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Outlining social physics for modern societies—locating culture, economics, and politics: The Enlightenment reconsidered

(physical reductionism/social sciences/social theory)

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ABSTRACT A groundwork is laid for a formulation of the modern human social system as a field continuum. As in a simple material physical field, the independent implied relationships of materials or processes in flux have to be based on local conservations of mass, energy, and momentum. In complex fields, the transport fluctuations of momentum are transformed into action modes (e.g., $\oint pdq = \Sigma H_i = H$, a characteristic quantum of action over a characteristic cycle time). In complex living systems, a fourth local conservation of population number, the demographic variable, has to be added as a renormalized variable. Modern man, settled in place via agriculture, urbanized, and engaged largely in trade and war, invents a fifth local conservation—value-in-trade, the economic variable. The potentials that drive these five fluxes are also enumerated. Among the more evident external and internal physical–chemical potentials, the driving potentials include a sheaf of internal potential-like components that represent the command–control system emergent as politics. *In toto*, culture represents the social solvent with the main processes of economics and politics being driven by a social pressure.

The general idea that this note attempts to build on is how physics identifies the fundamental variables in a system—all those and only those that are necessary and sufficient to determine the dynamics of a system without being redundant—and where, in human societies, culture, the economic variable of value-in-trade or value-in-exchange, and political command–control fit in. The attempt to achieve an essential descriptive parsimony in concept will only permit the following outline.

A physical field with material constituents is made up of atomistic entities engaged in motion and its change—e.g., molecules, cells, people.

Such motion in a physical field goes on persistently by the propagation of conservations, interaction by interaction.

In simple systems, the three conservations propagated persistently—in space and time—are mass, energy, and momentum (for example, the Navier–Stokes field description of hydrodynamics is derived solely from these three ideas). In composite, that persistent motion defines the physical field.

With laws of chemical combination (chemistry: the making, breaking, and exchanging of bonds), the conservations for each persistent mass species are similarly propagated.

In complex systems, with long time-delayed internal fluid mechanical processes (1), memory-delayed by localized associational transport, the same three conservations are transformed to mass species, energy, and action modes. The role of action modes (2)—action = energy × time—is derived from momentum via such a quantizing rule as $\oint pdq = H = \Sigma H_i$, a classical representation of Bohr's early version of quantum theory where p is momentum, q is displacement, H_i is the spectrum of individual daily actions, H is total quantized action, and $\oint$ is integration over an entire cycle of atomistic performance in a complex system. Complex systems repeat their entire spectrum or menu of performance over some characteristic period, referred to as their "factory day," which is a period that is long compared to the time scale for atomistic interaction. The repetition of some such cycle of performance, at least with some small memory links, is the only way that the performing form can be recognized as a long-lived persistent system, rather than some evanescent process. The characteristic energy associated with that characteristic "daily" action spectrum is H. Thus, for example, that action in the human case would be $\approx$2000 kcal·day/day (1 cal = 4.184 J), a measure of dissipation that is nearly mass specific in scale for all adult mammals (3, 4).

In systems whose atomistic constituents continue reliably to be born, live, and die—e.g., complex living systems—such renormalized systems must effectively evolve and support a fourth conservation of number as distinct from mass species; generation must continue to beget generation. (Thus, for example, biomass and bionumber are distinct variables. Energy might go to fatten up an existing herd, or to increase their number.) The possible existence of a thermodynamic steady-state would imply a constancy of number.

Whether systems are simple or complex, that combination of variables represented by the local space–time averages of the conservations—the ones that provide a field description of the space–time processes—are presented by mean state field variables, by a connecting equation of state, and by flows for each conservation out of each local space–time region. The mean values of the conservations making up the equation of state are correlated into that equation because the fluctuations in any local region making up the conservations are correlated (5).

The movement of these local mean state field variables toward (or away from) a more global equilibrium takes place by virtue of the action of potentials—storage bins for the materials and energy that make up the flows. For example, for simple localized systems, the common potentials are temperature baths, pressure sources, walls, and concentrations of mass species.

For complex living systems on earth, the operational potentials are the atmospheric temperature bath, the solar flux, the chemical potentials of materials and energies from the earth (e.g., proteins, carbohydrates, fats, minerals, water, atmospheric gases, trace metals), the earth's near surface as substrate, and the chemical potential of the onboard genetic code.

The field dynamics of any living species on earth, as either a historical process, scaled generation by generation, or as an evolutionary process, propagated at the great number of generations time scale, should be describable via the four conservations and the operative potentials. What should emerge is a description via a memory-exhibiting cascade spectrum of processes in which lower frequency processes

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are coupled to higher frequency processes, basically as an energy cascade.

The set of conservations and potentials is not complete for the hominid species. Man and his hominid ancestors have operated from one more potential—the technological (tool-using) rate potential. A tool is neither self nor outer world, but an object manipulated between self and outer world that, as power amplifier, has changed the effectiveness of hominid actions. The technological rate potential represents an epigenetic memorizable heritage that can add new tool-making potential each generation. As a nearly constant rate potential, it has represented the change in effect of hominid actions over the Plio–Pleistocene epoch achieved by the evolution of increasingly effective tool traditions.

With the emergence of *Homo sapiens sapiens* ≈40,000 years ago, man added one more potential out of mind, the epigenetic value potential. Mind represents the totality of patterned processes within the brain. [In ref. 5, it was shown that there exists a component additive to the hydrostatic pressure that emerges from the internal associational action processes in complex systems. This was defined as the social pressure. Pressure in simple gas systems has one causal component, the kinetic pressure; in simple liquid systems it has two causal components, the kinetic and virial component pressures; in complex systems with time delayed internal action (representable, in measure, by a bulk or associational viscosity), there is a third causal component. Social pressure emerges from action developed by the internal memory trace in all complex systems, whether there exists a well developed epigenetic value potential or not, in response to and as an equilibrant to external stress.] That potential, which creates culture in the anthropologist's sense (6), is the transmission, generation to generation, of a memorizable heritage via an extensive language capable of being used at high (up to ≈10 Hz) frequency. This represents a further extension of man's tool-making and tool-using capability in the direction of abstract, almost arbitrary, linkages among actions (i.e., the action content identified with cognition). This new potential made man the superb hunter–gatherer, nearly the master of all other living species on earth (except for the disease-producing capability of simpler life forms, and the challenge of high-energy natural vicissitudinal processes, such as severe storms, tornados, earthquakes, volcanos, floods, drought). Atomistic man operates, in ensemble, as a sea of culture. Culture is not a perfect solvent. Like hydrophobic faces on folded proteins in water solution, culture comprises a mixing pot of ethnicity rather than a melting pot.

When man settled in place, 10,000 years ago, via horticulture, he had to invent one new conservation and variable in flux—value-in-trade—to be able to deal convectively with the other four flux variables, particularly as exterior action might involve strangers. [In a localized marketplace of exchange of conservations, whether as goods or services, value-in-trade is conserved at the moment of exchange. This may take place either as barter or as symbols of exchange. Forms of exchange and trade more primitive than marketplaces have existed (7).] The reason for this new variable is of interest. In any field system, there are only three kinds of field processes going on, two local and one global. The two types of local processes are diffusion (of all the conservations and potentials) and wave propagation. The global process is convection. Settled in place at appreciable population density levels, man could not satisfy and transport all of his requirements from place to place rapidly enough via diffusion and wave propagation. Much of the fluxes had to be convected. It was cheaper and faster to convect the symbol of value-in-trade among strangers than the good itself. Thus, the economic variable was invented as another renormalized conservation (see refs. 8–10).

At the same time, settlements and convection involving neighbor and stranger required the evolution of an external command–control system. Thus, within the cultural "solvent" both the economic process via value-in-trade and the political process via external command–control (e.g., "political power" beyond band or tribe leadership) became the forms (and functions) of the human social system. Storage, high flows, ownership, class (the rulers and the ruled), calendric monitoring of events, trade, and war became the realizations of the internal dynamic processes.

The objective function (e.g., like a principle of action) that social control has to satisfy is not, for example, optimization of utility but rather management of the major "factory day" velocities of the flux variables in the culture—e.g., velocities of materials, energy, human action, number, and value-in-trade—by social pressure independent of ideology in both trade and war, good times and crisis, with the given available potentials (including the technological rate potential and the epigenetic value potential).

In summary, a field system is made up of atomistic entities.

These entities are organized locally into space–time morphologies (11).

An equation of state ties together the local field variables (5).

Temporally, complex fields exhibit their menu of performance by modes of action (2).

These modes occur as cascade spectra (5).

For modern man, the field variables associated with microscale process conservations are those concerned with the flow of materials, energy, action emergent from atomistic interiors, population number as the demographic variable, and value-in-trade as the economic variable. These five field variables, given a set of driving potentials, are necessary and sufficient to describe dynamics—the equations of change in the social field.

Since potentials drive fluxes (the specific flows), it is necessary to identify the potentials that drive modern man's social fluxes. These potentials are the atmospheric temperature bath; the solar flux; the chemical potentials of earth, ocean, and atmosphere; the chemical potential of the onboard genetic code; the technological rate potential emergent from the hominid mind as tool-making; and the epigenetic value potential emergent from man's mind as the value system of human culture. The "dimensions" (categories, each with their complex value measure) of that potential are as follows: internal world images of self, interpersonal relationships, society, nature, ritual and institution, other living organisms, technology, spiritual causality (fathers, leaders, gods), and art forms. That epigenetic potential creates the field variables of value-in-trade (the economic process) and the sheaf of potential-like processes making up external command–control (the political process). Command–control (see ref. 11) "simply" represents a fantastic gain in autoregulatory immunity by the temporary or more permanent inclusion of some relatively simple apparatus or mechanism into the interior of a system. [One of the simplest physical examples of such a gain in regulatory immunity is exhibited by a chimney and partition added outside of a candle, which prevents the flame from being blown out. Further extensions, of course, can be achieved by the addition of passive and active moving parts—e.g., nervous and motor systems (12).]

Social physics is the field play of these variables—the governing fluxes and potentials, the play of economic and political processes within the cultural solvent milieu.

Some of the salient time scales in a modern social system that make up its cascade spectrum are as follows: (*i*) 3- to 4-hr unit action scale [physiologically governed, a time scale for thermodynamic equilibrium in the mammalian organism (13, 14). It thus becomes a measure for the nominal relaxation time to equilibrium for major action modes, such as eating or working at a task]; (*ii*) 1-day basic action scale [governed by a light/dark daily earth cycle, the organism proceeds largely through its entire action matrix from sleep through activity and back to sleep (2)]; (*iii*) 30- to 90-day attitudinal turnover in the individual (governed by internal biological processes that tend to tie the organism to the seasons, it is a measure of the average turnover time for molecular constituents); (*iv*) 1-year socioeconomic scale (governed by the attachment of the species making up the trophic web of the ecology to the year cycle of earth); (*v*) 3- to 6-year political and economic scale (a period measuring significant change in elite political policy in the local polities; ongoing fluctuations in the economic variable); (*vi*) 1–1.5 generational time scale (a demographic scaling of changing players, as well as the related major scale of war to war and its perception in the ecumene); (*vii*) 300- to 500-year civilizational time scale (significant turnover of polities and the other main social networks in the ecumene).

The function that command–control has to fulfill is adequate management of the velocities of the major flux variables in the culture—of materials, energy, human actions, number, and value-in-trade—via the components making up social pressure, for the salient factory days (e.g., day, season, year, political time scale, and generation, of the culture).

This construct is offered as a scientific alternative to the path taken by the social sciences at the end of the Enlightenment, notably in contrast to the pioneering works of Saint-Simon (15), Marx and Engels (16), and the lines that they spawned—e.g., positivism and its offshoots; Marxism, whether by proponents or in opposition.

Most primitively, the basic process that permits the extension of normal physics to such complex hybrids—biological and social physics—is epitomized by Einstein's theory of brownian motion. Any particle, whether microscopic or macroscopic, immersed in an active atomistic ensemble, equilibrates energy with that ensemble. This is very easily to be seen at the level of bacteria and sperm. Operationally extending the scope of a Navier–Stokes description of material flow fields (stars, atmospheres, plasmas, galaxies, vascular systems) has become routine in physics. Its further extension (e.g., to societies) is now timely.

This journal article may be regarded as a scientific statement of kinetics for political interns. Its brevity and shape was only made possible by an enormous indebtedness to my social science colleagues and to my friend Harry Soodak.

1. Soodak, H. & Iberall, A. (1978) *Science* **201,** 579–582.
2. Iberall, A. & McCulloch, W. (1969) *J. Basic Eng.* **91,** 290–294.
3. Iberall, A. (1972) *Ann. Biomed. Eng.* **1,** 1–8.
4. Iberall, A. (1973) *J. Dyn. Syst. Meas. Control* **95,** 291–295.
5. Iberall, A., Soodak, H. & Arensberg, C. (1980) in *Perspectives in Biomechanics*, eds. Ruel, H., Ghista, D. & Rau, G. (Harwood Academic, New York), Vol. 1, pp. 433–528.
6. Kroeber, A. & Kluckhorn, C. (1952) *Pap. Peabody Mus. Archaeol. Ethnol. Harv. Univ.* **47.**
7. Sabloff, J. & Lambert-Karlovsky, C., eds. (1975) *Ancient Civilization and Trade* (Univ. New Mexico Press, Albuquerque).
8. Hamblin, D. (1973) *The First Cities* (Time-Life, New York).
9. Mellaart, J. (1965) *Earliest Civilizations of the Near East* (McGraw-Hill, New York).
10. Jacobs, J. (1984) *Cities and the Wealth of Nations* (Random House, New York).
11. Llinás, R. & Iberall, A. (1977) *BioSystems* **8,** 233–235.
12. Elliott, H. (1967) *The Shape of Intelligence* (Scribners, New York).
13. Goodwin, B. (1969) in *Towards a Theoretical Biology, Vol. 2: Sketches*, ed. Waddington, C. (Aldine-Atherton, Chicago), pp. 140–165.
14. Iberall, A. (1969) in *Towards a Theoretical Biology, Vol. 2: Sketches*, ed. Waddington, C. (Aldine-Atherton, Chicago), pp. 166–178.
15. de Saint-Simon, H. (1964) *Social Organization, the Science of Man, and Other Writings* (Harper & Row, New York).
16. Engels, F. (1939) *Anti-Duhring* (International Publications, New York).