The Law-Idealization

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There are few, perhaps no known, exact, true, general laws. Some of the work of generalization is carried by ceteris paribus generalizations. I suggest that many models continue such work in more complex form, with the idea of ceteris paribus conditions thought of as extended to more general conditions of application. I use the term *regularity guide* to refer collectively to cp-generalizations and such regularity-purveying models. Laws in the traditional sense can then be thought of as idealizations, which idealize away from the conditions of application of regularity guides. If we keep clearly in mind the status of laws as such idealizations, problems surrounding traditional topics—such as lawlikeness, corresponding counterfactuals and modality—no longer look to be intractable.

1. The Law-Idealization. Laws are in trouble. In 1983 Nancy Cartwright published *How the Laws of Physics Lie*. Chapter 3 of Ron Giere's 1988 *Explaining Science* presented a view with much the same implications, and his 1999 *Science without Laws* also puts the bad news for laws into the title of the book. This symposium has contributed to the catalogue of problems with laws. Winsberg shows how the assumption of universal applicability of laws seems responsible for insoluble problems in the interpretation of statistical mechanics. Frisch details how classical electrodynamics runs afoul of any viable universal distinction between laws and initial conditions to which our conception of laws would appear to be committed. Koslow discusses general problems with any uniform treatment, thought to be required by our concept of laws, of the connection between laws, on the one hand, and counterfactuals and modality on the other.

It is also noteworthy how few are the known exact, true, and general

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‡Readers will note important points of comparison between ideas in this paper and Cartwright's 1999, especially in Sections 2 and 6. To whatever extent the present might constitute an elaboration of Cartwright's metaphor of a "nomological machine," I will be very happy if this elaboration further illuminates the subject.

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laws that apply to actual as opposed to idealized conditions. There may be none at all. Quantum field theory and general relativity each idealize away from the subject matter of the other. We have theoretical reason to think that no conservation laws are perfectly correct, for they are tied to symmetries, and in the real world symmetries never hold exactly. The velocity of light is c—in a perfect vacuum. But there are no absolutely perfect vacuums. And so on.

Cartwright and Giere see the role for laws as "tools in our model building tool kit." But what are we to say about the familiar, inexact, regularities, such as "all crows are black," "matches light when struck," "emeralds are green," and Hooke's spring law? Cartwright addresses such regularities under the rubric of mechanisms, or as she calls them, "nomological machines" (1999); but she and others do not much discuss what, when we let go of laws, happens to law-notions, some of which my co-symposiasts have done much to cast into doubt—projectability, modality, the counterfactual connection, and the contrast between accidental and lawlike regularities. I offer a perspective that both clarifies the nature of the difficulties and provides a sensible framework for understanding these important notions.

I submit that characterization of science in terms of laws is itself an idealization. Just as the hydrodynamic idealization, for example, is excellent for certain objectives, the law-idealization serves for many purposes. But, as with any idealization, we get hash if we mistake the idealization for an exact, completely correct characterization. I will set out how I take laws to be an idealization and how the intractability of problems associated with laws, especially the topics of lawlikeness, counterfactuals, and modality, look to be artifacts of mistaking the law-idealization for exact truth.

2. Regularity Guides. Traditionally, the word 'laws' has been reserved for universally applicable, exceptionless generalizations. Laws, in this sense, are contrasted with ceteris paribus generalizations (cp-generalizations), held not themselves to be genuine laws. I will defer to this traditional terminology.

What sort of general knowledge do we actually have? As I have mentioned, if we require truth we have very few or no known laws. In practice we use many cp-generalizations, but these do not cover a great deal of our general knowledge. When, following Cartwright and Giere, we see laws as functioning as "tools in a model building tool kit" we realize that it is models that are the purveyors of a great deal of our general knowledge. I want to develop the idea that we can see models as generalizing the way in which cp-generalizations give us general knowledge.

Let's begin with a look at the kinds of things we think of as "models."

There is much variation. At the abstract end, something can be called a model when what is so described has not yet, or need not, or is only sometimes used to represent characteristics in the world: for example "the harmonic oscillator," or "Markov processes," or "exponential decay." We can think of models at this level of generality as functioning somewhat like predicates in that each can be applied to a great many different specific cases.

Many other things called models are clearly understood as applying to specific or to general things, events, or behaviors. At the specific end, consider a physical model of the Empire State Building. Abstract models can also apply to individual objects, as for example a detailed version of the harmonic oscillator deployed as a model of the motion of the pendulum in Giere's grandfather clock. There are various big bang models of the beginning of the universe. More general is Watson and Crick's physical model of "DNA," the application of the simple harmonic oscillator to represent the motion of pendula (of "a pendulum") or the motion of springs (of "a spring"). There is Bohr's model of the atom, the liquid drop model of the nucleus, the BCS model of superconductivity, rational agent microeconomical models of an economy, etc.

From the foregoing list of examples only the model of the Empire State Building does not obviously convey a great deal of general information. Furthermore, in many of these examples the general information conveyed will defy explicit and exact restatement by verbal generalizations of the simple "all As are Bs" form, or really, by any explicit propositional presentation. Models are often, to lesser or greater degrees, open ended with respect to what explicit verbally formulated consequences can be derived from them. This is more transparently so with examples such as the liquid drop model of the nucleus or the BSC model of superconductivity and less so with examples like the simple harmonic oscillator model of the motion of pendula. In the former sort of examples the models are clearly open ended and can be minded for a range of ceteris paribus general information that is not initially determinate. The later sorts of cases are themselves much more like common cp-generalizations. This range of cases is very much to the point that I will be making, that we should see cp-generalizations and models as on a continuum, a range of a kind of general knowledge.[1]

To further examine what many models and common cases of cp-gen-

1. If one takes models to be quite specific we could instead locate what is open ended in this subject in what we do with models, analogously to thinking of "Matches light when struck" as perfectly specific and locating the ceteris paribus character of such generalizations in how we use then. What follows could generally be understood in this spirit.

eralizations have in common, let us turn to how we use cp-generalizations. We use cp-generalizations as practical guides, knowing that they will sometimes fail us. For a cp-generalization to function reliably as a guide requires skill or procedural knowledge in its application. Such procedural knowledge can to some extent, and sometimes in great detail, be explicitly formulated; and when so formulated can be incorporated in explicit statement of a more exactly expressed cp-generalization. We can refine "matches light when struck." to "dry matches light when struck in the presence of oxygen with little or no wind blowing." But our procedural knowledge always defies complete and exact specification and incorporation into the specific statement. How to characterize the exact amount of wind that is too much? Strike the match with just what force and at what angle? It is the fact that no explicit statement of the needed procedural knowledge is ever foolproof that confines us to generalizations that count as ceteris paribus and that inescapably separates them from exact laws.

We can take the relevant procedural knowledge as functioning to determine conditions of application of a cp-generalization. Cp-generalizations provide reliable guides to covariation of various properties explicitly described in their statement. But the covariation can only be counted on when the conditions of application hold. I will take something to count as a condition of application for a cp-generalization only if the condition is not explicitly described in the generalization. The conditions of application may be well understood (wet matches don't light when struck), or really a matter of skill (just how hard you have to strike a match to get it to light). What makes a generalization ceteris paribus is that there are conditions of application, which have not been explicitly stated, and what makes cp-generalizations so puzzling from the point of view of exact laws is that the conditions of application of cp-generalizations can never be fully specified.[2]

I can now state the point that brings models into the relevant relation to cp-generalizations: All the ways in which the last two paragraphs characterize cp-generalizations applies equally to models and their application.

2. In 1999 Cartwright proposed a similar idea—see her 1999, 138, 143, and 148. Her proposal differed in seeing an essential connection with her "natures picture" (139) and in requiring that the ceteris paribus condition "does not mark yet another variable . . . that has mistakenly been omitted from [the generality statement]" (143). On my proposal ceteris paribus conditions may always be partially absorbed into a refined statement of the generalization, but we expect that the process can never be completed, presumably because nature is simply too complicated. My proposal looks to be much closer to Cartwright's as she formulated it in 2000: ceteris paribus regularities are ones that "hold only so long as all the causes that operate are causes described within the [relevant] theory" (2000, 220; also 210, 211, 213, 214; also 1999, 10 and 188).

Reread the last two paragraphs with 'models' substituted for 'cp-generalizations'. Replace the example of matches lighting when struck with application of any of an extremely wide range of scientific models. It is notoriously difficult to get a model and an experimental situation to fit or to acquire the needed procedural knowledge. It is impossible entirely to encode the required skill in explicitly stated protocols.

The claimed generality-providing character does not hold for all models, but exceptions, such as a model of the Empire State Building, are few and far between. Let us call the relevant sort of models that extend the work of cp-generalizations *generality-purveying models*. We can see these generality-purveying models as "elaborate cp-generalizations," as carrying on the kind of job done by what we call cp-generalizations in more and more involved form. Conversely, we can see ordinary cp-generalizations as simple limiting cases of generality-purveying models. In cp-generalizations and generality-purveying models we have not two clearly distinguished modes of representation but two general ways of referring to relatively simple and more complicated forms of a variety of general representational activities that lie on continuum. Like 'tall' and 'short', 'cp-generalizations' and 'generality-purveying models' are two imprecise terms that indicate relative extremes. When the contrast does not matter I shall refer to them collectively as *regularity guides*.

3. Are Laws Primary? Laws are often taken to be primary. It is expected that the success of regularity guides should be explained in terms of laws. Why?

Because laws tell us what things are "at bottom," providing the "ultimate ontology"? We have few or no exact laws, and the best approximations we have are extremely limited in what they can tell us about what things are. Our understanding of the approximate microstructure of matter is of great interest, but hardly exhausts the information we value about objects in the world. Most of what we know and would like to know about objects in the world we cannot learn even from the approximations to exact laws that we take ourselves to have, because the subject matter is too complicated. And even where we do use fundamental theory to help us understand what things are and how they behave, most of the applications involve modeling in the extreme.

Or it may be held that laws are primary because, unless regularity guides are explained in terms of laws, in particular by an exact specification of conditions of application, regularity guides remain mysterious.

We must ask: Are laws any the less mysterious? If we were to have an exact generalization, would it be any the less mysterious why it holds than why an inexact regularity guide usually holds?

An advocate of laws might concede that all regularity in the universe, exact as well as inexact, is mysterious but insist that inexact regularity guides involve additional mystery: not only why it is that they hold when they do, but also why they fail when they fail. Very often one can explain specific failures of regularities: the match not lighting because it was wet, or the circuit malfunctioning because a contact was dirty. Indeed, one approach to cp-generalizations is to claim that every failure can, at least in principle, be explained. However, explanation in terms of exact laws is never how these explanations go in practice, because we don't have the laws that could serve and we couldn't apply them exactly if we did. Thus the claim that an understanding of a regularity guide and its failures is really only given in terms of exact laws is to claim, implausibly, that we never really succeed in such explanations. One can maintain that for every regularity-guide and its failures we should be able to give an explanation in terms of other, often more exact, regularity-guides (something for which we have abundant evidence), while denying that there have to be some generalizations (the exact laws) that will suffice for all such explanations. To take the evidence supporting our confidence that there will be ever more detailed accounts as evidence for a "final" account would appear to commit the "UEEU" fallacy of taking evidence for a generalization of the form $(\forall x)(Ey)$ to be evidence for the logically stronger $(Ey)(\forall x)$.

So I propose that we should stand the traditional order on its head. Rather than seeing laws as primary and regularity guides as in need of explanation in terms of laws, we should see regularity guides as primary—as what we actually have—and see talk of laws as a sometimes usefully idealized way of talking about what are, more accurately speaking, regularity guides. Once we see talk of laws as idealized talk of regularity guides we will see the intractability of associated problems as an artifact of forgetting that the law-idealizations are just idealizations.

4. Projectibility, Reliability, Counterfactuals, and Lawlikeness. Traditionally important topics connected with laws have been projectability, lawlikeness, and the interrelation between these and counterfactuals. Work in the tradition of Cartwright and Giere that emphases the role of models and relegates law statements to "tools in our model building tool kit" has hardly addressed these traditional topics. Do these topics drop off the budget of issues if we reject law statements as truths about the world? I don't think so.

Projectibility has always constituted an issue for cp-generalizations just as for laws. Clearly the issue applies equally to generality-purveying models, another hint that models carry on the work of cp-generalizations in more elaborate form. One can describe "gruesome models" just as easily as gruesome predicates and cp-generalizations. A gruesome model receives no more confirmation from its successful applications than gruesome generalizations do from their positive instances.

Just as we test and confirm cp-generalizations, we test and confirm models. I have suggested that generality-purveying models carry on the work of cp-generalizations in more complex and multifaceted ways. Corresponding to the difference in complexity of cp-generalizations and generality-purveying models, there correspond differences in the ways we test and confirm. But what I am collectively calling regularity-guides are all general means of describing the world that, when well tested, we take to be reliable. Just as our generalizations are always ceteris paribus, generality-purveying models always come with their explicit or tacit conditions of application and corresponding domains of reliability, a range of circumstances that may be more or less well understood but that always defy exact specification.

If a generality-purveying model is reliable, we will say that if it were applied in its domain of application it would give an accurate description of what does or will happen. Such a claim is not vacuous to the extent that we can given an independent characterization of the domain of application or to the extent that we posses the skill to tell when the model can reliably be applied. Thus a Newtonian model reliably applies for velocities small compared to that of light and for masses small compared to, say, that of the sun. How small is small enough will depend on what is at stake; judgment of this issue immediately provides an example of how skill may be needed, skill in determining whether the values given by the model will serve well enough for purposes that themselves may be hard to formulate exactly.

Conversely, to the extent that we are willing to endorse counterfactual application of a model we are expressing confidence in the model's reliability, again subject to constraints required by the domain of application.

When it was laws that were under consideration we felt sure that there should be a correspondence between a law and the counterfactuals that the law "implied." But as soon as one looked at specific applications it appeared to be impossible to say exactly which counterfactuals should correspond to a law.

We resolve this tension by reconstruing talk about laws as an idealized way of talking about regularity guides, an idealization that abstracts away from the limitations of ceteris paribus conditions and restrictions to domains of application. If one takes for granted that the conditions of application obtain, then the counterfactuals that one takes to correspond to a regularity guide will hold. If we presuppose that the match is dry, there is no wind, and, if struck, the match will be struck "just right," then we will accept both that if the match were to be struck it would light and if it were not to light it would not have been struck. But often we can presuppose no such things. Moreover, often the very statement of a counterfactual can suggest failure of relevant conditions of application. One can easily hear "if this match were not to light" as calling into question some condition of application, and so hearing it inclines one to reject "if this match were not to light it would not have been struck."

Of course I have done no more than illustrate how the presence of ceteris paribus conditions complicates the correspondence between generalizations and correlative counterfactuals, and examples of regularity-purveying models and associated conditions of application will be much more complex. However, the example establishes the point that conditions of application will complicate the correspondence between regularity guides and counterfactuals, thereby helping to make sense of the conviction that there will be such connections while appreciating that they will be far from straightforward. And the example illustrates the kind of considerations that one can expect to be relevant in other cases.

Similarly, once we take conditions of application into account, an absolute distinction between the accidental and the lawlike is revealed as an artifact of the law-idealization. In ordinary cases it would be just an accident that all the coins in Goodman's pocket were quarters. But not if Goodman felt strongly that pennies, nickels, and dimes are not worth carrying around and systematically gave such small change to his five year old. Much regularity results when specialized circumstances effect a projection of a worldly structure too complicated for exact human discernment.

5. Necessity, Contingency, and Conditions of Application. As the subject is traditionally viewed, laws specify what is physically necessary. Alternatives compatible with the laws are physically contingent. The laws, together with contingent (initial and boundary) conditions, specify what will happen.

In his contribution to this symposium Frisch shows how these contrasts fail for classical electrodynamics and concludes by questioning the distinction between the physically necessary laws of the theory as opposed to contingent initial and boundary conditions. Once again, if we take talk of laws to be an idealization of our use of regularity guides, the conflicts can be seen as an artifact of the idealization. Recognizing the law-idealization predicts rejection of an all-or-nothing contrast between physical necessity and contingency while preserving room for a much more natural graded range of modalities.

If we take a regularity guide to be reliable we take ourselves to be able to count on the descriptions it provides, and in so doing to have learned something about the world. This something is fairly characterized as modal: It is the distinction between what the regularity guide excludes, permits, and requires.

But the reliability of a regularity guide is always qualified, as I keep stressing: The conditions of application must be satisfied. Thus, when we let go of the law-idealization, the modal force that goes with a regularity guide is always relativized, made conditional on satisfaction of the conditions of application. The modal force applies only where the regularity guide applies, and no regularity guide applies everywhere. Instead of a strict dichotomy between physical necessity and contingency we have a complex network of modalities. Thus the very same conditions that are endorsed as necessary according to one regularity guide will hold only as long as the conditions of application apply, which in turn may be something characterized as contingent relative to another regularity guide. We get just the sort of interplay observed by Frisch: The Dirac-Lorentz equations can be counted on to hold—to describe what must occur—but only under the assumption of accelerations tending to zero at large distances. So far as the model in which the Dirac-Lorentz equation is developed is concerned, if this condition does not hold the equation is up for grabs.

6. Where Does Regularity Come From? We have seen that when we reconstrue talk about laws as an idealization that abstracts away from the ceteris paribus conditions of regularities and the conditions of application of models we retain roles for the familiar law-ideas of projectability, reliability, counterfactuals, necessity, and contingency. But all the associated problems are seen in a new light. The problems are hardly "solved," but in many respects they have shed their apparent intractability and look susceptible to sensible consideration and study in specific cases. I will close by looking at one more respect in which questions connected with laws take on a more nuanced appearance when we recognize the law-idealization for what it is: Where does regularity come from?

Traditionally we take the regularity we observe to constitute fragments of the absolute, exact regularity described by exact, true laws. In turn, we take this unqualified regularity to be built into the objective structure of the world, a structure that it is the job of science to discern.

In "The FineWright Theory" (forthcoming) I urge, in agreement with Giere and with Cartwright in at least some statements, that we more sensibly take an agnostic attitude towards this picture, but that even should it be correct our best bet is that the world is so dauntingly complicated that we will never discern its structure exactly. The best explicit characterizations that we have now, and are likely to get anytime in the foreseeable future, are ones that work in terms of the inexact descriptions of regularity guides. All the regularity so described is based in "the world," to be sure; that is, such regularity is always at least partially, and most often entirely, out of our explicit control. Yet, even when a regularity is utterly out of our control in any explicit sense, there are usually senses and ways in which the regularity has a human component. What we describe with regularity guides is really a confluence of contributions from the world and from us.

In some cases we play a very active role in shaping regularity, as in the development of human rules and laws—in the legal sense—and the practices of enforcement that go along with them. Other human activities shape regularities in a less self-conscious way, as in the case of economic systems and social practices.

Social regularities are hardly the only ones to which human construction contributes. Every constructed apparatus or experimental situation, every bit of reliable technology, is also explicitly shaped by human design (a point much emphasized by Cartwright 1999). Nature constrains what options we have, but from among nature's options the regularities that emerge are guided by our choices. Other regularities have a human component in that they emerge by selection of propitious conditions of application. Hooke's spring "law" is a far cry from universal. It holds only approximately and only of—springs. As always the regularity is saved from vacuity by independent characterization of and skill in identifying materials that will function as springs—that obey Hooke's law to a degree of approximation adequate to the purposes at hand. The human element in such cases lies in our looking in the right places to identify limited regularities that are of interest to us.

Nature also contributes regularity by contributing accidents that project humanly accessible regularity from more complex structure. Examples are ubiquitous: the genetic code, the salinity of seawater, the planetary orbits, and so on.

At this point law advocates may protest that while the foregoing examples are, literally speaking, correct, they are misleading. They obscure the fact, it may be claimed, that all such examples are manifestations of the underlying exact laws governing the world. Well, maybe. But those exact laws look to be hopelessly out of human reach. And even if, or to the extent that, we were to have them, we would still expect their application to be so complicated that we would have to rely on almost all our regularity guides just as we do, without exact underpinning derived from laws. Thus the regularity guides we have are a confluence of what nature allows, what nature fortuitously crystallizes, and what we construct, design, set up, arrange, isolate, find, fall into, and happen upon by good luck. None of this is just a product of human imagination or will. But leaving out the human contribution is also misleading.

There is one more objection frequently made to the kind of attitude I have been urging. To see the regularity guides to which we have access as no more than, in Cartwright's phase, a patchwork is to ignore the extraordinary unification that the sciences have already provided and the detailed explanations from deeper principles, in so many cases, of why regularity-guides operate as they do.

This prima facie conflict can be reconciled. First, all such extant unification and explanation is in terms of what are still regularity guides. In fact one always uses modeling in the extreme to unify and explain regularities at one level from principles at a "more fundamental" level.

Second, such explanations are not cumulative or transitive. Not if we require of genuine explanations that they provide humanly accessible understanding. Referring to Putnam's old example of why the round peg will not go through the square hole, we use microtheory to explain the approximate rigidity of the material that constitutes the peg and the board with the hole. We then use the concluded rigidity, facts about the shape of the peg and the hole, and some basic geometry to explain why the peg won't go through the hole. These explanations do not compose to give an explanation from the microtheory. The same sorts of considerations apply to hydrodynamic explanations of the fluid properties of water, circuit theory explanations of the operation of radios, to say nothing of explanations of biological, psychological, and social phenomena.

Some may respond by acknowledging that characterization in terms of exact laws is an idealization but still insist that thinking of the world as governed by exact laws is valuable, even essential, in order to motivate us to look for unifications and explanations of one kind of regularity in terms of others. Without this mind set we would never have looked for, and so never found, these jewels of science.

Given the foregoing reconciliation, at least some will still find motivation without thinking in terms of the law-idealization. But we each take our motivation from where we can, and if the law-idealization provides such motivation, that constitutes one of the idealization's many virtues. The idealization has many other useful applications, generally freeing us from the distraction of conditions of application where those are tacitly understood or can be ignored for present purposes. Difficulties arise only when the law-idealization is mistaken for an exact truth. I have argued that many of the puzzles about laws are an artifact of this conflation and that when we recognize the idealization for what it is many of the issues surrounding regularity take on a more tractable guise.

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