. Accordingly, the observer can describe an entity only if there is at least one other entity from which he can distinguish it and with which he can observe it to interact or relate. This second entity that serves as a reference for the description can be any

¹⁷W. Ross Ashby, "Principles of the Self-Organizing System," *Modern Systems Research for the Behavioral Scientist*, 109.

¹⁸Piaget, *Biology and Knowledge*, 70.

entity, but the ultimate reference for any description is the observer himself.¹⁹

Maturana goes beyond claiming that systems are descriptive constructs of reality made by an observer. To understand the observer in this manner would be a mistake. For Maturana the description, the conceptual construct, is the *totality* of what is being objectified; *there is no other reality* but that which the observer generates through language. He sums the point, "language takes place in the praxis of living of the observer, and also generates the praxis of living of the observer."²⁰ Beyond language, there is no distinction to be described. The ontological implications of this view are obvious, but that discussion must be postponed. For the present purposes, the concepts and descriptions offered below are to be understood as the distinctions of an observer; they are not offered as correct definitions, nor even as the only or best definitions. They are simply descriptions and definitions gathered and, in some cases, synthesized, from the literature of systems science. They are intended as models whose justification is to be found in their usefulness in furthering the rational goals of inquiry.

¹⁹Maturana, "Biology of Cognition," *Autopoiesis and Cognition*, Humberto Maturana and Francisco Varela, (Dordrecht: D. Reidel, 1980), p. 9.

²⁰Maturana, "Ontology of Observing," In *Texts in Cybernetic Theory: Proceedings of An In-Depth Exploration of the Thought of Humberto Maturana, William Powers and Ernst von Glasersfeld* in Felton, California, October 18-23, 1988, by the American Society for Cybernetics, 1988, p. 36.

2. *System.* A system is a list of physical or conceptual action variables, denoting components and relations among components, their phenomenal properties and associated processes, specified by an observer as an organized whole.²¹

3. *Organism, Environment, and Structural Coupling.* Implicit with the isolation of some conceptual whole--a system--within an observer's perceptual domain is the notion that a part of that perceptual domain remains unincorporated within the organizational structure of the system. This exhaustive set of variables constitutes, for the observer, the system's *environment*. It is everything distinguished by the observer to surround the distinguished organization constituting the system. For living systems, according to Maturana, there are two additional useful constructs illuminative of a system's relations with its environment. These are *medium* and *niche*.²²

The *medium* of a living, organized unity or system, is the *environment* distinguished as two sets of phenomenal variables by the observer. These are (1) the total set of

²¹This definition has been synthesized from five sources: Maturana and Varela, *Autopoiesis and Cognition*, pp. 78-79.; Jay Forrester, *Principles of Systems*, (Cambridge: Wright Allen Press, 1972); W. Ross Ashby, *Introduction to Cybernetics*, (London: Chapman and Hall, 1956), p. 40.; A. D. Hall, *A Methodology for Systems Engineering*, (New York: Van Nostrand, 1962), p. 60; William Reckmeyer, private communication.

²²Maturana, "Ontology of Observing," 18-19.

perceived background variables surrounding the distinguished system, and (2) the subset of these variables perceived by the observer as variables with which the system interacts. This latter subset is defined by Maturana as the system's *niche*. The *niche* is a dynamic, variable list of distinctions and interactions by which, moment-to-moment, the system defines its domain of interactions as it "slides through the medium in continuous structural change."²³ For Maturana, living systems link themselves structurally to their niches through the attainment of specific states relevant to phenomenal circumstances. This is an activity he terms *structural coupling*.²⁴ It is important to make clear that the coupling takes place between two non-overlapping phenomenological domains. Varela explains:

The result is the structural coupling of two constitutively different phenomenologies: the phenomenology of the nervous system (and the organism) as a closed system, and the phenomenology of the environment (including the organism and the nervous system) as a different system.²⁵

This structural coupling, as Varela puts it, "braids" together the two domains as a function of the needs of the system to adapt within the medium so as to conserve its class identity or defining organization. Implicit within this model of structural coupling or adaptation is the

²³Ibid., 19.

²⁴Ibid., 18.

²⁵Varela, *Principles of Biological Autonomy*, (New York: North Holland, 1979), p. 245.

notion that environmental constraints may limit the range of these system-and-medium interactions to a subset of possible interactions consistent with the system's conservation of its defining organization. The role of a living system in the specification of relations under which such constraints may impinge upon the organization is, for Maturana, a key difference between living and non-living organizations.

4. *Homeostasis*. If a living system functions so as to interact with its environment--its niche--in such a manner that it conserves its class identity, regardless of perturbations which could be said to threaten such conservation, then the system is *homeostatic*. *Homeostasis*, then, is the constant maintenance of a variable, under varying circumstances, which in the case above, is the fundamental variable of conservation of organization.

Homeostasis characterizes the result of dynamic structural coupling of system-environment organization consistent with the system's continued conservation of class identity. In short, the homeostasis exhibited by a living system is the result of its successful regulation of structural coupling so that only those states not inimical to the viability of the system are realized. The mechanisms by which such regulation is effected and the conditions which must exist for it to regulate adequately will be discussed further below.

5. *Organization.* What is it about living systems that enables them to maintain themselves in the midst of changeable surroundings? For an answer to this question, biologists looked to the organization of the system itself, rather than search for some singular component or "organ of regulation." Von Bertalanffy writes, for instance,

. . .the main objective of biological sciences [is] the discovery of the principles of organization at its various levels.²⁶

A peculiarity of living systems, according to Maturana and Varela, is that they exhibit a type of organization which operates so as to transform matter into itself.²⁷ It is this circular, recursive, self-conserving organization which constitutes the system's class identity. Maturana has termed this organization *autopoiesis*.

. . .there are systems that are defined as unities as networks of productions of components that (1) recursively, through their interactions, generate and realize the network that produces them; and (2) constitute, in the space in which they exist, the boundaries of this network as components that participate in the realization of the network. Such systems we have called autopoietic systems. . .²⁸

This model of living organization led to the distinction that organizational form (circular closure) and content (components and structure) fall within non-

²⁶Ludwig von Bertalanffy, *General Systems Theory*, (New York: Braziller, 1968), p. 12.

²⁷Maturana and Varela, *Autopoiesis and Cognition*, 82.

²⁸Maturana, "Autopoiesis," *Autopoiesis: A Theory of Living Organization*, ed. Milan Zeleny, (New York: Elsevier, 1981), p. 21.

overlapping phenomenological domains. These are the two phenomenologies that, Varela comments, are braided together under structural coupling. One domain, that of the form, or organization (class identity), is closed and determined, in any dt, only by its former states. The other domain, in which content, manifestation and structural coupling is apparent, contains the organism and its environment, and in this domain the organism is an open system, exchanging matter with its medium. Varela argues that by speaking of the domain of the organization itself in terms of "operation," and by speaking of the domain of the organism-and-environment in terms of "performance," we may avoid contradiction.²⁹

From the standpoint of the organization itself, it is closed in the sense that all structural transformations it may undergo are a function of its own prior structural transformations. Outside influences, as such, are not involved; there are only perturbations and corrections of internal states. Varela encapsulates the notion

that the nervous system operates as a closed network with no inputs or outputs, that its cognitive operation reflects only its organization, and that information is imposed on the environment and not picked up from it.³⁰

We shall return to consideration of organizational closure once it is clear how such corrections are effected.

²⁹Varela, *Principles of Biological Autonomy*, 239.

³⁰*Ibid.*, 238.

Turning to the organization, a key activity is its tendency to maintain itself at a homeostatic steady state. Von Bertalanffy comments that the achievement of a steady state is in contradistinction with the second principle of thermodynamics. According to that principle, he remarks, "the general trend of physical processes is toward increasing entropy, i.e., states of increasing probability and decreasing order."³¹ Yet, he continues, "open systems can maintain themselves in a state of high statistical improbability, or order and organization."³² This accumulation of "negative entropy" by system interaction with its environment is, according to von Bertalanffy, the basis for Schrodinger's statement that "the organism feeds on negative entropy."³³ To that statement Schrodinger adds:

Or, to put it less paradoxically, the essential thing in metabolism is that the organism succeeds in freeing itself from all the entropy it cannot help producing while alive.³⁴

Explaining steady state maintenance by appeal to the dynamic processes of living systems provided a means, according to von Bertalanffy, of advancing a physical formulation for processes previously explained by

³¹von Bertalanffy, *General Systems Theory*, 143.

³²*Ibid.*

³³*Ibid.*, 144.

³⁴Erwin Schrodinger, "Order, Disorder, and Entropy," *Modern Systems Research for the Behavioral Scientist*, 145.

metaphysical notions of vital forces or entelechies, which had proved resistant to empirical investigation.³⁵

6. *Boundary*. Another conceptual construct relevant to an observed system is that of *boundary*. This term refers to the conceptual limiting sphere of a system's organization, beyond which its organizational processes and relations are not defined.

The distinction of exact boundaries has been a matter of difficulty in systems science, since boundary demarcation can vary conceptually, depending on the observer's point of view and the non-overlapping phenomenal domains in which form and content are defined.

In the case of organizational closure this confusion is likely due to a failure to distinguish it according to its proper phenomenological domain. An illustration of Bateson's characterizes this confusion as the habit of conceiving boundaries as barriers rather than as transduction nodes.

If you ask anybody about the localization and boundaries of the self, these confusions are immediately displayed. Or consider a blind man with a stick. Where does the blind man's self begin? At the tip of the stick? At the handle of the stick? Or at some point halfway up the stick? These questions are nonsense, because the stick is a pathway along which differences are transmitted under transformation, so that to draw a delimiting line across this pathway is to cut off a part of the

³⁵Ibid., 133.

systemic circuit which determines the blind man's locomotion.³⁶

The organism/nervous system, as a closed organization, uses its neural states to determine, from among possible states which it also determines, which new states are most consistent with its viability goals through structural coupling. Additionally, it specifies what may, for the organism, constitute a perturbation.

Boundaries in relation to the phenomenological domain in which organizational manifestation is characterized are more intuitively grasped. These boundaries are the perimeter of the organization which defines the system as a homeostat. Aided by this distinction, Maturana addresses the question of system boundary against its medium. But in his description he also points out, according to the phenomenology of the environment, the signal transduction and circuit systems which may be said to facilitate structural coupling within that domain.

The organism ends at the boundary that its self-referring organization defines in the maintenance of its identity. At this boundary there are sensors (the sensory surfaces) through which the organism interacts in the domain of relations and effectors (the effector surfaces) through which the nervous system modifies the posture of the organism in this domain.³⁷

³⁶Gregory Bateson, *Steps to an Ecology of Mind*, (New York: Ballantine, 1972), p. 318.

³⁷Maturana, "Biology of Cognition," 20.

Cybernetic Systems Concepts

Since I characterize Piaget as an epistemological theorist whose genetic model of knowledge accumulation is cybernetic, and since Maturana and von Glasersfeld elaborate explicitly cybernetic models, it is appropriate to review some key conceptual building-blocks of cybernetics and control theory. These conceptual constructs include *variety, cybernetics, organizational closure, and purpose.*

7. *Variety.* Just above we considered the notion that among those relations between system and medium are signal pathways looping the system's cognitive activity through its medium. The blind-man's stick is such a channel. The concept of *variety* is a measure of the number of distinct elements or possible states that may be distinguished by an observer within a particular cognitive domain, i.e., on either side of a transduction node. Ashby notes the role of the observer in the determination of variety.

. . . a set's variety is not an intrinsic property of the set: the observer and his powers of discrimination may have to be specified if the variety is well defined.³⁸

Ashby defines variety as the number of distinct elements (choices or possible states) in the set under consideration, or the logarithm to the base 2 of that

³⁸Ashby, "Variety, Constraint, and the Law of Requisite Variety," *Modern Systems Research for the Behavioral Scientist*, 130.

number.³⁹ For instance, Ashby explains, the variety of the sexes is logarithm base 2 of 2, or 1. Similarly, one can say that a set of identical variables, all of one type, has no variety since logarithm base 2 of 1 is 0. In short, a system's variety is a factor of its range of choices in a given circumstance.

Variety is important in the sense that a *constraint* obtains as a *relation* between two sets of unequal variety.⁴⁰ Ashby explains with the analogy of a boy's school's relation to the total population of children. The school only takes boys, so its variety is 0; however, the total population of children contains boys and girls, so its variety is 1. Therefore, a constraint exists as a relation between the school and the total population, a constraint limiting the possible interactions the school may take with the population for its identity to be conserved, i.e., as a *boy's school*.

Summing the situation so far, we have seen how the constraint placed upon a system by virtue of its having a lesser variety (possible choices or states) than its medium makes it vulnerable; it may be unable to regulate the range of system-medium-relationship outcomes so as to conserve its identity. The variety of the medium being greater than that of the system constitutes a threat to the system. However,

³⁹Ibid.

⁴⁰Ibid.

the system may reduce the variety of the medium, thereby regulating the range of outcomes of its relationship within a range congenial to the system's conservation of identity. The system may effect this reduction of the medium's variety, performing the necessary regulation, *only by increasing* its own variety. This fact constitutes Ashby's Law of Requisite Variety: "Only variety can destroy [reduce] variety."⁴¹

Ashby comments on the significance of this law to living systems:

There is first a set of disturbances D, that start in the world outside the organism, often far from it, and that threaten, if the regulator R does nothing, to drive the essential variables E outside their proper range of values. The values of E correspond to [possible] "outcomes". . . Of all these E-values only a few (n) are compatible with the organism's life, or are unobjectionable, so that the regulator R, to be successful, must take its value in a way so related to that of D that the outcome is, if possible, always within the acceptable set n, i.e., within physiological limits.⁴²

Precisely in the sense that a system, following Maturana, alters its configuration of "structural coupling" relations that define its niche, it is creating new states and *increasing its variety* so as to regulate the set of relational situations to include only those consistent with its conservation of organizational identity. If the system is able continuously to "slide" through the medium, altering

⁴¹Ibid., 135.

⁴²Ashby, "Regulation and Control," 299.

its niche-relations just so as to conserve identity, the system may be said to exhibit requisite variety.

Considering, as we did earlier, relations between a system and its medium as signal channels intersecting the system boundary, such as the channel containing Bateson's blind man's stick, let us consider the role of such channels in variety reduction. The blind man uses the stick to *transduce* perturbations which are potentially salient for his structural determination of further neuronc states. The stick, and the way the he has learned to use it, increases the blind man's variety sufficiently to effectively organize perturbations, thus reducing the medium's variety to within safe limits. The law of requisite variety states that the *capacity* of the channel, under transduction, limits the capacity of the blind man to regulate his possible interactions with his medium. Ashby puts it this way:

The law of Requisite Variety says that R's capacity as a regulator cannot exceed R's capacity as a channel of communication.⁴³

Pressing further the analogy of the system-medium relations as communication channels we can see the significance for these relation-channels--and for the system which specifies them--of the original formulation of Ashby's law, which took the form of Claude Shannon and Warren

⁴³Ibid., 300.

Weaver's Theorem 10 from their 1949 *Mathematical Theory of Communication*. Ashby paraphrases this theorem, saying,

if noise appears in a message, the amount of noise that can be removed by a correction channel is limited to the amount of information that can be carried by the channel.⁴⁴

If we consider Shannon and Weaver's *noise* to be analogous to *phenomenal disturbances* perceived by the system, while Shannon and Weaver's *correction channel* is analogous to Ashby's *regulator*, then, for the system to regulate the disturbance--suppress the noise--its correction channel-regulator must have channel-capacity commensurate to the types of noise-disturbances it encounters. The system, through its various structural couplings with its medium, must exhibit requisite variety. Ashby sums the analogy:

Thus the use of a regulator to achieve homeostasis and the use of a correction channel to suppress noise are homologous.⁴⁵

8. *Cybernetics, feed-back and control*. We now have laid the groundwork for elucidation of what makes a system *cybernetic*. Cybernetic systems are those systems that effect regulation and control of specified variables. How are such systems organized that such regulation is possible?

Systems may exhibit the following capabilities: they may detect, select, effect, and correct.⁴⁶ These activities

⁴⁴Ibid.

⁴⁵Ibid.

⁴⁶These terms taken from William Reckmeyer, seminar lectures. San Jose State University.

require the system to possess the following properties: (1) they must have *receptors* for input of signals reporting phenomenal conditions, (2) they must have a reference signal, either externally or self-programmed, constituting the *desired* value of the signal delivered by the receptors, (3) they must have a *comparator* computational function by which receptor signals are *subtracted from* reference signal, (4) upon the event of a transient non-zero value at the comparator an *error* or deviation from a desired perceptual state is computed and, (5) *effectors* are be activated so as to bring about *behavior* impacting the system's phenomenal domain so as to diminish subsequent error computations toward zero.

If the comparator returns a value close to zero, then receptor signals are close-to-parity with reference signal and little or no corrective behavior is required. On the other hand, there are two ways in which significant new behavior can be required, even though at a time t , receptor and reference signals were stable at a minimum error. First, at time $t+1$, a phenomenal *disturbance* or *perturbation* has been propagated by receptors which makes the receptor signal deviate suddenly from the controlled steady state close to reference; second, the reference signal may change, causing a net difference between receptor and reference signals. Under either condition a transient non-zero value

is computed at the comparator and behavior is activated to regain the minimum error steady state. The difference is that in the first case, what changed was the receptor signal; in the second case, what changed was the reference signal.⁴⁷

In short, a cybernetic system is a control system. What it controls, however, is not its behavior; it controls its receptor signal, or perception.⁴⁸ In this sense, what is controlled--the controlled variable--is a matter of experience.⁴⁹ This fact requires a non-intuitive view of the relation between the control system and its observed environment. The activity of the control system does not respond to stimuli originating in the environment, it responds to stimuli originating within the system itself--an error computation. Thus, the signal path does not begin in the system's environment, it passes through it. This view will be expanded shortly when we view the control system as

⁴⁷Powers, "An Outline of Control Theory," In *Texts in Cybernetic Theory: Proceedings of An In-Depth Exploration of the Thought of Humberto Maturana, William Powers and Ernst von Glasersfeld in Felton, California, October 18-23, 1988*, by the American Society for Cybernetics, 1988, p. 16. See also: Powers, *Behavior: the Control of Perception*, pp. 62 & 76.

⁴⁸This view is consistent with Powers's control-theory interpretation, and it supports the epistemic shift of constructivism as drawn from the implications of Piaget's work, to be examined. But it does not necessarily represent the view of systems scientists in general.

⁴⁹*Ibid.*, p. 15.

organizationally closed and structure determined. Figure 1 represents a cybernetic control system.⁵⁰

Fig. 1. A cybernetic control system

Cybernetic systems like the control system in figure 1 are systems that behave in order to regulate. They perform actions so as to minimize the error signal resulting from a mis-match of reference (desired perceptual state) and receptor (actual perceived state) signals. In order for the comparator to compute an error value it must have at its disposal two input values, (1) the reference value and, (2) the receptor value. We will discuss the reference value under the heading of *purpose*, below. The receptor value is a combination of phenomenal inputs to the system including the perceived effects of controlling behavior to which are added random disturbances or perturbations from elsewhere in

⁵⁰Diagram is synthesis of a) Ibid., 15a, and b) Powers, *Behavior: the Control of Perception*, 61.

the system's phenomenal domain. Upon computation of an error at the comparator, the system acts to effect phenomenal changes so as to compensate for the disturbances and bring the error value back toward zero. This consistently minimizing error is maintained by *negative-feedback* transform functions of the system.

Varela argues that such circular transformations raise objections to the validity of linear cause-and-effect models. Additionally, and more importantly, it provides, for living systems, an organizational design which is independent of properties of various system components. This independence is reflected in the distinction, noted above, that organizational closure and manifest structure fall within non-intersecting phenomenal domains. He writes:

The picture seemed closer to a circular causation, where one can deal only with the ensuing totality and its manifested stability. In other words, the nature of feedback is that it gives a mechanism, which is independent of particular properties of components, for constituting a stable unit.⁵¹

While negative feedback is necessary for enabling systems to regulate controlled variables, it is not the only kind of feedback systems exhibit. There is also transformation by *positive feedback*. This may be exhibited any time a system accumulation level (integral) may, by virtue of its incremental increase, effect a non-linear increase in its own rate of accumulation. Examples of

⁵¹Varela, *Principles of Biological Autonomy*, 166.

positive feedback are compounding interest or an uncontrolled nuclear reaction.

Control-theorists note that positive feedback, since it is the inverse of negative feedback, is the inverse of a controlling function and would, in a regulating capacity, perform pathologically.⁵² But there is a wider recursive sense in which positive and negative feedbacks may be seen as *complementary aspects* of the dynamics of complex systems. An ecological system contains many dynamic subsystems, such as individual species, which, absent constraints, may tend toward population increases. These oscillatory dynamics may be described as positive feedback transforms. Yet, in a relatively stable ecological system, all the populations appear to oscillate along narrow amplitudes around a mean value. Thus, it appears that ecological systems exhibit a complementary dynamic of expansion and control, as a function of constraints set for subsystem populations by the dynamics of the system as a whole. This complementary dynamic between positive and negative feedback is a useful metaphor for describing the interplay of functions of incremental learning to be examined in the next chapter.

It is also useful to note that, for the observer, the contents of a control channel may be either a signal

⁵²Powers, *Behavior: The Control of Perception*, 45; Van Court Hare, *Systems Analysis: A Diagnostic Approach*, (New York: Harcourt Brace, 1967), p. 46.

(constituting information), or it may be matter/energy as in a nuclear reaction or a dynamic industrial system involving manufacturing, inventory, and sales. Such systems typically exhibit the interplay of positive and negative feedbacks and time delays resulting in controlled quantities of matter, energy, and information.⁵³

9. *Organizational closure.* Returning to the phenomenological domain of the organism/nervous system, the significance of viewing living systems as control systems is that we no longer view the state of the system (state of the organism's nervous system) as *determined by environmental events*. Instead, the living system is, in neurocomputational terms, organizationally closed and structure determined.⁵⁴ As noted briefly above, organizational closure refers to the notion that an autopoietic control system is organized to maintain signal vectors within certain ranges, according to its own specifications.⁵⁵ It does not matter to the system *what has caused* perturbations in these vectors resulting in error computations. What matters to the system is the fact

⁵³Thanks to William Reckmeyer for making this point. See Forrester, *Principles of Systems* for details.

⁵⁴Maturana, "The Ontology of Observing," 13-14.

⁵⁵The use of the term "control" as an apparently operational predicate for autopoietic functioning is, according to Maturana, a confusion of phenomenological domains. Strictly, "control" does not occur in the organization operationally. But we are allowing it here since we have adopted Varela's more liberal view that symbolic distinctions are required for a sufficient explanation, on this model, of living phenomena.

of an error and the activation of efferent signals aimed at its correction. As Mingers remarks, "nervous activity results from and leads to further nervous activity in a closed cycle."⁵⁶ This closed cycle is what is meant by organizational closure. Nervous activity is controlled activity, triggered, in part, by random vector perturbations which an observer might see as causally located within an organism's environment. But to the organism, vectors are simply combinations of signals to be controlled. In this sense the transform path of signal control, from efferent signals to sensory signals *passes through* the environment, but does not originate there.⁵⁷

It follows that control systems organized in this closed fashion are *structure determined* systems. The range of possible states it may take, and the types of perturbations which may trigger changes of state are all determined by the system itself, not some outside agent. Mingers expands this argument with an illustrating example.

. . .the nervous system is structure dependent. Its possible and actual changes of state depend on its own structure at a point in time, not on some outside agency. At most, such an agency can act only as a trigger or source of perturbation. It cannot determine the reaction of the nervous system. This can easily be shown by recognizing that it is the structure itself that determines what can be a trigger for it. By definition, only systems with

⁵⁶John Mingers, "Cognitive Theories of Maturana and Varela," *Systems Practice* 4, no. 4 (August 1991): 323.

⁵⁷*Ibid.*

light-sensitive neurons can be affected by changes in light.⁵⁸

Living systems are control systems that utilize negative feedback transforms to direct and regulate their interactions with their phenomenal domains.⁵⁹ Weiner suggests that the presence of negative feedback systems in behaving organisms is essential for "effective action" by the organism.

. . .for effective action in the outer world, it is not only essential that we possess good effectors, but that the performance of these effectors be properly monitored back to the central nervous system, and that the readings of these monitors be properly combined with the other information coming in from the sense organs to produce a properly proportioned output to the effectors.⁶⁰

The notion of "effective action" supposes a goal or purpose against which perceptual signals are measured to monitor how effective the actions or behavior might be toward minimizing computed error, or maintaining a goal-state. "Effective action" or "adequate action" will resurface in our examination of Maturana as constituting his evidence for cognition in living systems.⁶¹

10. *Purpose.* Clearly, without some means of registering a desired state or goal, error values in negative feedback control systems could not be computed--making regulation impossible. In a control system the

⁵⁸Ibid.

⁵⁹Powers, *Behavior: the Control of Perception*, 47.

⁶⁰Norbert Wiener, *Cybernetics*, (New York: Wiley, 1948), p. 114.

⁶¹Maturana, "Ontology of Observing," 5.

vehicle for establishment of the purpose toward which behavior is to be directed--the desired regulation--is the reference signal. Recall that we have already characterized the reference signal as a measure of the desired perceptual state. If that perceptual state wanders due to some perturbation, then the difference between receptor signal and reference signal is not zero, and behavior is effected proportionately to a measure of the error value. Far from being an indistinct quantity, the reference value of a control system is, according to Powers, "that state of the environment being observed by the subject that calls for no response."⁶² He adds, "This reference condition is exactly what is meant by a goal."⁶³ If we as observers could hypothetically know a control system's reference signal and similarly observe its perceptual domain so as to recognize when conditions varied from the reference condition, then we would perfectly understand the system's subsequent transient behavior, assuming it commands requisite variety, so as to bring the phenomenal controlled quantity back to parity with the reference signal.

The notion of purpose, out of the context of negative feedback control systems, has, however, suffered philosophical and scientific discredit. This discredit is in part because classical empiricists who had no blueprint

⁶²Powers, *Behavior: the Control of Perception*, 45.

⁶³*Ibid.*, 65.

for control system organization saw no observable phenomenon to which purpose could be connected. Another difficulty, largely due to Aristotle's concept of final cause, was the notion that future events or goals could somehow be "dynamic agents in their own realizations."⁶⁴ This notion is commonly labelled teleology and, by its additional discredited biological association with the notion of guiding forces driving evolution, has led to the dismissal of the notion of goal-directedness in general across a range of twentieth-century scientific practice.⁶⁵ This critical attitude was especially directed against biologists who, according to Nagel, sought to provide "teleological analysis" of functions and processes "directed toward attaining certain end-products."⁶⁶ Nagel himself concluded that even apart from confusion with final causes,

Purposes and deliberate goals admittedly play important roles in human activities, but there is no basis whatever for assuming them in the study of physicochemical and most biological phenomena.⁶⁷

Early proponents of cybernetics only compounded the confusion, von Glasersfeld observes,

the founders of cybernetics, intent upon mechanizing goal-directed behavior in artificial devices, helped

⁶⁴Ernest Nagel, *The Structure of Science*, (New York: Harcourt Brace, 1961), p. 402. I owe knowledge of this reference to Ernst von Glasersfeld.

⁶⁵von Glasersfeld, "Teleology and the Concepts of Causation," *Philosophica* 46, no. 2 (1990): 33.

⁶⁶Nagel, *Structure of Science*, 401.

⁶⁷*Ibid.*, 402.

to perpetuate the ambiguity by calling their constructs 'teleological'.⁶⁸

Evidence of this mistake can be found directly in Weiner, Rosenblueth and Bigelow's classic paper, "Behavior, Purpose and Teleology," in which they argue for a feedback interpretation of purposeful behavior. They write:

Purposeful active behavior may be subdivided into two classes: "feed-back" (or "teleological") and "non-feedback" (or "non-teleological").⁶⁹

Von Bertalanffy is another who may have contributed to the confusion with statements like this:

. . .teleological behavior directed toward a characteristic final state or goal is not something off limits for natural science. . .Rather it is a form of behavior which can well be defined in scientific terms and for which the necessary conditions and possible mechanisms can be indicated.⁷⁰

Yet another point of confusion surrounding the notion of purpose or goal in explaining control system behavior is the preconception that a goal is something to be striven for. According to Powers, a more accurate notion of purpose in the control system model is that "goal-directed behavior means behavior which maintains perceptions at the goal state all of the time," not just at some end point.⁷¹

⁶⁸von Glasersfeld, "Teleology and the Concepts of Causation," 33-34.

⁶⁹Arturo Rosenblueth, Norbert Weiner and Julian Bigelow, "Behavior, Purpose and Teleology," *Philosophy of Science* 10, no. 1 (1943): 19.

⁷⁰von Bertalanffy, *General Systems Theory*, 46.

⁷¹Powers, *Behavior: the Control of Perception*, 66.

It is clear from the above that without a control system model of behavior, such as that depicted in figure 1, notions of purposeful behavior must appear unscientific. However, incorporated within a control system as a reference value, observable as the phenomenal condition under which no corrective behavior is emitted, *purpose* takes on a distinctly empirical character.

According to von Glasersfeld, biologists have recently introduced an new term, *teleonomy*, in order to differentiate their homeostatic type of goal-directedness from confusion with vital principles or final causes.⁷²

Summary

I suggest that problems of inquiry into situations exhibiting complexity require new kinds of knowledge, but it is apparent that science and philosophy have lost a sure epistemic footing on unproblematic certification of knowledge as traditionally conceived. Clearly called for is an examination of what it means to know anything at all.

Piaget's genetic epistemology is offered as a naturalistic attempt to clarify the source, nature, development, and purpose of knowledge. This examination reveals that Piaget's model of equilibrating knowledge structures is cybernetic and autopoietic and subordinate to

⁷²von Glasersfeld, "Teleology and the Concepts of Causation," 34-35.

the conservation of organization of the physico-cognitive totality.

The philosophically skeptical position implied by Piaget--constructivism--is developed and found to focus epistemic interest on self-organized experience rather than correspondence with assumed reality. This position--dubbed arealism--is found relevant to the empiricism-realism debate in philosophy of science, where even realist positions appear to converge, at least methodologically, with the epistemic position taken here.

Systems concepts are introduced as guidelines for the distinction of organizations and structures in an observer's domain of experience. On a higher level of recursion, systems exhibiting regulatory processes and structures are likely to be related more to the goals or aims of inquiry of the observer than to any so-called ready-made compositions awaiting random discovery. But it is not enough to merely declare that our conceptual models of systems, environments, and control mechanisms are our own invention. We still have not provided an argument for why we should have confidence in these models and how they appear to consistently assist us in the accumulation of knowledge. For this argument we shall now turn to Jean Piaget.

CHAPTER II

PIAGET'S GENETIC EPISTEMOLOGY: A DEVELOPMENTAL APPROACH TO KNOWLEDGE ACQUISITION

Introduction

One of epistemology's toughest riddles is expressed in the question: how to account for the apparent fact that we, as cognitive agents, develop knowledge of our phenomenal world? A deeper riddle is encountered when we ask, what is the source, nature and purpose of such knowledge? In this chapter we explore how Piaget's genetic epistemology may be viewed as progress toward clarification of these riddles. In the following sections we examine Piaget's genetic account of knowledge accumulation, its terminology, its active, transform character, its lawlike stages of development of intelligence, and the types of knowledge differentiated as the stages unfold. Genetic epistemology is positioned as a philosophically naturalistic tradition, and Piaget's use of key terms: *structure*, *assimilation*, *accommodation*, and *scheme* is elucidated. Genetic epistemology is offered as, first, the account of knowledge as a developmental process proceeding from a lesser state of comprehensiveness and efficacy to a more complete one, and second, the method of understanding and analyzing this

development scientifically.¹ This progressive development of knowledge is depicted not as a passive reflection of reality gained through reason but as an active process through which the learning subject transforms and, through this transformation, organizes both the structures of knowledge and the phenomena of experience. The development of knowledge is seen to proceed through a series of lawlike stages upon the completion of which the subject constructs an ever-increasing store of experimental knowledge and a folio of organizationally closed structures of pure, symbolic (operational) thought. These two forms of knowledge, experimental and operational, are seen as the complementary development of a single cognitive organizing function.

Fundamentals of Genetic Epistemology

Piaget's genetic epistemology marks an attempt to explain the nature and origins of knowledge through the conduct of scientific inquiry. This reliance upon scientific practice for the development of epistemological conclusions constitutes Piaget's work as a *naturalized* epistemology.² Under this conception, knowledge is defined

¹Piaget, *Psychology and Epistemology*, (New York: Grossman, 1971), p. 6.

²See: Quine, "Epistemology Naturalized," *Ontological Relativity and Other Essays*, (New York: Columbia University Press, 1969); ed. Hilary Kornblith, *Naturalizing Epistemology*, Cambridge: MIT Press, 1985; Robert Almeder, "On Naturalizing Epistemology," *American Philosophical*

as both architect and fruit of an organism's interactions within its phenomenal domain, with no appeal to a priori epistemological norms. This naturalistic sentiment echoes Dewey, who writes,

Knowledge is not something separate and self-sufficing, but is involved in the process by which life is sustained and evolved.³

Interestingly, we find a naturalistic-sounding sentiment at the headwaters of modern empiricism--in Hume. As Fenton Robb points out, Hume appeared to prescribe scientific inquiry into the human mechanisms by which we somehow come to know about phenomena rather than attempt to delve in vain into the "secret nature" of things. Hume, Robb writes,

is more interested in the psychological basis for knowledge and understanding, into which we may gain some insight, than he is about the metaphysical basis of an external world about which we can know nothing for certain.⁴

Though the atomistic, discrete empiricism of Hume's classical phenomenalist descendents is a target of criticism for later naturalistic empiricists such as Dewey,

Quarterly 27, no. 4 (1990): 263-279; Susan Haack, "Recent Obituaries of Epistemology," *American Philosophical Quarterly* 27, no. 3 (1990): 199-212; Giere, "Philosophy of Science Naturalized"; Laudan, *Science and Values*; Laudan "Progress or Rationality? The Prospects for Normative Naturalism," *American Philosophical Quarterly* 24, no. 1 (1987): 19-31; and Laudan "Normative Naturalism," *Philosophy of Science* 57, no. 1 (1990): 44-59.

³Dewey, *Reconstruction in Philosophy*, 2nd edition, (Boston: Beacon, 1948), p. 87.

⁴Fenton Robb, "David Hume and Systems Practice," *Systems Practice* 4, no. 4 (August 1991): 370.

the methodological kernel of naturalism--that epistemology should focus within experience rather than beyond it--is to be found in Hume. He writes:

But still our curiosity will be pardonable, perhaps commendable, if it carry us on to still farther researches, and make us examine more accurately the nature of this *belief*, and of the *customary conjunction*, whence it is derived. By this means we may meet with some explications and analogies that will give satisfaction. . .⁵

Hume's suggestion that inquiry is warranted into the mechanisms of belief, irrespective of nature's apparent impenetrability, may be seen as a suggestion in favor of genetic epistemology. Varela has recognized the work of Piaget and some others considered here as developments of naturalized epistemology. He writes that current

concepts of control and information are at the heart of an epistemology that needs to be revised. . .The basic stance taken here is such revision leads to a naturalized epistemology, weaving together philosophical and empirical insights into a coherent fabric. This follows the tradition represented by Piaget,⁶ Bateson, McCulloch and Maturana in recent years.

Piaget's four concepts: *structure*, *assimilation* and *accommodation*, and *scheme* are briefly clarified according to his usage; they will play a prominent role in the elucidation of his model of the genetic accumulation of knowledge.

⁵David Hume, *An Enquiry Concerning Human Understanding*, 2nd ed., (Oxford: Selby-Bigge, 1902), p. 47.

⁶Varela, *Principles of Biological Autonomy*, 271-272.

Structure. For Piaget, a *structure* is an organized, active distinction by an observer, "a system of transformations" which may be a distinction of an externalized, physical whole or an internalized, conceptual whole.⁷ His definition proceeds:

We shall define structure in the broadest possible sense as a system which presents the laws or properties of a totality seen as a system. These laws of totality are different from the laws or properties of the elements which comprise the system.⁸

As distinctions of coherent wholes, structures require no validating reference, they are "self-sufficient" and self-defining by virtue of the holistic *distinction* they comprise.

Assimilation, Accommodation, and Scheme. Piaget identifies as *assimilation* and *accommodation* the "functional conditions" of the equilibrating control process by which cognitive structures are alternately strengthened or adapted to constraints.⁹

In order to show how Piaget intends these functional conditions to apply in the progressive differentiation and elaboration of the generalizable structures that he believes constitute the basis of knowledge, it is necessary to

⁷Piaget, *Structuralism*, (New York: Harper, 1971), pp. 4-5.

⁸Piaget, *Six Psychological Studies*, (New York: Random House, 1967), p. 143.

⁹Piaget, *Biology and Knowledge*, (Chicago: University of Chicago Press, 1971), p. 172.

examine those cognitive structures, which he calls *schemes*, or *action schemes*. A scheme is a cognitive structure that is defined by its generalizable behavioral pattern. Piaget defines *scheme*:

Whatever is repeatable and generalizable in an action is what I have called a scheme.¹⁰

Piaget offers an illustration:

. . .sucking reflexes create a scheme. . .which manifests itself. . .by a certain number of generalizations (empty sucking, sucking any object in the presence of the lips) and of recognitions (finding the nipple again when moving slightly aside and distinguishing it from the surrounding teguments).¹¹

Once a "sucking" scheme is manifested, it may be used in a variety of circumstances, and not just with the breast nipple. This generalization may result in "thumb sucking," for instance, in which behavior the thumb is integrated or assimilated into the scheme. These integrations of different objects within a coherent behavior pattern, or scheme, is *assimilation*. Piaget explains that, by virtue of the behavioral exercise of schemes, cognitive subjects tend to

incorporate things and people into the subject's own activity, i.e., to "assimilate" the external world into the structures that have already been constructed¹²

¹⁰Piaget, *Genetic Epistemology*, (New York: Norton, 1971), p. 42.

¹¹Piaget, *The Child and Reality*, (New York: Grossman, 1973), p. 66.

¹²Piaget, *Six Psychological Studies*, 8.

He places this notion in the form of a postulate:

First postulate: Every assimilatory scheme tends to incorporate external elements that are compatible with it.¹³

As a scheme gathers power for performing action transforms the child continues to employ it under more general circumstances, but eventually, Piaget argues, "pressures of circumstance" will constrain the successful application of schemes and result in their adjustment or reorganization. This reorganizing activity, constitutes Piaget's conception of accommodation. Under circumstances in which a scheme is inadequate or results in anomalous experience those subjects executing such schemes must

readjust these structures as a function of subtle transformations, i.e., to "accommodate" them to external objects.¹⁴

This notion results in Piaget's "second postulate" which also incorporates a key condition for scheme accommodation: the conservation of organization, identity or continuity.

Second postulate: Every assimilatory scheme has to be accommodated to the elements it assimilates, but the changes made to adapt it to an object's peculiarities must be effected without loss of continuity.¹⁵

¹³Piaget, *The Equilibration of Cognitive Structures*, (Chicago: University of Chicago Press, 1985), p. 6.

¹⁴Piaget, *Six Psychological Studies*, 8.

¹⁵Piaget, *The Equilibration of Cognitive Structures*, 6.

Piaget requires the conservation-of-continuity provision because modification of a scheme places the integrity of the scheme at risk.

In short, assimilation integrates and incorporates phenomena under a scheme, accommodation differentiates and reorganizes schemes under phenomenal constraints. It is clear that Piaget considers assimilations to be the precursors of complex cognitive judgments involving intelligence; in fact, the key function of *schemes* is to ensure assimilations.¹⁶

Genetic Epistemology: A Break With Tradition

Jean Piaget's contributions to experimental developmental psychology are well known, yet Piaget considered himself also an epistemologist, one who sought a scientific, empirical answer to the questions: 1) what is knowledge?, and 2) under what conditions may it be accumulated?¹⁷ He writes, for instance, that the question to be asked and clarified is

. . .how any science is possible, in other words, what the necessary and sufficient conditions are that will take account of how far our intellectual equipment is adequate to the world around us.¹⁸

¹⁶Jean Piaget and Barbel Inhelder, "The Gaps in Empiricism," *Beyond Reductionism: New Perspectives in the Life Sciences*, ed. Arthur Koestler and J. R. Smythies, (New York: MacMillan, 1969), p. 128.

¹⁷Richard Kitchener, "Piaget's Genetic Epistemology," *International Philosophical Quarterly* vol. 20, no. 4 (December, 1980): 377.

¹⁸Piaget, *Biology and Knowledge*, 214.

Piaget's genetic approach to epistemology results in the scientific description of a developmental process of construction, differentiation and equilibration of cognitive structures that, for Piaget, explain "how the transition is made from a lower level of knowledge to a level that is judged to be higher."¹⁹ He offers this definition of genetic epistemology:

Genetic epistemology attempts to explain knowledge, and in particular scientific knowledge, on the basis of its history, its sociogenesis, and especially the psychological origins of the notions and operations upon which it is based.²⁰

In other words, as Kitchener puts it, "genetic epistemology is the study of the growth of knowledge as a function of its development. . . ."²¹ While Piaget appears to limit the application of genetic epistemology, in his above statement, to a clarification of scientific knowledge, he intended to extend genetic epistemology, in a general sense, to the "study of the mechanisms of the growth" of all human knowledge.²²

¹⁹Piaget, *Genetic Epistemology*, 13.

²⁰*Ibid.*, 1

²¹Kitchener, "Piaget's Genetic Epistemology," 402.

²²Piaget, "Programme et methodes de l'epistemologie Genetique," *Epistemologies genetique et recherche psychologique: Etudes d'epistemologie genetique*, Vol. 1, ed. W. E. Beth, (Paris: Presses Universitaires de France, 1957), pp. 13-14, quoted in Kitchener, "Piaget's Genetic Epistemology," 402.

Piaget's Transform Model of Knowledge
and his Critique of Classical Epistemology

The active role of the subject in the process of knowledge accumulation is of critical importance to Piaget's conception of knowledge. This action-role of the subject is incompatible with classical epistemology's view of the knowing subject-mind as a passive, tabula rasa, merely reflecting knowledge of supposed invariant, natural truths. Classical empiricism, according to Piaget,

tends to consider experience as imposing itself without the subject's having to organize it, that is to say, as impressing itself directly on the organism without activity of the subject being necessary to constitute it.²³

At the same time, Piaget attacked the static, atomic, discrete-state description of classical epistemology:

Scientific thought, then, is not momentary; it is not a static instance; it is a process. More specifically, it is a process of continual construction and reorganization.²⁴

Piaget's action-view of factual knowledge involves more than just behavior by the knowing subject. It involves the organization of experience by a dynamic, transformative process of interaction between the subject and his/her phenomenal world. On this view, thought operations are not to be considered *states* but "*systems of transformation.*"²⁵ A result, for Piaget, of this subject-transformative,

²³Piaget, *The Origins of Intelligence in Children*, (New York: Norton, 1963), p. 362.

²⁴Piaget, *Genetic Epistemology*, 2.

²⁵*Ibid.*, 14.

process conception of knowledge is his dismissal of knowledge as a copy of reality.

I think that human knowledge is essentially active. To know is to assimilate reality into systems of transformations. To know is to transform reality in order to understand how a certain state is brought about. By virtue of this point of view, I find myself opposed to the view of knowledge as a copy, a passive copy, of reality.²⁶

Piaget points out that the "copy theory" of knowledge in empirical matters entails a vicious circularity, since the "copy" may only be evaluated upon the basis of prior, synthetic knowledge, which itself must be a "copy." Thus, an infinite regress of mere copies. His argument is that the copy theory

is based on a vicious circle: in order to make a copy we have to know the model that we are copying, but according to this theory of knowledge the only way to know the model is by copying it, until we are caught in a circle, unable ever to know whether our copy of the model is like the model or not. To my way of thinking, knowing an object does not mean copying it--it means acting upon it.²⁷

In fact, according to Kitchener, Piaget argues that the copy theory of knowledge, or the "spectator model," sets up the epistemological question to fail and mislead by virtue of its very formulation; it is a formulation that winds up begging three important questions: (1) it presupposes a Cartesian dualism (separation of mind-substance from body-substance), (2) it presupposes the subject's self-knowledge

²⁶Ibid., 15.

²⁷Ibid.

as differentiated from surroundings, and (3) it presupposes the subject's knowledge "that objects are permanent types of entities that exist in space and time, that have certain general kinds of causal properties."²⁸ While this last problem carries implications for some underlying conflicts with realism implied in Piaget's epistemology, conflicts to be examined later, the combined impact of these uncritical assumptions is to hopelessly mislead epistemological inquiry. Kitchener observes:

The misleading way the problem is posed forever prevents us from arriving at an adequate answer since the formulation of the problem itself begs several questions.²⁹

The action-orientation of Piaget's epistemological model is also central to an understanding of his conflict with Kant's synthetic a priori, a conception which at first glance seems congenial to Piaget's constructivism. Kant held that the categories of our perception such as space and time were innate forms imposed upon the manifold of experience by the perceiving subject. Yet, the completed-from-the-start (universality, necessity) nature of these subjectimposed categories made Kant's conception non-genetic in either a transformative or developmental sense. Kitchener sums Piaget's differences with Kant:

In short, the basic problem with Kant's categories is that they are static (temporally a priori) and do

²⁸Kitchener, "Piaget's Genetic Epistemology," 390.
²⁹Ibid.

not develop. Piaget believes he has over-whelming evidence to show that they do develop and hence that Kant's views are empirically false.³⁰

Of equal importance, according to Kitchener, with the nongenetic character of Kant's categories is, for Piaget's critique, Kant's inability to explain the fact of their necessity. But Piaget, Kitchener remarks,

believes he can explain their necessity by showing. . . that their necessity is in part a developmental necessity.³¹

Precisely how perceptual structures and modalities such as necessity are developed through experience it is the task of genetic epistemology to clarify. To this clarification we now turn.

Piaget's Model of Developmental Stages

We have seen that the task of genetic epistemology is to clarify the mechanisms by which the human mind goes from a state of lesser knowledge to a state of higher knowledge and, thus, to specify the conditions under which this development may proceed.³² Modeling cognitive mechanisms is required, in addition to simply describing the transition, if the transition from one epistemic state to another is to be explained in functional terms.³³ Piaget claims, through empirical research, to have isolated a series of stages of

³⁰Ibid., 387.

³¹Ibid.

³²Piaget, *Genetic Epistemology*, 14.

³³Kitchener, *Piaget's Theory of Knowledge*, (New Haven: Yale University Press, 1986), p. 145.

intellectual development in children ranging in age from birth to early adolescence. These stages have a characteristic logical structure and always unfold in a particular order.³⁴ Additionally, upon completion, they become integrated within the structures of succeeding stages, each of which is more stable and wider-ranging than the one integrated.³⁵

For Piaget, three main periods (important developmental unities), divided into numerous stages and sub-stages mark the progress of cognitive development. The three periods are (1) the period of sensorimotor intelligence (assimilation to and accommodation of schemes through physical action, construction of self and external world, 0-2 years), (2) the period of preparation and organization of concrete operations (formation of physically-based logical relations, 2-12 years), and (3) the period of formal operations (purely propositional logic and reversible relations, 12-15 years).

What follows is an outline of the stages of development of sensorimotor intelligence, during which Piaget claims reality is constructed into stable, perceptual invariants. Later periods of cognitive development will, for the most part, be ignored.

³⁴Ibid., 17.

³⁵Piaget, *The Child and Reality*, 51.

Development of Sensorimotor Intelligence

Stage 1. The first stage of this period, reflex exercise (roughly, 0-1-month), opens the infant onto a perceptual tableau of "chaotic undifferentiation" in which neither "objects nor spatial, temporal, or causal objectifications are possible."³⁶

Focusing upon the reflex actions prominently observed in stage one, Piaget infers from progressive observations of instances that from the start each reflex gives "rise to a systematization which exceeds [its] automatization."³⁷ That is, the reflex becomes more useful in a general sense, and it becomes more efficient as an action tool. Piaget makes the point that however hereditarily programmed reflex actions may be, they are, at first application, inefficient and awkward, but that repeated exercise "modifies" and refines the reflex schemes.³⁸ Piaget argues that in addition to accommodation of a reflex to surroundings, making it more functionally effective, there is a simultaneous, progressive assimilation of surrounding items to the reflex by which, through application (of, say, sucking) under different circumstances (fingers, thumb,

³⁶Piaget, *The Construction of Reality in the Child*, 399.

³⁷Piaget, *The Origins of Intelligence in Children*, 24.

³⁸*Ibid.*, 30.

etc.), the reflex is "consolidated and strengthened by virtue of its own functioning."³⁹

Stage 2. This stage (from one to four-and-a-half months) is distinguished, for Piaget, by the formation of the infant's first *habits*. These "conditioned reflexes" are identified as "acquired behavior" but not as acts of intelligence.⁴⁰ What is missing in these habits, which, for Piaget must be operative before intelligence may be claimed, is a "differentiation between means and ends."⁴¹

Stage 3. This stage (four-and-a-half to eight or nine months) is marked by the coordination of vision and prehension. This coordination, the intentional grasp and manipulation of objects within the infant's close visual field, enables the coordination of action schemes.⁴² A typical coordination of vision and prehension takes place when an infant has learned that a certain action has occasioned an interesting result, i.e., shaking a cord is followed by the sound of rattles (hung on the cord). Even though the infant will shake the cord to "cause" any interesting phenomenon (say, a music box sound), this action

³⁹Ibid., 32.

⁴⁰Piaget and Inhelder, *The Psychology of the Child*, 9.

⁴¹Ibid.

⁴²Piaget, *The Child and Reality*, 66-67.

"constitutes the beginning of a differentiation of means and end."⁴³

Stage 4. During this stage (eight or nine months to eleven or twelve months) the infant learns to coordinate, from known schemes, means and ends, in new and different ways for each encountered situation. Formerly, during stage 3, the infant would apply indiscriminately the same means to achieve divergent goals or ends.⁴⁴ What is new is the utilization of known means, chosen from among a variety of potential action schemes, to achieve a new objective.⁴⁵

Piaget's observations of sequential searching among known actions schemes for achievement of a given goal imply an important heuristic ingredient to the child's problem-solving routine. That ingredient Piaget refers to as "groping" or "trying out different known schemata and. . . adjusting them to the goal pursued."⁴⁶

Stage 5. this stage (eleven or twelve to eighteen months) continues the coordination of action schemes to the achievement of specific ends, but, during this stage the schemes considered are not limited to the known repertoire of already-developed schemes; new schemes are invented through a coordination, differentiation or synthesis of

⁴³Piaget and Inhelder, *The Psychology of the Child*, 10.

⁴⁴Ibid., 11.

⁴⁵Piaget, *The Child and Reality*, 56.

⁴⁶Piaget, *The Origins of Intelligence in Children*, 151.

known schemes for application in novel circumstances. This activity constitutes the "discovery of new means."⁴⁷

Stage 6. This stage (at about twenty-four months) marks, for Piaget, the completion of the purely sensorimotor period and the emergence of a symbolic function mediating the internalization of schemes and problem solutions resulting in sudden insights and comprehension.⁴⁸ In the invention of means by thought operations alone, the trial and error, physical groping gives way to a kind of internalized simulation of schemes.

Decentration: Experimental and Symbolic Knowledge

The progression of sensorimotor schemes described above serves two functions: it is a basis for the internalized development of symbolic thought and for the externalized development of experimental knowledge.⁴⁹

Externally, sensorimotor intelligence has an equally important organizing effect upon the child's perceptual universe: the concepts of object permanence, space, time and causality are constructed, differentiated and stabilized.⁵⁰ Piaget and Inhelder stress, "none of these categories is given at the outset."⁵¹ The unfolding of this

⁴⁷Piaget, *The Child and Reality*, 55.

⁴⁸Piaget and Inhelder, *The Psychology of the Child*, 11-12.

⁴⁹*Ibid.*, 13.

⁵⁰*Ibid.*

⁵¹*Ibid.*

differentiating process is to be found in the elaboration of a concept which Piaget terms *decentration*.⁵² At the beginning of this process the infant does not differentiate the self from the external world, the self and the world

simply exist in a dissociated block or are spread out on the same plane, which is neither internal nor external but midway between these two poles.⁵³

This relationship is made clear by the diagram, figure 2, in which the two terminus points represent the complementary progression of differentiation of the self X as a member of, not the locus of the phenomenal world Y.⁵⁴ The midpoint A marks the genesis point of undifferentiated consciousness which, for Piaget, characterizes the newborn's experience. It is that midpoint from which knowledge development proceeds in opposite directions, internally toward the development of logico-mathematical, symbolic structures; and externally toward the development of synthetic knowledge through experience.

Fig. 2

⁵²Kitchener, *Piaget's Theory of Knowledge*, 20-21. See also: Piaget, *The Construction of Reality in the Child*, 400.

⁵³Piaget, *Six Psychological Studies*, 12.

⁵⁴Piaget, *The Construction of Reality in the Child*, 400.

According to this bi-directional differentiation, experimental and symbolic knowledge develop, as we have seen, in complementary directions while they remain completely dependent upon the development of action schemes.

. . . knowledge is then built up in two complementary directions, while still based on actions and action schemata outside which it has no hold either on the exterior world or on internal analysis.⁵⁵

Piaget concludes that this process is the means by which intelligence simultaneously organizes the self and its surroundings.

Intelligence thus begins neither with knowledge of the self nor of things as such but with knowledge of their interaction, and it is by orienting itself simultaneously toward the two poles of that interaction that intelligence organizes the world by organizing itself.⁵⁶

This brief outline of the development of sensorimotor intelligence has sketched (in small part) Piaget's empirical case for his contention that cognitive structures are built up incrementally through the active exercise and generalization of nascent action schemes, and through the accommodation of those schemes to phenomenal constraints. Let us now examine in closer detail Piaget's conception of the process of development and differentiation of experimental knowledge structures and the logico-mathematical knowledge structures.

⁵⁵Piaget, *Biology and Knowledge*, 28.

⁵⁶Piaget, *The Construction of Reality in the Child*, 400.

The Construction of Knowledge

Piaget holds that there are three kinds of knowledge: (1) innate, instinctual knowledge; (2) action-generated experimental knowledge, and (3) internalized, logico-mathematical knowledge.⁵⁷ Later I show how, on Piaget's view, these forms of knowledge presuppose an "organizing function," characteristic of the organism as a totality, which gives rise in the first place to "assimilatory schemes and their coordinations."

Piaget draws a distinction between the goals of knowledge-development for experimental action and conceptual thought. Since sensorimotor development is the development of action skills for dealing with phenomenal surroundings (as those "surroundings" are themselves "developed"), experimental success or failure is a practical matter, having nothing to do with notions of "truth." On the other hand, the later development of logico-mathematical knowledge consists in the equilibration of the formal tools of conceptual thought. These tools of operational thought gradually generalize and become factually empty and tautologous as closed, analytical systems, dissociated from experience. Thus, these are truth functions.⁵⁸

⁵⁷Piaget, *Biology and Knowledge*, 267.

⁵⁸Piaget, *The Construction of Reality in the Child*, 406.

Experimental Knowledge and Induction

We have seen that the development of sensorimotor intelligence is characterized by the progressive equilibration of assimilation and accommodation as the fruit of active experimentation and groping by the infant. It is important to remember Piaget's emphasis on action; knowledge in general is the result of the subject's transformative interactions through assimilation and accommodation of schemes.⁵⁹

An important function of sensorimotor intelligence is the coordination of assimilatory schemes by virtue of recognition of *similarities* among various phenomena assimilated. Piaget remarks that actions are transposed, generalized, or differentiated from one situation to another by virtue of "whatever there is in common between various repetitions or superpositions of the same action."⁶⁰ This classificatory disposition will be discussed momentarily at greater length under examination of the roots of logico-mathematical structures, but I mention it here to emphasize the basis in experimentation Piaget claims for the discovery of phenomenal similarities.

A related, additional function of experimental knowledge is the progressive extension of accommodation by inductive anticipation of circumstances. Piaget notes, "it

⁵⁹Piaget, *Biology and Knowledge*, 27-28.

⁶⁰*Ibid.*, 7.

derives from a capacity for inference or transfer, based on information previously acquired."⁶¹ This forward-reaching accommodation involves two functions: memory and anticipation.⁶² Piaget writes that an essential function of "knowing is to bring about foresight." Memory, in the form of conserved schemes previously acquired (information), contributes to foresight or anticipation by virtue of its internalized activation upon the expectation of certain future circumstances. Piaget can offer no firmer logical ground for inductive success than Hume's appeal to habit.⁶³ But on Piaget's model, it may be allowed that habits of expectation of relations that have held through multiple iterations of assimilation and accommodation of a particular scheme may, because of the refinement of the scheme, be considered more highly probable to hold in the future than expectations borne of the representation of a newer, more recently coordinated scheme.

Development of Logico-Mathematical Structures

Logico-mathematical structures are operations of thought; for Piaget their roots are partly hereditarily determined (in a manner to be examined later), and partly to be found in the coordinations of action schemes of pre-linguistic children. An "operation" is defined by Piaget

⁶¹Ibid., 185.

⁶²Ibid.

⁶³Ibid., 192.

first, as "an action that can be internalized; that is, it can be carried out in thought as well as executed materially."⁶⁴ Second, an operation is a reversible action; "that is, it can take place in one direction or in the opposite direction."⁶⁵ An example of reversibility is simply the negation or inversion of an action, for instance, Piaget explains, "subtraction is simply the reversal of addition--exactly the same operation carried out in the other direction."⁶⁶ Two types of reversibility are *inversion* and *reciprocity*. Inversion, as mentioned, is negation, for instance, $(A - A = 0)$; reciprocity is simply a reversal in order, for instance, $(A = B) = (B = A)$.⁶⁷

Piaget has isolated three "mother structures" from which, he claims, all the later stages of formal thought operations are constructed through differentiation or combination.⁶⁸ The first of these structures is the "algebraic" prototype, or "mathematical notion of a group" from which the later concept of *class* derives.⁶⁹ The second logico-mathematical mother structure is the "order structure." This structure applies, for Piaget, to "relationships" such as seriation, "greater-than," and so forth. The third mother structure is the "topological

⁶⁴Piaget, *Genetic Epistemology*, 21.

⁶⁵*Ibid.*

⁶⁶*Ibid.*, 22.

⁶⁷*Ibid.*

⁶⁸*Ibid.*, 24.

⁶⁹*Ibid.*

structure."⁷⁰ It is based on the notions of "neighborhood, borders, and approaching limits" and its operational actions are "dividing space" or ordering forms in space.

Evidence of operations involving the algebraic structure include, Piaget notes, "operations of simple classification, that is, just dividing a group of objects into piles according to their similarities."⁷¹ Even though children appear to divide things into piles of similar things, cautions Piaget, they may not yet be capable of understanding the relationship of "class inclusion." A child of six years, for whom Piaget claims the structure is not fully developed, will not be able to deduce that, for example, "the total class must necessarily be as big as, or bigger than, one of its constituent classes." If asked which class was larger, birds or ducks, the child would reply that he would have to count them to find out. However, for the child of over eight years, for whom, in Piaget's view, the structure is fully developed (equilibrated and reversible), class inclusion is understood and the deduction would be made without inspection that there are more birds than ducks.

Turning to the second mother structure, *order or seriation*, Piaget claims to have found evidence that children command a primitive ordinal logic which develops

⁷⁰Ibid., 25.

⁷¹Ibid., 27.

into the cognitive relationships "bigger-than," or "smaller-than."⁷²

Evidence of topological intuition, the third mother structure, include Piaget's account of responses of children (younger than four years) who are able to reproduce drawings of closed shapes as closed shapes and crossing lines as open shapes after having been shown a number of circles, rectangles and crosses.⁷³

Logico-mathematical structures, like the order structure, become completed, "whole and closed," when they may be applied freely in thought operations "without recourse to anything outside the system."⁷⁴ That is, they may be used without recourse to experience. Closure of structures enables the child to understand deduced relations, i.e., there are more birds than ducks, as a necessity, whereas, before closure the child, without confirming experience, might consider the relation "not necessary but simply possible or probable."⁷⁵ It appears from this that Piaget is claiming a genetic development of logical structures, at first requiring concrete confirmation, but finally achieving closure as purely formal

⁷²Ibid., 29.

⁷³Ibid., 32.

⁷⁴Piaget, *Biology and Knowledge*, 316.

⁷⁵Ibid.

logical tautologies, needing no recourse to experience. He makes this clear:

. . . a study of the development of logico-mathematical structures in a child reveals that the necessity for them is imposed on the subject, not from the beginning, but, as we have already said, very gradually, often until such time as it crystallizes rather suddenly.⁷⁶

The final closed (equilibrated) state of the structure then appears, in short, *analytic*. Quine characterizes the traditional view of analytic statements as those "grounded in meanings independently of matters of fact," which, as truths of reason, could not "possibly be false."⁷⁷ In short, analytic judgments appear to correspond precisely with a Piagetian closed logico-mathematical structure. They both deliver judgments necessary as a function of the thought structure without recourse to experience. The difference separating Piaget's necessity from traditional necessity is that Piaget's structure only achieves necessity at the end of its development, not a priori. In effect, Piaget's necessity is *analytic posteriori*! Piaget observes that

this logical "necessity" is recognized not only by some inner feeling, which cannot be proved, but by the intellectual behavior of the subject, who uses the newly mastered deductive instrument with confidence and discipline.⁷⁸

⁷⁶Ibid.

⁷⁷Quine, "Two Dogmas of Empiricism," *From a Logical Point of View*, (Cambridge: Harvard University Press, 1953), p. 20.

⁷⁸Piaget, *Biology and Knowledge*, 316.

This last finding of Piaget's illustrates an aspect of the factually-normative dimension of genetic epistemology; that is, the evaluation of the completion of cognitive structures, the tools of knowledge. He writes, "necessity is the sign of the completion of the structure."⁷⁹ It is a norm that is actualized, however, only at the end of the developmental process, not at the beginning. The analysis of means by which such cognitive structures reach completion also appears to carry prescriptive weight, in the sense that, for Piaget, a single developmental process is at work in the development of all stable states; this process is *equilibration*.⁸⁰

That equilibration is the process of foremost importance for the acquisition of knowledge, in Piaget's view, is clear. He writes, "The development of cognitive functions consists, above all, of a process of equilibration."⁸¹

Summary

This chapter has provided an examination of Piaget's concept of genetic epistemology. Since it is an attempt to use the methods of science to understand the nature of knowledge, this doctrine is an example of a naturalized epistemology. It differs from traditional epistemology in

⁷⁹Piaget, *Six Psychological Studies*, 157.

⁸⁰Ibid.

⁸¹Ibid., 107.

the sense that it describes an action-oriented, progressive construction of knowledge rather than a passive registry of unproblematic facts. It deals effectively with traditional problems of explaining universality and necessity by arguing that these attributes are evidence of operational closure of cognitive structures of symbolic thought, which are the internalizations of behavioral schemes acquired during the various stages of intellectual development. Two kinds of knowledge are distinguished by Piaget, experimental and symbolic or operational. These two kinds of knowledge are complementary and develop in opposite directions according to Piaget's notion of decentration throughout the process of the development of intellect and the closure of logico-mathematical cognitive structures.

If the maturation of intellect is a process of progressive closure of cognitive structures by virtue of the complementary interplay of assimilation and accommodation then a dynamics of development is implied. Piaget holds that such dynamics are reflected by a model of cognitive structures which is self-regulating and self-conserving. To an examination of this model of dynamic functioning we now turn.

CHAPTER III

PIAGET'S SELF-REFERRING MODEL FOR BIOLOGICALLY-BASED COGNITIVE STRUCTURES

Introduction

Equilibration implies control. In view of Piaget's emphasis of the role of equilibration in his genetic account for how we have knowledge, it may come as no surprise that he models this process as the self-equilibration of a control system. Moreover, his notion of why we have knowledge can be understood only insofar as cognition is viewed as a biological phenomenon, differentiated and organized as--indeed an extension of--the biological system. Specifically, I make two claims: (1) that Piaget's genetic process of knowledge accumulation is modeled as a cybernetic, control and regulation process, and not a merely dialectical process, and (2) that Piaget proposed that the organization of the cognitive control transforms by which knowledge structures develop are the result and extension of a biological organization the equivalent of Maturana's self-conserving model of autopoiesis. In short, I argue that, for Piaget, the clarification of the fact, nature, and purpose of knowledge flows directly from viewing it as an aspect of the self-organizational functioning of the physico-cognitive whole.

Though Varela has explicitly recognized Piaget's conception of knowledge as self-organizing, this interpretation of Piaget's work apparently is not widely acknowledged.¹ For instance, Marvin and Netta Kaplan recently wrote, "the self-organizational perspective has been neither accepted nor well recognized among psychological theorists."²

The Cybernetics of Genetic Epistemology

Cybernetics, or Dialectics?

Piaget's iterative, self-refining model of cognitive development, along with his own declarations that it is dialectical, has led commentators to label his genetic account of knowledge as dialectical without asking what *mechanisms* may control the progression. Kitchener, for instance, concludes that Piaget's "theory of equilibration is thus an excellent example of methodological dialectics."³ It is not so much that this is a wrong assessment, but that it looks no further into Piaget's own model of the mechanisms driving the equilibrating activity. For Piaget's purposes of explication, a cybernetic model is preferable to the more commonly invoked dialectical model since the

¹Varela, *Principles of Biological Autonomy*, 256.

²Marvin Kaplan and Netta Kaplan, "The Self-organization of Human Psychological Functioning," *Behavioral Science* 36, no. 3 (July 1991): 161.

³Kitchener, "Piaget's Genetic Epistemology," 388.

cybernetic model explains how equilibration is held at steady state, and because it offers a model for an invariant organizational identity, while the dialectical model simply describes the output of the equilibrating function without making the *function* clear.

As we have seen, for Piaget, equilibration is the dynamic result of the interaction of assimilation and accommodation.⁴ The functional process of this dynamic activity of the developing intellect constitutes, for Piaget, the process of *adaptation*--a balancing act under continually novel conditions. He explains:

In assimilating objects, actions and thought must accommodate to these objects; they must adjust to external variation. The balancing of the processes of assimilation and accommodation may be called "adaptation." Such is the general form of psychological equilibrium, and the progressive organization of mental development appears to be simply an ever more precise adaptation to reality.⁵

Piaget defines equilibration in terms of three functional characteristics which make it appear like the homeostasis achieved by a cybernetic control system: (1) a stability that is "mobile" and reorganizing, (2) compensating activity upon the occasion of external intrusion, and (3) from 1 and 2 it follows that equilibration is "essentially active" and "not something passive."⁶ Elsewhere he offers this simpler definition, which appears identical to the activity of a

⁴Piaget, *Six Psychological Studies*, 103.

⁵*Ibid.*, 8.

⁶*Ibid.*, 151.

negative feedback control system: "We shall. . .define [psychological equilibrium] very broadly as the compensation resulting from the activities of the subject in response to external intrusion."⁷ Indeed, for Piaget, it is not the equilibrium "state" that is psychologically or epistemologically interesting; it is the explication of the actual process. He states, "equilibrium is only a result, whereas the process as such has greater expository value."⁸

Equilibration, Error-Correction, and Feedback

In describing the activity of equilibrium Piaget observes that an organism must do work to maintain equilibrium.

Equilibrium by no means expresses a state of rest but a play of compensations involving a maximum amount of activity on the part of the subject.⁹

In view of Piaget's emphasis upon the compensating characteristic of the equilibrating mechanism consider William Powers's definition of a control system at work:

The subject can be said to control a variable with respect to a reference condition if every disturbance tending to cause a deviation from the reference condition calls forth a behavior which results in opposition to the disturbance.¹⁰

Piaget stresses that the "goal" of the equilibrating process is not achieving a "balance" but minimizing error:

⁷Ibid., 101.

⁸Ibid.

⁹Ibid., 109.

¹⁰Powers, *Behavior: the Control of Perception*, 47.

"the situation suggested by the facts is not that of a precise balance but of a protection against error."¹¹ Powers observes that, in a control system, "The response to an error is always such as to reduce the error."¹² Piaget makes it clear that he is considering cybernetic, error correcting, negative feedback transforms as his model for the equilibration of cognitive structures:

[the nature of] cybernetic regulations. . . is to supply, by means of retroactive control, corrections or modifications in case of error. Either the regulation will bear on the outcome of a process and so amount to accepting the normal working or success of that process, or else it will compensate for deviation and correct any errors. . . These classic models of regulation are found yet again, in this same role of correcting or anticipating error, on the level of elementary cognitive structures.¹³

Though Piaget stresses the role of negative feedback in regulation, the overall process of equilibration may be seen as an interplay of negative and positive feedback dynamics. In terms of assimilation and accommodation, clearly the adjustment regulation of accommodation is predominantly error-correcting or negative. But assimilation, with its emphasis on scheme-nourishment and strengthening by virtue of its progressive incorporation of phenomenal objects--a progression invigorated by the increasing strength of the scheme--is clearly positive. Piaget contends that, for learning to take place at all, both negative and positive

¹¹Piaget, *Six Psychological Studies*, 108.

¹²Powers, *Behavior: the Control of Perception*, 45.

¹³Piaget, *Biology and Knowledge*, 206-207.

feedbacks must be represented in the process. He writes, "Without the general characteristic of opposing processes [negative and positive feedbacks], it would be difficult to see how regulations could improve actions."¹⁴

A Control-Theory Model of Induction

Piaget recognized the importance of feedback control and regulation transforms that reach forward in experience and anticipate probable events in order to effect corrections upon probable errors before they are made. He writes that the regulation must be more than just a reaction to a stimulus or event, it must be *proactive*, it must

contain some anticipatory dimension and consist of a guiding power which again serves to confirm useful tendencies and to correct, or compensate for, bad ones.¹⁵

Piaget stresses that the emergence of operational thought capabilities increase the power of the inductive precorrections.

If regulation of the lower or ordinary (sensorimotor) type is a process for correcting or modifying errors, then operational regulation is seen as a process for precorrecting, avoiding, or eliminating errors, which is something much greater.¹⁶

It is clear that Piaget conceives anticipation to be increasingly successful as an inductive method of cybernetic

¹⁴Piaget, *The Equilibration of Cognitive Structures*, 146.

¹⁵Piaget, *Biology and Knowledge*, 206.

¹⁶*Ibid.*, 210.

regulation as the line of equilibrium between assimilation and accommodation becomes further differentiated through experience.

Thus, it can be seen that during the gradual extension of the knowledge "environment," that is, the sum total of external objects on which the intelligence is brought to bear. . .the regulations whose task it is to control cognitive exchanges with this environment, that is, to organize experience in terms of deductive frames, will reach a level of precision never found in elementary regulations. . . they carry out a function of precorrection in the proper sense of the word.¹⁷

In addition to the anticipatory action of inductive error correction is the notion of the damping of oscillatory fluctuations of first-order feedback transforms by second-order transforms.

Moreover, on all forms of feedbacks, feedforwards are superimposed, and these remedy slowness or excess in the feedbacks by constituting, as it were, regulations to the second power or controls of the regulation itself.¹⁸

Purpose and Autoregulation of Cognitive Structures

We have seen how Piaget views the development of knowledge as the progressive fruit of the complementary (cybernetic) interplay of assimilation and accommodation--an equilibrating process that knowledge, at various stages, also guides. Implicit in this view is the notion that knowledge and purpose are related.

¹⁷Ibid., 211.

¹⁸Ibid., 207.

What knowledge really consists of is not just the acquisition and accumulation of information, since that alone would remain inert and sightless, as it were. But knowledge organizes and regulates this information by means of autocontrol systems directed toward adaptation, in other words, toward the solving of its problems. Every cybernetic concept thus acquires immediate significance in the cognitive field. . .¹⁹

Piaget explains his concept of compensations as the result of negative feedback in action, relative to a purpose which, on Powers's model, would correspond to the "reference" signal.

If we say that compensations are actions opposed to and tending to cancel or neutralize some effect, it goes without saying that negative feedback, as a corrective instrument, plays the role of compensation. When it is a matter of correcting action itself, as with someone learning to ride a bicycle, these motoric negations are obvious. They are necessary to keep from tipping sideways or to balance oneself in a turn where being too upright would threaten equilibrium. When on the other hand, a perturbation arises because of some external obstacle, that obstacle may be set aside or gone around. This, too, amounts to compensating for a perturbation by a complete or partial negation.²⁰

Piaget adds to the model a "comparator" implicit in the fact that he requires an "evaluation" of the degree of error correction effected.

. . .compensations. . .involve an evaluation of success or failure. This is linked to the source of the compensations themselves. Since compensations are set in motion when assimilation and accommodation are disequilibrated by perturbations that impede reaching the goal set by the scheme employed, this evaluation consists in a judgment of

¹⁹Ibid., 61.

²⁰Piaget, *The Equilibration of Cognitive Structures*,

the degree to which there has been accession to the goal.²¹

Behavior: the Control of Cognitive Equilibration

Returning to Piaget's emphasis on action and, in fact, "groping" and experimental action in the growth of knowledge, we can see, in light of his control-system model of cognitive construction, the cybernetic importance of such actions:

Learning by groping or trial and error is simply the progressive construction of a schema, but in stages of successive regulations, such that the result of each action has a modifying effect, either positive or negative, on the following one.²²

As soon as the subject is seen, according to Piaget,

as a progressive organization making active attempts at discovery, then it will be obvious that groping is a succession of regulations following the line of an equilibration by means of assimilations and corrections brought about by the subject itself.²³

It is important to emphasize that the "line of equilibration" of cognitive organization Piaget alludes to above must remain unbroken, that is, that the organization remain continuous. This distinction forms a part, as we have seen, of his "second postulate of assimilation." He explains:

This postulate indicates that modifying a scheme must destroy neither its closure as a cycle of

²¹Ibid., 24.

²²Piaget, *Biology and Knowledge*, 207.

²³Ibid.

interdependent processes nor its previous powers of assimilation.²⁴

He lists a number of mature cognitive structures that have achieved a stable equilibrium approaching the ultimate in self-conservation: closure, equilibration and, thus, organizational invariance. Emergence of analyticity or necessity as the condition of operational closure, as we saw earlier, is an example of such invariance.

Throughout it has been clear that action plays a key role in Piaget's cybernetic model of the equilibrating mechanisms at work in assimilation and accommodation--without action there would be no assimilation of schemes in the first place. This action is behavior. It is clear also that Piaget sees behavior as the activity of a control system, controlling perceptual and cognitive circumstances.

Behavior, as with all kinds of organization, includes regulations, whose function is to control constructive accommodations and assimilations on the basis of the results obtained.²⁵

This formulation of Piaget's is strikingly similar to one advanced by Powers:

. . .the concept of behavior as a feedback process organized around the control of perception, and reorganized as a way of maintaining ourselves in a peculiarly human condition defined by intrinsic reference levels.²⁶

²⁴Piaget, *The Equilibration of Cognitive Structures*, 6.

²⁵Piaget, *Biology and Knowledge*, 364.

²⁶Powers, *Behavior: the Control of Perception*, 272.

The Biological Organization of Cognitive Structures

Understanding Piaget's cybernetic-genetic model of equilibrated assimilation and accommodation, guided by reference values--knowledge (logico-mathematical and experimental)--that the process itself, in circular fashion, refines, has reflected the essentials of Piaget's description of the process of knowledge accumulation. Moreover, his analysis of the control system organization of the psychogenetic process has offered a functional model of the mechanisms by virtue of which this process proceeds. However, we can, at this point, no longer ignore the question: by what agency does this process acquire its organization? Piaget's answer is to be found in the guiding hypotheses of *Biology and Knowledge*: That cognitive functions are the reflection and extension of self-referring, autoregulative physical structures. Furthermore, in humans, these cognitive functions constitute a specialized organ for regulating the cognitive (living) subject's exchanges with its environment. Finally, this cognitive organization is only partially differentiated by virtue of the hereditary organizing of gross reflex behavior, but these nascent behavioral schemes--mere genetic hints--become increasingly strengthened and refined through abstract thought and active experiment.²⁷ Cognitive

²⁷Piaget, *Biology and Knowledge*, 369.

structures are functionally similar to organic organizations (self-conservation), and they exhibit at least partial isomorphisms with organic organization from which they spring. He hypothesizes

that cognitive functions are an extension of organic regulations and constitute a differentiated organ for regulating exchanges with the external world. The organ in question is only partially differentiated at the level of innate knowledge, but it becomes increasingly differentiated with logico-mathematical structures and social exchanges or exchanges inherent in any kind of experiment.²⁸

In short, Piaget claims that cognitive structures, like those of logico-mathematical operations, have "biological roots," and these structures are organized as these biological roots, but on the "conscious-symbolic-linguistic level."²⁹

Putting aside, for now, consideration of how biological functioning may be extended to the organization of cognitive functioning, let us examine Piaget's general model of organizational self-conservation through autoregulation.

Piaget and Autopoiesis

Structures in general exhibit, for Piaget, a self-regulating, self-conserving organizational activity. This stance is made clear in *Structuralism*.

These properties of conservation along with stability of boundaries despite the construction of indefinitely many new elements presuppose that

²⁸Ibid.

²⁹Piaget and Inhelder, "The Gaps in Empiricism," 152.

structures are self-regulating. There can be no doubt that it is this latter conception which makes the idea of structure so important. . .³⁰

Piaget makes clear his conviction that physical and cognitive structural organizations are functionally similar. They do the same things: maintain equilibration on the physical and psychological levels. He writes, "The living organization is essentially an autoregulation."³¹

Since I argue here that Piaget's model of cognitive and physical organization is self-conserving, by virtue of its organizing function, in a manner analogous to Maturana's notion of autopoiesis, it may be useful to review the definition of autopoiesis from Maturana and Varela.

Autopoietic machines are homeostatic machines. Their peculiarity, however, does not lie in this but in the fundamental variable which they maintain constant. An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in the space in which they (the components) exist by specifying the topological domain of its realization as such a network.³²

As we have seen, Piaget holds that cognitive structures are transforms developing along a course of controlled equilibration which "maintains the system as an invariant

³⁰Piaget, *Structuralism*, 14.

³¹Piaget, *Biology and Knowledge*, 354.

³²Maturana and Varela, *Autopoiesis and Cognition*, 78-

totality."³³ But he then declares, referring to the organic system, that

This same definition could be applied to the living organism itself, since its two basic properties are that it serves as the field for multiple interactions (= transformations), though at the same time leaving unchanged both the overall form (= conservation) and even a certain number of invariant relationships.³⁴

The persistency of these invariant relationships implies conservation of the organization. But, for Piaget, self-conservation is only one function of living organizations. Piaget gives a list of three general characteristics of the *functioning* of self-organizing physical systems. The first characteristic of this organization function is that it is a conservation function:

. . .it is the essential reaction of every organized being to conserve its essential overall shape and thus to go on living as an organized whole.³⁵

The second characteristic of the self-organizing function is that the "differentiated parts interact" by virtue of processes that constitute the organization. "If there were no interactions. . . there would be no organization. . ."³⁶ A third characteristic, when added to the first two, suffices, on Piaget's view, to define, in *functional terms*, a homeostatic organization "as opposed to physical systems

³³Piaget, *Biology and Knowledge*, 34.

³⁴Ibid.

³⁵Ibid., 148-149.

³⁶Ibid., 149.

that move." That property is conservation of form, as distinguished from content.

. . . the contents of the organization are perpetually renewed by means of reconstructions (metabolism). This amounts to saying that the conservation of the whole is the conservation of a form and not of its contents.³⁷

From this it is clear that Piaget stresses the importance of distinguishing organization from components, or, in his terminology, "form" from "content." For Piaget, the importance of this distinction is that the "functioning" of the system--to conserve its "organization"--is an outcome of the activity of the organization, considered as a whole; so, while form and content are distinct, they are also related. He writes:

From the biological point of view, organization is inseparable from adaptation: They are two complementary processes of a single mechanism, the first being the internal aspect of the cycle of which adaptation constitutes the external aspect.³⁸

It is the totality that the organization constitutes; "the partial processes have no existence apart from one another," since the removal of any link in the concatenated series of circular relations breaks the circle and functioning ceases.³⁹ But, whatever the cause, should functioning cease, the organization ceases too. He says,

with respect to functioning, the dynamic solidarity between "forms" and their content is still more

³⁷Ibid.

³⁸Piaget, *The Origins of Intelligence in Children*, 7.

³⁹Piaget, *Biology and Knowledge*, 149

obvious, for if functioning ceases, the "form" is destroyed, which means that it dies and returns to physico-chemical structures of a "nonorganized" kind.⁴⁰

For Piaget, the autoregulatory maintenance of "solidarity" between form and content--organization and its various components, processes and relations--is apparently a defining functional condition of conservation, which amounts, for biological systems, to viability. He writes:

Without autoregulation the mechanism would lose its identity and continuity, which means that it would disintegrate into a multitude of changes without self-conservation and so without "life."⁴¹

It appears that Piaget uses "solidarity" in the same sense that Maturana and Varela use "structural coupling." The key is to view the organization's architecture and operation as closed, while viewing its manifest structural plasticity, exchange, and, in short, performance within its distinguished environment, as open. This distinction enables a structural model (actual manifestation of the organization) to be built. This model is organizationally closed; it changes according to its own states and not as a function of environmental events. Yet, it is open to exchanges with the environment and to alterations in its own structures to be determined through its own specifications in relation to its overall control purposes. These purposes include the conservation, through structural change in

⁴⁰Ibid., 153.

⁴¹Ibid., 203.

relation to signal perturbations, of organizational integrity. Piaget outlines his model:

The material or dynamic elements of a structure with cyclic order we shall call A, B, C, . . . , Z, and the material or energetic elements necessary for their maintenance, A', B', C', . . . , Z'. We shall then have the following figure, the sign X representing the interaction of the terms of the first range with those of the second, and the sign --> representing the end point of these interactions:

$$\begin{array}{ccccccc} (A & X & A') & \text{-->} & (B & X & B') & \text{-->} & (C & X & C') & \text{-->} & . & . & . \\ & & (Z & X & Z') & \text{-->} & (A & X & A') & \text{-->} & \text{etc.} \end{array}$$

In a case like this we are confronted by a closed cycle qua cycle, which expresses the permanent reconstitution of the elements A, B, C, . . . , Z, A, and which is characteristic of the organism; but each interaction (A X A'), (B X B'), etc., at the same time represents an opening into the environment as a source of ailment.⁴²

Piaget elaborates this circular organizational model in such a manner as to show how it might be able to reorganize its structure in light of environmental perturbations while conserving the class identity of the overall cyclic-relational (organizational) order.

. . . suppose . . . that the environment is modified in such a way as to replace the element (or group of elements) B' by B'', slightly differing from B'. One of two things happens: either the cycle is interrupted and the organization is destroyed through failure to adapt, or else the cycle maintains itself as before or modifies itself by substituting, for example C₂ for C, but still without losing its cyclic form. It will then be said that an adaptation has taken place in the sense of a process:

$$\begin{array}{ccccccc} (A & X & A') & \text{-->} & (B & X & B') & \text{-->} & (C & X & C') & \text{-->} & . & . & . \\ & & (Z & X & Z') & \text{-->} & (A & X & A') & \text{-->} & . & . & . \end{array}$$

⁴²Ibid., 156.

. . .[if] B' is modified into B" and C into C₂, then, when adaptation takes place:

(A X A') X [sic] (B X B")-->(C₂ X C')-->(D X D')-->
 . . .(Z X Z')-->(A X A'). . .⁴³

Thus, Piaget concludes,

the whole is modified in its structure if at least one of its parts already is, but then either it will die out and so cause dislocation of the whole, or else something will survive as a *totality*, and it is in this respect that we speak of general functioning.⁴⁴

For Piaget, the "constant functional conditions" of this circular regulatory process of self-organization are two familiar concepts: *assimilation* and *accommodation*.⁴⁵ Assimilation strengthens and "nourishes" the relation (scheme) (A X A'), for instance, while accommodation differentiates the reorganization of C to C₂ in the relation (C X C'), in the presence of an environmental perturbation in the form of the substitution of B" for B' in the relation (B X B'). Thus, Piaget concludes, "adaptation may be defined as an equilibrium between assimilation and accommodation."⁴⁶ At the same time, for Piaget, "'organization' simply designates the internal aspect of a system which is in a state of perpetual adaptation."⁴⁷

Varela has commented on the congeniality between Piaget's model and autopoiesis, observing that "the

⁴³Ibid., 171-172.

⁴⁴Ibid., 326.

⁴⁵Ibid., 172.

⁴⁶Ibid.

⁴⁷Ibid., 345.

Piagetian perspective of biological assimilation can be rephrased very naturally in the context. . .of autonomous systems and structural plasticity."⁴⁸ However, it must be stressed that while Piaget considers the self-conserving, invariant organization necessary for life to manifest, he clearly must hold to Varela's stance on the complementarity of organizational transforms and symbolic distinctions for a *sufficient* explanation of living phenomena--without such a stance, his entire model of genetic epistemology, as a system of lawlike processes and distinctions, would appear epistemically superfluous. In any case, Varela acknowledges Piaget's generalization of biological organization to cognitive structures:

. . .from the psychological point of view, Piaget was led to an understanding of cognitive operations that can be rephrased, without doing any violence to it, in terms of the *autonomous* organization of the nervous system. . .Piaget makes it a point to show how cognitive structure and assimilation are functionally isomorphic to general biological phenomena.⁴⁹

Considering the organization of knowledge structures as an extension of biological organization requires us to ask how biological organization is extended into cognitive structures. Such questions have led Piaget to formulate a model of genetic transmission of primitive knowledge tools. It is a model which characterizes an individual's capability

⁴⁸Varela, *Principles of Biological Autonomy*, 256.

⁴⁹*Ibid.*, 256-257.

to elaborate instinctive cognitive structures as an aspect of the ontogenetic and phylogenetic organizing functions.

The Differentiation of a Biologically-Based Knowledge Organ

So far we have seen that Piaget's experimental evidence with children has led him to adopt a model for cognitive development and the accumulation of knowledge that is genetic, cybernetic and an extension into cognitive structures of autopoietic organization. In addition, he suggests that developing cognitive structures show "functional connections" and at least "partial structural isomorphisms" with physical organizations.⁵⁰

The task now is to understand Piaget's conception of the role of knowledge--as cognitive structure--in subordination to its functional connection with biological organization. Piaget claims to have discovered, in cybernetic equilibration with conservation, a "profound analogy" between cognitive and organic structures.

The profound analogy is. . .that both of them have constantly to struggle against the irreversibility of events and the decay of energy and information systems. Again, both of them succeed in their struggle by means of elaborating their organized and equilibrated systems, the principle of which is the compensation for deviations and errors.⁵¹

But Piaget has found differences, too, that make the functional and structural analogy only a partial one.

⁵⁰Piaget, *Biology and Knowledge*, 348.

⁵¹*Ibid.*, 359.

Physical homeostats reach a stability within which reorganization (accommodation) with conservation may proceed within very narrow tolerance ranges; on the other hand, cognitive structures appear to be limited by no such strict constraints. Rather, they appear to be generalized tools applicable to invention and anticipation of future perturbations, in addition to the control of instantaneous perturbations. What makes the equilibrating cognitive organization "something more than a mere extension of regulations" on the organic, or even reflex level is the increasing power of emerging symbolic intelligence to generalize and "overtake" limitations on both cognitive and organic system levels.⁵²

. . .insofar as human intelligence uses logico-mathematical structures as an instrument of integration that is more and more independent of [physical] experiment, it achieves an ever greater conquest of the environment on which it experiments.⁵³

The more the schemes of intelligence dissociate from "concrete operations" (tied to physical action) and become "pure" form, the more "mobile" they may become.⁵⁴

. . .with hypothetico-deductive operations. . .a formal logic can emerge in the form of an organizing structure applicable to any content whatever.⁵⁵

⁵²Ibid.

⁵³Ibid., 356.

⁵⁴Ibid., 358.

⁵⁵Ibid.

The role of equilibration and autoregulation in the organization of logico-mathematical structures is made clear by Piaget's comment that such dynamic activities drive the structure to the asymptotic limit of error correction which is represented by necessity.

The necessary character of logico-mathematical structures. . . emerges from their progressive equilibration by dint of autoregulation. It has already been seen. . . how operations represent the final limit of regulations of error, leading to a level of pre-correction and avoidance of error which shows that deductive equilibrium and "necessity" have been reached. This characteristic of internal equilibration which such structures is enough to explain their generality and, above all, their endlessly mobile extension. . .⁵⁶

The complete dissociation (generalization) of conserved cognitive form from (concrete, specific) content marks "an important difference" between cognitive structures and organic ones. "Organic conservations are never anything more than approximate"; nor does it make sense, as we have seen from standpoint of solidarity, to speak of an organic organization or structure *completely apart* from the concrete components and process-relations of production of components that give the organization closure.⁵⁷

Piaget argues that organic structures reorganize much too slowly, in the presence of perturbations, to achieve anything more than approximate conservations or equilibria. Thus, they are assisted by intelligent behavior to

⁵⁶Ibid., 317.

⁵⁷Ibid., 358.

"compensate" for the "incapacity" of the organic structure. This behavior is a form of regulation of current environmental couplings, or it can, as we have seen, anticipate future circumstances and regulate inductively on the basis of past equilibria. It is precisely in this sense that Piaget echoes Maturana's definition of *cognition* as *adequate action*.

Behavior. . . includes regulations whose function is to control constructive accommodations and assimilations of the basis of the results obtained as the action goes on, or by means of anticipation, which allows it to foresee what events may prove favorable or unfavorable and to make sure the necessary compensations are provided. It is these regulations. . . that constitute cognitive functions.⁵⁸

Maturana writes:

I shall take adequate behavior or adequate action in any domain specified by a question, as the phenomenon to be explained when explaining cognition.⁵⁹

Mingers comments that the extension of control-capabilities cognitive systems impart to the physico-cognitive whole amount to an overall increase in the variety of the whole.

The nervous system is an evolutionary biological development which increases the range of behavior that can be displayed by an organism--its requisite variety.⁶⁰

⁵⁸Ibid., 364.

⁵⁹Maturana, "The Ontology of Observing," In *Texts in Cybernetic Theory: Proceedings of An In-Depth Exploration of the Thought of Humberto Maturana, William Powers and Ernst von Glasersfeld in Felton, California, October 18-23, 1988*, by the American Society for Cybernetics, 1988, p. 5.

⁶⁰Mingers, "Cognitive Theories of Maturana and Varela," 322.

It is important to note, in view of Piaget's and Maturana's arguments for a biological basis for cognitive structures, that researchers in other fields have arrived at similar conclusions. Nicolson, in a review of Georges Canguilhem's *The Normal and the Pathological*, acknowledges Canguilhem's emphasis throughout on "continuities between social and biological phenomena."⁶¹ He observes that Canguilhem connects the "making of discriminations" with the satisfaction of the organism's biological needs, needs which include viability:

Canguilhem argues that the ability to process information, to discriminate between positive and negative biological value, arose during the course of evolution because of the crucial relevance of such activities to the survival of the organism. Knowledge, therefore, has its origins within the making of discriminations at the level of the distinction between food and non-food. In other words, our interaction with the outside world in the process of making knowledge is not different in kind from our interaction with the outside world in other biological activities. On the contrary, we are knowledge-producing animals because of the role the material world plays in our lives as biological organisms.⁶²

The Phylogenetic Transmission of Cognitive Structures

It is finally time to tie our loose ends together. We have seen that Piaget's genetic model of the development of human intelligence requires, (1) a hereditary seed including

⁶¹Malcolm Nicolson, "the Social and the Cognitive: Resources for the Sociology of Scientific Knowledge," *Studies in History and Philosophy of Science* 22, no. 2 (June 1991): 352.

⁶²*Ibid.*, 356-357.

prototype reflexes (sucking, etc.) and the three prototype logico-mathematical mother structures (class, order and topology), and (2) the active exercise (and gradual refinement) of these prototypes through behavior, an exercise culminating, for the logico-mathematical structures, in closure and generalization which dissociates them from experience and confers upon them reversibility, necessity and analyticity. Piaget has modeled the knowledge-building process from its genetic and biological roots to the organizational closure of formal cognitive structures and beyond.

A key question, postponed throughout, is: how does Piaget conceptualize organic organization to be transmitted to cognitive organization?

Let us turn first to Piaget's argument for the hereditary mechanism of transmission of logico-mathematical, and reflex prototype structures. Once this is clear, we examine the entire model of the genesis and growth of knowledge. His task is to show how it is possible for a certain organizational property to be extended, genetically, from the organic system into nascent cognitive structures. That organizational property or, rather, function is *self-conservation* by autoregulation and equilibration.⁶³

⁶³Piaget, *Biology and Knowledge*, 323.

Focusing back upon the genesis of logico-mathematical knowledge, Piaget asks, in view of the primitive dispositions toward class inclusion, for instance, whether such dispositions imply a hereditary source for the structure. His answer is "yes and no."⁶⁴

Yes, if this only means that logico-mathematical knowledge draws its substance from the living organization. . . No, if it means that logic and mathematics correspond to clearly defined characteristics which are present in the genome⁶⁵

Piaget appears to be saying that the organization of cognitive structures is a projection of physical organization somehow through the genome, yet such projection is nowhere coded genetically as a hereditary trait! The secret of transmission of organization-without-encoding appears to be found through recognition of the organizational similarities of physical and cognitive structures: they are self-conserving, autoregulative organizations that, through exchange, are continuously equilibrating. If, on Piaget's hypothesis, *some kind of* hereditary transmission must be accepted (he argues that the structures cannot be simply learned because of structural invariances from the start), and if a coded genetic content must be ruled out, there remains a "fundamental reality" which is the "organizing function" of these structures on *all levels of recursion*.

⁶⁴Ibid., 313.

⁶⁵Ibid.

There still remains this fundamental reality. . . namely, the organizing function with its absolute continuity--a function which is not transmitted but is continuous, conserving itself from transmission to transmission. This is not at all the same thing as hereditary transmission, since it is itself the necessary condition.⁶⁶

On this view, the organizing function of the organism as a whole--self-conserving and continuous--is also the organizing function of autonomous structures on all lower levels of recursion--all the way to the genome itself. Piaget declares, "Once organization is seen in everything," then the genome, too, is "seen as a regulation system."⁶⁷ To regard the genome as a cybernetic system, for Piaget, is to regard recombinations as compensations and variations as reequilibrations, not chance mutations.⁶⁸ Accordingly, Piaget specifies two levels of "process must necessarily be distinguished in any hereditary transmission": (1) genetic encoding which acts on morphology, and (2)

autoconservation, which perpetually reconstitutes itself, not only by some internal metabolism but also by autoregulation of its organization and functioning during all its many activities, from the complex events of fertilization onward.⁶⁹

Piaget speculates on how this organizing function is actually transmitted with the conjecture that

this kind of autoconservation presupposes that there must be some function which runs right through all the transmissions but is not actually transmitted in

⁶⁶Ibid., 322.

⁶⁷Ibid.

⁶⁸Ibid., 323.

⁶⁹Ibid.

the normal sense of the word, since all it does is simply to endure and continue uninterruptedly. So it is not transmitted as a message is transmitted, but is conserved during each transmission and is, in fact, the necessary condition for this transmission. It is still a sort of transmission, if you like, but more elementary than a real transmission because it is an active continuation.⁷⁰

This model suggests that, in addition to all the characteristics genetically encoded and transmitted across generations, there are also transmissions of the "general properties of life, being organizations," and that transmission is an organizational continuation, on all recursive levels at once, in the sense that,

at every stage of hereditary transmission, a *living* organization subsists, which is the necessary condition for the particular transmissions.⁷¹

In summary, Piaget has suggested that the necessary condition of all living unities, across all recursive levels, is the continuous conservation of the entire system as a totality. Maturana appears to hold a similar view of a phylogenetic organizing function which is organization-conserving on a trans-individual recursive level. He comments that a "phylogeny or lineage lasts only as long as the organization that defines it is conserved. . ."⁷²

The Differentiation of a Knowledge Organ

But Piaget requires more if he is to adequately explain the sheer power of human intelligence. Merely accepting his

⁷⁰Ibid.

⁷¹Ibid.

⁷²Maturana, "The Ontology of Observing," 28.

argument for the meta-hereditary transmission of logicomathematical intuitions does not explain their progressively successful and generalizing application by intelligence. Piaget draws upon psychogenesis to provide an answer; it is an answer which he believes establishes a condition for the existence and accumulation of knowledge. He attempts to establish this condition by referring to his tripartite model of human knowledge: instinctive, experimental and logicomathematical. When a human child is born, according to Piaget, "cognitive regulations begin by using the only instruments" available at the time, which are primitive instincts, at best rigidly programmed and only vaguely appropriate under a given circumstance. But shortly, in the course of the active assimilations and accommodations, alternately strengthening and reorganizing schemes, a differentiation of intelligence occurs in humans that amounts to

the bursting of instinct, leading to dissociation between its two component parts--internal organization and the phenotypic accommodation.⁷³

What follows, by means of complementary constructions in opposite directions (decentration) is the development of, on the one hand, internal logico-mathematical structures; and, on the other hand, externally oriented experimental knowledge. In children, the first kind of knowledge,

⁷³Piaget, *Biology and Knowledge*, 365.

instinctual programming undergoes an "almost total disappearance" upon the differentiation, under the exercise of action schemes, of the second two.⁷⁴

Piaget is now ready to supply the condition required under which human knowledge may exist and accumulate. That condition is the *differentiation of the organizing function of autoconservation and autoregulation into a new "organ of deductive verification and of construction."*⁷⁵ This new organ constitutes the expression of the organizing function in reference to itself and to all recursive levels of the organism as a whole. What remains of instinct is merely the residual of its organizing function and the genetic results of its initial role in intellectual development. Therefore, Piaget says, "a new cognitive evolution" begins and the "work to be done thereafter is phenotypic"--that is, the human child must *make decisions*. S/he is left to act as a function of regulatory purposes developed by the interiorization of logical relations and by active experimentation.

Looking back over the course of this examination, for Piaget, the innate dispositions to recognize *similarities* and group phenomena under classifications such as "natural kinds," may be seen in light of the progressive closure of the algebraic mother structure, which is sensitive to

⁷⁴Ibid., 366.

⁷⁵Ibid., 367.

"groupings" just in case such sensitivity contributes to the autoconservatory, control activities of all recursive levels of the organism-system. The "groupings" perceived need be salient only to the control transform needs of the system; in no way is "information" as a copy of external facts relevant to the error-correction process. Similarly, *regularities, relationships and form-recognition*, distinguished perceptually for error computations within the system, are formatted, on this view, for the computational convenience of the system. On this view, it is no surprise that certain regularities appear obvious in experience; it is from among these regularities that we learn to distinguish between poisonous spiders and harmless beetles. Understanding the difference between natural kinds (for instance, spiders with eight legs vs. beetles with 6 legs), may prove valuable for the computation of error vectors for the ultimate control purposes of the physico-cognitive whole.

Summary

We have seen how, in the work of Piaget, science has attempted to apply itself to the discovery of the epistemological foundations of its own method. That is, it focuses on the cognitive activity of making distinctions and applying other distinctions--logico-mathematical relations--to those distinctions. The circularity of this process is

seen, not as a logical mistake, but as an organizational model of the cyclic process by which cognitive control systems progressively assimilate surroundings into behavioral action schemes, and activate accommodation or reorganization under the pressure of phenomenal constraints.

This circular development of cognitive structures--the constructed tools of knowledge--follows, on Piaget's view, a line of equilibrium which marks the adaptation of these structures to the conservation purposes of the organism as a totality and to the phenomenal constraints it encounters. This adaptation is an energetic, dynamic interplay between assimilation and accommodation which is adequately modeled as a cybernetic control system. Adopting a cybernetic model in place of a merely dialectical one allows for the explication of the mechanisms of transform that drive the equilibrium, a level of explanatory detail the dialectical model does not afford.

It is clear that Piaget considered cognitive structures to be the extension of self-referring, self-organizing biological structures. This combined biological and cognitive organization, when taken along with the general functioning of the combined structures, constitutes a self-conserving totality. This totality is organizationally closed and structurally flexible, in the sense that, should a component or relation of exchange of a component be

modified by some perturbation, then the structure is also modified, but the totality always acts so as to conserve its organization which defines its class identity.

We have seen that, for Piaget, the role of cognitive structures is to perform cybernetic regulations of phenomenal circumstances far beyond the regulatory abilities of the organic organization. But these cognitively directed regulations, using the tools or logico-mathematical structures and amassed experimental knowledge (in the form of coordinated action schemes), always act in subordination to the overall conservation requirements of the organization as a totality. From this argument Piaget claims to offer an explanation of knowledge, from common sense application to scientific knowledge, in terms of adequate behavior on behalf of the self-conservation of the (structure determined) totality, which is the *defining condition*, or variable which must be maintained, of the totality.

Considering, however, the source, structures and aims of knowledge as intimately biological, suggests further investigation into the physical mechanisms by which perceptual signals become distinctions. These investigations have led to some startling epistemic conclusions. We shall now turn to consideration of some of the implications Piaget's model holds for philosophical issues of epistemology, ontology, skepticism, and realism.

CHAPTER IV
KNOWLEDGE, CONSTRUCTIVISM, AND CONTROL THEORY

Introduction

If knowledge is, as Piaget suggests, the constructed vectors of a gradual process of active experimentation aided by the development of logico-mathematical tools of abstract thought, then the generative mechanism for the perceptual world and our knowledge of it would appear to be the cognitive organizing function of the subject. In short, the world of phenomena, including the subject him/herself, are, qua phenomena, actively constructed by the subject for the control of circumstances to within conservation tolerances of the organizational totality. The position that our experiential field of phenomenal structures and causal relations is our own construction has come to be known as constructivism.

A philosophical consideration of the implications of constructivism involves epistemological and ontological questions of the most fundamental sort. Questions of epistemology and ontology naturally arise when it is claimed, as Piaget does, that the perceptual world is organized as a function of the self-organization of intelligence. If Piaget's account of how we come to have

knowledge is accepted as empirically adequate and perhaps useful, then we are moved to an immediate reconsideration of our notions of *what it is* that we actually know when we claim knowledge. Moreover, these same questions require a reevaluation of our norms for conferring ontological status upon independent things and relations.

This chapter examines the doctrine of constructivism. This doctrine, an elaboration and systematization of the philosophical implications of genetic epistemology, implies a focus for epistemology which abandons knowledge of nature's truths and resolves instead upon the constructed regularities and constraints of experience. This case is supported by a control-theory explanation of behavior and some findings of neurocomputational research. The epistemic shift implied by constructivism forms a case for a benign form of skepticism--a skepticism that does not entail antirealism. It is an *epistemic* skepticism that, while not denying the existence of an external world, holds that news of such a world, beyond our constructions, is epistemically irrelevant.

Constructivism and the Epistemic Shift

Piaget's genetic epistemology calls for an account of the phenomenal world and its relations as gradually-stabilizing, phenomenal constructions of an active subject. The question naturally arises: on Piaget's view, is there

any reality beyond our constructions? Piaget appears not to have addressed this question head-on. However, he has left hints in his path suggesting that while he may not deny the existence of an independent reality, he remains clear that our knowledge is not of it. Recall his contention, cited above, that a correspondence or copy theory of knowledge involves one in a vicious circularity. He notes elsewhere that

such a copy could not possibly be made, since only the copy could supply us with the knowledge of the model being copied, and, moreover, such knowledge is necessary for the copy to be made.¹

The point Piaget is making is that we can never get beyond our representations to more epistemically privileged information that we would need to "check" the copy. But Piaget then remarks, "if the true is not a copy, then it must be an organization of the real world."² He comments that

Knowing reality means constructing systems of transformation that correspond, more or less adequately, to reality. They are more or less isomorphic to transformations of reality.³

Piaget here appears to be assuming an independent reality, at least its possible existence, but, since knowledge is, for Piaget, a constructed system of transformation, it cannot be known what correspondence, if any, that

¹Piaget, *Biology and Knowledge*, 361.

²Ibid., 362.

³Piaget, *Genetic Epistemology*, 15.

construction has to any substrate beyond it. This is precisely the point: Piaget occasionally does [at least in English translation] appear to reference some causal realm beyond knowledge, but he makes it clear that our knowledge is not of this realm, regardless of whatever its ontological status may be. He dismisses as failure attempts of philosophers to achieve some absolute or transcendental realm of pure, idle knowledge of reality. He replies with the naturalistic sentiment that

what we must try to do here is not to get away from nature, for no one can escape nature, but to penetrate it gradually with the aid of science. . . and before we locate the absolute up in the clouds, it may well be helpful to take a look inside things. Once we do that, if the true is an organization of the real, then we first need to know how such an organization is organized, which is a biological question.⁴

Since, for Piaget, knowledge is constructed completely and with no remainder by the active subject through assimilation and accommodation, "the transformational structures of which knowledge consists are not copies of the transformations in reality," but simply "models among which experience can enable us to choose."⁵ He declares, finally that knowledge is "a system of transformations" that results in adequate action by a cognitive agent.⁶ Piaget claims that human knowledge is born of human action and is without remainder

⁴Piaget, *Biology and Knowledge*, 361.

⁵Piaget, *Genetic Epistemology*, 15.

⁶*Ibid.*, 15.

relevant to human action. There is no possible knowledge of a transperceptual reality, nor is any required. Von Glasersfeld echoes this sentiment starkly,

There is no knowledge of an independent ontological reality, nor is any such knowledge needed. The system must discover activities that enable it to maintain its equilibrium, or it must perish.⁷

Though we shall return to this issue--it is of central importance to our later distinction of epistemological questions from ontological ones--it is necessary here to emphasize that even the constructivism of Piaget did not deny an external reality, it merely transformed it to an epistemically null set. It is in this sense, in which the notion of a "knowledge" of "reality" beyond cognitive structures is at best irrelevant, that von Glasersfeld argues that Piaget's "genetic epistemology entails a drastic break" with traditional philosophical conceptions of "knowledge."⁸ This break occasions a redefinition of both "knowledge" and "perception." Richards and von Glasersfeld elaborate:

We thus redefine "knowledge" as pertaining to invariances in the living organism's experience rather than to entities, structures, and events in an independently existing world. Correspondingly, we redefine "perception." It is not the reception or

⁷von Glasersfeld, "Feedback, Induction and Epistemology," *The Construction of Knowledge*, (Salinas, CA: Intersystems, 1987), p. 226.

⁸von Glasersfeld, "Radical Constructivism and Piaget's Concept of Knowledge," *The Impact of Piagetian Theory*, ed. Frank Murray, ((Baltimore: University Park Press, 1979), p. 109.

duplication of information that is coming in from outside, but rather the construction of invariances by means of which the organism can assimilate and organize its experience.⁹

Constructivism's epistemic shift, therefore, is as follows: "knowledge," rather than reflecting an independent reality that is supposed to exist, now designates a cognitive structure used by an organism in organizing and systematizing its experience.¹⁰ From another angle, the shift requires us to view the contents of experience, not as a function of information about external objects but as a function of the possible (genetically organized) perceptual states a cognitive agent's organization allows. Varela remarks:

[permanent objects] don't say much about the structure of the world; they say much about the animal's way of structuring its behavior.¹¹

In view of this epistemic shift, implied by Piaget's conception of knowledge as active construction, let us turn to the radical constructivism of von Glasersfeld which appears an elaboration of Piaget's message. Von Glasersfeld sketches his position as follows:

The constructivist approach is "radical" because it embodies not only the view that cognition must be considered a process of subjective construction on the part of the experiencing organism rather than a discovering of ontological reality, but also the belief that there can be no *rational* access to any

⁹Richards and von Glasersfeld, "The Control of Perception and the Construction of Reality," 40.

¹⁰von Glasersfeld, "Radical Constructivism and Piaget's Concept of Knowledge," 117.

¹¹Varela, *Principles of Biological Autonomy*, 249.

world as it might be, prior to, and independent of, our experience.¹²

Von Glasersfeld outlines the "basic principles" of radical constructivism. These are:

- 1 a) Knowledge is not passively received either through the senses or by way of communication:
- b) knowledge is actively built up by the cognizing subject.
- 2 a) The function of cognition is adaptive (in the biological sense of the term):
- b) cognition serves the subject's organization of the experiential world, not the discovery of an objective ontological reality.¹³

Von Glasersfeld emphasizes, like Piaget, that his position limits him to the construction of models, not representations of reality

radical constructivism itself must not be interpreted as a picture or description of any absolute reality, but as a possible model of knowledge and the acquisition of knowledge in cognitive organisms that are capable of constructing for themselves, on the basis of their own experience, a more or less reliable world.¹⁴

¹²von Glasersfeld, "Radical Constructivism and Piaget's Concept of Knowledge," 109.

¹³von Glasersfeld, "An Exposition of Radical Constructivism," In *Texts in Cybernetic Theory: Proceedings of An In-Depth Exploration of the Thought of Humberto Maturana, William Powers and Ernst von Glasersfeld in Felton, California, October 18-23, 1988*, by the American Society for Cybernetics, 1988, p. 2.

¹⁴von Glasersfeld, "An Introduction to Radical Constructivism," *The Invented Reality*, Paul Watzlawick, ed., (New York: Norton, 1984), p.39.

Is Piaget a Constructivist?

Though, on the strength of his conception of knowledge as active construction, Piaget appears to take a constructivist line, it has not been clear or widely agreed that he intended this position. The source of disagreement, however, seems more likely traceable to a misunderstanding of Piaget, constructivism, or both. For instance, Kitchener writes that "von Glasersfeld's radical constructivism is not the correct interpretation of Piaget." On Kitchener's reading, Piaget's epistemology commits him to a form of realism. But Kitchener's argument reveals three mistaken notions: (1) that Piaget maintained some epistemic stake in the existence of an external world, (2) that constructivism is self-defeating in the sense that epistemic generalizations from the observed constructions of a subject to those of an observer should be logically inadmissible, and (3) that a result of constructivism, the prohibition of appeal to a priori epistemic norms, rules out any claim constructivism may have to epistemic validity.¹⁵

On the first count, we have already seen that Piaget appears to allow the *ontological* possibility of an external world, but it is clear from the above that he would have considered such a world cognitively inaccessible and, in any case, of no *epistemic* interest since, for Piaget, the

¹⁵Kitchener, *Piaget's Theory of Knowledge*, 118-120.

totality of human knowledge is psychogenetically constructed and in no way a copy or discovery of the deep structure of things-in-themselves. He clearly states, "knowledge is essentially construction."¹⁶

The second and third counts are related in their assumption of logical or methodological norms that a naturalistic genetic epistemology and constructivism explicitly rejects.

Kitchener claims, regarding the second count, that a key notion of constructivism is contradicted by constructivism's own doctrine that knowledge is a subjective construction; i.e., nothing beyond one's constructions may be known. This doctrine is contradicted, Kitchener claims, when the constructivist generalizes to his own case (of world-construction) from an observed case of a, say, child constructing his/her world. According to Kitchener, this amounts to an unwarranted *epistemic transference* from an epistemic object (an observed organism) to an epistemic subject (the observer)--unwarranted on the grounds that, for the observer, there is only knowledge of his/her constructions and not of those of any other organism. Therefore, the position is self-defeating.¹⁷ Kitchener makes two mistakes here, first, he fails to realize that the *observed constructions* the observed organism builds are, in

¹⁶Piaget, *Biology and Knowledge*, 362.

¹⁷Kitchener, *Piaget's Theory of Knowledge*, 120.

fact, *constructions* by the observer, from his/her point of view; Kitchener's second mistake is in assuming that the epistemologist, qua epistemologist, is attempting to infer "reality" from the epistemic transference from object to subject. But in fact, as both Piaget and von Glasersfeld have stressed, they are not interested in "copying" reality but in building cognitive models of methodological value. Piaget and von Glasersfeld have adopted a naturalized epistemology, one that develops its own norms through practice rather than appeal to the *a priori*, while Kitchener is working from a more traditional stance of privileged epistemology.

On the third count, Kitchener's mistake is a clearer case of the same mistaken application of traditional epistemic norms to what is a naturalized epistemology. Kitchener argues that if all knowledge is construction, then there is no "objective basis" for the claim that the subject constructs his/her world. Thus, constructivism is "self-refuting and leads to a skepticism" concerning even itself.¹⁸ Once again, it is clear that the *objective basis* for genetic epistemology and constructivism is to be found in construction itself, and that this appeal, while certainly circular, is a description of how knowledge and epistemological norms are, for Piaget, in fact, developed.

¹⁸Ibid.

It is, I would venture, the same circularity of which Dewey
brashly declared,

That this circle exists is not so much admitted as
claimed. It is also claimed that the circle is not
vicious; for instead of being logical it is
existential and historic.¹⁹

Kitchener has clearly applied traditional
epistemological norms of validation from an epistemically
privileged position, prior to experience, to what is
essentially, a naturalized epistemic position. It is no
wonder that he has found conflict. But Kitchener has made a
deeper conceptual error, based on his adherence to
traditional epistemic norms, he has assumed that an
explanation of "why knowledge progresses the way it does"
entails a commitment, by Piaget, "to some kind of
realism."²⁰ But the progress of knowledge would entail
realism for Piaget only if he had some epistemic stake in
the ontological fact of an external world. We have seen
that he apparently does not have such a stake, but
Kitchener's assumption evinces a confused blending of
epistemic and ontological questions on the matter of the
external world, a confusion which arises naturally when one
fails to adjust the scope of epistemic inquiry to comply
with Piaget's construction-definition of knowledge. It is

¹⁹Dewey, "Nature in Experience," *On Experience, Nature, and Freedom*, 247.

²⁰Kitchener, *Piaget's Theory of Knowledge*, 121.

for this reason that we shall, for purposes of clarity, distinguish epistemic concerns from ontological ones.

The Distinction of Epistemology from Ontology

Von Glasersfeld forces this distinction with the admonition that knowledge of the *ontological* status of things independent of our investigations is inaccessible. He cautions that

for the constructivist, "existence" must not be interpreted ontologically but epistemologically. That is to say, it refers to the realm of cognitive operating and structuring, and not to the realm of "being" in the traditional sense.²¹

It seems clear that this caution relegates talk of "existence"--itself a symbolic construct--to the phenomenal domain of distinctions and not to any realm of ontological fact. The price we shall pay for holding to such a distinction (between phenomenologies) will be that we shall be denied access to one kind of so-called "knowledge," that is any conception of *knowing about* the deep structure of an external world, which would amount to reifying distinctions and begging the ontological question. In any case, on Piaget's account, this "sacrifice" appears benign; there is no knowledge beyond active construction, regardless of any (inaccessible) ontological facts.

²¹von Glasersfeld, "An Interpretation of Piaget's Constructivism," *The Construction of Knowledge*, 241.

A Constructivist Method of Science

This epistemic shift is reflected in Maturana's view of scientific method. He characterizes scientific statements as *modeled* explanations of phenomena amounting to instruments which entail no ontological commitments. For instance, we find the assertion that

Scientific statements are consensual statements valid only within the community of standard observers that generates them; and science. . .does not need an independent objective reality, nor does it reveal one.²²

According to Maturana, the "criterion of validation of scientific explanations" is that they *explain* phenomena, within a give linguistic domain; a further stipulation that the entities to which they refer must exist is, on his view, unnecessary. He declares that the method of validation of explanations should proceed in four stages: (1) the observation of a phenomenon to be explained, the explanandum; (2) the proposition of a hypothetical explanans constituting a "generative mechanism" which "when allowed to operate" would give rise to the explanandum; (3) the deduction from the explanans of some, as yet unobserved, novel phenomena; and (4) the observation of the predicted novel facts.²³

It is clear that the "generative mechanism" to be stipulated in (2) may postulate unobservable entities, but

²²Maturana, "The Ontology of Observing," 8.

²³Ibid., 7

these entities are to be considered hypothetically as instruments facilitating an adequate explanation, not as actually existing things. In this sense, constructivism may be viewed as a kind of instrumentalism.²⁴

Before continuing with examination of the philosophical implications of constructivism, it is important to consider some models of the physical neural networks which mediate perception, and of the nature and types of signals that are propagated within such networks. Studying these networks and signals will assist in the clarification of how it is possible, in practical terms, to act adequately from a position of epistemic skepticism. We shall see that this posture may be attained by modeling a physico-cognitive agent as a control system.

Constructivism, Control Theory, and Perception

As we noted in the previous chapter, Piaget models the physico-cognitive organization of living systems as a concatenation of cybernetic control systems at work to conserve the integrity of the organization as a totality. The mechanisms by which such organizations maintain equilibration on any recursive level are reflected in the complementary transformations of assimilation and accommodation of cognitive structures. These two functions

²⁴von Glasersfeld, "An Interpretation of Piaget's Constructivism," *The Construction of Knowledge*, 239-240.

can be temporally modeled as feedback processes, positive in the former and negative in the latter.

From the view that models are distinctions of an observer, it must be reemphasized that these modeled structures are not advanced as certified representations of reality; they are simply models which may have explicatory value. This value is to be found in the similarity the functioning of the model exhibits relative to the functioning of the system being modeled, from the standpoint of an observer. For the constructivist the system modeled is, epistemologically, a black box because knowledge has no access to any system's structure independent of its distinction. Von Glasersfeld writes, "a model is a good model whenever the results of its functioning show no discrepancy relative to the functioning of the black box."²⁵ Constructivism does not allow itself an epistemically privileged perch from which to certify that the model is a representation of reality, since the constructivist has no access to such a perch.

Neural Reality: Perception as a Controlled Variable

If the best we can do, on the constructivist view, is make models, regardless of any correspondence they may or may not have with nature's deep structure, we may then turn to making those models which best fulfil our scientific

²⁵von Glasersfeld, "Feedback, Induction & epistemology," *The construction of Knowledge*, 230.

aims--aims including explanatory value. Let us accept that this aim is embodied in the hypothetical imperative: *if one wants to learn how living systems may be said to maintain equilibrium in physical and cognitive structures, then model control circuits and transforms as generative mechanisms by which it may be achieved.* To a brief look at such models we now turn.

The first matter in need of further clarification concerns the signal processing characteristics of the human physico-cognitive system. Early attempts to understand the dynamics and logic of neuron activity resulted in a linear, digital logical representation of signal processing, but this view was abandoned for a non-linear, analog model of neuron activity.²⁶ McCulloch and Pitts, in an attempt to model the fundamental signal propagation and transmission characteristics of neural networks, developed a "logical calculus" of neuron interactivity.²⁷ While a linear, digital picture of neuron activity has been abandoned for a non-linear, analog model, some newer models have offered an analog version of AND-NOT gating in neuron

²⁶Christof Koch, "Biophysics of Computation: Toward the Mechanisms Underlying Information Processing in Single Neurons," *Computational Neuroscience*, ed. Eric Schwartz, (Cambridge: MIT Press, 1990), p. 103. Thanks to William Powers for pointing out the analog model of neural processing.

²⁷McCulloch and Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity," 93.

relationships.²⁸ In addition to these mounting complexities, other questions have been raised concerning the study of general cortical activity (involving many neurons) from a single-neuron, bottom-up approach.²⁹ Regardless of competing perspectives toward neurocomputational activity, there appears consensus that signal propagation is mediated according to analog transformations involving fluctuations in neuron chemistry and differences between excitatory and inhibitory incoming signals.³⁰

Taking a more holistic approach, experimenters have found structural evidence in biological neural nets to warrant the distinction of multiple levels of system organization spanning a range of scalar levels of organized functioning from molecules through synapses, neurons, networks, maps and whole systems to the central nervous system as a functional whole.³¹ Each of these organization-

²⁸Koch, "Biophysics of Computation: Toward the Mechanisms Underlying Information Processing in Single Neurons," 98.

²⁹Ibid., 111. See also, Christine Skarda and Walter Freeman, "How Brains make Chaos in Order to Make Sense of the World," *Behavioral and Brain Sciences* 10, no. 2 (June 1987): 161-195, and Gerald Edelman, *The Remembered Present*, (New York: Basic Books, 1989).

³⁰Powers, "Comments on Genetic Epistemology" private e-mail correspondence [to Jeff Dooley], 14 October 1991, CSGnet.

³¹Patricia Churchland, Christof Koch and Terry Sejnowski, "What is Computational Neuroscience," *Computational Neuroscience*, Eric Schwartz, ed., (Cambridge: MIT Press, 1990), p. 52.

levels exhibits a distinct functional activity in support of the operation of the whole. For instance, sensory and other signals are transformed at the structural level of neuron interactions by virtue of microcircuits of synaptic connectors.³² According to Powers, these signal transformations include algebraic summation, multiplication, time integration and differentiation.³³ Accepting that propagated sensory signals undergo repeated processing, including time-integration and differentiation, it is clear that signals reaching cortical areas must already be *functions* of many earlier transformations. Moreover, these transformations also involve recurrent, or reentrant, signals mapping from within the system according to widely divergent physical and temporal properties.³⁴ Richards and von Glasersfeld note the epistemological importance of this fact.

The [sensed] disturbance. . . is never sensed discretely but merely creates a fluctuation in the total sensory signal. Hence the organism can never discern to what extent a fluctuation is due to disturbance and to what extent a fluctuation is due to its own activity.³⁵

The neuronc microcircuits that integrate these signals have been shown to exhibit a functional plasticity in the

³²Gordon Shepherd, "The Significance of Real Neuron Architectures for Neural Network Simulations," *Computational Neuroscience*, 83.

³³Powers, *Behavior: the Control of Perception*, 33.

³⁴Edelman, *The Remembered Present*, 68.

³⁵Richards and von Glasersfeld, "The Control of Perception and the Construction of Reality," 51.

sense that the output (firing) functions may be altered over time by virtue of changes in synaptic weighting.³⁶ The combination of the facts of this synaptic-weight plasticity and the transform functions neuron microcircuitry allows implies a hypothetical case for local, Hebbian type, inductive learning. Such a rule, based on the form of synaptic plasticity reported by Artola et al., has shown, according to Hancock et al., that

It can learn more random paired associates than the optimal classical Hebbian rule, and its performance continues to improve with repeated presentations of the training set.³⁷

This finding provides evidential support for the hypothesis that experimental learning by biological systems may have a basis in the structural plasticity of the nervous system's signal processing transforms. For modeling purposes, on this view, the structural and functional conditions necessary for the operation of a control system: signal channels (afferent, reference and efferent), transform capabilities and error-correcting by synaptic-weight-plasticity, appear present throughout biological nervous organization.

³⁶A. Artola, S. Brocher and W. Singer, "Different voltage-dependent thresholds for the induction of long-term depression and long-term potentiation in slices of the rat visual cortex," *Nature* 347, (1990): 69-72.

³⁷Peter Hancock, Leslie Smith and William Phillips, "A Biologically Supported Error-Correcting Learning Rule," *Neural Computation* 3, no. 2 (Summer 1991): 211.

Powers has suggested that perception is regulated by control system operation at all levels of nervous activity, and that the ultimate output (at any dt) of the nervous system, which is behavior, involves the physical organism in the active control of perception by virtue of the error-correcting effect of behavior through interaction with phenomenal surroundings.³⁸ He argues that only a control system interpretation of behavior could explain how, for instance, a rat, trained to press a lever when a light comes on, achieves the same result, the depression of the lever, by carrying out widely divergent and sometimes opposite behavioral acts, depending on where in the cage the rat happens to be when the light comes on. Powers observes, "variable acts produce a constant result."³⁹ The decoupling of action from outcome suggests that the organism executes behavior adequate to correct a perceived error state. For Powers's rat, the suddenly perceived error is the momentary fact of the light being on and the lever not being depressed. The rat behaves adequately to reduce the error value to zero by moving to the lever and depressing it, regardless of the various types of behaviors required at different times (rat locations) when the light comes on. This account echoes an argument advanced by Rosenbleuth,

³⁸Powers, *Behavior: the Control of Perception*, 50.

³⁹Powers, "Feedback: Beyond Behaviorism," *Science* 179, no. 4071 (26 January 1973): 351.

Wiener, and Bigelow, an argument which emphasizes the role of purposiveness on the control-system model of behavior:

When we perform a voluntary action what we select voluntarily is a specific purpose, not a specific movement. Thus, if we decide to take a glass containing water and carry it to our mouth we do not command certain muscles to contract to a certain degree and in a certain sequence; we merely trip the purpose and the reaction follows automatically.⁴⁰

Powers has developed a hierarchical model of concatenated cognitive control systems including sensory, computational and efferent signal regulation capabilities working as a function of recursive reference goals. The result is that while perception is controlled in a global way by the behavior of the organism as a totality, perception is also progressively transformed, controlled and regulated at each integrative step along the afferent nervous pathways.⁴¹ Powers stresses that the purposiveness of a control system model of behavior is empirically accessible:

The purpose of any given behavior is to prevent controlled perceptions from changing away from the reference condition. Purpose implies goal: The goal of any behavior is defined as the reference condition of the controlled perception.⁴²

The goal is, then the perceptual state that equals the reference condition, while the purpose of behavior would be

⁴⁰Rosenbleuth, Weiner, and Bigelow, "Behavior, Purpose and Teleology," *Philosophy of Science* 10, no. 1 (1943): 19.

⁴¹Powers, *Behavior: the Control of Perception*, 70ff.

⁴²*Ibid.*, 50.

to counteract phenomenal perturbations affecting that unity of perception and reference signals.

Let us now examine more closely the *signals* under discussion. I have referred to, (1) an afferent or input signal, activated by sensory surfaces; (2) a reference signal, or goal vector, and (3) an efferent or output signal activated to effect behavioral error-correcting so as to maintain a near-zero-error state. It is important to emphasize that these signals are initiated from within the nervous system. But what are the functional requirements of the perceptual signals themselves in a control system model of purposeful cognitive activity?

In the first place, Powers distinguishes perceptual signals from consciously perceived signals. He takes the view that a perception is underway if a receptor signal is transmitted. Thus, the humming of the computer hard disk, while not heard a moment ago, was at that time, a perception accessible to consciousness had it focused there. Conscious or not, according to Powers, first-order sensory signals, from the point of initial receptor excitation, transmit *intensity* only.⁴³ Only after multiple microcircuit transforms are these signals integrated into *sensations*. Further along, whatever signal processing is effected, the perceptual input signals to those processes are the ones

⁴³Ibid., 33.

propagated by the previous transforms; they are neural currents with measurable values. From these signals is human experience, in its richness, constructed.

The fact that human sensory signals are activated and propagated from within the nervous system has some implications for our concept of perception. Perception, as an analog series of vectors activated within the closed nervous system, need not represent whatever lies beyond the organism in any manner denoting true representational correspondence, it need only provide the organism's nervous system with salient regularities according to formats *convenient for the nervous system* to compute errors and effect adequate, regulating action. This point is made by Varela in the following fashion:

A perception is a process of compensatory changes that the nervous system undergoes in association with an interaction. Correspondingly, a perceptual space is a class of compensatory processes that the organism may undergo. Perception and perceptual spaces, then, do not reflect any feature of the environment, but reflect *the invariances of the anatomical and functional organization of the nervous system in its interactions.*⁴⁴

Powers comments, similarly, that

the brain may be full of many perceptual signals, but the relationships between those signals and the external reality on which they depend seems utterly arbitrary. At least we have no assurance that any given perception has significance outside of a human brain. . . We may strongly suspect that there is a real universe out there, beginning a millimeter

⁴⁴Varela, *Principles of Biological Autonomy*, 254.

outside our nervous systems, but our perceptions are not that universe.⁴⁵

He adds that "these signals--perceptual signals--are reality as far as the brain experiences reality";⁴⁶ and, "the brain's model of reality, as far as consciousness is concerned, is reality--there is nothing else to perceive."⁴⁷ On a control system model of cognition as evidenced by an organism's adequate action, regular neural currents, formatted appropriately for the system processing them, are all that the system has or requires. One-to-one representational correspondence with a supposed external causal agent is unnecessary or superfluous. Powers sums the point this way:

For the organism to have control over any sensed condition of the environment, all that is necessary is for it to possess the means to cause that condition as perceived to vary in each of the possible ways it can vary. Given only that, a negative feedback control system can be set up by suitable connections inside the organism. There is no need to sense the causes of any disturbance, because all that disturbance can do is tend to make the controlled condition change in one or more of the possible ways it can change--and the mature organism is already set up to exert forces that can prevent those changes.⁴⁸

Powers suggests that, on this view, it would be more neurocomputationally accurate to say that we operate cognitive functions that "construct perceptions" rather than

⁴⁵Powers, *Behavior: the Control of Perception*, 37.

⁴⁶*Ibid.*, 39.

⁴⁷*Ibid.*, 24.

⁴⁸*Ibid.*, 48.

assume our perceptions accurately reflect some feature of an external reality.⁴⁹

This view is strengthened by findings of McCulloch and Pitts that, due to the recurrent organization of axonal connectors within the system, it is impossible to know what part of the integrated input signals are a function of a stimulus at t_{-1} or of the recurrent signals. they write:

. . .the regenerative activity of constituent circles renders reference indefinite as to time past. Thus our knowledge of the world, including ourselves, is incomplete⁵⁰

The facts of perception, then, result from a mixture of integrated and differentiated sensory signals to which are added recurrent network activity so that, for McCulloch and Pitts, to the "real" we can attribute not so much as one quality of "form."⁵¹ Following this line, *from the standpoint of the signal*, the sight of my pen on my desk is, in neurocomputational form, identical to MacBeth's vision of a floating dagger.

Summary

Piaget's conclusion that the forms, processes and displacements of experience are organized by intelligence according to its own developing organizing function implies

⁴⁹Ibid., 114. Powers has made clear in private communication that his use of the term "construct" here bore direct reference to the work of von Glasersfeld.

⁵⁰McCulloch and Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity," 96.

⁵¹Ibid.

the doctrine of constructivism. This position has reached its most systematic development in the radical constructivism of von Glasersfeld, though Maturana's position is also characterized as a form of constructivism. While Piaget's position is ambiguous, his view of knowledge as active construction places him among the constructivists.

The organizationally closed and structure determined living, cognitive system is organized to keep certain neural state vectors within certain ranges, ranges specified by the organization itself. Some of these vectors are perceptual vectors. If an error is computed as the difference between an afferent signal transform and a reference value, it *does not matter to the system what causes the perturbation* among vectors which results in an error value. What matters is the activation of new neural states aimed at bringing the perceptual error-state to a minimum. These states are states of the system itself, not states of anything beyond it. Phenomena, therefore, are not of epistemic interest as things-in-themselves, but as distinctions along an error-correction, signal transform pathway. Therefore, the focus of epistemology is shifted from the aim of discovering a correspondence with attributes of the external world to the study of control of neural states peculiar to the organization of the physico-cognitive totality within which the nervous system lies.

Having examined some fundamental facts about the structure and functioning of biological neural networks, we have seen that these facts are congenial to the modeling of living cognitive systems, their behavior and perception, as functions of a control system that is, as Piaget would put it, equilibrating cognitive structures. It is also now possible, these same facts in view, to see that perceptual input signals are themselves products of the nervous system organization, and, furthermore, that this is all they need to be. These conditions appear necessary and sufficient for the activation of adequate behavior, through specification and control of neural states, as an aspect of the structural coupling of the organism with its surround.

Let us proceed to consider some additional philosophical implications of a control-system model of cognition and behavior, and of the constructivist view point within which Piaget appeared to frame it.

CHAPTER V

AREALISM: A CONSTRUCTIVIST ONTOLOGICAL ATTITUDE

Introduction

If knowledge consists in our own cognitive constructions, and not in correspondence with an external world, philosophical questions arise. For instance, if the objects of perception are our own constructions, why do different peoples' worlds appear to be so similar? Why do we seem to recognize similar regularities of experience, and what light, if any, does constructivism shed on the mystery of why induction works so well? If knowledge is subordinate to the organizing function of the organism, then how does it support this function? If knowledge is derived from neural activity, is constructivism then merely a return to phenomenism, and to the inelegant dualisms of mind from body that sense data theories of perception imply? Additionally, how is it possible to hold epistemic skepticism and avoid the more pernicious ontological skepticism that is, in effect, solipsism?

In view of the ontological issues raised, an additional, more general, question is unavoidable: what relevance does this constructivist position have for the

debate between empiricism and scientific realism? This is a debate centering on a familiar perplexity, as Dilworth comments, "over the relation between one's experiences and the world, or between phenomena and reality."¹ This chapter seeks clarification of these questions. It is a clarification which offers a reason why the epistemic inaccessibility of an external world is not considered an occasion for skeptical worry.

Constraints and Induction: Viability in the Niche

If sensory signals are transforms of excitations originating within the organism, transforms that include an unknown quantity of recurrent neural activity, then inference to supposed causal agents of sensory input from an observed environment seems irretrievably subjective and arbitrary. One could ask, what is to distinguish adequate cognitive functioning from hallucinatory madness? The constructivist reply pivots upon Piaget's complementary process of assimilation and accommodation in relation to phenomenal *constraints* and the role inductive inference plays in it. The discussion will lead us to consideration of the dynamics of an organism's structural coupling with its niche.

¹Craig Dilworth, "Empiricism vs. Realism: High Points in the Debate During the Past 150 Years," *Studies in History and Philosophy of Science* 21, no. 3 (September 1990): 431.

Regardless of whether a substrate of reality exists or not, the constructivist holds that cognitive agents have epistemic access to the *phenomenal materials*--their own neural activity--required to maintain viability of the organism as a totality. As I have argued, this activity need have no correspondence with any possible substrate of reality.

These phenomenal materials--afferent signals--consist in the regularities and *constraints* that develop through experience into perceptual invariants. Once these invariants are constructed, according to Piaget, the cognitive tools used by organisms in isolating and classifying them are to be found among the primitive logico-mathematical dispositions, for instance, the algebraic mother structure by which, Piaget contends, pre-operational children are able to divide a "group of objects into piles according to their similarities."²

It may be best at this point to introduce a hypothesis and then develop the constructivist arguments aimed at supporting it. The hypothesis is as follows: A cognitive living system utilizes its subjective, inductive capabilities to isolate phenomenal regularities and constraints for the purpose of regulating the relations of

²Piaget, *Genetic Epistemology*, 27.

structural coupling through which it fits dynamically with its medium, thereby conserving viability.

Phenomenal Constraints: Why We Can't Fly

Let us first consider what the constructivist means by phenomenal constraints. Neither are they arbitrary constructs nor representations of any independent substrate.

The constructivist schools. . .are well aware of the fact that no organism is free to construct any reality he might wish to construct and that, instead, there are certain constraints with regard to all construction; but these constraints are not specifiable in terms of ontological characteristics of independently existing real structures. . .³

It is important to reemphasize that, under constructivism, knowledge is concerned with active construction of cognitive regularities from experience, not correspondence with nature. The invariants impinging upon an organism's physico-cognitive equilibrium are constructed, assimilated and regulated cognitive structures. Richards and von Glasersfeld comment:

Constructed invariances of that kind correspond exactly to what Piaget has called "operative schemas". . .It is these invariances that give the apparent stability and durability to our representations and enable us to recognize and to know.⁴

³von Glasersfeld, "Piaget and Radical Constructivist Epistemology," *The Construction of Knowledge*, 106.

⁴Richards and von Glasersfeld, "The Control of Perception and the Construction of Reality," 49.

Von Glasersfeld stresses that constraints are to be considered among these constructed invariances:

. . .it is important to realize that "constraints of our experience" do not necessarily refer to constraints that have to be thought of as inherent in an ontological reality. . .many, if not all, the constraints that govern our actual and potential experience stem from our own construction.⁵

These constructed invariances are the products of active assimilation and accommodation by the cognizing subject in interaction with his/her phenomenal domain. Von Glasersfeld stresses that the purpose of viability is served, on both physical and cognitive domains, through the organism's accommodation to phenomenal constraints.

From the organism's point of view, on the biological level as on the cognitive one, the environment is no more or no less than the sum of constraints within which the organism can operate.⁶

What is important for the viable organism in dealing with phenomenal constraints, however, is neither overcoming nor even adapting to them; rather, it is fitting within them. Moreover, structures which prove beneficial to conservation of viability are not the *only* or the *best* structures possible; they are members of the set of indefinitely many possible structures which could have been useful in the avoidance of fatal constraints. What the

⁵von Glasersfeld, "The Concepts of Adaptation and Viability in a Radical Constructivist Theory of Knowledge," *The Construction of Knowledge*, 139.

⁶von Glasersfeld, "An Interpretation of Piaget's Constructivism," *The Construction of Knowledge*, 235.

organism may conclude from such avoidance, according to von Glasersfeld, is only that the sum of those knowledge structures which have not clashed with constraints constitutes, at present, "a viable way of managing."⁷ In this way the structure doesn't adapt to an environment, it *fits* within it by not being eliminated.

That *fit* manifests itself whenever a cognitive structure, a scheme, a theory, remains viable in the face of new experience or experiments.⁸

Von Glasersfeld argues that natural selection proceeds in similar fashion. Constraints eliminate those individuals and species which cannot accommodate and let live those which happen to fit.

. . . nature does not. . . select "the fittest," it merely lets live those that have the characteristics necessary to cope with their environment and lets die all that have not.⁹

In the cognitive sphere, constraints encountered along the way either force accommodation or elimination of schemes which do not fit.¹⁰

This argument may seem a back-door maneuver to surreptitiously reify an ontological substrate as a causal agent of phenomenal constraints, but, since constructivism is not antirealism, such a maneuver would be unnecessary.

⁷Ibid., 239.

⁸von Glasersfeld, "Feedback, Induction & Epistemology," *The Construction of Knowledge*, 229.

⁹von Glasersfeld, "An Exposition of Radical Constructivism," 10.

¹⁰von Glasersfeld, "Feedback, Induction & Epistemology," *The Construction of Knowledge*, 229.

It is ultimately unnecessary since, the ontological status of a substrate of reality is of no epistemic concern; rather, the concern is with conservation of viability. Von Glasersfeld comments that

If we accept this concept of viability, it becomes clear that it would be absurd to maintain that our knowledge is in any sense a replica or picture of reality. It does not have to be. . . it has to be useful to us in that it reliably helps us to achieve our purposes.¹¹

The upshot of this emphasis upon selection by constraint avoidance or fit is that organisms can know only that they were *not eliminated*; they *cannot know* whether they may exhibit some positive attribute *chosen* by an assumed evolutionary process. Similarly, knowledge structures, by their viability, cannot be assumed to have positively corresponded with the deep structure of nature; they have only been proved not to have fatally clashed with constraints. Von Glasersfeld remarks,

the crucial aspect of this theory of knowledge is that the idea of correspondence with reality is replaced by the idea of fit. Knowledge is good knowledge if it fits within the constraints. . .¹²

Induction and Control

I have mentioned that the process of identifying and classifying phenomenal regularities, including constraints,

¹¹von Glasersfeld, "The Concepts of Adaptation and Viability in a Radical Constructivist Theory of Knowledge," *The Construction of Knowledge*, 138.

¹²von Glasersfeld, "Feedback, Induction & Epistemology," *The Construction of Knowledge*, 227.

is accomplished by the subject's active assimilation and accommodation by which it regulates a dynamic line of equilibrium. It is important to note that this model is incorporated into von Glasersfeld's radical constructivism along with Piaget's "widening spiral" of knowledge. This process is an inductive one. Phenomenal things and relations, by virtue of salient regularities, are assimilated into schemes, strengthening them; conversely, such schemes are accommodated in the face of constraints or they are eliminated. With the aid of memory, the process becomes one of controlled equilibration of cognitive structures, assimilated or accommodated by virtue of inductive inference. If we accept this view of induction's role in the physico-cognitive equilibria resulting in viability, then we can consider the entire process of equilibration and progressive constraint management as a function of an induction-driven control system. Von Glasersfeld comments that governing experience through inductive equilibration of structures implies, for the continuing viable system, a process of

the incremental equilibration that proceeds in spirals, incorporating more and more items and events in the developing organism's experience.¹³

¹³von Glasersfeld, "The Concepts of Adaptation and Viability in a Radical Constructivist Theory of Knowledge," *The Construction of Knowledge*, 140.

Piaget, recall, considered the groping, trial and error action of the infant a crucial component of the development of sensorimotor intelligence. It is clear that he considered this a process of induction and discovery, regulation and control.

Learning by groping or trial and error is simply the progressive construction of a schema, but in stages of successive regulations, such that the result of each action has a modifying effect, either positive or negative, on the following one.¹⁴

Piaget remarks that when infants' trial and error actions are seen as

a progressive organization making active attempts at discovery, then it will be obvious that groping is a succession of regulations following the line of an equilibration by means of assimilations and corrections brought about by the subject itself.¹⁵

Piaget's evidence of a primitive disposition to classify things according to similarities suggests, on his view, an aspect of biological organizing function, extended into the cognitive sphere, by which the whole (on n recursions) sustains its viability and continuity.

But we are no longer able to accept uncritically the notion of a "primitive disposition" to recognize similarity. Appeal to "genetic transmission" of such intentionality merely pushes the burden of inquiry onto biology. Fortunately, Maturana has addressed the general problem surrounding the explanation of supposed vitalistic,

¹⁴Piaget, *Biology and Knowledge*, 207.

¹⁵Ibid.

emergent, etc. properties, of which we may view any proposed disposition toward induction as a special case.¹⁶ Maturana argues that, once we distinguish a system's organization function from its components, we are able to view instinctive dispositions as functions of relations of the overall self-organizing activity of the totality. This way we avoid having to look for emergent properties among the components, a search which implies the acceptance of at least a kind of property dualism. Maturana concludes that

the properties of the system to be explained are generated by relations of the components of the system and are not to be found among the properties of those components.¹⁷

In this way, instinctive classificatory behavior, such as that observed by Piaget, would be an aspect of an ontogenetic and phylogenetic organizing function, by which the individual and its species conserves continuity of organization, on respective recursive levels.

Once inference from constructed regularities has succeeded, von Glasersfeld observes, induction may become a goal in its own right.

. . .given that inferring regularities has been successful in the organism's past experience, to infer regularities will be likely to become a goal in its own right and the organism will begin to enlarge its range of experience, and will foster or

¹⁶Maturana, "Biology of Language: the Epistemology of Reality," *Psychology and Biology of Language and Thought*, ed. George Miller and Elizabeth Lennenberg, (New York: Academic Press, 1978), p. 30.

¹⁷Ibid.

create new experience simply for the sake of establishing regularities.¹⁸

He makes it clear that the role of induction is to repeat error-corrections that have been successful for the control system in the past.

in each occurrence of a perturbation, the system will select the activity that reduced or eliminated that specific kind of perturbation in the past.¹⁹

Piaget's emphasis on the role of anticipation of future circumstances, enabling anticipatory accommodations, points out a further role of induction in the regulation of cognitive structures and the accommodation to constraints. On this view it is possible to also consider the modification of constraints in addition to simple avoidance.

Anticipation. . . is something much greater than an extension of accommodation; it makes possible the formation of anticipatory accommodations, but, in its general form, it derives from a capacity for inference or transfer, based on information previously acquired--based, that is, on the conservation of their assimilation schemata.²⁰

Applying the control-system model to the inductive activity of establishing and utilizing regularities from among perceptual signals clarifies why knowledge of some trans-phenomenal realm is irrelevant. Richards and von

¹⁸von Glasersfeld, "The Concepts of Adaptation and Viability in a Radical Constructivist Theory of Knowledge," *The Construction of Knowledge*, 140.

¹⁹von Glasersfeld, "Feedback, Induction & Epistemology," *The Construction of Knowledge*, 222.

²⁰Piaget, *Biology and Knowledge*, 185.

Glaserfeld explain what it means to be an inductive cognitive system:

. . .this means that a control system, if it has a repertoire of several activities, and a primitive form of memory that enables it to keep a record of error signals, ensuing activities, and subsequent changes in the error signals, will be able to make its own connections on the basis of what activity helped to eliminate what error signal. The salient point in this is that now the system can learn without the assumption of any environment, merely by recording and exploiting recorded sequences of activity and ensuing change in the sensory signal toward the reference value.²¹

Hume could do no more than attribute inductive inference to habit, but now it is possible to see, on Piaget's control-system, genetic account, how that habit contributes to the incrementally widening circle of knowledge structures. In addition to offering a genetic explanation of how the inductive habit can be successful, constructivism appears to have offered an explanation for why it is successful. This explanation is to be found in Maturana's notion that functions peculiar to a self-conserving physico-cognitive organization serve to assist in this conservation, according to the viability needs of the organization as a whole.

Dynamics of Structural Coupling: Knowledge and Niche

According to Maturana, an observed living system specifies, by virtue of its self-conserving organizing

²¹Richards and von Glaserfeld, "The Control of Perception and the Construction of Reality," 49.

function, the mutable interactions it maintains with its phenomenal surround. This dynamic functioning constitutes structural coupling.²² Therefore, it is through the relations that constitute structural coupling that a living system avoids or modifies constraints, exchanges resources, and, in short, *fits* within its phenomenal domain. Since the phenomenal domain may include perturbations or disturbances, such coupling relations must be fluid and able to accommodate disturbance. Everything distinguished within the environment that is involved in a structural-coupling relationship with the organism is functionally identifiable by virtue of the role it plays, under the organism's control, in the continued viability of the organism. In this sense, the epistemic shift of the constructivist can be understood as the shifting of inquiry from things as they *might be* (in some idle substrate) to the way things are in perceptual relation to the control purposes of the organism.

As we have noted, according to Maturana, the organism's *niche* is constituted by that part of the organism's environment, or *medium*, that is, at any observed instant, under interaction with the organism.²³ As a consequence of the notion that phenomenal perturbations require accommodation of the organism's structural coupling with its

²²Maturana, "Biology of Language: the Epistemology of Reality," 35.

²³Maturana, "The Ontology of Observing," 18.

niche, altering or perhaps eliminating certain relations, the niche is not specified by a fixed set of relations.

Maturana explains:

. . .a unity continuously realizes and specifies its niche by actually operating in its domain of perturbations. . .As a consequence, the niche of a unity is not a fixed part of the medium. . .nor does it exist with independency of the unity that specifies it; it changes as the domain of interactions of the unity changes. . .²⁴

Maturana illustrates the total picture of organism, niche and environment as follows:

. . .a dynamic [living system] is seen in an environment as an entity with a changing niche that it specifies while it slides through the medium in continuous structural change with conservation of class identity. . .²⁵

For Maturana, a unity observed to be acting so as to conserve its autopoietic structure, or class identity, is a unity engaged in adequate action within the domain in which it is observed; hence, Maturana concludes, "*living systems are cognitive systems, and to live is to know.*"²⁶ Knowledge, as action, then, is the continual carving of a viable niche. From the standpoint of structural coupling, this carving is seen as the continuous equilibration, by the organism, of commensurability (requisite variety) between the possible states of the nervous system and the domain of possible states of the environment.²⁷

²⁴Ibid.

²⁵Ibid., 19.

²⁶Ibid., 33.

²⁷Varela, *Principles of Biological Autonomy*, 245.

Earlier, we adopted Powers's notion that behavior is to be viewed as the control of perception. In the further light of dynamic structural coupling, through adequate behavior, we can now offer additional clarity to this view of behavior. Varela defines behavior in terms of its subordination to autopoiesis.

Behavior can be defined succinctly as the structural changes an organism can undergo while maintaining its autopoiesis. The nervous system allows the organism a varied and rich range of possible behaviors.²⁸

On the constructivist view, borrowing Piaget's terminology, this notion of behavior as adequate action constitutes the regulation and control of phenomenal circumstances, through equilibration under assimilation and accommodation, so that the viability of the physico-cognitive totality is conserved.

Epistemic Skepticism, Ontology, and Critical Challenges

In this section we examine the constructivist ontological position and parry a worry that constructivism is a return to phenomenalism. We consider criticism of the epistemic shift and note that the realist position defended is not one constructivism attacks.

²⁸Ibid., 239.

A Constructivist Ontological Attitude

Now that it is clear that, under constructivism, the control of phenomenal regularities, through the equilibration of the organism's possible states with those of its environment, is the task for which knowledge is accumulated, the benign quality of epistemic skepticism becomes apparent. But the view that knowledge is limited to the realm of controlled experience makes it no less *real*, on this view, than if it mirrored nature's truth. The epistemic irrelevance of a world behind experience in combination with the ontological *reality* of experience itself is what enables this view to avoid ontological skepticism which would amount to solipsism. Richards and von Glasersfeld elaborate:

An organism's introspection, his awareness of his own constructive activity, leads to the realization that his representation of a world, his knowledge, must be of his own making. That is, it leads to what we should call *epistemic solipsism*.²⁹

But, they argue, this cannot be considered insidious since the contents of experience are ever-present and *real*.

They are "real" in the sense that we *do* organize our experience in that way. *Ontological solipsism*, which would be insidious, can get no foothold in this construction. . .³⁰

On this view it is no paradox that regularities and constraints are both real and constructed. The locus of reality is simply shifted from outside of experience to

²⁹Richards and von Glasersfeld, "The Control of Perception and the Construction of Reality," 55.

³⁰Ibid.

within it. From the standpoint of our separate phenomenologies, reality is shifted from the phenomenology of distinctions to the phenomenology of the closed, structure-determined organization.

Is it Phenomenalism?

Upon consideration of the evidence from neuroscience that perceptual signals are transforms and integrations of signals originating within the nervous system of a biological organism, it is difficult to avoid concluding that these findings, combined with the notion of a constructed phenomenal domain, imply that constructivism is just a new kind of phenomenalism. This conclusion, based on the notion that sensory signals are the only hints available to us concerning our surroundings--meaning the adoption of a sense data theory of perception--is wrong. On this view there are no sense data; there are only sensory signals. The notion of "data" contains the assumption that there is something about which the "data" is a coded representation. On the phenomenalist view, this "something" is the external world, to which the "sense data" correspond. Furthermore, under phenomenalism, the sense data are impressed upon a passive, tabula rasa conception of mind.

We have already seen that constructivism rejects the possibility of knowing whether sense "data" are or are not about anything at all, that it has no use for a

correspondence theory of knowledge, and that the knower is active author of the forms of perception. Von Glasersfeld comments on this last point, "Instead of a passive recipient of data or 'Information', the cognizing subject is now the maker of knowledge."³¹ On the strength of these differences, it appears that constructivism is not phenomenalism.

Epistemic Skepticism and Critical Commentary

Constructivism is characterized by a thorough-going skepticism concerning alleged knowledge of an external world. Furthermore, because of the epistemic shift away from the ding-an-sich and toward phenomena as constructions of the self-conserving organism, ontological disputes over what exists independently of our investigations appear to dissolve in irrelevance. On the constructivist view, everything we know, we know because of our active control of circumstances in support, ultimately, of continuing viability.³² This is due to the redefinition of knowledge

³¹von Glasersfeld, "Aspects of Constructivism: Vico, Berkeley, Piaget," *Evolution and Cognition--The Heritage of Jean Piaget's Genetic Epistemology*, Bergamo, October 6-8, 1990, p.³²4.

³²Since, on this view, cognitive structures and organic structures are conserved in an identical functional manner, through regulation and control, viability may be conserved on many levels of recursion other than that of the viability of the physico-cognitive totality. For instance, a living unity may have developed a "classical music" scheme into which it has assimilated, say, Mozart's *Jupiter Symphony*. This structure is conserved by the adequate action of attending a Mozart festival.

to that of construction in support of structural coupling, involving distinctions relevant only to the conservation of an organism's unity on all levels of recursion. Because this view conceives an ontology beyond structural coupling as no more than an ontology of possible perturbations and occasions for assimilation and accommodation of cognitive structures under active inductive equilibration, traditional questions of ontology collapse into epistemology. It is in this sense that constructivism is not antirealism, nor is it realism; there is only construction and perturbation-correcting control by the cognizing subject through adequate action. Because this view holds no position on trans-experiential ontology, neither confirming nor denying, I prefer to designate it *arealism*. Before overlaying this view upon the current debate within philosophy of science over empiricism vs. realism, it may be beneficial to consider some criticism of the epistemic shift that warrants the distinction of *arealism*.

The epistemic shift and consequent abandonment of traditional ontological concern has attracted critical commentary from Mingers who, focusing on Maturana's constructivism, claims that ontology cannot be reduced to

epistemology, that Maturana's brand of constructivism is "ultimately inconsistent" and that it entails realism.³³

Mingers argues from a realist position, a position he mistakenly believes the constructivists von Glasersfeld and Maturana are attacking. He interprets the constructivist denial of the *possibility of knowledge* of the existence of an external reality as the *denial* of the existence of an external reality. This would be a denial, as we have seen, that the constructivist claims no epistemic warrant to make. The similarity of both interpretations is that talk of ontology becomes equally moot.

Mingers advances two main thrusts at what he feels is constructivist antirealism. The first attack is aimed at showing that constructivism actually *assumes* an external reality. The second is that constructivism makes a logical error by claiming that, according to Mingers, knowledge effectively limits what can exist. I shall deal briefly with each thrust in turn.

Mingers begins, in effect, wondering why we can't fly:

. . .if there were no reality independent of our descriptions, then we would be free to bring into existence any world that we desired.³⁴

³³John Mingers, "Philosophical Implications of Maturana's Cognitive Theories," *Systems Practice* 3, no. 6 (December 1990): 569-584.

³⁴Mingers, "The Philosophical Implications of Maturana's Cognitive Theories," 579.

Moreover, he takes von Glasersfeld's caution that this is not possible because constraints limit the range of our constructions as an entailment of an external reality. We know, however, that the constructivist believes he has overwhelming evidence that even constraints are constructions. Moreover, whatever the ontological status of supposed causal agents of our constraints, the epistemic goal is not denial of the idle existence of such agents but the specification and management of dynamic coupling relations between organism and niche. It is through knowledgeable management of these relations that the organism avoids fatal clashes with constructed constraints. Therefore, Mingers is defending a position which is not being attacked.

Mingers's second point, aimed at proving that constructivism entails an ontological commitment, centers on Maturana's insistence that an observed organism has an environment which is in perpetual, structural change. Further, he argues, Maturana himself requires more than just one observer for a consensual domain to be possible. These assumptions, Mingers claims, entail an ontological commitment by Maturana. For instance, Maturana writes:

the observer does not exist alone, because his existence necessarily entails at least an other being as a necessary condition for the establishment

of the consensual domain in which he exists as an observer.³⁵

The next sentence, however, reveals that the "existence" Maturana refers to is a construction out of the experience of an observer who is operating on multiple recursive consensual levels.

However, what is unique to each observer and makes each observer stand alone, is, on the one hand, his or her experiences, which remain necessarily secluded in his or her operational closure, and, on the other hand, the observer's ability through second-order consensuality to operate as external to the situation in which he or she is, and thus be observer of his or her circumstances as an observer.³⁶

While an observer can know only matters concerning constructed distinctions, distinctions which include the subjective "fact" of other observers, the freedom of the observer to construct and operate on multiple recursive levels, from which distinguished perspectives into other levels is possible, is unlimited. Again, no ontological commitment is made; ostensibly factual matters collapse into consensual domains of distinctions. The observer operates as if another observer is there, but neither has nor needs knowledge that this presence is evidence of an ontological fact.

On the basis of these considerations, Mingers's second main thrust appears equally a defense of a position that the

³⁵Maturana, "Biology of Language: the Epistemology of Reality," 60.

³⁶Ibid.

constructivist does not attack. Mingers concludes that the constructivist, in supposedly denying the existence of an external reality, has mistakenly adopted a position that entails the *limitation by knowledge* of what can be an ontological fact.

In denying the existence of independent entities on the basis of theories about the observer, Maturana is reducing ontological questions to epistemological ones, that is, trying to answer questions about what exists purely in terms of our knowledge of, or about, what exists. While it is true that our knowledge limits that which we can know to exist, it does not follow from this that it can limit what actually does exist.³⁷

But, clearly, the constructivist position does not, in the first place, deny the existence of independent entities; it merely shifts epistemic interest away from them as idle ontological furniture and places it upon the phenomenal coupling relations the observer specifies with his or her perceptual constructions. Any ontological facts obscured by these constructions, of supposed causal agents, is of no epistemic interest until, by a jump of recursions, the observer leaps to a new consensual perspective and makes some distinction concerning a causal agent of a distinction on another recursive level. In such a case the distinction is still a construction like any other, though it may be coordinated within a separate consensual domain.

³⁷Ibid., 581-582.

Mingers claims that the constructivist reduces ontology to epistemology when, in fact, the constructivist simply abandons traditional ontology for naturalized epistemology. This may seem a merely semantical distinction, yet it is not. Reducing ontology, on Mingers's model, is to *deny* it. Abandoning traditional ontology, for the constructivist, is to *deny only its epistemic relevance*, not its ontological status, which is forever obscured.

Constructivism, Empiricism, and Realism

I have argued that constructivism does not mount an attack upon realism, but that it makes an epistemic shift away from knowledge of ontological status to knowledge within a consensual domain. Consensual domains are defined, for standard observers, by distinctions or cognitive constructions. The observer may distinguish an organism (which could be the observer itself) in dynamic structural coupling which the organism specifies while conserving its organizational identity or autopoiesis. Through the use of knowledge, memory and inductive inference, the organism may specify changes in its structural coupling that may anticipate future assimilations and accommodations aimed at regulating the phenomenal world so that constraints are either modified or avoided. We have seen that this activity may be viewed as a vector of equilibration whose learning-trajectory is specified by equilibration through positive

and negative feedback transforms on physical and cognitive levels. The success of this process, which amounts to the conservation of organizational identity by the physico-cognitive totality, requires no external ontological commitment for two reasons, one negative and one positive, (1) negatively, epistemic access to any external reality is impossible, and (2) positively, epistemic interest is no longer correspondence with nature, but in the purposeful specification of relations of structural coupling by an organism within its phenomenal niche. These distinctions are what constitutes this position neither as an instance of (ontological) realism nor anti-realism. This position is therefore designated *arealism*.³⁸

³⁸A position similar to this is labelled "ontological realism" by Dilworth, who describes the position as one held by Comte. "Comte's main point is epistemological, not ontological. . . He is not denying that the domain of phenomena has a causal basis in a world transcending such phenomena (and he is thus an ontological realist by implication), but is arguing that the inaccessibility of this world makes it idle to posit hypotheses concerning its nature." Dilworth, "Empiricism vs. Realism: High Points in the Debate During the Past 150 Years," 432. I distinguish *arealism* from *ontological realism* on the grounds that it explains why it is not a problem that we have no epistemic access to any reality behind phenomena. A closer approximation of the purport of *arealism* is given by van Fraassen who characterizes his ontological indifference toward unobservables as "agnostic." But this term, fraught as it is with metaphysical overtones, appears less pertinent to scientific discourse than "arealism." See: van Fraassen, *The Scientific Image*, 72. See also: Jeff Foss, "On Saving the Phenomena and the Mice," *Philosophy of Science* 58, no. 2 (June 1991): 285.

Let us see what light, if any, the distinction of the arealist position sheds on the empiricism-realism debate in philosophy of science. Before proceeding, it may be useful briefly to encapsulate the two respective positions. A recent statement of realism is taken from Putnam:

A realist (with respect to a given theory or discourse) holds that (1) the sentences of that theory or discourse are true or false; and (2) that what makes them true or false is something external—that is to say, it is not (in general) our sense data, actual or potential, or the structure of our minds, or our language, etc.³⁹

The empiricist, or supposed antirealist, represented here by van Fraassen, takes the position that the aims of science can be properly served without concern for the literal truth of theories. He contends that

we can still say that there is no need to believe good theories to be true, nor to believe *ipso facto* that the entities they postulate are real. Science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate.⁴⁰

Van Fraassen, who brands his philosophy of science *constructive empiricism*, gives this explanation for the use of the adjective "constructive":

I use the adjective "constructive" to indicate my view that scientific activity is one of construction rather than discovery; construction of models that must be adequate to the phenomena, and not discovery of truth concerning the unobservable.⁴¹

³⁹Hilary Putnam, "What is Mathematical Truth?," 69-70.

⁴⁰van Fraassen, *The Scientific Image*, 11-12.

⁴¹*Ibid.*, 5.

A common misunderstanding of van Fraassen is that he acquiesces to the "reality" of entities we may observe, in principle, directly, such as the moons of Jupiter; while denying the reality of entities, such as electrons in cloud chambers, which we, given our sensory limitations, can not hope to view without the assistance of, say, an electron microscope.⁴² However, van Fraassen, while declaring the viewing of the moons of Jupiter as a "clear case of observation" (since astronauts could also view them unaided up close), holds that this case of observation is not to be taken as affirming an ontological commitment. He remarks, "observability has nothing to do with existence."⁴³ Van Fraassen has taken the methodological position that theories should "save the phenomena," that is, theories should explain them, and empirical adequacy is a sufficient condition of theory acceptance. He remarks, "To accept the theory involves no more belief, therefore, than that what it says about observable phenomena is correct."⁴⁴

Van Fraassen's epistemological and methodological position accords, quite clearly, with those of the constructivists Piaget, von Glasersfeld and Maturana. He

⁴²Richard Boyd, "The Current Status of Scientific Realism," *Scientific Realism*, 19. Boyd takes this line of attack upon van Fraassen. See van Fraassen, *The Scientific Image*, 13-19, for his discussion on observability-in-principle and differences in predication.

⁴³van Fraassen, *The Scientific Image*, 19.

⁴⁴*Ibid.*, 57.

endorses a method similar to Maturana's, of postulating a generative mechanism--a hypothesis, perhaps specifying unobservables--which, when allowed to operate (as an explanans) entails phenomenal consequences (an explanandum); but van Fraassen exhibits a constructivist indifference toward the ontological status of such unobservables.

I wish merely to be agnostic about the existence of the unobservable aspects of the world described by science⁴⁵

It seems clear, in any case, that the differences punctuating the empiricism-realism debate focus specifically on epistemic investment in, and methodological need for, the existence of theoretical entities, observable-in-principle or not, to which explanatory theories refer.⁴⁶ However, under recent versions of scientific realism, such as that of McMullin, ontological inference must, in some cases, be "hesitant" and viewed as "metaphor" only "suggestive" of

⁴⁵Ibid., 72.

⁴⁶Feyerabend, "Herbert Feigl: a Biographical Sketch," *Mind, Matter, and Method*, Paul Feyerabend and Grover Maxwell, eds., (Minneapolis: University of Minnesota Press, 1966), p. 4. Feyerabend declares that during the 1950's, among descendents of the Vienna Circle, the position that solipsism was a possibility and that "realism could not be proved" was adopted by many who were not persuaded by variations of what has come to be known as the miracle argument (the success of a non-referring science would be a miracle). In any case, Feyerabend comments that "the problem of the existence of theoretical entities soon became the problem." For a realist reply, see: Grover Maxwell, "The Ontological Status of Theoretical Entities," *Minnesota Studies in the Philosophy of Science*, vol. 3, ed. Herbert Feigl and Grover Maxwell, (Minneapolis: University of Minnesota Press, 1962), pp. 3-27.

nature's deep structure.⁴⁷ McMullin, in fact, is clear that the realist can never know whether his theories actually refer or not, and that verification of any truth of correspondence is out of the question.

The realist would not use the term 'true' to describe a good theory. He would suppose that the structures of the theory give some insight into the structures of the world. But he could not, in general, say how good the insight is. He has no independent access to the world, as the antirealist constantly reminds him.⁴⁸

A more naturalistic approach to realism is advanced by Boyd, who contends that the approximate truth of a scientific tradition rests on the cumulative instrumental reliability of its methodology, and that the ontological commitments of those theories may reasonably be adjusted over the course of the further development of total science, which is the context of any plausible theory.⁴⁹

Two conclusions may be drawn from these realist examples: (1) that correspondence of the truth of literal reference of theories to unobservables has been abandoned by some realists, and (2) that, instead, explanatory fruitfulness of theories appears more often as a realist argument for, at least, the metaphorical reflection in theory of nature's deep structure. This emphasis on

⁴⁷Ernan McMullin, "A Case for Scientific Realism," *Scientific Realism*, ed. Jarrett Leplin (Berkeley: University of California Press, 1984), pp. 34.

⁴⁸Ibid., 35.

⁴⁹Boyd, "The Current Status of Scientific Realism," *Scientific Realism*, 76-77.

explanation rather than truth of correspondence is, according to McMullin, characteristic of the bulk of the realist tradition.⁵⁰ Offering a similar argument, Dilworth declares that, for the realist,

the primary purpose of constructing theories which depict unobservable entities is not to describe those entities, but to explain observable phenomena.⁵¹

Fine has argued that realists who attempt to reinforce explanatory hypotheses by claiming that they are (approximately) true, are begging the question of truth by virtue of an abductive inference to the best explanation as a truth criterion. It is precisely this abduction that empiricists have called into question, so it cannot be used in defense of itself.⁵² Fine concludes that the realist is "chasing a phantom" by insisting on truth of reference in addition to explanatory or instrumental reliability, shrugging that "there is no possibility for justifying the kind of externality that realism requires."⁵³

In summary, it appears that the literature of scientific realism has moved away from literal interpretation of ontological commitments and has reasserted its emphasis on explanatory fruitfulness. The realist

⁵⁰McMullin, "A Case for Scientific Realism," 26.

⁵¹Dilworth, "Empiricism vs. Realism: High Points in the Debate During the Past 150 Years," 454.

⁵²Arthur Fine, "The Natural Ontological Attitude," *Scientific Realism*, 85-86. See also: Boyd, "The Current Status of Scientific Realism," 67.

⁵³*Ibid.*, 99-100.

position still, however, maintains that good theories at least refer metaphorically, or within the context of their consistency with total science. Thus, scientific realists are making ontological commitments, however subtle. Constructive empiricism, on the other hand, appears to endorse a methodology which requires only empirical adequacy, saving the phenomena, while avoiding ontological commitments.

What I am leading up to is that, pragmatically speaking, both sides of the empiricism-realism debate in philosophy of science appear to have converged, at least methodologically, upon a research programme similar to that of constructivism.⁵⁴ Very little, in any case, seems to separate the realist positions from the constructivist methodological position beyond the *belief in the importance of making ontological commitments*. Moreover, the empiricism of van Fraassen appears to be an *instance of constructivism*. Certainly van Fraassen's emphasis on model-making, empirical adequacy and the avoidance of ontological commitments appears consistent with the constructivism of von Glasersfeld and Maturana. Van Fraassen writes,

On the view of acceptance of theories which I have

⁵⁴Fine's *natural ontological attitude* (NOA) is an attempt at a practical intermediate position between empiricism and realism, but since it offers no clarification of the basic epistemic issue dealt with here, it will not be discussed. See: Fine, "The Natural Ontological Attitude," *Scientific Realism*, 83-107.

advocated under the name of constructive empiricism, it does not require belief that all significant aspects of the models have corresponding counterparts in reality. . . The locus of possibility is the model, not a reality behind the phenomena.⁵⁵

But van Fraassen gives a hint that his epistemological position may accord even further with Piaget's and Maturana's. He hints that experience is a function of our physico-cognitive organization. Consider the following comment by van Fraassen:

I regard what is observable as a theory-independent question. It is a function of facts about us qua organisms in the world.⁵⁶

Space limitations prohibit further exploration of the extent to which van Fraassen may be committed to the various dimensions of cybernetic, genetic epistemology as we have considered it in Piaget, von Glasersfeld and Maturana. But, on the basis of the similarities we have discovered so far, such exploration appears warranted. In any case, for our purposes here we may proceed under the provisional acceptance that constructive empiricist and constructivist methodologies are pragmatically and epistemologically indistinguishable.

For the realist, however, an epistemic investment in some notion of separate, idle ontological fact is apparent. It is, it appears, this epistemic investment, moreover, which amounts to the clearest distinction between the

⁵⁵van Fraassen, *The Scientific Image*, 201-202.

⁵⁶*Ibid.*, 57-58.

realist methodological position and that of constructivism. If, in fact, realist methodology--stressing explanatory value--is pragmatically similar to empiricist-constructivist methodology, and if the constructivist epistemological position avoids the difficulties of the realist position; if the constructivist position adequately explains *why it is no problem* that we have no access to a reality behind phenomena, then this would count heavily in favor of the explanatory fruitfulness of the constructivist position. It is precisely in the epistemic shift away from concern for a reality behind experience to the reality constituted by experience that such an explanation is offered by the constructivist. Richards and von Glasersfeld comment that

the fundamental question is not ontological: *What is the structure of the real world?* but cognitive: *What is the structure of our experiential world?*⁵⁷

The result for epistemology is that, while its focus is shifted, its application is not to be considered limited. The study of how the contents of experience are organized, and by what pragmatic norms these organizations may be evaluated must be considered, on the complexity of experience alone, an infinite enterprise.

Further warrant for a naturalized epistemological examination of the organization of experience may be found, according to Piaget and Maturana, in the conjectured

⁵⁷Richards and von Glasersfeld, "The Control of Perception and the Construction of Reality," 40.

grounding of the organizing function of cognitive structures in biological organization. Under Piaget's view, as we have seen, cognitive structures are held to be organized according to the circular, rather spiral, interplay of assimilation and accommodation, under the equilibrating control of inductive inference. It is clear that Piaget and Maturana characterized the transmission of instinctive cognitive structures, such as Piaget's classificatory structure, by which regularities are distinguished, as a necessary activity of the ontogenetic and phylogenetic organizing function. In this manner, for instance, the organization of an entire species functions so as to regenerate itself, on all the recursive levels in which that organization is defined.

Summary and Conclusion

It appears that, under a naturalistic methodological warrant, the application and development of an epistemology which seeks to establish descriptive and prescriptive accounts of human knowledge acquisition and purpose may find ample opportunity for scientific inquiry into our own physico-cognitive systems. Once it is considered that the knowledge we have access to is the knowledge we require, as individuals and as species, we can begin focusing our epistemological tools according to a perspective which may

lead us to becoming part of nature rather than seeking to leap beyond it.

Much earlier, we observed Hume make a characteristically naturalistic remark to the effect that our curiosity, in the face of an apparent philosophical dead-end to the search for certain, contingent knowledge, might be pardoned--perhaps commended--if we were to continue on with enquiry, shifted to focus upon the human mechanisms of belief and of the perceived regularities, *customary conjunctions*, which underlie it.⁵⁸ I have argued that such enquiry has continued in Hume's optimistic spirit--that of Piaget, Maturana, Varela, Powers and von Glasersfeld.

We have seen that Hume's skepticism has survived the attempts by philosophers to neutralize it with philosophy. However, under naturalism philosophy has the additional resources of science. Heeding Piaget's methodological admonition that we should "look into things," we continue to do so. The result, so far, has been the development of a cybernetic view of self-regulating models on indefinitely many recursions, recursions which include, on Piaget's model of the physico-cognitive whole, a range extending from the physical genome to the unlimited recursions of operational structures of pure thought.

⁵⁸Hume, *An Enquiry Concerning Human Understanding*, 47.

Within the scope of the physico-cognitive whole, we have modeled a purpose and control-system rationale for why, in fact, we do recognize regularities salient to our purposes. Many of those regularities are salient to the ultimate purpose of the physico-cognitive whole: viability.

Knowledge, on this view, is the fruit of experience and logico-mathematical thought which we use to invent action schemes. These action schemes are viewed as tools for the control of perceptual equilibria which originate and are transformed within the organism's closed nervous system. For this reason, the supposed independent characteristics of distinguished phenomena are of little epistemic interest. The perceptual signal vectors are what the control-system organism acts upon, acts upon them in order to maintain perception at, or near, a reference value, chosen by the organism. The phenomenology of the closed nervous system is braided together with the phenomenology of the open exchange system by virtue of structural coupling executed through adequate, controlling behavior. These two phenomenologies mark complementary aspects of the organizing function of the physico-cognitive totality, and epistemology focuses on this complementarity for a sufficient account of the phenomena of the living.

At the beginning of this essay I fancied that perhaps we should never reach an end point of perfection and truth

to which our search for knowledge would presumably have led us. Moreover, it is possible that science like that of Piaget and the others considered here may convince us that such a quest evidences a fundamental misunderstanding of what knowledge is, how we use it and why we have it. On this view, we would happily abandon any hope for reaching a point past which knowledge could not grow further. It is conceivable that the organism which continues to accumulate knowledge of its contingent, phenomenal domain, its ecstasies and disturbances, in an ever widening spiral of controlled equilibrium, determining its own states from exacting control over its own neural vectors, will be the organism which evolution continues to allow passage along the trajectory of its phylogenetic drift.

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