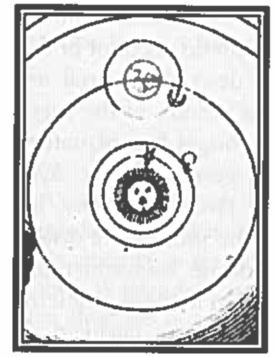
16. This line of criticism is also advanced in J. Alberto Coffa, "Hempel's Ambiguity," *Synthese* 28 (1974): 141–63.

17. This criticism originated with Paul Humphreys. See his "Why Propensities Cannot Be Probabilities," *Philosophical Review* 94 (1985): 557–70.

18. Wesley C. Salmon, *Scientific Explanation and the Causal Structure of the World* (Princeton, N.J.: Princeton University Press, 1984), chs. 1 and 4.



# 7 | Laws of Nature

## INTRODUCTION

Laws play a central role in scientific reasoning. As we saw in chapters 1 and 4, some philosophers of science think that using laws to explain things is an essential part of what it means to be genuinely scientific, and support for the view that scientific explanation must involve laws is widespread (though not unanimous). Many also believe that we are justified in trusting scientific inferences because these predictions rest, in part, on well-confirmed laws. Our expectations about the behavior of systems, instruments, and materials are reasonable to the extent that they are based on a correct understanding of the laws that govern them. Undoubtedly, much scientific activity is devoted to discovering laws, and one of the most cherished forms of scientific immortality is to join the ranks of Boyle, Newton, and Maxwell by having a law (equation or functional relation) linked with one's name. But despite the crucial importance of laws in science, it is difficult to find a general account of what sort of things laws are that can do justice to everything we take to be true of them.

In this chapter, two important and influential ways of understanding laws—the regularity approach and the necessitarian approach—will be discussed and criticized.[1] In terms roughly hewn, the regularity approach says that laws describe the way things actually behave, that they are nothing more than a special kind of descriptive summary of what has happened and what will happen. The necessitarian approach insists that laws are more than just summaries, that they tell us not merely how things actually behave, but, more importantly, how they must behave. For the necessitarians, both the universality and the necessity of laws are objective, real features of the world (although necessitarians disagree among themselves about the nature of that necessity).[2]

Modern adherents of the regularity approach trace their origins back to David Hume and his constant-conjunction analysis of causation. In "What Is a Law of Nature?" A. J. Ayer gives a sympathetic account of the epistemological considerations that drove Hume to deny that causal necessity is objective and hence to espouse the simple version of the regularity theory of laws. According to this simple version, a law of nature is nothing more, objectively, than a true universal generalization. Ayer explains the severe problems that afflict the simple Humean theory, including the problem of laws that lack instances and the problem of distinguishing between those generalizations that are genuine laws and those that are true merely by accident. Ayer's tentative solution to these problems is to add epistemic conditions to the regularity analysis of lawlikeness. Thus, according to Ayer's epistemic regularity theory, a law is a true universal generalization about which we have certain beliefs and attitudes and that plays a characteristic role in science.

In "Laws of Nature," Fred Dretske deals what he considers a lethal blow to Ayer's epistemic regularity theory. In its place, Dretske advocates a theory according to which laws are (express or describe) relations of necessitation between universals. Thus, instead of regarding laws as generalizations about events, Dretske regards them as singular statements about the properties events share. Dretske shows how his universals theory of laws can solve several of the difficulties facing the regularity theory.

Like other recent advocates of the universals theory of laws, and unlike earlier proponents of the necessitarian approach, Dretske insists that laws of nature are contingent, not necessary. This creates difficulties for Dretske's theory, since it requires that the nomic necessitation relation between universals hold contingently, not necessarily, and it is hard to see how merely contingent relations could obtain among abstract entities such as universals. One possible response to this problem is suggested by Saul Kripke and Hilary Putnam, who use their new theory of reference to argue that many laws of nature are not contingent but metaphysically necessary. D. H. Mellor criticizes the Kripke-Putnam argument in "Necessities and Universals in Natural Laws." Mellor also attacks the universals theory on the grounds that it cannot accommodate laws that have no instances. In this way, Mellor attempts to cast the regularity theory in a more favorable light by revealing the deficiencies of its rivals.

Despite their disagreement about whether laws involve an element of necessity, the regularity and necessitarian approaches share the conviction that laws of nature describe important facts about reality. That realist assumption about laws is challenged by Nancy Cartwright in the final piece in this chapter. In "Do the Laws of Physics State the Facts?" Cartwright argues that most of the laws physicists use to explain things are not even approximately true. They are false and are known to be false. Nonetheless, they provide excellent explanations. Cartwright argues that there is an irreconcileable tension between the goal of accurate description and the



goal of explanation. When lawlike statements are altered to make them describe the way bodies actually behave, they lose their explanatory power.

## Notes

1. An older approach to understanding laws of nature—instrumentalism—has largely fallen into disfavor (though Ronald Giere and Bas van Frassen have recently made attempts to revive it). Instrumentalists (such as Ernst Mach, Karl Pearson, Ludwig Wittgenstein, and Stephen Toulmin) hold that laws are neither true nor false; they are simply tools that scientists use to summarize data and to make inferences. Gilbert Ryle once described this view by characterizing laws as "inference tickets." According to instrumentalists, neither the necessity nor the universality of laws are objective features of the world; both are human inventions that we impose on the world for the purposes of representation and prediction. The main problem with instrumentalism is that, if laws are neither true nor false, then it is difficult to make sense of their being tested, confirmed, and refuted. See Ronald N. Giere, "The Skeptical Perspective: Science without Laws of Nature," in *Laws of Nature: Essays on the Philosophical, Scientific and Historical Dimensions*, ed. Friedel Weinert, (New York: Walter de Gruyter, 1995), 120–38; Bas C. van Fraassen, *Laws and Symmetry* (Oxford: Clarendon Press, 1989); and Alan Musgrave, "Wittgensteinian Instrumentalism," *Theoria* 47 (1981): 65–105.

2. Regularity theorists (of different types) include A. J. Ayer, R. B. Braithwaite, Rudolf Carnap, Richard Feynman, Carl Hempel, Ernest Nagel, Hans Reichenbach, Norman Swartz, and Peter Urbach. Necessitarians (of different types) include D. M. Armstrong, John Bigelow, John Carroll, Fred Dretske, W. C. Kneale, Christopher Swoyer, and Michael Tooley. See the bibliography at the end of this volume for references.

## 7 | Commentary






# 7 | Commentary


## 7.1 | The Regularity Theory: Ayer and Hume

A. J. Ayer defends a version of the regularity theory of laws in his article, "What Is a Law of Nature?" As Ayer notes, the regularity theory has its origins in David Hume's analysis of causation.

### Hume on Causation

In his *Treatise of Human Nature* (1739), David Hume (1711–76) advocated what is called the *constant-conjunction* (or *regularity*) *theory of causation*. According to Hume, the claim that one event, *a* (of type *A*), caused another event, *b* (of type *B*), means only that *A*-events are, as a matter of empirical fact, always followed by *B*-events. (From now on, we shall refer to events of type *A* simply as *A*s and to events of type *B* as *B*s.) Objectively speaking, the causal relation between *a* and *b* is nothing more than the constant conjunction of *A*s and *B*s. If *A*s always have been and always will be followed by *B*s, then *A*s cause *B*s and, in particular, *a* caused *b*. Hume denied any objective necessity "out there in the world" between *A*s and *B*s in virtue of which *A*-events produce *B*-events or make *B*-events occur. Our conviction that effects do not merely happen to follow causes but in some sense must necessarily occur given the appropriate cause results from a purely subjective feeling in our minds when we experience an *A* (or imagine an *A*) and expect a *B* to follow. Thus, on Hume's view, we regard *A*s as the cause of *B*s when past experience has induced in us the expectation that *A*s will always be followed by *B*s in the future.

Hume's constant-conjunction theory stands our commonsense view of causation on its head. For, typically, we think that we first discover the fact that *A*s causally necessitate *B*s, and then, on the basis of that discovery, understand why *A*s have always been followed by *B*s and predict that *A*s always will be followed by *B*s. As Ayer explains, part of the case for Hume's radical reversal of our usual thinking about causality rests on his skeptical, empiricist analysis of the idea of necessity. If there is a necessary connection between causes and their effects, then the necessity is either logical or nonlogical. Hume denies that the connection can be logical. If it were logical, then effects could be deduced from causes and we could know, prior to experience, that one kind of event (the cause) must invariably be associated with another kind of event (the effect). But no such deduction and no such a priori knowledge of effects is possible. For any cause, it is logically possible that its usual effect not follow it; moreover, our knowledge of causal relations is derived solely from experience. Thus, Hume and Ayer argue that the kind of necessity involved in causation cannot be logical.

Curiously, Ayer does not then consider Hume's case against the second alternative, namely that some kind of nonlogical necessity links causes with their effects. Hume's argument here is epistemological.[1] He considers the two sources most commonly claimed as the origin of our idea of causal necessity—namely, perception and the will—and argues that neither gives us any experience of necessity. When Hume examines his perceptual experiences, he cannot find in them any element (what Hume calls "an impression") of necessity. For example, when one billiard ball collides with another, what we literally see, according to Hume, is simply one motion followed by another, not the first ball making the second ball move. With regard to the willing of our actions, Hume denies that we know, independently of experience, which acts of will must be followed by which actions. Indeed, we are completely ignorant of the immediate effects of willing (presumably it is some change in the brain that then causes impulses to be transmitted by our nerves to our muscles), and only by experience do we learn which parts of our bodies we can control and which we cannot. As the possibility of sudden paralysis demonstrates, there is no logical or physical guarantee that a particular act of willing will be followed by a particular motion of one's body.

Having failed to locate any impression of necessity in either our perceptual experiences or in our ability to will actions, Hume concludes that the source of our idea of nonlogical necessity must be purely subjective. Hence, Hume sees nonlogical necessity as an imaginative fiction, something originating from our patterns of inference and expectation, which we then project onto nature and mistake for something objective.

So much by way of background in Hume's theory of causation: let us return to laws. The regularity theory of laws is often called the *Humean theory* because it, too, denies that any sort of objective nonlogical necessity connects the items appearing in a law. In its simplest form, the regularity theory says that laws of nature are nothing more than true universal generalizations. If it is a law that all copper conducts electricity, then what makes it a law is the fact that all pieces of copper, past, present, and future, conduct electricity. If it is law that all metals expand when heated, then it is a law because, as a matter of fact, that is how all metals always behave. According to the regularity theory, the objective content of laws is exhausted by what actually happens in the world.

## The Problem of Vacuous Laws

There are a number of serious problems with the simple version of the regularity theory of laws. These problems are discussed by Ayer, and briefly by Dretske and Mellor, in the readings in this chapter. First, there is the problem of avoiding what Ayer calls "vacuous laws." Modern logicians regard the generalization "All *A*s are *B*s" as logically equivalent to "It is false that there is an *A* that is not a *B*." Thus, "All copper conducts electricity" is true if and only if it is not the case that there is a piece of copper that is not a conductor. If we translate the same generalization using predicate logic, then we get $(x)(Cx \supset Ex)$. Literally, for any $x$, if $x$ is copper, then $x$ conducts electricity. But just as before, this generalization is logically equivalent to the statement "it is not the case that there is a piece of copper that is not a conductor." In symbols we would write $\sim(\exists x)(Cx \,\&\, \sim Ex)$: it is not the case that there exists any $x$, such that $x$ is copper and $x$ is not a conductor. Now the important point to notice is that if, as a matter of fact, there is no copper in the universe, then it automatically becomes true that it is not the case that there is a piece of copper that is not a conductor. But this last statement is logically equivalent to the generalization "All copper conducts electricity." According to the simple version of the regularity theory, laws are true universal generalizations. Thus, any generalization that is automatically true simply because there are no instances of its antecedent is a law. For example, according to the simple version of the regularity theory, it is a law that all perpetual motion machines weigh ten tons, that all mermaids contain chlorophyll, and that all particles traveling faster than light are red. Clearly, this is absurd. How can the regularity theorist avoid the problem of vacuous laws?

The most obvious response is to add a further condition, an existential condition, to the regularity analysis: a true universal generalization is a law provided there actually are objects satisfying the generalization. In symbols, "All *C*s are *E*s" is a law if and only if $(x)(Cx \supset Ex) \,\&\, (\exists x)(Cx)$. This eliminates the counterexamples mentioned in the previous paragraph, since there are no mermaids, perpetual motion machines, or particles traveling faster than light. Hence, on the amended regularity analysis, no vacuously true generalizations will qualify as laws.

## The Problem of Noninstantial Laws

Despite the advantage of modifying the regularity theory to avoid the problem of vacuous laws, Ayer and many other regularity theorists argue that the existential condition is too strong, because it rules out some of the most important laws in science. The classic example is Newton's first law of motion, which states the principle of rectilinear inertia:

> All bodies on which no net external force is acting either remain at rest or move at uniform velocity in a straight line.

Now it seems reasonable to assume that, since all bodies exert a gravitational pull on all the other bodies in the universe, no bodies are ever free from net external forces. Nonetheless, scientists accept Newton's first law not because it lacks instances but because it expresses an important truth about the world. Newton's first law is thus an example of a nonvacuous but noninstantial law. Here are some other examples of nonvacuous noninstantial laws: if two perfectly elastic bodies were to collide, the total kinetic energy of the system would be the same before and after the impact (discussed by C. D. Broad in the article referred to by Ayer); in a perfectly reversible process, the entropy remains constant; all lumps of plutonium weighing more than one million tons conduct electricity.

The natural inclination is to handle noninstantial laws in terms of subjunctive or counterfactual conditionals, that is, in terms of how objects of a certain kind would behave if there were such objects. But this approach does not seem to be open to the regularity theorist. For regularity theorists take statements of law to describe how actual objects behave, not how possible objects would behave if, contrary to fact, they were to exist.

Broad's proposal (reported by Ayer) for reconciling noninstantial laws with the regularity theory suggests that we distinguish ultimate laws of nature from derivative laws. Thus, all ultimate laws are taken to be instantial, but laws derived from one or more such ultimate laws may not be. Consider, for example, Newton's second law:

> If a net force, $F$, acts of a body of mass, $m$, then the body experiences an acceleration, $a = F/m$.

We can derive Newton's first law from his second law on the supposition that no net force is acting on a body. For according to Newton's second law, if the net force on a body were zero, then the acceleration of the body would also be zero. So Newton's first law is a noninstantial, derivative law because it can be derived from the instantial, ultimate second law. Similarly, there are ultimate, instantial laws of impact and motion which entail the nonvacuous, noninstantial law that, if two perfectly elastic bodies were to collide, kinetic energy would be conserved. But as Ayer notes, even if we could always find ultimate laws that would reconcile noninstantial laws with the regularity theory, that theory would still encounter severe problems with what are sometimes called *functional laws*.

### The Missing-Values Problem for Functional Laws

Functional laws assert a functional relation between two or more variables in the form of a mathematical equation. For example, Hooke's law, $F = kx$, says that the force, $F$, exerted by a spring is directly proportional to $x$, the amount the spring is stretched. Similarly, Hubble's law $V = HD$, says that the velocity, $V$, with which galaxies are moving away from each other is directly proportional to $D$, their distance apart. The ideal gas law, $PV = nRT$, asserts that the pressure times the volume of $n$ moles of gas is proportional to the absolute temperature of the gas. In all these functional laws, the magnitude of the variables range over an infinite number of values only a small finite number of which will ever be realized. For example, no gas will actually be heated to all possible temperatures, nor will every spring be stretched to all possible lengths. Nonetheless, the ideal gas law tells us what the pressure of the gas would be at a temperature of 1 million degrees, and Hooke's law says what force a spring would exert if it were stretched to a hundred times its normal length. Thus, the missing values problem leads us inexorably to using subjunctive conditionals to express the content of laws in counterfactual situations. Once again, the problem for the regularity theorist is making sense of these counterfactual conditionals while still regarding laws as descriptions of what actually happens in the world.



### The Problem of Accidental Generalizations

Closely related to the missing-values problem for functional laws is the more general difficulty of distinguishing between genuine laws and so-called accidental generalizations (what Ayer calls "generalizations of fact" as contrasted with "generalizations of law"). Consider one of Fred Dretske's examples. Suppose that, as a matter of brute fact, the only dogs that have been or ever will be born at sea are cocker spaniels. Thus, "all dogs born at sea are cocker spaniels" emerges as a true, universal generalization. But, clearly, we would not on this basis predict that, if the dog on board our ship were a dachshund, then she would give birth to cocker spaniel puppies. Our expectations about this and other counterfactual situations depend, not on accidental generalizations, but on genuinely lawful ones. We rely on the biological law that purebred dogs produce dogs of the same breed (at least, when mated with dogs of the same breed). But the simple version of the regularity theory cannot distinguish between those universal generalizations that are laws and those that are not. So the simple version of the regularity theory is inadequate.

## 7.2 | Ayer's Epistemic Regularity Theory

Because of the difficulty in distinguishing between laws and accidental generalizations, most proponents of the regularity theory advocate a more sophisticated version of the theory according to which laws are true, universal generalizations with some additional features. As Ayer puts it, "the difference between our two types of generalization lies not so much on the side of the facts which make them true or false, as in the attitude of those who put them forward" (822). In his paper "Laws of Nature," Dretske summarizes the sophisticated version of the regularity theory with the formula law = universal truth + X,

where the usual candidates for X include:

- our willingness to use the generalization in question to make predictions, especially about counterfactual situations;
- our acceptance of the generalization as well confirmed even though we have examined only a relatively small, finite number of its instances;
- the role that the generalization plays in a deductively organized system of (scientific) statements; and
- our recognition that the generalization (unlike a mere generalization of fact) explains its instances.

Because all of these candidates for X involve our beliefs and epistemic attitudes, this sophisticated version of the regularity theory is often called the *epistemic regularity theory*. Ayer's own proposal falls into this category. In Ayer's own words:

> Accordingly I suggest that for someone to treat a statement of the form 'if anything has Φ it has Ψ' as expressing a law of nature, it is sufficient (i) that subject to a willingness to explain away exceptions he believes that in a non-trivial sense everything which in fact has Φ has Ψ (ii) that his belief that something which has Φ has Ψ is not liable to be weakened by the discovery that the object in question also has some other property X, provided (*a*) that X does not logically entail not-Ψ (*b*) that X is not a manifestation of not-Ψ (*c*) that the discovery that something had X would not in itself seriously weaken his belief that it had Φ (*d*) that he does not regard the statement 'if anything has Φ and not-X it has Ψ' as a more exact statement of the generalization that he was intending to express. (824)

### Dretske's Criticism of Ayer's Theory

As Ayer himself acknowledges (in his concluding paragraph), his proposal completely ignores the missing-values problem for functional laws. Even more striking is Ayer's candid admission that his proposal cannot be construed as an attempt to define what laws are. A definition of a concept would give both necessary and sufficient conditions, but Ayer offers only sufficient conditions for lawlikeness. In other words, Ayer recognizes that many things could turn out to be laws, even though they fail to satisfy his conditions. As he says, "I do not claim that to say that some proposition expresses a law of nature entails saying that someone has a certain attitude towards it; for clearly it makes sense to say that there are laws of nature which remain unknown" (824).



Ayer's candid admission about the limitations of his epistemic regularity analysis of laws—that is, its inability to countenance the existence of unknown laws—is a powerful objection to the whole approach. Dretske thinks the objection is decisive. As long as X includes factors that refer essentially to human beliefs, attitudes, and practices, the epistemic regularity approach entails that there are no unknown laws. As Dretske sees it, the epistemic regularity approach has confused an epistemological issue (why we believe something is a law of nature) with an ontological issue (what sort of thing a law of nature is). A more promising approach, in Dretske's view, is to address the ontological issue directly. First we should understand what laws of nature are and then (but only then) explain why we adopt towards them the attitudes that we do.

## 7.3 | Dretske's Universals Theory

Dretske proposes a necessitarian analysis of laws. (Similar proposals have been defended by D. M. Armstrong and Michael Tooley.) Dretske thinks that the law that we would usually express by saying "All *F*s are *G*" really has the form

$$F\text{-ness} \rightarrow G\text{-ness},$$

where *F*-ness and *G*-ness are the properties of being *F* and *G*. The term *F-ness* refers to a universal, the property a thing must have in order to be *F*. Dretske suggests that we read the connective "→" as "yields" or "brings with it." (Tooley calls it "nomic necessitation," and Armstrong usually calls it "necessitation.") The Dretske-Armstrong-Tooley approach is called the *universals theory* because it regards laws of nature as being fundamentally about relations between universals (properties). Statements of laws of nature, on this view, are not universal generalizations about particulars but singular statements about universals.

Notice here one prima facie advantage the universals theory might, on a certain view of universals, be thought to have over the regularity theory. Adherents of the regularity view had difficulty explaining why laws, which are taken only to describe the way objects are, nevertheless support their counterfactuals. On the universals theory laws can support contrary-to-fact possibilities because universals are taken to be properties that can be variously possessed, or not, by objects that do, or could, exist. Given a law expressing (for example) the relation between electrical charge and magnetic field, we might reasonably go on to speak of the magnetic properties of vertebrates if they were electrically charged; likewise, if laws do indeed express relations among universals, we might reasonably state how a body would behave if, contrary to fact, no net force were acting on it.

## Extensions and Intensions

One of the keys to understanding the universals theory of laws is to appreciate the difference between the *extension* and the *intension* of a predicate. A predicate is any term that, like an adjective, can be used to describe a thing. For example, the words *cat*, *elastic*, and *copper* are all predicates. The extension of a predicate is the set of objects (animals, regions of space) to which the term correctly applies. For example, the extension of *cat* is the set of all the objects that the term *cat* denotes, namely all the cats in the world.

It is more difficult to explain what the intension of a term is, and philosophers have differed in their accounts of it. The basic idea is that the intension of a predicate is its meaning (or what Mill called its *connotation*). The intension of *cat* is whatever the term *cat* means—the property of felinicity if you like or, perhaps, the concept of catness. It is evident that two terms can mean different things (i.e., have different intensions) but apply to exactly the same set of objects (i.e., have the same extension). For example, all mammals (even whales and porpoises) have hair somewhere on their bodies, and mammals are the only animals that have hair. So the terms *mammal* and *hairy* (in the sense of having at least some hair) are coextensive, since they pick out the same group of objects. But clearly the intensions of these terms are different. Even though all and only mammals have hair, the term *mammal* does not mean *hairy*.

Now, suppose that it is a law of nature, a biological law, that all mammals have mammary glands. (It is biologically necessary for mammals, which suckle their young, to have milk-secreting glands.) If it is a universal truth that all mammals have mammary glands, then it must also be a universal truth that all Ys have mammary glands, where Y is any term that is coextensive with *mammal*. So, in particular, it is a universal truth that all hairy animals have mammary glands. But, as Dretske points out, from the fact that "All mammals have mammary glands" is a law and *hair* is coextensive with *mammal*, it does not follow that it is a law that all hairy animals have mammary glands. Laws, on Dretske's account, are *opaque* in a way that normal statements about universals may not be: statements that we can deduce from laws by the substitution of terms will themselves be laws only if the terms in question have the same intension. As Dretske puts it, "laws imply universal truths, but universal truths do not imply laws" (830).

## Dretske's Necessitarian View

One of the subtleties of Dretske's universals theory, which distinguishes it from earlier necessitarian analyses of laws, is the contrast he draws between treating laws as intensional relations between extensions and treating them as extensional relations between intensions. Many necessitarians in the



past have espoused the first position. That is, they have supposed that laws are opaque because of the special, intensional, nature of the relation connecting the extensions of terms in statements of laws. Thus, on this older necessitarian view, the reason for the lawlike character of "all copper conducts electricity" is the special strong relation of (nonlogical) necessitation connecting things that are copper to things that conduct electricity. On Dretske's alternative view, there is no need for such a special strong relation of necessitation. The items linked by the law are not physical objects or events but properties (universals, intensions). According to Dretske, a law asserts that one property (an intension) is invariably associated with another property (another intension). As long as one were to substitute another term that picks out the same property in a lawlike statement, the new statement thus generated would also be a law. When we construe terms intensionally (as denoting properties), they will be coextensive whenever they denote the same property. Thus, on Dretske's view, the relation symbolized by "$\rightarrow$" is extensional, while the things linked by the relation (namely properties, universals) are intensional.

We can summarize the difference between the two brands of necessitarianism by contrasting how they would represent the law that all *F*s are *G*. Earlier necessitarians would write, "$(x)(Fx \boxed{N}\!\!\rightarrow Gx)$"—to be read as, "anything that is *F* must (in some nonlogical, physical sense of *must*) be *G*." Dretske would write, "*F*-ness $\rightarrow$ *G*-ness"—to be read as, "the property of being an *F* necessitates the property of being a *G*."

There are several problems with Dretske's universals theory of laws, to which critics such as Bas van Fraassen and D. H. Mellor have drawn attention. Van Fraassen calls two of these problems the *identification problem* and the *inference problem*. The identification problem is the challenge—posed to defenders of the universals theory—of giving an adequate account of the necessitation relation that allegedly holds between those universals comprising a law. The second (and related) inference problem concerns the inferential relation between laws and their instances. The universals theorist insists that not only does the *FG*-law logically imply that all *F*s are *G*, but also that the *FG*-law explains the "mustness" or necessity that we think holds between the particular things that are instances of the law. Presumably, then, the *FG*-law implies either that it is necessary that all *F*s are *G* or that if some particular thing is *F* then it must also be *G*. As we shall see, it is difficult to make sense of either inference if, as the universals theory supposes, laws of nature are themselves not necessary but contingent.

## The Identification Problem

The identification problem is that of giving an account of the necessitation relation that, according to theories such as Dretske's, connects the universals that make up a law. Recall from our earlier discussion that empiricists such as Hume deny that we can make sense of any notion of objective necessity differing from logical necessity. As far as Hume was concerned, nomic necessity is simply subjective, a feeling; there is no objective, nonlogical necessity that connects objects, events, or universals. What if Hume were right about this? Does this rule out the possibility that laws involve a logically necessary connection between universals?

If the necessitation relation between the universals in a law were logical, then all laws of nature would be logically necessary. In that case, if "All *F*s are *G*" is a law, it would be logically impossible for there to be an *F* that was not a *G*. To many empiricist philosophers, this is a sufficient reason to reject reading nomic necessity as logical necessity, since we usually assume that laws of nature are contingent, not necessary, truths. But a degree of caution is advisable here. As Mellor points out in his "Necessities and Universals in Natural Laws," some philosophers (notably Kripke and Putnam) have argued that, although all the laws of empirical science are discovered through empirical research, nonetheless many of those laws are not contingent but necessary. This issue is explored later in this commentary, in the section "Mellor's Defense of the Regularity Theory."

### THE INFERENCE PROBLEM

The inference problem is that of explaining the "mustness," or necessity, that necessitarians believe to hold between the particular things or events that are instances of a law. For example, if necessitarians believe that it is a law that gold has an atomic number of 79 and that a particular piece of metal is gold, then they would infer that the piece of metal in question *must* have an atomic number of 79. As Dretske acknowledges, one of the main challenges for his universals theory of laws is to explain the "mustness" that appears in the conclusion of this kind of inference. On Dretske's theory, we can write out the inference as follows:

$$\frac{\begin{array}{l} F\text{-ness} \rightarrow G\text{-ness} \\ a \text{ is } F \end{array}}{a \text{ must be } G.}$$

Where does the *must* in the conclusion come from? Presumably, it derives from some *must* implicit in the first premise, which is Dretske's way of representing the law that all *F*s are *G*. In ordinary English, we could state the law using *must* in two different ways. We could say either "It must be the case that, if anything is *F*, then it is *G*" or "Anything that is *F* must be *G*."

Clearly, the first way of stating the law will not help. From the premises "It must be the case that, if *x* is *F*, then *x* is *G*" and "*a* is *F*," we cannot validly infer the conclusion that *a* must be *G*. All that follows is that, as matter of contingent fact, *a* is *G*.[2]



So we have to read the law as Dretske intends it to be read, as saying "Anything that is *F* must be *G*." But as far as Dretske is concerned, this is just another way of saying that the property of being *F* necessitates the property of being *G*. In other words, according to Dretske's theory, the law thus stated is not a generalization about objects or events (which are particulars); it is a singular statement about properties (which are universals). To repeat, on Dretske's view, the law does not say "Each individual thing that is *F* must also be *G*." Rather, it says that the property of *F*-ness necessitates, or brings with it, the property of *G*-ness. How, then, given Dretske's understanding of what the *FG*-law asserts, can we use it to deduce the conclusion that a particular thing must be *G*? As Dretske admits, the only inference that is uncontroversially valid is the inference from "*F*-ness → *G*-ness" to "All *F*s are *G*." But "All *F*s are *G*" does not validly imply that anything that is *F* must also be *G*. (Were this inference valid, the distinction between accidental generalizations and laws would collapse.)

In response to this difficulty, Dretske offers an analogy with the offices and branches of a government. There is a legal code in the United States that lays down what powers pertain to the office of the president, the two houses of Congress, and the Supreme Court, and how these branches of government are related to one another. The code itself is contingent; the Constitution of the United States could have been different. But given that Constitution, it is now true of anyone who holds the office of president that that person must consult Congress and receive its approval before declaring war. The law is not about the particular people who hold the various offices; the law is about the powers and duties of the offices themselves and the relations between them. But because the law is what it is, anyone who holds a particular office *must* behave in a certain way.

An analogy is not a proof, and Dretske does not claim to have proven anything. Some critics (such as van Fraassen) have stressed the disanalogies between a legal code and laws of nature. With a legal code, we understand the origin of the law's prescriptive force, namely the commitment of citizens to enforce it. But what is the origin of the analogously prescriptive force of laws of nature? Given the mystery that seems to surround the notion of contingent relations between universals, other advocates of the universals theory have candidly admitted that necessitation is an inexplicable basic concept that the theory is forced to postulate. The justification for accepting the concept lies in the superiority claimed for the universals theory as a whole in accounting for the essential features of laws.

### Mellor's Criticism of Dretske: Can Laws Be Noninstantial?

Recall the prima facie advantage discussed earlier that the universals theory might be thought to have over the regularity theory: that is, if universals can exist without being instantiated, then noninstantial laws can be accommodated easily by the universals theory but not so easily by the regularity theory. Mellor argues that this supposed advantage is illusory because the universals involved in laws must, after all, have instances. He reaches this conclusion by adopting the account of universals championed by the British mathematician and philosopher Frank Plumpton Ramsey (1903–30).

To appreciate the motivation for Ramsey's proposal, consider the traditional view that there are particulars—individual objects such as *this* apple and *that* apple—which exist in space and time—and universals—properties such as redness and greenness—which are neither spatial nor temporal. Somehow or other, on the traditional view, these two very different kinds of entity—particular objects and universal properties—combine to form facts, such as the fact that this apple is red. But how can this combination be possible given that particulars and universals are so utterly dissimilar? Taking his cue from Wittgenstein's *Tractatus*, Ramsey proposed that the world consists, not of particular things and universal properties, but of facts.[3] According to Ramsey, universals and particulars should be regarded, not as two fundamentally different sorts of thing each having an independent existence, but as mutually necessary parts of particular facts. On this view (which is a version of nominalism), particulars and universals alike are aspects of facts. For example, the particular denoted by *this apple* is what is common to all the particular facts about this apple, while the universal denoted by *red* is what is common to all the particular facts about red things.

Mellor agrees with Ramsey that if we make the mistake of thinking of universals and particulars as having some kind of independent real existence, then we will be led into such "dotty conundrums" (861) as worrying about how two such radically different kinds of thing can combine to form a fact. On Ramsey's view, universals are just the part that is common to all the facts of the relevant class. The relevant class of facts for the *FG*-law must include facts such as *Fa*. Therefore, *F*-ness, the universal in the *FG*-law, must have instances if the law is to be genuine. Genuine laws, on such an account of universals, cannot be noninstantial.



## 7.4 | Mellor's Defense of the Regularity Theory

In "Necessities and Universals in Natural Laws," Mellor defends the Humean regularity theory of laws. A key element of that theory is the insistence that laws of nature are contingent, not necessary, truths, and this insistence is one of the main differences between the regularity theory and traditional versions of the necessitarian theory. Until quite recently, it was thought that, whatever the defects of the regularity theory as an adequate account of laws, it was at least correct about the contingency of laws. And as we have seen, the conviction that laws of nature are contingent has proven to be a stumbling block for the newer, universals version of the necessitarian theory.[4]

The main arguments for the contingency of laws derive from Hume. Take any scientific law of the form "All *F*s are *G*." Even though the law is true, we can easily conceive that something could be *F* without that thing also being *G*. Since whatever is conceivable is possible, the FG-law could be false. Thus, it and all other similar laws are contingent. Moreover, laws of nature are discovered by empirical research, and this seems to be the only way we can find out which lawlike generalizations are true and which false. If laws of nature were necessary, then we should be able to discover them through a priori reasoning. But we cannot do this. Therefore, the laws of nature are contingent.

It is now widely acknowledged that Hume's arguments are unsound. Conceivability is not an infallible guide to possibility.[5] Moreover, as Saul Kripke has demonstrated, the fact that a proposition is a posteriori does not entail that it is contingent.[6] The classic example is the simple identity claim that Hesperus is (that is, is identical with) Phosphorus. The discovery that the two names *Hesperus* and *Phosphorus* refer to one and the same physical object (sometimes seen around sunset, at other times seen around sunrise) was empirical. No amount of a priori reasoning about the meanings of the names *Hesperus* and *Phosphorus* could have revealed this truth to us. Nonetheless, the fact that the object picked out by the name *Hesperus* (namely, the planet Venus) is identical with the object picked out by the name *Phosphorus* (namely, the planet Venus) is a necessary truth, since every object is necessarily identical with itself.

In understanding Kripke's view about the necessity of identity claims, it is important to appreciate the distinction between metaphysical necessity and logical necessity. As with logical necessity, it is impossible for a metaphysically necessary proposition to be false (that is, there is no possible world in which such a proposition is false). But unlike a logically necessary proposition, its necessary truth is not guaranteed solely by logic and definitions. The proposition that Hesperus is identical with Phosphorus is metaphysically necessary, but not logically necessary.

Kripke's case for the necessity of identity claims rests on his theory of reference, specifically his theory of rigid designation. Obviously, if it were possible for the names *Hesperus* and *Phosphorus* to refer to different planets, then the assertion that Hesperus is identical with Phosphorus would not be necessary. By saying that the names *Hesperus* and *Phosphorus* are rigid designators, Kripke is denying that this is possible. There is not time here to consider Kripke's ingenious (and, to many minds, convincing) arguments for his thesis that simple names such as *Hesperus* and *Phosphorus* are rigid designators.[7] Suffice it to say that part of the plausibility of his thesis rests on the fact that names such as *Hesperus* and *Phosphorus* are indeed simple names with no connotative meaning. So it is tempting to think that their reference, the things they refer to by virtue of some initial baptism, completely exhausts whatever meaning they have.

Of immediate concern to us is whether something like Kripke's view can be extended to laws of nature. The problem is that only a few scientific laws make identity claims, and when they do, those claims concern classes of objects and properties, rather than single objects designated by simple names. Saul Kripke and Hilary Putnam have argued that, as with the identity of Hesperus and Phosphorus, a significant class of laws of nature are metaphysically necessary, namely, those laws attributing essential properties to natural kinds. It is these arguments that Mellor tries to refute on behalf of the regularity theory.

## Kripke and Putnam on Natural Kinds and Essences

Natural kinds have traditionally been thought to include such things as chemical elements and compounds like arsenic and hydrochloric acid, and biological species like tigers and elm trees. The basic idea is that each member of such classes shares a common nature in virtue of which it belongs to that relevant kind. The intended contrast is with artificial kinds or groups, such as all animals weighing over fifty pounds or all compounds whose chemical name in English begins with the letter *A*, where there is nothing else that the items in these groups need have in common. Essential properties are those properties of a thing that it cannot exist without—or, perhaps, properties that a thing of some kind cannot lack while remaining of that kind. If the essential properties of tigers are $P_1$, $P_2$, and $P_3$, then nothing that lacks one or more of these properties can belong to the natural kind *tiger*. Thus, the doctrine of natural kinds and the notion of essential properties go hand in hand: natural kinds are classes of things sharing a common nature or core set of essential properties.

Kripke and Putnam usually take the essential properties of things to be their microstructural properties. They say, for example, that being $H_2O$ is an essential property of water; having atomic number 79 is an essential property of gold; having a particular set of genes is essential for membership in a biological species. Consider the example of gold. Undoubtedly, modern scientists believe that having atomic number 79 is a fundamental



property of gold. According to Kripke and Putnam, gold is, by its very nature, something that has 79 protons in its nucleus and 79 orbiting electrons. It is possible that some pieces of gold may not be hard, shiny, or yellow, but it is impossible that any piece of gold—any piece of that very element—could fail to have atomic number 79. So according to Kripke and Putnam, the law that gold has an atomic number of 79 is a necessary truth: given the essential nature of gold, it could not be otherwise.[8] Of course, the discovery of the law is empirical, but it does not follow from this that the law is contingent; statements can be necessary and yet a posteriori. Consider our earlier example that *Hesperus* is identical with *Phosphorus*. Given what *Hesperus* and *Phosphorus* designate (namely, the planet Venus), the identity could not fail to hold, since one thing could not be two distinct things; nonetheless, it was an empirical discovery that *Hesperus* and *Phosphorus* name one and the same planet.

Mellor rejects the Kripke-Putnam doctrine of natural kinds and essences, charging that their arguments are both unsound and question begging. Since Kripke and Putnam give different arguments and hold slightly different versions of the essentialist theory, we will focus exclusively on Putnam's account in what follows.

Putnam's task is to explain why the extension of natural-kind terms such as *water*, *gold* and *tiger* must include all and only those things that have the same essential properties. Let us focus on the term *water*. The traditional theory of meaning, stemming from John Locke (1632–1704) and developed by Gottlob Frege (1848–1925), maintains that extensions are determined by intensions: the intension (or meaning) of *water* is a list of properties that define what we mean by *water*. Since people were talking meaningfully about water long before the advent of modern atomic theory, the intension of *water* does not include "being $H_2O$." Presumably, *water* means something like "the colorless, odorless liquid that fills lakes and rivers, falls from the sky, and is the most common solvent." According to this traditional theory of meaning, the term *water* need not refer to the same substance, with the same microstructural properties, in all possible worlds. The most common solvent that is odorless and colorless and fills the lakes and rivers of a possible world might be something other than water—say, XYZ. So Putnam has to give us a new theory of reference in which natural kind terms, such as *water*, *gold*, and *tiger*, do not have their extensions fixed by their intensions.

## Putnam's New Theory of Reference

Putnam's new theory of reference comes in two parts. First, he contends that a natural kind term gets its reference fixed in the actual world by means of archetypal specimens and not by mere description or intension. In this picture, we fix the reference of *water* in our world by pointing to samples of that particular liquid and (for all practical purposes) saying "water is *this* kind of stuff, the stuff in our lakes and streams, the stuff that falls from the sky when it rains." The key here is that we fix the reference by employing the relation of *same stuff* or *same kind*—a deep relation among all those things sharing, not merely superficial characteristics, but important microstructural features. (In the present case, these important properties are taken to be the molecular properties of the compound $H_2O$). We thus collectively refer to all and only liquids standing in that same-kind relation to our particular sample.

Second, Putnam claims that we can then extend the reference of *water* to other possible worlds by saying (for all practical purposes) "Something is water, in any possible world, if and only if it is the same kind of stuff as this sample here." On such a view, then, nothing—in any world—can be water unless it stands in the same-kind relation to this liquid here in our glass or pitcher. That is to say, *water* refers to a single kind of stuff in every possible world: necessarily, whatever is water is $H_2O$. In this way, it emerges as a necessarily true law of nature that if $x$ is water, then $x$ contains hydrogen and oxygen.

## Mellor's Criticisms of Putnam's Theory of Reference

Mellor rejects both parts of Putnam's account. First, he denies that terms like *water* and *gold* get their reference fixed in this world by means of archetypes (rather than, say, by means of descriptions). One group of cases that Mellor thinks refutes Putnam's view are those in which there are no archetypes to point at when the term is first introduced. In an earlier paper (entitled "Natural Kinds"), he writes:

> Consider elements high in the periodic table, that do not occur in nature and have never been made. We have names for them, but there may never be archetypes to constrain our use of the names. Even if specimens eventually appear, the discovery, creation or synthesis of previously unknown fundamental particles, elements and compounds can surely be *predicted*. The term 'neutrino' applied to just the same particles when it was used to predict their existence as it has applied to since their discovery. Ostensive reference (say to a bubble chamber photograph) could not have fixed its extension then; why suppose exactly the same extension is fixed that way now?[9]

Second, Mellor thinks that Putnam's analysis of the same-kind relation across possible worlds begs the question. The issue, remember, is whether the term *water* must refer to exactly the same kind of stuff, with exactly the same essential nature, in all possible worlds. Putnam's procedure relies on "important" physical properties. But there is nothing in Putnam's procedure per se that guarantees that these important properties will be exactly the same in every possible world. Suppose, for example, that all samples of water share ten important properties but that water could lack any one of them.[10] Now imagine two possible worlds, PW1 and PW2. A liquid in PW1 shares nine of these important properties with water in the actual world. Let the property missing in PW1 be $P_1$. A liquid in PW2 also shares nine of these properties with water in the actual world, but in this case the missing property is $P_2$. When compared with water in the actual world, the liquid in PW1 and the liquid in PW2 both qualify as water. But the two liquids would not seem to be essentially the same, since they differ in two important properties. So Putnam's procedure for fixing the reference of *water* in other possible worlds does not entail essentialism; it does not guarantee that all the things referred to by the term *water* must have exactly the same essential properties in all possible worlds.



Putnam would reject Mellor's criticism because Putnam assumes that the same-kind relation across possible worlds is an equivalence relation and all equivalence relations are transitive. If the same-kind relation is transitive, then if the liquid in PW1 is the same kind of stuff as water in the actual world and if water in the actual world is the same kind of stuff as the liquid in PW2, then the liquid in PW1 has to be the same kind of stuff as the liquid in PW2. Thus, Putnam's assumption that the same-kind relation is an equivalence relation entails that all things that belong to the same kind have to share exactly the same set of important properties.

Mellor complains that this move of Putnam's begs the question because it illicitly takes for granted the very point at issue, namely, whether water has a fixed essence. In Mellor's words, "for Putnam to claim the same-kind relation to be transitive, which he does in taking it to be an equivalence relation, is for him gratuitously to assume the essentialist conclusion he is out to prove" (857).

Mellor's criticism seems to be correct. Putnam's new theory of reference does not, by itself, guarantee the truth of essentialism. Essentialism requires that the same-kind relation be an equivalence relation and hence transitive across possible worlds. Putnam's theory of reference does not, by itself, entail that the same-kind relation is transitive because, according to that theory, things in other possible worlds count as water by comparing them with archetypes in the actual world, not by comparing them with each other. Insisting that the same-kind relation be an equivalence relation entails that all possible things that are water must have the same fundamental properties as archetypes in the actual world. But that is simply to insist on the truth of essentialism, not to give an independent argument for it. Mellor's second criticism does not prove that Putnam's theory is false, but it does leave Putnam the task of responding to Mellor's first criticism (that archetypes do not seem necessary for fixing the reference of natural kind terms). And even if Putnam were to succeed in rebutting Mellor here, we would still be a long way from the conclusion that all laws of nature are necessary truths, for Putnam's theory applies only to natural kinds (such as molecules, animals, and plants), and it is not obvious that all laws of nature are about such kinds. (For example, consider the laws of thermodynamics and the laws of motion. None of these laws is about any specific class or category of objects having a common nature. They apply to all objects and systems *regardless* of their nature.)

## 7.5 | Cartwright's Antirealism about Fundamental Laws

It is noteworthy that at the end of his article, "Laws of Nature," Dretske limits himself to a conditional claim. He does not purport to have shown that there actually *are* universals and contingent relations of nomic necessitation between them. Rather, he asserts, *if* there are any laws of nature, then the universals account of them is correct. This raises the question that Cartwright addresses in "Do the Laws of Physics State the Facts?" Namely, are there laws of nature? Undoubtedly there are many generalizations in science, and many of these are called laws. But can any of these so-called laws play the role traditionally assigned to them, especially that of explanation, while at the same time being true? Do our explanatory laws truly describe how bodies actually behave? Cartwright thinks not.

Cartwright defends the following disjunction: either laws are false but can be used to explain things, or laws are true but are useless for explanation. There is, in her words, "a trade-off between factual content and explanatory power" (875). Thus, Cartwright admits that some laws—those referred to as phenomenological—can be fairly accurate descriptions of how bodies actually behave. But these phenomenological laws achieve their descriptive accuracy at the price of being highly qualified and thus highly restricted in their scope. It is the unqualified, fundamental laws of wide explanatory scope that are the target of Cartwright's antirealism. (For an extended discussion of antirealism, see chapter 9 of this volume.)

Much of Cartwright's case against fundamental laws rests on her illustration involving the laws of gravitational attraction and electrostatic attraction (and repulsion). If the gravitational law were true, then it would describe how bodies behave. In particular the law would predict the real, actual forces that act on gravitating bodies. But nearly all gravitating bodies are also electrically charged, and the smaller the body, the greater the role that charge plays in determining its behavior. Thus, taken at face value, the gravitational law seems false; it does not state correctly the actual net force acting on all gravitating bodies because the actual net force experienced by most bodies depends jointly on their mass and electrical charge.

One way of trying to retain the gravitational law as a true description of how bodies actually behave would be to limit its scope to just those bodies on which only gravitation is acting—to bodies that are not charged (or affected in any way by nongravitational forces). But that would drastically limit the number of bodies that the law describes and would render the law virtually useless for most explanatory purposes. Thus, Cartwright concludes either the laws we use for explanation are false, or the laws are true but virtually useless for explanation: we cannot be realists about explanatory, fundamental laws.



### A Response to Cartwright's Antirealist Argument

One way of responding to Cartwright's argument for antirealism about fundamental laws is to distinguish between the actual net force acting on a body and the component force due to gravity. Indeed, this is how most of us are taught physics and mechanics. First we use individual laws to calculate the component forces acting on a body due to gravitation, electricity, tension in a spring, and so on. Then we use vector addition (the parallelogram law) to sum these forces and derive the net force acting on the body. If the net force is not zero, then the body will accelerate in accordance with Newton's second law of motion.

Cartwright denies that this response is an adequate defense of realism about fundamental laws. Her main objection is that only the net force, the actual force that determines the acceleration of a body, is real. Nature does not add component forces. Indeed, component forces are fictitious; they are not real forces at all. Why not? Because if they were real, then they would act in addition to the net force and thus give the wrong prediction about the body's motion.

Cartwright's double-counting objection to the reality of component forces seems to depend on the assumption that real forces produce actual accelerations and are measured by those accelerations. Thus, Cartwright would say that if a body were pulled in opposite directions by equal component forces and thus remained at rest, then there is no real force acting at all. If this is indeed her view, then it seems mistaken. After all, a ball on which equal and opposite forces are acting is in a different state (a state of tension) from a ball that is free from external forces. Component forces can have real effects, even if they do not produce a net acceleration.[11]

One merit of Cartwright's paper is that it makes clear the price one must pay to be a realist about many laws in physics. Individual laws describe component forces, but component forces do not determine how bodies move (only net forces do that). So individual laws do not describe how bodies actually move. At best they describe, not actual behavior, but tendencies to behave. They specify capacities or dispositions of bodies by telling us how they would move if they were free from all other forces. And this, clearly, is a far cry from the traditional empiricist view of Hume and his followers, who would limit laws to describing what actually happens in the world. Taking laws seriously and realistically seems to require an ontology of powers and dispositions that is inconsistent with the regularity theory of laws.[12]

## 7.6 | Summary

Most philosophers attempting to explain what laws are adopt one of two approaches: the regularity approach or the necessitarian approach. Inspired by Hume's analysis of causation, regularity theorists (such as Ayer) insist that laws are simply descriptions or summaries of what actually happens in the world. In its simplest form, the regularity theory insists that the law that all *F*s are *G* says nothing more about the world than does the generalization that, as a matter of fact, all *F*s are *G*. This simple version of the regularity theory has a number of problems, such as the problem of accounting for those scientific laws that, like Newton's first law, have no instances. But the severest objection to the simple version of the regularity theory is that it cannot distinguish between genuine laws and accidental generalizations. In response to this difficulty, many regularity theorists impose further conditions on a true generalization before it can qualify as a law. Because these extra conditions refer to the beliefs and attitudes of scientists towards the generalization in question, this more sophisticated version of the regularity theory is often called the epistemic regularity theory. Ayer advocates one version of the epistemic regularity theory. But as Ayer acknowledges, the epistemic regularity theory makes laws inherently subjective by taking the lawlike status of a generalization to depend on whether scientists treat it as a law. Obviously, scientists cannot treat a generalization as a law if they have not yet discovered it. So the epistemic regularity theory entails that there are no unknown laws. This conclusion, that there are no unknown laws, is so counterintuitive that Dretske offers it as a sufficient reason for abandoning the entire regularity approach.

Dretske advocates a version of the necessitarian approach. Unlike older versions of this approach (which regarded laws as asserting a special relation of necessity between objects or events), Dretske's theory regards laws as relations between properties. Since properties are universals, Dretske's proposal is called the *universals theory*. One group of problems with the universals theory centers around the special relation that is supposed to hold between the universals that make up a law. Usually we think of the relations between universals as being logical relations. But if the necessitation relation were logical, then laws of nature would be necessary truths. Dretske himself rejects this, insisting that laws of nature are contingent. Against this view of the contingency of laws, some philosophers, notably Kripke and Putnam, have defended the claim that a wide class of natural laws, namely those that attribute essential properties to natural kinds, are metaphysically necessary. The case for the Kripke-Putnam doctrine rests largely on a new theory about how terms that refer to natural kinds get their meaning. Mellor, a regularity theorist, criticizes Putnam's new theory of reference on the grounds that, as a defense of essentialism, it is question begging. If Mellor is right, then Putnam has not given a compelling reason for regarding many laws of nature as metaphysically necessary. But this still leaves necessitarians such as Dretske with the task of explaining how the special nonlogical relation characteristic of laws can hold contingently between universals. This difficulty—the problem of identification—is closely related to a second difficulty—the problem of inference. The problem of inference is the problem of explaining how, according to the necessitarian, we can validly infer that a particular thing that is *F* must also be *G* (a conclusion about a particular object) from the law that *F*-ness necessitates *G*-ness (a premise about universals). Dretske offers an analogy between laws of nature and legal codes (such as the Constitution of the United States) that define the powers and relations between the branches of government. The laws are about offices and institutions, but they imply that the people who hold those offices or serve in those institutions must do certain things. Dretske admits that the analogy is imperfect and confesses that the necessitation relation is not easy to understand or explain. Nevertheless, he thinks that the regularity theory is so flawed that the universals theory must be on the right track, despite its difficulties.

One major difference between the regularity theory and older versions of the necessitarian theory is that the necessitarian thinks that the regularity theory is too weak. The regularity theorist regards laws merely as true descriptions of how objects actually behave. The necessitarian insists that laws do more than this: they not only describe how the world is, they also assert how the world must be. But both theorists agree that a generalization must be true in order for it to be a law. Nancy Cartwright challenges this assumption. Cartwright argues that many of the laws we use to explain things are, in fact, false because they do not describe what actually happens in the world. Laws about electrostatic, magnetic, and gravitational forces, for example, do not as a rule describe how bodies actually move. Rather, they specify how bodies would move were certain ideal conditions realized. But such conditions, as a matter of fact, hardly ever obtain. Although Cartwright's argument involves some controversial claims about the nonreality of component forces, one of her conclusions seems quite plausible, namely, that many laws specify the tendencies and dispositions of bodies rather than their actual behavior. Thus, neither the regularity approach nor the older necessitarian view can be deemed adequate, since both approaches entail that laws describe how bodies do or must behave. Universals theories such as Dretske's are not inconsistent with Cartwright's position but much more needs to be said by their supporters about the nature of the two ingredients in a law—the universals (properties) and the (contingent) relation of necessitation that holds between them—and about the relation between laws and the behavior of particular objects.

## Notes

1. See David Hume, "Of the Idea of Necessary Connection," Section 7 of *An Enquiry Concerning Human Understanding* (1748).

2. It is important not to be misled by language here. Rather than saying (i) "It must be the case that, if Jones was elected, then he received the most votes," we might say, more idiomatically, (ii) "If Jones was elected, then he must have received the most votes." But if we add to (ii) that (iii) "Jones was indeed elected," we cannot conclude from this that "Jones *must have*—that is, *necessarily*—received the most votes." Since, in this example, (ii) is merely an equivalent way of saying (i), all that validly follows from (ii) and (iii) is that, as a matter of contingent fact, Jones received the most votes. So, too, in Dretske's example. All that follows from "It must be the case that, if $x$ is $F$, then $x$ is $G$" and "$a$ is $F$" is that, as a matter of contingent fact, $a$ is $G$, not that $a$ must be $G$.

3. See the opening propositions of Ludwig Wittgenstein, *Tractatus Logico-Philosophicus*, trans. D. F. Pears and B. F. McGuinness (London: Routledge and Kegan Paul, 1961), p. 7.

4. For a lively attack by a fellow necessitarian on the contention (by Dretske, Armstrong, and others) that nomic necessitation between the universals of a law of nature is always contingent, see Martin Tweedale, "Universals and Laws of Nature," *Philosophical Topics* 13 (1982): 25–44.

5. Part of the difficulty with Hume's conceivability test is its vagueness. For it is one thing to conceive that something is water without also conceiving that it contains oxygen. Anyone who is ignorant of chemistry could do this. But can I conceive that something is water and that it does not contain oxygen? The problem is the unclarity surrounding the notion that I could properly be said to be conceiving of water—real, actual water—when I imagine a liquid that looks like water but does not contain oxygen.

6. See Saul A. Kripke, *Naming and Necessity* (Cambridge, Mass.: Harvard University Press, 1972).

7. For a good introduction see Kripke, *Naming and Necessity*, and Stephen P. Schwartz, ed., *Naming, Necessity, and Natural Kinds* (Ithaca, N.Y.: Cornell University Press, 1977).

8. A word of caution: Kripke and Putnam recognize that our best scientific theories might be mistaken. So, strictly speaking, their claim is conditional: if modern science is right about the nature of gold, then the law that gold has an atomic number of 79 is a necessary truth.

9. D. H. Mellor, "Natural Kinds," *British Journal for the Philosophy of Science* 28 (1977): 306.

10. The example and argument are from Mellor's "Natural Kinds." If Mellor's example seems implausible, consider biological species. Surely, not all tigers have exactly the same set of genes; but, presumably, tigers share a sufficiently large number of genes (or very similar genes) to be members of the same species. Similarly, we know that the stuff we usually call *water* is in fact a mixture of three compounds—hydrogen oxide, deuterium oxide, and tritium oxide—and although hydrogen oxide is by far the most common of the three in the actual world, it is logically possible that the ratio might vary. Moreover, it is at least imaginable that advances in elementary particle physics might reveal that not even all molecules of hydrogen oxide have exactly the same internal structure.



11. For more on Cartwright's double-counting objection to the reality of component forces, see Lewis Creary, "Causal Explanation and the Reality of Natural Component Forces," *Pacific Philosophical Quarterly* 62 (1981): 148–57; A. David Kline and Carl A. Matheson, "How the Laws of Physics Don't Even Fib," in *PSA 1986*, ed. A. Fine and P. Machamer (East Lansing, Mich.: Philosophy of Science Association, 1986), 1: 33–41. Cartwright replies to Creary in Nancy Cartwright, *How the Laws of Physics Lie* (Oxford: Clarendon Press, 1983), 62–67.

12. Cartwright develops such a view, which she traces back to John Stuart Mill, in Nancy Cartwright, *Nature's Capacities and Their Measurement* (Oxford: Clarendon Press, 1989). There has been a debate about whether Cartwright's realism about capacities (which includes such things as dispositions, powers, and tendencies) is consistent with her antirealism about fundamental laws (which she continues to maintain). See Alan Chalmers, "So the Laws of Physics Needn't Lie," *Australasian Journal of Philosophy* 71 (1993): 196–205; Steve Clarke, "The Lies Remain the Same: A Reply to Chalmers," *Australasian Journal of Philosophy* 73 (1995): 152–55; and Alan Chalmers, "Cartwright on Fundamental Laws: A Response to Clarke," *Australasian Journal of Philosophy* 74 (1996): 150–52.