Causal efficacy and the normative notion of sustainability science

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Sustainability science requires both a descriptive understanding and a normative approach. Modern science, however, began as purely descriptive knowledge, the core of which is that matter is dynamically inert and without purpose. The British philosopher David Hume concluded that the only type of causation in the material world is "efficient causation," which supported this purposeless view of a deterministic world "governed" by the causal laws of dynamics. But Hume did not argue against the existence of efficacious causation, only the error of humans projecting the mind's efficacy to objects. Though dynamically inert, a material object away from equilibrium can be thermodynamically reactive, suggesting the possibility of the object being efficaciously managed for a purpose. Furthermore, quantum physics has replaced classical physics as the fundamental theory of the material world. Its basic equation, the Schrödinger wave-equation, is deterministic but causally inert—it cannot govern, leaving the determinism door unlocked. This causal gap, according to the von Neumann-Stapp quantum measurement/activation theory, necessitates the pragmatic existence in an irreversible universe of the causal efficacy of mental effort and information management. The resulting "bigger" empirical science has room for "descriptive determinism" and "normative action," both of which are utterly essential in formulating sustainability science as an integral discipline.

KEYWORDS: theories, cause-effect relationships, interdisciplinary research

Introduction

Sustainability science requires both a descriptive knowledge and a normative approach. The knowledge of descriptive necessity presupposes the efficient causation of an orderly nature. The course of normative actions presumes, in addition, the efficacious causal decision that is based on sound descriptive knowledge. This article considers the existence and the nature of efficacious causation by first investigating the British philosopher David Hume’s philosophical position on efficacy and then placing the concept of efficacy in today’s frameworks of irreversible thermodynamics and Copenhagen-von Neumann quantum physics. The objective is the establishment of efficacious causation as a scientific concept.

Hume’s empiricism was rediscovered when the climate of philosophy and science in the twentieth century turned toward naturalism, materialism, and reductionism. Materialist naturalism, which admitted only efficient causation, denying the ontological existence of efficacy, came to dominate and define the past century of science and technology as the guiding vision of an extraordinarily productive modern era of pragmatic quantum physics and molecular biology.

At the dawn of the twenty-first century, however, “having benefited from the great gains in fundamental science that reductionism made possible, we again turn our attention to fundamental integration [the Humboldtian unity of nature]—whether called consilience...or sustainability science. Sustainability science returns to ask the question about the unity of nature” (Kates, 2000). Sustainability is a normative concept regarding not merely what is, but also what ought to be the human use of the Earth (Kates, 2001). The purposeful and normative nature of sustainability is meaningful only if human action is efficacious (Daly, 2008), a key concept in Hume’s argument against anthropomorphism. The first part of this article provides a critical philosophical analysis of Hume’s Treatise (Hume, 1985) to argue that the twentieth-century materialist naturalism inspired by Hume turns out to be the opposite of Hume’s real conclusion. Hume’s naturalism is not materialistic: he is not a reductionist. He denies the efficacy of physical causes, not the existence of efficacious anthropogenic power.

Hume did not elucidate the nature of efficacy. Indeed no one could find efficacy within the framework of the classical physics of the pre-Carnot and
The second part of this article suggests a scientific explication of efficacy based on the second law of thermodynamics and the pivotal role of information (and information processing in the context of the quantumneurophysical model of mind-body interaction).

The Sciences of Motion and Matter and the Philosophy of Causation

“Every science begins as philosophy and ends as art,” as Durant (1926) observed astutely. It may not be that every science began as philosophy, but certainly the best sciences began as philosophical problems. When a philosophical problem was solved successfully, it disappeared as a philosophical issue and became a scientific discipline. Such transformations started first with Galileo and Newton, who took the philosophical question of who is the unmoved mover(s) and transformed it into a scientific investigation of motion. The ancient philosophical controversy, between the atomist school of Leucippus and Democritus and the school of Socrates, Plato, and Aristotle, on the nature of matter remained unresolved after the Copernican-Newtonian revolution. However, since the beginning of the twentieth century, matter has been incontrovertibly shown to be made of molecules and atoms. The science of matter that had begun as philosophical atomism ended as the pragmatic quantum theory of matter—and led to quantum electronic/nucleus gadgets such as transistors and magnetic resonance imaging (MRI) scanners.

Another crucial question in science is the nature of causation. The philosophical debate of causation’s true meaning extends over millennia. In the Western philosophical tradition, the discussion stretches back to at least Aristotle. Over the centuries, many philosophers followed Aristotle and developed the view of cause and effect as a logical connection of some sort. This view equating causality with a logically necessary connection was overthrown by Hume, whose analysis concluded that the validity of science was based on empirical grounds, not logical necessity. And he could find only efficient causation in scientific laws, not power or efficacy. That is, Hume found no efficacious connection between event A and event B as described by scientific laws to justify claiming “A causes B.” As Russell (1945) noted,

The strongest argument on Hume’s side is to be derived from the character of causal laws in physics. It appears that simple rules of the form “A causes B” are never to be admitted in science, except as crude suggestions in early stages. The causal laws by which such simple rules are replaced in well-developed sciences are so complex that no one can suppose them given in perception;...So far as the physical sciences are concerned, Hume is wholly in the right: such propositions as “A causes B” are never to be accepted, and our inclination to accept them is to be explained by the laws of habit and association.

Hume’s great discovery is an example of the scientific capture of a broad philosophical concept of causation and the reduction of it into the narrower, but more precisely defined, scientific concept of efficient causation. Efficient causation may be scientifically defined as event-connection characterized by constant conjunction and invariable succession in conformity with [note: not “as governed by”] laws of nature. However, this process of capture did not transform causation into a purely scientific problem. The German philosopher Immanuel Kant’s powerful response to Hume’s skepticism was a philosophical one and the philosophical issue of causation did not disappear. The topic remains a staple in contemporary philosophy. A true transformation awaits a successful scientific response.

Causality for Sustainability Science

Sustainability is a normative concept. Clark et al. (2005) have argued that the fundamental difference between descriptive objective science since Copernicus and Galileo and the new sustainability science calls for a second Copernican Revolution.2 The new science emerging from this required revolution, while it is deeply rooted in the “exact and objective” tradition,3 must transcend it in three crucial ways:

1 In the period of pre-Carnot physics, a material object is dynamically inert without the understanding that it can be thermodynamically reactive when it is away from equilibrium.

2 The term “second Copernican Revolution” was first used by Schellnhuber (1999).

3 The exact and objective tradition is the Galilean and Newtonian tradition of descriptive science. In the twentieth century this tradition was already critiqued by Michael Polanyi (1958) who argued that even in the exact sciences, “knowing” is an art, of which the skill of the knower is a logically necessary part (a point not unlike one made by Kant who argued that “knowing” originates from presupposition or a priori categories of the mind). The tendency to make knowledge impersonal in our culture has split fact from value, science from humanity. Polanyi made the case for substituting the impersonal ideal of objective science an alternative ideal, the post-critical philosophical ideal.
1. Introduces a systems approach beyond the limits of an object approach to comprehend the existence of the Earth system at “far from thermodynamic equilibrium.”

2. Addresses the complexity and contingency of such a system as a result of it being brought about by efficacious causation, instead of it being limited to “clockwork” regularity as described by laws of nature (efficient causality).

3. Accepts the epistemological insight derived from Copenhagen quantum physics that abandons the sharp “borderlines between observing subjects and scrutinized objects.”

Others have made similar points by calling for the explicit need for a new kind of “knowledge to inform policy and management decisions” (Lubchenco, 1998). In her 1997 Presidential Address to the American Association for the Advancement of Science, Jane Lubchenco (1998) stated that, in recognizing the urgent need for knowledge to understand and manage the biosphere, I propose that the scientific community formulate a new Social Contract for science… [The Contract] should express a commitment to harness the full power of the scientific enterprise in discovering new knowledge, in communicating existing and new understanding to the public and to policymakers, and in helping society move toward a more sustainable biosphere.

Gallopin et al. (2001) argued for a “science for the twenty-first century” that involves “both natural and social scientists in the investigation of the necessary steps to develop a sustainability science.” Kay et al. (1999) referred to such science as post-normal science (a concept developed by Silvio Funtowicz and Jerome Ravetz4) and wrote that only post-normal science (a concept developed by Silvio Funtowicz and Jerome Ravetz) and scientific propositions are mere descriptions of the uniformities or regularities in the world since induction cannot establish the necessity of propositions; (2) the reductionist view (see Footnote 5) that causality is exhausted by (equal to) constant conjunction and invariable succession (i.e., as Curd & Cover (1998) put it, “causal connections are a species of lawful connections”), which do not imply causal efficacy.

It is reassuring for the author, as an engineer, to learn that “New Hume” scholarship (Wright, 1983; Kemp Smith, 2005) offers a revised interpretation of the philosopher’s position on matters relating to the first of the two views:

What, historically, until late in the Twentieth Century, was called the “Humean” account of Laws of Nature was a misnomer. Hume himself was no “Humean” as regards laws of nature. Hume, it turns out, was a Necessitarian—i.e., believed that laws of nature are in some sense “necessary” (although of course not logically necessary). His legendary skepticism was epistemological. He was concerned, indeed even baffled, how our knowledge of physical necessity could arise. What, in experience, accounted for the origin of the idea? What, in experience, provided evidence of the existence of the property? He could find nothing that played such a role. Yet, in spite of his epistemological skepticism, he persisted in his belief that laws of nature are (physical) necessities (Swartz, 2009).

Hume did answer his perplexity in the following way: “What principally gives authority to this system is, beside the undoubted arguments, upon which each part is founded, the agreement of these parts, and the

Causation and Hume’s Naturalism

Because David Hume is the most influential philosopher ever to write on causation, it is necessary to begin with a critical discussion of his thought. Standardly, it is common to interpret his great discovery as advancing two views: (1) the regularist view on laws of nature that scientific propositions are mere descriptions of the uniformities or regularities in the world since induction cannot establish the necessity of propositions; (2) the reductionist view (see Footnote 5) that causality is exhausted by (equal to) constant conjunction and invariable succession (i.e., as Curd & Cover (1998) put it, “causal connections are a species of lawlike connections”), which do not imply causal efficacy.

4. See Funtowicz & Ravetz (1993).
necessity of one to explain another” (Hume, 1985, 1.3.13.19). This method of achieving the physical necessity (Hume, 1985, 1.3.14.33) or “truth” of scientific propositions is expressed today as consilience, the unity of knowledge linking together propositions/laws from different branches/disciplines, especially when forming a comprehensive theory. We achieve a degree of “certainty” through “consilience/concurring” the totality of our established propositions/laws from different disciplines by canonical principles—in addition to the application of induction to each single proposition alone. The principle of energy conservation is an outstanding example of a canonical principle that applies to all scientific disciplines, linking together various other propositions in individual disciplines. As Quine (1951) puts it, “The totality of our so-called knowledge or beliefs, from the most casual matters of geography or even of pure mathematics and logic, is a man-made fabric which impinges on experience only along the edges.”

A principal source of old misunderstandings is that Hume used necessity and power interchangeably in many cases so that when he denied necessity he was actually denying power in physical causality, not physical necessity (or the doctrine of necessity). We now turn to our main concern with respect to Hume’s position on causality (matter relating to the second of the two views). In Treatise, he made the most sustained and systematic analysis on the nature of physical causality. A summary of the analysis is succinctly captured by Fiske (1874):

Physics knows nothing of causation except that it is the invariable and unconditional sequence of one event upon another. July does not cause August, though it invariably precedes it.

The invariable Necessitarian necessity does not come with the efficacy or power of a real causation; physical causality is only efficient causality, not efficacious causality. This subtle difference has wide-ranging implications. Hume’s position on this matter with regard to whether his naturalism was reductionistic is considered below.

First, Hume only denied the power or efficacy of physical causality, not the idea of power:

And this we may observe to be the source of all the relations of interest and duty, by which men influence each other in society, and are placed in the ties of government and subordination. A master is such-a-one as by his situation, arising either from force or agreement, has a power of directing in certain particulars the actions of another, whom we call servant. A judge is one, who in all disputed cases can fix by his opinion the possession or property of anything betwixt any members of the society. When a person is possessed of any power, there is no more required to convert it into action, but the exertion of the will (Treatise 59-60, 1.1.4.5).

It is this power or efficacy that he tried to find in the physical world of matter.

The heart of Treatise relevant to this search can be found in Book I: Part III: Section XIV: Of the Idea of Necessary Connexion. Here, Hume limits himself to considering the nature of causality in the physical world of pure matter. His conclusion is clear that there is no power or efficacy in the connection of material events: “matter is in itself entirely unactive, and depr’vd of any power” (Treatise 209, 1.3.14.9).

A large part of the misunderstanding of Hume derived from his use of the term necessity or necessary connexion: “I begin with observing that the terms of efficacy, agency, power, force, energy, necessity, connexion, and productive quality, are all nearly synonymous” (Treatise 206, 1.3.14.4). This is unfortunate, because he did not always use them as synonymous terms. A close reading reveals that he used “necessity” as a broader term than “power,” with at least two meanings: as physical necessity in his doctrine of necessity and as power or efficacy. What he repudiated in this section is the power and efficacy, not the necessity, of physical causality. “Upon the

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6 See Hume (2000) Chapter 8, Of Liberty and Necessity.

7 Millican (2008) writes, “This suggestion can be backed up with an analysis of Hume’s usage of the various terms concerned, which reveals an interesting and significant pattern in both main discussions of the idea in question. In Treatise I iii 14, he refers to the idea of ‘power’ or ‘efficacy’ roughly three times more often than he does to the idea of ‘necessity’ or ‘necessary connexion’, and the only parts of that long discussion where he prefers the latter terms are in the section’s title, the very first paragraph (as quoted in §1 above), and in a short passage of less than 250 words between the end of paragraph 20 and paragraph 22 (T 165-6). Shortly before this passage he introduces talk of ‘power or connexion’ (T 163), without any clear implication of strict necessity. In Enquiry VII, Hume refers numerous times to the idea of ‘power or necessary connexion’, though mainly in parts of his discussion where he is introducing (E 63, E 64) or reviewing (E 73, 78) the main stages of the argument, and in the section’s original title. Within the body of the argument itself, he almost always prefers either ‘power’ alone or various combinations of ‘power’, ‘force’ and ‘energy’, never referring to the idea of necessity or necessary connexion except in one short passage, the first half of a single paragraph (E 75) in which he refers initially to ‘this idea of a necessary connexion among events’ and later to ‘the idea of power and necessary connexion’.”
whole, necessity is something, that exists in the mind, not in the objects” (Treatise 216, 1.3.14.22) should be read as “power is something, which exists in the mind, not in the objects.” He could not find in the natural occurrences of the material world the power and efficacy that he referred to in human affairs, and, as one of the greatest champions against anthropomorphism, warned against the projection of mind to objects.

In this warning, Hume denied physical objects the anthropogenic power to govern:

I am, indeed ready to allow, that there may be several qualities both in material and immaterial objects, with which we are utterly unacquainted; and if we please to call these power or efficacy, ‘twill be of little consequence to the world. But when, instead of meaning these unknown qualities, we make the terms of power and efficacy signify something, of which we have a clear idea, and which is incompatible with those objects, to which we apply it, obscurity and error begin to take place, and we are led astray by a false philosophy. This is the case, when we transfer the determination of the thought to external objects, and suppose any real intelligible connexion betwixt them; that being a quality, which can only belong to the mind that considers them (Treatise 218-219, 1.3.14.27).

The error is the false philosophy of materialistic-reductionistic naturalism of causal closure (see below). Hume’s more important conclusion is not that physical causality is exhausted by (equal to) constant conjunction and invariable succession—i.e., there is no efficacy in physical causality—but that man should not project the efficacy in conducting human affairs to the natural events of physical objects. Hume did not reject efficacy: he was not a reductionist and the twelfth-century reductionistic interpretation is the opposite of his real conclusion as the next section further examines.

**Causal Closure vs. Hume’s Compatibilism**

“Matter is in itself entirely unactive, and depriv’d of any power” (Treatise 209, 1.3.14.9): matter is dynamically inert; it cannot strive or act. While God is omniscient and omnipotent, matter is not supposed to have any kind of power—definitely not the power to constrain. Hume was perfectly clear on this point (see below). A strange thing, then, happened to science: in the twentieth century, scientists and philosophers—in a move that showed the vestige of God’s omnipotence—gave governing power to the laws of nature. That is, force-driven interactions inclusively produce physical effects. Nothing else can cause physical effects according to twentieth-century materialist naturalism.

There is an interesting history to science’s view about the kinds of things that can “cause” physical effects. Early Newtonian physics did not impose exacting restrictions on possible causes of physical effects; indeed, Newton himself was not a Newtonian. The philosophes of the eighteenth-century Enlightenment formulated the worldview now known as Newtonianism; a few Newtonians in the eighteenth century were converted into strict materialists.

However, for the majority of scientists and philosophers, the first step of the conversion (hardening) of Newtonianism into naturalism took place, according to Papineau (2009), only in the nineteenth century with the discovery of the conservation of energy (and of evolutionary theory). Even so:

The nineteenth-century discovery of the conservation of energy continued to allow that sui generis non-physical forces can interact with the physical world, but…any such mental forces would need to be law-governed and thus amenable to scientific investigation along with more familiar physical forces…If mental or vital forces arose spontaneously, then there would be nothing to ensure that they never led to energy increases (Papineau, 2009; emphasis added).

When, during the course of the twentieth century, “detailed physiological research gave no indication of any physical effects that cannot be explained in terms of basic physical forces,” Papineau (2009) continued, “belief in sui generis mental or vital forces had become a minority view. This led to [the second step in] the widespread acceptance of the doctrine now known as the ‘causal closure’ of the physical realm” (emphasis added). This step completed the conversion to materialist naturalism. In a causally closed physical universe, a human lived in “a world that is deaf to his music, just as indifferent to his hopes as it is to his suffering or his crimes” (Monod, 1971).

The idea of a causally closed world also coincided with the transformation of the triumph of atomism into radical atomism—the philosophy according to which the absolute and timeless properties of elementary particles capture eternal reality (Smolin, 1997). The presuppositions of causal closure and radical atomism are, of course, metaphysical, not propositions based on scientific evidence. Smolin (1997) remarks, “I want to suggest that per-
haps the answer is that the belief in radical atomism in the existence of a final and absolute theory that governs the behavior of the elementary particles [thus, life and man]—is as much a religious as it is scientific aspiration.”

In a causally closed world without efficacy, matter is the sole determinate of physical effects. But, even so, “determination” is not governing, nor is “necessity” constraint. It is logically fallacious to repudiate anthropomorphism by stripping away from material objects their anthropogenic power as Hume argued, and then turning 180 degrees to impart to material objects that very anthropogenic power so that matter can govern over a causally closed world. Collingwood (1940) argued, “The so-called ‘materialism’ which was the favorite metaphysical doctrine of these anti-metaphysicians was in consequence only in name a repudiation of anthropomorphism; really it was anthropomorphic at the core.”

Hume’s doctrine of necessity is not the necessity of hard determinism, but of “soft determinism” (“descriptive determinism”) or compatibilism: “By liberty, then, we can only mean a power of acting or not acting, according to the determinations of the will… this hypothetical liberty is universally allowed to belong to everyone who is not a prisoner and in chains” (Hume, 2000) and “Liberty, when opposed to necessity, not to constraint, is the same thing with chance [see comment below with regard to the lack of understanding on chance and statistical physics in the eighteenth century]; which is universally allowed to have no existence” (Hume, 2000). Liberty is compatible with necessity, so is action; they are only opposed to constraint, not necessity. Here, Hume explicitly holds that physical necessity does not equal constraint, or restraint, or governing, contradicting squarely with hard determinism.

I thus define efficacious causation as event-connection in conformity with laws of nature resulting from action that utilizes matter’s internal thermodynamic “force.” This does not mean that matter has any kind of “free will.” However, it does mean that matter can be managed by the action of living things requiring no “heavy lifting” or mental force (as explained in the section below). What Hume’s philosophy does say is that it finds no efficacy in the material world alone; therefore, efficacy requires a nonmaterial origination. The following sections take a critical look at the two principal elements of the “man-made fabric” of causal closure: the absence of mental force in accordance with the energy-conservation law and the materialism of classical physics. The first part is an original proposal/result of my research and the second part is a proposal by Stapp (2001) based on orthodox Copenhagen-von Neumann quantum physics (see also Schwartz et al. 2005).

Comprehending Efficacious Causation in Terms of Force-Driven and Spontaneity-Driven Interactions

The first law of energy conservation is completely consistent with the dynamical laws of physical forces. Dynamical forces, however, are not the only cause for physical effects. Matter is dynamically inert. However, matter away from equilibrium can be thermodynamically reactive or subject to spontaneous changes (Prigogine & Stengers, 1984). These changes result from another kind of “forces”—entropic “forces.” The first law is also consistent with this “force” in the form of the principle of the increase of entropy, or the second law, which accounts for spontaneous natural processes (Wang, 2007; 2011). Their consistency is assured, in the first place, by the fact that the two laws were simultaneously formulated by Rudolf Clausius between the years 1850 and 1865 with the assistance of Lord Kelvin.

One aspect of the new “forces” remains completely in accord with the existing materialist naturalism: the mechanistic laws of dynamical forces, the great law of conservation of energy-mass, and the entropy principle remain a consistent set of core ideas for a worldview of a causally closed world, as seen in Figure 1. In this world, physical effects are caused by physical or efficient causality alone.

However, the full implication of the second law points to a fundamental departure from twentieth-century naturalism by creating room for managed application of the entropic “forces,” i.e., heat and spontaneity (Wang, 2011). As shown in Figure 2, once we admit the possibility of managed events taking advantage of the irreversibility of nature, the implication of the mechanistic laws of nature become much greater. As Poincaré (1946) pointed out, “In the deterministic hypothesis there is [in every event] only a single possibility [of invariable succession].” In view of the second law, however, the full implication of the mechanistic laws of nature is to provide a possibility space vastly bigger than that of the causally closed world (see Figure 2). Compton (1967) wrote,

A set of known physical conditions is not adequate to specify precisely what a forthcoming event will be. These conditions, insofar as they can be known, define instead a range of possible events from among which some particular event will occur. When one exercises freedom, by his act of choice he is

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8 This is the definition of “determinism” or “hard determinism,” a term invented by William James.
himself adding a factor not supplied by the physical conditions and is thus himself determining what will occur...Thus the way is cleared for our great task. We are free to shape our destiny. Science opens vast new opportunities.

That is, hidden in the quantum mechanical laws lay unimaginably rich possible options. But those laws provide only the possibility space for what can happen, not the construction of the reality that actually does happen. Ellis (2008) has made the same argument in recent times. Likewise, the conservation law of energy-mass is merely able to provide its version of possibility space. To make possibility into actuality requires both the entropic "forces" of nature and their management through information. Only spontaneity (the entropic "force") can determine whether, in accordance with mechanistic and conservation laws, a given possibility is entropically possible in the macroscopic reality space, for example, whether a given chemical reaction or a given fission reaction is entropically possible. The physical possibilities (though not their efficacious construction) of macroscopic events are jointly "determined" by (1) the mechanistic laws, (2) the mass-energy conservation law, and (3) the entropic "forces."

Moreover, what makes a spontaneity-driven or entropic forces-driven causation efficacious is (4) the information management of the entropic "forces"—the last of the four great ideas necessary for comprehending the real world. Hume wrote that power is something which exists in the mind. Actually, power is associated with information management with or without the mind; the possibility of information management exists for any living organism, including ones without minds. The ability to manage information is one of the characteristics of life. Let us consider for now (and in the next section) the example of efficacious causation in terms of the mind. The brain, the physical "mind," cannot bend a spoon because the spoon lacks its own spontaneity engine. But, the brain can set in motion by a remote-control signal an internal combustion engine's ignition, or command a dog to run to you, because both the engine and the dog have their own "spontaneity reservoirs" or "entropic 'forces' reservoirs." Entropic "forces" exist to be managed easily; this is not the case with dynamical forces. The brain generates no forces for physical effects; it is spontaneity that physically produces physical effects or physical events—the brain and information-signal merely set events in motion. This is what Hume meant, "When a person is possessed of any power, there is no more required to convert it into action, but the exertion of the will" (Treatise 1.1.4.5). Efficacious causation is the exertion of the will without having to do any physical heavy lifting.

9 An internal combustion engine is of course not alive as a dog is. What is common between the two is that both have their own spontaneity reservoirs. The agent is the only one that must be alive and thus can set both events in motion. The dog can just as well be a mechanical dog with its own battery, and it can be "commanded" by a remote control.
Scientists in the eighteenth century did not have an understanding of the second law of thermodynamics or of the nature of chance or statistical physics. It is not surprising that Hume was wrong about chance and had no conception of entropic "force." The identification of the possibility of efficacious causation with the second law here is consistent with the view of Ladyman & Ross (2007):

Because all the special sciences take measurements at scales where real patterns conform to the Second Law of Thermodynamics, all special sciences traffic in locally dynamic real patterns. Thus it is useful for them to keep epistemic books by constructing their data into things, local forces, and cohesion relations. As we will discuss in the next chapter, causation is yet another notional-world conceptual instrument ubiquitous in special science. The great mistake of much traditional philosophy has been to try to read the metaphysical structure of the world directly from the categories of this notional-world book-keeping tool...In this context, reductionistic scientific realism has the odd consequence of denying their existence.

Taking directed, irreversible transmission of influence, plus conservation principles, for granted is rational when you know you're taking all your measurements from regions governed by the Second Law. This practice conforms so closely to what is enjoined by a folk metaphysical endorsement of causation that no serious risk of misunderstanding arises if the scientist helps herself to the culturally inherited folk idea of causation. But she need not thereby endorse folk metaphysics."

Efficacious causation is when life and humans make use of matter, the spontaneity of the irreversible world, and information to prescribe and construct the reality space—the creative living world—within the possibility space provided by the mechanistic science and subject to the mass-energy conservation constraints.

**Figure 2** Ecological naturalism: a world of efficient and efficacious causation.
gressively more complex systems at far from thermodynamic equilibrium in the reality space.

One thermodynamic insight of efficacious causation is the concept of free heat in addition to the existing concept of waste heat (Wang, 2011). Instead of the inevitability of matter degenerating into waste heat, it is possible for life to harness free heat. Passive cooling and heating of buildings, maintained at far from equilibrium, are concrete examples of harnessing free heat (Meierhans, 1993; Wang, 2011). As I have written elsewhere, “The objective of thermodynamic management is not only the reduction/recovery of waste heat, but also the generation of free heat. Otherwise, no matter how successful man’s attempt in reducing/recoving waste heat is, it merely delays the eventual unsustainable doom” (Wang, 2011).

The Causal Gap for Information Management: The von Neumann-Stapp Quantum Theory

What makes a spontaneity-driven or entropic forces-driven causation efficacious is the information management of the entropic “forces.” But, “who” is the nonmaterial manager? The French philosopher René Descartes formulated the dualism of the mind and the body, with the mind as the manager. The important thing then was to inquire how the mind became aware (i.e., conscious and self-conscious) and how it succeeded in acting upon the body. A satisfactory answer cannot be found in classical physics, which is not surprising because classical physics is completely materialistic.

Just as the doctrine of causal closure and radical atomism reached its apotheosis, classical physics was shown to be empirically incorrect in the first quarter of the twentieth century and was replaced by quantum physics, a seminal discovery that turned the whole concept of what science is inside out. The core idea of classical physics was to describe the “world out there” with no reference to “our thought in here.” In quantum mechanics, “our thought in here” or “acts of knowing” become a fundamental reference point of the science:

Von Neumann capitalized upon the key Copenhagen move of bringing human choices into the theory of physical reality. But, whereas the Copenhagen approach excluded the bodies and brains of the human observers from the physical world that they sought to describe, von Neumann demanded logical cohesion and mathematical precision, and was willing to follow where this rational approach led. Being a mathematician, fortified by the rigor and precision of his thought, he seemed less intimidated than his physicist brethren by the sharp contrast between the nature of the world called for by the new mathematics and the nature of the world that the genius of Isaac Newton had concocted (Stapp, 2007).

Von Neumann carried out a detailed and mathematically rigorous analysis of the process of measurement to remove the ambiguity in the positioning of the “Heisenberg cut” by shifting parts involved in measurement into the physically described realm. Step by step, all parts of the universe that are conceived to be composed of atomic particles and the physical fields associated with them are positioned below the cut, and left above the cut is a residual experiential reality that von Neumann called the “abstract ego.” The physical processes below the cut are called “Process 2,” which evolve deterministically according to the Schrödinger equation between probing actions. The probing action by the abstract ego is called “Process 1,” which picks out from a potential continuum of overlapping possibilities of Process 2 some particular discrete possibilities. The third process, “Process 3,” is “choice on the part of nature” between “yes” and “no”—the statistically specified (based on quantum rules) outcome triggered by the probing action. Process 2 “governed” by the Schrödinger equation is deterministic, but causally inert because of Processes 1 and 3.

Stapp (2001; 2007) and his neuropsychologist collaborators (Schwartz et al. 2005) have extended von Neumann quantum mechanics into a new formalism, which contains a radical conceptual move insofar as quantum measurement is understood to involve efficacious conscious human choices. In particular, he postulates the mind’s effect on the activities of the brain as the connection between effort, attention, and so-called quantum Zeno effects. Stapp calls this “active Process 1” (Schwartz et al. 2005) or “Process zero” (Stapp, 2007).

I...will use here the more apt name “process zero,” because this process must precede von Neumann’s process 1. It is the absence from orthodox quantum theory of any description on the workings of process zero that constitutes the causal gap (emphasis added) in contemporary orthodox physical theory. It is this “latitude” offered by the quantum formalism in connection with the “freedom of experimentation” (Bohr, 1958) that blocks the causal closure of the physical, and thereby releases human actions from the immediate bondage of the
physically described aspects of reality (Stapp, 2007).

Quantum measurement problems become quantum measurement/activation problems.

It suffices to indicate the direction of this research program by reciting the abstract and the conclusion of Schwartz et al. (2005):

Contemporary physical theory brings directly and irreducibly into the overall causal structure certain psychologically described choices made by human agents about how they will act. This key development in basic physical theory is applicable to neuroscience, and it provides neuroscientists and psychologists with an alternative conceptual framework for describing neural processes …[The new framework] is able to represent more adequately than classic concepts the neuroplastic mechanisms relevant to the growing number of empirical studies of the capacity of directed attention and mental effort to systematically alter brain function.

Materialist ontology draws no support from contemporary physics and is in fact contradicted by it…These orthodox quantum equations, applied to human brains in the way suggested by John von Neumann, provide for a causal account of recent neuropsychological data. In this account brain behaviour that appears to be caused by mental effort is actually caused by mental effort: the causal efficacy of mental effort is no illusion (Schwartz et al. 2005).

The twentieth-century philosopher Anscombe (1971) made the insightful remark, “The laws’ being deterministic does not tell us whether ‘determinism’ is true.” The Schrödinger wave equation is deterministic but causally inert—it cannot strive or govern, leaving the determinism door unlocked. The von Neumann-Stapp causal gap necessitates the pragmatic existence in an irreversible universe of the causal efficacy of mental effort, which can be and will be subject to evidence-based scientific testing.

Looking Ahead and Up

The causal gap in the mathematics of quantum theory has the potential to overthrow the doctrine of causal closure of the material realm, which is fundamentally quantum mechanical. Rival proposed theories (of the von Neumann-Stapp quantum-theory) exist. One may look forward to a day when causation will disappear as a philosophical dispute and become a scientific subject. The concept of causation, which has room for “normative action” and “descriptive determinism,” and the second law will link together sustainability science and normal science (Kuhn, 1962). The resulting ecological-naturalism (Figure 2) accords equal objectivity to irreversible entropic “forces” as well as reversible dynamical forces, and to the world of information and mind as well as the world of matter and brain. “How can we know if any worldview is true? The ultimate test is the effect of the worldview in question upon the survival of its holders,” notes Robert Zubrin (2007). Ecological naturalism will help us to formulate what ought to be the human use of the Earth.

Murray (2003) commented on the materialist naturalism worldview this way,

It may well be that the period from the Enlightenment through the twentieth century will eventually be seen as a kind of adolescence of the species…In the manner of adolescents, humans reacted injudiciously, thinking that they possessed wisdom that invalidated all that had gone before.

But adolescents, eventually, will grow up and become explorers. In his sublime essay, Zubrin (2007) writes,

Humans are the descendants of explorers. Four hundred million years ago, our distant ancestors forsook the aquatic environment in which they had evolved to explore and colonize the alien world above the shoreline. It is remarkable when you think about it—sacrificing the security of the waters for the hazards of the land…On land it is possible to build fires. On land it is possible to see the stars.

Out of the security of a causally closed cave humans can learn to see the stars and hear the music.

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