INTRODUCTION

Although for a significant part of its professionalized existence the philosophy of science has waved the (motley) banner of the unity of science, few today would deny that the philosophical tide has clearly turned in favor of the plurality of science. The unity of science program of the Vienna Circle is dead as a linguistic program (and no resurrection is to be expected anytime soon). At least not yet dead but rather moribund is the philosophical search for *THE* scientific method (in the sense of a logic of justification, not to mention in the sense of a general methodology) and, rightly or wrongly, the related demarcation problem has not maintained much topicality in recent times. Theoretical unification, a long-standing quest and hallmark of scientific progress, is no longer seen as desirable across all disciplines, especially not in its reductive form. Establishing analogies, the other historically important way to connect phenomena, no longer attracts much philosophical attention: Pierre Duhem's illuminating analysis of this scientific practice, which was written back in 1906, remains a reference on the topic. The taxonomic thesis of unity stating that there is one fundamental and correct system of classifying things seems somewhat irrelevant to scientists' practice. The old platonic metaphor about nature being conceived as an animal whom the inquirer should carve at its joints may appear as just that: an old philosophical metaphor that is not very helpful in grasping the actual purpose of scientific classifications. Unsurpris-

ingly, the ranks of philosophers who endorse (at least openly) the underlying metaphysical beliefs that can be associated with these unification practices are rather sparse in the contemporary philosophy of science. For example, the metaphysical thesis of structure, described by Ian Hacking (1996, 47) as the belief that "there is a unique fundamental structure to the truths about the world, with central truths that imply peripheral ones" has little voice in the current philosophical debates on reductionism.

The idea of scientific unity, in its methodological dimension, has admittedly resurfaced in the work of philosophers and historians of experiment, but in a rather deflated, if not unrecognizable, form. Tools, instruments, and pieces of knowledge are what hold science together, rather than some alleged trend toward theoretical unity or common canons of reasoning. In other words, "it is not high level theory that has stopped the innumerable branches of science from flying off in all directions, but the pervasiveness of a widely shared family of experimental practices and instruments" (Hacking 1992d, 48). This "experimentalist" thesis offers a very modest view of unity: no grandiose integration of all theoretical knowledge, no bold claim about some ordered structure of the universe, no belief in the existence of a single best way of finding out about the world, just an insightful look at what scientists actually share in their practice.

Attention to actual scientific practice is certainly not a methodological recommendation that opponents of the thesis of the unity of science would contest. On the contrary, it should be remembered that one of the first systematic philosophical statements against the unity of science, Patrick Suppes's 1978 paper "Plurality of Science," invited philosophers precisely to make such a practical turn: "The rallying cry of unity followed by three cheers for reductionism should now be replaced by a patient examination of the many ways in which different sciences differ in language, subject matter and method, as well as by synoptic views of the ways in which they are alike" (1978, 9). To be sure, this plea for a practical turn has been heard, but it is not without irony that bold and general claims, both about the world and science, can now also be found on the pluralist side. For, as I shall discuss at length in this book, pluralist theses go far beyond the mere acknowledgment and description of the multi-

plicity of X (languages, objects, methodologies, theories, models, classificatory schemes, etc.) found in science today.

Some pluralist theses may be striking at first because of their metaphysical ambition, to the extent that they aim at invalidating the idea of an "ordered" world, which would translate into the existence of a unique fundamental structure of our knowledge. In Nancy Cartwright's book *The Dappled World* (1999), this metaphysical concern takes the form of an attack against different forms of reductionism, which is associated with the affirmation of the "dappled" nature of the world; that is, a world that displays some features that are precisely ordered whereas other features are unruly. John Dupré, who in the title of his book *The Disorder of Things* (1993) immediately announced his metaphysical ambition, grounds his defense of a disordered world in his rejection of both reductionism and the existence of natural kinds. Other influential pluralists, such as Helen Longino (2002, 2013), invoke considerations on the complexity of the world to champion the epistemic acceptability of the existence of several incompatible representations of a given phenomenon, claiming that the integration of these partial representations cannot be expected. Metaphysical considerations can also be found, as we shall see, in influential antireductionist arguments such as those made by Philip Kitcher (1983) and Jerry Fodor (1974), resulting in the irreducibility of a theory or a discipline to another also being conceived as a permanent feature of science.

Some pluralist theses may also be striking because of their general methodological prescriptive ambition. For instance, Hasok Chang's (2012) advocacy of the cultivation of multiple systems of practice and knowledge is intended to be generally valid; that is, valid in each field of study, independently of any possible specific features of a discipline with regard to its proper dynamic, maturity, and goals. Fueled by the conviction that "our beliefs about the structure of the world go hand-in-hand with the methodologies we adopt to study it" (Cartwright 1999, 12), Dupré's or Cartwright's pluralist views also have explicit general methodological implications: scientists' inclinations toward reductionist approaches to solve problems are rejected on the grounds that the world is dappled or disordered, without much consideration of possible local reductionist successes on specific issues.

Are such versions of scientific pluralism overly ambitious? Answering this question will be a recurrent concern throughout this book, but by no means its sole ambition. Given the variety of positions and issues that fall under the banner of scientific pluralism, a first goal is to offer a new structuring of the unity, or plurality, of science debate, which is focused on its methodological, epistemic, and metaphysical dimensions.[1] Going beyond this structuring enterprise, the book will also offer novel perspectives and theses on several important aspects of the debate. To further illustrate the motley nature of the debate, some of the main issues involved can be reframed as the following questions. Are there different kinds of things that can be known only in different ways? Or, in Rudolf Carnap's words, are "all states of affairs of one kind and known by the same method" ([1934] 1995, 32)? Should we expect that our best theories form a unique structure of a reductive type, or instead a kind of "patchwork" of which the pieces remain autonomous? Can the existence of a plurality of incompatible representations of a given phenomenon sometimes be epistemically satisfactory, or should science aim at a convergence of the representations it delivers? Is there only one correct way of classifying things that science should try to discover, or is the current existence of a plurality of taxonomic systems here to stay? These interrogations refer to distinct types of argumentations and viewpoints, so that it does not make much sense to claim to be a monist or a pluralist tout court about science today.

I propose to distinguish three main areas of argumentation, which will correspond to the three chapters of this book. The first area deals with the unity or plurality of languages, objects, and methods in science; the second with the structure of our theoretical knowledge, particularly when it comes to the possible relationship of reduction between theories belonging to different domains of discourse or scientific disciplines; and the third with representational plurality, meaning the simultaneous existence of several scientific accounts of a given phenomenon. The debates at the core of each of these areas have developed in a largely autonomous fashion. There are nevertheless connections between some topics that I will spell out as the arguments proceed. It may also be stressed that these three areas of argumentation do not occupy the same kind

of position in the current philosophical landscape. On the face of it, the first area seems to be predominantly of historical interest, whereas the second and the third raise more ongoing debates. Issues of plurality of languages and the related issue of the ontologico-methodological unity (or lack thereof) of the object domain of science were at the core of the Vienna Circle program. However major this first incarnation of the unity of science thesis was historically (at least within the tradition of analytical philosophy), it no longer shapes current philosophical debates. The monist positions challenged in the two other areas of pluralist argumentations are not those defended by the Vienna Circle. Intertheoretic reductionism, for instance, which is at the core of the second area dealing with the structure of our theoretical knowledge, was not a central tenet of its unity of science program, nor was the idea that "the ultimate aim of science . . . is to have for any given phenomenon the complete description of its essentials" (Kellert, Longino, and Waters 2006, xi), which is the current favorite target, as we shall see, of proponents of representational pluralism.

So why return to the Vienna Circle in a book that is mainly about current forms of scientific pluralism? My purpose is certainly not to contribute to the already very rich scholarship in the history of philosophy of science that is focused on that period. More modestly, I would just like to recall the main motivations and ideas at the core of the unity of science program, emphasizing that what the members of the group shared was not so much a common doctrine as a common concern for facilitating the cooperation between the various branches of science, a concern that is far from having lost its topicality. But more important, I believe that the question of whether or not there exist different kinds of things that can be known only in different ways, which was one of the central questions for the Vienna Circle, and especially Carnap, remains a very interesting question philosophically. Admittedly, it is interesting today for reasons other than those at the time of the Vienna Circle, and the conceptual tools I will draw on to answer that question are also different. But, as chapter 1 of this book aims to show, the philosophical analysis of forms of ontologico-methodological pluralism makes it possible to grasp certain features of contemporary scientific practices that I take as essential, but that are overlooked

by other forms of scientific pluralism related to the two other areas of argumentation.

More precisely, in chapter 1 of this book I begin by discussing Carnap's defense of the plurality of rational reconstructions of the sciences, which was formulated within the linguistic unity of science program of the Vienna Circle. I explain the grounds of Carnap's negative answer to the question of whether or not there exist different kinds of things that can be known only in different ways, which constitutes the common theme linking the various considerations developed in chapter 1. It will then be useful to revisit this issue of the unity, or disunity, of the domain of the empirical sciences by drawing on Hacking's concept of style of scientific reasoning, since this concept includes both an ontological dimension (styles create objects) and a methodological dimension in the justificatory sense (styles develop their own standard of validity). I investigate the ontological and methodological consequences of the existence of a plurality of styles of reasoning in science. My inquiry will lead me to propose the notion of "ontological enrichment," by styles of scientific reasoning, of the objects studied by science, and to develop the notion of "foliated pluralism." Foliated pluralism thus constitutes an extension of Hacking's thesis and, I hope, what is in Richardson's sense (2006, 5) a "philosophically interesting" form of ontologico-methodological pluralism, that is, a form of pluralism that goes beyond the banal acknowledgment of the existence in science of different kinds of things studied by different methodologies. Moreover, I explain how foliated pluralism makes it possible to capture essential features of contemporary scientific practices, such as the transdisciplinary and cumulative ways of proceeding to gain new knowledge, resulting from the simultaneous use of different styles of reasoning. The ontologico-methodological pluralist landscape that I propose in chapter 1 is therefore very different from the traditional "patchwork" forms of disunity that associate specific methods with specific types of objects.

Chapter 2 of the book focuses on a way to contemplate unifying science that is quite different from the kind of ontologico-methodological unification discussed in chapter 1, by addressing the issue of the relationships that can be established between the various theories developed at different levels of description, often

corresponding to different branches of science or scientific disciplines. This will lead to a discussion of a rather traditional aspect of the debate on the unity, or plurality, of science; to wit, the issue of intertheoretic reducibility. In its broader acceptation, intertheoretic reducibility amounts to the possibility that one theory or area of discourse is absorbed or subsumed into another.[2] One can be interested in reductionism for several reasons, depending on the kind of import one attributes to the question of the nature of intertheoretic links. "Local" inspections of intertheoretic relations mainly reflect a descriptive ambition, the point being to find out whether a given theory is reducible to another at a given time in the history of the disciplines involved, and in what precise sense of the notion of reduction. In this first type of analysis, the reducibility question remains "internal" to science: the conclusions obtained remain dependent on a given epistemic context and on the particular notion of reduction adopted. Following a more normative approach, the debate is interesting because of its methodological implication: favoring one discipline or a subdiscipline (for instance, molecular biology) over another (say, macrobiology) can be epistemically justified in a reductionist view of science, but much less so in an antireductionist one. Another reason to become involved in the debate on reductionism is the metaphysical import it displays: the structure, whether reductive or not, of our best theoretical knowledge is supposed to shed some light on what there is in the world (objects and properties) and on its degree of nomological order or disorder.

For my part, I first became interested in the debate on reductionism because I was dissatisfied while reading influential antireductionist theses such as those by Cartwright, Fodor, Kitcher, and Dupré, which display both normative methodological import and metaphysical import. Unlike in the descriptive approach, these authors do not formulate the issue of the reducibility of a theory or discipline to another as a question internal to science, the answer to which may vary over the course of the historical development of the disciplines involved. On the contrary, these antireductionist arguments appear as partially external, "over hanging" science, to the extent that their conclusions aim to remain valid independently of the evolution of the epistemic context. According to Kitcher

(1984), macrobiology, for instance, is taken to be irreducible to molecular biology, but this assertion is not indexed on the development of the disciplines involved. And the same goes for Fodor (1974) as regards the irreducibility of the special sciences to physics. It thus seemed necessary to me to question the source and the cogency of such an "overhanging" position, all the more because it goes hand in hand with a prescriptive methodological ambition. This concern leads me to investigate the role played by various (more or less implicit) metaphysical considerations in these influential antireductionist arguments. My conclusion is that the antireductionist views of science they advocate in fact presuppose accepting several metaphysical assertions, and that, I will claim, seriously weakens the credibility of the methodological prescriptions accompanying these antireductionist standpoints. I contend that, on the contrary, the fruitfulness (or lack thereof) of a reductionist approach is an empirical matter, internal to science. Philosophical standpoints grounded in metaphysical presuppositions cannot decree from outside which approaches, reductionist or not, should be favored. This aspect of my work on reductionism can thus be read as setting limits to the validity of antireductionist assertions, by restraining it to a given epistemic context.

As regards metaphysical implications, we have seen that images of the world are commonly derived in the pluralist camp from the failure of reductionist programs (for instance Cartwright's dappled world or Dupré's ontologically disordered world). I will show that this argumentative strategy encounters the following difficulty: not only do claims about the orderliness (or disorderliness) of the world remain dependent on a given theoretical framework but also, more radically, they remain dependent on the questions being asked by the inquirer within this framework. Consequently, if one adopts a naturalist take on metaphysics, it means that the image of the world in terms of order or disorder may vary not only according to the adopted theoretical framework but also according to the epistemic and contingent interests expressed within that framework. This thesis of twofold relativity will subsequently lead me to a defense of a specific pluralist thesis, which asserts the idealized and doubly pluralist nature of the ontological landscape drawn by science. I will then extend my discussion to nonreductive intertheoretic re-

lations (analogies and synthetic unifications) and also investigate their metaphysical implications.

Antireductionism goes hand in hand with a defense of the existence of a plurality of theoretical representations of the world so that it can be read as a form of representational pluralism. But other forms of representational pluralism are worth being investigated since the notion of representation in science includes not only laws and theories but also models, computer simulations, explanatory mechanisms, taxonomic systems, and so forth. Chapter 3 focuses on these other forms of scientific representations, by considering cases, very common in science, where several representations (models, simulations, etc.) of the same phenomenon or part of the world coexist. This representational plurality can be found, for instance, within a given discipline, when different models of the same phenomenon or process compete, reflecting different beliefs about its nature (e.g., the coexistence in planetary sciences of the giant impact model, the coformation model, and a capture model to account for the formation of the moon), or when different modeling tasks coexist, depending on the epistemic interests of the modelers (each partial model aims at accounting for a particular aspect of the phenomenon being studied). It can also reflect the existence of different theoretical approaches to the same phenomenon (e.g., genetic, neurobiological, social-environmental, and developmental system approaches coexist in the study of behavioral causal mechanisms [Longino 2006, 2013]). Representational plurality is also rather common when it comes to the way scientists differentiate and group things. Consider, for instance, the classification of living organisms: as is often noted, population ecologists do not group them in the same way that biologists do, not to mention taxonomic plurality within biology, which depends on the theoretical perspective adopted.

In view of these situations of scientific representational plurality, a number of different and more or less tolerant philosophical attitudes have developed, depending on how the source of this plurality is analyzed and conceived. I will identify what sorts of epistemological, methodological, and metaphysical commitments underlie these various philosophical attitudes, ranging from (realist) expectations of an integrated account (e.g., Kitcher's modest

form of realism) to epistemic tolerance to nonintegrable representations (e.g., Longino's ineliminable pluralism). This analysis will allow me to expound, sometimes critically, the main defining lines of the current debate on monism versus pluralism as regards scientific representations. In particular, I will emphasize the ambiguities affecting the pertinence of the pluralist standpoints that draw on considerations of an alleged complexity of the world to contend that some situations in which several incompatible representations of a given phenomenon coexist are inescapable.

My positive contribution to the debate on representational pluralism in chapter 3 will be twofold. First, I will propose a new analysis of a certain type of situations of incompatible representational plurality, involving composite computer simulations of real-world physical systems. Drawing on two case studies in astrophysics and cosmology, I will show that the persistence of these situations results from the way the representations involved are built over time (rather than from some alleged "complexity" of the world). My discussion of specific features of these kinds of simulations, path dependency and plasticity, will also encourage a reconsideration of the type of knowledge that is actually delivered. My main claim is that (empirically successful) composite computer simulations deliver plausible realistic stories or pictures of a given phenomenon, rather than reliable insights on what is actually the case. My second positive contribution concerns another kind of representational plurality mentioned earlier: scientific taxonomy. When delving into the abundant literature on scientific classifications and natural kinds, I was struck by a marked partition of domains. Proponents of a natural order emphasize the stability and unicity of the classifications in the physical sciences (Mendeleev's periodic table being their favorite example), whereas proponents of an impassable plurality of correct ways to sort out things often make their case by drawing on the current plurality of classifications in the biological sciences. My contribution to this debate begins with an analysis of the way stars are classified, a taxonomic domain that has not attracted much philosophical attention. On the face of it, taxonomic practices in astrophysics do not seem to fit well in this now well-established partition of domains, since taxonomic systems in this branch of the physical sciences appear very hospitable to pluralism. As it turns out, the

stellar case is not yet another case study that could favor one camp or the other in the monism versus pluralism debate. The pluralist position I defend in regard to stellar kinds and classifications also sheds new light on how the stability and unicity of certain classifications (e.g., the classification of the chemical elements) should be interpreted. More generally, I challenge the idea that a scientific taxonomy can grasp or reveal a natural order. This restriction of the metaphysical import of the stability of the classifications in the physical and chemical sciences goes hand in hand with my rejection of any realist take on the notion of natural kinds. Moreover, the questions raised by the stellar case to the current main standpoints in the monism versus pluralism debate encourage a reconsideration of the very purpose of a philosophical doctrine of natural kinds. I advocate an internal and local turn: rather than trying to elaborate a single concept that would satisfy this or that metaphysical inclination, epistemological inquiry should seek to identify types of properties and classes that are the most epistemically fruitful in a given branch of science, and to understand why this is so.

Finally, in my brief concluding remarks, I highlight some common features of the various positions I defend regarding specific aspects of the unity, or plurality, of science debate, even if one should not expect, given the motley nature of the debate, a new, general version of scientific pluralism.