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The New Mechanical Philosophy

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CHAPTER 1
WHAT IS THE NEW MECHANICAL PHILOSOPHY?

THE aim of philosophy, abstractly formulated, is to understand how things in the broadest possible sense of the term hang together in the broadest possible sense of the term.

Wilfred Sellars (1963)

The past twenty years has seen the emergence of a body of research in philosophy of science that has sometimes been called the New Mechanical Philosophy or New Mechanism. As I shall interpret it, the New Mechanical Philosophy fits squarely within Sellars' conception of the philosophical enterprise. It is an attempt to say how things hang together. The things in this instance are nature and science, understood in the broadest possible senses of these terms. It says of nature, that most or all the phenomena found in nature depend on mechanisms –collections of entities whose activities and interactions, suitably organized, are responsible for these phenomena. It says of science that its chief business is the construction of models that describe, predict and explain these mechanism-dependent phenomena.

My aim in this book is to provide a systematic exposition of the New Mechanical Philosophy – its central motivations, problems and prospects. While my views owe a great deal to the work of others who have been called New Mechanists -- especially Bill Bechtel, Carl Craver, Lindley Darden and Peter Machamer – this remains my account. Along the way, I will try to honor my debts by pointing to areas of consensus and disagreement, but my main goal is to craft a picture of nature and science that is both empirically informed and metaphysically and epistemologically coherent.

What is perhaps most distinctive about my account is its scope. The New Mechanism has developed chiefly as a set of views about explanation and discovery in biology and the life sciences – its primary domains of application have been molecular biology, neuroscience and cognitive science. Given the ubiquity of mechanism talk in disciplines as diverse as historiography, sociology and physics it is natural to wonder whether the insights of the New Mechanism apply more widely, or whether mechanisms and mechanistic explanation are distinctive features of some special sciences. I will argue that there is an informative way of thinking about mechanisms across the sciences – one that will support the philosophical aim of seeing how things hang together. Ironically though, one of the most important general things we can say about mechanisms is that they are particulars – each one different from the next. Sorting out the tension between the particularity of mechanisms the generality of the ways we represent them will be a central task of this book.

1.1 The Craving for Generality

Writing in the mid 1930s, Ludwig Wittgenstein suggested that one of the chief sources of philosophical error was a philosophical weakness he called "our craving for generality" (Wittgenstein 1958, 17). Whether or not it is an error, judging by Sellars' remark from thirty years later, he is certainly right about the craving. Wittgenstein thought of this philosophical affliction as arising out of certain bad philosophical habits. For instance, he saw it in "the tendency to look for something in common to all the entities which we commonly subsume under a general term" (17). Relatedly, he saw it in the "tendency rooted in our usual forms of speech to think that the man who has learnt to understand a general term, say, the term 'leaf,' has thereby come to possess a kind of general picture of a leaf as opposed to pictures of particular leaves" (18). Wittgenstein's initial philosophical target is no doubt Plato and his theory of the forms. Socrates' first move, familiar to any reader of Plato's dialogs, was to ask of any concept *X* (piety, virtue, justice, love…) what form all instances of *X* partook in that made them *X*. But the craving is by no means limited to Plato, and can be seen in any attempt to offer a general analysis of the nature of *X*s, from Descartes' account of the nature of body to Wittgenstein's own earlier attempt to characterize the general form of the proposition. Certainly, I am guilty of it in trying to offer a general account of mechanism.

While part of the source of our craving comes from our philosophical tradition and our forms of speech, it is particularly interesting for our account that he sees the other main source as "our preoccupation with the method of science" (18). He describes scientific method as

> the method of reducing the explanation of natural phenomena to the smallest possible number of primitive natural laws; and, in mathematics, of unifying the treatment of different topics by using a generalization (18).

He goes on to say:

> Philosophers constantly see the method of science before their eyes, and are irresistibly tempted to ask and answer questions in the way science does. This tendency is the real source of metaphysics, and leads the philosopher into complete darkness (18).

There is both insight and irony this passage. Scientists do seek generality, and many philosophers, both in Wittgenstein's time and today, deliberately seek to emulate the style and approach of scientists. The irony is in the presupposition of this passage – that there is such a thing as *the* method of science. To assume that the activities of all scientists are instances of some general kind of activity called "the method of science" is once again to commit Plato's mistake. Wittgenstein may be forgiven, as he was writing during the heyday of logical positivism and the unity of science movement – a movement that above all things exemplified the craving for generality. Subsequent research in the philosophy and history of science have taught us that there is not one scientific method but many, though these diverse methods may share, to use Wittgenstein's apt phrase, rich family resemblances.

The craving for generality is more widespread than Wittgenstein suggests. It afflicts scientists as well as philosophers, and not just them. Really the craving for generality is an essential part of the human condition (The irony of appealing in this context to "an essential part the human condition" is duly noted.) In science, the craving for generality expresses itself in the search for laws and generalizations; in human life generally it expresses itself in the search for patterns. Here is the nub of the problem: reality is particular, but the needs of anyone who seeks to understand and survive in the world are general. If I am to live with tigers, I need to know how to treat them. One tiger is different than another, and the same tiger will have very different properties on different occasions depending upon whether it is young, old, horny, hungry, or grumpy. Still I need general rules like "don't pet tigers" or I am not going to be around for very long.

I shall argue that the insight that reality is particular is at the very heart of the New Mechanical Philosophy. The phenomena that constitute our world are the products of mechanisms: car engines are mechanisms for rotating drive shafts; eyes are mechanisms for transducing light into neural impulses; oxidation is a mechanism that produces rust. And the crucial thing about mechanisms is that they are particular and local. One car (or eye, or oxidation reaction) is not exactly like another. And while we can and must look for similarities that allow us to understand cars or eyes or chemical reactions as types, each instance of these things is a little different, and the source of their causal powers lie in that particular instance. In contrast to Wittgenstein's view, the New Mechanists believe scientific methods are chiefly directed toward the discovery and representation not of laws but of mechanisms. The generalizations we sometimes call laws are heuristic; they do not reflect the deep reality of things.

To see both the sources of our craving for generality and the troubles it brings, consider an example somewhat removed from the natural sciences – the connection between terrorism and Islam. According to a report of National Consortium for the Study of Terrorism and Responses to Terrorism (START), a research center sponsored by the United States government, there were more than 16,800 terrorist attacks in 2015, which caused more than 43,500 deaths (Miller 2015).[1] A large number of these attacks are attributable to the activities of Islamic extremist groups, with

[1] Such claims have precision only to the extent that there are clear and non-arbitrary rules for counting acts of terror and distinguishing them from other kinds of acts. I shall not say anything about this here, beyond noting the obvious fact that any classification of a set of events as being of a kind like "terrorist acts" involves categorizing heterogeneous particulars according to criteria that are pragmatically driven and value-laden.

the top perpetrators being the Islamic State of Iraq and the Levant (ISIL), the Taliban and Al-Shabab in Somalia. While there are certainly non-Islamic groups that sponsor terrorist attacks--e.g. the FARC in Columbia ETA in Spain—acts of terrorism in the last decade have been committed disproportionally by people who identify themselves as Muslims.

Despite this data, it is clearly misguided to infer that Islam causes terrorism. For one thing, terrorist attacks are, for all of the fear they elicit, rare events. There are over 1.5 billion Muslims in the world, and even if every one of the 16,800 terrorist attacks in 2014 were carried out by Muslims, the proportion of Muslims engaged in terrorism would be vanishingly small. But the other reason, more important for our purposes, is that there simply is no property of being Muslim, which all or most people who identify as Muslims share, and hence it simply makes no sense to say that Islam, as such, either inclines or disinclines its adherents to terrorism.

Like any religious tradition, Islam is an amalgam of beliefs, practices and identities that share common historical antecedents but which find very different expressions as they have evolved over time and space in interaction with local social, economic, political and cultural contexts. While it is clear that many fighters acting on behalf of ISIL and other such terrorist organizations are motivated by their understanding of their religious identity, that identity is shaped not by Islam as such, but by the very local circumstances in which they acquired their identity. If any sort of Islam is causally connected to terrorism, it will be an Islam of a particular place and time, an Islam nurtured in Cairo or Riyadh, or Molenbeek, in which jihadist identities are constructed in response to the particular conditions of social, economic and political conditions.

Racial and ethnic profiling is a psychologically unsurprising but often epistemically and morally problematic expression of our craving for generality. But not all attempts to make generalizations about heterogeneous groups of individuals are either morally or epistemically inappropriate. Border security agents may be wise to concentrate their efforts on people from certain countries or of certain genders or ages, as members of certain groups are indeed statistically more likely to be engaged in illegal or terrorist activities. General if fallible heuristics can, properly applied, increase their effectiveness at detecting real threats. And in a more prosaic context, we profile in all sorts of ways in order to get about our daily lives. For instance, as a teacher I have generalized expectations about the capacities, interests, and aspirations and mores of my students that are based on general categories to which they belong – philosophy majors or biology majors, first years or fourth years, New Yorkers or Midwesterners and so on. Such generalized expectations are essential for planning courses, though they are sometimes flat-out wrong.

In the context of psycho-social questions like this, the point I am making is uncontroversial: What causes an individual to become a terrorist or a priest or a wine-maker is the product of the very particular history of that individual. We may be able to make statistical generalizations about the relationships between these properties, but such generalizations are simply local summaries of correlations among populations of heterogeneous individuals. The generalizations may be of local use, but they will not be projectable to different times or places. And these generalizations, while they may fallibly predict, will not explain. If we are really to understand what causes an individual to do anything, we must look at the particular properties and circumstances of that individual.

But if reality as a whole is particular, then these features of psycho-social properties and causation are not unique. Just as there is no one thing that it is to be a Muslim, there is no one thing that it is to be a cell or to be an oxidation reaction. Even for physical, chemical, biological, and other phenomena studied by the natural sciences, the causes of these phenomena are local, heterogeneous and particular. We live, as Nancy Cartwright says, in a dappled world.

1.2 Antecedents of the New Mechanism

The set of philosophical approaches and conversations that have come to be called the New Mechanism originate in the 1990s, and is commonly traced to three publications. Bechtel and Richardson's book, *Discovering Complexity*(1993), provided an account of biological discovery that characterized much work in biology as a search for mechanisms. Around the same time, I argued that causal relations are best understood as depending upon mechanisms (Glennan 1996). Finally, in 2000, Machamer, Darden and Craver, often referred to collectively as "MDC," published their immensely influential paper "Thinking about Mechanisms" (Machamer, Darden, and Craver 2000), which offered itself as a kind of manifesto for a new approach to philosophy of science.[2]

As with any other "ism," there is both value and danger in pulling together a set of not always consistent strands of thought under a name like "New Mechanism." Clearly the philosophers who have been called New Mechanists do not have identical views or interests, and their own views have in fact changed over time. In this book, as I articulate my own account of the New Mechanical Philosophy, many of these points of difference will emerge. At the same time, I think fair to say is that the New Mechanists – MDC, Bechtel and Richardson, myself and others – have been part of a common conversation and share many common commitments that distinguish this recent brand of Mechanism from other mechanical philosophies and other styles of philosophy of science. To situate this conversation, let me say just a bit about these common commitments and their relationship to other mechanical philosophies and other recent developments in the philosophy of science.

Mechanical philosophies and mechanistic approaches to understanding nature begin in antiquity with the atomism of Democritus and the Epicureans (Popa, n.d. forthcoming). The heyday of the

[2] To my knowledge, the term "New Mechanistic Philosophy" ("Mechanistic," not "Mechanical") first occurs in (Skipper and Millstein 2005). Jim Bogen used the term "New Mechanical Philosophy" as a title for his review of a collection of essays by Darden (Bogen 2008). In other literature, members of this group are referred to as "Mechanists" e.g., (Psillos 2004) or, tongue in cheek, as "Mechanistas." For brief overviews of the New Mechanism, see (Craver and Tabery 2015; Glennan 2015)

Mechanical Philosophy was in the seventeenth century, espoused in various ways by, among others, Galileo, Thomas Hobbes, Rene Descartes, Pierre Gassendi and Robert Boyle. Not without reason, many historians of science see "the mechanization of the world picture" as a central aspect of the birth of modern philosophy and of the scientific revolution (Dijksterhuis 1961; Westfall 1971; Shapin 1996). Most seventeenth century versions of Mechanical Philosophy are closely connected with atomic or corpuscular theory, holding that all visible natural phenomena are the product of the motions and interactions of microscopic atoms or corpuscles of various sizes and shapes.

While the 17th century Mechanical Philosophy was chiefly concerned with explaining manifest physical and chemical properties of inanimate objects (heat, light, color, gravity, etc.), discussions in the 18th and 19th century increasingly focused on Mechanical Philosophy as a way to understand the nature of living things. These Mechanists emphasized the continuity between living and non-living things. They shared with the 17th century Mechanists a suspicion of final causes, and they sought to explain the behavior of living systems by analogy to physical systems and especially to machines. A classic polemic in this vein was the French physician and philosopher de la Mettrie's 1747 treatise *L'Homme Machine*. Mechanism in this sense is opposed by vitalism or organicism, views that suggest that there is something essential (goal-directedness, self-organization, etc.) that renders living things of a fundamentally different kind than physical systems.[3]

While there are certainly historical and conceptual connections between the New Mechanism and these earlier incarnations of Mechanical Philosophy, there are important differences that bear emphasis at the outset. First, the New Mechanists are not committed to atomism either metaphysically or methodologically. New Mechanists have emphasized that nature is hierarchically arranged, with new and different kinds of entities and interaction arising at different levels of organization. Whereas the Mechanical Philosophy of Descartes or Boyle was committed to the idea that all phenomena could in principle be explained in terms of action by contact of variously shaped microscopic corpuscles, the New Mechanists think of mechanisms involving objects of diverse kinds and sizes (molecules, magnets, cells, organisms, stars) engaging in a variety of different kinds of activities and interactions (chemical bonding, electrical conduction, absorption, coagulation, predation). While New Mechanists believe that these objects and their activities and interactions as being composed of and explained by the activities and interactions of their constituents, they are not committed to atomism. Second, the New Mechanists emphasize that there are important differences between mechanisms and machines. Human-built machines have mechanisms by which they operate, and the machine metaphor can be helpful in understanding the behavior of many naturally occurring mechanisms;

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[3] For helpful discussions and further references on the historical development of mechanistic thinking in biology see (Craver and Darden 2005; Nicholson 2012; Allen, n.d. forthcoming). For an illuminating history of the concept of self-organization and its relation to mechanism in the physical sciences, biology and engineering, see (Keller 2008; 2009).

however, there are many kinds of mechanisms both in living and non-living systems that do not behave like the kinds of mechanisms we find in windmills, cars or toasters.[4]

The New Mechanism is not the only outbreak of Mechanical Philosophy in recent decades, and several related approaches should be mentioned. Salmon saw his approach to causation and causal explanation, developed in his seminal *Scientific Explanation and the Causal Structure of the World* (1984), as a reincarnation of Mechanical Philosophy, and the terms "Mechanical Philosophy" and "the causal-mechanical account of explanation" have often been used to refer to this work (Hitchcock 1995; Woodward 1989). Although principally concerned with explanation in the physical sciences, Salmon's approach shares many features with the New Mechanist approach.[5] Two other strands of Mechanical Philosophy are mechanistic approaches to cognitive science and medicine (Thagard 1999; Thagard and Kroon 2006; Russo and Williamson 2007), and a burgeoning literature on mechanisms and mechanical explanation in the social sciences (Hedström and Ylikoski 2010; Little 2011; Ylikoski, n.d. forthcoming).

Although the explosion of interest in mechanisms has occurred in just the last twenty years, the New Mechanism and other recent mechanistic approaches reflect a continuation of trends in philosophical thinking about nature and science that has occurred since the 1960s. I will summarize those trends as a shift in focus amongst philosophers from thinking about laws to thinking about mechanisms and from thinking about theories to thinking about models.

The laws and theories image of science, which finds its most mature expression in late works of logical empiricism Hempel's *Aspects of Scientific Explanation* and *Philosophy of Natural Science* (Hempel 1965; Hempel 1966) and like Nagel's *The Structure of Science* (1979), goes something like this: The sciences are ultimately concerned with the observation, explanation and prediction of phenomena in the natural world. Observations are expressible in terms of singular statements, ideally representable in the language of predicate logic. To understand and explain these phenomena, we must generalize. We start with empirical generalization (or experimental

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[4] It is still a point of controversy whether the New Mechanist approach is really adequate to explaining the character of living systems. While critics do not doubt that there are mechanisms at work in living systems, some believe that the New Mechanist approach is ineluctably entangled with the machine metaphor and that some of the characteristics of living things as wholes (especially their capacities for self-organization, self-maintenance and self-direction) are beyond the scope of mechanistic explanation (Dupré 2008; 2013; Nicholson 2013; Nicholson 2012). For one explication and defense of a New Mechanist approach to biological systems that answers some of these challenges, see (Bechtel 2011).

[5] Craver in particular (2007; 2013) sees his approach to mechanistic explanation as building on Salmon's approach. On the relation of New Mechanist approaches to Salmon see (Campaner 2013; Glennan 2002). I address the relation between Salmon's and my views of causation in Chapter 7, and explanation in Chapter 8.

laws) where we identify patterns in observable phenomena. But to extend our scope of explanation and prediction, we must extend our scientific enterprise with theory. Theories are understood to be collections of laws (theoretical generalizations) concerning entities not directly observable (like gravity or genes). But these theories, in combination with bridge principles connecting theoretical to observable terms, allow us to predict and explain -- unifying disparate phenomena under a single structure.

The mechanisms and models approach is distinguished from the laws and theory approach chiefly by its emphasis on particularity. Mechanisms are situated at particular locations in space and time, and while we may classify mechanisms into kinds – ultimately the properties of individual mechanisms, including their causal powers – are heterogeneous and local. There are few if any true laws. Generalizations may have heuristic value, but they don't represent the deep reality of things. The move from laws to mechanisms is paralleled by the move from theories to models. Models (as they are most often understood) are models of particular mechanisms – the Newtonian model of the solar system or the plate tectonics model of continental drift. And while it is routine for scientists to construct generalized models – e.g., models of a type of cell or a type of star – it is understood that modeling involves approximation and idealization.

Many philosophers have contributed to the shift to the mechanisms and models approach. A few of the more important motifs and representative references are the following:

- The world is complex and often disordered, and cannot be characterized in terms of global patterns or regularities; the regularities we find are of limited scope, and our characterization of them reflects our practical concerns (Cartwright 1983; 1999; Dupré 1993; Wimsatt 2007; Mitchell 2009).

- The special sciences are autonomous disciplines with unique problems and methods; there is no one scientific method (Putnam 1973; Fodor 1974; Kitcher 1984).

- There are few laws in the special sciences, and those they find reflect effects to be explained rather than deep truths that explain (Cummins 2000; Wimsatt 2007; Giere 1995).

- Inter-level reduction is best understood not as a relation between theories but as a relation between phenomena and the mechanisms that produce them; reductionist research strategies are heuristic and do not undermine the reality or autonomy of higher level phenomena (Wimsatt 1972; 1980).

- Science seeks to understand the causes of things, and causes cannot be reduced to regularities (Cartwright 1983; Salmon 1984; Dowe 2000; Woodward 2003).

- Models that are idealized, heuristic and often clearly false are key tools for representing and intervening in nature. A given system will typically have not one model but many (Cartwright 1999; Morgan and Morrison 1999; Giere 2004; Weisberg 2007; 2013; Wimsatt 2007).

In claiming these ideas as part of the intellectual provenance of the New Mechanism, I should hasten to emphasize that some of these authors have been explicitly critical of some claims of the New Mechanists, and others have research agendas that take them in different directions. Still, their contributions form the intellectual milieu of the New Mechanism.

1.3 THE PHILOSOPHY OF NATURE, THE PHILOSOPHY OF SCIENCE AND NATURALISM

As I understand it, the New Mechanical Philosophy is a view both about nature and about science. The philosophical views in this book are accordingly at the intersection of natural philosophy and the philosophy of science. Let me say something about what I take these fields to be and the methods I will use to approach them in this book. I use the term "philosophy of nature," and the related term "natural philosophy" to refer to philosophical inquiry into questions about the constitution of things in the natural world – i.e., the world that is the object of scientific investigation. That world is the whole world; it encompasses not just physical nature, but also the world of living things, of human beings, and the artifacts of human culture.

The term "natural philosophy" was popular at a time when there was no separation between philosophy and science. The early mechanists – Galileo, Hobbes, Descartes, Boyle, Newton– would all count as natural philosophers. Despite their differences, all of these philosophers espoused a natural philosophy that was concerned with characterizing how things in nature worked, and all of them saw continuity between what we would think of as philosophical and metaphysical work and empirical science. While seldom used to characterize contemporary philosophy, the term "natural philosophy" seems appropriate in light of what Werner Callebaut (1993) has characterized as "the naturalistic turn" in philosophy. Naturalism, in the sense that Callebaut describes, is primarily a methodological approach. It denies that there is a clear division of labor between philosophy and science. There is no first philosophy. Conceptual analysis and ordinary language may tell you what people mean, but they do not necessarily tell you how things are. The sciences collectively provide us our best source of knowledge about what things there are in the world and how they work, and metaphysical speculations that do not attend to that knowledge are groundless. On this view, natural philosophy simply represents the theoretical and conceptual pole of the philosophical-scientific enterprise.[6]

Although many philosophers of science engage in what I am calling natural philosophy, I want to distinguish natural philosophy from philosophy of science by their different objects of concern.

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[6] This conception of natural philosophy is in keeping with the pursuit of "naturalistic metaphysics" or "the metaphysics of science." These are good things, as opposed to "scholastic metaphysics," which is bad. For two opinionated polemics against scholasticism, one from philosophy of physics and one from philosophy of biology, see (Ladyman and Ross 2007; Callebaut 2013).

Natural philosophy is concerned with nature, while philosophy of science is concerned with science. Of course, from a naturalistic point of view, science is a part of nature because the human world is part of the natural world; science and its institutions are products of human culture, expressions of the extended human phenotype. Nonetheless, it is very helpful to separate out the peculiar part of nature that is science, so that we can understand its activities and products. To put the matter rather generally, science is a set of institutions created by human beings and their culture to help represent, understand, predict and control the world. In keeping with the naturalistic denial of the division between philosophy and science, we can profitably think about the philosophy of science as part of "the science of science" – that is the naturalistic and largely empirical study of science as a natural phenomenon. As such, the philosophy of science is the theoretical wing of science studies, but shares the same building with its other disciplines like the history, sociology and anthropology of science.

The account of nature and of science that I will offers presupposes a minimal form of scientific realism. It supposes that mechanisms and their constituents are things in the world that exist independently of the models we make of them. I will, to use a phrase of Stathis Psillos, adopt a realist framework. Psillos characterizes it as follows:

> The realist framework… is the framework that posits entities as constituents of the commonsensical entities and relies on them and their properties for the explanation and prediction of the laws and the properties of commonsensical entities. Accordingly, the realist framework is an explanatory framework, viz., a framework of explanatory posits. In particular, it is a framework that explains by positing constituents of macroscopic things (Psillos 2011, 303)

Psillos' view is that this framework is indispensable to this very common sort of explanatory approach within science. I concur, and would add that the explanatory goals for which this realist framework is indispensable are central to the New Mechanist's conception of the scientific enterprise. The realist framework is implicit in the assertion that mechanisms are things in the world that are actually responsible for the vast variety of natural phenomena.[7] But to adopt such a framework does not imply that the entities posited by any particular model or theory refer. Neither is it to suppose that our ways of representing nature are not deeply affected by our interests, cognitive capacities and other factors. To carefully explore the relationship between a mind-independent reality and our inherently perspectival representations of that reality will be a central task of this book.

For our investigation to be successful it will be crucial to disentangle three kinds of questions about our objects of study: semantic questions, ontological questions, and epistemological questions. Semantic questions are questions about concepts and meaning: what do we (philosophers, scientists of various persuasions, the folk) mean by the term "mechanism"

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[7] For an argument for an instrumentalist approach, see (Colombo, Hartmann, and Iersel 2014).

("cause," "process," "activity" etc.)? These questions are largely distinct from ontological questions – questions about what mechanisms (causes, processes, activities, etc.) are as things in the world. And these questions are in turn distinct from epistemological questions about how we come to believe and know things about these objects.

My primary focus will be on ontological questions. The first question in this book is what a mechanism is as a thing in the world, and this will spur other ontological questions: what is it to be a part of a mechanism, a causal interaction, a system, a cause and so forth. But these questions, while distinct, are not and cannot be isolated from the semantic and epistemological questions. To develop a coherent and plausible ontological account requires a proper understanding of how these questions bear on each other.

A view commonly held amongst analytic metaphysicians is that the proper starting point for ontological investigation is conceptual analysis; we get to the ontological questions by way of the semantic questions. David Lewis' views on causation provide a good example. Lewis (e.g., 1973; 1979) offers a reductive analysis of causation in terms of patterns of counterfactual dependence. It is reductive in the sense that singular causal claims (like the claim that Caesar's crossing the Rubicon caused the conspiracy to form) can be translated into a set of counterfactual claims (e.g., that had Caesar not crossed the Rubicon, the conspiracy would not have formed). By further analysis we find the truth conditions for counterfactual claims – and it is these that show what our causal claims are really about.

A version of this approach that has received considerable discussion in the last decade is often known as "the Canberra plan." The idea of Canberra planning is to provide a division of labor between the philosophers and the scientists. Philosophers go first – setting the stage by offering an a priori analysis of our concepts. This analysis explicates the role that a certain concept plays within our broader conceptual economy. Then we can turn the question over to the scientist (or to empirically informed philosophers perhaps) who can go look for what it is in the world that fills the role. A classic example of the method is found in Lewis (1972), who characterizes what it is to be a pain analytically in terms of its functional role (pain is what is caused by this and that, and causes this and that other thing); he then leaves it to the scientists to find what it is in the brain that plays this functional role.

In the recent literature on causation we find another notable outbreak of Canberra planning, particularly in the work of Peter Menzies (2009; 1996). Menzies argues that our starting point for understanding causation should be a folk conception, discernible from what he calls platitudes– for instance, that causes precede and are distinct from their effects, or that causes make their effects more likely. These platitudes provide a description of the functional role of the causal relation -- an account of what it does. Given this conceptual analysis, we then can look to science – in the form of what Phil Dowe (2000) has called empirical analysis – to find out what sort of features of the world could fit the bill.

There are definitely some things that are right about the Canberra approach. In the first place, it illuminates the difference between ontological and semantic questions. To cite a familiar example, it helps us see that water can be H_2O, even if being H_2O is not, or at least was not until the chemical revolution, part of our concept of water. Additionally, it gives us an account of how our concepts (even our folk concepts) help fix the referents of claims involving those concepts.

The trouble with Canberra planning is that the division of labor between the philosophers and the scientists, and between conceptual analysis and empirical investigation, is not as clean as examples like these suggest. There is for one thing the fact that our folk intuitions may be ambiguous and inconsistent, they may be in need of what Carnap famously called "explication." We also have the worry that not all concepts we employ need refer. We might have concepts like "witch" or "soul," but having these concept does not imply that there are any witches or souls to answer to them. And then there are the intermediate cases. If we have, for instance, a folk concept of belief, and our scientific investigations of animal behavior suggest that there is not anything in our mind-brains that quite fits the bill, what are we to infer – that really there are no such things as beliefs, or just that our beliefs about beliefs were wrongheaded?

Concepts, especially as they are employed in the sciences, have a way of moving around. Take any interesting concept found within the sciences – e.g., electricity, force, compound, gene, species, sensation, memory – and you will find that these concepts have histories, histories that are intertwined with empirical research in the fields. As Quine argued many years ago [xx ref] us, there is no clean break between the analytic and synthetic.

Where does this leave us? I suggest the following: Conceptual analysis has an important role in fixing the topic of our investigation, but this analysis is not the special province of philosophers, and it gives us no immediate insights into metaphysical questions, like what mechanisms or causes are as things in the world. We should begin our ontological investigations with the assumption that the well-confirmed claims of science and common sense are true, and we seek to understand what would have to be the case for these claims to be true. As we come to understand these conditions we will sometimes find that the things in the world do not quite line up with our concepts – and if so our concepts will be in need of revision. This is the back and forth that I understand to be characteristic of natural philosophy.

In focusing on ontological (and more broadly metaphysical) questions, I am departing from an emphasis found in much of the other New Mechanist literature.[8] The New Mechanism emerged from a focus on scientific practice, and has been able to make considerable progress by attending to the methods of discovery, reasoning and representation in specific cases of mechanistic

[8] What counts as ontology and metaphysics is by no means settled – and depending upon your views about metaphysics, these fields may be more or less coincident (Chalmers, Manley, and Wasserman 2009). As I understand it, ontology is concerned with what there is, while metaphysics is somewhat broader in considering other questions – like questions about relations of identity and dependence.

science. But as this research has progressed, I think it has been clear to many participants in the discussion that metaphysical questions are unavoidable. In writing this book, I hope to show both how examinations of scientific theories and practice provide good reasons for adopting certain metaphysical positions, and how clarifying these positions can help both illuminate the meaning of those theories and practices. As such, I hope this book will be of interest both to philosophers of science who have seen the need to get clearer on these metaphysical questions, and to metaphysicians who are interested in what mechanistic philosophy of science can do to illuminate their questions. And while I will sometimes dig deep into debates within philosophy of science, I have tried to write this book with language and examples that will make it broadly readable – in part in hopes that philosophically minded scientists will find here an interesting philosophical conception of the scientific enterprise.

1.4 The Book in Outline

This distinction between things in the world and scientific representations of those things is crucial to the argument and exposition of this book. Mechanisms in the world are one thing – a matter of natural philosophy – and scientific representations of those mechanisms, our models, are another. Our first task is ontological – to explore mechanisms in the world, and to understand the relationship between mechanisms and causation. Our second task is epistemological and pragmatic – to understand the means by which scientists construct representations of mechanisms and mechanism-dependent phenomena, and use them to understand, predict and control things in the world. But while we must distinguish conceptually between these two tasks, we cannot tackle them in isolation, since our ontological account should both make sense of and constrain our epistemological practices.

Here, more specifically is how we will proceed:

Chapter Two: Mechanisms

Chapter 2 provides an account of what mechanisms are as things in the world. It begins with a characterization that I call minimal mechanism, which says that a mechanism for a phenomenon consists of entities (or parts) whose activities and interactions are organized in such a way that they are responsible for the phenomenon. This characterization is minimal both in the sense that it represents broadly shared commitments among New Mechanists as to necessary (but not necessarily sufficient) features of a mechanism, and in the sense that it is permissive, allowing essentially all causal processes to count as mechanisms. The bulk of the chapter is devoted to clarifying this characterization by an explication of the concepts appealed to –phenomena, entities, activities and interactions, and organization. A central theme in this discussion will be the hierarchical character of mechanistic organization – the idea that the entities, activities and interactions of which mechanisms are made are themselves constituted by mechanisms. The upshot is a “new mechanical ontology” – a view of what there is that is sometimes at odds with traditional ontological presumptions of metaphysics and the philosophy of science.

Chapter Three: Models, Mechanisms, and How Explanations

This chapter shifts the focus from an ontological concern about the nature of mechanisms in the world to a methodologically and pragmatically focused discussion of how scientists represent mechanisms via models. I offer an account of models based upon Ron Giere's pioneering work (1988; Giere 2004), using it to distinguish between mechanistic and non-mechanistic models. This account of modeling suggests some revisions to claims of New Mechanists about what is required for a model to be mechanistic. On some readings, to give a mechanistic model is to fill in all the details of the entities, activities and interactions that are responsible for a phenomenon. I argue that for many phenomena that scientists study, it is misleading to take such a goal as a normative ideal. Information about complex and multi-level mechanisms often requires multiple models, and the desire for models that are tractable and general may make abstract and idealized models preferable to more detailed ones. Mechanistic models are the vehicles for conveying mechanistic explanations, which are distinguished from other forms of explanation by the fact that they show how the phenomenon to be explained comes about.

Chapter Four: *MECHANISMS, MODELS AND KINDS*

Mechanisms, as well as the parts, activities and interactions that make them up are particulars; and yet, it is part and parcel of scientific practice to cluster these particulars into kinds. In this chapter I explore the principles that underlie these classifications. I advocate a "models first" approach to mechanism kinds, where particular mechanisms fall under a kind in virtue of their being adequately represented by a certain kind of model. Mechanism kinds have no independent existence apart from their instances (they are not universals) and particular mechanisms are instances of a variety of different and overlapping kinds. Still, mechanism kinds are real in the minimal sense that they are grounded in the objective similarities that exist between particulars that allow them to be represented by common models. In addition to discussing mechanism kinds, I also discuss the way in which the entities and activities that are constitutive of mechanisms may be classified into kinds. As with mechanisms themselves, activity and entity kinds are abstractions, but abstractions grounded in objective similarities between fully concrete particular entities and activities.

Chapter Five: *TYPES OF MECHANISMS*

The strategy of minimal mechanism, as described in Chapter 2, is to offer a permissive definition of mechanism that encompasses a wide and diverse range of systems and processes. While this strategy has the virtue of honoring the diversity of mechanism-talk in the natural and social sciences and providing an account suitable for framing a mechanistic approach to causation, there is a danger that the account is so abstract as to be uninformative about the features of nature and science that it seeks to illuminate. In this chapter, I begin to address this problem by offering an account of types of mechanisms. I will suggest that mechanisms can be classified into types along several taxonomic dimensions –the types of phenomena produced, the types of entities and activities of which the mechanism is composed, the types of mechanistic organization, and the types of etiology, i.e., ways in which those mechanisms came to be. I will, following the models-first strategy, show how particular mechanisms can be classified into kinds via similarities in the models that are used to represent them. This account of kinds of mechanism will provide us insights into the various ways in which the sciences are unified and disunified.

Chapter Six: MECHANISMS AND CAUSATION

This chapter will sketch a mechanistic account of causation and situate it within the space of approaches to causation found in the contemporary philosophical literature. The account suggests that mechanisms provide the truth-makers for a variety of kinds of causal claims, and in particular that claims that one event caused another are made true by the existence of a mechanism by which the first event contributes to the production of the second. The particular and productive character of mechanisms in fact implies that we should think of causation as fundamentally a singular and intrinsic relation between events, rather than as something mediated by laws or universals. The virtues of the mechanistic approach will be illustrated by means of a comparison with counterfactual and regularity approaches to causation. The tension between singularity and generality is again shown in the contrast between the generality of evidence and the singularity of mechanisms and causal relations.

Chapter Seven: PRODUCTION AND RELEVANCE

It is now increasingly common to hold that there are two distinct concepts of cause, which I refer to as production and relevance. In this chapter I will explore how the mechanistic approach makes sense of these concepts and the relationship between them. On the mechanistic approach, production is the primary causal relationship, so much of the chapter will be devoted to developing a mechanistic account of production: How and in what sense does the productive character of a mechanistic process arise from the productive capacities of its parts and sub-processes? How can one appeal to the productivity of parts to explain the productivity of mechanisms as wholes without endorsing an overly reductionist thesis that "real causation" is all in microphysics? And, if mechanistic productivity is accounted for by the productive character of parts, what sense can be made of productivity if and when one runs out of mechanistic decompositions? The chapter will also discuss how a mechanistic approach to causation can make sense of intuitions about causal relevance. I will describe and assess standard objections to productive accounts of the nature of causation, arguing that the mechanistic account of production, in contradistinction to theories of physical production (e.g., Dowe 2000) are able to avoid problems of explanatory irrelevance and handle problems like causation by omission and disconnection.

Chapter Eight: EXPLANATION: MECHANISTIC AND OTHERWISE

In the final chapter of the book, I will explore how scientific explanation works in a world made of mechanisms. I shall argue that explanation, in its most general sense, is an activity that involves constructing models that represent dependence relations. Explanation is a matter of showing what depends upon what. I use this basic conception of explanation to address two topics that have been much discussed in the recent literature. First, I attempt to recast the debate over the so-called ontic and epistemic conceptions of scientific explanation, and to revive

Salmon's seldom-discussed modal conception of explanation. Second, I show how even in a world full of mechanism-dependent phenomena, many explanations will be neither causal nor mechanistic.

1.5 Conclusion

Our quick tour of the plan of this book may have already suggested a kind of paradox in its aims. While I have argued that recognizing the variability of mechanisms is central to overcoming our craving for generality, I offer the New Mechanical Philosophy as a highly general account of nature and of science. Even to a casual observer, it should be clear that such an effort goes against prevailing trends towards specialization both in the sciences and in naturalistic approaches to the philosophy of science. It also runs counter to much of the work of my fellow New Mechanists, who have tended to offer accounts of mechanisms, mechanistic explanation, strategies for mechanistic discovery, and so on, that are grounded in particular scientific disciplines or sub-disciplines.

In my defense, I can only repeat that there is nothing irrational in the craving for generality, so long as it is tempered with an understanding of its sources and pitfalls. Moreover the observation that the mechanisms responsible for particular phenomena are local and varied does not by itself imply that we cannot say some quite useful things about what mechanisms, in general are. This book is meant to show that there is indeed something useful that can be said generally about the character both of nature and of science. Thinking about mechanisms can help show how things, in the most general sense, hang together.

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