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What Makes Sammy–Samantha and Other Mammals Run? A First Round of Closure

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This article attempts to bring a first round of closure to an entire series of articles on *command control* (1960–1995). This contribution is of significance for the Gibsonian program (e.g., Iberall, 1995). This article attempts to complete a primitive physical foundation for that control process, for the basis of attention, action, and so-called purposeful or intentional movement or change in all complex systems, particularly mammalian and human. It assumes and neglects the very high-speed reflex actions that are dealt with by the autonomic nervous system. A discussion is included on the general character of the dynamic problem of command control in all of nature.

One of my previous articles in this journal (Iberall, 1995) sketched much of the homeokinetic (HK) framework but did not pursue the topics that are needed to complete the brain modeling that the HK approach makes possible. This article focuses on the role of pressure in running an animal (or plant) system and connecting that pressure, whether it be actual physical pressure or a transformed social pressure to the conduct of human activities, recognizing the entire range of possible value systems as studied, say, in cultural anthropology.

A brief summary of some of the views of the development of ideas and contributions to the physics of fluid systems at various hierarchical levels is given in Appendix A.

Throughout my career, while working out detailed accounts of processes at many levels of the physical, biological, and industrial world, I maintained commitment to strictly physical accounts and, in fact, to even achieving a thoroughgoing high hierarchical level of a social physics. The physics that has served best to span

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the gamut of the interests of those complex systems in a unified way is irreversible thermodynamics, its persistent alliance with statistical (almost invariably fluid) mechanics, and its energetic and atomistic material foundations. These conceptual tools have been used to develop such a physically grounded approach to complex systems, which also can be mathematically quantified but not promiscuously so. Because of the fundamental position of thermodynamics and hydrodynamics (via the Navier–Stokes equation set), these will be reviewed in a caricatured fashion, both in the text and in the appendixes, to make certain that readers can get the flavor of where these tools fit and what they can do. It is also worth noting that this approach emphasizes processes that function by moving a system toward an equilibrium state of sorts. This tends to be in contrast to approaches that emphasize "far from equilibrium" states such as those popularized by Prigogine (1978).

A BASIC FLUID LEVEL: THE NAVIER–STOKES EQUATION SET

The basic bottom macroscopic level of a fluid system, for which the *atomisms* (atomistic-like units) are the individual molecules, may be described by a set of nonlinear partial differential equations, called the *Navier–Stokes equations,* which follow the time variation of the macroscopic flow velocity and the local thermodynamic state variables at each location in the fluid for given initial values and given boundary conditions imposed from outside. A short review of the underlying thermodynamic principles is presented in Appendix B.

In situations with small amplitude departures from a state of rest and thermodynamic equilibrium throughout the fluid, the nonlinear terms in the equations can be neglected and solutions can be obtained describing simple behavior patterns. Finding those solutions requires the knowledge of the equations of state that relate the local thermodynamic variables. Increasing the departure amplitudes leads quickly to complications in both the behavior of the fluid and in the mathematical difficulty of finding solutions. Even for the simplest of fluid systems, such as gases or liquids composed of a single simple chemical species, there is an entire congery of 30 or more different kinds of dynamic fields. Adding the possibility of evaporation–condensation, uneven heating by the sun, interaction of atmosphere and oceans, atmosphere and land topography, and the rotation of the earth, gives rise to the complication of our weather patterns of meteorology. Further, adding the full complement of chemical elements in the cloud of gas and dust from which the sun and planets formed, leads us to the entire geo-chemo-bio-evolutionary history of the earth, involving flows within the earth, phase changes, chemical transports, and chemical reactions.

At the microscopic level, each atom or molecule is driven by the short-range forces exerted on it by close neighbors and by long-range forces, such as gravity and electric forces exerted by more distant objects, and moves according to the laws of motion. (The existence of two such sets of forces—short range and long range—will be denoted throughout this article as the physical field *world image* carried by every atomism at its scale. *Image* will have the meaning closest to that which a physicist would recognize given in a modern collegiate dictionary.) At the macroscopic level, described by the Navier–Stokes equations, each small macroscopic volume or mass element is driven by the net short-range force exerted on its boundary atom(s) or molecule(s) by neighbors outside the element and by the net long-range forces of gravity and possibly electric force. The short-range macroscopic forces are described by the *stress tensor,* which includes an isotropic component called the *pressure* and a shape-changing dissipative viscous component called the *shear stress,* which arises when adjacent fluid layers have different flow velocities (e.g., when adjacent fluid layers are slipping past each other). The net force exerted on a mass element due to these effects consists of the net long-range force plus a term proportional to the pressure gradient and a term involving the shear stress forces (and the associated shear viscosity coefficient). This net force plus an additional bulk viscosity force, discussed later, drives the motion of the center of mass of the mass element, according to the laws of motion. Alternatively, it can be said that it drives the flow of momentum.

In addition to the mass momentum flow, there are flows of various chemical constituents relative to the center of mass of each mass element (e.g., diffusion), heat energy or entropy flows, chemical reaction flows involving transformations among the chemical constitutents, and additional associated redistribution flows or actions that arise when the thermodynamic conditions are changing too rapidly for the mass element to remain in local thermodynamic equilibrium for the instantaneous values of the chemical composition. These additional redistribution processes are in the direction of returning toward equilibrium. All of these flows are dissipative; the mechanical dissipation coefficient arising from the redistribution actions is termed the *bulk* or *associational* viscosity. The macroscopic forces driving the chemical flows are described in terms of chemical potentials associated with each chemical constituent. The force driving the flow of a particular constituent is proportional to the gradient of its chemical potential; it is in the direction from higher to lower chemical potential. The force driving a chemical transformation from one set of constituents to another is proportional to the difference in net chemical potential of the two sets in the direction from higher to lower chemical potential. (There are also mutual cross-couplings between pairs of force–flow types, in which a force of each type generates a flow of the other type.) It should be noted that the various equations of state (thermomechanical, thermochemical, electrochemical, etc.), the relations between flow rates and forces, and the rates of chemical reactions are, generally, only partly and semi-empirically known (except for the simplest ideal systems). At best, numerical computation of the Navier–Stokes equations can only be performed using approximate thermodynamic equations of state and also using coarse meshing of space and time scales.

The additional redistribution actions mentioned earlier give rise to an augmentation of the pressure that is proportional to the bulk viscosity coefficient. For a fluid of relatively simple molecules, the energies and time scales of these additional redistribution processes are not larger than those of the direct molecular collision interactions responsible for the formation of the stress tensor. (The direct time scale is the time it takes a molecule to undergo several collisions, perhaps 10.) The bulk viscosity coefficient is part of the same or smaller order as the shear viscosity, and its effects are typically small.

COMPLEX SYSTEMS, SOCIAL PRESSURES, AND VALUE SYSTEMS

Major qualitative changes take place as we move up the hierarchical ladder to higher levels, such as to a bacterial colony where the atomisms are the individual cells or to a human society where the atomisms are individual persons. At such levels, in place of the normal thermodynamic equilibrium state of the basic fluid level, there is a renormalized equilibrium characterized by a repetitive set of basic maintenance action patterns within the atomism. Departures from this renormalized equilibrium are induced by interactions between the atomism and its surroundings (including other atomisms, as well as the physical–chemical external milieu) and by internal changes in still higher level processes, which in turn are or have been partly induced by external interactions. These departures take the form of shifts and reorchestrations in the maintenance modes and by the appearance of a different set of action modes pertaining to the interaction between the atomism and its surroundings. These departure processes comprise the renormalized forms of the simpler bulk viscosity processes at the basic fluid level. I have elected to describe this behavior in terms of a new stress system called the *social pressure.* In contrast to the mechanical pressure that drives the flow of ordinary momentum, the social pressure drives the flow of higher level interaction modes and the shifts and reorchestrations in the maintenance modes. We are now in the realm of complex systems. Llinás and Iberall (1977) made the cellular connection to the bulk viscosity as represented by the forming of membrane gates and some sense of their hierarchical nature in organisms, but it was not a complete model.

Whereas mechanical pressure always plays the central role of driving fluid mass at the basic level of all fluid systems, the social pressure plays an equally central role of driving the higher level interaction modes of the system. In humans, their effects can be as compelling as the action (energy–time product) that may be directly persuaded by the strength of bone or a brushed-on kiss or caress. As I earnestly enjoy attempting to persuade my listeners in energy measures, half of the energy expenditure of the daily action energetics of my life is devoted to my wife of now more than 60 years, and various friends (even some enemies) get their 10, 5, 2, and 1% portions. There is little that I have available for my own nonroutine actions, so I prefer to mix it with my friends or only in desperation with enemies. That is literally how a complex atomistic system operates. It is noted that the higher level maintenance modes may act to generate mechanical pressure as, for example, the osmotic pressure produced by intracellular chemical factories. (Osmotic pressure is the source of turgor in simple plants that undergo flexing motions by manipulating that turgor. It plays a significant role in driving water to the top of trees, and is a determining factor for the common nominal about 100 mm of Hg blood pressure in all mammals. The latter problem is not a simple one. It relates to Smith's (1959) famous attempt to depict the central role of the kidney as a basic chemical regulator in animals. Refer to Iberall (1976, chap. 6), where I began to develop a model that no one else really succeeded in bringing to completion. The mammalian problem was completed a few years later and presented as a paper at an international physiological meeting in Australia, but it still has not been published. For plants, it is to be noted that although turgor in cells or simpler plants starts out as a simple osmotic mechanical pressure, one finds that it may involve a complex of pressure changes in special cells or organs, involving coupled actions (see *Encyclopedia Britannica*, 1975, Vol. 17, "Stereotyped Response," subheading "Plant Movements," subsubheading "Turgor Movements," based on Stiles & Cocking, 1969). A short note on the path toward extending fluid mechanics to more complex systems is presented in Appendix C.

Interaction modes may be found by judicious observation of the behaviors of the atomisms. What determines which interaction mode(s) is (are) selected at any time? It is neither a homunculus nor a mathematical rule; it is a complex play of processes at several hierarchical levels arising in part from stored memories (the physical–chemical forms that differ in different kinds of systems). I have offered the concept that social pressure acts in a number of different value directions or dimensions, in a manner similar to that of mechanical pressure being directed into all three independent spatial dimensions. The concept is that of a multidimensional value system. Each component of the value system may be called a *value driving force* or *value potential* that acts to select an interaction mode (or modes) along its particular value direction. The actual selection is made as a higher level resultant or integration of all the value potentials acting in concert. How is that value system to be described? How does it come into being? I venture initial responses to these questions by discussing various aspects of the value system in humans. The social pressure and its associated value system components comprise the physical–chemical thermodynamic base that permits and furnishes the command control system in the complex organism. The hierarchical degree of complexity of that chemical drive differs among organismic levels. For example, it differs among the simpler organisms, whether single cell or multicell; among archaea (see Morell, 1997) and bacteria; and among plants, animals, sponges, and mammals (Elliott, 1967).

It is apparent that new strategies, new concepts, and indeed new languages are neccessary to describe and analyze complex systems and to provide a program for further progress. In this sense, the HK view appears to be a beginning along these lines; the concepts, strategies, and languages are to be developed, modified, and grown, study by study, system by system, and application by application. (Recall the far simpler and totally successful Newtonian world view of mechanical processes in the universe in terms of space, time, matter, and force. In this view, the laws of motion of particles provide a seemingly natural language for these processes and a clear program, described concisely by Newton in the *Principia* as "the whole burden of philosophy seems to consist in this … from the phenomena of motion to investigate the forces of nature, and then from the forces to demonstrate the other phenomena" [Cajori, 1934, pp. XVII–XVIII]. This program led Newton to discover the law of gravity force and his explication of the *system of the world,* the operation of the solar system.)

Before moving on to humans, it may be instructive to briefly consider a simplified model of a much simpler system, a colony of flagellated bacteria at low concentration (so that they do not interact directly with each other). The interaction modes for the bacteria are few: They ingest food, swim in a straight line by rotating their flagella in one preferred way, and tumble in motion by reversing their flagellar motion. The experimental findings were that in favorable media, the straight-line segments are longer. The resultant motion is an apparent diffusion of the collective group up a favorable food gradient. In addition, there is a grow and divide period, at the end of which the bacteria divide in half (double their number) by reproductive fission. That time scale depends on temperature; it is about 20 min at room temperature. The rudimentary value system for these bacteria—their world image—may consist simply of an image of its interior and its immediate surround. In Iberall (1993a), among the 20-hr lecture series given at Storrs, Connecticut, there is videotape that expounds in detail on the flagellated bacterial colony example. It is demonstrated by Scott (1963) that such a description is sufficient to control in a simple fashion the population number and location in space of a colony of such bacteria.

SAMMY–SAMANTHA: THEIR MAMMALIAN INTERACTION MODES

What is unique in HK theory, from my original article with McCulloch (Iberall & McCulloch, 1969), is the characterization of its dynamic operation by modes (modes of or modal action). That usage emerges from both physical thought and musical thought of what modes are. Modes were referred to several times before, specifically in the bacterial example. The core idea is that systems are best analyzed in terms of their cyclic behavior. However, as drawn in music, it is the complex orchestrated form of those cyclic processes. Many accounts of HKs have harped (as one does with the instrument's orchestration of its strings) on the centrality of finding a spectrum of cyclic processes both for theory and method. For biology, the delineation of cyclic processes is called *biospectroscopy.* Science offers inventories, such as primary data, to be accounted for in any candidate theory. (However, do not expect music in a dance mode composed by Salieri to be as rich as one composed by Mozart). These we take to be what is regulated in command and control as well as the means of the regulation. Although saturated in complexity, we do not think that even in humans the spectrum of processes is numerically large or densely packed. There is some basis for optimism in attempting to begin study of an art for decoding composition.

A generalized description of the interaction modes for mammals, as given by Scott (1963), is said to involve nine patterns, systems, or functions of behavior:

1. Ingestive behavior.
2. Eliminative behavior.
3. Sexual behavior.
4. Care-giving behavior.
5. Care-soliciting behavior.
6. Agonistic (conflictual) behavior.
7. Allelomimetic (mutually simulative common) behavior.
8. Shelter-seeking behavior.
9. Investigatory behavior.

These modes have both genetic and epigenetic bases for emergence. As suggested in Iberall & McCulloch (1969), a related set of nearly 20 behavioral modes was offered for our species as a neurophysiological–biophysical basis for an early HK characterization. It is often regarded as one of the hallmarks of HK. These modes, adding up in their time occupancy to nearly 100%, are

1. Sleep.
2. Work (directed motor activity).
3. Interpersonally attend (body or sense contact).
4. Eat.
5. Talk.
6. Attend (indifferent motor activity, involved sensory activity to nonpersons).
7. Motor practice (run, walk, play).
8. Anxiety.
9. Sex.
10. Rest (no motor activity, indifferent internal sensing).
11. Euphoria.
12. Drink.
13. Void.
14. Anger.
15. Escape.
16. Laugh.
17. Aggress.
18. Fear, fight, flight.

19. Envy.
20. Greed.

Note that we denote the general physical scheme as HK by which a viable autonomous system runs through all its operational modes in a self-regulatory way. The problems that we confront as students of society are (a) what are the drives or potentials that can make a command control system as a system of governance? and (b) how do they manage to solve the problem both for the individual running of the organism and for the social group, or the collective? Some of the potentials are clear. There is an energy flux from the sun. Then, there is the host of chemical potentials needed to supply carbohydrates, fats or oils, proteins, or a rich supply of 20 or more amino acids, some small atoms or molecules such as oxygen, nitrogen, carbon dioxide, and a fairly rich trophic web of other species required for a number of essential symbioses. Then, there has to be an onboard genetic potential in which the species involved is competent to reproduce its numbers. However, this has not gotten to all the other essential internal machinery, particularly that related to the central nervous system and how it manages the command control act. For the *Homo* line, in particular, *Homo erectus* and followers, studies have shown that there had to be an ability to create tools by means of an epigenetic rate potential that started as of 3 million years ago.

Value System

So far we have stressed that the common form by which atomistic motion is driven in a self-organizing fashion is by their collisions, which make up a pressure on up to a simple class of isotropic stresses. For systems that can evolve to more complex processes, that external form of stress is augmented by an internal physical process, the bulk viscosity. When the time scale of that internal set of processes is quite large compared to the external collision time, the atomistic player is identified as complex. Because this is a physical study, the only possible internal processes that emerge from the complex atomistic interiors have to be physical–chemical. We are forced to visualize that complex of internal actions as an orchestration of the internal mode developing players. Who and how the orchestration is led cannot concern us. Like many ensembles, one or more internal atomisms may be doing the job. Whether written or improvised, the orchestration comes out. Please note that in western orchestral music, the cyclic processes are written down for each instrument (or ad libbed) and the conductor, perhaps at first ad libbed but then set according to memory (remember how much more difficult this is for recreating a dance performance even if the music is cast). That format for retaining the orchestrating performance is called in HK the *value system.* It is an entire weighting of elements of cyclic and modal performance that is so represented. We would like to think of values as the dimensions along which directions of choices among modes are defined and selected.

Our depiction of the human value system as a set of nine directions, views, and images of the world was introduced first in a government report in 1981; it can be found in Iberall (1984a, 1984b, 1985). We later added a 10th direction or component, that of rational description. The nine views are internal world images of

1. Internal self and outer world.
2. Interpersonal relationships.
3. Nature.
4. Society.
5. Ritual and institution.
6. Other living organisms.
7. Technology, more broadly of culture.
8. Spiritual causality (fathers, leaders, gods).
9. Art forms (abstract representations designed to attract attention in sensory modes).
10. The 10th component relates to rational description as a form of influencing action.

At first these value system specifications will confuse you. Think of the musical form of *Peter and the Wolf.* We are told that each instrument (the cycling notes it plays), represents a person character in the story to be unfolded, and then the story is unfolded by the instruments representing the players, directed by a conductor. This almost precisely represents a value system specification. These value system components may be described more objectively (Appendix D) in forms that apply both to living and nonliving systems.

It is clear that the value potentials, as described, are richly endowed functions held in memory and that this memory must be in an underlying chemical form (largely endocrine and neuroendocrine). The chemical basis of the potentials and its translation into our higher level natural language are, however, beyond current capability. Each such description, as a higher ordered system description, has to be a very complex dense set of rules (processes) which would govern, on selection, how the person would interpose a view of quickly reacting to and solving a problem. Note what functions each of the 10 components have to provide in our construct. With chemical signals crossing through the appropriate membrane gatings, each of the world images has to be able not only to help in the switching among perhaps 20 or more modes, but it has to elect the kind of general conduct that would emerge in that mode. It has to suit many operational time scales. (In simpler forms, it has to suit many other complex systems. The basic idea is that the more primitive the complex system the more the value system would be associated with the minimum number of the first few value compartments, for example, world image of self and outer world by identification of very little else than a near field and far field at the local boundary.)

However, how can the value system accomplish the formidable task assigned to it in our construct? In reply, we say that the value system operates by a separation of labor involving different actions over different time scales. The shortest is the about 6-sec time scale of perception–cognition (in all mammals, as observed by Gerstner, 1992, every 6 sec there is reconsideration of the flow of cognition as a catalytic action stream via the nerves and the blood flows). A consequent choice of action, if it is to be by the value system, is not going to be by an entire logbook representing the stored value system. There is not enough time. All that can emerge is an action phoneme, a very small part of an entire complex value system. All that can take place is a very small change in a motor system, a small change in internal nervous system catalytic direction, or some continuation of what has already been started. (For the reader who feels perplexed, please start back from Young's, 1966, lectures on *The Memory System of the Brain,* on representations and engrams). Thus, the basic choice is only of a choice in directionality among the 10 value directions. The most common low-energy selection in all mammals is a motorsensory election to pursue the world image of self up through its proximal boundary. Thus, (a) you may continue your attention to scratching your nose, (b) you may switch to another motor process, or (c) you may switch to another value component, such as interpersonal attention. How many such compartment switches may you make? The nominal order is of 10 directions. In time, that will add up to represent the magnitude of your social pressure, which, as indicated in Iberall (1992), may be able to control as much as 500 kcal-days of action per factory day in Earth rotation time. What is not clear is what sort of pattern of modal action at the long time delay in bulk viscosity may be elected.

For an image of that process, we can consider the equivalent of 20 or so monitor screens running on continuously, producing interminable scripts of all the past actions in each of the interaction modes. (One suitable storage place for many of those scripts is the basal ganglia.) The totality of bits, or scripts, or scenarios that are running on indefinitely, interminably, for example, are of you in every way you conduct a sleep mode, a sex mode, or a personally attend mode, and so on, representing, in total, the content of your past modal performance. (Is this literal? Yes and no). To begin such a study, past its origins in the 1930s, it is useful to examine movement control as Russian investigators picked up on it and pursued its isolation in such preparations as the meso-encephalic cat (see Gel'fand et al., 1970). One finds that with a small segment of a cat's central nervous system, much of the rest cut off—with a decerebrate cat lying splayed out on a continuous belt treadmill—on startup of the treadmill, the cat picks itself up and begins to run off a patterned response of locomotion. Such a program is to be found in limited segments of higher nervous structure and function. The movement required no 6-sec integration into an organized cognition, only a limited amount of system machinery, and the treadmill switch. It is likely that there is an averaging or biasing function that blocks out too much repetition, filters out much of the past (except for characteristic or outstanding examples), censors painful examples, and stereotypes your performance to a particular form of running mode.

Why can we say that, expanding even more outrageously on our first example involving storage or patterned program information in the very unusual event of decerebration? Get on a bike after 20 years of neglect, or recognize a person you have not seen for a long time. Note how easily you fit a next action, for example, in 6 sec. The details of how you learned to ride or first met the person hardly matter. Your distributed nervous system running stereotypes permit you that capability. How you are inclined to switch directions in each of your value compartments into a sequence of modal changes represents your value system. It is a very highly ordered matrix with a complex of temporal periods that are periodic and episodic. Yet, as Iberall and McCulloch (1969), the entire performance unfolds posture by moment.

Thus, electing at 6-sec intervals, after a moderate number of such serial elections, the social pressure measure is near short-term equilibrium. The prevailing stresses outside are met by these compartment elections—a kind word, a kiss, a blow on the head, work with the hands, or a recognizing nod of the head. In a day, it adds up to a person's near energy average. However, the values are not yet totally defined for the longer term. One has to watch the scripts over days, often years; many such days of performance until the energy settles down to more predictable averaging script actions. It takes that much time for the people around to figure out whether a person is a nice person or a bastard. (I make this statement flat out, based on 80 years of experience. I have no indication that we know each other well in less than 60 years of experience. So, unless you are married or otherwise strongly befriended for that length of time, minimally, I have little reason to trust your judgment.) Other mammals do the same but from a poorer repertoire of switching and modes. After you have raised or lived with a dog, cat, bird, aunt, friends, husband or wife, employers and employees, and the like, you acquire some sense of their value system, and signatures of physical–chemical behaviors that make up their value system.

I try to help the reader to understand how the value system was fashioned among humans (particularly) but also that which is relevant to all other mammals. By birth, some of the value system compartments are already quite well formed, as well as many of the autonomic mechanisms. The former are ready to run at their near 6-sec election. However, the modal tapes, although they exist and have begun to form in utero (taught me by Paul MacLean), are rather impoverished. Particularly in the human but also to a lesser extent in many other mammals, the mothering one begins to interact and direct the play of behavioral modes as the newborn infant perceives them. Does she interact throughout all 6-sec cognitions? No. However, she interacts quite frequently. In humans, that process of binding and bonding occupies much of the first 3 or 4 years of the human infant. It is not only a language of speech and body gesture and comportment that the child learns but a body motor behavior language. That entire superego structure, as Freudians refer to it, or its Gestalt (or the 10^8 or so units of bulk viscosity content, see next paragraph), all of the nonautonomic volitional content of behavior, as driven by a value system, drawing from the learned content of modal tapes that the human child has stored away and then continued to develop for perhaps the 30 years of a more complete bulk viscosity measure of 10^9 units takes place. Remember that of the total action available to the human, only 500 kcal per day of energy is available for intentional action. The first article in which I was able to give some expression to the business of internal neural action was Iberall (1973b). That article referred to how I and Brian Goodwin attempted a kinetic-like measure for the nervous and chemical mechanical activity within cells and the brain by suitable notions of their rather specialized temperature measures. Value systems are running in all mammals with rather rapid metrics. It is the total experience of life that furnishes the content of the value system. It is not a system whose characteristics can be rapidly changed. You are constantly running with it in the characteristic way that your mothering and nurturing one had been developing in you.

As a consistency argument of the time scales of the value system election, note that we had provided the ratio measure of about 10^8 to 10^9 units of time scale in the human bulk viscosity measure to the translational shear viscosity momentum transport scale (Iberall, 1995). Suppose we assume that the translational information time scale from the environment is about 1 sec. This is a long time for a single neural unit reception but rather short for a 6-sec perception–cognition scale. Reacting to that many bulk viscosity units at the latter time measure represents a period of time on the order of 10^8 to 10^9 sec. At 10^5 sec per day this represents 1,000 to 10,000 days or 3 to 30 years of time in which a value system is built up. This agrees with our modeling. The short 3 year time is about the time that Freud's followers (e.g., Melanie Klein) viewed the child's superego or other higher ordered languages to emerge, and the 30-year scale is what is judged to be the beginning of adult maturity after an extended adolescence. The only other question we have to answer is whether in or at the 6-sec cognition scale there was enough time to make the election of 10 value compartments multiplied by 20 modes with some fast modal selection of a fitting action segment or phoneme. One 20th of 6 sec is about 0.3 sec. We believe that is just about the time to choose for or from well-practiced social pressure language. It is the beginning of a complex internal perception in the running storehouse of motion picture scenarios. As you may note, it is well stereotyped. You do not think about your values, you just do them. Well-practiced simple actions can be done volitionally at 10 per second. (Consider sight reading consecutive notes in a musical phrase. My mandolin playing partner and I did this every week as amateur musicians sight reading new music most of the time. We are hardly professional, but we have managed to play roughly in time at near indicated tempos. We play from the baroque violin repertoire—Corelli through Bach.) Magic number seven elections among modes can be done error free up to perhaps 20 bits per second. That, or some average of half that rate, is what you do informationally speaking day in and day out. (If you literally try magic number seven election of modes or they are forced on you for extended periods during the day, you will find how stressed out you can get. You can always think about the one individual who ran

168 miles in one 24-hr period, truly probing at limiting thermodynamic performance; just recently reported once again, the few individuals who have done, day in, day out, 100-mile runs; or individuals performing any of those other taxing ultra-efforts.)

A Day in the Life and a Commentary

One wakes in the morning out of the action of internal physical–chemical coordinates. A physical–chemical coordinate switch leads to food procurement. Is the entire script from waking to eating written? No. One starts and fills in the action stream both by stored routines and opportunistically via physical–chemical coordinates. You do not go out and hunt for breakfast; you walk to the fridge. Much of the pattern of those streams may have been culturally cast. Skipping all of the standard litany of the individual's Earth day, consider the more usual and exotic features of modern life. One is thirsty, the physical–chemical coordinates drive one to innumerable ways to obtain a drink. If stress is high, you might take a pill. If you cannot deal with the stress, you may do harder drugs. If you need some physical–chemical coordinates coordination, you may see a doctor, a psychiatrist, a psychologist, or a social worker; take up religion; or respond to some passing sex symbol or the next propaganda object designed to get your physical–chemical coordinate attention (e.g., excuse me, the phone rang; someone wants to sell me something). Go write the entire stream of 15,000 units of physical–chemical coordinates you elect each day. (At 6 sec per election, there are 15,000 in a day.) All of this can be done up to the ability you have to manipulate part of your 2,000 kcal day action stream per Earth day, or likely the more limited 500 kcal you have available each day for the more volitional component of your action stream.

After some period of long ago, about 2.5 million years, people began to invent and hold in memory scripts for increasingly greater action-producing capability (energy—time augmentation) in the form of external tools—language, coordination, manipulating with greater strength than bone, and new energy storehouses to tap. Our companion organisms—not the first in creation—make use of technology. Other living units build nests, structures, hives, cooperative patterns of motion, symbioses. However, the continued operation of an organism does not necessarily depend on such usage. Some creatures are deaf, dumb, or blind.

If you are not satisfied with the scientific detailing of our descriptions in broader or more detailed aspects, then jump in. Do better, improve the depiction; it is the best I could do in 35 years.

One has to appreciate that behavioral homeokinetics, behavioral thermodynamics, particularly for complex mammals, especially human (cf. the same complex metabolic processes for a flagellated bacterium) is indeed a hierarchical complex. Just as looking at the meteorological processes emerging out of a field of atoms, ions, and molecules (nitrogen, oxygen, carbon dioxide, water vapor, ozone, oxides of nitrogen, and other minor ingredients) chattering away at perhaps 10^{-10}-sec relaxation time processes, nevertheless producing an irreversible thermodynamics good down to perhaps 10^{-9} sec (representing one Gigahertz of fluctuating processes), is yet hierarchically involved in processes from single shocks (recall the last sonic boom you heard) up to processes as long as 10^5 years (do you think that the last earthquake or volcanic eruption you may have read about was the first one ever?). Is the storminess of weather that you perceive every day of your life any different that the storminess of the weather of your mind?

Are you capable of dealing with all that detail? The obvious answer is no. At scales less than fractional seconds, you know almost nothing; it is all handled for you. It is a slower stream of less than 20 bits per second that you have to confront. Psychologists are aware of how much is packed away into routines and the like so that the environmental stresses of the milieu are not overwhelming. Memory banks give an overwhelming sense of the past that you seldom have to confront, except in isolated bits and pieces. How large is that huge set? Can you really regurgitate the content equivalent of perhaps 30 books (of your life, not of other authors). So, as you see, a routine of motion pictures makes up a large component of your value system. It permits you to equilibrate the stresses brought to bear on you to the extent that it is barely the sort of content that you can handle. You can look at your favorite dog, cat, cow, pig, lion (cheetah?), monkey, ape, flower, and the like and wonder how extensive a value system that organism carries; that it carries one like yours is clear. It responds as frequently as you do; it survives and goes about its business with or without you. It seldom depended on the beginning of its life on you.

REPRISE: HOW AND WHERE I LIVE

So, let me end with a picture of a community that many of you are not familiar with; it is my community, a slightly gilded mausoleum for active seniors (about 20,000 of them), ranging in age from 55 to 100 years. They are middle class, ranging from somewhat impoverished to quite well off. It is possible that their outlook on living may very well have been that of the thanocratic society of ancient Egypt or the palace culture form of Crete.

This contrasts with another co-op where I grew up, which was one of the earliest in New York City, emergent out of the co-op movement and consisted of a few thousand families in our one set of dwellings. It still exists successfully after 72 years, with many descendants from its earliest memberships. My sister, for example, just gave up her apartment there a year or so ago. Life there resembles a much more normal, socially productive, middle-class life in the big city than my present retirement co-op.

For people in my community, procreation activities are not on their minds, although they are almost all endowed with children, grandchildren, and lesser numbers of great grandchildren. Sex or sexiness is quite frequently on many of their minds, although I am not prepared to say (but can guess at) their actual performance.

Physically, they are largely active and busy all day long. There are people out walking briskly in the wide streets of our gated community from about 6 a.m. to 8 p.m. They are commonly in bed by 9 p.m., although lights attest to TV and such perhaps to 11 p.m., very few even later. One should also note that a number of times a week, paramedics and ambulances come to take or to carry weaker members of the community to medical facilities for care.

However, let me dwell on the much more frequent activities. Any activity I name includes more than 100 people. Regardless of the activity, they cluster. There are swimmers; golfers; tennis players; dancers (folk, line, ballroom, tap); runners; horseback riders; bicyclists; walkers; machine exercisers; badminton players; archers; players of shuffleboard , lawn bowls, and table tennis; hikers, gardeners; bridge players; card players; players of mah jongg and scrabble; wood workers; lapidaries; sewers; photographers; painters (oil, water color, Chinese, pastels); actors; lecturers; music and opera appreciators; those giving music lessons or playing in group; social activists; and those who do pottery, participate in social clubs, play checkers, play chess, and work or play with computers. These activities are frequently at national championship senior competitive levels. The neighboring college has an entire spectrum of academic and nonacademic courses that it gives at the community for these people.

Note that there are specific rooms, clubhouses, and equipment for all these activities, including meeting rooms holding up to 800 people that are used from a few times each week up to nearly every day. People are also either in process of going or coming back from trips that are organized for days or several days.

Of course, to repeat, there is a moderate percentage who are inactive or nearly out of it, as the paramedics and ambulances also testify. The economic level of the management alone of the organized community is at a level of about $60 million per year.

Just to furnish you with one of my role models, there is a little frail lady, 88 years old, 4 feet 10 inches tall, and 98 pounds, who swims every morning at 7 a.m. Her vision is almost nonexistent. She walks more than a mile to and back from the pool, involving a steep hill climb. Heaven help any 55- to 80-year-old who tries to keep up with her on that hill walk. She buried an even frailer husband a few years ago, so she has to make out now from her own resources and intermittent attention from her children who are not too close. She lives with a quiet intensity or desperation off her activities.

I am serious in presenting you with this picture. These people are not gainfully employed in a social sense, although they contribute very largely to support the local economy. They have just become an incorporated city to defend against the encroachment of very rich developers with great political power. There are innumerable shopping centers and malls that have been built to serve and accommodate them. Their life may be described as hedonistic. They intensely survive to serve their own pleasures and needs. A person like myself, active in a remote world, is simply not understood in the community.

Deterioration after some point is a fact of life with them. However, their lives are made up of that directed flow of daily actions. Their connection with the real world of daily concerns of a working populace is very minimal. They operate in a county that is a modern model for a screwed-up community. It has become a model for near bankruptcy, it has lost its support industry, it has extremes of nonproductive wealth and nonemployed immigration, and it has a few pieces of this type of never-never land. All in all, it serves as a model for a busy life process with a minimum of creative productive social goods. If you write down individual action programs, down to a 6-sec level and up to a generation level, one could get a sense of how life can be conducted in a simplified and stereotyped trivialized human form.

Depending on a moderate bias in the choice of action concentration, their lives stretch on for about one generation out of a very busy stream of 6-sec elections that create their reactive social pressure to the stresses of the environment. They each write their true romance—Harleqinesque volumes of about 15,000 elections per day multiplied by 360 days multiplied by 30 years equal to about 150 million action phonemes, perhaps 30 million action words, 3 million action sentence streams. Out of that dense stored loom of experience, out of their diatomic pairings, or their broken monatomic remnants, they carry their memory banks. The permanent memories, overlooking the gaps and holes and lost materials, most often constitute a modest fraction of those sentences. If you socialize with them, you may hear endless repetition of a few handfuls of themes, perhaps hundreds of paragraphs. Economically, to put another face on it, they represent a yearly economic commodity of about a half billion dollars in expenditures. They do have a range of competences. They live and operate in a county of a wide range of wealths and a more limited range of productive output (not too far from Disneyland).

On the other hand, compare their lives and output with the nonharlequinesque poor, including the new immigrants into the county and the country. Their lives are not any such one-generation epoch. The state tends to overlook their future, offer them few services, and disregard their needs. They have to live truncated lives beset by poverty and by drugs. The books they write are smaller, different. Yet the total construct is similar for all members of the species. They likely represent the next soon-coming component of a new American civilization. It takes a conservative pope to remind our wild extremists how to maintain that society.

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I am currently retired from the Crump Institute of Medical Engineering, University of California–Los Angeles.

As with essentially all other technical articles produced by members of our group, it becomes increasingly impossible not to be aware of each person's HK roots. I have to acknowledge the magnificence and intensity of the contributions of the editor and of my colleague, Harry Soodak, who composed Appendix B at my urging. The fact that these names are not listed as co-authors is their prerogative, not my choice.

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APPENDIX A

A first system application, in loose form and which was so stated, is to be found in a well-known theoretical article (Iberall, 1950) used widely by engineers for the propagation of pressure in all long tubular lines. That article completed and unified 19th-century studies of Helmholtz, Kirchoff, and Rayleigh. Within that work, I and my National Bureau of Standards (NBS) colleague showed that the small amplitude equations in all Navier–Stokes fields of phenomena were factorable into subordinate process components. The Navier–Stokes equations, themselves, are a unification of the laws of physics at a macroscopic level, for example, Newtonian mechanics, coupled to a first order description of the microatomistic kinetic laws of localized field transports. By studying the complete Navier–Stokes equation set, for example in directed flow as in tubes or sheets, I was able to find the foundation on which it could be shown that all field processes were either diffusive, propagative, or convective (Iberall, 1976, chap. 3; Iberall & Soodak, 1987, chap. 27). In my original talk at the NBS in 1949, I indicated that the extension of the small amplitude linear results to large amplitude dynamic fluctuating phenomena would likely include about 30 odd different kinds of dynamic fields. That result encompassed the field phenomena in a fluid among all external collisional variables. However, more important for my purposes here, in other fields involving extensive nonsimple animation and other internalized processes welling forth from complex atomistic interiors, the same limitation held for transport of internal factory day action from those complex atomistic interiors (see Greenspan, 1954, 1959; Iberall, 1963). Thus, my basic conjectural proposition was that a Navier–Stokes type of description of all transports down to the sum of 10 factory days plus interactional external scale relaxation times and effective related space paths would hold (demonstrated, again, more simply in Iberall & Soodak, 1987, and Soodak & Iberall, 1987). That demonstration crosses the Rubicon from fast atomistic processes involving external collisions (the layperson's picture of physics as processes involving colliding billiard balls) to slow atomistic processes involving the extended internal memory functions represented within a complex physical–chemical factory in each atomism, or, to quote my (Iberall, 1993b) discussion of the *factory day concept*

> This transformation from the conservation of momentum to the conservation of a matrix or ring of action modes crosses ... from the domain of physics of simple systems to the physical domain of complex systems. ... Group action, associated bonding that arises from internal atomistic requirements, is what results. ... To the physical scientist we would point out that terms may exist in the diagonal components of the stress tensor which, even if the off-diagonal components (which depend on the velocity for a fluid) vanish, still influence action. This is the bulk viscosity mechanistic avenue through which atomistic complexity can emerge. Modern fluid theory clearly indicates that such internalized dissipative action can arise from correlated cyclic fluctuations that originate from volume associations at the atomistic level. (p. 57)

There is no homunculus inside a complex molecule, cell, organ, organism, or even most societies, but there is a complex extended spectrum of physical–chemical factory processes. Chemistry, to us, the making and breaking, exchanging of energetic bonds, regardless of the level of that chemistry, is essentially the physics of matter–energy fields engaged in electrical interaction.

On the base of kinetic theory, irreversible thermodynamics, Onsager's linear law, and Einstein's theory of Brownian motion—a set of ideas which leads to the completeness of the Navier–Stokes equations of hydrodynamics—irreversible thermodynamics, and even in extension to the Burnett equations (Hirschfelder, Curtiss, & Bird, 1964; Kennard, 1938)—we know that the direct forces driving such fluid-like systems, as externally applied surface forces, are various components of the stress tensor, such as the hydrostatic pressure and other deviator stress components involved with atomistic transports.

Paying careful attention to a considerable number of physical details, we can rather precisely state the applicable range of such descriptions (Greenspan, 1954, 1956, 1959; Herzfeld & Litovitz, 1959; Hirschfelder et al., 1964; Iberall, 1963; Kennard, 1938; Rossini, 1955). If there is a fundamental high frequency process (or relaxation time measure) and effective mean path space scale for the interactions among atomistic-like components (the atomisms in the field system; a history of an atomistic doctrine can he found in Toulmin & Goodfield, 1962), then the description will hold, according to a Navier–Stokes limitation, for field processes more extended in time or space than ten atomistic relaxation times or equivalent mean path space scales. Alternately, if Burnett extensions are carried forth fully down to three such unit measures, Einstein's Brownian motion theory, holding down to perhaps one and one half to two such unit measures, can be used to permit a scaling theory from the atomistic unit to the local near-equilibrium macroscopic field description in terms of recognizable thermodynamic measures like temperature, specific energy, pressure, entropy and the like by increasingly accurate atomistic stereotypes. See, for example, such application to molecular materials in Hirschfelder et al. (1964) or in NBS.

The mechanical pressure in a fluid in thermodynamic equilibrium arises as a balance between the short-range repulsion forces exerted between colliding atoms or molecules and the somewhat longer range attraction forces between atoms or molecules separated by a few atomic diameters. (See Kennard, 1938, for a more introductory presentation, or Moelwyn-Hughes, 1961, for a more detailed treatment.) The pressure in a fluid can be externally initiated or self-generated (e.g., by heat generation due to chemical reactions). It is noted that it is the existence of both the repulsive and attractive aspects of the interatomic forces that gives rise to separate low and high density phases, gases and liquids. For a fluid not in thermodynamic equilibrium, there is an additional pressure contribution associated with nonequilibrium adjustment processes within each fluid element. These processes give rise to a bulk viscosity and to an additional pressure contribution proportional to the bulk viscosity coefficient.

Quite some time after the long pressure line paper, we argued (Iberall, Soodak, & Arensberg, 1980) that the ratio of the internal transport measure, the bulk viscosity λ to the external shear viscosity transport μ, λ/μ, was essentially the internal time of the total factory day to the time delay of external atomistic interactions and that these concepts applied not only to the basic fluid level but also to complex systems in which the atomisms may be cells in a bacterial colony or persons in a human society. Further, the internal bulk viscosity adjustment processes generally give rise to a renormalized pressure that drives action streams, just as mechanical pressure drives mass flow at the basic fluid level. The term *social pressure* we believe, is apt. It wells out of all specific atomistic functional units in an organism, but it becomes an organized function of a collective, of cooperative action in complex molecules, of cells, of organs, of organisms (one or more), of an organized society of organisms, of the organized members in a species, of interactive interplay among species. As I said, Llinás and Iberall (1977) did make a beginning connection to the bulk viscosity, a single cellular membrane and its gates, but we could not get to higher ordered modeling at that time.

We chose to describe the social pressure in terms of a multicomponent value system and associated value potentials. Why potentials? Because we tend to regard the social pressure as ultimately deriving from a stored source of all the fragments in chemical memory by which the physical–chemical coordinates operate. Why value system? Because when we began to contemplate work within the scope of social science thought, as a further and perhaps last new extension of our homeokinetics physics, we had joined a newly formed American Association for the Advancement of Science devoted to the comparative study of civilizations, started a government project in that study, and began correspondence with a very old historian, Arnold Toynbee, before his death, and with the anthropologists, Leslie White and Conrad Arensberg. With the untimely death of White, we continued our interaction with Arensberg, and also began one with the political scientist—sociologist, Harold Lasswell. The *we* involved Harry Soodak and I. Lasswell put me onto the problem of us jointly determining and defining the basis for human value systems (for a flavor of his interest in value systems from the period before we met, see Lasswell, 1958, chap. 11). At the point, we had reached in our social physics research in the 1970s, that struck us as the missing problem description of determining what made the chemical bulk viscosity capable of driving the human stream of action, Lasswell and I discussed it for a number of years, but it was not until he died that I could bring our common hopes to fruition. Meanwhile, Soodak, Arensberg, and I got out what we regarded as our fundamental incursion into a physical theory for human society but unfortunately without Lasswell's contribution and a properly defined driving value potential (Iberall et al., 1980). That chapter had been invited by the book editors as a contribution to create a social mechanics, say for interdisciplinary engineering and engineering physics students. Our experience was felt to be just the right combination to be able to do it. and we were quite satisfied with bringing forth such a first document. I finally got to define the compartments in the value system (Iberall, 1984a, 1984b, 1985).

APPENDIX B

The most basic and most developed example of the micro–macro (atomism ensemble) relation is that of thermodynamics which is the study of the macroscopic properties of a piece of matter containing a large number of interacting atoms or molecules and the relation of these properties to those of the atomisms. (A more descriptive name for the subject would be *macrophysics*.) Because homeokinetics may be regarded as starting at this basic level of organization, the operating concepts and processes at this level contain important lessons for extending homeokinetics to higher levels.

Fundamental Fact: Thermodynamic (Macroscopic) Equilibrium

The fundamental fact of macrophysics, very well verified, is that the interactions among the atomisms of a system always move the system closer to a state of macroscopic–thermodynamic equilibrium; further, if the system is not externally stirred in some generalized sense, then the internal interactions eventually drive the system to thermodynamic equilibrium. If the system is contained within a container that is held stationary, then at equilibrium, the system is macroscopically dead; no macroscopic changes occur, no macroscopic flows of matter or energy occur.

Some of the macroscopic describers of an equilibrium state are the number of atoms or molecules of each type (the matter content), total energy, volume, pressure, temperature, and entropy. (The macroscopic describers are known more technically as the thermodynamic coordinates of an equilibrium state.) The following facts are true for a system at full equilibrium:

1. There is no macroscopic motion, that is, the center of mass of each small volume element is stationary, or equivalently, there is no momentum flow. The net macroscopic force exerted on every volume element (by neighboring elements and more distant objects) is zero. These properties describe mechanical equilibrium.
2. There is no heat energy flow. Temperature is constant throughout. These describe thermal equilibrium.
3. There is no flow of any chemical constituent (as in diffusion). The chemical potential of each type of molecule is constant throughout, which often signifies constant concentrations throughout. These properties describe chemical transport equilibrium.
4. There is no change in the numbers of each of the chemical constituents. The sums of the chemical potentials of the molecules are the same for the molecules on both sides of all possible chemical reaction equations. These properties describe chemical reaction equilibrium. (The chemical potential of any constituent is a well defined thermodynamic quantity, introduced by Gibbs. It may be defined as the change in the energy of a system per unit of the particular constituent added reversibly [at constant total entropy] to the system at constant temperature and pressure. It may, thus, be regarded as a kind of potential energy per unit amount of that constituent.)

It should be noted that in many situations a mass element or volume element is close to thermal equilibrium and chemical transport equilibrium (in the sense that the temperature and chemical concentrations are almost uniform throughout the element) and still far from chemical reaction equilibrium. This is true because the time to uniformize the temperature and concentrations in a small piece of matter is short, whereas the time to achieve chemical reaction equilibrium may be very long due to the slow rates of the chemical reactions involved. Similarly, a small matter element may be very close to thermal equilibrium and chemical transport equilibrium and yet be moving or even accelerating, as occurs in a volume element of a cup of tea or coffee that has just been stirred. In this case, the element is in thermal equilibrium but not mechanical equilibrium.

The microscopic description of a system is given in terms of a *microstate* which, in Newtonian mechanics, lists the positions and velocities of each of the many

many atomisms. At any one time, the system is in a definite microstate, and that microstate is continually changing due to the motions and the force-induced accelerations of the atomisms. The time course of the microstate is determined by the equations of motion of the system. Although a system at thermodynamic equilibrium is macroscopically dead, there is much action going on microscopically; the motions and interactions of all the atomisms.

Derivation of Fundamental Fact Requires Assumptions

The fundamental fact of macrophysics previously outlined cannot be logically derived from the microphysics of the individual atomisms, be that microphysics Newtonian or quantum mechanical. However, by introducing one of a number of different *ansatzes,* which may be physical-type assumptions, formal devices, or a combination of these, the desired derivation may be achieved. These ansatzes take different forms but all lead to a common equilibrium result. With no such ansatz, there is only the time varying microscopic description which is generally very complicated and replete with mathematical irregularities of many kinds.

One ansatz is the following. Assume that somehow, there are tiny uncontrollable unrecognized interactions occurring between the otherwise isolated system and the rest of the universe. Then it may be expected that these interactions act to introduce uncertainties or stochasticities or randomness into the system. That is, the time course of the microstates will be continually and randomly diverted from the natural and determined time course of the strictly isolated system, resulting in a statistical (stochastic) distribution of microstates. The thermodynamic equilibrium state would then correspond to that distribution of microstates that has the maximum randomness subject to the system constraints that remain constant or almost constant (for some significant time span) despite the tiny uncontrollable interactions. Such constraints are the matter content, total energy, volume, and total momentum and total angular momentum, which are usually tacitly assumed to remain at zero. Then, using a natural mathematical measure for the amount of randomness, maximizing this randomness measure results in a standard form for the so-called microcanonical equilibrium distribution. It then follows without further assumption that any small part of a large isolated system that is at equilibrium has a standard Boltzmann distribution for its microstates.

Boltzmann Distribution

In this Boltzmann distribution, the probability, or fraction of the time, that the system is in any particular one of its possible microstates, is proportional to the Boltzmann factor, given by $\text{Exp}[-E_{mic}/(k_B T)]$ where E_{mic} is the energy of the microstate, T is the temperature measured on the absolute thermodynamic scale (called the Kelvin scale), and k_B is a constant called the Boltzmann constant. The product k_BT is the natural unit of the thermal fluctuation energy at thermodynamic T. The entropy (S) is given as the product of k_B and the (natural) logarithm of the randomness measure of the distribution, and is determined as a function of the matter content, volume (V), and E of the macrosystem. The thermodynamic T is given by the differential quotient dE/dS, where dE and dS are the infinitesimal changes in E and S when the equilibrium state is infinitesimally changed keeping the matter content and volume constant. (Note that the equation $dS = dQ/T$, found in all first year physics treatments, is one form of the equation $T = dE/dS$.) S and thermodynamic T (and quantities formed using them, e.g., chemical potentials) are purely macroscopic describers, having no counterparts in the physics at the particle level. On the other hand, the numbers of each type of constituent, the E, V, and pressure (P) are directly related to microscopic describers for particles, or simple sums of them.

Equations of State

The macroscopic describers of a system in thermodynamic equilibrium are related by equations of state. The thermomechanical equation of state describes how the relation between pressure and volume depends on temperature. The simplest example is the ideal gas equation of state, $PV = Nk_BT$, valid for gases at low enough densities, where N is the total number of molecules. There are energy equations, giving the E in terms of the matter content, V, and T of the system. There are the chemical equations of state giving the chemical potential for each molecule type as a function of matter content, temperature, and pressure. Finally there is a class of equivalent fundamental equations of state that contain the complete macroscopic information in a single equation. One such gives the entropy in terms of the matter content, energy, and volume. The thermomechanical and thermochemical equations of state are all derivable from a single fundamental equation.

Departures From Thermodynamic Equilibrium

No system is actually isolated in nature. Our expanding evolving universe is not and has never been in thermodynamic equilibrium. Generalized stirring processes are invariably preventing systems from achieving full equilibrium. Departures from equilibrium are ubiquitous.

Departures from thermodynamic equilibrium may be regarded as having two different aspects, *side–side* and *local–distributional,* which may also be called *up–down.* In a side–side departure, each tiny macroscopic piece is imagined as being in equilibrium, having the equilibrium distribution, but the equilibrium state, described by its thermodynamic coordinates, varies with position. The degree of side–

side disequilibrium may then be measured by the magnitude of the gradients of the coordinates. In an up–down departure, each tiny piece is imagined as being homogeneous, with no spatial gradients but departing from the local equilibrium distribution of microstates. An obvious example of this is a departure from reaction equilibrium due to slowness of the chemical reactions. Another example arises when the temperature of one of the molecular constituents in the volume element is raised in temperature (by tuned laser heating, perhaps) above that of all the other atomisms. The same local region is then characterized by different temperatures for different constituents. More typical examples relate to internal motions within molecules and to associational correlations among molecules, such as clusterings. When the external conditions applied to a volume element vary rapidly enough, some of the rates of the processes that act to maintain or restore the local distributional equilibrium are not rapid enough, resulting in departures from that equilibrium.

Side–side departures result in side–side flows. A temperature gradient drives a heat energy flow from higher to lower temperature regions. A chemical potential gradient for a particular constituent drives a flow of those molecules from higher to lower chemical potential regions (usually higher to lower concentration). Side–side flows are in the direction to equalize the difference driving the flows. Thus, heat flow from hotter to colder acts in the direction of equalizing the temperatures. Significant mutual couplings can occur between pairs of these drives. A gradient of one type drives a flow of a second type, whereas a gradient of the second type drives a flow of the first type. When one type is thermal and the other chemical, it is a thermochemical coupling. (When the chemical constituent is the electron in a metal, the effect is called the thermoelectric effect. A temperature difference can generate a current flow and an electrochemical potential difference can generate a heat flow.) All side–side flows driven by departures from equilibrium are dissipative; they all lead to increases in the entropy of the system. An additional side–side flow in a moving fluid is a frictional, shear viscosity, momentum flow driven by the gradient of the macroscopic velocity of the fluid as a function of position.

Up–down departures drive redistributional actions in the direction to restore local distributional equilibrium. For chemical reaction departures, the chemical reaction moves in the direction from the side of the reaction equation with a higher group potential to the side with a lower group potential. (The group potential is the sum of the chemical potentials of the molecules on each side of the reaction equation.) For the example characterized by different temperatures for different constituents, energy flows by collisional interactions from the hotter to the cooler constituents. The associational departures alluded to previously result in redistributions of energies and correlations in the direction toward the equilibrium distributions. Like the side–side situation, all processes driven by the up–down departures are dissipative, increasing the total entropy. Also, couplings can occur among different up–down processes. Because of the various rates of restoring distributional equilibrium, an up–down disequilibrium can effect changes in the equations of state of a volume element that depend on the past history of the element. The introduction of a time dependence in the *P–V* relation, for example, leads to a mechanical dissipation within the volume element, characterized by the bulk or associational viscosity. The bulk viscosity is one example of more general couplings between side–side and up–down processes. In another example, a chemical reaction occurring at different rates in two adjacent volume elements generates a temperature gradient that drives a side–side heat flow.

Navier–Stokes Equations

What is new in the Navier–Stokes equations that is absent in the pure thermodynamics discussed earlier is the presence of the velocity flow field and its coupling with the thermodynamic coordinates. (Note that the macroscopic motion is affected by pressure and viscous forces, and the pressure is affected by the motion.) What is absent in most discussions and applications of the Navier–Stokes equations is a serious treatment of the local redistribution processes going on inside a piece that departs from local equilibrium. Although chemical reactions are included in some applications, the more subtle processes are typically "cartooned" in terms of a single parameter, the bulk or associational viscosity, leading to a simple augmentation of the pressure by a term proportional to the bulk viscosity.

Micro–Macro Relations

The microscopic action of a system at or near thermodynamic equilibrium is sometimes denoted as *thermal fluctuation.* It involves motions of atomisms, collisions between them, rotation and vibration inside molecules, clustering and unclustering of atomisms, and so on, all going on with thermodynamic stochasticity. At equilibrium, there is as much side–side fluctuational motion going in any pair of opposite spatial directions, resulting in no net spatial transport motion; (this is side–side equilibrium). At equilibrium, there is as much distributional fluctuation in any pair of opposite distributional directions (e.g., as much clustering as unclustering), resulting in no average net change (this is up–down or local distributional equilibrium).

In the presence of a side–side disequilbrium or side–side gradient, the side–side motions in opposite directions no longer balance, and there is a net side–side flow in the direction toward restoring equilibrium. In the presence of an up–down disequilibrium, the up-to-down fluctuations no longer balance the down-to-up fluctuations, resulting in net up–down processes.

Side–side equilibrium is achieved by collisional–interactional sharing of properties among atomisms in adjacent regions. The time scale for achieving side–side equilibrium in a piece of matter in which a macroscopic gradient is present (e.g. a concentration difference or temperature difference between two ends), depends on the collision rates and on the size of the region. For small enough regions, the time scale is usually some not large number of atomistic collision times, which is generally quite short.

Up–down equilibrium is achieved by collisional–interactional sharing of properties among atomisms in the same small region and by more involved associational processes. In the example characterized by different temperatures for different constituents, as stated earlier, energy flows by collisional interactions from the hotter to the cooler constituents. The time scale for this type of up–down process is again usually some not large number of atomistic collision times. However, for associational disequilibria, the time scale for restoring equilibrium can become much larger. This is frequently the case, as already noted, in chemical reaction disequilibrium, where the chemical reactions that restore equilibrium can be quite involved; the subject of chemical reaction rates is complicated. Complexities can also arise in other associational redistributions, depending on the complexities of the molecules involved and on the coupling between these redistributional properties and the flow properties.

Final Remark

One aspect of the challenge to homeokinetics is to adapt the previously described concepts to their operation at higher levels of complexity. At any higher level, what is the nominal, equilibrium, operational situation? What are the stereotypical atomistic behaviors corresponding to the equilibrium distribution of the atomisms in the basic example? How are changes or disequilibria to be described? What are the side–side disequilibria processes, and more important, the up–down?

APPENDIX C

The main purpose of this note is to offer the reader a very small idea of what sort of fluid mechanics—irreversible thermodynamics had to be developed to make it possible to reach the physics of all systems, simple and complex. The obvious interest of researchers had turned to the physics of complex systems, those identified—writ large—as nature, life, humankind, mind, and society. Their physics, as clearly ascertained, was that of fluid systems. Researchers did apprenticeship in that field, up through the physics and mathematics for laminar flow, issues of stability, up through turbulence studies. The American physicist and engineer were not tremendously interested in the nonlinear extensions. It turned out by following the leads of European technical people, west, middle, and east, we got the flavor of many pathways that attracted us with applied problems. Some of these were two phase flow, two or more stream flow, stability, rheology, thixotropy, and plasticity. In particular, by the

1950s, I was heavily into biological system flow. Through Katchalsky's and Onsager's interests, I began to master and develop techniques for dealing with multistream flow systems. Add Buckingham, Eyring, Taylor, von Karman, and all people who inspired me, the problems of all these complex fields line up to grab one's attention.

APPENDIX D

These represent a more objective identification of the 10 human value system components:

1. Space–time–action mappings of reality within an atomistic unit and in and within a near field envelope just beyond the boundary of the unit.
2. Force bonding (nurturing and affective relations).
3. Space–time–action mappings beyond the self boundary, thus, defining nature. This represents the far field character of the universe hierarchically detailed.
4. The matter–energy–space–time–action image of other equipollent (equal in force, power, or signification), like or unlike, atomistic units.
5. Hierarchically, transformation of the collections of interactive units into collectives of organized processes and forms.
6. Hierarchically, the more total ecology, images not only of equipollent units but extending to aspects of the external world of lesser significance.
7. Hierarchically, higher ordered transformations of action. (This was described earlier as technology, more broadly as culture. However, examine Iberall, 1972c, in which the third dimensional hierarchy of human mind is reverie, an ability to expand the notion of space–time–action into a very indefinitely extended sequence of action augmentations.)
8. As a hierarchical ordering principle, the relative strength of different driving forces creates inhomogeneous and anisotropic hierarchical governing orders (as for example, fathers, leaders, god-like figures—these figures are not isotropic) within the cell, within the organelle, within the organ, within the society. That such inhomogeneity can be maintained within complex systems is indication that they can move toward fluid–plastic–elastic near-solid organization (Iberall, Wilkinson, & White, 1993) as well as isotropic fluid-like states.
9. Hierarchically, the transformability of some processes involving low energy coupling is fittingly able to entrain directivity, as an affective order parameter system. (This was described earlier as the attention attraction of sensing subsystems in art modes. Play is likely an additional art form. Much more general, is the effectiveness of producing sensed, sensor, sensation processes to entrain a complex physical system. [As an indicator of such a process, the *LA Times,* September 7, 1995, indicated the fantastic pleasure that some, or all, dogs entered in a Frisky Canine Disc World Finals, that was to be held in about a fortnight, obtained from playing almost

incessantly with Frisbees and their masters or mistresses. The validity of the observation was verified at the trials on September 17th]).

10. (Earlier as a weak organizing augmenting principle, the intermittent use of rational study to govern decision making by the use of logical-mathematical rules of self-consistency.) Just as strings of coherence in limit cycles, language, dynamic actions, wave propagation, and kinematic chains can occasionally come into being, bulk viscosity processes are on the way to entrain such process chains of rationality. That internal entrainment represents the beginning of a number of hierarchical levels devoted to such weak rationality decision making.

The last element is the most difficult process that the human organism can attain in limited extent. Its limited range will result in dispute with mathematicians and philosophers. People are entitled to seek dialogues with systems other than members of our species. It distinguishes the physical–scientific belief system from these other belief operations and thereby leads to what became a commentary on dynamical systems issues. These are the kinds of processes in hierarchical systems that can lead to what becomes command control, largely at fast process scales.