# Laws of Nature: Do We Need a Metaphysics?

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**Abstract**

*In this paper, I briefly present the regularity and necessity views and assess their difficulties. I construe scientific laws as universal propositions satisfied by empirically successful scientific models and made — approximately — true by the real systems represented, albeit partially, by these models. I also conceive a scientific theory as a set of models together with a set of propositions, some of which are laws. A scientific law is a universal proposition or statement that belongs to a scientific theory. Scientific laws also are laws of nature since we can provide arguments in favour of natural causal powers that ground the truth of laws. I argue that the truth of counterfactual conditional statements and the occurrence of regularities in nature provide good reasons to believe that real causal powers exist in nature and that the (approximate) truth of scientific laws is based on a metaphysics of nature.*

In this paper, I defend an attractive (as it seems to me) philosophical position on scientific and natural laws. I first briefly present the regularity and necessity views and attempt to assess some of their main merits and difficulties. I then argue in favour of an account of laws which conceives *scientific* laws as universal propositions[1] satisfied by empirically successful scientific *models*, and also made — approximately — true by the real systems represented, *albeit* partially, by these models. Thus, I take laws to be statements and not "things in the world". I also construe a scientific *theory* as a set of models together with a set of propositions, some of which are laws. A *scientific* law is a proposition or statement of universal logical form that belongs to a *scientific theory*. I will show that scientific laws can also be considered to be laws of *nature* since we can provide arguments in favour of natural dispositions or causal powers that ground the truth of those laws. In the view I defend, all scientific laws are also laws of nature. I will argue that the truth of counterfactual conditional statements and the existence of regularities in nature provide good reasons to believe that real causal powers do exist in *nature* and therefore that the (approximate) truth of scientific laws is based on a metaphysics of nature.

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## 1. Regularists and neo-regularists

Philosophers with empiricist leanings inspired by David Hume favour a regularity view of laws. This hardly comes as a surprise. It is well-known that, according to Hume, no necessary causal connection obtains between — observable — events, even if those always occur together, such as fire and smoke. On the basis of sensory impressions only, it is illegitimate to claim that fire will *always* produce smoke or that fire *necessarily* causes smoke. The necessity of the causal connection springs from an unavoidable internal feeling of expectation, an irrepressible subjective tendency to infer the presence of smoke when there is fire[2] (or conversely). Such a necessity however has no objective external correlate in the events we observe. The inner feeling of expectation which has its natural source in the fact that we observe the constant co-occurrence of some types[3] of events does not imply that we are in a position to assert the existence of an objective causal connection among them.

For Humeans, the scientific nomological statements, like Boyle's law, are universal contingent propositions that state observed regularities, namely recurring but non-necessary connections among events. At best, scientific laws are *contingently true universal propositions* whose truth-makers are existing regularities.

In their account of laws, Humeans are confronted with a major problem, the so-called "identification problem". This problem has an *epistemic* and an *ontological* facet. The *epistemic* problem is old. It consists in devising criteria which would permit us to distinguish *bona fide* nomological statements from purely accidental generalizations. The *ontological* problem has been emphasized by van Fraassen and formulated thus: "(. . . ) one must identify the relevant sort of fact about the world that gives "law" its sense; that is the problem of identification" (van Fraassen 1989, p. 39). This means that we must be able to identify the feature of the world that makes the statement "It is a law that *p*" true. For the sake of clarity, it is crucial to realize that this problem is different from the — related but distinct — issue of identifying the kind of fact in the world that makes the statement "*p*" true. The meanings, and therefore the truth-conditions, of the statements "*p*" and "'*p*' is a law" are not the same.

Let us look at the *epistemic* problem first: how can we recognize the genuinely lawful statements and distinguish them from merely fortuitous truths? Our contemporary followers of Hume, called neo-Humeans, have struggled with this problem and attempted to devise criteria capable of distinguishing laws such as "All metals expand when heated" from propositions such as "All samples of gold

are smaller than 1000 cubic meters". The former is believed to be a genuine law, whereas the latter intuitively seems to only state a fortuitous characteristic of our universe. In order to single out the nomological from the accidental, John Stuart Mill ([1846] 1911) and Frank Plumpton Ramsey ([1928] 1978) pointed out the role played by laws in the context of deductive theoretical systems of statements. By doing so, they paved the way toward an elaborated regularity view which culminated in David Lewis' (1973, 1983) sophisticated proposal, called the *Mill–Ramsey–Lewis (MRL)* account of laws.

For Lewis, a law is a proposition that occurs "as a theorem (or axiom) in *each* of the *true deductive systems* that achieve the *best combination between simplicity and strength*" (Lewis 1973, p. 73 [my italics]). Strength is related to the capacity of a theory to account for observations and measurements. The more empirically successful and informative a theory, the stronger it is. Since we want to avoid theories that are mere compilations or lists of observational reports (such as the "almanacs" mentioned by Lewis) we organize a set of propositions into a hypothetico-deductive theoretical *corpus* based on axioms or postulates. In this process we gain in simplicity but we may lose in empirical power and no longer be able to predict some observational data. The simplest system is a tautology, which of course is compatible with all observations but whose predictive power is nil. The more balanced axiomatic systems result from a trade-off between these conflicting *desiderata*. Since a given set of propositions can be axiomatized in different ways, which may all equally satisfy the requirement of the best equilibrium between simplicity and informativeness, Lewis defines the laws as the propositions *common to all* these deductive systems. Let me stress that, according to Lewis' criterion, a proposition cannot qualify as a law in isolation, but only when it belongs to an axiomatically formulated theory. In this way, Lewis pretends to solve the problem of uninstantiated or vacuous laws, i.e., laws which are not in fact satisfied by any real system (such as the Newtonian law of inertia) by pointing out that the adjunction of such laws may contribute to the best balance in simplicity and strength of the whole axiomatic edifice.

Let us now examine how Lewis may solve the *ontological* problem of identification. Faithfulness to the core of Humean empiricism according to which laws express only some sort of regularities is meant to be the salient feature of their account. The facts about the world that make laws true are supposed to be the observed regularities. Laws are then considered to be universal *truths* expressing real regularities. But if what makes a law "*p*" true is a real regularity, it is not clear that vacuous laws have a truth-maker. On the other hand, what confers to "*p*" the title of law, i.e. what makes the proposition "it is a law that *p*" true is not a

regularity and not even a "fact in the world" but the belonging of "*p*" to a certain type of theoretical systems.

Several well-known difficulties thus plague Lewis' neo-regularist account of laws (Armstrong 1983, van Fraassen 1989, Carroll 1994, Ellis 2002, Psillos 2002, Dorato 2005). The application of Lewis' epistemic criterion of nomicity hinges on the availability of axiomatic formulations. Few theories are axiomatized in Lewis' sense,[4] even in physics, and some theories may not even be axiomatizable. Moreover, when an axiomatization is available, some alternatives are always possible in principle. It might then be the case that the axiomatizations that exemplify the greatest equilibrium between simplicity and strength are unknown to us. Even if all possible axiomatizations were available, the properties of simplicity, strength and balance between them are not delineated in a sufficiently precise and objective way. These properties may well be just in the "eye of the beholder", without reflecting any objective real feature of the world. Admittedly, the observed regularities are objective; yet, the extra ingredient that Lewis adds to some universal statements in order to raise them to the status of "laws" does not seem to correspond to something observable or real, but appears to be only relative to our human subjective and practical interests in organizing knowledge in a deductive handy fashion. Thus Lewis' criterion falls prey to the charge of being epistemic, even "chauvinistic" (Carroll 1990, p. 202), i.e. relative to the present-day state of knowledge and our current cognitive interests.[5]

In his version of the regularity view, Stathis Psillos (2002) improves on the MRL account in avoiding the defect of subjectivity. Psillos takes over Lewis' criterion of nomicity, but he defends a realist position according to which the simplicity of an axiomatic system reflects the objective simplicity of the organization of regularities in the world, which following Mill he calls the "web-of-laws" (Psillos 2002, p. 148). Despite the difficulties faced when attempting to capture the elusive notion of simplicity, such realism seems rather attractive. However, this web-of-laws view does not improve much on Lewis' solution of the *epistemic* problem of identification. It is plausible to contend that the simplicity of a theoretical system has an objective counterpart, but this does not help in practice to decide whether a given statement is lawful or not. Thus, Psillos' account faces the same difficulties as Lewis' as far as the epistemic problem of identification is concerned. On the other hand, Psillos can rightly boast some progress with respect to the *ontological* problem of identification. Following Ramsey, Psillos posits that "the *world has an objective nomological structure*" (2002, p. 154); and this is a fact about the world — as a whole — that grounds the nomicity of lawful statements.

Yet, another serious difficulty looms for the MRL account. The MRL crite-

rion of nomicity fails to comply with the widely accepted requirement that laws imply counterfactual statements, namely "if . . . , then . . . " propositions the antecedents of which do not actually obtain. The counterfactual conditional "If I had heated this piece of metal, it would have expanded" is true in virtue of being the consequence of a law. Since, according to Lewis, the law of dilation of metals is a contingent truth, it does not logically imply the truth of the conditional. In another possible world, in which the piece of metal would be actually heated, it may not expand (Armstrong 1983, p. 69). Although Lewis struggles to cope with counterfactual conditionals by relying on his view on nomicity, he only manages to do so by means of additional — and controversial — postulates on the similarity among possible worlds (1973). For the same reason, Psillos's web-of-laws account fails to account for the truth of conditionals. If we take Hume's lesson seriously, we have to accept that universal statements about empirical facts cannot logically imply the kind of necessity which is at work in counterfactual conditionals.

Adding to the MRL account's woes, many critics have pointed out that the simplicity of an axiomatic system depends on our choice of the predicates used to formulate the axioms (see for example Psillos 2002, p. 154–5). To dodge this difficulty, it has been suggested to eschew languages containing "unnatural" disjunctive predicates such as "*x* is *H* iff *x* is *F* or *G*" and also Goodmanian predicates such as "grue" ("*x* is grue if *x* is green until 1 January 2010 and blue after 1 January 2010"). The universal statements "All emeralds are green" and "All emeralds are grue" are equally well supported by the available empirical evidence on 10 August 2007, but only the first kind of statements may qualify as laws. These predicates intuitively look "artifical" and "unnatural" and, unlike natural predicates, do not seem to refer to real properties that "cut nature at its joints".

The hitch is that it has proved extremely difficult to provide a satisfactory characterization of natural predicates, which refer to natural properties, without appealing to the very notion of nomicity, a move which would plunge us into the whirl of circular reasoning. Of course, Lewis is well aware of this *aporia* and has attempted to characterize natural properties in various ways (Lewis 1983, p. 347–8). One of his attempts, which is more in line with empiricist orthodoxy, capitalizes on observed similarities among individual objects, called "particulars". "To be red" or "to be a raven", for example, would, according to Lewis, refer to natural properties because these properties are shared by a variety of particulars. The trouble with this move is that no immediate correlate in observation corresponds to most scientific terms such as "temperature", "heat", "charge" and even "to be metallic". It thus seems problematic to rely on observed similarities and

dissimilarities in order to detect which of the scientific properties are also natural properties.[6]

## 2. The necessity view

The opponents of the neo-regularists object that the latter are unable to solve the *epistemological* problem of identification since there is no objective feature of our theoretical systems that permits to recognize genuine nomological statements. They also object that the *ontological* problem of identification cannot possibly be resolved on the basis of any observable characteristic of the world. For the assertion "It is a law that *p*" to be true, it is not enough that "*p*" describes some (even possible) regularity. The assertion "It is a law that *p*" must have something real and objective that *makes* it true. All true propositions must have a *truth-maker*. This "truth-making principle" is a consequence of a correspondence view of truth according to which truth is some sort of relation between the proposition and a fact or real situation.

The *necessitarians* have attempted to solve the *ontological problem of identification* by contending that genuine laws, unlike accidentally true universal propositions, state some kind of *necessity between properties*. Fred Dretske (1977), David Armstrong (1983) and Michael Tooley (1977) claim, with some variations, that a scientific law is a *singular* statement that expresses a non-empirical fact, namely a *relation of necessity among universal properties*. What *makes* a lawlike universal statement, such as "All metals expand when heated",[7] *true* is the existence of a relation of necessitation, written "*N*", between the universals referred to by "heated metal" and "dilation". For two universals denoted by "*F*" and "G", the law is the statement "$N(F, G)$". This account of lawhood, the so-called *ADT view*, offers a *prima facie* plausible solution to the ontological problem of identification. Following Stathis Psillos (2002, p. 167–9), let us have a closer look at Armstrong's later elaborated version (Armstrong 1993) of the necessity view.

For Armstrong, a *universal* is a repeatable general feature of nature, such as being green, heavy, smooth etc. Only universals that have instances or are exemplified in the world can exist. On this issue at least, Armstrong sides with Aristotle against Plato. The necessitation relation *N* between universals *F* and G is a *contingent* relation that obtains in our world, and not necessarily in all possible worlds. In some other world some tokens of *F* could fail to be also tokens of G. This allows Armstrong to avoid putting *scientific* laws on the same footing as *logical* laws or tautologies, which are true in all possible worlds. Nomic necessity

is weaker than logical necessity. For Armstrong, a law is a law in our world only and may not be a law, nor even be accidentally true, in another possible world. For example, in another possible world, the universals denoted by the predicates "to be a fire" and "to produce smoke" may not be necessarily related. In such a world there could be instances of fire not followed by instances of smoke, unlike what we can observe in our actual world.

According to the ADT view, the necessity relation holding at the level of universals also *implies* a necessity relation at the level of the particulars that instantiate them. At this point the proponent of the necessity view is confronted with a logical problem, namely the *inference problem* (van Fraassen 1990, p. 39). It is far from obvious that a proposition stating a second-order relation N at the level of universals (properties, relations etc.) logically entails a statement expressing a relation of necessitation between the instances of these universals, i.e. the particular things that exhibit these properties. Does a necessity relation between the properties denoted by "heated metal" and "dilated" warrant the truth of the statement "All heated metals expand"? To put it formally, one may question the truth of the implication:

$$N(F, G) \rightarrow (x)N(Fx \rightarrow Gx)$$

Armstrong is confronted with the challenge of articulating an *explication*[8] of the second-order relation $N(F, G)$ such that it is weaker than logical necessitation but sufficiently strong to support a necessary connection at the level of the individuals which instantiate the properties $F$ and $G$.

Firstly, Armstrong postulates the existence of universals in order to *explain* the *similarities* between some particulars. Red things are red because they are instantiations (or tokens) of the same universal or (type) "red". Let us denote by $\varphi$ and $\psi$ second-order variables that range over properties (first-order variables range over individuals). Since experience shows us the constant conjunction or co-instantiation of some universals, such as the ones denoted by "heated metal" and "dilation", "fire" and "smoke" etc. Armstrong postulates the existence of a universal $N(\varphi, \psi)$ which accounts for the similarity of these various repeatable conjunctions. Given that the variables $\varphi$ and $\psi$ range over properties, $N(\varphi, \psi)$ is a second-order relation exemplified by $N(F, G)$, $N(G, H)$ etc.

Now, and this is a major move, Armstrong claims that the relation $N$ and the *causal* relation are one and the same. The necessitation relation $N$ between universals (types) $F$, $G$ is the very same relation that holds among instantiations (tokens) of these universals. Moreover, this causal relationship is *directly observable* in singular examples, like feeling the weight of my own body. This claim is

resolutely non-Humean. Empiricists emphatically deny that the causal relation is directly observable.

Equipped with all this machinery, Armstrong feels that he is in a position to claim that he has supplied the *explication* of the relation $N$ and that he has solved the inference problem. The implication "$N(F, G) \rightarrow (x)N(Fx, Gx)$" simply becomes "analytic or conceptual" (Armstrong 1993, p. 421–2).

Even if we accepted Armstrong's solution to the inference problem, several difficulties remain unresolved for the ADT view. First of all, the criterion of nomicity rests on the possibility of sifting out the right predicates, referring to correct universals — namely, the *natural properties* — from artificial predicates. This is the very same problem that we encountered above with the MRL account. The epistemic identification of natural properties is supposedly achieved by relying on sensory experience. But sensory experience doesn't ambiguously determine the "natural" properties. Failing to pick out the right properties could result in mistakenly taking accidental coincidences for *bona fide* instantiations of the necessitation relation. Therefore, the proponents of the ADT account do not seem to be in a position to overcome a major objection addressed to the regularity view, namely that it offers no satisfactory solution to the epistemological problem of identification. A second difficulty is raised by the need to account for probabilistic laws such as the laws of radioactive decay. Armstrong does deal in great detail with this problem, but his solution has been shown to be inadequate by van Fraassen (1990, p. 109–16). Thirdly, even if we concede that the causal relationship among particular tokens is observable, how can we justify the claim that the *same* causal relationship holds at the level of universals or types? (van Fraassen 1993, p. 436). Fourthly, most of Armstrong's examples are drawn from ordinary language and commonly observed facts. We can then raise against Armstrong the same objection that was levelled against Lewis. How can we make a case in favour of the naturalness of a scientific property since, more often than not, scientific properties are quite remote from direct experience?

*Last but not least* it seems problematic to identify a law with a relation of necessitation between properties. Lawful statements do not literally refer to such a relation but to some regularities. This is the origin of the inference problem encountered by the ADT view. As said above, I prefer to call "laws" a specific class of statements. It is then plausible to claim that what grounds the truth of "it is a law that $p$" is the existence of a relation of necessitation between natural properties, but what makes "$p$" true (at least approximately, see below) is the existence of regularities. Even if it can be shown, as Armstrong argues, that the relation of necessitation is causal and warrants the regular co-instantiation of

natural properties, the truth-maker of "*p*" is a regularity if "*p*", as I recommend, is to be literally interpreted.

## 3. Scientific realism

Confronted with the difficulties which beset both the regularity and the necessity views of laws, Cartwright (1983), van Fraassen (1989) and Giere (1999), among others, have urged to abandon all attempts to articulate a philosophical account of lawhood and to concentrate instead on the structure of scientific models. Typically, this attitude has been favoured by philosophers who advocate a *semantic* or *model-theoretic* approach of theories according to which theories are first of all models, i.e., mathematical structures susceptible of approximately representing some aspects of actual systems. In the opposite camp, we find those who mainly defend a *syntactic* view of theories, according to which theories are sets of propositions — preferably, but not necessarily — organized in axiomatic systems. The philosophers who prefer the syntactic approach are inclined to give a prominent role to scientific laws and have struggled, as we saw, to devise precise criteria of nomicity.

The appeal to scientific practice, which remains a recurring incantation in some circles nowadays, does not help to resolve the dispute. It certainly is correct to point out that scientists do construct models, but it is obvious that they also resort to what they call "laws" to construct them and that many scientists, especially in physics, but also in other disciplines such as biology and psychology, still strive to discover true general statements about real systems in the world. Even the staunchest partisans of the semantic approach stress that models not only function as possible representations of real systems, but that they also make true or satisfy some sets of propositions (Giere 1988). I am quite sympathetic to the model-theoretic approach whose main — though not sole — merit is to draw our attention to the non-linguistic ingredients of our scientific constructions and the ways in which these constructions succeed in representing. Nevertheless, it would be an error to neglect the importance of universal propositions and the information they convey about real systems. Fidelity to scientific practice — if I may resort to this argument too — forces us to recognize the prominent role that laws continue to play in science. Failing to do so would lead to a considerable impoverishment of our understanding of both scientific practice and scientific theories. Hereafter, I will take a *theory* to be made of a set of statements, which may be called a "theoretical *corpus*", supplemented with a class of models or rep-

resentations of real systems. Roughly, the *models* make the propositions of the theoretical *corpus* true, whereas these propositions, when applied to real systems, are approximately true if the theory is empirically adequate.[9]

I propose to *epistemologically* identify scientific laws as the *(approximately) true propositions (having a logical universal form) used to construct empirically successful theories in science*, without at this point entering the debate about the grounds for their truth (such as regularities in the world, relations between natural properties, causal powers etc.). As in the MRL approach, logically universal statements can be called "laws" within theories only. This criterion is rather liberal since it allows theorems to be laws. But it suffices to expel from the paradise of lawfulness not only isolated statements such as the worn-out example "All ravens are black"[10] but also accidental generalizations like "All pineapples in the hotel's restaurant are delicious". Granted, this criterion for identifying laws is parasitic on the previous acceptance of the distinction between scientific and non-scientific theories. Since I am unable to enter into a full discussion of this issue here, I will simply assume that a theory is scientific if it can be empirically tested by means of rigorous and reliable methods. In the — very rare — cases of the availability of "strongly empirically equivalent theories" (Reichenbach), that is theories that are confirmed or falsified by the same empirical data, the laws are the well-confirmed and true universal propositions common to them.

Within this perspective, the *epistemological* identification problem is solved by assessing the *truth* of laws in the context of scientific theories, leaving aside for the moment what their truth-maker is. This is a notoriously thorny issue. *Antirealists* at most believe in the truth of statements which describe the observable aspects of things. Accordingly, only generalizations about phenomena could qualify as scientific laws. *Realists* on the contrary insist that some, but not all, of the universal statements employed in the construction of successful theories hit on unobservable features of real systems. A satisfactory account of laws must rely on arguments in favour of the — at least approximate — truth of some of the universal statements which are parts of well-established theories. I have defended a *moderate* (*fallibilist*, *selective* and *parsimonious*) version of scientific realism (without relying upon de "no-miracle argument") on various occasions (see Ghins 1992, 1998, 2000, 2002, 2005). Recent arguments for scientific realism can also be found in the writings of Lawrence Sklar (2000), Howard Sankey (2001) and Stathis Psillos (2002), to only name a few.

*Fallibilism* stems from the fact that our theories, to the extent that they can only be confirmed by observations and measurements, are falsifiable and may contain ingredients that have no correlate in reality. We did not have to wait for

Hume to realize that mere observations, no matter how numerous, are incapable of establishing final and definitive truths. Many philosophers of ancient Greece — and Aristotle was among them — were well aware of that! For the better or the worse, the future may be full of surprises. *Selectivity* and *parsimony* are also crucial since we all know that our theories-models are constructed in such a way that, whereas some of their assertions may be true, some of them cannot possibly be so.

Some real systems approximately behave in accordance with scientific laws in the sense that the models which partially and approximately represent them are not only empirically successful but also represent some of their unobservable characteristics. Some laws are therefore approximately true for some systems and do not apply to others. The laws of the pendulum are true for oscillating systems satisfying certain conditions and inapplicable for other systems. If a system is not a pendulum which satisfies certain *ceteris paribus* conditions, also called *provisos*, then Galileo's "law" of isochronisms of oscillations of small amplitude cannot be successfully applied to this system.

Now, some laws are more general than others. Kepler's laws only hold for two masses which solely interact by means of a gravitational force. On top of that, external perturbations due to other masses must be weak and some initial conditions have to be satisfied. However, we have strong reasons to believe that all physical entities, fields and particles are affected by gravitation. Simply because when we are interested in the motion of a particle or the variation of a field and we want to construct a model that makes correct empirical predictions, we must take gravitation into account, or we have to make sure that its influence can be neglected.

The realist view (RV) of scientific laws briefly sketched above succeeds in solving the inference problem. If it is a law that $p$, then $p$. If a universal scientific proposition $p$ is approximately true, then the situations or processes it describes do approximately occur in the world. However, on this account, there is no reason to maintain that laws are in any sense necessary. If laws are epistemologically identified as true universal propositions belonging to scientific theories, they are descriptive only and carry no modal force. They may just be accidentally true.

## 4. A philosophy of nature with causal powers

It should be clear at this point that the *logical* problem of inference and the *epistemological* problem of identification of scientific laws, construed as statements,

can both be solved within the realist view. Yet, RV leaves open two questions, which can only be addressed by entering the territory of philosophy of nature.

First, RV does not explain why laws entail *counterfactual conditionals*. We feel that we are in a position to claim that "If I heated this piece of metal, then it would expand", i.e. that its length would vary proportionally to a variation of temperature according to the equation: $\Delta l = k\Delta T$. We believe in the truth of this counterfactual because it is a consequence of a well-established law. But since according to RV laws are merely descriptive statements they cannot logically imply propositions which involve modalities, namely possibility or necessity. Thus, if the inference from laws to counterfactuals is legitimate — and our intuition supports that claim — laws must have some "modal force". What then are the grounds of such a modal force?

Second, RV does not account for the existence of *regularities in nature*. This is an old problem, nearly as ancient as philosophy itself, and connected with the problem of the justification of inductive reasoning. It is a fact that many of our scientific theories are remarkably accurate and reliable. Numerous real systems in nature can be successfully modelled and their behaviour precisely predicted. They exhibit a regular and uniform pattern of behaviour in time. We may take this as a brute fact — as empiricist philosophers do — or attempt to explain it.[11]

A possible explanation of regularities in nature is that laws impose a regular pattern of behaviour on entities and systems which by themselves are passive and inert. This is the view inherited from the thinkers associated with the scientific revolution (Descartes, Kant), who were very reluctant to accept the existence of Aristotelian internal powers or potentialities rooted in the essences of things and believed that laws somehow govern[12] or rule a passive inert matter. However, laws construed as *statements* do not impose anything to reality. Statements are powerless in this respect. If what makes laws true are mere regularities, as the defenders the regularity view claim, laws only express regularities and do not explain why these must occur in nature.

On the other hand, if the truth-maker of "It is a law that $p$" is a relation of necessitation between natural properties, as maintained by the proponents of the ADT view, we would have an explanation of the existence of regularities, provided of course that the inference problem can be solved. But the above-mentioned difficulties which undermine that account prevent us from adopting it.

Following the Aristotelian tradition, according to which the observed regularities are grounded in forms or essences, i.e. internal principles of action possessed

by substances, Rom Harré and Edwin Madden (1975) have suggested to endow real entities with *intrinsic causal powers*. This position has been taken over and fleshed out, *albeit* with some variants, by Nancy Cartwright (1989), Brian Ellis (1992, 1994, 2002), Caroline Lierse (1992, 1994), John Bigelow (1992), Stephen Mumford (2004), Mauro Dorato (2005), among others. These causal powers are modalities or dispositions which manifest themselves in some favourable circumstances. For example, a body has the capacity to fall. This means that, if the appropriate circumstances are actualized, it would indeed fall. If these conditions obtain, the body cannot fail to fall. In other words, bodies do fall in virtue of some internal necessity rooted in them. All material bodies are endowed with a causal gravitational power which necessitates the occurrence of a specific causal process — namely, fall — in an appropriate environment.

According to Brian Ellis' "new essentialism", some properties are *natural kinds* in the sense that the entities (bodies, systems, fields etc.) that possess them will, as a matter of *necessity*, always engage in a certain kind of causal process, provided the adequate "triggering" circumstances are realized. These circumstances are expressed by propositions referred to in the philosophical literature as *ceteris paribus* conditions or *provisos*. Falling bodies are observed as a matter of course. All things being equal, i.e. in conditions that are the same in the important and relevant respects, all newly observed bodies will also fall. This is *because* material bodies possess an internal tendency, a causal natural power or disposition[13] to fall which cannot be withdrawn without the body ceasing to be what it is.

Many a contemporary reader will perhaps scoff at this neo-Aristotelian conception, which is believed to have been definitely refuted, at least in the context of current mainstream philosophy of science. Of course, the explanation of opium's capacity to induce sleep on the basis of the putative existence of an inner *virtus dormitiva* has been ridiculed long ago in *Le malade imaginaire* by Molière. However, if we are presented with a sample of opium, or another kind of substance, and if we are told that it is soporific, this gives us some precious information about what can be expected to happen when ingested by a human (see Chakravartty 2007). To be soporific is a disposition or modal property, a power to induce sleep in appropriate circumstances. I concede that calling this power "*virtus dormitiva*" does not cut much explanatory ice. Such a gloss would simply reveal, if anything, one's pedantry and desire to impress the audience with one's (limited) knowledge of Latin, rather than a dedicated search for a light-bringing explanation. It was such an attitude and empty use of words, rather than Aristotelian physics, which was the real target of Molière's irony.

Positing the existence of a capacity or power or potency, whatever one may

choose to call it, does provide an explanation of the regular behaviour of the entity in which this power is present. By positing a causal power, we do not merely re-describe a regular pattern in new words, but we add the extra claim that this regular pattern is grounded on a dispositional property rooted in an entity. This move effects a transition from the purely descriptive level to the modal level. The entities that possess specific internal powers must, as matter of necessity, behave according to definite patterns.[14]

I gracefully concede that such an explanation of a regularity is not scientific, but unashamedly metaphysical. A genuinely scientific explanation of opium's soporific capacity would rely on the presence of chemical components which react with human organisms in ways that should be accurately described. But the challenge of providing an explanation of regularities will re-emerge at the microscopic level and legitimate the attribution of causal powers to molecules, atoms, elementary particles ...

In science, as we saw, the laws are used in the context of theories-models and are more often than not formulated in mathematical language. Moreover, scientific laws mostly express relations rather than attributing monadic properties to some entities. Newton's law of gravitation states a mathematical relation between a distance, a force and two masses. The pre-eminence of relations has frequently been heralded as a revolutionary change with respect to Aristotelian natural philosophy, which lays emphasis on the individual properties of substances. But Aristotle's insight on potentialities can be transferred to a philosophy of nature which gives relations its due. For an entity, like a body or a particle, to have a mass — and the property of having a mass can be considered to be a natural property — implies that the entity has the disposition or power to *interact* with other massive entities in accordance with Newton's mathematical law. Similarly, for a particle to be an electron implies that it has the capacity of interacting with other charged particles in conformity with mathematical laws. Thus, causal powers can be conceived as capacities to enter in relations, and yet be inherent to the entities themselves.

Unlike Aristotle for whom potentialities are inherent to substances, new essentialists take dispositions, capacities or propensions to be *properties of properties*.

> We claim that among the essential properties of a *property* there is the propension or disposition of anything having it to show a certain kind of behaviour in a particular context. What science studies and codifies are the manifestations of these dispositions. (Bigelow, Ellis, Lierse 1992)

For my part, I favour an ontology of entities (conceived in a sufficiently broad

sense; for example, fields and systems are entities) endowed with modal properties, rather than an ontology of monadic or relational properties only. Yet, I agree with the new essentialists that the recourse to dispositions or powers provides an explanation of the regularities expressed by the scientific laws. In fact, scientific laws may inform us about the inner natures of things in a precise way, whereas common dispositions such as "soporific", "fragile" etc. usually refer to complex sets of dispositions of the individual components of everyday objects. I said "may inform us" because we are never certain that a scientific law hits on real natural powers; after all, we may err. Nevertheless, the well-established scientific laws are our best bet about what natural properties and relations exist in the world. Thus, scientific laws very likely also are laws of nature.

Instead of construing laws as truth-makers, I take laws to be *statements* or *propositions* expressing relations between (universal) properties possessed by some entities. For instance, the laws of the electromagnetic field — Maxwell's laws — express relations between natural properties such as "having a charge", "having a field intensity" etc. These natural properties and the way they are related capture the essence of the electromagnetic field, namely the causal power or disposition that such a field possesses in order to interact, typically with electric charges or magnets, as stipulated by the mathematical laws. In the same way, an electron, designated by a state function $\psi$ in quantum mechanics, has the power to behave in a certain manner described by Schrödinger's equation. Of course, laws have their domain of application; in some cases Maxwell's equations can be used, and in other situations, we have to mobilize the resources of quantum mechanics. This poses a problem for the new essentialists, which does not seem to be sufficiently addressed by them. Nevertheless, I believe that it can be argued (it is impossible to get into more technical issues here) that Maxwell's laws, for example, convey an approximate knowledge of the real causal powers of fields and charges.

It must also be mentioned here that probabilistic laws raise another sort of worry. Dispositions can be extended to propensities or tendencies to engage in a kind of process with some degree of probability, and are not restricted to deterministic processes only (see Ellis 2002, p. 78, and also Tanzella-Nitti 1997).

According to the view presented above, scientific laws are universally true propositions belonging to well-established scientific theories describing actual regularities in nature. Literally, laws do not assert that some entities are endowed with real causal powers grounded in their essential properties. But the statement "it is a law that *p*" asserts that the truth of "*p*" is grounded on the real natures of entities and the dispositions of these entities to engage into specific processes.

In other words, the truth-maker of "It is a law that *p*" is the existence of causal powers or dispositions in entities.

Within this metaphysical view, the *ontological* problem of identification is solved and scientific laws acquire the status of necessary laws of *nature*. An electromagnetic field or an electron could not continue to be the same sort of entity should the laws be different. Simply because changing the laws would be tantamount to modifying the essences of things. Ellis rightly stresses that electrons are the same in all possible worlds. There could perhaps exist worlds with no electron in them. But if electrons do exist, they must interact according to Maxwell's laws otherwise they just would cease to be electrons and be another type of particle. The necessity of a law is therefore rooted in the essence of some entities. Laws are, as Ellis maintains, *necessary a posteriori* because the causal powers of entities cannot be known *a priori*, by simple analysis of the meanings of the terms involved. They have to be discovered, through — often painful — scientific investigation.

According to the account I defend, there is no inference problem. If "*p*" is a law, then "*p*" states a regularity, even if approximately, as I have repeatedly said. Moreover, if "it is a law that *p*" is true, then some entities possess some specific real dispositions to behave in certain ways in given circumstances. It follows that, if these circumstances obtain, some regularities will occur in the world.

Although I find myself unable to subscribe to Ellis' physicalist pronouncements (2002, p. 86), I cannot help to find his grand view of nature and its laws particularly attractive, provided it is supplemented with the insights of the model-theoretic approach. Even if laws are metaphysically grounded on universal modal properties or powers, the only epistemic access we have to laws and natural properties is through the success of scientific models and the observation of recurrent regularities. The regularists surely are right on this count. But, in order to ground counterfactual conditionals and to account for the wide-ranging occurrence of impressive regularities, the appeal to intrinsic dispositions or causal powers of substances,[15] *albeit* decidedly metaphysical, appears to be the most promising option.

## 5. Conclusion: good or bad metaphysics?

Empiricists such as Bas van Fraassen will be quick to raise powerful objections against such a metaphysics of natural powers. For them, the absence of direct empirical access to modalities in general, and *a fortiori* to internal causal pow-

ers, pulls the carpet under the feet of the metaphysician and makes his ontology crumble. Moreover, it is illegitimate to work out philosophical problems by merely postulating the existence of entities for which no independent evidence is available (van Fraassen 2002, p. 10).

It is correct to claim that the sole ability to solve the ontological problem of identification cannot be considered a sufficient reason in favour of the existence of causal powers. Even if it could be shown that the solution offered is the best that could possibly be envisaged — which in most cases is an unreachable goal — we have no guarantee that the proposed solution allows us to reach out to external real modal properties. Thus, even if it could be shown that the existence of causal powers in nature delivers the best possible explanation for the occurrence of observed regularities and the truth of counterfactuals, these results alone would be insufficient to justify our belief in the existence of causal powers, simply because there is no *a priori* warrant that reality matches our human requirements (or desires) for understanding and intelligibility. This is why empirical evidence is indispensable to support any existence claim. The question we have to face is then: what empirical grounds can we muster in favour of the existence of causal powers and dispositions?

First of all, we may adduce an authority argument. David Hume himself believed in the existence of powers, *albeit* forever unknowable, as evidenced by the following citations:

> Notwithstanding this ignorance of natural powers and principles, we always presume, when we see like sensible qualities that they have like secret powers. (Hume [1748] 1975, § 33)
>
> We are ignorant of those powers and forces, on which regular course of objects and succession of objects totally depend. (Hume [1748] 1975, § 55)

Such citations are grist in the mill for those who favour a non-standard interpretation of Hume advocated by Craig (1987, 2000) and Strawson (1989), and known as the "New Hume". Weak as they are, arguments of authority encourage serious investigation of an issue instead of dismissing it beforehand under the influence of philosophical creeds.

Second, on the basis of my own inner personal experience, which I will call "presence to my body", I know that I have powers. While I am sitting, I know very well that I can get up and walk. On the contrary, I know that I am unable to get up if I feel a specific intense pain in my legs. And I also know that other people have all sorts of capacities and dispositions, on the basis of my own experience

and of what I can observe in the actual behaviour of others. This — admittedly trivial — remark is all we need to make the point that modalities cannot be easily dismissed, even by an empiricist.[16] I readily acknowledge that these remarks are not sufficient to support the universal claim that *all* existing entities have intrinsic powers or dispositions. Internal capacities may perhaps be confidently extended to animals, plants and even all living beings. But to further extend dispositions to rocks, electrons and galaxies may seem far too bold a claim, suspiciously tainted with anthropomorphic overtones.

Yet, if one embraces a physicalist and reductionist *credo*, which consists in the belief that all existing entities are made of fields and elementary particles (electrons, photons, quarks etc.) and that all properties supervene on the properties of these elementary entities, there is no reason to deny that these entities also have causal powers. Surely, I do not wish make a plea in favour of physicalism and reductionism. But I think it is important to realize that if one wishes to maintain that human beings are, at the end of the day, reducible to elementary physical constituents then it is only a matter of coherence to grant that all existing entities are endowed with causal powers. Within a physicalist and reductionist perspective, the dispositions inherent to human beings cannot spring from without and must eventually be based on the existence of causal powers at the level of the elementary physical entities.

The positive argument I would like to offer in favour of the existence of dispositions for *all* existing entities is the following. If we accept that we are endowed with causal powers, then we have the capacity to act on external *prima facie* "inanimate" or "inert" systems, i.e. systems which at first sight are passive and deprived of inner powers. Few would dispute that such a capacity of action has been enormously enhanced by science. In appropriate conditions, each time we decide to drop a stone, it falls according to a quantitative law which is verifiable at any time anywhere on the surface of the earth. Since external systems react in various and predictable ways to our actions, it does not seem unreasonable to suppose that external systems have the inner capacity to react to our actions and operations in specific, quantitative ways and that, when the appropriate circumstances hold, they will necessarily react in those ways. This contention is further buttressed if we accept the truth of counterfactual conditionals. Few doubt that an electron under the sway of an electromagnetic field would behave in accordance with Maxwell's laws. If we admit that counterfactuals such as these are true, one is led to posit the existence of internal dispositions, powers or potencies in virtue of which the systems endowed with them are constrained to behave in a certain way.

Bas van Fraassen, who is a leading self-proclaimed "immoderate empiricist" (2000, p. 1660), promotes a tolerant view on rationality, which he compares to the English law. Whereas in the Prussian legal system what is not explicitly allowed is prohibited, English law is based on the principle that what is not explicitly prohibited is allowed. Similarly, if there are no reasons against believing in something, then this belief attitude is rational.

> (...) what is rational to believe includes anything that one is not rationally compelled to disbelieve (...) *Rationality is only bridled irrationality*. (van Fraassen 1989, p. 171–2)

I will here refrain from engaging in a discussion on the merits of such a conception of rationality. My only hope is that I managed to convince the reader that the belief that the approximate truth of scientific laws is grounded on essential dispositions of natural entities is not irrational. On the contrary, it is an eminently rational belief. In fact, in the absence of knock-down argument against real causal powers, the objections to their existence fail to outweigh the positive reasons that can be adduced in their favour.[17]

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## Keywords

Law of nature, dispositions, causal powers, new essentialism, van Fraassen, Ellis.

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**Resumo**

*Neste artigo, apresento brevemente as concepções regularistas e necessitaristas e avalio suas dificuldades. Interpreto as leis científicas como proposições universais satisfeitas por modelos científicos empiricamente bem-sucedidos e tornados — aproximadamente — verdadeiros pelos sistemas reais representados, ainda que parcialmente, por esses modelos. Também concebo uma teoria científica como um conjunto de modelos juntamente com um conjunto de proposições, algumas das quais são leis. Uma lei científica é uma proposição ou enunciado universal que pertence a uma teoria científica. As leis científicas também são leis da natureza, uma vez que podemos fornecer argumentos em favor de poderes causais naturais que fundamentam a verdade das leis. Argumento que*

*a verdade de enunciados condicionais contrafactuais e a ocorrência de regularidades na natureza fornecem boas razões para acreditar que poderes causais reais existem na natureza e que a verdade (aproximada) das leis científicas é baseada em uma metafísica da natureza.*

**Palavras-chave**
Lei da natureza, disposições, poderes causais, novo essencialismo, van Fraassen, Ellis.

## Notes

[1] I draw the customary distinction between sentences, which are mere linguistic entities containing terms or words, and statements or propositions, which may be true or false. True propositions have "truth-makers" such as real situations or facts. Predicates are terms which refer to properties, natural kinds or universals, according to the terminology used by various authors.
[2] The statement "All fires cause smoke" is not a scientific law according to my criteria of nomicity. But Hume's analysis can be applied to genuine scientific laws, such as Boyle's law.
[3] The standard distinction between tokens and types is due to Charles Sanders Peirce. For example, there are many banknotes (tokens) that are worth one *real* (type) (the real is the Brazilian currency).
[4] Lewis adopts Hilbert's sense of axiomatization as a deductive organization of statements, and not Patrick Suppes' for whom to axiomatize a theory is to define a set-theoretical predicate (2002).
[5] However, Anjan Chakravartty pointed out to me that the charge of subjectivity is begging the question against the Humean since the core of his position is that lawfulness, as opposed to the mere truth of a universal statements, is something that depends on us and that there is no objective counterpart to lawfulness in the objective world.
[6] For the discussion of other difficulties encountered by Lewis' philosophical view on natural properties, see Carroll (1990, p. 199–202).
[7] To be complete, one should add the mathematical law of dilation of metals.
[8] There is a difference between an "explication" and an "explanation". An explication makes explicit a concept or a notion such as lawhood, whereas laws may play a role in the explanation of some phenomena.
[9] Boyle's law for example, is exactly true for an ideal "perfect" gas; when applied to a real gas, it can only be approximately true.
[10] I accept of course the truth of "All ravens are black" and other well-established empirical generalizations. I simply deny them the title of "*scientific* law", in line with the MRL account. Such generalizations may be useful for the progress of science and lead to the

construction of (successful) theories. One may object, as Mario Alai told me, that the blackness of ravens may be explained by the structure of their DNA. This may be correct. But even so, this would not be a sufficient scientific explanation of their blackness, which would have to be provided by natural selection processes etc.

[11] Many realists believe that the so-called "no-miracles argument" (Putnam) suffices to vindicate scientific realism as an explanation of the truth of empirically successful theories. This argument, however, is flawed (see Ghins 2002).

[12] On the conception of laws as governors or rulers of nature see Mumford (2004), Ellis (2006) and Psillos (2006a). I here agree with Psillos that the governing of laws is — at best — a metaphor.

[13] In what follows, the terms "disposition", "potentiality", "potency", "tendency", "capacity", "causal power" etc. will be regarded as synonyms.

[14] Granted, if the appropriate triggering circumstances are never realized, an entity may never engage in some kind of behaviour. A scientific theory may imply statements about the possible occurrence of regularities that never obtain.

[15] In a recent paper, Psillos (2006b) develops a strong conceptual argument against the thesis that *all* properties are pure powers (not grounded on non-power or categorical properties) and that current physics supports this thesis. Since I believe that no argument in favour or against a metaphysical view on properties can be drawn from physics or science in general (whether past, current or future) I agree with Psillos that current physics does not favour a metaphysics of powers: we need genuine philosophical arguments. My position is that *some* (not all) properties are powers. These powers are grounded in the — categorical — properties of substances, which, in virtue of these categorical properties, have causal powers. Unlike Ellis and Mumford, I do not believe in the existence of pure, irreducible, powers. This Aristotelian (and Leibnizian) position avoids the regress that invalidates a metaphysics grounded on pure powers.

[16] Stathis Psillos pointed out to me that we have the personal outer experience of the sun rising every morning. Yet, we know now that the earth rotates. Thus, our personal experience may be misleading. I quickly reply to his objection. First, the contradictor must advance an argument against the reliability of a particular experience, and not simply remark that we may err. Second, our knowledge of having the power to do things is different in several respects. For example, we know that we have powers with respect to a large variety of possible behaviours.

[17] This paper is a revised version of a paper presented at the *Second Workshop on The Relationship between Science and Philosophy: New Opportunities for a Fruitful Dialogue*. Vatican. 7-8 April 2006. I warmly thank Mario Alai, Anjan Chakravartty, Mauro Dorato, Brian Ellis, Michael Esfeld, Stathis Psillos and Howard Sankey for their comments on a first draft of this paper.