Newton's *Quantitas Materiae*

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It was more than ten years ago that one of the present authors, Masao Watanabe, published his view concerning Newton's concept of mass revealed in the *Principia.*[1] Commenting on this paper, a different opinion was then presented by Kiyonobu Itakura.[2] Watanabe replied to Itakura later in another paper confirming and strengthening his original point.[3] The present paper will first review this academic dispute, will then refer to John Herivel's more recent work, and will end with the presentation of some of the results of the recent studies made by the present authors.

Newton, in the first of the eight Definitions at the beginning of the *Principia,* defined "the quantity of matter" (*quantitas materiae*) as follows:

> The quantity of matter is the measure of the same, arising from its density and bulk conjointly.[4]

As cited by Florian Cajori, Ernst Mach criticized this definition as being circular, since density can only be defined as the mass of unit volume; but Cajori also noted that Henry Crew held that "it is both natural and logically permissible to define mass in terms of density" at the time of Newton when "the density of water was taken arbitrarily to be unity"; whereas Edmund Hoppe, according to Cajori, assumed that Newton's atoms were of the same size and consequently the densities of bodies were proportional to the numbers of such atoms in equal volumes.[5] Cajori himself was critical of Hoppe's interpretation because it did not accord with Newton's corpuscular idea as described in his *Opticks.*[6] E. A. Burtt, W. C. Dam-

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[1] Masao Watanabe, "Newton's Concept of Mass as revealed in his *Principia,*" *Kagakusi Kenkyu (Journal of History of Science, Japan)*, No. 54, 1960, pp. 1–4.

[2] Kiyonobu Itakura, "Newton's Definition of Mass in *Principia* and Galilei's Atomism in *De Motu,*" *Kagakusi Kenkyu,* No. 59, 1961, pp. 29–31.

[3] Masao Watanabe, "Newton's Concept of Mass—A Reply to Dr. Itakura," *Kagakusi Kenkyu,* No. 84, 1967, pp. 191–194.

[4] Isaac Newton, *Mathematical Principles of Natural Philosophy,* Motte-Cajori translation, Berkeley, 1947, p. 1.

[5] Ernst Mach, *Die Mechanik in ihrer Entwicklung* (ed. 8), Leipzig, 1921, p. 188; Henry Crew, *The Rise of Modern Physics,* Baltimore, 1928, p. 124; Edmund Hoppe, *Archiv für Geschichte der Mathematik, der Naturwissenschaften und der Technik,* n.s., Vol. 11, 1929, pp. 354–361 (according to Cajori's Appendix, Newton's *Principles, op. cit.,* pp. 638–639).

[6] Isaac Newton, *Opticks,* 3rd ed., 1721, pp. 375–376 (Cajori, *Ibid.*).