Introduction

James Robert Brown
University of Toronto

Feynman diagrams have fascinated physicists and philosophers since they were introduced to the world about 70 years ago. Clearly, they help in calculation; they have allowed nearly impossible problems to be solved with relative ease. This is agreed by all, but that is probably where the consensus ends. Are they pictures of physical processes? Are they just devices for keeping track of mathematical formulae, that do the real work? Are they some sort of mix of both?

They are almost as famous as representations of the Bohr atom, even though most people could not give even a sketchy account of what they do. In spite of this they have taken on a role as a cultural icon. Feynman used them to decorate his own van (Fig. 1). The van was even used in an episode of the popular TV series *The Big Bang Theory*. They have been used as art work in everything from posters, to coffee mugs, to wallpaper. But none of this is particularly helpful in understanding how they work.

If we ask working physicists who use Feynman diagrams what it is they are doing, we get a variety of responses. One is puzzlement; a shrug of indifference. Even those very skilled at using Feynman diagrams might be hard pressed to explain (to a philosopher's satisfaction) what's happening. After all, most of us can ride a bike but would be similarly hard pressed to explain in any detail what we're doing. A more common response might go like this: The diagram, or series of diagrams, is a schematic picture of some physical process, say, two electrons interacting, which we then link to mathematical terms. After writing out the mathematical terms in the

The contributors wish to thank one another. Even though these are individual papers, there is something of a group effort in putting together a journal issue on a single theme. We also wish to thank Alex Levine, the Editor of *Perspectives on Science*, for all his help, and encouragement in guiding this through, not to mention his tolerance of our tardiness.

Perspectives on Science 2018, vol. 26, no. 4

doi:10.1162/posc_a_00280

Figure 1. Feynman's van

form of a series, we calculate and get the probability of an interaction happening. This sounds good initially, but runs into trouble when we ask what a "picture of a physical process" could mean? This is, after all, the quantum world where things do not move continuously through space and time. It seems doubtful the diagrams could be diagrams of things in the physical realm. They are connected to physical reality and they are connected to wonderfully accurate predictions. And yet, mystery remains.

The following articles on Feynman diagrams address several timely issues, both historical and contemporary. These are metaphysical and epistemological questions related to models and how we represent the world. The papers are united by these themes, but otherwise are independent of one another. They are arranged alphabetically and can be read in any order.

James Robert Brown, "How Do Feynman Diagrams Work?" takes the view that they are not representations or models of the world at all. Like others, he stresses that they cannot be pictures of reality, since, thanks to the Heisenberg relations, there can be no such thing as a trajectory. Rather than seek some other more abstract type of representation, he introduces a distinction between descriptive and prescriptive flow charts. The latter could be a representation of physical reality, but not the former. A prescriptive flow chart is more like a recipe to bake a cake. He takes Feynman diagrams to be this sort of thing.

Mauro Dorato and Emanuele Rossanese, "The Nature of Representation in Feynman Diagrams," also reject the idea that Feynman diagrams can be considered to be pictures or depictions of actual physical processes. But unlike Brown, they do not abandon the thought that they can be models in some sense. They appeal to a famous account by RIG Hughes, known as the Denotation, Deduction, and Interpretation theory of models, where "models" are to be interpreted as merely inferential, non-representational devices constructed in given social contexts by the community of physicists.

Letitia Meynell, "Picturing Feynman Diagrams and the Epistemology of Understanding," assumes that Feynman diagrams are pictorial representations but agrees with Brown and Dorato and Rossanese that they do not represent actual physical processes. She then takes up the following puzzle: If Feynman diagrams represent states of affairs, but do not do so truthfully, what can their epistemic value be? She argues that Feynman diagrams have been epistemically powerful (at least in part) because, as pictorial representations, they facilitate an understanding of QED, and particle physics more generally. Appealing to Feynman's own remarks, she draws out what it might mean to have an understanding of something that is not factive. Although her approach allows for a thin sense of substantively non-factive epistemic success, it is continuous with a factive sense of understanding that is more familiar in the sciences.

Michael Stöltzner, "Feynman Diagrams: Modeling between Physics and Mathematics," analyzes Feynman diagrams within the context of recent debates about models in science and against the backdrop of other diagrammatic methods in mathematical physics when dealing with infinite or asymptotic series. This allows one to avoid the dichotomy of whether Feynman diagrams represent mathematical or physical objects, or a mere tool mediating between them. Along those lines one does not, however, obtain a universal answer to the question as to what Feynman diagrams represent. A single Feynman diagram, in actual scientific practice, can stand for a single mathematical expression or for a physical phenomenon depending on whether the diagram stands for a single term in an infinite series or for a subseries that is given a physical interpretation. Stöltzner's reading of the representation problem also derives support from the historical fact that Feynman was initially motivated by the Breit-Schrödinger model of a quivering electron and from interpreting this model within the context of stochastic processes.

Adrian Wüthrich, "The Exigencies of War and the Stink of a Theoretical Problem," approaches these topics from an historian's point of view, shedding light on the issues by focussing on debates in this historical context. As he put it in his subtitle, Wüthrich's aim is to understand the genesis of Feynman's electrodynamics as mechanistic modelling at different levels. Feynman's idiosyncratic method of dealing with quantum electrodynamic phenomena has been cast as an instance of a non-rigorous, modular and rule-based style of theorizing. Given such a characterization, it seems natural that significant changes in Feynman's style were triggered by work he was assigned during World War II, where quick fixes may have counted more than derivations from first principles. Indeed, Feynman's theoretical proposals of an improved electrodynamics do bear traces of Feynman's war-related work, which immediately preceded it. However, Wüthrich explains, the attempt to apply the vocabulary of the "new mechanistic philosophy" to lesser known pieces of archival evidence brings to the fore a new kind of shift in Feynman's style. Feynman's disposition for such a shift may also have been fostered during the war, but it was forced upon him by a specific theoretical difficulty, which was largely unrelated to his war-time research.

These articles contain some technicalities, but they should all be sufficiently accessible to general readers who would like to know more about Feynman diagrams and how they relate to theories, models, mathematics, and the world. The best philosophy of science is intimately linked to and draws upon current science and its history. It pays close attention to details: the details of theorizing, the details of models and how they function, the details of experimentation and measurement, and so on. We hope this collection of five articles on Feynman diagrams, by focussing closely on detail, will contribute to a better understanding of these strange but highly productive ciphers and symbols.