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What is "Language" that can Facilitate the Flow of Information? A Contribution to a Fundamental Theory of Language and Communication

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A theory of language is derived for complex systems by contrasting the difference between "hard" systems and "soft" systems. Complexity in a field system made up of atomistic entities is defined by the capability of the atomistic-like entities in soft systems to absorb energy internally into fluid-like, gel-like, dissipative processes rather than to equipartition energy rapidly among all degrees of atomistic freedom. Language then emerges as the "mechanistic" linkages that can catalytically switch or evoke changed atomistic states in such "soft" systems. A note on the source of syntax is also provided.

1. Introduction

Almost all of the intellectual communities who are concerned with systems find themselves confronted by a need to understand language and communication. The statement requires no documentation, being so obvious. Also, the communities who are involved in such study are so ramified that they need not all be enumerated. Yet it is appropriate to reference at least one of the more recent broad ranging discussions of the subject by a few major protagonists (edited by Piatelli–Palmarini, 1980). What is missing from all such discussions are fundamentals of what creates language and how language is to be expressed. Is language and communication part of the physical theory and specification of systems, or is it part of a dual construct lying outside of physical theory? (See, for example, Pattee, 1979.)

The object of this note is to suggest the fundamental character of language and embed it within physical theory. Such explanation is part of a continuing dialogue devoted to developing the physics of all complex systems.

We have noted (Soodak & Iberall, 1978) that the important fact which distinguishes a field of complex atomisms (atomistic-like entities, e.g.

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molecules, cells, people, stars, galaxies; like organism, atomism is used to denote both the doctrine and the entity itself) as compared to simple atomisms is that in their atomistic interactions, complex atomisms do not equipartition interactional energy (neither exactly nor nearly) among all accessible translational and internal degrees of freedom. (Degrees of freedom are defined by how many different ways the atomistic entity may move or change its state.) Instead they exhibit very significant time delays in the energy partitioning within the internal degrees of freedom of the system. We noted that there was no mystery to the physics of such interior time delays. The atomism internally represents a "factory", in which the internal factory processes are basically fluid mechanical, gel-like, dissipative, rather than possessing the more nearly internal spring-like character of simple atomisms. The net effect of such internal complexity is to make the local account of motion by translational momentum (i.e., Newton's law of motion) inappropriate. Instead, integration over the "factory day", a time much longer than the translational relaxation time, is needed, in which action modes (action = the integrated product of energy and time, i.e. the dissipative processes which are the "activities" that the species of atomisms perform), characteristic of the species, emerge. That "rate-independent" spectrum or matrix of processes makes up the factory day. (See Iberall & McCulloch (1969) for an account of such an action mode spectrum.) Language, in this modeling, represents the catalytic processes—partly internal, partly external—by which the system, over its factory day, is able to command-control its matrix of action modes which define its process states.

This idea was sufficient for us to derive a distribution function (a Zipfian distribution) for language (Iberall, Soodak & Hassler, 1978). (A Zipfian distribution is one in which the frequency of usage of a word is inverse to its rank ordering, i.e., the second most used word is used one half as frequently as the first, the third most used word is used one third as frequently as the first, etc. Empirically, such distributions are known to be applicable to word usage.)

But, since we have pursued a continued running dialogue with Pattee on the philosophic foundations of complex organization—on its structural, functional, linguistic, physical reductionistic aspects—the reader is invited to compare Pattee (1979) and Iberall, Soodak & Hassler (1978) to judge his or her own *a priori*, or perhaps preliminary, point of view with regard to language and communication. The purpose of this note is to advance our theme of the thermodynamic reductionist view of complex systems and language one step further. The central themes we intend to build this construction around are mechanisms (e.g., machines), (thermodynamic) engines, factories, modes, command-control, evocation, microstates, coupling. Contrary to Pattee, we seek a construct that is general for all complex systems, not just the living, and we neither seek nor need any direct confrontation with Pattee's concern with the quantum mechanical problem of measurement. Instead we key our arguments at a (hopefully) very clear, elementary, engineering-like formulation.

2. Themes

MECHANISM

In physics, the elementary machines are basically characterized as very closely coupled kinematic linkages (e.g., lever), and this notion furnishes the standard notion of mechanisms as elaboration of such machines.

(Dictionary definitions (abbreviated): *Machine*: supernatural material construction (archaic); a mechanical construction by human hands; a supernatural contrivance for dramatic presentation; a device with two or more resistant, relatively constrained parts, which by predetermined interaction produce some given effect, *or* a person or organization that acts like a machine. *Mechanism*: parts of a machine, taken collectively; mechanical operation or action; kinematic chain with a fixed link; a natural process, conceived as being machine-like.)

However, one must sense, from Aristotle's definitions of various kinds of causality, that the chained causality of machines and mechanisms represent only one statement of how "influence" is transmitted. The problem we face is how to deal with this issue of linkage (of cause, of effect)—or connection—in a more transparent reductionist fashion. We begin with the problem of discussing engines, for we are not concerned solely with the dramatic *deus ex machina* problem of producing an effect on the stage (e.g. of life). Instead we are concerned with the serious issues that physically really 'weld' systems together.

ENGINE

If we think of man-made engines, our general notion is that of a thermodynamic engine which is *hard molded, hard wired, hard geared, hard coupled, hard guided,* and *hard algorithmed.* This is achieved commonly by taking a soft coupled field and guiding it along hard constraints so as to do its thing. The "factory day" of the cycle tends to be simple. A few mental prototypes are the internal or external combustion engine, the fluid mechanical turbine, the electromechanical network. In each case, there are sources and sinks of potential, and a cyclic mechanism for extraction and transferring energy between the potentials, and potentially performing external work (or at least operating in a degenerate mode which can also be opened so as to do work. For example, "idling" systems simply dissipate energy because of internal losses and thus do not display their functional complexity unless "opened" via externally coupling).

But nature seldom builds engines with hard molded, hard wired, hard geared, hard coupled, hard guided, hard algorithmed constraints. Instead, each of the adjectives *hard* in the previous sentence has to be reviewed in the context of being changed to soft. (One small note may be useful for many technical readers who may wonder about the nature of the chemical combustion process in the internal combustion engine. The burning reaction is very nearly hard guided within its internal reaction coordinate space and within its external reaction path. Although such combustion is an explosion, the explosion has to be spatially controlled in almost a wave guide mode, very near the knocking limit. The very modern stratified charge engine has to have comparable or even more stringent control. All this development is taking place at the present time as the search for high efficiency energy extraction is becoming even more intense than it was during the period of the initial development of internal combustion engines at the turn of the century. These remarks are not idle. We can show that related process controls were also involved evolutionarily in the internal processes running biological systems.)

A couple of interesting intermediate engine prototypes to take for more "natural" systems is a falling leaf or seed (which can be simulated by the dropping of a rectangular strip of cardboard), *or*, as a modern substitute for a more classic aeolian harp, one might listen to the mournful clang-clang of the rope or chain on a tall flagpole sitting on a deserted shopping mall whenever the slightest breeze blows. One may not think much of the engine capability of these two examples—although the rotary spin of the former does act aerodynamically to increase the broadcast range (or to fan passing flies), and the clang-clang-clang of the latter tends to act to work harden the pole!

The examples are offered, not out of any facetious intent, but to illustrate very simple thermodynamic engines operating from potentials at hand (gravity, wind), *and* to introduce softer, more fluid-like couplings. Also one may note that the doing of work is not the basic objective that is attained (i.e. purpose), but that the capability of doing work may be used in a more degenerate mode to serve some functional "purpose" of the system. (The raising and lowering of our arms does no work in the external environment. It is degenerate (or lossy, or dissipative) of energy; yet it can perform whatever functions the body of the organism wishes to perform on itself.)

Thus the opposite prototype to the hard systems are those which are completely softly coupled in every respect.

It is in such systems (systems which are more or less fully softly molded, wired, coupled, guided, algorithmed), complex systems which appear quite fluidly coupled in so many of their degrees of freedom, that we arrive at the notion of communications and linguistics (catalysts) as coupling processes.

We have said that communication and language uses whatever materials are at hand in natural systems (Iberall *et al.*, 1978). What we haven't said is that these catalytic couplers or signals are used in whatever discriminable form suits the available modes of the system (e.g. motor, sensory—these are not purely living system characteristics). So while the hard system model may be exhibited as notes on a player piano (or a hard algorithmed computer program), or an amplifier and micro relay that controls the state of a system, the soft system may use "words", "symbols", or any other discriminable element at hand (e.g. hand sign, written word, mouth sound, body posture). Soft coupling of engine processes can be as compelling as the hardest coupling. In fact, extreme cases of soft fluid coupling can be almost as hard as the hardest gear coupling imaginable. One must add the proviso to both that the system we are examining persists. One finds that some inelastic soft yielding is required in the hardest geared coupling (else the gears will be too brittle and break), and a certain measure of directivity is required in the softest coupling. Systems tend to be mixed.

Language, thus, tends to be the catalytic linkages that make up the machines and mechanisms and engines in soft systems. That catalytic property helps make them capable of "evoking" (see, for example, Iberall, Soodak, Arensberg, 1980), as well as linking many microstates.

FACTORY

A factory consists of a collection of engines and machines which are loosely coupled to work in a number of distinct operational modes. The factory is served, at fast time scale, from external portals, which are supplied from external potentials and gradients. Even though the physical fluxes available through the external—translational—gates arrive quickly, in their factory interiors, the complex atomisms process and delay over lengthy periods of time. Autonomous factories also are self-serving (Iberall *et al.*, 1980). If one asks the question whether a factory of any complexity can be developed with all hard components and processes, the basic conjecture is no. The internal complexity will depend on soft coupled fluid-like, gel-like processes. In other words, language will be a major basic characteristic of such systems, much more so than for "just" engine component subsystems.

(This assertion has to be only a conjecture. Our limited engineering experience (this means one lifetime, reflections shared within that lifetime with a rather large engineering community, and the readings of a lifetime), is not sufficient to offer evidence of a convincing nature whether it is possible, say, to build hard systems that will "operate over a thousand years", to offer an interesting metaphor. The fact that some buildings have lasted for 3–4 millenia is not significant evidence. They have existed in the form of low stressed machines. On the other hand, if man made such man-made systems through a long evolutionary process, might he succeed? That is what we do not know.)

Developing the physics of a factory is a formidable task. We do not undertake it lightly. (On the other hand, many engineers know very well the process of engineering a factory.) But at least in this essay, we have managed to identify it as the central task of exploration for homeokinetics, the physics for complex systems. Our task now is to see if we can develop some idea of a general theory of linguistics and communications as major linkages applying to such systems. Since there is no general guide for developing such a physical construct, we can only pursue the quest piecemeal by whatever expositions strike us as illuminating. We have already alluded to our first illumination, on a parsimonious derivation, perhaps theory, for the Zipfian distribution of language as linkages.

3. On Hierarchy in Languages

A second note will deal with an inquiry into the nature of linguistic linkages. Are they hierarchical, or perhaps, in contrast, are there only "two" languages, a common metalanguage to which all members of the species share (or, to use a metaphor, if race denotes members of the breeding pool of a species who in fact do interbreed within small generation numbers, then members of a common cultural pool), and then various parallel specialist "dialects" which they use to discriminate different modal tasks. The latter, one might suppose, is the common view of language. We wish to explore the alternate hypothesis; that languages are very significantly hierarchical, as well as being somewhat parallel, somewhat heterarchical. It would be highly meritorious if we could carry on the discussion and analysis in the general terms of all complex systems, but at present we cannot. So the best we can do (at present) is to specialize the problem to human communication, and then reflect on what we might say more generally for other complex systems that also operate with linguistic linkages.

As the evolution of language has indicated, neither written nor spoken language has required a unique set of rudimentary elements, e.g. letters, phonemes. Yet the very notion of using materials at hand suggests that the thermodynamically complete human system would light on only a few possibilities or among possibilities that are very similar. But why spoken language? Loosely speaking, the selection is restricted to electromagnetic, acoustic, or chemical avenues. The acoustic is rich enough (via larynx, pharynx, and mouth cavity) to both provide speed comparable with the switch characteristics of the motor systems (i.e. there is a match among sensory, motor, and linkage "communicational" systems, which makes the system capable of acting hard connected-like), and a large enough repertoire of symbol linkages (e.g. of the order of 20–30 phonemes). Does this mean that number of communicational elements is restricted to those unit discriminable items at hand? No. Instead of using only m phonemes, one can make words, e.g. m^2, m^3, m^4, m^5,... (with perhaps m^5 being a most common human selection). Such an election already provides capability for say 10^7 nominally distinct words. *Or*, if that is not sufficient, words can be parlayed into sentences, sentences into paragraphs, paragraphs into chapters, chapters into books, books into libraries. These kinds of chains are not limited by the number of phonemes at hand, but by the memory and parallel processing capability of the system. Thus, as had been found, Miller's magic number of seven channels, 20–30 bits per second of near error-free information transmission, storage of the order of 10^4–10^5 words, and some undisclosed stereotyped number of sentences, "ideas", etc., are identifiable characteristics. How extensive is the band width of "language"? Extensive enough to evoke and command-control all of the actions required for survival. The verbal language of people may involve a rank ordered band width of 10^3–10^4 to 1 (i.e. 10^3–10^4 words in a Zipfian distribution), the "population" language of people in society (how people elect to live in urban areas of various sizes) may cover three decades (10^3 to 1, i.e. sizes of towns and cities from 5000 to 5 000 000); the $1/f$ noise spectrum of a paramecium may only cover two decades.

This "multiplexing" of signals (phonemes, words, sentences, etc.) is not a very rich notion of hierarchy, although it is often thought to be so. (It may be so for the hard coupled system designer. For the information theorist, it is much more an issue of materials or elements at hand. One may use binary switching if this is the only reliable capability of the element at hand, or one may use a 10, 100, 1000 state modulus if that is what is reliably available).

The hierarchy we are concerned with is the one that goes from principles to systems. The only model we consider reliable, being universal, is the one that goes from principles of physics to hierarchical systems in nature via physical strategies.

Principles of physics		*The hierarchical systems in nature*
		Cosmos
		Galaxies
Mechanics	Physical	Intragalactic structures
Electromagnetism	Strategies	Atoms–ions–molecules
Quantum field theory		Nuclei–electrons–photons
Relativistic mechanics		Leptons–quarks (?)
		Vacuum

We might imagine a "pure" physicist who knows all the principles of physics, who examines the systems of nature "out there", and who immediately develops a strategic path of description for each system discerned. Such a description is cast from a metalanguage of the human brain. It is made up out of materals at hand (internal—perception, introspection, cognition, self-dialogue (all poorly identified processes); external—vocal, written, motor signed). The symbols used are largely arbitrary. They are many. They seem to obey Zipf's law. They are sufficient to control and to evoke microstates, with a considerable degree of redundancy.

We have no idea what a necessary theory of strategic physics is like, so we can only be guided by historical fact (science, after all, is empirical study at its base).

It seems clear that early in human history (e.g. as judged from the artifacts—tools, "art objects, "religious" objects, structures)—given language—*beings* and *becomings*, *motion* and *change*, *structure* (form) and *function* were ideas that evolved as intellectual coin of the realm. Quickly mentioning dates of 40 000 y.b.p. (e.g. as a number that might denote appearance of homo sapiens sapiens), 35 000 y.b.p. (e.g. as a "first" appearance of "religious-art" objects), 20 000 y.b.p. (e.g. as a nominal dating for early animal cave paintings), these findings are indicative of the character of the early physical world view of sapient (scientific?) man. One might say that the initial intellectual strategy was an animistic spiritual description of the world. It is not our intent to develop this notion further. The interested readers might care to explore the subject via at least one introductory source, Eliade (1978).

As one moves through the origins of agriculture (e.g. c. 10 000 y.b.p.), agricultural villages, the Neolithic Revolution, into the beginnings of the Urban Revolution e.g. the first Anatolian and Armenian network of "cities"—diversified population centers engaged in trade, as far back as 10 000 y.b.p., followed by the start-up of Sumerian city-states 6000 or more y.b.p., or the start-up of an interacting network of Egyptian (Nilotic) "cities" (Hoffman, 1979), one finds the idea of a political person, as persona, as identifiable individual, beginning to be recognized. Thus by such a time, the idea of spirit, of gods, of specific individuals as movers and changers, as effectors, as command-controllers, had come into existence. By 5000 y.b.p., especially in the millenium 4000–5000 y.b.p., the ideas of the secular and ecclesiastic political effectors were developed. One even finds the first codes of man-made law being written in that epoch.

(The point at which command-controllers came into existence is debatable. Primates, or course, are known to display a pecking order of authority. Elite leader figures are known to exist in hunter-gatherer societies, and their oral memory—as father figures—does persist. But at least a qualitative difference arose with symbolic writing, and the widespread recognition by all that the specific individual existed, not as a stereotype, but as a specific historical figure, involved in specific historical events. Evidence for identifying an individual exists in cave figures from about 20 000 y.b.p. There is a considerable gap to a first known leader figure.)

(As dictionary definitions: *politics*: the science and art of government; *govern*: to direct and control actions by established law or arbitrary will.

The point we would like to emphasize within the definitions is that the discovery of such images, of how to describe motion and change, e.g., by spirits, how to direct and control actions either by man-made law or "natural" law, are all world images of the beings and becomings of the real world. As such they are *all* strategic descriptions of the world of phenomena. This evolution, and history, is not different, in principle, from the evolution of descriptive strategies that emerge in the developing child. These are both related to the characteristics of the development—history and evolution—of the human brain.)

In principle there is little difference between man-made law and natural law. One relates more to internal degrees of freedom and how they may operate consistent with external degrees of freedom (noting that in complex systems, because of extensive time delays between internal and external action, some sort of strategic construct is needed to match the regulation), and the other relates more to external degrees of freedom. Yet they both require "strategy" for their level of description. Why? Because the linkages are soft coupled, namely "linguistic", and thus have to be forged "on the spot", out of "materials at hand".

It isn't until classic Greek times, of 2500 y.b.p. (e.g., Thales of Miletus) that the notion of a parsimonious description by abstract principles—that study which we denote as science—begins. The major principle used? As far as we can see, leaning heavily on Aristotle's summaries of 300 years later, it was the topology of accounts by the one, the few, or the many, and the typology of classification.

We believe that what we are saying, as a major theme and thesis, is that by a few such logical-philosophic-metaphysical principles, man begins the task of constructing the hierarchical-linguistic soft coupling between his brain and the hierarchy of nested natural systems as strategic couplings. That is, the principles of physics constitute a logical-historical-strategic construct, the linkages from principles to systems represent a logical-historical-strategic construct, and the discovery of the natural hierarchy of systems out there constitute a logical-historical-strategic construct.

Wherein lie the "true" principles? We do not know. We may never know. All we can do, as the line Aristotle-Newton-Maxwell-Einstein-etc. suggest, is to build and build on what came before till we have a game so parsimonious, so embracing, that no one can seem to come up with a more parsimonious, more embracing statement (e.g., as Einstein attempted to do in his search for a unified field theory). Wherein lies the "true" natural hierarchy? Out there. But, again, we may have to continue a search time and time again until we believe that we have exhausted all that may be discovered experimentally.

It is all such linkages, soft in nature, that constitutes linguistics in general, or here the search for science in particular.

4. On Descriptions for Complex Autonomous Systems

This brief third note will point out a consequence of the soft linguistic mode of coupling subsystems (and atomisms) in complex autonomous systems via autonomous variables. Such coupling is not well achieved by analytic descriptions. We have worried (with and by) this point for a long time. Our simplest statement (e.g., regarding a complex system like the brain) was to say that the brain does not operate via an electrical logic (i.e., by network elements such as resistors, capacitators, inductors, gyrators, e.m.f. sources, which relate voltage V and charge q by $V = R\dot{q}$, $V = q/C$, $V = L\ddot{q}$, $V = E$). Rather, the brain operates basically via a chemical field logic which biases the electric networks, and in fact even colors their connectivity. But we are still reaching beyond that, e.g., in referring to our search as a search for the chemical languages of the brain. It is the question of how a hierarchy of such chemical languages is developed that we are currently concerned with. The logic of that problem (or its psychologic) has to be solved before we can be concerned with the analytic description of the linkage. At present we would be satisfied, strategically, with primitive linguistic couplings, for example:

atomism A is *coupled linguistically to atomism B*
to affect *change in mode C*

5. On Syntax

As a final brief fourth note, we would like to make an introductory comment on syntax in language. We cannot claim to have a well developed theory of syntax, but we believe it possible to begin such a theory. We have no idea whether what we are developing is a "true" theory, an *ad hoc* or a *post hoc* conjecture. Let it be viewed as a first (or perhaps second, third, . . . , or even tenth) effort at a strategic description. (*Syntax*: connected system or order; harmonious adjustment of parts; sentence structure. Note that the "primary" definition of syntax, e.g., of a structure, system, language, already contains the notion of connection and order, and thus a clue as to its theory.)

The problem we face in a theory of syntax of language is elementary strategic notions of connection and order. Bohm notes that there is a vast totality of notions of order in the mind (see discussion in Iberall, 1972), so such richness is not the problem. The problem is what might the simplest logical constructs for language be and why do they seem to have such widely scattered (in space and time) stability and universality? Chomsky, in fact, refers to language as embedded in deep structures (of the brain?).

We prefer to note that the Greeks classically could only reduce that which is out there to the beings and becomings. Is this subject and predicate? Would it matter tremendously if the form was predicate and subject? Or is the order of such ordering itself become the basis for changed meaning? etc.

It would seem to us that the answer to the first question is yes. Such logical ordering, as it might be used by any serial machine, could very well become the basis for descriptive or command-control linguistic chains (*being*: existence; *becoming*: to pass from one state to another).

Linguistics, in such a Greek sense of its ordering, affirms an existence, and then affirms something about change in that existence. *Or*, as Bateson raises the question (see Iberall, 1972), the question of mind and how it knows is decided in cybernetics by the fact that mind deals in pattern, and that we know (pattern) by differences, e.g., by differences in sensory perception. Thus being and becoming, as elementary linguistic elements, is a rather rich schema for identifying a discriminable pattern (e.g., its fixed spatial character) and its change (e.g., its temporal character). One senses that such a view of linguistic linkages is sufficiently rich to get to the principles (and strategies) of physics, as well as the hierarchy of nature. *Linguistic linkages seem rich enough to deal both with internal degrees of freedom and external degrees of freedom,* both with what can be "seen" (direct sensory perception) and what can only be "cogitated" about (indirect internal perceptions or cognitions).

For us to go beyond these simplistic ideas, at this time, e.g., what is required to deal with ambiguities, what is rich enough to evoke "coherent" chains of description or command-control is beyond our present scope.

(One notes, in writing complex sentences in which the promised orderliness of linguistic syntax might arise, the inordinate pressure to get the linear order out in a form where the reader will not lose or confuse the meaning, or be led off to some ambiguous interpretation. Few would doubt that such composition is an art form.

Art: skill in performing certain actions acquired by experience, study, or observation; skill in adaption of things in the natural world to the uses of human life; a science such as grammar serving as an instrument of knowledge; a system of rules or of organized modes of operation serving to facilitate the performance of certain actions; systematic application of knowledge in effecting a desired result.

Note that all of these definitions stress command-control by experience to effect modes of action or the outcome of modes of action. Nuff said!)

Yet these responses seem too subjective. Can we begin a more objective statement about syntax?

We do not insist on a unique ordering. There may be many equivalent orderings, e.g., there may be many analogues for the syntactical question among the various complex systems out there. Llinas and I have postulated that all such views (of reality) have to agree (Llinas & Iberall, 1978).

So we take the simplest physical set (i.e., mathematical) that seems to suit, a two-member ordered set involving state, e.g., x_i, and rate e.g., $\dot{x}_i$, $\{x_i, \dot{x}_i\}$. Many readers will begin to detect that we are building toward, or can build toward, a set theory, a theory of propositions, and a physical theory. That is true. We do not wish to pursue details here. It is sufficient to point out that rudimentary characteristics of language, including the parsimonious language of physical science, can be so written.

Let us throw in one parsimonious theme from physics. Suppose we inquire, once more to the many times the question has been asked, why the equations of physics have to have the second order temporal symmetry of

$$m_i\ddot{x}_i = f(\ldots)$$

We would answer, this time, because the solution set has to permit the independent solutions of state and rate, and it is only the existence of a second order constraint that makes the two lower orders independently prescribable (at least initially, regardless of the subsequent space-time linkages). Thus linguistics and physics seem to start from the same point.

If one asks whether such ordered simple sets exhaust "all" of linguistics or "all" of physics, the answer is no. Some rudiments of linguistics, say among children, can be interestingly inspected in a rather recent N.Y. Academy Meeting on child language (edited by Teller & White, 1980), in particular articles by Horgan, and by Nelson. There may be a gap between a description of the rudimentary language(s) of the child and its historical development of syntax and that of the "language" properties of the logician and the physicist, but we do not sense that much divergence. It may not be possible to close the theorematic set for arithmetic, language, or perhaps even physics, yet a rich enough historical-evolutionary description can be written that gets on with a great deal of each of these fields, with a great deal of convergence. Mostly they all seem to require a great deal of continued experimental study before they might give the impression of being stereotyped.

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