Is the World Really "Dappled"? A Response to Cartwright's Charge against "Cross-Wise Reduction"*

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Nancy Cartwright's charge against horizontal reductionism leads to a claim about how the world is, namely "dappled." By proposing a simple thought-experiment, I show that Cartwright's division of the world into "nomological" machines and "messy" systems for which no law applies is meaningless. The thought-experiment shows that for a system, having the property of being a nomological machine depends on what kind of questions you ask about it. No metaphysical conclusion about the world being unruly or not can be drawn from a division that is question-dependent. Moreover, I argue that this predicament undermines Cartwright's attempt to provide an illustration of how bad metaphysics of science translates into bad scientific methodologies and policies.

1. Introduction. Does bad metaphysics of science translate into bad scientific methodologies and policies? The philosopher of science Nancy Cartwright believes it does. And that's why it matters so much for her to get the metaphysical picture right. Her target is the longstanding quest for generality in science. That quest for generality, she claims, too often takes the shape of "imperialistic" methodologies that may have harmful social and epistemic consequences. For instance, harmful epistemic consequences follow from the take-over of superstring theory as the new candidate for the theory of everything: by monopolizing a significant part of the resources allocated to physics, string theory deprives us of breakthroughs that may have been achieved in other domains of physics, if

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sufficiently funded (1999, 16). Another example given by Cartwright is the take-over of genetics as the dominant approach to try to cure a disease like breast cancer. In this case, harmful consequences are not only epistemic but also social. As Cartwright somewhat abruptly puts it: "I am afraid that women are dying of breast cancer when they need not do so because other programmes [than genetics] with good empirical supports for their proposal are ignored or underfunded." (1999, 18) Underlying such quests for generality is for Cartwright the metaphysical belief in an ordered world lending itself to a complete description by universal, fundamental laws. Her strategy is then the following: in order to get rid of the harmful methodological inclination for generality, one needs to get rid of the false metaphysical image that underlies it.

My aim in this paper is to investigate whether Cartwright's strategy succeeds. On the face of it, the strategy may fail in two ways. First, Cartwright may fail to make a convincing case for a metaphysical picture different from the picture of an ordered world described by fundamental laws. Second, she may fail to show that the abandonment of this metaphysical picture will "cure", so to speak, scientific methodologies from their imperialistic tendencies. Let me explain why I think that Cartwright has failed in both ways.

2. Cartwright's Charge against the Universality of Laws. A brief clarification is first in order here. Philosophical attacks against generality in science have traditionally aimed their arrow at "vertical" reductionism, to wit, at the view that all our scientific theories could be reduced to one master theory in microphysics. Today very few people—even among physicists—are still defending vertical reductionism, be it in principle or in fact, and Cartwright is not primarily interested in arguing against it. Her target is another species of reductionism, still very much alive and unchallenged: "horizontal" reductionism.[1] Horizontal reductionism is a view about the scope of applicability of scientific laws. It states that there are such things as *universally valid* laws. For instance there are laws about all charged particles. Or take Newton's law $F = ma$, and suppose for the sake of the argument that it is literally true (i.e., ignore that it is only a limit-case of Einstein's equations). Horizontal reductionism is the idea that this law is valid for all instances of force and acceleration. Such universal applicability is what Cartwright is challenging. As regards physical laws, here's how she formulates the issue more precisely in her latest book *The Dappled World:*

1. Cartwright focuses on physics and economics, since she takes those disciplines as both having imperialistic tendencies. In this paper, I will focus exclusively on physics, physical laws being paradigmatic of scientific laws.

"Do the laws of physics that are true of systems (literally true, we may imagine for the sake of the argument) in the highly contrived environments of a laboratory or inside the housing of a modern technological device, do these laws carry across to systems, even systems of very much the same kind, in different and less regulated settings?" (1999, 25)

For Cartwright we have no good reason for giving a positive answer: we have no good reason for believing that laws which apply to orderly systems also apply to less regulated real-world systems. Orderly systems can be provided by Nature (as regards Newton's laws, the solar system is one example of these very few "naturally ordered" systems) or they can be set up in our laboratories (as for instance a simple harmonic oscillator or a small compact sphere dropped in a vacuum) (1999, 49). To illustrate what she means by "less regulated systems", Cartwright gives us the colorful example, borrowed from one of the founders of the Vienna Circle, Otto Neurath, of a ten thousand dollar bill swept away by the wind in St Stephen square (1999, 27). So, why do Newton's laws fail to carry across to such a real-world system? It's because Newton's laws do not enable us to predict and explain the motion of the bill; for instance they cannot predict where it will land. And how is it that Newton's laws are useless in this case? It's because in this real-world situation, the physicists are not able to specify and compute the total force function exerted by the wind on a soft and flexible body like a dollar bill (remember that Newton's laws describe the behavior of point particles and rigid bodies subjected to standard types of physical forces such as gravity). And moreover, we have no good reason either for believing that *in principle,* if not in practice, physicists could compute the total force function and apply Newton's laws. To believe they could partakes, as Cartwright puts it, of a "fundamentalist faith". And note that the same objection goes for the Navier-Stoke equations of fluid mechanics or any other dynamical laws for that matter[2]: Cartwright wants us to acknowledge that to believe there cannot be motions not governed by dynamical laws is just an article of faith (1999, 27).

It is at this stage important to distinguish between two levels of attack in Cartwright's charge against the fundamentalists. On a first level, as

2. Note that at this point the following rejoinder is still available to the fundamentalist: it is indeed the case that Newtonian mechanics (or any other laws *currently* available to us) does not apply to every real-world situation, and Cartwright is indeed right to doubt that *in principle* it could, but that only shows that we are still lacking a proper dynamics, one that will govern the motion of *all kinds* of objects. And it is easily to imagine that when we come up with such a dynamics, Newton's laws (as well as Lagrange, Navier-Stoke equations, etc.) will appear to us as special cases of those more general laws. But sure enough, Cartwright is likely to remain unmoved by this rejoinder, for to envisage the existence of such a dynamics is nothing but another article of faith.

previously discussed, Cartwright is essentially adopting a skeptical stance on the universal rule of laws such as Newton's laws. And such a stance is on the face of it quite compelling and rather unproblematic. We do know indeed very well, as Cartwright puts it quoting the great British physicist Kelvin, that "the Newtonian models of finite numbers of point masses, rigid rods and springs, in general of inextendable, unbendable, stiff things can never simulate very much of the soft, continous, elastic, and friction-full world around us." (1999, 48) So that challenging a positive answer to the question: "Do Newton's laws govern the motion of all matter?" smacks only of a prudent *bon sens* as well as of a welcome sensitivity to what is actually successfully achieved in physics. Moreover, Cartwright is also right to emphasize that acknowledging the limited scope of applicability of Newton's laws does not bear on the question of the truth of these laws (1999, 27). Indeed, being skeptical about the universal rule of Newton's laws "does not stop you from admitting that a crowbar is rigid and, being rigid, is rightly described by Newton's laws; or that the solar system is composed of a small number of compact masses, and, being so composed, it too is subject to Newton's laws" (1999, 48).

So far so good. But well-grounded skepticism about the metaphysical picture of an ordered world governed by universal laws does not amount to its dismissal. To undermine the fundamentalist picture, Cartwright does not content herself with showing that it partakes of faith. She makes a further step by trying to show that the picture is *actually false,* that is, it does not depict how the world is. On this second level of attack against the fundamentalist picture, her stance is thus explicitly metaphysical. She wants to make a case for a 'dappled' world, namely a world that displays some features which are precisely ordered, whereas other features are unruly (1999, 10). This picture of a dappled world is drawn from an analysis of the way science, and in particular physics, actually works. And the punchline in this analysis is the claim that "physics cannot account for everything that is in its domain" (2001, 210).[3]

3. A Problematic Metaphysical Division of the World. Let me explain now why this statement is problematic and thus fails to vindicate the metaphysical picture of a dappled world. The preceding formulation brings to the fore what is, I think, the snag in Cartwright's overall argument, namely an ambiguous treatment of the notion of domain of a scientific theory. So let's dwell shortly upon this notion.

What kind of thing is a domain of a physical theory? On the face of it, two readings of the notion are possible. On a first reading, a domain may simply be construed as what can be accounted for by the theory (whatever

3. This formulation constitutes a stronger version (than the previous skeptical stance) of Cartwright's attack against crosswise reduction.

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'accounted for' means exactly). This is quite evidently not Cartwright's reading, for her statement would be a contradiction. The other possible reading is ontological: a domain is a set of bits and pieces of the world, or a class of phenomena. The set of all charged particles and bodies are for instance the domain of electromagnetism. Motions of bodies are the domain of mechanics, etc. On this ontological reading, the domain of a physical theory is fixed, it cannot evolve. One might object here that inclusions of new entities or new kind of phenomena in the domain of a theory is a common feature of scientific inquiry.[4] It is therefore important to distinguish the actual domain of a theory, which is fixed, from *our view* of it, which may evolve. We may for instance have an incomplete view of the domain and a provisional, revisable description of it.[5] On this ontological reading, what Cartwright says, as regards for instance mechanics, is that there are bits and pieces of the world whose motion cannot be accounted for by mechanics (whatever our mechanical theory is).

At this point it is easy to pose to Cartwright the same kind of skeptical objection she poses to the fundamentalist. Such a rejoinder could go something like this: "There may be, or may be not, such bits and pieces of the world, but how do we know?" To escape this skeptical rejoinder, Cartwright needs to make a positive case for the actual existence of those bits and pieces of the world that belong to the domain of physics, but which physics fails to account for. And indeed, she provides us with an example: the dollar bill swept away by the wind. Let's see now why this example (or any other similar example) fails to do the job Cartwright needs it to do.

We have seen that the dollar bill swept away by the wind, as well as so many other "messy" systems around us in the real world, is supposed to stand in contrast to the (very few) orderly systems (like the solar system) supplied by Nature and for which physics can account for. Let me propose a very simple thought-experiment that will show that the solar system is intrinsically no more orderly than the dollar bill swept away by the wind. Imagine a creature (with a very long life expectancy, and hence a very long term life plan) in a spaceship somewhere in the vicinity of a very small asteroid.[6] This creature wants to plan a trip to another, very faraway

4. Here's an example of such an inclusion: until very recently, physics was not supposed to give an account of our intuitive notions of space and time. But works in string theory seem to suggest that space and time as we intuitively grasp them, are approximate concepts of a more fundamental and more precise set of organizing principles that are at work in the ultramicroscopic domain.

5. Many reasons for revision of a description of a domain can be thought of. For instance we may come to realize that a phenomenon is in the domain of a particular theory rather than in the domain of another. That happened in the case of sex determination: thanks to the works of Stevens and Wilson in 1905, we came to realize that sex determination was actually in the domain of genetics rather than cytology.

6. Being small bodies, asteroids are much more sensitive than planets to chaotic evolution of their trajectories.

asteroid, thousands of years from now. The solar system being a chaotic system (as any N-body system with N>3), applying Newton's laws won't help much here: the laws will fail to provide an accurate description of the actual motion of the asteroids and the creature will not be able to predict their positions. So the solar system will appear to the creature as a very unruly system that does not display any regularities[7]. Therefore, the creature will consider that the solar system is not the kind of system for which you can apply Newtonian laws, or any other law for that matter. That is to say, in Cartwright's terminology, it is not a nomological machine. Imagine now that for an obscure reason, the creature, endowed with extremely sharp eyesight, is very interested in dollar bills swept away by a (light) wind on the surface of the Earth. "Here's a nice nomological machine where Newton's laws apply!" she may exclaim: "Every time a dollar bill is swept away by a light wind (provided there are no human creatures around, you may need to add), ten minutes later it is on the ground. This is indeed a nice regularity, accurately described and predicted by Newton's law of gravity."

Where does this far-fetched thought experiment leave us? It seems that the frontiers of what physics can account for have become somewhat fuzzy: the solar system is not anymore part of what physics can account for. Inversely, the fall of the dollar bill is now part of what physics can account for, given Cartwright's own definition of what it means for science to account for, to wit, "a science accounts for a feature of an event when the laws or theories of the science can provide a regularity that subsumes the occurrence of that feature" (2001, 219).

The preceding little thought-experiment thus brings out the following predicament in Cartwright's argument: for a system, *being a nomological machine depends on what kind of questions you ask about it,* in the sense that it depends on the degree of precision and the degree of certainty being sought. The dollar bill swept away by the wind is a nomological machine if what you are interested in is for instance the final altitude of the bill, and not a fine-grained description of its motion. Inversely, the solar system is not a nomological machine if what you want to know about it is, say, the long term evolution of the trajectories of its small bodies. So that Cartwright's division of the world into nomological machines and "messy" systems for which no law applies turns out to be meaningless: no *metaphysical* conclusion about parts of the world being unruly or not can be drawn from a division that depends on the question being asked.

7. Note that the root of the unruliness is not indeterminism (the solar system is a deterministic chaotic system from the Newtonian perspective) and that the weird thing in this example is that the absence of regularities is a consequence of Newton's laws.

4. The Ill-Defined Notion of Fit. Let me now try to identify the source of the aforementioned predicament. On several occasions, Cartwright reformulates her central thesis about the limits of the scope of our best theories and laws in terms of their limited fit on to real-world situations. Scientific models available to us, she writes, "*fit* readily on to only very special bits of the world around us. [For instance] quantum theory extends to all and only those situations that can be *represented as* composed of central potentials, scattering events, Coulomb interactions and harmonic oscillators. As I pointed out in the last section, not much of the world on the face of it *looks like* that" (2001, 221; my italics).

At this point the following problem arises: to claim that a model or a theory fits or does not fit on to a certain bit of the world around us, without further specification, presumes that the notion of 'fit' between theories and real-world situations (and the concomitant notion of 'represented as') is well defined and independent of our cognitive motivations and expectations. But surely, this is not so. Let's rehearse quickly the preceding reasoning about nomological machines in terms of fit between laws and real-world situations. Does the motion of a dollar bill swept away by the wind fit Newton's laws? Well, it does if what you take as a 'good fit' is agreement between prediction and observation of, say, the final altitude of the bill. But it does not if you want to know much more about the final position of the bill than its altitude. My point is thus simply the following: if by 'fit to Newton's laws' one means perfect fit (i.e., at any conceivable degree of precision and in any respect) between predictions and actual positions of a body, then Cartwright is (trivially) right in the case of the dollar bill: it is not part of what physics can account for. But the solar system won't rank better as a candidate for members of what Newtonian mechanics can account for. Actually there would be no member at all![8]

Quite evidently, the notion of fit in science is never such an absolute and demanding notion. Without burying oneself into the complex normative issue of what counts as a good fit in science, it suffices to note here that a fit does not have to be perfect in the strong aforementioned sense to count as a good fit. It just has to be good enough for a certain purpose (be it epistemic or practical). But then, the frontiers of what a physical theory can account for are indeed shifting, depending on what this purpose is.

8. It might be useful to add here that the reason why there would be no member is not that we know now that Newtonian laws are only a limit-case of Einstein's equations (remember that for the sake of the argument Cartwright takes Newton's laws as literally true). Rather, there's no member only when one is committed to a strong sense of fit since laws, as Cartwright herself rightly emphasizes at length in her book *How the Laws of Physics Lie,* are only true of *models* of real-world situations. And quite evidently, models and real-world situations never fit perfectly on to each other since models are never exact duplicates of real-world systems but rather abstract simplifications of them.

Let me briefly review what has been undermined so far. Cartwright's metaphysical picture of a 'dappled' world goes hand in hand with her view about the limited scope of applicability of physical laws. She calls this view "metaphysical nomological pluralism". Here's how she summarizes it: "metaphysical nomological pluralism is the doctrine that nature is governed in different domains by different systems of laws not necessarily related to each other in any systematic or uniform way; by a patchwork of laws" (1999, 31). But what has been shown is that the frontiers of the domain governed by a law are question-dependent. Consequently, the domain of what a physical theory accounts for cannot be construed in the ontological sense of a domain, and 'ordered' and 'unruly' are predicates that can only apply to the question-dependent sense of domain, not to its ontological sense. In other words, *the motifs of the patchwork vary,* depending on your cognitive expectations.

To conclude now as regards the limits of crosswise reduction: how far crosswise reduction can go has turned out to depend on the stringency of your fitness criteria. It seems thus meaningless to attack or defend crosswise reduction without reference to an acceptable level of fit. The meaningful and relevant question is not how far Newton's laws apply but rather, *given a set of questions we need to answer at a certain level of precision and certainty,* will we succeed by modelling the system in a Newtonian framework?

A bit of precision may be in order here. I do share Cartwright's skepticism about the ability of physicists to be as good prophets for situations like the dollar bill swept away by the wind as they usually are for celestial motions. But I disagree *on the grounds* for such skepticism. As hopefully demonstrated above, these grounds cannot be metaphysical. In other words, physicists are bad prophets not because the dollar bill is a much more unruly system than the solar system, but because our mechanics is less successful, given the kind of questions we deem interesting about the fall of a dollar bill, in this case than in the case of the motions of planets. In a way I guess I am a more radical heathen than Cartwright: I don't even believe that bits of the world are nicely ordered since I am at loss to make sense of what it means for a real-world system to be ordered without reference to my cognitive and practical expectations.

5. The Problematic Ambiguity of the Concept of "Cross-Wise Reduction." How does this skeptical conclusion bear on the opening question of the paper, namely the question of the relationship between bad metaphysics of science and bad scientific methodologies and policies? On the face of it, as regards the necessity to give up quests for generality, aren't we better off with a world that is not even dappled, but for which 'ordered and 'disordered' are not meaningful predicates (recall that 'ordered' or 'disordered' apply to domains in the question-relative sense of the notion, not in its ontological sense)? After all, Cartwright may have indeed failed to make a convincing case for a metaphysical picture different from the picture of an ordered world described by fundamental laws, but for all that the 'fundamentalist picture' did not remain unscathed. On the contrary, it is equally undermined by the dismissal of the metaphysical notion of an ordered world (be it totally or only partially).

The remaining task is thus to investigate whether the abandonment of the fundamentalist picture leads to the abandonment of the harmful quests for generality described by Cartwright. I am quite sympathetic to Cartwright's warning against imperialistic tendencies such as the dominance of certain models in economics or the hold of genetics in medicine. But here again, I disagree with her on the alleged grounds for these tendencies, namely the fundamentalist faith in cross-wise reduction. The problem in Cartwright's argument is that 'crosswise reduction' does not seem to mean the same thing when Cartwright denounces it in her charge against dominant approaches in medicine or economics and when she denounces it in her charge against the universal rule of laws.

A telling symptom of this conceptual ambiguity is the very fact that to make her case, she draws almost only on the field that suffers the least from the crosswise reduction syndrome when crosswise reduction refers to dominant approaches: physics. Today physics appears as a rather pluralist field in the sense that physicists do not appeal to some unique, general overarching principle to account for all phenomena. But this is not to say that they never did. Actually, a very good example of the existence of a dominant approach in science can be found in the history of physics, to wit, the hold of the Mechanical Philosophy from the late seventeenth century to the early nineteenth century. This was indeed a time, as Cartwright puts it, when "we tried to reduce everything to the features studied in mechanics: electricity, magnetism, birth, development, the motion of the blood, chemistry, cooking . . . everything that behaved in any kind of systematic way" (2001, 221). The important point here is to see that this quest for general, overarching principles cannot be confused with the belief in the universal rule of laws Cartwright is arguing against. The Mechanical Philosophy was a view about the *relevant* properties of matter (shape, size and motion) to explain *all* change. But does the Mechanical Philosophy go hand in hand with the fundamentalist faith in an ordered world governed by fundamental laws? I doubt it. We may for instance very well imagine a proponent of the Mechanical Philosophy who would agree to the limited rule of Newton's laws. She could say that we just need other mechanical laws in addition to Newton's laws (for instance when we are not dealing with rigid bodies) to give a mechanical account of all phenomena. In other words, she could very well be happy with the idea of a patchwork of mechanical laws. Inversely, 'fundamentalist' physicists of today do not try anymore to account for all change from the same limited set of relevant properties of matter (remember here that we are not talking about vertical reduction): electrical, magnetic phenomena for instance are not studied any more in terms of size, shape and motion of constituents.

It thus seems necessary to clearly distinguish between the two following kinds of crosswise reduction: crosswise reduction as the thesis about the limited rule of physical laws, and crosswise reduction as the thesis of the existence of a dominant view about relevant properties and causes.[9] But then the following question arises: is not the hold of molecular genetics or dominant models in economics somehow comparable to the hold of the Mechanical Philosophy, to the extent that it is a general view about relevant properties and types of causes? If so, considerations of a field (physics) where there is no more 'dominant world view' is unlikely to shed light on what's going on in biology or economics. To believe it can is at the cost of a confusion between the question of the universality of laws and the question of the acceptability of general views about relevant properties and causes. That's why it seems to me that, regrettably, Cartwright has failed to provide a compelling illustration of how bad metaphysics of science translates into bad scientific methodologies and policies. And moreover, her confusion may unfortunately increase the chance of overlooking a network of more complex, contextual causes, when one tries to explain the existence of imperialistic tendencies in science in order to cure them.

6. Conclusion. To conclude I cannot emphasize enough the practical importance of the opening question of this paper, as well as the fact that the failure of Cartwright's strategy does not bear directly on the plausibility of her general claim that "our beliefs about the structure of the world go hand-in-hand with the methodologies we adopt to study it" (1999, 12). What has been dismissed in this paper is: 1) the alternative metaphysical picture of a dappled world and 2) the argument in favor of a relationship between the fundamentalist faith in an ordered world described by universal laws and the existence of harmful dominant approaches in genetics or economics for instance. So that the only positive outcome of this paper is the rather modest claim that the introductory question remains open and that an argument for a positive answer (as plausible as it may be) is still very much needed.

9. Actually, the very fact that Cartwright brings the example of the Mechanical Philosophy—a case of crosswise reduction in the latter sense—in the conclusion of her paper on crosswise reduction in the former sense (2001) suggests that she might not reject this double way of making sense of the notion, thereby showing that the notion is indeed ambiguous in her argument.

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