On the genesis of "is" and "ought"

A. S. Iberall

Am J Physiol Regulatory Integrative Comp Physiol 246:937-942, 1984.

On the genesis of "is" and "ought"

A. S. IBERALL
Crump Institute for Medical Engineering, University of California, Los Angeles, California 90024

IBERALL, A. S. *On the genesis of "is" and "ought."* Am. J. Physiol. 246 (Regulatory Integrative Comp. Physiol. 15): R937–R942, 1984.—Human beings are confronted by how things, including themselves, work and how they ought to work. Human beings are also confronted, relatedly, by movement and language. The purpose of this note is to suggest an objective physical base within which these philosophic, psychological, and physiological properties of complex systems can be anchored.

IN AN EARLIER ESSAY (8), I made some suggestions concerning the character of language. One central problem with which I concern myself is identifying all the natural processes, both inside and outside the observer of the real world, by which that observer conducts himself. I believe that the process of identification (of those processes) lies in the use of language, which lies within the observer and user of language in a private abstract language space (Note 1). Here the theme of where language fits into an integrative physical science is pursued further. Connection to language is made with the "is" and "ought" of behavior (i.e., why we do things, why we can do things, why we can think about things, why we can remember things, and why our thoughts can be communicated and can guide the things we may do).

In that earlier essay, I identified language as the linkages used to connect processes in complex soft systems within and among communicating member systems. Existing systems were characterized as being hard or soft molded, geared, wired, tracked, and guided. The notion of language was identified as characteristic of soft complex systems that possessed many internal states rather than hard systems capable of only discrete switch states. The linkages of language could be used either to switch actions catalytically or to evoke microstates within, between, or among language-using systems. The two major states identified by language were the *beings* and *becomings* (Note 2; e.g., nouns and verbs) of reality.

However, such simple pairs or groups (e.g., being and becoming; noun, verb, adjective, and adverb) suggest a rather impoverished language, one that seems to retain too much of the character of a hard switching or linking. Thus it is necessary to enrich the explanation of the program of language (see, e.g., 14) to where it has the full content of a value system and can literally be used as linking guide to conduct behavior for individuals, pairs, groups, or, in fact, societies.

ARGUMENT

Complex systems. Note that the salient character of a complex system, as we have defined such a system (17), is the nonequipartitioning of energy per degree of freedom in each atomistic entity making up the system and the corollary time delay into the complex atomistic interiors. Llinás and Iberall (15) have identified that ongoing process in the living (cellular) atomistic entity as a regulation of the bulk-to-shear viscosity ratio within the cellular organism, whereby it controls its admission gating in response to both the internal and external environment (Note 3). That control, mathematically, represents a bifurcation of states (into 2 or more states), that is, to respond to the vicissitudes (Note 4) of the external milieu by *response A* or *response B* (e.g., to be or not to be, . . . perchance to dream). It is understood that the external environment, a system above in the hierarchy, is continually flooding both the external and internal milieu with impulsive vicissitudes. The physics of systems basically asserts that no system can be shielded adiabatically for an indefinitely long period. Thus, minimally, a system will inevitably begin to encounter energy fluctuations that may in time induce matter fluctuations (e.g., of a physical or chemical nature). The inevitability of matter fluctuations is a weaker condition because of the greater degree of isolation possible for closure to matter fluctuations. However, this restriction is mainly for solid-state systems challenged by low surface stresses. For fluid (or mobile) systems, in which appreciable internal momentum delays may exist, lack of material closure is not much weaker than lack of energy closure.

Thus mobile complex systems, those we are concerned with, have to confront turnover of material and energy resources and their cooperative organization into formal and functional states. That is, such systems are continuously faced by the sustained processes of being and becoming (Note 5).

Sensing and moving. The central mechanistic scheme, by which this apparent conflict (of being and becoming) is resolved, is organization within the dual form of sensory modalities and motor modalities. A cyclic chain of the main line of behaviors is as follows: move to perceive (form a sensory pattern) to ingest to move. However, there is only one set of machinery within any organism. Thus this chain has to occur by reorganizing the one set of mechanisms again and again. Each such reorganized set of forms (e.g., organs) and coupled functions is described as a mode (a collection of players, elements, or subsystems of the organism, organized in a style of action). The total cycle of modes, making up a "factory day" (complex systems are characterized internally as factories) represents the near thermodynamic equilib-

0363-6119/84 $1.50

rium time scale of the organism. Over that factory day, the organism has both been and become at a great number of space and time scales.

Language. To enter into each such mode requires the cooperation of an ensemble of catalysts—"switches" in hard systems and more likely chemical steps in soft systems (e.g., enzymes). That complex coding, often marked by a leader signal, or a prototypic signal, represents language. In each such complex system or cooperative family of complex systems there is a specific symbol set, a syntax, and a semantics.

In evolutionary sequences, as they appear to us on earth among living systems, it is not until one reaches the upper levels of mammalian development, particularly in the primate, hominid, homo line, that we humans seem to recognize, with great clarity, a very soft coupling between modal behaviors, their catalytic determinants, and an even softer language that we identify as symbolic language—spoken, written, or signed by body parts or other representations.

What makes such very perceivable language possible? The same freedom, a motor freedom, makes it possible to move essentially every part of the exteriorized body and many parts of the interiorized body (Note 6). But that freedom is possible in essentially all living organisms, so that freedom is not sufficient to be recognized as the extra freedom presented in human speech.

Enabling brain. I have suggested an answer to the source of that extra freedom (7). It is based on the freedom emergent from the interposition of another neural level of language coordination centers (areas of Broca and Wernicke) and the relation of those added cortical elements to the limbic system. That additional layer, the equivalent of an added interneuronal processing level, floods the limbic system in a reverberating mode and makes it possible for the cortical system at the higher center level to consider the totality of mixed patterns presented in the limbic system (of food state, sex state, and emotional state) and view them as abstractions divorced from the outside or inside systems' reality. It intensifies and enriches the character of the logical categories that can be identified (e.g., class and relation). Thus those abstractions can serve to shape linguistic elements, but in what form? By whatever motor elements the organism chooses ("freely chooses") to elect to represent language. And in humans, vocal representation is sufficiently rich (25–30 phenomes), fast (10–20 Hz), and available to the manipulation of the organism with little energetic cost. Thus vocal language emerges in the same real time domain as nervous action. The "proof" (test) of that thesis is that very much later in human history—in fact perhaps 30,000–40,000 yr into that history—humans invent another language, written language, as a fully formal scheme essentially equivalent (or equally rich) to the voiced language.

Thus, in this soft coupled system, the motor and sensory and linguistic modes tend to dissolve into each other. The chain of behaviors therefore is enriched to move to perceive (both to sense and "speak" to self) to ingest to move; it is clear however, that the bifurcations are now richer (e.g., to be or not to be, to move or not to move, to speak or not to speak).

Movement, sensing, and language. Since the ingestion machinery is largely parallel and "automatic" (autonomic) in relation to the motor-sensory elements, one senses that the basic self-activated behavioral repertoire seems to be related mostly to moving and sensing. Fischer (4), in fact, has provided the elegant picture of a motor-sensory axis in behavior. The individual organism tends to alternate between "touching the walls" and moving. That patterned alternation between movement (or organized movement) and sensing becomes the programmatic content of most of behavior.

In the human, however, there is the continuing injection of language (as abstraction), used as a formal element meta to the continuing injection of local chemical (or neurochemical) catalysts associated with both sensing and movement. It is as if there were a nearly continuous stream of such metalinguistic "speech" [the kind identified in literature as stream of (sub)consciousness, but also possessing a nonconscious component] accompanying the continuous stream of chemical languages. That capability, in fact as an almost necessary intrusive capability, as we have said, stems from the extra layering components in the cortex and their particular connections from cortical areas to limbic system. The "simpler" languages, as seen in the chemical streams—or more generally as catalytic switch elements in soft systems—*nevertheless go on in all complex systems* in which appreciable time delay occurs in internal degrees of freedom. That long time delay, as far as exteriorized motion (or momentum transfer) is concerned, is a nonholonomic constraint (Note 7). This is the best physical description of the process. To the outsider, that delay process looks like "free will"! It is very impressive to most outsiders and often to the individual human organism itself that the organism has been able to make or state such a marvelous creative act (or statement). Yet many perceptive observers can look right through the act and see it as a rather expected or stereotypic response.

On language. Examine the problem (of conducting a life program) from the point of view of a simpler living system whose language needs are minimal (i.e., organisms that tend to be referred to as stimulus bound) vs. that of the human organism whose language needs (or at least usage) may be very rich. In the former, the motor-sensory connection is fairly tight. Many studies have indicated how small the diffusive (or spreading) component of decision making is in such organisms (e.g., the tracking performance of worms). A prototypic physical model of such behavior is contained in the action and actuation of behavior in flagellated bacteria (1). They swim long straight segments in chemically favorable media. They tumble (by reversing their flagellated motion) in chemically less-favorable media. The result, in uniform media, is an undirected spherical diffusion, a random walk; in media with concentration gradients, a motion apparently directed up the favorable gradient. This tends to give the impression of a "free will," yet, at the same time, to resemble the characteristic result of all random-walk diffusions. An ensemble of such organismic

systems (e.g., a social system) will respond to only a limited number of gradients and diffusivities (Note 8). Thus the soft coupled linkages that make up language, and the number of motor-sensory modes (also their number of degrees of freedom), are not far apart.

On the other hand, the large number of motor degrees of freedom and states in the human being, the considerable number of sensory modes and their large number of resolvable states, the number of chemical patterns internal to the organism (yet all very similar to those in many other higher animals), *and* the number of linguistic elements that can be used to identify these motor-sensory internal state patterns are so great that an extensive language has to be used (Note 9). How extensive? One could say that a low level of human speech can operate with perhaps a thousand (10^3) linguistic word elements (using, e.g., 5–50 object symbols, 30 phonemes). More extensive "vocabularies" (potential bins, "dictionaries" of words) may use 10^4 word elements. Extreme vocabularies may use as many as 10^5 word elements. As is well known, and as we too have discussed (11), the selection of such usage (election from the word bin with automatic return after usage) conforms to Zipf's inverse rank-ordering law ($\sim 1/n$). Such language is used to couple sensing elements and motor elements, as bursts of frequency and amplitude modulated linguistic elements up to 10-Hz rates, conforming to Miller's "magic number 7" election of modes of description (Note 10). The amount of amplitude or frequency discrimination used corresponds to the sensitivity of discrimination of the human organism. You cannot slur or smudge verbal signals, written symbols, or touch signals to a point that neither you as sender-receiver nor you and others as sender-receiver pairs can discriminate the elements. In that sense, these soft linkages become or are made up of a core of "hard" elements (i.e., all flow fields are made up of atomistic entities).

On "is" and "ought." But what does that stream or flux of linguistic elements do? It helps to regulate and control the flux of motor-sensory elements and to evoke internal microstates in the organism. That latter flow appears through the intervention of the former flow. The former flow carries the "information" (the catalytic capability) of controlling the is and ought of the latter flow, but it has two (bifurcated) paths to that state. It (the pattern of mind in the neurophysiological-neuroendocrinological brain) can examine the switched state in the action-suspended patterns of the mind (introspection)—as the oughts of behavior—*or* it can unleash the pattern on the neuroelectric-neurochemical catalysts (the "machine" language) within the brain, whereupon the result is the "is" of behavior. Thus the soft coupling of internal pattern language to internal physical-chemical language to body motor-sensory patterns of coupling to a stream of behavior represents the ongoing sustained flux of the is and oughts of the organism. All this is played out in the mind space (patterns within) of brain.

The same linkage inside, which by a Freudian metaphor might be identified as the "super ego" of the organism (Note 11), also takes place between and among individual organisms to govern the is and oughts of their coupling (bonding) and evocation of common microstates. That process, similarly viewed as an extended super ego of the societal ensemble, thus governs morality, the is and oughts of society.

ON VALUES

This introduction of themes is sufficient to permit an identification of what makes social value systems. A social value system is a social potential, the inheritable epigenetic system of knowledge (about society) and its cultural aspects used by the member elements (organisms) to guide the streams of social behavior. Such an extensive epigenetic value system potential exists only in and among human beings and societies. It requires the full free extensibility of human language. It is the long time-delayed pool of the is and ought language of society (e.g., the codes of Ur-Nammu of Ur, of Hammurabi, of Moses, and of the American Constitution; Note 12). Yet the content of even that value system is not exceptionally rich.

We have examined the question of what makes up the potential pool of the epigenetic value system (9). We have tentatively decided that we do not yet understand its metrics, but we do understand its dimensionality. I believe the epigenetic value potential to be the linguistic pool of internally stored patterns that represents the following nine world images: *1*) of self, *2*) of interpersonal relationships, *3*) of nature, *4*) of society, *5*) of ritual and institution, *6*) of other living organisms, *7*) of technology, more broadly of culture, *8*) of spiritual causality (fathers, leaders, and gods), and *9*) of art forms (abstract representations designed to attract attention in sensory modes). The organism, in this model, manipulates motor, sensory, patterned perceptions, internal patterned linguistic cognitions of the passing vicissitudes, both internal and external, in accord with these centrally held world images *and* the physiological-physical constraints of the "real" physical-chemical world inside and outside (Note 13).

SUMMARY AND SYNTHESIS

I have suggested, by linguistic imagery, how *1*) the thermodynamics of complex systems, *2*) memory, *3*) brain, *4*) mind, *5*) language, *6*) motor action, *7*) sensing, and *8*) values and morality are tightly linked by soft couplings. The notion of is and ought has been coupled within the individual organism, interpersonally between bondable organisms, and within a socially cooperative ensemble of organisms. The thoughtful physical scientist may be led to inferences concerning how these key notions might be reduced to hard empirical objective measures.

In the individual organism, the ought has been identified with a higher-level command-control flux, which perhaps (i.e., a conjecture) polarizes the chemoelectric conduction fields throughout the organism into patterns (as an electric bilayer?) and which is identifiable as a natural language by its mapping from cortex to limbic system. Those patterned responses represent the "evo-

cation of microstates." The is, on the other hand, is a lower-level command-control flux discharged as a flow of catalysts on the neuroelectric and neuroendocrine channels within the organism.

In the interpersonal relationship, that internal net is contained outside the organism by mapping into external physical-chemical catalytic language elements which then transform back into higher-level command-control fluxes.

Within the society, the patterned net exists in common within the cooperative ensemble which live together. That net comprises both a language and a culture. This latter thesis requires some elaboration.

On the generality of both language and culture. Although complex value systems are carried only by humans in *their* memory trace, language is more general in complex systems. For a descriptive model of how language and movement emerge in such complex systems as living systems, we have offered the prototypic case of the single cell (see 15). It is our impression that the more modern work in this field of molecular biology (e.g., more modern than Lazeridis) has tended to confirm the validity of our description.

My sense of having grown further, in understanding of our model, is that its key characteristics have extended in two directions.

1) It now strikes me that our descriptive model extends to language and movement in all internally complex action-oriented, time-delaying systems (see 10, 17), not only the living systems examples. That internal time delay, arising as factory processes, involves some kind of internal field that provides the system with an in-out and in-in memory trace. Since the internal states cannot differ tremendously in energy levels, else a relatively uniform dissipation rate that will be associated with such systems could not negotiate the many energy levels of action required for the complex time delay, that chain of internal actions has to be negotiated by a language of catalysis equivalent to that used by cells and other living organisms. Namely, language and movement are ubiquitous in all complex systems.

2) Even more drastic than this assumption is the following: if the players within this internal factory scene, for example, atomisms of various sorts (in the living systems, small molecules, ions, larger molecular fragments—"informational macromolecules") are to have competence to enter into the dynamics of such language and such usefully controlled movements, then that local environment has to be a "culture" in an anthropological sense (Note 14). One must picture the problem, at any level system for which this model is projected into, as possessing an external street life, for example, the extracellular (or extraorganelle) vascular field in which the processes common to the society (e.g., of cells, organelles, or binding sites) are taking place, and one must picture the more private "home" life (e.g., intracellular, intraorganelle, or intramembrane) that goes on withdrawn from the social scene. The societal process is a continuing transport, shuttling of major field ingredients back and forth, all with a cultural memory trace that binds generation to generation. Even if and when that memory trace originates from the most specific or hard chemical potential of a genetic code, it becomes configurationally "soft" and "epigenetic." Thus it truly is cultural (Note 15).

NOTES

Reviewers asked for expansion of particular points. Since these seemed to involve notions that broke the continuity of flow of ideas, I include them here.

1. Our notion of language as a soft coupling catalyzer and evoker of microstates (see 8, 10, 11) is really that of a chemical thermodynamic nature. A field chemical thermodynamics does not take place in an unconstrained *x, y, z, t* physical space but in a more private reaction coordinate space. It is such a space that one finds identified by the use of quantum mechanics (see, e.g., 6). The operational space within the geometric confines of the language-using living organism is of that physical-chemical nature. Language is not carried only within the neural structures in the nervous system but, more generally and richly, as chemoelectrohydrodynamic adjuncts to electrical and chemical flux paths.
2. The problem of understanding the nature of form and function (or process), of that which persists and that which changes, was attacked by the Ionian philosophers (see 19). Telegraphically, that problem which remains with us in philosophy, physics, neurophysiology, psychology, and linguistics is known as the antinomy of being and becoming. The early philosophic discussion of the problem is identified with the names of Parmenides, Plato, and Aristotle. The discussion has been continued among philosophers of all ages (e.g., Aquinas, Descartes, Leibnitz, Hegel, Dewey, Moore, Heidegger, Ayer, Quine, and Weiss). Here I seek to identify the problem with the very nature of an inhomogeneous world, which language use requires for its existence.
3. The cooperative action of the cells in an organism controls the shear viscosity of the extracellular fluid (e.g., via the hematocrit in the intravascular space or via other gel-like components). The bulk viscosity (how action is transported into and out of the cells into the extracellular stream), however, is governed by the introduction of gating channels into the cell's membrane by the cell. This differentiates the common or public space within the organism from the private space within each cell. Currently, biophysicists are beginning to achieve some success in accounting for the detailed processes involved in the gating of the various types of channels.
4. The literary word, vicissitudes, while quite precise, seems to put current scientists off. They may substitute for the word vicissitudes the more cumbersome statement "both the random and nonrandom fluctuations, 'normal noisiness,' that one finds in the field environment of any complex systems." Perhaps "vagaries" might suit some.
5. *On resolving the conflict between being and becoming*, if one examines the philosophic literature associated with being and becoming, one finds recognition of both monistic and dualistic notions associated with this question. Invariably most thinkers have recognized a serious problem in describing the process of proceeding from precipitated form and its dissolution back into motion and change. Many have recognized that this dual process confronts the operational organism at every moment in its existence. At this point we are focusing on such an operational organism. In this instance, the use of the terms being and becoming is representative of the physical inhomogeneity maintained in the real world. If isolation were strictly possible, the thermodynamics of the field would suggest a relaxation toward greater homogeneity. Thus some kind of openness in the local system is implied.
6. Whether it be made possible by muscle fibers in the complex organism or by the microfilament-microtubule structure within the individual cell.
7. It is not hard geared. A holonomic constraint represents couplings between degrees of freedom that are integrable. Such coupling may fail because of lack of an integrating factor or because of lack of temporal coupling (e.g., randomizing time delay).
8. For biologists, psychologists, engineers, and physical scientists who

need some background to these modern findings about cellular movements (e.g., beyond Jennings, 1906), see Adler (1) or Canale-Parole (2). They may find (5, 16, 18) interesting windows into past achievements and points of view in this field of simple movements.

9. Not only can all the perceptions of all internal states be linguistically mapped, but also the perceptions of all external states—both those perceived and those in memory—can be so mapped. *And*, as seems clear, for perhaps the past 20,000 yr—more certainly for the past 10,000 yr—even the internal states and conjectured states beyond can also be linguistically mapped.
10. In the development of information theory, there was concern with both the possible rate of error-free information flow rate (e.g., no. of binary yes-no decisions the organism could make per unit time) and the number of channels the organism might elect to make decisions within (e.g., to interlace walking, talking, and chewing gum simultaneously, to use a humorous example). George Miller, in his magic number 7 ± 2 theme, indicated that humans can deal linguistically with 5–9 disparate objects. Subsequent work indicated that at most one could trade off information flows among a similar number of different neural (e.g., sensory-linguistic) channels, albeit with some variation in the maximum error-free rate.
11. As Llinás and I, among many others, have said there are no homunculi, or loaners of intelligence, inside, only field processes, I do not wish a super ego metaphor to be viewed as a thing, only as a field process, which is that aspect of the field by which command-control emerges. The super ego is a memory trace of early formative experiences, the result of both neuroelectric and neuroendocrine streams that have marked the networks during an early plastic and impressionable stage. One surmises that the capability for both genetic and epigenetic processing was comparable in that developmental phase.
12. One simply had to listen to a recent televised debate between an American and a Russian team of students to realize that the values contained in the American Constitution are not universal for all mankind.
13. It is interesting to note how Levi-Strauss (see 14) identifies the character of language (in his terms, its bricolage). To him, it is a net that spans the heterogeneities of necessity by a finite and concrete choice of symbols. In our sense, the heterogeneities of necessity are embedded in the world view held among the aforesaid 9 dimensions.
14. If one wishes, one can trace all the shadings of meaning that anthropologists have attached to the notion and word culture [e.g., starting from Tyler's original definition, "Culture is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society," or one can examine the review of Kroeber and Kluckhohn (13)]. The following illustrate a few major sources: Kroeber's (12)—culture is the mass of learned and transmitted motor reactions, habits, techniques, ideas, and values—and the behavior they induce; Leslie White's (20)—"culture is a continuum . . . that flows freely down through time from one generation to another and laterally from one race [breeding pool] or habitat to another . . . the determinants of culture lie within the stream of culture itself . . . language, custom, belief, tool[s] or ceremony . . ."; also the social morphology—institution through civilization. A modern dictionary definition offers the total pattern of human behavior and its products embodied in thought, speech, action, and artifacts and dependent on the human's capacity for learning and transmitting knowledge through the use of tools, language, and systems of abstract thought. The body of customary beliefs, social forms, and material traits constitutes a distinct complex of tradition of a racial, religious, or social group.

    However, it is sufficient to take one modern author as a fair derivative source and indicate the general notions by which the anthropologist's definition can be "translated" and generalized into a general physical notion appropriate to all complex systems. (Note: When the definition includes the exclusionary aspect that it is a property exclusive to human beings, such generalization would appear to be strictly not possible. But most physical scientists understand the task of generalizing a concept to be able to see whether it remains useful.)

    Thus, according to Farb (3), one finds that culture contains two ideas: *1*) it is "a word used in referring to the totality of learned behaviors in the context of a social system," and *2*) "above all, every society is organized in such a way that codes, rules, habits, expectations, customs, and etiquette ensure appropriate behavior by its members. These social contracts begin in infancy—through a process technically known as 'socialization' and they continue throughout the life of every individual."

    Of course, Farb (3) means these ideas to apply exclusively to humans, not even to other mammals. Nevertheless I ask that they be considered simultaneously for a newborn galaxy, a mammal, an organ, a cell, a complex molecule, and the quark complex in any hadron.

    The ideas and rules of transformation are the following: *1*) all these systems are field systems that carry along memory traces appropriate to their coordinated actions. That memory trace represents, in a general way, what they have "learned"; whether it carries strict analogies to the human short-term and long-term memory is, of course, a detail that requires specialized study, but in general it appears to be true. The individual particle memory trace and the group (or field) memory trace are not precisely the same. *2*) Although the behavioral characteristics of the system do not seem to be immediately discernible or "emergent" from the initial start-up of its atomistic element—to that extent, the start-up contains the characteristic of a "genetic" origin—the subsequent system's evolution, its dynamics, seems to be generally "epigenetic." Although each emergence seems to be unique, at least in space-time character, nevertheless there is a considerable similarity in how the force structures act to form the system (e.g., the emergence of hadrons, the emergence of stars, many associated with a main sequence of types, the emergence of nuclear species, and the ubiquity of cellular forms). *3*) Although the total energy available to the system in its factory day (a time scale that requires detailed study for each system but one that is appropriate to the space scale), the energy available locally (e.g., as an energy density) is used only parsimoniously (illustratively near a minimum entropy production limit) to produce a generalized catalytic "language" to govern local processes. Every physical scientist "knows" by the seat of his pants, even if not intellectually, the initial frustration that exists in deciphering the language of any new system he undertakes to study. Typical examples include the language of quarks, cells, flux channels in the brain, meteorology, and of the "meteorology" within a galaxy. The physical scientist quickly learns how far from stereotyped that language is in any complex system. *4*) But why call it "culture"? For the very reason that the physical scientist has so much difficulty in decoding the extreme complex system of forces and fluxes that govern any system. Certainly the physical scientist "knows" the system behaves in accordance with the "laws" and principles of physics (e.g., mechanics, electrodynamics, quantum field physics, and relativity). Nevertheless, in their renormalized form, appropriate to whatever level of system these principles are applied to, there emerges the equivalent of memory, language, custom, institutions, and tools just as binding on the local ensemble of players as they are on humans. I offer this notion as a provocative evoker of microstates. We will see what it may catalyze.

    Each complex system has a "genetic" encoding, a primitive "chemical" potential whence the complex originates. Each has a dynamic history of start-up. Each system has to develop an assemblage of internal elements (very commonly from vorticity or matter condensation) whereupon there is a distinction between those processes that are private to the interior subelements and carry their memory trace and the common "street" processes that serve the community.

    Thought is represented by the internally time-delayed processes wherein command control (of all the action modes required for survival) emerges. One may assert that these processes are stereotypic (e.g., the tropisms of some of the simpler forms of life), yet objectively one may note how difficult the scientific task is to decipher even those stereotypic responses and to determine how they are so fitted to contribute to the survivorship of the complex system.

    Speech, as always, uses whatever materials are at hand [a notion also strongly stressed by Levi-Strauss (14)]. The most difficult aspect of translating this common notion of culture is as the

transmission of a learned heritage, but it was precisely this facet of behavior that is responsible for this attempt at generalization. We attempted to confront the issue first, lightly, in Llinás and Iberall (15) by studying how the nucleus in the eucaryotic cell could govern its autonomous persistence. It has finally dawned on me, as a conjecture, that command-control has to proceed on a two-way street. It has to deal with a private life within the cell—the "home" of the process, and it has to deal with a public life out in the socialized street of the organism. However, the atoms-ions-molecules out in the social street have to be "socialized." How? By a common process in which all eucaryotic cells in the organ (the polity) or organism (the ecumene) cooperate to produce that internal socialized environment, and that environment consists of small atomic-ionic-molecular moieties, monomers, polypeptides, etc., a socialized polyglot community of players. Without that socialization, just as true in the "streets" of the ocean as in the vascular streets of the mammal, the autonomous life process could not persist, and the analogies of that process exist in every autonomous complex system. Every player met in the street has been "enculturated" for that meeting.

15. Although this theme of culture is offered as a far-reaching explanatory proposal here, it is not completely original. Its precursors have been Sechenov's mid-19th century insistence that the external environment is part of the system. (His ideas were thus a perfect match to Bernard's ideas about the regulatory independence of the internal environment in the complex living system.) L. J. Henderson's theme captured as *The Fitness of the Environment* (for the living system) the modern physicist's notion of the anthropic principle (in which the principles of physics are in fact constrained by their physical expressions or embodiments (e.g., that they are in fact constrained by the existence of life)—here I would claim that in fact their higher-level planetary embodiments have to provide the culture within which existing life can operate (This echoes the theme of Lovelock's *Gaia*, in which the start-up of life modified the operating physical conditions on the planet.)

This work was supported by the Crump Institute for Medical Engineering, University of California, Los Angeles, and by University of Southern California-University of California, Los Angeles Biomedical Engineering Grant GM 23732 from the National Institute for General Medical Science. I thank F. E. Yates for this support.

REFERENCES

1. ADLER, J. The sensing of chemicals by bacteria. *Sci. Am.* 234: 40, 1976.
2. CANALE-PAROLE, O. Mobility of spirochetes. *Annu. Rev. Microbiol.* 32: 69–99, 1978.
3. FARB, P. *Humankind.* Boston, MA: Houghton, Mifflin, 1978.
4. FISCHER, R. A cartography of the ecstatic and meditative states. *Science* 174: 897, 1971.
5. FRAENKEL, G., AND D. GUNN. *The Orientation of Animals.* New York: Dover, 1961.
6. GLASSTONE, S., K. LAIDLER, AND H. EYRING. *Theory of Rate Processes.* New York: McGraw-Hill, 1941.
7. IBERALL, A. A proposed neurophysiological basis for war. *Ann. Biomed. Eng.* 1: 446–454, 1973.
8. IBERALL, A. What is "language" that can facilitate the flow of information—a contribution to a fundamental theory of language and communication. *J. Theor. Biol.* 102: 347–359, 1983.
9. IBERALL, A., AND S. CARDON. *Physical Science Modeling of Social Processes—Macroscopic Impacts of Increased U.S. Foreign Trade.* Cambridge, MA: US Dept. Transportation, 1981. (DOT Rep. DTRS57-81-P-80357).
10. IBERALL, A., H. SOODAK, AND C. ARENSBERG. Homeokinetic physics of societies—a new discipline: autonomous groups, cultures, polities. In: *Perspectives in Biomechanics*, edited by H. Reul et al. New York: Harwood Academic, 1981, vol. 1.
11. IBERALL, A., H. SOODAK, AND F. HASSLER. A field and circuit thermodynamics for integrative physiology. Power and communicational spectroscopy in biology. *Am. J. Physiol.* 234 (*Regulatory Integrative Comp. Physiol.* 3): R3–R19, 1978.
12. KROEBER, A. *Anthropology: Culture Patterns and Processes.* New York: Harcourt, Brace, World, 1963.
13. KROEBER, A., AND C. KLUCKHOHN. Culture: a critical review of concept and definition. *Pap. Peabody Mus. Archaeol. Ethnol. Harvard Univ.* 47: 3–223, 1952.
14. LEVI-STRAUSS, C. *The Savage Mind.* Chicago, IL: Univ. of Chicago Press, 1966.
15. LLINÁS, R., AND A. IBERALL. A global model of neuronal command-control systems. *Bio-Systems* 8: 233–235, 1977.
16. PEREZ-MIRAVETE, A. *Behavior of Micro-Organisms.* New York: Plenum, 1973.
17. SOODAK, H., AND A. IBERALL. "Homeokinetics: a physical science for complex systems. *Science* 201: 579–582, 1978.
18. SUKHANOV, V. *General System of Symmetrical Locomotion of Terrestrial Vertebrates and Some Features of Movement of Lower Tetrapads.* Leningrad, USSR: Nauka, 1968. (Republished by Smithsonian Institution, Washington, DC, 1974).
19. *The Encyclopedia of Philosophy.* New York: Macmillan, 1967, vols. 1 and 2.
20. WHITE, L. *The Science of Culture.* New York: Farrar, Strauss, Giroux, 1969.