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Mεtascience

Scientific General Discourse

No 2–2022 Edited by François Maurice

Metascientific Ontology

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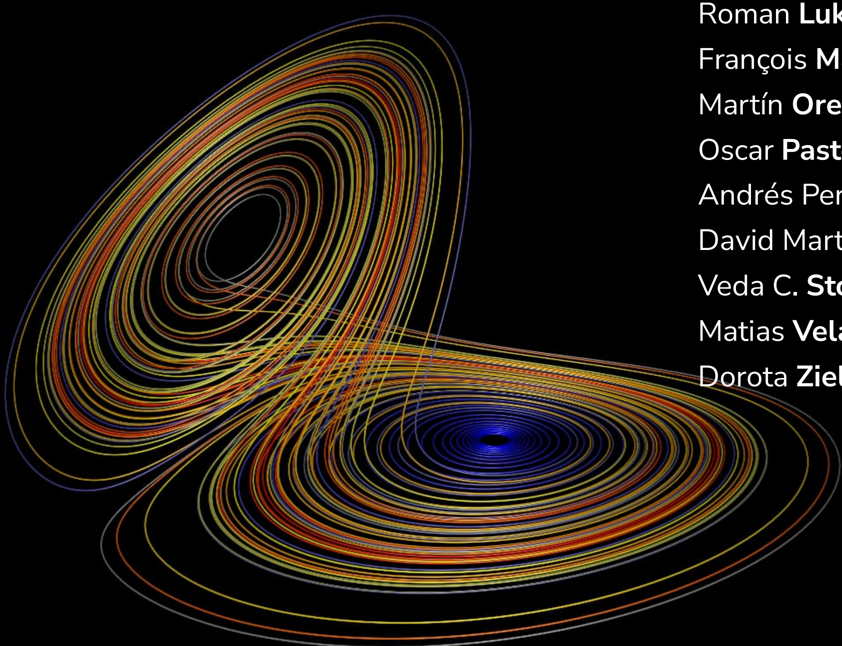

Society for the Progress of Metascience

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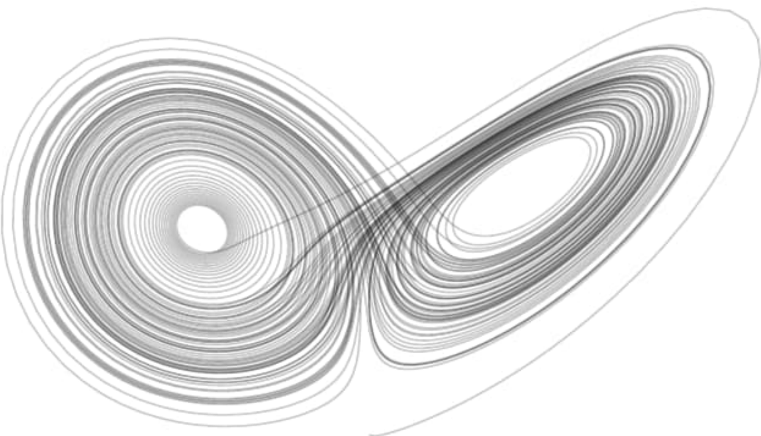

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The French edition of this second issue has one more article by Jean Robillard.

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Metascientific Ontology

François Maurice

Science and Ontology

Debates about the links between science and ontology are very active in contemporary philosophy, and, in fact, they have always were present[1]. We can distinguish five main positions: 1) this is a false debate because there is no connection between science and ontology and therefore one does not influence the other; 2) ontology determines science; 3) ontology and science influence each other; 4) science determines ontology; 5) this is a false debate because that there is no ontological or metaphysical reality.

The first position is not interesting for all those who want to account for the success of science, especially since ontology or metaphysics is supposed to provide the foundations of reality by revealing “items”, “entities” or “structures” that are not quite physical or material, in order to account precisely for this material world. But if we maintain the position that the two fields, the two magisterium, although real, have no connection, then ontological research and scientific research cannot influence each other. This is still a widespread position since many philosophers produce ontologies or metaphysics without worrying about the sciences.

It is positions two, three and four that are being debated. What is the nature of the *metaphysics of science* and how does it relate to science? It is under this name that this movement is known and that tries to find a place for metaphysics or ontology alongside science. Thinkers agree that there are links between ontology and science but disagree on the nature of these links. On the one hand,

[1] As for the expression “metaphysics”, we reserve it to designate the metascience of physics, in the same way that there is metachemistry, metabiology, metapsychology, metasociology, etc. We discuss the reasons for this choice of terminology in our article “Metascience: For a General Scientific Discourse” published in the first issue of *Metasicence* at Éditions Matériologiques in 2020.

there is an a *priori* metaphysics on which science is based (position 2). On the other hand, there is a science that entirely determines responses to metaphysical questions (position 4). And, between these two extremes, all variants are possible (position 3).

It is important to note that many of the thinkers who defend the idea of a complete determination of ontology by science (position 4) claim that they practice a *scientific metaphysics* that would oppose traditional or a *priori* metaphysics. Scientific metaphysics would be distinguished from other metaphysics because it would solve metaphysical problems only with scientific tools and results. This is to say that scientific metaphysics does not deny the existence of a metaphysical reality, but it is through the sciences that we have access to this reality. In any case, from position 1 to position 4, the existence of a metaphysical reality is taken for granted[2].

Mεtascience, for its part, defends the idea that the problem of the existence of a link between science and ontology is a false debate since the existence of a metaphysical reality has never been demonstrated (position 5). In particular, Bungean ontology is not a philosophical discipline, but rather a metascientific discipline. As a metascience, ontology studies scientific constructs and not concrete reality, let alone metaphysical reality. It is this position that we defend in our article “What is Metascientific Ontology?”.

Metascience would be very poor without a metascientific practice. We are fortunate to be able to rely on the work of Mario Bunge, the first accomplished metascientist, but a living discipline is a discipline that discovers and invents. This same work has shown us that metascience is a varied activity that is practiced in various ways. Let’s follow our common thread, the Bungean or metascientific ontology, and briefly examine the articles in this second issue of *Mεtascience*. We pick up on these and several other articles in the next section, but at this point we want to highlight the diversity of metascientific research and the usefulne4ss of metascience. Where philosophy has failed, is metascience possible? This is what we have called the Bunge’s wager (Maurice 2017).

Chemistry is undoubtedly the branch of scientific knowledge that philosophers are least interested in. This lack of interest probably

[2] In order to better situate the metaphysics of science and scientific metaphysics, the reader can consult Cristian Soto’s article, “The Current State of the Metaphysics of Science Debate” (2015).

stems from a preconceived idea that chemistry is just one branch of physics. Matias Velázquez remedies the situation by offering us a metachemistry article in crystal chemistry entitled "On Some Features of the Scientific Hylorealistic Background of Crystal Chemistry". Not only does the author demonstrate the autonomy of chemistry, but he also obtains particular metachemical results and general metascientific results. We are in *hard metascience*!

Theories are good, but theories with applications are better. Mario Bunge's ontology has long been known in information technology. An ontology widely used in information systems, especially for conceptual modeling, is the BWW (Bunge-Wand-Weber) ontology, based on Bunge's ideas and synthesized by Wand and Weber (Wand and Weber 1988; 1990; 1995). In their article "Foundations of Information Technology Based on Bunge's Systemist Philosophy of Reality", Lukyanenko, Storey, and Pastor propose replacing the BWW ontology with a new ontology based on Bunge's more recent work: *Bunge's Systemist Ontology* (BSO). This new adaptation of Bunge's ontology doubles the number of ontological categories made available to researchers in information technology.

Even if we adopt the idea that metascience does not have the same objectives, does not use the same methods, and does not study the same objects as philosophy, that it does not then ask the same questions and that it does not present the problems in the same way, the fact remains that a comparison between the two is inevitable since both are general discourses. Martín Orensanz invites us in his article "Bunge and Harman on the General Theory of Objects" to compare Bunge's theory of objects to that of Harman, then in his article "Causation according to Mario Bunge and Graham Harman" to compare the theory of causality of these two authors. The comparison of metascience to philosophy allows a faster understanding of metascience since we use our philosophical knowledge to set up a network of metascientific notions.

Another form of comparison is undertaken by François Maurice in his article "Bunge's Metascience and the Naturalization of the General Discourse". The scientific metaphysics referred to earlier (position 4) would aim to naturalize traditional metaphysics. But the naturalization of metaphysics can be understood in several ways. The author therefore proposes to compare the naturalization of the general thought in Bunge to the naturalization of metaphysics as conceived by Ross and Ladyman. Superficially, the two projects are similar, notably in their harsh criticism of the philosophical tradition and the ambition to take into account the results of the sciences, but the results are antithetical.

Among all the doctrines that seek to establish links of beneficial influence between philosophy and science (position 3), Pradeu, Lemoine, Khelfaoui and Gingras have discovered a movement in philosophy of science that they call philosophy *in* science. Philosophers of this movement would use philosophical tools to solve scientific problems. In his article "When Philosophy is No Longer Philosophical", François Maurice argues that the tools in question are not strictly philosophical and thus thinkers of this movement would rather practice a metascience.

The general theme of the seven articles mentioned is ontology, but we must not lose sight of the fact that metascientific disciplines, like scientific disciplines, do not operate in a vacuum, that metascientific ontology, semantics and epistemology study the same object, science, and not the concrete world, which is the domain of science, nor a metaphysical world, reserved for philosophy.

Contributions

As with the first issue of *Mεtascience*, the twelve contributions to this issue come from authors from different backgrounds, as it should be for a general thought that is intended to be useful to all fields of knowledge. Like Bunge's project, the following contributions are neither part of the analytical nor the continental movement in philosophy.

It should be noted, however, that the contributors to this issue of *Mεtascience* do not necessarily support the research program of the Society for the Progress of Metasciences, nor the editorial policy of the journal. These are authors who are interested in various aspects of Bunge's thought. Although ontology is a common thread that links some articles in this issue, we distinguish four types of contribution: 1) studies on Bunge's system; 2) metascientific contributions; 3) applications of Bungean thought; 4) around metascience.

1] Studies on Bunge's System

François Maurice, in "**What is Metascientific Ontology?**" continues his work of characterization of metascience undertaken in his article "Metascience: for a General Scientific Discourse" published in the first issue of *Metascience*. Bunge's ontology differs from philosophical ontologies for its purposes, objects, and methods. In particular, this ontology does not postulate the existence of objects other than those postulated and studied by the factual sciences.

Martín Orensanz, in a first article, "**Bunge and Harman on the General Theory of Objects**", compares Mario Bunge's general theory of objects to that of Graham Harman's by identifying the similarities between the two theories, despite the significant differences between the two philosophies. In a second paper, "**Causation according to Mario Bunge and Graham Harman**", Orensanz establishes that Bunge and Harman reject the conception of causality according to which concrete objects come into direct contact with each other. To Bunge, events connect things, while to Harman, they are sensual objects.

François Maurice examines in "**Bunge's Metascience and the Naturalization of the General Discourse**" the structure of the *Treatise on Basic Philosophy* in order to identify the metascience found therein, despite Bunge's attempt to inscribe his thought in the philosophical tradition. Rather, Maurice shows that Bungean thought is part of the long process of naturalization of human thought. Finally, the author shows that this naturalization of general discourse is different from the movement of naturalization known as scientific metaphysics or naturalized metaphysics, despite the superficial affinities between Bunge and these philosophers.

2] Metascientific Contributions

Matias Velázquez, in "**On Some Features of the Scientific Hylorealistic Background of Crystal Chemistry**", offers an ontological and epistemological study in crystal chemistry. Philosophers of chemistry devote much thinking to the periodic table of elements, the nature of the chemical bond, the ontological status of the atom-in-molecule, etc., in writings that mainly address the question of the reduction of chemistry to physics, and secondarily that of determinism. Crystal chemistry, which covers the growth of crystals, their reactivity, and the chemistry of and with crystalline imperfections, is hardly touched upon in this philosophy which, in its current state, looks like the poor relative of philosophy of science.

In this contribution, the author tackles the materialist and realistic question by taking the opposite approach of the philosophers of chemistry, recalling that the most fundamental crystalline imperfection in crystal chemistry, namely the atomic vacancy has no atomic number, electronegativity, chemical bonds, box in the periodic table, that it can be electrically neutral, etc., and that yet its materiality—its *scientific hyloreality* one might say—is unquestionable. Vacancies, rigorously defined in statistical thermodynamics, possess energy, are capable of change, in short, they are as real as they are material. The ontological proof is based on the Bungean mode of reasoning and makes it possible (i) to show that the "ontological atom" in a crystal is a building unit, (ii) to introduce the distinction between a constituent and a component, and (iii) to understand that mass is not the foundation of materiality. Moreover, it is shown that vacancies, like any building unit, are concrete things irreducible to atomic physics and particle physics. Possessing no properties—other than energy—studied specifically in particle physics and atomic physics, for example in a highly covalent semiconductor, they can only be defined a chemical potential (and therefore free energy) provided that the number of crystallographic sites is conserved in all chemical reactions in which they are involved. Crystallographic sites have nothing trivially material but are defined only from a set of spatial relations synthetically expressed in a set of reduced coordinates and a group of site symmetry, and so it is necessary to appeal to the extremely subtle Bunge's ontology of space to fully grasp the metachemical meaning of these construction building units.

David Martín Solano, in "**A Constructive Critique of Mario Bunge's Theory of Truth**", takes note of Bunge's observation of the shortcomings of the truth-correspondence theories proposed to date, including Bunge's theory, while Bunge considers this to be an essential element of any serious theorization of science. Martín therefore proposes a new theory of truth-correspondence as an extension to Bunge's theory, not without first having dispelled the confusion maintained between truth and some other notions, including that of coherence. Martín's proposal will make truth a privative concept.

3] Applications of Bungean Thought

In "**Foundations of Information Technology Based on Bunge's Systemist Philosophy of Reality**", Roman Lukyanenko, Veda C. Storey, and Oscar Pastor expose the BWW (Bunge-Wand-Weber) ontology, widely used in information systems, especially for conceptual modeling, and synthesized by Wand and Weber from Bunge's ideas. Since this ontology was developed from an older version of Bunge's philosophy, the authors present a new version based on Bunge's more recent work. This new ontology, which the authors call *Bunge's Systemist Ontology* (BSO), incorporates a greater number of Bungean concepts and reverses the relationship between the concept of thing (concrete object) and that of system: for BWW a system is a thing, while for BSO a thing is a kind of system. The authors specify that BSO is not just an extension of BWW: "BSO rather offers a new way of thinking about reality." The authors finally put forward suggestions for various ontological studies and identify questions that could feed into a research program in both conceptual modeling and information technology in general.

Dorota Zielińska, in "**Linguistic Research in the Empirical Paradigm as Outlined by Mario Bunge**", presents the limitations of research in clinical linguistics, dominated by an approach that accumulates data without them being theoretically linked. She thus presents a way to conduct linguistic research using the theory of science as exposed by Bunge and limited by Altmann's hypothesis on the self-created and self-regulating nature of language. She establishes a linguistic law concerning the order of adjectives in Polish noun phrases.

4] Around Metascience

Andrés Pereyra Rabanal, in "**Scientism after its Discontents**", after reviewing the various conceptions of scientism, defends a positive conception of scientism against some of its critics. Thus, he argues that science is the most reliable approach to acquiring knowledge without harming other important human activities as long as these do not address factual or cognitive issues or contradict the scientific worldview.

Sven Ove Hansson, in "**With all this Pseudoscience, Why so Little Pseudotechnology?**" questions the fact that pseudotechnologies are more rarely mentioned than pseudosciences. To answer the question, the author first presents a definition of pseudotechnology, once completed a work of analysis and clarification by examining the previous uses of the term pseudotechnology, the nature of technology, the nature of science and pseudoscience and the relationship they maintain, then, finally, he characterizes what a technological malfunction is. In a second step, the author will define what an immediately falsifiable statement is, a notion that he can apply to pseudotechnology. This study shows that pseudotechnologies are more often immediately falsifiable than pseudosciences.

François Maurice examines in "**When Philosophy is No Longer Philosophical**" the idea of the existence of a philosophy *in* science suggest by Thomas Pradeu, Maël Lemoine, Mahdi Khelfaoui and Yves Gingras in their article "Philosophy in Science: Can Philosophers of Science Permeate through Science and Produce Scientific Knowledge?"[3]. A philosophy *in* science would address scientific problems using philosophical tools. We show that thinkers of philosophy *in* science practice rather a metascience.

Joseph Agassi proposes in "**Versions of Determinism**" a reexamination of Karl Popper's article "Indeterminism in Quantum Physics and in Classical Physics". Popper claimed to have refuted any form of scientific determinism. Agassi disputes Popper's assertion by appealing to the conception of science put forward by Popper himself.

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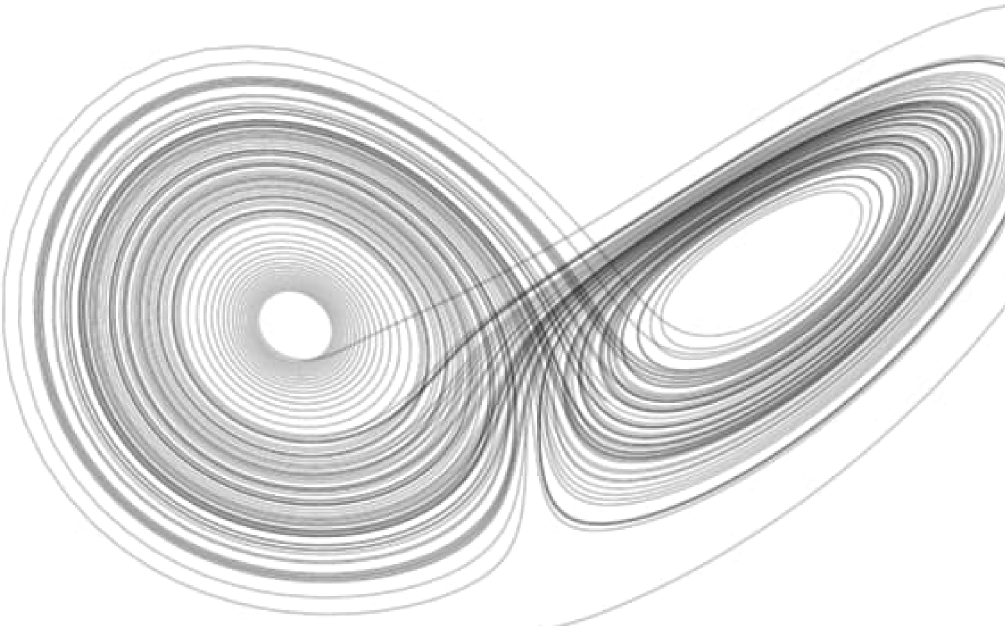
Studies on Bunge's System



What is Metascientific Ontology?

François Maurice[1]

Abstract — Metascientific ontology differs from philosophical ontologies in its objectives, objects and methods. By an examination of the ontological theories of Mario Bunge, we will show their main objective is a unified representation of the world as known through the sciences that their objects of study are scientific constructs, and that their methods do not differ from those that one expects to find in any rational activity. Metascientific ontology is therefore not transcendent because it does not seek to represent objects alien to the world we inhabit and to the sciences that study it, and therefore does not need special faculties and methods to carry out its research.

Résumé — L'ontologie métascientifique se distingue des ontologies philosophiques par ses objectifs, ses objets et ses méthodes. Par un examen des théories ontologiques de Mario Bunge, nous montrerons que leur principal objectif est l'élaboration d'une représentation unifiée du monde tel que connu par les sciences, que leurs objets d'étude sont des construits scientifiques, et que leurs méthodes ne diffèrent pas de celles qu'on s'attend à trouver dans toute activité rationnelle. L'ontologie métascientifique n'est donc pas transcendante parce qu'elle ne cherche pas à représenter des objets étrangers au monde que nous habitons et aux sciences qui l'étudient, et par conséquent elle n'a pas besoin de facultés ni de méthodes spéciales pour mener à bien ses recherches.

We continue our characterization of metascience we have undertaken in our article "Metascience. For a General Scientific Discourse" (Maurice 2020). In order to better understand the nature of metascience, and thus better understand what distinguishes it from philosophy, we will compare metascientific ontology to philosophical ontology. Since we argue in the just-mentioned article that Bunge's philosophical theories are in fact

[1] Graduated in social statistics, mathematics and philosophy, independent researcher, founder of the Society for the Progress of Metasciences and translator in French of the *Philosophical Dictionary* by Mario Bunge published at Éditions Matériologiques under the title *Dictionnaire Philosophique*.

metascientific theories, we will use Bunge's ontology to carry out this comparison.

We will therefore examine the ontological theories as set forth in Bunge's writings, particularly those found in volumes 3 and 4 of the *Treatise on Basic Philosophy*. This paper will make clear the non-philosophical nature of Bunge's theories, notably through his refusal to postulate the existence of entities other than those postulated and studied by the sciences as well as his rejection of philosophical methods.

In several texts, Bunge has endeavored to define or characterize metaphysics or scientific ontology[2]. In general, Bunge considers ontology and metaphysics to be synonymous, just as scientific ontology and scientific metaphysics are synonymous, although Bunge leans towards the use of the second expression before 1977 and the use of the former from 1977. Note that we should not confuse *scientific ontology,* as characterized by Bunge and other philosophers, with *metascientific ontology,* as we will characterize it from the way Bunge practices ontology, and not from what he says about it, although in the end, once we no longer refer to Bunge's conception or those of other philosophers, we consider the two expressions to be synonymous. In fact, if we are in a strictly metascientific framework, we can speak of ontology only. At the end of this study, what interests us is to show that the scientific or metascientific ontology as we conceive it is different from any *philosophical ontology*.

Like the expression scientific ontology, the expression *scientific metaphysics* is used not only by Bunge, but also by some philosophers[3]. For our purpose, let us note that we have redefined metaphysics as the metascience of physics, in the same way that there is metachemistry, metabiology and metapsychonology[4]. For us,

[2] The five main texts in Bunge that deal with the nature of scientific ontology are: an article with the explicit title, "Is Scientific Metaphysics Possible?" (1971), Chapter 2 of *Method, Model and Matter* entitled "Testability Today" (1973a), a text in French entitled "Les présupposés et les produits métaphysiques de la science et de la technique contemporaines" (1974), an article proposing a typology of scientific theories entitled "The GST Challenge to the Classical Philosophies of Science" (1977b), and the introduction of *Ontology: The Furniture of the World*, volume 3 of the *Treatise on Basic Philosophy* (1977a).

[3] See *Scientific Metaphysics* (Ross, Ladyman & Kincaid 2013).

[4] We group under psychonology all the disciplines that deal with the human based on the existence of a fourth level of organization of matter, the thinking matter, in the same way as there is a physical, chemical and living matter (Maurice 2020).

ontology and metaphysics are not synonymous, although for reasons different from those put forward by philosophers (Maurice 2020).

Finally, the expression *scientific philosophy*, used by Bunge to define his philosophy, is a contradiction in terms[5]. Our appreciation of philosophy as a *transcendent general discourse* does not allow it to be scientific (Maurice 2020)[6]. The non-scientificity of philosophy will become clear once Bunge's metascientific ontology is exposed as an illustration of a *scientific general discourse*.

We dwell in this article on the referents of the ontological theories exposed in volumes 3 and 4 of the *Treatise*. We therefore leave aside the form that these theories can take or their formalism, the use that can be made of them or their implementation, and the way in which these theories can be evaluated or their testability. We will also leave aside the Bungean thesis that abstract scientific theories, such as Lagrangian dynamics, as well as systems theories, such as cybernetics or automata theory, are ontological theories. Most notably, Bunge argues that there are no boundaries between factual science and ontology, but that there is a continuity that ranges from the most peculiar factual sciences to the most general ontologies: "A complete ontology must include both universal and regional ontological theories. The former serve as frames for the latter, who in turn will somehow illustrate and test the former" (Bunge 1977a, p. 11). Thus, in philosophical jargon, Bunge supports a form of naturalization of ontology, even if in practice, as we will see, Bunge

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[5] Romero has published a book called *Scientific Philosophy* (2018) that follows the structure of Bunge's *Treatise* quite closely. Despite the small number of pages, about 200, Romero's work is not necessarily more accessible than the *Treatise* since Bunge comments at length on his formalism. The fastest and simplest introduction to the *Treatise* remains the *Philosophical Dictionary* (Bunge 2003). More demanding is *Philosophy of Science* (Bunge [1967a] 1998, [1967b] 1998), a reissue of *Scientific Research*. Several of the themes of the *Treatise* are addressed.

[6] Even if we try to broaden our characterization of philosophy, even if we assume that there are non-transcendent doctrines, philosophy cannot be scientific. Once we have managed to convince ourselves that concrete objects exist beyond our senses, that these objects are knowable, that the best way to know them is to appeal to science, in other words, once we no longer question the world and the sciences that study it, we find ourselves outside philosophy, especially if our general discourse does not postulate any metaphysical entity, appeals only to natural faculties and uses only standard tools, procedures or methods.

does not naturalize in the same way as philosophers[7]. We will not examine this thesis of the continuity between factual science and ontology, but our results indicate a dichotomy between the two disciplinary fields. It should be noted that Bunge does not defend the idea of continuity between the factual sciences and mathematics. On the contrary, it postulates a dichotomy between factual and formal propositions. In addition to the referents of ontological theories, we will be interested in the methods, techniques and tools used by Bunge to construct these theories. We will then find that Bunge does not use any approach associated with philosophical doctrines. In short, we will follow Bunge's advice: "When in doubt about the authenticity of an intellectual endeavor, the right thing to do is to perform a candorous [*sic*] reexamination of its three components: subject matter, method, and goal." (Bunge 1973b, p. 1).

In the case at hand, i.e., the nature of Bungean ontology, we will examine the ontological theories set out in volumes 3 and 4 of the *Treatise* devoted to their elaboration: *Ontology I: The Furniture of the World* and *Ontology II: A World of Systems*. Specifically, for the task ahead, we must consider only chapters 3 through 6 of *Ontology I* and chapter 1 of *Ontology II*. Why this restriction of our field of investigation? Our goal is to show 1) that the Bungean ontology does not postulate the existence of any particular object, but takes for granted the existence of the objects studied by the factual sciences, and 2) that the methods, techniques and cognitive faculties used to achieve this are those expected to be found in all rational activities, be it scientific research, management, law, etc. The chapters mentioned above set out the fundamental concept of the Bungean ontology, the *concrete object*[8]. In fact, the Bungean system is designed to account for the concrete object in the light of science. Whether it is semantics, epistemology, methodology or ontology, it is always the concrete object that is at issue because the factual sciences only study concrete objects since the world is made up only of

[7] For more details, see our article "Bunge's Metascience and the Naturalization of the General Discourse" in this issue.

[8] See in this issue Orensanz's article, "Bunge and Harman on the General Theory of Objects", for the general notion of object, and not only that of concrete object. See also in this issue the article by Lukyanenko, Storey and Pastor, "Foundations of Information Technology Based on Bunge's Systemist Philosophy of Reality", for a defense of the idea that the notion of concrete system is gradually replacing that of concrete object in Bunge's writings after the *Treatise*.

concrete objects. Let us understand that these metascientific disciplines do not study the concrete objects of the world, which is the responsibility of the various factual disciplines, from physics to sociology, but rather that they elaborate a generalized notion of concrete object. If an examination of this central concept of Bungean thought reveals no transcendence, it is implausible to find it in other places in the work.

We can divide these two volumes into six distinct moments. Chapters 1 and 2 of *Ontology I* serve to introduce the concepts of *substantial individual* and *substantial property* respectively. These concepts are used in Chapter 3 to define the concepts of *concrete object* and *totality of concrete objects* (section 1.1). Chapter 3 also puts forward two postulates, the ontological one of the *existence of concrete objects* (section 1.2) and the methodological one of the *dichotomy between concrete and conceptual objects* (section 1.3). Once these two definitions and postulates are in place, Bunge is able to introduce a large number of ontological notions (while appealing to semantic, epistemological and methodological considerations), which ranges from section 1.4 of chapter 3 to chapter 6, the last chapter of *Ontology I*. In Chapter 1 of *Ontology II*, the very first definition is that of a *concrete system*, defined using the notion of concrete object, just as for the ontological concepts of *Ontology I*. Subsequently, and from the second definition, it is this notion of concrete system that takes the front of the stage and will play as important a role in *Ontology II* as the role played by the notion of concrete object in *Ontology I*. Chapters 2 to 5 of *Ontology II* are then devoted to the study of concrete chemical, biological, psychological and social systems[9]. Finally, Chapter 6, the last chapter of *Ontology II*, generalizes some results concerning concrete systems.

To assist us in our characterization of metascientific ontology, we will use Bunge's definition of science (2003, see entry "Science,

[9] In other words, Bunge offers some ontological elements of what we have called metachemistry, metabiology, metapsychology and metasociology (there is also a semantics, epistemology and methodology of metachemistry, etc.) (Maurice 2020). There is no chapter on physical systems (a chapter on metaphysics in the metascientific sense) in *Ontology II* because, according to Bunge, they are the best known of all and he dealt with these systems in *Ontology I* (Bunge 1977a, p. 45). Technically, Bunge's second claim is false since he dealt with the notion of concrete object in *Ontology I* and not that of a physical system.

Basic")[10]. A factual science is characterized using ten criteria, to which we add an eleventh criterion, E. All of these criteria can be represented by $\mathcal{R} = \langle C, S, E, D, G, F, B, P, K, A, M \rangle$, where each component is detailed as follows:

(1) C, the *research community* of $\mathcal{R}$, is a social system composed of persons who have received a specialized training, hold strong communication links among themselves, share their knowledge with anyone who wishes to learn, and initiate or continue a tradition of inquiry (not just of belief) aiming at finding true representations of facts;

(2) S is the *society* (complete with its culture, economy, and polity) that hosts C and encourages or at least tolerates the specific activities of the components of C;

(3) the *domain* or *universe of discourse* D of $\mathcal{R}$ is composed exclusively of (actual or possible) real entities (rather than, say, freely floating ideas) past, present, or future;

(4) the *ethos* E of members of C characterize by the free search for truth, depth, understanding, and system (rather than, say, the ethos of faith or that of the quest for sheer information, utility, profit, power, consensus, or good)[11];

(5) the *general outlook*[12] G of $\mathcal{R}$ consists of (a) the ontological principle that the world is composed of concrete things that change lawfully and exist independently of the researcher (rather than, say, ghostly or unchanging or invented or miraculous entities); (b) the epistemological principle that the world can be known objectively, at least partially and gradually;

[10] The definition of science is based on the more general notion of epistemic or cognitive field. Using this notion, Bunge deals with several other notions, such as paradigm, epistemic revolution, field of research, research project, etc. (Bunge 1982, sections 2 and 3, 1983a, pp. 90-93, 1983b, chaps. 13 and 14, 1984, 1985a, pp. 21-28, 1985b, pp. 242-252, 1989, pp. 296-300, 1996, chaps. 7, 2001, sections 8.3 and 8.4, Bunge & Ardila 1987, sect. 3.5). Bunge's attempt to demarcate science from pseudoscience based on the notion of epistemic field would seem ineffective (Mahner 2021).

[11] Our component E is for Bunge a subcomponent of G. But for us ethics does not belong to a scientific general discourse, but rather to a general discourse of convivence independent of metascience, philosophy and religion, even if there are philosophical and religious ethics (Maurice 2020).

[12] Bunge also uses as a synonym the expression "philosophical background", which we can dispense with since for us philosophy is not mistaken for a scientific general discourse or a metascience.

(6) the *formal background* F of $\mathcal{R}$ is the collection of up-to-date logical and mathematical theories (rather than being empty or formed by obsolete formal theories);

(7) the *specific background* B of $\mathcal{R}$ is a collection of up-to-date and reasonably well confirmed (yet corrigible) data, hypotheses, and theories, and of reasonably effective research methods, obtained in other fields relevant to $\mathcal{R}$;

(8) the *problematics* P of $\mathcal{R}$ consists exclusively of cognitive problems concerning the nature (in particular the regularities) of the members of D, as well as problems concerning other components of $\mathcal{R}$;

(9) the *fund of knowledge* K of $\mathcal{R}$ is a collection of up-to-date and testable (though rarely final) theories, hypotheses, and data compatible with those in B, and obtained by members of C at previous times;

(10) the *aims* A of the members of C include discovering or using the regularities (in particular laws) and circumstances of the Ds, systematizing (into theories) general hypotheses about Ds, and refining methods in M;

(11) the *methodics* M of $\mathcal{R}$ consists exclusively of scrutable (checkable, analyzable, criticizable) and justifiable (explainable) procedures, in the first place the general scientific method.

From this characterization, Bunge defines the *material framework* and the *conceptual framework* of any factual science. The material framework consists of the first three components, C, S and D, while the conceptual framework consists of the last seven components, G, F, B, P, K, A and M. Between these two frameworks, we insert the *conventional framework*, component E. If we reason in terms of objects of study, that is to say the referents of a discipline, the concrete objects of component D are the objects of study of a particular factual science, whether it is physics, chemistry, biology, psychology, sociology, etc., while the concrete objects of components C and S, that is, scientists, scientific communities and the societies that host them are the objects of study of the history, sociology and psychology of science. Now, conceptual objects, or scientific constructs from components G, F, B, P, K, A, and M are the objects of study of the metasciences, that is, metascientific semantics, ontology, epistemology, and methodology. Thus, some of the scientific constructs lend themselves to either semantic, ontological, epistemological, or methodological research, and other constructs, perhaps the majority, are studied using two or more of those metascientific disciplines. In other words, the same scientific construct can be studied from several angles, not to mention that it can be the subject of logical analysis and mathematical synthesis if it is incorporated into a mathematized metascientific theory. Finally, component E has as its object the conventions necessary for the smooth running of scientific activity. Thus, the factual sciences study the material objects of the C, S and D components, the metasciences study the conceptual objects of the G, F, B, P, K, A and M components, and the convivence disciplines study the conventional objects of the component E.

As fields of research, the metasciences can be characterized in a similar way to the factual sciences. At this point, the constructs or conceptual objects of the G, F, B, P, K, A and M components of the factual sciences are found as elements of D of the metasciences, that is, the objects of study of a scientific general discourse. In this article, among the components D, G, F, B, P, K, A and M of a metascientific ontology, we will therefore focus on the next section on component A, the objectives of such an ontology, and then in section 2, we will examine component D, the objects of study of this ontology, and, finally, in section 3, we will look at the M component, the methodic of the metascientific ontology. We will use the Bungean ontology to illustrate our point.

1] Goals of Ontology

Bunge has stated the objectives of his ontology in several places and these objectives are diverse, as they are related to certain theses as to the nature of ontology which we discussed briefly in the introduction[13]. Bunge's characterization of ontology and the goals he assigns to it are ambiguous and inconsistent with the way he practices his ontology.

If we stick to the introduction of *Ontology I* of the *Treatise*, we find the following characterizations and objectives:

> Metaphysics is *general cosmology or general science:* it is the science concerned with the whole of reality—which is not the same as reality as a whole. "Its business is to study the most general features of

[13] See note 2 for a list of Bunge's texts on the nature of ontology.

> reality and real objects" (Peirce). It "is concerned with all questions of a general and fundamental character as to the nature of the real" (Montagu). In other words, metaphysics studies the generic (nonspecific) traits of every mode of being and becoming, as well as the peculiar features of the major genera of existents. […] We adopt the latter position: we maintain that the ontologist should stake out the main traits of the real world as known through science, and that he should proceed in a clear and systematic way. He should recognize, analyze and interrelate those concepts enabling him to produce a unified picture of reality. (The word "reality" is here understood in a strict and non-Platonic sense, namely as the concrete world.) (Bunge 1977a, p. 5, italics and quotations in the original text)

It is not clear, for example, what the study of the "most general features of reality and real objects" can mean, since for Bunge there are only concrete objects, endowed with concrete properties, and in interaction with each other. For example, Bunge does not believe in the existence of general properties in nature. What are these "generic (nonspecific) traits of every mode of being and becoming"? If the features and traits in question are those of real or concrete objects, then they cannot be general or generic.

The interpretation we give of them is to say that it's not "general characteristics" or "generic features" of concrete objects which ontology studies, but rather scientific constructs that refer to reality. In other words, an ontology proposes generalized constructs based on the constructs used and produced by the factual sciences. For example, the sciences study concrete properties, while the metasciences study a generalized notion of property. These constructs used and produced by the factual sciences are of various kinds. Let us think, among other things, of general postulates such as the existence of the external world, of certain concepts called constitutive by Bunge such as that of association, of certain other more well-known concepts that scientists spontaneously use such as those of property, of fact, of event, of processes, of system, and of others less known as those of emergence and level of organization.

The passage quoted above is quite complex, but the characterization that seems to us the most accurate is that which specifies that ontology must "*recognize, analyze and interrelate those concepts* enabling him to produce a unified picture of reality". Here, we approach a conception of ontology whose task is to study implicit or explicit scientific and metascientific constructs[14]. However, the idea of a factual ontology that would study concrete objects is reaffirmed a few paragraphs later:

> We take factual (natural or social) science and ontology to be the only disciplines concerned with concrete objects. And we assign ontology the task of constructing the most general theories concerning such and only such objects. (Bunge 1977a, p. 6)

We find this ambiguity concerning generality, but here from the angle of a very general theorization of concrete objects. Do such general theories, such ontologies, have the same status as the general theories of certain factual sciences, such as quantum mechanics or the theory of evolution? Finally, in another place, Bunge clearly announces what ontology does not study:

> Ontology does not study constructs, i.e., ideas in themselves. These are studied by the formal sciences and epistemology. (Bunge 2003, p. 201)

The statement is surprising when one considers the way Bunge constructs these ontological theories in volumes 3 and 4 of the *Treatise*. For example, he analyzes how scientists represent concrete properties by asking what this construct is, not by studying a general property in nature, a property that does not exist, but by studying certain concepts of property such as mass, the latter representing a concrete property studied by physicists. So, there is an ambiguity in Bunge's characterization of his research. He conceives ontology in a vague and general way and then practices it in a precise and rigorous way. His characterization of ontology is not interesting since it is not distinguishable from several characterizations found in philosophy. On the other hand, his metascientific practice of ontology deviates radically from the philosophical practice of ontology. He studies and tries to theorize certain scientific constructs, including general postulates often implicitly used by scientists, but he

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[14] *Implicit metascientific constructs* are essentially general unformulated postulates, traditionally associated with philosophy, such that the objects of the world interact. *Explicit metascientific constructs* are those used by scientists to communicate, such as the use of the notion of property, but without specifying or formalizing them. *Explicit scientific constructs* are those produced by any science, such as a concept, a proposal, a classification, a theory, etc., and the *implicit scientific constructs* are those borrowed from other disciplines, and even from other research projects of the same discipline, without formulating them.

does not postulate the existence of any object, takes for granted the existence of objects studied by the factual sciences, uses methods, techniques and cognitive faculties used in all rational activities. There are no metaphysical objects that a first philosophy could study. There is no more philosophy.

If we summarize, the goal of metascientific ontology is to study scientific constructs to produce an abstract, generalized, unified picture of the world[15]. If we return to the definition of a factual science, these constructs are to be found among the objects that are found in the components of the conceptual framework of the factual sciences: *G*, *F*, *B*, *P*, *K*, *A* and *M*. Other constructs of a conceptual framework may be the objects of study of semantics, epistemology, methodology, and some constructs may require the contribution of several metasciences. The study of scientific constructs justifies conceiving the metascience as conceptual sciences, forming a triad with factual sciences and formal sciences (Maurice 2020).

2] Objects of Ontology

The notion of concrete object is at the heart of the Bungean ontology. It is this notion that is the subject of a theorization elaborated in *Ontology I*. Virtually all the ontological notions discussed are related to the concrete object. But the definitions and postulates concerning the notion of concrete object and the associated notions are nourished by the knowledge of the concrete objects studied by the physical, chemical, biological, psychological, and sociological sciences, more precisely by the constructs used, implicitly or explicitly, by scientists to represent concrete objects. There is therefore a back and forth between scientific constructs, which must be analyzed and interpreted, and the construction or synthesis of an abstract notion of concrete object and associated notions.

The notion of concrete or material object in Chapter 3 of *Ontology I* is defined in a formal and complex way. Bunge needs a theory of substance (Chapter 1) and another of form (Chapter 2) to arrive at a definition of concrete object. We will not examine these two

[15] Even if for Bunge, the ultimate in the outcome of all research is a theory, a hypothetical-deductive system, he is aware that several results exposed in *Ontology I* and *II* are not strictly speaking theories. He thus introduces the notion of *ontological framework*, a construct that lies between a set of ideas that are closely related to each other and a hypothetical-deductive system or a theory (Bunge 1977a, pp. 11-12).

theories and will adopt a more intuitive characterization of the concrete object proposed by Bunge himself, which will suffice for our purpose (Bunge 1977a, pp. 240, 2000)[16]. The concrete object is the object that is subject to change. But since change is impossible without energy or without any energy transfer, the concrete object is the object endowed with energy. This definition justifies the postulate, again in chapter 3 of *Ontology I*, of the dichotomy between concrete objects (things) and conceptual objects (constructs). The concepts, propositions, theories and formal objects of logic and mathematics are not endowed with energy, are therefore not susceptible to change, and consequently have no concrete, material, or real existence. Concrete objects change and conceptual objects are replaced.

Note that the definition of a concept is not proof of the existence of the object to which the concept refers. Thus, in chapter 3 of *Ontology I*, we have seen that there is a definition of the concrete object, but also the postulate of existence of concrete objects[17]. Thus, Bunge takes for granted the existence of concrete objects although he theorizes the notion. Moreover, for Bunge, the criteria and demonstrations of the existence of particular concrete objects such as atoms, living cells or social groups do not belong to ontology, but to the factual sciences (we will come back to this). Bunge does not attempt, therefore, in *Ontology I: The Furniture of the World*, to determine the "furniture of the world" if by furniture of the world we mean the concrete objects studied by the factual sciences:

> What is there?—we shall abstain from answering it. That is, we shall not list the kinds of constituent of the world but shall leave the task to the special sciences. For, no sooner does the metaphysician pronounce the world to be "made of" such and such kinds, than the scientist discovers either that some of the alleged species are empty or that others are missing in the metaphysician's list. (Bunge 1977a, p. 153)

So, there is no metaphysics in the philosophical sense for Bunge. We can, however, understand "furniture of the world" in a general sense. In this case, the conceptual objects to which the ontological

[16] It is not clear to us that the developments in chapters 1 and 2 in *Ontology I* are necessary for the development of a metascientific ontology.

[17] Similarly, change (Bunge 1977a, p. 261) and energy (Bunge 1977a, p. 240) as phenomena are taken for granted, although these notions are theorized in Chapter 5 of *Ontology I*.

concepts refer are seen as the "furniture of the world". But there are no general concrete objects in the world, nor general properties or laws, nor general states or events, nor general processes or changes. All that exists are particular objects, endowed with their particular properties, in particular nomic interaction: "The real thing is the substantial individual with all its intrinsic and mutual properties. Everything else is fiction." (*ibid.*, p. 101). Or, in a pithy way: "To be, to really exist, is to be a thing"[18] (*ibid.*, p. 158). Or:

> […] *all* things, and *only* things, possess the property of existing really—a property represented by E_{Θ}. This vindicates Aristotle's principle that *real existence is singular*. There are no general things: every real existent is an individual. (ibid., p. 157; italics in the original text)

We construct a general concept of concrete object, property, state, event, process, and change. Without these general concepts, often used only implicitly, all theorization and communication, even in the factual sciences, would be impossible. It is for this reason that there are metascientific concepts, inherent in science, wrongly assimilated to philosophical concepts. In other words, we need general concepts to represent the world and to communicate, but these concepts do not refer to particular real objects and even less to metaphysical objects; they are the result of an abstraction and a generalization on the basis of a study of scientific constructs. For example, concrete properties are conceptualized in certain ways by the factual sciences, and it is the way of conceptualizing them that interests the Bungean ontology and not the properties themselves. Thus, Bunge analyzes the way scientists represent concrete properties by asking what is this construct that is called property, not by studying a general property that would be found in nature or in a metaphysical reality, but by studying certain concepts of property such as that of mass, the latter concept representing the concrete property of mass with which certain objects of the world are endowed, each individually. In the strict sense, in fact, concretely, massive objects do not share or do not have in common a general mass property; each of them has its own mass by the nature of the objects that compose them and the relationships they maintain.

[18] For Bunge, "concrete object" and "thing" are synonymous.

Thus, Bunge postulates the existence of concrete objects and puts forward several reasons to justify such an assumption, including this one, the most important:

> Another reason for having to postulate the existence of things is that, if we want to prove anything about existents, we must posit them. *We cannot prove the existence of concrete things any more than we can prove the existence of deities or of disembodied minds*. What can be proved is that, unless there were things, other items—such as acting on them and investigating them—would be impossible. (*ibid.*, p. 112, our italics)

A demonstration or logical proof of existence is impossible. It is through reflection, through our experience and through our acquired knowledge that we can convince ourselves of the existence of the world and the concrete objects that compose it. And much of that thinking, experience, and knowledge is fueled by science. More specifically, we cannot demonstrate the existence of the general concrete object because it does not exist. Only the existence of a particular concrete object postulated by the factual sciences can be the subject of empirical proof (in fact, it is enough to find only one):

> Our theory of things supplies no criterion for either establishing or refuting any hypothesis to the effect that such and such an object really exists. It is not the business of metaphysics to offer existence criteria […] (*ibid.*, p. 160).

Or:

> Metaphysics, on the other hand, is hardly in a position to admit or rule out any fact. What metaphysics can do is to clarify some of the concepts involved in scientific judgments of possibility or impossibility. (*ibid.*, p. 178)

So, an essential notion for Bunge is that of a *concrete object* or *thing*. Concrete objects are objects that are subject to change because they are endowed with energy. In contrast, we find *conceptual objects* or *constructs*. They are not subject to change because they do not have energy. Are we then in the presence of an ontological duality? No, since one of the axioms of the Bungean system is that only concrete objects exist. Duality is therefore methodological. It is also necessary to allow us to treat fictions or constructions of the mind *as if* these constructs were autonomous. But this necessary methodological duality is often perceived by the mind as an ontological duality (Maurice 2020).

Among the concrete objects, we have, for example, the objects immediately considered concrete by most people, such as a stone or a table, but also objects whose concreteness is not immediately apparent, such as a quantum object, a physical field, a chemical compound, a living organism, a family, a company, etc. Thus, the meaning of "concrete" for Bunge has a much broader scope than that of common sense or even that of philosophy. The concrete objects of the world are mostly of a different type from the billiard balls hitting each other. This type of object forms only a small set of all concrete objects. Again, everything that is endowed with energy, and therefore susceptible to change, is a concrete object.

Among conceptual objects, there are objects of logic and mathematics, but also any construct that refers to concrete objects or that represents them, whether or not this construct has a well-defined logical or mathematical form. Thus, functions and mathematical sets are constructs, but also the concept of metabolism, which should not be confused with the concrete metabolism to which it refers. Metasciences study the concepts of metabolism and not concrete metabolisms, as Bunge points out in the last quote above by assigning to metaphysics the role of conceptual clarification. Again, you have to pay attention to the words. A conceptual clarification or conceptual analysis for Bunge has nothing to do with their philosophical equivalent. Bunge uses standard methods widely used in logic (formal logic, not philosophical logic), mathematics, and science. It does not postulate the existence of any reality other than concrete reality and distinguishes this reality from the fictions we use to represent it.

This dichotomy between the factual and the formal led Bunge to propose a metascientific theory of factual properties and another of natural classes because the predicates of logic cannot be equated with concrete properties and mathematical sets cannot be confused with natural classes:

> We now have a theory of properties, distinct from the theory of predicates, and a theory of kinds, different from the algebra of sets. We can therefore use without qualms the concepts of a property and a kind. The differences between predicates and properties, and between sets and kinds, suffice to ruin the ontological interpretations

> of logic and of set theory. There is no reason to expect that pure mathematics is capable of disclosing, without further ado, the structure of reality. (Bunge 1977a, p. 150)

In the same way that a mathematized physical theory is not assimilated to a mathematical theory, a mathematized ontological theory *à la* Bunge is not assimilated to a logical or mathematical theory. Logic and mathematics have no ontological significance in metascience. Only certain philosophical, religious, and mystical doctrines grant the formal sciences the power to account for the world without concern for the factual sciences.

From the moment Bunge is in possession of the notion of concrete object, many of the postulates and definitions of his ontology are constructed using this notion. Here is a partial list of these concepts: state, space of states, nomic statement, natural class, population, communities and species, real existence, nothingness, real possibility and necessity, disposition and propensities, change, events, processes, space-time, concrete system, level of organization. Thus, all these ontological concepts are based on the notion of concrete object. For example, it is not uncommon for a definition to begin with "Let X be a thing…" or "If $T \subseteq \Theta$ is a set of concrete objects, then… ", Θ being the set of the totality of concrete objects. Take for example definition 4.3 of *fact*:

> Let X be a thing. Then f is a *fact* involving X iff either
>
> i) f is a *state* of X, i.e. there is a state space $S_{\mathbb{L}}(X)$ for X such that $f = s \in S_{\mathbb{L}}(X)$, or
>
> ii) f is a *change of state* of (or *event* in) X, i.e. there is an $S_{\mathbb{L}}(X)$ such that $f = e = \langle s, s' \rangle \in S_{\mathbb{L}}(X) \times S_{\mathbb{L}}(X)$ (Bunge 1977a, p. 169)

In other words, "*a (real) fact is either the being of a thing in a given state, or an event occurring in a thing*" (*ibid.*, p. 267; italics in original). The notions of state and change of state in points (i) and (ii) are defined in a similar way by appealing to the generalized notion of concrete thing or object. The examination of the other ontological notions on which Bunge dwells only confirms the interest of the latter for the concrete object, but not just any concrete object since the general notion of thing is supposed to conform to more particular notions produced by the sciences, such as those of physical field, atom, cell, person, society, etc. We can say that Bunge is interested in the *scientific object* if we understand that this expression refers to the *scientific study of concrete objects*. Bunge is not interested in how one conceives of the concrete thing or object in everyday life, although some factual sciences such as psychology or sociology may be interested in it. Common sense does not have as its primary aim or its sole end the production of objective knowledge, whereas it is this objective knowledge, produced by the factual sciences, which deserves to be studied in a general way by the metasciences. In other words, common knowledge cannot be the subject of a general discourse because its concepts are not objective or coherent enough and therefore cannot be generalized, while the objectivity of scientific knowledge makes possible the existence of a scientific general discourse, a metascience.

When we examine the definitions and postulates of *Ontology I* and *II*, Bunge's ontology, unlike philosophical ontologies, is not intended to make us discover a reality to which the factual sciences would not have access. Not only does Bunge not posit the existence of conceptual, ideal, or spiritual objects, Bunge does not affirm the existence of particular concrete objects. It is the factual sciences that postulate the existence of concrete objects, establish criteria for their existence and elaborate the means of studying them.

3] Methods of Ontology

Bunge has had little discussion of his method of constructing semantic, ontological, and epistemological theories, perhaps because for the author of the *Treatise* it is obvious that there are no special faculties or tools for theorizing science. Bunge appeals to the entire arsenal of cognitive faculties, starting with reflection[19], and does not favor *a priori* any mathematical formalism based on a philosophical doctrine. Discussing the nature of the philosophy of science, or rather metascience, Bunge clarifies what its subject, method, and goal are:

> The object should be real science (both natural and social), and the method should be essentially the same as the method of science—since in either case one tries to know something given. The goal should be to dismount and then to reassemble the mechanism of

[19] Ordinary or natural reflection, which we are all endowed with, and not philosophical reflection. Thinking, even in general, does not prove that we philosophize (Maurice 2020).

> science in order to expose its structure, content, and functions. (Bunge 1973b, p. 21)

And more particularly in the case of ontology:

> Any means should be permitted in constructing a metaphysical theory as long as it leads to a good theory: pinching from another field, analogizing, extrapolating, looking for models of abstract theories, and of course inventing radically new ones. Here, as in science and in mathematics, there is no royal road, and theories are judged by their works not by their scaffoldings. (Bunge 1971, p. 509)

Thus, in terms of methods and techniques of analysis, Bunge practices a methodological conservatism and opportunism. Several philosophers, including Bunge, make little or no use of the tools or methods of reflection and analysis recognized by philosophers. These methods seem to cause more problems than they solve, which may explain why they are not used in the formal and factual sciences. Here is a non-exhaustive list of tools, methods and approaches, essentially associated with philosophy and which Bunge does not use[20]: transcendental argument, philosophical counterfactuality, philosophical thought experiment, philosophical logical analysis, philosophical conceptual analysis, philosophical linguistic analysis, philosophical necessity and possibility, philosophical conceivability, philosophical intuition, dialectics, *Epochè*, and analyses using possible worlds (modal techniques), etc.[21] Bunge also did not seek to develop a doctrinal method, a method associated with a philosophical doctrine, as is the case with several philosophers: Plato developed dialectics, Aristotle syllogistics, Descartes wrote the

[20] We must qualify as *philosophical* most of the approaches listed here because some of them also have a meaning and utility outside of philosophy, but without being used philosophically.

[21] For an overview of some philosophical methods, see the *Oxford Handbook of Philosophical Methodology* (Cappelen, Gendler & Hawthorne 2016) and the *Cambridge Companion to Philosophical Methodology* (Overgaard & D'Oro 2017). These two works, like similar works, appropriately use an encyclopedic style that does not account for the scope of philosophical methods. Only the reading of a few philosophical works makes it possible to understand that the ways of thinking of philosophers, on the one hand, differ radically from the ways of thinking of rational discourses, scientific or otherwise, on the other hand, that they are designed to differ radically since the objective is to know a reality that would escape the sciences.

Discourse on the Method, Husserl proposed phenomenological reduction, and the Vienna Circle, logical analysis.

Throughout his work, Bunge has consistently criticized these approaches or methods and has always denied the existence of any cognitive faculties necessary for philosophical practice. It would be futile to seek *the* Bungean method, as it is customary to do in the case of the great philosophers, the method then coming to characterize the philosopher. In this way, a Platonist cannot surpass Plato, a Cartesian cannot surpass Descartes, and a Kantian cannot surpass Kant. The method is inseparable from the philosopher. If you change the method a little too much, you develop another philosophical doctrine. In Bunge's case, a general discourse on the world does not require a particular approach different from what is practiced in any rational activity, whether in science, management, law, education, health, etc. Bunge can therefore be overtaken by anyone who has the capacity and who takes the trouble to do so. This is an important and even essential quality of the Bungean approach to a general discourse about the world that distinguishes it, again, from the philosophical approach.

So, for Bunge, for example, there is no distinction between what is ontologically, metaphysically, or philosophically possible and what is factually, concretely, materially, actually, or physically possible. Metaphysical necessity and possibility do not exist in Bunge, implying that he does not resort to philosophical methods to establish what would be philosophically or metaphysically necessary or possible[22]. This situation alone should convince anyone that Bunge's ontological theories are not philosophical, but metascientific.

Cordero pointed out the fundamental aspect of the Bungean approach: all rational activity uses experience, reason, imagination, and criticism. (Cordero 2019, pp. 94-96) Note that the experience, reason and imagination in question have no transcendent significance. In other words, it is the experience of the concrete world,

[22] Bunge distinguishes conceptual possibilities from real or factual possibilities, in accordance with his methodological postulate of the dichotomy between concrete and conceptual objects. These notions of possibility are discussed in Chapter 4 of *Ontology I*. Suffice it to mention here that the real possibilities depend on the laws of nature, that is, on the nomic relations that exist between concrete properties. That is, philosophical and metascientific possibility have only the name in common.

including and above all the concrete world revealed by the factual sciences, and the use of reason and imagination as natural faculties and not as faculties that would give us access to a philosophical reality. The cognitive psychology of science as well as the cognitive neuroscience of science, which studies cognition and cognitive processes in scientists, assume that these processes are of the same nature for all humans:

> […] scientific thinking involves the same general-purpose cognitive processes—such as induction, deduction, analogy, problem solving, and causal reasoning—that humans apply in non-scientific domains. (Dunbar & Klahr 2013. p. 702)

Bunge differs from philosophers because the latter believe that there are special faculties to bridge the "gap" between reality and appearances, or if these faculties do not exist, then reality is unknowable. But, from the start, this is a false problem[23].

4] Conclusion

To understand the distinction between metascience and philosophy, it is useful to remember that we do not have direct access to reality, that there is no proof or general demonstration of the existence of things, that we must then take for granted the existence of the "external world", that there is no possible answer to the question of the existence of one property rather than another. It is through reflection and our experience that we arrive at this observation (Maurice 2020).

Our representation of the world therefore passes through the study of scientific constructs, which is the task of metascientific ontology. If we also think that a general discourse on science is valid, useful for the advancement of knowledge, then we can study science itself, which is devoted to metascientific semantics, epistemology, and methodology.

The Bungean ontology therefore does not postulate the existence of any object and does not use any philosophical method, despite its desire to be part of the philosophical tradition: doing does not follow saying. If a discipline is characterized by its objects and methods,

[23] We examine the dichotomy established by philosophers between appearance and reality in section 3 of our article "Bunge's Metascience and the Naturalization of the General Discourse" in this issue.

then Bunge's scientific ontology bears little resemblance to philosophical ontologies. Bunge does not problematize science in the same way that philosophers do. In philosophical jargon, Bunge is a materialist, but his materialism is reduced to accepting the concrete objects studied by the physical, chemical, biological and psychonological sciences. He therefore relies on science to determine the furniture of the world. It is then abusive to reduce Bunge's thought to a materialist doctrine insofar as even these doctrines, because philosophical, postulate the existence of objects and processes alien to science and use methods unknown to scientists. We do not need materialist doctrines, we only need to adopt the same general postulates as the sciences, to analyze and interpret their constructs, and then to abstract and generalize, all with the help of our natural faculties. The role of Bungean ontology, but also of semantics, epistemology, and methodology, is similar to that of metalogic and metamathematics. And since the scientific beast is just as complex as the logical beast or the mathematical beast, it's no wonder that it took Bunge to compose a nearly 2,400-page treatise to lay the foundations of metascience[24].

Bunge tells us in his autobiography that he had set himself the goal of linking philosophy and science. In doing so, he annihilated philosophy to produce a scientific general discourse. This general discourse is designed for science and for scientists, more precisely for metascientists, that is, scientists interested in a general discourse about the world and science. It is easy for any scientist interested in a general discourse on science and the world to understand Bunge's thought. Nothing he says is extravagant and nothing he does go off the path of a normal research process. Because he was able to summarize the spirit of the Bungean approach so well, let us leave the last word to Joseph Agassi:

> The idea behind the program is as commonsense as could be. This may sound disappointing, as it lacks all extravagance, but then this is what the program is all about. The idea is to stay well within one world […]. (Agassi 1990, p. 117)

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[24] We exclude here volume 8 of the *Treatise* on ethics because, for us, metascience, a scientific general discourse, is dissociated from a general discourse of convivence or living together. There is no metascientific imperialism as there is philosophical imperialism (Maurice 2020).

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Bunge and Harman on the General Theory of Objects

Martín Orensanz[1]

Abstract — Although there are significative differences between the philosophies of Mario Bunge and Graham Harman, there are also some fundamental similarities. One of the core features that they have in common is that both of them claim that it is possible to develop a general theory of objects. The former believes that the theory in question is logical-mathematical, while the latter suggests that it is ontological. Regardless, they agree that all objects have to be considered, no matter if they are real or not. Furthermore, they suggest that even though no objects should be excluded from the theory, it is necessary to distinguish different kinds of them.

Résumé — Bien qu'il existe des différences significatives entre la philosophie de Mario Bunge et celle de Graham Harman, il existe également des similitudes fondamentales entre elles. Ces penseurs affirment tous deux qu'il est possible de développer une théorie générale des objets. Le premier estime que la théorie en question est logico-mathématique, tandis que le second suggère qu'elle est ontologique. Quoi qu'il en soit, ils conviennent que tous les objets doivent être considérés, qu'ils soient réels ou non. En outre, ils suggèrent que même si aucun objet ne doit être exclu de la théorie, il est nécessaire d'en distinguer différents types.

In a sense, Mario Bunge and Graham Harman could not be further apart as philosophers. The former advocates for scientism, while the latter criticizes it. One of them has a low opinion of the work of Bruno Latour, while the other appreciates it. Despite these and other key differences, I argue that there are certain core

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similarities between their philosophies. We will see several examples, but the first one is that both thinkers agree that it is possible to develop a general theory of objects, and that there is no reason to exclude fictional objects from its domain. In other words, a general theory of objects must deal with all kinds of objects, no matter if these are real or not.

Harman had advanced this idea early in his career. The opening paragraph of *Guerrilla Metaphysics: Phenomenology and the Carpentry of Things* is an example of the general idea:

> This book calls for what might be termed an *object-oriented philosophy*, and in this way rejects both the analytic and continental traditions. The ongoing dispute between these traditions, including the sort of "bridge building" that starts by conceding the existence of the dispute, misses a prejudice shared by both: their primary interest lies not in objects, but in human *access* to them. The so-called linguistic turn is still the dominant model for the philosophy of access, but there are plenty of others—phenomenology, hermeneutics, deconstruction, philosophy of mind, pragmatism. None of these philosophical schools tells us much of anything about objects themselves; indeed, they pride themselves on avoiding all naive contact with nonhuman entities. By contrast, object-oriented philosophy holds that the relation of humans to pollen, oxygen, eagles, or windmills is no different in kind from the interaction of these objects with each other. For this reason, the philosophy of objects is sometimes lazily viewed as a form of scientific naturalism, since it plunges directly into the world and considers every object imaginable, avoiding any prior technical critique of the workings of human knowledge. But quite unlike naturalism, object-oriented philosophy adopts a bluntly *metaphysical* approach to the relations between objects rather than a familiar physical one. In fact, another term that might be employed for object-oriented philosophy is *guerrilla metaphysics*—a name meant to signify that the numerous present-day objections to metaphysics are not unknown to me, but also that I do not find them especially compelling. (Harman, 2005: 1)

Bunge, for his part, had also been philosophizing about objects throughout his career, particularly in the third volume of his *Treatise on Basic Philosophy*, titled *Ontology I: The Furniture of the World*. In that work, though, he was skeptical of the possibility of a general theory of objects:

> Because unreal objects have nonphysical properties, they satisfy nonphysical laws if any. For this reason it is impossible to make any nontautological statements applying to all objects: ontology, as conceived by Meinong and Lesniewski, i.e. as a general theory of objects of any kind, and yet different from logic, is impossible. (Bunge, 1977: 5)

However, several decades later, it seems that Bunge changed his mind. In 2010 he published *Matter and Mind*, and in Chapter 14 of that book, titled *Appendix A: Objects*, he outlined a general theory of objects. It will be worthwhile to quote the opening paragraphs in full:

> In ordinary language, the word "object" denotes a material thing that can be seen and touched. By contrast, in modern philosophy "object" (*objectum*, *Gegenstand*) stands for whatever can be thought about: it applies to concrete things and abstract ones, arbitrary assemblages and structured wholes, electrons and nations, stones and ghosts, individuals and sets, properties and events, facts and fictions, and so on.
>
> The concept of an object is thus the most general of all philosophical concepts. In fact, this concept is so general that it is used in all the branches of philosophy in all languages—though not always consistently. For instance, someone might say that the subjects of this chapter are objects, whereas its object or goal is to elucidate "object".
>
> Yet, to my knowledge there is no generally accepted theory of objects. True, mereology, or the calculus of individuals, was expected to fill that gap. Regrettably, this theory is extremely complicated, uses an awkward notation, and does not accomplish much because, following the nominalist program, it eschews properties. As for the theories of objects proposed by Meinong and Routley, they are only moderately well known, possibly because they include impossible objects on a par with possible ones. The goal of this paper is to formulate a general theory of objects free from those flaws. However, the reader with no taste for symbolism is invited to skip this chapter. (Bunge, 2010: 267)

Contrary to what he had written in the third volume of the *Treatise*, in this small but important appendix to *Matter and Mind* he now believes that it is entirely possible to develop a general theory of objects. This is particularly evident in the list that he provides, since he mentions ghosts as an example of fictional objects. Thus, Bunge and Harman agree that a general theory of objects must include fictional entities. It cannot be reduced to a theory that deals exclusively with real objects.

According to Harman, the general theory of objects has at least two phases. The first one is called "flat ontology". During this phase, all objects have to be taken into consideration, no matter if they are real or fictional. However, he also indicates that this is only a starting point, not a final destination. In his book *Object-Oriented Ontology: A New Theory of Everything*, he says:

> Briefly put, flat ontology is a good starting point for philosophy but a disappointing finish. For example, earlier in this chapter I argued that philosophy needs to be able to talk about everything—Sherlock Holmes, real humans and animals, chemicals, hallucinations—without prematurely eliminating some of these or impatiently ranking them from more to less real. We might well have biases that make us think that philosophy is obliged only to deal with natural objects but not artificial ones, which we might dismiss as unreal. In this case as in many others, an initial commitment to flat ontology is a useful way of ensuring that we do not cave in to our personal prejudices about what is or is not real. Yet flat ontology would also be a disappointing finish for any philosophy. If we imagine that after fifty years of philosophizing a OOO thinker were to say nothing more than 'humans, animals, inanimate matter and fictional characters all equally exist', then not much progress would have been made. In short, we expect a philosophy to tell us about the features that belong to *everything*, but we also want philosophy to tell us about the differences between various *kinds* of things. It is my view that all modern philosophies are too quick to start with the second task before performing the first in rigorous fashion. (Harman, 2018: 54–55)

In this sense, Harman suggests that two kinds of objects must be distinguished: real objects and sensual objects. The former exist by themselves, independently of other objects, while the latter only exist in relation to a real object. We will say more about this distinction later.

As we have seen, Bunge would agree with Harman that a general theory of objects must acknowledge all kinds of objects, without excluding fictional ones from its domain. He would also agree that the theory in question has to distinguish different kinds or types of objects. Thus he says:

> So far we have not distinguished between concrete objects, such as numerals, and ideal objects, such as numbers. We proceed to introducing this distinction. (Bunge, 2010: 269)

He says this after discussing the concept of individuals and properties. Generally speaking, Bunge thinks that individuals can be either real or fictional, and the same can be said about properties. This can be interpreted as a fourfold, not entirely unlike Harman's.

As a note in passing, Bunge and Harman agree on another point: that an assembly or a collection of objects is also an object in its own right. Harman had discussed this point in his book *Immaterialism: Objects and Social Theory*. There, and contrary to Leibniz, he argues that groups of objects are also objects, no matter if those groups are arbitrary assemblages. Bunge would agree, since he says:

> A concatenate need not be a system; that is, no bonds need be involved: an arbitrary assemblage of things counts as an object. (Bunge, 2010: 269)

Before we examine the different kinds of objects that these thinkers recognize, we must address another issue: should the general theory of objects be a formal science, as Bunge claims, or an ontology, as Harman suggests?

1] Formal Science or Ontology?

One difference between Bunge and Harman regarding the general theory of objects has to do with the nature of the theory in question. For Bunge, it logical-mathematical, and for Harman it is ontological. Part of this disagreement has to do with the fact that they define the term "ontology" in different ways.

In his *Treatise on Basic Philosophy*, Bunge had traced a fundamental distinction between things and constructs. He claimed that ontology can only be a theory about things, but not constructs. The latter should be studied by the discipline of semantics, and more generally, by mathematics and logic. Even though, decades later, he changed his mind regarding the possibility of a general theory of objects, he did not change his mind regarding the definition of the term “ontology”. Thus, he says that “ontologies are theories about the world” (Bunge, 2010: 275).

In this sense, and from the point of view of *Matter and Mind*, ontology would be a branch of the general theory of objects, the one that deals with things and everything pertaining to things. Constructs would be excluded from ontology, but not from the general theory of objects.

Harman defines the term “ontology” in a different way. Noting that the terms “ontology” and “metaphysics” have been defined in several different ways by various thinkers, he proposes the following definitions:

> Henceforth, let ‘ontology’ refer to a description of the basic structural features shared by all objects, and let ‘metaphysics’ signify the discussion of the fundamental traits of specific types of entities. (Harman, 2007: 204)

For Bunge, the terms “ontology” and “metaphysics” are synonymous, for Harman they are not. However, one cannot help but wonder how divisive this difference really is, since both thinkers agree that it is possible to develop a general theory of objects. The only difference regarding this point is that one of them calls it “ontology”, while the other one prefers to reserve this term for one of the branches of the theory in question.

It seems to me that, regarding this point, if one asked, “who is right here, Bunge or Harman?” then it would be necessary to indicate that what is being discussed here is not a matter of fact, but of terminology. It is not as if one of these philosophers declared “there is a cat on the mat” and the other one declared, “it is not the case that there is a cat on the mat”. Because, for a situation like that, one would only have to look at the mat to see if there is a cat on it or not. That would be enough for determining who is right. But when the discussion is about using the term “ontology” to refer to the general theory of objects, one cannot explore the world to find some piece of evidence that corroborates or refutes what is being claimed, there is nothing similar to finding a cat on the mat for determining “who is right” in a terminological discussion.

If I may suggest an example taken from chess, it does not matter if I call a certain piece a “knight” or a “horse” or an “apple”, what matters is how the piece moves. In a similar fashion, I suggest that it does not matter what the general theory of objects is called, what matters are the "rules of the game" that the theory proposes. And, in this sense, despite the important differences between the "rules" that Bunge and Harman propose, they do seem to agree on some of these "rules". Namely, that it is possible to develop a general theory of objects of any kind.

Having said this, let us take a look at the different kinds of objects according to the theories of Bunge and Harman.

2] Kinds of Objects

In the *Treatise on Basic Philosophy*, Bunge claimed that objects are divided into two fundamental kinds: things and constructs. In *Matter and Mind*, this is no longer the case. Instead, the most general kinds of objects that he recognizes in that text are individuals and properties. He says:

> We shall presently propose an axiomatic theory of individuals of any kind. The first section presupposes only the classical predicate calculus with identity, a bit of set-theoretic notation, and another of semi-group theory; the balance of the chapter also uses the concept of a mathematical function. The specific primitive (undefined) concepts are those of individual and property. Like all primitives, these are elucidated by the postulates where they occur. (Bunge, 2010: 267)

In the *Treatise on Basic Philosophy*, Bunge had also traced a fundamental distinction between properties and attributes. He defined the former as real, and the latter as fictional. Things have properties, while constructs have attributes. However, in *Matter and Mind*, he seems to have abandoned this terminology, since he speaks of properties in a general sense, no matter if these pertain to real or fictional objects. Since individuals can be either real or fictional, and since the same holds for properties, we can represent this as a fourfold: 1) real individuals, 2) real properties, 3) fictional individuals, 4) fictional properties. This is similar to, though not identical, to Harman's fourfold: 1) real objects, 2) real qualities, 3) sensual objects, 4) sensual qualities.

Recall that Bunge claimed in the *Treatise on Basic Philosophy* that "it is impossible to make any nontautological statements applying to all objects" and that for this reason it would be impossible to conceive a general theory of objects distinct from logic. However, none of the definitions and axioms that he advanced decades later in *Matter and Mind* are tautological. Consider his *Definition 1* and his first three axioms: "*Definition 1* Every object is either an individual or a property", "*Axiom 1* No object is both an individual and a property", "*Axiom 2* All individuals have at least one property", and "*Axiom 3* Every property is possessed by at least one individual" (Bunge, 2010: 268). This seems like additional evidence for our suggestion that during the thirty-three years between the third volume of the *Treatise* and the publication of *Matter and Mind*, Bunge changed his point of view on the possibility of general theory of objects.

We must examine Bunge's and Harman's quadripartite distinctions in more detail, because there are some key differences between their philosophies on this point. According to Bunge, fictional objects are brain processes. As such, they can only be found in living animals endowed with nervous systems. They do not have an autonomous existence. Thus he says:

> For example, the Pythagorean theorem exists in the sense that it belongs in Euclidean geometry. Surely it did not come into existence before someone in the Pythagorean school invented it. But it has been in conceptual existence, i.e. in geometry, ever since. Not that geometry has an autonomous existence, i.e. that it subsists independently of being thought about. It is just that we make the indispensable pretence that constructs exist provided they belong in some body of ideas—which is a roundabout fashion of saying that constructs exist as long as there are rational beings capable of thinking them up. Surely this mode of existence is neither ideal existence (or existence in the Realm of Ideas) nor real or physical existence. To invert Plato's cave metaphor we may say that ideas are but the shadows of things—and shadows, as is well known, have no autonomous existence. (Bunge, 1977: 157)

It might strike the reader as strange that Bunge mentions the Pythagorean theorem as an example of a fictional object. One could think, as Quentin Meillassoux (2008) does that mathematics is capable of disclosing the primary qualities of things. Thus, Meillassoux traces a distinction between mathematical statements and their referents. He says that the former are ideal, while the latter are real. Bunge thinks that all mathematical objects are fictional, no matter their complexity. Thus he says:

> The mathematical objects, such as sets, functions, categories, groups, lattices, Boolean algebras, topological spaces, number systems, differential equations, vector spaces, manifolds, and functional spaces, are not only *entia rationis*: they are *ficta*. (Bunge, 1997: 51)

If we had to express this idea using Harman's terminology, we may say that mathematical objects are not real objects, but sensual objects instead. What this means is that the number 3 or a differential equation, for example, cannot exist by themselves. They can only exist in relation to a real object: the person that is thinking about them. If the previous quote was, for some reason, insufficient for convincing the reader that Bunge is quite adamant about this point, then consider the following one:

> Mathematical objects are then ontologically on a par with artistic and mythological creations: they are all *fictions*. The real number system and the triangle inequality axiom do not exist really any more than Don Quijote or Donald Duck. (Bunge, 1985: 38–39)

Which is similar to the way in which Harman speaks about fictional characters such as Sherlock Holmes. Bunge reiterated the previous idea several decades later, so on this point, he did not change his mind:

> In short, mathematicians, like abstract painters, writers of fantastic literature, 'abstract' (or rather uniconic) painters, and creators of animated cartoons, deal in fictions. To put it into blasphemous terms: ontologically, Donald Duck is the equal of the most sophisticated nonlinear differential equation, for both exist exclusively in some minds. (Bunge, 2006: 192)

Initially, it could seem ridiculous to compare a sophisticated mathematical equation to a cartoon character like Donald Duck. But, as Jean-Pierre Marquis noted, that is not the case:

> Donald Duck is not the problem. And it is not *a priori* ridiculous to compare Donald Duck to mathematical objects with respect to their ontological status. It is, in fact, rather fashionable these days and has been for some time. It certainly goes in the right direction, but one has to travel carefully to avoid certain pitfalls. (Marquis, 2019: 590)

A greater pitfall than the ones that Marquis alludes to, as far as I am concerned, is the one that Meillassoux fell into in *After Finitude*, the pitfall of believing that mathematics can disclose the primary qualities of an object. Because, for that to be the case, mathematical truth would have to be absolute, not relative. Bunge is against that idea:

> Allow me to repeat a platitude: Mathematical truth is essentially relative or context-dependent. For example, the Pythagorean theorem holds for plane triangles but not for spherical ones; and not all algebras are commutative, or even associative. (Bunge, 1997: 53)

According to Bunge, no matter how simple or complex an idea is, it is entirely fictional, in the sense that it does not have an autonomous existence. Harman's point of view is similar, though not identical. No sensual object has an autonomous existence, it can only exist in relation to a real object. Thus, one of the basic principles of his object-oriented ontology is the following one:

> Objects come in just two kinds: *real objects* exist whether or not they currently affect anything else, while *sensual objects* exist only in relation to some real object. (Harman, 2018: 9)

Contrary to Bunge, Harman suggests that sensual objects are everywhere, not only in relation to animals with nervous systems, but even among inanimate objects such as rocks. This is because the concept of a sensual object is a more general notion than that of an idea. While all ideas are sensual objects, not all sensual objects are ideas. To understand this point better, we must discuss a key element of Kant's philosophy: the distinction between the phenomenon and the thing-in-itself.

Kant held that we cannot know what an object is as a thing-in-itself, we can only know it as a phenomenon. What this means is that it appears to us in a particular way, not only due to the specific nature of our five senses and their corresponding organs, but also due to the way in which our sensory experience is conditioned by the pure forms of intuition and the categories of the understanding. We cannot get rid of these in order to know what the thing-in-itself is, as a thing that is absolutely untainted and unfiltered by the senses and the mind. In other words, we know things through filters, and it is because these filters exist that the object of knowledge is a phenomenon, not an unfiltered thing-in-itself. Let us see what

Bunge thinks of the conceptual difference between appearance and reality:

> The perception of a fact is called a *phenomenon* or *appearance*. (In ordinary language 'phenomenon' is equated with 'fact': beware of the imprecisions of ordinary language.) There are imperceptible facts but there are no phenomena without sentient organisms. Appearance, then, is an evolutionary gain: it emerged together with the first animals equipped with nervous systems. Before them facts appeared to nobody: there was no appearance, there was only reality. Phenomena are facts of a special kind, namely facts occurring in nervous systems. So, *phenomena are real*. Consequently there is no opposition between appearance and reality. My seeing the Moon larger on the horizon than overhead is a fact no less than the two positions of the Moon: only, the former is a perceptual, hence *subjective*, fact, whereas the latter are *objective* physical facts. There is then nothing wrong with admitting phenomena alongside nonphenomenal (or transphenomenal) facts. The opposition is not between appearance and reality but between subjective facts or accounts and objective facts or accounts. (Bunge, 1983: 150–151)

Contrary to Kant, who believed that the distinction between appearances and things-in-themselves pertains only to human beings, and contrary to anthropocentric philosophers in general (or "philosophers of access" to use Harman's expression), Bunge does not reduce the concept of appearance to *human* appearance:

> We must define appearance, or the totality of phenomena, as the collection of all (actual or possible) perceptual processes in all animals past, present and future. (We may also specify and speak of human appearance, blue jay appearance, sardine appearance, etc.)." (Bunge, 1983: 153)

Appearances are different depending on the species of animals. In Harman's terms, there are different sensual objects for the same real object. The way a certain thing appears to a human being is different from how it appears to a blue jay, or to a sardine. For example, the way that an acorn appears to a blue jay is not the same as it appears to a squirrel, or to a human. Even though the real object is always one and the same—for it is always the same acorn—, there are many different appearances of it, depending on the animal that interacts with it: human appearance, blue jay appearance, squirrel appearance, etc. One thing-in-itself, many phenomena; one real object, many sensual objects. And these different appearances of the acorn are always limited versions of what the acorn really is as a thing-in-itself independent of the animals that encounter it. Or, to use Harman's terminology, these appearances are distortions, caricatures, translations, they are never as rich and fully featured as the real object.

The question here is if the distinction between the sensual object and the real object stops at the level of animals endowed with nervous systems, or if this distinction can be found everywhere, even among inorganic objects such as rocks and crystals.

> Philosophical discussions about inanimate objects can sometimes be more complicated than what one would initially expect. We began by recalling Kant's definitions of "phenomenon" and "thing-in-itself", he thought that these pertained exclusively to human beings. We then considered Bunge's redefinitions of these terms, since there can be many different appearances relative to different species of animals. Now we must philosophize about inanimate objects. As Iain Hamilton Grant wrote, with great wit: "Life acts as a kind of Orphic guardian for philosophy's descent into the physical" (Grant, 2006: 10).

Let us descend then, into the realm of the inorganic. One conclusion that Kant did not seem to explore enough is the following one: if the conceptual distinction between phenomenon and thing-in-itself is exclusive to human beings, then, in the absence of human beings, nonhuman entities must interact with each other as things-in-themselves. Consider the following example. When I perceive a raindrop that falls on my hand, I am not interacting with the raindrop as a thing-in-itself, but as a phenomenon, since I feel the raindrop through the filters and conditions of my sensory experience. But when a raindrop falls on a rock, the rock is not interacting with the raindrop as a phenomenon, it is interacting with it as a thing-in-itself. If we can only know external objects as phenomena, then in our absence these external objects must interact with each other exclusively as things-in-themselves.

It seems that Bunge would agree with Kant on this point, although he would not agree with Kant's anthropocentric definition of the terms "appearance" and "thing-in-itself". Nevertheless, Bunge seems to believe that inanimate objects interact with each other as things-in-themselves. Recall that he says that before the emergence of animals endowed with nervous systems "there was no appearance, there was only reality". Thus, when a raindrop falls on a rock, there is no "rock appearance" of the raindrop. There can only be a "human appearance" of the raindrop when it falls on a human being, or a "blue jay appearance" of the raindrop when it falls on a blue jay, and so on. But this never happens in the case of inanimate objects. For it is clear that a rock does not have a nervous system, so the raindrops that fall on it do not "appear" to it in any way.

By contrast, Harman claims that inanimate objects do not interact with each other as things-in-themselves, but as sensual objects. While all appearances are sensual objects, not all sensual objects are appearances. Therefore, if one agrees with Harman on this point, it is not necessary to claim that the raindrops that fall on a rock "appear" to it, it suffices to say that the raindrops interact with the rock as sensual objects, which is to say, as objects in a relation to it. And they are in a relation to it because, among other things, they fall from a certain direction: from above, not from the sides or from below.

Instead of defining the term "thing-in-itself" as a thing that exists independently of the way in which human beings interact with it, it can be defined as a thing that exists independently of the way in which other entities in general interact with it, not just human beings or other animals endowed with nervous systems. When I look at a bird flying through the sky, the bird exists independently of the fact that I am looking at it. But it also exists independently of the rocks on the ground, and of the trees that it flies over. For if it did not, then by removing the rocks and the trees, the bird would suddenly cease to exist. Things-in-themselves, or real objects, to use Harman's terminology, not only exist independently of human beings, they also exist independently of each other as well.

Similar considerations apply to the term "phenomenon". Instead of defining it as an object that exists in a specific relation to human beings, it can be defined as an object that exists in a specific relation to another object, not necessarily a human being or other animal. To use the example of the bird again. The bird exists independently of the fact that I am looking at it, but the specific silhouette of the bird that I see does not. If I only see the bird from the left side, then this specific profile or silhouette cannot exist independently of the observer that is looking at the bird from that specific angle. But the rocks on the ground are also in a specific relation to the bird, since they are below it. And notions such as above and below, left and right, are entirely relative. If I stand next to a tree, such that it is to my left, and then I turn around, so that it is to my right, then the tree as a thing-in-itself has not changed. But as a thing-in-itself, the tree cannot be either to the left or to the right "in itself", since it can only be to the left or to the right in relation to other things. The "tree to the left of X" or the "tree to the right of X" are examples of what Harman calls "sensual objects". They only exist in relation to a real object.

However, this does not mean that the many different silhouettes or profiles of the bird, or of a certain tree, or of any other object, are simply a bundle of qualities, as Hume and Berkeley argued. Harman argues that sensual qualities are always supported by an underlying sensual object. This idea was inspired by Husserl, and in particular by his critique of the "bundle of qualities" theory. Harman provides the following example:

> Consider the example of a snowmobile. What Husserl gives us is the new insight that the snowmobile is not just a bundle of snowmobile-qualities, but an enduring object that is different from the relatively small array of profiles or features that it shows in any given moment or any sum of moments. We see the snowmobile from one side or another, at a greater or lesser distance, speeding towards us or away from us, standing motionless or spinning wildly in a dangerous jump over a perilous crevice. In all of these cases, we consider the snowmobile to be the *same* thing, unless something happens to suggest that we have misidentified or confused it with a similar vehicle. In OOO terminology, Husserl splits the *sensual object* snowmobile from the *sensual qualities* of the snowmobile, since the former does not change but the latter change constantly. (Harman, 2018: 78-79)

The many different silhouettes of the bird that I see from different angles could not exist by themselves, without the bird as an object that is being viewed by me. When I stand next to a tree, either to the left or to the right, these are not simply relations and nothing more, they are relations between a certain object and myself.

3] Knowledge and the Thing-in-Itself

Another key difference between Bunge and Harman is that the former believes that it is possible for human beings to know the thing-in-itself, while the latter denies this. Here is what Bunge has to say on this issue:

> Yet, however insignificant appearances may be from an ontological point of view, they occupy a central position in epistemology. In fact, there is no way of gaining some deep knowledge about reality except by combining phenomena with hypotheses and processing both by reasoning. (Bunge, 1983: 153)

He then quotes several passages from William James. One of them sums up the general idea:

> Strange mutual dependence this, in which the appearance needs the reality in order to exist, but the reality needs the appearance in order to be known! (James, 1890: 301)

Harman does not believe that human beings can know the thing-in-itself. This may sound perplexing at first, but there is an argument for it. In order to address this issue, it will be useful to discuss Kant's point of view further. While Kant claimed that humans cannot *know* the thing-in-itself, he also claims that it is entirely possible for humans to *think* about things-in-themselves. Subsequent philosophers such as Hegel questioned this point, because in order to think about something, there has to be a thinker. Therefore, it is not possible to think of things-in-themselves, independently of humans, since this act requires the existence of thinking humans. In this specific sense, it is not the case that things-in-themselves do not exist, rather it is the case that it is impossible for humans to know what these things are independently of humans. So it is for blue jays and sardines. A blue jay cannot have a "blue jay appearance" of an acorn independently of the way that acorns appear to blue jays. A sardine cannot have a "sardine appearance" of a small crustacean independently of the way that small crustaceans appear to sardines. But what Harman suggests is that this situation should not be limited to appearances, he argues that the thing-in-itself cannot be accessed by any means. Practical relations, for example, do not give us access to a thing-in-itself any more than perceptual or theoretical relations do.

To use an example: when I look at a hammer, what is presented to my eyes is not the hammer as a thing-in-itself, what is presented to me is an appearance of the hammer. And, to use Bunge's terms, it should be emphasized that this is not any kind of appearance, but a very specific one, a "human appearance", to be distinguished from the kinds of appearances that would be presented to other animals. Now, if instead of simply looking at the hammer, I decide to pick it up with my hand and *use* it, this does not give me access to the hammer as a thing-in-itself either. Even in this case, the hammer is still related to a human, precisely because it is being used by one of them.

Furthermore, there are many things about the hammer that I do not know, no matter if I am looking at it or using it. If I do not know how to recognize different types of wood, then I will not know what type of wood the hammer's handle is made of. It could be oak, mahogany, or pine, among others. Merely looking at the hammer without any knowledge of the types of wood will not give me this information. But using the hammer will not give me this information either. And of course, this does not mean that the handle is not made from a specific type of wood, because it is. It merely means that I have no access to this information. So even though I might believe that I am using the hammer as a thing-in-itself, that is not exactly the case, because I ignore what type of wood the hammer's handle is made of. I am only interacting with a very limited version or distortion or caricature of what the hammer really is. In Harman's terms, I am interacting with the hammer as a sensual object, not as a real object.

We saw that Bunge claims that science is able to know the things-in-themselves. We also saw that he claims that mathematical objects are fictional, since they do not have an autonomous existence, we only feign that they do. In this sense, I argued that, using Harman's terminology, mathematical objects are not real objects, but sensual objects instead, which is contrary to Meillassoux's point of view. One question that can be asked at this point is: what about the empirical sciences? Mathematics alone cannot give us any knowledge of things-in-themselves, but surely the empirical sciences can, as Bunge claims. I believe that the problem with that point of view is that the objects that are studied by the empirical sciences are related to those sciences in a particular way, insofar as they are objects that are being studied. They are not entirely unrelated to, or disconnected from, the scientists that study them. However, this does not mean that those objects, insofar as they are real objects, do not exist independently of the scientists that study them. As real objects, they do exist by themselves, independently of humans. But insofar as they are being actively studied by a group of scientists at any given moment in time, they are sensual objects. Consider the following example, taken from Philip Kitcher:

> Start with a relatively simple situation. A behavioral biologist is observing a baboon troop. Over a period of several hours he records the episodes in which one of the animals grooms another, carefully noting the names of the animals (who groomed whom) and the time interval through which grooming occurred. Each entry in the note-book records the perceptual acquisition of a belief. Focus on any one. The observer is initially scanning the troop. He sees the male he calls "Caliban" approach the female he calls "Miranda." There is a sequence of facial expressions and gestures, at the end of which Cal-iban crouches behind Miranda and plucks at her fur. Our biologist presses a button on his stopwatch and quietly moves to a position from which he can gain a better angle on the interaction. After a few minutes, Miranda shrugs and moves away. Another button on the stopwatch is pressed, and the biologist writes in the notebook, "Caliban—Miranda, 6:43." That notation serves as an extension of declarative memory, something from which the biologist can later retrieve the belief that Caliban groomed Miranda for a period of six minutes and forty-three seconds." (Kitcher, 1993: 222)

We feign that mathematical objects exist independently of the people that think of them, and in a different sense we also feign that the objects studied by the empirical sciences exist independently of the people that study them. In the case of mathematical entities, these are brain processes that do not have an external referent, but in the case of the objects studied by the empirical sciences, these do exist by themselves in the external world. But here is the point: if the behavioral biologist from Kitcher's example did not exist, then the baboons that he is observing would not be called "Caliban" and "Miranda". They would be male and female baboons, but they would not have names. That is not to say that they would not have specific features that distinguish them as individual baboons. As real entities, they exist independently of the biologist that is observing them. But they could not be called “Caliban” and “Miranda” if no one gave them those names.

4] Concluding Remarks

The idea that there can be a general theory of objects might seem absurd at first. As we have seen, Bunge did not agree with this idea when he published *Ontology I: The Furniture of the World*. However, he changed his mind several decades later, when he developed a general theory of objects in an appendix to *Matter and Mind*. To my knowledge, that theory has not been further developed.

It is my belief that anyone who wishes to further elaborate Bunge’s general theory of objects can greatly benefit by studying Harman’s works. I also believe that anyone who wishes to further develop object-oriented ontology can greatly benefit by studying Bunge’s works. There are key differences between these thinkers, but they also have important things in common.

One point that will be worthwhile to explore in future works is a comparison between Bunge and Harman regarding the terms “matter” and “materialism”.

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Causation According to Mario Bunge and Graham Harman

Martín Orensanz[1]

Abstract — Imagine a billiard table, with several red billiard balls. Suppose that one of them impacts another. It could be claimed that the first billiard ball, the cause, makes direct contact with the second one, the effect. If we had to generalize this for all things, not just billiard balls, we would say that "thing A causes thing B". As we shall see, both Bunge and Harman reject the preceding view of causation. They would agree that the statement "thing A causes thing B" is false. This is because things do not make direct causal contact with each other, there has to be a third element that links them. In Bunge's case, two things are linked by events. In Harman's case, two real objects are linked by a sensual object.

Résumé — Imaginez une table de billard, sur laquelle se trouvent plusieurs boules de billard rouges. Supposons que l'une d'entre elles en percute une autre. On pourrait prétendre que la première boule de billard, la cause, est en contact direct avec la seconde, l'effet. Si nous devions généraliser cela pour toutes choses, pas seulement pour les boules de billard, nous dirions que « la chose A cause la chose B ». Comme nous le verrons, Bunge et Harman rejettent tous deux la conception précédente de la causalité. Ils s'entendent pour dire que l'affirmation « la chose A cause la chose B » est fausse, parce que les choses n'entrent pas en contact causal direct ; il doit y avoir un troisième élément qui les relie. Dans le cas de Bunge, deux choses sont liées par des évènements. Dans le cas d'Harman, deux objets réels sont liés par un objet sensuel.

1] Causation According to Bunge

Bunge wrote on causation throughout his career. The first systematic treatment of this issue can be found in his book *Causality: The Place of the Causal Principle in Modern Science.* He returned

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to this topic in subsequent works. His general idea is that causation is a relation between events, not things. Thus, in *Chasing Reality*, he says:

> We start by making the usual if sometimes tacit assumption that the causal relation obtains between events (changes of state in the course of time), not between things or their properties. A simple classical example is Hooke's law: The strain or deformation of an elastic body is proportional to the applied tension or load. Because only events can cause, we must disallow such expressions as "Gene *G* causes trait *T*" and "Brain causes mind." We should say, instead, that the expression or activation of gene *G* causes it to intervene in the biochemical reactions resulting eventually in the emergence of phenotypic trait *T*. (Bunge 2006, p. 90)

In other words, things-in-themselves do not causally relate to each other directly, they do so indirectly, by way of events. I believe that this point should be emphasized, because it has often been overlooked by Bunge's readers, including myself. In another article published in this volume, I argued that according to Bunge, inorganic objects interact with each other as things-in-themselves. I realize now that my claim about Bunge was wrong, since he claims that causation is not a relation between things, but between their events. It was only through my reading of Graham Harman's works that I gained a better understanding of Mario Bunge's concept of causation. Given Harman's idea that causation is not a direct relation between two real objects, since it requires a sensual object that functions as a link, I had set out to compare that idea to Bunge's concept of causation. My question at that point was a simple one: would Bunge agree with Harman on this issue, or would he disagree? I had supposed that the latter was the case, but I was surprised to find out that it was the former.

But what was more surprising was the fact that I had overlooked Bunge's entire point about causation: that it is not a relation between things-in-themselves, but between their events. Even though Bunge's point may sound trivial, since it appears to be a simple technicality, that is not the case. What is at stake here is no small matter, since his concept of causation provides the answer to the following crucial ontological question: in the absence of humans and other animals endowed with nervous systems, do inorganic objects interact with each other as things-in-themselves? The answer is no, they do not. They can only relate to each other indirectly, through some kind of link, which, in turn, is not a thing-in-itself.

A change, according to Bunge, can be either an event or a process. He defines an event as an instantaneous change of state, while a process is a series of events. For this reason, sometimes he speaks of causation as a relation between events, as in the preceding quote, and at other times he is more precise, defining causation as a relation between changes, which can be events or processes. The following is an example of this:

> To hold that "brain processes cause consciousness," as Searle [...] does, is like maintaining that bodies cause motions, or that the gut causes digestion. Things do not cause processes: they undergo processes; and these in turn cause changes (events or processes) in other things. Shorter: the causal relation holds only among changes (events and processes). (Bunge 2006, p. 90-91)

Bunge's critique of Searle and of other philosophers of mind consists in showing that they do not have an adequate ontology. Causation, according to Bunge, is an ontological concept, and it is difficult to develop an adequate account of it without a general ontological framework. Thus, in *Matter and Mind*, he says:

> Other philosophers of mind are not so much narrow-minded as confused for lack of a broad and clear ontology. Thus John Searle [...], who has published extensively on this subject, tells us that he opposes both materialism and psychoneural dualism. Yet he also claims that mental states are *caused* by brain processes at the neuron level. States of one kind caused by processes of another? This talk of upward causation sounds dualistic to me. Moreover, it is reminiscent of the nineteenth-century vulgar materialist Karl Vogt, who famously claimed that "the brain secretes thought just as the liver secretes bile." There is an elementary ontological confusion here: By definition, processes are sequences of states, and only events are supposed to cause events [...]. For instance, not LSD by itself, but taking LSD, causes hallucinations. (Bunge 2010, p. 144-145)

The example of LSD mentioned at the end of the preceding quote is noteworthy. Clearly, the drug by itself, laying idly on a table, does not cause hallucinations. It has to be taken by someone for that to occur. Likewise, it may be said that a glass of water by itself does not quench thirst, drinking the water does that. A red billiard ball laying idly on a billiard table does not cause another one to move, it must undergo a change in order to do that. This being so, we can see why the statement "thing A causes thing B" is false, since causation is not a direct relation between things. Compare that statement to the definition of causation that Bunge offers in *Chasing Reality*:

> Definition 4.1 Event *C* in thing *A* causes event *E* in thing *B* if and only if the occurrence of *C* generates an energy transfer from *A* to *B* resulting in the occurrence of *E*. (Bunge 2006, p. 90-91)

One could formulate a possible objection here: if there is an energy transfer from A to B, as the preceding definition states, then there is a contradiction, because that energy transfer is occurring between things (A and B), not between events (C and E). My reply to that possible objection is that the energy transfer from A to B can only occur by means of C and E, so there is no contradiction. Bunge offers some additional clarification on this point:

> The concept of energy may be used to define that of causation, and to distinguish the latter from correlation. Indeed, causation may be defined as energy transfer, as in the cases of the light beam that burns a dry leaf or activates a photocell. (In both cases the cause is light absorption, not light; likewise, the effects are processes: combustion in the first case, and electron emission in the second. To generalize, the relata of causal relations are events or processes.) (Bunge 2010, p. 66)

If in doubt, consider the following example. Imagine that a thing "A" does not undergo any changes, all of its energy remains within it. And imagine that a thing "B" does not undergo any changes either, it does not receive any energy. How is energy suppose to flow from thing "A" to thing "B" if they do not undergo any changes at all? It can only be transferred from one thing to the other if these things undergo changes. Thus, when thing "A" transfers energy and thing "B" absorbs it, both things have undergone changes, and it would be impossible for the energy transfer to occur directly, that is, from "A" to "B" without the changes "C" and "E".

2] Causation According to Harman

We will now consider Harman's view of causation. He addressed this problem at length in *Guerrilla Metaphysics*, and he continued to refine this notion throughout his subsequent works. Harman does not deny that real objects interact with each other. What he denies is that they do so directly, since there has to be something that links them. Bunge would agree, since he says that causation is not a relation between things, but between their events. Thus, in O*bject Oriented Ontology: A New Theory of Everything*, Harman says:

> Since real objects exceed the grasp not only of all human theory, perception and practical action, but of every sort of direct relation, then I wonder how it is possible for one entity to influence another in any way. Obviously, I do not question the existence of such influence, but only wonder about the mechanism behind it. (Harman 2018a, p. 150)

The mechanism in question, according to Harman, is that a sensual object functions like a vicar or an intermediary for the causal relation involving two real objects. Let us remember that, in Harman's terms, real objects exist in themselves, not only independently of humans, but also independently of each other as well. By contrast, sensual objects can only exist in relation to a real object. Consider the example he offers of a red billiard ball that impacts a blue one:

> We now have the basic OOO model of the cosmos: it is packed full of objects that withdraw from each other, incapable of direct contact. Here we encounter another aspect of this philosophy that many critics find hard to swallow. For is it not obviously the case that objects influence each other all the time? Does science not calculate these interactions with extraordinary precision, using the results to make badly needed medical devices and launch probes deep into the solar system? OOO is aware of this, of course. Its point is not that objects do not make contact, but that they cannot do so *directly*. In an obvious-looking case such as two billiard balls colliding on a table, the collision obviously occurs; we do not dispute this point. But as seen from the OOO reading of Heidegger's tool-analysis, the collision of these balls is really a question of both balls interacting only with the most superficial features of each other.

> When the red ball strikes the blue ball, it is not striking the blue ball itself, but only a translated blue ball accessible to the red ball's fairly impoverished world. By way of these impoverished blue-ball-features, the red ball makes indirect contact with the blue ball itself, which also makes contact with its own blue-ball-features, though in a different way. It is a question of indirect causation or, as OOO calls it, *vicarious* causation. (Harman 2018b, p. 127)

Thus, according to Harman, a real object can indeed interact with another real object, but not directly, only by means of a sensual object. Causation, according to him, is not only vicarious, but also buffered and asymmetrical. I cannot discuss the details of these characteristics here because it would involve a more thorough discussion of Harman's philosophy in general, and it would be necessary to examine other key concepts of his philosophy that I have not mentioned yet, but that pertain to his view of causation, such as allure and black noise, among others. I plan to address this issue in more detail in a future publication. For now, it should be noted that one of the fundamental features of vicarious causation is that it always creates a new object. Consider the example of two airplanes that crash into each other:

> When two fighter planes collide at an air show, we think that their impact caused damage so severe as to lead to the crash and explosion of both. But according to the model just sketched, this is merely a 'retroactive effect on its parts' of a larger collision-entity, to which we never pay attention because it lasts so briefly and takes on little or no physical form. (Harman 2010, p. 13-14)

If we analyze this example by distinguishing a series of phases, we may say the following. Initially, both planes, "A" and "B", exist separately from each other. Then the crash occurs, what happens here is that plane "A", as a real object, encounters a limited or sensual version of plane "B", and in addition to this, the encounter generates a new real object, "C", which contains the real plane "A" and the sensual plane "B". This new object "C" is the collision itself, the "situation", if you will. It lasts for a brief moment, but it is still real. In the final stage, the collision as a new object interacts with the two real planes, but not directly, it does so by way of a sensual version of plane "A" and a sensual version of plane "B", and through these intermediaries, it affects the real plane "A" and in the real plane "B".

3] Concluding Remarks

Despite the fact that Bunge and Harman disagree on some specific issues regarding causation, they agree on a more general and fundamental point: that it is not a direct relation between things-in-themselves, since it requires the existence of a link between those things, and that link is not a thing-in-itself.

What Bunge calls an "event" meets the criteria for being classified as a sensual object, because he thinks that there are no events in-themselves. What he means by this is not that events do not exist independently of human beings, since he says that they do. Rather, he uses the term "in-itself" as a synonym of "by-itself". There are no events in-themselves because they cannot exist by themselves, independently of things. Every event is a change of state of a thing. In other words, there are no thingless events.

I encourage other readers of Bunge to take notice of the profound ontological consequences that his concept of causation has. In general, when thinking about the concept of the thing-in-itself, we tend to differentiate this notion from the concept of phenomenon, surely due to the influence of Kant. This being so, we take it for granted that before the emergence of the first animals endowed with nervous systems, "there was no appearance, there was only reality", as Bunge (1983, p. 150-151) says. But this does not automatically mean that, before the emergence of those animals, things-in-themselves were causally relating to each other directly, since they were doing so indirectly, by way of events.

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Bunge's Metascience and the Naturalization of the General Discourse

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Abstract — We will explain why the *Treatise on Basic Philosophy* is a metascientific work and not a philosophical one. We will then argue that this meta-science is part of a long process of naturalization of thought that begins at the end of the Middle Ages to give birth to the scientific thought of the study of the world. For Bunge, naturalization takes the form of the naturalization of the general thought which makes it possible to replace philosophical general discourse with scientific general discourse. Finally, this naturalization of general discourse should not be confused with the projects of naturalization of philosophy, in particular one of many projects of scientific or naturalized metaphysics known as ontic structural realism.

Résumé — Nous expliquerons pourquoi le *Treatise on Basic Philosophy* est une œuvre métascientifique et non pas philosophique. On soutiendra ensuite que cette métascience s'inscrit dans un long processus de naturalisation de la pensée qui débute à la fin du Moyen Âge pour donner naissance à la pensée scientifique de l'étude du monde. La naturalisation prend la forme chez Bunge d'une naturalisation de la pensée générale qui permet de remplacer le discours général philosophique par le discours général scientifique. Finalement, cette naturalisation du discours général ne doit pas être confondue avec les projets de naturalisation de la philosophie, notamment un des projets de la métaphysique scientifique ou naturalisée connu sous le nom de réalisme structurel ontique.

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[…] though young and far from guaranteeing success, the scientific point of view is the best because it is the most demanding and the most open of all.

MARIO BUNGE

From a Scientific Point of View

Following a discussion with Gerardo Primero, one of the administrators of the Facebook group *Lectura y análisis de las obras de Mario Bunge*[2], we think it is necessary to provide some clarification as to our interpretation of Bunge's thought. The scientific general discourse we propose is virtually extracted from the Bungean system, but to do so we must redefine the boundaries between the disciplines traditionally associated with philosophy. What for? We wish to dissociate the scientific general discourse from any transcendent discourse, whether philosophical, religious or mystical, to the extent that we adopt the scientific point of view concerning knowledge of the world. Once recognized that the best knowledge of the world is that produced by the sciences[3], philosophical doctrines no longer have any use, because at that moment the scientific general discourse takes science for granted and does not seek to found it philosophically, metaphysically, logically, or in any other way[4].

That said, it is true that Bunge wishes to inscribe his thought in the philosophical tradition, while we propose an interpretation of his thought that would rather place him in a metascientific framework. This metascience is not our own; it is inscribed in the work of Bunge. This metascientific mark in Bunge is not found in an isolated passage of a little-known article from a little-known journal; it runs through the whole work and structures Bunge's *magnum opus*, the *Treatise on Basic Philosophy*. It is then necessary to extract this metascience from Bunge's work, but to do so we cannot

[2] Some of Bunge's leading scholars frequent this group, including Gustavo Romero, author of *Scientific Philosophy*. Although the group's exchanges are mostly in Spanish, we can express ourselves in English.

[3] For a defense of this position, known in philosophy as scientism, see in this issue the article by Andrés Pereyra Rabanal, "Scientism after its Discontents", as well as the chapter "Scientisme méthodologique" from *Sociologie fondamentale* by Dominique Raynaud (2021).

[4] Science essentially *produces conceptual* or *propositional* knowledge, but there is also *sensorimotor* knowledge and *perceptual* knowledge (Bunge 1983, p. 72, Romero 2018, p. 52).

rely on Bunge's conception of his own thought since he tries to situate it within the limits of philosophy, while if we dwell on his results, it appears quite quickly that the Bungean discourse has nothing in common with philosophy but the name. Bunge's discourse about his own writings does not reflect the results achieved by his practice. In other words, if we focus on what Bunge does and not on what he says, it appears that his practice is moving away from philosophical practice. With regard to the Bungean ontology, we have demonstrated this in our article "What is Metascientific Ontology?" in this issue.

We will try in what follows to generalize this idea: doing does not follow saying in Bunge. We will first propose a metascientific reading grid of the *Treatise*. We will then put forward the idea that the Bungean approach is part of the process of naturalization of thought that goes back to the very beginning of modern science. Finally, this Bungean naturalization should not be confused with recent attempts at naturalization of metaphysics.

1] Metascience in the *Treatise*

Bunge has always defended the idea that philosophy should be practised *with* or *in* science, while supporting a traditional division of philosophical fields. Yet, with Bunge, philosophy is only about science, even if he claims something else. The situation is complicated because Bunge uses both the expressions "philosophy" and "philosophy of science", even though he does in his own way *only* philosophy of science or, even better, metascience. Thus, the title of his *magnum opus*, *Treatise on Basic Philosophy*, and titles of the volumes which compose it, *Semantics I* and *II*, *Ontology I* and *II*, *Epistemology and Methodology I*, *II* and *III*, this book III having for subtitle *Philosophy of Science and Technology*, then finally *Ethics*, suggest that he will expose a complete philosophical system composed of semantics, ontology and epistemology, to then develop a philosophy of science and technology, to finally crown it all with an ethical theory, which is indeed a traditional division of philosophy into theoretical philosophy and practical philosophy.

In fact, Bunge's semantics, ontology, and epistemology address, among other things, but not exclusively, problems that usually fall within philosophy of science, and the two volumes devoted to the philosophy of science extend and apply to physics, chemistry, psychology and the social sciences, the results obtained in the previous volumes. Thus, in these two volumes devoted to philosophy of science, Bunge discusses principles or postulates specific to the sciences he examines, principles that would not have been the subject of an analysis in the first six volumes, such as the principle of correspondence in physics; he attempts to elucidate certain concepts that are the subject of debate, such as that of biological species, or he reports on scientific results using the concepts of the first six volumes, which means that it provides the sciences with a common vocabulary[5]. However, the results of the first six volumes of the *Treatise* were obtained by a reflection on the sciences and by an analysis of them. He thus practices from *the outset* a philosophy of science, which means that the expression "philosophy of science" is redundant in Bunge. In other words, Bunge does not propose a priori semantics, ontology or epistemology that would precede his philosophy of science. Bunge does not have a philosophical doctrine that would support its semantics, ontology, epistemology, philosophy of science, and ethics. Bunge deals only with science because his "philosophy", that is, his semantics, ontology, and epistemology, are designed from the beginning to account for science through the study of scientific constructs.

We then consider that the ethical theory of the *Treatise* is independent of the semantics, ontology and epistemology that precede it. For us, ethics, like axiology and praxeology, is part of a *general discourse of convivence* or living together, a discourse independent from a scientific general discourse (Maurice 2020). A metascience is not an attempt to bring together under the same name knowledge and convention. Moreover, Bunge does not establish any logical, philosophical, or metaphysical link between the ethics of volume 8 and the scientific general discourse that precedes it in the first seven volumes of the *Treatise*. If an ethics want to be reasonable, rational and humanistic, it will surely use results from science and metascience, which Bunge does not hesitate to do in volume 8 of the *Treatise* on ethics.

[5] In fact, this vocabulary can be used in any rational and objective discourse, whether in technology, ethics, management, law, etc. For an example of the use of this vocabulary and associated concepts in the field of information technology, see in this issue the article by Roman Lukyanenko, Veda C. Storey, Oscar Pastor, "Foundations of Information Technology Based on Bunge's Systemist Philosophy of Reality".

Thus, the apparent division of philosophy in Bunge does not reflect his practice. The real boundary lies between a scientific general discourse and a general discourse of convivence, two discourses that Bunge brings together, like philosophers, under the expression "philosophy", and this scientific general discourse in Bunge does not distinguish a "first philosophy" from a "philosophy of science" since this discourse is based on the same postulates as those of the sciences and is built on the conceptual results of the latter. Bunge does not question science, he studies it, in the same way that scientists do not question the world, they study it. One of the most striking examples is his refusal to postulate metaphysical entities or properties, as we indicated in our previously mentioned article on Bungean ontology. Bunge relies on the sciences as to what exists.

In summary, the semantics, ontology, and epistemology from the first six volumes of the *Treatise* are *general metasciences*, while volume 7, which deals with physics, chemistry, biology, psychology, and sociology, exposes *particular metasciences*: metaphysics[6], metachemistry, metabiology, metapsychology and metasociology. This metascience, which lies at the heart of the *Treatise*, is the naturalization of human thought and the naturalization of the general discourse, a naturalization that should not be confused with the various attempts at naturalization in philosophy.

2] Naturalization of the General Discourse

Bunge's thinking is part of this long process of developing a reasonable, humanistic, rational, and practical approach to study the world, including human beings. This process was born at the end of the Middle Ages, gained momentum in the Renaissance, accelerated during the Scientific Revolution, and imposed itself in the Age of Enlightenment[7]. We are, of course, talking here about the birth and rise of modern science. As the factual sciences developed, general questions found themselves in the hands of philosophers, who steered questioning and results into a transcendent mode. Now,

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[6] We have redefined metaphysics as the metascience of physics. For details of our classification of the metasciences see our article "Metascience: for a Scientific General Discourse" (2020) published in the first issue of *Metascience*.

[7] The Greeks had begun such a process, but it aborted at the end of the Hellenistic period or at the beginning of the Roman Empire. The history of the naturalization of human thought is told by Gaukroger in the first three volumes of his tetralogy *Science and the Shaping of Modernity* (Gaukroger 2006, 2010, 2016).

why didn't any thinker long before Bunge offer a non-philosophical approach to general discourse? We believe that science (and many other sectors of activity) was not mature enough before the nineteenth century to be able to see clearly. For example, physics as we know it today took shape in the early nineteenth century, during the period that some authors call the second scientific revolution (Cohen 2015, pp. 269-278, Kuhn 1961, Morus 2005, p. 6). It was during this same period that several other disciplines acquired individuality as well as autonomy through their divorce from natural philosophy, at least through their rejection of what was still transcendent in natural philosophy, in particular the search for a philosophical theory of matter which was to be the ontological foundation of all disciplines, like the vitalist one of Aristotle, or the mechanistic one of Descartes.

In other words, it is not possible to study an object if it is not well developed. For example, a star can only be studied once it has formed. On the other hand, we can study the formation of a star. In the same way, one could not study science in the manner of Bunge, metascientifically, before it had taken a certain form, the one that we have known about it since the second half of the 19th century. Everything that precedes this period is part of the formative period of science. Just as a protostar is studied in one way and a star is studied in another way, a protoscience is not studied in the same way as a science. This situation suggests that there are diachronic metasciences and synchronic metasciences. There is the study of the formation of scientific constructs through time and the study of scientific constructs at a given time. We must therefore pay attention to the idea, which we have also supported, that the history of science can serve as a "laboratory" for metasciences. A thorough reflection is necessary to clarify the meaning of this proposal, especially when we know that historical anecdotes or "case studies" have served just as well to defend a utopian vision of science as to affirm that anything goes in science.

The sciences, that is, the conceptual products of the sciences, but also the ways of thinking about the world, must have reached a certain stage of development to allow a metascience to be constituted. A metascientific is interested in the study of the *conceptual* *framework* of science at a given time or its changes over time[8]. We must be careful about using our analogy since a star is a concrete object and science is a construct. A concrete object changes because it is endowed with energy, while a construct is replaced by another. In the strict sense, a construct does not change. It should also be noted that it was not only the factual sciences that had to reach a certain level of development in order to allow the birth of the metasciences, but also the formal sciences. Like the sciences, the metasciences can use logic and mathematics to formalize ideas, but modern formal logic and mathematics most useful to metascience did not appear until the late nineteenth century, for example set theory and group theory[9].

Thus, general thinking in Bunge is part of this long process of naturalization of human thought, and by the same token of naturalization of knowledge of the world. How to think about the world in a natural way? Over the past few centuries, the factual sciences have focused on developing a way of *thinking about the natural world in a natural way*. In other words, it is not enough to discourse on the natural world for a discourse to be naturalized, since philosophical, religious, and mystical doctrines discuss the natural world in a transcendent framework. It is also necessary that the modes of thought of a discourse be natural, that they do not appeal to supernatural faculties that would give access to a transcendent reality more fundamental than the concrete reality, or that they do not appeal to non-standard methods such as philosophical intuition (whose nature varies from one doctrine to another).

That said, the modes of reasoning accepted in the formal sciences and factual sciences are not limited to logical and deductive reasoning, but also include investigative strategies, heuristics, analogies, methods, and techniques specific to each discipline, etc. On the other hand, even if science cannot be reduced to logic, there are logical conditions necessary for scientific activity and for any rational activity. Some fundamental principles and logical rules have been used for centuries, even millennia, without which any rational discourse would be impossible. We think of the principle of non-

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[8] On the Bungean notion of conceptual framework, see our article "What is Metascientific Ontology?" in this issue.

[9] For examples of formalization in metascience see the first four volumes of Bunge's *Treatise on Basic Philosophy* (1974a, 1974b, 1977, 1979).

contradiction and inference by *modus ponens*: “Even if the works of logic are constantly progressing, the logical rules are stable: the syllogism ($p \subset q \subset r$) or the *modus ponens* ($p \supset q$, $p = q$) have never changed over time, and are as valid today as they were in Aristotle’s time” (Raynaud 2021, p. 412). Another necessary condition for scientific activity, but this time empirical, is the confrontation of statements against the world. Here we see the two modes of naturalization at work in the factual sciences. The objects of study of the factual sciences must be *natural* or concrete objects, not “metaphysical objects”, and the study of natural objects must be done with the help of *natural faculties*, such as reflection and reasoning, from which stem the use of proven standard rules, such as the confrontation of ideas with reality and the use of elementary logical rules. It is this union of the two modes of naturalization that was the great success of the scientific revolution and that characterizes the Bungean approach to general discourse.

This process of naturalization of knowledge has not been done in a linear way. Not only did the new scholars have to fight the Aristotelians, the Platonists, the Stoics, the scholastics, and some religious (not all, since many religious welcomed the idea of getting rid of Aristotle), they also had to debate among themselves the various possible approaches. Should they favor a very empirical, Bacon-style approach and collect only data? Should they favor a mathematical approach? A theoretical approach, but without mathematics? Should they trust experiments? Did the new instruments of observation, microscope, telescope, scale, etc. distort reality or did they help us to study it better? Are the classifications of natural objects or phenomena relevant? How to approach the human? Study the body? Study the spirit? Both at the same time? Everything was on the table because (almost) everything had to be done. In the end, scientists favored an eclectic approach by adopting any technique or method that could help study the world. Scientists have long practised “methodological pluralism”[10], or, more simply, developed over time various ways of apprehending the world.

[10] In philosophy and the social sciences, methodological, epistemic or scientific pluralism is used to justify attacks on science on the pretext that science has a narrow view of scientific practice. Scientists did not wait for philosophers and gurus of cultural studies to diversify their ways of doing things. Even a cursory reading of the history of science shows that scientists, far from being conservative in their practices, are multiplying the ways of thinking about the world. Chemistry and

Thus, scientists have developed an approach to think about the world without appealing to transcendence, and now metascientists, following Bunge, can think about science and the world in general without appealing to transcendence. We can see Bunge's approach as the naturalization of the general discourse on the world and on science, but this naturalization does not constitute a reduction of the general discourse to the factual sciences, and even less to the natural sciences alone, as is the case for some naturalization projects in philosophy. It is not a question of transforming metascience into a factual science, as some philosophers have wanted to transform epistemology into psychology or ontology into physics. Metascientific ontology and epistemology, like philosophical ontology and epistemology, are not factual sciences. The former, because they study scientific constructs and not concrete objects, the latter, because they are interested in transcendent or metaphysical objects.

There is naturalization of general discourse in Bunge because there is a rejection of the unnatural way that philosophers think, and not because metascience studies natural or concrete objects. But this naturalization implies that there is an adoption of the general postulates of science from the outset. Again, metascience does not study the concrete objects of the world, but the constructs used by science to represent these objects. Metascientific results, in turn, make sense only if they are based on the same general assumptions on which scientific results are based[11]. Thus, metascience, like Bunge, thinks from a scientific point of view[12].

General scientific or metascientific postulates are not *a priori* philosophical postulates, although the former are equated with the latter, which makes philosophers, including Bunge, say that scientists do philosophy without knowing it and, therefore, that science is based on philosophical postulates and that it is up to philosophers to analyze these postulates in order to ensure a true *foundation* for science. The general postulates of science and metascience are

biology, as well as psychology and the social sciences, could not have emerged from the dominant mechanistic paradigm of the seventeenth century without the existence of several modes of investigation and several criteria for evaluating ideas, including that of confronting them with reality.

[11] For examples of general postulates see our article "Metascience: for a Scientific General Discourse", published in *Metascience*, n° 1-2020.

[12] A book by Bunge is entitled *From a Scientific Point of View* (2018).

hypotheses that we make based on both our experience of the world, including our scientific experience of the world, and our reflections on it. These are non-testable assumptions, but they can be abandoned if they prove useless or frankly harmful to science. If we want to keep the notion of foundation, we can either characterize it by associating it with metascientific practice, and then metascientific research is foundational research, or, more prosaically, following Bunge, we can assert that the only foundation for scientific knowledge is reality.

We must specify that the reality in question is the concrete reality since among the philosophers who defend scientific realism and scientific metaphysics some affirm the existence of a metaphysical reality. Let us examine this new wave in the metaphysics of the sciences[13] to highlight the difference between this program of naturalization of metaphysics and that of a metascientific naturalization previously identified.

3] Naturalized Metaphysics?

Bunge's way of naturalizing general discourse differs from all the naturalization strategies that philosophers have resorted to. This is not surprising once one understands that Bunge does not believe in the existence of a metaphysical reality, a central aspect of Bunge's thought. Although Bunge formulates a conception of ontology or metaphysics in a similar way to philosophers, he differs from them in his practice, as we have shown in our article "What is Metascientific Ontology?" in this issue, a question to which we have returned in the first part of this article. His practice clearly demonstrates that he does not believe in any metaphysical reality and that he rejects all forms of transcendence. The rejection of a metaphysical reality implies that it cannot naturalize metaphysics using any of the naturalization strategies that philosophers have resorted to.

We will examine only one of these trends whose promoters have given it the name of *scientific metaphysics*. Bunge also uses this expression, notably in his article "Is Scientific Metaphysics Possible?" (1971), and we are interested in this trend because in principle it represents what is closest to Bunge's scientific metaphysics when we compare only Bunge's description of metaphysics with the description made by the authors of this trend. The practice of each

[13] The expression is from Soto (2015).

other will turn out to be very different. Our goal is not to make an in-depth critique of them, but to highlight the transcendent aspect of these doctrines, since they are, after all, philosophical doctrines, and to emphasize the difference in approach between the scientific metaphysics of these authors and the scientific metaphysics of Bunge. Hence, the same name can refer to really different activities.

In general, these philosophers do not question the existence of a metaphysical reality, unlike Bunge. The way to the naturalization of metaphysics is *using scientific results and practices to answer metaphysical questions*. This scientific metaphysics should not be confused here with philosophy *in* science examined in our article "When Philosophy is no Longer Philosophical" in this issue. The latter does, so to speak, the reverse of the new wave scientific metaphysics by *using philosophical methods to approach scientific problems*.

Thus, Kincaid, in the introduction to *Scientific Metaphysics*, briefly describes the conception of a scientific or naturalized metaphysics, a conception similar to what Bunge argues: "The thesis is that any legitimate metaphysics and conceptual analysis must be tied into the results and practices of the sciences." (Ross, Ladyman & Kincaid 2013, p. 1). This characterization is just as ambiguous as one of the characterizations used by Bunge: metaphysics *informed* by science. In our article "What is Metascientific Ontology?" in this issue, we have discussed what is vague in a characterization of metaphysics in general both in Bunge and in other authors. Here, we dwell on what is vague in a characterization of a scientific or naturalized metaphysics.

What does it mean to be "tied into the results and practices of the sciences"? Scientific results and practices are varied and diverse in nature. For example, in terms of practices, there are social practices, creative practices, methodological practices, heuristic practices, etc. With regard to scientific results, let us focus on two types among several: factual results and conceptual results. The results of an observation or experiment are factual results, such as the demonstration of the existence of atoms. Scientists also produce constructs, concepts, theories, classifications, etc., which form the conceptual results of science. Among thinkers of the different trends of naturalization in philosophy, it is not clear whether "being in agreement with science" or "being informed by science" refers to factual results, conceptual results, or both, or other types of results.

Kincaid is more accurate in his characterization of scientific metaphysics in the following passage. Scientific or naturalized metaphysics maintains:

> […] 1) an extreme scepticism about metaphysics when it is based on conceptual analysis tested against intuition, and about any alleged a priori truths that such intuitions and analyses might yield; and 2) the belief that scientific results and scientific methods can be successfully applied to some problems that could be called metaphysical. The conjunction of these two theses then provides some pressure for the stronger view that it is only by means of scientific results and scientific methods that metaphysical knowledge is possible, for it is not clear what third activity metaphysics might be if it is not conceptual analysis or scientifically inspired metaphysics. (Ross, Ladyman & Kincaid 2013, p. 3, our italics)

As for the first point, it is not enough to be skeptical, we must reject any approach that claims to appeal to a supernatural intuition to achieve a *priori* truths. The second point is just as problematic as the expression discussed above, although it is more precise. In the first place, we still do not know what "scientific results" refer to. Second, we don't know which "scientific methods" are used, especially since these methods (and the scientific results obtained by them) must address "metaphysical problems" or produce "metaphysical knowledge". But the meaning of "metaphysics" is unclear since no one understands what a metaphysical reality can be. If we exclude any form of *a priori* metaphysics based on a philosophical supernatural intuition, as this trend rightly requires, there is only one solution, that adopted by Bunge in his practice of metascience, to undertake analyses of scientific constructs (conceptual results), followed by metascientific syntheses (description, classification, contextualization, theorization).

If ontology is a conceptual science, then it does not study the *factual results* of science, but rather the constructs used and produced by science, such as a general postulate, a nomic statement (a law statement), a classification, a theory, etc. Care must be taken here not to confuse the conceptual analyses mentioned by Kincaid in the previous quote, with our conception of metascience as a conceptual science. If we paraphrase Kincaid, the results of *philosophical conceptual analyses* are tested using *philosophical intuition*, which would produce *a priori* truths. There is nothing more alien to the

Bungean approach than this "method" that has never been proven. Bunge's conceptual analyses are not those of philosophers. Bunge uses his natural faculties and standard methods to think, and if metascience is a conceptual science it is because it studies scientific constructs and not because it engages in conceptual analyses of a philosophical type.

This vague characterization of scientific metaphysics would cause little harm if the results of the new wave scientific metaphysics were not transcendent. After all, Bunge's characterization is just as vague, but its practice is clear, and it produces thoughtful and reasonable results. Take as an example Ladyman and Ross, possibly the two most prominent philosophers of scientific metaphysics. They are the authors of *Every Thing Must Go: Metaphysics Naturalized* (2007), a widely cited work. The authors defend *ontic structural realism*, which "has become the most fashionable ontological framework for modern physics" (Kuhlmann 2012). This doctrine claims that the thing, the concrete object, does not exist hence the expression "*every thing*" and not "*everything*" in the title of the book. Quantum and relativistic theories would rather indicate that there is "modal structures" between "phenomena" that exist[14]. Yet, to my knowledge, even microphysics researchers interact with objects endowed with energy like those studied using particle accelerators. This does not prevent the authors from asserting that "[t]he history of science undermines not only materialism and classical views of space and time, but also the claim that science describes the true objects that lie beyond the phenomena". (Ladyman & Ross 2007, p. 106)

It is true that the classical conception of space and time no longer holds, but neither science nor the history of science undermines the existence of objects "beyond phenomena", an expression just as misleading as that of "external world", associated with the fundamental philosophical dichotomy between appearance and reality (see the next paragraph). The refutation of materialism is based according to these authors on the strategy of attaching to certain thinkers a classic and obsolete conception of matter or concrete objects. In a

[14] The notion of a phenomenon here is that of philosophy, that is, "phenomenon" is synonymous with "appearance", which appears to consciousness. For common sense and science, "phenomenon" is synonymous with "fact", what happens in the world.

provocative style that we appreciate, the authors reject any "ontology of little things and microbangings" (Ladyman & Ross 2007, p. 4). We know that quantum objects are not small balls that collide with each other's (Bunge 2012, Lévy-Leblond 2003, 2006). In any case, even the objects accessible to our senses do not all obey the laws of classical mechanics: chemical substances, living organisms, social groups, etc. It is then easy to imagine that objects inaccessible to our senses may not obey these laws. The fact that objects do not obey the laws of classical mechanics, that they have properties that seem strange to us, and that we cannot form images of them does not imply that these objects do not exist or that they are unknowable.

In fact, from the outset, these objects inaccessible to our senses do not interest these authors, like most philosophers, since, according to them, the history of science and contemporary physics show that there are no objects beyond phenomena, beyond what is perceived by a conscious subject or beyond appearances. It is not the history of science or contemporary physics that prompts these authors to deny the existence of objects that interact with us, at least to be skeptical of their existence, but a fundamental philosophical position.

Ladyman and Ross, as philosophers, support the fundamental position of philosophy: they pose a dichotomy between appearance and reality. More precisely, as Raynaud put it well in another context, by "exploiting the idea that reality is not directly accessible" (Raynaud 2021, p. 419), that is to say by abusing an elementary observation, philosophers produce a fallacy that we have called the logicist fallacy (Maurice 2020). The absence of a *direct*, *necessary*, *metaphysical*, *logical,* or *philosophical* link between objects and what appears to consciousness makes philosophers suspicious of the existence of these objects. A classic formulation of this fallacy is that of Hume, taken up by the authors in the following passage:

> Scientific realism without a commitment to objective modality is unable to explain the success of science, because *there is no connection between unobservable entities and the phenomena we observe* other than constant conjunction in the actual world, and that doesn't explain anything. (Ladyman & Ross 2007, p. 123, our italics)

Since the authors claim to defend a variant of scientific realism and to explain the success of science, they must then reject the idea of constant conjunctions, because "that doesn't explain anything", but since the logicist fallacy excludes the existence of concrete, material stable links between objects and phenomena (what appears to consciousness), assuming that these objects exist since the history of science and contemporary physics would have demonstrated the non-existence of these objects, they then postulate the existence of "objective modalities" or "modal structures" that would give structure to otherwise messy appearances. These relationships and structures are fundamental in the metaphysical universe of Ladyman and Ross:

> […] there is a minimal metaphysical commitment that we think structural realism must entail. This is that there are mind-independent modal relations between phenomena (both possible and actual), but these relations are not supervenient on the properties of unobservable objects and the external relations between them. Rather, this structure is ontologically basic. (Ladyman & Ross 2007, p. 128)

In other words, there would be a metaphysical reality independent of the mind that structures phenomena (what appears to consciousness). The structural, modal, physical or mathematical relations[15] of this metaphysical reality connect the phenomena that appear to consciousness in a nomic way. What, then, is the difference between postulating concrete objects to account for appearances and postulating structures to account for them? Why would these independent structures, postulated by these authors, would have a link with the appearances, while the unobservable concrete objects, postulated by scientists, would not? This "minimal metaphysics" is at odds with their fundamental philosophical position of separating reality from appearances. In short, concrete objects are replaced by immaterial entities on the basis of an arbitrary dichotomy between appearance and reality and a sophism that concludes that there are

[15] No one agrees on the nature of these relations and structures. Thus, Ross and Ladyman write: "What makes the structure physical and not mathematical? That is a question that we refuse to answer" (Ladyman & Ross 2007). See Ainsworth's article, "What Is Ontic Structural Realism?" (2010), for a critical account of two variants of ontic structural realism, while proposing a third.

no links between concrete objects and phenomena they provoke in us.

If Ross and Ladyman didn't want to separate reality from appearances, they could simply change their conception of concrete objects! Instead of seeing them as marbles that collide with each other, they could include within concrete objects class all the objects studied by the sciences, from physics to sociology. But Ross and Ladyman argue that it is quantum theories and relativistic theories that indicate the existence of independent "structures". These theories do not attest to the existence of structures or even that of concrete objects. We cannot directly read these positions in these theories. It is through our experience of the world, including our experience of the world through science, and a reflection on this experience that we conclude to the existence of concrete objects in the same way that we conclude that there is no gap between reality and appearances.

We could try to defend the idea of concrete object by pointing out the fact that scientists reason in these terms. In fact, even the logico-mathematical formalism used by scientists is based on the notions of object and property (variable-object and predicate). However, the scientists' habits of thought and the thingness of formalism they use are not proof that they represent reality in the right way. On the other hand, our experience of the world and a reflection on it lead us to believe that scientific representations are adequate. If some people feel that this approach is not adequate, then they have the burden of proof. In the same way that logical positivists have attempted to rewrite scientific proposals in observational terms, ontic structuralists must rewrite scientific statements in a new formal language in order to replace predicate logic, set theory, and mathematics used by scientists. The new community of researchers who will use this new formalism will have to produce new results, that is, results that the traditional approach does not produce, otherwise the new formalism risks being only a formal equivalent of the old formalism without saying anything new about reality.

Ross and Ladyman's approach is typical of some philosophical approach that consists of establishing *a priori* desiderata to which a metaphysical system will have to submit. This is an exercise in consistency. In this case, the authors want metaphysics freed from concrete objects, but realistic, naturalistic, objectivist and non-reductionist physicalist. By proceeding in this way, we can actually elaborate many fairly coherent metaphysics, such as that of Plato, Aristotle, Descartes, Berkeley, Kant, Hegel, etc. The outcome will depend on, among other things, the thinker's "philosophical intuition", how he conceives of "common sense" and "scientific reasoning", what he thinks are the right ways to argue, including what he allows himself to use among existing scientific and technological theories, such as the theory of evolution and information theory in the case of the two authors who interest us here. Ross and Ladyman fiercely criticize *a priori* metaphysics, but it seems that they themselves have fallen into the traps of analytic metaphysics. They wanted to get rid of all the things in the world, but they should have started by cleaning up their intellectual toolbox, starting by rejecting the philosophical dichotomy between appearances and reality, and accepting the metascientific dichotomy between formal and concrete objects.

Thus, for Ross and Ladyman, contemporary physics studies immaterial structures. In fact, physics have no choice since it had itself demonstrated that concrete objects do not exist and that it had challenged materialism by the same token. What can a "naturalization" of metaphysics mean in this context? What should we think of those philosophers who postulate the existence of immaterial entities and who claim to support "scientific realism"? All the more reason to drop the use of -isms, even if it means using paraphrase to make oneself understood.

4] Conclusion

We have shown that Bunge's major work is a metascience, not a philosophy. Bunge does not propose a first philosophy on which his research in philosophy of science would be based. On the contrary, from the outset, Bunge reasoned within a scientific framework that he did not question and that he did not seek to found.

But this is possible because by rejecting the dichotomy between appearance and reality, Bunge rejects by the same token what makes philosophy philosophical:

> In the philosophical tradition appearance is the opposite of reality. This is mistaken, for an appearance is a process occurring in the nervous system of some animal, hence it is just as much of a fact as

> an external event. Appearances constitute just facts of a special kind […]. (Bunge 2003, p. 26)

Disagreement is not about direct access or not to reality, since we all admit it, philosophers, scientists, metascientists, and, indeed, anyone who thinks about the question that there is no such access[16]. Disagreement depends on the position taken to address what Dicken (2016) called the problem of coordination between objects and our conception of them, which will determine in which camp we are. If you are a philosopher, you will conclude that the lack of direct access to reality is a serious problem that alone justifies the philosophical project since its beginnings.

But, if we refuse the search for direct links between appearances and reality, especially associated with the rationalist project, or if we do not question the existence of objects or the knowledge of them, rather associated with the empiricist project, then there are no philosophical problems and by the same token there are no problems of foundation in science. On the other hand, there are metascientific problems. Thanks to Bunge's effort to naturalize the general thought, the philosophical general discourse was replaced by the scientific general discourse.

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[16] It can be argued that a direct link exists since the facts outside the brain are causally related to it and that there is therefore an exchange of energy. In other words, there is a concrete direct link.

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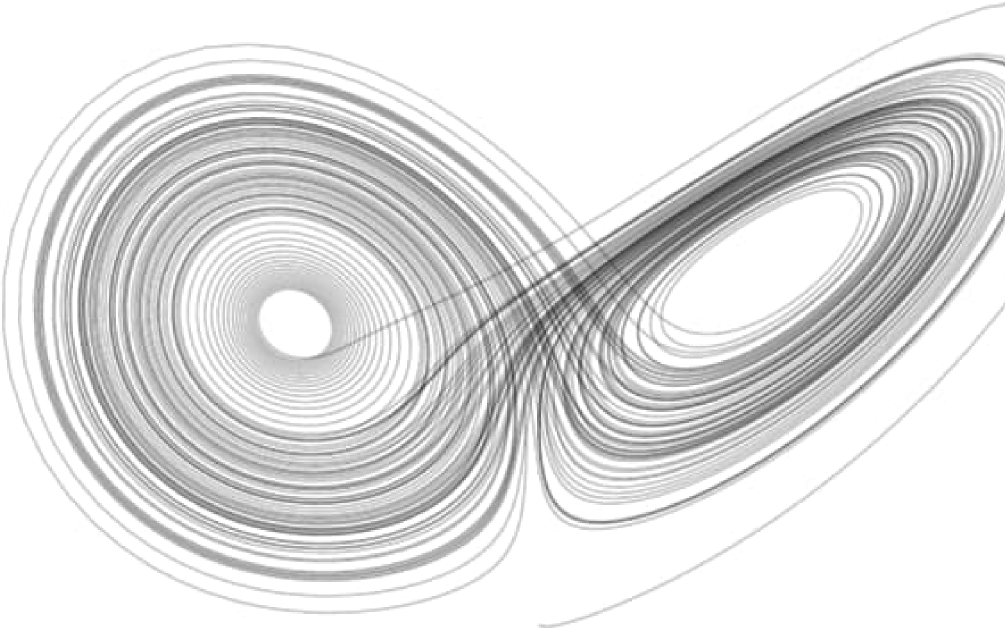

On Some Features of the Scientific Hylorealistic Background of Crystal Chemistry

Matias Velázquez[1]

Abstract — In this paper, we try to understand how Bunge's scientific hylorealism can fit with several crystal chemistry's objects and their properties. It is found that many of them, lying at the very core of this discipline, bring support to ontological emergentism. Building units, such as vacancies, their chemical potential, the non-stoichiometry, the crystal quantum number and many aspects of the spectroscopic properties of 4f electrons in ionic crystals, are presented as striking examples of emergent (or submergent) objects or properties encountered in the single crystalline state. Among all the types of building units, vacancies are shown to be ontologically real and material.

Résumé — Dans cet article, nous essayons de comprendre comment l'hyloréalisme scientifique de Bunge peut s'accommoder avec plusieurs objets de la chimie des cristaux et leurs propriétés. Nous montrons que plusieurs d'entre eux, constituant le cœur de la discipline, soutiennent l'émergentisme ontologique. Les unités de construction, comme les lacunes, leur potentiel chimique, la non stœchiométrie, le nombre quantique cristallographique et plusieurs aspects des propriétés spectroscopiques des électrons 4f dans les cristaux ioniques, sont présentés comme des exemples remarquables d'objets ou de propriétés émergents (ou submergents) rencontrés dans l'état cristallin. Parmi tous les types d'unités de construction, nous montrons que les lacunes s'avèrent ontologiquement réelles et matérielles.

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> There is a fact, or if you wish, a law, governing all natural phenomena that are known to date. There is no known exception to this law—it is exact so far as we know. The law is called the *conservation of energy*. It states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same. (…) It is important to realize that in physics today we have no knowledge of what energy *is*. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way.
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> RICHARD FEYNMAN, 1963

> If you want to say that "God is energy," then you can find God in a lump of coal.
>
> STEVEN WEINBERG, 1992

> Indeed, physics does not define the general concept of energy. This is why Richard Feynman claimed that physics does not know what energy is. Which suggests that the general concept of energy, like the general concepts of thing, fact, and law, is ontological.
>
> MARIO BUNGE, 2006

In spite of both the scientific and technological importance of crystals for mankind since more than two millennia (Theophrastus 1956; Maitte 2014), Bunge did not write very much about these objects, their formation, their structural (multiscale) description and consequently, about their properties. In the thousands of pages of his *Philosophy of Physics* (1973), *Scientific Materialism* (1981), *Treatise on Basic Philosophy* (1974–1989), *Chasing Reality: Strife over Realism* (2006), and of his *Causality and Modern Science* ([1959] 2009), the occurrence of the term "crystal" is rather limited, a little bit anecdotal or exclusively associated with molecular crystal or related to molecular biology. The "chemical potential" and "vacancy" terms and concepts are totally absent of these works (while other "potentials" and the adjective "chemical" are abundantly used, and the concept of "quasiparticle" is evoked in

Philosophy of Physics (1973)). In *Philosophy of Physics*, the "*lattice plus the electron cloud*", modeled by means of Bloch's theory within the more general framework of quantum mechanics, is just said to constitute the "*model object*" of a crystal. X-ray diffraction pictures are mentioned as "*the main empirical tool of analysis for molecular biologists*" and, in order to emphasize the role of theory in telling us the meaning of "*natural signs*", their patterns are said to "*bear no obvious relation to the spatial configuration of the atoms in the crystal*". Diffraction patterns are schematically shown to arise from X-rays and molecular structure theory, and Bunge noted that quantum chemistry, which had "*been around for four decades*" was yet unable to deduce all the possible configurations that any given set of atoms could fit. In *Scientific Materialism* (1981), crystals are qualified—among other systems—as remarkable for the variety of their properties, and their properties of undergoing or causing change. Chemistry investigates not only the composition and the structure of chemical compounds, but also the formation and transformation processes of such compounds. He also stated that "*the very core of chemistry*" is constituted by chemical reactions. The 4th volume of his *Treatise on Basic Philosophy*, dealing with systemism and emergentism (1979), proceeds by increasing degree of assembly, from the atom to the molecule, to macro(bio)molecules, to cells, to multicellular organisms, and so on until human societies. In this broad and impressive ontological perspective, crystals stay completely out of the map. It looks like Bunge was a philosopher of science, grounded in theoretical physics, who liked to jump quickly from physics to biology[2], disregarding the atom to building unit and building unit to crystal-increasing degree of "assembly". "*Crystals out of a solution*" are only quoted as an example of "*self-assembly by condensation of units of the same kind*". The "*cooling of a liquid until it solidifies forming a crystal*" is used as an illustration of "*reorganization*" or "*restructuring*" as a "*change in the structure of the system, i.e., a change modifying some of the links among the system*

[2] Especially from definition 2.4 page 51, to figure 2.6 page 63, where he seemed to completely disregard the crystallographic properties of sugars, proteins and many other biomolecules. More profoundly, if someday his ontology is to include crystals, it will need to be rewritten from the start, pages 46-47, by taking into account more than the atomic number Z alone as the "*root property*" of an atom, namely the electric charge and the nonequivalent crystallographic sites properties (coordinates and symmetry group), and probably, by paying more attention to the "*concatenation*" operations performed page 49 and following.

components though it may not alter appreciably the intrinsic properties of the said components". In the 6th volume of his *Treatise on Basic Philosophy*, dealing with epistemology and methodology (1983), Bunge wrote that "*one of the most spectacular successes of the reductionist program is contemporary solid state physics*", and to illustrate his judgment, he took the example of the copper wire, in which, while every one of the atoms that composes it can be accounted for, in principle, by the quantum theory of atoms, the body composed of these atoms has, however, bulk properties, which are emergent with respect to the component atoms. These properties (such as electrical conductivity) "*are not represented in the quantum theory of atoms, hence they cannot be explained by the latter without further ado. However, solid state physics explains those emergent properties on the basis of quantum mechanics, namely adding to it certain hypotheses concerning the copper crystal lattice, the electrons wandering through it, and the interactions among the copper ions and the electrons moving about in the lattice*". In the 7th volume of his *Treatise on Basic Philosophy* (1985), a comparative comment is found, which says that "*the grammar of a language is not detachable from the language itself, anymore than the structure of a crystal can be detached from the crystal*". Bunge also explained that "*according to classical statistical mechanics chance is neither in the individual system components nor in the eyes of the (blind) beholder, but in the nature of things: it is an emergent property on the same footing as other system properties such as entropy and temperature. (…) The simplest randomness (or chance) hypotheses in statistical mechanics concern the initial positions and velocities of the system components. But these are not the only ones. Thus the modeling of the crystallization process in a liquid calls for probabilistic hypotheses concerning the nucleation process. Since these events are random in space and time, neither the place nor the time of the emergence of the first crystal can be predicted exactly.*" In this volume too, he touched a few words on symmetry properties, warning against "*Platonic delusions*": "*(…) the theorist investigates the group-theoretic structure of that space: he conjectures, say, that the structure is an US(2), US(3), or some other symmetry group. Once he is done he glances at the 'particles' chart and, if lucky, discovers that nature does contain 'embodiments' of such conjectured symmetries; and if very lucky, he will predict one or two still unknown 'embodiments'. But this is no evidence for the power of pure mathematics to mirror the world: all such* *symmetry groups are constructed on the basis of law statements such as commutation formulas for dynamical variables. Nor do symmetries hover over things, let alone produce them; in physics every symmetry is a property of either a physical entity, such as a crystal, or of a feature of a physical entity, such as the hamiltonian or the state function of a molecule. Melt the crystal, or dissociate the molecule, and the corresponding symmetry disappears*". In his *Philosophical Dictionary* (2003), crystals are recognized as systems and also as "*quantons*", i.e. "*a physical entity that quantum physics accounts for adequately and classical physics does not*". He was fully aware of the existence of "*defective crystals*", as natural imperfections, which he used as an example contradicting "Intelligent Design"-like (pseudo-)arguments, and he defined chemistry as the science of molecular composition and transformation. A chemical system, or a reactor, is a system where chemical reactions occur. So much so that, according to him, when reactions are completed, the chemical reactor ceases to be a chemical system, and turns into a physical system, the components of which are necessarily atoms and molecules (Bunge 1979) (or radicals (Bunge 1982)). Here again, the repeated use of the "molecular" adjective, together with the emphasis put on "reactions", seem to discard crystal chemistry from the definition[3]. Indeed, so many crystals are not molecular at all (metals, salts, semiconductors), and chemistry also investigates state changes intimately "coupled" with chemical reactions (like, for instance, the growth of an incongruently melting crystal, or the growth of a crystalline thin film by chemical vapor deposition). In addition, as we shall see in this contribution, the most fundamental building unit at the atomic scale in crystal chemistry (and in chemistry *inside* crystals) are not atoms, nor molecules, nor radicals, but *vacancies*, a kind of quasi-particles which do not possess atomic number (hence, no box in the Periodic Table, and no electronegativity), nor mass number, nor very often electrical charge (absolute or relative) and does not relate to any of the elementary particles of the Standard Model either. In *Chasing Reality: Strife over Realism* (2006), Bunge gave a fair account of the strategy deployed to determine the crystal structure from a diffraction pattern analysis, in a dedicated section entitled "*Reading diffraction patterns*", a problem he

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[3] For a historical text on solid-state chemistry, at the French level, see Pierre Teissier, *Une histoire de la chimie du solide. Synthèses, formes, identités* (2014).

classified as "*inverse (or backward) cognitive problem*". In *Causality and Modern Science* ([1959] 2009), classical crystallography is designated as an "*outstanding member of the class of noncausal and morphological theories*", which need not contain a causal element, although they may turn out to be explainable in terms of a theory containing a causal element.

In this paper, we will confront crystal chemistry's main objects, and some of their properties, to Bunge's scientific hylorealism, the only complete philosophical system designed in the 20th century, which combines systemist and emergentist materialism with ontological, epistemological, semantic and methodological realism and scientism, at its ontological and epistemological levels and keeping the "analysis" broad, without axiomatization. The goal of this text is to convince that vacancies are real and material, and that more broadly speaking, building units, their chemical potential, the non-stoichiometry they generate, and some of their most elegant properties of properties (like crystallographic site symmetries), the crystal quantum number and many aspects of the spectroscopic properties of 4f electrons in ionic crystals, bring strong support to Bunge's ideas on scientific hylorealism. It will also emphasize, by calling for a necessary clarification of the definition of the system components and of the corresponding levels of organization of reality, the interface where philosophy of chemistry and crystal chemistry itself exactly meet together.

But before we do so, we need to recall what "scientific hylorealism" stands for in Bunge's philosophy, and also what a crystal is.

1] Scientific Hylorealism in a Nutshell

In Bunge's ontological and epistemological views (1981; 1979; 2003), matter is the collection of all material entities, also called things. Only changing things can be considered as material. Being a collection, matter is conceptual, not material. A material entity is a thing capable of change. For example, its properties can change. A material entity does not necessarily possess mass. Mass is a property of only certain things, like protons and electrons, whereas photons do not have any mass, so that to possess a mass is sufficient but not necessary to be material. Gravitational and electromagnetic fields are examples of material things without mass. "To be able to change" means to be able to be in at least two different states, and to change from one state to the other. In order to avoid verbal compulsions, Bunge insisted on the necessity of expressing this possibility of change by means of a mathematical theory which defines a state space containing at least two elements. Materialism is a group of ontological doctrines that have in common to postulate that all that really exists is material or, formulated negatively, that immaterial objects such as ideas have no independent existence on things (like brains that think them). Materialism postulates that reality is only made of material entities. Bunge coined the term *scientific materialism* because in his view, it is *the* ontology of science and technology, the ontology that gets inspired by science and which is tested as well as modified by the advancements of science. Anything that exists either in the outer world (independently on the subject) or in the subjective experience (because mental states are brain states) is considered as real. All natural things are real. Scientific realism states that things by themselves are existing and at least partially knowable. Realism is the epistemological view according to which knowledge, or at least scientific knowledge, seeks to represent reality. Scientific realism identifies reality with the collection of all material entities, that is, things that are likely to change in one way or another. It also implies that to grasp reality and take into account its complexity, mathematics-based theories, in addition to empirical data, are needed. This postulate of the independent existence of the outer world is a strong incentive to explore it and by doing so, to enrich and deepen our already acquired factual truths.

Energy is not a material entity, it is not a thing, but rather a property of it, which determines to which extent material entity changes or can change. It turns out to be the most universal property that real things possess, more universal than location in spacetime. Hence, to be material means to possess energy. As energy is a property and not a thing, it does not exist by itself in the same way as matter does. The famous "$E=mc^2$" theorem of relativistic mechanics which relates energy to the mass of a particle does not say that energy converts into matter and matter converts into energy. This is impossible because energy and mass are properties, and not things, and so any energy and mass are energy and mass of something. The combination of scientific materialism with realism can be summarized very simply:

1) all that *really* exists *is* material;

2) "to be material" means to be able to *change*, that is, to be *endowed with energy*.

Electrons, electromagnetic fields, atoms, and so on, are good examples of that, which sound familiar to the chemist. However, the properties of material entities, and the changes of these properties are only material indirectly, because they do not exist independently, outside of these material entities. Numbers have no energy and so they do not exist in the same way as atoms or crystals do: their existence is ideal, or fictitious. As Bunge puts it: there is matter without ideas, but there cannot be ideas without matter. Ideas are to be created or invented, but not discovered. One discovers the world, one invents ideas about the world as well as pure ideas which have no relation to it: "*Try to cut a brain with an idea or to divide a number with a knife*", or, "*To repeat, energy is not just a property among many. Energy is* the *universal property, the universal* par excellence. *Moreover, energy is a universal* in re*: it inheres in things instead of being either* ante rem *(prior to them) or* post rem *(after them)*" (Bunge 2006).

Any structured ensemble can be conceived as a space. If this structure is endowed with a distance, then this space has a metric. Contrary to the diversity of mathematical spaces that can be invented, there is only one physical space, which is an important feature of the real world. A physical geometry is built by appropriately interpreting a mathematical geometry. While mathematical geometries are only tested against their internal and formal consistency, physical geometries must be submitted, in addition, to empirical tests. Physical geometry studies physical space, which is the basic structure of the collection of all material entities. Scientific materialism endorses a relational interpretation of physical space, which is made of the collection of things which change continuously and are related by the intermediarity relationship. Space (or rather space-time) is intimately related to matter. Without matter, there would be no physical space. The association of the collection of things and of their separation function can be called the space of things. So, real space turns out to be the basic structure of the collection of things. However, space is not the property of any particular thing. Like "public space", it is common to everything, or said more specifically, the space relative to a reference frame is common to all the things that can be related to this reference frame. Things do no float in some space-time container, that would exist independently on them. Rather, things have spatiotemporal (and changing) relationships which can be expressed with space and time concepts, and those relationships are just relationships (not bonds) between things and their changes. Space is neither a thing nor a property of a thing, and has no causal power. But even if space does not exist independently of things and their changes, it is no less real than any of the important properties of real things. Indeed, a relationship can be thought of as real if and only if it exists between real things, which is the case of spatial relationships. That coordinate values in a 3D Euclidean space just label points in a 3D space is true, but it does not imply this Euclidean space fails to represent the objective relationships among material entities, as shown by the absolute nature of some invariant distances. In fact, many invariant distances do not change upon the substitution of one coordinate system by another one, they do not depend upon the viewpoint, the location and the movement of the observer. Space has no autonomous existence, and from that no causal power either. No spatial relationship exists on its own, separated from the elements that are connected. They are real relations because they occur between real things. Space is the fundamental structure or framework of the real world. A physical theory must not only contain concepts with physical meaning, which means concepts referring to physical things. A theory of space should bring mathematical force, a close connection with contemporary physics, and clarification power.

Bunge's hylorealistic ontology does not stop here. It contains two important additional features: systemism and emergentism. A system is a complex thing each component of which is related to at least one other component. For instance, an atom is a physical system composed of protons, neutrons and electrons. To assess the systemic nature of something, Bunge proceeded to the so-called "CESM" analysis:

1) the *composition* of a system is the collection of its components (or parts), and it is defined at each level;
2) the *environment* of a system is the collection of things that act on the components of the system or upon which the components of the system act;
3) the *structure* of a system is the collection of relationships (in particular bonds or links) between the components of

the system, as well as between its components and elements of the environment;

4) the *mechanism* of a system consists of all the internal processes that make it work, that is, that make the system change upon some conditions, and not upon other conditions.

Only material systems have mechanisms. Any of these four features is likely to change with time.

A new system is said to be emergent if new properties of it can be identified and characterized. A property is emergent, as a static concept, if it is not the property of any of the system's component. The theoretical genesis of the emergence notion traces back to the epistemological distinction between a resultant effect and an emergent effect. While the former can be calculated from its causes, the latter cannot. If a system has a composition at a given level, then any property of the system is said to be resultant at this level if and only if it is possessed by all the components at the considered level of the system, and it is said to be emergent at this level if the property is not possessed by none of the components of the system at the considered level. If several causes produce one effect, or if we can predict their result from a law of composition of causes of classical physics, the effect will be said to be resultant. If the effect cannot be predicted that way, it will be said to be emergent. A phenomenon is qualified as emergent if it:

1) requires a certain amount of material constituents and/or preceding causes as necessary conditions of existence;
2) presents qualitatively new properties with respect to its preceding causes and/or its constituents;
3) remains unexplainable from the properties of the preceding causes and/or constituents of the said phenomenon, which raises the question of "unexplainability until now" or "unexplainability by principle".

The goal of a scientific study of a system is to explain its systemic (emergent) properties either from the point of view of the interaction between its components or from that of its history. Only systemism can account for emergent phenomena. Emergent materialism assumes that all material entities do not belong to the same level of organization of the reality. Instead, they are bunched in several levels of organization: physical, chemical, biological, social and technical. A level of integration, or of organization of the reality, is made from a collection of material entities that possess common properties and laws. Entities of supraphysical levels are made of entities of preceding levels. Members of the superior levels have emerged with time by association or by development of members of preceding levels, and members of each level above the physical level are systems endowed with particular properties which emerge from the interaction of the components of these systems or the interaction between these components and their environment. Emergent materialism provides a strong incentive to the search for an explanation of emergence in terms of properties and processes from preceding levels. In a more recent book chapter (Kistler 2013), Max Kistler defines an ontological concept of emergence for a property, provided it is:

1) systemic, which is to say that none part of the system possess it;
2) qualitatively different from properties possessed by the system's parts;
3) consistent with physicalism, that is, completely determined by the properties of the system's parts, as well as by their mutual interactions and interactions with the environment;
4) stable or "robust", that is, unchanged by small perturbations in the underlying microscopic properties.

Bunge also pointed out that any sufficiently advanced scientific theory contains some conservation laws, for instance total mass conservation theorem, or of the total kinetic moment, or of the total energy, and so on. Such conservation laws state the invariance of a particular property of a certain type of material entity along the change it undergoes. These properties are constants of the movement or, broadly speaking, constants of the transformation of things. "*Ex nihilo nihil fit*", in other words, everything emerges from another thing and transforms into something else. This principle, due to Epicure and Lucrece, is the oldest and the most general statement of the conservation of matter principle.

2] What is a Crystal?

The crystalline state is a solid state of matter in which, ideally, all the atoms order periodically in the three directions of (the Euclidean) space. The crystal is "built" by translation along all the space directions of one specific block which is called the unit cell. This unit cell is chemically and geometrically defined by its atomic content and number of unit formulas, three vectors which describe the periodicity and give the crystallographic space its metrics, the set of symmetry operators which constitute the space group of the crystal and spatially relate the atoms to each other within the unit cell and from cell to cell, as well as the positions of atoms not related to each other by some symmetry operator within the unit cell. The crystal space group is the set of all symmetry operators which allow to "jump" from any point of the crystal to an equivalent point, for instance, when this point is occupied by an atom, to "jump" from this atom to the same atom elsewhere in the crystal. The International Union of Crystallography (IUCr) defines a material as being a crystal if it has essentially a sharp diffraction pattern, "essentially" meaning that most of the intensity of the diffraction is concentrated in relatively sharp Bragg peaks, besides the always present diffuse scattering. The main radiation sources currently used to collect diffraction patterns are X-rays, neutrons and electrons. Symmetry operators leave invariant an object or a structure when they are applied to them. They transform the object into itself, without modifications. The crystal structure describes the way atoms order themselves to form a crystal. A basic crystal structure model contains: a space group, lattice parameters (the vector lengths and angles between them), a number of unit formulas, a set of atoms and atomic coordinates, site fractional occupancies, site symmetry group and atomic anisotropic displacement parameters. The latters are directly related to their thermal agitation energy, which makes them vibrate around some equilibrium position, and the existence of which is a sufficient proof of their material and real existence. Inside the unit cell, atoms occupy specific positions, called block positions[4]. These positions are defined by a set of coordinates, a multiplicity factor, a fractional occupancy and a site symmetry group. General positions represent a collection of symmetry equivalent points which remain invariant only by the application of the

[4] Or Wyckoff positions.

identity operator[5]. Special positions represent a collection of symmetry equivalent points which remain invariant by the application of at least two symmetry operations of the space group. The site symmetry group is the ensemble of symmetry operations which leave invariant the crystallographic site. This ensemble is determined exactly and exclusively by the unit cell content. All these informations can be obtained from the Rietveld analysis of an X-ray or a neutron diffractogram, which primarily gives the Fourier-transform of the electronic density of the atoms. X-rays lead to an average ideal crystal structure over typically ten-twenty thousand unit cell distances. But real crystals often possess local compositional and/or structural deviations from the ideal (average) model, as probed by different techniques such as Nuclear Magnetic Resonance (NMR), Mössbauer or Raman spectroscopies for middle range disorders (extending typically over hundreds of unit cells distances), high-resolution transmission electron microscope (HR-TEM), and Electron Paramagnetic Resonance (EPR), positron annihilation spectroscopy (PAS) or optical spectroscopy for short range disorders (at the level of the unit cell or so)[6].

Now that we have worked out the broad strokes of both scientific hylorealism (matter, reality, energy, space, systems, emergence, components, levels of organization) and the crystalline state of matter, we can get to test Bunge's ontology to crystal chemistry.

3] Discussion

3.1] From Atoms to Structure Elements … to Building Units

One thing is to "build" a crystal according to crystallographical geometry rules, the other thing is to do it with thermodynamically sound components. When it comes to model reactional equilibria and reaction-diffusion processes inside a crystal, one needs to identify a minimal set of independent components of the chemical system. This set allows us to apply Gibbs phase rule[7] and to perform mass action law reasoning with components which have a well-

[5] Their site symmetry group, or "point group" symmetry is symbolized as C_1.

[6] Needless to say, this list of techniques widely used to characterize crystals is not exhaustive at all.

[7] Which dictates the number of chemical potentials which can be varied independently of each other.

defined chemical potential. Atoms, molecules, ions, ionic coordination polyhedra, so-called "building blocks" made of the latters' assembly, embedded into a crystal, do not have well-defined calculable chemical potentials, neither computable nor measurable. This issue was solved when the concept of building units was introduced in crystal chemistry (Rickert 1982; Schmalzried 1995; Kröger, Stieltjes, and Vink 1959). Building units permit us to differentiate components of identical chemical nature ("*Z-equivalent atoms*" (Bunge 1979)) in a crystal. This differentiation is more specific than in gas, liquid or amorphous matter chemistries. Indeed, the site symmetry group applies to the hamiltonian of the atom (or the ion) located in its particular block position, and so it is relatively straightforward to understand that a chemical property, such as dissolution or solubility limit, may not be the same for two identical elements occupying two crystallographically nonequivalent sites. While the way Bunge insisted on not to characterize (and qualify) a system only by its composition and environment, but also by its structure and mechanisms, finds here a striking relevance, it is above all the remarkable finesse of his hylorealistic ontology of space[8] that should be appreciated, for a site symmetry group contains symmetry operators which are noncausal properties of the most universal property possessed by chemical elements: energy.

Atoms occurring at particular site types, occupying certain lattice positions, are structure elements. Separated structure elements have no well-defined chemical potentials, because their numbers in a crystalline compound are not independent from each other. This is due to the fixed ratio of crystallographically nonequivalent sites in a crystal lattice. Hence, if one increases the size of the crystal or if one changes the number of atomic imperfections it contains, one must either add or withdraw a combination of structure elements. It is not possible to calculate the Gibbs free energy change due to the addition of a structure element, hence to calculate a structure element chemical potential. The latter equals the partial first derivative of the Gibbs free energy with respect to the number of particles of the considered structure element, at constant pressure, constant temperature and constant numbers of the other remaining structure elements (Rickert 1982). A structure element,

[8] Bunge was neither a topodenial, a topoclast, nor a topolatrous.

which is characterized by three kinds of "root" properties[9] instead of only two in a gas or a liquid phase, does not exist outside the crystal lattice and is therefore not an independent component of the crystal in a thermodynamic sense (Schmalzried 1995). Two ways of describing crystal atomic imperfections are known to date:

1) the structure elements description, in which atomic imperfections are defined with respect to the empty space, in which lattice positions (and interstitials) are fixed with respect to an imaginary coordinate system;
2) the building units or relative building units description, in which crystal atomic imperfections are defined with respect to the ideal perfect crystal.

A building unit is a structure elements combination with a composition such that fixed relationships between the numbers of the varied site types, required by the crystal structure, remain unchanged upon addition of this combination to the crystal. The most obvious one is the "crystal molecule", which is the smallest assembly from which the perfect crystal can be built[10]. When an infinite number of lattice molecules are sticked to each other in the three dimensions, we obtain an ideal defect-free crystal. The introduction of atomic imperfections (relative) building units in this ideal crystal produces a real crystal (Rickert 1982). Relative building units are defined with respect to the perfect crystal, and so they consist of differences between a structure element and a structure element corresponding to the normal occupancy of the same site (Kröger, Stieltjes, and Vink 1959). Corresponding to suitable combinations of structure elements, building units can be subtracted or added to the crystal independently of other building units. The number of types of building units necessary to describe the crystal is small: the lattice molecule, the interstitial particles, the vacancies and substitutional particles. A building unit belonging to a set of mutually independent building units can be considered as a component in the phase rule's sense—the minimally sufficient set necessary to build any crystal without taking into account any internal equilibrium.

[9] Chemical element, electric charge and type of (nonequivalent) crystallographic site (reduced coordinates and site symmetry group).

[10] Building units were introduced by Wagner and Schottky in 1930 (Wagner & Schottky 1930). "*Gittermolekül*" is a poor choice of words, maybe the use of "asymmetric unit" (of the unit cell) would be better.

In the relative building units system, chemical atomic imperfections are defined with respect to the perfect and ideal crystal. Consequently, crystal chemistry forces one to formulate correctly the constraints which crystal structure and symmetry impose on their thermodynamic derivations (Schmalzried 1995). In principle, there are only three different types of irregular structure elements: vacancies on regularly occupied lattice sites, interstitial atoms (ions) on regularly unoccupied lattice sites, and impurity atoms (ions) present either on the interstitial lattice site or substituted for regular structural elements. In the simplest relative building units system, it is assumed that relaxation processes around the irregular structure elements are sufficiently fast so that thermodynamic state functions can be defined, that they keep the site symmetry group of the perfect crystal structure and that structure elements have no internal degrees of freedom[11]. In a structure element, the effective electric charge is defined with respect to the perfect crystal. There is no experiment that permits the determination of a structure element's chemical potential, and so it is by subtraction that one can introduce a chemical potential. The "lattice molecule" introduced by Schottky corresponds to a formula unit, the chemical potential of which stands as the reference molar energy value and can arbitrarily and conveniently be fixed to 0[12]. It is in equilibrium with all the vacancies distributed over all the types of crystallographic sites. These vacancies are the most necessary irregular structural elements to construct the crystal lattice[13], and we shall come back to them in a forthcoming section.

In order to keep this concrete, we need to take an example which is not too simple (like monoatomic, or diatomic crystals with a 1:1 stoichiometry and atoms occupying only one block position in the structure) and not too complicated (like ternary compounds, or binary ones with so many crystallographically nonequivalent sites). Tb_2O_3, an ionic crystal adopting the cubic bixbyite structure at room temperature (with Ia-3 space group), is likely to meet our purpose,

[11] The latter two assumptions are less frequently fulfilled.

[12] In diluted solutions, by the application of the Gibbs-Duhem relation, it is straightforward to show that the "lattice molecule" building unit's chemical potential can be approximated as the standard chemical potential of the compound in its Raoult reference state.

[13] For a technical introduction to these problems, read: https://hal.archives-ouvertes.fr/cel-00934568.

because it contains only two elements, Tb and O, occupying three crystallographically nonequivalent sites.

3.2] O^{2-} Anions as Resultant Things

In a fully ionic crystalline oxide, the oxygen species is always found to be the O^{2-} anion. The "2-" oxidation state of the oxygen anion exists only because it is stabilized by the Madelung field, which is the crystalline electric field resulting from the electric charges of the cations and the anions located at crystallographic positions specified by a set of symmetry operators belonging to the crystal space group. The O^{2-} anion does not exist in the gaseous (or in the "free ion") state. What exists in the gaseous state is the O_2 molecule with standard chemical potential -0.64 eV at 25°C, while that of the O atom at the same temperature amounts to +2.08 eV. The O atom first ionization potential is +13.6 eV and its second ionization potential is +35.1 eV, so that the dissociation and ionization energy costs for the existence of O^{2-} in the gaseous state are definitely prohibitive. This is a good example of resultant effect, because the crystal structure makes possible the Madelung field which is the cause of the stabilization of the O^{2-} anions, and this cause can be easily calculated by summing the electrostatic charges over the crystal lattice positions.

3.3] Components and/or Constituents?

If the O (and the Tb) atoms do not exist as such in the Tb_2O_3 crystal, i.e. without the properties they possess in the crystal lattice, it raises the question of the composition of the "physical level of organization of the reality". Any atom occurring in a crystal formula is actually a constituent. A constituent is not a component, the major qualitative difference between them being that the latter has a well-defined chemical potential, while the former does not. Even if we assume that the "physical level of organization of reality" in the Tb_2O_3 crystal is composed of the three halves of the Tb^{3+} cations which have a C_2 site symmetry group, the one half of the Tb^{3+} cations which has a C_{3i} site symmetry group and the remaining three crystallographically equivalent O^{2-} anions which have a C_1 symmetry group, and if we consider them as structure elements, their chemical potentials in a crystal is not either definable in terms of statistical thermodynamics. There is just no way one can change the concentration of only one of them maintaining the 3/2:1/2:3 ratio of crystallographic sites constant. To define the chemical potential of the oxygen (and the terbium) building units, one must comply with three conservation rules: the mass conservation, the charge conservation and the number of crystallographic sites conservation (Rickert 1982; Schmalzried 1995; Kröger, Stieltjes, and Vink 1959; Kröger 1964; Schottky, Ulich, and Wagner 1929). In our example, this leads to the following equilibrium between the Tb_2O_3 crystal lattice "molecule" and its building units, expressed in the modern Schottky notation: $Tb_2O_3 \Leftrightarrow -3|O|^{\bullet\bullet} - 3/2|Tb(C_2)|^{'''} - 1/2|Tb(C_{3i})|^{'''}$. Strictly speaking, the free energy variation of this reaction is 0, so that

$$\mu_{Tb_2O_3} = -3\,\mu_{|O|^{\bullet\bullet}} - 3/2\ \mu_{|Tb(C_2)|^{'''}} - 1/2\ \mu_{|Tb(C_{3i})|^{'''}}$$

with μ symbolizing the chemical potential. The building units chemical potentials exist because of the constraints imposed on their definition by the number of crystallographic site conservation rule, which is itself related to the space group symmetries. These symmetry operators do not exist at the "physical" level (atomic, molecular). In fact, as the building units combine not only mass and electric charge properties of a chemical entity, but also the relational properties specific to a crystallographic site, it is a striking example of component that instead of being defined at the "physical" level, emerges at the crystal chemical level. Even if a crystallographic lattice site is clearly not the analog of a chemical element, only constitutive building units can be added to or withdrawn from the crystal structure in such a way that the crystal chemical potential remains constant, that is, without modifying the electric charge and lattice site equilibria. Consequently, only building units can be considered as genuine components in the Gibbs phase rule, which is not the case of individual atoms (ions) and related structure elements. Here, crystal chemistry imposes to distinguish components from constituents, and one is forced to recognize that what Bunge used to designate as components (or parts) are actually *constituents* in the chemical sense. This is a logical consequence of the fact that the energy concept, in his ontology, remains an extremely general concept, not as specific as in (crystal) chemical thermodynamics. Nevertheless, even if an atomic (ionic) constituent does not have a well-defined chemical potential, it still has an energy, and so it is a concrete thing. While the building units, which as components have a chemical potential[14], are atoms endowed with a relative combination of primary properties (mass–or Z–, electric charge) and of *invariance properties of* properties that turn out to be relational (crystallographic site symmetry group). Their chemical potential is a good example of emergent property, which exists only at the crystal chemical level and in addition, they constitute a core property of statistical thermodynamics[15]. While a mass and an electric charge have physical dimensions and can interact with a gravitational and an electric field, respectively, a crystallographic site is defined by reduced coordinates, a multiplicity factor, an occupancy fraction and its site symmetry group, i.e. pure numbers and symmetry operators[16]. Thus, it is unlikely—to put it mildly—to interact with some surrounding field. Note, however, that the change in bond strength with the nearest, second nearest and third nearest ions, and subsequent lattice positions relaxation (due to the change of mass and/or electric charge) upon the formation of the crystalline imperfection, induces an elastic strain and a stress field that decay over several unit cells, with which the associated building units can interact (including when this building unit is a vacancy). In addition, the relative building unit concept and related symbol bear the difference between two (equilibrium) states, the initial reference state, and the final state of the crystalline imperfection, which implies that the chemical potential discussed here is already a Gibbs free energy variation divided by the precise amount-of-substance variable quantifying the impurity, say $\Delta G/\Delta n$, possessing the three former properties. Leaving aside the trivial "lattice molecule"

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[14] And so a Gibbs free energy from which it derives.

[15] The conceptual difficulties undergone by solid state chemists to define properly the structure elements chemical potentials led to a controversy between Schottky and Kröger in the 1950s (Kröger, Stieltjes, and Vink 1959), which is now part of the classical academic education, and the basic ideas were refined at the end of the 1970s to account for possible surface or dislocation specificity (Schmalzried 1976; Kröger 1980). The two formalisms, based on structure elements or on building units, are strictly speaking equivalent, but the former (Kröger-Vink's one) leads to the definition of and search for *paired virtual* structure elements chemical potentials, which do not modify our conclusions in the sense that it is not possible to define, calculate and measure the chemical potential of a structure element *alone*.

[16] The three of them, namely Z, electric charge and type of nonequivalent crystallographic site (reduced coordinates and site symmetry group), should be regarded as "*root properties*" in the very premises of any ontological theory of crystals for, so to speak, building units are the ontological "atoms" of the crystalline state of matter.

building units, relative building units, on the other hand, due to their relative subtractive nature, bear, in addition to the three already mentioned integrated properties, another property, namely the change itself, the change by chemical substitution, insertion, or removal of an atom (ion). What the $|O|^{\bullet\bullet}$ symbol also means is: "on this specific crystallographic site, an O^{2-} anion escaped from the lattice and was not replaced by another ion"[17].

3.4] "*There isn't one in a hundred, and yet they exist*"…

At T=0 K, an absolutely pure crystal is expected to be perfectly well ordered in terms of both cationic and anionic crystallographic sites occupancies. Nevertheless, when temperature becomes nonzero, which is the case for all practical situations, the second law of thermodynamics makes it necessary that, for instance, in a Tb_2O_3 crystal, a combination of Tb and O vacancies form. Indeed, if the Gibbs free energy of the crystal is to be found at a minimum, then there must be a nonzero vacancy concentration that permits minimizing, at concentrations such that they do not interact between themselves, the configurational entropy. As Bunge's systemism so rightfully stresses, the crystal structure knowledge is necessary but not sufficient to describe, explain and predict how the crystal composition and structure will form and change under external constraints from its surroundings. This takes a bit of classical and statistical thermodynamics and of thermodynamics of irreversible processes, which contain causal elements of explanation and have predictive power[18]. Besides, the knowledge of the atomic (or ionic) constituents' list of the crystal is also insufficient to discover and understand the mechanisms of crystal formation, of impurities dissolution and, more broadly speaking, of chemical reactivity. For the most fundamental component of a crystal, and of its crystal chemistry, at the angstrœm scale of description, is not exactly a constituent, but rather a quasiparticle. These quasiparticles cannot be viewed as "impurities"[19], they are not a chemical product one can

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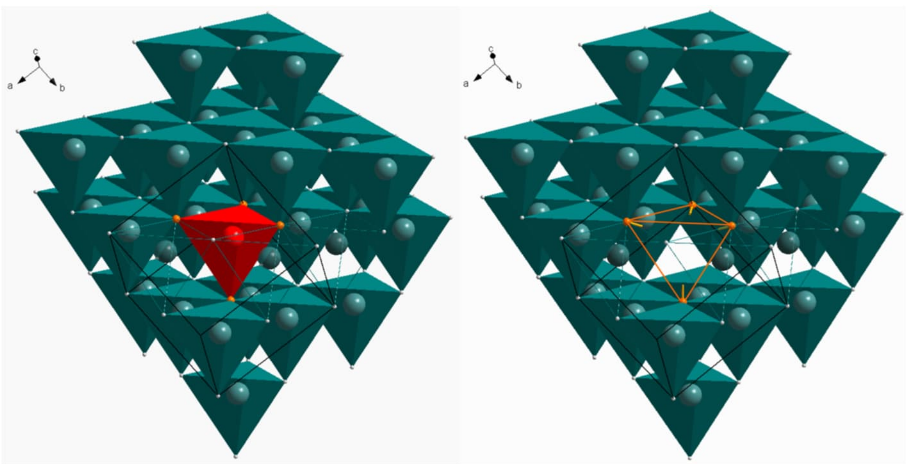
[17] For instance, if a chlorine anion would substitute for it, then the symbol would become $Cl|O|^{\bullet}$.

[18] In some sense, the periodicity of Mendeleyev's Table of elements and the (chemical) process—(multiscale) structure relationships prevail over the crystal lattice periodicity and structure-property relationships in determining the kind of chemical bonds, non-stoichiometries and crystal structures likely to be obtained.

[19] They are called crystalline imperfections.

purchase on the market and get delivered with a certificate of purity warranted by the vendor. They do not form a gas (they actually have no vapour pressure (Schmalzried 1995)), nor some liquid phase, not even a powder, beads or chips one can handle on the bench, with spatulas or pairs of tweezers, a mortar and a pillar , and this, in spite of the fact that they do belong to the *solid* state of matter. They have no mass (no atomic number : no proton, neutron nor electron[20]), very often they have no electric charge (relative, effective or absolute), they have no (nuclear, electronic) spins, no parity, no isospin, no rotational nor internal vibrational degrees of freedom, … We are, of course, talking about vacancies[21] (Figure 1).



[20] In transport by diffusion theory though, it might be possible to define a generalized effective mass, scaling in fraction of the missing atom mass, but this is another concept of mass in solid state physics, which does not lead to molar mass in chemistry.

[21] Random vacancies are not to be confused with interstitial sites, gaps, voids, pores, crystallographic cages, porosities, and so on and so forth.

Figure 1. Simplified and stylized drawing of the sphalerite structure (cubic, space group F-43m) adopted at ambient temperature and pressure by many crystals whose standard formula is “AB” and with a predominantly covalent bond (such as InP, AlAs, InSb , etc., much studied in optoelectronics, high frequency electronics, among others), therefore being able to form electrically neutral vacancies. Atoms are represented by spheres of arbitrary dimensions and of different color depending on whether the atom is “A” (grey) or “B” (green). All “A” atoms are crystallographically equivalent to each other (tetrahedral point group -43m), and all “B” atoms are also equivalent to each other (with the same point group) but not to “A” atoms. The drawing shows that the atoms “A” nearest neighbors of the atom “B” form a tetrahedron, and that these tetrahedra pile up by their vertices in the three directions of the crystallographic space defined by the reference frame (**a**,**b**,**c**). The figure on the left highlights in red an atom “B” surrounded by four atoms “A” in orange inside the unit cell (cubic) represented in solid black lines, and oriented in such a way as to put the whole perspective. The figure on the right shows exactly the same structure but with the “B” atom missing, and the broken chemical bonds with the “A” atoms in the form of truncated yellow lines: this is a (random) “B-vacancy”. Strictly speaking, this drawing should show that the atoms nearest to and following the missing atom “B” shift a little bit from their initial positions (adopted in the figure on the left) by a distance which decreases with the distance to the initial “B” atom. This local deformation, which may or may not modify the initial point group of the vacancy site, is at the origin of the middle range elastic stress field which propagates in the real crystal, and with which another vacancy located further away can interact.

In their intrinsic regime of formation, their concentration remains very low[22], and their volume is delimitated—in the simplest case—by the set of the outer shells electrons of the nearest atoms immediately surrounding them. To put it metaphorically, vacancies form the most important “active minority” of a crystal, the most systemic and emergent one that shakes up the “established order”[23] and always forces the crystal to evolve (provided changes of external constraints are made). One very interesting thing about these crystal chemical objects which do not refer to any chemical species is that not only the same line of reasoning that applied in the previous sections to the definition of building units chemical potentials applies now to that of their chemical potentials ($\mu_{|O|}^{\bullet\bullet}$, $\mu_{|Tb|}^{'''}$), but above all, that they can be discarded as constituents at some “physical level of organization of reality”. While the existence of an atom,

[22] Typically less than $\sim 10^{20}$ cm^{-3}, for instance in the disorder-prone β-AgI crystals, intrinsic vacancy concentrations range from $\sim 8\times 10^{16}$ cm^{-3} at 25°C to $\sim 1.5\times 10^{20}$ cm^{-3} at 770°C.

[23] But that, not without a sense of irony, also gives rise to the propagation of the crystal structure by generating dislocation-based crystal growth sources.

an ion, a molecule, a free radical can only make sense at the latter level, the existence of a vacancy makes sense only at the crystal chemical level. In a 1982 paper which, we believe, might stand as Bunge's most original contribution to the philosophy of chemistry, he explained that "*what is physical about a chemical system is its components rather than the system itself (…). The composition of a chemical system is then a set of atoms or molecules, each of which may be regarded as a physical system. (…) And the composition of a chemical system is included in the reference class of physics.*" (Bunge 1982)[24]. How can a Z-less, electrically neutral, inner structureless thing fit in "*the reference class of physics*"? Vacancies are entities of their own in the crystal lattice reference system, which must be taken into account when calculating the partition function of the crystal. Schottky's symbol for a vacancy building unit means "withdrawal of an atom" and has the significance of a "negative atom", or "- atom" ("minus one atom"). In the symbol for a vacancy structure element, the suffix represents only the site type and not "some atom has been withdrawn". Consequently, the vacancy structure element is to be looked upon as a "zero particle" or "nil particle". When building units symbols are used to describe them, vacancies simultaneously have the significance of a "negative particle", whereas *a vacancy as structure element has no material significance.* Vacancies have no vapour pressure but they surely have a chemical activity, they are thermalized by the crystal lattice vibrations and they locally undergo a "pressure" (a stress) on the order of magnitude of the crystal's shear modulus. Their related building units having a chemical potential, they necessarily have an energy (of formation, of interactions, of thermal agitation, and so on): vacancies are as real as material. Full-fledged matter! Which leads us to a somewhat funny observation that in the $|O|^{\bullet\bullet}$ building unit symbol, an O^{2-} anion escaped from the crystal lattice not being replaced by anything but rather by *some* thing… Vacancies can introduce narrow electronic energy levels in an insulator or a semiconductor bandgap. They can

[24] Moreover, two of the "*extra assumptions*" he thought must be added to make quantum chemistry follow from quantum mechanics are not completely true when extrapolated to a crystal, namely that "*all the interactions among the components of a molecule are electromagnetic*" and that "*every chemical reaction consists of either the combination or the dissociation or the substitution of atoms or polyatomic systems, such as molecules and radical*". These claims neglect mass effects for instance, in the lattice relaxation processes, and in isotopic phase segregation phenomena.

interact by coulombic (long range) and elastic (middle range) interactions resulting from their relative electric charge and the crystallographic distortions arising from the atomic (ionic) neighbours position relaxation, respectively. They can pair, and when their concentration increases, they can order (by adopting periodic crystallographic positions instead of being randomly distributed through the crystal lattice) and lead to new structural types. They can also help forming clusters, as in the well-known Koch-Cohen cluster in wustite $Fe_{1-x}O$[25], or dislocations[26], and can even trap mobile electrons and form so-called polarons[27]. In doing so, they behave like a system *per se* inside the crystal which in turn is to be viewed as the reactor for crystalline imperfection reactions. They also have a tremendous technological importance (Gunkel et al. 2020; Debuisschert 2021). Due to the modification of the bond strength arising from the mass and electric charge variations entailed by the removal of an ion, the presence of a vacancy implies that the nearest ionic neighbours are shifted with respect to their positions in the normal ideal crystal, so that in the vicinity of the vacancy some lattice distortion occurs, producing a specific contribution to the vacancy formation enthalpy variation (in the form of elastic stress and strain) and entropy variation (resulting from the local lattice vibration frequencies modifications). Nevertheless, at longer range—at several lattice sites away from the vacancy, the crystal lattice remains unchanged. One may identify at least two ways vacancies (and their properties) bring about emergent (or submergent) features:

1) Bunge firmly defined the composition of a system at a certain level as the set of parts of the system belonging to the considered level. The molecular composition of a body of water is the set of its H_2O molecules, and the atomic composition of the same body is the set of H and O atoms that

[25] According to Robert Collongues (1973), it is iron protoxide which "from 1927, drew the attention of chemists and appeared as the archetype of non stoichiometric compound", and "the first attempt at demonstrating a non random distribution of vacancies in a non stoichiometric compound was performed by Bertaut" in a pyrotine crystal Fe_7S_8.

[26] Extended one-dimensional defects which stem from periodically missing atoms.

[27] Mobile electrons (or holes) are, with vacancies, the only two known quasiparticles in a crystal which do not refer to a chemical species. When an electron is trapped on a vacancy site, it generates an additional distortion that stabilizes it on the crystal lattice, and so the electron plus the local distortion it carries is called a classical (dielectric) polaron.

compose it. In Bunge's words, a chemical system is one whose components are reacting chemicals (atoms, molecules or radicals). The axiomatized formulation of this definition completely excludes the recognition of the interdependencies between the constituents, so it is abundantly clear from his writings that what he calls a component is in fact a constituent in the chemical thermodynamics sense[28]. A way to circumvent the difficulty could be to define the "physical level" by means of some sort of building unit composition of the crystal system, which could, of course, include the vacancies building units. After all, quasiparticles should "fit in the reference class of physics". However, in that case, it would also mean that the immediately preceding level of organization of the crystal would less be defined objectively than *ad hoc*[29], that is, with respect to constraints imposed by its structure. Vacancies suggest a new criterion for qualifying a thing as emergent: anything that is a component of a system which cannot be as well referred to as a constituent (or a part) is ontologically emergent. Neutral vacancies are examples of real and material things, the emergent nature of which is completely related to their type of (non-equivalent) crystallographic site, namely their space location (in the crystal lattice reference frame) and set of spatial relationships with other building units in the crystal (site symmetry group);

2) the crystallographic site symmetry group is the set of symmetry operators that leaves invariant the crystallographic site, as well as the hamiltonian and the wavefunction of any particle or quasiparticle that occupies it. Hence, it is a property of the most universal properties of things: their energy and their location in spacetime. It just so happens that due to ionic positions relaxation processes at play in the formation of a crystalline imperfection, this site symmetry group, which in the perfect ideal

[28] It is obvious from volumes 3 and 4 of his *Treatise*, that he uses both terms almost as synonymous.

[29] Although fully consistently with the exact definition 1.8, page 13 of the volume 4 of his *Treatise.*

crystal is determined exclusively by the unit cell content, can change. Some new symmetry operators can emerge, while some others can submerge, and it is even possible that emergent and submergent behaviours occur during the same transient regime leading to equilibrium. We shall see some examples of this in the next section[30].

3.5] Spectroscopic Properties of RE^{3+} Cations in Insulating Dielectric Crystals

Because the crystal-field possesses the same symmetry operators as the electric charges, dipoles, quadrupoles, etc., that give rise to it, the study of the optical spectra of several rare-earth 3+ (RE^{3+}) cations dissolved in crystals permits us to characterize the crystallographic site symmetry group properties. In the case of Eu^{3+} cations, symmetry "trees" have been established that allows us to quickly identify from optical absorption and/or luminescence spectra their site symmetry group. Let us have a look at sesquioxides TM_2O_3 (TM=Sc,Y,Gd,Lu,In) doped with Eu^{3+} cations. In these

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[30] Actually, there might be an additional way vacancies bring about submergent features, but the topic would deserve a full article of its own. The phenomenological (macrochemical) equation describing the formation kinetics of Schottky vacancy pairs, which is a law of chemical kinetics, i.e. a property possessed by the population of vacancies, is not symmetrical by time inversion (nor is the law describing the related entropy increase). On the other hand, at the microscopic level, the Schrödinger's equation describes the spatiotemporal trajectories of the vacancies, and it is well-known that this equation is invariant with respect to the time reversal operation $t \rightarrow -t$. To the best of our knowledge, two physics theoreticians (Léon van Hove (1955) and Joseph Seiden (1957)) were the first to firmly establish the mechanisms of relaxation towards equilibrium, in different systems, with different assumptions, and to ground the entropy increase at the microphysical level (we mean, to establish Boltzmann's H-theorem—including the loss of the "invariance by time inversion" property—starting from the Schrödinger's equation), for a specific class of initial conditions. They demonstrated that it is fully possible to get rid of arguments and concepts of statistical nature or *ad hoc* (Gibbs ensembles, phase space, ergodicity, molecular chaos, random phase approximation, Dirac's method of constant's variation, etc.) to establish "mechanistically" the relaxation towards the equilibrium state of a system with a very large number of particles: internal molecular movement (semi-rotation of chlorine in molecular crystals containing –CCl_3 molecular groups)—strong coupling, quadrupolar interaction mediated coupling to the Brownian motion of molecules in a liquid—weak coupling, phonon-phonon, magnon-phonon and/or magnon-magnon collisions—weak coupling. These works hold "only" for a specific class of initial conditions and so far (and not by principle), the time reversal symmetry loss upon passing from Schrödinger's equation to macrochemical kinetics equation can still be viewed as a submergent property, and the full reduction of the latter to the former does not seem to be a piece of cake.

crystals, there are two new building units that are dissolved in very small amounts, and their well-defined chemical potential $\mu_{Eu|TM(C_2)|}$ and $\mu_{Eu|TM(C_{3i})|}$ [31]. As explained before, in the cubic crystallographic form of this oxide, TM^{3+} cations occupy two crystallographically nonequivalent sites in a ¼(C_{3i})-¾(C_2) proportion[32]. The majority site bears no inversion operation so that it is said to be noncentrosymmetric. This induces odd components of the crystal-field which force electric-dipole allowed optical intraconfigurational transitions between crystal-field sublevels. These sublevels, constituting the so-called "fine structure" of the Eu^{3+} cations' 4f electrons in cubic TM_2O_3's, arise from the degeneracy lifting, by the crystal-field, of the spin-orbit multiplets of the Eu^{3+} cations $4f^6$ electronic configuration. In the gaseous state, or in the "free ion" state (of atomic physics), where no (odd and even) crystal-field components exist around the Eu^{3+} ions, such transitions are strictly electric-dipole forbidden, and no visible absorption and luminescence are observed. So, these specific (and possibly polarized) absorption and luminescence, are emergent properties at the crystal chemical level, which do not exist at the "physical level of organization". The electronic energy level diagram is also *partly* an emergent one, because the degeneracy of the free ion spin-orbit multiplets is lifted by the crystal-field, which gives rise to crystal-field sublevels that are labeled by the crystal quantum number (Margerie 1965; Hellwege 1948). The crystal quantum number, which is related to the atomic or free ion quantum number L for angular orbital momentum but not reducible to it, expresses the group theory properties and, in the crystal-field theory, all its possible values correspond to one of the irreducible representations of the site symmetry group. Hence, its

[31] To which the same considerations as those developed in the previous sections apply. Since its concentration remains very small, the chemical potential of the building unit formed by the lattice molecule TM_2O_3 is taken as the standard chemical potential of this compound in its Raoult's reference state.

[32] It was found recently that the statistical distribution of Eu^{3+} cations dissolved in a flux-grown Y_2O_3 crystal, does not follow the 25-75 % "share" of the crystal structure, but a shifted 16-84 % distribution in favour of the crystallographic site endowed with C_2 symmetry group. This illustrates our previous remark on the necessary differentiation of "*Z-equivalent*" cations in a crystal structure. Another example is that of chrysoberyl Cr^{3+}-doped $BeAl_2O_4$ crystals, in which the Al^{3+} cations occupy octahedral sites and Be^{2+} ones occupy the tetrahedral sites. The two crystallographically nonequivalent Al^{3+} sites in this structure occur in equal numbers, but ~80% of Cr^{3+} impurity ions occupy the C_s mirror sites, which play an exclusive role in laser action.

possible values are constrained by site symmetry. It just so happens that in cubic TM_2O_3's, there is a difference between the site symmetry group and the (kind of) "molecular" dominant symmetry that can be inferred from a continuous symmetry analysis of the crystal structure at an intermediate level, between the crystal chemical and the so-called "physical" levels, which might be defined by the nearest neighbours coordination sphere of the Eu^{3+} cations. While the former is C_2, the latter is quasi-C_{2v} (Krupke 1966; Linarès 1968)[33]. If one would perform a very simple calculation of crystal-field parameters by lattice summations based on the multipole expansion of the electrostatic interaction between ions in this crystal structure, one would expect that the parameters imposed by the C_2 symmetry, namely iB_{42}, iB_{44}, iB_{62}, iB_{64}, iB_{66}, are almost systematically nil, which would lead to the *a priori* conclusion that the crystal-field parameterized hamiltonian must be invariant by the C_{2v} site symmetry group operations. In fact, it was firmly established by means of combined experimental spectroscopic energy levels determination and parameterized crystal-field hamiltonian calculations, that these imaginary crystal-field parameters are far from being negligible (Antic-Fidancev, Hölsä, and Lastusaari 2002). This proves that the site symmetry C_2, lower[34] than C_{2v}, which results in measurable and computable spectroscopic properties of the 4f electrons, is truly an emergent symmetry non-deducible from the atomic physics level nor from some kind of intermediate level between the atomic and the unit cell level. Thus, the value of the crystal quantum number labelling each of these crystal-field sublevels is (at least partly) an emergent property. While the number of crystal-field sublevels arising from the degeneracy lifting of the spin-orbit multiplets of the Eu^{3+} cations, and the allowance of forced electric-dipole optical intraconfigurational transitions (absorption, luminescence, including polarization effects), are to some extent emergent properties of the 4f configuration electrons at the crystal

[33] Another example where the dominant "molecular" or "polyhedral" symmetry group is of higher order than the actual site symmetry group is in the $ZnCu_3(OH)_6Cl_2$ herbertsmithite crystal structure, around the Cu^{2+}(2) cationic site: while the former is D_{4h}, the latter is D_{2h}. The fourfold rotation axis is lost upon addition of the unit cell atomic content beyond the first coordination sphere.

[34] Interestingly, when the degree of "assembly" increases here, from the O^{2-} second nearest neighbours of the Eu^{3+} cations to the full content of the lattice unit cell, the vertical mirror symmetry operator disappears, which can be qualified as a quasi-submergent phenomenon.

chemical level, the energy splitting between the sublevels, the strengths and cross-sections of these optical transitions are resultant properties. One should be dissuaded from thinking that an inversion symmetry operator has a causal power[35]. One way to understand this is to realize that under the parity conservation general principle and the Wigner-Eckart theorem application, there is a separation between the features of these spectroscopic properties which depend only on spatial relationships (site symmetry group) and those which depend on the details of the multipolar electrostatic interactions between ions (Weissbluth 1978)[36]. Some transition selection rules are rigorously deduced from symmetry considerations, some others depend on the angular momenta specific coupling scheme. Moreover, optical spectroscopy of Eu^{3+} cations (and of some other RE^{3+} cations) is also helpful in demonstrating that site symmetry group properties may emerge and/or submerge during the relaxation processes taking place during their dissolution in the crystal structure. For instance, the dissolution of Eu^{3+} cations in crystallographic sites of the KPb_2Cl_5 structure that bear only the identity operator (C_1 group) leads to the emergence of higher order symmetry operators, like a threefold rotation axis or a vertical mirror (C_3 and C_{2v} groups) (Cascales, Fernández, and Balda 2005). The same happens when Eu^{3+} cations are dissolved in orthorhombic α'-Sr_2SiO_4 crystals: while the two Sr^{2+} cations crystallographically nonequivalent sites have a C_1 symmetry group, Eu^{3+} cations adopt a C_{2v} and a C_{3v} site symmetry group when substituting for the ninefold coordinated Sr^{2+} cation and for the tenfold coordinated one, respectively (Gupta, Kadam, and Pujari 2020). While, on the other hand, the dissolution of the same cations in α- and β-forms of $NaYF_4$ crystals is accompanied by a loss of many symmetry operators, characterized by the decrease in symmetry order from O_h (α-form) or C_{3h} (β-form) to C_2/C_s symmetry groups (You et al. 2018). In $Ca_2La_3Sb_3O_{14}$ (Srivastava et al. 2014) and $SrZrO_3$ (Gupta, Kadam, and Pujari 2020) crystals, the same chemical reaction on centrosymmetric crystallographic sites leads to the submergence of the inversion point symmetry (as evidenced by visible emission spectra), as in $CsCdBr_3$, where two Eu^{3+} cations form an associated complex with a Cd^{2+}-vacancy and lower the site symmetry from D_{3d} to C_{3v}

[35] Electrons have, through their charge, angular momentum, and so on.

[36] Check for example pages 159-167, 500-504 and chapter 28.

(submergence of an inversion point, three perpendicular twofold rotation axes and a sixfold improper axis) (Pellé et al. 1995).

4] Conclusions

We hope we have been convincing in trying to establish that relative building units and their chemical potential illustrate the fact that crystal chemistry is not reducible to atomic and lepton physics. While the existence of O^{2-} anions, or the magnitude of the crystal-field parameters are examples of resultant effects, vacancies, and more broadly speaking relative building units, are examples of ontologically emergent objects, and the building units chemical potentials, the crystal quantum number (itself an undefinable quantum number at the atomic or free ion level of description), are other examples of emergent properties poorly reducible to microphysics. Relative building units constituting, at the angström-scale of description, the "atomic" basis for non stoichiometry, it is straightforward to understand that the latter, which, to quote Robert Collongues, expresses the existence of a composition variation of a single phase in a solid, in contradiction with the Proust-Dalton laws, is an emergent property of crystals.

We have argued that vacancies[37] are ontologically as real as material. Note that the discussion about the O^{2-} anion might be generalized to all ions said to exhibit unusual oxidation states and that crystal chemistry may supply the philosophical reflection with other interesting objects such as clusters embedded in crystals and dislocations patterns, likely to illustrate ontological emergentism at play in condensed matter processes. We have also seen that crystallographic site symmetry properties that are (invariance) properties of properties of things (like energy, wavefunctions), may also be viewed as emergent (or submergent) properties. In this discussion, we have been concerned with properties that are not only well-defined, but also at the very core of statistical thermodynamics (the chemical potential) and quantum mechanics (the crystal quantum number which labels the eigen wavefunctions and upon which the hamiltonian algebra directly acts) of crystal chemistry, and we believe that makes our arguments much stronger than if we had manipulated vague, non-dimensional and purely qualitative properties as is sometimes the case in the philosophical literature on reduction

[37] Including electrically neutral vacancies.

and emergence. Perhaps a strategy to find emergent objects and properties could be to look for symmetries that appear only at some level of organization, resulting in closely related conservation rules necessary to define root properties, and then to look for intrinsic (and local) deviations from these symmetries and their impact on the preceding level. In the ontology and epistemology of crystal chemistry, this leads for instance to the distinction between a component and a constituent, and the recognition of the vacancy as a strikingly emergent thing.

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A Constructive Critique of Mario Bunge's Theory of Truth

David Martín Solano[1]

Abstract — Truth is the degree of accuracy when representing reality. We postulate three cognitive stages: the psychon, produced by perception; the construct, produced by intellection; and the speech act, produced by communication. Truth lies in the second; only constructs are alethic. Truth is a quality which takes place in degrees. Certainty is the unreachable perfect tip of this gradation, so it is an ideal concept. A thesis is deemed true if its alethic degree is acceptably efficacious, otherwise the thesis is deemed false. In other words, we deem true any thesis not having enough fails to deem it false.

Résumé — La vérité est le degré d'exactitude d'une représentation de la réalité. Nous postulons trois étapes cognitives : le psychon, produit par la perception ; le construit, produit par intellection ; et l'acte de parole, produit par la communication. La vérité se trouve à la seconde étape ; seuls les construits sont aléthiques. La vérité est une qualité qui vient en degrés. La certitude est le point d'aboutissement parfait et inaccessible de cette gradation ; il s'agit donc d'un concept idéal. Une thèse est réputée vraie si son degré aléthique est acceptablement efficace, sinon la thèse est considérée comme fausse. En d'autres termes, nous jugeons vraie toute thèse n'ayant pas assez d'échecs pour qu'elle soit considérée comme fausse.

Those who study knowledge, or who use it to study some theoretical or practical problem, take as a goal to represent reality in an accurate manner, i.e. to beget ideas informing the person about how it is the universe surrounding her, for her to get on

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successfully in it. A requisite entailed by this aim is to tackle one of the oldest and more important problems in philosophy: what truth is. All philosophical currents include this question in their problematics and diverse solutions struggle for acceptance. We propose a correspondence theory, built upon the Bungean theory of truth, which we try to complete.

We dismiss hermeneutic theories of truth because the concept they consider, wrongly referred to as "truth", is distinct from the one we consider here. They are valid theories—the ones that turn out to be valid—, but theories about another issue, namely, conviction assessment. We postulate a radical distinction between, from one side, intendment[2] (*Erklärung* in German), which consists in the obtainment and organization of notions (as objective as possible) and which corresponds to honorness[3], i.e. non-deceitful conveyance of facts and knowledge, and, from the other side, understanding (*Verstehen* in German), which consists in the obtainment and organization of convictions (sensibly subjective) and which corresponds to honesty, i.e. non-deceitful conveyance of feelings or desires or opinions. The former produces a system of ideas representing reality, whose only validity criterion is its resemblance to this reality. The latter produces a system of ideas that reorganizes this representation around the subject whose validity criteria are others, only retaining from the former system the principle of not transgressing truth.

Another class of alternative theories, reasonable but wrong, are those that identify truth with its hypernym, the justification of its validity (Sáez Rueda 1995, 176). This is the so-called "consensual theory of truth", proposed by the current named "critical theory" and which in fact deals with one of the properties of the theses, namely, that they are acceptable. Once again, these are more or less correct theories about a distinct issue.

The best Bungean contribution to this question is not, as he said, definitive (Mario Bunge 2012). He continued investigating the problem because he knew that he had not found a satisfactory conclusion (Mario Bunge 2014, 149, 215; Romero 2015). The path starts on a smooth slope "as for the problem of truth as adequation, […] all

[2] "Intendment" in the sense of "entender" in Spanish. (Ed.)

[3] "Honorness" in the sense of "honradez" in Spanish. (Ed.)

realists believe in this 'theory' of truth, but no one has been able to formulate it" (Mario Bunge 2008); "all scientists use tacitly the so-called theory of correspondence or adequation of things to facts. But nobody has yet formulated this theory" (Mario Bunge 2009, 125). But it goes rather complex quite soon. Without his now impossible permission, we propose a plausible way of solving it.

1] Adequating The Mind to the Things

In order to elaborate our proposal, we offer two conjectures of our own: the theory of the three stages and the theory of cognitive maquetting.

Instead of the traditional scheme {fact → construct → speech act}, we propose three processes producing three cognitive stages: {fact → psychon[4] → construct → speech act}. The first process is apprehension and consists of sensing or imagining a fact and processing the resulting image by means of a mechanism called "perception" that adjusts it to the cognitive system, in which it gets integrated. The second process is inference and consists of psychons combining with each other so they beget new psychons, more complex than them. This process resembles perception and increase the cognitive stock. Both mediate and immediate cognitive psychons get integrated in the cognitive system. The third process is formulation and consists of making a second representation: the constructs and its relations with signs that, by means of semiotic mechanisms, form a message, i.e. a communication act which allows another person to think a construct analogous to the one represented by the person who formulates. Note that the sender and the receiver may be the same person; in this case, the sender tries to make him or herself to think again a certain construct.

Truth is in the third stage, produced by the second process. Bunge claimed its distinction from the previous stage: propositions are alethic (i.e. they have the quality of being either true or false) (Mario Bunge [1996] 1999, 78); in their turn, it is impossible for concepts to be alethic. And he is also the one who found the yearned key in a revealing paragraph where he distinguished the idea,

[4] A psychon is a collection of neurons interacting to produce an idea, or an idea's part, or a collection of ideas. For this concept, see Bunge, 1983.

which is the factual mental element, from the proposition, which is its formal counterpart:

> Thoughts are, unlike constructs, cerebral processes. Hence, there cannot be two thoughts completely identical. Nobody thinks twice in exactly the same manner the number 5 or the moon, at least we never experience exactly the same states. What we can suppose is that all thought processes producing the number 5 (or any other construct) use the same neural patterns, that is, they are equivalent in an essential aspect (Mario Bunge 2011, 176)

We add the distinction of the next stage. On the one hand, a proposition's alethic properties shall not be confused with its semiotic properties: the ways of formulating it and the ways of interpreting this formulation. On the other hand, they shall neither be confused with their social properties: their acceptance by the investigative community or by the society in which this is contained, and its validation as an argument in a debate among members of this community or this society.

In the second conjecture we tackle the problem of what is the representation of reality. One of the suggested solutions is Wittgenstein's (Wittgenstein [1922] 2012) pictorial theory: the mental representation and the represented reality are isomorphic. We excuse not to expound the vehement refusal it aroused and its profuse refutations. Nevertheless, we believe that Wittgenstein almost hit the mark. The mind does not reflect reality like a burnished surface, but it builds an image from cognitive pieces analogous to real elements[5]. This mental construction mimics the structure of a universe's fragment, and it does it by discarding some elements and adding others of its own. It is partial maquette, both defective and exceeding.

2] Formal Consistency

All constructs must abide the requisite of formal consistency if they are to possess the alethic quality, that is, if they are to be either true or false. The so-called "formal truth" is not an alternative or complementary truth, with its own theory, nor a component of truth, with its corresponding part in the theory, nor anything like

[5] Tootell *et al.* (1982, 1998) and Kosslyn (in Gärdenfors 2014) demonstrate that cortical neurons order themselves in a way that configure the perceived object.

this. Our conjecture opposes the deflationary theories, led by Tarski, which conflate the test of epistemic theories, a task for epistemology, with the test of epistemological theories, also a task for epistemology (Tarski 1944). Put otherwise, they conflate the analysis of truth with the analysis of the theory of truth.

Bunge seemed to agree: one has to distinguish the alethic status a proposition has, from whether it is correct or wrong to attribute it to the status (Mario Bunge [2006] 2007, 354)[6]. But he swung from distinction—testing formal validity must precede testing truth or falsity, which is factual by necessity (Mario Bunge 1959, 72)—to indistinction—it is incomplete and thus flawed that a theory does not satisfy the two classes of truth: formal and factual (Mario Bunge 2014, 203)—, and this alternation is one of the hurdles that impeded him to bring a solution to the problem. He even took a stance near to ours (Mario Bunge and Mahner 1997, 129): we need a theory of coherence to tackle "formal truth" and a theory of correspondence to tackle "factual truth". Had he remarked and maintained the distinction, he would have made a crucial stride in the matter.

3] Truth as a Privative Concept

Abstractions are concepts without real correlate, but useful as epistemic supports. For the present inquiry we are interested in those based on negation. Shortage consists of an ens (a being) possessing a quality in less quantity than it is normal for the entia of its category. Lack consists of an ens not possessing a quality that the entia of its category used to possess. Defective concepts are those which consist of a lack such as bald or amputee. Privative concepts are those which consist of a shortage such as cleanness or security. Ideal concepts are those which consist of a zero degree of shortage, which *ex hypothesi* is unattainable, such as immaculateness and certainty. Rebic[7] concepts are a class of negative concepts consisting not in the possession of a differential quality but in denying a quality or property. Some rebic concepts are "non-smoker", because it cannot be specified what a person has to do to qualify as

[6] Besides, truth and knowledge are interdependent. Marquis is wrong when he says that knowledge is independent of truth since some animals are able to know without needing it. He conflates truth per se with truth as a subject matter (Marquis 1990).

[7] We coin both the concept and the term. The word comes from the mythological character Rebis.

this, and “atheist”, for there is no set of beliefs that a person has to profess in order to be this. Rebic would be the contrary concept for “bald” or a concept opposite to “vegetarian” and “vegan”. Rebic concepts are “active voice”, “direct problem” and “darkness”. However, neither “right-handed” nor “heterosexual” are rebic, because, contrary to the non-smoker”, these persons do perform actions that characterize them as such.

And, finally, the conjecture. Truth and falsity are two intervals in the same gradation: the degree of structural correspondence of constructs with the elements of reality that they represent. The uppermost degree of correspondence is unreachable, so truth is necessarily partial and meliorable. A proposition may be more or less truth, or else more or less false. Between truth and falsity there is a threshold, that is, there are liminal cases amid them in which the distinction is not clear. Both *gnosis* (daily knowledge) and *episteme* (professionalized knowledge) narrow this threshold. As it can be said of any acceptable proposition that it has a degree of truth, it can also be said that it has a degree of falsity. Unacceptable propositions also have a degree of falsity, albeit it uses to be omitted, for the sake of clarity, in which tiny degree they are true.

Bunge argued that, “strictly speaking, no theory can be assigned a truth value, because this assignation requires to check its infinite formulas” (Mario Bunge 1983, 6:137). We reply that only actual ideas, whatever they are, are that which is under consideration. Said otherwise, the expressed ideas are propositions whose veracity is to be evaluated. We also rebut the traditional thesis: “false: untrue” (Mario Bunge 2003, 105). According to our theory, “true” is defined as “unfalse enough”.

4] Conclusion

This article proposes a readjustment of the investigation of truth. Firstly, taking it back to its original track: to fit as tightly as possible what one thinks of what indeed takes place. There are other intellectual activities which thoughts abides to distinct criteria; these are not truth, which is exclusive to intellectual activities of knowing. Secondly, restating this centenary approach. Instead of considering the positive aspect, that inevitably drains from the epistemologist’s hands, its reverse is what ought to be considered. This is the real alethic substance, the property possessed by propositions and inquirable in them. The first movement follows Bunge's steps; the second departs subtly from him, perhaps (we hope) to the crux of the matter.

In order to sustain this eversive thesis we have postulated: (i) a formal thesis to distinguish factual truth testing from formal consistency testing, the latter a requisite for truth and not a part of it; (ii) a theory amid ontology and semantics to explain negative abstractions; and (iii) two theories belonging to applied psychology: on the stages of the formation of knowledge and on the structuration of knowledge.

We think that our restatement of the classical approach to truth may be productive for enhancing theoretical and practical advances in this field and as a reference to evaluate other theories of truth by comparing their postulates and conclusions with theirs.

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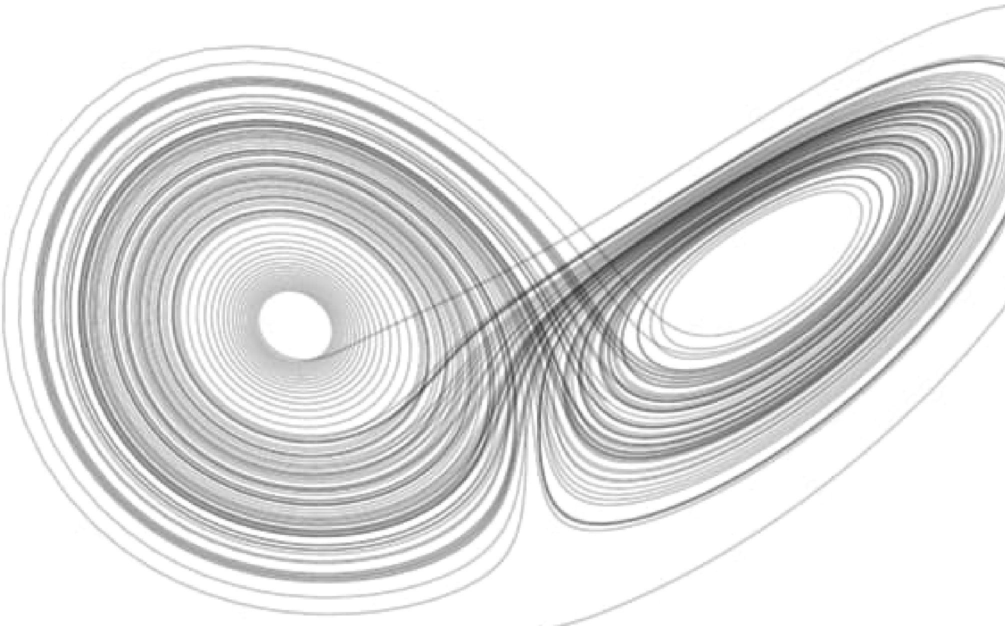
3
Applications of Bungean Thought



Foundations of Information Technology Based on Bunge's Systemist Philosophy of Reality

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Abstract — General ontology is a prominent theoretical foundation for information technology analysis, design, and development. Ontology is a branch of philosophy which studies what exists in reality. A widely used ontology in information systems, especially for conceptual modeling, is the BWW (Bunge–Wand–Weber), which is based on ideas of the philosopher and physicist Mario Bunge, as synthesized by Wand and Weber. The ontology was founded on an early subset of Bunge's philosophy; however, many of Bunge's ideas have evolved since then. An important question, therefore, is: do the more recent ideas expressed by Bunge call for a new ontology? In this paper, we conduct an analysis of Bunge's earlier and more recent works to address this question. We present a new ontology based on Bunge's later and broader works, which we refer to as *Bunge's Systemist Ontology (BSO)*. We then compare BSO to the constructs of BWW. The comparison reveals both considerable overlap between BSO and BWW, as well as substantial differences. From this comparison and the initial exposition of BSO, we provide suggestions for further ontology studies and identify research questions that could provide a fruitful agenda for future scholarship in conceptual modeling and other areas of information technology.

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Résumé — L'ontologie générale constitue un fondement théorique important pour l'analyse, la conception et le développement dans les technologies de l'information. L'ontologie est une branche de la philosophie qui étudie ce qui existe dans la réalité. Une ontologie largement utilisée dans les systèmes d'information, en particulier pour la modélisation conceptuelle, est l'ontologie BWW (Bunge-Wand-Weber), fondée sur les idées du philosophe et physicien Mario Bunge, telles que synthétisées par Wand et Weber. Cette ontologie a été élaborée à partir d'une ancienne version de la philosophie de Bunge ; cependant, de nombreuses idées de Bunge ont évolué depuis lors. Une question importante est donc la suivante : les idées les plus récentes exprimées par Bunge appellent-elles une nouvelle ontologie ? Dans cet article, nous analyserons des travaux récents et antérieurs de Bunge afin de répondre à cette question. Nous présentons une nouvelle ontologie basée sur les travaux plus récents de Bunge que nous nommons *ontologie systémiste bungéenne* (Bunge's Systemist Ontolgy ; BSO). Nous comparons ensuite BSO aux constructions de BWW. La comparaison révèle à la fois un chevauchement considérable entre BSO et BWW, ainsi que des différences substantielles. À partir de cette comparaison et de l'exposition initiale de BSO, nous proposons des suggestions pour diverses études ontologiques et identifions des questions qui pourraient alimenter un programme de recherche tant en modélisation conceptuelle qu'en technologie de l'information en général.

Human society is relentlessly increasing its reliance on information technology (IT). This reliance will only grow stronger as a result of the COVID-19 pandemic, providing a new impetus to move even more human activities online (Watson et al. 2020; Weinhardt et al. 2020). The human world is becoming digital, which is happening especially rapidly since the last decade and a half (Floridi 2012; Recker et al. 2021; Yoo and Lyytinen 2005). It is thus particularly concerning that the IT projects that support this digitalization frequently fail (Gupta et al. 2019; Nelson 2007). IT usability is often low (Eveleigh et al. 2014; Stephanidis et al. 2019); digital data continues to be of poor quality (Batini et al. 2015; Daniel et al. 2018). These problems have a common characteristic in that they either directly or indirectly deal with how IT shapes and represents real-world domains.

It is critical to build IT based on solid theoretical and methodological foundations (Guerreiro, van Kervel, and Babkin 2013; Henderson-Sellers 2015; Weber 1997). However, IT development often continues to be conducted in an ad hoc manner, with the outcomes heavily dependent on the skills and training of developers (Anderson et al. 2013; Duboue 2020; Pastor 2016). At its core, information technologies manipulate symbols making it further important to ensure that the relationship between the symbols upon which IT is based, is anchored appropriately in their real-life referents (Weber 1997). For example, the physical inventory of cars at a dealership may be represented symbolically using binary patterns stored on a computer hard drive and managed and organized by a database management system. The database, in turn, can be accessible to prospective buyers over the Internet via a web interface. In order for the prospective customers of the dealership to gain an accurate knowledge of what cars are actually available, it is essential to ensure that correct patterns of bits and bytes are properly governed by the database management system. The patterns, in turn, must be correctly designed based on the accurate model of the car dealership domain. Hence, the goal of building better IT involves the investigation of the relationship between what is being stored and manipulated in a computer and its real-world referents.

Historically, one of the most prolific and effective foundations for IT analysis, design and development has been *ontology*. Ontology is a branch of philosophy that studies what exists in reality, as well as what reality is (Gonzalez-Perez 2015; Guizzardi 2005). In this research, we focus on a *general ontology*, also known as a foundational or upper level ontology. A general ontology can provide IT development with theoretically grounded, consistent, formalized and rigorous meaning for the basic notions of what exists in reality.[4]

Due to their potential to put IT development on stronger methodological foundations, ontological studies are widely embraced by the IT community. Applications are especially prolific in research on *semantic web* (Berners-Lee, Hendler, and Lassila 2001; Burton-Jones, Purao, and Storey 2002), which aims to move beyond syntactic matches to deeper interoperability, and on *conceptual data and process modeling* which develops representations of application domains and user requirements (Mayr and Thalheim 2020; Mylopoulos 1998; Recker et al. 2021). Ontologies have also been used in knowledge management, artificial intelligence, interface design, database schema integration, analysis of software performance, information quality, and other applications (Ferrandis, Pastor, and

[4] A general ontology is thus different from a *domain ontology*. A domain ontology is a description (often formal) of constructs in a particular domain (McDaniel and Storey 2019). Examples include an ontology of Software Defects, Errors and Failures (Duarte et al. 2018), database design (Sugumaran and Storey 2002; 2006), or ontology of research validity (Lukyanenko, Larsen, et al. 2019), and many others in diverse domains (McDaniel and Storey 2019; Purao and Storey 2005).

Guizzardi 2013; Guarino 1995; Guizzardi 2005; Pastor, España, and González 2008; Recker, Rosemann, and Krogstie 2007; Reinhartz-Berger, Itzik, and Wand 2014; Storey, Goldstein, and Ullrich 2002; Verdonck et al. 2019; Wand and Wang 1996; Weber 2021). Empirical benefits of adopting a specific domain ontology for conceptual modeling or to improve data quality have been documented (Bera, Burton-Jones, and Wand 2014; Bodart et al. 2001; Burton-Jones and Weber 2014; Cheng, Lu, and Sheu 2009; Lukyanenko, Parsons, and Wiersma 2014; Recker et al. 2011; Sugumaran and Storey 2002; Verdonck et al. 2019).

Various general ontologies have been used for IT analysis, design and development. Prominent examples include Unified Foundational Ontology (UFO) (Guizzardi et al. 2015), social ontology of Searle (March and Allen 2014), General Formal Ontology (Herre 2010), DOLCE (Gangemi et al. 2002), Phenomenological Foundational Ontology (PFO) (Jonsson and Enquist 2019), ResearchCYC (Conesa, Storey, and Sugumaran 2010), and others (for more discussion, see, e.g., Guizzardi 2005).

A major ontology for conceptual modeling and other IT applications is the Bunge-Wand-Weber (BWW), based on works of the philosopher and physicist Mario Bunge (1919–2020), and synthesized and applied by Wand and Weber and colleagues (Wand, Storey, and Weber 1999; Wand and Weber 1988; 1995). The BWW has been applied in theoretical, empirical and design research across a wide range of disciplines (Wand and Weber 2017; Burton-Jones et al. 2017). It has also provided the conceptual background to design and implement conceptual programming-based tools (Embley, Liddle, and Pastor 2011; Pastor and Molina 2007), which facilitate the design of an ontology-driven conceptual modeling system with industrial support (e.g., Integranova, www.integranova.com).

At the same time, the BWW ontology has been criticized (e.g., Wyssusek 2006), especially with respect to the assumptions underlying the ontology roots; that is, the philosophical beliefs of Bunge. Notably, BWW was developed on a subset of Bunge's ontology (1977; 1979) which is now over 40 years old. Since the publication of these two primary sources for the BWW ontology, Bunge published over 100 books and 300 papers (Bunge et al. 2019), in which his ideas were further expanded, refined, and sometimes altered. These additional writings lead to the following research questions.

Is there a need to revise the original BWW? Are statements such as "Bunge believes the world is made of things" still appropriate, given the evolution of Bunge's work? Is an expansion of BWW needed (Rosemann & Wyssusek, 2005) or do the ideas expressed by Bunge, which are not part of BWW, call for a new ontology? Can the initial tenets of this new ontology be formulated? What are the implications of such a new ontology for the development and use of IT?

To address these research questions, we first discuss the basic tenets of BWW to establish a common understanding of Bunge's ideas. We then consider the more recent ideas of Bunge and present them as a proposed, new ontology, which we call Bunge's Systemist Ontology (BSO). The new ontology is compared to BWW, the results of the comparison are discussed and implications for future research are detailed.

1] Background: Bunge–Wand–Weber Ontology

Yair Wand and Ron Weber offer a first-hand account (Wand and Weber 2017) of their motivation to ground information systems research in a foundational ontology, as well as of how they developed a set of theories based on what became known as the Bunge-Wand-Weber ontology (BWW). The theories were: ontological expressiveness, a representation model, and a good-decomposition model. Although they consulted other sources, the primary foundation of BWW are two seminal manuscripts on ontology by Bunge (1977; 1979), which are part of his eight-volume *Treatise on Basic Philosophy*.

The BWW ontology (Wand and Weber 1988; 1995; 1990a) argues that the world is made of *things*—substantial individuals—which possess properties. Things may form composite things and interact with each other, leading to the acquisition of new properties or loss of existing properties. Properties are not directly accessible to human observers, resulting in the notion of attributes, which humans ascribe to things, but which may or may not be accurate or complete representations of the underlying properties. Sets of things form systems if, for any bi-partitioning of the set, coupling exists among things in the two subsets. The main constructs from Bunge as adopted into BWW are: thing, property, attributes, functional schema, state, law, state space, event, history, coupling, system, class, kind, and their derivatives (e.g., lawful state space) (see Table 1, p. 222 in Wand and Weber 1993)

The BWW ontology, as well as the theories, models and methods derived from it, have been used widely in conceptual, empirical and design work in information systems, conceptual modeling, software engineering and other areas (Wand and Weber 2017), making it an important development in the area of ontology in IT (Jabbari et al. 2018). Despite its influence (Jabbari et al. 2018; Recker et al. 2021; Saghafi and Wand 2014), the ontology has been criticized for its narrow physicalist focus, lack of attention to social and psychological phenomena, and postulates which may be problematic for modeling certain types of domain rules. Examples are proscribed optional properties, denied independent existence of properties, and properties of properties (Guizzardi 2005; March and Allen 2014; Veres and Mansson 2004; Wyssusek 2006).

A generally overlooked issue is that the BWW ontology is based on only selected references from Bunge. Although there were some attempts to expand BWW to incorporate other ideas of Bunge (Rosemann and Wyssusek 2005), these were still narrow in scope and did not realize widespread adoption.

The basis for BWW is two, albeit seminal, manuscripts by Bunge. However, as Bunge frequently noted, ontology is inseparable from other beliefs, such as on how to acquire knowledge in the world (Bunge 2006). Indeed, the *Treatise* contained many additional beliefs, related to semantics, epistemology, methodology, ethics, and technology. During the 40 years since the publication of the 1977 and 79 volumes, and even since the last book of the *Treatise* on ethics (Bunge 1989), Bunge published over 400 manuscripts, in which his ideas were further expanded, refined, and sometimes, altered.[5] Some of these more recent ideas are of great potential relevance to IT, because they directly dealt with issues of information technology (e.g., Bunge 2019).

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[5] An example of a reversal is Bunge's admiration for Marxism-Leninism (an extensive set of beliefs transcending the general public's most familiar ideas about politics and economy). It was Bunge's first major philosophical doctrine, according to his own confessions. But over the years he distanced himself and, eventually, became a vehement critic of Marxist-Leninist "ontology and politics" (Bunge et al. 2019, vii; Bunge 2016).

2] Fundamentals for Constructing Bunge's Systemist Ontology

The task of understanding the differences between Bunge's ideas enshrined in BWW and his other, and more recent thinking, meets a challenge: the ideas which comprised BWW were carefully distilled, whereas the more recent ideas were not. Although based on two volumes, BWW was founded on a self-contained *Treatise on Basic Philosophy* which developed and presented ideas systematically and with great internal consistency. These began with semantics (Bunge 1974), then ontology (Bunge 1977), followed by epistemology (Bunge 1983), methodology (Bunge 1983) and ethics (Bunge 1989). In contrast, Bunge's works since the *Treatise* (1974–89) are not assembled into a dedicated, self-contained single compendium. Rather, it is a collection of over 400 essays, papers and books (Bunge 2006; 1996; 2017; 2018; 2019), which require dedicated synthesis.[6]

To address our research questions, we, thus, engaged in a comprehensive and systematic effort to catalog and distill these beliefs. This project was conducted over five years (2015–2020) and includes the last known publication by the late Bunge.

First, we began to assemble a library of publications by Bunge and conducted a scoping survey of his writings to gain a preliminary understanding of the extent of the modifications and expansions compared with BWW. Second, half-way into the process, the first author of this paper contacted Mario Bunge, who kindly agreed to meet and presented a general overview of his earlier and most recent thinking, answering numerous clarifying questions. Third, we reviewed all pertinent publications using *Google Scholar* and Bunge et al., (2019) as sources.[7] Fourth, we followed the logical path outlined in the *Treatise* (i.e., ontology, epistemology, methodology and ethics) as re-iterated and explained by Bunge in other sources (e.g., Bunge 2006) to catalog the ideas. We began with basic assumptions about reality, followed by the problem of knowledge of reality, and then the application and use of knowledge in society (e.g., in policymaking, science and daily life). Fifth, we began synthesizing the ideas, favoring the most recent publications (e.g., Bunge 2017; 2018) and referencing earlier publications (e.g., Bunge 2006), Bunge's

[6] For example, although Bunge has made a stronger emphasis toward *systems*, his recent writing is still rich in references to *things*, including in the same texts where he discusses systems being preferable to the notion of things (Bunge 2017, 174).

[7] https://scholar.google.com/citations?user=7MmcYgEAAAAJ&hl=en&oi=ao

own memoirs (Bunge 2016), and authoritative studies on Bunge (Bunge et al. 2019), for clarification or expansion of ideas, as needed.[8]

The intended result is a systematic synthesis of Bunge's publications aimed at distilling and presenting a single, coherent and consistent set of beliefs with the aim of using these ideas within the context of information technology. Bunge kindly clarified some of the ideas of his ontology and also shared a copy of his unpublished manuscript.[9] However, all claims made here are justified either through direct references to published works by Bunge or are explicitly noted as our inferences and derivations.

To report the findings, we analyze the constructs of BWW (Table 1, p. 222 Wand & Weber, 1993) and compare them to what we coin as *Bunge's Systemist Ontology (BSO).* The BSO captures broader and more recent set of ideas developed by Bunge. Indeed, Bunge uses multiple labels to describe his set of beliefs (e.g., "emergentist materialism" (Bunge 2003), "hylorealism" (Bunge 2006, 27)), but the most frequently used term appears to be "systemism" (Bunge 1979; 2000; 2018), thus giving the name to the new ontology. This label was also confirmed to be preferable by Bunge himself during our interactions with the philosopher-physicist.

3] Understanding Bunge's Recent Works

We first compare BSO with BWW by focusing on the constructs they have in common. Since BSO is broader than BWW, we also provide an overview of the constructs in BSO that extend beyond those of BWW.

3.1] Bunge's Systemist Ontology Versus BWW

The BSO claims *reality* is all that we know to exist and distinguishes five "kinds" or "levels" of *reality*, including physical, chemical, biological, social and technical (Bunge 1996, 25). One level emerges from another (e.g., social from biological) via emergent

[8] Bunge describes systems in (Bunge 1996, 270), and in many other sources. To obtain a more detailed discussion of properties of systems, one can consult, for example, (Bunge 2006, 10–19).

[9] This was during a personal meeting with Mario Bunge at his residence in Montreal, Canada in September 2018.

properties (discussed later) and higher levels are grounded in the underlying physical level.

The BWW ontology postulates that *reality* is made of *things*, which have properties (Bunge 1977, 26–29). Things are “substantial individuals,” which could be *composed* of other individuals or be *simple*, structureless and atomic (Wand and Weber 1990a, 126). However, many things also form systems, which have things as their components. Hence, Bunge poignantly titled his 1979 volume of the *Treatise*, “Ontology II: A World of Systems” (Bunge 1979).

In his most recent writings, Bunge put forward a more intriguing idea: every *thing* is likely a *system*, which we deem an essential claim of BSO. In BSO a system is the ontological primitive. Per BSO, *the world is made of systems*. What precipitated this change for Bunge and what is its basis? We suggest the postulate “the world is made of systems” is grounded in three more recent beliefs of Bunge.

First, using *the notion* of a system allowed Bunge to reason about entities for which the notion of a *thing* was either ontologically inapplicable with respect to modern scientific knowledge (e.g., consider photon’s wave-particle duality), or linguistically awkward. Bunge (2017) explains (p. 174):

> The word ‘system’ is more neutral than ‘thing’, which in most cases denotes a system endowed with mass and perhaps tactually perceptible; we find it natural to speak of a force or field as a system, but we would be reluctant to call it a thing.

Second, Bunge, following recent advances in particle physics, became convinced that *there are no simple, structureless entities*. Bunge (2017) explains (p. 174, emphasis added):

> By calling all existent “concrete systems” we tacitly commit ourselves *in tune with growing suspicion in all scientific quarters*—that there are no simple, structureless entities.

Bunge notes that the history of science teaches us that things once thought to be irreducible and fundamentally simple (e.g., atom), have later proven to be complex. Bunge asserts that simple and structureless things, if exist at all, exist only at the quantum level (Bunge 2000, 148):

> Only particle physicists study non-systems, such as quarks, electrons, and photons. But they know that all such simple things are parts of systems or will eventually be absorbed by some system.

Thus the idea that "there are no simple, structureless entities" is not only an ontological, but also a normative belief: "[t]his is a programmatic hypothesis found fertile in the past, because it has stimulated the search for complexities hidden under simple appearances" (Bunge 2017, 174). It may very well be that the elementary particles of today (e.g., quarks, bosons) presently considered atomic, in time can be found to be complex. In numerous of his writings, Bunge stresses that he views his ontology, not only as a theory of what exists, but also as a normative template for the kinds of questions to ask when inquiring about the nature of reality (Bunge 1996; 2006; 2016).

Third, systemism for Bunge offered a more balanced approach for *describing reality* (an idea of especial interest to conceptual modeling in IT). For Bunge, systemism holds numerous advantages, as it conceptually lies between individualism (which under-represents internal structures of a system, its relationship with the outer environment, its levels of composition and emergence) and holism (which is not interested in the components and specificity of subsystems). Systemism represents the best of these two ideas, without sacrificing the benefits of each (Bunge 2000). This is how Agazzi, a friend and close associate of Bunge, summarizes his views, which he debated with Bunge extensively (Agazzi 2019):

> [Bunge] explicitly presents his position (which he calls "systemism") as intermediate between two erroneous extremes, "atomism" and "holism". The weakness of atomism resides in that it ignores the relevance of properties and especially relations, without which it is impossible to distinguish a single "aggregate" from a "system". The weakness of holism resides (according to Bunge) in its pretension that the knowledge of the whole must precede and make possible the knowledge of the parts. Systemism avoids both mistakes by recognizing that the whole "results" from the correlation of its parts and at the same time has influence on their functioning.

Thus, the tenet that "the world is made of systems" is an ontological hypothesis and a normative postulate. It offers interesting possibilities for modeling in IT, as discussed later. However, it also offers a notable challenge. Indeed, it could be possible that there are no simple, structureless entities and that even elementary particles may be systems (i.e., composed of other systems), yet this possibility implies an infinite recursion. Within the context of IT, we suggest two ways to address this problem, while simultaneously providing the foundation for future studies to conduct a dedicated analysis of this issue.

First, the majority of extant applications of IT deal with domains beyond the domain of elementary particles and quantum physics. For example, the typical use cases of systems analysis and design such as ERP, social media, e-commerce, personal productivity software, deal with entities such as customers, suppliers, orders, social media friends. These entities are indeed systems and are composed of other systems which in turn are composed of other systems. This is an important realization, because it liberates such applications from the need to resolve the fundamental ontological status of the "component" or "system part" and deal with the possible infinity of subsystems.

Second, some applications do engage with elementary particles and may involve modeling entities, for which there is no presently known structure (e.g., quarks, bosons) (Seiden 2005). For these cases, we suggest using Bunge's construct of a system, but not showing the components of it. Indeed, as Bunge suggested, the notion of a thing would not suffice for some of the entities in this domain (e.g., forces, fields, photons). In such an approach, the construct of a system is, not only a construct of convenience, but also a hypothesis based on the most recent speculation of Bunge that such elementary particle may, indeed, have structure that could be discovered later. Thus, adopting BSO within the context of IT allows us to potentially remove the notion of a thing, simply replacing it with the system construct.

Having established the basic tenet of BSO, we now consider the basic notions related to systems. In the *Treatise*, Bunge postulated that any system should have "a definite composition, a definite environment, and a definite structure. The composition of the system is the set of its components; the environment, the set of items with which it is connected; and the structure, the relations among its components as well as among these and the environment" (Bunge 1979, 4).

In later writings, this initial idea was developed into a Composition, Environment, Structure and Mechanism or *CESM model*. In CESM in addition to the composition, environment, and structure (present in BWW), Bunge added "mechanism" (Bunge 2000). Mechanism is defined as "characteristic processes, that make [the system] what it is and the peculiar ways it changes" (Bunge 2006, 126). The CESM model is a principal model of systems in BSO, which can be used to reason about and describe systems. To illustrate, Bunge provides an example of a traditional nuclear family—a type of a social system (Bunge 2006, 127):

> Its components are the parents and the 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 the central mechanism breaks down, so does the system as a whole.

The inversion of the relationship between things and systems, and the potential obviation of the need for *things* in BSO, represents a major change, as the construct of thing has been a founding one for BWW and has been the conceptual foundation for many studies that adopted BWW (Lukyanenko, Parsons, and Wiersma 2014; Parsons and Wand 2000; Pastor and Molina 2007; Wand, Storey, and Weber 1999). However, *things* in the social and technical levels of early Bunge were effectively systems (Bunge 1979). This change can be easily accommodated by much of the prior work that used BWW with a mere replacement of a label.

As in BWW, BSO upholds beliefs about the relationship between systems and properties. Systems have properties. Properties do not exist outside of systems (Bunge 2017, 175): "Property-less entities would be unknowable, hence the hypothesis of their existence is untestable; and disembodied properties and relations are unknown." As in BWW, properties according to BSO do not exist in themselves: "However, … can be material only derivatively …: there are neither properties nor relations in themselves, except by abstraction." (Bunge 2006, 11).

Notions of classes and kinds are used in BSO. In BWW, classes are sets of things sharing "a common property", whereas *kinds* are sets of things which share "two or more" properties (Wand and

Weber 1993, 223). Systems with "one or more" common properties in BSO (Bunge 1996, 111) form *classes* and those with properties which are interrelated, form *kinds* (Bunge 2006, 13).

The emphasis on systems carries other implications, as this new postulate is propagated throughout Bunge's recent works. According to BSO, some, but not all (an important caveat), systems undergo change, resulting in emergence (addition of new) or submergence (loss of old) of properties. To account for this situation, BSO continues to use the construct of *state*. Bunge (2017, 171) defines *state* as "the list of the properties of the thing at that time." This definition is similar to that of BWW (Bunge 1977, 125). A state can describe multiple properties (at the same moment in time) (Bunge 2006). A given system has the properties of its subsystems, as well as its own, termed *emergent properties* (an idea unchanged since BWW), but now gaining greater focus in BSO, as a key implication of systemism.

In BWW, there are postulates that deal with changes of states (i.e., events) and how the properties that make up the states are perceived by humans (i.e., attributes) (Bunge 1977). Whereas BWW applied the notion of a state to all things (Bunge 1977, 123), per BSO, Bunge (2006) makes an important distinction between systems which undergo change and those that do not. Per BSO, Bunge distinguishes two kinds of system: *conceptual* and *concrete* (Bunge 1996, 270). A *conceptual* (or formal) system is a system all the components of which are conceptual (e.g., propositions, classifications, and hypothetico-deductive systems-i.e., theories). This is contrasted with *concrete* (or *material*) systems which are made of concrete components (i.e., subsystems, such as atoms, organisms, and societies), and may undergo change.[10]

What distinguishes concrete and conceptual systems is the essential property of *mutability*, as a key element of BSO, which *only concrete systems possess*: "mutability is the one property shared by all concrete things, whether natural or artificial, physical or chemical, biological or social, perceptible or imperceptible" (Bunge 2006, 10). Bunge thus explains that changes in systems may only occur if the systems are concrete (Bunge 2006, 11):

[10] Bunge (1996, 270) also distinguishes a *symbolic* (or *semiotic*) system as a type of a concrete system some components of which stand for or represent other objects.

> heat propagation, metabolism, and ideation qualify as material since they are processes in material things. By contrast, logical consistency, commutativity, and differentiability can only be predicated of mathematical objects.

Concrete systems change in the virtue of energy transfer. For Bunge, "the technical word for 'changeability' is energy" (Bunge 2006, 12), such that:

> To repeat, energy is not just a property among many. Energy is the universal property, the universal par excellence.

We, thus, obtain a more formal definition of a *concrete system* in BSO as a system that has energy (Bunge 2006, 12).

In BSO, when systems interact, they transfer energy from one to another. Bunge dedicates considerable time to the notion of energy. He considers different kinds of energy, including mechanical, thermal, kinetic, potential, electric, magnetic, gravitational, chemical (e.g., in Bunge 2006). Energy transfer leads to change in states of things, as they acquire or lose their properties. This produces events and processes. Energy when paired with *artificial code* (instructions which correspond to ways to understand meaning) may transmit *information;* that is, carry meaning for an observer. This idea is not found in BWW, but of special relevance to information technology.

In contrast to concrete systems, conceptual systems do not change since they, themselves, do not possess energy. Naturally, in thinking about and communicating conceptual systems, energy transfer occurs. However, this energy transfer occurs within and between concrete systems (i.e., humans who are thinking and communicating these ideas). Bunge suggests that per se, conceptual systems do not harbor energy. They are mental tools that humans use to reason about concrete and other conceptual systems. Conceptual systems cannot transfer energy from one conceptual system to another. Conceptual systems, therefore, do not change per se; what changes is the knowledge of them in the mind of the observer (i.e., a concrete system). One conceptual system can be replaced by another when the latter is found to be more useful, convenient or expedient in some other way (e.g., simpler to remember or learn).

The consequence of the re-definition of systems as either energy-bearing or not, implies another change compared to BWW. Thus, whereas in BWW an event has been understood as a "change in state of a thing" (Wand and Weber 1993, 222), in BSO, an event is understood in terms of energy, thus being applicable only to *concrete systems*[11]. Bunge views event as an energy-involving construct (Bunge 2006, 91):

> Event C in thing A causes event E in thing B if and only if the occurrence of C generates an energy transfer from A to B resulting in the occurrence of E.

Multiple events form *processes*, defined as "a sequence, ordered in time, of events such that every member of the sequence takes part in the determination of the succeeding member" (Bunge 2017, 172).

The demarcation between events applicable to concrete versus conceptual systems affects the definition of the notion of *law*, which is now applicable to concrete systems only. Laws are stable patterns which hold "independently of human knowledge or will" (Bunge 1996, 27). In BSO, *conceptual systems* do not obey laws, but rather obey rules of logic or other considerations imposed by humans who create or use these systems (Bunge 2006).

3.2] BSO Beyond BWW

Although Bunge considered himself an ontologist, for him the connection between ontology and epistemology was inseparable. Notably, however, issues of ontology, epistemology, methodology and ethics were separated into standalone volumes in the *Treatise*. This could potentially explain why BWW focused on the constructs related to material reality. In recent writings, Bunge enmeshes the discussion about systems and their properties with epistemological issues within the same volumes. As a result, in BSO, the connection between his ontological beliefs and his beliefs about the nature of knowledge of reality becomes explicit.

In BSO, an event or a process as it appears to some human subject is termed *phenomenon* (Bunge 2017, 173). It is an occurrence registered by the sensory apparatus of humans or other animals triggered by a change or a series of changes in the state of a concrete system. For example, the sensation of wind blowing in the face or

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[11] This may potentially resolve the criticisms levied against Bunge's ontology as being too physicalist (March and Allen 2014; Wyssusek 2006). The original ideas of Bunge captured in BWW without explicit qualification have indeed been casted by BSO as belonging only to material reality.

an act of watching YouTube videos produce a complex chain of biochemical reactions in humans who experience these *events*. These sensations are produced by the interaction between systems external to the human observer and the human observer (who is a system also) (Bunge 1996). Phenomena, therefore, are special kinds of energy transfer, present when sentient beings are interacting with the world. Phenomena may arise due to direct interaction with physical systems (e.g., pressing an elevator button) or indirectly (e.g., via a signal or information). Phenomena are always "in the intersection of the external world with the cognitive subject" (Bunge 2017, 173).

Events, processes, phenomena, and concrete systems are material instances of the mental concept of *fact*. That is, they lie "in the extension of the concept of fact" (Bunge 2017, 174). Thus, Bunge uses the notion of *fact* (which is an epistemological construct) to group important related ontological constructs that have special relevance to humans. Facts for Bunge are kinds of *objects:* "whatever is or may become a subject of thought or action" (Bunge 2017, 174). What makes them special compared to other types of objects is that facts are "known or assumed—with some ground—to belong to reality" (Bunge 2017, 171). It does not appear that Bunge seeks to demarcate reality from non-reality (Bunge believed in a single world). Rather, Bunge indicates that all objects belong to reality, with only facts representing specific, important aspects of systems. Through the fact construct, BSO connects the fundamental ideas concerning the composition of reality to the mental world of humans.

Bunge asserts that phenomena are merely small fractions of the *facts* constituting the object of an investigation. This makes Bunge equate phenomena with "observable facts" that is, the facts that can be sensed directly. As BSO states, "the observable facts or phenomena are data suggesting or confirming the existence of more interesting facts behind" (Bunge 2017, 177).

It is a subject of centennial debates in philosophy whether human observers have access to more than just phenomena. The position of the *phenomenalism* holds that only direct sensations and experiences are knowable (Hirst 2002). In contrast, various strands of *realism* generally posit that reality beyond sensations can be known (Hempel 1966). This can be accomplished with the aid of experimentation, theory testing, imagination and logical inference. Bunge is a proponent of the latter (Bunge 2017). For Bunge (2017), the pragmatic benefit of realism is that it encourages thinking and action beyond sensations and motivates an active, inquisitive stance toward reality.

For Bunge, facts are iceberg-like in that they are largely submerged under the surface of immediate sensory experience. Furthermore, the phenomena are often quite different from the concrete systems upon which they are based. An example is the difference between the visual sensations caused by a flash of lightning compared with the actual chemical and electric other physical processes involved in the unraveling of this concrete system.

In both BWW and in BSO, Bunge distinguishes between properties and attributes. However, it is BSO that offers an expanded explanation for what constitutes an *attribute.* An attribute is a mental concept (i.e., an object of thought), which may correspond to phenomena. When we, as humans, experience lightning, we experience a bundle of properties associated with this complex concrete system. However, not all sensory experiences related to lightning have associated attributes. Thus, we may label lightning as “bright” and “dangerous”, but generally do not have an established attribute to describe specific smells associated with lightning. In other words, certain properties of systems may be experienced as phenomena, with some of the phenomena grouped into attributes human find useful. However, not every attribute can be traced to an underlying property. Because attributes are mental objects, Bunge admits there is a possibility of humans having attributes that may not correspond to any underlying physical properties of material systems (e.g., “magical” is an attribute of a shield of a fictitious hero). Thus, not all attributes are grounded in phenomena.

Bunge extensively deals with non-observable facts or what he calls, “submerged” facts. For Bunge, they are especially interesting because they underscore the value of science and scientific thinking for humans. Since most reality is inaccessible to direct observation, it must be hypothesized. A *hypothesis* is a conjecture about the relationship between the observed and the unobserved facts (Bunge 2017). A hypothesis need not be a scientific one. Humans routinely hypothesize, without being consciously aware of doing so. For example, when looking out of the window, we may observe clouds forming in the sky. Doing so may lead us to take an umbrella when we venture outside. These physical events are linked with a number of hypotheses about the relationship between facts about systems.

For Bunge more interesting hypotheses are those which require extensive elaboration and thinking. These types of hypotheses, although still present in day-to-day life, are most commonly found in science. To test such hypotheses, definite relationships between the unobserved and the observed facts must be developed, by which the observed can count as evidence for, or against, the existence of the hypothetically unseen, and the unseen can explain what can be seen. These relationships are represented by hypotheses and *theories* (Bunge 2017, 177).

To reason about deeper levels of reality, one needs to connect phenomena with unobserved systems. Hence, *observation* becomes a key construct of BSO at the nexus of ontology and epistemology. Observation is defined as "purposeful and enlightened perception" (Bunge 2017, 181). It is purposeful or deliberate because it is made with a deliberate goal and enlightened because it is guided by prior knowledge of the observer. The object of observation is a *fact* in either the external or the inner world of the observer. The former, for example, can be the sight of an approaching passer-by, whereas the latter could be thoughts, memories, and mental images that are available to the observer through introspection.

The subject or observer includes, of course, their perceptions. The circumstances of observation are the environment of the object and subject. Both the observation media and the body of relevant knowledge are means for the observer, but not for the instrument designer or for the theoretician. Observation statements have the following form: "w observes x under y with the help of z".

There is no "end" to the BSO per se. Recall that BSO is not published in a self-contained treatise. Bunge continuously stresses the interdependency between ontology and other beliefs. Indeed, Wand and Weber engaged with other ideas of Bunge, as did other scholars (e.g., Rosemann and Wyssusek 2005; Milton 2007), and acknowledged the existence of other constructs and more recent beliefs. As they note, Bunge "has written extensively about social phenomena using constructs based upon his ontology" (Bunge 1998; Wand and Weber 2017). Yet, much of the IT community adopted the views of Bunge stemming from BWW, making this an important benchmark comparison.

3.3] Similarities and Differences Between BWW and BSO

Based on the exposition of BSO, which captured more recent beliefs by Bunge in comparison to BWW, we draw the comparisons summarized in Table 1 (see appendices).

First, it is evident that more recent thinking by Bunge remains partially consistent with BWW. Table 1 compares BWW and BSO, demonstrating that many ideas in BSO are the same as in BWW. These include the notion of things, properties, events, attributes, classes, laws. The relationships between many constructs remain the same (e.g., properties and attributes, properties and things). Thus, BSO carries many of the same design implications for IT, as does BWW. Included is the denial of the existence of properties, which has known implications for conceptual modeling research, such as problems of optional properties or properties of properties (Bodart et al. 2001; Bodart and Weber 1996; Burton-Jones and Weber 2003; Gemino and Wand 2005), emergence, and lack of direct human access to reality (i.e., to the properties of systems).

Second, many of the changes introduced by BSO could be handled by appropriate qualifications or more precise specifications of the already existing notions (e.g., that concrete systems undergo change via energy transfer, but conceptual systems do not). The notions of *things* and their properties are still present because some systems can be viewed as systems for which no structure is modeled (as we discussed earlier). The relationship between properties and attributes can now be understood by the notion of *phenomenon*. Notably, however, as the example of properties and attributes demonstrates, in some respects, BWW can be considered a subset of BSO, which abstracts from the richness and nuances of BSO but has greater parsimony.

Thus, there is an important continuity between BSO and BWW. This continuity is critical for assessing the status of impressive theoretical, conceptual and design research that stemmed from the ideas of Wand and Weber (1990a; 1993; 2017). Hence, BSO could still be used to posit that classes “tyrannize” instances (Parsons and Wand 2000) or that optional properties should be proscribed (we leave the issue of whether such design proposition is appropriate for conceptual modeling outside our discussion). However, in BSO, this is true for concrete systems only, since conceptual systems do not follow the same principles as concrete ones do.

As with BWW, BSO continues to adhere to the tenets of scientific realism and grounds thinking into interpretation of the state-of-the-art knowledge in physics and other disciplines. The two ontologies are products of conceptualizing and synthesizing knowledge about the nature of reality as derived meticulously from what Bunge, as a physicist (Bunge, 1945), assumed to be tenets of science. This makes the two ontologies especially valuable, as they promise to ground representations of reality based on these ontologies into solid scientific beliefs, thereby attempting to realize repeated calls of researchers to ground IT into deeper, more fundamental foundations (Pastor 2016; Wand et al. 1995).

On the other hand, BSO covers more compared with BWW. We suggest, BSO is not an expansion of BWW that could be achieved by simply adding epistemology to BWW. Rather, BSO suggests a new way of thinking about reality. Furthermore, the basic tenet of BSO—the world is made of systems—departs remarkably from BWW. Hence, BSO embeds ideas about systems at its very core, taking it as its fundamental premise. As Bunge writes, this is not only an ontological, but also a normative stance (Bunge 2017). It impels the users of his ontology to proactively seek complexity beneath the seeming simplicity. It is in this complexity that Bunge sees a path for uncovering the fundamental nature of reality. This is a core idea around which other elements revolve.

Furthermore, in BSO, Bunge made a concerted effort to shift the focus from material things to physical, biological, social and mental systems. This is evidenced by the many new constructs that are not part of BWW (Table 1). BSO, much more than BWW, is concerned with the relationship between physical and mental phenomena, advancing numerous novel constructs, such as observer, observation, hypothesis, theory, and fact.

BSO further deepens the understanding of the relationship between fundamental constructs of BWW, such as classes, kinds and things, and properties and attributes. In all cases, in order to gain a deeper understanding of this relationship, a closer examination of the mental world of humans was required. Although not examined in this paper in detail, Bunge also discusses social reality at length, including engaging with ideas of Searle (Searle 1995). For example, Bunge (1996) makes contributions to social ontology, which has been cited as a limitation of BWW (e.g., March and Allen 2014).

When comparing BWW with BSO, we can also use the analogy of comparing classical physics with quantum physics. Classical physics is applicable to macroscopic particles, providing a coarse-grained perspective of reality, but hiding the microscopic world dimension that quantum physics analyzes. Since classical physics can be derived from quantum physics in the limit that the quantum properties are hidden, BWW can be considered a simplification of the BSO when BSO's systemist perspective is reduced to material systems the internal complexity of which is abstracted away. We can then interpret BWW as the beginning of a fundamental way to represent reality. The BSO concepts provide a more complete and refined knowledge of reality.

Considering the differences between earlier and more recent thinking of Bunge, we therefore propose *Bunge's Systemist Ontology* or BSO, as a new ontology, and a new, practically applicable, addition to the theoretical toolbox of IT.

4] Implications of BSO for Areas of IT

The comparison between BSO and BWW implies that the broader and more recent ideas of Bunge carry exciting implications for ontology-based IT research and practice.

4.1] Reinvigorating Ontological Debates in IT

BSO contributes to the long-standing research on using Bunge's ideas as theoretical foundations for IT. Bunge is among the most influential ontologists for the fields of conceptual modeling, systems analysis and design, and software engineering research. Bunge's ideas were, not only at the core of BWW, but also used widely in design and empirical studies on conceptual modeling (Evermann and Wand 2006; Opdahl and Henderson-Sellers 2002; Pastor and Molina 2007; Weber 2003), business process modeling (Bider et al. 2005; Recker et al. 2011), information quality (Lukyanenko, Parsons, and Wiersma 2014; Lukyanenko, Parsons, et al. 2019; Wand and Wang 1996), data modeling and database design (Parsons and Wand 2000; Wand, Storey, and Weber 1999; 1999), software engineering (Pastor et al., 2008; Reinhartz-Berger et al., 2012), information systems requirements (Itzik, Reinhartz-Berger, and Wand 2015; Soffer et al. 2001; Vessey 2004), and ontology engineering (Becker et al. 2010; Bera, Burton-Jones, and Wand 2011). Bunge's ideas have also been frequently used as a benchmark for other ontologies and when analyzing the value of ontologies for IT (Guarino 1995; Guizzardi 2005; Wyssusek 2006).

Our research considers whether the ideas as expressed by BWW capture the most recent thinking of Bunge. As our work suggests, Bunge makes broader and deeper contributions than previously recognized. Although there is an overlap between BWW and BSO, BSO contains many new ideas, and hence carries new implications for the assessment of the applicability of Bunge for various disciplines of IT.

Future research could further examine the benefits and limitations of Bunge more broadly (i.e., BWW and BSO) for conceptual modeling, information quality, software engineering, and other areas which have thus far benefited from the exposure to Bunge's thought.

4.2] Supporting Modeling in New Domains

With a new way of conceptualizing reality and additions of epistemological constructs, BSO should be able to support design and use beyond that of BWW. Using the iceberg metaphor for representation of reality enables a specific example to be discussed. BWW provided the ontological basis of a conceptual programming approach called "OO-Method" (Pastor & Molina 2007, Embley, Liddle & Pastor, 2011), together with its associated industrial tool, Integranova. Conceptually, OO-Method focuses on organizational systems and their associated database-based applications. It works well within this context, but, by considering BWW as the tip of the *reality representation iceberg*, several other systems appear to fall out its natural scope (e.g., deep learning reasoning, machine learning algorithms, AI conceptual applications as Explainable AI). With the ontological commitment provided by the "basic" BWW, it is very difficult to go beyond the notion of an organizational system (taken from the FRISCO Manifesto, IFIP WG 8.1. (Falkenberg et al. 1998)), that is a type of concrete system well-characterized by using the "thing" concept of BWW. BWW can work well for representing the components of these concrete (material) systems, but it has difficulty representing conceptual systems (i.e., conceptual components of those organizational systems, as algorithms, functions, theories).

For BSO, that hidden part of the reality representation becomes accessible, especially through the explicit distinction between concrete and conceptual systems, and the coverage of reality beyond sensations, as well as the consideration of facts as being largely submerged under the surface of immediate sensory experience. All of these notions provide a way to understand the conceptual fundamentals of deep learning, machine learning, and any other conceptual (not concrete) system that BSO distinguished explicitly. For instance, applying BSO to neural networks could be considered as a connection between a concrete system (composed by other systems) and a conceptual system. An example is a neural algorithm that takes an image (for computer-based neural networks) or a perception (for human-based ones) of a concrete system as input and determines what systems are present in the image/perception as output.

The many new ideas of Bunge represented in BSO can provide a strong ontological foundation for many emerging applications in IT. To illustrate, we suggest two notable examples of potential applications of BSO into domains of applied machine learning based on complex models, such as deep learning and into explainable artificial intelligence.

Deep learning applications could benefit from BSO as this domain is based on a strong conceptual (but not material) basis. Deep learning is a type of machine learning that uses neural networks with multiple hidden layers, resulting in highly complex, but also very powerful models (Bishop 2006). These models tend to capture what mostly corresponds to the tacit knowledge humans possess. This task requires the use of purely conceptual notions (high-level semantic variables) whose representation and reasoning capabilities form the basis for natural language communication and express algorithmic knowledge in software (Bengio 2020). Hence, it is difficult to reason about the systems based on deep learning on the basis of a purely materialistic ontology. In contrast, BSO has more nuanced conceptual constructs, such as unobservable facts, hypotheses, observation and, broadly, the notion of hidden versus observable. These all appear to be of value for reasoning and modeling deep learning applications, as a future area of research.

Explainable artificial intelligence (XAI) is a socio-technical challenge due to the growing need to allow a machine to precisely explain a taken decision (Došilović, Brčić, and Hlupić 2018; Gunning and Aha 2019). It is, therefore, crucial to obtain a shared understanding of the domain under consideration (Lukyanenko, Castellanos, et al. 2019; Lukyanenko et al. 2020), what again requires a conceptualization process that is hard to achieve using only the concrete (material) fundamental background that the original BWW provides. On the contrary, BSO provides constructs to support the characterization of a conventional XAI-based process (Spreeuwenberg 2019). Here, after designing the shared conceptual model, the task must be understood, the right scope selected, and the right data collected and its quality improved. In addition, the AI techniques that deliver results must be selected, in order to generate good explanations that adequately evolve over time. All of this is challenging and, obviously, requires future research, which could benefit from the idea captured in BSO.

4.3] Evaluation and Development of Modeling Grammars

The new constructs of BSO can also become valuable in evaluation (and possibly, development of new) conceptual modeling grammars. To illustrate one opportunity, recall that in BSO systems can be material or conceptual. For BSO, a critical demarcation is the absence of presence of *energy*, and the nature of energy exchange between systems. The nature of energy is a new consideration for conceptual modeling research and practice. As Bunge (2006) argues, depending on the type of energy transfer, different interactions among systems become possible. If we model systems using, for example, classes in the UML grammar, the interaction among classes can be modeled using the association construct. However, this construct does not distinguish the types of energy that is being transferred during the interaction among the objects (instances of the classes).

Consider an example of an online order delivery domain (with a fragment of a possible diagram shown in Figure 1 in which real-world complexities are abstracted away). The diagram, which uses a UML notation, represents a domain with three kinds of real-world systems from the point of view of BSO: customers, orders and delivery drivers (with their internal complexity abstracted away for the purposes of the illustration). Their interactions are shown using the association construct. However, the nature of the interaction differs due to the different kinds of energy being transferred. In the case of a customer placing an order, it, presumably, involves the use of a mobile app over the Internet. In the case of a delivery driver, it involves an actual physical displacement, frequently at a considerable distance, guided by the mobile app and supported by other machinery and tools, which, in turn, also consume specific kinds of energy. Thus, the energy flow and energy requirements of the two associations differ in remarkable ways. Recognizing these differences could lead to a different appreciation for the kinds of resources needed to enact, manage and support the interactions of these systems. Many kinds of valuable inferences can be drawn from the knowledge of the nature of energy transfer between the systems (e.g., that delivery drivers require fuel, whereas customers require a stable Internet connection and enough battery charge in their cellphones). Each of these inferences can prove beneficial for building effective information technologies which support and enable interactions of systems in this delivery domain.

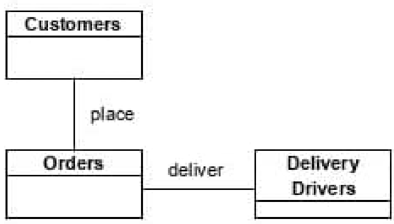

Figure 2: Fragment of a hypothetical UML diagram in an online order delivery domain

The notion of energy is new to conceptual modeling research. Therefore, future studies are needed to explore the implications of this new idea. Modifications to existing modeling grammars may also be needed to allow constructs that represent associations among systems to capture the different kinds of energy transfer, if such capture proves to be valuable for modeling purposes.

4.4] Support and Guidance for Novel Design Patterns

Some of the design implications of BSO, while not necessarily requiring modifications to modeling grammars, may be useful as best design practices or design templates. To appreciate this potential, consider the fact that BSO provides several new ontological constructs—ontological primitives, including observation, hypothesis, and fact. These constructs of BSO appear particularly useful for a variety of modern applications; for example, the observation construct can, potentially, be used to model scenarios where people observe some things in reality and post these on social media.

These ontological primitives will not likely require a modification to existing conceptual modeling grammars, as they can be modeled as classes, or entities using grammars such as UML, ER or ORM and incorporated into existing modeling grammars as *modeling patterns*. The notion of a modeling pattern has been adapted in conceptual modeling research (Garzotto et al. 1999) from the field of architecture and "describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over" (Alexander 1977).

Likewise, BSO can contribute a variety of new design patterns. Figure 2 depicts one such possible pattern using UML, in which an observation in a domain is modeled (again with real-world complexities abstracted away, for the purposes of the illustration). In addition to modeling the observation object itself, the contribution of BSO is to suggest modeling conceptual and concrete tools used to make the observation. Such pattern, for example, can be used for modeling social media applications where an observation can be an observation of a hotel (within the context of submitting a review). An app designed following the modeling pattern in Figure 2 can also capture whether there are any photographs made along with the observation (i.e., corresponding to the concrete tool object), and also goals, assumptions, biases and intentions of the person making the observation (i.e., the conceptual tool). Such modeling pattern can facilitate the collection of more complete information, which allows for better interpretation of social media data. Future research can consider such design patterns, as well as propose and evaluate any new ones.

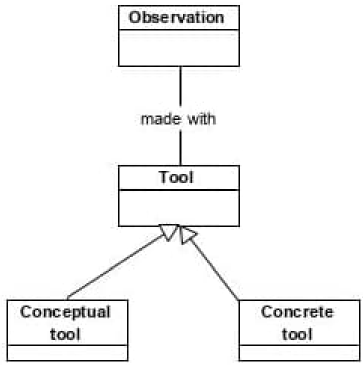

Figure 3: Pattern based on BSO illustrating typical observation made within a domain

As another case of useful design patterns, BSO provides new and expanded expressiveness for modeling systems. Consider, for example, the relationship between things and systems. In contrast to BWW's emphasis on *unique things*, BSO highlights the importance of representing structure, relationships between systems, emergence, levels, and interactions among subsystems. In BSO, Bunge clearly wishes to balance his views between the value an individual-focused perspective may bring versus a perspective that is more sensitive to the whole.

Information systems development, including conceptual modeling and user interface design, can incorporate Bunge's CESM model (composition, environment, structure and mechanism) as a modeling pattern for describing systems and capturing user information regarding systems. Thus, a conceptual model of a domain can contain and represent elements consistent with CESM and incorporate them into conceptual modeling grammars as constructs. Then, for example, a project interested in recording data on some systems (e.g., sales, customers, markets, or natural phenomena, such as climate) could represent internal structures of the observed system, its relationship with its outer environment, its levels of composition, and the components and specificity of subsystems.

To illustrate further, consider a citizen science project (Bonney et al. 2009; Castellanos et al. 2020; Lukyanenko, Wiggins, and Rosser 2019), which involves collecting citizen observations of lichens (a focal system of interest). Following BSO, the analysts could produce data collection interfaces and requisite database structures that capture: citizen observations of the structure of the lichens observed; the hosts to which the lichens are attached (its environment) and other external systems (e.g., the ecosystem); the individual strands that make up a collection of lichens (its components); and the properties of individual strands of lichens. By adopting the CESM modeling pattern or template, the citizen science projects can collect more complete data on systems of interest, thus increasing the potential of such data for insights and actions.

Many studies that follow early work of Bunge base modeling choices on the assumption of the primacy of individuals in logical database design, conceptual modeling grammars, information quality, and design collection processes (Parsons and Wand 2000; Lukyanenko et al. 2017; Lukyanenko, Parsons, and Samuel 2019; Samuel, Khatri, and Ramesh 2018). Bunge extensively discusses the limitations of an individual-focused perspective and suggests that a more balanced approach—one that considers both individuals and collectives—may be more fruitful (Bunge 1996; 2000). BSO seeks to promote such balanced perspective, and thus can pave the way to even more expressive conceptual modeling grammars and IT designs realized in future studies.

4.5] Work on Formalizing BSO and Evaluating Its Implications

Much work remains to study BSO in its own right, including formalizing BSO into a finite set of postulates (analogous to Wand and Weber (1990b)). Part of this effort should involve ensuring the final ontology is internally consistent; for example, BSO's notion of event is defined based on things, rather than systems. The work should also continue investigating areas of IT practice that could benefit from the application of these ideas.

Although not directly engaging with conceptual modeling in IT, Bunge investigated issues of technology design and representations in science (Bunge 1974; 1985; 2019). In these writings, he briefly considered the implications of his ontology for representing reality in artifacts, including social policy plans or architectural blueprints. Here, Bunge (1985, 7:244) suggested that "a design or plan is *defective* if it overlooks any of the three features of any system: its composition, environment or structure (both internal and external)" (emphasis added).[12] Thus, Bunge, himself, believed his ontology should be incorporated into design and action models and advanced an empirical claim that these models would be defective otherwise. This is a strong assertion that will require future research to corroborate or falsify.

5] Conclusion

The philosopher Mario Bunge made a profound impact on the fields of conceptual modeling, software engineering, information quality, and database design. Much of this influence has been via the BWW ontology, which has made substantial contributions to the theory and practice of IT and conceptual modeling.

Recognizing that there are many concepts and ideas that have deep implications for understanding the reality that IT needs to model, we conducted a multiyear analysis of Bunge's writings, which included personal consultations with Bunge. As a result, we gained a new perspective on the ideas and beliefs of Bunge. These ideas do not constitute a mere expansion of prior work. Rather, we synthesized the recent thinking of Bunge in the new ontology, the *Bunge Systemist Ontology* or *BSO*. Parts of BWW and BSO overlap precisely, so an important continuity between ontological work based on Bunge in IT is preserved. In addition, BSO promises new opportunities for IT as it orients the modeling efforts from individuals to systems, and ushers in much greater consideration of epistemology and axiology. Hence, a new ontology is warranted.

BSO contains concepts that can raise new prospects and possibilities for information technology, including for conceptual modeling, software engineering, ontology engineering and other areas of IT. We detail some of these possibilities in a set of research opportunities that focus on further discovering and applying the philosophical works of Bunge. In the world which deepens its reliance on IT, these new ideas of Mario Bunge could prove useful for further improving the way IT represents and shapes reality.

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[12] Here, we see a reference to the CESM model (composition, environment, structure), but the mechanism as a component was only developed by Bunge in the early 2000s, and thus is missing from this passage written in 1985.

6] Appendices. Table1: Comparison Between Foundational Constructs of BWW and BSO

Comparison between foundational constructs of BWW and BSO*			
Note, the comparison is based on constructs from BWW as provided in Wand and Weber (1993, 222–23). Some constructs of BSO (e.g., process, fact) have been part of the *Treatise*, but were not included in that original source for BWW			
Construct	**Definition from BWW***	**Definition from BSO**	**Comparison and Analysis**
Thing	"A thing is the elementary unit in our ontological model. The real world is made up of things. A composite thing may be made up of other composite things or primitive things"	N/A	In BWW thing is the fundamental ontological primitive which stands in its own. In BWW a system is a kind of a thing—a thing that has structure. In BSO, we suggest all things to be systems (note our caveat re elementary particles explained above)
System	"A set of things is a system if, for any bi-partitioning of the set, coupling exist among things in the two subsets"	"complex object every part or component of which is connected with other parts of the same object in such a manner that the whole possesses some features that its components lack—that is, emergent properties" (Bunge 1996, 20)	In BWW system is understood in terms of things—the fundamental ontological primitives. In BSO, thing is defined in terms of a system, a thing is a kind of system
Property	"Things are known via their properties. A property maps the thing into some value"	The substance (matter and energy) that make concrete systems what they are and predicates of conceptual systems (Bunge 2017, 175)	Neither BSO nor BWW have formal notions of property. Bunge's recent writings (e.g., Bunge 2017, 175) reiterated his early ideas that properties do not exist in themselves and propertyless entities also do not exist. The new notion of energy in BSO gives the

Comparison between foundational constructs of BWW and BSO*

Note, the comparison is based on constructs from BWW as provided in Wand and Weber (1993, 222–23). Some constructs of BSO (e.g., process, fact) have been part of the *Treatise*, but were not included in that original source for BWW

Construct	Definition from BWW*	Definition from BSO	Comparison and Analysis
			property concept more formality, albeit it only applies to concrete systems
Emergent property	"A property of a composite thing that belongs to a component thing is called a hereditary property. A property that does not belong to any of the composing things is called an emergent property"	"To say that P is an emergent property of systems of kind K is short for "P is a global [or collective or non-distributive] property of a system of kind K, none of whose components or precursors possess P" (Bunge 2003, 25)	Emergent property has undergone a shift from BWW to BSO, wherein the latter ontology defines it as property of systems
State	"The vector of values for all properties of a thing is the state of the thing"	"list of properties of the [system at a given instant of time]" (Bunge 2017, 171)	In BWW and BSO state has the same meaning
History	"The chronologically-ordered states that a thing traverses in time are the history of the thing"	"a sequence of states [of a system]" (Bunge 1996, 24)	Same notion, only applied to systems
Subsystem	"A subsystem is a system whose composition and structure are subsets of the composition and structure of another system and whose environment is a subset of the environment of the other system in union with the things that are in the composition of the other system but not in the composition of the subsystem"	"[system] is "both a system and part of another system" (Bunge 1996, 270)	The construct is the same in BWW and BSO. Note, BWW's version is consistent with the systemist approach (i.e., subsystems are systems)

Comparison between foundational constructs of BWW and BSO* Note, the comparison is based on constructs from BWW as provided in Wand and Weber (1993, 222–23). Some constructs of BSO (e.g., process, fact) have been part of the *Treatise*, but were not included in that original source for BWW			
Construct	**Definition from BWW***	**Definition from BSO**	**Comparison and Analysis**
Event	"An event in a thing is a change of state"	"Event C in thing A causes event E in thing B if and only if the occurrence of C generates an energy transfer from A to B resulting in the occurrence of E" (Bunge 2006, 91)	The construct is the same in BWW and BSO. Note the inconsistency in BSO, as event is still defined in terms of things, rather than systems
Class	Set of things sharing "a common property"	Systems with "one or more" common properties (Bunge 1996, 111)	Notable change in BSO of conceptualizing classes as (conceptual) systems
Kind	Set of things which share "two or more" properties	Classes with properties which are interrelated (Bunge 2006, 13)	A change in BSO which stipulate kinds to have interrelated properties—a notion more consistent with definition of natural kinds by other researchers (Fletcher 2013; Hacking 1991)
Process	N/A	"sequence, ordered in time, of events such that every member of the sequence takes part in the determination of the succeeding member" (Bunge 2017, 172)	New construct in BSO
Phenomenon	N/A	"is an event or a process such as it appears to some human subject: it is a perceptible fact" (Bunge 2017, 173)	New construct in BSO
Fact	N/A	"whatever is the case, i.e., anything that is	New construct in BSO

Comparison between foundational constructs of BWW and BSO*			
Note, the comparison is based on constructs from BWW as provided in Wand and Weber (1993, 222–23). Some constructs of BSO (e.g., process, fact) have been part of the *Treatise*, but were not included in that original source for BWW			
Construct	**Definition from BWW***	**Definition from BSO**	**Comparison and Analysis**
		known or assumed—with some ground—to belong to reality" (Bunge 2017, 171)	
Object	N/A	"whatever is or may become a subject of thought or action" (Bunge 2017, 174)	New construct in BSO
Observability	N/A	"x is observable only if there exist at least one recording instrument w, one set of circumstances y, and one set of observation tools z, such that we can register x under y helped by z" (Bunge 2017, 185)	New construct in BSO
Observation (direct observation)	N/A	"purposeful and enlightened perception: purposeful or deliberate because it is made with a given definite aim; enlightened because it is somehow guided by a body of knowledge" (Bunge 2017, 181)	New construct in BSO
Observation (indirect observation)	N/A	"hypothetical inference employing both observational data and hypotheses" (Bunge 2017, 181)	New construct in BSO
Observer	N/A	"subject [of observation]" (Bunge 2017, 184)	New construct in BSO
Hypothesis or factual hypothesis	N/A	corrigible proposition about yet	New construct in BSO

Comparison between foundational constructs of BWW and BSO*			
Note, the comparison is based on constructs from BWW as provided in Wand and Weber (1993, 222–23). Some constructs of BSO (e.g., process, fact) have been part of the *Treatise*, but were not included in that original source for BWW			
Construct	**Definition from BWW***	**Definition from BSO**	**Comparison and Analysis**
		unexperienced or in principle unexperientable facts (Bunge 1998, 254)	
Theory	N/A	"a system of propositions some of which are hypothesized and the remainder of which are deduced from the former" (Bunge 1996, 113)	New construct in BSO

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Linguistic Research in the Empirical Paradigm as Outlined by Mario Bunge

Dorota Zielińska[1]

Abstract — In view of the critique of the methodology of the dominant interdisciplinary research involving language studies as the main component, in particular clinical linguistics, Cummings (2014) proposes that "It is perhaps appropriate at this point to move the debate onto non-empirical grounds." In Cummings (2014) she starts such a debate on the grounds of the philosophy of language and pragmatics. In this article, I propose to expand that debate by including the input of the philosophy of science. I start the discussion by presenting the way one may carry out language research in the paradigm of empirical sciences from the perspective outlined in Bunge (1967, 1973, 2003) and constrained by Altmann's (1978) assumption about self-originating and self-regulatory nature of language.

Résumé — Compte tenu de la critique de la méthodologie de la recherche interdisciplinaire dominante impliquant des études linguistiques comme élément principal,

[1] **Dorota Zielinska** has M.S. in Physics and Ph.D. in English Philology from the Jagiellonian University, Poland. She started her career as a physicist at Fermilab and at Northeastern University. Upon returning to the Jagiellonian University, she turned to adapting the methodology of socio-natural sciences in the framework of Mario Bunge to linguistics. In 2013, she received qualification for a professorship in philosophy of language from MIUR, Italy, and now she continues as an independent researcher. She has established two linguistic laws, in the sense of Mario Bunge's paradigm: one concerning the ordering of adjectives in Polish noun phrases (described in this article), and the other concerning the position of "counterfactual if clauses" in English and Polish sentences, which can be found in "The Field Model of Language and Free Enrichment", *in* A. Capone, M. Carapezza & F. Lo Piparo (eds), *Further Advances in Pragmatics and Philosophy: Part 2 Theories and Applications*, 2019. Her related research is "Utterance and Sentence Meanings from the Perspective of the Theory of Empirical Models" *in A. Capone, M. Carapezza & F. Lo Piparo (eds), Foundations of Philosophical Pragmatics*, 2013. On ResearchGate, the reader may access preprints of parts of her book *How Does Language Work*? describing her latest research concerning language with the emphasis on the role of emergence and convergence in language self-organization and self-regulation as understood by Mario Bunge. These, importantly, include the chapters entitled "How Does Language Work?" and "The Brain for the Linguist" as well as Appendix 8, "Can Linguistics Be an Empirical Science in the Light of Mario Bunge's Defense of the Scientific Treatment of Biology?".

en particulier la linguistique clinique, Cummings (2014) propose qu'« il est peut-être approprié à ce stade de déplacer le débat sur des bases non empiriques ». Dans Cummings (2014), elle entame un tel débat sur la base de la philosophie de la langue et de la pragmatique. Dans cet article, je propose d'élargir ce débat en incluant l'apport de la philosophie de la science. Je présente la façon dont on peut mener des recherches linguistiques dans le paradigme des sciences empiriques tel qu'exposé dans Bunge (1967, 1973, 2003) et limité par l'hypothèse d'Altmann (1978) sur la nature autocréée et autorégulatrice du langage.

1] Background

As it is becoming more and more common to study bio-cognitive-social aspects of language, more and more researchers attempt to study language the way it is done in core empirical sciences. Yet, this is largely a descriptive effort. As Cummings (2014: 113) warns, for instance in relation to clinical pragmatics, if current trends keep dominating, clinical pragmatics may "develop into a field that collects findings in the same way that the geologist collects rock samples or the botanist collects plant species." What differs today's chemistry and biology from such a "pre-empirical" classificatory biology and the mainstream contemporary linguistics is that many concepts in contemporary biology and chemistry have their measurable counterparts, and today's typical biologist collects data also in an objective manner, posit hypothesis, and tests them using objective measuring techniques.

Note also, that in the process, the biologists have changed the questions they ask. They know that because of the contingencies involved, biology could not have predicted the existence of today's elephants a million years ago, no more than it can predict the exact features of a baby elephant that will be born to a specific female elephant. Yet, they may predict the likely range of parameters of the elephant to be born, and why the history of the environment on the Earth allowed for modern day elephants to develop. General linguists, on the other hand, for instance, when concerned with meaning, are still typically interested only in the interpretation of a specific linguistic construct, and not in any quantitative parameters that could be objectively measured and used to posit and test hypothesis. And, as Cummings (2009) complains, even in empirically oriented clinical pragmatics, there is "a proliferation of clinical findings with little sense of how these findings are related to each other or to theoretically significant questions. It is not an exaggeration to say that a relentless growth of clinical findings which are largely devoid of theoretical implications has been the dominant trend in clinical pragmatics to date." Cummings (*ibidem*: 113) goes on to point out three pragmatic theories that are capable of modelling clinical disorder processes—she notes, however, that "all three theories have succeeded in bringing forward experimental evidence in support of their claims. Given that these theories involve competing or opposing claims, one is led to conclude that experimental evidence should not be treated as a final arbiter in an assessment of the validity of theories. It is perhaps appropriate at this point to move the debate onto non-empirical grounds".

When referring to non-empirical grounds, Cummings means classical philosophy of language and pragmatics. What else, however, will help the discipline, and a touch of which is the topic of this paper, is the philosophy of empirical sciences. Empirical sciences could bring in a lot of valuable insight, not only concerning the issue of hypothesis formation and verification, but also, it could offer powerful ideas for structuring data.

The philosophy of science has a long tradition and it is impossible to discuss it all in one article. There are even no general definitions of such concepts as a theory, principle, law, hypothesis which would mean the same across all of its sub-disciplines. For an overview of the vast progress concerning the specificity and diversity of scientific explanation in biology, for instance, one might go to Braillard and Malaterre (2015), "Explanation in Biology", or consider the contents of the *Biolinguistics* journal. The overview of Zipfian linguistics, on the other hand, will be found in the *Journal of Quantitative Linguistics* and accompanying book series. Therefore, at this place I must start from selecting a specific perspective to see whether it could be relevant for language studies. I decided to limit myself to the theory of science as explicated by Bunge (1967, 1973, 1996, 1999, 2003), and constrained by Altmann's (1978) assumption about self-originating and self-regulatory character of language. Therefore, before proceeding further, first I shall outline Bunge's (1973) view of the methodology of empirical sciences.

2] Scientific Methodology: An Overview

Amazing progress that has been taking place in every walk of life these days has its roots in the empirical paradigm developed in natural sciences. The empirical paradigm in natural sciences is based on researching material reality through building and testing its models. Models are created in order to explain the old and predict new characteristics and behaviour of a given fragment of the reality under study. Building a model of a given object, or process, involves selecting its most relevant features, given the aspects of that object, or process, we want to account for. For instance, in relation to modelling a flight of birds it means that an ornithologist interested in bird migration will consider different characteristics of a bird than a hunter who is concerned with estimating the place where a bird he has just shot will drop. The former will consider factors such as the characteristics of the environment in which the given species can be found, its endurance and reproduction circle; while the latter will characterize a bird in terms of the parameters relevant in Newton's dynamics—he will set out to estimate the force of the muscles and the mass of the bird at stake.

Scholars select the relevant features of an object under scrutiny based on what they know about it at a given stage of the development of a relevant discipline and based on their own intuition. In new disciplines such knowledge and experience are initially expressed in natural language. As a given discipline advances, the core of the respective knowledge is increasingly expressed through received formalized theories (systems of (mechanistic) universal laws, such as the laws of Newton's dynamics) that express some general aspects of the mechanism sustaining the processes present in the class of phenomena. These theories, not testable per se, let one formulate testable hypothesis (phenomenological laws) concerning models of specific phenomena, or specific theories. (In the case of Newton's dynamics such a specific theory could concern the movement of the Earth around the Sun). Importantly, the resultant testable hypotheses (phenomenological laws), typically, are not implied solely by a given mechanistic law being tested, but also by some additional assumptions made while constructing the model of a given phenomenon. These additional assumptions are of two types. First, these are approximating assumptions, such as approximating Earth as a material point with a zero volume when modelling its movement around the Sun with the help of Newton's laws. Second, there can be some additional, already well tested mechanistic laws that are also relied on when describing the specific theory to be tested.

In empirical sciences one says that a given phenomenon (its model, also called a specific theory) has been fully explained (corroborated and tested) when two conditions have been met. First, one has explicated the mechanism that brings about and/or sustains that phenomenon in terms of some mechanistic laws and the assumptions made when constructing the given model (specific theory). Second, the explication proposed implies some hypothesis, which can be and has been tested. Historically speaking, one begins with searching for empirical rules (also called phenomenological laws), which capture patterns in data (the way Kepler did, when he analysed the data collected by Tycho Brahe, finding that the mathematical formula for ellipsis summarizes the observed positions of planets revolting around the Sun). Only later does one search for some mechanistic laws that (along with the assumptions made when constructing the given model) imply the respective formulae—hypothesis. (This was what Newton did in relation to Kepler's results). Yet, one may also begin with constructing a theory and next searching for a model (specific theory) that will imply some regularities which can be tested objectively.

3] Developmental and Self-Regulatory Character of Lan-guage

Before proceeding further, in view of what has been said about the empirical paradigm, we need to stipulate some general characteristics of language as a phenomenon that could be studied as an empirical science. To this end, first of all, let us note that for language studies to belong to empirical sciences, language must be treated as an aspect of a material system—it must be treated as a semiotic system, which is a result of communication process taking place in the brains of linguistic community members. In other words, language is a socio-natural phenomenon. Therefore, empirical linguists will be interested in characteristics of *parole* not *langue*. (It will consider *langue* only when preparing a descriptive framework.)

We may also note that given the structure and origin of human brains, which is a result of a long developmental self-organizing process, conditioned by very specific environmental events, it is likely that language, a spinoff of linguistic activity, becomes self-organized and self-regulated, too. The likelihood of that hypothesis has been corroborated by a number of the quantitative characteristics of language, such as demonstrated by Zipf's, or Pareto's laws, which characterize self-organizing and self-regulating phenomena. Altmann (1978) proposed that this self-organization and self-regularization of language are a result of optimization process in individual brains, which result from selection processes taking place in societies, aiming at some sort of economy of language use on the parts of speakers and listeners[2].

Optimization processes with their source in the sum of individual verbal behaviours of a given linguistic community members, must in turn, depend strongly on the contingencies involved in the actual individual histories of language use (*parole*). Therefore, in empirical linguistics carried out in the paradigm of empirical science as outlined by Bunge and based on Altmann's (1978) hypothesis, only statistical laws and principles make sense—can be proposed, searched for, and tested objectively (Grzybek 2006, Koehler 2012). Interestingly, language speakers are not always aware of such statistical patterns in language.

Linguistic principles in empirical linguistics as just delimited may concern either local or global processes. Local regularization processes in language may take place due to the capabilities of individual human brains alone. For instance, the ability to select the most alike option during categorization (thus to correlate referents with symbols) depends on the capabilities of an individual speaker. This, as shown by Skousen (1989), may alone lead to some linguistic regularization, such as the regularization of past tense suffixes in Finnish. After such a regularization, the resultant semiotic system is easier to remember and use, thus, more economic. Another well-understood mechanism which economizes communication locally is shortening highly predictable lexemes. This process results in lowering the production effort practically without increasing the comprehension effort.

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[2] Related principles have been known since Zipf (1949) (the principle of least effort) and advocated e.g. as the principle of the effective means by Kasher (1982, p. 32): "Given a desired end, one is to choose that action which most effectively, and at least cost, attains that end, *ceteris paribus*". What differs importantly Altmann's proposition is that this need no longer be an individual, who is said to behave optimally, although in some respects he may, but the society. So according to Altmann, in the long run it is an average cost of a given solution for a given linguistic community that matters. This may be attained through optimal behavior of individuals, but need not.

Yet, language seems to be also optimized globally to a significant extent as evidenced e.g., by implicational universals. In other words, some uneconomic solutions allow economizing some other aspects of language, which outweighs the loss of economy in another aspect of language use. (For instance, having suffixes marking gender in Slavic languages, allows these languages to limit the usage of pronouns, as well as to make word order more flexible thus produce cohesive discourse in a more economic fashion.) Such cross-optimization could not have happened locally due to conscious effort of an individual speaker. In such a case natural selection-like mechanism, as proposed by Altmann (1978), could have been involved—language efficiency factor could have selected among early language varieties. In line with Altmann's (*ibidem*) proposal, having reviewed research based on neural nets modelling, Kwapień (2010) found out, for instance, that OSV languages take considerably more time to learn than SVO and SOV languages, making them less efficient. Another proposal of this sort is that, at least early on, people speaking a more efficient variety of a local language (e.g., communicating faster, more precisely, using a language variety easier to imitate) were more successful in a given linguistic community, which, in turn, increased the exposition of their speech variety, resulting in the increase of its replication among the remaining community members.

Before moving on to the next section, I would like to comment on the potential influence of the normativity on language formation, as brought up by a reviewer. The issue of normativity is a very complex one and a topic of heated debate. For an overview see "The Normativity of Meaning and Content" in the *Stanford Encyclopedia of Philosophy*. One of the foundational issues related to normativity is parallel to that of basic encoding, which cannot be shared between different individuals. As far as basic encodings are concerned, the proposition of Bickhard and Campbell (1992) presented in a special issue of *Journal of Pragmatics* was groundbreaking in solving that latter problem. If one followed a similar reasoning, normativity would be a derivative of language formation mechanism, not its cause. Luckily, I do not need to discuss this extremely complex issue here, because as noted by the reviewer, "The example study given later by the Author escapes this issue, because adjectives can be exchanged in order without breaking linguistic norms." So whatever stand we take as far as normativity is concerned, we may safely skip discussing it here.

4] An Example of an Approach to Linguistics as Outlined by Mario Bunge and Constrained by Gabriel Altmann

To recap, the foundational stage of any research requires a description of the phenomenon studied. Current mainstream research in general linguistics, however, stops on that. Research in line with the methodology of empirical sciences can be of two types. The first type of activity consists in the search for statistical patterns (phenomenological laws). An excellent example of the application of the scientific method of this type to studying language are studies done by Héléne and André Włodarczyk at CELTA, Paris, using *Semana* software to categorize all sorts of linguistic data (Włodarczyk 2007, 2009). Another significant research effort in this category has been led by Stefan Gries, the editor of *Corpus Linguistics and Linguistic Theory*. Numerous research in characterizing quantitative aspects of linguistic data, all analysed in statistically rigorous manner, have been collected for years in *Journal of Quantitative Linguistics* edited by Reinhard Koehler. An interesting example of such studies, published in mainstream linguistic journals is Jary (2008).

Another way of doing empirical research consists of proposing principles implied by some properties of material systems, which could account for the patterns already found in objectively measured data, or which could suggest new patterns to look for. In case of linguistics, linguistic research of this type consists of hypothesizing bio-cognitive and social principles, which can account for statistical patterns found in linguistic data, e.g. in linguistic corpora, or which could imply some new patterns (phenomenological laws) to test. Royal Skousen, Gabriel Altmann, and Reinhard Koehler, have each proposed such an explanatory theory of language. Royal Skousen introduced Analogical Modelling. Altmann proposed Grand Unified Theory and Koehler—Synergetic Linguistics. All three of these propositions are in line with Bunge's (1967) perspective on empirical research, which position advocates the description of the world solely in terms of formalized theories implying phenomenological laws and treats models as temporary solutions for specific issues before general theories can be found. Such approaches, however, limit significantly the scope of which aspects of language can be modelled—it tackles only aspects of the phenomena definable in full by formalized theories—and often result in formalizations, which are not particularly intuitive.

Yet, as already explained in “Scientific methodology: an overview” section, Bunge (1973) argues that models[3] are indispensable at any stage of development of any discipline, because they contain approximating conditions coming from beyond theories (we mentioned the approximations involved in modelling the revolution of Earth around the Sun). Models of specific phenomena are necessary to test theories, because theories postulate so general characteristics of a class of phenomena, that there are not directly testable. This newer perspective presented in Bunge (1973) has two important consequences, a negative and a positive one. On the one hand, if a test of a given model (empirical law) becomes falsified experimentally, we cannot say what is wrong: the theory, or the simplifying approximations made when constructing the model. On the other hand, now more aspects of the phenomena considered can be studied—also those whose modelling involves significant approximating conditions—and, methodologically speaking, a given discipline is primarily partitioned into its aspects that correspond to models reflecting direct observations. Therefore, singling out models in a theoretical framework the way Bunge (1973) recommended also results in a more intuitive connection between the phenomenon described and a relevant statistical hypothesis. For an example of such an approach, see Zielinska (2007a, b, c, 2013, 2014).

While emphasizing the role of models in scientific endeavors, Bunge (1973) also stresses the value of qualitative theories when formalized theories are not available, and recommends applying qualitative theories to models, too. He does so because qualitative theories may imply some simpler and less restraining, yet scientifically sound hypotheses of the sort “the more of A, the more of B”, which, albeit less strongly, corroborate the respective theories. This is what I am going to show next when illustrating how qualitative linguistic laws (principles) can account for phenomenological laws (patterns) in linguistics in analogy to the way it is done in empirical sciences.

To show how qualitative linguistic laws (principles) can account for phenomenological laws (patterns) in linguistics in analogy to the

[3] A “model” can also be defined as a “specific theory”, or else “theory with a rather narrow reference class”.

way it is done in empirical sciences, I shall present an account of a statistical preference in the order of certain categories of adjectives in Adjective, Adjective, Noun (AAN) phrases, such as a big black bear, with the help of the procedural model of language presented in Zielinska (2007a, b, c, 2010, 2013, 2014). Procedural model of language (also called a field model of language) is a qualitative theory of form-meaning correlation in natural language based on two general assumptions: first, that language self-regulates because people keep replicating its more efficient varieties (of which latter fact, they need not be conscious) and second, that language change—a prerequisite for self-regulation—is possible because when using language, speakers categorize not only resorting to Aristotelian mechanism (encoding), but also to selective one—choosing the best match for the encoded item used for selection *among options viable in a given situation*.

In other words, according to the procedural model of language, linguistic items may serve either to encode, or to select, or both. For instance, the items *red* and *rose* encode red items and roses, respectively. But the item "red rose" typically does not so much encode an item that is both a rose and that is red, but it selects among roses, the one which is redder than other roses, thus pointing out a flower that consists primarily of a green stem and leaves and whose tiny part (the flower) has red petals (rather than white, yellow, or pink). Encodingly (when used in its dictionary encoded meaning), a red rose should have a red stem and leaves, too. So selection takes part as if "outside-in", to use Mey's (2001) view. [See also Mey's comments on procedural model of language in a footnote in Zielinska (2007c)]

So coming back to the order of adjectives in AAN phrases, it has long been known that in English there is a visible preference for placing adjectives representing the following semantic categories in that order: (measuring from the adjective the farthest from the noun) 1. "opinion", 2. "size", 3. "shape", 4. "age", 5. "colour", 6. "nationality", 7. "material". A similar dependence between the following semantic categories and their distance from the noun: I. (opinion, size) II. (age colour), III. (nationality, material) has also been observed, for instance, in German, Vietnamese, Chinese, Hungarian, Polish, and, with some reservations in French, which suggests a universal cause for the phenomenon. A more modern approach to this issue is to analyse the dependence of the distance of a given adjective from the associated noun on some concept, which characterizes a given semantic category and which can be quantified. Next, one will search for the mechanism that would account for the dependence observed. Two of such measurable factors influencing the distance between a given adjective and the associated noun turn out to be gradability and categoriability.

Gradable adjectives are the ones whose values typically strongly depend on the noun they modify: cf. the value of the lexeme *big* in the phrases *a big star* and *a big virus*, respectively. The degree of gradability of a given adjective can be defined quantitatively (operationalized) as the ratio of the number of occurrences of a given adjective in some corpus in comparative and superlative forms to all its occurrences in that corpus (cf. Wulf 2003). The first two semantic categories mentioned above, these of "opinion" and "size" seem to be the most gradable ones, while the categories of "origin" and "material" intuitively seem to be the least gradable. Consider for instance the phrases, a *big child*, and an *American girl*.

A categorizing adjective in an Adjective Noun phrase is the one that typically singles out a subcategory of the members of the category selected by a given noun, i.e., who also share some additional characteristics besides the ones referred to with the given adjective and the given noun. "A wooden bridge" for instance, is not only a bridge made of wood, but it has a certain kind of a structure characterized by a typical range of sizes and shapes. Operationalizing categoriability is not very straight forward, but can be done, for instance, by calculating how often a given adjective accompanies a given noun in relation to accompanying any noun in a given corpus. Intuitively speaking, we may expect that the semantic categories expressing "material" or "nationality" will tend to be strongly categorizing. Consider, for instance, the qualities of the following phrases: a *Turkish carpet*, a *steel bed frame*. Note, also that, in fact we are speaking about typical uses of some adjectives, rather than types of adjectives, because in some situated speech acts, a given lexeme can be used gradably, in others, categorizingly. Defining the degree of being gradable or categorizing, we state what usage is typical for a given lexeme.

In view of the above, the observed dependence of the order of adjectives in noun phrases on the semantic factors mentioned earlier can be substituted now by the following model: "The more categorizing and the less gradable a given adjective located in a Adj + Adj + Noun phrase is, the closer to the noun it is likely to be."

I propose the following explanation (qualitative theory) for the observations just mentioned. Given the assumptions that language self-organizes and self-regulates due to speakers' opting, consciously or not, for more efficient solutions, and that linguistic items are used not only to encode but also to select from sets of possibilities silent in the given situation (as assumed by the procedural model of language), the order of adjectives in noun phrases described above (the more categorizing and the less gradable an adjective is, the closer it is placed to the noun) is favoured because it increases the efficiency of linguistic communication.

The increase in linguistic efficiency in the situation under discussion takes place at least for two reasons. The first reason is that placing a categorizing adjective first, i.e., further from the noun (thus, interpreting it last), and placing a gradable one second, i.e., closer to the noun (thus, interpreting it first), increases the precision of the interpretation of a given A_1A_2N phrase. Since categorizing adjectives impose additional limitations on the subcategories they co-identify, they narrow down the range of the parameter values from which gradable nouns will be selecting. In other words, a gradable adjective (or even better, an adjective used gradably[4]) applied after a categorizing one, operates on a more exact scale defined by the parameters of a given subcategory than if it were applied first, i.e., to the whole category of the nouns defined solely by the given noun. For instance, "a long wooden bridge" will be typically significantly shorter than an average "long bridge" because these days bridges are typically made of reinforced concrete, or steel, and one may construct much longer bridges with steel, or reinforced concrete than with timber. So using the phrase a *wooden long bridge* would require re-evaluating the value of "long" after interpreting the lexeme *wooden*.

The second reason is that placing the gradable adjective closer to the noun could skew the resultant encoded value of the non-

[4] Note that adjectives when used gradably, or categorizingly, do not encode content, but select it from a set of options, which phenomenon is postulated by the procedural model of language. Procedural model of language postulates that all lexical categories, not only pronouns or demonstratives, can serve to select content in the context.

gradable adjective applied second (placed further away from the noun). If we assume that the encoded value of a given lexeme is a sort of average of its past uses, [as assumed e.g., in the procedural model of language (PML)], an atypical value of a particular usage of that lexeme skews its resultant coded meaning. Placing a gradable adjective next to the noun (applying it first), selects a subset of referents, which may well have atypical parameters. In this case, the non-gradable adjective applied second, which will be selecting its value from an atypical scale of options, may end up having assigned an atypical value. If this happens sufficiently often, the current encoded value of that non-gradable adjective will become skewed. To illustrate the point, let me consider the meaning of red used in the phrase *a red big bird*. In Cracow zoo, this phrase will select a pelican, whose colour differs significantly from a prototypical red. Therefore, if a given speaker keeps using that phrase in similar contexts, the encoded value of *red* will become altered for him. On the other hand, since the values of gradable adjectives each time depend on selected scales, their encoded meanings will always be imprecise no matter where they are placed and will always need to be used selectively—on a given scale. After all “a big virus” must be interpreted as a significantly smaller size than “a tiny star”, no matter what the average meaning of *big* is.

The hypothesis under discussion that gradable adjectives tend to precede categorizing adjectives in AAN phrases (counting from the left), implied by the law postulated above, can be corroborated with linguistic data in the following ways. First, it can be corroborated qualitatively with the help of the classical observation mentioned at the beginning of this section. According to this observation, the categories of the adjectives most distant from the noun are these of “opinion” and “size”, whose meanings, as just explained, typically depend on the category of the referent they assess, thus are used gradably. The categories of adjectives placed the closest to the noun, on the other hand, are these of “material” and “nationality”, which, along with the noun they assess, often single out a subcategory sharing not only the encoded features of the given set of lexemes, cf. *brass instruments*, *wooden instruments*, *Irish cheddar cheese*, *Turkish carpets*, thus are used categorizingly.

A better way to argue for the hypothesis discussed would consist of using quantitative data from linguistic corpora. This could be done, for instance, in the following way. The hypothesis that the order of adjectives, starting from the noun (which reflects the order of their operation) goes: categorizing first and gradable second) implies the following. If we divide two semantic categories of adjectives, which typically follow each other (let us call these A and B), into a "more gradable" and "less gradable" subcategories each—$A_{m\text{-}grad}$ and $A_{l\text{-}grad}$, $B_{m\text{-}grad}$ and $B_{l\text{-}grad}$—then the statistical dominance of the occurrence of the order $A_{m\text{-}grad}B_{l\text{-}grad}N$ over $B_{l\text{-}grad}A_{m\text{-}grad}N$ in AAN phrases should be even stronger than the statistical dominance of the order of total categories ABN over BAN, which, in turn, should be stronger than the dominance of the order of $A_{l\text{-}grad}B_{m\text{-}grad}N$ over that in $B_{l\text{-}grad}A_{m\text{-}grad}N$ categories. This hypothesis was indeed confirmed statistically using British National Corpus by Zielinska (2007a, b, c) in relation to the categories "age" and "colour". (She split the category "colour" into {dark, light, vivid, pale, and such} and {red, blue, yellow, green, black, violet, etc.} and the category "age" into {old, young, elderly, new, etc.} and {centennial, yearly, annual, n-year old, etc.}). Interestingly, Zielinska (*ibid.*) found that while the category of "age" statistically precedes (counting from the left) that of "colour", the subcategory "less-gradable age" follows the subcategory of "more-gradable colour". In the same way, Zielinska (2007a, b, c) showed with quantitative data the dependence of the position of the given adjective in AAN phrases on its degree of being categorizing.

Finally, it is also possible to test the main hypothesis discussed in a purely formal way, without resorting to semantics. To this end, we propose to express the degree of gradability for a given adjective as the number of tokens of a given adjective used in a superlative or comparative case to the number of all occurrences of that adjective in the given corpus, following Wulf's (2003) formalization of the opposite concept—that of not being gradable (comparable). Wulf (2003) finds out in her study that the mean values of IndComp (independent from comparison index) for $adjective_1$ (adjectives standing far away from the noun in AAN phrases) and $adjective_2$ (adjectives standing next to the noun in AAN phrases) differ highly significantly ($p < .001$). In other words, the adjectives standing further from their head noun occur with more forms of degree than adjectives directly preceding the head noun. This translates directly into the statement that the adjectives standing further from the noun are more gradable, (in other words, are more often used selectively).

Wulf (*ibidem*) also considered a number of other factors which influence the position of specific adjectives in AAN phrases. Yet, she has not found any acceptable formalization of a factor which could guide one in proposing an operationalization of the degree of its being categorizing for a given adjective. What seems to be a good candidate for operationalization of that concept, but has not been tested yet, is Average Mutual Information (AMI). AMI can be defined for a given adjective A_i and Noun N_j in terms of some relevant frequencies of occurrence. What else could be considered as the operationalization of the degree of categoriability in the case of Polish language is the ratio of the postpositional uses of a given adjective to all its uses in AN phrases in a linguistic corpus. (In Polish, when a single adjective is used in a noun phrase postpositionally, this adjective tends to indicate a subcategory, cf. barszcz czerwony, [borsch red], is a type of soup made of beets, which is of crimson colour. Polish nouns used prepositionally, on the other hand, tend to convey the encoded value of the adjective. For instance, the adjective *red* in the phrase *a red scarf* indicates simply the colour of the scarf in question. Yet, such ordering is not a grammatical rule for Polish, but a preference.)

Finally, note, that it follows from what has been said above that the categories which are neither often used gradably nor categorizingly will be placed in the middle between the two groups. And if an adjective is neither truly gradable, nor categorizing, in other words, it is not used selectively, it is used encodingly. So it means that the adjectives representing the categories of "age" and "colour" typically serve to convey their relatively stable, dictionary meanings. This corroborates our intuition.

Interestingly, language users are not aware of statistical correlation in language. Consider for instance the following comment of another reviewer of this paper pertaining to the statistical pattern describing the order of adjectives in AN phrases.

> I would like to see the evidence supporting this claim about the order of adjectives in English. I see no grounds for saying that English speakers prefer "five year old, white cat" to "white, five year old cat."

This objection does not undermine the claim I made, because my claim is statistical in nature. I do not claim that this preference concerns every instance of an AAN phrase. The statistical preference hypothesized was noticed first by Bolinger (1967), albeit he did not express them in statistical terms. With time, typical ordering of semantic categories in AAN phrases became a common stock knowledge presented in grammar books such as Sidney Greenbaum and Randolph Quirk, *A Student's Grammar of the English Language* (1990), published by Longman in London, which are read by thousands of advanced ESL students all over the world. More recently, Bolinger's observation was supported with quantitative corpus research by Wulf (2003) and Zielinska (2007a, b, 2014). Thus the reviewer's comment shows how wrong a native speaker's intuition, concerning statistical facts can be, even if that native speaker happens to be a famous philosopher of language.

A similar situation took place in Polish academic world. Despite the fact that, due to being non-native speakers of English, Poles are quite familiar with Bolinger's research concerning English language presented in ESL books, the possibility of researching the ordering of adjectives in Polish noun phrases was not entertained until proven by Zielińska (2007a, b, c). She showed a statistical preference in the order of three categories of Polish adjectives representing the categories 1. "highly gradable adjectives", 2. "neither highly gradable, nor highly categorizing", 3. "highly categorizing", which turned out to be represented by semantic categories defined by Bolinger's combined categories: 1. "opinion and size" 2. "colour and age" and 3. "nationality and material". One reason that such a hypothesis with respect to Polish had not been entertained, could have been the fact that Polish language having a considerably free word order makes this proposal particularly counter-intuitive.

The role of statistical patterns in language is underestimated by many. The reviewer mentioned also said: "In 'Developmental and self-regulatory character of language' section you make the claim that empirical linguists will be interested in *parole* and not *langue*. I do not see the justification for that. The fact that English speakers use 'knife and fork' more often than 'fork and knife' is a fact about *parole*. The fact that both conjunctions are meaningful and grammatical in English is a fact about *langue*. Both are descriptions of empirical, linguistic facts."

Well, if we treat language as a set of patterns and a list of vocabulary items with respective representations assigned to them, then the qualitative yes/no (grammatical/non-grammatical) judgements are sufficient and it makes sense to say that *parole* is a matter of the usage of *langue*. Yet, if we treat language as an evolving system (mind you that Nicaraguan sign language originated within about 10 years), a theory of language aiming at modelling change—the self-organization and self-regulation of language—must be more precise than yes/no (grammatical/ungrammatical) judgements allow it. To model change, such a theory needs to take into account the frequency of usage of specific patterns and then *langue* no longer is independent from *parole*. It can be treated only as some percept of *parole*—possibly a set of statistically dominant patterns found in *parole*. In other words, there is an ontological difference between the two perspectives compared. Mine—concerns language as a self-organizing system and self-developing system subject to evolutionary processes, that represented by the reviewer—concerns language viewed as an unchangeable set of patterns.

By the way, in British National Corpus, there are 87 *knives and forks* but also 4 *forks and knives*. One may choose to disregard these latter examples, as proponents of language as an abstract structure view recommend, just as well as one may disregard the fact that 20% of people say *in the train* and not *on the train*. Yet, if one starts considering frequencies, they note that there are many features and correlations which can be expressed only by rankings or statistical preferences. As Altmann and Koehler point out in the *Introduction to Quantitative Linguistics*, there are dependencies of homonymy of grammatical morphemes on their dispersion in their paradigm, the length or complexity of syntactic constructions on their frequencies and on their ambiguity:

> […] the dynamics of the flow of information in a text on its size, the probability of change of a sound on its articulatory difficulty … in short, in every field and on each level of linguistic analysis—lexicon, phonology, morphology, syntax, text structure, semantics, pragmatics, dialectology, language change, psycho- and socio-linguistics, in prose and lyric poetry—phenomena of this kind are predominant. They are observed in every language in the world and at all times. Moreover, it can be shown that these properties of linguistic elements and their inter-relations abide by universal laws, which can be formulated in a strict mathematical way—in analogy to the laws of the well-known natural sciences. Emphasis has to be put on the fact that these laws are stochastic; they do not capture single cases (this would neither be expected nor possible), they rather predict

> the probabilities of certain events or certain conditions in a whole. It is easy to find counter-examples to any of the examples cited above. However, this does not mean that they contradict the corresponding laws. Divergences from a statistical average are not only admissible but even necessary—they are themselves determined with quantitative exactness. This situation is, in principle, not different from that in the natural sciences, where the old deterministic ideas have been disused since long and have been replaced by modern statistical/probabilistic models.

Similarly, it would not be very useful to collect information about the heights of 12-year-olds without also noting how many children fall into which height range. Only if you collect such statistical information will you be able to find, for instance, the correlation between height and other factors, such as diet, or lung capacity, and propose hypothesis stipulating the impact of one characteristic on another. For instance, you may use such correlations to find out what is the norm for the capacity of one's lungs given one's age, height and weight. Departure from this average serves as a primarily indicator of asthma. Of course, you could limit yourself to enumerating possible height ranges of 12-year-olds, their mass and lung capacities, and this is how biology and medicine started out. But significantly, these disciplines took the next step—embraced the scientific method, i.e., started observing patterns, hypothesizing, and testing correlations in the parameters of a given category of items. This started the incredible progress in medicine we are observing today. Note that transition in emphasis has taken place without neglecting traditional, classificatory work—describing newly found plants and new sicknesses, which is as important as it ever was.

5] Conclusion

Currently, an important transition is taking place in linguistic methodology. What dominated in language studies (in general linguistics) so far, and still dominates today, is observing and describing individual sentences and utterances. Yet, nowadays, more, and more linguists and interdisciplinary scholars concerned with language are looking for solutions guided by the methodology used in empirical sciences. Therefore, it would be good to present available solutions to work out the most appropriate ones for language studies. I started that debate here by considering the application of Mario Bunge's (1973) perspective on empirical sciences.

The philosophy of empirical sciences, however, offers not only a way of organizing research, but also ideas on how to structure data. Since language is characterized by emergent phenomena on every level, I built on Bunge (2003) when proposing a qualitative model of utterance interpretation in Zielinska (2013) [cf. Dlugosz 2000, 2016].

By advocating empirical linguistics research, I do not mean to undermine the value of a traditional study of language and the power of human intuition. As is the case in biology, the two approaches to the study of language should complement, rather than contradict, each other. The depth of treatment of indirect reports in Capone (2010, 2012, 2014), for instance, cannot be easily quantified today, yet I bet, it will guide some quantitative research of the future—form grounds for novel, quantitative analysis. The other way round, the results of quantitative research can well serve to inform classical linguistic propositions. For instance, the Zipf kind of relationship describing the distribution of many types of linguistic data, characterizes most of self-organizing systems, which indicates strongly that language is a self-organizing system, too. This in turn, lets one eliminate some, and support other theories of language.

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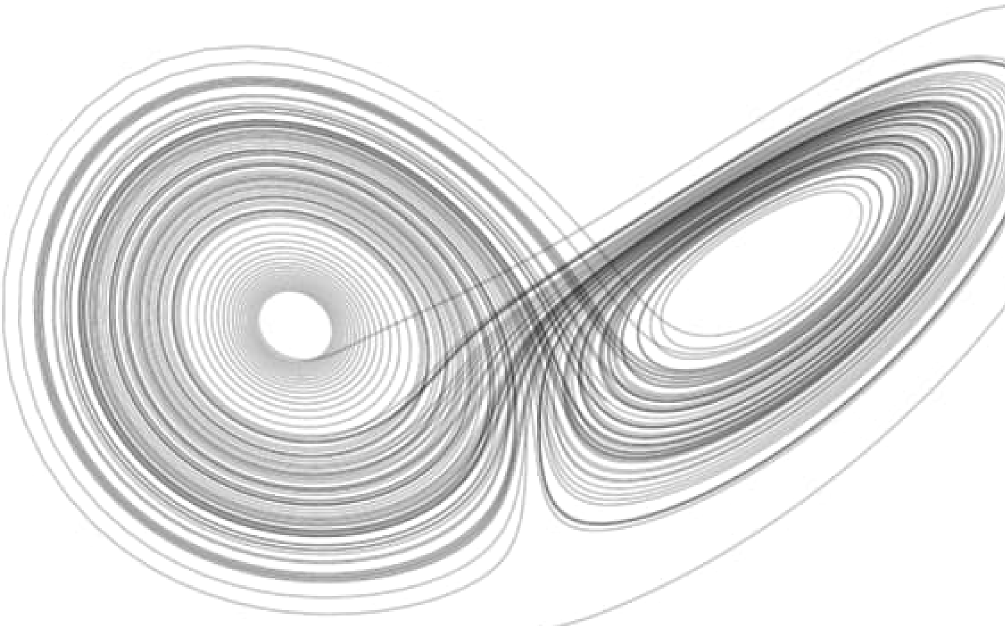

Scientism after its Discontents

Andrés Pereyra Rabanal[1]

Abstract — Scientism has more notoriety than history proper for it has been identified with "positivism", "reductionism", "materialism" or "Marxism", or even held responsible for the enforcement of science at the expense of other human affairs. The idea that scientific research yields the best possible knowledge lies at the very definition of "scientism". However, even when science has shown a considerable amount of theoretical and practical successes, a rational confidence put on it as a mean for solving any factual problem has been denounced as illegitimate, defective, or dogmatic. Thereby, after revisiting the varieties of the meaning of scientism, I argue for a reasonable defense of scientism against some of its prevailing criticisms. Hence, it will be sustained that science is the most reliable approach for attaining knowledge without detriment of other valuable human activities insofar these do not address factual or cognitive questions nor are at odds with a scientific worldview.

Résumé — Le scientisme a plus de notoriété que l'histoire proprement dite, car il a été identifié avec le « positivisme », le « réductionnisme », le « matérialisme » ou le « marxisme », ou même tenu pour responsable de l'application de la science au détriment d'autres affaires humaines. L'idée que la recherche scientifique produit les meilleures connaissances possibles réside dans la définition même du « scientisme ». Cependant, même lorsque la science a montré un nombre considérable de succès théoriques et pratiques, une confiance rationnelle mise sur elle comme moyen de résoudre tout problème factuel a été dénoncée comme illégitime, défectueuse ou dogmatique. Ainsi, après avoir revisité les variétés de la signification du scientisme, je plaide pour une défense raisonnable du scientisme contre certaines de ses critiques dominantes. Par conséquent, on soutiendra que la science est l'approche la plus fiable pour acquérir des connaissances sans nuire à d'autres activités humaines précieuses dans la mesure où celles-ci ne traitent pas de questions factuelles ou cognitives ni ne sont en contradiction avec une vision du monde scientifique.

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Science has shown a considerable amount of successes since the early modern period. Progress was not limited to astronomy nor mechanics but reached the discovery of oxygen, the development of cell theory, the principles of natural selection, and research on the neural basis of learning. Social research has neither dispense with the use of the scientific method as seen in cognitive linguistics, economics, and mathematical sociology. Proposals such as string theory or evolutionary psychology have received criticism but have not eclipsed the advancement of contemporary science on matters of all kinds. Testimony of emerging disciplines from computer sciences to behavioral neurosciences is an evidence of the pivotal role of science in our age.

The departure from mythological explanations can be traced back to the studies on geometry, medicine, and natural philosophy made in ancient Babylonia, Egypt, and Greece. Even technological innovations in Chinese, Indian and Roman cultures are evidence of the growing adoption of a rational approach for understanding reality. Except for the romantic revolt led by Hegelian philosophy, no development in culture, health, or industry have been done in foreign ways of science and technology. Certainly, neither warfare nor global warming would have been possible without scientists, but this is not the fault of science itself but rather of partisan politics to the extent that German eugenics and Lysenkoism share the same ideological bankruptcy.

If we cannot deny the historical achievements of science, shouldn't we adopt a scientific worldview instead of relying on religious authority or cultural tradition? Such worldview exists and is commonly—and derogatory—called "scientism". Moreover, it is denounced as illegitimate or even vicious. One can revise the historical evolution of the term in Schöttler (2017). Suffice is here to say that scientism has been identified with "positivism", "reductionism", "materialism" or "Marxism", and even held responsible for the enforcement of science to the detriment of other human practices, the condoning of industrialism in third-world countries, and even for the spread of atheism. Such diversity of meanings suggests that scientism has more notoriety than history proper which will not be addressed here. I am going to argue instead for a reasonable defense of scientism against some of its prevailing criticisms.

1] Against Scientism

Scientism was endorsed as early by adherents of French Enlightenment, laymen and arguably most contemporary scientists and scientific philosophers (Bunge, 2016). The term was coined by the time of Renan, Renouvier or Bernard Shaw albeit as an "arbitrary use" of science (Schöttler, 2017). Fauverty criticized the "orthodoxy" of science while attempting to reconcile reason and religion. Similar objections were shared by spiritualists, occultists, and firm believers (Raynaud, 2017). Conversely, scientism was openly defended by La Mettrie, Condorcet, D'Holbach, Le Dantec, and Lalande. According to Haack (2012), these authors may have overestimated science and even denigrated other valuable human activities. Against this trend, Dilthey, Bergson, Hayek, the Frankfurt School, postmodernists, radical skeptics or constructivists reacted against whatever they identify as "scientism" in Comte's positivism, the Vienna Circle, or Western industrialism. Moreover, any vigorous defense of science will be quickly labelled as "dogmatic", "lame", "narrow", "pedantic", "pretentious", or worse, "false" (Schöttler, 2017, p. 40). Thus, it is the influence of scientism that may have been overestimated or consciously exaggerated by its critics as it was neither a dominant phenomenon nor a well-received stance in society.

The view that "scientism" meant a mode of thought that considers things from a scientific viewpoint was soon superseded by its current negative connotations spread by Hayek (1942) in the human and social sciences. The following definitions are representative of the "anti-scientism" sentiment in academia and comprehensive perspectives of the debate can be found in De Ridder *et al.* (2018), Boudry and Pigliuci (2017) and Andrade (2017).

For instance, Haack (2012) conceives scientism as "a kind of over-enthusiastic and uncritically deferential attitude towards science, an inability to see or an unwillingness to acknowledge its fallibility, its limitations, and its potential dangers" (p. 76). Famed authors as Hawking, Krauss, Harris, or Rosenberg are to be found guilty of this trend for their contempt of philosophy and the humanities which is noticeably on the rise as much more pervasive as thought. Pigliuci (2017) defines it as an "activity that projects itself into domains or areas of inquiry where it does not (allegedly) properly belong" (p. 187). Scientism is also seen responsible for making extraordinary claims on behalf of science but delivering little to nothing to support them (Pigliuci, 2015). Unwarranted assertions are, however, usually unreasonable. If those assertions met any rational or acceptable standard, can we carry on with scientism after all, or will it still be condemned because of certain "boundaries" science is said to cross in order to encompass other academic disciplines or even realms of reality?

But what are those fields science should not dare to venture? Remarkably Haack (2017) is thinking in other valuable forms of inquiry such as the historical, legal, and literary as well as human activities such as music, art, storytelling, joking or cooking. But excluding historical research, none of them seems to have descriptive, explanatory, or predictive aims as they do not constitute scientific enterprises of their own. Of course, the legal system can (and should) be aided by scientific techniques such as blood sampling, facial recognition techniques and reliable psychological measurements but Law Schools do not produce laboratory or field lawyers. On the other hand, no one studies culinary arts for a better understanding of the cultural or economic impact of food (less for learning its nutritional values) but for improving their cooking skills. The problem appears to be Hayek's (1942) blending of "physicalism" with "scientism" as the social sciences don't need to cling upon radiocarbon dating or geological remote sensing but to their own techniques such as cohort studies, scatter plots or field surveys adopting the "methods and language of science" (although certainly not those of the "natural" sciences). Other human activities are not at odds with science insofar as they do not have factual content but follow instead practical, social, aesthetic, or recreational ends with the clear exception of religion and ideology.

Gould's (1997) famous complaint against overlapping magisteria between science and religion seems to be a direct confrontation with scientism. This can also be mirrored in Snow's depiction of the incomprehension between the natural sciences and the humanities. True is that neither art, music, or literature make factual claims so extending the domain of science to them would be rather unilluminating and misleading (Mahner and Bunge, 1996b). But religions and ideologies do pretend to tell us something about reality, so they are actually crossing these boundaries with claims at times incompatible with those made by science about the world. Surely one can discuss whether descriptive or explanatory assertions can overshadow normative claims but what matters is that scientists are often intimidated to research assertions of nonscientific disciplines even if they are blatantly false (e.g. psychoanalytic accounts of repressed memories), or at least questionable (e.g. biological basis of gender roles) for fear of being labelled as "pretentious" or "defective".

It is also important to notice how science already assists long-lived philosophical issues such as moral cognition (e.g. whether our ethical intuitions are universal or not), philosophy of mind (e.g. fMRI record of parietal activation), or even ontology (e.g. an understanding of emergent properties). As Buckwalter and Turri (2018) state, contravening boundaries is not always amiss. Moreover, the distinction between human sciences (*Geisteswissenchaften*) and natural sciences (*Naturwissenschaften*) was stillborn when Dilthey came up with the idea that social studies deserve an intuitive or "empathic" method of interpretation (Bunge, 2016). Neuropsychology, biological anthropology, and population geography are living examples that the dichotomy between nature and culture is spurious and in clear contrast with the dubious inferences of "interpretative sociology" and "cultural studies".

Regrettably "anti-scientism", namely, the rejection of scientism mainly for its negative connotations, is well spread in intellectual circles and it would not be surprising that even scientists themselves dismiss it. Hereby, Haack (2012) makes a sober characterization of scientism in terms of certain "signs" to avoid.

First, the use of terms like "science", "scientific" or "scientifically" is denounced as a gratuitous endorsement of epistemic praise. As noticed earlier, any claim raised with unwarranted assertions is not scientistic per se but an example of defective arguing. Moreover, the examples given by Pigliuci (2017) seems to be a case of media sensationalism such as popular advertisements or science divulgation gone mad. But blind enthusiasm and dubious marketing is to be considered a psychological or sociological sign rather than an internal feat of scientism. A second sign is the improper usage of scientific language or mathematical terms to make apparent sense of nonsense. While a valid point, it is neither an essential feat of scientism as even authors of the so-called Sokal's affair were accused of using incorrect or meaningless concepts (e.g. "lacanian" topography or Irigaray's ludicrous account of fluid mechanics), but not of committing to scientism. Here again clarity is a form of courtesy that both the philosopher and men of science owe.

Haack's third sign is rather suspicious as she marks out the preoccupation with demarcation as a distinctive sign of scientism but shortly afterwards admits that there is indeed a distinction (although not a sharp one) between sciences and other activities. Scientific research is described as "more systematic, refined and persistent" (2012, p. 26) with the familiar procedure of conjecture-and-checking along the specialized techniques devised in various fields (Haack, 2017). It happens that later she characterizes "bad science" as done carelessly, mainly too vague, with decorative symbolism and purely speculative statements. It is then a sample of kindness not to call this a "pseudoscience" or a "faulty science" as these feats are commonly found within claims falsely pretending to be a scientific (see also Romero, 2018). On the contrary, Pigliuci (2017) replies that "scientistic" research is not one of demarcation but of "expansionism" as everything worth inquiring must be amenable to scientific analysis (p. 192). What is relevant to be researched is flour from another sack, but certainly scientism follows Russell's (1946) conviction that whatever can be known, can be known by the means of science.

A special concern for scientific method is another alleged sign of scientism. There is an extended idea that adherents of scientism advocate for the existence of a single method to rule them all. In fact, scientism endorses the superiority of scientific method in matters of all (cognitive) kinds, but not the neglecting of other forms of inquiry. Haack would agree with the idea that there may be a general method ("an underlying pattern of all serious scientific research") coexisting with more specific methods developed for each field. With the aid of a systematic method we can tackle factual issues, but it would be indeed an exercise in bad praxis to look to science for answers to questions beyond their scope. In any case, technology, ethics, and wise decisions help solve social or political problems, not science alone.

Last but not least, Haack's (2012) final objection against scientism is its devaluation of the diverse. Government efforts to focus resources on science education at the expense of other fields is a denigration of scientism of other valuable activities (Haack, 2017). Of course, investment in Latin American science remains considerably inferior to blocks such as the European Union or the United States, so third-world countries would be free of scientism according to this. Certainly, asking for the importance of science over cultural expressions is a misguided question. Worrisome is the paternal attitude adopted about the displacement of "old traditions" by scientific practices blaming them for the "impersonal" character of, for example, modern medicine (Haack, 2012, p. 36). Beyond a personal right to long for these beloved traditions, this is not a sign of intellectual opening but of cultural conservatism.

One cannot deny that there is a complementary risk of the underestimation of science, namely, its overestimation. But the problem does not lie on an enthusiastic confidence for its achievements over religious or traditional knowledge are undeniable. Neither is that scientific discourse is recalcitrant to internal or external criticisms for philosophy and sociology of science are responsible for giving accounts of these. It is providing a caricature of science that can hamper scientific progress that does not do justice to the efforts, setbacks, and bias present in science. Enemies of scientism react by mocking the whole enterprise as an outcome of "Western rationality", by greeting "alternative" or pseudoscientific practices, or by limiting even more public funding of science. In line with Haack's reasoning, this is not so much a problem of scientism but an example of media portrayal of scientism. (For a criticism of science in media culture, see Elias, 2018).

It may be further objected that to question the limits of scientific knowledge belongs to philosophy turning scientism self-refuting as it cannot be empirically proven. Naturally, one could circumscribe philosophy to conceptual or logical analysis (Ayer, 1936). This is, however, not needed as scientism can be deemed as an epistemological or methodological postulate presupposed by the bulk of scientific knowledge. Philosophical theses too can become scientific if they test their theories by their interaction with more specific theories of science while using as many exact tools as possible (Romero, 2018). Haack (2017) admits that proceeding in philosophy should be as rigorous as the best scientific inquiry if it also takes into consideration everyday experience. If the role of philosophy is to frame the semantical, ontological, epistemological, and methodological aspects of various issues, the question then is if there is a tenable or equally compatible type of inquiry other than science.

2] The Varieties of Scientism

Nor only should we accept that there are multiple usages of the term “scientism” but also that it would be untenable if it does not rely on a suitable philosophy. As there are many recent trends in philosophical inquiry such as constructive empiricism, naturalized epistemology, or theoretical structuralism, not all of them understand “scientism” in the same way. The kind of philosophy here endorsed aligns with “scientific realism”. (For a comprehensive review see Sankey, 2008; Bunge, 2006; Niiniluoto, 1999). Accordingly, we need first to refine the varieties of scientism.

Peels (2018) distinguishes between academic and universal scientism. The former is divided into methodological scientism (i.e. disciplines should adopt the methods of the natural sciences) and eliminative scientism (i.e. disciplines other than the natural sciences have nothing to add to our bulk of knowledge). But the author misguidedly identifies observation and experimentation as the methods of natural sciences as if they were not already used in the social sciences. On the other hand, eliminative scientism is reductionism be towards physics (Neurath) or biology (Wilson), but can also be towards sociology (Woolgar), politics (Foucault) or economics (Marx). Thereupon, “methodological scientism” can be redefined just as the expansion of the methods of science to other academic disciplines.

“Universal scientism” is also a rather misguided term as it also encompasses eliminative reductionism. Here science attempts to answer the once epistemological, ontological, or moral problems. Peels (2018) concludes that the conceptual core of scientism is the expansion of its boundaries. Some claims are indeed unwarranted such as that all genuine knowledge is to be found only through natural science in detrimental to the human and social sciences. But factual science comprises both kinds of sciences. And although optimistic, we can neither rule out some limitations of scientific research while keeping a reasonable confidence in its endeavor.

For their part, Buckwalter and Turri (2018) contrast “radical scientism” (i.e. science as the only way to acquire knowledge about reality) with “moderate scientism” (i.e. science is a good way of answering any factual question). The former is likewise false as there are other forms of inquiry and even other organisms gain knowledge about their surroundings without being practicing scientists while the latter coincides with the strategy of scientific expansionism (Pigliuci, 2017; Stenmark, 2014). Nonetheless, according to this view, science can be deemed as a useful tool for deepening our understanding of the world but nowhere is stated to be the best one. Therefore, it represents science as only helpful (but not the only one) for answering questions typically thought to fall outside of it.

"Radical" or "strong" scientism can be tracked in Quine's naturalized epistemology and Stitch and Churchland "revolutionary scientism" (Haack, 2009). But it is hard to know whether they would accept the label of being radical. As Mizrahi (2017) notices, these characterizations are usually persuasive definitions which express disapproval of scientism. Only Rosenberg (2018) is an exemplar of the advocacy of "strong scientism". He vocally states that there is no meaning in the universe, that metaphysics and ethics are derived from science, and that all we need is the scientific method, although he seems to encompass eliminative and causal realism to a certain extent.

But on a more positive trend, certain philosophers have openly defended scientism as Ladyman and Ross (2007). These authors attempt to take contemporary science seriously enough for building a "naturalistic metaphysics" that enriches our "relatively unified picture of the world" (p. 27). In a rather critical tone, they also reject what they label as "neo-scholastic metaphysics" found in analytic philosophy and propose instead that our ontology should not rest upon intuition or common sense but on science itself. They go beyond criticizing philosophers who use "outdated or domesticated science" (p. 17) or make generic rather than specific claims. It is further argued for the "primacy of physics" based on its maturity and the asymmetry between physical science and other disciplines. Although reductionists, Ladyman and Ross end up mentioning that explanations in other sciences should at least be consistent with what is known in the physical and biological sciences. In their views, "scientism" is to be considered as a stance which encompasses a certain version of empiricism and materialism (p. 63).

The case of Bunge (1986) is similar although he adopts critical realism as a distrust of sense data that encourages the building of sophisticated conceptual systems which include some concepts that have only a remote relation with reality but refer nonetheless to a certain domain of facts (p. 23). The acceptance of emergent levels favors the merger or convergence of disciplines and frees us from the charges of reductionists. Therefore is the idea that scientific research yields the best possible knowledge of reality which lies in the very definition of "scientism" (Bunge, 2016).

Sorrell (2013) attaches a valuative element on scientism as a matter of putting too high a value on science in comparison with other aspects of society. This is important as Mizrahi's (2017) account of "weak scientism" (i.e. science is not the only way to attain knowledge) would be indistinguishable from moderate scientism without a value put on it (e.g. science or technology are the best among others and even considered prized commodities). With everything revised, we can sketch three versions of "scientism" according to what kinds of boundaries it crosses and how much confidence is deposited in scientific enterprise:

1. Strong scientism—Science is necessary and enough for yielding knowledge
2. Moderate scientism—Science is necessary but not enough for yielding knowledge
3. Weak scientism—Science is enough but not necessary for yielding knowledge

Only *cognitive aims* are to be supposed here, so this distinction is strictly epistemological ruling out ontological or moral implications. Strong scientism argues that scientific enterprise is necessary for yielding knowledge as it has proven to be the only reliable source of knowledge against superstition or speculation. But what stands more about it is not that science is enough but either theoretical physics, evolutionary biology, or neurosciences at best. Hence most of the advocates of strong scientism are also reductionists.

It is striking that Ladyman and Ross (2007) argue for a "weak metaphysics" as long as it is not an activity that has a specialized science of its own (p. 65). This "deflationary" project (whether defensible or not) is further criticized by Haack (2017) as barely more than promoting a meta-science. But the mere idea of a science-oriented philosophy is not necessarily dependent upon reductionism (Rescher, 2003), nor need to abdicate from scientism (Romero, 2018; Bunge, 2012). The case against strong scientism consists of establishing whether other forms of inquiry are nonexistent or illegitimate.

While "strong scientism" as represented by Rosenberg, Hawking and Stitch may deny that other nonscientific disciplines produce legitimate knowledge, Mizrahi's (2017) "weak scientism" admits that scientific knowledge is the best among others. But to have such a clear conviction of the superiority of science does not seem to be a weak stance but rather a moderate one. Compare this to Buckwalter's and Turri's (2018) "moderate scientism" which is actually weaker as it asserts that scientific knowledge can be good enough but not the best one as there can be other means to attain knowledge. Arguably Buckwalter, Turri, Pigliuci, Haack and many practising scientists would endorse "weak scientism" without the label while admitting that it is trivial and uninteresting to keep it.

Moderate scientism further states that science cannot rest upon pragmatic justification only. As Raynaud (2017) points out, there is no practical utility in Young's experimental test of the ondulatory nature of light, or in discovering that the Beck's tree frog can be divided into two different species in spite of their morphological similarities (p. 73). Science certainly works but should also be theoretically sustained. In fact, most utilitarian attitudes applied to science cannot be directed towards basic research while ignoring that science as a social activity rests upon institutional norms (Ladyman and Ross, 2007) or research communities (Romero, 2018).

Shermer (2002) defines scientism as "a scientific worldview that encompasses natural explanations for all phenomena, eschews supernatural and paranormal speculations, and embraces empiricism and reason as the twin pillars of a philosophy of life appropriate for an Age of Science" (p. 35). Scientific realism follows this by including scientism as the epistemological and methodological branches of the matrix of scientific progress (Bunge, 2012). Therefore, science is not only one form of inquiry among others but the most reliable one. And although valuable in itself, it does not need to deter other human activities. Innovations in vaccines, medicines, roads, and industrial processes are all due to advancements in basic research, but without music, art, literature, or jurisprudence neither would we be far from having left Altamira's cave. It seems that the insistence of Haack (2017) in everyday experience is due to the so-called "Big Questions" whatever these are (likely Kant's questions). Surely intuition and ordinary experience can lead to ordinary or literary reflections and some of them are valuable. But having sophisticated science-oriented systems, committing to folk philosophy still be necessary?

3] In Defense of Scientism

The boundaries scientism is said to cross is any cognitive domain with a factual reference to it. After all, no one has accused a mathematician or logician of scientism no matter how much confidence he or she has to their formal or abstract procedures. Now we can state the principles found tenable for scientism and why we should endorse it:

1. Science is the most reliable approach for attaining knowledge of the world
2. Scientific methods address intellectual problems, not things
3. There should not be a blockage of scientific inquiry

As repeated until weary, scientism is defined as the thesis that cognitive problems are best tackled by adopting the scientific approach as it can yield the truest and deepest possible knowledge of things (Bunge, 2016; 1986). There are indeed other kinds of inquiries and knowledge, but science is a pattern of inquiry which provides systematic knowledge and no alternative system be it religion, mythology, ancestral wisdom, or pseudoscience has matched its success in solving conceptual issues. Moreover, it was science by (pleasantly) crossing boundaries that lead to the discovery of the recession of nearby galaxies thus suggesting the idea of cosmic expansion, the common ancestry between man and beast, or the mechanisms of aspirin from the native uses of Spiraea. Against divine creation, intelligent design, or herbal healing, science successfully gave a better account of the phenomena purportedly explained by them. Certainly, scientists like Newton or Lemaître were religious, but science progresses not due to cultural and religious tradition which anyway can encourage or hamper research, but in *spite* of them.

Haack (2017) admits that scientists have amplified the process of inquiry, so they have figured things out *better*. Scientific enterprise allegedly uses the same procedures and inferences as everyday inquiry, so scientists have improved, refined, amplified, and augmented them but holding the conviction that it is nothing more than refined common sense. Nonetheless, while herbal medicine can yield useful results, botany gives us a deeper account of their therapeutic effects by analyzing their mechanisms and efficacy, e.g. isolating the active compounds, and conducting double-blind studies. By deepening the state of affairs, science is a better account of ordinary knowledge. But it also gives us counterintuitive information such as rejecting the flatness of the Earth contrary to common sense. So, science does not only provide a more refined representation of reality but also corrects our intuitions.

Precisely Ladyman and Ross (2007) criticizes the dependence on intuition and common sense that might lead to an outdated scientific image (p. 10) and can be extended to ordinary language analysis and phenomenology (Buckwalter and Turri, 2018). Although ordinary knowledge is to some extent indispensable, scientific research starts by acknowledging that background knowledge is indeed insufficient or even conflicting with our current theories. Therefore, science gives us counterintuitive pieces of knowledge (Bunge, 2016). But how can we quantify how much better is scientific knowledge in comparison to other forms of inquiry? The measurement of the impact of research papers and academic journals is a relevant index, but its qualitative evaluation has deep roots in the philosophy of science regarding its explanatory, instrumental and predictive success (Azrahi, 2017).

Literature and the arts are also said to help us grasp a deeper meaning of the human condition. Actually, experimental psychology teaches us that art is influenced by emotional state, ambiguity, perception, and expectations (Jakesch and Leder, 2009; Jacobsen, 2006). Art is not scientific but its investigation as a cultural artifact that produces aesthetic responses can be scientific (Romero, 2018). Moreover, allegories and metaphors can be vicariously descriptive or reformulated as saying something factually true or false (Mahner and Bunge, 1996b). For example, the insight of the morals of a fable can be seen as the formulation of a rule of behavior. And when conveniently interpreted by theologians, some biblical myths are symbolic rather than literal. At best they can fulfill a pedagogical or vicarious purpose as in Plato's allegories. But in general, art does not need to rely on describing the nature of reality but on producing aesthetic experiences, so there is no actual conflict between science and the arts.

Naturally, philosophy and the humanities are open to more mundane reflections through everyday experience, but this can be one point of departure insofar common sense cannot be taken for granted. Otherwise we run the risk of transforming philosophy into naïve physics or folk psychology. And for most of their branches, the humanities can benefit from adopting a more scientific approach by making grounded conjectures, weighing the reasons or evidence, arriving to a conclusion and carefully examining it (Haack, 2012) while avoiding ad hoc guessing and metaphorical talk.

As stated earlier, the scientific method is a general pattern of inquiry and should not be restricted to any kind of science but as the kernel of scientism as such (Bunge, 1986). Although philosophers throughout history have doubted about the method (Popper) or even denied its very existence (Feyerabend), its employment has proven to be superior to relying on intuition, authority, or revelation (Peirce, 1955, p. 18). Moreover, it is not enough to hold true propositions but to be able to give an account of how we come to know that a statement is true. We also must consider that the scientific approach is applied to the full gamut of cognitive or intellectual problems (Bunge, 1998). That means that indistinctly from its subject matter, be it protons, tectonic layers, ape behavior, economic recessions, or political crisis all can be studied with the aid of the scientific method. The "myriad specialized techniques" devised by scientists (Haack, 2017) from the microscope to the psychometric questionnaire obey a general strategy of research that begins with identifying a problem and using our intellectual and empirical resources for reaching a tentative solution.

The last principle states that any factual question can be formulated in intellectual terms. Although there may be *de facto* beyond scientific investigation, there is nothing that could not be *de jure* studied scientifically (Bunge and Mahner, 1996, p. 103). As everything is open *in principle* to scientific research, we must avoid any attempt of blocking the way of inquiry (Peirce, 1955, p. 54). Its imperative form can be reformulated as stating that any factual domain worth being inquired should lack of border patrols. Noticeably Peirce suggested that the first rule of reason is to try any theory so long as it is adopted "in such a sense as to permit the investigation to go on unimpeded and undiscouraged" (p. 54). And the first impediment to this is admitting the unknowable. What is unwarranted is not our scientific attempts to understand better or our "epistemic optimism", but to call out for dogma where no reason nor evidence but tradition and revelation might play a better role.

There are no royal roads in science or philosophy so we should go on without assuming intrinsic boundaries of scientific inquiry. While conjectures are at first speculative and some are eventually abandoned, science can correct itself progressively. It is then not clear why this kind of scientism would be considered "dogmatic", "lame", "narrow" or "pretentious". As a methodological principle, scientism relies upon an ontology that fathoms our scientific worldview. In short, scientism is not only tenable, but also desirable for our intellectual heritage. But there is a major risk of "anti-scientism", namely, that it denies not only that science is our best strategy but as equal as any other knowledge. And when everything is the same, then nothing, not a single intellectual endeavor or a sincere fervor for knowing would really matter.

4] An Addendum on Pseudo-Scientism

As any other human idea or device, scientism can also be falsified. Its core idea, that is, that any cognitive problem is best tackled by adopting the scientific attitude and method, can be accepted by both laymen and specialists alike. Yet there are abuses of the term which both can share the label of "pseudo-scientism".

A first meaning arises from the concept of which it is an -ism itself, i.e. "pseudoscience". By arranging our previous definition, pseudo-scientism defends the idea that pseudosciences are reliable or legitimate approaches for acknowledging or influencing the world. For instance, psychoanalytical lessons are usually tolerated along behavioral and physiological approaches, or homeopathic "medicine" can be found in the curricula of scientific medicine. Hence "pseudo-scientism" can be defined as the promotion of pseudosciences as if they were authentic sciences because they exhibit some of their attributes (e.g. use of mathematical symbols) (Bunge, 2017, p. 27). Nonetheless pseudosciences struggle for passing the litmus test of internal consistence, compatibility with previous knowledge, or empirical testability, not to mention they are based on non-scientific philosophies.

Canonical examples of "pseudo-scientism" can be found in orthodox psychoanalysis, Lysenkoism, creationism and doctrinal Marxism. These do not denigrate science per se but support it under the condition that they are included against "bourgeois", "reductionistic", "materialistic", "positivistic", "colonialistic" or "Western" science while thickening their "protective belt" against refutations, empirical proofs or any other standard of scientific contrasting. There is not much more to say about this meaning of pseudo-scientism. Insofar as pseudosciences are identified and denounced, they should not be promoted either by universities or by the State as they can be hazardous in terms of health and educational policy. We must not forget the denunciation of "Jewish science" that delayed Germany from relativistic physics. Their pervasiveness in culture and why people believe weird things is rather a matter of psychological and sociological research as Sharmer puts it.

Another widespread and more relevant meaning should be, however, discussed. From the "two cultures" chasm, a tendency arises to grant greater confidence to the "hard sciences" to the detriment of the "soft sciences". This sense of pseudoscientism is detrimental as governmental funding is usually directed to the former and does not help to extend the idea that science is necessary to understand phenomena not addressed by physics or chemistry alone. On the contrary, it gives the idea that either everything is to be reduced to physics or biology, or there are aspects that cannot be explained due to their "complexity" thus giving rise to pseudoscientific and religious narratives.

A vivid example are scientists carrying out research in the *Specola Vaticana*. There is no doubt about the seriousness of their astrophysical queries, but it is also common to oppose them to non-religious laymen who stress the incompatibility between religious and scientific education but happen not to have a PhD in physical sciences. Most of the Catholic priests are physicists, cultivated philosophers, and theologians, but what counts are the argumentative soundness and the available evidence on these issues in despite theological indoctrination. If it were a matter of accumulation of academic degrees, an economist can be a lawyer and a psychologist; or an educator can also be a historian and a social worker. As the reader can suspect, it is implicit that here some sciences are given a greater epistemic prestige though is no more than an authority argument degraded in fallacious reasoning. One needs no to be an astrophysicist nor a neuroscientist for discussing gods, politics, morals, or sports.

This pseudo-scientism privileges fundamental physics and molecular biology over psychology and anthropology. For example, while a pandemic crisis is mainly a medical and political issue, there is no reason not to listen to economists on the topic. Or rather, we should not hand over the Ministry of Economy and Finances to a physician as surely this one would demand not to offer the Ministry of Health to a journalist. More than a "war on science", this can be seen as a "battle royale of sciences" competing against each other though with clear disadvantages such as public funding and social prestige still reserved for the natural sciences.

To be clear, we have to recognize which sciences are competent to answer certain issues such as physics for the formation of the galaxy, or economics and demography for avoiding an economic disaster. But denigrating some sciences over others fosters their underdevelopment by warding off funding instead of attracting human talent to these fields. Including them in the public discourse will help them grow more scientific and socially relevant. Genuine scientism not only rejects the promotion of pseudosciences, but also the expansion of this kind of pseudo-scientism.

One can see similarities of this to the "scientistic thought" of Hawking, Nye o DeGrasse who subordinate philosophical queries to science. This attempt is not sound. For example, the abortion debate cannot be settled within biology or medicine. An embryo is a human being, not a future calf. What is in dispute is not its genetic identity, but whether it is ethically justified to interrupt the process. Nonetheless, this "pseudo-scientism" is also a false portrayal of science disregarding other sciences. Hence, we must not stop our rational confidence in sciences, but in men of science. Sometimes, scientists themselves can be imprisoned by their own fame, prejudices, or philosophical misconceptions. Luckily, scientific psychology already knows more about this than organic chemistry or astrophysics.

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With all this Pseudoscience, Why so Little Pseudotechnology?

Sven Ove Hansson[1]

Abstract — After a review of previous uses of the term "pseudotechnology", a definition is proposed: "A pseudotechnology is an alleged technology that is irreparably dysfunctional for its intended purpose since it is based on construction principles that cannot be made to work". The relationship between pseudotechnology and pseudoscience is discussed, and so is the relationship between pseudotechnology and the much weaker concept of technological malfunction. An explanation is offered of why pseudotechnology is much more seldom referred to than pseudoscience: dysfunctional technology usually reveals itself when put to use, whereas dysfunctional science tends to be more difficult to disclose.

Résumé — Après un examen des emplois antérieurs du terme « pseudotechnologie », une définition est proposée : « Une pseudotechnologie est une technologie présumée, irrémédiablement dysfonctionnelle pour l'usage auquel elle est destinée, puisqu'elle est basée sur des principes de construction qui ne peuvent pas être mis en œuvre ». La relation entre la pseudotechnologie et la pseudoscience est examinée, tout comme la relation entre la pseudotechnologie et le concept beaucoup plus faible de malfonction technologique. Une explication est proposée de la raison pour laquelle la pseudotechnologie est beaucoup plus rarement mentionnée que la pseudoscience : le dysfonctionnement d'une technologie se manifeste généralement au moment de son utilisation, tandis que le dysfonctionnement d'une science est généralement plus difficile à établir.

The influence of pseudoscience in today's world is **obvious** and in important respects ominous. Creationism blocks basic understanding of biology, anti-vaccinationism and quackery threaten public health, and climate science denialism endangers the future of humankind. With so much pseudoscience, one might

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expect a similar abundance of pseudotechnology. Gustavo Romero (2018, p. 67) rightly remarked that "as most human products, science and technology can be faked", and that one can therefore expect to find "activities and artifacts presented or offered as scientific or technological which actually are not". But in practice, there is a striking difference in the frequencies with which the concepts of pseudoscience and pseudotechnology are referred to. This was pointed out more than twenty years ago by James McOmber (1999, p. 140), who noted that "[s]cientists may accuse creationists, parapsychologists, and others of pseudoscience", whereas "few accusations of 'pseudotechnology' ever appear". This was confirmed by a Google search in April 2020, which yielded almost 700 times more occurrences of the word "pseudoscience" than the word "pseudotechnology" (7,910,000 respectively 11,600).

Is this because pseudotechnology does not in fact exist? Perhaps there is nothing, or very little, that stands in the same relation to technology as pseudoscience to science? This is what the late historian and philosopher of technology Ann Johnson indicated in one of her papers:

> Scholars in the technology as knowledge tradition have carefully avoided limiting definitions of technological knowledge in an explicit effort to avoid some of the restrictions that have arisen through the epistemology of science. We may speak of pseudo-science, but never of pseudo-technology. (Johnson 2005, p. 555)

This article attempts to answer two questions: First, is pseudotechnology an oxymoron, or is it a phenomenon that can and does exist? Secondly, if it can exist, why is it so seldom referred to, in particular in comparison to pseudoscience?

In order to answer these questions, we first need to clarify the meaning of the term "pseudotechnology". In Sect. 2, previous scholarly usage of the term is summarized. Section 3 is devoted to the definition of technology, and Sect. 4 to the relationship between science and pseudoscience. Based on these preparations, a definition of pseudotechnology is proposed in Sect. 5, which also answers our first question. The second question is answered in Sect. 6, and our conclusions are summarized in Sect. 7.

1] Previous Usage of the Term

The first documented usage of the term "pseudotechnology" appears to be in a book on science fiction from 1960 by the English novelist and critic Kingsley Amis (1922–1995):

> Science fiction is that class of prose narrative treating of a situation that could not arise in the world we know, but which is hypothesised on the basis of some innovation in science or technology, or pseudoscience or pseudotechnology, whether human or extra-terrestrial in origin. (Amis 1960, p. 18)

Amis's definition has been much quoted in the literature on science fiction, usually without any attempt to further clarify the meanings of its key terms. This usage has sometimes also spread to other areas; for instance Susan Schneider (2016, p. 21) refers to Derek Parfit's philosophical investigations of personal identity as employing "the classic science fiction pseudotechnology of the teleporter and the example of split brains from actual neuroscience cases". Several authors have described pseudotechnology as including, or perhaps being synonymous with, concepts such as magic, superstition, and ritual action (e.g.: Jennings 1987, pp. 39–40; DasGupta 2006, pp. 447–448; Cottingham 2009, p. 206). In contrast, Richard Dale Mullen (1915–1998) made an interesting distinction between three versions of technology that appear in science fiction: natural technology (usually called just technology), supernatural technology (also called magical technology), and pseudonatural technology (also called pseudotechnology). Supernatural technology was based on the assumptions "that mind and spirit may exist independent of body and that minds can act on distant bodies". In contrast, pseudotechnology was congruous with the assumptions that "mind is necessarily dependent on body and that an individual mind can act only on the body in which it exists". As examples of pseudotechnology he mentioned Icarus's wings and Isaac Asimov's thiotimoline, which is a fictitious chemical substance with highly unusual properties (RDM 1978, p. 292).

Mario Bunge (1919–2020) was the only major philosopher who has repeatedly and extensively discussed pseudotechnology and its relations to technology. His discussions on pseudotechnology have to be understood against the background of his somewhat unconventional definition of technology. In an article published in 1966 he took "technology" and "applied science" to be synonyms (Bunge

1966, p. 329). In 1976 he defined technology as a body of knowledge that satisfies the following two criteria:

> i) it is compatible with science and controllable by the scientific method, and
>
> ii) it can be employed to control, transform or create things or processes, natural or social, to some practical end deemed to be valuable. (Bunge 1976, p. 154)

This definition has two notable consequences. First, in line with Bunge's previous work, technology is still considered to be applied science. Secondly, he treats technology as covering a much larger range of human activities than what is common. His notion of technology is rather similar to the older notion of practical arts (see Sect. 3). As examples of pseudotechnologies he included astrology, alchemy, homeopathy, chiropractic, Lysenkoism, psychoanalysis, and graphology, most of which would more commonly be described as distortions of other activities rather than of technology (Bunge 1976, p. 157).

In later publications, Bunge has recognized that technology is not entirely based on science, but also on "the work of highly skilled and imaginative artisans", whose ideas are not based on science (Bunge 1985, p. 220. Cf. Bunge 1988). This is in line with modern research in the history and philosophy of technology, which has increasingly emphasized the independence of technology and its extensive use of knowledge not derived from science (Radder 2009; Hansson 2013b). However, this modification of his previous standpoint did not have much impact on his view of pseudotechnology. His most well-developed definition of pseudotechnology is part of a joint definition for "pseudoscience or pseudotechnology". Both of them are said to have "a community of *believers* who call themselves scientists or technologists although they do not conduct any scientific or technological research". Furthermore, both are said to have a fund of (alleged) knowledge that "contains numerous untestable or even false hypotheses in conflict with well confirmed scientific hypotheses". He does not directly address the distinction between pseudoscience and pseudotechnology, but indicates that those so-called pseudosciences that are devoted to "practical problems concerning human existence" rather than "cognitive problems" are pseudotechnologies, rather than pseudo- sciences (Bunge 1983, pp. 223–224).

Thus, Bunge identifies pseudotechnology as technology-like phenomena that fail to be based on science. Several other authors have taken a similar approach. Barry Beyerstein (1996, p. 4) defines technology essentially as applied science, and like Bunge he considers the so-called pseudosciences that are devoted to practical achievements as "really pseudotechnologies". Martin Mahner follows Bunge in defining technology as a practical design process performed "with the help of knowledge gained in basic or applied science", and he consequently defines a pseudotechnology as "a technological field based on some pseudoscience". He introduces a special term, "paratechnic", to denote "a crackpot technic without any elaborate pseudoscientific background, or at most with a traditional magical background theory" (Mahner 2007, pp. 539 and 548). Schoijet (2009, p. 434) classifies eugenics as a pseudotechnology, largely because of its lack of a scientific basis, and Tuomela (1987, p. 95) maintains that if a pseudoscience is concerned with practical problems about "how to bring about a certain effect", then it contains aspects of pseudotechnology.

In a discussion on different forms of medical technology, Lewis Thomas used the term "pseudotechnology", or synonymously "magical technology", for traditional technologies with no base in science, lamenting that we have got used to pseudotechnologies when they have "gone through our cyclical fads and fashions, generation after generation, ranging from bleeding, cupping, and purging, through incantations and the reading of omens, to prefrontal lobotomy and metrazol convulsions" (Thomas 1974, p. 100). This usage has not received much following in the discussion on medical technologies.

Ingemar Nordin (2000, p. 303) used the term in a somewhat different way. After pointing to "the condition that therapies must *work* in order to be useful and that functionality may be determined by scientific means", he wrote: "Functionality is also the criterion of demarcation between quackery and real medicine, between pseudotechnology and real technology." Here, the main focus is on functionality rather than on a scientific base. Lack of functionality may, but need not, be determined with the means of science. A similar usage of the term can be found in an article by Stanley Changnon (1973, p. 642) on a quite different topic, namely weather modification technology. He deplored that "the majority of the public, and many decision makers, believe that weather modification is a pseudo-technology". Although he is not entirely clear, he seems to mean by this that the functionality of the technology was questioned by the general public and by decision makers.

In summary, we have identified two major usages of the (comparatively rare) term "pseudotechnology". One of them originates in the literature on science fiction, but it can also be found in a few texts referring to philosophical examples, medical technologies, and weather modification. Its main criterion for distinguishing between technology and pseudotechnology is the *severe and irreparable non-functionality* of the latter. In order for an object or a process to be a pseudotechnology, it is not sufficient that it does not work, like a hammer with a loose handle or an elevator with a motor too weak to hoist the cab. The criterion is instead that its very construction principles cannot work, like Superman's X-ray vision or Dr. Whos's time machine.

The other major usage originates in Mario Bunge's writings, and can mostly be found in texts directly influenced by his work. It is based on a conception of technology as highly dependent on science, and it defines pseudotechnology as a (putative) technology that *lacks a scientific basis*. Writers in this tradition seem to implicitly assume that this lack of a scientific basis makes the pseudotechnology non-functional. We can therefore interpret this usage as referring to a subset of the cases covered by the first usage, namely to (putative) technologies that exhibit a *severe and irreparable non-functionality due to lack of a scientific basis*.

2] What Is Technology?

In order to clarify the meaning of "pseudotechnology", we need to have a clear picture of what we mean by technology. This is a fairly new concept. It has largely replaced the previously more popular concept of "practical arts", which had a much wider scope and included not only the crafts but also agriculture, hunting, medicine, warfare, and much of what we today call the fine arts. (Hansson 2015 pp. 13–15).

The word "technology" is of ancient Greek origin, but it was not much used until the nineteenth century, when it was increasingly employed to denote knowledge about the practical arts, in particular those that were executed by craftspeople. Increasingly, it referred primarily to knowledge about how to construct and use tools and machines, especially in factories and large workshops. The 1909 *Webster's Second New International Dictionary* defined technology as "the science or systematic knowledge of industrial arts, especially of the more important manufactures, as spinning, weaving, metallurgy, etc." (Tulley 2008, p. 94). In the English language the word "technology" also acquired another meaning: It referred to the tools, machines, and procedures used in industry, rather than to knowledge about these tools, machines, and procedures. This usage arose around the year 1900 (Sebestik 1983; Mertens 2002; Tulley 2008; Hansson 2015, pp. 16–17). Today this is the dominant usage, and it is also the sense in which we use the term here.

3] The Science-Pseudoscience Relationship

In both the major usages referred to in Sect. 2, the term "pseudotechnology" is conceived in analogy with "pseudoscience". We therefore need to study the relationship between science and pseudoscience as a prolegomenon to defining "pseudotechnology".

As a first rough approximation, a pseudoscience can be defined as a doctrine that is claimed to be scientific in spite of not being so. Since the concept of pseudoscience is based on that of science, we cannot make the meaning of "pseudoscience" more precise without having a reasonably clear concept of science. The two major problems in defining science concern the scope and the quality required of its constituents.

The scope of science, or in other words the areas of knowledge included in that description, is the result of historical contingencies. The English word "science" originally referred broadly to various kinds of both practical and theoretical knowledge. It acquired a new, much more restricted meaning in the eighteenth century when it was adopted by researchers performing empirical studies of natural phenomena. They used this term at least in part to distance themselves from the less empirically minded "natural philosophers" at the universities (Layton 1976, p. 689). Today, "science" refers to the natural sciences and other fields of research that are considered to be similar to them. In contrast, the German word "Wissenschaft" and its cognates in other Germanic languages have a wider scope, and cover all the academic disciplines, including the humanities.

The larger scope of Wissenschaft has the advantage of accentuating that all these knowledge disciplines form a community with common values and principles, and with mutual respect for each other's methods and results. This is particularly important in discussions of the science–pseudoscience demarcation, since the divergence between legitimate history and pseudohistorical teachings such as Holocaust denial largely coincides with that between science and pseudoscience (Hansson 2007, pp. 260–261; 2009 pp. 238–239). It is therefore a sensible choice to focus on the wider concept of Wissenschaft ("science in a broad sense"). However, for our present purposes we can leave the choice between the traditional and the broadened view of science as an open issue.

Let us now turn to the quality criterion of science. What legitimizes science is that it provides, at each point in time, the most epistemically warranted information in its areas of knowledge available at that time. Many attempts have been made to specify philosophical rules for determining whether or not a statement or practice satisfies this criterion. I have argued elsewhere that due to the unceasing development of science, which involves fundamental changes in methodologies and modes of inference, no time-less specification of the criterion of epistemic warrant is possible (Hansson 2009, p. 239). (This has the important implication that the determination whether a particular claim or doctrine is scientific is a task for experts in the respective area. It is not an issue to be solved by philosophers examining the statements per se.) For our present purposes we can leave it open whether or not the criterion of "currently most epistemically warranted information" can be further specified with timeless methodological criteria.

Importantly, not all knowledge claims that fail to satisfy the quality criteria of science can be classified as pseudoscience. For instance, we need to distinguish between pseudoscience and various forms of bad science and fraud in science. The major characteristic of pseudoscience that distinguishes it from these other aberrations from science is the presence of a *deviant doctrine*. Bad science usually results from failed attempts to do good science and to adhere to the evidential criteria applied in *bona fide* science. It has no ideology of its own. In contrast, all the pseudosciences—homeopathy, creationism, Lysenkoism, etc.—are characterized by staunch commitment to doctrines that are irreconcilable with legitimate science.

In summary, the three defining criteria of pseudoscience are that it refers to issues within the domains of science (the criterion of scientific domain), that it has severe shortcomings in terms of reliability or epistemic warrant (the criterion of unreliability) and that it involves a doctrine falsely claimed to represent the most reliable knowledge on its subject matter (the criterion of deviant doctrine) (Hansson 2013a).

4] Defining Pseudotechnology

As we saw in Sect. 2, most usages of the term "pseudotechnology" refer to devices or processes that lack the functionality ascribed to them. This is unsurprising, since our expectations on a technology or technological device can usually be expressed in terms of a function, or a way in which we can use it (Kroes 2012). It would be strange to classify a device or process as a pseudotechnology if we can use it successfully for its intended purpose. Consequently, non-functionality is a necessary criterion for pseudotechnology. Notably, this implies that a putative technology can only be a pseudotechnology in relation to a particular function or intended usage. If we do not know the intended use of an artefact, then we cannot determine if it fulfils its intended use, and therefore we cannot know whether or not it is a pseudotechnology.

Extensive historical evidence and thorough philosophical analysis have given rise to a broad consensus among technology scholars that technology is not, and has never been, based exclusively on science. Advanced technology has existed since long before modern science. Even today, the construction and use of technologies is largely based on more or less systematized practical experiences, such as rules of thumb and tacit knowledge, rather than (or in addition to) science (Houkes 2009; Hansson 2013b; Norström 2013). Against this background, it would be inadequate to require, as some authors have done, that putative technologies have to be based on science in order to avoid being classified as pseudotechnologies.

Comparisons between pseudotechnology and pseudoscience can be facilitated by the observation that the distinction between science and pseudoscience can also be expressed in terms of functionality. We can identify the function of science as that of providing us with explanations, understanding, and systematic knowledge about the world. For instance, one of the major differences between creationism and evolution theory is that the latter is an indispensable tool for explaining and systematizing biological knowledge, whereas creationism serves no such purpose. In general, we can describe pseudoscience as dysfunctional (putative) science, and pseudotechnology as dysfunctional (putative) technology.

However, there is an important difference that makes it necessary to qualify the analogy. We noted in Sect. 4 that science represents the currently best available (most epistemically warranted) information about its subject matter. This means that in order to determine whether a statement or a doctrine is scientific, we compare it to the maximally functional information in its area. This is not how we conceive technological functionality. For your computer to be functional, it is certainly not necessary that it functions as well as the best computers available.

Since "pseudo" means false, that which we call "pseudo-X" should indeed not be X. This is true of pseudoscience; that astrology is a pseudoscience implies that it is not a science. Applying this criterion to (pseudo)technology will further highlight how low the threshold of functionality is that distinguishes between technology and pseudotechnology. Suppose that your bicycle has two flat tyres and the chain is broken. It is then completely dysfunctional; you cannot ride it. However, it is still a bicycle, and it is certainly also still a technological artefact. Calling it pseudotechnology would be equally inadequate as calling it a pseudo-bicycle. An immediate reason why it is a bicycle is of course that it can presumably be repaired, and will then be functional again. But suppose that you take it to the repair shop. The technician tells you that both the top tube and the down tube have big cracks that cannot be repaired. This means that you will have to downgrade the bike from "in need of repair" to "beyond repair", but it is still a bicycle, and neither a pseudo-bicycle nor pseudotechnology.

If even a permanently useless device is not pseudotechnological, how can the criterion of lacking functionality be employed to demarcate pseudotechnology? Can there be a lower degree of functionality than that of not functioning at all? Yes, there can, if we also consider potential functionality, or functionality in principle. Although the bicycle in this example cannot be made to work, it is based on well-functioning principles, and other devices based on these same principles can be made to work. In this it differs for instance from a perpetuum mobile, which is based on principles that cannot be made to work. In summary, pseudotechnology can be characterized as follows:

> A pseudotechnology is an alleged technology that is irreparably dysfunctional for its intended purpose since it is based on construction principles that cannot be made to work.

The construction principles mentioned in this definition have a role similar to that of the deviant doctrine mentioned in the definition of pseudoscience in Sect. 4. However, as already mentioned, although the construction principles may refer to science, they need not do so.

The application of this definition will be ambiguous if it is unclear what the construction principles are. One potential example of this is dowsing. The movements of a dowsing device (rod or pendulum) depend on the dowser's own expectations, conveyed through small subconscious muscular movements. If a dowser searching for water recognizes plants that only grow in soil with high humidity, then this can induce muscular movements that move the dowsing-rod when he is close to these plants. However, if the dowser's chances to achieve better- than-random expectations are eliminated with methods such as proper blind-folding, then the results will not be better than random (Zusne and Jones 1982). Dowsing is usually presented as being based on some sort of (non-existent) "energy field", which is claimed to be detectable by humans with a dowsing-rod, but not with physical instruments. This description of a dowsing-rod is a clear case of a pseudotechnology. However, if the dowsing-rod were instead presented as a method to elicit the dowser's intuitive beliefs about suitable sites for well-drilling, then it could not so easily be dismissed as a pseudotechnology. In practice, it is implausible that anyone would promote dowsing with reference to its actual mode of action as an indicator of the dowser's expectations. Therefore, for practical purposes, dowsing is a clear example of a pseudotechnology.

5] The Viability of Pseudotechnology

In the previous section we answered one of our questions from the introduction, namely whether pseudotechnology is a misconstrued conception or a well-definable phenomenon that can and does exist. We found that it can in fact be plausibly defined, and that there are clear examples of devices that satisfy the description. We will now turn to the second question, namely: Why do we hear much more seldom about pseudotechnology than about pseudoscience? In order to answer that question, we will have use for the following concept:

> A claim is *immediately falsifiable* if a single, easily made, observation is sufficient to conclude that it is false.

For instance, if I tell you when you are at home that there is a white horse standing at your front door, then you can easily check my claim by opening the front door and looking out. If the claim is wrong, then it is an easily exposed falsehood. Many, perhaps most, of the technological devices we use—at home and at work—come with claims of a very high degree of functionality. They are supposed to work every time we put them to use. This makes their claimed functionality immediately falsifiable. For instance, a desk lamp should light every time you turn it on. If it does not light, then you know that the salesperson was wrong when she claimed that it would work. That claim was immediately falsifiable. This is the reason why few attempts are made to sell lamps that do not light, clocks with immovable hands, or ovens that do not heat.

In contrast, scientific claims tend to be much more difficult to evaluate. For instance, it is easy to determine if a light bulb based on new physical principles actually emits light, but it can be much more difficult to assess and offered physical explanation of how it works.

There are a few cases in which pseudotechnologies have been peddled with some success although their claimed functionality is immediately falsifiable. The clearest examples are perpetual motion machines and cold fusion (Park 2008). These are of course machines that should produce energy reliably if they worked. There are essentially two ways to fool people into investing in them. One is to claim that the machine is under development. The other is to equip it with hidden contrivances giving the incorrect impression that it is actually producing energy. Similar methods have been employed in so-called gold-from-seawater schemes (which are in fact gold-from-duped-investors schemes) (Naylor 2007). However, these scams seem to be relatively marginal phenomena, due largely to the immediate falsifiability of the claims in question.

Instead, most cases of successfully promoted pseudotechnologies are claimed to have effects that are not immediately falsifiable. The alleged effects of these devices are so ill-defined and/or irregular that it is difficult to determine if the effects are real. This applies to various devices claimed to have positive effects on human health, such as appliances for magnetic healing (Macklis 1993), Wilhelm Reich's orgone accumulator (Gardner 1957, pp. 250–262; Lugg 1987, pp. 227–228), and energy-balancing bracelets (Barrett 2008). Other examples are the e-meter used by scientologists (Bigliardi 2016), cameras for aura photography (Nickell 2000), and various gadgets used to detect ghosts (Nagar and Choudhary 2016).

A particularly interesting case is cryonics, the low-temperature freezing of human corpses with the stated purpose of future resurrection. The chances that the persons who are now being frozen will return to life are practically indistinguishable from nil (Monette 2012; Shoffstall 2016; Shermer 2018). However, since the promised resuscitation attempts are supposed to take place far into the future, the outcome of the cryonic process is very far from immediate falsifiability, which may be an important part of the explanation why this business has customers.

6] Conclusion

We set out to answer two questions. The first was whether pseudotechnology is a well-definable concept denoting something that exists. After some preparative work we answered that question in Sect. 5. The conclusion was that pseudotechnology can reasonably be defined as a putative technology that is irreparably dysfunctional since it is based on construction principles that cannot be made to work. There are indeed examples of pseudotechnology in that sense.

Our second question was why there is much less discussion about pseudotechnology than about pseudoscience. In Sect. 6 we found an explanation: Many, probably most, technological devices are required to have an immediate effect, which will ensue every time we employ them. If such a device does not work, then that is easily discovered. This leaves no scope for permanently dysfunctional pseudotechnologies.

However, there are exceptions to this. Some technologies have effects that cannot be so easily tested. This is usually because the intended effect is ill-defined or irregular. Such pseudotechnologies can survive simply because their dysfunctionality cannot easily be ascertained. These are also the devices that vigilance against pseudotechnology should put focus on. Dysfunctional devices claimed to have well-defined and regular effects will reveal themselves as soon as they are put to use.

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When Philosophy is No Longer Philosophical

François Maurice[1]

Abstract — We examine the idea that there is a sub-discipline in philosophy of science, philosophy *in* science, whose researchers use philosophical tools to advance solutions to scientific problems. Rather, we propose that these tools are standard epistemic, cognitive, or intellectual tools at work in all rational activity, and therefore these researchers engage in scientific or metascientific research.

Résumé — Nous examinons l'idée selon laquelle il existerait une sous-discipline en philosophie des sciences, la philosophie *dans les* sciences, dont les chercheurs utiliseraient des outils philosophiques pour avancer des solutions à des problèmes scientifiques. Nous proposons plutôt l'idée que ces outils sont des outils épistémiques, cognitifs ou intellectuels standards, à l'œuvre dans toute activité rationnelle, et, par conséquent, ces chercheurs se consacrent à la recherche scientifique ou métascientifique.

1] What is Philosophy *in* Science?

We mentioned in our article in the first issue of *Metasicence* that one of our goals is to find thinkers in philosophy of science who no longer practice philosophy (Maurice 2020). The task seemed impossible to us since we do not have a team to undertake the arduous work of finding and evaluating thousands of philosophers with metascientific potential. We were pleasantly surprised when we read an article that listed about 160 authors who appeared to us as metascientists.

Thus, in "Philosophy in Science. Can Philosophers of Science Permeate Through Science and Produce Scientific Knowledge?"

[1] Graduated in social statistics, mathematics and philosophy, independent researcher, founder of the Society for the Progress of Metasciences and translator in French of the *Philosophical Dictionary* by Mario Bunge published at Éditions Matériologiques under the title *Dictionnaire philosophique*.

Thomas Pradeu, Maël Lemoine, Mahdi Khelfaoui and Yves Gingras propose the idea that there is a subfield in philosophy of science that they call *philosophy in science* or *PinS*:

> Most philosophers of science do philosophy 'on' science, that is, they contribute to our knowledge of the methods, concepts, objects, and problems of science, and/or address philosophical problems using lessons taken from science [...]. By contrast, some philosophers of science do philosophy 'in' science, that is, use philosophical tools to produce scientific knowledge rather than knowledge about science [...]. Instead of studying, discussing or talking about science, they permeate through science and try to participate in resolving problems that scientists raise or encounter in their work—problems that most other philosophers of science consider local and technical. We propose calling this trend in philosophy of science, in which philosophers use philosophical tools to address scientific problems and provide scientifically useful proposals, 'philosophy in science' ('PinS'). (Pradeu *et al.*, forthcoming; italics in original)

Thus, philosophy of science is divided into two: on the one hand, philosophy *on* science, practiced by the majority of philosophers of science, on the other, philosophy *in* the sciences, practiced by a minority of philosophers of science. The authors selected three criteria to identify philosophers who practice philosophy *in* science: 1) they tackle *scientific problems*; 2) propose *scientific solutions*; 3) but use *philosophical tools* to achieve this. There is nothing wrong with the first two criteria. This is the third characteristic that is problematic for us. Philosophers who practice philosophy *in* science would use philosophical tools and it is this characteristic that makes the authors say that "PinS papers do not cease to be philosophical because they are also scientific".

The authors therefore offer us a partial list of six philosophical tools used by philosophers of science belonging to the PinS:

– Investigating and/or proposing a scientific **definition or distinction**.

– Rooting a scientific problem in its broadest philosophical or historical **context**.

– Questioning the **consistency** of a set of claims made in a scientific field.

> – Questioning **methods** on the grounds of broader views on methodological concepts.
>
> – Questioning a scientific **claim**.
>
> – Proposing a **combination** of scientific domains.
>
> […] These tools are not intended to define philosophy of science, but only to detect its presence. The list is non-exhaustive, as other tools may be added to the list; moreover, it is not entirely specific to philosophy of science, as scientists may also resort to them, albeit less frequently and less thoroughly. […] The philosophical dimension is not highly visible in all PinS papers, but the key point is that it is never entirely absent. (Pradeu *et al.* forthcoming; emphasis in the original)

The authors defined PinS philosophers as those who tackle a *scientific problem* and propose a *scientific solution*, but with *philosophical methods*. What therefore connects these thinkers to philosophy would be the tools, techniques or methods used to address a specifically scientific problem. But according to the authors, these tools are also tools used by scientists, which is right. Moreover, even if we were to complete this list with an analysis of all the texts of the PinS, it is doubtful that we can find approaches, methods or tools that are strictly philosophical, that belong only to philosophy, and of which scientists make no use. Let us think of the following philosophical tools, techniques or methods[2]: transcendental argument, philosophical counterfactuality, philosophical thought experiment, philosophical logical analysis, philosophical conceptual analysis, philosophical linguistic analysis, philosophical necessity and possibility, philosophical conceivability, philosophical intuition, dialectics, *Epochè*, the Canberra program, and analyses using possible worlds (modal techniques), to name a few. The very use of these strictly philosophical approaches, methods or tools would make it impossible for these PinS thinkers to participate in the advancement of science.

It would in fact be impossible to propose something intelligible to scientists, and by the same token, scientists would not be able to assess whether the proposal is a scientific contribution or not. In

[2] We must label most of the approaches we list "philosophical" because most of them have also meaning and utility outside of philosophy.

short, it is no coincidence that the previous quotation mentions only tools that have proven themselves and whose use is widespread in all spheres of rational activity, unlike philosophical tools.

2] Five PinS Contributions Reviewed

We studied five articles among those identified by the authors as belonging to the PinS articles (Bernat, Culver & Gert 1981, Godfrey-Smith 2015, Kaptchuk *et al.* 2010, Sarkar 2000, Vandenbroucke, Broadbent & Pearce 2016). There is room for debate in our review of the articles just mentioned. For example, what are the strictly metascientific elements and those strictly scientific? There may be continuity between metascience and science, but that is not the question we dwell on here. Above all, we want to emphasize the fact that some tools, approaches, and methods associated mainly with philosophy, but also used by scientists, as the authors of the study acknowledge, are not philosophical because they are tools, approaches and methods that are part of the arsenal of any reasonable and rational activity, theoretical or practical, be it science, law, technology, literary or artistic criticism, management, ethics, etc.

Let's begin our examination of the five articles we have selected in order to assess their "philosophicity", because that is what is at stake, namely that these contributions are both philosophical and scientific. Bernat, Culver and Gert (1981) propose a definition, a criterion and a test of death in humans, after having distinguished definition, criterion and test. There is therefore a metascientific aspect since the authors dwell on the nature of definition, criterion and test, and a scientific aspect since they propose a definition, a criterion and a test. Godfrey-Smith (2015) offers a conceptual (non-philosophical, however) analysis of the notion of reproduction and illustrates his point with examples. We are therefore in the presence of a contribution that is intended to be scientific, and not metascientific (and even less philosophical), since the author does not linger to identify the nature of definition, criterion, conceptual analysis, etc., because just like scientists, he takes these notions for granted. Scientists do not hesitate when necessary to use conceptual analysis, but most of them avoid conceptual analyses of a philosophical type, that is, conceptual analyses practiced within the framework of a philosophical doctrine, because this leads to transcendent results, which are of no use for the advancement of science[3].

Kaptchuk *et al.* (2010) conducted a randomized controlled trial that demonstrates that a placebo effect is caused even when patients know they are being prescribed a non-active substance. It is therefore a common scientific experiment. Sarkar (2000) criticizes the idea, supported in particular by Maynard Smith that genes are carriers of information. To do this, he introduces two metascientific distinctions. The first distinguishes a heuristic from a substantial role that a concept can play in the development of a "scientific entity", a distinction that falls under metascience since it is based on an analysis of scientific constructs (concepts, propositions, classification, theory, etc.) in order to determine which are heuristic and which are substantial. The second historically distinguishes three information concepts used in genetics: cybernetic, communicational, and semantic information. The first distinction is synchronic and the second is diachronic. Everything happens at the conceptual level and not at the factual level, even if the goal is the advancement of science. Sarkar's conceptual analyses are not philosophical since he uses standard tools and does not think based on a philosophical doctrine.

Vandenbroucke, Broadbent & Pearce (2016) criticize an approach in epidemiology, which tends to impose itself as the only possible approach for causal analysis, which they call the *restricted potential outcomes approach* (RPOA). The article is metascientific since this is about methodology, although the authors use concrete examples to show the shortcomings of RPOA to establish causal links. The authors then propose a pragmatic pluralism where

[3] In our article published in the first issue of *Metasicence* (Maurice 2020), we discuss the transcendent nature of philosophical discourse, that it is only a general discourse among others, which leads us to conclude that it is not the general discourse *par excellence*. Let us recall that for us empiricism is transcendent because, as Dominique Raynaud puts it so well in another context, "exploiting the idea that reality is not directly accessible" (Raynaud 2021, p. 419), empiricists deny either the existence or the possible knowledge of concrete objects, invoking the absence of *philosophical* or *metaphysical*, *logical* or *necessary* links (in the sense of philosophical logic) between our perceptions and the objects that produce them, which in turn implies that there would be a particular faculty to settle the question, whereas ordinary reflection is sufficient, and that if such links existed, they would be neither formal (in the sense of formal logic) nor material (in the sense of Bunge), which implies that they would be of a different nature and therefore transcendent.

various approaches produce a body of evidence to demonstrate the existence of a causal link.

The authors of the PinS study discovered the existence of thinkers with the title of philosopher, but who no longer practice philosophy, at least at times. The tools mentioned by these authors in the last quote above are quite standard ways of thinking, approaches and methods not only in the sciences, but in any rational enterprise, such as technology, engineering, medicine, law, management, etc. Thus, philosophy *in* science cannot exist because the third characteristic, the use of philosophical tools, does not apply to the articles selected by the authors. For this discipline to exist, it would be necessary to find articles that use exclusively philosophical tools or methods backed by philosophical doctrines to address scientific problems and propose solutions that scientists consider useful.

What seems true is that in philosophy of science, compared to any other field of philosophy, there are fewer thinkers who make use of modes of thinking that are alien to the standard ways of thinking of any normal rational activity (as opposed to philosophical rationality). In this case, if thinkers maintain a general discourse on the world and on science without this discourse being transcendent, without using non-standard tools or faculties, and without their goals being philosophical (according to the various philosophical doctrines), one wonders what remains of philosophy in such a discourse. Do these thinkers not rather practice a metascience, or even in some cases a science? Are they not closer to a Bungean approach to general discourse than to a philosophical one?

3] Conclusion

PinS thinkers are naturally part of a metascientific approach as we have identified it in Bunge[4]. Like the latter, these thinkers do not use any philosophical approaches or tools, methods and techniques specific to philosophical doctrines. They are content with the standard tools, methods and techniques used in the factual and formal sciences. This practice of *philosophy in science* distinguishes the latter from traditional philosophy of science, called *philosophy on science* by the authors of the study.

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[4] See our article "Metascience. For a Scientific General Discourse" published in the first issue of *Mɛtascience*, and our article "What is Metascientific Ontology", in this issue.

You can in principle take any philosophical doctrine and then talk about science. By the same token, you will use an approach, assumptions, tools, methods, and techniques specific to this doctrine. There is empiricist, positivist, rationalist, realist, antirealist, idealist, objectivist, subjectivist, analytical, continental, etc. philosophies of science. The doctrinal approach of traditional philosophy of science clashes with the non-doctrinal approach of philosophy *in* science. PinS thinkers, like Bunge, take the scientific approach for granted, at least in their scientific and metascientific texts. It is then difficult to argue, as the authors of the study do that PinS is a component of the philosophy of science since the various doctrines in philosophy of science tend to question the scientific approach because the latter is not adequately founded philosophically.

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Versions of Determinism

Joseph Agassi[1]

Abstract—Karl Popper's "Indeterminism in Quantum Physics and in Classical Physics" suffers unjust neglect. He judged determinism false: the future is open. In principle, replacing Laplace's variant of predetermination with predictable predetermination renders "scientific" determinism scientific and so refutable. Popper claimed that he had refuted it. Now a metaphysical system may have an extension—in the mathematical sense—that may render it explanatory and testable. If it exists, then it is not unique but has many alternative extensions. Popper's proof is then inconclusive.

Résumé—L'article de Karl Popper « Indeterminism in Quantum Physics and in Classical Physics » est tombé dans oubli injustement. Popper jugeait le déterminisme faux : l'avenir est ouvert. En principe, remplacer la variante de Laplace de la prédétermination par une prédétermination prévisible rend scientifique, et donc réfutable, le déterminisme « scientifique ». Popper a affirmé qu'il l'avait réfuté. Maintenant, un système métaphysique peut avoir une extension – au sens mathématique – qui le rend explicatif et testable. Si une extension existe, alors elle n'est pas unique, et de nombreuses autres extensions alternatives existent. La preuve de Popper n'est alors pas concluante.

Keywords—Laplace's Metaphysical Determinism, Popper, Determinisms, Indeterminism, Fault, Variant, Extension, Quantum Physics.

[1] **Jospeh Agassi**, Israeli philosopher, born 1927, editor of more than 10 books, author of more than 20 books and of over 600 papers in the learned press in diverse fields, chiefly in scientific philosophy and in politics. He studied with Karl Popper and taught at the London School of Economics. He then taught at University of Hong Kong, University of Illinois, University of Boston and York University in Canada. He had dual appointments in the last positions with Tel Aviv University. He believes that philosophy is nothing if not rationalist. For more than fifty years, he studied the rationality of science, metaphysics, and democratic politics. An advocate of Popper's philosophy with variations, Agassi ignores many of the problems that concern some philosophers of science, chiefly that of theory choice. The problems of the philosophy of technology engage him, including the problem of choosing scientific theories and ideas worthy of application and implementation.

1] An Outline

The attraction of determinism is in its avoidance of judgment. Heinrich Heine notes that Friedrich the Great had expelled Voltaire from his court for his view that soldiers do not deserve flogging, as they are mere automata. Popper responded to that story, saying, the monarch expelled Voltaire because he had no response to him, but there is a simple one: if they are automata, then I may flog them to my heart's content! The last word against determinism is that of Alfred Landé: it renders miraculous the possibility of any meaningful activity (like writing) since the laws of physics fully determine it and yet it also follows its rules (namely, grammar). This is overdetermination. The simplest example is from elementary algebra: values of n variables are fully determined by n independent equations; adding another independent equation makes it insoluble and the likelihood that the additional one will depend on the other is very slim.

2] Popper: *Indeterminism* and *Determinism*

Karl Popper's *Indeterminism in Quantum Physics and in Classical Physics* (Popper 1950, 1957, 1982, Agassi 1975) suffers unjust neglect. It discusses a variant of Laplace's determinism. Laplace offered a solution to a metaphysical problem: he wrote about probability that seems to clash with the determinism that he took for granted; is the clash real? The answer of Laplace is the subjective interpretation of the axioms of probability. All his life Popper argued against this interpretation and for a realist one.[2]

The preface to Laplace's *Philosophical Essay on Probability* of 1814 (Poincaré [1902] 1905) introduces an intellect—the literature refers to it as to "Laplace's demon"—armed with Newtonian mechanics, an image of the universe at any single moment, and an unlimited ability to compute. That intellect, Laplace declared, can

[2] Popper (Popper 1935, end of §27) declared that his methodology is open to both the subjectivist and the objectivist interpretation, and that his preference for the objectivist one is personal. In his preface to its 1959 English translation, he declared a change of mind: he viewed his position as objectivist and anti-subjectivist. The most challenging part of this reading was the chapter on probability. He made two great contributions here that he worked on for the rest of his life: he offered the first autonomous axiom system for probability, namely, a system that is open to all interpretations. Moreover, he developed the objectivist one, namely, his propensity interpretation of the axioms of probability.

know every past and every future event in the whole universe. This claim is Laplace's determinism; it is a version of "scientific" determinism. The discussion of determinism that followed the publication of his book centered on his version of it: obviously received opinion deemed it the best version. First, the versions of "scientific" determinism are all superior to religious fatalism — to the mere declaration that the future is predetermined — in that they appeal to science. Second, Laplace's determinism is a more detailed version of "scientific" determinism than that of Spinoza, as it appeals to a specific, highly corroborated scientific theory.

The first attack on the version of determinism of Laplace was mathematical; Henri Poincaré (Poincaré [1902] 1905) and Jacques Hadamard refuted some assumptions that Laplace had made about the power of mathematics. They refuted his assumption that in principle mathematics offers solutions to all the problems that it raises. Their just and historically very significant mathematical arguments are not relevant to this essay, that concedes the supposition of Laplace that in principle mathematics is complete—in order to examine the rest of his assumptions.

Popper judged determinism false: the future is open, he declared. His interest in determinism was to discredit it as much as he could, and mainly but not only for moral and political reasons: he viewed the thesis of historical inevitability a corollary to "scientific" determinism and he found it responsible for much political iniquity and moral irresponsibility.[3] He conceded that both the thesis of historical inevitability and "scientific" determinism are irrefutable and hence[4] possibly true. Replacing mere predetermination with a stronger claim, namely predictability in principle, and so of testability in principle, renders "scientific" determinism scientific and so refutable and then, Popper claimed, he had refuted it by the observation that already Henri Poincaré has made: it is impossible to

[3] Popper (Popper 1945, Ch. 13) rightly emphasized that it is possible to hold a metaphysical version of determinism and consider one's behavior as if determinism is false—as Spinoza did quite successfully and as Einstein did. Nevertheless, Popper also observed in that chapter, determinism did influence conduct, at least that of Karl Marx.

[4] Modal logic validates the inference from "*x* is irrefutable" to "*x* is possibly true". (Dummet 2011, p. 19) The verification principle denies meaning to the irrefutable and the possibly true. Its popularity at that time explains the neglect of Popper's discussion of determinism.

know our future predictions while keeping them in the future. Clearly, then, this observation of Poincaré (Poincaré [1902] 1905) proves inconsistent any Laplacian system that contains a predictor. It describes a universe containing a predictor able to predict every future event yet unable to predict at least one future event, namely, at least one item out of its own future behavior, namely, any future prediction of its own.

One might object to this line of thought: although you cannot predict your own future prediction, I can. This objection is easy to refute: a pair of predictors comprises a predictor, as is a community of predictors—since no limitation on the space that the predictor occupies is irrelevant here. True, when you and I try to predict the outcome of each other's prediction of each other prediction, the outcome is the same as any Popper-type short-circuit. J. W. N. Watkins (Watkins 1970) has adduced non-trivial and informative instances of Popper-type short-circuits, both in history and in game theory.[5] This sound too sophisticated; it seems we may exclude *ad hoc* self-prediction at least in the early stages of the discussion, as hardly possible anyway and so as scarcely relevant to the discussion of the impact of science on philosophy, and then ignore Popper's discussion. Not so: in his discussion of our inability to predict our own predictions Poincaré referred to our inability to predict the course of science; since science has tremendous and unforeseeable influence on our lives, no significant prediction of the human future is possible.[6] Yet, Popper admitted, determinism irrefutable. It is thus

[5] Cf. Watkins. Predictions that players make about each other's prediction about each other's conduct, refute the idea that full knowledge precludes risk (Watkins 1970, pp. 197-198). Extending this to the prisoners' dilemma refutes a basic assumption of some versions of traditional game theory (Watkins 1970, p. 206): it creates the situation—known from tense international borders—of an undesired Nash equilibrium of mutual distrust where the desired one is of mutual trust.

[6] Two examples. First, Marx used the fact that the efficiency of a steam engine increases with its size to predict the concentration of wealth due to competition, consequently the inability of the middle classes to compete with big capital, and thus their disappearance. Soon after he died, the new applicability of the electric dynamo and motor enabled the rise of the Edison Electric Company and its likes, and these enabled the creation of a new middle class of small entrepreneurs whose production depended on the available electric current. Second, Keynesian economic proposals prevented the allegedly ever-increasing misery due to economic crises that Marx deemed unstoppable, thus leading inexorably to the socialist revolution. Instead, this led to the rise of the welfare state that Marx had wrongly deemed impossible. It may be appropriate to mention science fiction here: Isaac Asimov's

possibly true. This situation he found disagreeable. There is one technique for handling such situations, already repeatedly illustrated in Plato's early dialogues: the disagreeable idea is too thin to be applicable; for this, it needs strengthening and its strengthened version is open to criticism. Popper undertook the task of enriching[7] Laplacian determinism so as to render it open to criticism and then to try to criticize it. The assumption that it is possible to perform this task raises the problem, then, as to whether other adequate extensions of the system are available. Still, let us first go over Popper's presentation of the situation. Popper's extension of the Laplacian system adds to it a Laplace-predictor, namely, the intellect of Laplace's initial description. Is this system, Popper asks, allowing the assumption of Laplace that our universe is determinist, is it still so after assuming that it contains predictors like you and me? (This addition of the Laplace-predictor to Laplace's system is the view that the intellect in his initial description of his system is an idealized version of Laplace himself.) The Laplace-predictor cannot perform every prediction, not the prediction that one Laplace-predictor should make about what another Laplace-predictor will predict. A Laplace-predictor thus cannot predict its own future prediction. This is a short circuit. To be able to prove his thesis, Popper replaced predetermination with predictability (within agreed limits of accuracy), which may be testable.

3] Popper's *Variant*

Popper claimed that his *variant* of the Laplace thesis is scientific, since it is inconsistent. This is an error: by his demarcation of science, a scientific system of statements must be:

Foundation (Asimov 1951) trilogy has its hero, Hari Seldon, made people in power forget his own prediction—to avoid defeating it.

[7] Diverse synonyms name enriching or increasing the content or the force of a system or extending it in the mathematical sense of the word. Popper notices in his *The Logic of Scientific Discovery* (Popper 1959, §15, Note *1), that the enrichment of a theory is self-understood. Incidentally, this he had to state since the reading of his book as a theory of scientific language—his protestation notwithstanding—renders highly problematic this rather intuitively admissible process. The extensions under discussion here are rather organic: otherwise, the mere conjunction of any two theories extends them. The reverse is also significant: of given variants of a given theory, Popper's methodology recommends the preference of the less informative but equally testable one (e.g., Mach's version of Newton's mechanics minus its assumption of the existence of absolute space).

(a) consistent

and

(b) inconsistent with at least one conceivable[8] observation report.

Hence, by Popper's own criterion of demarcation of science, his variant of the system of Laplace is unscientific. Hence, at most Popper has shown that "scientific" determinism is impossible; he has not refuted the metaphysical thesis extended to be scientific *à la* Popper, as he had not constructed one. (His extended version adds too much.)

A metaphysical system may have an extension — in the mathematical sense — that may render it explanatory and empirically testable. The paradigm case for this is the case of atomism, ancient and modern, as these are metaphysical and scientific respectively.[9] All sorts of writers[10] have taken for granted the ability to render metaphysics scientific, including those most hostile to metaphysics. Thus, when members of the Vienna Circle dismissed theology as meaningless on the ground that the Holy Name does not designate clearly, they explained that had it clearly and unequivocally designated, say, the column of fire that supposedly went before the Children of Israel in the desert (*Exodus*, 13:21-22), then they would consider assertions about the Divine false, not meaningless. The method of extension, however, is in great neglect. The characterization of metaphysics remained for long unstudied, although repeatedly some commentators took it for granted that metaphysics is a

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[8] The metaphysics of Parmenides is refutable, as already Antisthenes has claimed (by moving back and forth). Parmenides would not admit the refuting observation, and Zeno tried to prove him right on this. To meet this, Popper replaced the requirement for tests with the requirement of admissible ones: he allowed for the conventionalist's refusal to admit the possible refutation of a significant theory, and offered in opposition to it the convention to avoid the apologetic rescue of a theory. This convention will nullify Parmenides theory as scientific but not as a metaphysics. This is important since that theory led to the atomism whose importance is beyond contest. See Popper 1953.

[9] Admittedly, a theory can have metaphysical and scientific readings. Thales theory does, since water is decomposable and since Einstein has demolished the substance theory.

[10] The literature on this item is immense. It is all elaborations on Wittgenstein "[…] whenever someone else wanted to say something metaphysical, to demonstrate to him that he had failed to give a meaning to certain signs in his propositions". (Wittgenstein [1921] 1922, §6.53) For, they all took for granted his "what can be said at all can be said clearly, and what we cannot talk about we must pass over in silence" (Preface). This is a false assertion and an objectionable demand.

system of general suppositions for science, and thus a general outlook or a general framework or a worldview of sorts.[11] Ludwig Wittgenstein declared high-handedly that all efforts to state metaphysics in sufficiently clear statements are impossible. He thereby blocked all effort to characterize metaphysics.[12] Popper's early publications characterized scientific systems (not sentences); ignoring here logic and mathematics, as the status of these is uncontested, he advised disregarding all non-science, including systems of superstition, of religion, of metaphysics, and of pseudoscience, calling them all "metaphysical" even though they clearly differ from each other in many respects. He noted that metaphysical systems such as ancient atomism have heuristic value (Popper 1935, §4, §78, §85 and Appendices) but while insisting there on leaving aside all heuristic. After his famous clash with Wittgenstein, he discussed the problems that philosophy (metaphysics) comes to answer as rooted in scientific theories (Popper 1952). These problems appeared there as cosmological, namely, in search of a worldview, and in this study of his ancient atomism played a major role.

4] Popper's *Extension*

Some metaphysical systems may not be open to "natural" (see below) extension, much less to scientific ones. What is necessary for it? Popper has constructed one trivial extension of an obviously untestable system to a testable one: a system containing one purely existential statement—there exists a mermaid—may become testable by the addition to it of space-time specification—a mermaid is now present in the neighborhood aquarium. Rudolf Carnap has suggested that this cannot hold for statements with universal and existential quantifiers (as if this makes any difference for this example to be a refutation of his system). Watkins called these "all and some statements" and refuted Carnap's suggestion by an example. His example is, "everyone has a soul mate": it is untestable and a specification of it, "everyone is married to one's soul mate", that is a scientific extension of it, and that is refutable (and refuted). Now "every event has a cause" is metaphysical determinism; Popper's

[11] A metaphysics is of science in general and, by courtesy, of any specific science (Agassi 1977, Ch. 1, note 21).

[12] Nevertheless, Carnap characterized metaphysics as the confusion between language and metalanguage. Atomism refutes this proposal.

extension of it to "every event is predictable from its cause" is refutable. It is, but, by Popper's own magnificent theory of scientific character, to be scientific a theory must be both consistent and empirically refutable; yet, as he has claimed, his extension of determinism is inconsistent. Popper's *extension* of determinism by specifying decidability to predictability achieves its aim of making it unattractive. His view of it as scientific was a technical error. Still, this leaves open the question, is there a possible "natural" extension of determinism (not by rendering it predictable but) by adding to it another qualification that would enable it to depict some event as (erroneously) predictable? If there were such an extension, then there would be no reason to assume that it is unique. Moreover, the determinism could be subject to many alternative extensions. Then there would be no reason to assume that this holds only for determinism and not for any other metaphysics. Indeed, ancient atomism underwent extensions into diverse scientific theories–all of them refuted by now.[13]

Traditionally, metaphysics was not just the presuppositions for (some) science but also what claims some comprehensiveness in some intuitive sense of the word. Take the metaphysical system of Newton's *Principia*, namely, Euclid's space populated with point-masses interacting with central forces (namely, with forces that obey his famous three laws). It is metaphysical and it is untestable. Adding to it his law of gravity (or Coulomb's law of electricity) will yield a testable system *par excellence,* and this is an extension in the obvious sense of specification (of the laws). It is not necessarily an extension in the strict ("natural") sense of being comprehensive. The view, once quite popular, of it as possessing one and only one force (the idea that all forces are reducible to one) is comprehensive and so it is more "natural" an extension of the theory that renders it a metaphysics proper. Another possible extension of it would be a list of the forces governing the system of the world, plus the claim that the list is complete, namely that all known phenomena are in principle thus explicable. (An alternative is to list all the possible forms of energy; deciding that the list is complete makes the law of conservation of energy comprehensive and thus refutable, as

[13] To be precise, the initial version of atomism is not as thin as the enriched one. This, however, is understandable. We do not have the full ancient story; quite possibly Democritus distinguished between the thinnest version of his doctrine and the thickest version that he could (and intended to) generate.

Poincaré noted (Poincaré [1902] 1905, Ch. 5) he advised against this—to escape testability). Any scientific theory, such as Newtonian theory of gravitation that conforms to Newton's metaphysics, is a possible part of the "natural" extension of it. This proves that if Newton's metaphysics can undergo extension its extension is not unique, even if its "natural" extension may be. The claim that an extension need not be unique is commonsense. Hence, the onus of proof is on anyone who claims uniqueness. Hence, in principle, what extension is "natural" or comprehensive is unclear.

5] Conclusions

The fault with Popper's extension of Laplace's metaphysical determinism into scientific version is the tacit but very clear claim for uniqueness: Popper took it for granted that he had refuted all possible scientific versions of determinism. Now, supposing Newtonian metaphysics were extendable to a scientific system, and suppose, with Laplace, that all problems within it have unique solutions, then, clearly, each such extension is already both deterministic in Laplace's original sense, predictable in principles and scientific as refutable in principles.

To put it generally, when a metaphysics has a set of scientific theories that conform to it, and we add to that set the claim of completeness, then the metaphysics evolves into a scientific system (Agassi 1964). Here scientific character is considered a refutable explanation; if one wants refutability alone, then it is much easier to extend a metaphysics that has some scientific theory conforming to it: one can simply claim completeness anyway and have the completeness claim trivially refuted. Also, metaphysics is here taken in the traditional sense, not in the (much broader) Wittgenstein-style sense or Vienna Circle-style sense, in which "non-science" and "metaphysics" are synonyms. In this sense, determinism is not a metaphysics proper. It is nonetheless metaphysical, as it is a character in some metaphysical systems.

To put all this most generally, there is still no consensus about the traditional dispute within philosophy between intellectualism and empiricism, although most philosophers of science are empiricists. Historically, this was the verdict of Laplace: the scientific choice between the Cartesian and the Newtonian systems of the world was also the methodological choice between the intellectualists and the empiricists; and when Newton won, he won on both fronts. Nevertheless, the metaphysics of Descartes fascinated Laplace sufficiently to try a system of the world (with *fluide gravidique*) that should comply with both Descartes' and Newton's systems. He never tried his hand with the parallel system that should comply with both Descartes' and Newton's methodologies. The idea that a theory has both an empirical base and an *a priori* justification looks either encumbered with redundancy or a matter of course. For, logically, the idea of redundancy is that the redundant item follows from the rest. It is easy to see that neither intellectualism nor empiricism entails each other. At most, both justify the same system, yet not very likely. This would be a serious impediment for classical methodology that requires proof; not for Popper's system, as it requires openness to criticism. In this sense, Popper's extension of Laplace's "scientific" determinism is in line with his methodology, but this does not mean that his extension is the only one possible; hence, we have so far no refutation of all possible, reasonable versions of "scientific" determinism.

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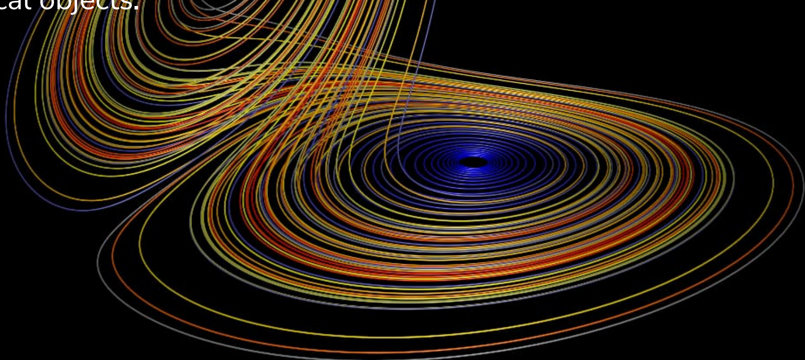
This second issue of the journal ***Mεtascience*** continues the characterization of this new branch of knowledge that is metascience. If it is new, it is not in a radical sense since Mario Bunge practiced it in an exemplary way, since logical positivists were accused of practicing only a mere metascience, since scientists have always practiced it implicitly, and since some philosophers no longer practice philosophy but rather metascience, but without characterizing it or theorizing it, that is, without realizing that they have abandoned one general discourse for another. The novelty therefore lies in this awareness that a general discourse without philosophy is possible: a scientific general discourse.

The twelve contributions gathered in this volume illustrate the metascientific approach to knowledge of the world as well as to knowledge of knowledge of the world, that is, science. And like Bunge's project, they are neither part of the analytical movement nor the continental movement in philosophy. We will read here studies about the Bungean system, some applications of Bungean thought, some metascientific contributions, and some reflections around metascience.

Among metascientific disciplines, ontology occupies a prominent place in this issue of ***Mεtascience***. Metascience differs from philosophy in its rejection of the fundamental philosophical distinction between appearance and reality. Metascientific ontology therefore does not postulate the existence of any metaphysical reality. But metascientific ontology, no more than philosophical ontology, is a factual science. The first, because it studies scientific constructs and not concrete objects, the second, because it is interested in transcendent or metaphysical objects.



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