The Enigma of Leibniz's Atomism[1]

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1. The Enigma

Reminiscing about his early views on the continuum problem in a dialogue penned in 1689,[2] Leibniz recalled the period in his youth when he had enthusiastically subscribed to the "New Philosophy", embracing the composition of the continuum out of points and the doctrine that "a slower motion is one interrupted by small intervals of rest."[3] Speaking of himself through the character Lubinianus, he continues:

> And I indulged other dogmas of this kind, to which people are prone when they are willing to entertain every imagination, and do not notice the infinity lurking everywhere in things. But although when I became a geometer I relinquished these opinions, atoms and the vacuum held out for a long time, like certain relics in my mind rebelling against the idea of infinity; for even though I conceded that every continuum could be divided to infinity in thought, I still did not grasp that in reality there were parts in things exceeding every number, as a consequence of motion in a plenum.

That "atoms and the vacuum held out for a long time" among Leibniz's cherished views is readily confirmed by an examination of his manuscripts. One may find papers containing some measure of commitment to atomism intermittently throughout the period from 1666 to 1676; moreover, if his later memory is to be trusted, he first "gave himself over to" atomism as early as 1661.[4] As for his reasons for rejecting atoms, Leibniz's mature

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[2] From the second dialogue of his *Phoranomus: Ôr, on Power and the Laws of Nature* [*Phoranomus*] (July 1689); these dialogues have been transcribed and annotated in a critical edition by A. Robinet, in *Physis*, v. 28, n. 3, 1991, 429-541, & v. 28, n. 23, 1991, 797-885. The extracts to follow are from 803. They are my translation, as are all English renderings of Latin or French passages in this paper; 'ôr' translates *seu* or *sive*, the 'or of equivalence'. Many of the translated passages from Leibniz are quoted from *G. W. Leibniz: the Labyrinth of the Continuum Writings from 1672 to 1686* [*Labyrinth*], ed. and trans. R. T. W. Arthur (New Haven: Yale University Press, 2001).

[3] This position, proposed by the "Zenonist" faction of Jesuit philosophers, was endorsed by Rodrigo Arriaga in his *Cursus Philosophicus* (Antwerp, 1632; 490ff.), and by Pierre Gassendi in his *Animadversiones in decimum librum Diogenis Laertii* [*Animadversiones*] (Lyons, 1649; reprint ed. N.Y./London: Garland), 455-56. Leibniz might have learnt of it from reading Libert Froidmont's refutation in his *Labyrinthus sive de compositione continui* (1631), 62ff. See also Philip Beeley's discussion of this doctrine in his *Mechanismus und Kontinuität* [*Kontinuität*] (Stuttgart: Franz Steiner, 1996), 298-300.

[4] In a letter to Rémond in July 1714, Leibniz recalls: "As for Gassendi, ... I am not as content with his meditations at present as I was when I was starting to abandon the opinions of the school, while still myself a schoolboy. Since the doctrine of atoms is satisfying to the imagination, I gave myself over to it completely, and the void of Democritus or Epicurus, together with the impregnable corpuscles of these authors, appeared to me to relieve all difficulties. . ." (GP III 620). In a letter the previous January, he described himself as having begun to deliberate whether to opt for the moderns over the scholastics "at the age of 15" (GP III 606). Willy Kabitz argues that Aristotelian principles in his early writings at university show that Leibniz must have misremembered, and that he could not have gone over to the moderns until 1664 at the earliest (Willy Kabitz, *Die Philosophie des jungen Leibniz* (Hildesheim/NY: Georg Olms, 1974), 49-50.

objections based on the actually infinite division of matter are well known. This passage from the correspondence with Clarke is representative:

> The least corpuscle is actually divided *ad infinitum* and contains a world of new created things, which the universe would lack if this corpuscle were an atom, that is, a body all of a piece and not subdivided… What reason can be assigned for limiting nature in the process of subdivision?[5]

According to this scenario, then, one would expect to find some definitive text or texts from the 1670s in which Leibniz discovers his mature objection to atoms, and presents it accordingly. This is the line taken by the French scholar André Robinet, for example, who locates the crucial change in Leibniz's thinking as his rejection of indivisibles in the fragment *De minimo et maximo* (Nov. 1672-mid-Jan. 1673).[6] He then identifies the text in which Leibniz gives a definitive statement of the resulting position as the dialogue *Pacidius Philalethi*,[7] a detailed investigation of the problems of the continuum which Leibniz wrote in November 1676[8] on board a ship from England to Holland (where he would visit Spinoza and other leading Dutch scholars on his way back to Hanover). For in that dialogue Leibniz's spokesman Pacidius eloquently presents the position that has become familiar to us in his mature works:

> I myself admit neither Gassendi's atoms, ôr a body that is perfectly solid, nor Descartes' subtle matter, ôr a body that is perfectly fluid… (A VI.iii 554; *Labyrinth,* 185)

> But there is no reason why these miraculous leaps should be ascribed to this rather than that grade of corpuscles—unless, of course, we admit atoms, ôr bodies so firm that they do not suffer any subdivision or bending... But I do not think that there are such bodies in the nature of things… since there is no reason why God should have put a stop to his handiwork at this point and left only these creatures without a variety of other creatures

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5 Postscript to Leibniz's fourth paper, *Leibniz: Philosophical Writings*, transl. Mary Morris and G. H. R. Parkinson (London/Vermont: J. M. Dent/Charles E. Tuttle, 1995), 220, 221.

6 André Robinet, *Architectonique disjonctive automates systemiques et idealité transcendentale dans l'œuvre de G. W. Leibniz* [*Architectonique*], Paris: J. Vrin, 1986: 186-187. This fragment is edited by the Akademie as "*De minimo et maximo. De corporibus et mentibus*", A VI.iii n5, and translated as "On Minimum and Maximum; on Bodies and Minds" in *Labyrinth,* 9-19. Robinet cites it by its *incipit* (opening words) *Nullum datur Minimum…* , rather than by the Akademie title.

7 Robinet, *Architectonique*, 187-189, esp. 188: "[Dans le *Pacidius Philalethi*] les points ne sont pas des indivisibles, les points sont des extrémités, des limites... Il s'ensuit que la conception de la matière ne peut plus reposer sur l'indivisible-point puisqu'elle est infiniment divisible en acte, passant sous le modèle de la poursuite de la division vers l'infiniment petit... Et remarquons ensuite que l'éviction du vide et de l'atome s'ensuite."

8 Leibniz wrote the *Pacidius* during the last ten days of October (OS) on board a ship bound for Holland, whilst waiting in the Thames estuary for cargo and optimal sailing conditions. I give all dates here New Style, which makes its composition the first ten days or so of November.

> inside them, as if they were paralyzed or dead… (A VI.iii 561; *Labyrinth,* 199)
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> Accordingly I am of the following opinion: there is no portion of matter which is not actually divided into further parts, so that there is no body so small that there is not a world of infinitary creatures in it. (A VI.iii 565; *Labyrinth,* 209)[9]

Awkwardly for this interpretation, though, Leibniz does not give up atoms as soon as he gives up indivisibles. In fact, over three years after *De minimo et maximo* and only a few months before he wrote the *Pacidius*, Leibniz was writing in his unpublished papers of being more and more persuaded of the very same "perfectly solid" atoms he rejects in the latter.[10] Still, one might put this down to the fact that Leibniz took a long time to convince himself that the infinite division of the continuum was not merely theoretical, and that "there really were parts in things exceeding every number." The real enigma, I propose, is that this thesis, that the continuum is not just potentially but actually divided into an infinity of parts, is one he seems to have held from as early as 1666, and consistently from then on, even while proposing atoms. Here is the evidence:

In his *Dissertatio de arte combinatoria* of March 1666, Leibniz advocates a combinatoric of atoms as "the only way of penetrating into the secrets of nature—if it is indeed true that large things are composed of small ones, whether you call these atoms or molecules" (A VI.i 187), citing Kepler's *Harmonice* as well as Gassendi's *Animadversiones* (1649), Magnen's *Democritus reviviscens* (1648), and the classical atomists (A VI.i 216). Yet in the fourth axiom of the demonstration of God's existence preceding the dissertation he had proposed that "Each body has infinite parts, ôr, as is commonly said, the Continuum is divisible to infinity" (A VI.i169). Granted, at first sight this seems to fit the description Leibniz gave in the *Phoranomus* of his early views. Atoms still have a certain claim on his thought, but he has only conceded that the continuum is infinitely *divisible.* The mention of infinite parts in the first clause of axiom 4 seems dubious as evidence for his subscribing to an infinity of parts in things in reality,

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[9] He has the interlocutor Gallutius respond: "This is an admirable idea of reality you are presenting us with, since so much would have to be missing in order for there to be atoms; whereas the idea that there should rather be a kind of world of infinitary things in any corpuscle you please is something which, as far as I know, has not been adequately considered before now." (A VI.iii 566; *Labyrinth,* 211)

[10] Indeed, he still advocates them *after* writing the *Pacidius*, if the dating of the *Catena Mirabilium Demonstrationum de Summa Rerum* as December 12, 1676 is correct. He writes: "Supposing plenitude, *atoms* are demonstrated; indeed, even without plenitude, from the mere consideration that every flexible body is divided into points. It seems very much in accord with reason that primitive *bodies* should all be spherical..." I am inclined to doubt that Leibniz could have written this piece then, however, although I will not argue that here.

an *actually* infinite division. For on the standard Aristotelian interpretation, a body has infinite parts only *potentially*, i.e. in the sense that any parts into which it is actually divided are susceptible of further division. However, as Philip Beeley has argued, Leibniz uses this axiom to prove that the force of motion of a body must be infinite, on the grounds that the motion of the body as a whole presupposes the coming-into-motion of every single part, and thus a moving principle in each one. But the infinitude of the force follows from this only if a body has infinite parts that are actual, and not merely potential. Therefore a body must have an actual infinity of parts.[11]

Five years later Leibniz is unequivocally committed to actually infinite division, but now sees it as refuting atomism, just as in his mature work. In the fragment "On Primary Matter" of 1671, he writes (his stress): "*Matter is actually divided into infinite parts. There is in any body whatever an infinity of creatures. All bodies cohere with one another. Yet every body separates from every other, although not without resistance. There are no atoms*, ôr bodies whose parts never separate." Yet later in 1671, in the *Hypothesis de systemate mundi*, he describes the world as "a space full of globes, touching each other only at points," with voids in the gaps between them. All bodies are either "naturally dissoluble, or they are indissoluble, i.e. atoms". Although atoms are "the only integral bodies", "it suffices for a body to be integral only at its surface", and to be "again composed of infinite globes inside" (A VI.ii 294). Similarly in his Paris manuscripts of 1676 one may find Leibniz explicitly upholding both the reality of atoms and the actually infinite division of the continuum, sometimes even in the same passage, as we shall see.

Thus the enigma of Leibniz's atomism is this: if we take atoms in the orthodox sense of finite parts of matter that are not further divided, then Leibniz's thesis that matter is actually infinitely divided *directly precludes them*, as he himself urges in his mature writings. Yet this thesis of the actually infinite division of matter is one he had maintained throughout the period in which he had intermittently advanced atoms.

2. Leibniz's Atoms: Some Interpretations

At first blush this difficulty seems intractable. For if atoms are physically indivisible finite parts of matter beyond which it cannot be further divided, this is in blatant contradiction

[11] See Philip Beeley, *Kontinuität*, 57. The suggestion that this axiom does concern actual parts had been made previously by Daniel Garber in his "Motion and Metaphysics in the Young Leibniz," in Michael Hooker (ed.), *Leibniz: Critical and Interpretive Essays* (Minneapolis: University of Minnesota Press, 1982), 160-184, at 168.

with the thesis that matter is infinitely divided. Although the difficulty has perhaps not been pointed out before in quite so stark a fashion, several commentators have shown some awareness of the problematic nature of Leibniz's dalliance with atoms in his youth, and in this section I wish to consider some of the different approaches that have been taken. This will introduce us economically to many of the central features of Leibniz's early atomism, as well as motivate my own resolution of the enigma in the following sections. One such approach is that of Robinet already mentioned above, who identifies Leibniz's atoms, not with finite parts of matter, but with the infinitely small parts or indivisibles he espoused in the early 1670s. Another, that of Philip Beeley, is to deny that Leibniz was ever "committed" to atoms after he went to university, and to interpret his appeals to atoms or physical indivisibles as simply the trying out of hypotheses. A third, that pursued by Christia Mercer, is to interpret his atoms as atoms of substance of the type he advocated in the 1680s and 1690s: these would have bodies that are physically divisible, even though the substantial atoms themselves would be metaphysically indivisible. Although each of these proposals has merit, I shall argue that none can be regarded as providing a wholly satisfactory resolution to the enigma.

According to Robinet, Leibniz's atoms are identical to the *indivisibles* he had posited in his *Theoria motus abstracti* [*TMA*], composed together with his *Hypothesis physica nova* [*HPN*] in 1670, and sent to the Royal Society and Academie des sciences in 1671. On the one hand, the indivisibles are inferred from the fact that continuous matter is actually infinitely divided, not just indefinitely divided, as Descartes had proposed. On the other hand, indivisibles of a line (identified with the indivisibles of Cavalieri's geometry) are justified in terms of motion: an indivisible line is the space traversed by a body with a definite endeavour (*conatus*) at an instant: the greater the endeavour, the greater the indivisible space traversed. One of the main results that Leibniz derives from this theory is that "bodies are momentaneous minds" (A VI.ii 266). This Robinet interprets to mean that the body itself is the point that is proportional to endeavour: "the «conatus-body» which is a point and not a line, does not endure longer than a moment".[12] But at the same time this «conatus-body» is a «conatus-mind», a mind lasting no longer than a moment.[13] According to Robinet, this strong connection of Cavalierian indivisibles with minds undergirds Leibniz's early theory: "under the atomistic model of Cavalieri's indivisible

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[12] "Ainsi le «conatus-corps» qui est point et non pas ligne, ne dure pas plus d'un moment: il reste «intra-punctum»." (*Architectonique*, 162)

[13] "...les structures de la *TMA* et de son environment métaphysique postulent ... un concept du «conatus-corps» qui est un esprit momentané, un concept du «conatus-esprit» qui practique l'auto-conservation..." (*Architectonique*, 162)

point, the science of mind had to be compatible with the mechanical treatment of the physics of body: the concept of «conatus» and its double acceptation furnished the argument..."[14]

As Robinet observes, however, within two years of devising this novel theory of indivisibles, Leibniz has rejected them.[15] In his *De minimo et maximo* written in the Winter of 1672-73, Leibniz now identifies indivisibles with the minima he had hitherto eschewed, and rejects both. He still upholds the existence of "infinitely small things in the continuum, that is, things smaller than any given sensible thing." But these infinitely small things cannot be indivisibles, he now recognizes, on pain of the same contradictions as arise from trying to compose a line from points.[16] This is the decisive change of position that Robinet is alluding to when he says "*l'éviction de l'indivisible ruine le concept de l'atome physique* (the eschewing of the indivisible lays the concept of the physical atom to ruin)".[17] So we get a neat explanation of Leibniz's adoption and subsequent rejection of atomism. As long as he upholds his early theory of the continuum, he supports atoms as the indivisible constituents of the material continuum, the indivisible parts into which it is infinitely divided.[18] Once he abandons indivisibles, he is bound to reject atoms too. There is of course the embarrassment of the nearly four year gap between this paper of 1672-3 and his rejection of atoms in the *Pacidius* in late 1676, during which time Leibniz entertains atoms on various occasions. But Robinet explains these away as the "ephemeral hypotheses" of the experimental style of his philosophy in this period.[19]

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[14] "Jusque-là sous le modèle atomistique du point indivisible de Cavalieri, la science de l'esprit devait être compatible avec le traitement mécaniste de la physique du corps: le concept «conatus» et sa double accentuation en fournissaient l'argument..." (*Architectonique*, 185).

[15] Actually, as Philip Beeley has observed, Leibniz seems to have decided to reject the identification of points with indivisibles a year earlier than Robinet had supposed, having already written in a letter to Arnauld dated November, 1671: "there are no indivisibles, but there are unextended things" (A II.i 172). See Beeley's discussion in his *Kontinuität*, esp. 258-9. See also A VI.ii 165.

[16] Since "every indivisible point can be understood as the boundary of a line" (A VI.iii 97), one can show that the number of such indivisibles in the diagonal of a square is both equal to and greater than the number in the side, thus yielding a contradiction.

[17] "S'il n'est pas question de remettre en selle l'atomisme physique, cependant les arguments plaident en sa faveur sur le plan métaphysique: mais *l'éviction de l'indivisible ruine le concept de l'atome physique*. Par contre il se pourrait qu'il y eût des atomes métaphysiques qui seraient indivisibles, mais dont la nature serait mentale." (*Architectonique*, 189)

[18] "Le corps et l'âme sont ponctualisés, rendus indivisibles par l'essence même du modèle de Cavalieri." (*Architectonique*, 160).

[19] "Car le concept de l'atome subit de violentes torsions pendant ce travail fragmentaire de 1676... Ce reclassement des structures [leading to metaphysical atoms] est obtenu à la suite

This identification of Leibniz's atoms with his indivisibles has some obvious attractions. First, since atoms traditionally *are* the indivisibles that are inferred from the division of matter, it would seem redundant to have two kinds of physical indivisibles. Second, even if classically the physical continuum is composed of only a finite number of atoms,[20] there was ample precedent for claiming that it was composed of an actual infinity of them: in his *Two New Sciences* Galileo Galilei had resolved the continuum into infinitely many atoms separated by indivisible voids. Third, even though Leibniz cites Cavalieri as considering *indivisibles* as the rudiments or beginnings of lines and figures, there was a precedent for identifying *atoms* as the rudiments of lines, not only in the Platonic tradition, but in Magnen's more recent revival of Democritean atomism.[21]

Still, despite these points in its favour, I believe there are several reasons why this tidy hypothesis of Robinet's will not work. First and foremost, Leibniz's indivisibles are *points*. Although they compose the physical continuum and some are smaller than others, they are not themselves bodies.[22] Instead, they are described as the unextended boundaries or "beginnings" of bodies.[23] Second, in the *Theoria motus concreti* [*TMC*], the concrete part of the *HPN* that Leibniz sent to the Royal Society in England, he explicitly criticizes standard atomism and corpuscularianism, writing:

> I have always believed that whatever may be said about atoms with various figures, about vortices, shavings and branches, about hooks, claws, globules and so much other apparatus proper to the game of the learned, is too remote from the simplicity of nature and from any experiments, and too naïve to be connected in any obvious way with the phenomena (A VI.ii 248).

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d'hypothèses éphémères, toutes ces pièces restant sur le style du «videndum est»" (*Architectonique*, 189)

[20] Cf. Magnen, *Democritus reviviscens sive De atomis* [*Democritus*] (Lyons, 1648), Prop. XIX, 174: "*Continuum componitur ex atomis, sive corpusculis finitis numero* (The continuum is composed of atoms, ôr corpuscles finite in number) ...".

[21] Cf. Magnen, *Democritus*, 160: "*Atomi simplices, sunt elementorum indivisibiles particulæ, & linearum physicarum radices*. (Simple atoms are the indivisible particles of the elements, and the roots of physical lines.)" The Platonic origin of this doctrine is reported by Aristotle: "[Plato] called indivisible (atomoi) lines the origin of the line, and this he often postulated" (*Metaphysics* I 9, 992a19-22).

[22] Thus Leibniz writes to Oldenburg: "for indivisibles are boundaries of things... therefore the two points or extremities of body, that of the one pushing and that of the one pushed, penetrate one another (for there is such a thing as a penetration of points, although not of bodies)" (A II.i 64).

[23] In Robinet's defence, Leibniz is not very clear on this issue in 1671. Certainly he describes bodies as momentary minds, but he also sometimes describes minds as consisting in a point, which would seem to entail that bodies are momentary points. But in the *TMA* he describes a point as corresponding to a single endeavour, i.e. a thought, not a mind. In order to constitute a "harmony" or "storehouse of endeavours", it seems that a mind needs a structure in which more than one endeavour can be conserved, and thus a plurality of such points.

He proposes instead a theory of the constitution of matter from *bullae*, tiny hollow bubbles formed like glass beads in a glassworks by the action of the sun on the earth's aether.[24] The great advantage of his theory, he claims, is that with it he can explain the cohesion of these ultimate constituents in terms of the overlapping of indivisibles, whereas the atomists and corpuscularians alike have to take the cohesion of their basic particles as an "αρρητον" or unexplained given.[25]

Leibniz's theory of cohesion is of great interest in its own right, although rather too complex to explain in detail here. The basic idea is that the indivisibles of a body are not minima, or partless points, but have an infinitely small quantity that is proportional to the body's endeavour to move at a given instant. The endpoint of a body in motion therefore occupies a greater (yet still infinitely small) space than one at rest. Consequently, when one body impels another, or endeavours to move it, it has already begun to penetrate it. This is because at the moment of contact, the extreme point of the impinging body occupies a space that is greater than the extreme point of the body at rest, so that they overlap. Therefore "whatever things move in such a way that one endeavours to enter the other's place, cohere together while the endeavour lasts."[26] As he writes to Pierre de Carcavy in June 1671, it is by means of "my theory of abstract motion that I explain the original cohesion by means of which certain insensible bodies, as if fornicating, obtain their *primary hardness* (which cause suffices for those of us of intelligence to suppose, for otherwise nothing will prohibit there from being a progression to infinity...)" (A II.1 126-27). This done, he can explain the "*secondary hardness*" of his *bullae*, "how they are made firm by a by a motion returning on itself around their own centers," so that, with the infinite regress thus broken, he has "explained the elements of sensible things by the origin of *bullae*" (127). These spinning hollow *bullae*, together with the

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[24] "For whenever subtle things endeavour to break through dense ones, and there is some obstruction, the dense things are formed into certain hollow bubbles, and an internal motion of parts, and thus a consistency or cohesion, is produced... . The same thing is established in the workshops of glassmakers, where, by a circular motion of fire and a straight one of spirit, glasses, the simplest artificial kind, are produced; similarly, by a circular motion of the earth and a straight one of light, bubbles are produced" (*TMC*: A VI.ii: 226).

[25] In a letter to Oldenburg in September 1670, Leibniz writes "Hobbes himself assumes a consistency ôr cohesion in things as a kind of αρρητον" (A II.i 63-46). As Beeley reminds us (*Kontinuität*, 71), this objection, that explanations of cohesion in terms of particles already assumed to be cohering would lead to an infinite regress, had been made by many opponents of atomism such as Froidmont, White, Glanvill and Hobbes himself.

[26] Leibniz to Oldenburg of 28 September 1670 (A II.i 64). He gives a similar account in late 1672: "Hence it follows that whatever endeavours to move into another's place already at its boundary begins to exist in the other's place, i.e. their boundaries are one, i.e. penetrate each other; and consequently one cannot be impelled without the other. And consequently these bodies are continuous" (A VI.iii 96; *Labyrinth,* 21-23).

solid globules which he also assumes in the early 1670s, are then Leibniz's "atoms" of this period, although he prefers the collective term *terrellae* (literally, "earthlets").[27]

Of course, even if Leibniz's atoms are not the indivisibles themselves, but the *bullae* composed from them, Robinet could still be correct in his claim that Leibniz's rejection of atoms is a consequence of his "*éviction de l'indivisible*" in 1672. But we are now in a position to see that this does not follow. For nothing in Leibniz's theory of cohesion depends on the points being indivisible, but only on their proportionality to the infinitely small elements of motion, ôr endeavours. As can be confirmed by an examination of Leibniz's manuscripts and letters from this period, this construal of points in terms of endeavours is strengthened rather than weakened by the rejection of indivisibles; and Leibniz continues to promote his endeavour theory of cohesion for some years afterwards.

To summarize: Robinet's identification of atoms with indivisibles fails because in the *TMA* indivisibles are *points*, not bodies,[28] and because Leibniz offers his theory of *bullae* in the *HPN* as a preferable alternative to atomism in that, unlike the latter, it gives an explanation of the cohesion of its elementary particles. Thus he does not begin by supposing bodies that are physically indivisible, but explains their firmness in terms of his endeavour theory of mutually cohering, unextended points. Moreover, since his rejection of indivisibles in 1671-2 is only a reinterpretation of his theory of points in terms of endeavours, it is not in itself inimical to his endeavour theory of cohesion, or to the *bullae* or globules whose cohesion is explained in terms of this theory. It is therefore insufficient to explain any change of attitude towards atoms between 1671 and 1676, or why, by his own testimony in the *Phoranomus*, "atoms and the vacuum held out for a long time" after he had "become a geometer" and abandoned his earlier views on the continuum.

A different tack is taken by Philip Beeley, who objects to the idea that Leibniz can be seen as "committed to atomism" at all during the Paris period. Granting that Leibniz "does at this time in numerous philosophical drafts refer to atoms", he argues that the mere

[27] I give more extensive accounts of Leibniz's views on cohesion in Richard Arthur, "Cohesion, Division and Harmony: Physical Aspects of Leibniz's Continuum Problem (1671-1686)," *Perspectives on Science,* **6**, nos. 1 & 2, 110-135, 1999; and in *Labyrinth,* Introduction, xxxvii-xliii.

[28] This criticism must be softened by the qualification that on two other occasions Leibniz did refer to bodies as points: in his letter to Duke Johann Friedrich of May 1671 Leibniz refers to "physical points" as atoms (A II.i 115), and in February 1676 he refers to "points, i.e. bodies smaller than any that can be assigned" (A VI.iii 473-74; *Labyrinth,* 47).

mention of atoms or physical indivisibles is not enough to warrant a claim that Leibniz is committed to atomism. The idea that for a time in Paris he embraced atomism is "a mistake" resulting in part "from over-interpretation of work-shop drafts". The various manuscripts involving atoms should properly be regarded, he claims, as further experiments in "Leibniz's workshop of ideas", hypotheses studied for the sake of theoretical exploration.[29] These are what Catherine Wilson has called "momentarily adopted trial positions",[30] and what Robinet has likewise aptly referred to as "a series of ephemeral hypotheses ... in the style of «*videndum est*» [i.e. "It must be seen whether …]".[31] In a similar vein, Beeley has observed more recently that Leibniz was surprisingly open to exploring hypotheses with which he did not entirely agree for the sake of a co-operative pursuit of knowledge.[32] Although in his interchanges with other scholars he holds fast to certain ideas deeply entrenched in his metaphysics (what we might call, following Lakatos, the "hard core of his research programme"), such as in this case the actual division of matter to infinity and the consequent rejection of atoms, Leibniz nevertheless "finds it perfectly acceptable that the physicist set a certain limit to the analysis of matter" in his scientific practice.[33]

Beeley's point here about Leibniz's lack of dogmatism must, I believe, be granted without reservation, especially with regard to the heady and inspired manuscripts penned in Mainz and Paris. In these Leibniz seems prepared to let the logical current of his reasoning carry him into uncharted waters, and even to relish this, despite the heretical shores he sometimes reaches in his conclusions. An explanation in terms of his lack of dogmatism, then, might well explain Leibniz's apparent commitment to atomism in certain cases. Perhaps it explains the atomism of the draft *Hypothesis de systemate mundi*, which is explicitly based on hypotheses (such as the non-existence of the plenum) which contradict those of the *Hypothesis physica nova*, in which it is mentioned

[29] All of these quotations are from Beeley's comments in "Response to Arthur, Mercer, Smith and Wilson" (a discussion forum on his *Kontinuität und Mechanismus* (1996), 65-82 in *Leibniz Society Review*, **7**, December 1997; esp. 74, 82.

[30] Catherine Wilson, Review of Beeley's *Kontinuität und Mechanismus*, *Leibniz Society Review*, **7**, December 1997, 61.

[31] "Ce reclassement des structures est obtenu à suite d'hypothèses éphémères, toutes ces pièces restant sur le style du «videndum est»." Robinet, *Architectonique*, 189.

[32] Philip Beeley, "Pragmatism and Perspectivism in Leibniz", ["Pragmatism"] in Hans Poser (ed.), *Nihil Sine Ratione*. (Berlin: Gottfried-Willhelm-Leibniz-Gesellschaft, 2001), 86-92.

[33] Beeley quotes Leibniz's letter to Des Billettes of March 1697, which I translate: "... thus there are no atoms, nor perfectly fluid matter, nor perfect globes, and I believe I have a demonstration of that. But just as architects only need to push the analysis of materials down to a certain point, I believe that physicists likewise can arrive at a certain analysis of sensible bodies which serves their practical needs." (A I.xiii 656; Beeley, "Pragmatism," 87).

as a separate project lying outside the scope of that work.[34] It is also consistent with the way Leibniz broaches the issue of atomism in "On the Secrets of the Sublime" in Paris in February 1676: "Does it seem in accord with reason for there to be atoms?" On the other hand, though, the answer given to the question in the sequel is unambiguously affirmative: "If an atom once exists it will always exist. For the liquid matter of the surrounding plenum will immediately endeavour to dissipate it, since it disturbs its motion, as can easily be shown. If some large body that to some extent resists dissipation moves in a liquid, it will at once form a kind of terrella, and a vortex." (A VI.iii 473; *Labyrinth,* 47). And in manuscripts written in the succeeding months, Leibniz's tone grows progressively more assertive:

> Since, therefore, I have established on other grounds that that there is some portion of matter that is solid and unbreakable —for no adhesive can be allowed in the primary origins of things, as I judge to be easily demonstrable— and since, moreover, connection cannot be explained in terms of matter and motion alone, as I believe I have shown satisfactorily elsewhere, it follows that thought enters into the formation of this portion, and that, whatever its size, it becomes a body that is single and indissectible, i.e. an atom, whenever it has a single mind. (A VI.iii 393; *Labyrinth,* 57).

> I am more and more persuaded about indissectible bodies; and since these did not originate through motion, they must be the simplest, and therefore spherical, for all other shapes are subject to variety. So it seems indubitable that there are infinitely many spherical atoms. (A VI.iii 524; *Labyrinth* 61).

Although Leibniz certainly changes his mind about whether he has indeed "satisfactorily shown" that connection cannot be explained in terms of matter and motion, the talk of "indubitablity" and "demonstration" shows him writing in a decidedly affirmatory mode; that is, even if the existence of atoms is a hypothesis, it is one that at this time he regards himself as having demonstrated.

Beeley also buttresses his case for a consistent anti-atomism on Leibniz's part by a subtle re-interpretation of the doctrine of indivisibles in the *TMA*. On his reading, Leibniz, like Ockham, understands points in terms of lines, though not as their endpoints: they are not minima, or smallest assignable parts, but lines smaller than any that can be assigned.[35] According to Beeley, this means there is an "ontological relativization of the

[34] See A VI.ii 225 ll.20-22.

[35] Such a point may therefore be understood as containing parts, as Leibniz explains to Oldenburg in 1671: "especially admirable is the nature of points: for although a point is not divisible into parts supposed *extra partes*, it is still divisible into parts ... previously penetrating one another" (A II.i 64).

concept of a point" (1996, p. 243). Points, as lines smaller than any assignable, are indivisible relative to the division of the original continuum, for there are none smaller in relation to the line; but they themselves may be infinite in comparison with other points, and so on down. As for Leibniz's rejection of indivisibles in 1671-72, Beeley claims that his abandoning of this feature is not a major change of position, but merely a making explicit of something already implicit in the nature of point, the fact that it is not partless. This is therefore not so much a change of doctrine as Leibniz's finally recognizing the inconsistency of construing points both as indivisible and as infinitely small lines. Points, therefore, were never really indivisible for Leibniz; and after 1671-72 indivisibles are only endpoints of lines, absolute minima, distinct from the actually infinitely small actuals. Thus, in keeping with his anti-atomism, Leibniz was never committed to physical indivisibles in any absolute sense.

The problem is that in de-emphasizing the importance of this change, Beeley makes it harder to see how Leibniz could ever have invested his talk of "indivisibles" in the *TMA* with any philosophical significance.[36] Yet he certainly did, going so far as to explain the indestructibility of minds as due to the indivisibility of the points in which they inhere. In his "On the Use and Necessity of Demonstrations of the Immortality of the Soul", sent to Duke Johann Friedrich in May of 1671, Leibniz wrote:

> For I shall demonstrate that mind consists in a point... Whence it will follow that mind can no more be destroyed than a point. For a point is indivisible, and therefore cannot be destroyed. Therefore body is obliterated, and dispersed to all corners of the earth. Mind endures forever, safe and sound in its point. For who can obliterate a point? (A II.i 113)

Now with his rejection of the indivisibility of points, this warrant for the non-dissolution of minds is lost. On Beeley's interpretation, however, it was only ever an illusion, which Leibniz recognized as such in late 1671, after which he consistently distinguished actually infinitely small actuals from indivisible elements in matter, which latter he rejected from then on. But then this will not explain why in 1676 he should have begun to experiment in earnest with atoms that are strictly indissectible and perfectly solid, whose "solidity ôr unity ... is due to mind" (A VI.iii 509; *Labyrinth,* 117), arguing that "If

[36] Since writing this I have discovered that substantially the same criticism of Beeley's interpretation has already been made by O. Bradley Bassler in his "The Leibnizian Continuum in 1671", *Studia Leibnitiana* 30 (1998), no. 1, 1-23. Bassler writes: "Since Beeley takes the identification of the point with an infinitely small (divisible?) line in the *TMA* as an indication that points are homogeneous with lines, Beeley's reaction is understandably to see this [rejection of indivisibles] as «Bedeutungswandel ohne inhaltiche Konsequenz» (*Kontinuität*, 258)" (19). Bassler charges that Beeley "fail[s] to take Leibniz's declared position—in particular the indivisibility of points—seriously from the outset" (21).

there were no atoms, everything would be dissolved, given the plenum" (A VI.iii 525; *Labyrinth,* 61). Beeley claims that in these drafts Leibniz was not embracing atomism; rather, in his opinion, "what he was really trying to do was to solve the fundamental problem with which the *Theoria motus abstracti* and *Hypothesis physica nova* had left him: how to integrate minds into the system." But granting that in 1676 his atoms perform this function, they would seem to be something more substantial than an arbitrary limitation of the physicist's analysis of the division of matter; and granting that this function was previously performed by indivisible points, it would seem that the idea of physical indivisibles of some kind is more than a "momentarily adopted trial position". Nor is it clear how the fact that atoms contain minds is supposed to detract from Leibniz's being committed to them.

This last feature of Leibniz's thought on atoms, their connection with minds and metaphysical unity, prompts consideration of a third interpretation of Leibniz's thought on atoms, that offered by Christia Mercer, first in concert with Robert Sleigh and subsequently in her new book, *Leibniz's Metaphysics*.[37] In this connection we may note that in Leibniz's early metaphysics it is the union of matter with a concurrent mind that constitutes *corporeal substance*; in the *TMA* and associated manuscripts "the door is opened for pursuing the true distinction between bodies and minds" by means of the Hobbesian identification of thoughts as endeavours (*conatus*), with Hobbes's materialist intent inverted so that minds are more basic; in the Paris writings thought is described as "entering into the formation" of a portion of matter, so that "whatever its size, it becomes a body that is single and indissectible, ôr an atom, whenever it has a single mind"[38]; and finally, in the 1680s, corporeal substances, explicitly identified as *substantial atoms*, are described as containing indestructible minds, souls, or substantial forms, making it "probable that they have always existed from the beginning of things".[39]

Such considerations have led Mercer to propose a continuity thesis that is in a way the obverse of Beeley's: Leibniz *always* upheld atoms, from 1668 onwards, although these are to be conceived of as *atoms of substance* or corporeal substances, *not* the purely material atoms of Democritus and Epicurus, which Leibniz rejects (on the latter

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[37] Christia Mercer and R. C. Sleigh, Jr., "Metaphysics: The Early Period to the *Discourse on* Metaphysics" ["Early"], 67-123 in Nicholas Jolley (ed.), *The Cambridge Companion to Leibniz*, (Cambridge: Cambridge University Press, 1995); Christia Mercer: *Leibniz's Metaphysics*: *its Origins and Development* [*Leibniz's Metaphysics*] (Cambridge/New York: Cambridge University Press, 2001).

[38] "Notes on Science and Metaphysics", 18 March 1676; A.VI iii 393; *Labyrinth,* 57.

[39] "*Wonders concerning the Nature of Corporeal Substance*", A VI.iv 1466; *Labyrinth,* 265.

point, Beeley and Mercer agree). The origins of this position, according to Mercer, are to be found in Leibniz's theological project of 1668 where he gives his first theory of substance, with mind functioning as an active, organizing principle for body, playing the role of an Aristotelian substantial form. "A mind makes the body substantial by constituting its principle of activity", says Mercer (75), quoting Leibniz's "the substance of the body is union with a sustaining mind" (A VI.i 508-9).[40] In the first version of this theory, the substance of each human body is provided by union with its human mind, whereas non-human bodies are made substantial by union with the "universal mind" or God. Moreover, this union is not merely metaphysical but physical. In the *Confession of Nature Against the Atheists* of 1668 Leibniz offers the necessity of a divine origin for the firmness or cohesion of atoms as an opportunity for proving the existence of God:

> Thus in providing a reason for atoms, it is right that we should have recourse to God, who is responsible for the firmness in these ultimate foundations of things. And I'm surprised that neither *Gassendi* nor anyone else among the very acute philosophers of our age has noticed this splendid occasion for demonstrating Divine Existence. (A VI.i 492)

But by 1671 a different conception has emerged, in which every body contains its own principle of activity (84). In a letter to Duke Johann Friedrich of May 1671, Leibniz asserts that every substance has a "kernel of substance" that can either "spread throughout the body" or "draw itself back into an invisible center". Mercer identifies this "kernel" with the mind or principle of activity, writing: "the mind or kernel of every corporeal substance causes and maintains its organization, ... an organization of matter that can be more or less 'spread out'" (82). This combination of variable matter with constant substantial form, claims Mercer, is what Leibniz means by his references in 1676 to "indissectible bodies":

> Mind takes some portion of matter, acts as the "cement" of the parts of matter, and thereby produces a "naturally indestructible" atom [A VI.iii 474ff.]. Nor should the term *atom* mislead us: for Leibniz an atom is indestructible, but it is not invariable; it is the fundamental unit of the physical world, but it is constituted of mind and matter. Mind functions as the metaphysical glue or "cement" of an atom or corporeal substance by persistently producing an organization with some chunk of matter; exactly which chunk it organizes is unimportant. (88)

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[40] Here I shall follow the account Mercer gives in her part of the article with Sleigh ("Early"), which is more explicit than her recent book about her views on Leibniz's atoms. Her position in the latter, however, seems essentially the same: Leibniz was committed to substantial atoms from 1669 onwards, despite his fluctuating views on cohesion, continuity, and motion. See e.g. Mercer, *Leibniz's Metaphysics*, 282, 293. (Page number references in the text are to the article, unless otherwise stated.)

Thus for Mercer there is a perfect continuity from Leibniz's speculations of 1671 concerning the "kernel of substance" to his mature theory of corporeal substance. The natural indivisibility of atoms or corporeal substances, i.e. "the indestructibility of the union formed between mind and matter", is a consequence of the fact that "whatever acts cannot be destroyed" (A VI.iii 521; *Labyrinth,* 121), and that mind "will organize some matter as long as it acts" (88).[41] Moreover, in addition to acting as the "metaphysical cement" or organizational principle, "mind constitutes both the identity of the substance whose cement it is and the source of its individuation" (88). Although there is an important modification in 1678 or shortly thereafter, when Leibniz rehabilitates the notion of a substantial form, and distinguishes minds as a privileged subclass of such forms or souls, the basic idea is the same. It is the mind's (or mind-like substantial form's) ability to retain memories of its past actions that distinguishes it from a merely material body, which would by itself be incapable of action and passion.

Again, this interpretation has much to recommend it. Most obviously, it explains how Leibniz could simultaneously countenance both "atoms" and the actually infinite division of matter: the atoms are indestructible by virtue of the mind they contain, even while their matter varies and is divided infinitely within. Moreover, the commonality Mercer identifies between many of the themes and ideas from Leibniz's first writings about substance and those of his mature metaphysics seems undeniable. There can be little doubt that the same concern with the inadequacy of a purely materialist account of body that informed his earliest writings also informs his later ones: throughout he saw it as necessary for body, or at least certain bodies, to be united and organized by an immaterial principle of unity. Unless somewhere in matter there are such perduring substantial unities, he never tired of arguing, there would be nothing substantial at all in matter, which would long ago have dissolved into a powder of points. As Leibniz mentions on numerous occasions, this is the very argument that Cordemoy had used to promote his own version of atomism.[42]

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[41] In her new book, Christia Mercer separates out the problem of cohesion from the problem of metaphysical unity, arguing that in the *TMA* and letters to Hobbes and Oldenburg of 1670, a body consists in "an infinity of substantial atoms which have momentary minds, and whose momentary endeavors constitute the cohesion among the atoms" (*Leibniz's Metaphysics*, 282). This seems to equate Leibniz's substantial atoms with his indivisible points, in agreement with Robinet.

[42] "Yet if there were no true substantial unities there would be nothing substantial or real in such a collection. It was this that forced M. Cordemoy to abandon Descartes and adopt Democritus' doctrine of atoms" (*New System of the Nature of Substances* (1695); quoted from the translation of R. S. Woolhouse and Richard Francks, *Philosophical Texts* [*Texts*] (Oxford: Oxford University Press, 1998), 148-49. See also his letter to Arnauld (8 December 1686), *Texts,* 119.

Undeniable also is the theological connection to which Mercer draws our attention. As she points out, it was certainly part of the context of Leibniz's early atomism that he was trying to solve traditional problems such as the resurrection of the body, the topic of the essay he appended to his letter to Duke Johann Friedrich in 1671. "Because substantial identity depends wholly on the mind, as long as the mind remains the same so will the body or corporeal substance" ("Early", p. 89). Thus despite the dramatic change in death, where the volume of matter organized by the soul shrinks to some minute portion, at resurrection the kernel of substance can diffuse itself through a quantity of matter equal to what it did before death, and thus reconstitute the same individual. This prefigures Leibniz's later doctrine of *transformationism*, according to which death is merely a transformation of the organism in such a way that the domain of influence of its dominant monad shrinks to a physical point.[43] Mercer is surely right to see the origins of this biological doctrine in these speculations of 1671.

But although Mercer has identified several important continuities in Leibniz's thought, in accentuating them she has perhaps glossed over some real discontinuities. Chief among these is the difficulty that the atoms Leibniz entertains in 1676 are explicitly described as "indissectible" (*insecabilis*), as "simplest bodies" which lack variety in all respects but size, and which (unlike his *bullae*) "did not originate through motion" (A VI.iii 524; *Labyrinth,* 61). They are "perfect solids", moving in a perfect fluid constituted by infinitely small points lacking any original cohesion. That is, like classical atoms, they are maximally hard. And although a mind is indissolubly planted in the matter of each, "this matter is of a definite magnitude (*esse certae magnitudinis*)" (A VI.iii 477; *Labyrinth,* 51), unlike that of his earlier corporeal substances, or indeed his later ones, of which he writes in 1683: "A corporeal substance has no definite extension (*nullam habet extensionem definitam*)" (A VI.iv 1466; *Labyrinth,* 265). Granted, the atoms of 1676 differ from classical atoms in that each contains a mind which organizes matter as a kind of accretion that may vary over time. But this matter is described as organized not around the mind, but around the atomic body itself: "Body is as incorruptible as mind, but the various organs around it are changed in various ways" (A VI.iii 510; *Labyrinth,* 119).

[43] A representative statement of this is given in Leibniz's *Specimen Inventorum* of ca. 1686: "Indeed, just as some people have proposed that every generation of an animal is a mere transformation of the same animal now living, and a kind of accretion that renders it sensible, so by parity of reason it seems defensible to hold that every death is a transformation of the living animal into another smaller animal, and is a kind of diminution by which it is rendered insensible" (A VI.iv 1623-4; *Labyrinth,* 317). Cf. Leibniz's letter to Arnauld of October 9, 1687, where he cites both Leeuwenhoek and Swammerdam in support of his belief in transformation.

This suggests that the atoms of 1676 are not to be directly identified with corporeal substances, but are instead their indestructible cores or centers.[44]

This in turn invites a similar re-reading of the theory Leibniz proposed to Duke Johann Friedrich in his letter and accompanying essay on the immortality of the soul in May of 1671. Here, too, mind is encased in an indestructible center, analogous to the *Luz* of the Rabbis, organizing matter around this central core. Only at this juncture Leibniz considered the central core or kernel to be a "physical point", containing the soul at a mathematical point inside it: "this kernel of substance, consisting in a physical point (the proximate instrument and as it were vehicle of the soul constituted in a mathematical point) remains always, ..." (A II.i 109); "Mind endures forever, safe and sound in its point" (A II.i 113). Thus the *corporeal substance* would be the whole complex of mind together with an organized portion of matter of varying magnitude, as Mercer has observed: but this would not be the *atom*, which would instead be the indestructible core. Leibniz says as much in his *De resurrectione corporum*, which he appended to the essay that he sent to Duke Johann Friedrich. For in his discussion of cannibalism there he equates the physical point that contains the soul or mind with an atom: "... even if not even an atom (other than that point in which the mind is implanted) is now left of me, ..." (A II.i 115).[45]

Secondly, although there is a clear continuity in Leibniz's belief that an incorporeal principle of activity is necessary to explain the perdurance of a corporeal substance and its means of individuation, the precise way in which mind is supposed to organize matter seems to have been an open problem for Leibniz in this period, and one on which he changed his views more than once. Indeed his thinking throughout the whole ten years from 1668 onwards is characterized by constantly changing views on how mind is relevant to the cohesion of matter. We have already noted how the young Leibniz was

[44] The mind-containing atoms are also the centers of the associated vortices, as Catherine Wilson has observed (in her unpublished paper "VORTEX: The significance of inertial circular motions in Leibniz's Paris notes, with reference to Aristotle, Hobbes, and Descartes"). She suggests that Leibniz's strong association of mind with vortical motion in this period is connected with his identification of the latter with the eternal circular motion of Aristotle's fifth element. Mind occupies a singularity, as it were, at the center of the vortex, encased in an indivisible material kernel. Wilson suggests that this way of conceiving mind comes to an end with Leibniz's "Thought is Not Motion" at the end of the Paris period (A VI.iii 586-87).

[45] As noted above, this seems to accord with Robinet's interpretation of points as atoms. But Leibniz distinguishes the (concrete) physical point from an (abstract) mathematical point, or indivisible, in much the same way as he does much later in the *New System*: "when a corporeal substance is contracted, all its organs together make what to us is only a *physical point*... *mathematical points* are their *points of view* for expressing the universe" (GP IV 483; Woolhouse and Francks, *Texts*, 149).

elated to be able to explain what the atomists could not, the cohesion of their primary particles, in terms of his endeavour theory of original cohesion. Cohesion around the equator and latitudinal lines of his *bullae* is explained by the spin of the particle, forming a closed chain of overlapping points. To be sure there is a continuity between the atoms of 1676 and the *bullae* or *terrellae* that preceded them, for in each case the particle is immersed in a fluid at the center of a vortex, and each such particle-vortex is associated with a mind. But whereas in 1671 the *bulla* is actually created by the action of light on the aether causing a vortex, and its cohesion is explained in terms of this spinning about its own axis, in 1676 the atom is a perfectly solid body whose solidity is perhaps explained by mind and whose firmness is the cause of the associated vortex: "It is necessary that as many vortices are stirred up as there are firm bodies in nature, solely by the motion of the firm bodies. And there are in the world as many minds, ôr little worlds, as there are vortices".[46] So we see that, on the one hand, Leibniz does not in 1676 separate the problems of metaphysical unity of a body from its physical cohesion, as he later would, after he has finally rejected atomism; and on the other, the idea that mind or soul accounts for body's cohesion and unity is more a statement of an ongoing research program than a solution to a problem that remains constant.

3. Leibniz and Chemical Atomism

At this point it may seem that all we have done is to muddy the waters. For apart from still having to explain how Leibniz could uphold infinite division and atoms simultaneously, we are now also faced with elements seemingly extraneous to atomism as normally understood: the individuation of substances, the indestructibility of minds or souls, and the biological theory of transformation. In addition we have the problem of why in 1676 Leibniz should have reverted to atoms lacking all variety except size, and subsequently replaced them with his theory of corporeal substance.

In what follows I shall argue that not only the original enigma, but also the seemingly extraneous elements of Leibniz's atomism, are all resolvable once the traditions of atomism on which Leibniz is drawing are properly identified. For the resistance on the part of Beeley and Mercer to ascribing atoms to Leibniz is due at least in part to their conceiving atoms as *absolutely indivisible, purely passive chunks of extension, devoid of any qualities, forces or internal complexity*, in evident opposition to the hard core of

[46] A VI.iii 393; *Labyrinth,* 59. Cf. also "There are as many vortices ... as there are indissectible bodies" (A VI.iii 525; *Labyrinth,* 63), "there are as many minds as vortices, and as many vortices as solid bodies" (A VI.iii 509; *Labyrinth,* 117).

Leibniz's metaphysics. This is indeed one notion of atom that became prevalent after what we may term the "Cartesian Revolution." But it is not the conception of atom that was most prevalent in the first half of the seventeenth century, where many authors proposed atoms that were regarded not only as divisible, but also as possessing a variety of qualities, powers and inner complexity.[47] This is worth elaborating on in some detail.

Classically, atoms were posited as homogeneous lumps of "being" moving around in the "non-being" or void. In contrast, the Stoics posited a plenum of matter which was indefinitely divisible. Accordingly we are wont to assume that there could hardly be a more clear-cut alternative than that open to a mid-seventeenth century matter theorist: either, on the one hand, infinitely hard atoms and the void, as advocated by Epicurus and revived by Gassendi, or, on the other, the infinitely divisible corpuscles moving in a plenum advocated by Descartes in his Stoic-inspired cosmology. But the starkness of this opposition does not seem to have been evident to many of the players themselves. Robert Boyle's refusal to commit himself one way or the other is well documented, although this is usually attributed to a distrust of metaphysical reasoning. Yet the lack of acknowledgement of any such polar opposition between atomism and plenism seems to have been almost universal. Hobbes, for instance, was unequivocally opposed to the vacuum even in the face of Boyle's experiments. Nevertheless, despite opting for a plenist metaphysics and the actually infinite divisibility of body,[48] he was quite happy to talk of *atoms* in his physics:

> Since we already supposed earlier that innumerable atoms, some harder than others and having several simple motions of their own, are intermingled with the aethereal substance; from this it necessarily follows that … some of these atoms on colliding with others, and to the extent that their motions and mutual contact demand, will attach to one another and cohere together; and that, seeing as there is no vacuum, it will not be possible for them to be pulled apart, except by as much force as is necessary to overcome their hardness.[49]

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[47] The existence of this tradition is, ironically, recognized by Beeley, who acknowledges that Leibniz advocated "chemical atoms" that were internally divided.

[48] "*There is no minimum divisible thing***:** whatever is divided, is divided into parts that are further divisible; ôr, there is no minimum divisible thing; ôr, as most geometers express it, for any given quantity, a smaller one can be assumed." (*De Corpore*, II, ch. 7, §13; *LW* I 386) "Therefore there is no tininess of a body that is impossible… For we know there to be certain animalcules so tiny that their whole bodies can scarcely be discerned; yet these too have their embryos, their little veins and other vessels, and their eyes perceptible by no microscope..." (*De Corpore*, IV, ch. 27, §1; *LW* I 363).

[49] *De Corpore*, IV, ch. 28, §8: *LW* I 386. Cf. also: "In the first place, therefore, I suppose that the immense space we call the world is an aggregate of bodies: both of those that are consistent and visible, [*viz.*] the earth and the stars; and of those that are invisible, [*viz.*] the minutest atoms which are scattered in the gaps between the earth and the stars; and finally,

Nor is this mix of atoms and the plenum some Hobbesian oddity; rather, it is a feature of much seventeenth century thought. Hobbes had been preceded in this by his compatriot Sir Kenelm Digby, who had also asserted divisible atoms and denied the void. And before them the French atomist Sébastien Basson, whilst urging the merits of classical atomism, had rejected the interstitial vacuum, appealing instead to the Stoics' all-pervading aether, "an extremely tenuous corporeal substance, which in the rarefaction of air, for example, insinuates itself among the particles of air", and which produces all material changes, including the arrangement of the atoms.[50] Likewise the early seventeenth century German chemical atomist Daniel Sennert had made no appeal to the void as a principle in his influential work; and in England, Sir Francis Bacon had advocated atoms or *semina rerum* (seeds of things) whose *virtutes* enabled them to assume any shape by folding and unfolding so as to fill any space. This made the vacuum redundant, and Bacon denied that there was one in nature, whether aggregated or interstitial.[51] Even later atomists such as Huygens and Newton speculated freely about subtle fluids penetrating all apparent vacua. In this vein Leibniz himself introduces his *New Physical Hypothesis* with the disclaimer that "It is all the same whether you affirm or deny the *vacuum*, since I freely acknowledge that whatever is exhausted of air is filled up with aether; in short, whether little empty spaces are left is irrelevant to the gist of our hypothesis" (*TMC*; A VI.ii 246).

Now accompanying this non-classical mixing of atoms and plenum were distinctly non-classical conceptions of the atoms themselves, with few scholars upholding the traditional conception of atoms as passive, rigid and strictly indivisible units of matter. Sennert, for instance, inferred his atoms from phenomena such as sublimation, solution of metals in acids, and putrefaction, and equated them with the Aristotelian *minima naturalia* promoted by Julius Caesar Scaliger, that is, to the smallest but qualitatively different indivisible particles of which each of the four elements is composed, rather

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of a very fluid aether, occupying every remaining place, wherever it is in the universe, in such a way that no place is left empty." (*De Corpore*, IV, ch. 26, §5; *LW* I 347-348.)

[50] Sebastiano Basso, *Philosophiae naturalis adversus Aristotelem Libri xii In quibus abstrusa Veterum physiologia restauratur, & Aristotelis errores solidis rationibus refelluntur* Geneva: Pierre de la Rouiere, 1621; 335. See also J. R. Partington, *A History of Chemistry* [*History*] (London/New York: Macmillan 1970), 388.

[51] For an excellent study of the atomisms of this period, see Antonio Clericuzio, *Elements, Principles and Corpuscles: a Study of Atomism and Chemistry in the Seventeenth Century* [*Elements*] (Dordrecht/Boston: Kluwer, 2000), 82. I am indebted to Dan Garber for bringing this valuable resource to my attention; it confirms (and goes well beyond) many of the conclusions I had reached previously in my own research in primary sources.

than to the homogeneous and infinitely hard atoms of the philosophical tradition.[52] In this he was followed by Kenelm Digby, who asserted that "it is evident that the Elements must remaine pure in every compounded body in such extreme small parts as we use to call atomes: for if they did not, the variety of bodies would be nothing else, but ... so many pure homogeneall Elements, and not bodies composed of heterogeneall parts: ... nor could produce the complicated effects which proceed from them."[53] And while Digby denied that there were any strictly indivisible particles of matter at all, Sennert characterized his atoms as merely physically but not mathematically indivisible, "not further divisible through natural processes," and "so small as to escape detection by the senses."[54] As Robert Boyle wrote in an early manuscript summarizing this tradition, the assertors of atoms do not understand them to be

> indivisible or Mathematicall points which are so void of quantity that the subtle rasor of Imagination it selfe cannot dissect them, but *minima Naturalia* or the smallest particles of bodyes, which they call Atomes not because they cannot be suppos'd to be divided into yet smaller parts ... but because tho they may be further subdivided by the Imagination, yet they cannot by Nature, which not being able in her resolutions of Naturall bodyes to proceed *ad infinitum* must necessarily stop somewhere.[55]

These atomist conceptions of Bacon, Sennert, Digby, Hobbes and Boyle should be compared to Descartes's comment in his *Principles*: "No one ever rejected Democritus' atomic theory because it admitted particles that are so small that they elude the senses, ... but [*inter alia*] because it supposed the atoms to be indivisible" (*Pr* IV 202; AT VIII 1 325). It is interesting to note that shortly after Descartes wrote this, his compatriot Magnen (teaching in Pavia, Italy) had advocated "simple atoms" which, though physically

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[52] Daniel Sennert, *De Chymicorum Cum Aristotelicis et Galenicis Consensu ac Dissensu, Liber I* [*De Chymicorum*] (i.e. "On the Agreement and Disagreement of the Chemists with Aristotelians and Galenists, Book I"), Wittenberg 1619, 356. Sennert's most elaborate presentation of atomism is in his *Hypomnemata Physica* (Frankfurt, 1636). See also Partington, *History*, 273.

[53] Kenelm Digby, *Two Treatises: A Treatise of Bodies* [*Two Treatises*], ch. xvi. Paris: Blaizot, 1644, 143; London: J. Williams, 1645, 178; cf. Clericuzio, *Elements*, 82.

[54] Andrew van Melsen quotes Sennert as saying: "[atoms or minima of nature] owe their names to the fact that they cannot be further divided through natural processes, and, reversely, form the building blocks of all natural bodies. They are, however, so small that they escape detection by the senses" (*Opera* I, 151; in van Melsen, *From Atomos to Atom: the History of the Concept of Atom* (New York: Harper, 1960), 85). I was unable to find this edition of Sennert's works.

[55] Robert Boyle, 'Of the Atomicall Philosophy', Royal Society Boyle Papers, xxvi, folios 162-175 (dated as 1651-1653); 227-235 in *The Works of Robert Boyle*, ed. Michael Hunter and Edward B. Davis, (London: Pickering & Chatto, 2000), Vol. 13; also quoted in Clericuzio, *Elements*, 117. Cf. Digby: "By which word *Atome*, no body will imagine we intend to expresse a perfect indivisible, but onely, the least sort of natural bodies." (*Two Treatises*, 1644 edition, 38; 1645, 48).

indivisible and insensible, were not only infinitely divisible in the mathematical sense but able to undergo radical changes of shape, just like Descartes' particles of the third element. No wonder, then, that Descartes' corpuscles were often assimilated by his contemporaries to atoms,[56] since seventeenth century atoms were regarded not as absolutely indivisible—beyond God's power of dividing them—but as beyond ours.[57] Leibniz himself drew attention to this point in his reading notes on Descartes's *Principia* in 1675. To the latter's claim that "There cannot be atoms, since they could at least be divided by God", he adds laconically: "this Gassendi would not have denied." (A VI.iii 215; *Labyrinth,* 25).

It should not be thought, however, that the divisible atoms of Sennert, Hobbes and others were indistinguishable from Cartesian corpuscles. The latter, whose parts cohere only by virtue of their being mutually at rest, would eventually be divided and dissolved by the jostling of other particles in the plenum. An atom, on the other hand, is naturally indissoluble, indivisible by natural means, so that atoms of various kinds form the building blocks of all matter (Sennert), even if they do not maintain the same shape or size (Bacon, Hobbes, Magnen). Their different properties are posited above all to explain the different natures of chemical elements or principles. But a second major reason for positing them, as I shall discuss below, is that atoms—or rather certain molecules formed from them—are able to serve as units for the propagation of natural kinds, with their indivisibility ensuring the assumed incorruptibility of forms; they were also generally assumed to have the power to fashion other particles. Clearly there is nothing analogous to these properties in a purely mechanical natural philosophy like that of Descartes.

In sum: in order to understand Leibniz's atomism it is vital to recognize that there was a flourishing tradition of atomism in the seventeenth century deriving from chemical, biological and medical sources, rather than from the classical metaphysical tradition. Thus the term 'atom' did not necessarily, or even usually, carry the connotation of a corpuscle that is absolutely indivisible, remaining rigid, perfectly hard, and possessing the same shape and size for all eternity (Democritus, Epicurus, Lucretius), or at least for the duration of the created universe (Gassendi); these we may agree to call *classical*

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[56] Famously, Gerauld de Cordemoy will substitute atoms for divisible Cartesian corporeal substances. Henri LeRoy (Regius), in his *Philosophia naturalis* of 1661, and Adriaan Heereboord were other prominent Cartesians to advocate atomism (see Clericuzio, *Elements*, 185-186).

[57] Cf. Descartes to More, February 5th, 1649: "It implies a contradiction for there to be atoms, ... since although God could have made things so that they are not divided by any created being, we certainly cannot understand him as having been able to deprive himself of the faculty of dividing them", AT V 273.

atoms. In the chemical tradition represented by Sennert, the basic meaning of 'atom' is a particle that is not further divisible by any physical or chemical process, with no particular connotation of sameness of shape or rigidity.[58] Thus an atom is rather a corpuscle of matter of a particular element (air, fire, water, etc.) that is the irreducible building block of that element, and which remains intact through all chemical reactions. These are generally called *chemical atoms*. Now because chemical reactions can be quite violent, many writers in this tradition endowed their atoms with powers —energy, sympathy, etc.— properties that were incompatible with a purely mechanical interpretation of classical atoms as purely passive chunks of extension devoid of qualities.

Here I must immediately add that the latter conception of classical atoms is not necessarily to be thought of as historically more accurate. The interpretation of atoms as biological seeds can be found in Lucretius, Epicurus' atoms were endowed with an innate tendency to action or *energeia*, and there was a strong tradition of regarding Plato's atoms not simply as geometrical shapes, but as being attracted to atoms of the same kind by a force of sympathy. Thus the division between classical and chemical atoms is by no means a strict dichotomy. It was certainly possible, for example, to maintain that atoms are absolutely indivisible and perfectly hard, yet still possess active powers of various kinds. Indeed, Gassendi himself not only strove to correct the interpretation of classical atoms as purely passive, but was no stranger to the chemical tradition, as recent scholarship has established.[59] He did not, as a matter of record, subscribe to the narrow mechanist program of reducing the whole of nature to the motions of a purely passive matter, but allowed activity, forces, and even formative powers in his atoms and molecules.[60] For although he agreed that all phenomena or effects should be explained in terms of matter in motion, this did not for him entail that all

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[58] It can, of course, be seen as a beautiful irony that the early seventeenth century conception of atoms is far closer to the modern one than the classical conception that was later re-established by Dalton and nineteenth century chemistry.

[59] As Olivier Bloch notes in his *La philosophie de Gassendi* [*Gassendi*] (The Hague, 1971), Gassendi had explicitly responded to Campanella's imputation of an inert matter to Epicurus, objecting that "Epicurus dreams of nothing less than passive matter, unmitigatedly assigning a restless motion to his atoms, from which he also deduces the actions of all concrete things" (B. N. Nouv. acq. lat. 2643, folios 49v-50r, Bloch, *Gassendi*, 212, n. 39). See also Gassendi's comment in (Tours 709 folio 185r): "Epicurus believes all atoms to be endowed with a certain internal energy, ôr inborn vigor, by which they set themselves in motion" (Bloch, 215, n. 55). Bloch gives a good account of Gassendi's views in relation to the chemical tradition. On this, see also Clericuzio, *Elements*, 63-74.

[60] cf. Clericuzio: "Gassendi's theory of *semina* and spirits … are to be understood as part of a theory of matter which does not dispense with forces, activities and powers." (*Elements*, 63).

causes were so reducible. And contrariwise, just as Gassendi was influenced by the chemical tradition, so authors in that tradition were not shy of claiming Democritus, Epicurus and Plato as precedents for their views.

In any case, taking into account this well-established alternative tradition which justified atoms through chemical and medical arguments enables us to relieve the apparent inconsistency in most of Leibniz's statements about atoms in the early 1670s. We may grant that, having opted for the moderns, Leibniz would not have accepted, say, atoms that were qualitatively different for each specific element, nor "sympathies" and "attractions" as original propertied of atoms.[61] Nevertheless, the properties Leibniz singles out in his rejections of atoms—their absolute indivisibility, their passivity, and their rigidity—are all properties of classical atoms interpreted according to a strict mechanical philosophy. The atoms he rejects are "bodies whose parts never separate" (A VI.ii 280; *Labyrinth,* 344), "perfect solids" or "bodies so firm that they do not suffer any subdivision or bending" (A VI.iii 561; *Labyrinth,* 199), or bodies containing nothing but extension (A VI.iv 1799; *Labyrinth,* 279). On the other hand, the "atoms" he upholds are very small, very hard corpuscles which are "naturally indissoluble", yet still divisible, and which have an internal complexity—all of which are properties of chemical atoms, and for which there were also precedents in Gassendi, Hill, Bacon, Hobbes, Digby, Bérigard, van Goorle and others not usually thought of as chemical atomists. Certainly, Leibniz's own primary corpuscles in the *HPN*, the *bullae*, are of this kind: although not perfectly hard, they will endure for the duration of the present world. Thus we may say of Leibniz's atomism in the early 1670s: he rejects classical atoms (which indeed he may never have espoused, except perhaps in his adolescence), but, like many of his contemporaries, advocates flexible and divisible atoms that are indissoluble by natural processes, but which possess considerable (indeed, for Leibniz, infinite) internal complexity. His atoms, like theirs, are indivisible in the sense that they remain intact, but divisible in the sense of possessing internal parts.

There is in fact more than circumstantial evidence for Leibniz's indebtedness to the chemical atomist tradition. As Beeley has observed, his *Hypothesis physica nova* is

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[61] More accurately, Leibniz accepted the idea of bodies sympathizing with one another, but tried to give it a reductive interpretation, first in terms of motion in common (see A VI.iii 80, 104; *Labyrinth,* 4-5) and later in terms of his doctrine of expression (A VI.iv 1618; *Labyrinth,* 309). He takes this kind of rational reduction a step farther with his later rehabilitation of the atomists' *appetitus* in the guise of an instantaneous tendency to change state. Given the other correspondences (though not necessarily influences) of Basson's views and Leibniz's in the *HPN*, particularly the predominant role of aether, the relationship between these thinkers is probably deserving of further study.

replete with references to the chemical literature, and his theory of *bullae* may be seen as a reinterpretation of chemical atoms (or, better, molecules) along acceptable mechanical lines.[62] Indeed, as I have suggested elsewhere,[63] the theory of cohesion of his *bullae* offered by Leibniz bears a close affinity to the theory of chemical composition or mixtion (*mistio*) of Julius Caesar Scaliger, which was widely accepted in the seventeenth century, and with which Leibniz would probably have been familiar both in the original and through the work of Sennert, who had adopted it. Instead of regarding mixtion simply as "the union of the miscibles", as had Aristotle, Scaliger defined it as "the motion of minimum bodies towards mutual contact so that a union is made" (a definition that Sennert explicitly endorsed).[64] In the same Exercise Scaliger comments: "For it is not just that they touch one another, like Epicurean atoms; so do our corpuscles, but in such a way that a continuous body and unity is made. For it becomes one by a making continuous of the boundaries, which is common to all that has entered into the mixtion."[65] This theory was adopted not only by Daniel Sennert but also by Robert Boyle, according to whom the concretions of particles that form the basis of chemical processes (what Gassendi had termed "molecules" and Boyle calls "corpuscles of the second order") are formed by a close union of *minima naturalia*.[66] Although in his early work Boyle had interpreted these *minima* as Sennertian atoms, in his published works he reinterprets them as simple corpuscles possessing only mechanical properties.[67] It does not seem too fanciful to regard Leibniz as extending this kind of rationalization of Sennert's theory begun by Boyle. The difference in Leibniz's case is that, unlike Boyle, Scaliger and

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[62] See Beeley, *Kontinuität, Kapitel 7.* See also his "Reply", in which he writes "Leibniz also provides an ingenuous model of the chemical atom, composed of cortex and nucleus, which he is without difficulty able to adapt to his theory of the infinite dividedness of matter, while at the same time serving to explain the chemical processes of decomposition and synthesis" (75).

[63] See references cited in fn 27.

[64] *Julii Caesaris Scaligeri Exotericarum Exercitationum Libri XV de subtilitate ad Hieronymum Cardanum* [*Exotericarum*] (i.e. "Fifteen Books of Exoteric Exercises on Subtlety, for Hieronymus Cardan," by Julius Caesar Scaliger), Paris 1557; Ex. 101, 143: *mistio est motus corporum minimorum ad mutuum contactum, ut fiat unio*. This was endorsed by Sennert in chapter xii of his *De Chymicorum*, 356: "I confess I am now won over by the opinion of Scaliger, who defines mixtion to be the motion of minimum bodies towards mutual contact so that a union is made". See also Clericuzio's discussion of Scaliger's *minima naturalia* on 9-15 of his *Elements*.

[65] Scaliger, *Exotericarum*, 143.

[66] See Clericuzio, *Elements,* 122-23.

[67] On Sennert as the source of Boyle's early atomism, see W. R. Newman, 'The Alchemical Sources of Robert Boyle's Corpuscular Philosophy", *Annals of Science* 53 (1996), 567-85. See also A. Clericuzio, "A Redefinition of Boyle's Chemistry and Corpuscular Philosophy", ["Redefinition"], *Annals of Science* 47 (1990), 561-589, and Clericuzio, *Elements,* 103-148, es117, 123.

Sennert, he did not have to presuppose primary particles whose original cohesion is unexplained: cohering bodies are formed from an actual infinity of overlapping points, as exist in the circles of latitude around the axes of the spinning *bullae*.

There is, however, a second difference in Leibniz's understanding of the internal composition of atomic particles that is crucial to the resolution of our enigma. We have seen that his *bullae* are held together by the cohering bands of overlapping points in their surfaces, and that, like the naturally indivisible molecules of his contemporaries, they contain within themselves smaller particles possessing their own individual motions. But for Leibniz the differing internal motions of the parts of a body are precisely what constitute these parts as individually different, *and therefore divide the body within*. As he wrote in an unpublished tract of 1672,

> It is manifest that a body is constituted as definite, one, particular, distinct from others, by a certain motion or particular endeavour of its own, and if it is lacking this it will not be a separate body... And this is what I have said elsewhere, that cohesion comes from endeavour or motion, that those things which move with one motion should be understood to cohere with one another.[68]

Thus the cohesion of the *bullae* is explained by the motion in common of the points in each concentric band of its surface (the cohesion of the bands being further explained by means of a principle of minimization of disturbance of motion). The *bullae* themselves, however, are composite, divided within by the differing motions of their component parts. And it is the individual motions or endeavours of these parts that individuate them as actually differing parts, dividing them off from one another.[69]

This conception of parts being individuated by their differing motions is in fact Cartesian in origin, and forms the basis for Leibniz's argument for the actually infinite division of matter.[70] It derives from the argument Descartes gave in his *Principles* for the "division of certain particles of matter to infinity" (*Pr* II 34; *Labyrinth,* 358). Although Descartes had further qualified this to mean an *indefinite* division in certain spaces, Leibniz habitually took it to demonstrate the actually infinite division of matter everywhere. Descartes' argument was that in order for motion to occur through unequal

[68] Proposition 14, *Propositiones Quaedam Philosophicae*, (A VI.iii 28). Leibniz wrote this tract, probably intended for publication, in early-to-mid-1672.
[69] Indeed, without motion to give these parts their individuality, Leibniz argues on several occasions, matter, being undifferentiated, is nothing at all. See e.g. "On Primary Matter" (A VI.ii 280; *Labyrinth,* 344).
[70] See the analysis given in Richard T. W. Arthur, "Russell's Conundrum: On the Relation of Leibniz's Monads to the Continuum", 171-201 in *An Intimate Relation*, ed. J. R. Brown and J. Mittelstrass (Dordrecht: Kluwer, 1989), esp. 182-189.

spaces in a plenum, "all the imaginable particles of [a certain] part of matter … must be to some degree displaced from one another; and such a displacement, however slight, is a genuine division". There is therefore "a division of matter into actually indefinite particles, although these are incomprehensible to us" (*ibid.*) In a typical comment on this passage in 1675 Leibniz writes: "In Part II, §3[4] [of Descartes' *Principles*] matter is admitted to be really divided into parts that are smaller than any assignable, and therefore actually infinite" (A VI.iii 214; *Labyrinth,* 25). He had made implicit reference to this argument in support of his claim for the actually infinite division of the continuum in the *TMA*, but he spells it out explicitly in many other places. Thus in "Created Things Are Actually Infinite" he writes: "Any body whatever is actually divided into several parts, since any body whatever is acted upon by other bodies" (A VI.iv 1393; *Labyrinth,* 235).[71] But the internal division of bodies does not detract from the spinning motion that gives them coherence. This privileged nature of circular motion for individuating bodies is a recurring theme in 1671. Thus in "On Primary Matter", Leibniz attributes the origins of bodies to "particular circulations" of matter, arguing that bodies have infinite parts and that "there are infinitely many creatures in any body whatever" (A VI.ii 280; *Labyrinth,* 344). In the *Hypothesis de systemate mundi*, as we saw above, he describes space as "filled with globes" spinning on their axes, these being "the only integral bodies", the "naturally indissoluble" atoms. But he also says that "it suffices for a body to be integral only at its surface", and to be "again composed of infinite globes inside" (A VI.ii 294; *Labyrinth,* 344-45).

So there are two senses of division here: a body is actually divided *within* by the differing motions of its internal parts despite the fact that, if it is atomic (i.e. "integral" or "indissoluble"), it will not be dividable by any natural process from *without*. That is, an atom for Leibniz can quite literally be a terrella or little world, if it has an impenetrable crust. Beneath that crust, as if beneath the Empyrean, is a world of inner motion and activity that is perhaps in principle explicable in the same terms as our world but on a vastly smaller scale. Hence Leibniz's sustained commitment to the thesis of "worlds within worlds to infinity", often in the very same tracts in which he defends atoms.

With respect to the latter thesis, however, it must be observed that Leibniz's conception of actually infinite division is highly unorthodox. For he appears to hold that the thesis of the division of matter into worlds within worlds without end *entails* its

[71] See also: A VI.iii 474, 281, 553-4; *Labyrinth,* 47, 113, 183, resp; A VI.iv 1399, 1623, 1799; *Labyrinth,* 245, 317, 279, resp.

division into "points". Thus as late as Spring 1676 he writes: "if it is true that any part of matter, however small, contains an infinity of creatures, i.e. is a world, it follows also that matter is actually divided into an infinity of points" (A VI.iii 474; *Labyrinth,* 49). In one sense this seems to be a rewriting of Descartes' argument, with the latter's "indefinite particles" reinterpreted as actual Galilean points. But this runs counter to the Anaxagorean conception of "worlds within worlds to infinity", which would normally be interpreted as precluding such least elements or minima. Leibniz seems to have believed that he could finesse this difficulty and assimilate the two conceptions by rejecting the existence of minima and redefining points as "parts smaller than any assignable". It is almost as if "part smaller than any assignable" is a "syncategorematic" formula, as Beeley suggests (*Kontinuität*, 59-60, 244), not denoting points as independently existing entities but standing for the idea of an unlimited containment of spheres within spheres. But this leaves it hard to understand how matter could be regarded as composed of such points. I will return to this issue in the next section. For now let it suffice to note that well into 1676 Leibniz seems to have regarded the worlds within worlds thesis as entailing the composition of matter from infinitesimal points.

To summarize: the solution I am offering to the enigma posed in the first section is this. I had said that *if* we take Leibniz's atoms in the orthodox sense of finite parts of matter that are not further divided, then his thesis that matter is actually infinitely divided would indeed preclude them. But the point is that the atoms he upholds are not such orthodox atoms; rather they *are* further divided within. Like the chemical atoms of Sennert and the young Boyle, Leibniz's atoms are complex corpuscles that are naturally indivisible (physically unbreakable), even though they possess internal parts. But the very fact that they have internal parts with different motions entails that they are actually divided within; and the fact that there is an infinity of different motions means that the division is an actual division to infinity.

4. The Road to Corporeal Substances

So far I have argued that our original enigma is resolved by a comparison of Leibniz's atoms with the naturally indestructible yet composite corpuscles of many of his contemporaries. For by the Cartesian criterion of actual division subscribed to by Leibniz, every such corpuscle containing internal parts in differing motions is actually divided, and if every part of matter is individuated by its motion, then each of its parts is further divided. This would explain how Leibniz could advocate atoms and the infinite division of matter at the same time, and also why he advocated actually infinite division.

But it does so at the expense of raising other perplexities. For it does not explain what motivated him to be attracted to atomism in the first place, nor why he came to abandon it. Nor does it explain why, if Leibniz did not originally conceive atomism to be incompatible with infinite division, he eventually came to think it so. It is to these issues that I want to turn in this section of the paper.

With regard to Leibniz's motivations for atomism, again the connection I have sketched between his atoms and those of the chemical atomist tradition is illuminating. Indeed, a reconsideration of Leibniz's views in relation to those of Sennert and Gassendi will also throw some light on the seemingly extraneous elements of his thought on atoms mentioned above: the individuation of substances, the indestructibility of minds or souls, and the biological theory of preformation.

As we have seen, Leibniz was from the beginning concerned to argue the inadequacy of a purely mechanical account of body. His argument, already articulated in the *Catholic Demonstrations* of 1668, was that Cartesian *res extensa* does not contain the basis for motion or the activity of a body, that a purely passive substance would be unable to act, and therefore could not qualify as a substance in the proper sense.[72] This may seem incompatible with any meaningful commitment by Leibniz to the "material atomism" of Gassendi.[73] But it appears in a different light when it is compared to the actual views of Gassendi, for whom matter is intrinsically and incessantly active. In this respect Leibniz was largely echoing the criticisms of Descartes which Gassendi had published in his *Disquisitio Metaphysica*:

> Concerning body, I note only this, that if its whole nature consists in the fact that it is *res extensa*, then every action and the faculty of every acting thing is outside corporeal nature, since extension is purely passive, and whoever

[72] "It must be demonstrated against Descartes that space and extension are really different from body because otherwise motion would not be a real thing in body" (A VI.i 510); "Substance is a being which subsists in itself. ... A being which subsists in itself has a principle of action within it... If that which has a principle of action within itself is a body, it has a principle of motion within itself... No body has a principle of motion in itself apart from a concurrent mind" (A VI.i 508-512).

[73] Christia Mercer, for example, in rejecting any important role for Gassendi on the formation of Leibniz's thought, seems to understand him as having advocated material atoms that are purely passive. This may be why she persists in ascribing to me the view that "Leibniz flirted with material atomism in the 1660s and 1670s" (*Leibniz's Metaphysics*, 295) on the basis of my taking seriously Leibniz's admission of having subscribed to Gassendi's atomism. On the contrary, I agree with her about Leibniz's eclecticism, and his attempts after 1668 to found mechanism in a metaphysics that is basically Aristotelian and Neoplatonic (for which I refer readers to her excellent book). But I do not see this as incompatible with his interpreting Gassendi's active atoms as containing an immaterial principle of action.

> says a thing is only extension says, among other things, that it is not active. Therefore there will be no action, and no faculty of acting, in bodies.[74]

Gassendi, in fact, was not the only proponent of the New Philosophy to ascribe an innate activity to matter: Beeckman, Hill, Hooke, Charleton and others all subscribed to the same thesis.[75] However, he was the most explicit in assigning it a cause that was not in keeping with the mechanical philosophy narrowly conceived. Atoms, he claimed, following Epicurus, possess an *impetus* or *energeia* by which they spontaneously resume their motions after collisions.[76] Although in his posthumous *Syntagma Philosophicum* (1658) Gassendi repudiated his ascription of innateness to the atoms' impetus, he continued to uphold the idea of an active matter resulting from the incessant activity of atoms, and in an essay on this subject in 1669 Boyle took the same position.[77] Moreover, Gassendi was explicit that such activity in bodies required a principle of action, just as the young Leibniz would insist. Indeed, when he talks about agents and principles of action in matter, as he does in the following passages from the *Syntagma,* Gassendi sounds a lot like Leibniz:

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[74] Pierre Gassendi, *Disquisitio Metaphysica*, III 305b in *Opera Omnia* [*Opera*]*,* Lyons, Anisson, 1658; quoted by Bloch, *Gassendi*, 207. Leibniz acknowledges his debt to Gassendi on this point even while rejecting Gassendi's atomism. In December 1676, in the context of an indignant response to Honoré Fabry's accusation that he favoured Democritus and Gassendi over Aristotle, he asserts "Truly, I hold for certain that there are incorporeal substances, that motion does not come from body but from outside; ... Nonetheless I agree with Gassendi rather than Descartes that the essence of body does not consist in extension..." (A II.i 289)

[75] John Henry, in his "Occult Properties and the Experimental Philosophy: Active Principles in Pre-Newtonian Matter Theory" (*History of Science* 24, 1986, 335-81), argues that many English philosophers regarded matter as endowed with activity, among them Petty, Glisson, and even Boyle. Clericuzio disagrees ("Redefinition", 572), quoting passages showing Boyle's trenchant opposition to ascribing self-motion to matter. Nevertheless, Boyle certainly upheld the incessant motion of matter, and in his *New Essays* Leibniz mentions only Boyle in this connection, citing "Mr. Boyle's book attacking absolute rest" in support of his view that "there is never a body without movement", which "is one of my proofs that there are no atoms" (i.e. classical atoms): G. W. Leibniz, *New Essays on Human Understanding*, ed. and tr. Peter Remnant and Jonathan Bennett, (Cambridge: Cambridge University Press, 1981), 53.

[76] "Whence also the motive force which is in each concrete thing owes its origin to atoms; nor is it in fact distinct from their weight (*pondus)* or impetus." Gassendi, *Animadversiones*, 309. "Supposing (as Democritus did not deny) that motion is ascribable to atoms, he judged it absurd not to attribute to them a special force by which such motion is initiated: of this kind is gravity ôr weight, ôr impulsion, and also the impetus by which whatever moves is made to act." *Syntagma Philosophicum* [*Syntagma*], *Opera,* I 280; cf. Clericuzio, *Elements*, 64.

[77] In the *Syntagma* Gassendi wrote that the thesis "that atoms have in themselves a motive force ôr impetus must be disapproved" (*Opera*, I, 280); see Clericuzio, *Elements*, 64-65. Boyle also considered and rejected this Epicurean thesis in *An Essay of the Intestine Motions of the Particles of Quiescent Solids; where the Absolute Rest of Bodies is called in Question* (*The Works of Robert Boyle*, ed. Michael Hunter and Edward B. Davis, Vol. 6, 189-211). This is the book by Boyle referred to by Leibniz (see footnote 75).

> But certainly in natural things there is an Agent operating inside them, and it is indeed distinguished from matter in part, but not from matter as a whole... since in everything there is a principle of action and of motion, ... and as it were the flower of the whole of the matter, which is also the very thing that is usually called Form.[78]

In these same passages, however, Gassendi attempts to account for this principle of action as "that most mobile and active part" of the matter, a materialist construal that Leibniz evidently did not find convincing. Nevertheless, it is difficult to resist seeing something of Gassendi's *flos materiæ* ("flower of matter") in Leibniz's talk of a *flos substantiæ* ("flower of substance") in his letter to Duke Johann Friedrich in May 1671 and subsequent writings. Indeed, it seems to me that once it is realized that Gassendi advocated a principle of action in every body, and indeed "forms" in matter whose effects would always be motions of parts of matter, one can begin to appreciate that Leibniz's later remarks about his early debt to Gassendi may not have been framed simply for their rhetorical effect.

Particularly important for assessing Gassendi's possible influence on Leibniz is his interpretation of *semina rerum* ("the seeds of things") as clusters of atoms of a certain type. Having already followed Sennert in distinguishing certain concretions of atoms (his *molecules*) as the principles of most chemical reactions, Gassendi also followed him in identifying certain of these compound corpuscles as *semina*, created by God at the beginning of things, containing all the "genetic information", as it were, needed for the generation and development of minerals, stones, gems and biological organisms.[79] Although there was a longstanding interpretation of seeds as active principles originating with the Stoics' *logoi spermatikoi*, to which Plotinus and Augustine gave an immaterialist interpretation that was later adopted by van Helmont, the identification of these seeds (*semina*) with certain atoms or compound corpuscles also had the warrant of the whole tradition of atomism from Epicurus and Lucretius to Bacon and Boyle. Here I do not think it necessary to say that Leibniz was influenced by atomism *as opposed to* Neoplatonism.[80] But I would urge that the dual roots of the idea of seminal principles (and

[78] Gassendi, *Syntagma, Opera,* I 336a, 337a; cf. Bloch, *Gassendi*, 216.

[79] For a good recent account of Gassendi's views, see Clericuzio, *Elements*, 63-74. Leibniz could also have been influenced by Gassendi through his reading of Boyle, who followed Gassendi's identification of primary concretions of particles with seminal principles. See Clericuzio, "Redefinition," 583.

[80] As Mercer has explained in her recent book, Leibniz inherits the doctrine of *rationes seminales* of Plotinus and Ficino through his teacher Thomasius, and is seriously committed to it (*Leibniz's Metaphysics*, 200ff., 223ff.); see also Catherine Wilson, "Atoms, Minds and Vortices", 223-243 in S. Brown, ed., *The Young Leibniz and his Philosophy (1646-1676)* (Dordrecht: Kluwer, 1999; 226).

the resulting ambiguity of the term) were particularly useful for his conciliatory purposes: every atom or *bulla* is a seed precisely because it contains a seminal reason or mind.

At any rate, to return to Gassendi, the importance of his interpretation of *semina rerum* as indivisible compound particles is that it constitutes the theoretical basis for his advocacy of *preformationism*, which explained the growth of complex organisms from a pre-existing invisible seed. In this it was opposed to the rival hypothesis of *epigenesis*, which explained growth and development in terms of the action of a vital spirit acting on a purely passive matter.[81] Gassendi (again following Sennert) interpreted the pre-existing seed as an invisibly small and indivisible body which is itself active, containing an active principle or form responsible for taking it through the organic changes and accretions it would undergo. The indivisibility of the molecules by natural processes thus accounts for the persistence of natural kinds from the beginning of time, even if the individual organisms developing from these seeds do not so persist.

This feature of preformation, finally, is of great importance for Gassendi, because of its connection with the doctrine of the propagation of souls that he favoured: *traducianism*. This doctrine, upheld by most Lutherans, had been promoted by Sennert before him, and Leibniz too was committed to it from an early age.[82] It maintained that souls are propagated *per traducem*, i.e. through the parents' seeds, as opposed to being introduced at conception from the outside. Gassendi's preformationism thus puts this theological doctrine on a firm natural philosophical footing by identifying the seeds as indestructible corpuscles containing forms or souls (immortal souls in the case of humans), passed on in biological generation.

Leibniz's transformationism can therefore be seen as a modification or variant of Gassendi's preformationism.[83] What Gassendi holds to be true of the natural kinds generated by the seeds, is for Leibniz true of the individual substances. In each case the forms were created at the beginning of the world by God, and will last for all

[81] For a succinct account of the opposition between epigenesis and preformationism, see Richard S. Westfall, *The Construction of Modern Science* (Cambridge: Cambridge University Press, 1977), 99ff.

[82] On Sennert's traducianism, see E. Michael, "Daniel Sennert on matter and form: at the juncture of old and new", *Early Science and Medicine* 2/3 (1997), 272-99. For an interpretation of Leibniz as piously committed to Lutheranism, see Ursula Goldenbaum, "Leibniz as a Lutheran", 169-192 in A. P. Coudert, R. H. Popkin and G. M. Weiner (eds.), *Leibniz, Mysticism and Religion* (Dordrecht: Kluwer, 1998).

[83] As noted in footnote 43, Leibniz saw the microscopists Leeuwenhoek and Swammerdam as agreeing with his transformationism; they are usually regarded as among the most prominent seventeenth century preformationists.

creation. And for the young Leibniz, as for Gassendi, their indestructibility is explained in terms of indestructible material casings, with the growth and development of the organism explained in terms of an accretion of matter around this indivisible core, organized by the active principle within. But what Gassendi holds to be the case for human souls is generalized by Leibniz into a general solution for "the vexatious problem of the origin of forms": for him all forms, not just human souls, are principles of individuation, and all forms are immortal. This immortality, in turn, follows from their immateriality. Thus Leibniz's main divergence from Gassendi lies in his rejection of materialism, and his persistent attempts to explain by means of rationalistic principles how mind organizes matter around the nucleus. Not to be forgotten too, of course, is the Anaxagorean strain in Leibniz's thought: since the physical continuum is not merely finitely divided into atoms, but infinitely divided, each atom is as it were a miniature world.

To summarize: even if we do not take Leibniz at his word for his claimed debt to Gassendi's atomism, a comparison of their views does much to explain the motivations for his own atomism. The hypothesis of active atoms containing an organizing principle or form explains the origin and persistence of natural kinds, as well as the indestructibility of souls, and the generation of biological organisms and minerals from seeds. It also grounds the theological doctrine of traducianism, which is strongly linked to the biological doctrine of preformation. Two marked differences of Leibniz from Gassendi, though, are his hypothesis of the infinite dividedness of matter, and his insistence on the immateriality of souls, from which he wanted to derive their immortality.

But if Leibniz's thought is distinguished from Gassendi's in his insisting on the immateriality of forms, this does not distinguish him from Daniel Sennert, who was perfectly explicit that forms, in keeping with religious orthodoxy, must be immaterial. In his *De Chymicorum*, Sennert wrote

> Forms are the divine and immutable principle that determines all actions and passions of a natural thing; and they are, as it were, the instrument and hand of the most wise Creator and Workman God, who in creation freely bestowed this force and efficacy onto these his instruments, than which nothing more marvellous can be thought. This is what J. [C.] Scaliger has rightly also taught... For there is in every natural thing, and in the parts of body, besides the matter that the elements supply, a certain divine principle and fifth nature, by which they are that which they are, and are reduced to a certain family of a natural kind. For the elements are material, and so are not capable of giving rise to action. (pp. 353, 358)

Thus Leibniz's investing of his atoms with an immaterial form is in keeping with the views of one of the chief proponents of seventeenth century atomism. For both him and

Sennert it is the immaterial form or soul that makes matter organic and able to sense, and is the source of its actions and passions. In fact, this contextualizing of Leibniz's thought within the atomist tradition sets his "rehabilitation" of substantial forms in quite a different light. For Sennert had effectively already proposed such a rehabilitation when, in his *Hypomnemata Physica* of 1636, he opposed the rejection of substantial forms by the atomist Basson. Now, I am not claiming here that Leibniz was directly influenced by Sennert, or by any particular texts, only that certain key features of his position were implicit in the atomist tradition with which he was certainly familiar. There is also the very great difference that Leibniz was concerned to give a rehabilitation that was consistent with mechanical principles. In the important manuscript "Metaphysical Definitions and Reflections" (Summer 1678-Winter 1680/81), for instance, Leibniz argues that "Even though all things are animate, nonetheless they all act according to the laws of mechanics, for sensation and appetite are determined by organs (i.e. parts of a body) and objects (i.e. by surrounding bodies)." (A VI.iv 1398; *Labyrinth,* 245).

The discussion so far has given us some insight into Leibniz's continued motivation for upholding a kind of atomism, namely one in which each atom constitutes the indivisible kernel of a corporeal substance, and contains a form or mind which individuates the substance and constitutes its active principle. But it leaves some features of the enigma of Leibniz's atomism outstanding: it still does not explain why he returned to perfectly solid atoms in 1676, nor why he eventually abandoned them altogether.

A full answer to these questions would take us too far afield, and must await another occasion. But let me sketch what I take to be the key to understanding these developments. In a nutshell, the answer I propose is that the changes in Leibniz's position on atoms are precipitated in large measure by changes in his understanding of the physical continuum, and the implications of this for his theories of cohesion and division. In particular, these changes make it impossible for him to sustain the endeavour theory of original cohesion that was foundational to his theory of *bullae*. As we have seen, this depended on the idea that a body impelling another has already begun to enter its place at the moment of impact by a part smaller than any given part, i.e. by an actually infinitely small part of space. But when Leibniz begins to doubt that the continuum can be regarded as composed from actual infinitesimal parts, the idea that a body's cohesion can be explained though the spatial continuity of such overlapping physical points becomes untenable. Once that theory is abandoned, however, Leibniz has no explanation of original cohesion, or of how it is that a body does not dissolve into its constituent points. It is at this juncture that he reconsiders the possibility of atoms in the strict sense: bodies that are indissectible, perfect solids, which are discrete aggregates of minima or physical points held together by minds. For if a body is actually infinitely divided into "all the parts into which it can be divided", these must be, he supposes in February 1676, otherwise unconnected physical points. In order to compose an atom, some principle seems required other than what can be derived from matter and motion alone. Leibniz therefore proposes that this is "mind": once "thought has entered into a portion of matter" this portion becomes indissectible, or a "perfect solid". Mind, as we saw above, is no longer contained in a mathematical indivisible, but organizes matter around an atomic nucleus which is its indestructible kernel.

During this same period, however, Leibniz develops a new understanding of the infinite that militates against this conception of a body's being divided into an infinity of distinct points. We saw earlier that he seemed in his early work to understand infinitesimals as somehow standing for an unending containment of spheres within spheres. But this is at variance with his formula for an infinitesimal: a part smaller than any assignable. The latter is naturally paired with the *categorematic* infinite, to use the medieval term, that is, a number greater than any assignable. But in 1676 Leibniz comes to reject infinite number in this categorematic sense in favour of a properly *syncategorematic* understanding: to say that there are infinitely many things in this sense is to say that there are so many things that, no matter how large a (finite) number one assigns to them, there are more. This leads Leibniz to abandon the idea that an infinitely divided body does issue in "all the parts into which it can be divided", as if it is the mere collection of these parts. "If we suppose any body we please is actually resolved into still smaller bodies", he writes in late April 1676, "i.e. if some worlds are always supposed within others, would it thereby be divided into minimum parts? Thus being divided without end is different from being divided into minima, in that there will be no last part, just as in an unbounded line there is no last point" (A VI.iii 510; *Labyrinth,* 119). To say that the body is actually infinitely divided is to say rather that, no matter how many parts are assigned, there are more, but not that there is an infinite number of them. This syncategorematic understanding parallels Leibniz's interpretation of infinite series, which he reached in the same period: to say that an infinite series has a sum is not to say that one collects together and adds an infinite number of terms; rather it is to say that there is a number such that, for any specifiable error, some finite series with the same rule and first term will sum to that number within the specified error.[84]

This position reaches fruition in November 1676 in the dialogue *Pacidius Philalethi*, mentioned at the beginning of this essay. For there Leibniz explicitly rejects the "perfect solids" and "perfect liquids" he had entertained in the Spring, replacing this with a conception of matter much more reminiscent of Bacon's, where *plicae materiae* fill all of space through their folding and unfolding, with no need for a void or perfect fluid composed of points:

> If a perfectly fluid body is assumed, a finest division, i.e. a division into minima, cannot be denied; yet a body that is everywhere flexible, though not without a certain and everywhere unequal resistance, still has cohering parts, although these are opened up and folded together in various ways. Accordingly the division of the continuum must not be considered to be like the division of sand into grains, but like that of a sheet of paper or tunic into folds. And so although there occur some folds smaller than others infinite in number, a body is never thereby dissolved into points or minima. (A VI.iii 555; *Labyrinth,* 185)

This explains why Leibniz denies the existence of atoms in the *Pacidius*: all that exist are portions of matter that are themselves further subdivided. In accordance with his denial of the categorematic infinite, Leibniz conceives worlds to be contained within worlds to infinity without this infinite division ever issuing in minima:

> Accordingly I am of the following opinion: there is no portion of matter that is not actually divided into further parts, so that there is no body so small that there is not a world of infinitary creatures in it... This does not mean, however, either that a body or space is divided into points, or time into moments, because indivisibles are not parts, but the extrema of parts. And this is why, even though all things are subdivided, they are still not resolved all the way down into minima. (A VI.iii 565-566; *Labyrinth,* 209-211)

Thus there are no actual infinitesimals, or parts of a continuum smaller than any assignable part. Nonetheless, one can still treat infinitesimals as fictional parts, on the understanding that they are (finite) parts small enough that no error will arise.[85] In

[84] Cf. Leibniz's "[to say] that a certain infinite series of numbers has a sum ... [is to say] that any finite series with the same rule has a sum, and that the error always diminishes as the series increases, so that it becomes as small as we would like" (A VI.iii 503; *Labyrinth,* 99). See my defence of this interpretation of Leibniz on the infinite in my exchange with Gregory Brown in the *Leibniz Review*, culminating in "Leibniz on Infinite Number, Infinite Wholes and the Whole World: A Reply to Gregory Brown", *Leibniz Review* 11, 2001, 103-116.

[85] For a lucid explanation of Leibniz's syncategorematic interpretation of infinitesimals in his mature work, see Hidé Ishiguro, , *Leibniz's Philosophy of Logic and Language*, 2nd edition (Cambridge: Cambridge University Press), chapter V, 79-100. In a paper in preparation, I

parallel with this, there are no atoms, in the categorematic sense of bodies so small that they cannot be further divided. Nevertheless, it is permissible to hypothesize them for the sake of physics or chemistry: an atom on this syncategorematic understanding would be a part assumed small enough that no error will arise, although in reality no part is so small that it is not further subdivided. An atom in this sense is what Leibniz also calls a "physical point".[86] All this is in keeping with Leibniz's interpretation of the infinite as exceeding every finite number that can be assigned, but not as a number greater than all finite numbers. It is to this syncategorematic conception, I submit, that Leibniz is referring in the passage in the *Phoranomus* I quoted at the beginning of this essay, when he writes that he was not able to abandon atoms and the void until he finally "grasp[ed] that in reality there were parts in things exceeding every number, as a consequence of motion in a plenum".

Still unexplained by this new position on division, however, is the problem of substance. We have seen that Leibniz is deeply committed to minds in matter, acting as principles of individuation, bearers of genetic information, organizing principles for chemical reactions and biological and mineral growth, and the font of a substance's actions and passions. But until he can explain how it is that mind enables a given substance to be the same over time, Leibniz cannot claim to have solved the metaphysical problem of substance. For if there are no atoms, and matter is a mere aggregate of parts, how is it that a form or mind is attached to this aggregate of parts at one time, and to that at another? What Leibniz appears to be actively seeking in the late 1670s is some principle which would explain the self-identity of a corporeal substance through time: if it is not conservation of a certain mass, then it appears likely that mind is connected with the conservation of motion.[87] "Anyone seeking the primary sources of things," he writes in his "Metaphysical Definitions and Reflections" (Summer 1678-Winter 1680), "must investigate how matter is divided into parts, and which of them is moving" (A VI.iv 1401; *Labyrinth,* 251).

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trace the development of Leibniz's thought on infinitesimals in his early work, and how this evolves into a syncategorematic interpretation in 1676.

[86] Thus in a chemical manuscript dating from 1678-81, Leibniz writes: "*Physical minima* are those parts into which every single one of the components of a mixture is divided, but here they are taken as points. This portion may also be called an atom" (A VI.iv N367$_4$: 2024). For the distinction between physical, mathematical and metaphysical points, see footnote 45 above.

[87] In "On Motion and Matter" (early April 1676) Leibniz favours the idea that it is the universal mind that effects the conservation of motion, not the individual minds in each body: "For when two bodies collide, it is clear that it is not the mind of each one that makes it follow the law of compensation, but rather the universal mind assisting both" (A VI.iii, 493; *Labyrinth,* 77).

But by 1678 Leibniz has finally found a solution to this problem, with his recognition that "matter is divided not even into parts of equal bulk (*moles*) as some have supposed, nor into parts of equal speed, but into parts of equal power, but with bulk and speed unequal in such a way that the speeds are in inverse ratios to the magnitudes." (A VI.iv 1401-02; *Labyrinth,* 251). Something is the same corporeal substance, as I interpret this, not when it retains the same or equal matter, nor simply when it conserves the same quantity of motion through collisions, but when its parts before and after a collision have equal power (mv^2). (Here it must be remembered that Leibniz held that no force is transferred in collisions, "but each body moves by an innate force, which is determined on the occasion of, i.e. with respect to another" (A VI.iv 1620; *Labyrinth,* 333).[88] Any apparent loss of force in an inelastic collision is carried away by invisible parts.) This discovery of conservation of mv^2 in early 1678 then clears the way for Leibniz's new reinterpretation of substantial forms as forces. This change is evident in the "Conspectus For A Little Book On Physics" composed later that year, where, after rejecting atoms, Leibniz argues that the laws of motion follow from the equality of cause and effect, from which the conservation of power is derived.[89] But from this there follows the necessity of souls or forms:

> It must also be demonstrated that every body is actually divided into smaller parts, i.e. that there are no such things as atoms, and that no continuum can be accurately assigned in body...
>
> Following this, the subject of incorporeals: There turn out to be certain things in body which cannot be explained by the necessity of matter alone. Such are the laws of motion, which depend on the metaphysical principle of the equality of cause and effect. Here therefore the soul must be treated, and it must be shown that all things are animated. Unless there were a soul, i.e. a kind of form, a body would not be an entity, since no part of it can be assigned which would not again consist of further parts, and so nothing could be assigned in body which could be called *this something*, or *some one thing*. That it is the nature of a soul or form to have some perception and appetite, which are passions and actions of the soul... (A VI, iv 1988; *Labyrinth,* 233)

Thus I interpret the final configuration of Leibniz's thought on atoms as follows: there are no atoms, in the sense of parts of matter that are not actually divided.

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[88] Cf. also: "Rigorously speaking, no force is transferred from one body to another, but every body is moved by an innate force (*insita vi*)" (A VI.iv 1630; *Labyrinth,* 333).

[89] "Force or power ... must be estimated from the quantity of the effect. But the power of the effect and of the cause are equal to each other, for if that of the effect were greater we would have mechanical perpetual motion, if less, we would not have physical perpetual motion. Here it is worth showing that the same quantity of motion cannot be conserved, but that on the other hand the same quantity of power is conserved." (A VI.iv 1989; *Labyrinth,* 235).

Nevertheless one can proceed in natural philosophy on the assumption that there are atoms, provided these are understood to be parts assumed small enough that no error will arise on their being supposed undivided. On the other hand, metaphysically there must be atoms in the sense of substances having a real unity. These are the sources of actions and passions, and their conservation is necessary in order to explain a thing's self-identity, and its development according to its own nature. The essence of these metaphysical atoms is force, and they are manifested in physics in the form of a substance's conserving its own force, rather than a constant quantity of matter or of motion.

5. Conclusion

As was perhaps only to be expected, the enigma of Leibniz's atomism has required a rather complex resolution. I have argued here that his long attachment to atoms is only explicable once it is seen in the context of the rich variety of atomisms current in the early seventeenth century. For Leibniz never (except perhaps in his teens) subscribed to atoms in the sense of purely material chunks of extension devoid of any internal complexity. Like Gassendi, whom he claimed to have followed, and also like Sennert, he appealed to atoms (or concretions of them) as the physically indivisible seed-cases within which the soul or organizing principle of organic bodies was contained. This allowed him to give a similar solution to Gassendi's of the problem of the origin of forms—namely a version of preformation—and by this means to uphold traducianism, the Lutheran doctrine of the transmission of souls through the parents' seed. On this interpretation of atoms, derived from those of Sennert, Sperling, Gassendi, Hobbes, Digby and Jungius, they are physically indivisible in the sense of not being further divisible by natural processes, especially chemical ones, and thus as lasting for the duration of this world; but they are further divided within by intestine motions, and so are not indivisible in this sense.

This latter property of inner complexity and heterogeneity is one Leibniz's atoms shared with those proposed by a great variety of early modern thinkers. What distinguished Leibniz's various attempts in atomist physics from those of his predecessors, however, is his commitment to a "modern" conception of qualities and forces. Where Magnen appealed to sympathy as an original quality of atoms of the same element, Leibniz construed it in terms of motion in common; where Gilbert and Kepler appealed to magnetism as an attractive force, Leibniz attempted to explain it in terms of a minimization of disturbance of motion. But, most importantly, where other atomists had supposed the cohesiveness of the atoms themselves as an original quality, Leibniz sought to give an explanation in terms of matter in motion.

But where Leibniz differed most decisively from Gassendi and other atomists was in his conception of matter as not merely mathematically divisible, but actually infinitely divided by the differing motions within it. This, of course, accentuated the difficulty of accounting for cohesion. In 1670, however, Leibniz thought he had found a way of reconciling infinite division with "atoms" of a certain kind, these being the "terrellae" or "*bullae*" of his *HPN*. On this theory, matter is infinitely divided into points or indivisibles, which differ in size in proportion to their corresponding indivisible motions, or endeavours; the overlapping of such points then explains the cohesion around meridian lines of the surface of each *bulla*. Thus in this period we find Leibniz rejecting classical atoms, but nevertheless making positive references to atoms in the sense of chemical units or biological seeds, containing a soul or mind which individuates them.

Two further threads lead Leibniz to a final resolution of these issues. One is his reinterpretation in 1676 of actually infinite division as not issuing in a least part or minimum. An atom then becomes a hypothetical minimum part of matter, a part assumed small enough that no error will arise, although in reality no part is so small that it is not further subdivided. The second thread concerns the principle of activity and individuation that must be supposed in any body, no matter how small, if it is not to be a mere phenomenon. When in 1678 Leibniz locates this in his new conception of force, he is finally free to abandon the idea of a physically indestructible atomic core to corporeal substance. The sameness of a substance, formerly explicated by means of its possession of a mind, is now construed in terms of the conservation of living force. Now not only is the self-identity of a certain quantity of matter organized by the soul no longer required, the atomic core itself becomes redundant. Thus it is that after 1678 atoms are firmly rejected by Leibniz, their only role being as hypothetical minimal parts of elements enabling certain explanations in natural philosophy.

The enigma I set out to resolve in this essay was how in his youth Leibniz could have advocated atoms for so many years after he had reached the conclusion that matter is actually infinitely divided. For if atoms are taken in the sense of finite bodies that are not further divided, then this conclusion directly precludes them, as Leibniz himself urged in his mature writings. I have argued that the enigma is resolved once it is realized that Leibniz never did subscribe to atoms of this sort. His atoms, far from being devoid of internal complexity, were further divided within by the intestine motions of their parts, and contained within them a mind or soul that is the principle of their activity, and is responsible for their individuation and the accretion and organization of surrounding matter into an organic body. In all these respects Leibniz's atomism, for all its modernism regarding forces and qualities, is best regarded as continuing the lively seventeenth century tradition of atomism articulated by Sennert and Gassendi.