# Are Functional Laws Universal Generalizations?

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## I. The Form of Functional Laws

Scientific laws, it is claimed, cannot be verified on account of (the problem of) induction; and cannot be falsified because of Duhemian holism. It follows that the laws are metaphysical in Karl Popper's celebrated sense of the term. This (il)logic of science roots itself in an ubiquitous assumption that has survived all vicissitudes in the philosophy of science, viz. that the form of scientific law is universal generalization. It is within the context of this first-order predicate logic that the Scylla of induction and the Charybdis of holism rear their ugly heads.

Is the presumption justified? Laws in mathematical physics which state functional dependencies do not seem to betray this logic. Consider the second and third laws of Newtonian mechanics: Put baldly these state respectively that 'force is proportional to acceleration' or that 'f=ma'; and that '$v_1$ is proportional to $v_2$' or that '$m_1v_1 = m_2v_2$'. In themselves, these are statements of a relation of mathematical proportionality between properties—with no (essential) reference to bodies, or the predication of properties to such bodies; and the law-likeness of the statements subsists precisely in this relation of proportionality between properties, and not in the universality of ascription of the properties to any kind of body. The predication comes later. Objections might be raised here. 'F = ma' for example, could be construed as reading 'For all bodies, the force on the body is equal to mass times the acceleration of the body', which makes the law look as if it concerns physical bodies. But to realize that this is not really so, we have only to compare it with a genuine universal generalization like 'All emeralds are green'. This says that all emeralds anywhere anytime are green. Or again that all bodies of a certain kind (i.e. emeralds) are unconditionally green. Whereas 'f=ma' is to be interpreted as asserting that for all bodies of any kind the force is equal to mass times the acceleration, only if there are no perturbing conditions, i.e. 'f=ma' holds for all kinds of bodies, but only conditionally. Hence the law-likeness of 'f=ma' cannot reside in its universality of occurrence. The universality signaled by the 'all' pertains only to the generality of application of the law viz. to all kinds of bodies; whereas the law-likeness of the law resides in the relation of proportionality between the properties of force, mass and acceleration; a relationship which holds only conditionally, i.e. in the absence of perturbing conditions.

## II. Implications of Holism for Verification

The testing of laws of functional dependencies involves measurement and calculation. Instruments therefore, are an indispensable part of the experimental set-ups designed to test functional laws. The really interesting aspect of this Duhemian situation is that instruments measure by exemplifying some functional law/s; so that, as Duhem[1] pointed out a long while ago, if the experiment fails, blame may be apportioned to the laws of the instrument/s, instead of being directed at the theory under test. But what if the experiment succeeds? A successful experiment presupposes successfully functioning instruments; and what is it for an instrument to function successfully but to exemplify the laws/principle of its construction; and what is it for an experiment to succeed but to exemplify the laws under test? The point of Duhemian holism, I think, is not just that functional laws can only be tested together, but more importantly that (sets of) such laws can only succeed together. Duhemian holism which is a hydra-headed Gorgon in the context of

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falsificationism, leaves unscathed the successful context of a verifying experiment.

But do successful experiments verify (a set of) functional laws? If functional laws were universal generalizations, no number would. But for functional law what counts as verification is just that the (measured) results of a particular experiment tally with those of (theoretical) calculation. What such as result establishes of course is that the relationships of mathematical proportionality stipulated by theory are satisfied in the particular case; but since the law-likeness of functional laws subsists precisely in this (claim of) systematic inter-relatedness of properties, and not in the universality of their co-occurrence; if the relationships are satisfied in the particular instance, then the demands of laws-likeness are fully met. It is the particular experiment therefore, and indeed only a particular experiment at a time, that can verify a set of functional laws. This is in stark contrast to the verification of universal laws, precisely because the law-likeness of universal laws pertains to the universality of co-occurrence of properties; so that what is verified in single experiments is not so much the laws, as that the laws hold in the particular case. But (it cannot be sufficiently emphasized) for functional laws, law likeness subsists in the relationship of mathematical proportionality between properties and not in the universality of their co-occurrence; relationships which if they hold, wield the material context wherein they are exemplified, into a systemic whole. Successful experiments constitute physical systems governed by mathematical laws. Functional laws therefore, are systemic and structural in a way that universal laws are not.

## III. Prediction and Confirmation in Functional (Law) Contexts

Where does this leave prediction? Hempel's[2] D-N model and Popper's[3] H-D model, both embedded in the traditional logic of the square of opposition, assume the symmetry of explanation and prediction. Present and past cases are explained and future instances predicted. But functional laws predict not (cases of) fresh instances, but future behaviour of the same tried and tested system/s. If the laws hold in the particular case, it constitutes a system; and if the system continues to hold, then given values of some variables, other values may be computed (predicted). And no one would pretend that physical systems hold forever. Hence the claim of functional law-likeness is just not the claim of universal law-likeness viz. that the laws hold everywhere, every time. Since prediction for functional laws is relative to a physical system, its scope extends just to the life of such systems. In general we have thumb-rules for calculating the life-spans of different physical systems; and in any case, every physical system has but a finite life span. This renders the calculation of probabilities for functional laws with respect to finite reference-frames; a situation in stark contrast to the calculation of probabilities for universal laws. Confirmation then, for functional laws would consist in the probability of a particular physical system, for which the laws have been verified as currently holding, continuing to hold over a finite life-span to be estimated on the basis of thumb-rules. The computation of such probabilities would, of course, have to be relative to the (projected) particular conditions or context in which the physical system has to operate; hence probabilities for the same set of laws and for the same system would vary from context to context, rendering the confirmation of functional laws a concept for the pragmatics, rather than of the logic of science. It is verification which remains the central logical concept.

## IV. Semantic Implications: Quantitative vs. Qualitative Concepts

If the verification, prediction, probability and confirmation of functional laws is relative to the context of a particular physical system, so is predication when it comes. Thus it is for a Newtonian system and not for all bodies as such that we may predicate 'inertia is . . .', 'force is. . . .' etc. Does this sneak in universality through the back door? The answer to this question leads directly to the semantics of the situation. A statement like 'A Newtonian system is . . .' Is definitional, but it is not conventional. This is because theoretical terms like 'Newtonian system' which define physical systems, have for their principle of application, sets of functional laws, which are not merely testable but verifiable. On the other hand, terms both scientific and non-scientific, which are defined in terms of essential properties, have for their principle of application, universal laws which are neither verifiable nor falsifiable. This renders the application of systemic terms empirical in a way that other terms are not. Philosophers of science like Feyeraband[4] however, have been quick to point out that the terms of the functional laws themselves, are vulnerable in exactly the same way that the non-systemic terms are. They emphasize that terms like 'force' and 'mass' are theoretically defined, and what is worse, viciously defined, in terms of the very theory which serves to introduce them, leading it is claimed, to theory dependence, relativism and incommensurability.

The way out of the imbroglio consists in noticing the following: Firstly the distinction between statements of 'essential' properties and structural laws, is best understood in terms of the logical distinction between universal statements and functional statements. Statements about essential properties have the form 'All things of a certain kind have (essentially) properties xyz ...' Functional laws on the other hand, state relationships of proportionality between properties of the system. Testing of the universal law would involve testing singular statements of the form, 'an entity has properties xyz . . .' and hence having to pick out an entity and to describe it. The testing of universal laws is thus embedded in the logic of reference and predication, within which all semantic discussions of scientific laws are conducted. Ti does not seem to me that functional laws exemplify this logic. For example in the statements 'f=ma', the term 'force' performs neither the job of reference nor of predication. Rather its job seems to be to indicate the systemic property to be measured/ calculated, and how i.e. by what measuring device this might be done. Of course (the act of) measurement presupposes (the act of) reference, for properties must be picked out in order to be measured. But such identification is not the function of 'force' as a term of theory (as manifested for example, in Newton's second law). We may therefore, following Kuhn[5] distinguish between the qualitative concept and the quantitative concept of, for example 'force'. The qualitative concept is modified by the first law. But the quantitative concept is introduced by the second law (or by Newton's gravitational law). This way of putting the matter, does not however, quite distinguish between the notions of a qualitative concept and the corresponding quantitative one. It cannot be sufficiently emphasized that the semantic function of the qualitative concept would be to pick out a 'force' by its essential properties, whether superficial or underlying; whereas the job of the corresponding quantitative concept is to indicate how the force/s thus picked out may be measured/calculated. Thus as Kuhn[5] points out the term 'force' is introduced in Newtonian theory by means of the spring-balance. Obviously 'force' neither refers to the spring-balance nor describes it. Instead the point of the spring-balance is to indicate how force/s may be measured. It would seem therefore, that quantitative concepts encompass neither reference nor predication, hence they cannot be adumbrated in terms of these standard notions of traditional semantics; nor therefore are they subject to the travails thereof. The conclusion we may draw is that theories which share the same qualitative concepts are not incommensurable either as regards meaning or as regards reference.

Further, to maintain of two theories that they differ in respect of their quantitative concepts, is tantamount to saying that the systemic properties or variables of state, are measured differently, i.e. by the use of different measuring instruments. Just what does this difference in instruments amount to? Since instruments measure by exemplifying some functional law's, a difference in instruments implies a difference in the functional laws into which the property to be measured enters. Does this difference in laws render theories incommensurable? Does it, even, render theories incompatible?

## V. Metaphysical Implications

At this juncture we may review the metaphysical implications: To reiterate, functional laws are tested by measuring instruments which measure by exemplifying some (other) functional laws. The resultant experiment, if falsifying is ambiguous; but if successful vindicates the whole set. Further, a successful experiment verifies the set, for the single (successful) experiment exhausts the claims to law-likeness of functional laws. More pertinently, the successful experiment in verifying the set, verifies that the laws of the instruments are being exemplified, so that nothing need be stipulated, nothing taken for granted. There is no distinction therefore, in experimentation, between the laws of the instrument and the laws under test, except perhaps the epistemic one of known versus unknown, old versus new. Both are equally under test, and success implies that the mathematical interrelationships of properties, postulated by the set, are being exemplified in the particular, concrete experiment. It follows that the verification of functional laws is about successful experimentation. Now a long tradition of post modernists from Hacking[6] to Latour[7] would have it that successful experimentation is all about successful manipulations. Just what are the metaphysical implications? There are two scenarios here: philosophers of science who accept an ontology of actualities would argue that since it is the scientists who manipulate into existence the physical systems which exemplify the law-like relationships of properties, it follows that Nature has no role to play in the creation of what are essentially scientific artifacts. So it is humans who create and use science. This is the dogma of the closure of the laboratory to Nature. The opposing ontology of causal powers and potentialities, envisages science as a collaborative enterprise between Nature and Man. Scientists manipulate the experimental conditions for the exemplification of law-like relationships; but in doing so they only actualize the potentialities/possibilities inherent in Nature. On this view, differing (successful) experiments, exemplifying variant sets of functional laws, realize different possibilities in Nature. Are then the variant laws/theories incompatible?

## Notes


1. Duhem, P. (1976), 'Physical Theory and Experiment' in S. Harding (ed.), *Can Theories be Refuted*, Dordrecht Reidel Publishing Company, Holland, pp.1-39.
2. Hempel, K. (1966), *Philosophy of Natural Science*, Prentice-Hall, Inc. Englewood Cliffs, N.J., pp.51-53.
3. Popper, K., *The Logic of Scientific Discovery*, Hutchinson of London 1959, 1965, pp.32-34.
4. Feyerabend, P.K. (1976), 'The Rationality of Science', in S. Harding (ed.), *Can Theories be Refuted*, Dordrecht Reidel Publishing Company, Holland, pp.289-315.
5. Kuhn, T.S. (1990), 'Dubbing and Redubbing, The Vulnerability of Rigid Designation' in C.W. Savage (ed.) *Scientific Theories*, University of Minnesota Press, pp.301-308.
6. Hacking, I. (1992), 'The Self-Vindication of the Laboratory Sciences', in A. Pickering (ed.) *Science as Practice and Culture*, University of Chicago Press, pp.29-64.
7. Latour, B. (1987), *Science in Action*, Milton Keynes: Open University Press.



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