

Laws, Exceptions and Dispositions

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Abstract Can laws of nature be universal regularities and nevertheless have exceptions? Several answers to this question, in particular the thesis that there are no laws outside of fundamental physics, are examined and rejected. It is suggested that one can account for exceptions by conceiving of laws as strictly universal determination relations between (instances of) properties. When a natural property is instantiated, laws of nature give rise to other, typically dispositional properties. In exceptional situations, such properties manifest themselves either in an unusual way or not at all.

Keywords Law of nature. Exception. Disposition. Proviso. *Ceteris paribus*.


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1 Introduction

Science strives to establish general truths. One way of making the demand for generality precise is to require that nomological hypotheses can contain only *strictly qualitative* predicates. Such predicates must not contain any reference to objects, time instants or particular places. The statement ‘all people in this room have a heart’ is not a nomological hypothesis because it violates this requirement. No matter whether it is true or false, such a statement cannot express a law of nature simply because it is not sufficiently general.

2 The Problem

The following statements are generally taken to express laws, but they are true only if they do not have a strictly universal form. Insofar as their form is strictly general, the statements are not true.

(1) The practical syllogism is fundamental to the common sense explanation and prediction of human behaviour. It can be expressed in a nomological form: if person x wants A and believes B to be an optimal means to achieve A , then x will attempt to do B . Simply put: “If a person wants something, she’ll take steps to get it” (Earman, Roberts 1999, 447; Schiffer 1991, 2). Of course, such a generalisation has its exceptions: right now I have many desires – like the desire to lie in the sun on the beach – towards whose satisfaction I take no steps at all, either because the satisfaction of such desires is out of reach or because I decide to pursue instead the satisfaction of some higher-ranking desires, like writing down what I think about exceptions.

(2) The economic generalisation: “If the price of a good falls, the demand for it will raise” (Earman, Roberts 1999, 460) expresses a real dependence of demand on price, but suffers from exceptions. If the price for a better good B falls even more than the price of good A , so that B becomes cheaper than A , the demand for A may well fall in spite of its falling price.

(3) There is a biogeographical law according to which: “The equilibrium number S of species of a given taxonomic group on an ‘is-

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land' (as far as creatures of that group are concerned) increases exponentially with the island's area A : $S = cA^z$. The (positive-valued) constants c and z are specific to the taxonomic group and island group" (Lange 2002, 416-17). However, there are exceptional islands with respect to such a law: a smaller island lying close to the mainland may have more biodiversity than a larger island far out in the ocean. Similarly, a smaller but climatically heterogeneous island may contain more species than a larger but climatically homogeneous island. However, the existence of those exceptions does not prevent statement (3) from expressing a real dependency between island surface and biodiversity.

(4) In biology, Mendel's law of segregation states that among sexually reproducing diploid organisms, for every allele pair (genes that occur at the same site on the two chromosomes of a chromosome pair), each of the two alleles occurs in 50% of the gametes. In other words, the two alleles are equally distributed over the gametes. Yet, this regularity is subject to exceptions, for certain genes undergo a 'meiotic drive' which makes them over-represented, that is, they represent more than 50% of the gametes (Sterelny, Griffiths 1999, 58; Sober 1993, 107-9; Mitchell 2002, 331).

(5) According to the chemical law of definite proportions, any chemical compound consists of elements in invariant proportions. However, there are exceptional substances, such as ruby, which is composed of aluminium (Al), chrome (Cr), and oxygen (O). The proportions of aluminium and chrome are variable; this is represented in the chemical formula of ruby as follows: $(Al, Cr)_2 O_3$. A ruby can be modelled as a regular crystal where aluminium atoms are bonded to oxygen atoms in a regular structure, in a proportion of 2 Al atoms to 3 O atoms. In this network, some Al atoms are replaced by Cr atoms which are similar in size and bonding capacities. The proportion of Al and Cr varies from ruby to ruby, which violates the law of definite proportions (Lange 2002, 408).

(6) The most remarkable fact is, perhaps, that we can find generalisations subject to exceptions even in physics. Hempel gives the following example: for every bar magnet b , "If b is broken into two shorter bars and these are suspended by long thin threads close to each other at the same distance from the ground, they will orient themselves so as to fall into a straight line" (Hempel 1988, 148). There does not seem to be any way of interpreting this statement so that it is both strictly universal and true. In exceptional cases, in which there is a strong air current or a strong external magnetic field, the two halves of a bar magnet will not orient themselves along a straight line.

(7) Moving on to an even more fundamental level, it seems that even the generalisation regarding acceleration due to gravitational attraction is not free from exceptions: if the centre of mass of a massive body with mass m_1 is at a distance d from the centre of mass of a second body with mass m_2 , the first body undergoes an acceleration of $G \frac{m_2}{d^2}$ towards the second body. In this form, the generalisation is subject to many exceptions: most massive objects situated at some distance from a second massive object will not accelerate towards that object, either because they are even more strongly attracted by other massive objects, or because their movement is subject to other forces. A helium-filled balloon rises even though it is close to the Earth, and electrostatically charged bodies can repel each other rather than get closer according to the law of gravitation (Cartwright 1983, 57-8; Hempel 1988, 151; Pietroski, Rey 1995, 86; Smith 2002).

We can express the problem of exceptions to laws in the form of a dilemma. Science tries to discover laws. Exactly what it takes for a regularity to be a law is controversial, but it is generally agreed that it takes at least strict universality. In order for "All A are B " to qualify as a law, it must at least be strictly true that all A s are B s. The fact of giving nomic sentences a strictly universal form leads to the first horn of the dilemma: in this form they are false. This is precisely what Nancy Cartwright is saying when she claims that laws, even physical ones, "lie" (Cartwright 1983). However, what possible benefit could science draw from discovering false generalisations that are not false merely because of our general ignorance (in other words, by virtue of the problem of induction)?

We can try to avoid the problem of the falsity of nomic statements by giving them a form which is not strictly universal, but this leads to the second horn of the dilemma: construing generalizations allowing for exceptions as 'non-strict' laws with a *ceteris paribus* clause attached to them. It seems possible to preserve the truth of troublesome nomic statements by adding a proviso: the alleles are equally distributed across the gametes, *provided that nothing interferes*. The idea that laws subject to exceptions have a particular logical structure has been developed in two main ways. According to the first, there is only one kind of law, but it is expressed by two kinds of statements: ordinary law statements and *ceteris paribus* law statements. According to the second, the difference in logical structure between statements mirrors an objective difference between two kinds of laws: strict laws and *ceteris paribus* laws.

3 *Ceteris paribus* Statements

Let us examine the hypothesis according to which the difference between laws subject to exceptions and strict laws lies on the level of the statements that express them. Laws subject to exceptions are expressed by statements containing a *ceteris paribus* (hereafter cp) clause. According to this hypothesis, that clause plays the role of an *indexical* expression that refers to a paradigmatic type of situation in which the regularity in question holds (Hausman 1992; Keil 2000; Glymour 2002). To say that the generalization also more generally holds if “all else is equal” means that it holds in all those (real or counterfactual) situations outside this paradigmatic class, in which all factors independent of the antecedent but capable of influencing the consequent have exactly the same values as in the paradigmatic class. We can express this suggestion by saying that cp statements have an ineliminable indexical component: “cp, the alleles are equally distributed across the gametes” means, with respect to a given concrete population and sample of gametes, that 1) in this sample, let us call it the paradigmatic sample, alleles distribute equally across the gametes, and that 2) the same is true for all those populations and samples of gametes which share all other relevant features with the paradigmatic sample.

The problem with this proposal is that generally the set of relevant factors is not a well-defined class. First of all, it is impossible to enumerate explicitly the relevant factors *present* in the sample class that must be also present in all populations to which the law should apply. What is even more problematic is that there always seem to be infinitely many possible interfering factors which are *absent* from the paradigmatic sample and which must also be absent from all populations to which the law is intended to apply. To use Joseph’s (1980) expression, a cp statement is generally true only *ceteris absentibus*. This is just a new form of our problem: there is no way to express a cp statement explicitly, so that it is strictly universal and true; there seems to be no general way to specify explicitly which factors must be absent. As a consequence, it seems that cp statements do not have a well-defined content; in other words, they do not express any definite proposition (Schiffer 1991). Insofar as the conditions in which the generalisation holds cannot be explicitly stated, it risks being trivial or vacuous: “cp, all *F* are *G*” might not have any more content than “all *F* are *G* unless they are not”, or “all *F* are *G* or they are not”.

Along similar lines, Marc Lange has suggested that a cp nomic statement includes an ineliminable reference to *paradigmatic exceptions*: the ruby exemplifies a kind of exception to the law of definite proportions. However, we cannot avoid the problem in this way, for it is impossible to provide an explicit and complete list of all kinds of exceptions. This is apparent in the form which Lange gives to the law

of definite proportions: all chemical compounds consist of elements in invariant proportions, “unless the compound is a network solid or a polymer *or something like that*” (Lange 2002, 409).

4 *Ceteris paribus* Laws

David Armstrong holds that laws with exceptions belong to a special category of laws: he calls those laws that have no exceptions “iron laws” and those that are true *ceteris paribus* “oaken laws”. Oaken laws have the following form: “It is a law that Fs are Gs, except where Fs are Hs, are Js, and Ks...and so on for an infinite set of distinct properties” (Armstrong 1983, 28). Insofar as the gap indicated by “...” cannot be filled, statements in this form specify the content of the law in an incomplete way. Consequently, it is unclear how such a law can be tested, and how it can play an informative role in scientific explanations.

I propose to interpret Pietroski and Rey’s (1995) account as an attempt to clarify Armstrong’s distinction between iron laws and oaken laws. Pietroski and Rey agree that it is impossible to complete the antecedent of a cp statement so as to remove the gap expressed by “...”. However, they offer a condition under which such a kind of law is neither trivial nor vacuous. A law can have exceptions without being trivial if, in all situations in which the antecedent is true but the consequent false, there is an independent factor which explains why the consequent does not hold.

Here is their analysis of the logical structure of cp laws.

cp $[(x) (Fx) \Rightarrow (\exists y) Gy]$ is nonvacuous, if: [...] $[(x) (Fx) \Rightarrow (\exists y) ($ either Gy or $(\exists H)(\exists w)(H \neq F) \ \& \ I([Hw], [\neg Gy])$ and: either $[Hw]$ explains $[\neg Gy]$ or $[Hw] \ \& \ (Fx) \Rightarrow (\exists z) Gz$ explains $[\neg Gy]$ ¹ and (iii)[...]. (Pietroski, Rey 1995, 92; emphasis added)

“I (x,y)” means “x plays an explanatory role independent from y”. (Pietroski, Rey 1995, 92)²

This may be read as: “The nomic statement ‘*Ceteris paribus*, for all x, if x is F then there is a G’ is not vacuous if: for all x which are F, there is an object y that is either G or is not G but there is some other object w with property H, such that $H \neq F$ and the fact that w is H plays an explanatory role independent of the fact that y is not G, and

¹ The text says “ $\neg Gz$ ”, but I suppose this is a typo.

² I skip over other conditions that Pietroski and Rey set for non-vacuous cp laws.

the fact that w is H either explains on its own why y is not G , or it explains it together with the law according to which, for all x , if x is F then there is a G , and [...]”.

This ingenious proposal faces two problems.

Insofar as Pietroski and Rey’s proposal is interpreted semantically, as an analysis of the peculiar logical structure of cp laws, it makes laws ‘holistic’. On this semantic interpretation of Pietroski and Rey’s proposal, the consequent of a cp law contains a quantification over possible interfering factors: $(\exists H)(\exists w) \dots$ Such interferences are themselves due to laws linking the presence of an interfering factor (Hw) to the lack of instantiation of the consequent of the main law ($\neg Gy$). These other laws sneak into the content of the main law because they make true the explanation of the non-occurrence of the consequent of the main law. Now, at least some of those laws are themselves cp laws which contain other quantifications over interfering factors and still other laws, and so on. Thus, the semantic interpretation of Pietroski and Rey’s proposition leads to the ‘holistic’ result according to which every single cp law has the tendency to incorporate a large number of other laws. This point seems to contradict the very notion of law, which includes the idea of a determinate relation between a small number of factors that can be described independently of other laws. This undesirable consequence seems to me to stem from the fact that Pietroski and Rey erroneously try to incorporate an (epistemic and heuristic) strategy for distinguishing situations that refute a law from exceptional situations into a semantic analysis of the very content of the law. Pietroski and Rey do not succeed in giving cp laws a well-defined content that excludes the sum of scientific knowledge called upon during the testing process.

Pietroski and Rey’s account faces a second and probably even more serious problem. Earman and Roberts (1999, 453-4) have noted that it trivializes the notion of cp law, for Pietroski and Rey’s conditions yield the result that any two properties whatsoever are linked by a cp law. Pietroski and Rey’s analysis has, for example, the absurd consequence that it is a cp law that all spherical objects are conductive: it is indeed very plausible that for all spherical objects that are not conductive there is an independent factor that 1) explains why the object is an insulator and 2) explains other facts that are logically and causally independent from its being an insulator. Such independent factors can be found in particular in the molecular and atomic structure of the object.

More generally, the very idea that there is a special category of cp laws seems to fail for the following reasons: there seems to be no way of explicitly spelling out the conditions under which the consequent of such a law is satisfied, leaving the content of the cp statement vague and indeterminate. This is what Lipton (1999, 157) calls “the problem of content, the problem of seeing how cp law statements

succeed in saying anything at all". This problem brings other subsidiary problems with it: "the problem of falsification" (Smith 2002, 235) is that no situation containing an instance of the antecedent but not of the consequent suffices to refute a cp law. Given the indeterminacy of what factors must be present or absent together with the explicit part of the antecedent, one may always blame those factors for the non-occurrence of the consequent, which amounts to immunizing the law from refutation. The other side of the coin is that there do not seem to be any clear criteria for the *confirmation* of such a law. A situation where the consequent occurs confirms the law if it occurs owing to the antecedent rather than interfering factors. For the same reason it is doubtful whether such a law could lend support to counterfactual conditionals: we have good reasons to think that the consequent occurs only insofar as the counterfactual situation is sufficiently similar to the paradigmatic one: the problem, then, is that we do not have explicit criteria to judge this similarity. Finally, at least some cp laws, in particular those belonging to physics, seem to face the "problem of instantiation" (Lipton 1999, 157): there do not seem to be any situations at all to which statement (7), which links acceleration to gravitation, applies. In this case at least, other factors interfering with the consequent of that 'law' are never absent, which makes the need for an explanation of why such a law can play a useful role in science especially pressing.

5 No Laws Outside Fundamental Physics?

The failure to spell out the logical form of cp laws has led many authors to the radical conclusion that our examples 1-7 are no laws at all. A proper law is necessarily strict and does not need any qualification by a *ceteris paribus* clause; however, such strict laws can only be found in fundamental physics. Sheldon Smith traces the main mistake that leads to the concept of cp law back to the failure to distinguish between fundamental laws and equations of motion, which laws allow us to derive: only equations of motion, not laws, concern specific systems and hence can be used to explain and predict their behaviour. Smith works with the mode of analysis of scientific reasoning that he calls "the Euler recipe" (Smith 2002, 245). In order to derive the equation of motion of a mechanical system, we must proceed as follows:

- (a) Specify the class of objects constituting the system to be studied.

- (b) Specify the qualities giving rise to mutual forces between these objects, according to 'special force laws'. For example, mass gives rise to gravitational attraction, and electric charge gives rise to electrostatic attraction or repulsion according to Coulomb's law.

(c) For each object O in the system, calculate the vector of the force acting on it, which results from its relation to each other object in the system with which it shares such a force-generating quality. For example, given an electrically charged object, determine the force it exerts and the force it undergoes with respect to all other charged objects in the system by virtue of Coulomb's law.

(d) For each object in the system, calculate the vector sum of all the forces that acted on it.

(e) For each object, set the sum of forces acting on it equal to

$$G \frac{m_1 m_2}{d^2}$$

This analysis indeed shows that special force laws, such as the law of gravitation, which says that the force between two massive objects equals $G \frac{m_1 m_2}{d^2}$, are not used to directly derive any prediction about the evolution of concrete objects to which they apply. If the prediction of the evolution of the system is wrong, this does not show that the law (or laws) used in (b) and (c) are false. The law can be true even if its application to the system is subject to the proviso that all non-negligible factors have been included in the description of the system. Such a proviso does not concern the law, but rather the entire algorithm. If the acceleration of a real object does not correspond to the law of gravitation, we need to look for the error in the first two steps of the algorithm: the description of the system has neglected to include some objects (step 1) or qualities (step 2) that are sources of non-negligible interactions.

Smith concludes that fundamental laws do not concern the evolution of concrete systems and that the equations of motion describing this evolution should not be called laws. Smith's argument recalls that formulated by Russell against the principle of causality:

As soon as the antecedents have been given sufficiently fully to enable the consequent to be calculated with some exactitude, the antecedents have become so complicated that it is very unlikely they will ever recur. (Russell [1917] 1959, 188)

Russell concludes that there are "two sorts of laws: first, those that are empirically verifiable but probably only approximate; secondly, those that are not verifiable, but may be exact" (Russell [1917] 1959, 197). The former correspond, within Smith's schema, to the equations of motion, while the latter correspond to the laws.

6 Laws and their Application

Smith's analysis contains an important point that I agree on: giving an account of the existence of exceptions requires making sense of the distinction between laws and their application, rather than looking for a peculiar logical form of cp laws. However, Smith's interpretation of the equations describing the evolution of systems is unsatisfactory. Contrary to his thesis, equations of motion bearing on particular systems are laws according to all traditional criteria for lawhood: they can be refuted and confirmed, and they can be used for explanation, prediction and counterfactual reasoning. Smith's account remains silent about the content of fundamental laws; Smith is happy with the negative thesis that they do not concern concrete systems. As far as his analysis goes, fundamental laws could be mere calculating devices. Yet, at least as far as special force laws are concerned, the causal criterion of reality³ gives us grounds to regard the forces they determine as real: forces resulting from those laws are real to the extent that they cause - or causally contribute to determine - the evolution of concrete systems.

There are several ways to interpret the reference of expressions belonging to the statements of cp laws in a realist way. According to Silverberg (1996) and Hüttemann (1998), cp laws bear on *ideal* circumstances that are rarely if ever realized. Hüttemann (1998, 129) states that "laws *describe* the behaviour of physical systems under very special conditions that are hardly ever realized, namely, in isolation". Yet, this suggestion does not solve our problem: if laws concern isolated systems, how is it possible that they determine the evolution of non-isolated systems in such a way that we can predict, explain and counterfactually reason about them?

7 Dispositional Properties and Dispositions

The most promising account of the nature of laws makes use of the notion of dispositional property. Let us abandon the theory - endorsed by both defenders and critics of cp laws - according to which there is a general difference between fundamental laws and cp laws. This move is possible if we make the hypothesis that laws bear directly not on concrete systems, but rather on *aspects* or *properties* of these concrete systems.

³ According to this criterion, dating back to Plato (*The Sophist*, 247d-e), it is a necessary and sufficient condition for an entity to be real that it modifies causal interactions. In Armstrong's terms, "everything that exists makes a difference to the causal powers of something" (Armstrong 1997, 41). I analyse the consequences of the application of this principle to natural properties for the modal status of laws in Kistler 2002.

The difference between fundamental laws and “system laws” (Schurz 2002) is one of degree.⁴ The simpler the properties to which a law applies (e.g. mass, electric charge, and partial forces) in order to express relations of dependency between such properties – which are *dispositional properties*, or ‘powers’ – the more fundamental the law is. Dispositional properties, such as mass and electric charge, are not directly observable, but they endow their bearers with a certain number of *dispositions*: the identity of a dispositional property can be specified – albeit not exhaustively analysed – by reference to a set of dispositions D_i , which consist in manifesting M_i in test-situation T_i .

Consider an object O_1 with mass m_1 which is at distance d from a second object O_2 with mass m_2 . According to the law of universal gravitation, O_1 is subject to a force F with magnitude $G \frac{m_1 m_2}{d^2}$. To be subject to force F is a dispositional property: it is not directly observable or manifest, but its possession makes true a set of conditionals applied to O_1 . If O_1 is subject to F but not to any other force, then O_1 will accelerate with $G \frac{m_2}{m_1 d^2}$, towards O_2 . If O_1 is subject to F and to a second force F_2 of the same size as F but going in the opposite direction, then O_1 won’t accelerate at all. If O_1 is, in addition to F , also subject to F_2 , which goes in the opposite direction but has twice the strength of F , then O_1 will move with acceleration $G \frac{m_2}{m_1 d^2}$ away from O_2 .

8 What is an Exception?

It would be paradoxical to construe exceptions to the law $(x) (Fx \rightarrow Gx)$ as situations in which an object O is both F and non- G . Rather, such a conjunction of facts constitutes a refutation. This shows that the statement $(x) (Fx \rightarrow Gx)$ is false and does not express a law. Such a situation cannot therefore be considered an exception to that law.

To avoid this paradox, exceptions should be defined within the framework of the distinction between the law itself, which bears on certain properties, and the concrete objects (or systems) that possess those properties and to which the law is applied. This distinction is grounded in the distinction between 1) concrete objects and events, which have many properties, not necessarily lawfully linked to each other, and 2) the natural properties that those concrete objects possess. Laws bear directly on properties; more precisely, they are determination relations between natural properties. They have only an in-

⁴ I borrow the expression “system laws” from Schurz (2002). Gerhard Schurz uses the expression “laws of nature” to describe what I call “fundamental laws”, thereby suggesting that system laws are not laws of nature. However, system laws – just like Smith’s equations of motion – are laws of nature according to all traditional criteria: they can be used in explications, predictions and counterfactual reasoning. Moreover, they are ‘natural’ to the extent that they are discovered rather than created.

direct impact on the concrete objects possessing those properties and on the regularities wherein these objects partake.⁵ On the dispositional account of laws, a law, such as the law of gravitation, bears directly not on the concrete massive object O , but rather on one of its properties, namely its being massive. This law is the (strictly universal) fact that, in situations in which another object with mass m_2 is at a distance d , the property of bearing m_1 always brings with it (without exception) the dispositional property of being subject to the force $G \frac{m_1 m_2}{d^2}$.

We can thus stick to the traditional thesis that such a law is universal. There is no exception to the association between the presence of two masses m_1 and m_2 at a distance d and the presence of an attractive force F whose precise size is determined by the law.

Here, though, we should prevent a major mistake that Nancy Cartwright seems to make repeatedly when offering her version of a dispositional account of laws.⁶ Calling the property of being subject to a force F a “dispositional property” might erroneously suggest that the massive object O only has the disposition to be subject to the force, but is not always actually subject to it. Indeed, Cartwright seems to suggest that there can be exceptions in which the object O is not subject to the force determined by the law. I disagree with Cartwright on this point. I reject her idea that laws, especially fundamental physical laws, are only true *ceteris paribus*, in the sense that a property instance of the antecedent does not always bring with it a property instance of the consequent, which is typically a ‘capacity’.

Coulomb’s law says that the force between two objects of charge q_1 and q_2 is equal to $q_1 q_2 / 4\pi\epsilon_0 r^2$. Yet, this is not the force the bodies experience. [...] Coulomb’s is never the force that actually occurs. [...] Coulomb’s law tells not what force charged particles experience. [...] To say it is in their nature to experience a force of $q_1 q_2 / 4\pi\epsilon_0 r^2$ is to say at least that they would experience this force if only the right conditions occur for the power to exercise itself “on its own”. (Cartwright 1999, 82)

The idea developed in the above passage spoils the solution to the problem of exceptions that led to the introduction of dispositional properties in the first place. For if Coulomb’s law itself has exceptions, that is, if there are situations in which its antecedent is present but not its consequent, then we are back to where we started: we do not have any explanation of the origin of such exceptions, and interpreting the consequent property dispositionally is of no help; at

⁵ I do not have space here to argue in favour of the thesis according to which those properties are particular entities, rather than universal entities. See Kistler 1999, 2002.

⁶ This mistake is clearly analysed by Markus Schrenk (2007).

best, such a conception pushes us to postulate a *second* dispositional property which endows the object with the disposition to experience the force – where this disposition is not always manifest. Therefore, we are once again faced with the problem of understanding what distinguishes exceptional situations in which the disposition does not manifest from regular situations in which it does, leading to an infinite regress. It is better to face the problem directly.

The hypothesis that laws bestow dispositional properties on objects having their antecedent properties allows us to solve the problem of exceptions only to the extent that it enables us to situate the origin of exceptions outside the law, between the possession of the consequent property and the behaviour by which this property typically manifests itself. The hypothesis that the consequent property is dispositional allows us to stick to the traditional idea that the law itself is strict and has no exceptions. Exceptions, in the proper sense, are thus test-situations for the dispositional property, in which it does not manifest itself in the typical way.

In a situation that is exceptional with respect to the law of gravitation, an object is subject to a gravitational force but does not exhibit the behaviour that is usually associated with that force. The application of the law – the inference from the law to the generalisation bearing on concrete systems possessing the properties on which the law bears – is legitimate only under a ‘proviso’: it is legitimate as long as nothing interferes, that no other force acts, or *ceteris paribus*.

According to the traditional view, laws are generalisations over concrete objects. If this were true, these laws would be false. Instead of reasoning by *modus ponens*, and concluding – to quote the title of Cartwright’s (1983) book – that the “laws of physics lie”, I think we should reason by *modus tollens*: given that the laws are not *all* false, for a reason that has nothing to do with their particular content, they are not generalisations bearing on concrete objects, but rather generalisations bearing on the properties of these objects.

Certainly, in most normal cases – outside of metaphysics seminars – we are interested in explaining, predicting and reasoning counterfactually about *concrete* objects. Reflection on exceptions teaches us that the transition from the law to its application to concrete objects is a far from trivial step.⁷

The analysis of the situation is the same in the case of fundamental laws and in the case of laws that are valid only for a limited category of objects, i.e. ‘system laws’. In both cases, whether the law applies, i.e. whether it is sufficient for a satisfactory explanation or prediction, depends on the strength of the influence exerted by all

⁷ It is not an inductive inference. Not only does the consequent not *always* manifest in the typical way but, generally, it doesn’t even do so *often*.

factors present in the situation, other than those mentioned in the antecedent of the law.

The difference is only due to the number of factors that are not mentioned in the antecedent of the law: this number is much greater in the case of fundamental laws, for their antecedents contain only a small number of simple factors, whereas the antecedent of a system law contains the specification of the type of system for which the law is supposed to hold. Such a specification implicitly contains a large number of properties: Mendel's law of segregation, for example, is a system law to the extent that it can only be applied to sexually-reproducing diploid organisms, i.e. a particular type of system with numerous properties. In Cartwright's terms, sexually-reproducing diploid organisms are "nomological machines": the law applies only to them. Both in the case of fundamental laws and in the case of system laws, the consequent is a dispositional property that does not, in so-called 'exceptional' circumstances, manifest in the typical way. Simply, in the case of system laws, the inference from the instance of the consequent to its manifestation seems less problematic than in the case of fundamental laws, because in the former case the antecedent contains a specification of the system and thus excludes many potentially interfering factors. Yet, this is only a difference of degree, to the extent that factors that are not specified in the antecedent can in any case prevent the consequent from manifesting.⁸

9 The Challenge of Circularity

Peter Lipton (1999) and Markus Schrenk (2007) have put forward a powerful objection to the analysis of exceptions in terms of dispositional properties. They note that the attribution of dispositions is faced with a set of well-known difficulties that are very similar to the problems raised by exceptions to laws.

A fragile object is an object such that, if it fell on hard ground from a height, it would break. As we have already seen, we must distinguish between the dispositional property itself (fragility) and the various 'behavioural' dispositions its possessor is endowed with in different test-situations. A dispositional property bestows many dispositions on its bearer (normally, an infinite number); we do not need to know all

⁸ According to Leszek Nowak (1972, 536), fundamental laws undergo a process of "concretization": step by step, the idealizations found in the antecedent of a fundamental law are dropped. At each step the law becomes more concrete, i.e. it comes closer to describing real systems where conditions are not ideal and many factors contribute to constraining their evolution, eventually resulting in a system law. This approach is further developed in Hanzel 1999.

of them in order to ascribe a disposition to an object. It is impossible to explicitly enumerate all the dispositions – specified in conditional form (test-situation, manifestation) – bestowed on the bearer by the dispositional property. This impossibility is one of the reasons in support of the idea that a dispositional property has a proper reality beyond the finite set of its particular manifestations. The same reasoning applies when we argue for the existence of theoretical properties:⁹ they allow us to explain different phenomena in a simple and unified way even if they cannot be identified with the conjunction of the finite number of events they produce. Similarly, the ascription of a dispositional property allows us to give a unified explanation of a potentially infinite set of manifestations in different situations.

The infinite number of the dispositions bestowed by a dispositional property is not the only reason why we cannot completely analyse the dispositional property D in conditional terms as follows: if an object possessing D is subject to test T_i , it produces manifestation M_i . Carnap (1936) has shown that the analysis of D in terms of ‘test-manifestation’ conditionals is inadequate if we give these conditionals the form of *material implications*. Recent research (Martin 1994; Mumford 1998; Bird 1998; Schmitz 2007) shows that dispositions cannot even be analysed completely and exclusively in terms of *counterfactual conditionals*. The reason is that every disposition comes with its ‘antidotes’: given a disposition D , an antidote to D is a property whose presence in a test-situation T for D inhibits the disposition’s typical manifestation M . The fragility of object O does not guarantee the truth of the conditional: if O fell on hard ground from a height, O would break. The impact could be absorbed by an air flow acting against the direction of the fall. It seems that the test of the disposition leads to the manifestation only *ceteris paribus*, i.e. on condition that no antidote is present.

Here is Lipton and Schrenk’s objection: the analysis of laws in terms of dispositional properties merely postpones the problem of exceptions or, even worse, it merely renames it instead of solving it.

⁹ In my article “The Causal Efficacy of Macroscopic Dispositional Properties” (Kistler 2007), I mention three aspects that distinguish dispositional properties from theoretical ones: 1) In order to be (conceived as) dispositional, a property needs to be one among other properties of the object and of the situation in which the object is set. Part of those other properties are unknown. No restriction of this kind conditions the ascription of a theoretical property. 2) Each disposition bestowed on the possessor by the dispositional property is expressed by a counterfactual conditional which necessarily contains a *ceteris paribus* clause. However, the ascription of a theoretical property may entail strict counterfactual conditionals. 3) We conceive of a property as dispositional to the extent that we conceive it as establishing a relation of dependence (*ceteris paribus*) of a manifestation with respect to a test-situation, which are both specified in *observational terms*. The identity of theoretical properties is in general determined by laws that do not necessarily involve observable properties.

The problem raised by the fact that the property referred to by the consequent of nomic statements 1-7 is not always present when their antecedent is present, arises again in the framework of the dispositional analysis of laws, on account of the fact that the dispositional property which constitutes the consequent of the law does not always manifest.

Lipton (1999, 166) uses the expression “Hume’s revenge” to refer to the thesis that “the detour through the disposition has made absolutely no difference so far as the problem of content is concerned”. Exceptions make the application of laws tricky because the fact that object *O* has property *F*, and that there is a law that $(x) (Fx \rightarrow Gx)$, allows us to infer that *O* is *G* only *ceteris paribus*, that is, under the proviso that nothing interferes. If we suppose that *G* is a dispositional property, then we can safely conclude that *O* is *G* regardless of the circumstances. However, we are faced with the analogous problem that, given a test-situation *T* for the presence of the dispositional propriety *D*, we can infer only *ceteris paribus* that *D* manifests in the characteristic way *M*. According to Schrenk, this shows that the dispositional analysis does not solve the problem of exceptions: “the disposition is a veiling strategy, hiding the *ceteris paribus* clause under the *burka* of the capacity term” (Schrenk 2007, 239). He concludes that “dispositionalism cannot claim to have solved or avoided the problems *ceteris paribus* clauses in laws create” (Schrenk 2007, 247).

10 Reply: Metaphysics and Scientific Method

We should not be surprised to discover that our thesis that laws directly bear on properties and express the fact that one property brings with it another, dispositional, property, does not make the problem with which we started *go away*. The problem of exceptions to laws and the problem of dispositional properties are both first of all scientific problems. Philosophical analysis cannot make them disappear; its goal can only be to understand the origin of these problems, as well as the scientific way of solving them, without aiming at solving them once and for all. Lipton and Schrenk’s objection seems to rest on a misunderstanding of the aim of philosophical analysis, to the extent that they object to our analysis that it does not yield an algorithm for solving scientific problems.

Euler’s algorithm is a schema that allows us to find scientific solutions to the problem of applying laws in classical mechanics. It is difficult to predict and explain the evolution of concrete systems using laws because we do not know *a priori* which properties and laws are relevant.

It is difficult to predict and explain the behaviour of a system starting from the attribution of dispositional properties for a similar rea-

son: the attribution of elasticity and resistance to the wings of an aeroplane, of viscosity to a motor oil within a range of temperatures, or of a certain hardness to an alloy used for dental inlays, can be used to predict and explain an object's behaviour in a concrete test-situation only if all relevant dispositional properties are taken into account, together with their antidotes.

The objection that the dispositional analysis does not 'solve' the problem of exceptions reveals the same questionable conception of the task of philosophy as Earman and Roberts express when they praise "Hempel's insight" and decry the futile "metaphysics of irreducible capacities" (Earman, Roberts 1999, 448). According to them, "there is no distinctively philosophical problem about *ceteris paribus*, but there is a scientific problem: what is needed is not finer logic chopping but better science" (Earman, Roberts 1999, 460). One could, with just as much – or, I would suggest, as little – reason, claim that there is no philosophical problem of induction, and no 'distinctively philosophical' Duhem-Quine problem concerning the empirical test of theoretical hypotheses, because all these problems are of an exclusively scientific nature. Science, to be sure, struggles with instances of these problems, but it ignores the philosophical task of analysing their general nature. Our way of explaining their origin and science's limited and fragile successes in overcoming them in particular cases consists in sketching a general metaphysical analysis of the objects of scientific explanations and predictions.

In particular, the metaphysical thesis that laws determine dispositional properties is not intended as an alternative to Hempel's analysis: on the contrary, its aim is to provide a conception of reality that helps us make sense of Hempel's insight about the difficulty of applying a law and of inferring an observable property on the basis of the theoretical properties constituting the law's consequent.

Let us recall Hempel's own example. The theory of magnetism predicts that the two halves of a bar magnet which has been cut are both magnets. Hempel's problem is that the inference from the satisfaction of a theoretical predicate to the satisfaction of an observational predicate is justified only under a proviso. Our construal of laws as relations between dispositional properties is a semantic hypothesis concerning the interpretation of Hempel's inferences. In other words, it is a hypothesis regarding the truth-makers of Hempel's conditionals. The theoretical sentence " $S^1_c \rightarrow S^2_c$ " states that: if b is a magnet, then "if b is broken into two bars b_1 and b_2 , then both are magnets and their poles will attract or repel each other" (Hempel 1988, 148). The statement " $S^2_c \rightarrow S^2_A$ " associates S^2_c - b 's satisfaction of the theoretical predicate that constitutes the consequent of the theoretical sentence - with the observational predicate S^2_A . Predicate S^2_A is: "if b is broken into two shorter bars and these are suspended by long thin threads close to each other at the same distance from the

ground, they will orient themselves so as to fall into a straight line” (Hempel 1988, 148).

Hempel does not interpret the theoretical sentence S^2_c independently from the inference to the observational sentence S^2_A . Thus, he refrains from explaining the need for a proviso. According to our interpretation, the predicates contained in S^1_c and S^2_c refer to our dispositional properties: S^1_c refers to the property of being a magnet; S^2_c refers to the property of being an object such that, if cut in two, its resulting pieces are magnets attracting or repulsing each other. The inference from S^2_c to S^2_A is the inference from the instantiation of the dispositional property to its characteristic manifestation: in the test-situation where we suspend the bars by long thin threads, the dispositional property S^2_c manifests in the fact that the bars orient themselves so as to fall into a straight line (S^2_A has the form of a test-manifestation conditional).

Such a ‘metaphysical interpretation’ enables us to understand two things: firstly, provisos about the legitimacy of the latter inference stem from the fact that the observed manifestation is the result of the whole set of dispositional properties of the whole set of objects composing the system. We should expect the pure manifestation indicated by S^2_A (the alignment) only insofar as the influence of other factors remains negligible.

Secondly, contrary to what Hempel claims, the proviso conditioning the inference from S^2_c to S^2_A has the same source as the Duhem-Quine problem. According to Hempel,

this consideration differs from the Duhem-Quine argument that individual hypotheses cannot be falsified by experiential findings because the deduction from the hypothesis of falsifying V_A -sentences¹⁰ requires an extensive system of background hypotheses as additional premisses, so that typically only a comprehensive set of hypotheses will entail or contradict V_A -sentences. The argument from provisos leads rather to the stronger conclusion that even a comprehensive system of hypotheses or theoretical principles will not entail any V_A -sentences because the requisite deduction is subject to provisos. (Hempel 1988, 154)

The proviso conditions the inference from the satisfaction of the theoretical predicate S^2_c to the manifestation described by S^2_A in a con-

10 Hempel calls “ V_A ” sentences in observational language; the latter contrasts with the theoretical language in which hypotheses and theories are expressed. However, in order to avoid assigning an absolute character to the distinction between observational language and theoretical language, Hempel opposes theoretical language to a language which is “antecedently understood”, that is, which is understood independently from the theoretical language at issue.

crete situation. According to our hypothesis, the issue is whether it is the *typical* manifestation of the dispositional property indicated by S^2_c in the described situation. This question is equivalent to whether the strength of the influence of all other dispositional properties present in the situation is negligible. However, the answer to this question depends on the whole set of laws that rule the set of properties instantiated in the system. In this sense, the inference from S^2_c to S^2_A depends on a whole set of hypotheses that do not directly bear on S^2_c and S^2_A : it is, after all, an aspect of the problem described by Duhem and Quine.

11 “Completers” and Absolute Exceptions

The dispositionalist account of laws may also shed light on the debate on the existence of what Fodor (1991) calls “absolute exceptions” and distinguishes from mere exceptions. Realizers $A(R_i)$ of the antecedent A of the law $cp(A \rightarrow B)$ are usually not sufficient for B in themselves. However, there are typically circumstances C consisting of sets of properties at the level of A 's realizers $A(R_i)$ which are, together with $A(R_i)$, sufficient for B , where neither $A(R_i)$ nor C alone is sufficient for B . Such a set of properties C is called a “completer” (Fodor 1991, 23).¹¹ According to Fodor, the law $cp(A \rightarrow B)$ has *mere* exceptions if there exists a completer for every realizer of A but if some instances of some realizers $A(R_i)$ of A are not accompanied by any completer. *Ceteris paribus* laws, then, are laws for which mere exceptions are nomologically possible. However, according to Fodor, there are also absolute exceptions, where a realizer of A does not have any completer. Fodor somewhat hesitantly accepts the existence of such exceptions, together with others (Mott 1992, 337; Silverberg 1996, 203; Earman, Roberts 1999, 458-9). An absolute exception to $cp(A \rightarrow B)$ is a situation in which some $A(R_i)$, though being a realizer of A , nevertheless makes B nomologically impossible. An absolute exception may arise because “certain realizations of M may themselves be among the defeating conditions alluded to in the *ceteris paribus* clause” (Schiffer 1991, 7).

It is hard to find examples of absolute exceptions. Mott suggests the case of a person on hunger strike: there are no circumstances under which the hunger striker will eat. However, this is hardly compatible with a law according to which hunger strikers (A) *do* eat (B). On the contrary, the fact that there is no completer that would be sufficient, with $A(R_i)$, for B shows that there is no law $A \rightarrow B$, whether strict, or cp .

¹¹ The concept - though not the expression - is found in Schiffer 1991.

Fodor's proposal, then, is not relevant: Fodor states that $cp(A \rightarrow B)$ can be a law if A figures in a sufficient number of other laws that have no absolute exceptions. Earman and Roberts show that this condition would trivialize the notion of cp law. Fodor's suggestion would transform "the ludicrous statement that *ceteris paribus*, if a person is thirsty, then she will eat salt" (Earman, Roberts 1999, 458) into a law with absolute exceptions.

However, contrary to what Mott, Earman and Roberts suggest, it is not only Fodor's solution that is unsatisfactory. The very concept of absolute exception contains a mistake. In our analysis, there cannot be any such absolute exceptions. In an absolutely exceptional situation, A 's realizer makes either the consequent or the manifestation of the consequent impossible. The first case refutes the law because we stick to the traditional thesis that laws are strictly universal. The second case also refutes the law because the dispositional property that is its consequent necessarily makes a difference to the observable evolution of the system, even if it may be 'hidden' or 'overshadowed' by the influence of other factors. According to the causal criterion of reality, a property - be it dispositional or not - that has no effects at all is not really instantiated, so in that case too the law is refuted. Mott, Earman and Roberts do not go far enough in their criticism of Fodor's solution to the 'problem of absolute exceptions'. Those situations are really refutations rather than exceptions.

12 Conclusion

Earman, Roberts and Smith, together with Woodward (2002), are right when they say that "there are no cp laws". However, they are wrong in inferring from this that scientific explanation shouldn't be conceived as relying on laws (Woodward 2002), or that laws can be found only in fundamental physics (Earman, Roberts, Smith 2002). Rather, the mistake lies in the idea that the existence of exceptions to a law shows that the law is not strictly universal.

The difficulties raised by the notion of cp law can be avoided if we stick to the traditional idea that laws are strictly universal. Exceptions are situations in which the consequent of a law is a dispositional property that does not manifest itself in a typical way. It is not tautological (or vacuous) to state that the consequent is instantiated, for it always contributes to the manifest behaviour of the system possessing the dispositional property. This makes it possible to detect its presence by empirical means.

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