Introduction

There are two very different theories about how the laws of nature relate to the world. One is that they are somehow imposed on things whose identities are independent of the laws. The other is that the laws are immanent in the world, not superimposed on it. On the second theory, the laws of nature depend on the essential properties of the things on which they are said to operate, and are therefore not independent of them.

The first is the dominant world-view of modern philosophy. It is a view that was shared by Descartes, Newton, Locke, Hume, and Kant – the founding fathers of all of the major philosophical traditions of Western Europe. This view is closely associated with seventeenth- and eighteenth-century mechanism, and like mechanism, it implies that the laws of nature are contingent and operate on things that are essentially inert or passive. If things were naturally active, then they would be bound to act according to their natures, rather than as the imposed laws of nature might require. Consequently, the dominant world-view implies that what happens in the world depends essentially on what the laws of nature happen to be. It does not depend only on what kinds of things there are in the world, or in what circumstances they exist.

The second world-view is essentialism. It is the sort of theory I will be defending in this book. It is not a view that has been widely accepted in modern times. One has to go all the way back to Aristotle to find a truly notable defender of essentialism. Yet, essentialism is precisely the sort of theory that one would expect any modern scientific realist to accept. For a realist would now be hard pressed to make much sense of the passive, and intrinsically inert, world on which the laws of nature are supposed to operate. The world, according to modern science, seems not to be innately passive, but fundamentally active and reactive. It is certainly not a mecha-

nistic world of things having only the attributes of extension and impenetrability, as Descartes' and Locke's worlds were. Rather, it is a dynamic world consisting of more or less transient objects which are constantly interacting with each other, and whose identities would appear to depend on their roles in these processes.

I will assume that this appearance is also reality. Thus, I will assume that it is impossible – metaphysically impossible – for a proton or any other fundamental particle to have a causal role different from the one it actually has. The assumption is plausible, I suggest, because a proton would appear to have no identity at all apart from its role in causal processes. If this is right, then the laws concerning the behavior of protons and their interactions cannot be just accidental – that is, laws which could well have been otherwise. On the contrary, it is essential to the nature of a proton that it be disposed to interact with other things as it does. Its causal powers, capacities, and propensities are not just accidental properties of protons, which depend on what the laws of nature happen to be, but essential properties, without which there would be no protons, and which protons could not lose without ceasing to exist (or gain without coming into being). The idea that the laws of particle physics are superimposed on intrinsically passive things which have identities that are independent of the laws of their behavior thus lies very uneasily with modern science.

Scientific essentialism is proposed as a metaphysic for scientific realism which is compatible with this intuition, and also with the evident dynamism of modern science. It is not a reversion to Aristotelianism, or an attempt to resuscitate medieval views about the nature of reality. On the contrary, its origins are decidedly twentieth century. It depends, for example, on the existence of quantum discreteness in the world. For it is this discreteness at the quantum level which ultimately guarantees that there are real, ontologically based distinctions of kind in nature. That is, the discreteness of quantum reality is the generator of the real distinctions between natural kinds of substances, properties, and processes. And this fact is crucial for the viability of modern essentialism. Aristotle was able to believe in natural kinds (although he did not call them this) because of the diversity and apparent distinctness of the various animal and plant species that he knew about. But the idea that biological species are natural kinds has not survived criticism, especially in light of Darwin's theory of evolution. The new essentialism, however, is not a defense of Aristotle's theory of *biological* kinds, and does not depend on it. It depends rather on the recognition that there are hierarchies of natural *physical* kinds, formally like

the supposed hierarchies of biological species, but real kinds, nevertheless, based on quantum discreteness, and existing at a deeper level.

The distinctions between the chemical elements, for example, are real and absolute. There is no continuum of elementary chemical variety which we must arbitrarily divide somehow into chemical elements. The distinctions between the elements are there for us to discover, and are guaranteed by the limited variety of quantum mechanically possible atomic nuclei. Many of the distinctions between kinds of physical and chemical processes are also real and absolute. There is no continuum of processes within which the process of β-emission occurs, and from which it must be arbitrarily distinguished. The world is just not like that. At a fundamental level, the processes that occur often allow real and absolute distinctions of kind to be made. Therefore, if there are natural kinds of objects or substances, as I believe there are, there are also natural kinds of events and processes.

Scientific essentialism is thus concerned with natural kinds, which range over events or processes, as well as with the more traditional sort, which range only over objects or substances. The natural kinds in these two categories evidently occur in natural hierarchies. At the apex of the hierarchies, I postulate that there are two very general natural kinds. The most general natural kind in the category of substances includes every other natural kind of substance existing in the world. This is the global kind, for our world, in the category of substances. It defines the range of natural kinds of objects or substances that can exist in our world. The most general kind in the category of events is the global kind, which includes every other natural kind of event or process which occurs in the world. This global kind effectively defines the range of kinds of events or processes that can occur in our world.

At the bases of these two hierarchies are the infimic species of objects and events. These are species that have no sub-species, and whose members are therefore essentially identical. To illustrate: The most fundamental particles that we know about are plausibly members of infimic species in the hierarchy of natural kinds of substances. In the hierarchy of natural kinds of events, the infimic species are plausibly just quantitatively identical natural kinds of events or processes. These infimic species have all of the formal characteristics of classical universals, except that they range over different kinds of things. I call them *substantive* and *dynamic* universals, respectively, in order to distinguish them from each other, and also from the more usual *property* universals, whose instances are tropes, or property instances.

I postulate that the world itself is a member of a natural kind that is distinguished from worlds of all other kinds by the global natural kinds of objects or events, to which it is host, and by its fundamental ontology of objects, events, and properties. If this is right, then the most general laws of nature can be seen to arise from the essential properties of these most general natural kinds of objects and events. The more specific laws of nature – the causal laws and the laws defining the structures of the natural kinds of substances that exist in the world – might then be seen as deriving from the essential properties of the more specific kinds of substances and events occurring in the world. According to scientific essentialism, therefore, all of the laws of nature, from the most general (for example, the conservation laws and the global structural principles) to the more specific (for example, laws defining the structures of molecules of various kinds, or specific laws of chemical interaction) derive from the essential properties of the object and events that constitute it, and must hold in any world of the same natural kind as ours.

Scientific essentialism challenges orthodoxy in philosophy in a number of ways. It requires us to believe that there are ontologically irreducible causal powers in nature – dispositional properties that define the causal roles of their bearers. In the standard Humean view, dispositional properties are all ontologically dependent on the categorical (non-dispositional) properties of things, and on what the laws of nature happen to be. They cannot therefore be fundamental properties, but must supervene on an underlying categorical reality. But, according to scientific essentialism, there are causal powers in nature, and some of them are ontologically primary. They do not depend on what the causal laws of nature happen to be. On the contrary, the causal laws just describe the natural kinds of processes involved in their display.

Scientific essentialism also requires us to reject the thesis known as Humean Supervenience – the thesis that all modal properties (for example, natural necessity, natural possibility, objective probability, and so on) supervene on non-modal properties. This thesis derives its plausibility from the Humean conception of reality as consisting of "atoms in the void" – of self-contained atomic objects or states of affairs that are located in space and time, and succeeding one another in ways determined by the laws of nature. The intuition to which this conception naturally gives rise is that if one can say which objects possessing what intrinsic qualities exist at which points in space and time, then one can describe the world completely. Therefore, any properties that describe what a thing must or might do in given circumstances must supervene on those that describe

things as they are in themselves. That is, there could not be two worlds that are identical in respect of all non-modal properties that nevertheless differed in respect of modal properties.

If one accepts the Humean Supervenience thesis, then the problem of explaining what modal properties are, or what makes statements attributing such properties to things true, becomes acute. Some Humeans have gone to quite extraordinary lengths to accommodate them, interpreting all modal statements as claims about relationships holding between possible worlds. But since every possible world, according to Humeanism, is a world without modal properties, it is hard to see how this is supposed to solve the problem. A universe of worlds without modalities is a universe without causal powers. Scientific essentialists simply reject the Humean conception of reality, and the Supervenience Thesis that it entails. From the perspective of scientific essentialism, the world is not an agglomeration of logically independent states of affairs or self-contained atoms of any other kind. The world consists ultimately of things that have their causal powers essentially that determine what they can, must, or cannot do in relation to other things.

The causal powers of things are displayed in processes belonging to natural kinds. Processes of these kinds can only be brought about by appropriate activating events or circumstances, and what is essential to them as processes is precisely that they are the actions of such properties in such circumstances. There is therefore a close link between natural kinds of processes, causal powers, and the circumstances of their display. Specifically, if anything has a given causal power, then it must be disposed to act in the appropriate way in the appropriate circumstances. Moreover, if anything has this power essentially, then it is necessarily the case that it will be disposed to act in this way in circumstances of this kind.

It is one of the aims of physical science to discover and to describe the inherent causal powers of things. For these powers are the truth-makers for those laws of nature that are generally known as causal laws. Causal powers thus have a very important role in the world, for they are the sources of the immanent causal laws of nature.

The causal powers of an object are those of its properties that determine how it is disposed to behave. These properties are all essentially dispositional. That is, their identities depend on the dispositions they underpin. For any specific causal power, there is a range of possible displays, normally related by a probability function from the state of the object that possesses it, and the properties of the circumstances in which it can be activated. The range of possible ways in which a given causal power

can act then defines a natural kind of process. For there is no process, however similar in appearance, that is a process of this kind but is not an action or display of this causal power. Causal powers and the natural kinds of processes that are their displays thus go hand in hand, and are interdefinable.

The possible displays of any given causal power are all processes that are essentially similar in their structure and that differ from each other only in ways that lie within the permitted range variation for the kind of process concerned. The causal powers of an object are thus the real essences of the causal processes that can occur when that object acts causally. The gravitational mass of an object, for example, is the dispositional property it has that determines its causal role in generating gravitational fields, and hence the effects it has on other objects immersed in these fields. The charge on an object is the dispositional property it has that determines its causal role in generating electromagnetic fields, and hence the effects it has on other objects that are in or moving through these fields. Therefore, if anything, say a fundamental particle, has a certain mass and a certain charge essentially, then it must generate such fields in any world in which it might exist, and have precisely the same effects on things of just the same kinds.

The fact that the causal laws all ultimately depend on the causal powers of things belonging to natural kinds, and the manners and circumstances of their displays, has many implications. First, it implies that these laws of nature are metaphysically necessary. Since they are immanent in the world, the laws of nature cannot be changed, without the world itself being changed. And things of the kinds that do exist in this world could not exist in any other world in which the laws of nature affecting them are supposed to be different. Second, it implies that causal laws can only be found in areas concerned with natural kinds of objects, properties, or processes. Consequently, there are no laws of nature to be found in the social or human sciences, not even in economics. Third, it implies that the laws of nature are not just observable regularities. For natural processes are normally superimposed one on top of another, and to say anything sensible about any of them, they need to be separated, at least in thought. Therefore, the laws of nature, which are concerned with the description of natural kinds of processes, must often be expressed abstractly with reference to idealized objects in ideal circumstances.

This book will elaborate and defend a modern essentialist metaphysic, based on an ontology of natural kinds of objects, properties and processes.

This ontology will be developed in Chapter 2. As a metaphysic, it stands opposed to some widely held views about the nature of reality. These views mostly derive from the common seventeenth- and eighteenth-century belief in the essential passivity of matter. It is a view which is still widely held by English-speaking philosophers. Somewhat ahistorically, I call the metaphysic that derives from this belief, "Humeanism." Humeanism will not be the subject of any one chapter or section of the book, but will come under attack, in one way or another, throughout. For my aim is to present a comprehensive metaphysic that can be seen as an alternative to Humeanism.

As well as holding that matter is essentially passive, Humeans generally subscribe to the following theses:

1. That causal relations hold between logically independent events.
2. That the laws of nature are behavioral regularities of some kind that could, in principle, be found to exist in any field of inquiry.
3. That the laws of nature are contingent.
4. That the identities of objects are independent of the laws of nature.
5. That the dispositional properties of things are not genuinely occurrent properties – which would have to be the same in all possible worlds – but are somewhat phoney world-bound properties that depend on what the laws of nature happen to be.

Against these theses, I will argue for the view that nature is active, not passive, and that:

1. Causal relations are relations between events in causal processes. If an event of a natural kind that would activate a given causal power in a certain way occurs, an event of a natural kind which would then be an appropriate display of that power must also occur (even though the effect may sometimes be masked by other effects).
2. The laws of nature are not just behavioral regularities, although they imply the existence of underlying patterns of behavior, but descriptions of natural kinds of processes arising from the intrinsic properties of things belonging to natural kinds. There are, accordingly, no laws of nature in fields such as sociology or economics.
3. The laws of nature are not contingent, but metaphysically necessary. The same things in the states in which they currently exist would have to have the same behavioral dispositions in any world in which they might exist.
4. The identities of objects are not independent of the laws of nature. If the laws of nature were different, the things existing in the world would have to be different.

5. There are natural dispositional properties that are genuinely occurrent, and which therefore act in the same ways in all possible worlds. These include the causal powers of the most fundamental kinds of things, so that things of these same kinds, existing in any other world, would be disposed to behave in just the same ways.

In Chapter 1, I will develop some of the machinery that will be required for essentialist analysis, and elaborate on some of the themes to be developed in the book. The aim of this chapter is to set the stage for what is to follow. Most of the issues raised in this chapter will be taken up again and more thoroughly investigated in later chapters. Some of the concepts will no doubt be familiar to readers, and may be passed over fairly quickly. But others will not be. The causal concept of intrinsicality, for example, is non-standard. It is nevertheless one of the basic concepts of the essentialist framework, and it is one which science itself could not do without. The essential properties of things belonging to natural kinds are all intrinsic in the causal sense of intrinsicality, and they are the key to understanding what the truth-makers for the laws of nature are. They include such properties as causal powers, capacities, and propensities.

Chapter 2 describes the ontology that is suggested by the natural-kinds structure of the world. It is an ontology that includes hierarchies of natural kinds of objects, processes, and properties. It is not argued here that this hierarchy is irreducible. A more frugal ontology of some kind may be viable, or more useful in other ways. However, I am more concerned with explanatory adequacy than frugality. A good ontology should provide insight into, or offer some kind of explanation of, the salient general features of the world that have been revealed to us by science. One of these is surely the hierarchical structure of laws. Another is the hierarchical structures of natural kinds of objects, processes, and properties. One would therefore expect a good ontology to recognize the existence of these hierarchical structures, and a good metaphysic to link these two general features of reality in some way – which is precisely what scientific essentialism does.

Two important concepts required for the construction of any ontology are those of *ontological dependence* and *ontological reduction*. These concepts are developed and applied systematically to explain the relationships of ontological dependence between species in any given hierarchy. Interestingly, the required concepts imply that quantities and other generic universals are not ontologically dependent on their infimic species, as many have supposed must be the case, but rather the other way around. Specific quantitative universals are ontologically dependent on the generic quan-

titative universals of which they are species. Some, especially those who fail to distinguish clearly between infimic species and instances, may find this result surprising. However, while the existence of the genus plausibly depends on the existence of some instance of some infimic species, the existence of the genus does not depend on the existence of any particular infimic species. If this is right, it explains the primacy of quantities in laws of nature, and the relative unimportance of specific quantitative measures of things.

Chapter 3 begins the process of articulating a more active role for the things in the world in determining what the laws of nature are, and hence how things are naturally disposed to behave. The chapter contains a defense of the somewhat heretical view that there are genuinely occurrent dispositional properties in nature, as well as categorical ones. The arguments of the categorical realists and other Humeans that dispositional properties are world-bound, and depend on what the laws of nature happen to be in any particular world, are countered. Some dispositional properties, it is argued, are at least as fundamental as any categorical properties, and are plausibly essential properties of some of the things that have them. The thesis to be defended is one that we called "dispositional essentialism," and was defended in a paper (1994a) by Caroline Lierse and me with this title. There are genuine dispositional properties, we argued; and these are not properties that things have because of what the laws of nature are. Rather, the laws of nature are what they are, we contended, because things of various kinds have the dispositional properties they have essentially. That is, they would not be things of the kinds they are if they lacked these properties. Consequently, they would not be things of the kinds they are if they were not disposed to behave as the relevant laws require.

The view that things have causal powers of various kinds is not new to science. Such properties are presupposed in all causal explanations. It is of course possible that causal explanations might be reduced somehow to explanations of other kinds. They might, compatibly with Humeanism, be just covering-law explanations in disguise. But most scientists, I imagine, believe in causality, or would at least agree that some events may make other events objectively more likely. The search for causal mechanisms is indeed founded on this assumption.

In Chapter 4, I argue that wherever we are concerned with explaining the behavior of anything qua member of a natural kind, the search for causal mechanisms takes a particular form. It becomes a search aimed at discovering the real essence of the kind in question. What is the structure or composition of the kind, in virtue of which it is a member of this kind,

and what causal powers does it have in virtue of its having this structure? Explanations that answer these questions I call *essentialist explanations.* They are essentialist because if they are true, they are necessarily true. A substance could not be a substance of the kind it is if it did not have this structure or these powers. The explanations of the chemical kinds are manifestly explanations of this sort. Insofar as these explanations are successful, they not only distinguish the chemical kinds from each other, they also explain the specific causal laws involving them.

At the most fundamental level of physical inquiry, it may be that the search for structure must drop out. For it may be that the most fundamental things have no structure, and therefore no structure in virtue of which they have the powers they have. In that case, we may have to distinguish between natural kinds solely on the basis of their causal powers. In other words, there may be causal powers that lack even a partial categorical basis. If this is so, then so be it. I see no objection other than David Armstrong's Meinongian one to this possibility (considered at the end of Chapter 3).

It is a corollary of this essentialist theory of explanation in the natural sciences that there can be no essentialist explanations constructed in any field where the subject matter is not naturally divided into kinds. Consequently, there can be no genuine causal laws in any of these areas. That is, there can be no proper causal laws of history or sociology or anthropology, a conclusion with which few would disagree. There is, however, a sophisticated body of theory – economic equilibrium theory – which bears most of the hallmarks of a genuine scientific theory, but is evidently concerned with social institutions that are not very plausibly members of natural kinds. So this branch of economic theory presents something of a test case for scientific essentialism. If the laws of nature derive from the essential properties of natural kinds, as the scientific essentialist maintains, then there ought not to be any genuine laws of economics. This challenge is taken up in Chapter 5, where it is argued that the so-called laws of economics have a status similar to that of the axioms of Euclidean geometry. They are true by definition or convention, and so have only a kind of *de dicto* necessity.

Chapter 6 begins a more focused discussion of the laws of nature. Laws are classified on the bases of scope and role. There are global laws which apply to all events and processes of the kind that can occur in our world, and the general structural principles that set limits to the kinds of structures that can exist in our kind of world. These laws are of the widest possible scope. There are also the structural laws, which pertain to specific