Review of Marc Lange, *Because Without Cause: Non-Causal Explanations in Science and Mathematics*

Mark Povich and Carl F. Craver

The consensus in the philosophy of science, at least since the 1980s, has been that Hempel's covering law model fails largely because it ignores the central role of causation in scientific explanation. Most subsequent work on scientific explanation has focused on understanding how causal (Salmon 1984; Woodward 2003; Strevens 2008) and mechanistic (Craver 2007) explanations work. Some have even asserted, perhaps in incautious moments, that all scientific explanations are causal (Sober 1984; Lewis 1986). Lange's collection of expanded, mostly previously published essays, packed with numerous, beautiful examples of putatively non-causal explanations from biology, physics, and mathematics, challenges this increasingly ossified consensus and, in so doing, launches a new field of philosophic investigation.

Lange defines non-causal explanations negatively as those that don't work "in virtue of describing the world's network of causal relations" (xi). He identifies three types: explanation by constraint, "really statistical" explanation, and dimensional explanation. Explanations by constraint work by showing that an explanandum fact follows from modally stronger facts. For example, Mary failed to divide her 23 strawberries evenly among three kids *because* 23 is not evenly divisible by three. Or a more ornate example: Some cicada populations tend to suffer less from predation by predators with periodic life cycles than other populations *because* the cicada populations have prime life-cycle periods and prime life-cycle periods minimize the frequency of intersection with the periodic life-cycles of their predators. The mathematical facts are "more necessary" than facts about cicadas or cookies and, indeed, than facts about causation. Not all explanations by constraint are "distinctively mathematical." For example, conservation laws (might) explain the force laws by constraint, but only if the conservation laws are counterfactually resilient: i.e., if "energy would still have been conserved even if there had been additional kinds of force threatening to undermine its conservation" (72). If this subjunctive is false, the conservation laws are coincidences, and the explanation by constraint fails.

The consensus against Hempel was erected on a foundation of examples of bad explanations that conform to Hempel's normative analysis. Lange's three types of non-causal explanation face similar challenges. For example, suppose Mary distributed all the strawberries evenly among the three kids. If so, she necessarily didn't start with 23 strawberries. But the number of berries she started with presumably is explained by her picking, not by her subsequent dividing. This is because the picking, not the dividing, *caused* the pile's size. Likewise, suppose some population of cicadas doesn't have a prime life-cycle period and we want to know why. Here's a putative, distinctively mathematical explanation: Because that population doesn't tend to suffer less from predation by predators with periodic life-cycles than other populations, and prime life-cycle periods minimize the frequency of intersection with periodic predators. While this argument provides evidence that the cicada population doesn't have a prime life-cycle period, it is an implausible explanation precisely because it fails to track the relevant causal structures. (See Craver and Povich 2017 for similar "reversals" of many of Lange's examples).

Do the conservation laws constrain, and so explain, the force laws? Only if they are counterfactually resilient (a matter Lange leaves to scientists). And what would make them resilient? A plausible answer: An empirically discoverable *mechanism* that would work the same even if new gauge bosons (i.e., force-carrying particles) were added. One might reasonably wonder if the appearance of non-causal explanation here is maintained by hiding the crucial causal, or more broadly ontic, work as merely an empirical detail. Lange spends very little time defending the claim that these explanations fail to describe the world's causal network (even elliptically) in just the sense that Lewis or Woodward (though probably not Salmon) might have intended.

Next, consider "really statistical" explanations, which reveal their explananda to be statistical "facts of life" (190). One might explain why students with the lowest scores on the first exam tend not to have the lowest scores on the next exam by appeal to regression toward the mean. This explanation can also be reversed. Suppose we find that the scores on the two tests aren't related by a statistical relation rather than a perfect correlation. We might ask, then, why isn't there a statistical relation rather than a perfect correlation between the outcomes of the two tests? Because the students with the lowest scores on the first exam tend to be the students with the lowest scores on the second. And we know as a theorem of the probability calculus that when there is a statistical relation rather than a perfect correlation between two variables, extreme scores in one variable tend to be associated with less extreme scores in the other. Like yellow fingers and smoking, we have a useful evidential, but non-explanatory, relation. But it seems to fit Lange's model of really statistical explanation.

Lange toys with the idea that really statistical explanations are, in fact, merely rejections of the need for explanation (see Ch. 5, note 3), i.e., assertions that the explanandum is "just chance" and so "has no explanation". This is belied by the fact that we can give different kinds of explanation for why chance events happen that rely on different assumptions and features of the set-up. Many of those assumptions, however, are about the kinds of causal processes involved in producing the events in question. In what sense, then, is this not a kind of stripped-down causal explanation: i.e., that with chancy causal structures, this is the default behavior one expects? When, exactly, does a text describe the "world's network of causes"? Many causal explanatory texts describe how the system behaves in the absence (omission or prevention) of causes. Lange does less than we would like to specify the boundary between causal and non-causal explanations and, so, to clarify whence these many impressive examples of putatively explanatory texts derive their explanatory force.

Last, consider dimensional explanations, which putatively explain by appeal to dimensional considerations alone. Lange attributes the first such explanation to Galileo in his defense of the odd number rule: that if a body in free fall traverses *s* in the first time interval, it should cover, 3*s*, 5*s*, 7*s* … in successive time intervals. More precisely, Galileo's is an argument against alternative rules: that distance increases with the interval of natural numbers or with the sequence of powers of two (205). Of these proposals, only the odd number rule is dimensionally homogeneous, i.e., yields the same result for different units of measure. The others give divergent results if time is measured in seconds versus minutes; so, they cannot be right. We see this as an argument that the failed views are incoherent. Lange takes it, in addition, to be explanatory of their falsity (207). Although Hempel, Salmon, and Lewis were sometimes interested in explaining why something is not the case, they were explicitly not interested in explaining why certain beliefs must be false. Is there perhaps a subtle equivocation on the very notion of scientific explanation here? Does every reductio ad absurdum derived from a scientific hypothesis, or any restriction on the space of plausible hypotheses, count as an explanation? If that is the intended view, it appears to blur (or erase) the distinction between evidence and justification, on the one hand, and explanation, on the other.

Lange offers another example: the period T of a circular orbit of radius r of a planet of mass m around a star of mass M is proportional to $r^{3/2}$. Why? We know T is proportional to $m^{\alpha}M^{\beta}G^{\gamma}r^{\delta}$, T's dimension is T, m's dimension is M, M's dimension is M, the gravitational constant G's dimensions are $L^3M^{-1}T^{-2}$, and r's dimension is L. Since the dimensions of T and $m^{\alpha}M^{\beta}G^{\gamma}r^{\delta}$ must balance (via "dimensional homogeneity"), their exponents give us $0 = 3\gamma + \delta$, $0 = \alpha + \beta - \gamma$, and $1 = -2\gamma$. Solving for δ yields 3/2. Thus, T must be proportional to $r^{3/2}$. This argument demonstrates that the proportion follows from these other facts. But does this demonstration constitute an explanation? After all, given the proportionality of T to $r^{3/2}$, the proportionality of T to $m^{\alpha}M^{\beta}G^{\gamma}r^{\delta}$, and the dimensionality of the variables, including that G has dimensions $L^xM^{-1}T^{-2}$ (excluding the exponent of L), it follows that the exponent of G's L dimension is 3. But the fact that the exponent of G's L dimension is 3 (rather than some other exponent) would appear to be a natural fact calling out for a natural (causal or nomological) explanation. If Lange agrees, then something must account for why one explanation succeeds and the other fails. A complete model of dimensional explanation should illuminate the difference.

We hasten to add that we aren't (intentionally) begging questions in favor of the ossified consensus. Rather, we are continuing a line of scrutiny that started with Hempel: We are asking what non-causal explanations are, how they work, and what norms distinguish the good from the bad. The possibility of non-causal explanation is exciting, but whether these examples buck the consensus depends on whether they constitute bona fide explanations and whether they are non-causal (or non-ontic). Those who embraced causal monism about explanation did so because appeal to causal factors sorts many good from bad scientific explanations and because the explanatory force of many good explanations seems to derive from revealing the relevant causal (or ontic) structures. The taxonomic project of collecting examples and sorting their types is an essential starting place for a theory of non-causal explanation. But the title of Lange's book requires something stronger: showing that the putative explanations are, in fact, explanatory and revealing the non-causal source of their explanatory power. The project is incomplete if there are examples of putative non-causal explanations that fit the form but that nobody accepts as explanatory (absent a radical revision of intuitions). That is, if we are playing by the rules by which Hempel, Sober, Salmon, and Lewis played, a pluralist taxonomy cannot suffice as a philosophical theory of scientific explanation. Given that Lange's models of non-causal explanation all involve deriving the explanandum from premises, the classic reasons for doubting that any such theory of explanation could possibly be adequate, for thinking that any such theory must confuse explanation with justification, are not question-begging nuisances but central problems any such model must confront.

Our reservations about one of the book's central theses should not detract from the fact that *Because without Cause* brilliantly makes the case for non-causal explanation in mathematics and science and opens our collective eyes to many kinds of scientific argument that have escaped philosophical attention. The book shows one of the generation's best philosophers of science operating at the top of his game (so far), displaying wide-ranging knowledge of the sciences and generating challenging, creative insights on almost every page. Lange has not given us the last word on this topic. Instead he has assembled a research program and populated it with detailed examples and controversial theses that deserve sustained discussion. This work is essential reading for philosophers of science and, indeed, for anyone interested in the nature of explanation in science and mathematics. These rich essays could fuel important work for decades.

References

Craver, Carl F. *Explaining the Brain: Mechanisms and the Mosaic Unity of Neuroscience*, Oxford: Oxford University Press, 2007.

Craver, Carl F. and Mark Povich. "The Directionality of Distinctively Mathematical Explanations". *Studies in History and Philosophy of Science Part A* 63 (2017): 31–8.

Lewis, David. "Causal Explanation". In David Lewis (ed.), *Philosophical Papers* (Vol. 2). New York: Oxford University Press, 1986. pp. 214-40.

Salmon, Wesley. *Scientific Explanation and the Causal Structure of the World*. Princeton: Princeton University Press, 1984.

Sober, Elliott. *The Nature of Selection*. Cambridge, MA: MIT Press, 1984.

Strevens, Michael. *Depth: An Account of Scientific Explanation*. Cambridge, MA: Harvard University Press, 2008.

Woodward, James. *Making Things Happen*, Oxford: Oxford University Press, 2003.