# Chapter 2
# Systemic Materialism

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**Abstract** I present a condensed *exposé* of systemic materialism, a synthesis of materialism and systemism originally proposed by Mario Bunge. Matter is identified with mutability of propertied particulars, and a concrete or material system is defined as an object with composition, structure, mechanism, and environment. I review different aspects of this ontology, and discuss some of its implications for epistemology, ethics, and aesthetics. I also try to identify some problems of this view and offer some ways to overcome the difficulties. I conclude that systemic materialism is a promising philosophical project still in the making.

## 2.1 Introduction

Systemic materialism, also known as emergent materialism, is a collection of ontological views mainly developed by the Argentine-Canadian philosopher and physicist Mario Bunge (1919–2020). Bunge was trained as a physicist (his PhD thesis on the kinematics of the relativistic electron was supervised by Guido Beck, who was research assistant to Heisenberg in Leipzig). Very early in his career Bunge displayed a strong interest in philosophy and, in particular, ontology (Bunge 2016). In the 1950s he published papers on the concept of chance, philosophy of physics (especially quantum mechanics) and causality (e.g. Bunge 1951, 1959). By the early 1960s Bunge was a well-established philosopher. In that decade he published two seminal books: *Foundations of Physics* (Bunge 1967a) and *Scientific Research* (1967b).

*Foundations* was an in-depth analysis of all major theories of physics, where Bunge attempted to implement a rigorous axiomatization of the formalism of

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various theories in an attempt to clarify their interpretations. The second chapter of this book was a programatic research project of all major branches of philosophy, including philosophical semantics, ontology, and epistemology (see Romero 2019a for an assessment of the achievements of *Foundations of Physics*). Bunge's ambitious philosophical view was then fully developed along the next two decades in the 8-volume *Treatise on Basic Philosophy* (1974–1989). The third and fourth volumes of this monumental work were devoted to ontology and contain the most detailed exposition of his materialist metaphysics (Bunge 1977, 1979). These views were later expanded and refined in a series of important books (Bunge 1981, 2003a, 2006, 2010) and many papers (a full bibliography of Mario Bunge is given by Silberstein 2019; an almost complete catalog of his writings, including correspondence, can be found in Huerta Martín 2019).

Bunge's version of materialism is distinctive in several aspects. Perhaps the most noteworthy feature is his rejection of physicalism and his emphasis on the concept of emergence. Bunge considers that reality is organized in different levels, all of them material. Although he regards the physical level as the most basic one, the higher levels are populated by material systems endowed with peculiar properties (some of then not belonging to the physical substratum) that emerge from the interactions among the components of the systems and from the interactions between system and its environment. Bunge tries to formalize his theory of material systems along with the concepts of ontological composition, mechanism, emergence, and ontological levels in several of his books. Although Bunge sometimes talks of matter as some kind of substance and occasionally claimed to be monist, I will argue below that his views are consistent with a materialist pluralism. In this sense there are some similarities with the materialism of the Spanish philosopher (Bueno 1972; see also the chapter by Pérez Jara on discontinuous materialism in this volume). More clearly, Bunge's views are related to those of Roy Wood Sellars, who in the early twentieth century defended materialism and emergence, along with realism (Sellars 1969 [1922], 1970). Bunge's debts with Aristotle, Paul Henri Thiery (Baron d'Holbach), Karl Marx, and Hans Vaihinger are also important.[1] Bunge's inclination toward the use of formal tools in philosophy are mostly due to his fondness of the work of Hilbert, and his familiarity with some classical works of Beth (1964) and Martin (1958).

Another key feature of Bunge's ontology is that it is formulated as a hypothetic-deductive system. The hypotheses are informed by our best current scientific theories and are not intended as a part of a dogmatic system, but as provisional propositions that might be revised in the light of potential disagreements with science. The test for an ontological theory, according to Bunge, is internal coherence, agreement with scientific knowledge, and fertility for cognitive advances. Since

[1] Bunge rarely mentioned Vaihinger in his publications, although he was clear in private conversations with the author about the importance he gave to some ideas that Vaihinger expressed in his book *The Philosophy of 'As If'* (Vaihinger 1911), and the impact these ideas had on his views on the nature of mathematics.

scientific knowledge is movable, so it should be the ontology. Actually, as I will show in this paper, some of Bunge's views should be adjusted to follow recent developments in gravitational physics and research in quantum gravity.

Bunge himself was prone to introduce changes to keep the pace of scientific advance. As a trained research scientist and an indefatigable reader of scientific journals, he was well-equipped for the task. As time went by, however, it was the task of other philosophers to explore the implications of his ontology and to make changes and adjustments. In the last few years, many papers and books have expanded Bunge's ontological views in new directions (e.g. Marquis 2011; Romero 2018a; Wang 2011, and the many papers included in Weingartner and Dorn 1990 and Matthews 2019).

In this chapter I will try to present the basics of systemic materialism to the general reader. I will offer definitions of the main concepts, I will try to show how this ontology is articulated into a coherent system, and I will try to illustrate how some traditional problems are dealt with in this worldview. I will discuss how, in my view, some positions defended by Bunge should be adjusted in the face of criticisms and new scientific developments. From the beginning I waive any claims to completeness. By the end, nevertheless, I hope to have conveyed the idea that materialism remains as a very powerful and down-to-earth ontology.[2]

## 2.2 The Concept of Matter

Basic research shows that the universe is populated by a huge number of particular entities. These entities cannot just be, without further qualification; they must be one way or other. These ways of being are called 'properties'. Basic entities, entities that are not formed by anything else, are called 'substances'.[3] Substances are mereologically simples. Substances and properties are complementary in the sense that there are not unpropertied substances or orphan properties. What actually exists are always some substances that are in one way or another. Substances are not bearers of properties, or bundles of properties, or can fail to be propertied. Properties, on the other hand, are not parts of substances; they are just the way substances manifest. Substances and properties cannot be separated except by a conceptual operation of abstraction: they are complementary categories of being (Heil 2012).

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[2] I will not necessarily follow Bunge's nomenclature. What I am presenting is not a transcription of Bunge's views, but rather a simplified and updated version of systemic materialism. If the reader wants to compare my presentation with Bunge's own views, I recommend to go to his *Treatise* (Bunge 1977, 1979) and his books *Scientific Materialism* and *Mind and Matter* (Bunge 1981 and 2010, respectively).

[3] Bunge uses the term 'individual', but since individuals can be conceptual or abstract as well, I prefer to use the traditional word 'substance' to designate basic, non-reducible stuff, following Heil (2012).

Properties should not be confused with predicates. Predicates are conceptual tools we use to represent properties when we talk about the world. Nor should properties be conceived as universals that are shared by some particulars. Rather, they are the specific *modes* particulars are.

All substances are simple: they have no parts. However, substances can combine to form more complex entities. We call these entities *things*. Examples of things are planets, chairs, human beings, books, galaxies, and rocks. Substances themselves can be defined as basic or elementary things. Although there are no complex substances, things can be very complex. Things with parts are called *systems*, and I will discuss them in more detail below. For now suffice to say that systems also have properties. Some of these properties are inherited from the composing substances and some others are specific of the system. These specific properties arise by a process called *emergence* (see Sect. 2.5).

Any system has properties. The collection of these properties conforms the *state* of the system and this state can *change*. A change can be construe as a displacement in a *space of states*. Usually, a state space has many dimensions, one per property. If we quantify the properties, for instance representing them by mathematical functions, then the evolution of the thing will be represented by a trajectory in a functional space that represents the state space. At this point we can introduce a definition of matter in the following way.

**Definition 1** Let be $x$ a thing (either basic or complex), $y$ some other thing considered as a reference frame, and $S_y(x)$ the state space of $x$ with respect to $y$. Then, $x$ is material if, and only if, $S_y(x)$ contains more than one element.

More briefly, if $Mx$ means '$x$ is material', then

$$Mx \stackrel{\text{def}}{=} \exists y\ (|S_y(x)| \geq 2). \tag{2.1}$$

Some comments are in order. Material simple things do not exist in absolute isolation, because otherwise there would be no reference frame with respect to which the thing might change. In the absence of another thing, even intrinsic changes are meaningful only if the thing has parts, i.e. if it is not simple. It might be objected that a simple thing, for instance a muon, might exist in isolation and then decay producing changes. However, the changes are determined with respect to the decay products. In four dimensions, there are 4, not just 1 basic thing. The decay chain of the muon is $\mu \rightarrow e^- + \nu_\mu + \bar{\nu}_{e^+}$. The products on the right side are an electron, a muon neutrino, and anti-electron neutrino. In the state space the decay occupies more than a single point.

Another relevant comment is that change always requires energy. Energy is the most universal property of things: it is the ability to change, i.e. to do work. Hence, Bunge offers an alternative definition of material thing in the following way (Bunge 2003b):

**Definition 2** $Mx \stackrel{\text{def}}{=} E(x)$,
where $E(x)$ means '$x$ has energy $E$'.

I note that (1) Energy is a property, not a thing. Hence, there is no 'pure energy'. Energy is always associated with some thing. (2) To have zero energy is not the same as having no energy. Having no energy amounts to non-existence as a material being.[4] But a given material system, the universe for instance, can have equal amounts of positive and negative energy so the total sum can be zero. (3) Although all objects with mass have energy and then they are material, the converse is not true: there are massless material things. The famous formula derived by Einstein that relates mass and energy for a system at rest, $E = mc^2$, is just a special case of a more general energy-momentum relation $E^2 = (mc^2)^2 + (cp)^2$. For massless particles such as photons, the energy is $E = cp$, where $p$ is the momentum and $c$ is the speed of light.

I can offer an objection to this second definition provided by Bunge. Although change always requires energy, and then it is correct to say that all material things have energy, it is not true that energy always allows for change. If a complex system is in thermodynamic equilibrium, i.e. if its entropy is at a maximum, then the system will not change. This is because it is not the total energy what matters for change, but the difference of energy between different parts of the system. This difference is quantified by entropy. Bunge's definition, I think, only applies to simple things, substances, and not to systems. In general, energy does not amount to mutability, which is the true trademark of materiality. Hence I will adopt in what follows the first definition of material thing: any substance, system, or aggregate with a non-trivial state space.

A final remark about these definitions is that they do not involve the concept of time. Change is determined just by motion is the state space. This space can be parametrized in terms of time or other dimensions. Our definition is completely general.

We are now in position to define the concept of *matter*.

**Definition 3** Matter ($\mathcal{M}$) is the set of all material things.

Symbolically,

$$\mathcal{M} \stackrel{\text{def}}{=} \{x : Mx\}. \tag{2.2}$$

Matter, then, is not a substance but a concept: an abstraction from concrete material things. What actually exists are material beings, not matter. Matter, in words of Bunge, is not material. It is conceptual (Bunge 1981).

If matter is not a substance, how many substances are there? The answer is simply as many as basic things. The actual number and nature of these things should be determined by science, not by ontology. This is the 'Primacy of Physics' constraint advocated by Ladyman and Ross (2007). Physical research of the elemental

[4] A non-material being can be said to exist *conceptually*, if it is conveniently introduced by stipulations formulated in some conceptual framework developed by material beings. See below, Sect. 2.9.

constituents of the world would offer provisional answers to this question. I will say more on this towards the end of this paper.

Before formulating the central thesis of materialism, it is convenient to introduce the associated concept of *reality*.

**Definition 4** An object[5] $x$ is *real* if, and only if, (a) there is at least another object $y$ whose states would be different if $x$ were absent, or (b) some parts of $x$ induce changes in some other parts of $x$.

This is the definition of real object proposed by Bunge (1981). It relies on the idea that whatever is real is something that can be acted upon or can affect other things. We now define *reality* as:

**Definition 5** Reality is the set of all real objects.

Again, as it was the case with matter, reality is a concept, and hence it is not real. What is real is the *universe*, i.e. the *system* formed by all real objects. Being a system, the universe, has many emergent properties such as temperature, density, and expansion rate, among others. Reality, instead, do not have properties, although we may assign attributes to the concept in our speech, as when we say: 'a sad reality'.

We are now ready to state the central thesis of materialism:

**Postulate 1** Only material objects are real.

An immediate corollary is that the universe is material.

A consequence of *Postulate 1* is that for materialism changeless objects such as numbers, functions, triangles, God, relations, and fictional characters are not real (see Romero 2018a and my discussion with C. Madrid in this volume for the status of fictions and mathematical objects).

**Postulate 1** is shared by all forms of materialism. We need now to introduce some additional qualifications to fully characterize *systemic materialism*. Before moving on, I offer a chart in Fig. 2.1 with a summary of the proposed classification of objects.

## 2.3 Laws

In the definitions offered in the previous section, change, the ability of a thing to go from one state to another, plays a fundamental role in the characterization of the concept of matter. Change, however, is not arbitrary. Change follows patterns, as already noticed by the first pre-Socratic philosophers (see Chap. 1 of this book). Such regularities can be represented as restrictions upon the state space of real objects. Since we represent the properties by mathematical functions, then the

[5] An object is anything we can refer to.

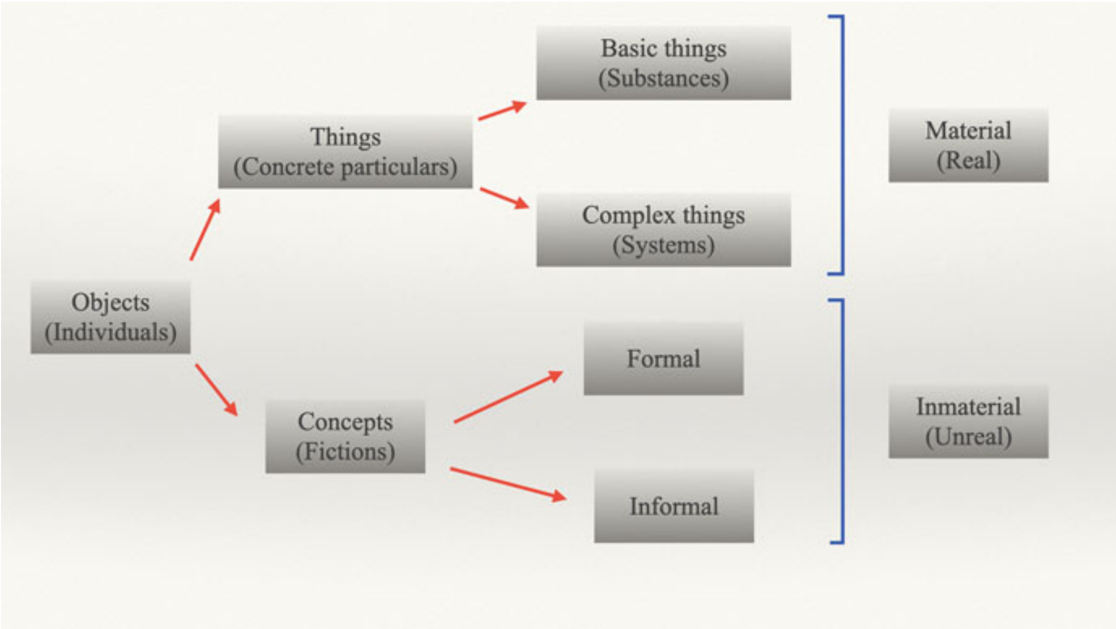


**Fig. 2.1** Classification of objects according to systemic materialism. Basic things have fundamental properties. Systems have emergent properties. Concepts have attributes, assigned either formally, i.e. through a formal system, or informally (e.g. through a narrative). See Romero (2018a, Chapter 7) for details

restrictions are usually represented by differential equations (occasionally, integro-differential or algebraic equations can be used). In order to solve an equation and find the trajectory (succession of changes) experienced by a particular thing in a specific situation, we need to characterize that situation through the specification of initial and boundary conditions.

It is important to emphasize the difference between the universal, stable, and objective patterns occurring in the universe, i.e. *the fundamental laws*, and the representation of such laws by equations, i.e. from the *law statements*. This is similar to the distinction between property and predicate. The predicate represents the property in our conceptual network. Law statements represent the natural laws in our theories. A consequence is that law statements, being just conceptualizations, can be tested, corrected, ruled out, or improved. Such modifications are a key ingredient in the dynamics of science (e.g. Bunge 1967b).

In addition to fundamental laws, i.e. the laws followed by basic things or substances, we can introduce *derivative laws*[6] that follow from the regular behavior of complex things and systems. Most law statements in our theories represent laws of this kind. They are not strictly universal, but stuff-dependent. They apply to some particular kind of things and cannot be expressed using unrestricted logical quantifications. Examples of fundamental laws are the laws of gravitation, basic

[6] Bunge called them *constitutive laws*, because they depend on the nature or constitution of the system to which they apply.

conservations laws, or the laws of the basic fields of the standard model, whereas examples of derivative laws are laws of elastic bodies, laws of plasma physics, most laws of chemistry, etc.

A third type of law is given by the regular patterns shown by laws themselves. These patterns conform laws of laws or *meta-laws*. These meta-laws are represented by *meta-nomological statements* such as the principle of general covariance or the principle of minimal action (Bunge 1967a).

Finally, Bunge also introduces what he calls *nomo-pragmatic statements* (Bunge 2003b). These are pragmatic statements obtained from one or more laws of the first two types and a specific situation. Examples are law statements for electric circuits and most laws applied in social sciences.

Since all material systems change according to laws, we can refine **Definition 1** to:

**Definition 1'** Let be $x$ a thing (either basic or complex), $y$ some other thing considered as a reference frame, and $S_y^{\mathrm{L}}(x)$ the *lawful* state space of $x$ with respect to $y$. Then, $x$ is material if, and only if, $S_y^{\mathrm{L}}(x)$ contains more than one element.

Material things only change lawfully. From **Definition 1'** and **Postulate 1**, it follows trivially:

***Theorem*** *Magical (i.e. unlawful) events are not real.*

What is the origin of the fundamental laws? Why the universe displays regular patterns of change? Traditionally, there are two kinds of attempts at explaining the existence of laws. On the one hand we have the *externalists* conception of laws. According to this view, laws are some kind of entities in the universe existing in addition to material things. If properties are conceived as universals, then laws would be second-order universals that relate them (e.g. Armstrong 1983). Externalists, crudely expressed, think of laws as governing the behavior of things.

On the other hand we have the *internalist* view which tries to explain lawful changes without resorting to anything above the individual things that populate the universe. Perhaps the more popular internalist view considers laws linguistic items adopted to systematize our experience of nature (e.g. Cartwright 1989). Bunge himself never expressed conclusively his position about the topic, to my knowledge at least. But it is clear that an externalist conception of laws is incompatible with the kind of materialism he espoused.

I think that the kind of internalist position that suits better to materialism is one where the laws are understood, as we have already mentioned, as restrictions imposed on the state space of the individual things. But if we adopt such a view, we should also ask what imposes the restrictions? The only possible answer in the context of materialism is that the restrictions are imposed by the material things themselves. To be something necessary implies to be in some way. If something is in some way, i.e. if something has some properties, the very existence of these properties restricts other possibilities of being for other entities.

If we think that properties plus some external conditions are *powers*, i.e. sources of change and action, then it is natural to think that out of all powers in the world some equilibrium will be achieved.[7] The patterns that define such equilibrium are what we call fundamental laws. If the properties and conditions were different, different laws would result. Actually, it might be the case that some laws could evolve as the universe develops. Although current observations impose some strong limits to the variation of fundamental constants and laws, there is some room for evolution on very long scales (Uzan 2003). I, then, complement the **Definition 1'** with the following proposal:

**Proposal** Lawfulness is the result of the mutual equilibrium of all the powers in the universe.

Here, a power is defined as:

**Definition 6** A power is an active (i.e. capable of changing) property in a material thing that, under the right environmental conditions, can trigger changes in other things.

## 2.4 Systems

In the previous sections I have referred to systems, loosely defining them as 'complex things' or 'things formed by substances'. Given the importance of the concept of system for systemic materialism, it is time now to introduce it more properly.

**Definition 7** A system is a complex object every part or component of which is related to at least one another component.

If the components are material, the object in question will be a material system. Examples: living organisms, atoms and molecules, books, hospitals, galaxies, the universe. If the components are formal concepts, the system will be conceptual, as a theory.

Given our definitions of systems and real objects, the following theorem is immediate:

***Theorem*** *A system is real if, and only if, it is composed exclusively by real parts.*

This means that conceptual systems such as models and theories, no matter how complicated or exact they may be, are not real: they are fictions. What is real are the creators of such models and theories as well as the media we use to formulate, transmit and teach them, from inscriptions in paper to electronic devises.

Now, we can state the basic specific assumption of *systemic* materialism (Bunge 1981):

**Postulate 2** Every material object is either a system or a part of a system.

[7] For a discussion on powers see Harré (1970).

This postulate implies that there are not completely isolated things. If something is material, it should interact with at least something else. If something is material, another material thing must be able to affect it.

Any system is characterized by its *composition*, *environment*, *structure*, and *mechanism*.

The composition of a system is the collection of its parts. These parts can be other systems, as for instance cells in a living organism, or basic things (substances), as perhaps quarks in a proton.

The environment of the system is the collection of things that interact with the system. Everything, but the universe, is located in some environment. The *boundary* of the system is the collection of parts that are in direct interaction with the environment. Because of the complexity of some systems and their surroundings, boundaries can be very fuzzy at times. Even particles in the intergalactic medium are exposed to interactions with photons from the Cosmic Microwave Background radiation and the effects of the curvature of spacetime and hence they are not completely isolated.

The structure is the collection of relations (bounds or links) among the components of the system, as well as with the environmental objects. The former is the endostructure, the latter the exostructure. The total structure is the union of the two. Only substances lack of structure. If a collection of objects do not interact, if they are not linked somehow, then they do not form a system: they are just a set, and sets are conceptual objects, not material ones.

Finally, the mechanism is the collection of all internal processes that occur in the system. A process is just a lawful succession of changes. Mechanisms are what make the system to behave in the particular way it does. For instance, thermonuclear reactions form part of the complex mechanisms that allow a star to be in approximate equilibrium and emit radiation. Potential discharges caused by concentrations of neurotransmitters are part of the mechanisms that allow neural networks to perform their specific functions.

A *subsystem* is a system such that its composition and structure are part of another system. Example: the neural system is a subsystem of the human body, the Earth is a subsystem of the Solar System, and so on.

The maximal system is the universe, i.e. the system of all subsystems. As I already mentioned, the universe should not be confused with the *set* of all material things. In particular, I remark that there is no maximal set. This is not valid for systems, which admit a system of all systems. The universe has a composition (all real things), it has an empty environment (it is the only system with null environment), it has a structure determined by all the interactions among material systems, and its mechanisms are the totality of processes. Among the emergent properties of the universe as a system we can mention its density, temperature, expansion rate, baryon content, dimensionality, topology, and metric structure.

Nowadays, speculations about multiverses are popular both in the press and in some technical literature. If such universes are thought as non-interacting, then for systemic materialism they are not considered real. There is no way to establish their existence. Instead, if ‘other universes’ have some kind of manifestation or interaction with 'our universe', then they are not other universes at all but parts of a more complex universe than previously thought.

We can model any given system $x$ by an ordered quadruple in the following way:

$$\mu(x) = \langle C(x),\ E(x),\ S(x),\ M(x)\rangle\,, \tag{2.3}$$

where the components are sets that represent each one of the four collections that characterize the system.

The system can change because it changes its composition, or because of interactions with the environment. It can change because new internal links are formed or old ones are destroyed or decay, and it also changes because of the manifold processes that occur in it. Every system, except the universe, interact with other systems in some respects and is isolated from other systems in other aspects. The finite speed of the propagation of interactions actually introduces a network of internal constraints to the universe, making impossible for everything to be in interaction with everything else.

Conceptual systems, contrary to material ones, do not change. Their composition is fixed (e.g. the number of axioms in a theory), the environment is just given by other theories within a larger conceptual context, the structure is also fixed given by the internal formal relations, and there are not mechanisms operating because mechanisms are purely material since they require processes. When we talk of the "evolution of a concept", the "dynamics of a theory", and the like, we are using figures of speech. What evolves actually is our attitude toward some concepts, theories, etc.

One of the most important implications of systemism is that there are emergent properties, i.e. properties of the system that are not properties of its parts. I will discuss this issue next.

## 2.5 Emergence

Systems, as substances, must be some way or other, i.e. they have properties. A star, for instance, has temperature, pressure, and luminosity, among many other properties. These properties are called *emergent* because the basic components of the star lack them. Other properties can be present in both the basic components and the systems. Energy, for instance, is one of them. Mass is another. We can define an emergent property as:

**Definition 8** Let $x$ be a system with a composition $C(x) = \{y_1,\ y_2,\ y_3,\ \ldots\ y_n\}$ and let $P$ be a property of $x$. Then, $P$ is an emergent property if there is no member of $C(x)$ such that it is the case that $Py_i$, $(i = 1, \ldots, n)$.

Formally,

$$P \text{ is an emerging property} \stackrel{\text{def}}{=} \exists x(y)(Px \wedge y \in C(x) \Rightarrow \neg Py). \tag{2.4}$$

Emergent properties are present everywhere: atoms and molecules form cells, but the former are not alive while cells are. Molecules are not elastic but strings formed by huge numbers of molecules might be elastic. A single atom has not entropy, but an atomic gas has measurable entropy; some animals can walk, although cells and tissues formed by cells cannot, and so on.

Emergence should not be confused with *supervenience*, which is a weaker, although related concept. Supervenience is the dependence of one set of properties on another. It is used, for instance, to state that a given set of mental characteristics are supervenient upon physical or biological properties. Emergence, instead, requires the occurrence of qualitative novelty: systems in general are not similar to their parts (fractal systems are the exception, not the rule). Bounds and interactions among components produce effects that are not present in mere agglomerations of elements. This is because systems, conversely to aggregates, have a structure and mechanisms resulting in new properties and powers (see Mahner and Bunge 1997 for more on the differences between emergence and supervenience).

Emergent properties can be local, as an acute pain in my knee, or global as the overall equilibrium of my body. Scientific research of systems of any kind tries to explain emergent properties and the associated behavior in terms of internal interactions among parts of the system and external influences of the environment. For instance, our knowledge of the internal structure and composition of atoms allows us to understand and explain why some elements are more stable than others.

Things with emergent properties are also emergent, i.e. they do not exist at a more basic ontological level. Molecules or cells are not found in the sub-atomic level of quarks and gluons. Galaxies do not exist at the level of stellar objects, and so on. Emergent things can lose properties with the weakening of their internal bonds and through interactions with the environment. Such process can lead to the disappearance of properties and, finally, to the *extinction* of the emergent thing and its dissolution into the constituent parts or in surviving subsystems. In such a case there is a level reduction and a destruction of complexity. The most dramatic example of this is perhaps the extinction of the mental faculties as the brain deteriorates in humans and other evolved animals.

The emergence and extinction of things is mostly an evolutionary process: a series of changes where some properties are acquired and others are lost. Bunge (2003a) proposes the following postulate:

**Postulate 3** The evolutionary process of a thing is always associated with the emergence of some properties and the extinction of others.

I notice that emergence and assembly of new systems can be understood as a decrease in the dimensionality of the state space of the corresponding agglomeration of components. A gas, for instance, has a smaller state space than the myriad of particles from which it emerges. Similarly, extinction involves the recovery of the state space of the free components: the links are destroyed along with the structure that gives identity to the emergent system.

One important consequence of emergence is the already mentioned formation of *levels* of organization in nature. A level is not a thing or a system, but a collection of them, namely the collection of all things that have certain properties in common. Levels of organization can be defined with respect to a set of properties. The more complex is the composition and the structure of the systems in a given level, the higher is the level in the evolutionary process.

**Definition 9** Let $A = \{P_i\}$ be a set of properties that are specific of certain things $x$. Then, $L_A = \{x : P_i x\}$ is the ontological level formed by things $x$ with respect to the set of properties $A$.

**Postulate 4** The set of all levels forms an ordered structure $\mathcal{L} = \langle \mathcal{L}, <\rangle$, where the relation $<$ is such that for any level $L_i$, $L_i < L_{i+1} \overset{\text{def}}{=} (x)(x \in L_i \Rightarrow C(x) \subset L_i)$, where $C(x)$ is the composition of $x$.

We also postulate:

**Postulate 5** The systems on every level have emerged in the course of some process of assembly of things from lower levels.

Bunge (1979, 2003a) differentiates five great levels of organization: physical, chemical, biological, social, and technical (see also Blitz 1992). Each level is populated by entities with some properties that are specific of that level alone. For instance, chemical stuff undergoes specific reactions and processes not showed by purely physical systems, biological organisms have a number of novel functions not observed in chemical substances, societies and biological populations exhibit very distinctive patterns of behavior, and machines have some properties that are not present in the preceding levels.

All this, of course, is just a tentative classification. Disagreement is possible about some levels, and the issue should be solved by investigation of the way the world is actually organized.

Notice that not all properties are emergent in each level: some properties such as energy, mass, etc., go up through the whole scale and can be found in every level. And also some properties disappear when complexity increases; for instance, societies are not alive, although they are composed in part by living beings.

The composition of things in a given level is formed by items of the previous levels in the hierarchy of systems. Only at the very bottom of the scale we have basic things (substances).[8] And of course many sub-levels can be proposed to refine our view of the organization of nature and the emergence of complexity. Each sub-level should be specified with respect to a well defined set of properties.

Emergence is of paramount importance to systemic materialism because it avoids the collapse of this kind of materialism to mere physicalism. For the physicalist,

[8] Someone might disagree with this statement, since future research might indicate other possibilities. I will say something about this in Sect. 2.8.

only the basic substances of fundamental physics have true properties. All the other things we observe in the world, from apples to galaxies, are actually "particular dynamic configurations of substances" (Heil 2012). According to this view, there are not emergent properties because such properties should be properties of emergent substances, and a substance, being mereologically simple, cannot emerge. When we say that an apple is juicy, say, we are attributing a property just by courtesy, a pseudo-property. What we really mean is that there is a complex dynamic arrange of substances and what we call a property of the apple is just the name we give to the effect of the constituent substances upon us. Heil illustrates his point with figures similar to the ones in the left and central drawings of my Fig. 2.2. There, we see an aggregate of substances, $x1$, $x2$, $x3$, and $x4$ each one with a specific property $P1$, $P2$, etc. Imagine that such a configuration of substances is what we call an object O. And let us suppose that we want to attribute to this object a new property P(Emergent). The argument goes that there is nothing to attach this property to since it is not a property of the basic substances. And only substances have properties. The conclusion seems to be that there is not, actually, such a new property. The presumed emergent property is just a name for the complex effects of the basic properties that the vast arrangements of substances have.

I think that the flaw with this argument is that it neglects the links and interactions among the basic things that form the object. The object is not a mere aggregate. It is a system and emergent properties are properties of emergent things. Emergent things are not substances, but are formed by them. However, systems cannot be simply reduced to their parts because interactions and internal processes are as important as composition to determine their functions and properties, i.e. their ways of being.

This is illustrated in the right drawing of Fig. 2.2, where I show, symbolically, the internal bonds of the system. The emergent property is a property of the system and the system is more than its parts. The system has qualitative novelty and hence it has its own ways of being: it has emergent properties.

Summing up: substances have basic properties, and composed things have emergent properties. Because emergent things are more than mere aggregates, they have their own ways of being, i.e. we can attach properties to them.

Because of these reasons systemic materialism should not be confused with a form of physicalism. A consistent systemic materialist does not think that everything is reducible to physics. The basic substances of physics (fields, say) may well be the ontological foundation on which the whole building of beings is supported, but as complexity increases, more mechanisms and links are established among parts and the resulting systems acquire new ways of being, i.e. emergent properties, that cannot be found in the purely physical world. Chemical reactions, biological functions such as digestion or vision, intensional behavior, and abstract thinking are not proper of the physical level albeit they are impossible without it. These specific properties (functions) are acquired by material systems through evolutionary processes.

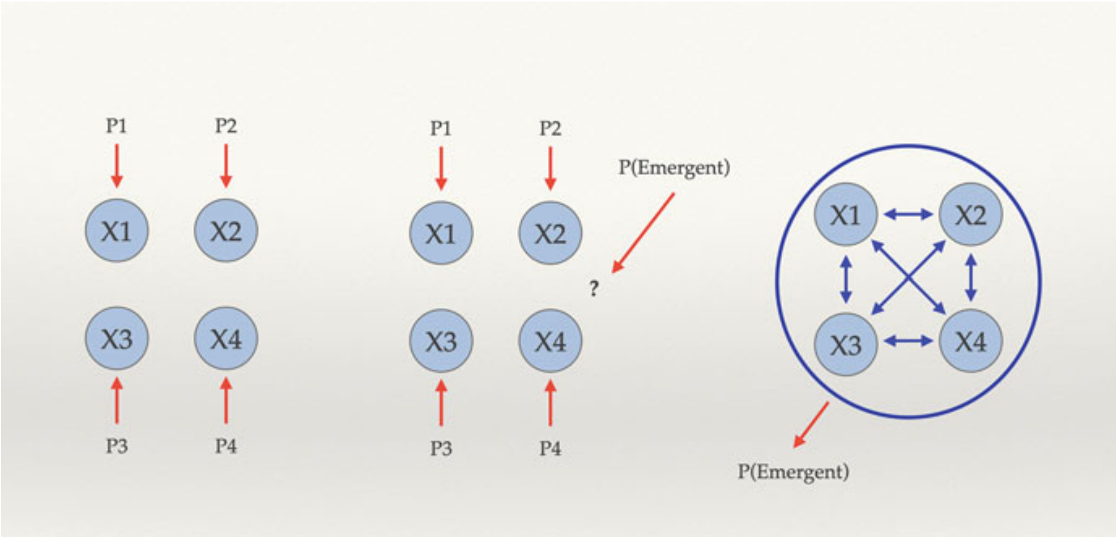


**Fig. 2.2** This sketch illustrates the difference between mere aggregates and systems with emergent properties. On the left, we have 4 basic things with 4 properties. In the middle, I illustrate the failed attempt to ascribe a property to the aggregate. Since the latter is nothing else than its components, there is no entity to which we can assign the new property. In the right, I represent not an aggregate but a system, with links among the different components, a structure, and an environment from which it is separated by a boundary. Now the new property can be ascribed to the system

## 2.6 Mind

Many current discussions on materialism in the philosophical literature revolve around the nature of the mind. Sometimes even materialism is defined negatively as the view that there are not mental substances. In the case of systemic materialism, the mind-body problem is an important one, but hardly the central issue. The view that what we call *mind* is a collection of functions of the brain arises naturally from the ontological framework I have outlined above when it is nurtured with the insights of biology and, in particular, neurosciences (Sellars 1969 [1922], Chapter XIV; Hebb 1949; Smart 1963). Bunge himself has devoted several books to the topic (Bunge 1979, 1980, 2010), some of them in his polemic partisan style. Because of that, and since the issue is discussed at length in other parts of this book, I will limit myself to offering some definitions with the purpose of just framing the problem. These definitions, conversely to those given by Bunge in the mentioned texts, are general enough as to make room for artificial mental activity (artificial intelligence, AI).[9]

**Definition 10** A complex material system is *plastic* if, and only if, being part of a larger system, it is able to change its structure with time in response to external stimuli and spontaneous internal activity.

[9] Bunge notoriously opposed to the possibility of AI, e.g. Bunge (1956, 2010). I do not share his views. This is not the place, however, to discuss the issue.

Science shows that the neuronal systems of some animals (including humans) contain subsystems that are plastic.

**Definition 11** A plastic system learns when new and stable internal links are formed as result of activity and interaction with external stimuli.

**Postulate 6** Some plastic material systems capable of learning have plastic subsystems that can monitor, register, and cause some specific activities (functions) performed by the entire system.

The human brain seems to be capable of such activity. Also, the brains of some apes, dolphins, and elephants might be able to perform such tasks.

**Definition 12** A *conscious* being is a material being self-aware of its existence, its environments, and some process occurring in it.

**Definition 13** A *mental* process is any process occurring in a plastic sub-system of a conscious being.[10]

The basic postulate of systemic materialism (and many other forms of materialism as well) regarding the philosophy of the mind is:

**Postulate 7** For every mental process $M$ in a conscious being, there is a process $N$ in a plastic material system of the same being, such that $N = M$.

In other words, materialism postulates that all mental process are actually processes occurring to a certain class of material systems. There are not mental or spiritual substances.

Several corollaries follow trivially. These are a few examples:

**Corollary 1** *Mental disorders are disorders of plastic material systems.*

**Corollary 2** *Mental activity disappears with the destruction of the plastic material systems where it takes place.*

**Corollary 3** *The mind is not an entity. It is a collections of processes and specific functions of a material system.*

## 2.7 Spacetime

The nature of space and time has always troubled materialistic-oriented philosophers. The early Greeks notoriously differed in their views of space and time. In the Middle Ages the discussion continued along the paths already delineated by Aristotle and Plato. Only after the scientific revolution the discussion started to be informed by physical science, from the Leibniz-Clarke correspondence onwards.

[10] Non-conscious beings with plastic sub-systems can also experience psychic activity, related to perception and other biological functions. Also notice that mental activity in conscious beings can go unaware, i.e. it can be unconscious.

This is not the place to retell the history of the concepts of space and time, a task that has been admirably accomplished by Jammer (1983) and Sorabji (1983). Here it is enough to note that Bunge, as well as Sellars, were strongly influenced by the Leibniz-Machian relationist positions, espoused also by Einstein in his early works.[11]

In the volume 3 of his *Treatise*, Bunge (1977) presents what he thought was a consistent relational theory of physical space compatible with systemic materialism. He tried to construct space and time *á la* Leibniz from the interactions of material systems. However, his theory only achieved a partial success: space and time remained separated and Euclidean. In 1998, Perez-Bergliaffa, Romero and Vucetich (1998) generalized the approach to recover a pseudo-Euclidean spacetime (Minkowskian). Subsequent efforts to extend the work to encompass pseudo-Riemannian spacetimes failed. Such a series of failures made me to embark into a research of problems associated with the energy content of curved spacetime and issues related to gravitational waves and quantum field theory in curved spacetimes. Such a research convinced me that spacetime is material. Some arguments can be found in Romero (2012, 2013a, 2015, 2017, 2018a, and 2018b).

With the detection of gravitational waves in 2015, Bunge himself started to change his mind about spacetime, and published a short article (Bunge 2018) arguing for the substantival character of spacetime. However, as I showed in a companion paper (Romero 2018b) some of his reasonings were defective, because he still conceived spacetime as a metric field. This led him to some misunderstandings in the interpretation of the problem of a gravitating shell in general relativity.

Here I will summarize some of the arguments for the materiality of spacetime (more arguments can be found in Combi's chapter in this book and in Romero 2018a). The argument presented by Bunge (2018) can be cast in the following terms (Romero 2018b):

P1. Gravitational waves activate detectors.
P2. Detectors react only to specific material stimuli.
P3. Gravitational waves have been experimentally detected.

Hence, gravitational waves are material.

P01. Gravitational waves are ripples in spacetime.
P02. Gravitational waves are material (first argument).

Hence, spacetime is material.

The argument is, I think, valid. P1–P3 are well-proven premises from experimental physics. Some confusion, however, can arise because of the somewhat vague form of P01. Gravitational waves actually are perturbations in the *curvature* of

[11] Einstein abandoned these views after discussions with de Sitter and Lorentz around 1917. By 1921 Einstein was a convinced realist (what we call today a substantivalist) about space and time. His final field program was actually supersubstantivalist: he tried to reduce all physics to the dynamics of spacetime; see the discussions in Smeenk (2014) and Kostro (2000).

spacetime. Curvature is represented by the Weyl tensor in the absence of matter fields and by the Riemann tensor in the presence of such fields. These are 4-rank tensors formed by the second derivatives of the metric of spacetime. If we conceive spacetime as represented just by the metric field, it is possible to have null curvature, and hence not energy flux through gravitational waves, but nonetheless the metric might differ from a pure flat Minkowskian metric. This will occur, for instance, when the first derivatives of the metric are different from zero, but the second derivatives are such that the Riemann tensor is identically null over all spacetime.

Spacetime is material because we can define its energy content over a region. This means that if such region is perturbed there will be an energy flux because curvature will change with respect to some dimension and work can be exerted, i.e. spacetime interacts with other material objects. It can act and acted upon. This is what means to be material.

Other arguments for the materiality of spacetime can be based on black hole thermodynamics (Romero 2021). Black holes are regions of spacetime, whose curvature allow the formation of trapped surfaces. Such surfaces act upon the vacuum state of any quantum field producing a polarization that results in the emission of thermal radiation with a blackbody spectrum. This makes possible to assign a temperature to the horizon. Then, purely gravitational perturbations can be used to change that temperature. So the follow argument can be formulated (Romero 2017):

P1. Only material things can be heated.
P2. Spacetime can be heated.

Hence, spacetime is material.

Issues related to the dimensionality of spacetime can be applied to argue for eternalism, the view that present, past, and future moments (and hence events) exist. I will not insist about this here, since it is not essential to the materiality of spacetime, and I refer the reader to previous papers (Romero 2012, 2013a, 2015, 2017).

Summing up: modern physics and astrophysics lend support to the view that spacetime is material. An important open problem is whether it is a substance or an emergent system.

## 2.8 Monism and Matter

In *Scientific Materialism*, p. 26, Bunge (1981) states:

> Materialism is a kind of substance monism: it asserts that there is only one kind of substance, namely matter.

This a puzzling assertion, especially if we take into account that just 4 pages before we writes that "*Matter* is (identical with) the set of all material objects." Then he adds:

> Note that this is a set and thus a concept not an entity: it is the collection of alI past, present and future entities. (Or, if preferred, $M$ is the extension of the predicate $\mu$, read 'is material'.) Hence if we want to keep within materialism we cannot say that matter exists (except conceptualIy of course). We shall assume instead that individual material objects, and only they, exist.

Systemic materialism, as it is enunciated by Bunge and also in the reconstruction presented here, admits only the existence of particular objects. Matter is presented as the class of all material *particular* things (Bunge calls them sometimes concrete individuals). And the members of that class are the only ones that exist (see **Postulate 1** above). Among the particulars we have those that are compounds (systems) and those that are simple or basic. The latter are the ones we have identified with 'substances', i.e. entities that are mereologically simple. How many of such substances there are is something that must be decided by empirical research. Bunge (2003b) mentions as examples of basic things electrons, quarks, and photons, and he emphasizes that 'simple' should not be understood in the sense that these entities lack complex behavior. Actually, their properties can be rather complex. Although I agree with the second part of the statement, I think there are some difficulties with the first part: the identification of substances with elementary particles.

The problem is the following: there are myriads of individual electrons, muons, quarks and the other elementary particles identified so far. If we accept that they all are individuals, i.e. different substances, we face the problem of why all electrons have exactly the same intrinsic properties. And the same question applies to every kind of particle. They should be connected in some way if, for example, their electrical charge is identical. Of the infinite possible values of charge, why that exact value, in all cases? This is of course the old ontological problem of the unity of the one and the many, clearly identified and enunciated by Mainländer (1876). If there is not a single universal substance, why we observe such connectedness among things?

I think that the answer to this problem is that the correct ontology suggested by current physics is an ontology of fields, not one of particles (Romero 2018a, Chapter 9; Hobson 2013; see also my chapter on Quantum Matter later on in this same book). Particles are understood in quantum field theory (QFT) as discrete excitations of fields. The ultimate substance is the field not the particle. Particles are one of the ways fields are, i.e. they can be seen as a kind of property of the field. The properties we associate with the particles of a given type come from the underlying symmetries of the field.

There is just one field for each type of particle. This reduces the ontological plurality of many substances to just a few. The basis of the problem of the many does not, however, disappear. The many fields share several properties. Why, for instance, some families of particles are electrically charged, and other families are not? Amazingly, physics points to a possible answer in the same direction as Mainländer did: The conflict can be resolved by introducing the time dimension, i.e. by considering plurality as an effect of different stages of the development of the universe.[12]

The universe expands so its temperature decreases over time, as does the energy exchanged in physical interactions. The different fields seem to be just an effect of symmetry breaking at low energies, as suggested by the successful electroweak theory that unifies electromagnetic and weak interactions. This is the basis of the standard model of quantum physics, that includes only two types of fields: the quark field and the lepton field.

The similarities between quarks and leptons, for example the fact that they both come in three generations and that they are treated in exactly the same way by the electroweak interactions, strongly point to a common origin. In addition, the fundamental interactions among them share a common description in terms of gauge theories which seem to predict that the strengths of the interactions converge to the same value at very high energies (about $10^{15}$ GeV). At such energies, quark-lepton fields should interconvert by very massive $X$ bosons. The associated physics would be manifest only when the temperature of the universe was higher than $10^{28}$ K, about $10^{-35}$ s after the outset of the cosmic expansion. At that time, the many substances (fields) should have been reduced to one. Since then, progressive decay resulting from the shattering of symmetry caused by the universal cooling produced the current ontological plurality. This image strikingly resembles Mainländer speculations of a single primordial substance, called by him 'God', that fragmented yielding the universe.

Very close to the beginning of the cosmic expansion, about 13.8 billon years ago, only two quite different kinds of matter seem to have existed: a grand unified quantum field[13] and spacetime. Spacetime, as we have seen before, is endowed with energy and interacts with the other fields. Can these two substances be reduced to one or somehow explained away?

Some physicists try to include gravitation, and not spacetime, in a comprehensive field theory. The most popular of these approaches is string theory. After more than 30 years of research, however, such attempts look more and more like a dead end, and many (including me) consider them little more than (quite abstruse) mathematical games …and epistemologically problematic (see Baggot 2013; Ellis and Silk 2014; Hossenfelder 2018; Romero 2020; Smolin 2006; Unzicker 2013; Woit 2006 for criticisms of string theory).

Another way to attack the problem is to consider the nature of spacetime itself. Is spacetime really a substance, a basic thing? Or is it emergent from non-spatiotemporal entities? Several lines of research such as loop quantum gravity, emergent gravity, and causal set theory look for a constructive formulation of space-time from more fundamental stuff. These approaches are background independent

[12] See also the generating substance theory of Anaximandro, who was perhaps the first person to deal with this problem (Chap. 1, Sect. 1.1 of this book).

[13] I emphasize that at the time being there is not a fully satisfactory, well-established, theory for this grand unification.

treatments in the sense that they require the defining equations of the theory to be independent of the actual shape of the spacetime and the value of the various fields within the spacetime.

But why to think, in the first place, that spacetime might have composition and structure, as other material systems do? A simple argument goes like this (Romero 2017):

P1: Spacetime has entropy.
P2: Only what has a microstructure has entropy.

Then, spacetime has a microstructure.

P1 is a consequence of spacetime having the property of being able to exchange energy. P2 is true of all thermal systems. Then, spacetime seems not to be simple. Other, more technical arguments can be offered in the context of various quantum gravity approaches. The very fact that essential spacetime singularities naturally appear in general relativity suggests that a pure classical picture of spacetime is incomplete (see Romero 2013b for the ontological meaning of spacetime singularities).

Relations among basic timeless and spaceless substances, or 'ontological atoms', can be the substratum from where substantival spacetime emerges. I discuss a possible path towards discrete spacetime based on such ontological atoms in Romero (2016). One might speculate that such atoms could give rise not only to the spacetime continuum but also to the matter fields. This is the old supersubstantivalist program, envisioned by Einstein and Wheeler, and advocated by some contemporary philosophers as Schaffer (2009). Whether it is possible or not, is something to be established (see Lehmkuhl 2018 for a balanced discussion of the program).

## 2.9 Knowledge of the Material World

An biological organism is, roughly, a material system such that

1. Its composition includes proteins (both structural and functional, in particular enzymatic) as well as nucleic acids (which make for its reproducibility and the likeness of its offspring).
2. Its environment includes the precursors of all its components (and thus enables the system to self-assemble most, if not all, of its biomolecules).
3. Its structure is such that enables mechanisms that enforce the abilities to metabolize, to self-repair, and to reproduce.

All organisms interact with their environment, and they will survive only if they can recognize things such as food and potential dangers. Organisms with plastic neural networks can map their environment. They will survive if such mapping approximately matches reality. One consequence of such activities is the production of *knowledge* by evolved organisms. Knowledge is neither a thing nor a substance, but a series of changes in the brain of the knower. The outcome of learning is a collection of brain processes that cannot exist outside the brain.

**Definition 14** Let $a$ be an animal endowed with a plastic neural system $NS$, and consider a time interval $\Delta t$. Then, $a$ acquires knowledge of an item $F$ over period $\Delta t$ if the $NS$ is modified as a consequence of interactions with $F$.

Knowledge acquisition requires a modification of the neural system[14] of the knower, and such a modification can only be the result of interactions with other material systems. Even if we learn abstract concepts and ideas, the knowledge must be acquired by interactions with books, teachers, visual media, or other material stuff.

There are different kinds of knowledge according to how it is acquired. We can distinguish at least three kinds: sensory-motor knowledge, perceptual knowledge, and conceptual or propositional knowledge, which is the most advanced type.

Notice that I do not define knowledge as true belief, because: (1) One can know false or fictional things, (2) some forms of knowledge are non-propositional (for instance, I can know how to ride a bike or how to swim), and (3) one can know perceptually or by conditioning (e.g. my dog knows when she has to stop and not cross the street without me).

Human beings are also capable of formulating conceptual representations of the world in the form of theories and models (see Romero 2018a, Chapter 4, and Bunge 1983, 2006 for the epistemology of a materialistic-oriented philosophy). Theories are systems of statements, where general concepts and mathematical expressions abound. Theories, however, are too abstract to be compared to reality, so we construct models to represent mechanisms operating in specific things (Bunge 2006; Romero 2018a). In the conceptual construction of any model we use a number of theories and specific assumptions. Models are, then, nurtured with concrete data in order to produce singular statements that can be compare to empirical data (basic statements) obtained by experiment or observation. In this way we obtain some advanced knowledge about the world and acquire the ability to make quantitative predictions.

Such intensive recourse to abstract entities such as concepts, propositions, and mathematical objects seems to be at odds with a materialist view. After all, numbers, linear spaces, matrices, and the like do not seem to change or interact with anything material, so they cannot be material. And hence, according to our materialist **Postulate 1** they should not be real. Nevertheless, we refer to such objects constantly in our scientific representation of the world. How is it possible?

Some materialists adopt an inscriptionalist stance and they identify mathematical objects with the very physical inscriptions we use to denote them (e.g. see the chapter by C. Madrid in this volume). This is a form of nominalism that denies the existence of concepts behind the mere inscriptions we use in mathematics

[14] I mention the neural system and not just the brain in order to allow for creatures with decentralized nervous system.

and formal sciences. In one of the discussion chapters below I argue against this position. Mathematics is too rich to be reduced to mere physical objects. Concepts lurk everywhere in our language, not only in mathematics. To relinquish them is to abandon thinking.

I maintain the thesis that mathematical objects and other concepts are *fictions*. They are free creations of human beings, but they do not have autonomous, material existence. We *pretend* they exist, for convenience, but the existence criterion for such fictions is quite different from that used for material systems. We *say* that fictions exist if they are well defined in a well-formulated system of statements.

To say that mathematical objects and other concepts are fictions does not imply that they should be arbitrary or subjective. They are constrained through rules in formal systems. Their existence, then, is relative to such systems. They are relative albeit objective, because the rules are the same for anyone willing to use the concept. For this reason, mathematical objects, contrary to the more free creations of art, do not leave room for arbitrariness. Although we can imagine a character of a novel doing different things as those stipulated in the novel where he or she was introduced, we cannot think of a mathematical object with attributes different to those stipulated in the formation rules (e.g. we cannot think the number 4 being prime). To differentiate well-formed fictions from loose ones, I use the expression *conceptual artifact* for a fiction rigorously introduced by stipulations within a formal system (see Romero 2018a, Chapter 7 and my discussion with C. Madrid later on in this book).

The thesis that mathematical objects and other well-defined concepts are conceptual artifacts is called *formal fictionalism*. It is a form of conceptualism that is consistent with materialism because conceptual artifacts can only be formulated by material beings such as humans. Mathematics is ontologically neutral: it makes no assertions about the world. Various aspects of fictionalism have been discussed by Vaihinger (1911), Woods (2009[1974]), Bunge (1985, 1997, 2006), Thomasson (1999), Bueno (2009), and Romero (2018a).

Now, an important issue that a coherent materialist should address is, why, if mathematics do not refer to objects existing in the world, can be used in our theories to represent many features of material systems?

The answer, I think, is that precisely because pure mathematics is ontologically neutral, mathematical concepts and structures result portable across various and different research fields. Mathematical concepts, being formal and exact, can be used with profit to represent certain features of real things in the context of our theories. This can be done only if we equip the mathematical apparatus we want to adopt in empirical science with semantical statements that link the abstract structures and the different mathematical objects with factual referents we assume exist in the world. It is not that we apply mathematics to reality, but rather that we can make our ideas about reality more exact through their mathematization.

A same mathematical equation can be used in different fields, provided we change the interpretation. For instance, the continuity equation appears in theories of fluids and in electrodynamics, but obviously some of the functions represent different physical properties in these different theories.

The adoption of an exact language based on mathematics allows the scientists to have a greater expressive power to describe with precision the world, much greater than with a mere natural language. So, mature science resorts to mathematics to formulate its empirical theories.

Not all mathematical theories are useful to formulate ideas about the world, and theories once considered irrelevant for physics might become indispensable when new phenomena need to be understood. A classical example is Riemannian geometry, which had little use in physics before the advent of general relativity. Another example is matrix algebra, which was scarcely known by scientists before quantum mechanics. Sometimes, physicists even need to invent the mathematical formalism they need, as it was the case of Newton and Leibniz.

Most mathematical theories, however, are never adopted in the factual sciences. There is not an a priori way to determine whether a given mathematical theory will be useful or not to represent the material world. This is simply because we do not know in advance how the world is. It is wise, however, to keep our conceptual toolkit as well-supplied as possible, and it is for this reason that mathematical research explores paths that are not, and may will never be, related to anything existing in the world.

## 2.10 Values in a Material World

Most organisms and some complex machines can evaluate items of their environment and perform actions in accordance with such valuations. For instance, animals can identify some objects as food, and look for them. Some animals value more some kind of food than other, showing a clear preference. In humans, valuation becomes conceptual and some people value not only material objects and processes but also ideas.

Normal animals strive to attain or retain a state of well-being. This state, however, is not the same for all. Hence, normal animals value positively, i.e. they find good, anything they need for their wellness and, in the first place, for their survival. I think, as Bunge (1989), that needs and wants—biological, psychological, or social—are the origin of the valuation process in human beings. However, I disagree with him when he states that values are objective properties of things, states, or processes (Bunge 1989, and 2003b p. 307). Only things can have properties, and among such properties, we never find values, it doesn't matter how carefully we investigate. Bunge states that values are objective relational properties; if they were to exist as ways of substances or systems relate to each other, research should disclose them, as it reveals other relational properties such as the velocity of a system. A very same thing can be valued positively by an individual and despised by another. In general, there is not a well-defined set of transformation rules for values from one individual to another, as there are transformations of the velocity between different reference frames. The existence of such transformations is what indicates that some relational property is objective and exists independently of our thoughts and feelings.

Instead, when we value, we assign worth to objects and processes if we think or feel that they are good to us. And they are good if they meet some need. When we value some thing $x$, we attribute to it *a fiction* that we call the value of $x$. This value is not in the thing; rather, it is a disposition formed in our brain. It is a convenient way to express our need of $x$. There are not values in themselves: *there are valuable things for some organisms in some specific conditions at a given time.* A very same thing might be very valuable to an individual at some time $t_1$and then completely indifferent or disgusting to the very same individual at a different time $t_2$.

Since it is common that in a society many individuals have similar needs, they tend to valuate similar things in a similar way, and hence the illusion might come that the values exist by themselves. Education, knowledge, indoctrination, and whatever might affect our brain and body can influence the way we valuate.

Hence the importance of education and knowledge for learning to valuate in a way that is in accordance with our goals. Conditioning, manipulation, propaganda, mere ignorance, and social or emotional pressure can take some of us to valuate positively extremely harmful things. In addition, goals are not universal: they strongly depend on non-basic needs of humans. Such needs can be intelectual, emotional, or a mixture. Similarly, morals do not exist independently of the human beings that codify and decide to follow them. Morals are not given by God, found through research, or received by sudden illumination. Morals are invented, they are social artifacts design to coordinate and guide social behavior. For this reason, morals should be adapted to each society and should evolve with the society.

I develop these views, that we can dub *ethical fictionalism*, in Chapter 5 of *Scientific Philosophy* (Romero 2018a; see also Teixidó 2019 for a comparison with Bunge's views). In what follows, I offer some definitions and postulates taken with some modifications from that book.

**Definition 15** An item $a$ of a collection $A$ is valuable in its aspect $b$ for organism $c$ with goal $e$, in the circumstance $d$, at time $t$ and in the light of the body of knowledge $f$ if and only if $c$ assigns an ordering relation $V$ to $a$ with respect to other items of $A$.

**Definition 16** A *table of values* is an ordered set of items

$$V = \{A, >\}, \tag{2.5}$$

where '$>$' is a value ordering relation. Being a set, $V$ is conceptual, not material. What is material is any particular code expressing $V$ in some language.

Values in themselves are fictions. Occasionally, the ordering relation can be specified to a function, and then we can explicitly define the value quantitatively for each item of a set. In such a case, values can be represented by mathematical functions of the form:

$$V : A \times B \times \ldots N \times U \rightarrow \Re, \tag{2.6}$$

where $A$ is the set of items to be valued, $U$ is a set of units that characterizes some scale of valuation, and the remaining sets are those of whose elements are mentioned in Definition 15.

Since values are created by material beings they have a material origin although they are not material themselves. Nor they are relational properties. They have the same ontological import of mathematical objects and concepts: none. They are conceptual artifacts projected upon things to facilitate the pursuit of our goals. In the same way we use mathematical structures to represent reality, we use values to guide ourselves through it.

**Definition 17** An object $x$ is considered *good* for a human being $b$ in circumstance $c$ if $x$ satisfies a need of $b$.

**Definition 18** An object $x$ is considered *bad* for a human being $b$ in circumstance $c$ if $x$ avoids the satisfaction of some need of $b$.

If we adopt some scale of valuation where 0 corresponds to indifference, and goods to positive real numbers, then evils (i.e. bad things) correspond to negative numbers.

Finally, I define a *moral code*:

**Definition 19** A moral code is an ordered system of norms specifying what is right and what is wrong for a group of individuals.

While some moral norms regulate interpersonal activities, others guide the behavior of individuals. Every moral code is (or should be) supplemented with meta-moral (or ethical) norms stating that such and such norms are superior to such and such other norms. Ethical theory should be informed by science if it aims at being effective in testing and improving moral norms.

Mario Bunge stated in several opportunities (e.g. Bunge 2003b, 2016; Romero 2019b) that valuation in aesthetics is completely subjective, and that this has the consequence that there are not testable aesthetic hypothesis, let along theories. Again, I disagree. In Romero (2018a), Chapter 6, and Romero (2018c) I propose a materialist theory of aesthetics based on the same fictionalist approach here adopted for the theory of moral values. The reader is referred to those texts to complete the views of this section.

## 2.11 Conclusions

In this chapter I have set myself the task of outlining systemic materialism, an ontological view mainly developed by Roy Wood Sellars and Mario Bunge during the twentieth century. Systemic materialism considers that material individuals are those with changing properties. Such changes are always lawful, so real individuals exist in multiple states that develop according to regular patterns. Contrary to physicalism, systemic materialism emphasizes the importance of qualitative emergence and novelty resulting from the association of individuals. Complex entities formed by connected individuals, make up systems. Such systems have emergent properties, a structure determined by their internal and external links, and mechanisms operating in them, i.e. lawful series of changes or processes.

Emergence allows the organization of reality in levels of complexity, each level being characterized by a set of resembling properties. Major levels are those associated with physical, chemical, biological, and social properties. More basic or more complex levels have been proposed by some authors.

Systemic materialism denies the existence of a mental level. The mind is equated to a set of functions occurring in very complex material systems, such as the human brain. Also, for systemic materialism abstract entities do not exist by themselves; they are the product of human activity. Mathematical concepts as numbers, functions, and the like are fictions, conceptual artifacts, constrained by strict rules of formation. Values are also fictions, projected by social individuals upon the world and adopted to guide their behavior.

Systemic materialism is a form of scientific ontology in the sense that its theories are, or aspire to be, informed by the best available science. Its worth should be tested by how fruitful it results to help us in understanding the world. Contrarily to dogmatic philosophy, systemic materialism is not immune to scientific progress. I have tried to illustrate this showing how recent advances in physics had forced changes in some materialistic conceptions related to spacetime and the ontology of basic entities. But without doubt more work must be done to update some materialistic conceptions in philosophy of the mind, ethics, and aesthetics (the latter is a territory virtually unexplored so far).

Above all, I hope to have been able to show that systemic materialism is a project under construction, which requires permanent interaction with the special sciences. A project promising enough as to attract the attention of scientists and philosophers alike.

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