Ontology Schmontology? Identity, Individuation, and Fock Space

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The aim of this paper is modest. It is argued that if the nature of the "equivalence" between first-quantized particle theories and second-quantized (Fock Space) theories is examined closely, if the inadequacies of de Muynck's "indexed particle" version of Fock Space are recognized, and if the question is not begged against modal metaphysics, then van Fraassen's attempted deflation of ontological issues in quantum theory can be seen to fail.

1. Introduction. The mathematical "equivalence" of first-quantized particle theories and second-quantized (Fock Space) field theories has figured in recent discussions of the ontological interpretation of quantum theory. My purpose here is to assess van Fraassen's proposal that the balloon of ontological interpretation can (and should) be popped with two pins: first, with the "equivalence" of the representations just mentioned, and second, by embracing *semantic universalism*—the thesis that all factual description can be given completely in terms of general propositions that make no reference to individuals. I will argue that the equivalence in view does *not* deflate ontological issues, rather they remain quite pressing, and that van Fraassen's semantic universalism ends by begging the metaphysical question at issue. His attempt to downplay the metaphysical significance of quantum field theory for micro-individuality by eliminating the necessity for "moribund" metaphysics is therefore unsuccessful. It may be puzzlingly true that field quanta are not individuals, but it is *not* true as a matter of metaphysics that "the loss of individuality is illusory, since there is no individuality to be lost" (van Fraassen 1991, 436).

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2. The Nature of the "Equivalence" between First and Second Quantized Theories. Before we approach van Fraassen's discussion, we need to understand that the "equivalence" between the first and second quantized theories is limited, and that there remain significant respects in which the representations are *not* equivalent. Rather than going through all of the details, let me just introduce some basic notation and state the results (for a complete exposition, see Robertson 1973).

If explicit expression of the spin coordinates is suppressed, quantum field theory then employs a linear operator $\psi(\mathbf{x})$, which is a function of position $\mathbf{x}$, so there is a different operator ψ at each point in space. This operator and its Hermitian conjugate satisfy:

$$[\psi(\mathbf{x}), \psi(\mathbf{x}')]_{\pm} = 0, \tag{1a}$$

$$\left[\psi^{\dagger}(\mathbf{x}), \psi^{\dagger}(\mathbf{x}')\right]_{\pm} = 0, \text{ and} \tag{1b}$$

$$\left[\psi(\mathbf{x}), \psi^{\dagger}(\mathbf{x}')\right]_{\pm} = \boldsymbol{\delta}(\mathbf{x} - \mathbf{x}'), \tag{1c}$$

where $\boldsymbol{\delta}(\mathbf{x}-\mathbf{x}')$ is the Dirac delta function, and the brackets describe the anticommutation (FD) and commutation (BE) relations respectively when the upper (plus) and lower (minus) signs are used. A linear operator N is defined by:

$$N \equiv \int d^3x \psi^{\dagger}(\mathbf{x}) \psi(\mathbf{x}). \tag{2}$$

Since this operator is Hermitian ($N^{\dagger} = N$), its eigenvalues are real. The operator $\psi(\mathbf{x})$ chosen must have at least one nontrivial eigenstate $|\varphi\rangle$ with associated eigenvalue n_{φ} such that

$$N\,|\,\varphi\rangle = n_{\varphi}\,|\,\varphi\rangle. \tag{3}$$

Under these conditions, it can be shown that

$$N\psi(\mathbf{x})\,|\,\varphi\rangle = \left(n_{\varphi} - 1\right)\psi(\mathbf{x})\,|\,\varphi\rangle, \tag{4}$$

so that $\psi(\mathbf{x})|\varphi\rangle$ is either identically zero or a new nontrivial eigenstate of N with eigenvalue $n_{\varphi} - 1$. So $\psi(\mathbf{x})$ is a step-down or lowering operator. Thus, starting with any nontrivial eigenstate of N we can obtain a decreasing sequence of eigenvalues with corresponding nontrivial eigenstates by application of ψ, until the sequence ends with an application of ψ to an eigenstate that yields zero identically. This shows that the only possible eigenvalues of N are the nonnegative integers 0, 1, 2, 3, ... We denote the eigenstate corresponding to $n_0 = 0$ by $|0\rangle$ and therefore have:

$$\psi(\mathbf{x})\,|\,0\rangle = 0, \qquad \textit{for all } \mathbf{x}. \tag{5}$$

Using these eigenvalues, we can construct corresponding eigenstates by applying the $\psi^{\dagger}(\mathbf{x})$ operator. Since

$$N\psi^{\dagger}(\mathbf{x})\,|\,\varphi\rangle = \big(n_{\varphi}+1\big)\psi^{\dagger}(\mathbf{x})\,|\,\varphi\rangle, \tag{6}$$

we see that $\psi^{\dagger}(\mathbf{x})$ is a step-up or raising operator, because if $|\varphi\rangle$ is an eigenstate of N with eigenvalue n_{φ}, then $\psi^{\dagger}(\mathbf{x})|\varphi\rangle$ is an eigenstate of N with eigenvalue $n_{\varphi} + 1$. So eigenstates of N have the form

$$|\,0\rangle, \psi^{\dagger}(\mathbf{x}_1)\,|\,0\rangle, \psi^{\dagger}(\mathbf{x}_2)\psi^{\dagger}(\mathbf{x}_1)\,|\,0\rangle, \ldots \tag{7}$$

with respective eigenvalues 0, 1, 2, ... These eigenfunctions are multiply degenerate since, for example, $\psi^{\dagger}(\mathbf{x})|0\rangle$ and $\psi^{\dagger}(\mathbf{x}')|0\rangle$ with $\mathbf{x} \neq \mathbf{x}'$ both have eigenvalue 1.

We can use these eigenstates now to express the Fock Space state in terms of the corresponding many particle quantum mechanical wave function, and get the inverse expression for the wave function in terms of the Fock Space state as well. The n-particle state, represented by a vector in Fock space, when expressed in terms corresponding to the n-particle wave function $\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n)$, is

$$|\,\Psi_n\rangle = (n!)^{-1/2}\int d^3x_1 \ldots \int d^3x_n \psi^{\dagger}(\mathbf{x}_n) \ldots \psi^{\dagger}(\mathbf{x}_1)\,|\,0\rangle \times \Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n), \tag{8}$$

where the coefficient $(n!)^{-1/2}$ is the normalization constant. We use Dirac kets to represent Fock states like $|\Psi_n\rangle$, and distinguish them from the wave functions, which we denote as $\Psi(\mathbf{x}_1, \ldots, \mathbf{x}_n)$. It can be shown that $|\Psi_n\rangle$ is an eigenstate of N, that is, that $N|\Psi_n\rangle = n|\Psi_n\rangle$. Since the eigenvalue n is the number of arguments in the wave function $\Psi(\mathbf{x}_1, \ldots, \mathbf{x}_n)$, and hence the number of particles, we see clearly that N is the particle number operator. Furthermore, since $N|0\rangle = 0$, $|0\rangle$ is the vacuum state, which is devoid of particles. From this it follows that $\psi^{\dagger}(\mathbf{x})$ is a particle "creation" operator and that the operator in (8) describes the creation of n particles with wave function $\Psi(\mathbf{x}_1, \ldots, \mathbf{x}_n)$. It also follows that the lowering operator $\psi(\mathbf{x})$ is an "annihilation" operator that eliminates a particle at $\mathbf{x}$. With this in mind, using (anti-) commutator identities, the permutation symmetry

$$\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) = \pm\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_{i-1}, \mathbf{x}_n, \mathbf{x}_{i+1}, \ldots, \mathbf{x}_{n-1}, \mathbf{x}_i)$$

of the wave function (where the plus sign applies to BE and the minus sign to FD particles), and relabeling some of the dummy integration variables, it can be shown that (7) is complete in the sense that every state which can be formed with the operators $\psi(\mathbf{x})$ and $\psi^{\dagger}(\mathbf{x})$ can be formed using this set. Equation (8) gives the Fock state $|\Psi_n\rangle$ in terms of the wave function. The inverse expression for the wave function in terms of the Fock state can be shown to be

$$\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) = (n!)^{-1/2} \langle 0 \,|\, \psi(\mathbf{x}_1), \ldots, \psi(\mathbf{x}_n) \,|\, \Psi_n \rangle. \tag{9}$$

It follows from (9) that Fock Space states $|\Psi_n\rangle$ and $|\Phi_n\rangle$ will be orthogonal just in case the wave functions $\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n)$ and $\Phi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n)$ are, and that the state $|\Psi_n\rangle$ is normalized just in case the wave function $\Psi_n(\mathbf{x}_1, \ldots, x_n)$ is. Equations (8) and (9) readily lead us to an expression for the inner product of two Fock Space states:

$$\langle \Psi \,|\, \Phi \rangle = \sum_{n=0}^{\infty} \int d^3x_1 \ldots \int d^3x_n \Psi_n^*(\mathbf{x}_1, \ldots, \mathbf{x}_n) \times \Phi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n). \tag{10}$$

The inner product can then be used to construct a complete orthonormal set of states spanning Fock Space.

This is enough background to state the extent to which the representations are "equivalent" and the respect in which they are not. They are equivalent in the sense that the solution of the (second quantized) Fock Space Schrödinger equation

$$[i\hbar(\partial/\partial t) - H] \,|\, \Psi_n \rangle = 0 \tag{11}$$

can be put in the form (8), with the n-particle wave functions Ψ_n satisfying the many-particle equation

$$[i\hbar(\partial/\partial t) - H_n)\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) = 0. \tag{12}$$

But they are *inequivalent* in the important sense that *not every solution has this form,* but only ones that that are simultaneous eigenstates of the total number operator N. In this respect the Fock Space formalism is more general than that of many particle quantum mechanics, because it includes states that are superpositions of particle *number,* whereas many particle quantum mechanics obviously does not. On the other hand, not all solutions of the wave equation (12) have the form (9) with $|\Psi_n\rangle$ satisfying the Fock Space equation (11). The only ones that do are those satisfying the symmetry condition:

$$\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) = \pm\Psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_{i-1}, \mathbf{x}_n, \mathbf{x}_{i+1}, \ldots, \mathbf{x}_{n-1}, \mathbf{x}_i).$$

So in this regard, the wave equation is more general than the Fock Space equation because it includes the case of n nonidentical particles by allowing for unsymmetrized wave functions. So the representations are equivalent only for Fock space states that are eigenstates of N, and only for wave functions that are either symmetric or antisymmetric.

It is also instructive to note that total particle number is conserved in every system having the Fock Space Hamiltonian Operator H in (11), because in this case the total number operator commutes with the Hamiltonian, i.e., $[N, \mathrm{H}] = 0$. But *not all* Hamiltonians commute with the total number operator. In quantum field theory it is possible to have a situation when two or more fields are interacting and the interaction term does *not* commute with the number operator for one of the fields. This highlights another aspect of the difference between nonrelativistic quantum field theory and many particle quantum mechanics. The "equivalence" between the two representations is therefore anything but complete, so any conclusions put forward on the basis of this relationship will have to be very carefully circumscribed indeed. In particular, the *differences* between the two approaches will turn out to play a significant role in the evaluation of van Fraassen's attempted ontological deflation.

3. De Muynck's "Indexed Particle" Quantum Field Theory. Since van Fraassen's argument also relies on Willem de Muynck's attempted construction of an "indexed particle" version of Fock Space, we need to make a brief excursion into it as well. De Muynck begins his discussion with a well-worn distinction due to Jauch (1966) between the *intrinsic* and *extrinsic* properties of quanta. Intrinsic properties are defined as those that are independent of the state of the quantum system, whereas extrinsic properties arise from the state of the system. Quanta are "identical" when they have all of the same intrinsic properties. De Muynck's suggestion is that labels (indices) might be regarded as intrinsic properties of quanta, because they are independent of the state of the system, that is, they are not supposed to have dynamical consequences. This proposal motivates the attempt to construct an indexed quantum field theory that allows for the conceptual distinguishability of individual quanta despite their observational indistinguishability.

The central problem that de Muynck confronts in the context of nonrelativistic quantum fields is the construction of a formalism permitting the creation and annihilation of *indexed* quanta. He takes as his starting point the Fock Space description of nonindexed quanta and the "equivalence" to many particle quantum mechanics that we discussed in the last section. An indexed theory cannot get by with a single field operator $\psi(x)$, however. Rather, if all of the quanta are indexed, a different field operator $\psi_i(x)$ has to be associated with *each* quantum. The vacuum state $|0\rangle$ in this context is the direct product of the vacuum states $|0_i\rangle$ of all of the quanta in the system (indexed by $i \in \mathrm{I}$), and defined, as is customary, by

$$\psi_i(x)\,|\,0\rangle,\ \text{for all}\ \ i \in \text{I}. \tag{13}$$

By analogy with (8), the state vector corresponding to a system of n quanta with different indices and wave function $\Psi_n\ (\mathbf{x}_1, \ldots, \mathbf{x}_n)$ is defined by

$$|\,\Psi_{1,\ldots,n}\rangle = \int \mathrm{d}x_1 \ldots \int \mathrm{d}x_n \Psi_n(\mathbf{x}_1,\ \ldots, \mathbf{x}_n)\psi_n^{\dagger}(\mathbf{x}_n)\cdots\psi_1^{\dagger}(\mathbf{x}_1)\,|\,0\rangle, \tag{14}$$

where (cf. (9)) the wave function is related to the state vector by

$$\Psi(\mathbf{x}_1, \ldots, \mathbf{x}_n) = \langle 0\,|\,\psi_1(\mathbf{x}_1)\cdots\psi_n(\mathbf{x}_n)\,|\,\Psi_{1,\ldots,n}\rangle. \tag{15}$$

De Muynck then goes on to impose as restrictions on the individual field operators *only* those relations that are equally valid for *both* bosons and fermions, deriving a number of results that are independent of the "statistics" of the quanta and therefore hold for uncorrelated quanta as well. With no symmetry requirements imposed on (14) and (15), what we get is not ultimately that interesting because it is *not* an indexed version of Fock Space yielding quantum statistics, but rather a theory with no application. If symmetry considerations are introduced, the indexed theory will have to be permutation invariant in the requisite sense if it is going to produce the same results as nonrelativistic quantum field theory. De Muynck protests that the idea of permuting quanta requires an interaction in order to make physical sense, and suggests that an indexed theory creates a new possibility—an interaction that exchanges just the quantal *indices* (de Muynck 1975, 340). From a *de re* perspective, where the indices are intended to be rigid designators for the quanta in question, the idea of index swapping is a metaphysical impossibility. De Muynck seems to recognize as much, since he remarks:

> when index exchanging interactions are present it is no longer possible to use this index for distinguishing purposes. As a matter of fact precisely the presence of this kind of interaction would give the index the status of a dynamical variable. So a theory of distinguishable particles is possible only when the interactions are index preserving. (de Muynck 1975, 340)

In short, if the indexed theory were capable of reproducing the experimental predictions of Fock Space, the indices would have no *de re* significance.

Be this as it may, de Muynck's purpose is to develop an indexed theory as far as he can, and he pushes on to present a theory of indexed boson operators (1975, 340–345). Presenting the technical details in full is not relevant for our purposes. Suffice it to say that de Muynck succeeds in developing a formalism involving annihilation and creation operators for indexed bosons, reproducing to a limited degree the correlations of symmetric bosonic statistics. These operators are not, however, simply interpretable as creating or destroying a particle with a given index in a single particle state, because the single particle states have a restricted meaning in light of the quantum correlations. For example, although the indexed creation operator adds a quantum with a specific index and single-particle state to the initial state of the system, due to (potentially nonlocal) interaction correlations, the quantum may be in a different single-particle state at the end of its interaction with the system (1975, 342). The indexed annihilation and creation operators also have the undesirable property of being defined outside the Fock Space of symmetric states, where they have no physical meaning (1975, 341). Furthermore, the dynamical description of a system of indexed bosons using the indexed annihilation and creation operators diverges from the Fock Space description in significant ways, not least of which is that the Hamiltonian sometimes has a different energy (1975, 343). Also, in the indexed theory, the order in which particles are created or annihilated is dynamically relevant, but this is not the case in Fock Space. For this reason, the probability amplitudes associated with the indexed and nonindexed theories are different when the initial and final states are coherent superpositions of states with different numbers of particles (1975, 344–345).

What we see, then, is that an indexed theory is not capable of reproducing the experimental predictions of the Fock Space description, and to the extent that it is empirically feasible, the quantal indices have no *de re* significance (i.e., they are fictions). This, along with the realization that the indexed theory of "bosons" that de Muynck develops retains the nonlocal correlations and quantal nonlocalizability characteristic of the standard formalism, confirms that quantal individuality cannot gain a foothold in the context of nonrelativistic quantum fields by way of an empirically deficient theory of indexed quanta.

4. Ontological Deflation? This brings us finally to a consideration of Bas van Fraassen's project of ontological deflation, and his tenacious attempts to purge metaphysical questions from the domain of the philosophy of science. Van Fraassen (1991) argues that metaphysical issues of individuation and modality with respect to identical particles are in principle unresolvable and a species of "twentieth-century medieval metaphysics" from which it is best to abstain. He sides with Reichenbach in maintaining that the ontology we adopt, be it of objects, events, or whatever, rests on convenience, convention, or superfluous metaphysics, and that science itself forces no choice. "Whether persistent individuals are real, or only events, or some third sort of miasma, is not the question. Which forms of language are and are not adequate is an objective matter, and then, only relative to the criteria of adequacy we impose—that is all'' (1991, 454). His quest to validate this contention leads him down two paths of argument that we will now examine.

Van Fraassen's first argument revolves around the "equivalence'' between first and second quantized theories, which he speaks of respectively as the "particle and the particle-less picture'' (1991, 448). He describes this equivalence as a sort of representation theorem, in the sense of showing the representability of one sort of mathematical object as another sort, and takes it to imply that the theories are "*necessarily* empirically equivalent'' (1991, 450). As further evidence of this equivalence he cites the paper by de Muynck (1975) that we discussed as carrying through a reformulation of quantum field theory with individual particle labels reinserted. He takes de Muynck to have demonstrated that Fock Space can be interpreted as both an individual particle theory and a particle-less one (1991, 448), that is to say, both haecceitistically and anti-haecceitistically. Because of these equivalencies, he maintains that the structure of the theories *cannot preclude* either interpretation of their content, even though these interpretations are metaphysically incompatible (1991, 451). The lesson he draws from this is that the physics has no metaphysical import, and an ontological choice will emerge only from convenience of description, conventional stipulation, or prior metaphysical prejudice.

There are a number of difficulties with van Fraassen's argument that show this conclusion to be incorrect.[1] The first is that it presupposes that the mere presence of particle labels entails that a theory is properly interpretable as a theory of individuals. This need not be the case. The particle labels might be outright *fictions*. In fact, given that the labeled tensor product Hilbert Space formalism of many-particle quantum mechanics allows, in virtue of the indices, nonsymmetric states that do not occur in nature, it would appear that the labels are not just otiose, but misleading (cf. Redhead and Teller 1991, 1992; Teller 1995, 1998). This is one of the respects in which the first quantized formalism is *not* equivalent to Fock Space, and its deficiency suggests that the labels may *indeed* be fictions. Secondly, van Fraassen takes the constrained mathematical equivalence between many particle quantum mechanics and Fock Space to be

1. Paul Teller (1998) also has expressed some reservations about van Fraassen's argument, some of which parallel my own. On the whole, however, Teller agrees with van Fraassen that quantum theory does not force the rejection of haecceities (1998, 135), a view with which I disagree, particularly in light of the failure of de Muynck's indexed particle QFT. Teller is also inclined to take a more sanguine view than I am of the metaphysical consequences of an absence of material haecceities at the quantum level, partly because he thinks there is a viable notion of an *ersatz* haecceity that can do all of the work that real haecceities are supposed to do (1998, 136–137). I disagree, but cannot take up the issue here.

indicative of their *empirical* equivalence, thus showing that a decision between the representations cannot be made on the grounds of phenomenological adequacy. This does not seem to me to be the case. Aside from the first quantized theory predicting the existence of nonsymmetric states that do not exist, as we saw in the first section, the theories are only isomorphic for Fock Space states of a fixed particle number. There is thus a critical *non*equivalence between the theories because in field interactions, particle number need not be conserved. So the theories are *not* empirically equivalent, and Fock Space provides a more adequate description of experimental phenomena than many particle quantum mechanics. The ontology of Fock Space, whatever we might take it to be, is to be preferred over many particle quantum mechanics for this reason alone. Thirdly, contrary to what van Fraassen seems to be suggesting, de Muynck's (1975) paper does *not* demonstrate that Fock Space has an individual particle interpretation. As we saw, de Muynck's indexed bosonic field theory is neither mathematically nor empirically equivalent to a bosonic Fock Space. In fact, de Muynck (1975, 344) clearly emphasizes the empirical *inequivalence* of his theory of labeled bosons to the standard nonrelativistic bosonic Fock Space quantum field theory. So the first part of van Fraassen's argument for the ontological ambiguity of nonrelativistic quantum theory does not seem to work as he intends. Taken on their own terms, it would appear that second quantized theories *do* have metaphysical implications. Of course, we should also note that Fock Space is not the final context for interpreting the significance (metaphysical or otherwise) of quantum theory. Relativistic interacting quantum fields in curved space-time are the more realistic situation, and in this setting Fock Spaces are a very specialized subset of representations, often not able to be used at all (Fulling 1989).

What then of the second argument van Fraassen develops to the end of deflating discussions of the metaphysics of individuality? The crux of this argument lies in his thesis that all factual description can be given completely in terms of general propositions that make no reference to individuals, a view he calls *semantic universalism*. His argument for semantic universalism does not draw on physics per se, since it is of a logical and philosophical character. But there is an apparent analogy that can be constructed to the Fock Space occupation representation of quantum statistics in that van Fraassen's model-theoretic argument for semantic universalism involves demonstrating the equivalence between models containing individuals and models without individuals that only involve patterns of cell-instantiation given by occupation numbers (van Fraassen 1991, 465–480; see especially 475–476). This analogy is highly suggestive, but I think it ultimately succumbs to some overriding dissimilarities.

Let me explain. The analogy gains its initial plausibility from van Fraassen's assertions about Fock Space that we criticized above. It requires that the "equivalence" between first and second quantized representations be stronger than it actually is. The fact that many-particle quantum mechanics arguably predicts unobserved nonsymmetric states whereas Fock Space does not, shows not only that the two representations are neither mathematically nor empirically completely equivalent, but that the first quantized formalism is markedly deficient. The analogy also requires Fock Space to have an empirically adequate indexed particle model, and de Muynck's efforts in this regard have given us a good reason to think that this is not possible. So for van Fraassen to maintain convincingly that the Fock Space representation is *not* incompatible with there being individual particles, he would have to show the that the theory was incomplete in some *other* sense. The apparent incompatibility between Fock Space representations and particle individuality would then be seen as being due to epistemic ignorance. He opposes ignorance interpretations of quantum mechanics, however, and such an argument would involve the postulation of hidden realities that run counter to his empiricist proclivities. It seems, therefore, that not only does semantic universalism gain no power from an analogy to quantum statistics, but the analogy is methodologically inadvisable as well, since it pulls in a direction counter to van Fraassen's philosophical orientation.

Appearances to the contrary, however, this may not be the strain of argument van Fraassen wishes to develop. At the beginning of his discussion he gives us this promissory note (1991, 434, 436):

> The most satisfying way to end a philosophical dispute is to find a false presupposition that underlies all the puzzles it involves. . . . I shall argue that the "loss of identity" dispute can be so dissolved. The questions rest on a mistake—or, more precisely, on a metaphysical position which has already been moribund for centuries. . . . I shall argue that the loss of individuality is illusory, since there is no individuality to be lost.

If we emphasize this polemical strategy, then rather than relying on a problematic analogy with quantum statistics, we might regard him as developing an independent strain of argument to the effect that semantic universalism shows that the metaphysical notion of an individual is a mistake. It is not entirely clear what *sort* of mistake it would be, however. Van Fraassen thinks that Quine's program of deriving ontology from syntax is a mistake (1991, 456–459), so it seems unlikely that he is proposing to deduce a metaphysical absence from a technical discussion in formalized semantics. The inference from formal semantics to a metaphysically definitive ontology devoid of individuals would be an error of equal proportion. Just because we cannot, or more accurately from the perspective of van Fraassen's argument, *need not* talk about something does not mean that it does not exist. So it is more likely we should interpret him as maintaining that the metaphysics of individuality is a *semantic* mistake in the sense that *there is no legitimate sense attributable to the notion*.

How could van Fraassen be seen as defending this idea? Under what condition would this be true? Van Fraassen argues that there is an equivalence between models containing individuals and models without individuals that only involve patterns of cell-instantiation given by occupation numbers. If no metaphysical notion of individuality could countenance such an equivalence, then his argument, if valid, would show that contrary to surface impressions, metaphysical individuality is semantically (model-theoretically) incoherent in a deep sense.

There are two responses to be made here. The first is that, if this is an attempt to obviate the ontological peculiarities of quantum statistics, the strategy will not work. It is true that under restricted conditions Bose-Einstein and Fermi-Dirac occupation number statistics can describe particles that are assumed to be distinguishable (Tersoff and Bayer 1983; Cufaro-Petroni et al. 1984). The problem is, as Alexander Bach (1984) has shown and van Fraassen (1991, 414) is aware, quantum statistics only works for distinguishable particles in contexts of maximal ignorance since this is the only situation in which classical and quantum statistics can agree. Tersoff and Bayer's result is actually a corollary to de Finetti's representation theorem proved earlier by Richard Jeffrey (1965), and it embodies a purely classical notion of exchangeability related to epistemic ignorance, not ontological indefiniteness. In conditions of less-than-maximal ignorance the distinguishability of classical particles entails a divergence from quantum statistics. But the *in*distinguishability of quantum particles remains and points to a puzzling ontological indefiniteness that transcends mere epistemic ignorance. So an equivalence between models containing individuals and models without individuals that only involve patterns of cell-instantiation (occupation numbers) holds just in case the individuals in those cells are ontologically distinguishable but we are, because of maximally limited knowledge, unable to tell them apart.

The second response is that a dedicated metaphysician has little to fear from van Fraassen's argument because it begs the question against both essentialism and haecceitism by invoking anti-essentialist and anti-haecceitist restrictions in the process of model construction. To review the construction very briefly, van Fraassen (1991, 465–476) defines a proposition as *purely general* relative to a model just in case the set of worlds (within the model) where it is true is closed under permutations, a permutation of a world being specified to be *qualitatively* identical to the original but differing in terms of which individuals are assigned to which cells (predicates). He further defines a *full model* as one in which the set of worlds W is closed under permutations in such a way that the binary accessibility relation on worlds explicating the possibility and necessity operators ensures that purely general propositions will be closed under those operations. The thesis of *semantic universalism* is then articulated as the requirement that every model be a full model, and every full model include only general propositions. Van Fraassen goes on to define an *abstracted model* as one whose set of worlds W consists of nothing more than maps from cells to natural numbers, so that each world in W is nothing more than a set of occupation numbers specifying how many objects are in each cell, and shows that every abstracted model corresponds (up to isomorphism) to a unique full model (1991, 475–476). Through the lens of semantic universalism, this is intended to constitute a demonstration that worlds containing individuals are model-theoretically equivalent to ones without individuals, the latter being specified only by the occupation numbers of their cells (predicates).

Aside from the fact that there is little reason to prefer this procedure of model construction, let alone to regard it as inevitable, it is fairly simple to see that it doesn't generate the conclusions van Fraassen wants without making some assumptions that beg the question against the metaphysics of individuality. How are the predicates that constitute the occupation cells to be interpreted? There is no nonprejudicial reason for disallowing them to include single-occupation cells representing haecceities, even though van Fraassen has precluded this possibility by his use of general propositions that only countenance qualitative properties. But if a cell *can* represent an haecceity (and there is no logical reason why it could not do so), then the only permissible permutations will be those which map haecceitistic cells identically into themselves (for only this map will be truth-value preserving), and haecceitistic individuation will be model-theoretically coherent. The same sort of strategy works to preserve essential properties as individuative devices. If an object has an essential property or a set of essential properties, van Fraassen's full models will not be able to get off the ground. Since full models include *any* permutation of *any* world they contain, some of those permutations will not respect the necessity inherent in the object's essential possession of certain properties, and therefore not represent a genuine possibility. So with anti-essentialism and anti-haecceitism *assumed* at the outset, and the question begged at a very basic level, the results that van Fraassen proves regarding full models are completely irrelevant to the tenability of the classical metaphysics of individuality.

Finally, in respect of the issue of semantic universalism, as Jeremy Butterfield (1993, 470) has pointed out, the doctrine cannot require the use of only full models because it is *consistent* with the possibility that there are essential properties. If the requirement of permutation invariance of truth-values for qualitative properties constituting the definition of general propositions is weakened to require only invariance for those permutations that yield genuinely possible worlds (by not violating any essential property attributions), then semantic universalism is consistent with essentialism.

So van Fraassen's attempt at ontological deflation is unsuccessful.[2] While there are theoretical and empirical reasons for preferring Fock Space quantum field theory over many particle quantum mechanics, *both* these theories create difficulties for *de re* attributions to individual quanta because of the ontological indefiniteness inherent in quantum statistics and because of nonlocality and nonlocalizability in relativistic contexts. Beyond this, we conclude by remarking that Fock Space itself is not the full story because it only applies to free fields in flat spacetime. Ultimately, the ontological implications of fundamental physical theory need to be addressed in the context of relativistic interacting quantum fields in curved spacetime, but that is a topic for another essay.

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2. Steven French has suggested to me that the difficulties with van Fraassen's attempted dissolution of the ontological conundrums of quantum theory could be obviated by adopting a quasi-set theory for quanta of the sort developed by Maria Luisa Dalla Chiara et al. (1998). I'm skeptical of this assertion on three grounds. First, it is not obvious to me that a quasi-set-theoretic account of "objects" in fact resolves the difficulty. Second, while quasi-sets are viable mathematical constructions, I am skeptical that they give genuine metaphysical insight into the microrealm: at best, they would seem to be a re-description of the basic problems of quantum-theoretic ontology rather than a resolution of its difficulties. Finally, as French himself acknowledged in making his remarks, regardless of whether Dalla Chiara's approach would salvage van Fraassen's construction, it seems unlikely that van Fraassen would be any more kindly disposed to a quantum ontology of quasi-sets than he is to an ontology of haecceities: it is still metaphysics!

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