that life is essentially suffering. Because the will experiences *both* joy and pain, we have no ground to dismiss the (albeit ephemeral) experiences of happiness we do have (81-82). Dühring fights against the quietism advocated by Schopenhauer (85). While the optimist is insensible to the suffering of the world and the pessimist withdraws from it, the positivist demands us to *change it realistically* (89). A positivist account of the facts of life, instead of forcing us to accept life at face value, calls for political and economic reforms to make it more worth living (108-111). Hartmann, in his turn, re-conceptualizes Schopenhauer's pessimistic metaphysics. Inducing from the empirical sciences, he argues the cosmic will is not blind, but purposive (126-129). While we must, when *individual* happiness is under consideration, be "eudemonic pessimists" (152-156), because the goal of history is the growth of the *species* through natural selection, we can be "evolutionary optimists" (156-161). Promoting this goal, realized in human culture, our lives assume greater meaning by participating in a cosmic plan for us.

The pessimistic metaphysics of the next two figures propose an even more radical approach than Schopenhauer himself ever dared. Mainländer contends that the universe exists because of the *death of God*, whereby its primordial unity *fractures* into self-standing individual wills, each of which, part of the dying corpse of God, suffers and has a death wish of its own (215-219). While suicide is the ultimate release (as Mainländer's demonstrates) (206), our compassion for fellow sufferers entails we should, even if happiness is impossible, reduce suffering by revolutionizing the social order. This new order, he says, is one of communism, patriotism, and free love (225-228). Similarly, Bahnsen proclaims that there is no cosmic will, but only individual wills (244-246). While this spares individuality, he also maintains that each will is *self-contradictory*, leaving all hope for dialectic resolution foreclosed (271-276). We see this most acutely in our ideals: in actualizing one, we necessarily violate others (263-267). But, rather than giving up, we are called upon to make the best of it, to be tragic heroes—pessimism demands not quietism, but the courage to fight against all odds (282-283).

It must be noted just how influential these positions were in their times. A bibliography published in 1881 on Hartmann literature alone listed around 750 items (122). It is no surprise, then, that by 1938, Reclam Verlag noted that their popular edition of Schopenhauer's *The World as Will and Representation* had sold almost 800,000 copies (14 note 5). It is, therefore, shocking that these figures have been forgotten in mainstream nineteenth century scholarship. Beiser must be lauded for bringing them to our attention.

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Quantum Ontology: A Guide to the Metaphysics of Quantum Mechanics

PETER J. LEWIS
Oxford: Oxford University Press, 2016; 207 pp.; $35.00 (paperback)
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In *Quantum Ontology*, Peter Lewis accomplishes two tasks: he provides a non-technical presentation of the important discoveries and debates within the history of quantum

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mechanics (QM) and compares these findings to contemporary metaphysical debates. To clarify, Lewis does not show what *implications* quantum phenomena (QP) have for metaphysics; physical theory on its own doesn't dictate metaphysical conclusions since it may turn out to be false. Rather, this book broadens the scope of metaphysical debates and shows how QP can revise classical notions assumed within current metaphysics.

The book is separated into two main sections. The first section (Chapters 1-3) introduces the experimental findings that motivate quantum theories and revisits debates about what QM entails for metaphysics. For the former, Lewis pays special attention to entanglement and interference patterns in double-slit experiments. Lewis summarizes interference patterns in the conventional manner: electrons exhibit both wave-like behaviour (producing interference patterns) and particle behaviour (producing individual flashes on screens). What is revisionary is not that electrons turn out to be waves, but that they are *both at once*. Entanglement, or the phenomena that disturbing one particle instantaneously effects a separated entangled partner, Lewis argues challenges classical intuitions since it affects electrons with no common origin (i.e., no original electron that decays into two ½-spin particles). Lewis then describes Werner Heisenberg and Pascual Jordan's matrix mechanics and Erwin Schrodinger's wave mechanical descriptions of these QP.

For the latter, Lewis spends Chapter 2 arguing that realism, the thesis that scientific theories can give approximately true descriptions of the world, remains a live option. The dominate approach to QM has been the Copenhagen interpretation, pioneered by Niels Bohr. Bohr's argument that QM will always be a mere instrument for prediction, which is unfortunately absent from this chapter, runs roughly like this: since basic concepts like 'particle' and 'wave' *necessarily* presuppose classical notions of space and time, which are inapplicable in atomic domains, there can never be a full description of QP. Lewis then provides the infamous 'EPR' response, which states that there exists a physical entity (or property) for every predicable quantity, which attempts to give room for 'hidden variable' strategies to save realism. Lewis then details John Bell's theorem and the Kochen-Specker theorem and highlights their assumptions of 'locality' (disturbing one particle cannot affect the properties of a sufficiently spatially separated second particle) and 'independence' (particles cannot be physically interacting). He then details spontaneous-collapse theories, many-worlds theories, and Bohmian theories which circumvent purported 'impossibility proofs' to retain a realist position. In Chapter 3, Lewis outlines these views in more detail and argues that QM is underdetermined by QP.

Lewis states that the purpose of the book relies on realism being a live option. Otherwise, there is no way to physically interpret the formalisms of QM and therefore no possible ontological consequences. However, it seems strange that Lewis rests the fate of realism (and underdetermination) on the *fact* that realist options have been conceived. If realist interpretations of QM fail, then realism fails on Lewis' account. However, even if these *particular* theories turn out to fail, we can *always* conceive of new interpretations that may turn out to be empirically successful. As Bell famously stated, impossibility proofs do not prove realism is impossible but only that we lack the imagination to construct a realistic interpretation that circumvents the assumptions of impossibility proofs. This doesn't refute Lewis' argument, but makes it simpler and stronger.

In Chapters 4-8, Lewis unpacks the ontological consequences of realist interpretations of QM and explore their implications for debates on indeterminacy, causation,

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determinism, dimensionality, and holism. Lewis spends Chapter 4 surveying issues surrounding compositionality and determinate properties; Michael Tye, for instance, argues that properties like 'size' are indeterminate since the atoms at the boundaries of an object will not remain consistently within those boundaries. Lewis points out that this problem is amplified when we abandon the classical notion of an atom and replace it with electrons understood as clouds with probabilistic positions. He then suggests a number of ways of understanding the link between what is determinable and determinate properties using resources from matrix mechanics and many-worlds interpretations. In Chapter 5, Lewis shows how classical conceptions of causation (which are local and only require intrinsic properties and the immediate environment) were revised in deterministic interpretations of QM. Lewis spends Chapter 6 discussing the implications realist theories of QM have for determinism and its cognate issues (free will and identity). Lewis argues that both formulations of many-worlds (the 'single-mind' and 'many-minds' views) are committed to an unattractive version of dualism and suggests that quantum indeterminism may support libertarianism about free will. In Chapter 7, Lewis discusses the nature of dimensionality. Depending on one's interpretation of the wave function, explaining the 3-dimensionality of our experience seems exceedingly difficult. Lewis chimes in on the Albert-Maudlin debate about whether a high-dimensional wave function needs to be supplemented by a 3-D 'primitive ontology' and ultimately argues that such a primitive ontology would be superfluous. Finally, in Chapter 8, Lewis argues that entanglement entails that holism is ineliminable since properties (other than, perhaps, spatial properties) become properties of *physical systems* rather than individual bodies. None of these chapters are meant to provide definitive answers. Rather, each one considers sets of closely connected metaphysical positions and considers potential responses based on QP.

Quantum Ontology makes good on its promises. It provides a clear exposition of the primary experimental results and a comprehensive introductory overview of the more notable philosophical issues of QM. The first two chapters provide excellent reading material for introductory courses to philosophy of quantum mechanics. The final five chapters can act as stand-alone chapters that can complement graduate level metaphysics courses that touch upon these subjects. While the reader may not find every argument fully convincing, Lewis has certainly achieved his primary goal of stimulating discussion between QM and metaphysics.

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Towards an Arithmetical Logic: The Arithmetical Foundations of Logic

YVON GAUTHIER

Bâle, Birkhäuser/Spinger, 2015 («Studies in Universal Logic»), 184 p.
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Ce livre entend remettre à l'honneur l'œuvre de Leopold Kronecker, qui a été mal comprise et globalement oubliée, excepté par les mathématiciens. Le grand mathématicien André Weil, dont les conseils ont inspiré le travail d'Yvon Gauthier, estimait ainsi que le travail de

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