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A SUM of Science: The Taxonomy and Methodology of Sociophysics

Arnopoulos, P.: **A SUM of science: The taxonomy and methodology of sociophysics**
Knowl.Org. 20(1993)No.3, p.139-149, 80 refs.
Attempt to order the main parameters of scientific theory into a coherent taxonomy. To that end, a System Unification Model (SUM) is constructed which serves as a formal frame classifying the salient structures and functions of empirical existence. The terse presentation should give a synopsis of the scope and method of knowledge organization applicable in a global scale.
The methodology used is based on a Triadic Interface Paradigm which combines dialectic and syllogic algorithms to arrive at synthetic conclusions of general application. This holistic perspective situates the static and dynamic contents of matter, energy and information systems in their space-time context. Finally, these dimensions are manipulated by formal operational codes to produce systemic and systematic knowledge.
The Model has been used to demonstrate a new Theory of Sociophysics which integrates the basic principles of social and natural sciences into an all-inclusive conceptual framework. Sociophysics assumes the fundamental isomorphism of nature and culture, thereby projecting heuristic metaphors between them. As a result, it contributes in enhancing, understanding and appreciating the global picture of human reality. (Author)

Introduction

Human beings have always tried to describe and explain their experiences in various ways. This article continues this tradition by integrating the main aspects of the scientific way. To that end, we outline here a System Unification Model (**SUM**) which serves as a formal framework classifying the salient structures and functions of existential systems. This presentation should give a general idea of the scope and method of knowledge organization applicable to both cultural and natural domains. As culture and history change, so do paradigms and metaphors. The simple analogies and generalizations used in the past at the early stages of science no longer suffice in a more sophisticated age. In order to understand the complex systems which span the contemporary world, we need to translate the latest scientific theories into the social arena. But, the critical discontinuities and deep contradictions in both historical periods and geographical regions, require a more complicated and often counterintuitive approach which traditional studies may not provide. Since the social sciences deal with cultural rather than natural phenomena, they are more sensitive to space and time. Admittedly, culture influences our assumptions, agendas and explanations. Scientific rationalism, however, decreases cultural relativism, at least among the initiated. As the world develops a global scientific culture, it also develops a planetary ideology and standardized terminology. Thus, although it would be impossible to divorce science from society; it is possible to extend its scope to the global system and so raise it above parochial cultures to human universals. The reality of a global village emerging at the dawn of the Third Millennium demands an interdisciplinary approach of systemic synthesis. This demand may not be as difficult as it seems at first sight. According to modern science, reality shows a remarkable tendency for uniformity and consistency. Although they apply to different realms, its fundamental laws have been found to be the same everywhere and always. This Principle of Universality has by now been established as the cornerstone of the natural sciences and we hereby intend to extend it into the social sciences as well. We therefore accept the thesis that there exist isomorphic structures and functions not only throughout space and time but at all levels of existence, thus reflecting the essential unity of reality. Whenever this unity seems to be broken at one systemic level, it is in order to maintain itself at a deeper and more fundamental one. Ultimately, the infinite variety of unique forms comes down to a few typical generic patterns. By focusing on these patterns, this article is necessarily very abstract and theoretical. Covering such large area means diminishing depth. The gains made in macroscopic synthesis have to be paid by the losses incurred in microscopic analysis. To be able to see the grand pattern and regularity of the whole, we have to ignore the unique character and singularity of the individual. Specific details will therefore be sacrificed on the altar of general principles: *de minimis non curat lex*. This sacrifice need not be in vain because the details can be filled in later studies. The heuristic fall-out from framework theories can provide powerful incentives for further in-depth research into the various areas covered therein. Once the grand lines have been sketched, their particular applications and rigorous interpretations eventually follow. Meanwhile, we adopt the universality thesis that it is not necessary to know specific details in order to understand the overall scheme of things. For this reason, its synthetic approach has been utilized in the composition of a Theory of Sociophysics which describes and explains particular empirical phenomena in terms of general conceptual systems (see the references). The theory is developed within a triadic interface paradigm which provides the Archimedian fulcrum of underlying assumptions and leve-

rage for the operating procedures characterizing this outlook. On that basis, we start by making some common sense assumptions taken on faith. Upon them, a conceptual isomorphic model, adequately representing relevant aspects of the subject under investigation, is then constructed. Finally, as a result of the fruitful interaction of many factors, a theory of reality emerges: mediating between whatever may exist out there and whatever awareness we have of it in here. From this human perspective, we can distinguish three kinds of structural relations, depending on the systems involved in them. On the one hand, each person is related within oneself. These internal connections constitute the inner realm of the personality and create a mental or **egosphere**. On the other hand, we also relate to the external world which exists apart and independently. These relations connect humans to their natural environment and create the **ecosphere** which includes them. Between those two types of relations are those which exist among people themselves. These interpersonal relations form the **sociosphere** - which are at the focus of our concerns here. The three distinct worlds can best be illustrated as concentric circles shown in Diagram 1. The innermost ring represents the internal world of each human being, surrounded by the social system and the natural environment. For purposes of this study, we shall marginalize whatever lies beyond person or nature, leaving these externalities to the *terra incognita* of either the subconscious or the supernatural. This conceptualization surrounds the social by the natural sciences, indicating that to understand society requires a wider knowledge which must include nature. Of course, that alone cannot explain the specifics of the inner realm; but it will do for interpersonal behavioral analysis. This study will therefore focus on the middle ring and the fundamental relations which bind it to both its internal and external components. Accordingly, the construction of this conceptual model begins by postulating the existential polarity between the real and ideal worlds as mediated by human nature. The three terms of the Aristotelian dictum - **physis-anthropos-polis** - and their interrelations, as illustrated in the triangular figure of Diagram 1, thus become the foci and loci of our concerns.

For all these reasons, the triadic format used here will serve as our general paradigm because it illustrates the idea of a basic existential duality, tempered and alleviated by an intermediate condition which contains and transcends it. It is felt that this modular construction has both heuristic and mnemonic advantages which orders, reflects and explains complex systems. Just as Gauge Theories try to combine the golden triangle of the fundamental ingredients of nature: particles, forces, and codes; we hereby specify the three dimensions or parameters within which any theory should be framed:

1 Context:
- boundary conditions of existence in space-time;

2 Content:
- substantive elements of matter-energy systems;

3 Codex:
- operating program of formal processes.

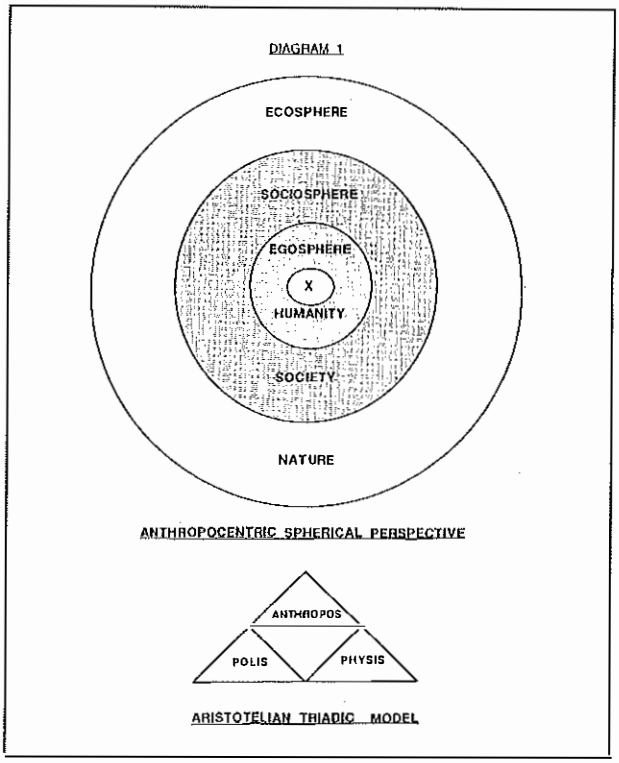

Diagram 1: Aristotelian Triadic Model

These (C^3) aspects form the three pronged approach shown in Diagram 2 and define our universe of discourse. The diagram's taxonomic tree contains all the factors considered relevant for scientific knowledge Following Occam's razor as well as Einstein's dictum that science should cover the largest number of empirical facts by

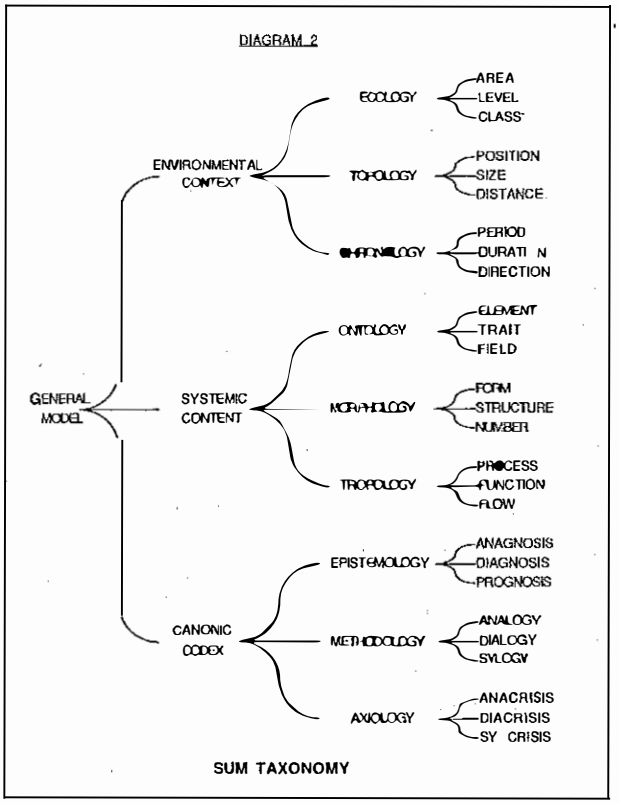

Diagram 2: SUM Taxonomy

logical deductions from the smallest number of hypotheses; we hereby present the main elements of SUM's abstract conceptualization and describe them as succinctly as possible in the next three sections.

Ad 1 Context

This exposition begins with the contextual reality of the subject at hand because it provides the background or infrastructure which defines and supports whatever one wishes to study. In this case, since the topic is sociophysics, the context is the natural environment within which human and material systems exist. We use this context to form the conceptual framework which sets the scope of this work. Accordingly, the environmental perspective of our reality is a trilateral construct which composes the basic axiom of this theory-building attempt. Following Kant's intuitive predicate, we begin *a priori* by assuming that what is considered as real depends on one's experience in space and time, symbolically shown as:

$$R = f\{s,e,t\}$$

The **set** (space-existence-time) postulate emphasizes the formal interdependence of all three aspects of reality and combines them into the three-dimensional framework described here. The three aspects of set are reflected and studied by topology, ecology and chronology. Together, they suffice to define the attributes of reality in complete and concrete terms. Although these notions are so elementary that they cannot be formally defined; our intuitive grasp of them will be further elaborated in the following discussion of each.

1.1 Ecology

The ecological aspects of our theory may be said to comprise the various areas and levels of generality within which the relevant systems of this study coexist. The most important point to be made here is that our field of vision distinguishes between inclusive and exclusive spheres of existence. Reality may be presented within a number of concentric spheres, much like those of Diagram 1. The outermost, inclusive sphere is the entire universe, while the innermost, exclusive sphere is the elementary particle. Between these two extremes, there are layers upon layers of different existential realms. These divisions may be said to form the framework for the general ecological taxonomy we shall use here. The classification scheme not only distinguishes between vertical levels and horizontal areas, but recognizes a hierarchical structure which permeates both. The scheme is thus predicated upon the combination of three parameters: areas, levels and classes. The environmental **areas** of this model are evenly divided into the inner and outer worlds, as described at the beginning of this introduction. This dichotomy is an innate separation of the self from the rest of reality. Every sentient being can make this distinction between its internal and external worlds and so separate its own ego from various alter egos. Humans, therefore, have two main environments: an interior and an exterior: the former belonging to the personal and the latter to the social or natural realm. This dichotomy between inclusive and exclusive, not only distinguishes between two different worlds quantitatively, but assigns a qualitative degree upon each: the first is considered at a lower **level** than the second. Exclusivity is considered a characteristic of superiority. By differentiating between inferior and superior realms, the vertical stratification creates a hierarchy of existence and without going as far as the exactitude of the medieval Great Chain of Being, it does give humanity a general orientation for its value priorities. Supplementing this vertical and horizontal frame of reference, there is a third parameter which distinguishes between the natural and artificial worlds. Human beings realize that they are creatures of the first and creators of the second. Unlike other natural creations, man is also a *homo faber*, who shapes and is shaped by nature. This capacity to produce artifacts has built a new **class** of artificial environment: i.e. the social **technosphere**, which supplements and even dominates the natural part of society. These inner-outer, higher-lower, and natural-artificial dichotomies set the stage for our model and put it in the proper perspective. Such perspective will serve to situate the discussion in the main text and thus relate the systems upon which we shall focus attention. Thus, the ecological framework must be kept in mind as a necessary background for understanding what is to follow.

1.2 Topology

That we exist in a three-dimensional space is a common sense as well as a common place assumption. Although some scientists, especially String Theorists, believe that reality is multidimensional, we need not go into higher dimensions in the present context. Three dimensions suffice to describe and explain most sociophysical phenomena, so we will contend ourselves with these. It is they that form the conceptual basis of distance, size and position. Accordingly, things are located in ordinary three dimensional space and their **position** can be pinpointed by altitude, latitude and longitude: with the well known Cartesian (**x-y-z**) coordinates providing their inertial reference frame. Within this frame, various points are located by measuring the **distance** which separates them as a vector joining their respective positions. Finally, going beyond dimensionless points, ordinary things occupy a certain amount of space proportional to their **size**, as measured in the same three dimensions: length, width, height. Topological taxonomy ranges things by size from the micro to the macroscopic. All things from the subnuclear to the universal can be fitted within the range of 10^{60} Planck lengths. As it happens human size is in the middle or mesoscopic region. Just above it, the social world ranges between ten and ten million square meters, i.e. the area of the smallest community (family) on the one hand and the global society (world) on the other. Our central position along the spatial scale of things accounts for our relative sense of size and distance. Human perception can distinguish between small and large as well as between near and far. Finally, we can differentiate between rest and motion by fixing stationary

objects in a single location and following the trajectory of moving objects between successive points in space.On the basis of this human sense of space, we shall locate our model in the proximate range, where we perceive social systems. From this anthropocentric vantage point, we acquire a good perspective of our position in the overall scale of things. Moreover, we use space as an explanatory variable for the operational range of different laws. Although there is a basic similarity in all things regardless of scale; where things are located, how big they are and what distance separates them, are all significant factors in describing or explaining them. Space will therefore serve as one of our two most important frames of reference.

1.3 Chronology

Time has often been called the fourth dimension of space, and indeed it is inextricably woven into it. As space is a container for things, time is a channel for events; as the former measures dimension, the latter measures duration. Together with the existential *what*, the two coextensive frameworks determine the *where* and *when* of all phenomena.As we did above for space, we shall now analyze time according to three parameters: direction (past-present-future); duration (short-medium-long); motion (slow-average-fast). Looking upon time from these three angles will describe their timing and pacing. In any case, *tempus fugit*: time never stands still. Unlike space, time seems unidimensional and everflowing. For all practical purposes, its motion can only be in a single **direction**. The arrow of time flies inexorably through three successive periods: from the past, via the present, to the future. Accordingly, to the space's three degrees of freedom (up-down; left-right; fore-back), time has none (only forward).This apparent unidirectionality of time is neither absolute nor deterministic and may manifest itself so on the human level only. In the microscopic realm of elementary particles time could flow in both directions; whereas in the cosmic world of the universe, it hardly flows at all. This temporal relativity makes determinism a flexible concept and shows that events are not necessarily predestined. Although the past cannot be relived, nor history changed; the future consists of many possibilities, so destiny can be shaped to some extent. As we shall see later on, humans as well as other living beings have some degree of volition which give them a freedom of choice within the constraints imposed by the circumstances of time and space. Between the ineluctable past and the uncertain future, the everlasting present is a fork on the road of time, therefore it always offers some options from which to select one's future. Time, like space, began with the Big Bang over ten billion years ago. That momentous **event** of universal genesis can be considered as the origin of time when **t=0**. Consequently, our past is about twenty billion years and it is at the end of that period where the present is located. Only five billion years ago, the solar system was created and it is estimated that it will last another five billion years, at which time the sun will become a supernova and eventually burn out completely. The rest of the universe, however, may go on for another 10^{100} years before all matter has disintegrated into radiation at maximum entropy. Accordingly, it seems that there is much more future than past, since at present the universe is still very young.As distance measures space, so **duration** measures time. The life-time of things varies from the almost instantaneous **chronon** or jiffy (the time it takes light to cross the diameter of a proton), to the almost eternal galaxy. Here again, human time is found in the midrange between the second it takes for human reaction to the ten thousand years of history. Thus both for space and time, human social activities occupy the central focus of our conceptual framework.As to the **pace** of time, we shall consider this parameter from both its physiological and psychological aspects. The former looks upon motion either as an absolute or relative combination of time and space. The latter compares the objective measurement and subjective sensitivity about the passage of time. Here again, it will become evident that temporal flow is perceived differently, depending on one's psychological state and biological age.In order to summarize and synthesize the three contextual parameters discussed in this section, we have combined them in Diagram 3, showing the relationships between realm, space and time. In this context, the distance and duration of humanity and society are midway between the micro and macro regions of reality. This synoptic view shows the centrality of human existence in a cosmic perspective. We shall keep this perspective throughout, thus retaining the image of man in relation to the rest of nature.

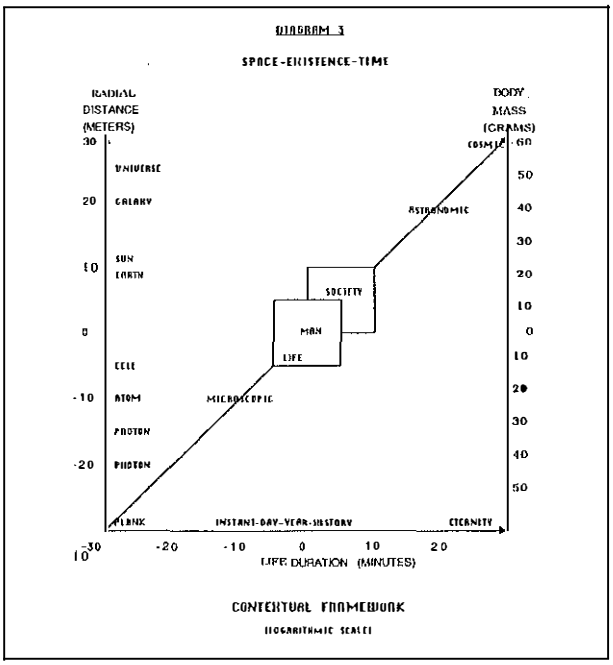

Diagram 3: Contextual Framework (Logarithmic Scale)

2. Content

Following the basic framework just constructed, we can now introduce the various **units** which exist therein. The fundamental assumption here is that our contextual reality is filled with some existential content. This content can

best be described as a variety of distinct entities, which are nevertheless interrelated and interacting. As such, any number of entities taken together as a group may be said to form a **system**. The members of the system compose its substance, their relationships form its structure and their activities determine its operation. As a group of interconnected units, a system can be anything one defines it to be, depending on where its border with the environment is drawn. Once the object of inquiry has been identified and defined, its complete description requires information about three ●'s (quiddity, quality, quantity). These three aspects mean that one must know the system's essential ingredients, characteristic attributes, and core values. On that basis, anything may be identified by its substance, shape, and weight. Since Bacon, a distinction has been made between primary and secondary traits. The former are objective and quantitative, such as matter, motion, form; while the latter are subjective and qualitative, such as color, taste, smell. These distinctions have now been reaffirmed by modern science, so they shall be accepted here as the descriptive aspects of reality. For our purposes, we have devised the following identifying parameters: substance; structure; and operation. Accordingly, we look into ontological, morphological and tropological characteristics of relevant systems. By doing so, we can describe phenomena and situate them into the larger scheme of things. The following three sections will cover the necessary details of each of these elementary aspects.

2.1 Ontology

The discussion here can begin by distinguishing three existential domains: The first and most inclusive is that of **reality** which may include all possible beings. The second is that of **actuality** and includes only beings which have an existence independent of us. The third and most exclusive is that of **sensuality** which applies only to empirical beings, like ourselves. These distinctions are based on the *a priori* assumption of our own existence and then go on to determine *who* else exists, what are they like and how are they related to us. To do so, they set the criteria of evidence which could prove one way or another what constitutes something in distinction to nothing. The criteria will be set here in three parameters dealing with elements, attributes and relations. The first concerns the identity of an entity; the second describes its traits and the third determines its affections. The above three aspects are the necessary and sufficient parts of a complete description of our components. It is the primary hypothesis here that everything existing and happening in reality involves these and only these elements in some way or another. This ontological model will therefore be built on their parameters. Human capacity to experience and define reality has been primarily justified by common sense and eventually confirmed by natural science. Since present knowledge rests on the foundation of physics, it will be used to support our contentions here. Accordingly, we admit the postulate that reality may ultimately be reducible to certain elementary **particles**. It is they which eventually make up everything, from the most banal material things to the most exalted ethereal ideas. These particles, named fermions, are of two kinds: leptons and quarks. The former, of which electrons are the most prevalent example, are very antisocial in that they exist alone; while the latter are quite sociable and so are always found in groups. ●quarks combine to form protons and neutrons, which make up the atomic nucleus. As the fundamental units of matter, various combinations of atoms, composed of nuclei and revolving electrons, build up all material structures, from molecules and cells, to planets and stars. In between, there is the realm of human society with its own kind of individual and collective entities. The traditional ontological dichotomy between matter and mind may be explained, perhaps in an oversimplified way, by the fundamental difference between quarks and leptons. Ideas are basically systems of electrons, rooted in the quarks of a brain. From the simplest symbol to the most complex theory, mental entities arise from the various activities of material elements; at the same time as they in turn affect their material hosts. Mind and matter are thus interrelated in various degrees, as exemplified in human beings. Throughout history, great thinkers have made various analogies between the elements of natural and social systems. From Plato's *Politea* as *anthropos* writ large to Bronowski's man as a social atom, these metaphors have persisted in all periods and regions of human contemplation. We then accept such attempts as valid comparisons to be elaborated upon at various levels of abstraction. Elementary particles exhibit three basic **traits**: mass, charge and spin. The first gives being its substance; while the second gives it essence and the third corresponds to a self-referential activity. At the material end of the existential spectrum, mass reigns supreme but tapers off as we move towards the mental end. Charge, on the other hand, is to be found, in various quantities (strong or weak) and qualities (positive or negative), throughout existence. These traits give all beings certain proclivities which demonstrate their particular character and distinguishes them from each other. In combination, they manifest the crucial phenomena of attraction and repulsion which account for natural and social dynamics. All entities, whether fermions or humans, need some mediating agency to interconnect them into systems. This indispensable role of interrelating and interacting is ultimately played by some kind of **field** particles, named bosons.

Unlike fermions which are characterized by a significant mass and charge, bosons do not partake of these two attributes. Rather, they only have spins and provide connections as they are exchanged among fermions. Such exchanges are basically of three kinds: weak or strong nuclear, electromagnetic and gravitational. The first exist by sharing gluons and thus hold together the atomic nucleus. The second take place by exchanging photons and thus explain most of our ordinary phenomena. The third operate by the displacement of gravitons and thus provide the overall attraction between all things in the universe. Similar phenomena occur up the ontological ladder to describe social, as well as atomic and gallactic bonding.

Societies, like all systems, are held together by certain forces of varying strength and extent. From the very strong and tight bonds of the organic family to the weak and loose threads of cultures, these connecting links form all kinds of structures and institutions: organic and social alike.

2.2 Morphology

As particles combine, they form structures. This process of morphogenesis means that systems take shape and form. Beyond the elementary particles, how systems are structured becomes an important aspect of their identity. Thus, the number and kind of connections in a system determine its crux and form. Structural forms are so diverse that it is difficult to classify them. But, for purposes of this model, we use three criteria. These will pertain to the quantity of their components; the quality of their form; and the anatomy of their structure. As to quantity of components: systems are distinguished by the **number** of units which belong to them. Thus, beyond isolated particles, there are small systems, made up of very few members, as well as large systems of numerous elements. At the minimal end, the smallest system requires at least two parties: such as the two quarks which form a proton. At the maximal end, of course, is the all-inclusive universe. In between, are to be found intermediate systems, including organic and social ones. The simplest way of defining systems is by the kinds of their units. In this way, an atomic system may be distinguished as a group of elementary particles and a solar system as a group of heavenly bodies. Similarly, a material system is a group of massive objects, whereas an ideal system is a set of mental concepts. Determining components, thus, defines the type of system one wants to focus on. What serves as the component of one system, however, may itself also be a system. So, human beings who are the units of social systems are themselves organic systems made up of a great number of living cells. Furthermore, each of these has a molecular system and each molecule has an atomic system. This hierarchy of units within systems and systems within units could extend itself indefinitely up and down the scale from the infinitesimally small units to the infinitely large. Present knowledge limits this range between the elementary particles as the smallest units and the universe as the largest system. In between are to be found several distinct levels of different qualitative and quantitative characteristics. Apart from size, these levels may be also distinguished by the complexity of their units. On these criteria, we can discern three types of material systems. Starting from the bottom, there are nuclear or **atomic** systems composed of elementary particles as their units. These form the simplest kind of systems of which there are about one hundred different kinds forming all the elements (e.g. hydrogen or iron) of the universe. Large agglomerations of these make up inert materials (e.g. metals or stones) and mechanical parts (e.g. cogs or rods). At the next level are **molecular** systems, composed of atomic systems as their units. Molecules make up the more complex substances (e.g. earth, water, air) which are usually compounds (e.g. ceramics or plastics) of various elements. At the top are the **cellular** systems, whose units are molecular systems. At that level the accumulated complexity of the units (e.g. proteins or enzymes) makes the systems (e.g. fibers or muscles) qualitatively different than the previous ones because they possess the attribute of life. Since these levels are hierarchical, their characteristics are cumulative, so that organic systems contain both molecular and atomic ones, whereas molecular systems only contain atomic. For now, these three fundamental types were selected as the building blocks of all reality. This is evidenced by the most advanced of the scientific disciplines which study these three levels: i.e. physics; chemistry; biology. Social systems result from a complex combination of these levels. The degree of connectivity among the elements of a system determines the second formal parameter considered here. This means that if the connections are strong, they result in rigid **structures**; whereas when weak, they form fuzzy sets. In this range between rigidity and flexibility is found the difference between solids, liquids and gases: from the most crystalline to the most cloudy. The degree of anatomical order thus produces the exactitude of form and differentiates systems according to their structural state: from natural bodies to social institutions. Finally, the sequence in which elements are arranged is as important as their number and strength. The quality of this arrangement determines both their structures and actions and so serves as a major distinguishing characteristic. In this respect, **forms** may be classified from the minimal one of a single point, through a string of points forming unidimensional straight or curved lines and bidimensional planes, to the most complicated tridimensional forms combining many different shapes and sizes: from the simplest sphere to the most complicated organ. The importance of form at its primary level is evident from the famous particle-wave duality in elementary physics. Extending this phenomenon, it seems that systems at various levels sometimes behave as particles and other times as waves, depending on how they are approached and manipulated. This individual-collective duality has produced many paradoxes in physics and politics alike which have not yet found a complete explanation.

2.3 Tropology

In addition to form and substance, particles and systems have a behavior or *tropos*. All particles act in a certain way and some action takes place within all systems, as well as between them and the environment. An understanding of system dynamics, therefore, requires knowledge of *how* it behaves, which we now add to our model. We begin by distinguishing three parameters which characterize systemic activity: flows, processes and functions. Different types of systems have several combinations of these activities. Complex systems, like societies or organisms, have all three types. Simple, isolated systems, like an asteroid at the edge of the universe, has very little of any of them. Let us then describe each one. By **flow** are meant the dynamic elements moving along the connecting channels of a sy-

stem. As mentioned above, bosons provide the most elementary flows of any system; but at a level closer to the middle range of reality, one can distinguish three kinds of flows: materialistic, energetic, and symbolic. At the material end of the spectrum, various forms of matter can be transported between points in space; such as the flow of blood in the arteries of organic systems or the movement of goods and people in social systems. Similarly, energy, as the other manifestation of matter, flows through dynamic system channels as electricity or heat. Finally, at the mental end of the spectrum, information can be communicated via either material or energetic vehicles. These flows may be considered as **processes** when they undertake or undergo some transformation along the way. In this case, the flows entering a given system are its inputs and those leaving are its outputs. In between these two are the transforming throughputs of the systemic process. Because of their serial connectivity, the input-output flow is identified with the cause-effect process. Since outputs depend on inputs, there is some causal relationship between the two which indicates the flow of influence from one point to another. In open systems, input-output flows run between the system and its environment. These flows to and from the environment may transport materials, carry energy or communicate information, using different transmitting and receiving channels. Systems act as converters which transform inputs into outputs. These three **functions**: reception (stimulus); conversion (transformation); expedition (response); thus characterize the dynamics of all complex systems. A function signifies the correlation between at least two variables: x and y; so that for every value of x there is a corresponding value of y. The basic function of a system requires that the output y is dependent on the input x: i.e. $\mathbf{y=}f\mathbf{(x)}$. Where y is the dependent variable, x is the independent variable and f (operator) is some function. If the relationship is linear, the function takes the form of: $\mathbf{y=Ax+B}$; where A and B are parametric constants. Complex systems, of course, have much more complicated functions with the addition of intervening variables. The principle, however, is the same in all cases: i.e. a complete knowledge of how a system functions must account for all its flows. In considering the functions of a system, one also gets involved with questions of role and purpose. These try to find the instrumentality of systems by determining their priority in the chain of causality. In this respect, we can distinguish between original and final stages in the systemic function. Some systems serve the purposes of others and thus are means to an end. Other systems intervene between immediate and ultimate chains of causation; therefore they are both means for some and ends for others. In order to summarize and illustrate the interrelations among elements, structures and processes, Diagram 4 below shows the various intersecting ranges of system contents as they were discussed above. The main point to be made from all this is that the continuum between simplicity and complexity is the combined result of all the parameters mentioned here. The difference between simple and complex systems is of course one of degree, which carried to extremes becomes one of kind. As relatively complex systems, human beings can look both up and down this existential ladder and compare their position in an overall perspective. In doing so they engage in mental and physical activities according to certain rules. Identifying these rules and describing their operation will then be the subject of the next section.

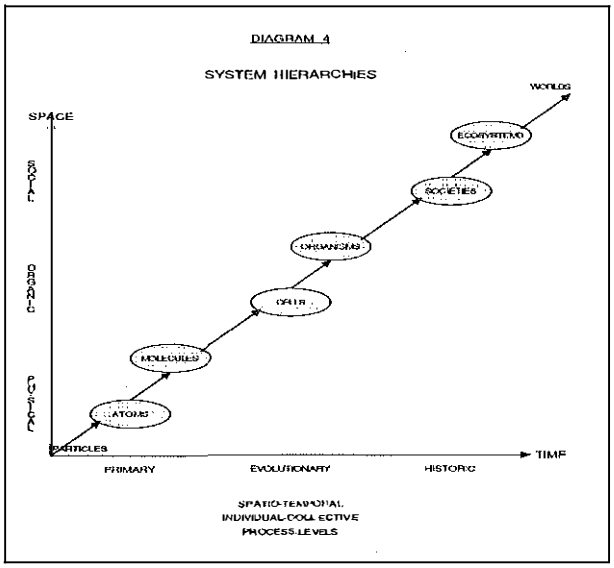

Diagram 4: Spatio-Temporal Individual-Collective Process-Levels

3. Codex

Having outlined the content and context of SUM, we now present its operating procedures or working programs. These are the means and methods according to which particles and systems function. Codes are thus indispensable not only for practical but for theoretical reasons; because they guide the actions of systems as well as explain their dynamics. If law means a manifestation of regularity or a description of tendency, then it is an expression of invariances maintained in spite of transactions undertaken. Thus, laws may be likened to plans or programs which guide particular actions under certain conditions, based on the Cosmological Principle that nature behaves uniformly and consistently in space-time. Laws are of varying intensity and extensity: from the strong to the weak and from the general to the specific, or from the ante to the meta. Natural laws seem to be the most general because they have the widest scope and admit few exceptions; whereas social laws are more specific to human interactions and are full of conditional limitations. This distinction, however, is one of degree and level, so it does not contradict the fundamental qualities perceived in both. It should be noted in this respect that like social legislation, certain natural laws, i.e. superconductivity, are not merely discovered but created by human intervention. According to the Principle of Covariance, there is a general correlation between natural and social laws. Contemporary science accepts natural laws to be much more like social laws: i.e. encouraging or guiding behavior, rather than commanding absolute obedience. In that sense, all laws predispose things to act in a certain way, they do not predetermine them to do so. Moreover, like common or customary rather

than civil or positive, natural laws have developed over eons of time and patterns of habit, thus enjoying the advantages of primogeniture. The search for a real-ideal complementarity between natural and cultural codes attempts to specify how the basic rules of the game operate in the universe at large and how they apply in the human domain as special cases. These rules combine to form the **etiology** of sociophysics and include the scientific laws of correlation and causality, as well as its grammatical canons, aesthetic norms, prescriptive morals and plain common sense. Since we face an immense existential reality with a limited mental capacity, we cannot explain everything by reason alone. Therefore, some things have to be taken on faith, speculated by imagination and sensed by experience. Under such conditions of uncertainty and incapacity, it is best to utilize a **triangulation** by overlapping ideological (axiomatic, dogmatic, poetic), rational (logical, deductive, analytic) and empirical (scientific, inductive, historical) methodologies. These will be cross-referenced with three kinds of propositions: descriptive (objective, perceptive, sentient), evaluative (subjective, judgmental, preferential), and prescriptive (operative, imperative, demanding). This multiple approach also reflects a three-valued logic which not only admits a binary true-false, and-or, more-less, good-bad, do-don't alternatives, but includes an indeterminate or combinatorial maybe-both-neither possibilities. Admitting the truth-values of Boolean algebra, our approach raises various triadic sorting methods which could be quite useful in agnostic information-validating as well as uncertain decision-making: the famous or infamous **triage** procedure, being one of them.We begin the elaboration of this coding scheme by the common sense premise that reality presents us with certain patterns in space and regularities in time which are perceived and emphasized. In this way, we notice similarities and differences, according to which we abstract and classify things in conceptual categories, as we have been doing in this presentation. On this basis, we have constructed a classification schema to serve as the framework of this model-building exercise. As the basic premise in this respect, we discern two opposing nomothetic conditions of reality: static and dynamic. The former applies to things which are rather stable in space and constant in time; whereas the latter applies to things which are relatively variable and changing. General laws deal with how things change, while they also remain the same. As a result, cogent explanations are metaphors between puzzling phenomena and conservation-variation principles. The language of mathematics provides a rigorous medium for these fundamental laws by the terse symbolism of differential equations; the archetype of which is: $\mathbf{dx/dy=}f\mathbf{(x,y)}$.

Along with wave functions which we will see later on, this equation can describe everything in reality. Whenever they can be found to have unique, solvable and stable functions, reducible to the general form: $\mathbf{X=kY}$

these equalities are the most effective means of explaining natural phenomena. What should be particularly noted in this connection is that great mathematical formulae are simple equations usually correlating three factors (one constant and two variables) by a single operation (addition or multiplication). This means that any two variables are correlated by a constant ratio of proportionality. If that is the case, we have a primordial triangular relationship hinged upon the value of **k**.

Such architectonic structures are quite significant because they fit in our paradigm by showing how dichotomous variations may be mediated by a third position which partakes of both. In that sense, the constant in the above equation may be seen as the conjunction or translator between the two variables. The general hypothesis here is that this trilateral connection may be found among statics, dynamics and dialectics, so it will serve as the fundamental canon and one of the three dimensions of our model.Based on this canon, the programmatic aspects of the model will be dealt with by three fields: epistemology, methodology, and axiology. In this order, we will look successively into the codes of verification, validation and evaluation; thus outlining the operating rules of the model. The following sections will deal with each one in turn.

3.1 Epistemology

The theory of knowledge adopted here centers around the modern empirical paradigm which combines rationality and sensitivity as the dual road to human understanding. On the basis of sense inputs and thought flows, one can form a coherent overall picture of reality. Human knowledge (justified true belief) consists of a system of conjunctions between perceptions (experiences) and conceptions (explanations). We are convinced of knowing something, if we can fit it in the general scheme of things forming our *weltanschauung*. Understanding, thus, involves the successful integration of particular diverse phenomena into a general ideological paradigm by the combination of scientific induction and logical deduction. The correct juxtaposition between facts and ideas permits us to verify experiences and test the facticity of our perceptions. The complicated process of doing so may be simplified by three analytic phases: Diagnosis; Anagnosis; Prognosis (DAP). The successful application of such **analysis** should provide adequate knowledge about anything. It shall thus be incorporated into the model in its simplest form.The process begins by a **diagnosis** of the object or situation under study. This means the identification, definition and description of an existing condition by accurate perception and classification of signs and facts, using proper criteria of evidence and proof. Diagnosis differentiates between true and false symptoms in order to arrive at the correct correlation between nooumena and phenomena. Thus, the first critical step is that of verification which distinguishes factive from fictive images. If truth measures the correspondence between mental and material phenomena, then we want to make sure that our internal images are true representations of external objects. Diagnosis does this by constantly comparing and correlating the inner world of concepts and outer world of percepts.Once a correct diagnosis of the present is made, the next step is to find the

causal chain that led to it. This requires an **anagnosis** or prior knowledge of history in order to discern the sequence of events which produced the actual situation. The proper reading of the past will lead to the etiology of the present and thus explain it causally. Anagnosis, therefore, assumes that there is some cause-effect relationship between antecedents and consequents; so that temporal order rather than chaos determines the sequence of events. Explanation, as we shall see, does not only involve deterministic chains of causality, but also random and intentional elements, which must be taken into account for complex system behavior. If that is done, knowledge of the past and present should inevitably lead to determination of the future. Thereby, on the basis of diagnosis and anagnosis, one should be able to present not only a plausible description and explanation of a problem, but also a prediction of its evolution. This last step of **prognosis**, projects into the future the trends established in the past, as they are transformed by the present. In this way, it calculates the probable within the limits of the possible, given the proper theory which connects these aspects of reality. Together, these three steps follow the arrow of time, and allow a study of the temporal development of significant events. Since realistic exposition, historical explanation and conditional extrapolation are an integral part of mental activity; we follow this diachronic process in order to understand the dynamics of social systems, especially as they apply to the macrohistorical progress operating on the global world scale. Ideally, this method should produce complete knowledge on any subject. Yet, for various practical and theoretical reasons, it is now admitted that such knowledge is impossible. Both the inadequacy of facts and the incompleteness of laws, as well as the inherent uncertainty and indeterminacy of reality preclude an exact knowledge of anything. Thus we have to accept this epistemological limitation and resign ourselves to partial knowledge.

3.2 Methodology

Even if it can never be complete, knowledge can be acquired by certain methods better than by others. Methodology is such a search for a systematic and optimal way of reaching a given objective. As a means to an end, a method is the bridge crossing from ignorance to knowledge. Finding the best vehicle to move in that direction, therefore, becomes the purpose of this search. Since the way to knowledge has been found to relate empirical phenomena with mental nooumena, we follow this road back and forth between its two end points. For this journey, we use **logic** as the main vehicle of manipulating symbols and communicating ideas. This method provides three rational criteria: Syllogism; Analogism; Dialogism (SAD), which determine the validity of both the process and its results. First and foremost is the **syllogistic** method which is identified with classical Aristotelian logic. Although this method proceeds by deduction from the general to the specific; the opposite sense, from specific to general, can easily be derived by induction. The former applies unified theories to explain diverse experiences; whereas the latter builds broad theories from a lot of statistical data. Together, deductive and inductive logic provide the rules for both rationalizing and generalizing in a valid manner. As a rational method, science combines the two processes, by trying to discover empirical events as well as construct conceptual laws. These laws supply the necessary broad prerequisites with which the sufficient specific conditions combine to formulate meaningful explanations. Thus, explaining unique empirical facts in terms of universal ideals or formal abstractions is accepted as valid by positivist thinking. The ultimate explanatory statement of a physical entity, known as a Lagrangian, is a mathematical equation which provides the operative code of the system under consideration and thus explains its behavior. Most natural system dynamics can be described by second order differentials. But, these equations work best in conditions of smooth and continuous change; they are not so well adapted to abrupt discontinuities as those experienced in complex systems. For that reason, the ideal abstractions of symbolic logic and mathematics, cannot always fit the behavior of very complex systems, such as human or social ones. Relativistic thinking therefore emphasizes the specific and contingent aspects of behavior in order to explain incidental or circumstantial events. In these cases, **analogic** thinking is more appropriate for purposes of consistency. According to this comparative method, *exegesis* is best achieved by juxtaposing the similarities and differences among the various aspects of reality. To this end, the analogical method serves a purpose by comparing the known to the unknown and the social to the natural. In addition to syllogy, we also utilize analogy as a valid criterion for extending knowledge from one field to another. Comparing the simpler and well-known laws of nature with the complex phenomena of society, we thereby expect to widen understanding of both the natural and the social realms. Finally, through the third, the **dialogic** method, the proper meaning can be established for different conditions. *Hermeneutics* believes that understanding is only possible by subjective interpretation of recorded evidence. Such textual analysis tries to explain human actions by grasping the intentions and rationales that people give in justifying them and thereby clarifying the ambiguities of words and deeds. This position assumes the complete dichotomy between nature and society, by assuming that human beings control their actions, whereas natural forces do not. Although, the differences between men and atoms are well noted here, such diametrical opposition between the human and natural worlds must be rejected. It is increasingly evident that the differences are not as great as all that. Our evolving knowledge is reconciling their differences and thus closes the gap between them. In doing so, it is preferable to admit a single fundamental scientific method which is then subdivided into: theoretical (regulatory-explanatory); empirical (phenomenal-historical); and practical (pragmatic-mechanic) aspects. This Mengerian typology recognizes the continuum between a general-abstract and individual-concrete polarity and is thus a more realistic and humanistic point of view: corresponding, if not coinciding with the SAD aspects of

our methodology.

3.3 Axiology

In order to complete the codex, we should now present its axiology. This area deals with the axioms and values which underlie choice; so it is indispensable in any normative work. Although, it is often said that pure science is value-free, human concerns are not. Therefore, we admit certain value preferences and go on to justify them on the basis of three critical standards: Diacrisis; Anacrisis; Syncrisis (DAS). The first standard establishes the relevance among things or ideas. By the process of discrimination or **diacrisis**, a judgement can be made between the trivial and the important. The extent or degree in which something affects something else is obviously the basis of relevance and provides the main criterion of importance. On this basis, importance is a relative concept which depends on the strength of influence in particular relationships and not on an absolute standard of reality. The second criterion establishes responsible behavior by distinguishing between necessary and voluntary action. Since one can only be responsible for intentional acts, there must be a clear difference between determinism and voluntarism. Interrogation or **anacrisis** provides the judgement for such distinction by defining the area of free will and human control from the realm of superior force and necessity. The third and last standard of evaluation concerns the *preferences* exhibited by all systems. According to these preferences, certain things are desirable and others avoidable. On the basis of certain natural proclivities regarding love and hate, human beings develop moral codes of good and evil. As the evaluation of social behavior, morality follows the process of **syncrisis** or judgement which guides human conduct by entering a consideration of others in any intentional action that concerns them. In this way, ethics establishes the proper relations between the self and its environment.

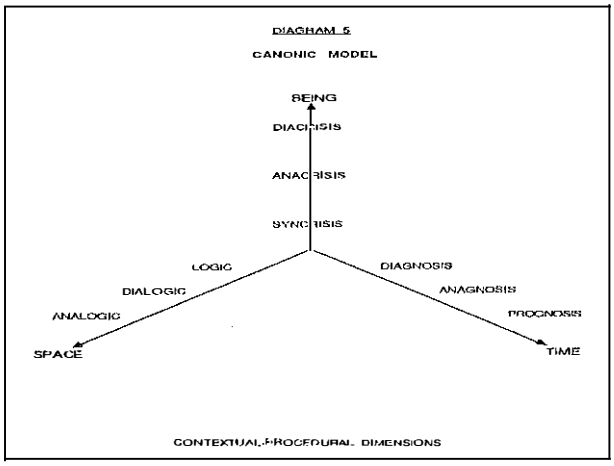

Diagram 5: Contextual-Procedural Dimensions

Diagram 5 outlines the DAP-SAD-DAS canon in a three dimensional perspective. Furthermore, this codex has been made to coincide with the content and context of human knowledge. This method of presentation shows the correspondence among all three aspects in an orthogonal framework and forms the skeleton of any systematic synthesis.

Conclusion

With this exposition of **c3**, we have completed the outline of SUM. Now, in order to apply it in sociophysics, we utilize its parameters to construct the three dimensional framework depicted in Diagram 6.

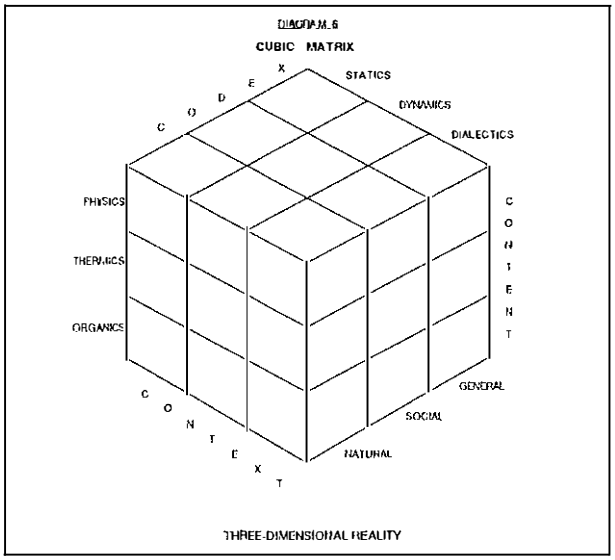

Diagram 6: Three-Dimensional Reality

Following the dicta of conceptual elegance, the diagram illustrates a 3x3x3 or 27 cell cubic matrix representing our model and containing all its aspects. We therefore close this article by putting forth the general guidelines used in this endeavor. To begin with, the first parameter, corresponding to the space-time context, will be adapted to frame what is considered as the three typical conditions of reality: statics; dynamics and dialectics. The first reflects the constant or conservative aspects of reality; the second reflects the opposite tendencies for variety and change; whereas the third combines both to reflect its fluctuations and contradictions. Every one of these conditions is governed by equivalent Conservation, Alteration, Fluctuation (CAF) laws. The second parameter corresponds to the existential content of reality: i.e. matter; energy; life (MEL). From it sociophysics selects subjects covered by the natural sciences, because it is they that provide our fundamental concepts. In effect, this involves physics, chemistry and biology, as the primordial disciplines upon which the social sciences are based. Finally, the third parameter concerns operating methods. It juxtaposes the natural and social sciences as the two premises of a syllogism and then draws the appropriate general conclusion from them. These steps begin with natural laws as the major premise, continue with the social phenomena as the minor premise, and end with a global conclusion. In this way, we cover the environmental, systemic and universal aspects of any subject and extend physical laws into general principles which apply to society as well as to nature. This process then transforms natural science inputs into unified system outputs, via the intervention of social science. Consequently, the basic laws of nature demonstrate their adapta-

bility and convertibility to society; at the same time as social and natural phenomena are contained within the same all-inclusive codes.The reason for the precedence of natural over social considerations is that the former has simpler and more well-known patterns than the latter. As a result, there is an obvious tendency to proceed from the simple and familiar to the strange and complex, thus advancing step-by-step the accumulation of knowledge and understanding. This logical-positivist bias, however, does not mean that there is no feedback from the social to the natural domain; since as already noted, culture affects science as nature affects society.Either way, our fundamental axiom is that reality always presents us with at least three faces. Two of these are the classical opposites of *yin* and *yang* which are joined by a third which is at the same time an affirmation and a denial of both. These three central conditions are at the base of the triadic paradigm which pervades this work and frames its concepts.

References

(Selected background bibliography)

(1) Alexander, J. et al.: The Micro-Macro Link, Berkeley, CA: California Univ.Press 1987.(2) Armstrong, D.M.: What is a Law of Nature. Cambridge Univ.Press 1983.(3) Arnopoulos, P.J.: Sociophysics. New York, NY: Nova Science Publishers 1993.(4) Augros, R.M.; Stanciu, G.N.: The New Story of Science. New York, NY: Bantam 1984.(5) Atkin, R.H.: Mathematical Structure in Human Affairs. New York, NY: Crane 1974.(6) Bachelard, G.: The New Scientific Spirit. Boston, MA: Beacon Press 1984.(7) Barrow, J.D.: The World Within the World. New York, NY: Oxford Univ.Press 1990.(8) Berlinski, D.: On Systems Analysis. Cambridge, MA: MIT Press 1976.(9) Bernstein, R.J.: Restructuring Social and Political Theory. Oxford Univ.Press 1976.(10) Berlin, I. Concepts & Categories. New York, NY: Oxford Univ.Press 1980.(11) Berrien, F.K.: General & Social Systems. New Brunswick, NJ: Rutgers Univ.Press 1968.(12) BertalanffY,L.: Perspectives on General Systems Theory. New York, NY: Braziller 1975.(13) Boltzmann, L.: Theoretical Physics & Philosophical Problems. Dordrecht, NL: Reidel 1974.(14) Brown, H.: The Wisdom of Science. Cambridge Univ.Press 1986.(15) Black, M.: Models and Metaphors. Ithaca, NY: Cornell University Press 1962.(16) Bunge, M. (Ed.): Methodolgocial Unity of Science. Dordrecht, NL: Reidel 1973.(17) Buckley, W.: Sociology & Modern Systems Theory. Prentice-Hall, N.J. 1967.(18) Cartwright,N.: How the Laws of Physics Lie. Oxford, GB: Clarendon 1983.(19) Collier, A.; Scientific Realism & Socialist Thought. Boulder, CO: Rienner 1989.(20) Cunningham, G.: Objectivity in Social Science. Univ. of Toronto Press 1973.(21) Danto, A.C.: Connections to the World. New York: Harper & Row (Perennial) 1989.(22) Davies,P.C.W. (Ed): The New Physics. Cambridge Univ.Press 1988.(23)DoreianP.; Hummon, N.: Modelling Social Processes. Amsterdam: Elsevier 1976.(24) Douglas, M.: Natural Symbols. London, GB: Barrie & Jenkins 1970.(25) Eddington, A.S.: Fundamental Theory. London., GB: CUP 1946.(26) Elliott, J.; Dawber P.: Symmetry in Physics. Oxford Univ.Press 1979.(27) Elster, J.: Logic and Society. Chichester: Wiley 1978.(28) Elkana, Y. (Ed): Interaction of Science & Philosophy. Humanities, N.J. 1974(29) Flew, A.: Thinking about Social Thinking. Oxford, GB: Basil Blackwell 1985.(30) Foster, D.: The Philosophical Scientists. New York: Dorset 1985.(31) Fuller, S.: Social Epistemology. Bloomington, IN: Indiana Univ.Press 1988.(32) Harre, R.: Principles of Scientific Thinking. London, GB: Macmillan 1970.(33) Heisenberg, W.: Physics & Philosophy. New York, NY: Harper & Row 1962.(34) Hesse, M.B.: Models & Analogies in Science. Notre Dame 1970.(35) Homans, G.C.: Nature of Social Sciences. New York, NY: Harcourt, Brace 1967.(36) Keat, J.R.; Urry,J.: Social Science as Science. London 1975.(37) Kitchner, P.: The Nature of Mathematical Knowledge. Oxford: Oxford Univ.Press 1983.(38) Klee, P.: The Natureof Nature. New York: Wittenborn 1973.(39)_Kline, M.: Mathematics & the Search for Knowledge. New York, NY: Oxford 1985.(40) Krishnan, P. (Ed.): Mathematical Models in Society. Univ. of Keele 1977.(41) Kuhn, A.: The Logic of Social Systems. San Francisco: Jossey-Bass 1976.(42) Lave, C.A., March, J.G.: Models in Social Sciences. New York, NY: Harper & Row 1975.(43) Lessnoff, M.: The Structure of Social Science. London, BG: Allen & Unwin 1974.(44) Lilienfeld, R.: The Rise of Systems Theory. New York: Wiley 1978.(45) Lincoln, Y.; Guba, E.: Naturalistic Inquiry. Sage, B.H. 1985.(46) Menger, C.: The Method of the Social Sciences. New York Univ. Press 1985.(47) Merton, R.K.: Social Theory & Social Structure. New York: Free Press 1963.(48) McKinney, J.C.: Constructive Typology & Social Theory. Appleton, N.Y. 1966.(49 Nagel, E.: The Structure of Science. New York: Hackett 1979.(50) Northrop, F.S.C.: The Logic of Sciences & Humanities. New York: Mcmillan 1947.(51) Odum, H.T.: Systems Ecology. New York: Wiley 1983.(52) Overman, E.S.: Methodology & Epistemology. Chicago Univ.Press 1988.(53) Pagels, H.R.: Perfect Symmetry. London, GB: Michael Joseph 1985.(54) Pantin, C.F.: The Relations Between the Sciences. Cambridge Univ.Press 1968.(55) Parsons, T.: The Social System. Glencoe: Free Press, , Glencoe. 1951.(56) Poincare, H.: Science & Hypothesis. New York: Dover 1952.(57) Rosen, J.: A Synunetry Primer for Scientists. New York: Wiley 1983.(58) Rosenthal-Schneider, I.: Reality & Scientific Truth. Detroit, MI: Wayne 1980.(59) Ruberti, A. (Ed.): System Sciences & Modelling. Dordrecht: Reidel; Paris: UNESCO 1984.(60) Rudner, R.S.: The Philosophy of Social Science. New York: Prentice-Hall 1966.(61) Salem, L & C.: Most Beautiful Mathematical Formulas. New York: Wiley 1991.(62) Savage,C.W.: Between Positivism & Relativism. Boulder, CO: Westview 1991.(63) Schumacher, E.F.: Guide for the Perplexed. Toronto: Fitzhenry & Whiteside 1977.(64) Schwartz, N.: The Concept of Physical Law. Cambridge Univ.Press 1985.(65) Scott, A.: Basic Nature. Cambridge, GB: Blackwell 1991.(66) Shlain, L.: Art & Physics. Camp Hill, PA: Quality Paperbacks 1992.(67) Simon, H.: Models of Thought. Yale Univ.Press 1979.(68) Spencer, H.: A System of Synthetic Philosophy. Osnabrück: Zeller 1966.(69) Spielberg,N.: Seven Ideas That Shook the Universe. New York: Wiley 1987.(70) Strawson, P.F.: Skepticism & Naturalism. New York: Columbia Univ.Press 1985.(71) Sutherland, J.W.: Societal Systems. Amsterdam, NL: North Holland 1978.(72) Sylvan, D.; Glassner,B.: Rationalistic Methodology. New York: Harper-Row 1975.(73) Turchin, V.F.: The Phenomenon of Science. New York: Columbia Univ.Press 1977.(74) Trefil, J.: Reading the Mind of God. New York: Anchor 1990.(75) Van Fraassen, B.: The Scientific Image. Oxford: Clarendon Press 1980.(76) Young, A.M.: The Geometry of Meaning. Mill Valley: Robert Briggs 1976.(77) Wallace, A.B.: Choosing Reality. Boston: Shambala 1989.(78) Wechsler, J. (Ed): Aesthetics in Science. Cambridge, MA: M.I.T. Press 1978.(79) Weizsäcker, C.F.: The Unity of Nature. New York: Farrar-Straus 1980.(80) Zee, A.: Fearful Symmetry. New York: Collier-Macmillan 1986.

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