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Does Intention Have a Characteristic Fast Time Scale?

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The homeokinetic approach to behavior (applied to humans, the approach is described in Iberall & McCulloch, 1969; and more generally in Soodak & Iberall, 1978) is extended in this article to argue that free will is exercised at a temporal scale of approximately 6 s. The homeokinetic theory of complex physical systems, including living systems, analyzes activity into component sets of oscillators, action modes, each with a characteristic time scale. A full set of nested time scales involved can be thought of as a spectrum. In this article, I argue that a survey of human action modes, as a spectral analysis, allows for the free election of acts only at the 6-s scale.

Intention (per Hebb, see Wolman, 1973, p. 437): central guidance of behavior by an enduring system that maintains its independence despite sensory input.

Volition: act of willing or choosing.

This article is concerned with establishing a physical foundation for such actions in mammals, particularly human.

THE HOMEOKINETIC (COMPLEX PHYSICAL) THESIS ABOUT NATURE'S SYSTEMS

As living, functioning, organic systems (particularly as mammals) we find a universe of sensation, perception, and cognition forced on us. With our particular internal machinery, brain and its mind, ultimately we humans have discovered the problem of science, explanation in terms of a parsimonious set of

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abstract principles that orders phenomena both inside and outside of ourselves into compact and predictive mappings or chains of description. In an abstract sense, the classic Greeks identified those mappings as the Beings and Becomings of nature. In actuality, those abstract mappings are information rich matter–energy realizations. Stored in permanent or temporary form, they can be used to evoke, represent, or switch states in our type of organisms. That is the physical character that we associate with the term *language*.

Probably the most extensive set of such principles is represented as the science of physics. I am concerned with the application of that science to all material–energetic systems found in nature. In pursuing such interests I am obviously not unique. However, recognizing that there are many layers of systems, that systems at quite a few layers are complex, and that standard physics has to be extended if it is to reach up to those complex hierarchically nested layers, I have sought to develop a directed applied physics of such complex hierarchical systems. I commonly use the subtitles nature, life, humankind, mind, and society as identifying catch-phrases for the sort of study of complex systems that my colleagues and I investigate.

We refer to our program as a *homeokinetic physics*, a study of the hierarchical nested character of complex systems in nature. The basic schema recognizes an alternation of levels as follows: A layer of atomistic units of one or more types (e.g., a heterarchy, W. McCulloch's, 1965, coinage) that interact in sufficient number to create a near-continuum field of such units. At sufficient field scale, the field becomes unstable under the action of forces acting differentially at near and far range and breaks up into a level of superatomistic units. (Examples are: a collapsing pile of bricks under gravity force—the planet, Jupiter, nearly illustrates how a large planet can strip its atoms by the action of its intense internal gravitational stress; or a gas cloud in a galaxy creating stars). These interact to form a higher near-continuum field level, and so forth. In addition, rather than only one chain, at various points there also may be branching chains. This process continues both up and down until chains at either end become singular. There are only a few forces in nature; these self-entwine and entwine in pairs to form many space–time process scales.

In nature's systems, the atomistic alternation is: cosmos, galaxies, stars, planets, and other intragalactic objects (e.g., gas, and dust clouds). At a level below, we find atoms, ions, and molecules. Below that fundamental particles, ending—as far as we know now—in leptons and quarks. The entire system is currently viewed as being immersed in a vacuum. Representative of some branchings, gas, liquid, and solid field objects on planets can form local lithospheric, hydrologic, and atmospheric systems, also geochemical and biochemical systems. At the moment still only recognized on Earth, these biochemical unit systems may self-organize into cellular organs, organisms, and societies of organisms. We recognize physics as experimentally based, so that we cannot guarantee that such detailed depiction of levels will not change in time. At one time, one cosmological ideology offered turtles all the way down; the Greeks offered the geometric notion of spheres within spheres; some current mathematicians hold for fractals; now we recognize with a great deal more empiricism, a variety of inhomogeneous levels, few organizing forces, and a large diversity of forms and processes from relatively few atomistic materials.

In my reductionist construct, the principles of physics sit off to one side and connect, by strategies, to the systems in nature. It would seem clear that all of the known physics of forces and material–energetic systems will be used in the account of what is bound together to form any level, and that thermodynamics, the up-down flow of material–energy will be the major tool used to describe the space–time fields, field variables, and processes that represent state and change in the pertinent descriptive account of the system under study. What I expect to encounter, when we come to a complex systems level, is long time delayed actions within the internal atomistic unit processes, long in particular as compared to the external process interactions among the atomistic components. A hallmark of a homeokinetic description will be its identification of the many spatial levels that are involved in a complex system level, and also of the many frequency or temporal process scales that are involved. There is no mystery in that type of description. It simply is an acknowledgment that the atomistic interior consists of a factory-like fluid field, and that the fluid processes act like thermodynamic engines at many scales. The complex of processes and actions that emerge implies that the forces and their potentials (storage bins for matter, energy, and momentum) tend to act like memory functions that extend over vast vistas of time. Thus in any complex system, we expect to find a hierarchical complex of many space and time scales.

Election of Action in Complex Living Systems

The keynote of this current application is to the property of a complex living organism, particularly ourselves, from which a command–control process can arise competent to permit free, arbitary, intentional election or choice of actions. That is, I wish to inquire to what extent we may prescribe some character to movement and change that does not appear to emerge in a hard predictable sequence. I view this as a general problem to be found in all complex systems, because of their many degrees of freedom, and of their fluid-like nature. Simple systems, commonly involving only pair by pair interactions, most often do not involve us in that problem of less than fully determined choice of a subsequent action. Although the problem of complexity can be viewed as general (e.g., predict tomorrow's weather or the next stellar explosion), in this article I confine the examination to mammalian, more particularly human, command–control. It is the storminess and changing weather within the mind that I wish to pursue, rather than that of society, the atmosphere or oceans, or within galactic clouds.

To provide a taste for my technical approach, I mention some physiological physics problems I have investigated that provide a physical foundation for command–control. The first is not the election of a temporal process, but of the mechanistic localization of a process. The question we raised was how central pressure is governed in a mammal. That pressure is the major governing mechanical potential in such multicellular organisms. All mammals have a central pressure near 100 mm Hg (as compared, say, to about 30 mm Hg in other animal classes). The question is how is that 100 mm Hg physically determined. Obviously we know that there is a peristaltic heart pump that produces pulses of flow and pressure. Further, Starling's law of the heart (Ruch & Fulton, 1960) essentially states that the heart is a sump pump that will pump all blood flows that the venous system returns to a near zero gauge pressure in the heart's entrance. Nervous constriction in each organ's vascular subsystem determines the relative flow of blood that the organ currently demands, but that still does not determine the central pressure. One cannot assume that each organ, in turn, takes on the duty of determining and regulating the central pressure at the near 100 mm Hg level. That regulating duty has to belong to one organ. Although many have tried to implicate the mammalian kidney in that regulation, they have not really succeeded physically. We have been able to develop a model that shows how and why the kidney's vascular subsystem can perform that regulation, both in the face of the extraordinary flow demand of various tissues, including the 20 to 1 flow demand of muscle, and in the face of ancillary biasing hypo- or hypertensive producing mechanisms.

Or, as a second illustration, we have been able to study and account for multiple scale processes that are involved in the organism's intermediate metabolism, from the scale of the single breath of input oxygenation (e.g., 6 s in humans), to a 3½ hr scale for chemical thermodynamic equilibrium, to a 30–60–90-day scale representing atomic–molecular turnover of the organism's material (architectonic) ingredients.

Note that these examples—one spatial, one temporal—are both of autonomic regulations, which the organism does not have to invoke volitionally, yet for which the organism can also take volitional corrective action. Of course, these schemas are very basic, for without such regulations, the *homeostatic* basis of operation (actually, automatic dynamic regulators that require homeokinetic accounts), there would be no way that conscious or near conscious elections of actions could take place. The organism would be swamped with near infinite minutiae. Thus we are now ready to approach a delimitation or circumscription of so-called free will choice. Every operational time scale cannot be pursued by free will election of actions at that scale. (Just imagine, e.g., the task of electing an 83-year life scale and also taking care of every muscular twitch in the body at a fractional second level). We do not pretend that we are solving the entire problem. We intend to show how homeokinetics can furnish us objective ideas of a time scale to which conscious or near conscious decision making is largely, perhaps even exclusively confined. We believe it may be enough to run the organism at both short- and long-time scale, but that may not be. There perhaps may be a time scale for longer term decision making, although we do not think so. We believe that the brain constantly uses the time scale we prescribe for continued turn over of perception and cognition. If these ideas are correct, what constitutes long-term planning and decision making is a sustained review of already existing internal *idée's fixes*.

The problem of a scientific account for free will is not exceptionally different from that of accounting for a physical scientific theory of chemical binding, particularly as it may be influenced by catalysts. In the chemical binding case, its account emerges as a quantum mechanical theory of two or more body interactions among atomistic, specifically atomic, units. Catalysis, in general, attempts to use intermediate chemical complexes that promote or retard on-going reactions. The free will problem can be stated physically to be the problem of a circumscribed field of interacting units, for example, molecules, organelles, cells, organs, circumscribed into an organism, and how such a field can elect or not elect a future course of cooperative action. We believe that language, as in the chemical binding and catalyzing case, is a catalyst that can switch or evoke modes, by speeding up or inhibiting ongoing processes of making, breaking, or exchanging of bonds.

This note does not develop any such rich physical theory as quantum mechanics for the account of such election. Instead, in a physical sense, it circumscribes and limits the election—among a broad range of physiologically known processes—to a very specific limited domain of process. It is like discovering the hydrogen line spectrum, and thereby suspecting the existence of underlying mechanisms. Such a discovery directs attention to the scale of the catalytic switchings. We assume that you are always ready to act.

For those who might worry, in a Popperian sense, whether this note is philosophy or science, it is simple enough to test and falsify its proposed answer. The complex field organisms to which free will is ascribed have both short- and long-term memory processes. In this note, the exercise of free will is ascribed to a particular class of short-range processes. If it can be shown that such a field organism can continue to make a lifetime of elections solely from a long-time memory process, with the short-term memory process eliminated, then the basic mechanistic notion in this note will have been falsified. It would appear simple enough by careful ablational studies to show that the organism has had its short-time scale process destroyed. The counterclaim here would be that an organism operating only with a long-term memory could persist in a number of autonomic functions for some period, but—like any animal in a coma—its field functions would fade into disruption. To offer a physical example, an aircraft, ship, or automobile that has lost its high frequency steering control system, and just depends on the responses of very low frequency sensors and regulators will soon crash.

Free Will or Intention From a Homeokinetic Point of View

The nature of free will has been an age-old subject for philosophic inquiry. Scientists, within modern traditions, have been hesitant to grasp the problem, as scientists, because of its apparent slippery nature. This note attempts to find defensible scientific clues, constraints, and bounds for the concept.

I embed the required biological systems' science in what colleagues and I have called the homeokinetic physics of complex systems (Iberall, 1972b; Iberall & Cardon, 1964, 1965; Iberall & McCulloch, 1969; Iberall & Soodak, 1978; Soodak & Iberall, 1978). Such field systems consist of underlying atomisms, and a near continuum field emergent from their persistent interactions—this being the physicist's underlying decompositional concept. See, for example, Toulmin and Goodfield (1962) for its beginning history. The key concept behind such systems is the long-time delay in internal action among the complex atomisms making up the field, as compared to the relaxation time scale for translational or external interactions among these complex atomisms (Soodak & Iberall, 1978). What emerges in such complex field systems is an external social pressure (Iberall, Soodak, & Arensberg, 1980) that deals with all of the emergent memory laden institutional arrangements and processes in the field (i.e., all of such cooperative or socialized processes, beginning at the primitive level of condensing liquid-like van der Waal attractive forces in molecules, and continuing further to condensing solid-like organization such as the imperfect crystal state; but reaching up to modern human social processes as well). These institutional arrangements can be captured as a temporally distributed cascade spectrum (energy flow through all scales from low to high frequency) and spatially nested arrangement of form and function (or process) at many scales. As part of our homeokinetic physics, we have illustrated the construct for human biological (Iberall & Cardon, 1964; Iberall & McCulloch, 1969) and social (Iberall & White, 1988; Iberall & Wilkinson, 1987) processes.

Quasi-Ergodic "Ringing Through Modes"

A cursory introduction to salient process modes that the mammalian organism rings through whose spectral result has a quasi-ergodic character, consists of the following time scales. We derive the notion of these process time scales from both our own experimental explorations, seeking formally to find the operational spectral lines just as physicists did with atomic, molecular, and nuclear spectra, and from literature study involving other investigators.

One tenth of a second is approximately the unit nervous impulse time scale. In a range as extensive as 0.03 to a few tenths of a second, this represents scaling up to the level of a reflex arc or of primitive sensations.

1. One to 2 s is approximately a local minimal perception scale.
2. Six seconds is approximately the time scale for the cognitive present.
3. Thirty to 120 s is approximately the time scale for the faster blood-borne hormones, for example, the catecholamines, the governing of circulating glucose, capillary bed vasomotion.
4. Four hundred seconds is the time scale for regional blood regulation, which empowers and enables the continuation of local organ processes.
5. Twenty minutes is the time scale for pH carbonate regulation in the blood compartment.
6. Three and one half hours is the period for thermodynamic equilibrium, probably dominated by cortisol.
7. Eight to 10 hr is likely the period for the regulation of free fatty acid fuel in the blood.
8. Twenty-four hours is the widely discussed near circadian period the complex regulation of which has not yet been definitively been determined. Evolutionarily related to and developed out of the light–dark driven cycle of the Earth's daily revolution on its axis, in mammals it likely involves the superior cervical ganglia, the suprachiasmatic nucleus, the pineal, the hormone melatonin, and the visual system.
9. Three and one half days is likely the regulation of the pressure grounding of the extravascular, extracellular water compartment in the body. This may be run by the thyroid, and as such likely becomes the longer range regulation of metabolism. Before being switched to this task after adolescence, the system is more probably concerned with monitoring and regulation of the growth process.
10. Thirty to 90 days is likely the turnover scale of all atomic constituents, particularly centered on central nervous system atomic constituents.
11. Longer processes, the year, the generation, a few generations, 500 years, are found governing ever more integrative social–biological systems in the human.

I add one more note to our findings. Rather than as commonly thought, these processes act essentially independently. More specifically, on the basis of experimental tests, we believe that their binary cross correlations are essentially negligible. There is no one master clock. Quite the contrary, one notes that there are a large number of thermodynamic engine process regulators that at longer and longer integrative time take up more and more of the autonomic and volitional process functions of the organism. It takes very careful observation to become aware of many of these rhythms, except for some of the more obvious driven ones, such as the day–night spectral alternation of activity, the yearly variation of weather on Earth, a menstrual cycle, or an adolescent growth phase. For example, the highly prominent heartbeat, which is used extensively by the body to regularize many internal functions, is hardly ever noted externally. Yet if one is taught that, or by accident falls into a posture in which the heartbeat becomes quite consciously evident, as some psychiatrists have identified it, the sensation can provoke what they have called the terror or anxiety of the heart. Thus it is not only persistent static processes that reach saturation, that may be wiped out of consciousness. A number of periodic processes commonly also disappear as a dynamic saturation.

Time Scaling Free Will

Having already outlined a nominal spectrum for some of the salient thermodynamic engine processes in the human or other mammalian organisms, here now I turn our homeokinetic physics attention to the institutional arrangements for the ones that deal with human command–control at the individual organism level, namely of the brain and its mind.

The most rapid way into the argument, as I have perceived it, is as follows: Clearly there is the daily process scale in all the institutional arrangements of most if not all living organisms, including the human organism. It is described in the enormous literature devoted to the circadian process scale. Equally clearly, that process scale is not an epoch for which one can conscientiously claim free will. The reasons are numerous. I suggest some without attempting to be exhaustive.

1. The process scale is found embedded at essentially every living unit level with very mechanistic determinants for both stimulus bound and stimulus unbound organisms.
2. Binary cross correlation measurements between that scale and adjacent scales, for example a 3½ hr thermodynamic cycle below or a 3½ day cycle above, would show negligible correlation.
3. The processes that come together to fill the day scale are so tightly bound by physiological mechanisms and machinery to the extent that any component of that process that might be called free will would simply have to look like completely divorced noise. Take a million people from around the Earth. Did they sleep on a bed or on the ground yesterday? Did they get up on the right side or the left? Did they first attend to body voiding functions, brush their teeth, put on shoes, or get the newspaper, and so forth with endless mostly irrelevant ordering detail. Yet the basic outlines of the daily functions are essentially commonly and physiologically determined, with their ordering and detailing noise. Namely, it is largely only their daily phasings that are random or free will elected.

Carrying the argument on to longer scales (e.g., 3½ day water cycle, a monthly menstrual cycle, a yearly cycle scale) would demonstrate the same result.

So now I jump to a lower and faster scale. At the reaction time scale, in the nominal 0.1-s domain range, it is clear that no significant action can be initiated at any briefer time scale. Or, to be more precise, out of Grey Walter's work in the 1960s (e.g. Walter, 1967), it was demonstrated, in so-called expectancy wave discoveries, that there is a brief forerunner to the initiation of any volitional reaction, that—by any sense of causality—cannot be regarded as a time scale that one can penetrate by free will. This sort of first-cut argument, I propose, limits the issue of free will to a process time scale within the nominal bounds beyond 0.1 s up to 24 hr.

However, our thermodynamic studies (Iberall, 1960, 1986; Iberall & Cardon, 1964) uncovered a 3½ hr cycle in mammals, which in comparisons we made with Halberg and his circadian data (1962, personal communication) indicated that they too looked like noise at the circadian scale (see also Czeisler, 1978). Thus one can say that the existence of a 3½ hr thermodynamic scale is not predicated upon a free will. More constructively, one can assert that this biophysically designed epoch is constrained to involve selection of an action spectrum of not more than about 20 human actions (Iberall & McCulloch, 1969), each with a fairly determinate probability function of selection (or, looked at more broadly in an ethological context, not more than an election of about nine general classes of behavioral choice exist among mammals). What this assertion means is that our physical analysis of behavior has brought us close to a quantum mechanical-like freedom to choose among what are already physically foreordained process paths. (Of course we do not mean at a process scaled at Planck's constant of action h but at a much larger scale of action, e.g., approximately 2000 kg-cal days of action per Earth day for humans and comparable weight scaling for all other mammals; Iberall, 1972a, 1973.) The human action scale as compared to the Planck action scale is a crude indicator of how many elemental atomic actions are involved in its body's complex machinery. The measure of that action, the daily action per Earth day, is the daily energy expended by the organism. This is about 2000 kg-cal. Perhaps 1500 kg-cal are used each day for the internal thermodynamically dissipative maintenance or resting processes that run the body. Thus, perhaps at most, only 500 kg-cal are available each day for the ordering of the additional largely routine or stereotyped actions that the organism believes it can elect by its own intentions.)

The walls of a bounding physical determinacy thus seem to be pressing in. At this point we can assert that free will, in some very physiologically constrained sense, seems possible in the process time range beyond 0.1 s up to $3\frac{1}{2}$ hr.

This type of analysis finally leads us to the cognitive concept time (Iberall, 1978) at the global organism scale. We have argued the evidence for a characteristic attention or concept formation time of the order of 6 s (see also Iberall & McCulloch, 1969, which began to uncover the problem) in all mammals. This, in our modeling, begins to represent a time in which all internal systems have propagated and diffused their messages and state information of both inside and outside, and some minimal integrative internal construct has been arrived at. As we found a statement of support for the notion in the psychological literature (Woodrow, 1951). Citing older studies, Woodrow stated that with regard to a unitary perception of the present, as the temporal span of attention, ". . . the upper limit of the 'psychological present' is for a stimulus duration of about 6 seconds. . . . The limit probably lies between 2.3 . . . and 12.0 seconds . . . but it is possible that it may under some conditions be considerably higher" (Woodrow, 1951, p. 1230). Such results are obtained from a large body of multidimensional psychological experiments. We take this to mean, among other things, that such a unitary view may or may not be related to other ongoing sensations or perceptions. In some sense, we have to confront the triad of processes, of sensation, perception, and cognition, and say something about their discreteness or continuity. It seems quite evident that perceptions that go very long periods of time simply fade. Thus, although it is clear that a perception is not a sharp unitary image stored in memory, it does have some sort of characteristic fading time. It is some such fading time that I believe Woodrow and Iberall (1978) alluded to.

Let us understand what the evidence alluded to at this point has demonstrated. What we alluded to in Iberall (1978) was a variety of externally available action fragments that deal with attention. In these fragments, consciousness may have been present with regard to the process going on, yet the process was not being driven consciously. The examples discussed in Iberall (1978) included fluctuations in the form of ambiguous figures, the attention span in children, and a considerable variety of psychological experiments referenced in Woodrow (1951). Depending on the situation and the protocol, the findings gave a sense that the present existed for only a brief time. For evidence of the present, we did not include the eye blink, which in our original literature search in 1960 on dynamic organismic processes (Iberall & Cardon, 1964) was almost the first new physiological oscillator that we learned about (other than the heartbeat, the respiratory oscillator, and the middle metabolism cycles that we had uncovered in the 1950s). We had put it aside as a somewhat mechanistic oscillator the volitional function of which we could not describe with any great cognitive semantic depth.

However, one of the main occurrences that prompted this article was the accidental observation of a person dozing on a bus ride. Clearly the person maintained upright body posture. Thus deep sleep was not involved. Yet the head fell off in a rather regular near 6-s rhythm before being restored upright. What aspects were conscious, we do not wish to discuss. We have since arranged to make many such observations of similar phenomena and find that to be a near characteristic period. That is, we infer that there may be considerably more cognitive depth to the eye-blink cycle, certainly to its period, than is commonly supposed (e.g., as a period in which the eye is repeatedly washed). This point has also emerged in recent neuropsychological literature.

At that point in our conjectural construct, we found an article in *The Sciences* (Libet, 1989). It deals with the decision-making-process time in the human brain. While it discusses Kornhuber and Deecke's readiness wave, what was disturbing about that article, was its lack of any reference to Grey Walter's connected work. We began to realize that that work had disappeared into oblivion. So we went back into the literature to at least dig up one piece. Note what we are saying. External observational evidence gives interesting evidence for an outside time scale of the order of 6 s associated with attention and initiation of actions of a motor and sensory as well as some sort of internalized form. So now we turn to the question of whether there is any internal evidence for such a process. This is the significance of the earlier Grey Walter and associated work. We had discussed it with Grey Walter's colleagues in the late 1960s and the opinion we walked away with at that time was that it took a person of Grey Walter's skills to exhibit the internal processes, so that amateurs like ourselves were forewarned away. What I now realize, not inconsistent with these observations, is that the best technique for uncovering the electric–chemical character of the brain as a thermodynamic engine is not the electroencephalograph (EEG). We were fortunate to have a number of teachers to impart that message to us, for example A. Remond. But at no point could we claim acquisition of any real skills in studying internal brain structure and function. It was on our agenda, but we could never get support for our efforts. Our occasional collaborators, D. Jacobowitz and R. Llinas, did provide us with a little insight, from which we attempt to draw our knowledge.

An excellent single article to start from is Walter (1967) on expectancy, decision and intention. We consider its first three paragraphs to be excellent.

> Since the discovery of the Contingent Negative Variation (CNV) or Expectancy Wave (E wave) . . . several experimenters have begun to investigate the relation of slow potential changes in the human brain to various aspects of mentality. Cohen et al. (1965) have described the description of the E wave during semantic presentations and Irwin et al. (1966) have studied the CNV as a function of motivation. In a later publication (McAdam et al., 1966) these authors suggested that the clearest correlation of the CNV was with "Conation" and that the acronym be considered to imply this rather than Contingency. Low et al. (1966a) confirmed the relationship to conditioning but also considered that conation was an important aspect of the mental state associated with the appearance of the CNV.
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> In a series of experiments intended to examine synchronization and coherence of alpha rhythms preceding a voluntary motor act, Kornhuber and Deecke (1965) discovered instead a slow increase in negativity at the vertex during a period of about one second before their subjects decided to clench a fist. This effect is called the "Bereitschaftspotential," since it appeared only preceding voluntary spontaneous actions and not with passive movements.
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> Since the potentials generated in conditioning or readiness experiments are rarely more than 20 μV and can be seen clearly only by averaging from a dozen or so

> trials, contamination by extracerebral sources must always be suspected. Potentials due to eye movements are the most common source of interference but these can be checked by simultaneous averaging of channels connected to electrodes around the eyes. . . . (Walter, 1967)

The sequence abstracted from Libet (1989) and Grey Walter (1967) is that whether an act is consciously planned or not, conditioned or not, a short readiness pulse appears approximately a second before the act. Perhaps 0.3 s after the readiness pulse, human subjects knowingly decided whether they are going to act. Action then would or would not follow. When it followed, it would occur at the end of the intention wave at approximately 1 s. An expectancy wave would then follow. It could either decay or persist depending on compatibility of the results with future events.

Although the onset details of these processes certainly affect the detailed issue of free will, they are too technically involved in neurophysiological details for us to take much of a stand. The basic point, in our opinion, is the emergence of what Grey Walter viewed as the long term, for example, multiple seconds Conation Negative Variation (CNV) or Expectancy wave. Here, in our opinion, is when and where the perception–cognition fragment of free will is developed. As the present then dies out slowly, through the changing character of the world outside and inside, future segments of actions would then emerge.

What happened to the Grey Walter theses? Reaching into my own background of experience, I think I understand the answer. McCulloch introduced me to quite a few of the prominent EEG community. And in fact, during my biological laboratory years, I wanted to pursue dynamic systems analysis of the brain, starting both with EEG and other techniques. But both Remond and Grey Walter's colleagues dissuaded me. Why I did not understand fully until now. We built EEG simulation equipment for the biosatellite in the space program. What we found was that the simulation specification suggested by the biologists and their engineering technical associates exceeded physically achievable limits, for example, Johnson–Nyquist noise limits. So instead we proposed and did build extraordinarily elaborate electronic equipment right up to that limit. What I did not grasp until now, something that Grey Walter's colleagues warned me, was that only a few people, like Grey Walter, could manage to show cleanly those CNV and E and readiness wave processes. The technical problems were at or beyond the common state of the art. Thus to try to read real mental processes by those techniques was basically out of the question for most experimenters. The field drifted off toward simpler and other measurements and ideas. Now with new and different scanning instrumentation, and extended computational capability, it perhaps becomes possible to reapproach these questions neurophysiologically, and, I suppose in avant garde fashion, I am reraising these issues. I cannot read Grey Walter and make any claim for originating these ideas. I am simply rediscovering or revitalizing them. I begin to understand a little better what may be involved in a move toward a new generation of connectionism.

Thus, my contention would be that, instigated at reaction time scalings on the order of 0.1 to 1 s, a free will impulse can be propagated, carried forth, and held for the present of the next 6 s before it is buried as one more perception–cognition in the endless stream of cognition.

And to make the cheese more binding, I would suggest, conjecture, and/or predict, that the proof of this thesis is that the next (after one) concept is not open to the organism at this (present 6 s) time. Or, if that answer is not quite precise—for example, there may be some weak coupling for one or two additional concept times—then it is the next one or few concepts that are not open.

P. Lieberman, on a recent public television "Nova" program, put forth a related human linguistic keynote very well. The advantage of high speed neural rate (5 Hz) language in the human (see, e.g., Kelso & Tuller, 1984) is that it permits the full abstraction of sentences to the human, for—as he put it–how else could you hold the entire sentence, thought, abstraction (e.g., its meaning, in the short-term memory of mind) from beginning to end, if you were not creating the linguistic components at fast enough rates. Thus, one perceives that sentence thoughts, for example, 6 s-like segments, are strung together as free will associations to create the thread of meaning into all of the longer term processes. The books (e.g., of Life) that you write arise from commitments and introspections of many such 6-s epochs before you really commit yourself to write (or live) them.

Thus free will, it is conjectured and proposed, exists only within the frame of the present, that is, 6 s or so. And furthermore, such elections are made from a limited repertoire of actions the statistics of which rather rapidly converge when you get to know your specific species or organism. One final note of great significance is that the mammal, including the human, drives his or her entire repertoire of action from that time-scaled process, which amounts to about 15,000 choice segments per day of action. One must dwell on the fact that this appears to be sufficient to take care of the aggress, defend, and maintain modes of the organism in the most mundane extension of autonomic–automatic function, as well as what is viewed as most humanly sublime—the abstractions by which some of us create all the forms of art, all the concepts of science, all of the concepts of compassionate and loving association with our fellow beings. But neither can we neglect all of the horrors that we also can and do create. Dwell on that motion picture of 15,000 frames per Earth day with which we live. While on one hand it is freely produced, those who know us know how rapidly stereotyped it becomes. That is how they know us.

One more reference can be offered to begin to provide more substance to our conjecture. After our behavioral mode paper with McCulloch (Iberall & McCulloch, 1969), we tried to inspire investigators to extend the study of behavioral modes that we began there, but to no avail. In the past few years, in my current affiliation, one graduate student finally proposed to begin some such related study. Using zoo facilities and recording for many hundreds of hours data on a reasonable number of mammalian species, over a rather extended recording speed range, a wide variety of high frequency behavioral segments were isolated. A broadly common range of observed behaviors, covering many modes of action, were observed in the time range discussed here (Gerstner, 1991). Thus, as we have claimed, action is quite segmented at this proposed time—1 to 10s—and it is very difficult, from viewing such observations, not to realize that there is some common neurophysiological-neurochemical driving basis for that moving picture of about 15,000 frames of action per Earth day for all mammals. That is all that we can ascribe to the depiction of intention. At this point, it is an incomplete picture drawn from both internal and external mechanistic evidence, but it certainly warrants research extended both ways.

Some Further Speculation on Behavioral Linguistics

Having reached this theoretical status with a certain amount of experimental support, I am inclined to continue with some additional hypotheses about the content of a mammalian behavioral linguistics. The 6-s cognitive fragments (15,000 per day), I premise, represents mammalian behavioral phonemes. Judging from other linguistics, I assume that there are about five phonemes per word, that is, about 3,000 behavioral words per day. Further, I assume that modal sentences are built up from perhaps 10 words per sentence (e.g., according to Scott, cited in Havez, 1962, there are about nine general types of behavioral modes among mammals; according to Iberall & McCulloch, 1969, there are perhaps 20 modes among humans). We believe that the additional abstract linguistic competence of humans thus represents a further intensification of modal behavior. Thus, in either case, there may be perhaps 15 to 30 sentences per day per mode of behavior. Such a linguistic concentration represents a paragraph or very short story outline or synopsis of that day's modal action. Although these short synopses may differ somewhat from day to day, depending on organism location, and the character of the outside world, they are generally quite stereotyped, hardly representable as free will or intentional elections any longer. They are driven almost routinely by the internal, largely chemical fluid machinery. They are like brief daily diary entries.

I understand that the reader might regard these hypotheses as being too detailed, too far reaching. Nevertheless, I believe that they capture the essence of a homeokinetic prediction, and—similar to Gerstner's program—can be tested both externally (behaviorally) in natural environments, and internally by measuring biochemical streams. In these circumstances, I might as well be hung for claiming a sheep rather than simply a lamb. Gerstner's review of his findings (personal communication) also suggests reasonable evidence for behavioral fragments in the 30- to 120-s domain, within the domain that I suggested was associated with local capillary bed responses connected with circulating catecholamines, or possibly also with second messenger calcium transport (see Iberall, 1964). I would like to sketch out a feasible physical scenario that may nearly connect up to the 6-s process, all in the spirit in which I identified chemical phonemes and words in the behavioral repertoire.

What came to mind was Olds's findings (Olds & Milner, 1954) in which an animal (mammal) can be shown to elect continued electrical self-stimulation of a pleasure center in the CNS. What struck me was that the person repeatedly nodding his or her head every 6 s or so exhibited a similar kind of stereotypy in performance. At least what these two processes have in common is that they involve segments of the nervous system, but also some kind of integrative coordination. But then I recalled an experimental result that we had derived (Cardon, Ostermeyer, & Bloch, 1970), but one whose results of which I had not generalized enough. We had shown that a small mammal (rodent) encased in a pressure chamber, with a window permitting us simultaneous observations in capillary beds in a back muscle preparation, exhibited peculiar behavior as we changed the oxygen partial pressure that the rodent was exposed to, for example, from a fraction to a number of atmospheres. We had demonstrated regular red cell file flows in capillary beds at normal pressures. However what we showed was a level of pressure at which the cycle broke down and we demonstrated that the breakdown was associated with large aberration in the nervous system response. We found that with increased oxygen tension, the animal began to perform excessive grooming. We regarded this as a breakdown in nervous system performance, as an extreme extension of what might ordinarily be or begin as a more voluntary grooming.

What suggested itself to us, now, from that earlier data was that the ordinary behavioral language that we had just proposed was a behavioral repertoire of a few thousand words per day, in fact was the 30- 120- (nominal 100) s local bed cycle. That cycle, we had shown, exhibited no binary cross correlation with the 6-cycle process. However, as we have rather certain reason to surmise, the two processes are nonlinear. It occurred to us now that the high oxygen concentration experiments indicated a growing instability in such a nervous behavior as grooming, as a rather generalized motor–sensory searching over self, which seemed as compelling as pleasure center excitation or some other nervous center tic. In fact, we had first discovered the 6-s process as something that we supposed was a nervous tic. What we are now suggesting is that the ordinary 100-s unit behavior process is not quite unstable, so that—driven by 6-s volition or intention—it is rather noncostly to switch into or among 100-s local unit responses, for example, the few thousand per day that we surmise make up the language of behavior. Thus, we suggest that at extreme instability, these two processes can be forced to join each other. Our model of the 100-s process (Bloch & Iberall, 1982) is a generalized electrical zeta potential that rides along the capillary membrane double layer in local beds and that relates to the circulating chemical constituents in the capillaries, such as catecholamines, calcium, oxidation byproducts from the bathed oxygen user organ element, and histamine. On interacting with the red cell file, they determine that file and how much oxygen that nutrient capillary bed is carrying. We view that as the operative oxygen choke on the local organ element. We share the notion of an operative oxygen choke with A. Guyton. These few complicated suggestions on the underlying physics–chemistry of behavior may seem yet meager, but we perceive them to be a real if yet imperfect start on a true scientific account of a physics for a complex systems behavior. As one may find the point well made in a recent book review in *Science* (Purves, 1991), connecting molecular information in the brain with macroscopic behavior is still beyond the ability of most researchers, regardless of their transmitter expertise.

Postlude

At the urging of a reviewer, I read Gibson (1966, 1979/1986). This reading reinforced my belief that our respective philosophies are much in tune, that is, as Gibson emphasized, more physics is still needed. Second, it really is not too relevant how I introduce my final theme, as either classical or Gibsonian. What I have to do is establish a biophysical foundation for distinguishing sensation, perception, and cognition, and to provide cognition with a complex physical–homeokinetic-basis for further pursuit. As Gibson emphasized with regard to vision (more generally, all perception), perception needs more of a total Gestalt, as a system, rather than the disciplinary fracturing that it has received. With that I agree totally. I have done research on color shading and matching to very high precision on paints for one of the major paint companies, so I am at least aware of some of the problems of distinguishing the physics, the physiology, the physiological physics, and the psychology of light, color, and illumination. However, as a homeokinetic view in this article, we choose to deal with an element of cognition and want to clearly distinguish it from perception; I do not have to establish an extensive base for perception. Suffice it for me to reference only a few sources, such as Woodworth (1938), Gibson (1966, 1979/1986), and Geldard (1972), which I am certain my readers know more about than I do. Threshold sensitivity, even some integrative responses of the various sensory systems, are reasonably discussed in these sources. Quite commonly they are related to very real minimal thresholds in physical phenomena, for example, light quanta, signal–physical noise levels related to fundamental physical phenomena and their separation. What is surprising is that the time domain of perception and perceptive actions are presented much more obscurely than how perception in general is related. At thresholds (of single element fixations, or whole system's response), how perception is related to single or few nerve impulses is clear. So in some crude sense, I can characterize that time scale of response. Using the eye system as an illustrative sense, whether perfectly typical or not, we find: ballistic saccadic movements—of order 0.02 to 0.08 s. In this action there is little or no perception. Then we find fixations (taking a scanning fix)—of order 0.2 to 0.4 s. (Heller in Groner & Fraisse, 1982). What is clear about such numbers is that they represent not more than one- to a few-unit nervous impulses. Examining all these and many more books on motor or sensory responses, indicates that these few-unit registrations are sufficient to indicate a sensation of some sort, regardless of the sense, but are not sufficiently integrative to represent an integrative perception. So we have to infer what a perception is. I believe it necessary to quickly scan the ground of psychophysics up through Gibson to make my separations believable.

As a physical scientist, I am told that I am empathetic to the ends and means of ecological psychology. In earlier times, I was told that I was empathetic with an epigenetic doctrine in psychology. I accept both views as compliments. My understanding or view of a Gibsonian ecological psychology, which may not be precise enough for Gibsonians, is of a universe of dynamic inhomogeneous spatial–energetic character, in which transporting processes are going on within and between inhomogeneous regions, and that where or when any local form and process constitutes an autonomous system (one that will maintain form and function independent of time), there will be a complex system of handling and holding on to the consequences of those transports that are peculiar to the system and that tend to serve the system's persistence. And, of course, the specific directionality at which that program is directed is the *psychology* (loosely meaning the behavioral complex external, or *physiological psychology* if both inner and outer behavioral complexes are intended) of mammals, more specifically the human mammal.

But at the same time, I must serve my physical discipline. So I do not wish to get into ideological arguments, but to indicate that what I want to do is to determine how and from what does command–control of the complex human organism come. It becomes rather clear that the system operates from its motor–sensory machinery, and that these subsystems operate at relatively high frequency in order to keep the system going. Thus the task I have to confront is to tease apart—in a physical sense—the complex of the fast processes of sensation, perception, and cognition. As it seems that I only based my results on physical-physiological reasoning, it appears useful to touch one last time on more conventional psychological sources. For this I used two books of Gibson's, and a few more traditional sources. First, from my own physical view, I use the following definitions:

1. To sense is to receive and to detect trains of matter–energy. That can be done either by an instrument or a system.
2. Sensing for an instrument is such instrumental conversion of detected input to an instrument output.
3. Sensing for an autonomous system is some conversion complex that I am

not, a priori, prepared to identify. Each case or example has to be studied in its own right.

4. Perception, as far as I am able to understand it, is a pattern of internal action within a complex autonomous system in which a sensed complex achieves some sort of memory register. In space–time, it may be coextensive with a second complex, as long as the sensing lasts, or it may extend much beyond. Each example has to be studied in its own right.
5. Cognition, as far as I am allowed to stretch my biophysical knowledge, is a process about which I can only comment in mammalian species of complex autonomous organic living systems. It is a process in which diverse perceptions are integrated into a perceived pattern in higher nervous system centers, whether conscious or not. The memory trace of these perceived and cogitated patterns tends to fade. However, some of them are transferred into a long-term memory storage.
6. Consciousness is a pattern of awareness in which some mammalian higher nervous center holds a temporary memory storage pattern of other patterns of action going on within the organism. That pattern also tends to fade but with remnants held in a long-term memory storage.

The reader is invited to inspect large dictionaries, orthodox textbooks, Gibson and/or other sources for their operational definitions, if any, of these concepts. I add one physical proviso to my conceptualizations: I have to be able to point to experimental data sets that deal compatibly with the defining ideas I have the intent to pursue. Two books that deal with senses and sensing are: Geldard (1972) and Gibson (1966). Three books that deal with cognition are Gibson (1979/1986), Groner and Fraisse (1982), and Wolman (1973).

I have no great desire to explore all the extensive literature on all the senses. Insofar as they use comparable nervous connections, we can make reasonable estimates from a few senses at most about sensations.

It is clear that a book like Woodworth (1938) is an excellent overview of the early history of psychophysical findings. In certain significant ways, this article is a continuation of that point of view, but extended into new psychophysical directions. For example, its extensive studies on reaction time clearly provide an excellent view of the time threshold for sensation. Once again, this time for the last time, it is clear that such a threshold is of the order of a few tenths of a second. We need say no more. Details, old and new, can be inferred from or compared with Woodworth (1938). So this brings us up to perception. I believe, very much like with sensation, we need to separate the threshold for perception in some complex sense from the threshold for sensation, and we then have to make a distinction between complex perception thresholds from the more extended perception–cognition (Illustratively, Gibson clearly identifies sensationless perception). That is, as we suggested, cognition is a flow process in which the mind–brain–body has a first integrative sense of its current, more global, world image, whether focused or not.

Woodworth (1938) discusses many types of perceptions, such as color, distance, depth, direction, motion, relations, form. We can use one of the more forced complex ones, for example, reading, as a test example. Silent reading without any attempt to offer any oral content is faster than oral reading. What is found are saccades, rapid blurry jumps with no information being obtained, and fixations, typically perhaps 5 to 6 per line of text. Fixation time is on the order of ¼ s (as we said before). This represents about 1 ½ s per line of text, approximately 2 s or so per sentence. This provides a minimal idea of a complex perception. That is not necessarily a cognition, but it certainly is the threshold of a cognition. It is not inconsistent with the range we have inferred, and the range that we find in Gerstner's data. The way we interpret the extensive psychophysical data in Woodworth (1938) is that the perceptions are discrete, each one starting from some sort of attracting focus either in the external world image or the internal one. These pass through the relatively brief time scale. However, they are integrated into a flow of cognitions, which have the average time scale that we have named. The significance of Gerstner's data taken on free-acting mammals is to show that these task fixations (we choose to coin that sort of phrase to denote the atomistic character in the flow of cognition) are in fact discretely discernible, and in ensemble make up the flow of cognition in all mammals. (Our 1967 characterization was "How is action determined? Watch any animal, human or not. The state of the system does not remain fixed. It is basically unstable. . . . Whatever the inputs are, whether nearly constant, slowly changing or rapidly changing aperiodic, the system changes. It changes its postural dynamics. Further men do this routinely at a rate of approximately 10 per minute." We know now that the time scale is essentially constant for all mammals, as determined from a diverse sample of species; Iberall & McCulloch, 1969).

In turning to the Gibsons, what is most clear is that they are not concerned with a direct identification of mental processes in terms of a simplistic psychophysics. The living observer does not seek to decompose the world of physical–chemical form and function in terms of direct nesting of logical hierarchy, that is, of continuous matter–energy into atomistic components such as a local receptor. Instead, there is a great deal of transformation from psychophysical to psychological categories. As I said, my experience with paint color shading made that very clear to me, so I have no trouble with the Gibsonian program and language. (E.g., one can review our piece, Bloch & Iberall, 1982, on the complex requirements for defining the functional anatomical unit for even the simplest of organs, muscle, as a foreshadow of the problem. We had begun to do such studies as the forerunner to attempting to define the functional unit or units of brain–mind, but that is still far ahead of us. At the present, such studies as Gerstner's have to be assimilated before we can proceed on to further integration.) I have no trouble with the key idea that what is needed is a physiological–physical theory of object- and process-perception and cognition rather than a theory of stationary and cinematic picture production, "not how the brain responds to form itself, but instead how it responds to the invariant variables of ever changing form" (Gibson, quoted in Wolman, 1973; p. 439).

Nevertheless, in a physically founded theory, we must argue our search for system invariants in the physical variables of space and time and matter and energy and momentum and action. And, except when we deal with cosmological questions, we have to follow change in whatever process time is used internally in terms of external universal time. In that time, which tends to be considerably anchored and compared with some physiological processes such as the heartbeat and the nerve response and their relations to nerve propagation, the bottom time scales, of hundreds of milliseconds, is quite universal in nerve-possessing animals. We cannot say the same thing for more primitive living systems, in which other scalings can govern. Because of that electrically governed process, and its chemical related thermodynamics, we have to accept that higher ordered mental functions, such as perception, cognition have to fall into a time scale not more than a few orders of magnitude from 100 ms. This then connects with our studies at the microcirculation level, in which chemical transport governing local organ beds is to be found. At that level, we demonstrated the primacy of chemical processes beginning at the 100-s level. It was such findings that led me to declare to my colleague Warren McCulloch, after our ground breaking article on a fundamental organizing principle for living systems including its chains of behavior—the notion of hierarchy and of behavior as modal—that behavior had to be chemical rather than electrical. That thesis meant to me that behavioral complexes had to organize beyond the 100-s scale, and that the nerve cable processes of electrophysiology were just physical process primitives. It took me a long time to appreciate that the only way that the organism could have freedom for continuous plastic adjustments to change was by making a time scale near to but below the 100-s boundary the basis for free will—intention. What I believe remains the major task in a physiological physics, one that also includes a physiologic–psychologic physics, is a descriptive physics of processes at all scales. I believe that the Gibsonian program of searching for invariant conservations in behavior as the variables for psychology is one that is quite well suited to the task. But it has to be able to take on a thermodynamic foundation for its ultimate reductionism. At I expressed once to my Gibsonian friends, you can't do it with mirrors, as a geometric optics. It has to be fully thermodynamic. Here, I believe that with the fast processes of sensation, and this somewhat longer time process of perception–cognition, one has the atomistic scales for building up a physiological psychology of behavior, for linking both motor and sensory processes into the total program that governs a complex living form like a human being.

What I come to understand, as the Gibsonian program, is a nonlocalization of brain function, and an action unit basis for the emergent flow of behavior. I find this fascinating from a homeokinetic point of view. First, my earlier explorations on brain function led me to appreciate a difference between the American view of localization, such as centers for almost all functions. In contrast, I found basically a nonlocalization expressed by most prominent Russian theorists. When I presented the Iberall–McCulloch paper in Yerevan in the late 1960s, forewarned by friends not to emphasize any Freudian aspect, I was not so sensitive to the localization theme. However, as I found our work receiving considerable attention from Russian neurophysiologists, such as Anokhin, and cyberneticists, I began to realize that we shared a common view about nonlocalization. It was not only sympathy for a more general notion of mass action, but a different modal action of behavior. It is this view that I suppose Gibsonians found so appealing in homeokinetics. The same is true about our general sympathy to a physical modal view of action organization.

In a basic sense that is both Gibsonian (psychology) and homeokinetic (physics), the unit complex atomistic process I propose in this article is the mammalian quantum of action, the time part of the energy flow–time product that defines action. The degrees of psychological action freedom are to be found in the 6-s cognitive fragments. The task remaining is to identify the totality of linguistic complexes of action using a flow process of intention to determine volitional behavior. These higher ordered complexes, in a Gibsonian sense, constitute the invariants of a behavioral language and a physics of action, as a substitute for impulse and momentum.

FINAL NOTE

The latter remarks have finally permitted us to quantify the human action spectrum, and by scaling extension, all mammalian behavior. We have indicated that volitional behavior represents perhaps 500 kcal per day, or 500 kcal-days of action per day. With a flux steam of 15,000 intentional actions per day, the average energy cost per action is about 0.03 kcal. These are the intentional actions actually delivered to the outside world. The total cost of maintenance and the like is perhaps 1,500 kcal. Thus the nominal efficiency of this living machine is on the order of 20%, not tremendously different from many other chemical thermodynamic engines. The scaling of energy for mammals, we have shown, is with the four fifths power of average body mass for the species. However, the time scale of intentionality remains the same 6 s. Thus the cost per action for all mammals can be estimated. At the moment, such estimated calculations may seem trivial. However, I believe that as time goes by we will be able to develop them into a much more elaborate quantifiable physics of behavior.

REFERENCES

Bloch, E., & Iberall, A. (1982). Toward a concept of the functional unit of mammalian skeletal muscle. *American Journal of Physiology, 242,* R411–R420.

Cardon, S., Ostermeyer, C., & Bloch, E. (1970). Effect of oxygen on cyclic red blood cell flow in unanesthetized mammalian striated muscle determined by microscopy. *Microvascular Research, 2,* 67–76.

Czeisler, C. (1978). *Human circadian physiology. Internal organization of temperature, sleep–wake, and neuroendocrine rhythms.* Unpublished doctoral dissertation, Stanford University, Palo Alto, CA.

Geldard, F. (1972). *The human senses.* New York: Wiley.

Gerstner, G. (1991, December). *Quantifiable temporal and spatial patterns in six mammalian species: Evidence of evolutionary and functional limits, and hypothesized proximate causal mechanisms.* Unpublished doctoral Dissertation prospectus, University of California, Los Angeles.

Gibson, J. J. (1966). *The senses considered as perceptual systems.* Boston: Houghton-Mifflin.

Gibson, J. J. (1986). *The ecological approach to visual perception.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc. (Original work published 1979)

Groner, R., & Fraisse, P. (1982). *Cognition and eye movements.* New York: North Holland.

Havez, E. (1962). *The behavior of domestic animals.* Baltimore: Williams & Wilkins.

Iberall, A. (1960). Human body as an inconstant heat source and its relation to clothes insulation. *Transactions, American Society of Mechanical Engineers, Series D, Journal of Basic Engineering, 82,* 96–102, 103–112, 513–527.

Iberall, A. (1964, October). Study of the general dynamics of the physical–chemical systems in mammals. *General Technical Services Inc. Report to NASA Headquarters, NASA Contractors Report CR-129.*

Iberall, A. (1972a). Blood flow and oxygen uptake in mammals. *Annals of Biomedical Engineering, 1,* 1.

Iberall, A. (1972b). *Toward a general science of viable systems.* New York: McGraw-Hill.

Iberall, A. (1973). On growth, form, and function–A fantasia on the design of a mammal. *Transactions, American Society of Mechanical Engineers. Series G, Journal of Dynamic Systems, Measurement, and Control,* 95, 291–295.

Iberall, A. (1978). Cybernetics offers a (hydrodynamic) thermodynamic view of brain activities, an alternate to reflexology. In F. Brambilla, P. Bridges, E. Androczi, & G. Heuser (Eds.), *Perspectives in endocrine psychobiology.* New York: Wiley.

Iberall, A. (1986). Dynamics of mammalian thermoregulation and its circadian component. *Journal of Applied Physiology, 61,* 1230–1233.

Iberall, A., & Cardon, S. (1964). Control in biological systems–A physical review. *Annals of the New York Academy of Sciences, 117,* 445–528.

Iberall, A., & Cardon, S. (1965). Regulation and control in biological systems. In K. Kaneshiga & K. Izawa (Eds.), *Proceedings of IFAC symposium on systems engineering for control system design.* Tokyo: Science Council Tokyo.

Iberall, A., & McCulloch, W. (1969). The organizing principle of complex living systems. *Transactions, American Society of Mechanical Engineers, Series D, Journal of Basic Engineering, 91,* 290–294.

Iberall, A., & Soodak, H. (1978). Physical basis for complex systems–Some propositions relating levels of organization. *Collective Phenomena, 3,* 9–24.

Iberall, A., Soodak, H., & Arensberg, C. (1980). Homeokinetic physics of societies–A new discipline. Autonomous groups, cultures, polities. In H. Ruel, D. Ghista, & G. Rau (Eds.), *Perspectives in biomechanics* (Vol. 1, Part A). New York: Harwood Academic.

Iberall, A., & White, D. (1988). Evidence for a long term process scale for social change in modern man settled in place and engaged in trade and war. *GeoJournal, 17*(3), 311–338.

Iberall, A., & Wilkinson, D. (1987). Dynamic foundations for complex systems. In G. Modelski (Ed.), *Exploring long cycles.* Boulder, CO: Lynne Rienner.

Kelso, J., & Tuller, B. (1984). Converging evidence in support of common dynamical principles for speech and movement coordination. *American Journal of Physiology,* 246, R928–R935.

Libet, B. (1989, March/April). Neural destiny. *The Sciences,* 32–35.

McCulloch, W. (1965). *Embodiments of mind.* Cambridge, MA: MIT Press.

Olds, J., & Milner, P. (1954). Positive reinforcement produced by electrical stimulation of the septal area and other regions of the rat brain. *Journal of Comparative and Physiological Psychology, 47,* 419–428.

Purves, D. (1991). Molecules and the mind. *Science, 253,* 572.

Ruch, T., & Fulton, J. (1960). *Medical physiology and biophysics.* Philadelphia: Saunders.

Soodak, H., & Iberall, A. (1978). Homeokinetics: A physical science for complex systems. *Science, 201,* 579–582.

Toulmin, S., & Goodfield, J. (1962). *The architecture of matter.* New York: Harper & Row.

Walter, W. G. (1967). Slow potential waves in the human brain associated with expectancy, decision and intention. *Electroencephalography and Clinical Neurophysiology, 26*(Suppl.), 123–130.

Wolman, B. (1973). *Handbook of general psychology.* Englewood Cliffs, NJ: Prentice-Hall.

Woodrow, H. (1951). Time perception. In S. S. Stevens (Ed.), *Handbook of experimental psychology.* New York: Wiley.

Woodworth, R. (1938). *Experimental psychology.* New York: Holt.

APPENDIX

In preparation for this article, I found it necessary to adopt a series of definitions. It is my impression that they seem perfectly in tune with the issues that Grey Walter raises.

<u>Sensation</u>—A state of consciousness produced by impingement of an external object or physical process on the body; the awareness resulting from adequate stimulation of a receptor organ or body region in a living organism.

<u>Perception</u>—Mental image however represented; awareness of elements of environment through physical sensation; physical sensation interpreted by experience; the integration of sensory impressions of events in the external world by a conscious organism, especially as a function of nonconscious expectations derived from past experience and serving as a basis for or as verified by further meaningful motivated action.

<u>Cognition</u>—Act or process of knowing in the broadest sense, specifically an intellectual process by which knowledge is gained about perceptions or ideas—distinguished from affection or conation; a product of this act or process (also knowledge and perception).

Conation—Conscious drive to perform apparently volitional acts with or without knowledge of the origin of the drive; an instinctual motivated biological striving that may appear in consciousness as volition or desire or in behavior as action tendencies.

Thus—my inference—sensation is (a) receipt of a sensory stimulus at a site capable of such receipt and (b) conscious awareness of that receipt (time scale: about 0.1 s). Perception is integration or comparison of sensation within the conscious awareness memory bank. This may be only a short-term memory comparison—this is purely technical (time scale; about a few tenths of a second; it may be as much as 1 s). Cognition is the stream of perceptions that are bound into the present of the organism (time scale: about 6 s; i.e., 2–12 s). At present, I cannot distinguish between cognition and conation. I now find these remarks reinforced by the Grey Walter article.

ERRATUM

On pages 280 and 289 of Richard G. Coss's article, "Context and Animal Behavior III: The Relationship Between Early Development and Evolutionary Persistence of Ground Squirrel Antisnake Behavior" (*Ecological Psychology*, Vol. 3, No. 4), Figures 2 and 4 should appear as follows:

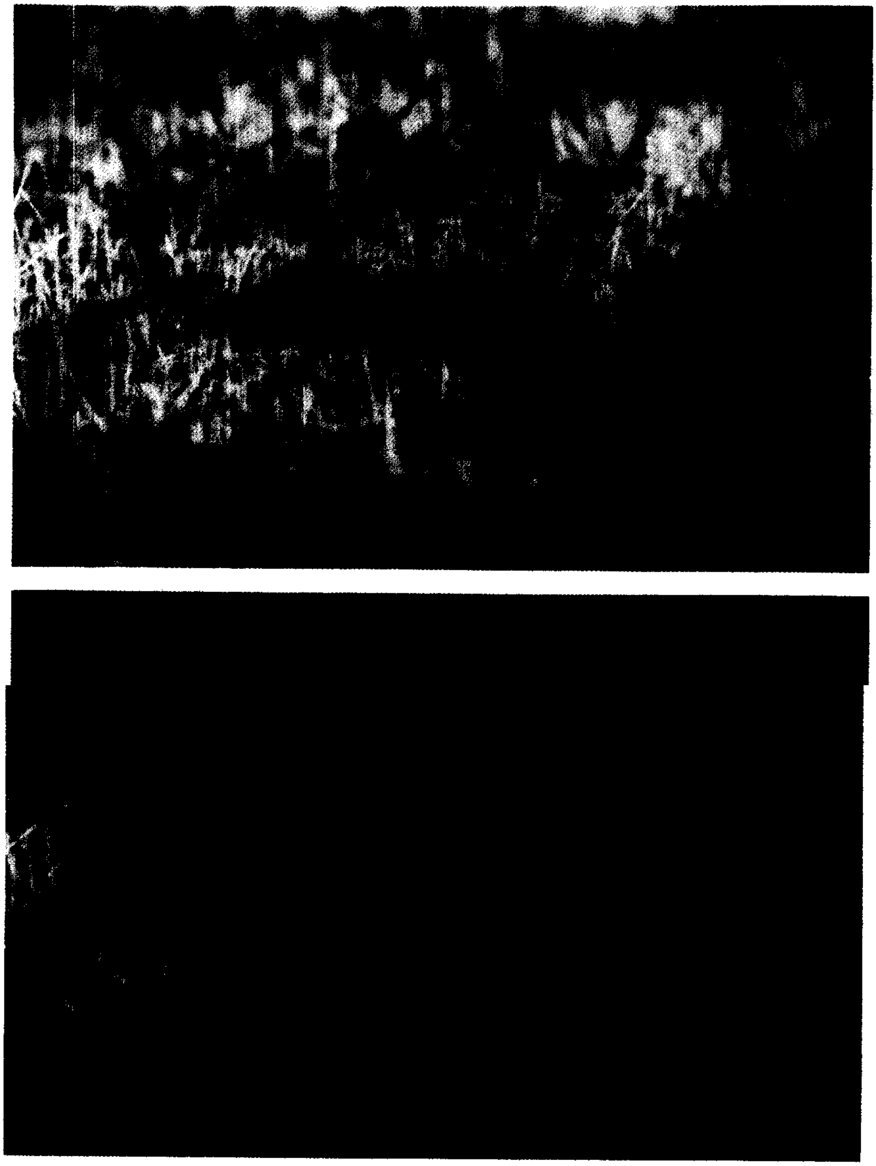

FIGURE 2 A newly emerged pup (top) exhibits an elongate posture as it cautiously approaches a snake-like stick (68 cm length, 16 mm dia) placed near its natal burrow. The mother (bottom) adopts a similar posture as she sniffs the stick; her tail piloerection declined markedly after this bout of close inspection. This behavior was repeated each morning for several days until mother and pups habituated to the stick at that location. Photographs by Eric Reeter.

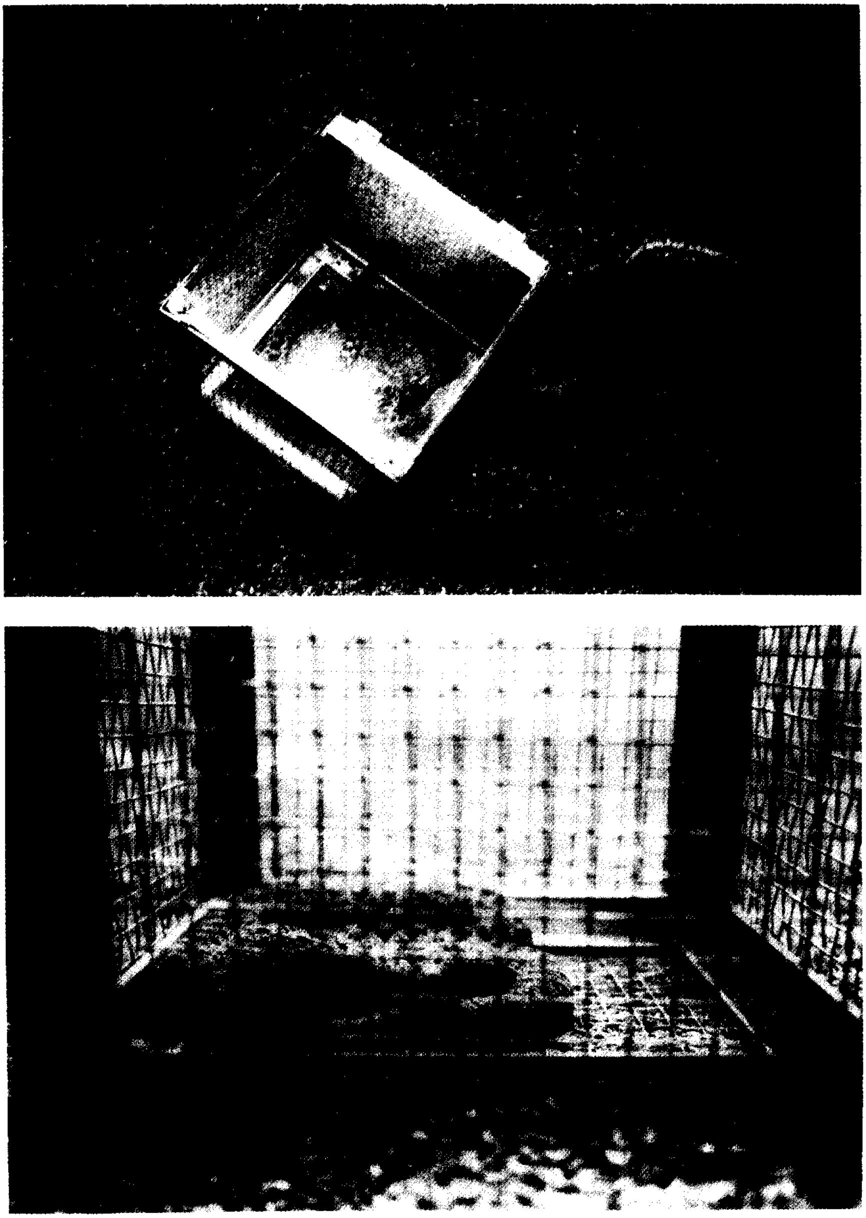

FIGURE 4 Douglas ground squirrel from Mount Shasta (top) cautiously inspects a gopher snake in the wire-screened compartment. This photograph is taken from an angle similar to that recorded on video. Compartment dimensions provide a scale index for measuring squirrel proximity and maximum tail piloerection. View of gopher snake from the squirrel's perspective (bottom).