Philosophy of the Social Sciences OnlineFirst, published on May 12, 2010 as doi:10.1177/0048393109350191

Two Conceptions of Fundamentality

Philosophy of the Social Sciences
XX(X) 1–27

DOI: 10.1177/0048393109350191
http://pos.sagepub.com
SAGE

Mariam Thalos[1]

Abstract

This article aims to show that *fundamentality* is construed differently in the two most prominent strategies of analysis we find in physical science and engineering today: (1) atomistic, reductive analysis and (2) Systems analysis. Correspondingly, *atomism* is the conception according to which the simplest (smallest) indivisible *entity* of a certain kind is most fundamental; while *systemism*, as will be articulated here, is the conception according to which the *bonds* that structure wholes are most fundamental, and scale and/or constituting entities are of no significance whatsoever for fundamentality. Accordingly, atomists maintain that the *basic entities*—the *atoms*—are fundamental, and together with the "external" interactions among them, are sufficient for illuminating all the features and behaviors of the wholes they constitute; whereas systemists proclaim that it is instead *structural qualities* of systems, that flow from *internal relations* among their constituents and translate directly into behaviors, that are fundamental, and by themselves largely (if not entirely) sufficient for illuminating the features and behaviors of the wholes thereby structured.

Systemism, as will be argued, is consistent with the nonexistence of a fundamental "level" of nondecomposable entities, just as it is consistent with the existence of such a level. Still, systemism is a conception of the fundamental in quite different, but still ontological terms. Systemism can serve the special sciences—the social sciences especially—better than the conception of fundamentality in terms of atoms. Systemism is, in fact, a conception of fundamentality that has rather different uses—and importantly, different resonances. This conception of fundamentality makes contact with questions

Received 20 April 2009
[1]University of Utah, Salt Lake City, USA

Corresponding Author:
Mariam Thalos, University of Utah, Salt Lake City, Utah, 84112 USA
Email: m.thalos@utah.edu

pertaining to natural kinds and their situation in the metaphysics of the special sciences—their situation within an order of *autonomous* sciences.

The controversy over fundamentality is evident in the social sciences too, albeit somewhat imperfectly, in the terms of debate between *methodological individualists* and *functionalists*/*holists*. This article will thus clarify the difference between systemism and holism.

Keywords

atomism, systemism, holism, degrees of freedom, reduction

A Building-Block Conception of Fundamentality in the Assumptions of Atomism

> I assume . . . that matter is ultimately particulate. I assume that every material thing is composed of things that have no proper parts: "elementary particles" or "mereological atoms" or "metaphysical simples."
>
> —Peter van Inwagen (1990, 5)

When physicists speak of the fundamental, they are expressing a reductionist ideology—it is an occupational hazard with them—to the effect that a certain primacy belongs to the smallest "independent" building blocks of the universe, as well as to the laws that govern these fundamentals *in relation to one another on their own scale.* A theory that treats comprehensively of these fundamentals will be, as they say in physics, a *theory of everything (TOE)*.[1] What's more, it is now very well known that formulations willy-nilly of the TOE is likely, if we are not very careful, to eventuate in more structure, for example in more space-time structure, than is absolutely required. It might, for instance, ascribe metric structure to our space-time in addition to mere symplectic structure; and this is more structure than is absolutely necessary for its purposes (as ably discussed by North [2009]). Or it might, for its expository purposes, utilize mathematical or logical structure that is not itself a feature of the subject matter—purely abstract structure (Field 1980). So to identify the fundamental entities in any purported TOE, an apologist of the "building-block" conception of fundamentality will have to examine all legitimate reformulations—the allowable variants—to identify what they all *have in common*, rather than simply what any one of them says on its own. And this means that, to diagnose the fundamental entities of a TOE, we must also display its allowable formulational variants. Thus on the building-block

conception of fundamentality, we shall be required to know a great deal, in excess of knowing that the purported TOE is true, to ascertain the truly fundamental—its ineliminable invariants.

The building-block conception of fundamentality derives from a conception of the unity of science with roots in conceptual analysis.[2] This model of unity originated within the Vienna Circle and was endorsed by Rudolf Carnap in his *Logical Construction of the World* (1928). On this conception, the sciences are unified through the unity of their subject matters, which is evident in the relations between their concepts. Roughly, scientific terminology makes reference to the world, perhaps even to the same regions of it, but different sciences make contact with the world at different "scales," "levels" or "strata." And this fact corresponds to the relations in which stand the conceptual apparatus of different sciences: the concepts of the sciences stand in hierarchy relations, corresponding to the hierarchy of the sciences themselves.

Carnap's own work was characterized by a concern for logical constructions out of basic concepts in axiomatic structures, and rigorous reductive logical connections between conceptual categories. This orientation led him to a privileging of a "most basic stuff" and a preference for physics as a privileged locus. And this consequently led him to a hierarchy of conceptual structures for the sciences. Many construals have emerged since Carnap's time, as to how precisely to make sense of the relations between the conceptual apparatus of different sciences. These shall not be primary objects of inquiry here, though I shall gesture at the two most aspirant of these today: supervenience-based models of unity and (with important overlap) emergentistic models. Both of them build implicitly on an assumption that there are fundamental entities or *atoms.* I shall use the term *atomism* to refer to the doctrine that there is a ground floor of *entities*, of *building blocks*, from and on which all the other entities are built, which fundamental building materials ("atoms") physics will—ultimately—describe. The fuss, when once this proposition is accepted, will revolve around how to account for the "granularity" of the world—the apparently nonatomic realities that "rest layer-like" on the atoms.[3]

Before proceeding, it is important simply to note that, as Jonathan Schaffer (2003, 505) concludes:

> [W]e do not, right now, have any evidence for atomism. We now have no evidence that there will be a final theory, no evidence that such a theory will postulate anything that could serve as a mereological atom, and no evidence that such a theoretical postulate will correspond to an ontological atom as opposed to a boringly decomposable composite. Evidence for fundamentality is lacking thrice over.

And so to the extent that there is pervasive confidence in a ground floor of entities, that confidence must be construed as rooted in simple faith.

While insistence on a theory of science as unified in Carnapian terms has waned, focus on its legacy of *levels* has only intensified. The effort has been focused on the formulation of nonreductive physicalism in a climate of antireductionism. In constructing layers, *supervenience* theorists articulate what (following O'Connor and Wong [2009]) I will refer to as *structuralist* relations. These amount to one-way grounding relations—sufficiency relations—between sets of facts (physical-to-mental, for instance). Similarly, *emergentistic* formulations of nonreductive physicalism, which utilize the notion of supervenience, articulate an "accummulationist" sufficiency relation between a (putatively large) set of facts and a "new" layer. This is true of O'Connor (1994); O'Connor's work since 2000 has rejected the supervenience basis, in favor of a more dynamical account: emergent properties are "nonstructural," for O'Connor (2000), "in that the occurrence of the property is not in any sense constituted by the occurrence of more fundamental properties and relations of the object's parts." Similarly Humphreys (1997a, 1997b) rejects the "structuralism" implicit in supervenience, but—like O'Connor (1994, 2000)—retains the notion of levels.

Still, a *fundamental theory* in the terms just sketched, assuming we had one and it were as true as it is earnestly wished-for, is not likely to shed much light on (for instance) the lives of biological entities. And so, the building-block doctrine of fundamentality deals with ontology in the most narrow sense. It is not concerned with metaphysics more broadly construed; not, for instance, concerned with the nature of the differences in the layers of order, or the scales in which they are manifested, not with their theoretical reliance on one another, nor finally with the various autonomies they enjoy. A fundamental theory in building-block terms, assuming we had one and it were true, is not yet a theory of science in the sense of the Vienna Circle—whatever its merits as a theory of entities. It is nowise concerned with the ideas, categories, or theories that are *key* to understanding a domain or phenomenon. *Key-hood* is (itself) the key to *epistemological* fundamentality. (An important and fascinating question is the question of the relationship between ontological and epistemological fundamentality—a question that I shall not address here.[4]) So, to the extent that a TOE, if such there should ultimately be, does/will *not* shed light on the nature of, for example, biological phenomena, we shall require some analysis—presumably in philosophical terms—of the relationship between the entities inhabiting the scale of description of the TOE and those residing elsewhere. It will have to be a metaphysic.

The reductionistic/physicalistic conception of fundamentality I have just sketched is an eligible element of such a metaphysic, happily reliant on the

(ultimate) identification of smallest (physical) independents—the *simples, as such*—it is thus a theory of *ontological-simplicity-as-ontological-fundamentality*. According to this theory, simplicity is counterposed to *complexity*, which is often characterized in terms of the interdependence of numerous factors or features on one another.

By contrast, disciplines that draw on engineering concepts focus on ineliminably interdependent aspects of the world—other features of ontology—to characterize and explain important realities operating at higher scales. This suggests—and I will indeed defend—the idea that theories reliant on ineliminable interdependencies for expository purposes will have a very different conception of ontological fundamentality than the now-pervasive conception of fundamentality-as-ontological-simplicity.

Simplicity and Its Antithesis

The assumption that there are absolute, noncontext-relative simples—"atoms" that are basic independents—is at the heart of one reductionistic orientation. I will throughout use the term "atom" in its original sense, as the smallest possible constituent, the smallest indivisible "part" that anything may possess. Specifically, atomism embraces the temptation to treat some one object type (or perhaps a small menagerie of types) as inalienably *independent*. This is a commitment that amounts to adoption of an *absolute* conception of independence, as well as an absolute conception of atomhood. Atomism is committed to the idea that independence belongs only to the atoms.

Along with this commitment comes another—a commitment to treating systematic correlations or coordinations amongst the purportedly independent parties (the atoms) as a matter of incidental, "external" or "ecological" interactions between them, rather than as systemic and inalienable properties of confederations among them. Atomism thus renders relations between fundamentals as *external*—rather than acceding to the possibility that relations may enter *internally* into the makeup of something that is itself, and despite being non-atomic, a fundamental.[5]

Thus assessment of atomism, to be thoroughgoing, must evaluate the entire reductionist package of model-building strategies, which includes: (1) independent building-blocks; and (2) no internal relations. Existing assessments of atomism have focused almost exclusively on the question of building blocks. On such assessments, the refusal of atomism amounts to entertaining instead the proposal that every entity has parts, and littler entities are comprised of littler parts—a proposal that Jonathan Schaffer (2003, 512-13) refers to as *infinite descent*, according to which there are no indivisibles:

> What would a metaphysic of infinite descent look like? The most striking feature of an infinite descent is that *no level is special.* Infinite descent yields an egalitarian ontological attitude which is at home in the macrophysical world precisely because everything is macro. Mesons, molecules, minds, and mountains are in every sense ontologically equal. Because there can be no privileged locus for the causal powers, and because they must be somewhere, they are everywhere. So infinite descent yields an egalitarian metaphysic which dignifies and empowers the whole of nature.

On this teaching, science—physics, its successors or offshoots—will continue to discover and identify entities on increasingly smaller scales, as further decomposables. And there will be no end in sight to these discoveries.

But a refusal to rule out internal relations (in other words, a refusal to accept the "no internal relations" plank of atomism) leads to a different conception of fundamentality, whether or not one adheres to the notion of building blocks, and so it is independent of the question of infinite descent. This article is devoted to fleshing out this second conception of fundamentality—*systemism,* as I shall be referring to it.

The antithesis of "no internal relations" involves adoption instead, as the fundamental unit of analysis, of the notions of a *System* rather than the notion of an independent entity. This is ultimately where countenancing internal relations will lead. What is a System? The notion of a System, with a capital S, is what the remainder of this article will be about. Adopting systemism will, appropriately, involve adopting a different vision of the relations among the sciences—and correspondingly a different theory of science. Importantly, this vision of the sciences does *not* simply solemnify the parody of nonreductivistic metaphysics, however attractive, that radiates from Augustus de Morgan's (1872, 377) lovely little verse:

> Great fleas have little fleas upon their backs to bite 'em,
> And little fleas have lesser fleas, and so *ad infinitum*.
> And the great fleas themselves, in turn, have greater fleas to go on,
> While these again have greater still, and greater still, and so on.

There is something profoundly lacking in this—decidedly antireductionist—vision of the order of the sciences. For it is simply false that there is biological order/organization in the nanosphere. And it is simply true that regimes of organization/order/regularity, while not exactly following an order of scale or size, are very much constrained by scale. To explain these facts should be a

priority of any theory of the sciences. It is worthwhile therefore, in service of a theory of science, to focus on the importance of scale, and the extent to which disciplines (biological, social, etc., and different, potentially competing theories within them) span the range of scales, and are constrained by scale. These are neglected areas of inquiry.[6]

The Social Sphere

The pioneers of sociology in the late nineteenth century faced a fundamentality dilemma. The social is the sphere of action, among related things. But how shall we conceive of action, its sources, and its authors? On what scale or scales does action take place? What sorts of entities can bear the responsibility for action, from a scientific perspective? One way with this question is simply to proceed axiomatically—in other words, dogmatically. At the turn of the twentieth century, Max Weber founded a school of thought by answering the fundamental question of methodology in sociology in an axiomatic way. Regarding multi-individual collectivities and institutions he wrote: "in sociological work these collectivities must be treated as solely the resultants and modes of organization of the particular acts of individual persons, since these alone can be treated as agents in a course of subjectively understandable action" (Weber 1914, 13). In other words, Weber proposed reserving the term "action" for human behavior that proceeds from the machinations of an individual human mind that conceptualizes (or, in the language of the school Weber would eventually establish, *understands*) the behavior in question in a particular way. This concept of action is, far and away, the most enduring legacy of the *verstehen* school of social science. It issues in what is now referred to as *methodological individualism*, according to which the individual is to be taken as the one and only unit of agency, because (again according to the doctrine) the individual is the one and only unit in which meaning and understanding, as rational enterprises, are manifest.

This doctrine is now dominant in the social sciences. Chieftains of the methodological individualism tribe routinely assert that theirs is an innocent doctrine, devoid of any political or ideological substance. Weber himself cautioned that "it is a tremendous misunderstanding to think that an "individualistic" *method* should involve what is in any conceivable sense an individualistic system of *values*" (Weber 1914, 18). Spokespersons have generally touted it as an incontrovertible metaphysical claim, roughly to the effect that the only things that exist, when it comes to action, are individuals, and that there is no such entity as Society with a capital S, or anything else that comes in units larger than a single individual, that can take the stage in the figure of an agent.

But this is in fact no innocent doctrine. If anyone, anywhere, has ever taken action out of a sense of being joined in a cause with others, then the tribal pronouncements are simply false. This is decidedly *not* because there are collective minds or collective consciences. Rather, it is because shared causes and collective identities have a way of pooling the action-taking resources of the individuals they unify, so that the joint efforts might as well be thought of as of a single action-taking entity. For good or ill, the efforts of entities capable of some cognition, when yoked together in a common cause, are as if they were internal to a single such agent again, given the cognitive resources enjoyed by so many species, including humans, for working collaboratively. There is nothing in the logic of action to prohibit this reality. And so, *if one takes seriously the notion that the subject matter of sociology is action, one is led to consider the possibility of collective action.* But the *verstehen* school simply denies this possibility credence.[7]

It is no innocent doctrine that simply pronounces *ex cathedra* that only an individual (more precisely, an individual human organism) can stand in the relation of agent—of author—to some piece of behavior that deserves calling an *action*. The matter concerns the fundaments of agency—the fundamentals of it—and it is not one to be settled simply by fiat. For there are alternative ways with the question—ways that challenge the very conception of what it is for something to *be* fundamental, with special attention to the social.

How to proceed after acknowledging the possibility of collective agency? How to proceed after rejecting the pronouncements of the methodological individualism tribe? There are important decisions to make. The first set concerns the question: is collective agency itself a single-species category, or an entire taxon? One may recognize a whole array of entities deserving the label of collective agent, distinguished by their agentic structures. Are these agentic structures fundamentally important? If so, how? Another set of decisions concerns the question: how are agentic entities identified on the ground? Does it take some expertise to identify agents? Are there, for example, agentic structures of which the individuals on the ground themselves are typically unaware? Do environments structure the agentic "terrain" in ways that encourage the growth of what we might want to refer to as "implicit agents"? If so, should these facts show up explicitly in a taxonomy of agents? The subject is very large, and deserving of considerably more attention than can be given here, even by way of survey. But we will make a few comments pertaining to our present topic.

A considerable mass of sociological research has sought to examine the nature of the bonds that hold groups together—to give an account of the "adhesive" that bonds the various forms of social relations and organizations. From the very beginning of the discipline, sociologists have sought to taxonomize

social organization, recognizing a great variety in the wild. For instance, the German sociologist Ferdinand Tönnies (1855-1936) is best remembered for a distinction between two types of social groups parallel to two purportedly basic forms of human will: the essential will, which is an organic or instinctive driving force; and arbitrary will, which is deliberative and goal-oriented. Accordingly Tönnies (1957) referred to associations that form or organize around essential will as *Gemeinschaft* (often translated as *community*), while those in which membership is organized or sustained by some instrumental and explicit goal were termed *Gesellschaft* (often translated as *civil society*). Tönnies held that *Gemeinschaft* is best or most perfectly exemplified by the family and *Gesellschaft* by the state.[8]

The *Gemeinschaft/Gesellschaft* distinction is clearly a fellow traveler of the more contemporary distinction between individualist and collectivist societies. The modern USA lies on one extremum of this continuum—the individualist extremum—while east Asian societies (China, Japan, and Korea, in particular) fall closer to the other end of the continuum. Younger societies, interestingly, with fewer ties to ancient civilizations, gravitate toward the individualist end of the scale. Numerous measures are now deployed to diagnose societies on the dimension of collectivism, with the diagnostic tools being statistical measures applied to aggregations of answers to a range of survey questions. Still, R. G. Collingwood's description (Collingwood 1927, 23) of the collectivist mind is hard to improve on:

> The individual counted for nothing except as the member of his guild, his church, his monastic order, his feudal hierarchy. Within these institutions he found a place where he was wanted, work for him to do, a market for his wares. He could devote himself to fulfilling the duties assigned him by his station in that great organism within which he found himself lodged.

The Renaissance, according to Collingwood and others, broke with this culture. It gave birth to modern individualism, expressed in "the freedom of discovering that one can leave one's ordained place and march out into the world without being struck dead by an offended God" (Collingwood 1927, 30-31).

Collingwood held that individualism is a newcomer, and indeed that the individualist quest for freedom led to decoherence of certain activities of mind—the aesthetic, religious, scientific modes—that originally cohered much more closely. According to Collingwood, God was indeed offended, for freedom to leave a social station comes at the price of an internal conflict, which is the disease of modernity. The curse of modern individualism is,

therefore, the deep cause of the miserable condition—this fragmentation—of modern consciousness. Alternatively, one may celebrate the proliferation of expertise, intellectual specializations, and disciplines—this multidimensional, even baroque, division of labor—both within and without the university. Whether this is to be celebrated or lamented, it gives rise to an important question, sometimes asked by sociologists: how is specialization related to social cohesion? And how is the latter related to collectivism?[9]

Emile Durkheim had rather a lot of interesting things to say on this topic—things that counter the methodological individualist's smug confidence. Long before Weber articulated his doctrine, Durkheim argued that in modern societies, by contrast with traditional ones, the highly complex division of labor results in "organic solidarity." This is a condition in which different specializations in employment and social roles create dependencies that tie people to one another. In less modern societies, which he referred to as "mechanical societies" held together by "mechanical solidarity," subsistence farmers live in communities that are self-sufficient and knit together by a common heritage. Mechanical solidarity thus comes from homogeneity, when people feel connected through similar work, educational and religious training, and lifestyle. The result of increasing division of labor, according to Durkheim, is that individual consciousness (and consequently "individualism") emerges as distinct from collective consciousness—often finding itself in conflict with collective consciousness. And so in modern societies, or at least so he predicted, we should see the dissolution of solidarity (Durkheim 1893).

Durkheim's analysis is provocative, suggesting the following paradox: to the extent that people are tied together by relations of economic dependence, to that same extent they experience themselves as individuals distinct from others whose concerns and lifeways are not always overlapping; and so to this same extent they will experience the Existentialists' *angst* over the burden of individual responsibility. This is a conundrum well worth dwelling on both from a sociological perspective, as well as from a psychological and existential one. It is a puzzle that repays revisiting from time to time. And coiled tightly within it are the seeds of a concern, which we can do little more than mention here, that promotion of solidarity works against individual liberty and autonomy.

While we can do no more than merely name the concern here, it is worthwhile mentioning that sociologists, like philosophers, are very much interested in it. It is, as much as ever, a very open question. The work of many sociologists outside of today's mainstream—among them members of the functionalist schools who were heavily influenced by Durkheim—has sought to grapple with this important question. Talcott Parsons and his students (Parsons 1991 [1951]; Luhmann 1996) developed a mode of analysis founded

on cybernetics (dynamical Systems), which focuses on the notions of *function* and *integration*, to which we shall give further attention below. Not only were their methodologies at odds with those of methodological individualism, but it seems that their focus on macro features of social systems gives offense of a different sort as well. We shall focus from this point forward on the style of analysis that Parsons and those under his influence sought to employ, however imperfectly, arguing that it presupposes a different conception entirely of fundamentality. While it did not originate with them, but rather in the work of Norbert Wiener (1948), they embraced it uncritically, though perhaps without giving due attention to its presuppositions. This style of analysis rejects the individual as the fundamental unit of analysis. Indeed it is not concerned with atoms at all. It is instead concerned with behavior and dynamics, with stabilities and equilibria, with "inside" versus "outside" and so with boundaries between Self and Environment. It is open to the possibility of relations—structures, social and otherwise—as potentially inalienable, and hence as potentially fundamental.

Systems

A System is not simply a network of independent entities standing in some random set of ("external") relations to one another—at a level superordinate to that in which its components are rooted. A System is, rather, a network of entities that stand in "nonelective" bonds to one another. These are the *internal relations*. What I mean by the term is this: it is not possible to assemble the entities in question, *as a System, without also* the bonds figuring in; it is not possible to assemble the entities in question, *as a System*, with arbitrarily chosen bonds. The bonds in question are ineliminable to the confederation of these entities, even if some of these entities can confederate, with other entities, to form a still different sort of System. The relations between the entities in question are thus "internal" to their confederation. The bonds are therefore also an ineliminable aspect of an apt analysis of their Systemhood.[10]

This idea is basic to the theory of Systems. It is why Systems theory is a study of dynamics—of behavior—rather than of primarily static features. For on the Systems view, behavior is not "external"—not simply an accident of circumstance; rather, behavior is characteristic; behavior is defining. Because the relations among entities within a System are fundamental to its Systemhood. This is an alternative conception of fundamentality—an alternative to the building-block conception of fundamentality.

One important point of clarification before we proceed further. Not every aggregation of entities is a System with a capital S. A true System is defined by a clear *boundary* between "inside" and "outside." A boundary comes into

existence once there exists a critical mass of *control* that is exercised, within a given region, on a number of control *variables.* There is no space here to treat of the means by which this control is achieved (but see Thalos [2009]). Suffice it to say that when control is achieved within a space-time region, certain macro states of an aggregation of entities that comprise a System S will form a set of interconnected equilibrium conditions that can be adjusted directly by means of making alterations to a (characteristically macro) feature of S. Cybernetics, consequently, is the study of the properties of networks of interconnected equilibrium conditions. It comprises precise treatments of the performance of control apparatus, and features special attention to defective behavior that tends to bring about oscillations (from mild to violent) in control-level quantities, when control apparatus is poorly designed, mishandled, diseased, infected by a foreign control apparatus, or generally overloaded.

Adoption of a System conception, then, lays the groundwork for a proposition to the effect that situated entities (entities *in situ*), in addition to potentially (though not invariably) retaining a certain amount of independence, may also coalesce, in the process forming molecular Systems that further interact in complex ways with each other, as well as with and on the atoms that compose them.

This conception of a System renders the bond fundamental to an entity's reality. Indeed it renders the bond itself an object to which fundamentality may attach. From a Systems perspective, bonding is *the* fundamental entity-building process. In fact, from a Systems perspective, bonding is the *most fundamental* characteristic or feature of (nonatomic) objecthood. Objects spring into existence as a result of many (and overlapping) such bonds. Because, from the Systems perspective, an entity *just is*—it is *fundamentally*—a thing bonded. It is just possible, on the Systems conception, that independent atoms exist, entities that possess no internal relations. And if it indeed is so, this would be a completely contingent fact. Where, by contrast, atomism simply assumes that it is a necessity.

Thus the contrast between atomism and *systemism*, as I shall call it, is the contrast, in ontology, between atoms (on the one hand) and situated entities (on the other). Situated entities are the subject of *dynamical Systems theory*, that brainchild of engineering science. From a Systems perspective, it is just as likely that there are internal relations "all the way down" as that there is a "ground" over which everything is constructed. Systemism is compatible both with atomism and with infinite descent. It is an alternative construal of what fundamentality itself consists in.

Another way to put this basic axiom of Systems theory is to say that the defining trait of a System is that it is a unit of aggregation. To appreciate this idea, it helps to bring to mind the engineering milieu from which it arises.

Dynamical systems theory is nowadays ubiquitous. From engineering (its point of origin and natural home), to physiology, and from psychology to ecology, it enjoys surprisingly wide application. Sometimes the analysis rings decisively false—as, for example, when adopted in certain treatments of historical narrative;[11] other times it is provocative and controversial, as when applied to the phenomena of mind and cognition.[12] Dynamical systems analysis (or "Systems Theory" with a capital "S") is a strategy of analysis whose defining feature is its rejection of atomism. It mobilizes the language and mathematical technology of differential equations, and brings into play the distinctive concepts of *equilibrium* and *attractor*, as well as *gain*, *coupling*, and *neighborhood*, that are not obviously proprietary to any particular domain of objects or regime in the world.[13] It is the ecumenical language of engineers, universal in scope. The unrestrictedness of the scope of Systems theory—the fact that it ranges over every scale of measurement—is key to understanding its founding ideas. It thus must apply as aptly to the social sphere as to the nanosphere.

The defining characteristic of a System in the engineering context is simply that it is a real-time construction built by a process—and so is subject to being added onto in the same manner. A System is essentially an integrated thing—a thing whose elements are integrated through organizational structures. Thus, whereas atomism adopts the point of view that wholes are *aggregates*, and thus not basic or fundamental, systemism adopts the contrasting view that *some* wholes are *integrates*, and that for these wholes their confederation is basic to them and thus fundamental. This is, ultimately, the core contrast to which the entirety of this article is dedicated to illuminating.

Systemhood is thus a phenomenon of integration; it is thus a phenomenon of *scale*. And by this, I mean that systemhood is that phenomenon on which the very fact of multiple scales is possible. Systemization, in the sense just defined, is the realizations of capacities for *bonding*, and thus for further *upscaling*. Bonding is a System's elemental or fundamental characteristic. The fundament of a System is not a ground or building block; it is a bond. A System is a One that is made out of many.

Herbert Simon (1973), decades ago, made remarks suggestive of this conception of systemhood. He thought that certain features of certain systems could not be captured correctly by analysis of their parts taken together with the specific and heterogeneously conceived interactions among them. His idea derives from his concern with building systems. The idea is that to build a complex system (as nature does), one proceeds in stages, with the result that at the end of each stage, what is constructed must possess a stable structure (so as to "hold still" whilst the next phase of operations is being launched).

Without these intervals or layers of stability, complexity (according to Simon) is unsustainable. This makes complex systems typically: (a) modular; (b) inter-substitutive in their parts; (c) qualitatively similar with a change to their parts or their number; and (d) stable under reaggregations of parts.[14] Simon thus grasped for the idea that a System as such has to be governed by high-order structures of stability (something that might reasonably be referred to as its *internal* relations) that are relatively independent of the sorts of interactions (physiological, chemical, mechanical, or what-have-you) that govern proceedings among their parts more locally. Relations of stability can be realized by any of such proceedings, or combinations of them; but their true significance is *as* relations of stability. A true System (with a capital S) is something special indeed, and subject to high-order relations among its constituents. A system that does not obey such laws is one that very soon falls apart; it is no true System. This amounts to saying that a System, with a capital S, is one in which the aggregation of the parts has undergone a *reduction in degrees of freedom*.[15] An illustration of how this happens is worth extended scrutiny.

Many biological systems, on an ecological scale, fall squarely and unapologetically within the scope of a Systems analysis. Consider the flocking of birds. Dynamicists have only recently developed the idea that the remarkable synchrony of motion among flocking species can be explained by simple local adjustments to motion ("rules of flocking"), mediated through sensory modalities such as vision, sound, pressure, or odor detection. Assuming that each organism in a flock can sense local flockmates as well as its environment, and adjusts its own motion on an ongoing basis, Craig Reynolds (1987) devised a computational model of flocking "boids" based on the following "rules of engagement":

1. Separation: steer to avoid crowding local flockmates in your "near neighborhood";
2. Alignment: steer toward the average heading of local flockmates;
3. Cohesion: steer to move toward the average position of local flockmates.

In effect, flocking requires uniformly of each flock member only that it reacts to flockmates within a certain small neighborhood around itself, characterized by a *distance* and an *angle* (measured from the organism's own vector of motion). Flockmates outside this local neighborhood can be ignored. Similar models have been devised to model the collective foraging behaviors of social insects; for example, ants in an ant colony.

Specifics of the large-scale features of the synchronized motion matter a great deal—because flocking needs to be very fine-tuned if it is to serve the interests of the flock. These are, effectively, the internal relations that make the mates together function as a single, unified flock. So how, precisely, does fine tuning of the "rules of engagement" *scale* to produce the collective properties of the larger motion? For example, how does adjustment of the size of the neighborhood affect sensitivity to environmental features? How does it serve in location of food and avoidance or predators? The answer might surprise: much depends on the precise specifics of the flock's "rules," and not at all on any feature of any given organism in the flock. The "rules" concern "all-over" characteristics, which might well be shared with flocks of very different species, and may in no way depend on the biology of the species. They are indeed internal relations, and not correlated with the characteristics of the atoms themselves. And they are, additionally, how a flock of N birds *reduces* its degrees of freedom when—and only when—they take to the air in their numbers.

We can illustrate this reduction in the context of our present flocking example. Close behavioral coupling among near neighbors in a flock allows a localized change in direction to be amplified and propagated across the flock. This allows each flock member to influence and be influenced by flockmates much farther away than their local neighborhood—it gives each a much larger "effective perceptual range" than their actual sensory range. Study of the details of the scaling relations reveals that it is hard for groups to maintain cohesion if the coupling distance is too short. Longer-range transfer of information is enabled by increasing the coupling distance. Increasing the coupling distance further still creates a cohesive group, but then "misinformation" can be more easily propagated, so the flock becomes more susceptible to irrelevant fluctuations or falsely interpreted signals. In contexts in which high sensitivity to motions of distant flockmates is unnecessary, because (for instance) speed of response is not critical, its implementation becomes inadvisable, since it exposes the flock to unnecessary or undesirable sensitivity to signal.

In the event that coupling can be moderated by context, this is a highly desirable flock characteristic. For example, if individual boids in flight can condition their reactions on context (under threat, for example, aligning more strongly with distant flockmates, increasing "system gain"), this could allow for some flexibility in response time. Of course this is an evolutionary challenge.

What becomes more and more clear as dynamical analysis of flocking proceeds in this fashion, is that a flock of hundreds of organisms, operating under a set of "rules of engagement" is decidedly *not* a system with degrees of freedom on the order of hundreds: it is instead a system with something on the

order of a dozen degrees, counting among them rough size, coupling distance, and level of context-sensitivity, as well as environmental variables that tend to couple with these features. From a flocking perspective, a flock is an entity with a reduced number of degrees of freedom than there would be without the rules. Some of these degrees lie in the environment itself! These degrees of freedom displace many or most of the "micro" variables that predominate—that are *fundamental*—when the boids are not flocking, as soon as the flock members begin governing themselves by the rules of engagement. This example thus illustrates the point that fundamentality is a different matter entirely within a Systems treatment.

Displacement, Not Reduction

From a Systems perspective, what transpires from one scale to the next when new features appear and others move to the wings, is just that—*displacement*. Reduction, in the contemporary physicist's sense (which, recall, harks back to the Carnap's conceptualistic ambitions), is inapt. Nothing is eliminated. Coupling distance simply appears as relevant, and subsequently—so long as the System persists as a System—dominates over features of the flock that would be more appropriate outside the flocking context. But coupling distance is never "reduced" to anything more "basic." Purportedly "more basic" features (i.e., birds and their individual locations, as such) are simply sidelined. They do not disappear; but neither are they relevant for the purposes of the flock and its life. When the birds form a flock—when we have a System of boids—coupling distance is a factor not to be ignored when explaining what transpires. Purportedly "more basic" features of the birds as such are irrelevant to flocking rules. They are simply ignored. Their relevance is recovered when the birds are literally "on the ground"; there, coupling distance is not needed to explain their behavior. The boids are simply birds then. And that is that. That is how Systems analysis proceeds.

This fact reveals something about Systems *as such*. Systems come into existence full with bonds, and they de-Systematize when these bonds dissolve—as many Systems (like flocks) are very much apt to do. Reductions in degrees of freedom is key to the process—it is indeed *the key metaphysic* by which Systems are built. ("Metaphysic" is the better term, for the name of "process" does not capture the correct level of abstraction.) And these reductions are by no means the reductions spoken of by atomists. These reductions are true reductions in complexity, a topic to which we shall return by way of concluding.

Thus what is fundamental to Systemhood is the bond. In strong numbers, bonds *in situ* can effect reductions in degrees of freedom. A sufficiency of

reductions in degrees of freedom is key to the (manifest) *granulation* of things into "level-specific" natural kinds. An aggregation of entities is not a System if no such reductions take place. To be eligible of Systems analysis proper, a configuration of entities must be more than a mere aggregation. And a "level" is nothing if not yet one more occasion for a new application of Systems analysis. Levels are constructed by the iteration of internal relations.

Systemism Elsewhere

Use of the term *systemism* is not original with me. Mario Bunge is its originator. He first utilized it (in the 1960s) in the process of articulation of a middle ground between methodological individualism, on one side of the debate in the philosophy of social science, and holism, on the other. The concept was revived in the 1990s in the context of a renewed discussion of so-called "mechanism," which has been taken up widely since. The "new mechanism" appears in the philosophy of biology (Bechtel & Richardson, 1993; Craver, 2001; Machamer, Darden, & Craver, 2000) as well as once more in the philosophy of social science (Elster, 1989; Hedstrom & Swedberg, 1998; and Little, 1998).

Bunge receives some credit for the notion of systemism,[16] but it is clear that those giving credit do not believe that Bunge's articulation makes it clear how systemism is any kind of clear middle ground between two poles. Keith Sawyer (2001, 2002), while tipping the hat to Bunge, puts forward his own articulation of this same would-be middle ground, in terms of the notions of supervenience, multiple realization and emergence. Now my articulation of the term "systemism" is different from Bunge's—and Sawyer's too, into the bargain—although I do believe it is what Bunge intended. Let me explain.

Early Bunge (1979) maintained that a system consists of an ordered set (therefore, an abstract object) of (1) the component entities; and (2) the set of relations in which they stand. Crucially, this definition of a system does *not* define an *object* with properties in a class distinct from those that characterize component objects. This characterization also skirts entirely the issue of whether the relations are internal or external, and so does not (as Richard Langlois was quite right to point out) provide an intermediate point between holism and individualism. True: a serious holist would find it objectionable; but "What is *not* true is that systemism somehow represents a new methodological alternative: the basic ideas of what Bunge calls systemism are essentially identical to what sophisticated methodological individualists have believed all along" (Langlois 1983, 586).

In the 1990s, Bunge began to speak the language of mechanism and process. And most recently (Bunge 2004, 188), he has arrived at the following:

"a system is a complex object whose parts or components are held together by bonds of some kind." He is thus now tending in the direction of "internal relations," though he has some way to go.

Now my approach, like Bunge's most recent efforts, is fundamentally ontological, nonabstract, and does not speak of theories, the laws at which they gesture, or how we come to learn them. And, unlike Sawyer's, my approach does not rely on a ready-made (but seriously flawed) metaphysical doctrine, such as supervenience.[17] Rather, and again like Bunge's, it seeks to articulate principles that ground dynamical Systems analysis and the ways engineers especially apply it to real-world Systems.

Finally, my articulation of systemism *really is* a middle ground between atomism and holism. For it has three properties: (1) it rejects atomism; (2) it does not ignore the (material) entities and relations that hold them together in a System, allowing them to interact with one another and with the System's more macro features; and (3) it speaks of the bonds that hold parts together as themselves fundamental, indeed as internal. And, despite (1)-(3), it falls shy of two objectionable (or at any rate objected-to) features of holism: (1) it does not define the parts in terms of the whole or its "functions," so that parts do have an ontological reality independent of the whole; (2) it clearly acknowledges the difference between simple aggregates and true integrates—only the latter of which are true Systems.

So whereas functionalism/holism might "seek to describe, to understand and in most cases to explain the orderliness and stability of entire social systems . . . [and in so far as it treats] individuals, the treatment comes after and emerges from analysis of the system as a whole" (Barnes 1995, 37), complete with characteristic "functions" such as the production of goods and services, systemism makes no such sweeping assumptions. Instead, systemism requires justification of each and every application of a Systems analysis to a set of social institutions (requiring demonstration of the propriety of employment of its defining concepts—the notion of boundary, for instance).[18] For it recognizes that some aggregates are not integrates in the relevant sense. And it recognizes too that even integrates do not enjoy "functions" in any defining or proprietary manner. So, to the extent that Durkheim and any sociologist under his influence fails to recognize these points, they are not systemists proper. They fail to apply Systems theory conscientiously.

Different Theoretical Linkages

Systemism as articulated here—namely, as a construal of fundamentality that contrasts and competes with the building-block construal—has rather different

resonations from those of atomism. It is linked with an entirely different range of theoretical issues. For systemism is intimately and uniquely positioned to draw into its conceptual orbit, and within the parameters of scientific metaphysics, the very notions of *definition* or *essence*, and so of discipline-specific natural kind terms. These are rarely called on these days to play key roles in *organization* of the special sciences, however eligible they present themselves for the job. (Nowadays "levels" are specified with reference to disciplines—for example, the "physical level" or the "biological level." Levels are in this way dependent, at least for definition, on the administrative units typically found in universities—hardly inspiring as "fundamental" categories.) But when natural kinds are brought into view, as they naturally can be now in the light of our articulation of systemism, as in some way fundamental, they are within range of playing a role in the founding of disciplines or their scope. Key questions in the philosophy of natural kinds, if drawn into the orbit of fundamentality, will become more lively. Here are a few examples.

Once the questions concerning internal relations are posed as key to explorations of (at least some) questions of fundamentality, and it comes clear that the defining question on the topic is *not* "Is there a fundamental level?" but rather "Are there internal relations?", the link to certain core questions in the philosophy of science will be open to engagement in a new way. Because atomism is now the reigning view of fundamentality, the reigning view on the subject of nature is that there are no fundamental natural kinds outside of physics. Consequently, there immediately arise questions as to the true autonomy of nonphysical sciences. Now, I have sought here only to establish a competing conception of fundamentality, and not to argue for the fundamentality of any specific kind, entity, or feature as fundamental under the new conception. This is the space that must now be mapped if we are to establish the autonomy of any nonphysical science, including of course psychology and sociology. But it becomes clear that there are important links to be forged—or refused—between conceptions of fundamentality and those that treat of the autonomy of different sciences.

Now, a critic of systemism as a construal of fundamentality might inquire as follows: Why suppose that the core question to which systemism is one answer (the question whether there are internal relations) is really a question about fundamentality at all? Why isn't it an entirely orthogonal question? Of course this query takes us to the very heart of concern for fundamentality in the final reckoning. What work does the notion of "fundamental" do in a conceptual economy?

But the proponent of systemism as a legitimate construal of fundamentality seems to have available a straightforward reply to this question: because

systemism is concerned with internal relations, it is core to a methodology for examining whether there are order-establishing entities that are not themselves atoms, but rather bonds or unifiers—adhesive, not substance. The question of internal relations pertains to the foundations of order. And this makes the question to which systemism is an answer worthy of the name of "fundamentality" simply on the basis that the concept of "founding" concerns orders of existents as to kind, for the purposes of knowledge regarding the order amongst things. It thus concerns the possibility of the origins of a One out of the many, where this is to be construed as pertinent to the organization of knowledge—to the organization of the sciences. Indeed, the very notion of "level" might itself suggest this, were it not for the dogma that often comes with the introduction of levels—to the effect that there is a hierarchy, and that the higher an entity's position in this hierarchy, the more derivative (and hence nonfundamental) it is. Systemism presents a key challenge to the dogma that presently links scale, hierarchy, and derivativeness.

Answering the question of whether in fact there are natural kinds outside of physics is not itself an object of this article. The object is instead to notice that the questions regarding natural kinds resonate intimately with certain questions concerning fundamentality construed in the way here articulated, because these questions are both intimately linked to issues concerning the difference between internal and external relations. There are many issues to explore in addressing these matters that we cannot enter into in this small space—such as (in no particular order):

(1) When a new sphere of order (if multiple such there be) is founded, are there other things, in addition to internal relations, that do the founding? Laws of nature, perhaps? If laws are required too, are they more fundamental still than the internal relations?
(2) Do internal relations found other things in the new sphere of order (if such there be)?
(3) How are internal relations (if there are any) related to (and different from) external relations, in the language of natural kinds?
(4) How are internal relations (if there are any) related to the "laws" of the new order (if these exist)? Are internal relations differentially related to the "laws"?
(5) Is there more than one set of possible internal relations for any fixed set of aggregants? What happens in such cases? Do the aggregants exercise any freedom in choosing the regime which shall govern them? Does the outcome depend on individual features of the aggregants?

Complexity

It has been said that we need Systems analysis because the world is complicated. Because there are far more "basic" entities, more bodies, more particles, and hence more quantities than a mathematical model founded on "fundamental" physical laws can handle. Moreover, things are supposed to get many orders of magnitude more messy as we broaden the scope of concern to topics outside of physics. The necessity for a less fastidious manner of analysis is a matter of practicality—an "applied" rather than a theoretical matter—not a matter of principle. Systems analysis is thus, according to this idea, a concession to human frailties (for instance: Teller [1992]). And we stoop to Systems analysis—where we do—because it is a simple and incontestable fact of life that only superhuman intellect or yet-unattained mathematical facility can handle the computational complexities we face when we attempt to treat in theory the many-entity systems we must navigate in real life. Complexity is, on this conception of things that is characteristically pragmatic, an occasion for being practical—for yielding to a lesser form of analysis.

If our discussion on the topic of fundamentality is right, however, this point must be repelled. For if our discussion is correct, then Systems analysis offers a *competing* analysis of complexity itself, as well as a competing analysis of fundamentality. If our discussion is correct, we must reply to Systems detractors as follows: we need Systems, *not* because the world is so complex (though it is frequently complex), but rather *in spite* of the purported complexity. For Systems does not oversimplify what is *genuinely* complex. Rather, as we have seen here, Systems analysis is capable of taking advantage, in an elegant way, of certain serendipitous *reductions in that complexity*. For if systemism is true, then we must amend the atomist's conception of the world in the following way: in addition to possessing structure at smallest scales, the world possesses fundamental structure also at higher scales: our world is possessed of layers of emergent order. And this is the order that Systems analysis is designed to capture. Systems analysis gives us a general, recursive analysis—that is to say, a meta-analysis—of how order at the next scale is structured, in neutral dynamical/metaphysical (not special-scientific) terms. Systems analysis is thus the metaphysics of higher order. And it rests on an alternative conception of *both* fundamentality *and* complexity.

Consequently to the critic of systemism we are bound to reply: we require Systems analysis because there is more order—and correspondingly *less* complexity—in heaven and earth than is dreamt of in the philosophy of atomism. Such a metaphysical platform of fundamentality is a more firm

foundation than we have had to date for a theory of science that aims to accommodate each special science as autonomous.[19]

Declaration of Conflicting Interests

The author declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

Financial Disclosure/Funding

The author received no financial support for the research and/or authorship of this article.

Acknowledgement

While all the errors of this essay are robustly and stubbornly mine, its virtues are thanks in large part to guidance, direction, and inspiration I have received from colleagues and friends, whom I vigorously thank: Chrisoula Andreou, George Bealer, Kathrin Koslicki, Patrick McGivern, Lije Millgram, Jill North, Jonathan Schaffer, Ted Sider, Barry Smith, Bill Wimsatt, as well as two very helpful anonymous referees for this journal, and its editor, Ian Jarvie.

Notes

1. This overreaching statement is hard to take seriously: after all, such a theory will shed no light whatever on, for example, the biological.
2. Bealer (n.d.) gives a penetrating treatment of the relationship between these ideas, while the tension between the reductionistic and nonreductionistic ideals among philosophers concerned with the unity of science is brought out nicely in Cat (2009).
3. Van Inwagen (1990) resists the "reality" of these layers, but he is an outlier.
4. The standard way of conceiving the relationship is to say that "laws" framed using the key concepts in one (higher-scale) domain do not yield to efforts to "reduce" them to laws framed using key concepts in another (lower-scale) domain, thus the key concepts of the higher-scale refer to causally autonomous features, and are ontologically fundamental. I do not endorse this view of the relationship between epistemic and ontological fundamentality, but nothing I shall say here depends on taking a position on the matter.
5. One might complain here that relations have been traditionally construed as supervening on the entities they relate, and hence that any time "parts" are in evidence, there are at least two orders or levels of entities. Hence the distinction between internal and external is problematic. The obvious reply to this complaint is that the conception of supervenience is itself the problem, and that leaving the nature of relations open to inquiry is the right way to proceed in the debate. We shall discuss the nature of relations here by and by.

6. Patrick McGivern (2008) makes a nice contribution to this small literature.
7. And under its influence, Anscombian and Davidsonian theories of action are similarly wedded to an untenable set of tenets regarding action and agency. For details on this see Thalos (2007). Thalos (2008b) is an instance of taking seriously the possibility of molecular agency.
8. More on these sorts of taxonomies can be found in Thalos (2008a). Individuals in *Gemeinschaften*, according to Tönnies, are regulated by shared norms that dictate the appropriate behavior and responsibilities of members of the association, to each other and to the association at large (there is a "unity of the will"; Tönnies 1957 [1887], 22). *Gemeinschaften* are broadly characterized by a moderate division of labor, strong personal and family ties, racial and ethnic homogeneity, and relatively simple organizational structures. In such associations, because there is a strong collective sense of loyalty and belonging, codes of conduct require little or no external enforcement. *Gesellschaften*, by contrast, lack shared norms of conduct and are maintained instead by individual self interest. They are associations in which, for the individual, the larger association never takes on more importance than individual self interest. A modern business is alleged to be a good example of *Gesellschaften*, where the workers, managers, and owners may share very little by way of concerns, beliefs, and motivations. Unlike *Gemeinschaften*, *Gesellschaften* emphasize secondary relationships rather than familial or community ties, and there is generally less individual loyalty to the association as such. Social cohesion in *Gesellschaften* presumably derives from the glue of an elaborate division of labor, which results in a profound and typically insurmountable material dependency of individuals on one another and the system of organizations under which their labor is coordinated.
9. The topic of social cohesion has been neglected since Collingwood's time. And its measurement not performed until quite recently. Rajulton, Ravanera, and Beaujot (2007) have broken ground in this area by articulating a measure of social cohesion in terms of a combination of aggregated behavioral measures covering political (voting and volunteering), economic (occupation, income, labor force participation), and social (social interactions, informal volunteering) measures.
10. Consequently, it will not always be possible to apply a standard causal path analysis to the interior workings of a System proper, since this analysis always assumes the probabilistic independence of contributions from different entities and factors—a Markov condition on them. The description of internal relations in the text paragraph defies the Markov condition. For more on this see Thalos (2009) and cf. Hitchcock (2008).
11. See, for example, the reaction of Roth and Ryckman (1995).
12. See books with such titles as *Stairway to the Mind* (Alwyn 1995) and *Thinking in Complexity: The Complex Dynamics of Matter, Mind and Mankind* (Mainzer 1994), and *Chaos, Creativity, and Cosmic Consciousness* (Sheldrake, McKenna,

and Abraham 2001). There are less ambitious treatments, but nonetheless in the same spirit: for example, Bedeau (1997).

13. Good introductions to the concepts and language of Systems analysis: Abraham (1992) and Broer and Takens (1992). Philosophical discussions of the foundations of Systems analysis can be found in Thalos (2009) and Thalos (2006); cf. the entire December 2007 (vol. 37, no. 4) issue of this journal.
14. Wimsatt (1976, 2006, 2007) makes reference to many of these conditions as well in describing the difference between aggregates (on the one hand) and composed or evolved Systems (on the other); and Bechtel and Richardson (1992) illustrate the ways in which scientific methodologies attain what they refer to as emergent phenomena utilizing these criteria.
15. I have articulated this point more at greater length in terms of the technically defined notion of *degree of freedom* in Thalos (2006) and Thalos (2009).
16. Two special issues of the journal *Philosophy of the Social Sciences* (2004, nos. 2 and 3) were dedicated to Bunge's contributions to the social sciences by way of his defense of that general idea.
17. It is nowise my intention to repeat the charges against supervenience here. For review of the issues, see McLaughlin and Bennett (2008). My own complaints are lodged in a series of articles, most importantly Thalos (2006).
18. That it must do so is spelled out in Thalos (2009).
19. The imperative of autonomy for the so-called "special sciences", as well as its prospects, are taken up in Thalos (n.d.).

References

Abraham, R. 1992. *Dynamics: The geometry of behavior*. Redwood City, CA: Addison-Wesley.

Alwyn, S. 1995. *Stairway to the mind*. New York: Springer-Verlag.

Barnes, B. 1995. *The elements of social theory*. Princeton, NJ: Princeton University Press.

Bealer, G. n.d. Analysis and definition. Unpublished manuscript.

Bechtel, W., and R. C. Richardson. 1992. Emergent phenomena and complex systems. In *Emergence or reduction? Essays on the prospects of Nonreductive physicalism*, edited by A. Beckermann, H. Flohr, and J. Kim, 257-88. New York: de Gruyter.

Bechtel, W., and R. C. Richardson. 1993. *Rediscovering complexity.* Princeton, NJ: Princeton University Press.

Bedeau, M. 1997. Weak emergence. In *Philosophical perspectives*: *Mind, Causation and World*, vol. 11, edited by J. Tomberlin. Oxford, UK: Blackwell Publishers.

Broer, H. W., and T. Takens, eds. 1992. *Geometry and analysis in nonlinear dynamics.* New York: Wiley.

Bunge, M. 1979. *Ontology: A world of systems.* New York: Springer-Verlag.

Bunge, M. 2004. How does it work? *Philosophy of the Social Sciences* 34:182-210.

Carnap, Rudolf. 1928. *Logical construction of the world*. Berlin: Weltkreis.

Cat, J. 2009. The unity of science. In *The Stanford encyclopedia of philosophy* (Spring 2009 edition), edited by E. N. Zalta. http://plato.stanford.edu/archives/spr2009/entries/scientific-unity/.

Collingwood, R. G. 1927. *Speculum mentis or the map of knowledge.* Oxford, UK: Clarendon Press.

Craver, C. 2001. Role functions, mechanisms and hierarchy. *Philosophy of Science* 68:31-55.

DeMorgan, A. 2007 [1872]. *A budget of paradoxes*. New York: Cosimo Classics.

Durkheim, E. 1893.*The division of labour in society*. Paris: F. Alcan.

Elster, J. 1989. *Nuts and bolts for the social sciences.* Cambridge, UK: Cambridge University Press.

Field, H. 1980. *Science without numbers*. Princeton, NJ: Princeton University Press.

Hedstrom, P., and R. Swedberg, eds. 1998. *Social mechanisms: An analytical approach to social theory*. Cambridge, UK: Cambridge University Press.

Hitchcock, C. 2008. Probabilistic causation. In *The Stanford encyclopedia of philosophy* (Fall 2008 edition), edited by E. N. Zalta. http://plato.stanford.edu/archives/fall2008/entries/causation-probabilistic/.

Humphreys, P. 1997a. How properties emerge. *Philosophy of Science* 64:1-17.

Humphreys, P. 1997b. Emergence, not supervenience. *Philosophy of Science* 64: S337-45.

Langlois, R. 1983. Systems theory, knowledge, and the social sciences. In *The study of information: Interdisciplinary messages*, edited by F. Machlup and U. Mansfield, 581-600. New York: John Wiley.

Little, D. 1998. *Microfoundations, method and causation*. New Brunswick, NJ: Transactions publishers.

Luhmann, N. 1996. *Social systems.* Stanford, CA: Stanford University Press.

Machamer, P., L. Darden, and C. F. Craver 2000. Thinking about mechanisms. *Philosophy of Science* 67, 1-25.

Mainzer, K. 1994. *Thinking in complexity: The complex dynamics of matter, mind and mankind*. New York: Springer-Verlag.

McGivern, P. 2008. Reductive levels and multi-scale structure. *Synthese* 165 (1): 53-75.

McLaughlin, B., and K. Bennett. 2008. Supervenience. In *The Stanford encyclopedia of philosophy* (Fall 2008 edition), edited by E. N. Zalta. http://plato.stanford.edu/archives/fall2008/entries/supervenience/.

North, J. 2009. The structure of physics. *Journal of Philosophy* 106:57-88.

O'Connor, T. 1994. Emergent properties. *American Philosophical Quarterly* 31:91-104.

O'Connor, T. 2000. *Persons and causes*. Oxford, UK: Oxford University Press.

O'Connor, T., and H. Y. Wong. 2009. Emergent properties. In *The Stanford encyclopedia of philosophy* (Spring 2009 edition), edited by E. N. Zalta. http://plato.stanford.edu/archives/spr2009/entries/properties-emergent/.

Parsons, T. 1991 [1951]. *The social system.* 2nd ed. New York: Routledge.

Rajulton, R., Z. Ravanera, and R. Beaujot. 2007. Measuring social cohesion: An experiment using the Canadian National Survey of Giving, Volunteering, and Participating. *Social Indicators Research* 80:461-92.

Reynolds, C. 1987. Flocks, herds, and schools: A distributed behavioral model. *Computer Graphics* 21 (4): 25-34.

Roth, P., and T. Ryckman. 1995. Chaos, clio, and scientific illusions of understanding. *History and Theory* 34:30-44.

Sawyer, K. 2001. Emergence in sociology. *American Journal of Sociology* 107:551-85.

Sawyer, K. 2002. Nonreductive individualism, part 1. *Philosophy of the Social Sciences* 32:537-59.

Schaffer, J. 2003. Is there a fundamental level? *Nous* 37:498-517.

Sheldrake, R., T. McKenna, and R. Abraham. 2001. *Chaos, Creativity, and Cosmic Consciousness*. Rochester, VT: Park Street Press.

Simon, H. 1973. The organization of complex systems. In *Hierarchy theory: The challenge of complex systems*, edited by H. Pattee, 1-27. New York: Braziller.

Teller, P. 1992. A contemporary look at emergence. In *Emergence or reduction? Essays on the prospects of Nonreductive physicalism*, edited by A. Beckermann, H. Flohr, and J. Kim, 139-53. New York: de Gruyter.

Thalos, M. 2006. Nonreductive physics. *Synthese* 149:133-78.

Thalos, M. 2007. Sources of behavior. In *Distributed cognition and the will*, edited by D. Ross and D. Spurrett, 123-67. Cambridge, MA: MIT Press.

Thalos, M. 2008a. Two conceptions of collectivity. *Journal of the Philosophy of History* 2:83-104.

Thalos, M. 2008b. On planning: Towards a natural history of the will. *Philosophical Papers* 37:289-317.

Thalos, M. 2009. Systems. *Monist* 92 (3): 456-82.

Thalos, M. n.d. Nonreductive materialism without hierarchies. Unpublished manuscript.

Tönnies, F. 1957 [1887]. *Community and society: Gemeinschaft und Gesellschaft*, translated and edited by C. P. Loomis. East Lansing: Michigan State University Press.

Van Inwagen, P. 1990. *Material beings*. Ithaca, NY: Cornell University Press.

Weber, M. 1968 [1914]. *Economy and society*, edited by G. Roth and C. Wittich. Berkeley: University of California Press.

Wiener, N. 1948. *Cybernetics, or control and communication in the animal and the machine*. Paris: Hermann et Cie–MI.

Wimsatt, W. 1976. Forms of aggregativity. In *Human nature and natural knowledge*, edited by A. Donagam, A. N. Perovich, and M. V. Wedin, 259-91. Dordrecht: Reidel.

Wimsatt, W. 2006. Aggregate, composed and evolved systems. *Biology and Philosophy* 21:667-702.

Wimsatt, W. 2007. *Re-engineering philosophy for limited beings.* Cambridge, MA: Harvard University Press.

Bio

Mariam Thalos is professor of philosophy at the University of Utah. Her research focuses on foundational questions in the sciences, especially the physical, social, and decisional sciences, as well as on the relations amongst the sciences. She is a former fellow of the National Endowment for the Humanities, the Institute of Advanced Studies of the Australian National University, the Tanner Humanities Center, and the University of Sydney Center for Foundations of Science, and in 2010 will hold one of the inaugural Professorial Fellowships at the London Institute of Philosophy. She is currently working two book projects: *The Natural History of the Will*, on decision making in the natural world, and *Philosophy is of Familiar Things: Philosophical Thought in Lay Contexts*, for a wider audience.