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2 Dynamic Foundations for Complex Systems

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It has been argued elsewhere (Wilkinson and Iberall in review, 1986) that physics (social or systems physics) can provide fundamental concepts for the social sciences, among them political science. One of these foundational notions is that, beyond *morphology* or *microscopy*, lies *spectroscopy*. Microscopy is the identification of the various levels of form in a system; spectroscopy is the identification of the various levels or scales of temporal processes going on in a system. We here present an illustration of how one might initiate a political spectroscopy.

Some Physical Preliminaries

The treatment of the processes of *organization*, *transformation*, and *change in space* and *time* are the hallmarks of the science of physics and its applications. In a prior note (Iberall 1985), a social physics for modern societies was outlined. A physical context for such a theory, in the form of some elementary physical principles, may be found in Soodak and Iberall (1978).[1] The foundational construct of social physics is based on the physical theoretic of an *irreversible field thermodynamics*. Since these three words may seem completely mysterious to political scientists, we shall first explain them, and then show how irreversible field thermodynamics compels all scientific researchers to seek *periodicities* and a *cascade spectrum* of nested processes. We shall then attempt to locate the social spectroscopy that must guide social researchers, and within that the political spectroscopy that can guide political scientists.

Thermodynamics
Classical Newtonian physics deals with a number of straightforward mechanical interactions between matter components --rigid body connections, elastic interactions, gravitational attraction--involving their matter measures, momenta, and energies. Thermodynamics, viewed commonly as merely the study of heat flow, is not confined solely to pure heat flow between matter components but, as a multilevel theory, covers all interactions including and beyond the purely mechanical. Many of these interactions will not, in general, be mechanically conservative of energy, but will include frictional losses, chemical transformations, and phase transformations.

The major laws of thermodynamics are two: the first law states that energy is conserved in all interactions, but the second law states that, as a result of natural processes, there has to be a net gain in disordered activities. Energetic order is degraded--transformed into lower levels of organization. (Technically, the net entropy--a negative measure of geometrically and energetically ordered processes in systems--of the universe will increase. Whether the disorder increases locally within the system or is diffused out of the system, energy will be dissipated, reduced to a less available form).

Irreversibility
Because all natural interactive processes are dissipative, they irreversibly represent a net gain in disordered activity whose consequences can only be undone at energetic cost. That dissipation is lawfully describable (in an irreversible thermodynamic description) by the transport processes of diffusion, which may include chemical and phase transformation. Because we can describe such dissipative flows, we can track them.

Field
We can track irreversible thermodynamic processes (diffusions) not only in a "lumped" or "contained" form (e.g., as the interaction or exchange of matter and energy in a confined beaker), but also out in an x,y,z,t (space and time) coordinate space. Such a general spatial domain, in which state and change in the coordinate measures of mass, energy, momentum, or action are described by a set

of partial differential equations, is considered a continuum *field*.

We can state the expectations of an irreversible field thermodynamics as applied to *any* complex field phenomena in *any* ongoing (changing) operational system. Prototypical complex field systems are the atmosphere, oceans, lakes, rivers, clouds, plate systems making up earth tectonics, dynamics within a star or galaxy, dynamics within a living organism, and now dynamics within a social system (in which the atomistic players also change as the birth-and-death process courses on). The descriptive equation set, when or where it can be derived mathematically, is a non-linear, partial differential equation set.

Under the conditions we have described--complex field phenomena in an ongoing operational system[2]--we are instructed by the mathematics behind irreversible field thermodynamics that we can expect to find an extensive cascade spectrum of ordered and related periodic or near-periodic processes, and a certain kind of Fourier decomposability of the processes and states into such harmonic components. A strict theory would require a theoretical account of such harmonic components and their relations. Physics, as a discipline, accepts such discovery by either empirical observation or by theory, with the expectation that both accounts can eventually be made to square. At this stage of a social physics, preliminary experimental discovery is perhaps as much as we might expect.

A cascade spectrum represents a descriptive statement that, as fundamental conservations--of mass, energy, momentum, or action, and which may include population number in the living case--flow through the system, fast processes emerge out of slow processes. (A useful catch phrase is that "authority," in a physical sense, just as in a political, ecclesiastic, or secular sense, flows down through the system as "information" flows up through the system). To identify and study such a "spectrum" of processes is viewed as a spectroscopy. The physicist offers two kinds of observations and methods: microscopy--the determination of spatial morphological forms at various spatial scales, and spectroscopy--the determination of temporal processes at various time scales. Social science has developed its microscopic analysis of forms more thoroughly than its spectroscopic analysis of processes; indeed, its process analysis has tended to be nonspectroscopic--a description by periodic, unique causalities of uniquely configured events (even though it is obvious, for example, that, socially, day follows day or that generation follows generation).

Social Spectroscopy

Elsewhere we have expounded a homeokinetic physics of complex systems (Iberall and Cardon 1966; Iberall and McCulloch 1969; Iberall 1972; Soodak and Iberall 1978) whose physical foundation assumes that the form of such systems is hierarchically nested and arrayed. Thus complex atomistic-like entities (atomisms) exist (at every level); in interaction, they make up a near-continuum field. Because of stability considerations, that field breaks up into super-atomisms, etc. (an alternation of levels ...-A-C-A-..., where A equals atomism, and C equals a field continuum (Iberall 1972, 9-13).

For the purposes of providing social and physical scientists alike with a neutral concept, we define a social system as a system of chemically bound atomisms that exhibit an extensive spectrum or matrix of atomistic modes of action. Their action spectrum emerges from the "temporary" bonding, in a considerable number of particularly bound configurational patterns, among interacting atomisms. Thus a group of cells, organs, or people can constitute a social system (as can a system of complex molecules, e.g., as in a cell).[3]

It is, of course, evident that our concern in this chapter is with human social systems. But the purpose of providing the generalized definition we have given is to make clear the basic fact that there will be a spectroscopy associated with every field atomistic level, and the fact that these spectroscopic levels will intertwine. Thus atomic, molecular, cellular, organismic, and human societal process patterns cannot be sharply differentiated and studied in isolation. That this problem is common to all vertically adjacent complex system levels constitutes the social physicist's way of assimilating, e.g., the celebrated "level of analysis" problem in world politics.

Since the individual is the atomistic unit of society, we begin our social spectroscopy with some of the salient spectral "lines" (process frequencies or periods) of the physiological individual. The introduction and identification of a few of these lines may help clarify how the identification of spectral lines in society should be carried on. The fact that a few of the processes have at least a marginal political significance illustrates the interaction of differently timed processes at various morphological levels.

Our spectroscopy is "social," not merely "political." The political system regulates, governs, commands, and controls society. It has its spectra--its characteristic mean durations and periodicities--but these are not drastically different from more general social durations and periodicities, which are often connected by related processes. The political system must deal with all the other durations and periodicities as well, either by adapting its processes to the expectation of the continuity of the social rhythm, or by trying to shift those rhythms, which are soft, toward one or the other end of their normal range (e.g., by trying to entrain them).

We are asserting that properly founded social rhythmicity must be given equal status in social science with structural analysis; we are not alleging that it has no current status at all. Clearly, the story of generational periodicity (how the events of one generation are causally connected to the next) has had some appeal to the historian--note, for example, the commonness of use of the pendulum-swing metaphor. The succession of generations is obvious; it makes a tale relatively easy to tell; it is cross-culturally applicable; it is what connects the kings of England, the pharaohs of Egypt, and the emperors of China. But the generational scale is by no means the only cross-cultural process scale at which a story can be told, change be observed, comparisons made, or control exercised. Indeed, it is likely that each of the spectral process scales that we distinguish in the next section involves a largely autonomous history, insofar as direct causality is concerned.[4]

To allege that sociospectral processes are "largely autonomous" amounts to the assertion that an empirical study of the spectra of human actions will show them to be neither evenly nor randomly distributed over all frequencies, and neither normally nor log-normally distributed around a single central frequency. Loosely speaking, they will instead appear moderately uniformly along a logarithmic scale.

A higher-ordered theory, dealing with fractality and the extent of such fractality, will eventually be required to bind together the sheaf of processes all going on simultaneously. Such a topological theory--a scaling theory of processes--is under process of development for complex systems. But, as yet, we can carry our social spectroscopy no further than to display the process distribution pattern. The data are lacking because social science theoreticians have, by and large, not yet consciously attempted to write nearly autonomous process histories wherein the very weak correlation coupling of these processes may, in fact, appear. (Since physical theory also is, as yet, incomplete in accounting fully for the historical development and evolution of the cascade spectra of complex atomistic systems, e.g., the patterns of weather, social scientists who take heed and begin to write weak-coupled, multilevel social history and theory may contribute to, not just draw from, complex systems physics).

The Spectroscopic Time Scales

0.1 Second

This time scale is associated with the unit of electrical action in neurons as small bioelectric batteries (the bioelectricity emerges from electrochemistry). As such, it becomes a measure of the reaction-time scale of the individual. Bond formation and interpersonal reactions (neural elements within social continuity) may take place at this most rapid of whole-organism scales (Iberall and McCulloch 1969).

Although this time scale may not be the subject of much political regulation, nevertheless its existence is implicit in a great deal of social regulation. For example, it tends to define a causality in the starting and stopping of events (who or what started what), such as vehicular traffic control--when traffic lights should change, what traffic speed to aim for, or what constitutes safe legal driving conduct. Political events cannot take place more quickly than the split-second decision-time of human decision makers.

1 Second

This societal time scaling, by happenstance of biophysical design, is associated with the period of the human heartbeat, a period in the cardiovascular system that is involved in cueing many higher-ordered, integrative processes in the body. It has no particularly general physiological significance, but may be used to illustrate something of the character of physical theory for spectral lines. It can be shown, and also found experimentally, that the resting heartbeat period is, in general, proportional to the one-fourth power of body weight for mammalian species of different adult sizes. The one-second time scale is thus a mechanistic system's parameter in the natural design of mammals.

6 seconds
This, loosely speaking, defines the attention span of the individual (Iberall 1978, 540-541). The reader can verify such an attention process by viewing any of the ambiguous figures--blocks, crosses, staircases, duck-rabbit, lady-vase --and noting the average time of reversal in a long sequence of observations. Verification of this six-second attentional time scale also can be found in the psychological literature (Woodrow 1951, 1230). The result of a great number of experiments is summarized in the statement "The upper limit of the psychological present [for the individual] . . . lies between 2.3 . . . and 12 seconds." One surmises that it is the temporal epoch for percept formation. This period, found also in other animals tested, is presumably determined by one or more compartments in the mammalian brain. It appears in social processes as part of implicitly accepted human cultural phenomena. Politically speaking, this epoch may be the optimal duration of a political commercial. It was found to be the time scale for delivering messages on Sesame Street and the Electric Company programs, independent of age in the young (Iberall 1978).

The preceding scales are socially significant only so far as representing lower limits for quasi-conscious individual decision-making and action. They limit performance at which athletes, musicians, intellectuals, police officers, fighter pilots, and assassins alike can perceive a situation and take minimal action, such as playing a note, reacting, starting to run, or pulling a trigger. Society may wish to make routine, slow down, or prevent a variety of such swift human acts; if it wants to have faster perceiving and acting (problems of real concern in an advanced technological age), it must employ automata.

The next five physiological scales are of social concern mainly because they bear on work organization. The first four scales represent process levels by which mammalian organismic chemistry supports the body's motor-sensory performance. Quite possibly, they color or limit social-intellectual performance. At the fifth scale, we finally reach the limiting atomistic scale for social processes.

90-120 Seconds
This physiological epoch in the metabolic processes of the individual relates to the local relaxational time scale for tissue oxygenation and, as such, is the empowering scale for significant muscle-organized motor action. Socially speaking, this scale may represent a time limit on peak performance of difficult tasks, perhaps intellectual as well as physical, e.g., spontaneous oral production and aural comprehension of complicated social or political interactions. One may conceive of studies directed at discovering the transition from biochemistry to socially biased activity.

5-10 Minutes
This appears to be the relaxation time for the accommodation of blood-flow rate supportive of an extended body task. It is probably socially significant only in work time-and-motion studies, and work-station and work-process organization but, again, it may have social-intellectual implications for actions or decisions.

20-40 Minutes
This is the likely relaxation time for carbonate (acid-base) balance in the human organism. All of the actions of the body's organs have contributed to the biochemical disequilibrium (redox), which the carbonate compartment in the blood reequilibrates. This time scale significantly relates to the capability for social attentivity.

It may be noted that there is no one-hour physiological cycle; what comes closest is a biologically significant ninety-minute scaling, that associated with rapid eye movement (REM) during sleep (and surges of activity during the wake period). The hour and the minute, unlike the second, the day, and the year, seem to be artifacts of intellectual convenience (e.g., the convenience of a scale of sixty), without physical or physiological justification.

2-4 Hours

At this cyclic time scale, thermodynamic equilibrium for the whole body can be found (Iberall 1960). Among a number of equivalent formulations of the second law of thermodynamics is one that assesses the effects on the environment of a system and its working substances (e.g., the chemicals involved in a cycle of a refrigeration system) being taken through a cycle in which the system's final state is a restoration to the initial state, as, for instance, via a period or cycle of performance. Maintaining so-called homeostatic equilibrium by the body's metabolic machinery during the performance of a sustained task by drawing from stores involves such a cycle, during which work may have been done and energy will have been dissipated. Whole-body thermodynamic equilibrium cannot be found for any period of time less than two to four hours; its existence is acknowledged by the use of state averages taken over such a period or cycle of performance. The two- to four-hour scale is common to all mammals as the time scale for major tasks (e.g., a major work epoch). It likely represents a process of daily metabolic regulation triggered by cortisol (Weitzman et al. 1971, 1983).

This is the first microscopic scale that is socially significant outside the small group context. At every sociospatial scale, from individual through family, hunter-gatherer band, farm and village, to urban settlement, the earth-day is fragmented and supplied with rituals and institutions by which human actions, e.g., marketing, eating, praying, resting, transporting (Iberall and McCulloch 1969), are regulated.

The regulating functions of society tend to be organized around time chunks of this two- to four-hour thermodynamic equilibrium epoch. As one might see in cortisol pulsing (Weitzman et al. 1971, 1983)--as opposed to, say, the faster fear-fight-flight reactions that are likely tied up with adrenaline at the near-two-minute scale--the day's events are fractured: chemically, not mechanically, driven into segments, e.g., sleep, work, foraging, and interpersonally attending segments. That rhythm of daily alternation, without being mechanically clocked, has an epochal character of this order (Iberall and McCulloch 1969). Restaurants, transportation systems, department stores, markets, and cities are structured and operate with awareness of these process-times; so are armies and state institutions and functions, such as policing and other public-regulating functions.

24 Hour

The day-night cycle determined by the earth's rotation on its axis is found in the circadian scale essentially marked within the biochemistry of every living organism. It represents the first microscopic scale for *physiological* equilibrium in the individual (except for short-lived species with a life-cycle less than a day), and is the beginning of general social behavior. Over this scale most, though not all, human *actions* are discharged--in twenty-four hours, essentially all individuals have eaten (replenished stores), slept, worked, voided, etc. (Iberall and McCulloch 1969).[5] The sex cycle is a notable exception.

The prudent ruler (whether of family, band, settlement, city, corporation, or nation) does not attempt to control, nor even account in detail for, the outpouring of *action modes*.[6] At most, he or she should only try to, and can perhaps hope to, orchestrate that outpouring. Rulers gate, valve, channel, and orchestrate rather than perform or control the emerging daily flow of human actions. The wise ruler knows or must know that locally all these human actions have to take place, have to be allowed to take place, and have to be supported in taking place. Understanding reality is prerequisite to prudent governance. For instance, public resentments, fears, or uncertainties should not be allowed (and normally are not allowed) to go on for much more than one day or so; soothing counter-rumors have to be released (and are released) at that scale, which becomes a propaganda turnover time measurable in news media production schedules.

Between the two-to-four-hour scale (that is, by a number of such two-to-four-hour segments) and the twenty-four-hour scale, much of the local social regulation has been accomplished. Urban settlements with their rituals and institutions are designed to take the daily action spectrum into account.

3 Days

Although the action spectrum is largely discharged in a day, not all balances are achieved physiologically. For example, copulation in humans doesn't take place every day--whereas voiding most likely has. Its nominal time scale (via the sex hormones) suggests discharge at more nearly three days (performance limited by the male).

A physiologically more significant balancing process exists at this time scale. Body water balances in the body in about a three-day cycle (Iberall et al. 1972) within an extravascular, extracellular compartment, possibly via thyroid hormone--hormones are the chemical regulators or "escapements." This epoch may enter into social phenomena at somewhat longer periods--the social week (at times five days, and other times seven days) may have a weak biological determinant related to the three-day epoch. In any case, the three-day epoch also seems to be a significant determinant of the miniscale for social decision making. This probably occurs as a result of neurophysiological processes, of a brain function related to the biologically entrained earth-day.

It is clear that man does not perform a simple chain of mechanistic actions tied tightly to his circadian day. We tend to see, as a characteristic highly accentuated among humans, that man decides and must decide what to do with each day. Most primitively cast, this is the question of whether to perform tomorrow the same routine pattern that one performed today, or to do differently. If humans had no memory function and no elaborate decision-making apparatus (the central nervous system), one would expect the kind of result one gets with coin tossing. The choice for each day would be effectively independent. But humans have memories associated with their action spectrum. What emerges, instead, is a weak cycle-of-three (or so) process. Some sort of memory function carryover *has* taken place. But the result of that elaborate decision-making apparatus has turned out *not* to be that elaborate. If yesterday went well, why change; if yesterday was bad, should one change or try again?

One finds this kind of memory function carryover in stock market fluctuations and in those of daily trade. That is, as a result of daily decision-making, practically binary in form, an approximate three-day (or so) cycle emerges, because memory introduces at least some pair correlation between days. In fact, a socially viable group (one containing a mix of human capabilities at sizes between, say 25 and 500), when exposed to the task of living together, will have begun to form significant bonding and will have begun to sort out a program of actions and some rudiments of command-control rule in a period of about this time scale. As an academic illustration, massive lecture classes are rarely held less frequently than twice a week, presumably for fear of memory-loss and decomposition of the social whole.

30-90 Days

Another weak cycle of a different kind of causality exists at about the thirty-sixty-ninety-day scale. It most likely has a physiological (biochemical) base, and it emerges socially as a mechanism for tying the organism to the seasonal variations (Strumwasser 1971). Its physiological base is probably the turnover of molecular constituents, particularly centered in the central nervous system. Schoenheimer (1946) demonstrated that all molecular constituents in the body turn over; the average time scale for all ingredients is about a month, with considerable spread. The spread is much narrower in the nervous system--for example, a month scale is a major repair time scale for brain injuries.

It seems quite unlikely that there can be a perfect turnover of all of memory and point of view of the individual from epoch to epoch (memory, after all, has to be stored in some chemical molecular form, presumably dynamic). We conjecture that this turnover period is a major scale for fluctuations between an individual's major psychological states (Iberall and McCulloch 1969; Iberall 1978), and also that it emerges as the scale at which social "mood" changes by entrainment from individual to individual.

Our conjecture is that the major mood fluctuation is between an "anxious" and "euphoric" mood. We submit that the organism holds a world-image of a satisfying state. In a euphoric mood, the organism responds to deviations from that satisfying "image-ideal" state: the progression of actions and cognitions is driven leisurely by the perceived deviations from a mentally held view of what is satisfying. Individual motor-sensory acts and thoughts are driven mainly by how far operating conditions are from the ideal state (e.g., whether it is warmer or colder than desired; whether the gastrointestinal tract is more or less full than desired; whether the level of excitation is more or less than desired). On the other hand, when switched to an anxious or dysphoric state, the organism has "jittery nerves" and responds to environmental fluctuations, to *events* rather than to *conditions*, that is to the derivative action of images of the state variables out in the environment (as a distribution function of such jittering changes). The sequencing of actions and perceptions is "jittered" or "jitter-driven" in the anxious mood because every passing event and signal now receives special interpretation. We surmise that these two image states are held for perhaps a thirty-sixty-ninety-day epoch, pulsed slowly by an integrated memory of recent changes. Thirty to sixty to ninety days is thus an emotional-intellectual scale.

Note that this time approximates the seasonal scales of the year. The simple conjecture is that this process time scale can easily be entrained by the ecological changes of wet-dry or cold-hot, which essentially strongly drive all other biological species. But beyond that, the ruler, administrator, or executive finds himself exposed to changes in which he or she can only hold or develop coherence in the social group for this kind of few-months period; we submit that rulers tend to sense and steer by this scale intuitively. The memory function has difficulty in holding sharp images, including intense emotions, for much longer. This is the longest scale of "spontaneous" political events and moods within a nation, e.g., waves of war hysteria or revolution hysteria. Lefebvre's *The Great Fear of 1789* (1982) documents vividly how a wave of public opinion formed and condensed throughout France in a period of about a month before the French Revolution; many studies of the outbreak of World War One find it necessary to treat in detail only the decision period from 28 June to 6 August 1914, relegating the previous centuries to the background, because the war mood formed in a little over a month.

The thirty-to-ninety-day epoch is a measure of a process in the individual that is entrained, through social interaction, in the larger society, for instance as a measure scale of public opinion manipulation. Whereas social and political propaganda and manipulation of outlook has been demonstrably practiced by leaders all through recorded history, the tools to effect these results were significantly complemented by printing, then by radio, and most compellingly by television (with its total capability for immediacy) operating through the most vulnerable sensory pathway, the visual (Iberall 1973a). We now have twenty years of very elaborate and highly supported experiments in opinion manipulation. The monies spent in public opinion research and development far exceed, without doubt, all of the monies spent on the so-called scientific crusade against cancer. Yet, despite all the expenditure on manipulation, the director of the *Los Angeles Times* political polls concludes, from extensive polling experience, "Any poll taken more than six weeks before an election is a waste of time as far as learning anything [is concerned]" (*Los Angeles Times*, 10 June 1985).

Whether an adequate neurophysiological model for the temporal process has or has not been adequately detailed, it seems to us, from both passively and actively driven social events and processes, that any coherent outlook in a person or group is subject to excitation or decay at this time scale.

1 Year

The year scale, presenting the seasons, originates from the revolution of the earth about the sun. That scale is embedded biochemically in the entire ecological web, from the lowest photosynthesizers on up. Since man is tied tightly to plant and animal species for food supply and many other material and energy usages, this scale becomes a dominant one for social processes. Essentially all social planners, national, corporate, or local, pay careful attention to this scale. It thus becomes one of the essential miniscales for political and economic planning.

The physics of an atomistic ensemble, seen as a field process, is dominated by the characteristic "factory-day" scaling of its atomisms. For a simple gas-like ensemble, that "factory day" is measured by one time scale, its atomistic collisional relaxation time. For more complex atomisms, the "factory day" may involve a sequence or nesting of internalized time scales, for which the longest significant action time or times will likely dominate.

Whereas the fundamental conservations of mass, action, and energy are probably determined by the "factory-day" of twenty-four hours or so, a fourth (demographic) field variable of population number (which, we have argued elsewhere, is a renormalized conservation, maintained by the chemical potential of the on board genetic code and expressed through the sexual reproduction action process) is not determined by a "factory-day" of less than a year or so.[7] Thus, while the social process begins with a day (as a scale for practically all actions of the individual), it is not completed among living human social atomisms (as a social molecularity) in less than a year. This reflects the character of a general correlation between expanding form and function. The more inclusive the field atomism, the more extensive the schedule of processes.

With human settlement via agriculture, technology, and an extensive division of labor utilizing technological tools to amplify human action, man required the management of his speeded up convective processes--of manufacture, of trade--by value-in-trade, a newly appearing economic variable (beginning perhaps ten to twelve thousand years ago).[8] The accompanying emergent processes were posttribal political regulation, control, and warfare. The temporal scale of the year, which is "long" (much beyond an atomistic physiological scale) for the individual human organism, is "short" (a "first" essential miniscale) for the human social field. It is at the year scale that the composite actions of social atomistic groups--as social molecularities--begin to appear.

3-4 Years

Again, this is probably a cycle-of-three (or so) process that depends on a memory function at the highest levels of economic and political organization. One finds this to be both a major fluctuational scale of the rhythm of economic activity (booms and recessions), of trade activity in general, and of the political process, with some in-and-out-of-phase resonance between processes.

Just as the "hard-wired" year is not a seamless mechanical process when it relates to the considerable fluctuations in seasonal subprocesses, the much less "hard-wired" generation scale (which fluctuates more than the geophysical year) has subprocesses, whose political aspects may be elicited by asking, how long *could* the average ruler rule? How long *does* the average ruler rule? What accounts for the differences?

The reader can doubtless imagine an ideal hereditary monarchy, each of whose rulers reigns for approximately a generation, or an ideal elective monarchy where tenure might be reckoned as the life expectancy less a maturation time, say about fifty to seventy years. Actual rule spans, no matter how measured, are markedly less, by an order of magnitude.

We are misled to think of leadership as of generational scaling by the impressive careers of "outstanding" rulers, but their typically long-term tenure is atypical of rulers in general. Political rulers can, in general, neither elect nor be elected to rule a generation; the memory function of the ruling elite and of the ruled populace interferes. Ruler power is curtailed at much shorter intervals--by custom or design (rulers may be expected or elected to serve for a particular period of years), and by intervention (rulers may be deposed), as well as by physiology and psychology (rulers may die or tire of the role). Political tenure of the highest offices tends to average two to six years rather than, say, one year or twenty to thirty years. For instance, Grant (1985) discusses ninety-two Roman emperors and mentions nearly one hundred others over the period from 31 B.C. to 476 A.D., implying, as one of many such illustrations, an average period of political rule of about two and one-half to five years. This short average tenure suggests an implicit, underlying, binary yearly evaluation process with memory and involving weak decision making: Did our leader do well or not? Shall we continue support or should we temper our support? The frequent reiteration of that question is enough to account for the proverbial unease of crowned heads, and the proverbial fickleness of public opinion.

Even in atypically long reigns and tenures, just as the year is fragmented into seasonal and shorter changes, or the day into thermodynamic modal segments of action, the generational scale of a major ruler will still be fragmented by the interpositional scale of many subrulers, who gain and lose confidence (the rulers's rather than the electorate's) at about the same scale.

There also tends to be an in-and-out-of-phase "resonance" of the political and economic processes with the war processes. The frequency of wars, for example, demonstrates both a "small quarrel" scale of about four years (Richardson 1960; Wilkinson 1980) against a background of "large quarrels' in the ecumene at the rate of about a generation (Dewey 1964; Iberall 1973b) to a lifespan (Wilkinson 1985).

20-30 Years

The human generational scale (time from birth to the age for average reproduction), basically biochemically determined, obviously keys the social process. However, a social process could only exist if there is social-force bonding (Iberall and McCulloch 1969). We have argued that in complex systems a social pressure wells up from the interiors of complex atomistic entities (Iberall, Soodak, and Arensberg 1980)--humans, in the present instance. It is from the variety of internal actions in complex atomisms that this social pressure arises.

It is an essential ingredient of a social physics that one can argue physically for the existence of a social pressure; if that were not true then the application of physical science to social science would be very suspect. From endocrine systems, through the action of catalytic molecules, there arises sexual bonding, mother-child bonding and mother-father-child bondings: whoever accepts this proposition has accepted the idea of social pressure welling up from the interior. Beyond these intimate bondings, and via a variety of exchange systems (Iberall and McCulloch 1969), there exists bonding due to congruence, similarity, and empathy of interests. Together, these connecting "threads," all basically electromagnetic-electrochemical in origin, guarantee generational bonding. We would argue that these threads of connection also guarantee force repulsions--hence distinctions between friend and enemy, and neighbor and stranger. Suppose then that one accepts that there must be, and that biochemical bonding is, a biological basis for socialization at this generational time frame. What are its major social consequences?

There must of course be a "progression," a changing of the players in each generation. Just as the memory of our individual selves has to change each few months with the changing of the molecular guard, so the memory of our social selves has to change each generation with the changing of the population cohort. (As the Old Testament points out, "And there arose a new pharaoh in Egypt who knew not Joseph.") The point of view of societal command-control has to change, to fluctuate. One such major fluctuation is the occurrence of large-scale war, whose periodicity must be somehow associated with a generation-to-generation change in perception in the political ecumene. (See, for example, Wilkinson 1980; Iberall 1973b; Wilkinson 1983.) The two major large-scale processes that well up in *settled* social life (e.g., post-Neolithic times), in this time frame, are the intercourses of trade and war.

70-90 Years

The human life span lies in the vicinity of this range (i.e., nominally, three generations, effectively 90 years; 115 years is near to an absolute maximum in a large population). This 70-to-90 year epoch is just at or beyond the reach of the individual. At the two-generation scale, a child's grandparents may provide reinforcing or alternative role models to its parents; its great-grandparents are rarely available to do so.

But at the same time that this epoch derives from the life span of the human individual, it tends also to be the upper limit for the life span of equipment and mechanistic systems (i.e., those that are hard-stressed and not built like monuments to stand up idly with little stress, save by chemical erosion). If one inventories industrial, military, and individual capital goods, one will find it is not uncommon to discover buildings, equipment, and machinery that go back to 1950, prewar 1940, 1930, and even back to 1910. It is rare to find earlier capital stock, except for gutted and renovated building shells and perhaps some machines, essentially all of whose parts have been replaced, like the timbers of Jason's *Argo*, leaving us to wonder if the whole remains the same when all the parts are different. This age span is not exclusively a property of this industrial age, nor is it uniquely American.

From these time-scale characteristics of material bodies there may also emerge the Kondratieff cycle. Investment decisions tend to be linked quite widely throughout an economy. If entrepreneurs tend, as they do, to invest in new equipment at similar exogenously driven wave fronts (e.g., the postwar investments of the 1920s and late 1940s), they will also tend to wear out equipment at comparable times, and entrain endogenous reequipment cycles thereby.

From the point of view of kinetic processes, a three-relaxation-unit, three-generation time scale tends to represent a near thermodynamic equilibrium time scale. One can make such an estimate from Einstein's theory of Brownian motion: in about three collision times, energy equalization has effectively taken place. This has been shown to be true for the mathematically complex Navier-Stokes description of hydrodynamic flow fields. That equation set for flow fields lies at the core of all such mobile field phenomena, whether inside complex molecules, planetary atmospheres, nervous systems, stars, galaxies, or the universe itself. There is thus little physical doubt that it applies to the fluid flux of society. Consequently, one suspects that this seventy-to-ninety-year scale is the macroscale for social thermodynamic near equilibrium. In three generations, the individual has been passed over and the net effects of the lives of all those who have lived them out (the social consequences of all the interacting individuals) have effectively begun to spread out through society.

Beyond the seventy-to-ninety-year scale, the atomistic individual no longer appears, and we can properly speak only of group forces and actions in the species, of sect and party, class and corporation, church and state, nation and empire and civilization, of epigenetic group values that make up the social (partial) pressure of individual groups. This is the spectral level at which one can see the rudimentary elements of a mere social chemistry (chemistry: the making, breaking, and exchanging of bonds among atomistic fragments), which exists independently of the atomistic level within the field ensemble. Among them are mixing-pot phenomena.

Ordinarily, in simple fields (ones which have no extensive time-delayed spectrum of internal atomistic action processes), one would tend to find a sharp separation of solution and nonsolution formation. A difficulty that the social (e.g., political) scientist must confront is that the social milieu is not a "melting pot." That is, people entering the social ensemble do not fully mix and bond by giving up a true, fixed energy of solution; instead, they enter into a mixing pot. The human mixing pot is illustrated by, and largely measurable in terms of, regions of ethnicity. (An ethnic group is not a species, which represents atomistic living organisms that can interbreed; an ethnic group represents those who *do* interbreed.) That human beings selectively, rather than randomly, interbreed produces ethnicity and limits the social solvent to mixing-pot status. But the human mixing pot is not unique or physically strange; mixing pots are already found at the level of large molecular moieties (e.g., protein molecules) among smaller molecules (protein among water molecules). In this situation, there may be faces of the large entities in true solution, and other faces not, so that complex associational processes can take place with or without true solution.

Nevertheless, a sustained mixing of a mixing pot can produce a near homogeneity that, after some critical duration, is not inordinately different from the solution state. The real problem the mixing pot presents is that a much more complex kind of physical description of its dynamics is required; and, the problem presented by society seen as a mixing pot is that, at the seventy-to-ninety-year time scale and beyond, some sort of phase description of social systems becomes necessary.

Following Maxwell's (and then Boltzmann's) demonstration that one can establish statistical distribution function laws for the characteristics of ensembles of molecules in motion in a gas, Willard Gibbs (the great American contributor to statistical physics and thermodynamics) developed a general method of determining distribution function properties of such atomistic ensembles by a statistical mechanics of very broad applicability. In his characterization of such statistical mechanical ensembles, Gibbs identified a canonical ensemble state--a rather sharply defined ensemble of all systems of the same energy and number, each running around within its phase space. A phase space is a presentation of state variables versus their rates of change, for each degree of freedom in a system. The multidimensionality of the Gibbsian phase space for a system reflects the number of atomisms that make up the system as well as the number of degrees of freedom that each atomism possesses. Time in such a "static" presentation is not explicit. (Yet, if one imagines state and rate plotted at uniform intervals of time, one would be watching a depiction of such a system dynamically unfolding--racing--through time.) Beyond presenting the phase space for a single system, Gibbs also presented the phase space of all similar systems of comparable energy and number (in which each such system with its own individual atomisms is performing independent actions). The advantage of this sort of conceptual plot is that it tends to be space-filling, and gives a picture of "density" of occupation in each region of phase space, and thus the probability of finding such systems in any particular region of that space. It provides the basis for estimating system averages.

In a mixing pot, an ensemble of all systems of comparable energies does not fill phase space uniformly in density. Instead it is blotchy, most likely with separated regions. The composite picture of human society in phase space could represent (a) a mapping of "all" of the possible political-economic systems compatible with some energy, population number, and technology constraints (in so-called systems' phase space), and (b) the accessible regions and densities in phase space available for a given system.

Gibbsian systems are viewed as *ergodic*; mixing-pot systems, at best, may be viewed as *quasi-ergodic*. From his physical construct, Gibbs was able to conjecture that the uniform density in phase space, having equal probabilities, also represented regions in which time averages and space averages were equal. This is the ergodic property. Systems whose phase-space portraits are only moderately blotchy are often also conjectured to be quasi-ergodic for the fairly densely occupied--not excluded--regions. One would hope and expect that in time, topologists, who deal with the mathematics behind these kinds of ideas, will suggest better means to treat such a quasi-ergodic, mixing-pot systems theory.

Given a scenario of changes in the vicissitudes of the earth's potentials (that is the actual history, or at least the expected and experimental statistical moment measures, of the atmosphere, hydrosphere, lithosphere, the sphere of geochemical processes, and the sphere of biochemical processes--the biosphere or ecosphere), this seventy-to-ninety-year time scale is suitable for predicting human society's relaxation response to such ecological transformation. (See, for example, Iberall, Soodak, and Arensberg 1980, 511-512.)

200-1200 Years

This is the major scale for macrosocial and macropolitical change, and this epoch averages 500 years. Although this is an epoch that has specific meaning for human beings in post-Neolithic times--settled in place in civilizations with interacting political units and making up an ecumene with interacting economic units--it nevertheless has its precursors. Before (or without) written records, small individual cultures, e.g., hunter-gatherers, nomads, forest cultures, and village cultures, did and do have oral traditions (legends, myths, stories of founder figures, cosmology, creation stories, spirits, gods, and heroes) that are carried along for many generations and many lifetimes.

In our experimental historical sample survey (Wilkinson and Iberall [in preparation]), we were able to ascertain two main facts. Examined for the entire time domain from the first Mesolithic cultures (13,000 years ago) to the present industrial cultures, we find a moving picture of changing field processes involving political change, ethnic change, technological change, or major cultural change, over periods on the order of 200-1,200 years, averaging approximately 500 years (basically distributed normally in a logarithmic sense). Further, we (Iberall and Wilkinson 1984) have been able to show, as an introductory theory to that time (and an associated space) scale, that this "civilizational" space-time scale is an appropriate transitional scale for diffusion, compatible with an earlier hunter-gatherer diffusion rate. In man's earlier, physically gas-like state, human operating groups diffused (a random walk or Brownian-like movement) at the rate of one roaming range (thirty miles) per generation (thirty years). Subsequently, after a stability transition, man, settled in place, continued that same diffusion process in civilization from multiple settlement regions, of about 200 miles (Iberall and Soodak 1978, 18-19), with a "life" time scale of about 500 years (Iberall and Wilkinson 1984). The fact that the 200-1,200-year time scale displays the same diffusion rate as that found for the generational scale suggests that the scaling processes are embedded precisely in the biological-social factors that make up culture in general. Two hundred to twelve hundred years is *not* solely an autonomous political time scale, although its political component will obviously be of most interest to our current audience.

The generality and abstractness of the underlying process suggests that it does not possess the quality of some mechanistic "changing of the guards" or "shifting of gears" as some mechanical clockwork advances. It theoretically suggests the unruliness of man's history, which is found observationally in human history.

Longer Scales
Longer human social time scales of interest that likely do exist, but in which no more than some underdetermined fraction of a cycle has as yet been completed, include global demographic and economic peaking and collapsing, and species turnover. Such human time scales can only be studied conjecturally and via other species' histories.

What the reader should understand about this temporal decomposition into scales is that if he or she elects to study human social history, i.e., its cultural, political, and economic dynamics, at any time scaling, those processes will appear continuum-like, but with their dynamic contours determined by the fluctuating content of the nearby underlying atomistic scales outlined. While each such underlying temporal fluctuation can be stereotyped, its specific form takes place as a locally constrained boundary value problem.

To this general spectroscopic depiction or decomposition we would add one final note of explanation. In seeking to find spectral lines in a cascade spectrum (the nesting and causal connections between process scales), one will have to realize that correlations between or among lines may be quite weak (even almost nonexistent) and causal connections both weak and quite varied (Bloch et al. 1971). One must further distinguish between "hard" resonator types of oscillations (mass-spring or inductive-capacitative oscillations) and relaxation-type (discharging) oscillations.

It is also necessary to distinguish between externally driven oscillations (e.g., driven by the earth's rotation or revolution), and internally (endogenously) generated oscillations. An Aeolian harp in a forest is endogenous, given a wind potential; the "clang-clang" of a flag chain or rope mounted on a flagpole on a deserted shopping mall is similarly endogenous. The ocean tides are exogenously driven, whereas the atmospheric tides are endogenously driven--they are self-generated within the atmosphere, given an external heat source potential. Furthermore, even among endogenous, self-generated types of rhythms, some will be found to be quite stationary with little frequency band width or variation, some will be quite warbling and broad (see, for example, H. Wold's discussion of flexible--stochastic--cycles; Wold and Jureen 1953, 149-168; Wold 1965, 115-166). Relaxation-type oscillations and endogenously driven oscillations tend to be broader, with warbling periodicity; most oscillatory social processes are of such relaxation-type, endogenously driven, "flexible" cycles.

Regardless of how generated, we contend that such cyclic processes are not epiphenomena to be noticed, wondered at, and passed by, but rather the dynamic spine or skeleton of the social system. Description and explanation in terms of such dynamically causal phenomena, not as kinematics but as kinetics or dynamics, will transform social science from its current weak theoretical foundations. Even though causality differs for each line process, the ensemble of spectral lines represents the force of an inexorable social pressure.

An Introductory Process Description

The spectrum we have thus far displayed, a picture of social frequencies, is perforce static. Mathematically, in nonlinear dynamics, one of the first descriptions of the dynamics of a persistently ongoing system is just such a topological picture of its so-called frequency response (e.g., the line spectrum for a heated gaseous system like the sun). A spectrum, static though it may seem, actually depicts a persistently ongoing dynamic system, albeit without picturing the phasing of these spectral processes.

A second description of the dynamics of a system often appears as a presentation of its so-called phase portrait, a description of its state and rate changes (Abraham and Shaw 1982-1985). We are not yet prepared to present a phase portrait of the human world-system. Instead, we shall simply provide an orchestral depiction of the process spectrum, a brief "motion picture" introduction to the operation of the human world social (and political) system in highly stereotyped form.

The individual receives a sensory influx, fluctuatingly presenting the environment and its potentials; he or she returns motor reaction at the 0.1-second scale. Although they can be driven to change more frequently by unusual external cues, perceptions and individual attentive postures tend to form and attention to shift autonomously (endogenously) approximately every six seconds (Iberall 1978).

Integrative body support for bundles of internal perceptions and external body tasks is provided at the two-minute scale (metabolic oxygen support), at the seven-minute scale (blood flow support for regional tissue), and at the thirty-minute scale (pH balance). One is dealing, of course, at all these time scales with perfectly conscious human beings, even though these three scales are automatic and mechanistic.

At the three-hour scale, the human chorus of organs and processes are fully assembled. The choirs sing, dance, and engage in steps in all their socially orchestrated activities: eating, sleeping, working, drinking, voiding, having sex, attending to nature and others, exhibiting emotions, or the like (Iberall and McCulloch 1969). Ergodically (essential agreement in space and time among all these human activities), that action spectrum is available all around the world: name the action, it is happening someplace at any designated time. Over the day scale, those actions are occurring sometimes at any designated place. The day's musical composition appears (and can be perceived) through the signature of its action modes (Iberall and McCulloch 1969; Iberall and Cardon 1969). The activities of the band or settled community are largely designed around this scale.

Of course, one day is like another, and the minirhythms of the life process appear more fully in program. At the months scale, anxiety and euphoria alternate, not only in the individual but also entrained within the group and the polity as spontaneous or directed moods and campaigns. The year's seasonal vicissitudes call forth the much richer program of all interacting species. At that scale, all of nature and the nations and political states of man are caught up and considerably driven by the fluctuating processes within earth systems (meteorology, hydrology, tectonics, and ecological interactions). In concert, man's actions appear through the minirhythms of trade and war. The fluctuating flow streams of materials, energies, actions, and birth and death of cohorts take place, and certain quotas or wars begin, continue, and end (Wilkinson 1980; Iberall 1973b). "Progress" and accomplishment (e.g., of social change) are perceived and plans modified; leaders accumulate credit and discredit.

At the generational and multigenerational scales, the large-scale patterns of dynasty and trade, of dominant powers and general wars appear (Wilkinson 1983, 1984a). Now we have to know our players--nations, states, rulers, empires, elites, groups, or ruling classes--and what it is that they specifically did and responded to. Even at that, in a physical sense, we view the process as a so-called "one-particle distribution function" picture. We ask how the individual acts or reacts to the mean field of all other individuals.[9]

So man's story, in a hurly-burly, random-walk sense, is constructed from these individual complex human atomisms interacting and fluctuating as the result of external and environmental forces, including the "external" (to the social system) forces generated by the on-board chemical (genetic) potential that all living organisms carry. Those forces interact with internal complex action-memory machinery, and so noisy history emerges. But such a hydrodynamic flow field also has large-scale patterns. Patterns of change emerge at the lifetime scale, and the "long" time scale of near 500 years. Historical memories are extinguished and myths born and modified; civilizations collide and slowly fuse (Wilkinson 1984); universal empires rise and vanish (Wilkinson 1983, 1986). Beyond, at this point beyond the scope of this chapter, lie the further scalings for biological history-evolution. Thus we start from physics, lay out the path of individual biology, and finally return to social biology. Our social history and theory is sandwiched in between.

This provides a taste of how physical science can help organize an understanding of the dynamic foundations for complex systems, such as human social systems. We believe that it is truly novel as an achievement although, as an undertaking, it is well precedented indeed, as we shall argue next.

Positivism, Marxism, and Social Physics

The claims of a social physics that can produce a temporal spectroscopy, such as outlined, or a credible morphology for social-historical processes, can only be evaluated by social scientists who are aware of how the history of social science has engendered its main paradigms.

There is an intertwined history of social physics with social science; it is, on the whole, a melancholy one. We would argue that there are reasons for the unsatisfactory performance of "social physics past." They represent no barrier to "social physics present," nor to "social physics yet to come," provided we ground our work on the foundations of contemporary physics (Iberall 1985; Iberall, Soodak, and Arensberg 1980), rather than pre-nineteenth-century physics, as did the nineteenth-century aspirants to a social physics whose work inspired the main contemporary social-scientific paradigms--positivism and Marxism.[10]

The story of the beginning of social physics is a story, in the main, of the Enlightenment.[11] A thorough inventory of the intellectual figures and notions involved in that transformation from sixteenth-century, moral-religious to eighteenth-and-nineteenth century, scientific-objective thought is given by Becker and Barnes (1961) and Artz (1980), and the philosophic transformation is exquisitely traced in *Great Ages of Western Philosophy* (1957); but they do not present, we believe, a sufficiently rich view of the degree to which that intellectual transformation was driven by the pre-Enlightenment progress in physical discovery. By examining them in combination with Thiel (1957), who provides a more technical history of those discoveries, one can more readily perceive the parallel and entwining development of physical and social themes. But it is Randall (1940) who best connects the two. Randall shows very clearly how the Enlightenment took up and generalized the Newtonian world-machine outlook, and justifies the remark of a reviewer of the Fourth International Congress on the Enlightenment that ". . . the Enlightenment is all a series of footnotes to that odd Diogenes-like figure of seventeenth-century Cambridge, Isaac Newton" (Wills 1975).

Saint-Simon

The seriousness with which the Enlightenment took on the application of the Newtonian world-machine to the perplexing problems of man, mind, and society is clearly illustrated in the writing of Henri de Saint-Simon (1964). Saint-Simon began his "Introduction to the Scientific Studies of the 19th Century" (1808) by asserting that "the advance of the physical sciences and the superiority they have over the theological sciences have been due to the theory of vortices." Translate vortex theory as the mechanics and thermodynamics of fluid-like fields and suddenly the idea is contemporary, and even germane. Saint-Simon held that the intention of the Newtonian revolution was to "base all reasoning on facts which have been observed and analyzed." Noting that physics and chemistry have been so reorganized, he expected that "physiology, of which the science of man is a part, will be brought under the same method as the other physical sciences." Physiology has indeed begun its assimilation to the method of the physical sciences, and we see no reason why anthropology will not succeed in its ambition, expressed at various times, to establish roots in physiology. The ambition and the incompleteness of the Enlightenment both are visible in Saint-Simon's conclusion (1813) that it would be "possible to organize a general theory of the sciences, physical as well as moral [social], based on the idea of gravitation regarded as the law on which God has founded the universe."

It is not possible to organize a general theory of the sciences around the idea of gravitation alone. If one could (as one now can) amend or stretch the Newtonian construct to include the twentieth-century point of view of physical forces taken in electromagnetism, relativity, quantum mechanics, and field theory, Saint-Simon's apparently weird proposal would become serious. But in its time, the Newtonian world-model without these addenda and, most particularly, without statistical physics (statistical mechanics and thermodynamics), was inadequate for its intended purpose--to deal generally and encompassingly with all of nature and life, including mind and human society. (Iberall 1985; Iberall, Soodak, and Arensberg 1980).

Comte

Saint-Simon's sometime secretary, collaborator, follower, and rival, Auguste Comte, nevertheless posited a very broad and general social physics, which he however transmuted into sociology (1830-1842) when the astronomer-mathematician Quetelet also employed "social physics" to denote what Comte felt was a more restricted statistical-empirical view of social phenomena.

Comte's notions were devoid of physical science content, beyond the suggestion that social studies must have a static and a dynamic component. His central contribution is commonly viewed as his suggestion that there is a "hierarchy of the sciences" (a progression of ideas, not just a parallelism) from physical science to biological science on to social science. Comte also usefully proposed the mathematical continuity of history, "the axiom of Leibniz--the present is big with the future, . . . the object of science is to discover the laws which govern this continuity." But Comte's "great philosophic law of the succession of three states--the primitive theological state, the transient metaphysical, and the final positive state--through which the human mind has to pass, in every kind of speculation" is not physical law nor even physical science, but utopian prophesy or tendentious historicism. Thus the pursuit of a hard social science based on physical law was over almost as soon as it had begun. The philosophic highpoint of Comte's thought, and its scientific poverty as physics, that is as a social physics, is already visible in his fourth early essay (Comte 1911). As that 1825 writing reveals, Comte simply lacked both the training and understanding to foresee any of the physical ideas that developed in the second half of the nineteenth century, and which he would have had to have mastered in order to succeed at the task he set himself. As he himself stated clearly: "The purpose of [our] work is not to give an account of the Natural Sciences . . . our object . . . is to go through a course of not Positive Science, but Positive Philosophy."

To probe more deeply into Comte's scientific thought, say into his *Positive Philosophy*, only leads to Ward's discovery (Ward 1883, 1:129) that "[Comte] seems to possess that rare power everywhere manifest throughout his works of weaving upon a warp of truth, a woof of error. The iron consistency of his general logic is in strange contrast to the flimsy fallacies that fill out its framework. . . . He is a great general in the army of thinkers, but, when he . . . meddles with the brigades, regiments, and platoons, he throws them into confusion by the . . . amazing stupidity of his commands."

Nevertheless, one has the sense that Lichtheim had it at least partly right (Lichtheim 1965) when he commented: "The conservative character of Comte's sociology [Comte's *Positive Philosophy* is somewhat better described as "wildly utopian" than as "conservative"!] and the triviality of his conceptual apparatus need not hinder the recognition that his positivism is in the general line of advance first sketched by the French Enlightenment . . . he is in the tradition of Turgot and d'Alembert who almost a century earlier had anticipated his quest for 'invariable' laws of nature and society."

Spencer and Ward

Despite all the differences in their systems, what is true of Comte from the viewpoint of social physics is also true of his rival Herbert Spencer, who likewise attempted to order the sciences. ("On the Genesis of Science," 1854; "The Classification of the Sciences," 1864). Lester Ward, one of the American fathers of sociology, noted the similarity of Comte and Spencer in his *Dynamic Sociology* (Ward 1883), and again in "The Filiation of the Sciences," a paper Ward read before the Philosophical Society of Washington in 1896, which compared Comte's and Spencer's systems and identified them as similar (M. White 1969). Spencer's and Ward's views are discussed in Ward's *Pure Sociology* (1925).

Ward's own works (1883, 1925, 1974) serve as evidence that sociological positivism as a soft social physics was still alive and thriving in the United States at the beginning of the twentieth century. But they also serve as evidence that positivism had by then become congealed as a philosophic posture, and not as a scientific enterprise. One finds in Ward a reasonable desire to create a theory of the laws of society, as positive as those of the body of physical law, side by side with views that amount to little more than a rechurning of Comte and Spencer with a sprinkling of Ward's special biological expertise.

Felix Markham's foreword to Saint-Simon's essays (Harper and Row, 1964) well displays the fundamental contribution that Saint-Simon made to the "positivist" outlook of the social sciences, as the precursor and mentor to Auguste Comte. The contributions of Comte and Spencer are already well recognized historically, better recognized historically than those of Saint-Simon (overlooking Marx); but each was of great importance to the quartet of the newly independent sciences of economics (starting with the notions developed by Quesnay, Adam Smith, and Malthus), anthropology (e.g., the notions developed by Tyler), politics (with its ancient origins in Aristotle, Mencius, and Polybius), and sociology.

Yet all three of these giants (Saint-Simon, Comte, and Spencer) have passed into obscurity--their works are mentioned more often in an antiquarian way than in serious critical dialogs, such as one still holds with the works of Aristotle and Smith. This is not totally unjust. By reading the works of these key promoters of social physics one is struck by the common thread of weakness in the physical background that they brought to their several attempts to develop a social science. Saint-Simon certainly tried--as we learn from Markham--when he "conceived the project 'of opening a new path for the human mind, that of the physico-political' [in 1798], he moved . . . near the Ecole Polytechnique, and studied physics for three years." But the physics of the time was inadequate to the task. Comte's fourth early essay, written in 1825, shows today's reader that its author lacked the training and perhaps the understanding to anticipate the statistical physics that developed in the second half of the nineteenth century. (Quetelet, by contrast, *was* an astronomer and *practiced* astronomy, as well as sociology. His input-output table analysis was much more in line with the physical and engineering sciences that have emerged. Comte might better have embraced than scorned Quetelet's statistics.)

The lineage of sociological positivism can be traced further from Saint-Simon, Comte, and Spencer, through Weber and Durkheim, to modern Parsonianism. Without disparaging the substantive achievements of this lineage, we would characterize it as a dead end in the quest for a social physics, since it evolved from a sociology based on an inadequate physics to a sociology based on no physics at all. Positivism has become a philosophic notion that there coexist a number of loosely ordered, weakly interacting, fundamentally empirical autonomous sciences, a philosophic talking point much like Popper's celebrated falsification criterion for the sciences, rather than any significant "positive" contribution to any of the sciences, e.g., to a generally applicable physics.

Henry Adams

The historian Henry Adams and Lester Ward were both founding members of the Cosmos Club (founded in 1902), a meeting place in Washington for scientists and other intellectuals of note and professional accomplishment. Some key intellectual themes that were emerging at that time were an experimentally viable theory of evolution and a statistical physics applicable even to the atomistic elements of nature. Adams apparently hoped to incorporate within a theory of history that emergent physical theory of natural phenomena. Although Adams did not know Willard Gibbs, it is clear that the ideas of statistical physics and thermodynamics (with which Gibbs was identified) influenced Adams to the point of persuading him that historians ought to try to account for the trajectories of human history by some such physical theory. It was the ideas developed in this new era of physical scientific thought (typified by Maxwell and Clausius, as well as Gibbs, by statistical mechanics and thermodynamics, and by a kinetic theory of atomistic motion) that focussed Adams's concern on the laws of motion of human history, a concern which, unresolved, turned to near-desperation in the last few essays in *The Education of Henry Adams* (1904).

As Henry Cabot Lodge, writing in 1919 to a posthumous preface for the *Education*, commented: "Any schoolboy could see that man as a force must be measured by motion from a fixed point. . . . Study had led Adams to think he might use the century 1150-1250. . . . From that point [as the thrust behind *Mont-Saint-Michel and Chartres: A Study of Thirteenth-Century Unity*] he proposed to fix a position for himself. . . . The 'Education' proved to be more difficult. . . . Probably he was, in fact, trying only to work into it his favorite theory of history, which now fills the last three or four chapters. . . . At all events, he was still pondering the problem in 1910, when he tried to deal with it another way which might be more intelligible to students [of history]. Thus he wrote 'A Letter to American Teachers of History'. . . ." In that 1911 letter, Adams appealed for historians to meet with and work with physicists on the basis of a thermodynamics of historical processes, implying thereby that the former must assimilate physics but also that they could not do so alone. Adams's appeal, one of the most quixotic outcries in the history of scientific and other intellectual thought, produced no direct issue. With its failure was lost a major opportunity to examine a first physically oriented theory of history, and, conceivably, to produce a first physics of history.

Marx and Engels

There is an unspoken or barely mentioned theme running through the positivist writings, provoked by the nineteenth-century unruliness of revolution, counterrevolution, and by the activities of Marx and Engels in particular. They too have a special relation to social physics with still another path to a dead end in the quest for a social physics. That path has been taken by the orthodox, Marxist, "dialectical materialist" tradition, which leads ultimately not to the sociology without a physics of positivism, or to the history without a physics represented by Adams' failed appeal, but to a social engineering without a physics.

That result is not what Marx and Engels intended. They were enemies of the enemies of the Enlightenment as much in science as in politics. They meant to be universalists in both spheres and, as such, they fell out of step as much with their intellectual as with their political milieu. The sciences, and especially the social sciences, fragmented following the Enlightenment's failures, trailing its successes in the American and French Revolutions. When the several sciences assumed their current disciplinary outlines, they concurrently shed all illusions of a universal Enlightenment science. One may conveniently date the earliest end of the Enlightenment's illusions by the guillotine; Napoleon's coronation would also serve, in that Bonaparte the revolutionary autocrat had offered the European intellectual the notion of a universal brotherhood of man to extend (and supersede) the particularism of Charlemagne's dream of a Holy Roman Empire. The crowning of Napoleon as a merely national emperor symbolized for many the victory of parochial political ideologies and the end of political universalism. The end of scientific universalism and the rise of disciplinary particularism might today seem unrelated to the rise of particularistic political nationalism; in view of the intimate relationship of Enlightenment philosophic thought, physical and social science, and engineering, we would argue the contrary.

Certainly among the great nineteenth-century dissenters against the mechanistic Newtonian enlightenment, Marx is notable precisely in that he *also* rejected *both* disciplinary and ethnic parochialism. Marx and Engels proposed a new science, different from the "vulgar mechanics" of Newton, and yet universally applicable to account for "motion and change" in natural systems (the traditional task assigned physics by Aristotle), and fully competent to deal with nature, mind, and society (Engels, writing in 1878 and 1882).

Despite their intentions, and because of their assumptions and influence, Marx and Engels are in their ways as significant key figures in the nineteenth- and twentieth-century failure to produce a physically based social science as are their positivist rivals--established in the West, heretics in the East--in anthropology, sociology, and economics. In their impact on social practice, of course, and in the number of social scientist equivalents they have influenced, they have far outdistanced all those rivals. Nevertheless, Bottomore and Nisbet are right to treat them as equal aspirants when they declare (1978) that "for more than a century there has been a close, uneasy continuous relationship between Marxism and sociology. The closeness is due to the fact that Marx's theory was intended, like sociology, to be a general science of society. . . ." (Also see Harris 1968.) In our view these rivals, alike in their admirable aspiration, are also alike in their lamentable failure. But the style and source of failure are somewhat different.

Scientific Marxism, for rudimentary purposes, can be divided into a theory of historical materialism, the theory that the economic thread is primary in human social evolution, and dialectical materialism, a general theory of action in all systems--natural, living, and social. It is the latter theory that we wish to discuss for its analogous character to physics. Such Marxian theory, we would claim, can only barely be discerned in "the young Marx" (Marx's doctoral thesis); in maturity it is best outlined in Engels's works (Engels 1939, 1935, 1940).

Because this sequence is one of a progressive emergence of scientific aspiration, and as we are concerned not with the failure to try science but with the try that failed, we are less interested than many of our contemporaries in "the young Marx," more in "the mature Marx," "Marx-Engels," and more literally in Engels writing alone ("the dead Marx"?) as the philosopher-theoretician expounding the foundations behind Marxism. (Those who find this usage constraining may, although at their peril, ignore Marx's maturation, evolution, collaboration, and bequest, and read "Engels" when we speak of "Marx"--provided they will also relabel the main twentieth-century offspring of the pair as "Engelism" and "Engelism-Leninism"; otherwise they must accept our usage as apt.)

Marx and Engels, Lyell, Darwin, Freud, even Comte and Spencer despite themselves, are the great dissenters from the populace's image of the Newtonian paradigm. Together these historical-evolutionist dissenters turned the fashion in their sciences away from simplistic "mechanistic" models. But the scientific aspirations of Marx and Engels were more sweeping than those of the other historicists and evolutionists, for Marx and Engels essentially proposed to reconstitute the foundations of physics itself.

The traditional task assigned physics by Aristotle was to account for "motion and change" in all systems. Marx and Engels proposed to abolish the "vulgar mechanics" of Newton as too "static," too "rooted in a metaphysical outlook," and in so doing to establish new laws for motion and change in all systems, whether in nature, mind, or society (Engels 1935, 1939). To replace the "vulgar" mechanics offered by Newton in his three laws of mechanistic motion and his identification of the law of gravitational force, Engels offered the three laws of dialectical materialism: interchangeable transformation of quantity into quality; identity of opposites (including denial of the law of the excluded middle); and the negation of the negation. All that Newton did for physics was anticipated and done better by Kepler, Engels claimed, and dynamics did not begin until Kant's views of the dynamics of nebular condensations. The logic of science is dialectic.

The key to Engels's belief system seems to lie in the following comments (Engels 1939, 26-27; also 1935): "When we consider and reflect upon nature at large, or the history of mankind, or our own intellectual activity [note this repeated election of systems: nature, society, mind], at first we see the picture of an endless entanglement of relations and reactions, permutations and combinations, in which nothing remains what, where, and as it was, but everything moves, changes, comes into being and passes away. . . . This primitive, naive, but intrinsically correct conception of the world is that of ancient Greek philosophy, and was first clearly formulated by Heraclitus; everything is and is not, or everything is fluid, is constantly changing, constantly coming into being and passing away."[12]

We shall not provide a detailed critique of those ideas at this point, only the following counterstatement. Dialectical materialism cannot be viewed as a foundation for any kind of physics whatsoever, and consequently not for social physics. The basic Marx-Engels conceptual physical image appears to be fluid mechanical, and its maximum claim might be that it provides a *metaphysical* resolution, perhaps idiosyncratic, of the antinomy of being and becoming in fluid processes. To make the contrast very explicit, there is a *physical*, scientific resolution of the flow-process problem, and one that requires no more than the physics of the 1820-to-1850 period, which permits deriving the Navier-Stokes equations of fluid mechanics precisely from the "vulgar" Enlightenment mechanics of Newton. The late twentieth-century physics of field-patterned unruliness, even of "chaos," has been largely identified within that very Newtonian description of flow-field phenomena, and via the kind of *spectroscopy* we provide in the first part of this chapter. Dialectics? No, physics!

If dialectical materialism could have displaced any part of physics, it ought immediately to have driven and guided the study of fluid mechanics--the most obvious potential physical application of dialectics. The modern study of fluid mechanics can very properly be said to have been begun with Reynolds's studies of turbulence in the 1880s, precisely in Engels's heyday, just in time to be guided by dialectical materialism, had such guidance seemed fruitful. This did not occur. Surely one would then expect, at minimum, that dialectical materialism would guide fluid mechanics in the Soviet Union, the first and foremost institution ever committed to use dialectical materialist metaphysics (Wetter 1963). We leave it to the reader to determine whether Engels or Newton and statistical physics and Navier-Stokes have shaped the development of Soviet fluid mechanics.

Social Physics After Ward, Engels, and Adams

The positivists, from Saint-Simon to Ward (e.g., in successive editions of Ward's work, as one might find them, say, up to 1902); the writings of Engels (to his death in 1895); and the writings of Adams (until his 1911 letter) show strikingly that these social (and biological) "scientists" felt perfectly competent to broker the science of physics and its applications. They really seemed to believe the ordering of complexity and hierarchy to be the simple motions of heavenly and physical bodies, the increased complexity of the biological organism, and the greatest complexity in society. One has to surmise that the notion that physics was "simple," elementary, and accessible did not falter until Einstein; then, perhaps, the physical dilettante grasped the notion that he or she was outclassed (one might infer a similar thought from the separation of the Proceedings of the Royal Society into Points A & B). At any rate, the claims and concerns died away, the effort was abandoned, and social scientists increasingly viewed physics as an "other" rather than as a "root" discipline.

Have the thus uprooted and disconnected social sciences flourished as equals parallel to physics? Such a view would be difficult to sustain. "Pure" economics has found its center in the equilibrium modeling of Marshall and the mathematical economists; "pure" sociology in Parsonianism; "pure" anthropology in Boas; "pure" political theory in Weber; "pure" history perhaps in Collingwood, Dilthey, or in Barzun. After a long eclipse in the West, fragments of Marxism, more or less "materialist," but hardly "dialectical materialist" (except for some current silliness in background theory for biological evolution), have returned to content with these pure, discrete disciplines, but still without attaining the florescence and momentum of growth that continue to characterize the "hard" sciences seeking their roots in physics.

On the whole, neither "pure" nor "materialist" social science is highly successful in categorizing facts (the precursor to a genuine scientific enterprise); it is yet--to the physical scientist--impressionistic and subjective as a science. It is clear to all that there is a required concern with a science or sciences of man, his behavior, and organization. But it is effectively impossible for a new student approaching the key works of these disciplines to discover a central core of scientific "laws" that underlie the empirical facts about society. The student is indeed schooled in various traditions, but not in principles. This is what has motivated us to write the first part of this chapter (and Iberall 1985, as a very brief statement of principles).

We are not prepared to give up the quest for a genuine social science; we consider that past failures may be attributed to the fact that until recently (Iberall, Soodak, and Arensberg 1980; Iberall 1985) there has been no genuinely physical basis, i.e., adequately physically grounded in an applicable physics, for a general theory of social physics. Many fragmentary applications of physical notions to social science are certainly to be found: e.g., the work of Stewart (1948, 1950), Zipf (1949), Warntz (1959), Richardson (1960), Prigogine (Prigogine, Allen, and Herman 1977; Schieve and Allen 1982), Haken (1975), Montroll (Montroll and Badger 1964). But these applications are precisely fragments; and the contributions of mathematical economists and sociologists, of cyberneticists, and of systems scientists are physically incomplete. Therefore we would claim that, before the two references cited above, there has been no attempt at a general theory for social physics. But the necessary physical basis for social physics does now exist. It is an extension of the Navier-Stokes-like description that has produced cascade-like spectra for geophysics, meteorology, stellar, galactic, cosmological physics, plasmas and biophysical flow fields; and we have herein begun its application to human society via an introductory spectroscopy.

Notes

1. To provide a social context, the history of that apparently exotic subject "social physics" is sketched in an extended section of this chapter. The social science reader who intends to take the spectroscopy outlined here seriously needs a sense of the Enlightenment themes that preoccupied social scientists involved in earlier failed efforts at creating a social physics, or physique morale in their language, and how those earlier efforts were transmuted into sociology and political economy, producing the two main conflicting contemporary lines of social scientific thought, positivism and Marxism.

2. That we are dealing with an operational system means that the equation set is confined to a space-time region in which particular boundary conditions are maintained; that we are dealing with an ongoing system means that the field equation solutions describe phenomena that persist indefinitely in time.

3. Social physics does not insist on the indistinguishability of all atomisms. Human organisms are made of molecules, which comprise atoms and nuclear constituents; but there may be and there are many types of organisms, organs, molecules, and atoms. Thus a lithium nucleus in the brain acts very unlike a sodium nucleus. This illustration reflects the discovery of a chemical diversity in the hierarchical character at all levels. Yet atomistic diversity in no way precludes the physics that accounts for such diversity by showing how atomistic fragments bind, compose themselves, and coexist.

4. In our physiological studies, e.g., those referred to in Iberall (1969) and the kind described in Iberall (1960), we measured the bivariate correlation xy between various fluctuational frequencies of metabolic processes and found such correlation to be negligible.

5. As well as simply identifying the action state descriptively, we must note that, physically, action is the product of energy and time, the "cost" of performing these actions in complex systems (Iberall 1960). All such actions are dissipative--it costs energy to perform these actions. (There is even an energy cost in the eating that provides the metabolic fueling, the "negentropy" to supply all of these actions, including the cost of eating.)

Modes, both in a musical and a physical sense, are the orchestral arrangement and style of playing, not the specific melodies.

Our use of should, can, prudent, and wise is not accidental nor extraneous. Social science and social engineering are as logically intimate and precisely related, although distinct, as science and engineering in general.

6. See note 5 above.

7. Postulating the appearance of a fourth conservation, albeit as a renormalized process with considerable fluctuations, is not to be regarded as a light indulgence that physical theory permits itself whenever perplexed. One has to note that taking on board a chemical potential capable of directing reproduction of living species was a chemically transformative process that began at least 3.5 billion years ago, representing a period almost as long as, at least comparable to, the period for which we reckon the conservation of angular momentum for our solar system.

8. One surmises that as of that time (past a Mesolithic transition, via horticulture and agriculture, to a Neolithic way of life with settlement and subsequent urbanization), man attempted to invent a new, a fifth, conservation of value-in-trade or exchange, out of mind. Why consider it a conservation? Because at the moment of an exchange, both parties in the exchange consider value to be symmetrically exchanged. (A thief holds a gun to your head and demands, "Your money or your life." You consider and make the exchange. Value given and received!) Value-in-trade is a renormalized conservation within the social field that reveals the capability of the chemical solvent character of that field to evolve; its post-Neolithic character represents a desire to deal in long range convective trade with stranger, as well as neighbor with neighbor. It clearly does not have the absolute character of the physical conservations. Thus its application is often breached (e.g., discounted) or not imposed, as in the family, among friends, or when conducted as exchanges that may or may not be sanctioned by law or custom: tribute, bribery, robbery, discount. Yet settled urban society operates with the fiction that money is a proper conservation measure for trade in all the other conservations: of materials, of energy, of action (e.g., as labor), of people (e.g., as in marriage exchanges, or slavery).

9. As individuals, we are not only conscious of the actions of other individuals with whom we interact, but we are also aware of the "pressure" of the whole society. Clearly, such social pressure begins to make itself strongly evident to the human atomism at the daily scale. That awareness and its consequences at all scales beyond the daily is what represents the social pressure and what we mean by an individual reacting with the mean field of all other individuals.

10. Those readers who do not feel sufficiently familiar with the themes and controversies of the social sciences may wish to peruse some or all of the following books, which have been selected to provide richness of ideas with economy of number: Harris (1968), Bottomore and Nisbet (1978), Heilbroner (1972), Schumpeter (1954), Skinner (1978), Pfeiffer (1978), Sabloff and Lamberg-Karlovsky (1975). A vigorous and brilliant demurrer to conventional (or classic) economic thought has recently been written by Jacobs (1984). The subject matter and art of the historian can be glimpsed very richly in Barraclough (1978) and Braudel (1981-1984). Two books that provide a flavor of the biological background for the social sciences have been written by Young (1971) and Elliott (1969).

11. Physics, currently, is attempting to develop a grand unified theory

of physical forces capable of reaching that early energetically dense period in history in which all of the forces in nature acted with the same strength. It is interesting, in the study of the origins of the Enlightenment's scientific themes, that one is confronted by a similar question as to how and when philosophy and science separated from theology. The significance of this question was not clear in Iberall 1973c, which could only make a start toward the Enlightenment by beginning with Jean Bodin in 1550. It now seems more appropriate to consider the "grand unified theory" age as beginning to end with Thomas Aquinas in the mid-thirteenth century. (Authentic unified theories of any merit may well require polymaths, like Aristotle and Aquinas. They were not unique.) It is difficult not to be impressed by the scope of the Bishop Oresme who, having made very significant contributions to philosophy, mathematics, and physics, is also now considered to be the greatest medieval economist, known, for example, for his late-fourteenth-century studies on the early invention of money, its purpose and function, and the effects of its debasement as it applied to the monetary system of fourteenth-century France. Or, what is one to make of the contribution of Copernicus--essentially the originator of the physical revolution in modern thought--who wrote a monetary treatise based on nine years of study, early in the sixteenth century (1519-1528), at the request of the Polish King Sigismund? The problem he addressed was similar to Oresme's, the significance of debasement of currency and the disorganization of the monetary system in the Prussian provinces of Poland.

One also notes that the Copernican astronomical system came about in response to a theological problem, the Lateran Council's request (1514) to provide a basis for a new calendar; indeed it was the pope who gave publication approval to Copernicus's findings (1536). Physical science took off as a completely independent discipline at the end of the seventeenth century; political economics also became a significant study in the seventeenth century, and part of the eighteenth-century Enlightenment package, seeking independent scientific status in the nineteenth century.

Nevertheless, to this day, the threads of theology, philosophy, and science have continued their common, imperfectly congruent writhings. An interdisciplinary study like this one must underscore the continuing and uneasy entwining of the intellectual threads engendered by these three now distinct outlooks. For the future, society would be well advised to underwrite polymathic training and research, just as it now underwrites specialization.

12. Whether Engels's philosophic construct has a great deal to do with Marx's theory of the evolutionary form and stages of social development, and the political-economic interpretation of the state, we shall not here explore. Lichtheim (1965) offers a carefully reasoned study of Marxism's connection to Engels's theoretic; see also Wetter 1963).