How Does It Work?
The Search for Explanatory Mechanisms

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This article addresses the following problems: What is a mechanism, how can it be discovered, and what is the role of the knowledge of mechanisms in scientific explanation and technological control? The proposed answers are these. A mechanism is one of the processes in a concrete system that makes it what it is—for example, metabolism in cells, interneuronal connections in brains, work in factories and offices, research in laboratories, and litigation in courts of law. Because mechanisms are largely or totally imperceptible, they must be conjectured. Once hypothesized they help explain, because a deep scientific explanation is an answer to a question of the form, "How does it work, that is, what makes it tick—what are its mechanisms?" Thus, by contrast with the subsumption of particulars under a generalization, an explanation proper consists in unveiling some lawful mechanism, as when political stability is explained by either coercion, public opinion manipulation, or democratic participation. Finding mechanisms satisfies not only the yearning for understanding, but also the need for control.

Keywords: *explanation; function; mechanism; process; system; systemism*

All of the sciences are known to have advanced from description to explanation, which may in turn be regarded as a deeper and more detailed description. Likewise, technology—from engineering to social policy making—advances from trial and error to design based on research. And in technology, as well as in basic science, to explain a fact is to exhibit the mechanism(s) that makes the system in question tick—such as fission or fusion, stirring or negative feedback, parenting or punishing, education or publication, work or trade, class struggle or bargaining, war or peacekeeping, research or peer review.

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These were some of the theses advanced in my *Scientific Research* (1967), which were restated and elaborated on in later publications (e.g., 1968, 1983, 1997). Recently, Machamer, Darden, and Craver (2000) rediscovered that science explains in terms of mechanisms. They have also asserted that "there is no adequate analysis of what mechanisms are and how they work in science." Though belated, these admissions are true. Regrettably, their own account of mechanisms as "entities and activities organized such that they are productive of regular changes" is not only imprecise but also incorrect. Indeed, besides putting things and their changes in the same bag, it misses the concept of a concrete system—one of the categories sadly absent from mainstream ontology, along with those of matter, energy, state, and emergence.

This is a serious omission because mechanisms—such as those of diffusion, clumping, negative feedback, metabolism, cooperation, competition, mediation, and debate—happen to be processes in material complex things, not in their individual constituents. Glennan (2002) realizes the mechanism-system connection but conflates the two. To be sure, this concept is consonant with the dictionary definition of a mechanism as a piece of machinery, such as the "works" of a watch. But it is at variance with the use of the word in science, where ordinarily 'mechanism' means a process in a system; and in technology, where it means an operation intended to force a system to change in a prescribed way. It is therefore necessary to elaborate on the concept of a mechanism and its role in explanation.

To elucidate these ideas, and motivate the subsequent discussion, let us begin by considering the following examples drawn from several sciences. Here is an example from elementary physics: Ohm and Kirchhoff described electric circuits but did not know what makes electricity flow. This explanation was only provided by electrodynamics: the electric charges (electrons) in a metallic wire are dragged by the impressed electric field (voltage).

Our second example is taken from chemistry. There are several mechanisms for the synthesis of molecules out of atoms. The most prevalent of them are electron transfer and electron sharing. In the first case, one of the atoms donates an electron to the other, as a consequence of which a positive and a negative ion are formed, which attract one another electrostatically. A textbook example is the combination of a sodium ion Na^+ with a chlorine ion Cl^- to produce a neutral sodium chloride molecule NaCl. By contrast to this (electrovalent bond), a covalent bond emerges when the precursor atoms share their outer electrons. The simplest example is the formation of the hydrogen molecule H_2. This is not just the juxtaposition of two hydrogen atoms, since the two electrons from the precursor atoms now interpose between the atomic nuclei (protons): here emergence results from restructuration.

Biological evolution had been suspected long before Charles Darwin established it. He explained it in terms of inheritance with modification and natural selection. Whereas the latter is a mechanism, that of inborn modifications was discovered only decades later. It turned out that they arise from genic mutations and recombinations, which are in turn explained in molecular terms. Focus on genes led Theodosius Dobzhansky to define evolution as a change in the frequencies of certain alleles in a population. But a frequency change—a statistical feature of a collection—is only an effect of the alterations occurring in the course of individual development. And these are changes in developmental pathways or mechanisms. These are the roots of speciation, as recognized by the new science of evolutionary developmental biology, or evo-devo (see, e.g., Wilkins 2002).

An interesting psychological example is the mechanism of the extinction of aversive memories, such as those of fearful episodes. This is not accomplished by Freud's mythical immaterial superego but by the cannabioids produced by our bodies: they wreck the neuronal processes in the amygdala that store aversive memories (Marsicano et al. 2002). Another recent finding in cognitive neuroscience is the experimental induction of "out-of-body" experiences (Blanke et al. 2002). This is achieved, not by extrasensory means, but by electrical stimulation of the somatosensory region (body map) of the cerebral cortex. Although the details of the mechanism are still unknown, the outline is clear: whether normal or illusory, perception is a process localized in the cortex and thus sensitive not only to external signals but also to internal stimuli.

Let us finally go to social science. In a classical paper, Robert K. Merton (1936, 154) identified the mechanisms of unanticipated purposive social actions. One of them, perhaps the most pervasive, is this: "with the complex interaction that constitutes society, action ramifies. Its consequences are not restricted to the specific area in which they are intended to center and occur in interrelated fields ignored at the time of action."

As for economics, Ludwig von Mises ([1949] 1966: 257) claimed that the market is not a thing or a collective entity but a process. But of course there are no processes except in concrete things. And a market is a thing, in particular a concrete system composed by people and fruits of labor, whose central mechanism and raison d'être is the exchange of goods and services.

Standard microeconomic theory focuses on market equilibrium, which it purports to explain as an outcome of the so-called price mechanism: Increase in supply → Drop in price → Rise in demand → Price hike → . . . . Regrettably, this zig-zagging and self-correcting mechanism works better in textbooks than in real markets, for it ignores oligopolies and overlooks the persistence of market disequilibria, in particular chronic unemployment. (See Bunge 1998 for further criticisms of standard economic theory.)

The actions of central banks and stabilization funds, monopolies and oligopolies, as well as the implementation of commercial codes and government regulations—though not the norms themselves—may in turn be regarded as mechanisms for the control of the trade mechanism. They are metamechanisms. So is the application of any free-trade agreement among unequal nations: it forces the weaker party to grant national treatment to foreign firms, hence to abstain from favoring national development. Unfettered free trade is thus a mechanism for strengthening the strong and thus perpetuating underdevelopment.

Socioeconomists have been baffled by the steady rise of income inequality in the United States and other countries since about 1980, despite spectacular gains in productivity and gross domestic product—the so-called Great U-Turn. Several mechanisms operating concurrently have been proposed to explain this trend, notably the following ones, that are involved in globalization (Anderson and Nielsen 2002): the de-industrialization caused by the export of manufactures; the cheapening of low-skill labor; and the weakening of the bargaining power of labor consequent upon both antilabor legislation and the increased labor supply. Thus, as Hobson ([1902] 1938) had observed a century ago with regard to the British empire, in the long run, economic imperialism is self-destructing.

Finally, a politological example: "Democracy is a social mechanism for resolving the problem of societal decision-making among conflicting interest groups with minimum force and maximum consensus" (Lipset 1959: 92). By contrast, military aggression, protracted dictatorship, and terrorism (both state-initiated and group-sponsored) are by far the most destructive, divisive, and irrational, and therefore also the most barbaric and immoral, of all political mechanisms. The moral should be clear: whereas constructive mechanisms should be oiled and repaired whenever necessary, the purely destructive ones should be thwarted. In either case, effective results follow best upon knowledge-guided actions.

The question in the title of this article induces its dual: why does this or that procedure fail to work? This question is particularly important with reference to pseudo-technology. For instance, why do magic, water dowsing, Feng Shui, homeopathy, faith healing, and psychoanalysis fail? The short answer is, because they do not rely on any real mechanisms other than the placebo effect (see, e.g., Kurtz 2001). Incidentally, placebos are mechanisms, since they trigger physiological processes that start in the cortex and may involve the release of neurotransmitters.

The relevance of mechanism to understanding is such that it is not uncommon to find in the scientific literature apologies of the form, "Unfortunately, no mechanism is known to underlay the fact [or the equation] in question." For example, the hypothesis of continental drift, proposed by Alfred Wegener in 1915, was resisted for nearly half a century because no mechanism for that movement was known. The plate-tectonic theory vindicated that hypothesis and explained earthquakes, mainly as an effect of the collision of plates.

Likewise, nobody believed in allergy until it was explained, several decades after it was discovered, in terms of antigen-antibody reactions. Again, physicians do not believe in homeopathic nostrums, except as placebos, because there is no mechanism whereby a few molecules of any "active principle" could affect entire organs. And scientific psychiatrists do not believe in the psychoanalytic stories, not only because they lack experimental validation, but also because they are not backed up by any known brain mechanisms.

In all of the above scientific examples, a mechanism was conceived of as a *process (or sequence of states, or pathway) in a concrete system, natural or social*. Besides, most mechanisms are concealed, so that they have got to be conjectured. This suggests the plan of this article: system, mechanism, mechanism guessing, and explanation. These and other concepts will only be sketched and exemplified here; they are elucidated in detail elsewhere (Bunge 1967, 1979a, 1979b, 1996, 1997, 1998, 1999).

SYSTEM AND SYSTEMISM

The Baron d'Holbach, one of the major Encyclopedists, became famous overnight with his 1770 book *Système de la nature*. Three years later, he started his influential work *Système social* ([1773] 1969) with this sentence: "*Tout est lié dans le monde moral [social] comme dans le monde physique*." Both books were banned as subversive by the government, but they circulated widely. (Incidentally, this was a case of conflict between two mechanisms, one of social control and the other of cultural expansion.) Besides, Holbach's systemic materialism (or materialist systemics) prospered in the natural sciences, all of which study material systems, whether tangible like nervous systems or intangible like molecules.

Some social scientists have realized that what they study are social systems. Thus the greatest economist of the twentieth century: "I am chiefly concerned with the behaviour of the economic system, as a whole" (Keynes [1936] 1973: xxxii). Likewise Wassily Leontief, whose input-output matrices concern national economies. And Braudel's most famous book ([1966] 1972) concerns no less than the whole Mediterranean basin.

On the other hand, systemic materialism did not prosper in the humanities. Along with scientism, another candle of the Enlightenment, it was snuffed out by the philosophy professors in the next century and remained in the hands of amateurs. What prevailed in academia were Hegel's idealist holism and the idealist individualism of the neo-Kantians such as Dilthey and Rickert (Weber's philosophical mentor). The Counter-Enlightenment has triumphed to such an extent that the ideas of the Encyclopedists are hardly taught in our universities. Thus, in his monumental *Sociology of Philosophies*, Randall Collins (1998) devotes to them a single page but gives very many to their enemies, from Hegel and Herder to Husserl and Heidegger.

True, a few anthropologists and sociologists, in particular Radcliffe-Brown, Parsons, and Luhmann, have written extensively about social systems. Others, like Giddens, have conflated 'system' with 'structure'—as if a structure could exist independently of the collection of entities that it binds. Still others, particularly some influential systems engineers, have called 'system' any black box with inputs and outputs, or even just a list of variables, with disregard for stuff, structure, and mechanism (e.g., Ashby 1963).

Because the word 'system' is used somewhat loosely in the social sciences, it will be convenient to adopt a definition of it. I use the following one: *a system is a complex object whose parts or components are held together by bonds of some kind*. These bonds are logical in the case of a conceptual system, such as a theory; and they are material in the case of a concrete system, such as an atom, cell, immune system, family, or hospital. The collection of all such relations among a system's constituents is its structure (or organization, or architecture). This concept of a structure is borrowed from mathematics. A large number of alternative notions, none of them clear, were introduced in the 1950s, when the word 'structure' became suddenly fashionable in the humanities and social studies (see, e.g., Centre International de Synthèse 1957).

Depending on the system's constituents and the bonds among them, a concrete or material system may belong in either of the following levels: physical, chemical, biological, social, and technological. The semiotic systems, such as texts and diagrams, are hybrid, for they are composed of material signs or signals, some of which convey semantic meanings to their potential users. Mechanisms are involved in the communication of such systems. For example, a conversation activates the mechanisms of speech production and comprehension of the speakers. However, there are no mechanisms in the signs considered in themselves, apart from their users.

THE CESM MODEL

The simplest sketch or model of a concrete system σ is the list of its composition, environment, structure, and mechanism, or

$$\mu(\sigma) = <C(\sigma), E(\sigma), S(\sigma), M(\sigma)>.$$

Here, $C(\sigma)$ denotes the set of parts of σ; $E(\sigma)$ the collection of environmental items that act on σ or are acted upon by σ; $S(\sigma)$ the structure, or set of bonds or ties that hold the components of σ together; and $M(\sigma)$ stands for the mechanisms, or characteristic processes of σ.

Note that we distinguish a system σ from its model(s) $\mu(\sigma)$, just as the electrician distinguishes an electric circuit from its diagram(s). (This remark was prompted by some of the papers in Hedström and Swedberg 1998.) Obviously, $M(\sigma)$ is empty for conceptual systems, such as theories, and semiotic systems, such as written texts, tables, and diagrams.

All four components of the model $\mu(\sigma)$ are taken on a given level, such as the person, the household, or the firm in the case of social systems. They are also taken at a given time. In particular, $M(\sigma)$ is a snapshot of those processes in the system in question that are peculiar to its kind, such as research in a scientific team, and combat in a military unit. In turn, a process is a sequence of states; if preferred, it is a string of events. And whereas the net effect of some processes is to alter the overall state of the system, that of others is to maintain such state. For instance, wind moves a sailboat, whereas the impacts of myriad water molecules on the hulk keep it afloat. And what keeps a business firm above the water is the sale of its products at prices above their cost.

The most familiar example of a social system is the traditional nuclear family. Its components are the parents and children; the relevant environment is the immediate physical environment, the neighborhood, and the workplace; the structure is made up of such biological and psychological bonds as love, sharing, and relations with others; and the mechanism consists essentially of domestic chores, marital encounters of various kinds, and child rearing. If any of the mechanisms breaks down, so does the system.

The neoclassical economists, obsessed like shopkeepers by price competition, failed to grasp the central mechanism of the capitalist economy, namely, innovation. By contrast, Schumpeter (1950: 83) exhibited this mechanism in a single magisterial page: He saw that what "sets and keeps the capitalist engine in motion" is nearly incessant "creative destruction." This is the introduction of qualitatively new consumer goods, new methods of production and transportation, new types of organization, and so on—and the concomitant destruction of their precursors. This is what he called an "organic process," that is, one that affects the entire economic system. It also has political and cultural repercussions, as when business captures political parties, and when the great literary, musical, and plastic arts classics are displaced by mass-produced pseudo-artistic merchandise.

Nor is creative destruction limited to material goods: it can also affect dreams and myths. One example is the so-called New Economy of the mid-1990s, centered in the illusion that e-commerce would soon replace snail-commerce. Another, related illusion, is the Nasdaq bubble, favored by the artificially low discount rate decreed by the U.S. Federal Reserve Bank—that alleged bulwark of free enterprise—that also helped form huge and vulnerable industrial conglomerates, some of which existed only on paper. Both bubbles were punctured at the dawn of the new millennium. They might not have been formed if a materialist ontology had prevailed—that is, if it had been realized that paper bulls do not charge.

Another topical subject is terrorism. Regrettably, knowledge of organized violence is poor, and as a result its prevention is equally poor. In particular, the most popular view of grassroots political terrorism is that it is incited by some perverse or demented individuals. While some terrorist leaders do meet this description, it does not explain either the devotion and abnegation of numerous terrorist foot soldiers or the persistence of their causes. In any event, a successful "war" (or rather mobilization) against terrorism from below must start by understanding it as "the poor man's war."

The first thing to understand about terrorism is that it comes in two main kinds: state-instigated and group-sponsored—and that the former is by far the more lethal of the two. Yet state terrorism is also the easier to explain, because it has a single source, namely the ruling elite; and a single goal, namely the suppression of dissent. By contrast, group-sponsored terrorism usually attracts people from different walks of life and is a mechanism of the weak for redressing at once grievances of various kinds: economic (natural resources or jobs), political (social order), and cultural (in particular religious). Any antiterrorist campaign that does nothing to meet genuine grievances is bound to succeed at best in the short term and at the cost of civil liberties. In general, systemic issues call for systemic and long-term solutions, not sectoral and near-sighted measures. This is the practical message of systemism—of which more anon.

SYSTEMISM

The twin concepts of system and mechanism are so central in modern science, whether natural, social, or biosocial, that their use has spawned a whole ontology, which I have called *systemism*. According to this view, *everything in the universe is, was, or will be a system or a component of one*. For instance, the electron that has just been knocked off an atom on the tip of my nose is about to be captured by a molecule in the air. Likewise, the prisoner who just escaped from the county jail is about to be either recaptured or absorbed by a family or a gang. There are no permanent strays or isolates.

Systemism is the alternative to both individualism and holism (Bunge 1979a, 1979b; Sztompka 1979). Presumably, it is the alternative that the historical sociologist Norbert Elias ([1939] 2000) was looking for in the late 1930s, when he felt dissatisfied with the conceptions of the person as the self-contained *homo clausus*, and of society as a black box beyond individuals.

Arguably, systemism is the approach adopted by anyone who endeavors to explain the formation, maintenance, repair, or dismantling of a concrete complex thing of any kind. Notice that I use the expression 'systemic approach,' not 'systems theory.' There are two reasons for this. One is that there are nearly as many systems theories as systems theorists. The other is that the 'systems theory' that became popular in the 1970s (e.g., Laszlo 1972) was another name for old holism and got discredited because it stressed stasis at the expense of change and claimed to solve all particular problems without empirical research or serious theorizing.

Systemism is just as comprehensive as holism, but unlike the latter, it invites us to analyze wholes into their constituents, and consequently it rejects the intuitionist epistemology inherent in holism. For example, whereas holistic medicine claims to treat patients as wholes, without regard for the specificity of their subsystems, scientific medicine treats patients as supersystems composed of several interdependent systems, every one of which calls for a specific treatment; likewise, whereas revolutionaries advocate total and instant changes of society as a whole, systemic social reformers favor gradual reforms of all the subsystems of society one at a time.

The systemic approach advocated here is not a theory to replace other theories. It is, instead, a viewpoint or strategy for designing research projects whose aim is to discover some of the features of systems of a particular kind. Although this approach is routinely used in science and technology, it is part of philosophy, and the latter is not equipped to tackle empirical problems. Philosophy can facilitate or block scientific research, but it cannot replace it.

MECHANISM

As stated at the start, mechanisms are processes in concrete (material) systems, whether physical, social, technical, or of some other kind. Biochemical pathways, electrical and chemical signals along neural networks, sexual competition, division of labor, publicity, polls, and military expeditions are mechanisms. By contrast, the conceptual and semiotic systems have compositions, environments, and structures but no mechanisms. The reason is that changeability (or energy) is the defining property of matter—whether physical, chemical, living, social, or technical. To coin a suggestive if paradoxical formula: to be (material or real) is to become (Bunge 2000.)

Modern natural scientists cannot dispense with the concepts of system and mechanism, although the corresponding words occur only occasionally in subject indexes. Even when they study elementary particles, those researchers inquire into the systems and mechanisms in which these entities become involved. The following examples should suggest that the same holds for the social sciences.

Our first example is Kondratieff's "long waves" of economic activity that still puzzle economic historians, from Schumpeter, Kuznets, and Braudel onwards. However, the very existence of such decades-long cycles has been questioned for three-quarters of a century because it is not clear what their underlying mechanism might be. Still, one plausible mechanism hypothesis is this: Obsolescence of the dominant techno-economic system → New techno-economic system & Social changes → Market saturation → Drop in prices (Berry, Kim, and Kim 1993).

An example from politology is this. The flaws of American democracy, such as the high cost of political office, are turning American youngsters away from politics. In turn, this voluntary disempowerment is one of the imperfections of that democracy, and it erodes even further political participation, which is the main democratic mechanism. (Concurrent mechanisms are the application of the rule of law, education, and the free formation and circulation of true information.) This is a case of feedforward (self-amplifying) control. And it explains why political apathy leads to bad government. Indeed, when the competent and honest citizens tend to stay away from politics, the incompetent and dishonest take over—which may be called Gresham's Law of Political Apathy.

Finally, an example from culturology: the cultural poverty of contemporary Islam, with its nearly total absence of original science, technology, and art, is in stark contrast to the brilliance of its culture in the Middle Ages. This fact is an aspect of a multifaceted stationary process. While the Islamic societies—particularly those rich in the Devil's juice—have imported some of the trappings of modern industry, such as cars and cell phones, most of them have kept a traditional social structure. Indeed, they have discouraged or even banned the quest for novelty—economic, political, and cultural—which is precisely the quest that built modern capitalism and keeps it going.

Highly complex systems, such as living cells and schools, have several concurrent mechanisms. That is, they undergo several more or less intertwined processes at the same time and on different levels. For example, a cell does not cease to metabolize during the process of division; a waking brain engages in a number of parallel processes—biochemical, vascular, cognitive, emotional, and motor-controlling; and the people who compose a school metabolize and socialize at the same time that they learn, teach, manage, or plot.

The coexistence of parallel mechanisms is particularly noticeable in biosystems and social systems. Think, for example, of the various mechanisms that operate in a scientific community, such as original research and criticism (the truth-and-falsity-finding mechanisms); peer-review (the social quality-control mechanism); and a combination of cooperation in the search for truth and the detection of falsity, with competition in the allocation of credits, jobs, and resources.

Because a number of mechanisms may operate in parallel in one and the same system, it is convenient to distinguish essential from nonessential mechanisms (see Schönwandt 2002). The former are those peculiar to the systems of a certain kind, whereas the latter may also occur in systems of a different kind. For example, contraction is essential to a muscle but inessential to a cell, and loaning money is essential to a bank but optional to a manufacturer.

We are now ready to propose and refine this definition: *an essential mechanism of a system is its peculiar functioning or activity*. In other words, an essential mechanism is the specific function of a system—that is, the process that only it and its kind can undergo. More precisely, we propose the following stipulations, based on the concept of a specific function defined elsewhere (Bunge 1979b).

Definition 1: If σ denotes a system of kind Σ, then (1) the *totality of processes* (or *functions*) in σ over the period T is $\pi(\sigma)$ = the ordered sequence of states of σ over T; (2) the *essential mechanism* (or *specific function*) of σ over the period T, that is, $M(\sigma) = \pi_s(\sigma) \subseteq \pi(\sigma)$, is the totality of processes that occur exclusively in σ and its conspecifics during T.

Definition 2: A *social mechanism* is a mechanism of a social system or part of it.

Note that the concepts of goal and utility are absent from these definitions. The reason is of course that some mechanisms are ambivalent, and others have unintended negative consequences. For example, free trade may make or undo a nation, depending on its competitiveness, aggressiveness, and political (in particular military) power. However, the concepts of goal and utility do occur in the characterization of the mechanisms that make evolved brains and artifacts tick. In this case, an essential mechanism is a process that brings about the desired changes or else prevents the undesirable ones.

MECHANISM AND FUNCTION

The above conflation of 'mechanism' with 'specific function' is not advisable when one and the same task can be performed by different mechanisms—the cases of functional equivalence. For example, some birds can advance by walking, swimming, or flying; documents can be reproduced by printing presses, mimeographs, or photocopiers; markets can be conquered by force, dumping, free-trade agreements, or even honest competition; and certain goods can be sold in markets, retail stores, department stores, or through the Internet.

Because the functions-mechanisms relation is one-to-many, we should keep the two concepts distinct while relating them. Another reason is that a purely functional account, such as "cars are means of transportation," though accurate, is superficial because it does not tell us anything about the mechanism whereby the function in question is carried out (see Mahner and Bunge 2001).

Some of what holds for our knowledge of cars also holds for that of systems of other kinds, such as towns. For example, it is not enough to know that African Americans tend to self-segregate in cities because they like living among themselves. One must add that they are being actively discriminated against and even encounter hostility if they attempt to move to predominantly White neighborhoods. Schelling (1978, 139) notwithstanding, racial segregation is not voluntary but the result of active racial discrimination. The latter is the invisible mechanism that manifests itself as segregation.

Another reason for keeping the mechanism-function distinction is that, unlike mechanisms, the functions they accomplish are ambivalent. Indeed, as Merton (1968) noted, social functions can be either manifest or latent (unintended); besides, social mechanisms generally have dysfunctions as well as functions. Thus, the manifest function of the peer-review mechanism is quality control; but one of its latent functions, or rather dysfunctions, is to entrench cliques and perpetuate their beliefs. Thus, intellectual quality control may be perverted into the control of thought and power.

A warning is in place: there are no universal mechanisms, hence no panaceas. All mechanisms are stuff-dependent and system-specific. For instance, only live brains, when properly trained and primed, can engage in original research; and only brains in certain abnormal states can hallucinate. Still, mechanisms, like anything else, can be grouped into natural kinds, such as those of fusion and fission, aggregation and dispersion, cooperation and competition, stimulation and inhibition, blocking and facilitating, and so on. The formal analogies among mechanisms involving substrates or stuffs of different kinds facilitates the task of mathematical modeling, since one and the same equation, or system of equations, may be used to describe mechanisms involving matter of different kinds.

For example, one and the same system of equations may describe cooperation and competition among organisms, in particular people, or among chemicals (see, e.g., Bunge 1976). Likewise, mechanisms of the so-called ying-yang kind—made up of couples of entities with opposing functions, such as stimulation and inhibition, or oxidation and reduction—are "instantiated" by molecules, neurons, social systems, and more. However, functional and structural similarities can go only so far. No stuff, no reality.

CAUSAL AND STOCHASTIC MECHANISMS

A causal mechanism is of course one "ruled" by causal laws, such as those of classical electrodynamics or classical ecology. An example of such mechanism is the electromagnetic induction that drives electric motors in accordance with Maxwell's equations. Another is the oscillation of the populations of organisms of competing species according to the Lotka-Volterra equations. A third is the cooperation between two persons, or two social systems, according to definite (though not necessarily explicit) contracts and norms, such as that of reciprocal altruism. A fourth example is a negative feedback mechanism such as Watt's regulator of steam pressure. However, all such causal processes are affected by some random noise, as illustrated by the fluctuations in electronic circuits and the accidental errors in precision measurements.

We have a tendency to think of all processes, hence all mechanisms, as causal (or deterministic in the narrow sense). But in fact, many a causal mechanism emerges from random processes on a lower level. Thus, a chemical reaction is usually conceived of as a causal process, or mechanism for the emergence of a product from one or more reagents. However, quantum chemistry shows that this is only an aggregate effect: The individual or microchemical reaction is a process with an important random component. Indeed, a reaction of the type "$A + B \rightarrow C$" is to be analyzed as the scattering of *A*s by *B*s, with a certain probability that *C*s will emerge. Roughly, the expected number of molecules of kind *C* resulting from *n* collisions of *A*s with *B*s, each with probability *p*, is *np*. Caution: this is not a process of the pure bottom-up type, because the value of the probability depends critically upon such macrophysical variables as temperature and pressure—which in turn are emergent macroproperties.

There are plenty more stochastic (or random) processes, such as scrambling, random walk, random self-assembly, random extraction of balls from opaque urns, atomic collision, genic mutation, and blind choice. However, arguably all these random processes have a causal component, and some of them result from causal processes on a different level. For example, shaking, stirring, and shuffling—all of them causal macroprocesses—result in random mixtures on the microlevel. In sum, there are random mechanisms along with causal ones, but it is doubtful that there are any purely random or purely causal processes.

At first sight, there is a third category of mechanism besides causal and random, namely, chaotic. However, most known cases of chaos are particular cases of causation, namely those whose outcome, like that of a roulette game, depends critically upon the initial conditions—small causes, big effects.

MECHANISM AND LAW

How are the concepts of mechanism and law-statement related? Elster (1998: 48) claims that "the antonym of a mechanism is a scientific *law*." Accordingly, explanations by reference to mechanisms would replace explanation by reference to law-statements. This opinion is mistaken: the fact that the pertinent mechanismic laws are unknown in certain cases, likely in most, does not prove that they do not exist. Elster seems to have been misled by the examination of only a few cases of two kinds: (a) known mechanisms with unknown laws and (b) known laws with unknown underlying mechanisms.

Mechanisms without conceivable laws are called *miracles*. For instance, the Aztecs claimed that human sacrifices kept the Sun alive, religious believers hold that prayer heals, and Sir John Eccles once speculated that the mind moves neurons through psychokinesis. Surely, these hypotheses are mechanismic, but they are also unscientific because they are inconsistent with the relevant laws, none of which refers to immaterial entities or processes.

I submit that scientific research presupposes (a) materialism, or the hypothesis that the real world is material, so that it contains no autonomous (subject-free) ideas; and (b) the principle of lawfulness, according to which all events satisfy some law(s). Trust in the first principle allows scientists to dispense with the ghostly. And trust in the second principle sustains their search for laws and the rejection of miracles (see Bunge 1959).

Elster's opinion, that mechanism is the opposite of scientific law, is further falsified by the following counterexamples. Statistical mechanics explains thermodynamics in assuming that the elementary constituents of a thermodynamic system "obey" the laws of classical mechanics; wave optics explains ray optics, in proving that light rays emerge from the interference of light waves; the atomic collision mechanism underlies Fourier's diffusion law; molecular biology explains Mendelian genetics, in proving that the heredity material consists of DNA molecules, some of which "code for" proteins, and thus ultimately control such biomechanisms as metabolism, cell growth, and cell division; and the last two mechanisms are "governed" by the ubiquitous logistic curve.

(Caution: molecular biology is still at a premechanismic stage since it does not explain the processes of "transcription" [DNA → RNA] and "translation" [RNA → proteins] in terms of intermolecular forces: so far, it just describes them. Much the same holds for preneuroscientific psychology: it is functional and descriptive, hardly mechanismic and explanatory.)

What is true is that, in the social sciences, law and mechanism are necessary but insufficient to explain, because almost everything social is made rather than found. Indeed, social facts are not only law-abiding but also norm-abiding; and social norms, though consistent with the laws of nature, are not reducible to these, if only because norms are invented in the light of valuations—besides which every norm is tempered by a counternorm (Merton 1976).

Elster's confrontation of law and mechanism may have originated in the popular confusion between laws and their mathematical representations. A law-statement is not a pure mathematical object, such as a function or an equation, because it is interpreted in factual terms. The same functions and equations occur and recur in a number of research fields, though every time with a different meaning. For example, the formula "$x.y$ = const" holds for ideal gases as well as for ideal markets; and the logistic curve describes the propagation of ideas as well as of sicknesses. But of course the variables involved are assigned different interpretations. And the underlying mechanisms too are different. Same syntax but different semantics because of different ontologies. More on this in the next section.

In sum, mechanism and law can be uncoupled only in thought. And explanation by reference to mechanism deepens subsumption instead of replacing it. The difference between the two kinds of explanation—subsumptive or shallow, and mechanismic or deep—as well as their commonality, emerges clearly upon analyzing them logically. Let us do this in two simple cases.

ANALYSIS OF THE MECHANISM-LAW CONNECTION

Consider the well-known law-statement, "Taking 'Ectasy' causes euphoria," which makes no reference to any mechanisms. This statement can be analyzed as the conjunction of the following two well-corroborated mechanismic hypotheses: "Taking 'Ectasy' causes serotonin excess," and "Serotonin excess causes euphoria." These two together explain the initial statement. (Why serotonin causes euphoria is of course a separate question that cries for a different mechanism.) Incidentally, the preceding example disproves Revonsuo's (2001) assertion that explanation via mechanism is not available outside physics, in particular in cognitive neuroscience.

An example from sociology and management science could be this: "The inertia [resistance to change] of a social system is proportional to its size." This explains why even friendly takeovers, which require quick adaptations, are hazardous to corporations. In turn, the relevance of size to inertia is explained by the need of face-to-face (or at least screen-to-screen) contacts to maintain the cohesion of the system and thus ensure its behaving as a unit. Schematically, we have split the initial statement "$\uparrow$Size $\Rightarrow$ $\uparrow$Inertia" into "$\uparrow$Size $\Rightarrow$ $\downarrow$Contacts" and "$\downarrow$Contacts $\Rightarrow$ $\uparrow$Inertia."

(The previous argument is clarified when expressed with the help of the standard symbolism of elementary logic. We started with a law statement of the form $\forall x(Ax \Rightarrow Bx)$ and analyzed it as the conjunction of hypotheses of the forms $\forall x(Ax \Rightarrow Mx)$ and $\forall x(Mx \Rightarrow Bx)$, where M

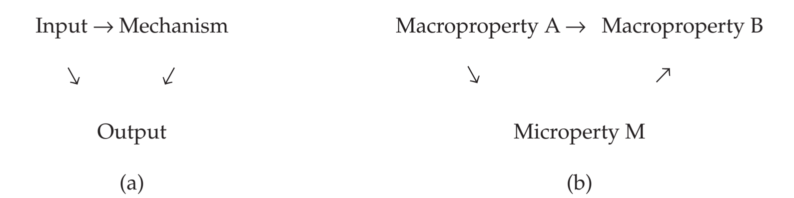

Figure 1: (a) An Input-Output Relation Mediated by a Mechanism. (b) Two Macroproperties Bridged by a Microproperty.

refers to a key feature of some mechanism. These formulas show clearly that a reference to mechanism is included in some law statements.)

All real mechanisms are lawful, but the laws-mechanisms relation is one-to-many rather than one-to-one. For example, pollen particles, drunkards, and financial markets move similarly (random walk); the exponential function, another ubiquitous pattern, describes both the growth of a population with unlimited resources and that of scientific papers; and the normal (or bell-shaped) probability distribution too occurs in all the branches of science, from statistical physics to psychology.

There are two main reasons for the laxity of the laws-mechanisms coupling. One is that any given input-output relation (or black-box) can in principle be mediated by different mechanisms (or translucid-boxes) (see Figure 1a). The second reason is that the macrolevel laws relate global features, such as growth or decline, concentration or dispersion, that are compatible with alternative microprocesses (see Figure 1b). Incidentally, the latter is what I have called a Boudon-Coleman diagram relating the macrolevel to the underlying microlevel.

Because the patterns-mechanisms relation is one-to-many, the search for either can be uncoupled from the search for the other. However, barring miracles, there are no lawless mechanisms any more than there are mechanism-less patterns. Hence, any mechanism-free account must be taken to be shallow and therefore a challenge to uncover unknown mechanism(s). By the same token, any mechanism unsupported by some law(s) must be regarded as ad hoc and therefore equally temporary.

In sum, satisfactory (and psychologically satisfying) explanations of both kinds, if scientific, resort to law statements. So, mechanismic hypotheses do not constitute an alternative to scientific laws but are components of deep scientific laws. In other words, 'mechanism' (or 'translucent-box') opposes 'phenomenological' (or 'black box'), not 'lawfulness' (see Bunge 1964, 1967, 1968).

GUESSING MECHANISMS

How do we go about conjecturing mechanisms? The same way as in framing any other hypotheses: with imagination both stimulated and constrained by data, well-weathered hypotheses, and mathematical concepts such as those of number, function, and equation. Let us consider a few examples.

Altruism and cooperation among humans are about as frequent as selfishness and competition. Why is this so; that is, what mechanism drives either behavior? Most sociobiologists claim that altruism and cooperation are confined to relatives, due to the animal's unconscious desire to protect and spread its genes: this is the kin-selection hypothesis (see, e.g., Sober and Wilson 1998). But this conjecture runs counter to the empirical evidence that there is often cooperation among nonrelatives, as well as rivalry, sometimes even violence, among kin (see, e.g., West, Pen, and Griffin 2002). Moreover, transgenic relationships can be more loving than same-species ones. Thus, President George W. Bush declared once that his dog is the son he never had.

An alternative hypothesis is that we do good partly because it feels good to do good even if we do not expect to be repaid. In fact, recent brain-imaging studies (Rilling et al. 2002) on people playing prisoner's dilemma games have shown that we feel good when behaving cooperatively toward strangers. Indeed, the neuronal systems in charge of reward (pleasure) "light up" in the process. An alternative is that humans and other animals tend automatically to cooperate with one another because they need help and expect reciprocity. These two hypotheses are of course mutually compatible. Thus, presumably cooperation involves at least two intertwining mechanisms on so many different levels, cellular and social.

There is no method, let alone a logic, for conjecturing mechanisms. True, Peirce wrote about the "method of abduction," but 'abduction' is synonymous with 'conjecturing', and this—as Peirce himself warned—is an art, not a technique. One reason is that, typically, mechanisms are unobservable, and therefore their description is bound to contain concepts that do not occur in empirical data. (This

(a) Input → Mechanism → Output ?,

(b) ? Input → Mechanism → Output,

(c) Input → ? Mechanism → Output.

Figure 2: Direct or Forward Problem (a) and Inverse or Backward Problems (b) and (c)
NOTE: The question mark points to the unknown. In principle, given a theory, solving (a) and (b) are matters of computation; by contrast, (c) calls for a theory that may not yet be available and is therefore the hardest.

is why mathematical modeling is so often used to identify mechanisms.) Even the mechanism that makes the pendulum clock tick involves unobservables, namely inertia (mass) and the gravitational field; likewise, the vision, managerial skill, reputation, and useful connections of an entrepreneur are unobservable.

Social systems are epistemologically similar. For example, factories are invisible: what one can perceive is some of their components—workers, buildings, machines, reservoirs, and so on—but not the way they work synergically, which is what keeps them together and going. Even the operations of a corner store are only partly overt. For instance, the grocer does not know, and does not ordinarily care to find out, why a customer buys breakfast cereal of one kind rather than another. However, if he cares he can make inquiries or guesses—for instance, that children are likely to be sold on packaging. That is, the grocer may make up what is called a "theory of mind," a hypothesis concerning the mental processes that end up at the cash register. If the grocer were a neobehaviorist, he might reason thus: Sight of package → Appetite → Purchase.

Observable inputs and outputs, such as publicity and consumer behavior, explain nothing. They only pose the problem of conjecturing the mechanism(s) likely to transduce inputs into outputs. Notice that this is a typically inverse problem, of the Behavior → Intention type. Once a solution has been found, it allows one to attack the direct problem: Input → Mechanism → Output (see Figure 2).

When powerful and reasonably true mechanismic theories are available, as in physics, most problems are direct or can be transformed into such. But this is not the usual case in social studies. Here one has to start nearly from scratch when tackling a new problem: no general equations of social motion are known that can help predict what an individual or a social system will do when acted upon by certain stimuli or figure out the stimuli and the internal processes that caused the observed reaction.

EXPLANATION

The standard account of explanation in the philosophy of science, from Mill to Popper, Hempel, Braithwaite, and Nagel, is the so-called covering-law model. According to it, to explain a particular is to subsume it under a generalization according to the schema: Law & Circumstance ⇒ Fact to be explained. For instance, one may say that Aristotle died because he was human and all humans are mortal; or that the price of soap went up because all merchandises became more expensive at that time, and soap is a merchandise. All this is true, but it does not elicit understanding and consequently does not qualify as explanation proper.

The covering-law model fails to capture the concept of explanation used in the sciences, because it does not involve the notion of a mechanism. For instance, one explains the drying of wet clothes exposed to sunlight by the absorption of light, which increases the kinetic energy of the water molecules in the wet cloth to the point that they overcome the adhesive forces. Senescence and death are explained by wear and tear, apoptosis ("programmed" cell death), and other mechanisms operating concurrently. Learning is explained by the formation of new neuronal systems that emerge when they fire jointly in response to certain (external or internal) stimuli. Unemployment of a certain kind is partly accounted for by the spread of labor-saving devices, which in turn is driven by the search for decreasing waste and increasing profits. Alejandro Portes explained the growth of the informal ("black") economy as a perverse effect of labor legislation designed to protect workers: "black" labor is cheaper, and therefore more in demand, than law-abiding labor. Mark Granovetter famously explained getting jobs by "the strength of weak ties," that is, information about openings supplied by acquaintances of friends. Wars are explained either by the desire of governments to retain or expand territories, natural resources, or markets or to win the next election by making the innocent rally around their Great Leaders at a time of a National Emergency—namely, the emergency engineered by the very same patriots.

In all such cases, *to explain is to exhibit or assume a (lawful) mechanism*. This is the process—whether causal, random, or mixed—that makes the system work the way it does. Of course, a mechanism need not be mechanical. There are thermonuclear, thermo-mechanical, electromagnetic, chemical, biological (in particular neurophysiological), ecological, social, and many other mechanisms as well. This kind of explanation is usually called *mechanistic*. I prefer to call it *mechanismic*, because most mechanisms are nonmechanical.

In the social sciences there is often talk of *functional* explanation rather than mechanismic explanation. And a functional explanation of a social item is one by reference to the role(s) that the item plays in preserving a social system. For instance, the specific function (activity) of the law-and-order forces is to maintain the social order. However, this is only a special case of mechanismic explanation. Indeed, in this case the activity (mechanism) and the system in which it occurs are social, and the status quo to be preserved is a particular state of the society in question.

DEMOGRAPHIC AND COHESIVE MECHANISMS

Let us consider briefly two comparatively simple cases: demographic change and social cohesion. To a first approximation, the changes in the numerosity $N(t)$ of a human group are represented by the rate equation $dN/dt = kN$. The solution to this equation is the exponential function $N(t) = N_0 \exp(kt)$, where N_0 is the initial value of N and k the rate of growth. If $k > 0$, the population grows exponentially; if $k = 0$, it remains stagnant; and if $k < 0$, it declines exponentially. So far, we have only a description—like with all rate equations.

However, the previous description is easily transformed into an explanation if the rate of growth k is analyzed thus:

$$k = \text{birth rate} - \text{death rate} + \text{immigration rate} - \text{emigration rate}.$$

This may be regarded as the overall demographic mechanism of a social system σ That is, we may set $M_{dem}(\sigma) = k$.

(Incidentally, the sociobiologists are so obsessed with reproduction that they underrate the three remaining demographic mechanisms. And yet evolution involves not only reproductive success—a large birth rate—but also physiological fitness and environmental adaptation—which show up jointly as a low death rate—in addition to migration.)

Our second example is one of the oldest problems in social studies, namely: what holds society together in spite of the different and often conflicting interests of its individual components? There have been many answers to this question, and some of them, though different, are mutually compatible. For instance, according to some, the cement of society is reciprocal altruism (quid pro quo); other scholars claim that the clue to social cohesion is exchange; still others hold that similarity breeds cooperation: that people with similar traditions, values, interests, and customs are bound to stick together; game-theorists will design prisoner's dilemma models where people learn to cooperate—or, on the contrary, to defect; finally, Hobbesians only believe in coercion. Every one of these views has something to commend it, but none of them seems fully satisfying.

We might learn something more by asking the dual question, namely: what are the roots of social disunity and marginality? The most obvious answers are gender, racial, class, and ideological discrimination. But these are motives or causes. How do they work; that is, what are the mechanisms that transform them into the observed segregations? It would seem that the mechanism common to all of them is exclusion or nonparticipation. For instance, women are excluded from most top management positions and clubs; blacks, Catholics and Jews from WASP clubs; the poor from leafy streets and good schools; agnostics and labor organizers from high political office, and so on.

If we now turn to the original question, we realize that the key mechanism of social cohesion is participation—of citizens in campaigns and polls, of women in jobs, of workers in the way their workplace is run, and so on. The notion of participation can easily be quantitated. Indeed, the degree or intensity of the participation of *A*s in a society (e.g., of adults in the labor market, of women in academia, or of youngsters in politics) may be set equal to the sum of the percentages of *A*s in the various relevant activities in the society in question. Thus a numerical index π of social cohesion (and its dual $\mu = 1 - \pi$ of social marginality) can be set up (García-Sucre and Bunge 1976). Since cohesion is sufficient for stability, we may set $M(\sigma) = \pi$. Note that far from being empirical, like most other social indicators, π is based upon definite *theoretical* assumptions about social structure and social cohesion.

The point of these exercises was to emphasize the difference between mere description and the concomitant view of explanation as subsumption, on one hand, and mechanismic explanation, on the other.

REALISM VERSUS PHENOMENALISM

Scientists have always known that to explain the behavior of a system is to exhibit or conjecture the way it works, that is, its mechanism(s). Thus, Archimedes explained floating bodies by buoyancy; William Harvey accounted for the circulation of the blood by conceiving of the heart as a pump; Descartes explained the rainbow in terms of the refraction of sunlight by the water droplets suspended in the air after a rainfall; Newton explained orbits in terms of inertia and forces; Berzelius explained some chemical reactions in terms of electrostatic forces; Tocqueville explained the fall of the ancien régime as a delayed result of the aristocrats' neglect of their properties and counties, which in turn followed upon their concentration in Paris and Versailles under pressure from Louis XIV; Darwin explained bioevolution by descent with modification cum natural selection; Marx and Engels explained history by both economic change and class struggle; Einstein explained Brownian motion as the effect of random molecular impacts; Bohr accounted for light emission by the decay of atoms from excited to lower energy levels; Hebb explained learning as the formation of new neuron assemblies—and so on.

We do not understand adequately the things whose mechanisms are still unknown. For instance, nothing but illusory understanding is gained by stating that the mind, or the brain, has *computed* this movement or that emotion. The computer metaphor is seriously mistaken, for (a) the most interesting mental processes, such as invention and problem-finding, are spontaneous rather than rule-directed; and (b) algorithms are artificial rules for performing computations on symbols, not natural and lawful processes (Bunge and Ardila 1987; Kary and Mahner 2002). This is why computers imitate some (not all) of the global features of some (not all) cognitive processes, and not the other way round. One can only imitate, never replicate, *in silico* some of what goes on *in vivo*.

A consequence of the computationalist fad is that some psychologists prefer computer simulations to brain research intent on finding neural mechanisms. And a consequence for psychiatry of such neglect of the minding organ is that schizophrenia, depression, and other disabling mental disorders are not yet being well treated because their mechanisms have not yet been fully unveiled. It is not enough to know that mental diseases are correlated with the imbalance of certain neurotransmitters. Indeed, to know how such molecular facts translate into mental experiences, such as sadness and delusion, we must find out the effect of the excess or lack of dopamine, serotonin, and so on, on neurons and neuronal systems: we must climb up and down the whole levels staircase, from molecule to cell to organ to central nervous system. No knowledge of mechanism, neither understanding nor control.

The phenomenalist and empiricist rule, "Describe only phenomena (appearances)," has had two functions. It served Hume and Kant to buttress their religious skepticism: if the world is just "a sum of phenomena" (Kant), and God is not one of them, He cannot exist except as an idea. But the same phenomenalist maxim led others—such as Ptolemy, Comte, Mill, Mach, Duhem, Kirchhoff, Ostwald, the behaviorists, the Vienna Circle, and the computationalist psychologists—to reject the search for mechanisms, such as atomic collisions, the formation of neuron assemblies, and competition.

Ironically, the builders of modern atomic physics paid lip service to this same positivist (phenomenalist and descriptivist) dogma. Thus, in his epoch-making paper of 1925, Heisenberg stated that one should use only observable variables; but at the same time he introduced position and momentum operators without classical and therefore measurable counterparts. In time, he realized this inconsistency and complained about his young colleagues who only wished to describe and predict facts. In 1969 he told me: "I am of a Newtonian cast of mind. I wish to understand facts. Therefore, I appreciate the theories that explain the working of things, more than any phenomenological theories" (Bunge 1971).

CONCLUDING REMARKS

The days of phenomenalism and descriptivism are over in science. In 1921, Emile Meyerson had to argue laboriously and at great length for this thesis. Now it has become quite obvious, since atomic, nuclear and molecular physics have finally triumphed; and so have field physics, molecular biology, cell biology, embryology, and more recently, cognitive, affective, and social neuroscience as well. The workers in all of these sciences endeavor to find out how systems work, that is, what their mechanisms are. Much the same holds for all productive social scientists, even if few of them use the terminology of this article: indeed, they try to show some of the ways society works, in particular what Mills (1959: 152) called the "mechanics of history-making." When they do not, when they restrict themselves to providing "thick descriptions" of observable phenomena, such as daily interpersonal encounters, they deny themselves the pleasure of understanding what they see or hear. The reason is that most of reality is unobservable—as the Greek and Indian atomists argued two and half millennia ago. The popular expression "they saw only the tip of the iceberg" has got it right.

Scientific anthropologists try to discover how primitive societies and other human groups manage; sociologists, how modern societies and their subsystems work; economists and socioeconomists, how the modern economic system operates; politologists and political sociologists, how the political system works; culturologists, what stimulates or inhibits the cultural system; and historians and archaeologists, how and why social systems have changed over time. This quest for understanding through hypothesizing mechanisms is what drove Thucydides, Aristotle, Ibn Khaldûn, Machiavelli, Hobbes, Locke, Holbach, Tocqueville, Marx, Durkheim, Simmel, Schumpeter, Keynes, Braudel, Merton, Coleman, Dahl, and Trigger, among others. The only recent novelty is that finally there is now more explicit talk of social mechanisms (see, e.g., Hedström and Swedberg 1998; Pickel 2001; Tilly 2001).

By contrast to scientists, the superstitious do not look for mechanisms. For example, some parapsychologists believe in the possibility of moving things by sheer willpower (psychokinesis). If they were to inquire into the way psychokinesis works, or rather fails to work, they would realize that it is impossible, if only because it involves creation of energy. A similar reasoning is used in evaluating inventions: no patent is ever granted unless the inventor explains how the novel device works. This is why the most effective way for the officer of a patent office to deny a patent for an allegedly revolutionary design is to point out that the proposed mechanism is incompatible with the known laws of nature, usually the conservation principles.

No law, no possible mechanism; and no mechanism, no explanation. No wonder then that the hallmark of modern science is the search for lawful mechanisms behind the observed facts, rather than the mindless accumulation of data and the mindless search for statistical correlations among them.

A few philosophers have realized the importance of mechanisms, and thus the superiority of translucent-box theories, and the corresponding mechanismic explanations, over black-box (phenomenological) theories and the concomitant subsumptions (e.g., Bunge 1964, 1967, 1968, 1983, 1997; Kitcher and Salmon 1989; Athearn 1994; Machamer, Darden, and Craver 2000). Who said there is no progress in philosophy? It may be slow because of the operation of conservative mechanisms—such as neophobia, willful ignorance, obscurity worship, the weight of authority, ideological censorship, and a peer-review process dominated by philosophical conservatives. Nevertheless, philosophical advances do occur once in a while due to the operation of countervailing mechanisms, such as grappling with new problems posed by society, science, or technology, institutionalized skepticism, and above all, the search for understanding—that is, for lawful mechanism.

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