Meinard Kuhlmann, Holger Lyre, and Andrew Wayne (eds.), ***Ontological Aspects of Quantum Field Theory***. Singapore: World Scientific (2002), 376 pp., $98.00 (cloth).

What does quantum field theory (QFT) tell us about the furniture of the world? Seventeen essays gathered in the four parts of *Ontological Aspects of Quantum Field Theory* address this question from different angles and with different objectives. Together, they form a wide-ranging and up-to-date volume that makes a valuable contribution to an ongoing discussion, which, due to the comprehensive introduction by the editors, can be of interest to experts and novices alike.

The essays in the first part, "Approaches to Ontology," explore different philosophical frameworks in which the ontology of QFT could be examined. Despite their differences, they all agree that traditional ontologies, in particular substance-attribute ontologies, are unsuitable for QFT. Peter Simons begins by pointing out why traditional ontologies are inadequate, then putting forward his own suggestion: factored ontology, the main idea of which is to posit basic features ('factors') and to view objects as suitable combinations of these. He expresses confidence that this framework will prove fruitful in the case of QFT, but does not make an attempt to formulate a factor ontology of QFT.

Johanna Seibt begins with some methodological reflections on philosophical ontology in general and then launches a sustained attack on substance ontologies. As an alternative, she suggests the so-called 'axiomatic process theory', which denies that all concrete individuals are particulars and postulates as basic entities so-called 'free processes'. These processes are concrete in the sense that they are spatiotemporally occurrent, but they are not particulars. Like Simons, Seibt merely puts forward her framework as a suggestion, without presenting a worked-out ontology of QFT.

In his comment on the former two essays, Meinard Kuhlmann compares the two frameworks, drawing attention to problems they face. The main problem with Seibt's account, he argues, is the lack of a satisfactory characterization of free processes, which leaves us in dark about what they really are. He then criticizes Simons' account as being too lavish and questions whether it can help us understand the ontology of QFT, given that its categories have no connection whatsoever to the formalism (or any other aspect) of QFT.

Sunny Auyang takes the question of how field theories refer to entities in the world as her starting point. She distinguishes between direct reference and reference by description, pointing out that the former presupposes an ontology of individual entities with numerical identity, while the

latter works against the background of bundles of qualities. Interestingly, both types of reference occur in QFT, from which she draws the conclusion that the ontology of QFT is much more complex than one might think.

The second part of the book, "Field Ontologies for QFT," is dedicated to a discussion of Paul Teller's suggestion that the basic entities of QFT are quanta, which, unlike classical particles, lack 'primitive thisness'. In the course of his discussion, Teller also dismisses an understanding of QFT that takes field configurations to be represented by field operators. Andrew Wayne aims at resisting this judgement and argues that, suitably developed, this way of thinking about quantum fields can provide a valuable basis for an interpretation of QFT. He does not provide a worked-out interpretation, but instead presents some preliminary results in this direction that center around the notion of vacuum expectation values.

Gordon Fleming agrees with Teller's characterization of quantum particles, but he does not believe that this provides a sufficient reason for the move from the labeled tensor product formalism to a Fock space formulation, because it is not true that the excess formal structure comes at the high ontological costs that Teller maintains. Regarding Teller's claims about quantum fields, Fleming by and large agrees with Wayne that the operator-valued quantum field is in closer correspondence to the classical field than Teller admits.

Teller replies to these criticisms by articulating two further differences between classical and quantum fields. First, unlike in classical physics where field configurations are contingent in that alternative sets of field values are possible, in the quantum context the actual configuration is necessary and no alternatives are possible. Second, classical fields, according to Teller, are causal agents in that they produce observable phenomena, while operator-valued quantum fields do no more than specify the structure of physically possible occurrences.

The third part of the book, "Relativity, Measurement, and Renormalization," begins with Jeffrey Barrett's contribution, which points out that there is a close connection between proposed solutions to the measurement problem and one's ontological commitments. This is bad news, because solving the measurement problem in relativistic quantum field theory (RQFT) is even more difficult than in nonrelativistic theories, due to additional relativistic constraints and Malament's theorem. (Roughly: Given certain plausible assumptions, there cannot be any detectable objects of finite size.)

Hans Halvorson and Rob Clifton defend Malament's theorem against criticisms by proving two no-go theorems, showing that no assumptions about the nonexistence of preferred reference frames and about precise localization are needed to sustain the point against localizable particles. However, to establish that a field, rather than a particle, ontology is

appropriate to RQFTs, a further step is needed. They formulate necessary conditions for a RQFT to permit a particle interpretation and then show that no RQFT can satisfy these.

Dennis Dieks points out that it is difficult to accommodate the notion of a localized event in algebraic relativistic quantum field theory (ARQFT). This problem can be solved by adopting an interpretation of the theory based on ideas of the modal interpretation of quantum mechanics. As a result, a system's properties are only defined with respect to a frame of reference. Supplementing this with a basic decoherence condition, we find that definite physical magnitudes can be associated with each space time region, which are the localized events we were looking for.

Brigitte Falkenburg approaches the ontology of QFT from a Kantian point of view, which regards all properties as relational and denies that there are any intrinsic properties. Falkenburg extends this view to QFT, arguing that quantum fields have no reality 'on their own' and only exist as 'strongly coupled' entities.

Nick Huggett raises the question of whether QFT can be a possible candidate for a true theory. Prima facie, the fact that full-fledged QFT is intractable and has to be supplemented with perturbative methods and renormalization techniques seems to be grist for the instrumentalist's mill. Huggett argues that this impression is wrong. Based on a detailed analysis of how renormalization proceeds, he claims that we can be realists about QFT, because the physics of the full-fledged theory is well-captured by perturbative renormalization.

At the beginning of the fourth part, "Gauge Symmetries and the Vacuum," Michael Redhead observes that physical theories often contain surplus structure, i.e., mathematical elements that lack a direct link to reality. Gauge transformations are transformations that only act nontrivially on these parts of a theory. Given this, how can gauge symmetries provide interesting information about the physical world? There are three answers to this question: First, one can move gauge potentials across the boundary of the surplus structure and interpret them realistically. Second, one can reformulate the theory in terms of gauge-invariant quantities, which renders it nonlocal. Third, and this is the answer that Redhead favors, one can allow for yet more surplus structure, such as ghost fields, antifields, and so on. This admittedly has the disadvantage of leaving us with the puzzle of how to clarify the nature of these objects, which is, according to Redhead, the most pressing problem in current philosophy of physics.

Michael Drieschner, Tim Oliver Eynck, and Holger Lyre do not agree with Redhead's assessment and defend his second option. They point out that all three options have nonlocal features; therefore, this does not count

against the second option. They then formulate an account of what they call 'prepotentials' (nonseparable equivalence classes of gauge potentials in the entire space), point out that these are equivalent to the loop integrals used in the second approach, and suggest that these are the basic entities of gauge field theories.

Simon Saunders asks whether the so-called 'zero-point energy' is real. He first puts this question into the context of the cosmological constant problem and then approaches it from a historical perspective by discussing the classical ether, Dirac's negative energy sea, and the Casimir effect. A discussion of zero-point fluctuations then leads him to conclude the zero-point energy should not be considered as both real and unreasonably large. He then suggests regarding the cancellation of the zero-point energy by the cosmological constant as a renormalization of the expectation value of the energy-stress tensor. This suggestion, if correct, would lend further support to the above conclusion.

Miklos Rédei points out that one of the noteworthy features of algebraic quantum field theory (AQFT) is its ontological silence: the axioms of the theory do not mention fields or particles at all. But this does not imply ontological neutrality. First, while AQFT is hospitable to field ontologies, it is incompatible with an ontology based on localized particles. Second, AQFT can accommodate the principle of the common cause, but it is still an open question whether there actually are such common causes.

The essays collected in this book do not present a definite and unanimous answer to the question of 'what there is' according to QFT, but as they are a valuable contribution to the philosophical discussion of QFT, they will be a reference point for future work in this field.

Roman Frigg, London School of Economics

Robert P. Farrell, ***Feyerabend and Scientific Values: Tightrope-Walking Rationality***. Dordrecht: Kluwer Academic Publishers (2003), 260 pp., $86.00 (cloth).

There is a popular misconception of Feyerabend's later philosophy according to which Feyerabend dropped *rationality* as the explanation of scientific advance, arguing that science's development is primarily guided by *power, propaganda, and prejudice*. Farrell exposes this error. He pinpoints Feyerabend's core insight that any complete set of methodological rules will necessarily be inconsistent. However, this does not make Feyerabend an irrationalist. Feyerabend's later philosophy can be reconstructed into a form of values-based rationalism: To be rational is to balance incompatible methodological demands.