Elementarity and Anti-Matter in Contemporary Physics: Comments on Michael D. Resnik's "Between Mathematics and Physics"[1]

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I believe that the nominalist-platonist debate which Professor Resnik tries to dissolve is even more of a non-starter than he appears to think, judging from his "Between Mathematics and Physics". I shall argue for this by showing, first, that conceptions of particles as mathematical, or quasi-mathematical, have a longer history than Resnik notices, and, second, that the current difficulties with thinking of elementary particles as tiny chunks of matters are more profound than he realizes. Finally, I hope to point toward a diagnosis of the confusion which leads nominalists to pursue ill-motivated debates and research programs.

As early as 1762 we find Roger Boscovich arguing against an atomistic or corpuscularian conception of particles. He used a conception of particles as simple, indivisible, and extentionless as one crucial feature in building a physical theory which he saw as superior to Newtonian mechanics in numerous respects, including both consideration of epistemic values, e.g., it is less *ad hoc* than Newtonian mechanics (pp. 13, 54-55), and greater agreement with empirical observations, e.g., his theory explains why the fixed stars do not "coalesce into one mass", whereas universal gravitation theory requires that the stars would collapse (pp. 16, 144-147). The most general motivation for his mathematical or quasi-mathematical conception of particles, though, came from his argument that a standard atomistic conception of particles leads to paradox in understanding collision. Boscovich argued that the standard view leads to any one of three unacceptable consequences: either a body involved in a collision has two distinct velocities at the same time, or there is compenetration of colliding bodies, or there are non-continuous changes in the velocites of colliding bodies (pp. 10, 24-25).

Boscovich conceived of points as "simply mathematical points surrounded by attractive and repulsive forces" (Gjertsen, p. 171). He distinguished between purely geometrical points and physical (or material) points. The *only* difference between the two is that any physical point "possesses the real properties of a force of inertia" and of other, attractive and repulsive, forces (p. 58). Perhaps, in order to preserve Boscovich's distinction, it would be best to label his points "quasi-mathematical", yet this label ought not obscure the fact that his points were not physical in the ontological terms used in the nominalist-platonist debate.

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Although Boscovich's theory, including his quasi-mathematical conception of particles, did not widely influence influence physicists of his day, his conception of particles did prove fruitful later in the development of science, especially in Michael Faraday's theory of electrical conductivity, in which particles were merely centers of force, not tiny chunks of matter (Gjertsen, p. 172).

Of course, Einstein has superceded Newton and his opponents, and quantum electrodynamics has superceded Faraday: we are not tempted to base our conception of particles on those of Boscovich and Faraday, even had their conceptions been uncontroversial when they were writing.

The threat posed by contemporary physics to the ontological assumptions traditonal in the nominalist-platonist debate is deeper than Resnik realizes. Indeed, the conceptual presupposition of the distinction between mathematical and physical objects is endangered. This conceptual presuppositon, which Werner Heisenberg argues must be abandoned, is the picture of elementary particles combining in geomtrical or dynamical configurations to form larger material objects.

Heisenberg sees the challenge to this picture as motivated by a variety of different features of early quantum mechanics, but especially from P.A.M. Dirac's relativistic theory of the electron and from the discovery of the positron. Of this, Heisenberg writes:

> I think that this discovery of antimatter was perhaps the biggest change of all the big changes in physics in our century. It was a discovery of utmost importance, because it changed our whole picture of matter (pp. 31-32).

How does this conceptual change emerge from Dirac's work, according to Heisenberg? For brevity sake's, I only sketch Heisenberg's answer. Dirac's suggestion that positrons could be produced by pair-production, along with the experimental discovery of positrons, leads to abandonment of the law of conservation of particle number. As Heisenberg writes, "For instance, ...one could say that the hydrogen atom does not necessarily consist of proton and electron. It may temporarily consist of one proton, two electrons, and one positron" (p. 32). For any particle, with pair-production creating particles from energy, the number and configuration of particles of which it consists is indeterminate, so long as the total symmetry of the system is the same as the symmetry of the particle itself. This leads us to realize that "the elementary particle [is] not elementary anymore. It is actually a compound system, rather a complicated many-body system, and it has all the same complications which a molecule or any other such object really has" (p. 32). The properties of such systems can best be calculated from natural law, just as we would calculate the states of complicated molecules. Then we can conceive of these elementary, non-elementary particles as complicated states, perhaps as mathematically-described states of fields.

A natural response to this situation, given our atomistic preconceptions, is to think that we were simply wrong about which particles are elementary; those we thought to be elementary have turned out to be complex, so let's search elsewhere for our simple chunks of matter. Heisenberg thought that this heuristic motivated much of the search for quarks (pp. 16-17, 35). Yet this response betrays a fundamental misunderstanding, for it simply postpones the problem until we have identified the new family of particles to which we are tempted to ascribe elementarity. As Heisenberg points out:

> ...even if...quarks were to exist, we could not say that the proton consists of three quarks. We would have to say that it may temporarily consist of three

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quarks, but may also temporarily consist of four quarks and one antiquark, of five quarks and two antiquarks, and so one. And all these configurations would be contained in the proton, and again one quark might be composed of two quarks and one antiquark and so on (pp. 35-36).

Heisenberg's point here is that the indeterminancy of quantum number goes all the way down — it occurs for all particles, so no family of particles can be elementary.

Another inviting response is to admit all this but to claim that it shows no more than that our concept of elementarity must be revised in the face of antimatter. Instead of ascribing elementarity to particles on the basis of simplicity, now we should ascribe elementarity on the grounds that a particle is not composed of particles of any different families (since any particle and its anti-particle are in the same family). Then, according to this response, protons are not elementary, since they are composed of quarks (and antiquarks), whereas quarks are elementary, since they can be composed only of quarks (and antiquarks).

But this response also misses Heisenberg's point: were any given quark composed of a particular number of quarks and antiquarks, this response would suffice, but the crucial difficulty which bothered Heisenberg is *numerical indeterminancy*. Although related to the numerical identity problem which Resnik notices (Ms., pp. 5-6), this is a different problem, for here an analogue of Benacerraf's multiple reduction problem, now for allegedly paradigm examples of physical objects, faces traditionalists in the nominalist-platonist debate.

Heisenberg's own response to this situation was to jettison the concept of an elementary particle and replace it with the concept of a fundamental symmetry group. This may seem like a simple expression of instrumentalist sympathies, and indeed Heisenberg's sympathies were instrumentalistic. But this response is not open to nominalists, at least not without a re-conception of their debate with platonists. Furthermore, this response misses the depth of Heisenberg's argument, for his considerations lead one to reject or reconceive the concept of matter even at the level of middle-sized dry goods; conceiving, e.g., a tin can containing artichoke hearts as a material object composed of smaller chunks of matter leads, ultimately, to the same indeterminancy that plagues quarks conceived as physical particles.

Heisenberg himself saw that the consequences of his argument were far-reaching. He recognized that his argument against elementary particles rests on undermining the distinction between elementary particles and compound systems (p. 59), which led him to understand particles as "stationary states of the physical system 'matter'" (pp. 59, 66), and he uses scare quotes around the word 'matter' in some instances. Particles are essentially described by their transformational properties under fundamental symmetry groups. But, then, as Heisenberg puts it, "theoretical understanding of particle physics can only mean an understanding of the spectrum of particles (p. 66). Particles, then, become, at their ontological (and realist) best, secondary structures, defined by combinng the dynamics of a system with the boundary conditions; the concept of a particle, or even of a spectrum of particle, has no role in the mathematical formulations of the dynamics of a system. So, for Heisenberg, dropping the concept of an elementary particle leads to downgrading the status of the particle concept itself; at best, the concept of a particle has a derivative conceptual status and particles are ontologically derivative as well, and the relations *divide* and *consist of* (obtaining between particles, or even larger chunks of matter) lose all literal meaning whatsoever. From here it is a short step to a re-conceptualization of matter itself. If the particle concept has been an inherent part of our concept of matter, as seems plausible, then undermining the particle concept is undermining the concept of matter. Fundamental symmetry groups provide a natural choice of replacement concepts (though there may be others), for it is by fundamental symmetry groups that we describe and understand what Heisenberg calls the "fundamental structures of nature" (p. 105), which we might think of as the physical system of matter. But this re-conceptualization leads us to believe that "these [fundamental] structures are much more abstract than we had hoped for" (p. 105) in the early days of quantum mechanics, prior to Dirac, to Pauli's and Fermi's work on beta-decay, and experimental detection of the positron.

If this picture is even along the right lines, the picture of physics with which we are left holds little consolation for traditionalists in the nominalist-platonist debate, for it undermines the legitimacy of the concepts used to draw the distinction between mathematical and physical entities. And, more importantly, this picture undermines the motivation for drawing the distinction in the first place: what is the significance of drawing an ontological distinction which is, at best, derivative from one side of the distinction alone (since clarification of the physical rests on clarification of (part of) the mathematical)?

Now, I believe, we have the conceptual tools needed to diagnose the confusion which leads nominalists to pursue ill-motivated, ill-conceived research programs. As Resnik points out, "Anti-realists in the philosophy of mathematics are invariably realits about physical objects" (Ms., p. 3). The challenge to the nominalist, as Resnik sees it, is to give a reduction of the mathematics allegedly necessary for physics to a physical ontology. So far, the nominalists' attitude toward physics looks to be an attitude which takes physics very seriously, giving it pride of place over other special disciplines (with the possible exception of epistemology). Yet nominalists change their attitude toward physics when confronted with its anti-atomistic themes; nominalists seem blithely to accept an ontological understanding of physics that, at a fundamental level, differs little from Newton's. Certainly nominalists accord strange quantum properties to little chunks of matter, properties which Newton never dreamt of; certainly nominalists do not believe that Newtonian laws accurately describe the behavior of these tiny chunks of matter. But still — there are those tiny chunks of matter — despite the early challenges of Boscovich and Faraday, and despite the much more radical challenge from contemporary "particle" physics. Thus, the nominalists' attitude toward physics is inconsistent or confused. If realism about physical entities and the primacy of physics are to be held, then the challenges to atomism coming from physics must be taken seriously. One cannot help oneself to the physics that is pleasing and dispose of the rest.

It seems that there is still a strong motivation for pursuing traditonalist problems: what is one to do otherwise? Rather than being tempted by the sway of tradition in this way, I would like to suggest that we should see the dissolution the nominalist-platonist debate as liberating, leaving us free to discover and pursue new problems. A cluster of new problems is suggested by Heisenberg's proposal that the particle concept be replaced by the concept of fundamental symmetry groups. Heisenberg, of course, did not know what physics would look like were this conceptual change to take place. For example, he did not know what questions would replace those which presuppose the concept of an elementary particle, such as "Can one divide quarks further, or are they indivisible?" (his own example uses `electrons', not `quarks'). He could not foresee the changes in directions of physical research to which his recommended re-conceptualization would lead. Nor could he foresee the overarching ontological consequences of such a change. Herein lie fresh, exciting conceptual questions for physicists and philosophers alike. Exploration into their answers may give us interesting directions to pursue in the epistmelogy of mathematics as well. The change Heisenberg proposes suggests that there is more continuity between the ontology of mathematics, the ontology of physics, and the ontology of the objects of our everyday experience than many philosophers have believed there to be, and we may find that a better understanding of this ontology suggests ways to better understand epistemology, including the epistemology of pure mathematics.

Note

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