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Du Châtelet and Descartes on the Roles of Hypothesis and Metaphysics in Natural Philosophy

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In this chapter, I examine similarities and divergences between Du Châtelet and Descartes on their endorsement of the use of hypotheses in science, using the work of Condillac to locate them in his scheme of systematizers. I conclude that, while Du Châtelet is still clearly a natural philosopher, as opposed to modern scientist, her conception of hypotheses is considerably more modern than is Descartes', a difference that finds its roots in their divergence on the nature of first principles.

Keywords: Du Châtelet, experimental and speculative philosophy, hypothesis, natural philosophy, systems.

Chapter 3

Du Châtelet and Descartes

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Émilie le Tonnelier de Breteuil, marquise Du Châtelet-Lomont has been regularly portrayed as a central figure in the emergence of what has been called the Enlightenment in France.[1] She has also regularly been portrayed as a vanguard figure in the rejection of Cartesianism and its replacement by Newtonianism in this French Enlightenment; indeed, at least in the field of natural philosophy, this shift from Cartesianism to Newtonianism is often taken as a key marker of the birth of the Enlightenment and, relatedly, the full flowering of the Scientific Revolution, which paved the way for the birth of science as we now know it.[2] While it is true that Du Châtelet does in general reject Cartesian natural philosophy, partly replacing it with Newtonian physics, it is also generally accepted that she is still squarely in the tradition of the natural *philosopher* who envisions the need for metaphysical foundations for physics.[3] And Du Châtelet famously turns away from Cartesian metaphysics in part toward Leibnizian and Wolffian metaphysics to provide those foundations for a broadly Newtonian physics.[4]

At the same time, Du Châtelet was admirably even-handed and fair-minded, and she championed thinkers swayed by neither national prejudice nor the authority of whatever great

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[1] Witness the title of a recent book collecting scholarly thoughts, Du Châtelet texts, photographs of artifacts relevant to Du Châtelet's context and so forth: *Madame Du Châtelet: La femme des Lumières*, under the direction of Elisabeth Badinter and Danielle Muzerelle (Paris: Bibliothèque nationale de France, 2006).

[2] For an articulation (though not an endorsement) of this approach, see Aram Vartanian, *Diderot and Descartes: A Study of Scientific Naturalism in the Enlightenment* (Princeton: Princeton University Press, 1958), 136.

[3] I do not mean to indicate that Newton himself was *not* a natural philosopher. Indeed, the conceptual relationship between Du Châtelet and Newton along multiple fronts, including an analysis of both on the role of hypothesis in science, and the relation between metaphysics and physics in their work, requires a separate and sustained study. On Newton as natural philosopher see, for example, Andrew Janiak, *Newton as philosopher* (Cambridge: Cambridge University Press, 2008).

[4] See Erica Harth, *Cartesian Women: Versions and Subversions of Rational Discourse in the Old Regime* (Ithaca: Cornell University Press, 1992), 190. For an account of Du Châtelet's developing views on the fall of Cartesianism and especially the rise of Newtonianism, see Sarah Hutton, 'Women, Science, and Newtonianism: Émilie Du Châtelet versus Francesco Algarotti' in *Newton and Newtonianism*, edited by J.E. Force and S. Hutton (Dordrecht: Kluwer Publishing, 2004), 183-203 (Hereafter, Hutton 2004b). For an argument in favor of the persistent prevalence of Newtonian over Leibnizian thought in Du Châtelet, even from 1738 (when she became acquainted with Leibnizianism), see Sarah Hutton, 'Émilie Du Châtelet's *Institutions de physique* as a document in the history of French Newtonianism,' *Studies in the History and Philosophy of Science* 35 (2004), 515-531 (Hereafter Hutton 2004a). For a continuation of these themes and the conceptual relation between Du Châtelet and Samuel Clarke, see Sarah Hutton, 'Between Newton and Leibniz: Émilie Du Châtelet and Samuel Clarke' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012).

men were most favored in a given circle at a given time. Rather, she prescribed being guided by truth in one's philosophical decisions about what to adopt and what to reject from the various metaphysicians and physicists whose work was animating intellectual circles in her time (IP *Avant-Propos* VII, X and XI). And she herself is remarkably in line with this principled approach. So while it is true that, in the main, she rejects Cartesian natural philosophy[5], she is still appreciative of Descartes' advances in, for example, geometry, dioptrics and method (IP *Avant-Propos* V).[6] This paper examines Du Châtelet affinities with and divergences from Descartes on one specific aspect of scientific method for which she is rightly well known: her embrace of hypotheses.[7] I shall argue that Du Châtelet and Descartes have notably similar general approaches to the use of hypotheses in science. Some of these similarities are not surprising for they capture broadly just what it means to make use of hypotheses in science. Still others of these similarities serve to underscore how squarely Du Châtelet still fits the role of natural philosopher rather than modern scientist. At the same time, she differs notably from Descartes both on a few crucial details and because of her historical moment, writing a full century after Descartes. These divergences serve to underscore how much she has moved away from Descartes toward a more contemporary understanding of scientific hypotheses. In the

[5] For a general endorsement, albeit with some caveats, of Du Châtelet's rejection of Cartesianism, see Linda Gardiner Janik, 'Searching for the metaphysics of science: the structure and composition of madame Du Châtelet's *Institutions de physique*, 1737-1740,' *Studies on Voltaire and the Eighteenth Century* 201 (1982), 87. See also Margaret Alic, *Hypatia's Heritage: A History of Women in Science from Antiquity to the Late Nineteenth Century* (London: The Women's Press Ltd., 1986), 139; William H. Barber, 'Mme du Châtelet and Leibnizianism: the genesis of the *Institutions de physique*' in *The Age of Enlightenment: Studies Presented to Theodore Besterman*, edited by W.H. Barber, J.H. Brumfitt, R.A. Leigh, R. Shackelton, and S.S.B. Taylor (Edinburgh: University Court of the University of St. Andrews, 1967), 208, and Sarah Hutton, 'Émilie Du Châtelet's *Institutions de physique*', 517.

[6] Others have noted Du Châtelet's positive intellectual evaluation of Descartes, including her explicit praise of him or (more significantly) her conceptual affinities with him. For example, there is an affinity between the argumentative structure of Descartes' *Principles* and Du Châtelet's *Institutions* one aspect of which is their shared method, which I address in the final section of this paper. On this point, see Judith P. Zinsser, *La Dame d'Esprit: A Biography of The Marquise Du Châtelet* (New York: Viking, 2006), 173; Marcy P. Lascano, 'Émilie du Châtelet on the Existence and Nature of God: An Examination of Her Arguments in Light of Their Sources,' in the *British Journal for the History of Philosophy* 19.4 (2011): 742-3. Zinsser also notes their shared commitment to 'reasoning from first principles', though I will examine their differences on this below. See Judith P. Zinsser, 'The Many Representations of the Marquise Du Châtelet' in *Men, Women, and the Birthing of Modern Science*, edited by Judith P. Zinsser (DeKalb: Northern Illinois University Press, 2005), 54. See also Janik, 'Searching for the metaphysics of science', 91 for a general statement of their limited affinity.

[7] Vartanian notes the enduring influence of Descartes' *method* in eighteenth-century thought despite the rise in popularity of Newtonianism during the same decades. See Vartanian, *Diderot and Descartes*, 136.

process of making these arguments, I add yet more evidence in favor of viewing Du Châtelet as no mere intellectual mimic of Voltaire, arguably her closest collaborator.[8]

3.1 Descartes and Du Châtelet on hypothesis I: shared ground

While Descartes leaves no clear role for hypotheses in his early and unpublished *Rules for the Direction of the Mind* (composed 1628)[9], this changed by the time he wrote the *Discourse on Method* and *Optics* (both 1637), and there remains a role for hypotheses in scientific method in his later *Principles of Philosophy* (1644). This is important because Du Châtelet was familiar with all three of the latter texts.[10] In this section, then, I will sketch the essential elements of Descartes' position on hypotheses as found in the last of these three texts, since the *Principles* essentially refines and expands upon the basic ideas first put forth in the *Discourse* and *Optics*.[11]

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[8] In the twentieth century, Ira O. Wade first made explicit the idea that Du Châtelet's thought was original and quite independent of that of Voltaire. See I.O. Wade, *Studies on Voltaire with some unpublished papers of Madame du Châtelet* (Princeton: Princeton University Press, 1947). See also his *Voltaire and Madame du Châtelet: An Essay on the Intellectual Activity at Cirey* (Princeton: Princeton University Press, 1941), where he suggests she took the lead over Voltaire on metaphysics, physics and biblical criticism (p. 195). William Barber argued against this view, concluding that she is 'essentially derivative' of a number of her male contemporaries, most notably Voltaire. See Barber, 'Mme du Châtelet and Leibnizianism', 200-22. Julian L. Coolidge, 'Six Female Mathematicians' *Scripta Mathematica* 17 (1951), 20-31 concludes (convincingly) that in the field of mathematics, she made no original contributions. Kathryn A. Neeley argues that women like Du Châtelet who made no original contributions were nonetheless important to the advance of science because of their role as mediators. See Kathryn A. Neeley, 'Woman as Mediatrix: Women as Writers on Science and Technology in The Eighteenth and Nineteenth Centuries' in *IEEE Transactions on Professional Communication* 35.4 (1992), 208-16. For an historical account of Du Châtelet's reception from her own time to the mid-twentieth century, see Lydia D. Allen. 'Physics, frivolity, and "Madame Pompon-Newton": the historical reception of the Marquise du Châtelet from 1750-1966' (University of Cincinnati: PhD dissertation, 1998). Since at least the mid-twentieth century, the vast preponderance of work has aimed to show Du Châtelet's originality at least in natural philosophy.

[9] The two modes of amassing (certain) knowledge as detailed in the *Rules* are intuition and deduction (both first mentioned in rule #3), leaving no room for hypotheses. On method in this early work compared with the rise of hypotheses in Descartes' later work, see Ernan McMullin, 'Explanation as Confirmation in Descartes's Natural Philosophy' in *A Companion to Descartes*, edited by Janet Broughton and John Carriero (Malden, MA: Blackwell, 2008), 87-8.

[10] On her familiarity with *Optics* and *Discourse*, see Du Châtelet's own *Institutions* (*Avant-Propos* V), which includes comments that Judith P. Zinsser convincingly believes refer to those two texts as well as to his *Geometry*. See Zinsser, *La Dame d'Esprit*, 172-3. In a 1739 letter to Laurent François Prault, Du Châtelet mentioned having some unnamed books ('les oeuvres') of Descartes; see *Les lettres de la Marquise du Châtelet*, edited by Theodore Besterman (Geneva: Institut et Musee Voltaire, 1958), vol. I, letter #186, p. 329. On her familiarity with the *Principles*, we know that she made notes on the French version of that text, notes which are preserved in the Voltaire Collection in St. Petersburg, vol. 9, pp, 122-25: see Zinsser, '*La Dame d'Esprit*', 148-9. For inventories of books in Du Châtelet's libraries, see Andrew Brown and Ulla Kölving, 'À la recherché des livres d'Émilie Du Châtalet' in *Émilie Du Châtalet: éclairages & documents nouveaux*, edited by Ulla Kölving and Olivier Courcelle (Paris: Publication du Centre International d'Étude du XVIIIe Siècle 21. Ferney-Voltaire: Centre International d'Étude du XVIIIe Siècle), 111-120.

[11] The account of Descartes' use of hypothesis, which I offer is not new. Many have acknowledged Descartes' use of hypothesis in the way, and for the reasons, I detail below. See, as just two of many examples, Larry Lauden, *Science*

So by consulting the *Principles*, we have both Descartes' mature thinking on the role of hypothesis in science, and a text with which Du Châtelet would have been familiar. I will then turn to Du Châtelet's account of hypothesis in *Institutions de physique* in order to show the striking degree to which Descartes and Du Châtelet overlap in their general approach to hypotheses.

In the *Principles*, Descartes embraces the same basic account of the role of hypotheses in natural philosophy that he offers in the *Discourse* and *Optics*. That is, the natural philosopher first intuits first principles (AT VI, 63-4; CSM I, 143-4), which set the confines upon any possible account one might give of the natural world. She then amasses empirical observations, many of which could have emerged from the first principles in multiple ways (AT VI, 64-5; CSM I, 144). She then posits a hypothesis about the actual way in which the observable effects in fact did emerge from within confines set by the first principles (AT VI, 76; CSM I, 150; and AT VI, 83; CSM I, 152-3). We get the same basic picture seven years later:

> From what has already been said we have established that all the bodies in the universe are composed of one and the same matter, which is divisible into indefinitely many parts…. However, we cannot determine by reason alone how big these pieces of matter are, or how fast they move, or what kinds of circles they describe. Since there are countless different configurations which God might have instituted here, experience alone must teach us which configurations he actually selected in preference to the rest. We are this free to make any assumptions [hypotheses] on these matters with the sole proviso that all the consequences of our assumption must agree with our experience (PP III, §46; AT VIIIa, 100-101; CSM I, 256-7).

Experience is necessary both to determine what actual phenomena obtain in the world from the many phenomena, which could have emerged from the incredibly fecund first principles, and to somehow (though not by *direct* observation, as we shall see) determine the means by which these phenomena probably did come about.

At the same time, in the later text, Descartes offers some clarification of essential elements of his theory of hypotheses. The first point of clarification offered throughout the

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and Hypothesis: Historical Essays on Scientific Methodology (Dordrecht: D. Reidel Publishing Company, 1981), 29-33; and Desmond Clarke, *Occult Powers and Hypotheses: Cartesian Natural Philosophy under Louis XIV* (Oxford: Clarendon Press, 1989), chapter 5, *passim*.

second part of the *Principles* is the greater detail provided on the actual nature of the first principles intuited by the natural philosopher: body's essence is extension merely (§4); space is therefore identical with body (§11) such that there is no empty space (§16); there are no atoms but rather an indefinitely divisible plenum (§20; §34); all diversity in phenomena is the result of the motion of matter thus defined (§23); and God is the primary cause of motion in the matter of the created world (§36). Absolutely crucial to Descartes' metaphysics are metaphysical claims about the mind of the knowing subject, specifically that the knowing subject is capable of rationally intuiting these metaphysical principles because God has implanted innate ideas within human souls.[12] Descartes' view will be the subject of greater discussion in the final section of this chapter as Du Châtelet differs notably on this point. Second, Descartes is much clearer on the nature of the assumed causes (the hypotheses), and thus on the difference between first principles and hypothetical causes. We see this in the passage just cited: hypothetical causes are, for example, the precise size of pieces of matter, how fast they move, what kind of circles they subscribe. We also get a clear contrast between hypothetical causes and intuited first principles in Part IV, §203 and §204. At the outset of §203, for example, he contrasts 'determined figures, and sizes, and movements [of] the imperceptible particles of bodies,' which he attributes to matter on the one hand, with 'the simplest and best-known principles (the knowledge of which is imparted to our minds by nature)' on the other (AT VIIIa, 325-6; CSM I, 288). The former are the assumed or hypothesized causes which he posits in order to try to discover the precise causal mechanisms by which the experienced effects of the natural world have come to be, and he admits that he could never experience these sorts of details; they are, after all, imperceptible. The latter are the rationally intuited first principles.

A third important point clarified in the *Principles* requires some background on different roles seen for hypotheses by those who make use of them. Historically, there have been two key directions in which thinking about hypotheses developed, indeed from Ancient times, and certainly throughout the seventeenth and eighteenth centuries as well. According to one approach – typified by Ptolemy in pre-modern thought and sometimes associated with 'save the phenomena' type explanations – hypotheses are posited merely because they are useful instruments, mere mathematical calculating devices especially useful for prediction and scientific

[12] For the significance of this innovation in Descartes in the meaning and scope of metaphysics, see Gary Hatfield, 'Metaphysics and the New Science' in *Reappraisals of the Scientific Revolution*, edited by David C. Lindberg and Robert S. Westman (Cambridge: Cambridge University Press, 1990), 111-7.

practice. The aim with hypotheses, according to this approach, is not to propose a *true* account of the nature of things, since reaching true conclusions about the world is not necessarily relevant when formulating hypotheses according to this tradition, which focuses more pointedly on prediction. According to the second approach – typified by Aristotle in pre-modern thought and sometimes associated with causal explanations – hypotheses are posited in order to provide an explanation of how experienced effects might have come about. The aim is to give a *true* account of the nature of things, especially the causal nature of things.[13] Both these approaches to hypotheses seem to appear in Descartes' early writings on the topic. Early in the *Optics* he defends his own reliance on hypotheses by referring to the astronomers 'whose assumptions are almost all false or uncertain' (AT VI, 83; CSM I, 152), and this harks back to the Ptolemaic tradition. In his letter to Morin of 13 July 1638 he suggests that any hypothesis which accounts for multiple effects, including those not originally under investigation, is likely 'the true cause from which they [effects] result' (AT II, 199/CSMK 107), and this harks back to the Aristotelian approach. In the *Principles*, Descartes comes down much more firmly on the side of hypotheses aiming for a true account of causes rather than on the side of hypotheses aiming simply to save the phenomena.[14] His reasoning in the later work captures something implicit, yet crucial, found in his letter to Morin, namely, that should hypothesized causes explain a plethora of effects, including others not initially under investigation, then this simplicity and systematicity indicates that the hypotheses are probably true. He repeats this in the *Principles*:

> [W]e shall know we have determined such causes [causes of what we see far off in the heavens… and of all these terrestrial phenomena] correctly afterwards, when we notice that they serve to explain not only the effects which we were originally looking at, but all these other phenomena, which we were not thinking of beforehand…. If a cause allows all the phenomena to be clearly deduced from

[13] For more on these two approaches to hypothesis, including the understanding of those such as Kepler and Galileo who believed these methods to be compatible, see Ernan McMullin, 'Hypothesis' in *Encyclopedia of the Scientific Revolution: From Copernicus to Newton*, edited by Wilbur Applebaum (New York: Garland Publishing Inc., 2000), 316-7; and Michael Friedman, 'Descartes and Galileo: Copernicanism and the Metaphysical Foundations of Physics' in *A Companion to Descartes*, edited by Janet Broughton and John Carriero (Malden, MA: Blackwell, 2008), 71.

[14] There is a moment in the *Principles* when he seems to allow for the latter use of hypotheses, but a careful reading of this passage leaves open the distinct possibility that what is going on in the passage is Descartes' recognition of their lack of certainty, not their mere instrumentality. See (PP III, §44; AT VIIIa, 99; CSM I, 255). The preponderance of Descartes' claims indicates that he takes the role of the natural philosopher to be the pursuit of true causes of phenomena.

it, then it is virtually impossible that it should not be true (PP III, §43-4; AT VIIIa, 98-9; CSM I, 255).

Thus, as noted above, experience is used indirectly to help determine the means by which our actual world likely emerged from the fecund first principles of matter, since if the hypothesized means can also account for many other experienced effects, the hypothesis is more likely to be correct.

So the general picture of the use of hypotheses remains intact from the *Discourse* through to the *Principles*. At the same time, Descartes is clearer on the above-mentioned points. There is also a significant development in the later work, and this captures a development in scientific epistemology, which Desmond Clarke and Ernan McMullin have recently detailed. They note, that is, the move away from treating less than certain knowledge in the form of hypotheses, for example, as merely speculative, toward treating such knowledge as more or less probable and therefore, more or less respectable. The degree of probability enjoyed by such hypotheses depends upon a number of factors, including how simple and systematic they are.[15] Clarke thus points out that throughout the 1600s a new scientific epistemology emerges which allowed for a respectable, because not wholly speculative, category of the probable. This came about due to 'philosophers significantly [adjusting] their epistemic intuitions to their laboratory practices' (Clarke 2011, 250); that is, accepting the merely probable as a legitimate category of scientific epistemology because experimental practice encourages this. Shortly after Descartes' time, this more palatable notion of probability is clearly articulated by Edme Mariotte in his *Essai de logique* (1678): 'An hypothesis of one system is more probable than that of another if, by assuming it, one explains all the phenomena or a greater number of phenomena more exactly, more clearly and with a stronger link with other known things…'.[16] In his later work, Descartes seems to embrace such a conception of probability, retreating from an all-out claim to the certain

[15] For accounts of Descartes' maturation on the relation between hypotheses and scientific epistemology, see Clarke, *Occult Powers*, chapter 7; Desmond Clarke, 'Hypotheses'in *The Oxford Handbook of Philosophy in Early Modern Europe*, edited by Catherine Wilson and Desmond Clarke (Oxford: Oxford University Press, 2011), 249-71; Ernan McMullin, 'Conceptions of Science in the Scientific Revolution' in *Reappraisals of the Scientific Revolution*, edited by David C. Lindberg and Robert S. Westman (Cambridge: Cambridge University Press, 1990), 32-44; McMullin, 'Hypotheses,'; and McMullin 'Explanation as Confirmation'. For a much earlier account of many of these themes recently developed by Clarke and McMullin, including a discussion of hypotheses, see Daniel Garber, 'Science and Certainty in Descartes' in *Descartes: Critical and Interpretive Essays*, edited by Michael Hooker (Baltimore: The Johns Hopkins University Press, 1978), 114-51.

[16] Edme Mariotte, *Essai de logique* (1678) in *Oeuvres*, volume ii, 624. Cited in Clarke, *Occult Powers*, 194.

truth of hypothesized causes (PP IV, §204), even while claiming 'moral certainty' of their truth (PP IV, §205), and suggesting that

> … if people look at all the many properties relating to magnetism, fire and the fabric of the entire world, which I have deduced in this book from just a few principles [hypotheses], then even if they think my assumption of these principles was arbitrary and groundless, they will still perhaps acknowledge that it would hardly have been possible for so many items to fit into a coherent pattern if the original principles had been false (PP IV, §205; AT VIIIa, 328; CSM I, 290).

That is, while not metaphysically – or absolutely – certain, Descartes' own posited hypotheses are, in his view, not thereby mere arbitrary speculation.[17] This will not be the last word on Descartes' method, but it is enough for the comparison with Du Châtelet I now draw.

At the close of her chapter on hypotheses,[18] Du Châtelet's writes:

> And so good hypotheses will always be the product of the greatest men. Copernicus, Kepler, Huygens, Descartes, Leibniz, and even Newton himself, have all devised useful hypotheses to explain complicated and difficult phenomena. The example of these great men, and of their successes, should make us see that those who wish to ban hypotheses from philosophy, intend harm to the interests of science (IP §71).[19]

It certainly seems that Du Châtelet sees virtue in this aspect of Descartes' methodology, despite any other negative evaluations of him she might have harbored. Still, it might be argued that the 'laundry list' of thinkers she includes in this statement should urge us to consider the

[17] For discussions on why Descartes' hypotheses are not merely speculative, see for example, McMullin, 'Explanation as Confirmantion', 89, and Clarke, *Occult Powers*, 141-4. The latter makes a distinction between arbitrary and reasonable hypotheses, with reasonable hypotheses being assumptions, which can be systematized and unified into a system, ideally bound by laws.

[18] I will use throughout, except where noted, Du Châtelet's 1740 *Institutions de physiques*. I acknowledge a few important developments between this text and her 1742 edition, renamed *Institutions physique*, in the final section of this paper. For details on other changes, which have no impact on my arguments, see Hutton, 'Émilie Du Châtelet's *Institutions de physique*', 529.

[19] See Keiko Kawashima for her evaluation of Du Châtelet's conceptual relationship with her close contemporaries on hypotheses. Kawashima, 'Les idées scientifiques de Madame du Châtelet dans ses *Institutions de physique*: un rêve de femme de la haute société dans la culture scientifique au Siècle des Lumières. 1ère partie' in *Historia Scientiarum* 3.1 (1993), 67-68, 67-68. For other discussions of Du Châtelet on hypothesis, see Ruth Hagengruber, 'Émilie Du Châtelet between Leibniz and Newton: The Transformation of Metaphysics' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012), 1-60; and Sarah Hutton, 'Between Leibniz and Newton: Emilie du Châtelet and Samuel Clarke' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012), 77-96.

possibility that her praise is not an accurate reflection of her assessment of Descartes' virtues. I take her at her word because an examination of Du Châtelet's own views on the use of hypotheses in science indicates remarkable general overlap with the views of Descartes' just examined. Unlike Descartes, Du Châtelet offers us explicit theorizing gathered in one place (chapter IV of *Institutions*) on the proper role played by hypothesis, thus making an explication of her position much easier.

Du Châtelet distinguishes those who use hypotheses well from those who use them badly, and she recognizes a third group – those who eschew the use of hypotheses altogether largely due to perceived misuse of them among their predecessors and contemporaries. Among those who use hypotheses poorly are those working in the Cartesian tradition and those in 'the Schools' who are especially guilty of spouting unintelligible jargon (IP *Avant-Propos* VIII, §55). The key downfalls of those who make bad use of hypotheses are the mistakes of taking them as truth (IP §62-63), and of building theories and systems upon them that resemble 'fables' and 'dreams' (IP §55) more than they resemble a science of nature firmly rooted in empirical knowledge of nature. As a consequence of previous abuse of hypotheses, Du Châtelet notes that many in her own century have entirely shied away from their use – or at least claim to have done so – which they regard as (quoting Newton) the 'poison of reason and the plague of philosophy' (IP §55). Du Châtelet stresses that it is a mistake, however, to believe that hypotheses are useless in physics just because they have been abused in the past (IP §63), and she suggests that hypothetical thinking is not only useful, but indeed necessary; without hypotheses, almost no progress would have been made in astronomy (IP *Avant-Propos* VIII, §57), and they are also valuable in physics (IP §55). She even goes so far as to claim 'without hypotheses… there would be no astronomy now' (IP §57). To bolster her case, she details a few recent successes in astronomy which relied pivotally on the use of hypotheses with theories of Copernicus (IP §57 and §67), Kepler (IP §58) and Huygens (IP §57 and §67) featured as evidence. Those who refuse to include hypothetical thinking in their scientific method are guilty of retarding the progress of science no less than are those who include such thinking but do so badly (IP §54).

Like Descartes, Du Châtelet believes that hypotheses are *necessary* because not all phenomena can be explained through reliance upon first principles alone – there is a gap between first principles and observed phenomena in the world in the sense that the scientist cannot deduce the cause of those phenomena directly or through chains of deduction from the first principles.

Neither can experiment directly tease out such a cause. 'Hypotheses are… sometimes very necessary… in all cases when we cannot discover the true reason for a phenomenon and the attendant circumstances, neither *a priori*, by means of truths [identified as principles in §53] that we already know, nor *a posteriori*, with the help of experiments' (IP §60). And: '[P]hilosophers frame hypotheses to explain the phenomena, the cause of which cannot be discovered either by experiment or by demonstration' (IP §56).

But what are these principles that Du Châtelet, like Descartes before her, identifies as setting initial constraints on scientific discovery? Once again, in *general*, there is remarkable overlap between Descartes and Du Châtelet. For both, there are epistemological principles of knowledge – clear and distinct ideas for Descartes, the principles of contradiction and sufficient reason for Du Châtelet (IP §4 and §8). Du Châtelet writes that 'a hypothesis… [must] not be in contradiction with the principle of sufficient reason, nor with any principles that are the foundation of our knowledge' (IP §61). But for both thinkers, principles constraining the positing of hypotheses also include metaphysical principles that can be derived directly from foundational principles of knowledge. For Du Châtelet, one can deduce from the principles of our knowledge, or from principles of knowledge together with empirical data from the world itself, a range of metaphysical truths which serve as principles which constrain scientific practice, including the range of possible hypotheses. She herself does exactly this in the first eleven chapters of the *Institutions*, deriving metaphysical truths about, for example, God (chapter 2), the nature of space (chapter 5) and time (chapter 6),[20] and the elements of matter (chapter 7). Other chapters in the early half of her text – those on the nature of bodies (chapters 8 and 10), and the nature of motion and its laws (chapter 11) – require a bit more discussion for they indicate a crucial point of departure from Descartes, and I turn to these in section III below.

Again in line with Descartes, Du Châtelet falls squarely in the Aristotelian tradition concerning hypotheses: they aim at identifying real causal truths about the natural world and are not mere (instrumental) calculating devices. This is front and center in her opening comments on hypotheses: 'The *true causes* of natural effects and of the phenomena we observe are often so far

[20] Du Châtelet reverses her position on space and time in the *Institutions*, endorsing Leibniz's position over that of Clarke and Newton, which latter she had presumably endorsed in 1738. See her letter of 10 February 1738 to Maupertuis in *Lettres*, vol 1, #120, p. 217, stating that Clarke was correct over Leibniz on all points of their correspondence with the exception of *forces vives*. See Hutton, 'Between Leibniz and Newton: Emilie du Châtelet and Samuel Clarke' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012), 77-96.

from the principles on which we can rely and the experiments we can make that one is obliged to be content with probable reasons [hypotheses] to explain them' (IP §53 emphasis added; c.f. §56). She anticipates that these probable reasons aim at truth about the causal structure of the world and not just an accurate description and prediction of phenomena, a point which will become abundantly clear as her chapter on hypotheses proceeds, and as I will show in what follows.

Du Châtelet thinks hypotheses are useful (in addition to their providing a necessary step in scientific method) because 'when a hypothesis is once posed, experiments are often done to ascertain if it is a good one, experiments which would never have been thought of without it' (IP §58). They are useful, that is, for suggesting innovative experiments. Such experiments can add plausibility to a hypothesis if the results of them indicate that the hypothesis captures the truth, but a single experiment which falsifies a hypothesis is enough to require the scientist to reject it, or at least, to reject whatever part of the hypothesis is deemed faulty, for a hypothesis 'can be true in one of its parts and false in another' (IP §65). As an example to explain how this might be the case, she cites Descartes' hypothesis of a vortex of fluid matter being the cause of the gravitational pull of bodies to the earth. As an example of her remarkable open-mindedness, she rejects the specifics of Descartes' hypothesis in light of Huygen's demonstrations that it does not square with observed facts, while also allowing that 'it cannot be legitimately concluded that a vortex, or several vortices, conceived of in a different way, cannot be the cause of these movements' (IP §65). In this case, then, falsifying data requires that we invalidate only part of Descartes' hypothesis.

So Du Châtelet, like Descartes, takes an extremely friendly view of the role of hypothesis in scientific reasoning. Still, wary of those who make bad use of hypotheses, Du Châtelet puts strict limits on their use, and once again, the overlap in general with Descartes is significant. A hypothesis must 'not only [explain] the phenomenon that one had proposed to explain with it, but also that all the consequences drawn from it agree with the observations' (IP §58). Herein, we have the same idea found in Descartes' defense of his method against circularity, namely, that a good hypothesis will explain a plethora of effects including many not originally under investigation. Again as with Descartes, Du Châtelet believes that the greater number of effects explained by a hypothesis (as well the greater number of experiments which are performed and which turn out as predicted by the hypothesis), the more probable the hypothesis is. Indeed, Du

Châtelet makes the very strong claim that 'hypotheses finally become truths when their probability increases to such a point that one can morally present them as certain' (IP §67). However, the *psychological* context of this passage ('as a very great degree of probability gains our assent, and has on us almost the same effect as certainty') indicates that a highly probable hypothesis merely seems like truth to us and is not to be taken as conclusively true. Thus, we should take Du Châtelet's considered position to be 'that hypotheses become the poison of philosophy when they are made to pass for the truth' (IP, *Avant-Propos* VIII). On this point, Du Châtelet may well diverge slightly from Descartes in that she clearly embraces the respectable epistemological category of the probable, while it may well be that Descartes was never fully successful at embracing this category (Clarke 2011, 259). This departure is surely the result of Du Châtelet's writing a century later by which time that epistemic category would have been well entrenched in theories about scientific practice.

According to Du Châtelet, part of the scientist's job is to 'have certain knowledge of the facts that are within our reach, and to know all the circumstances attendant upon the phenomena we want to explain… for he who would hazard a hypothesis without this precaution would run the risk of seeing his explanation overthrown by new facts that he had neglected to find out about' (IP §61). So the scientist must become acquainted with many empirical facts so as to ensure that she is not ignorant of potentially falsifying data (IP §64).

Du Châtelet's shared ground with Descartes, on the belief that hypotheses gain strength the more phenomena they explain, leads to a further point of overlap, and that is the idea of simplicity and systematicity of causes, and the orderly interconnectedness of cause and effects in the created world. These features are merely implied by Descartes' theory of hypotheses and scientific method, but they are explicitly associated with the principle of sufficient reason, and that principle's *metaphysical* dimension, by Du Châtelet.[21] For not only is the principle of sufficient reason a principle which guides our own search for knowledge, it is a principle which guided God in his choices when creating the world (IP §23) which, as the best possible world, is 'the one where the greatest variety exists with the greatest order, and where the largest number of effects is produced by the simplest laws' (IP §28). 'Without the principle of sufficient reason,

[21] Zinsser discusses this feature of Du Châtelet's thought in Zinsser, 'The Many Representations.' Notably, if Descartes' causal principles ultimately rest upon the idea of universal efficient causation, and if universal efficient causation is an expression of the principle of sufficient reason, then Descartes' causal principles also ultimately rely upon the principle of sufficient reason, even if this reliance is not explicit as it is in the case of Du Châtelet.

one would no longer be able say that this universe, whose parts are so interconnected, could only be produced by a supreme wisdom…' (IP §8). So the ability of hypotheses to explain a plethora of phenomena is a direct result for Du Châtelet, no less than for Descartes, of the real systematicity of the world's causal structure itself.[22] This point drives home the claim I made above that Du Châtelet (like Descartes) is squarely in the Aristotelian tradition with respect to hypotheses; hypotheses are meant to capture the true causal structure of our systematically interconnected world, and are not merely calculating or predictive devices by which the scientist gives an accurate description of the phenomena merely. I will revisit and qualify this claim in the last section of the chapter.

One final constraint Du Châtelet prescribes in the use of hypotheses indicates yet another point of commonality with Descartes. She requires that an 'intelligible' link be articulated between hypothesized cause and observed phenomena which the hypothesis is meant to explain. This is to guard against 'the unintelligible jargon of the Schoolmen' (IP *Avant-Propos* VIII). Later, in posing a contrast between the unintelligible vegetative soul of the Scholastics and intelligible explanations for the production of a plant, it emerges that for Du Châtelet, an intelligible explanation is, broadly speaking, a mechanical explanation according to which one must explain how a mechanism can produce a plant relying, for example, upon an explanation of how each particle of matter is able to produce the effect that it does (IP §10 and §12). Her general commitment, along with Descartes, to mechanism in some form is played out throughout the *Institutions*.[23]

Here, then, is Du Châtelet's definition of a useful hypothesis:

> So hypotheses are only probable propositions, which have a greater or lesser degree of probability according to whether they satisfy a larger or fewer number of the circumstances that accompany the phenomena that we want to explain by means of the hypotheses. And since a very high degree of probability encourages our agreement so as to have nearly the effect upon us as certainty, hypotheses

[22] On this point, I dissent from Janik who believes that Du Châtelet uses the principle of sufficient reason as only a rational, not a causal, principle. Janik, 'Searching for the Metaphysics of Science,' p. 104. Janik, however, seems to implicitly acknowledge that the causal aspect of that principle is at work in Du Châtelet's thought. See *ibid*, pp. 104-5.

[23] Du Châtelet's chapter on hypotheses captures many aspects of Robert Boyle's account of good and excellent hypotheses. See Robert Boyle, 'The Requisites of a *Good Hypothesis* are' and 'The Requisites of an *Excellent Hypothesis* are' in 'Unpublished Boyle Papers Relating to Scientific Method – II', edited by Richard S. Westfall, *Annals of Science* 12.2 (1956), 103-17.

> eventually become truths for us if their probability increases to such a point that this probability can morally pass for certainty.... In contrast, an hypothesis becomes improbable in proportion to the number of circumstances found for which the hypothesis does not give a reason. And finally, it becomes false when it is found to contradict a well-established observation (IP §67). [24]

As I have repeatedly indicated, the points of contact between Du Châtelet and Descartes in their theories of the role of hypotheses in scientific method are many. This is, in some respects, simply to be expected given the nature of hypotheses. But their shared commitments to simplicity and systematicity in hypotheses, and the implication that the world is thus too, as well as their commitments to hypotheses capturing the true causal structure of the world rather than serving as mere calculating and predictive devices, locate both Descartes and Du Châtelet squarely in the tradition of natural philosophy where metaphysical claims undergird claims about physical phenomena. This will not be the last word on this point, however.

3.2 Hypotheses: Metaphysics and Systems

At this juncture, I will pull back from a detailed consideration of Descartes' and Du Châtelet's thoughts on scientific methodology to give a bird's eye, admittedly schematic, account of a few aspects of the rise and fall of the fortunes of hypotheses in the early modern period, specifically looking at a few features of the relation between hypotheses and what was characterized by some early moderns as metaphysical systematizing and speculation.

One common tendency among some – but by no means all – thinkers of the seventeenth through to the eighteenth centuries is to align the use of hypotheses with speculative philosophy, with 'speculative philosophy' encompassing a wide range of ideas. According to this approach, a theorist who uses hypotheses in natural philosophy is also marked as a metaphysical systematizer. Moreover, many of those who make this connection disparage the use of hypotheses for this reason. As Peter Anstey notes, such thinkers 'agreed that hypotheses were the province of the speculative philosopher…. 'Hypothesis' in early modern natural philosophy

[24]Du Châtelet's work on hypothesis forms the foundations for the 1765 *Encyclopédie, ou Dictionnaire Raissonné des Sciences*, edited by Denis Diderot. Large portions of the entry on 'hypothesis' are lifted almost verbatim from chapter 4 of her *Institutions*. For a discussion of the role various concepts from her *Institutions* play in the *Encyclopédie*, see Koffi Maglo, 'Mme Du Châtelet, l' *Encyclopédie*, et la philosophie des sciences' in *Émilie Du Châtalet: éclairages & documents nouveaux*, edited by Ulla Kölving and Olivier Courcelle (Ferney-Voltaire: Centre International d'Étude du XVIIIe Siècle, 2008), 255-66.

could refer to a causal explanation, a metaphysical principle or maxim… or even a theory or system of doctrines such as the corpuscular hypothesis or the Copernican hypothesis. The word was also used as a synonym for conjecture, speculation and so on'.[25] Thus, a number of philosophers in England during the seventeenth century voice these sorts of reactions against hypotheses: 'I do not here reckon the several *Hypotheses of Des Cartes, Gassendi,* or *Hobbes*, as Acquisitions to real Knowledge, since they may only be Chimaera's and amusing Notions, fit to entertain working Heads.'[26] And:

> Experimental Philosophy reduces phenomena to general Rules & looks upon the Rules to be general when they hold generally in Phenomena…. Hypothetical Philosophy consists in imaginary explications of things & imaginary arguments for or against such explications…. The first sort of Philosophy is followed by me, the latter too much by Cartes, Leibniz and some others.[27]

Related to this general outlook is the belief that, crudely put, Descartes was an example of a metaphysical systematizer who relied excessively on hypotheses, that members of the Royal Society in Britain and Academie Royale in France eschewed both metaphysics and hypotheses, preferring a scientific focus on empirical facts, and that Newton captured the value of the Societies' approach in his scientific practice and in his famous motto *hypotheses non fingo*.[28] Among the most vocal spokespeople in eighteenth century France for this approach was Voltaire who, in his *Element of Newton's Philosophy*, contrasts Descartes and Newton along exactly these lines.[29] According to this developmental, historical story, the anti-metaphysics, anti-hypothesis

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[25] Peter Anstey, 'Experimental versus Speculative Natural Philosophy' in *The Science of Nature in the Seventeenth Century*, edited by Peter Anstey and John A. Schuster (Dordrecht: Spring, 2005), 223-24.

[26] William Wotton, *Reflections Upon Ancient and Modern Learning* (London, 1694), 244.

[27] Isaac Newton, 'Draft of a letter to Roger Cotes, March 1713' in *The Correspondence of Isaac Newton*, 7 volumes, edited by H.W. Turnbull, J.F. Scott, A.R. Hall, and L. Tilling (Cambridge: Cambridge University Press, 1959-77), 398-90. This associating of hypotheses with overly imaginative speculation is articulated by many thinkers at the time including Robert Boyle, Margaret Cavendish, Oliver Goldsmith, Henry Pemberton, Henry Powers, John Sergeant, Willem Gravesande, and Thomas Sprat. See Anstey, 'Experimental versus Speculative', *passim*, and Lauden, *Science and Hypothesis*, 103, fn. 3.

[28] Du Châtelet herself has a much more subtle – and arguably accurate – understanding of Newton's methodology than do many of her contemporaries including, for example, Voltaire. More recent commentators who have looked more closely at Newton's approach to hypotheses include I Bernard Cohen, 'Hypotheses in Newton's Philosophy' *Physis Rivista Internazionale di Storia della Scienza* 8 (1966), 163-84; and N.R. Hanson, 'Hypotheses Fingo' in *The Methodological Heritage of Newton*, edited by Robert E. Butts and John W. Davis (Toronto: University of Toronto Press, 1970),14-33.

[29] For Voltaire's challenge of Descartes' philosophy specifically because of his use of hypotheses, see Voltaire, *Eléments de la philosophie de Newton*, edited by Robert L. Walters and W.H. Barber in *The Complete Works of*

approach had truly triumphed in France by the 1740s with the occasional blip represented by, for example, Du Châtelet and her championing of hypotheses.[30] This narrative only serves to underscore a Descartes-Du Châtelet conceptual alliance, which would support the affinity noted in the previous section.

There is, obviously, a great deal of complexity in the brief comments provided above on the relations among hypotheses, metaphysical systematizing, and speculative philosophy, and the portrayal above is admittedly crude.[31] I cannot provide a full account of these issues here, but I can get some precision on a few crucial points in order to proceed with the work of this chapter. Specifically, I will make use of Etienne Bonnot, Abbé de Condillac's *Traité de systèmes* of 1749[32] to gain this precision, since he composed this text precisely to make sense of the many and tortuous contours of the 'systems debate' as it developed in the early eighteenth century – a debate concerned precisely with the nest of issues just sketched. Condillac's book also gives us some traction by which to locate Descartes and Du Châtelet within this debate, and it with Condillac's articulation of three forms of systematizing that I shall start.[33]

Condillac begins his book with a definition of a *system*:

> A system is nothing other than the arrangement of different parts of an art or science in an order in which they all lend each other support and in which the last ones are explained by the first ones. Parts that explain other parts are called

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Voltaire, volume 15, general editors W.H. Barber and Ulla Kölving (Oxford: University of Oxford Press, [1738] 1992), pp. 337, fn. 9; 401; and 699-700. For praise of Newton for avoiding the use of hypotheses, see *ibid.*, p. 729. For a direct comparison of the two to Descartes' disadvantage and Newton's advantage, see *ibid.*, pp. 733-4.

[30] Jeff Loveland, *Rhetoric and natural history: Buffon in polemical and literary context,* in the series *Studies on Voltaire and the Eighteenth Century*, issue 3 (Oxford: Voltaire Foundation, 2001): pp. 100ff. Loveland also includes Dortous de Mairan and Jean Le Rond d'Alembert among those championing hypotheses and systems.

[31] For another very satisfying approach to Du Châtelet, hypotheses, systems and the role of experiment, with different of her contemporaries serving as the intellectual context, see Robert Locqueneux, 'La physique expérimentale ver 1740: expériences, systèmes et hypotheses' in *Cirey dans la vie intellectualle: La réception de Newton en France*, edited by François de Gandt *Studies on Voltaire and the Eighteenth Century*, issue 11 (Oxford: Voltaire Foundation, 2001): 90-111.

[32] Etienne Bonnot, Abbé de Condillac, *A Treatise on Systems*, translated by Franklin Philip with the collaboration of Harlan Lane (Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers, [1749] 1982).

[33] For sustained treatments of Condillac's thoughts on systems, see Ellen McNiven Hine, *A Critical Study of Condillas's* Traité des systèmes (The Hague: Martinus Nijhoff Publishers, 1979); Robert McRae, *The Problem of the Unity of the Sciences: Bacon to Kant*, chapter V: 'Condillac: the Abridgement of All Knowledge in "The Same is the Same"' (Toronto: University of Toronto Press, 1961); Leonora Rosenfeld, 'Condillac's Influence on French Scientific Thought' in *The Triumph of Culture: 18th Century Persepctives*, edited by Paul Fritz and David Williams (Toronto: A.M. Hakkert Ltd, 1972); and Jeffrey Schwegman, 'The "System" as a Reading Technology: Pedagogy and Philosophical Criticism in Condillac's *Traité des systèmes*'. *Journal of the History of Ideas* 71.3 (2010), 387-409.

> principles, and the fewer principles a system has the more perfect it is. It is even desirable to reduce all principles to a single one (Condillac [1746] 1982, p. 1).

Notably, Condillac himself here seems to favor an approach which aims at *simplicity* in systems in the spirit of both Descartes and Du Châtelet who favor systems in which few principles (understood as causes) are able to account for a large number and wide range of phenomena.

According to Condillac, there are three types of systems classified according to the types of principles used therein. Condillac believes that only the third type of system can be legitimately used in physics. The first type of system relies upon abstract principles considered 'so evident or so well-proven that we cannot cast doubt upon them' (*ibid*., p. 1), and Condillac identifies Descartes as among those who ascribe to these sorts of principles, and therefore this first type of system (*Ibid.*, p. 2) which Condillac dubs 'abstract systems' (*ibid.*, p. 3). The second type of system relies upon 'suppositions formulated to explain things that we could not otherwise give an account of' (*ibid.*, p. 2), and these are what Condillac calls systems based on hypotheses (*ibid.*, p. 3). Third '[t]rue systems, the only ones that merit the name, are based on principles of' a third kind, namely 'well-established facts [taken] for principles' (*ibid.*), and Condillac indicates that for a fact to be well established it must be based on observations of 'many phenomena' (*ibid.*).

Condillac's general sketch of three sorts of systems immediately complicates my project in a number of ways. First, this sketch problematizes the tendency to equate hypotheses with metaphysical systematizing since according to Condillac's sketch, making use of hypotheses is just one form of systematizing, and arguably not the worst. Moreover, according to Condillac, Descartes belongs to the group of abstract systematizers, even while he also would seem to fit nicely among those who make use of systems based upon hypotheses given what I showed in the previous section. Related, it would seem that Du Châtelet may well be one who ascribes to systems based upon hypotheses. Finally, as we shall see, hypotheses can be radically different things in different thinkers, a fact Condillac himself knows, and this will complicate Condillac's three categories of systems as well as where to locate a thinker such as Du Châtelet in his scheme. To address some of these complicating factors, I shall now turn to a slightly deeper analysis of Condillac's thinking on systems in order to get a sharper picture of our two thinkers' roles in the theory of systems, which Condillac develops.

Condillac believes that abstract systems are useless and thus misused by those who employ them. His attack upon such systems is multi-pronged, but I will focus on two related criticisms. The first criticism is his denial of doctrine of innate ideas. He opens his consideration of the first type of system by noting that according to the champions of such systems 'in creating our souls, God is satisfied with engraving certain general principles thereon, and the knowledge that we acquire later consists merely of our own deductions from these innate principles' (*ibid.*, p. 6). According to Condillac, the doctrine of innate ideas – ideas which are allegedly the source of the abstract principles which are the mark of abstract systems – is indefensible at least in part because the champions of innate ideas (Descartes is identified here) do not know what ideas are, especially not the indeterminate and vague abstract ideas they identify as being those principles engraved upon our souls by God (*ibid.*, pp. 37-8). The second, related, criticism of abstract systems starts from Condillac's own conception of what an idea is, namely, an image in the mind derived from a determinate object. An *abstract* idea, then, is not an image but can only be the result of the mind deriving a general principle from several ideas of sensed particulars (*ibid.*, pp. 33-6). Given this conception of what an idea is, those who embrace innate, abstract ideas (the abstract systematizers) erroneously use as starting points principle which are actually end points, that is, the end result of abstraction (*ibid.*, p. 3; c.f. p. 123).

Descartes, as abstract systematizer, is thus faulted for his first methodological step I identified in the previous section: setting inviolable first principles derived from rational intuition, a derivation Descartes believes possible because these principles are innate and not traced back to original sensations. Note, however, that Descartes' method *also* makes use of hypotheses as a second step, and so would seem prone to whatever criticisms Condillac launches against systematizers who make use of hypothesized principles. And indeed, Condillac acknowledges that there can be systematizers who draw on different kinds of principles thus creating new, mixed, systems. Still, 'as [such mixed systems] would always be more or less related to one of the three I [Condillac] have just mentioned, there is no need to make up new classes of them' (*ibid.*, p. 3). And Condillac himself clearly associates Descartes most squarely with abstract systems.

In expanding upon the second type of system – systems based upon hypotheses – Condillac identifies two different types of hypotheses classified according to the degree of likelihood that they are true:

> … hypotheses or suppositions (for we use these words interchangeably) are not only means or hints in the search for truth, they can be principles, that is, first truths that explain others.
>
> They are means or hints because observations, as we have remarked, always begin by groping. But hypotheses are principles or first truths when they have been confirmed by new observations which we cannot doubt (*ibid,* p. 123).

Systems based upon hypotheses that are principles or first truths are preferable to systems based upon hypotheses which are mere 'hints' or suspicions that have not been properly established as likely truths. Condillac points to two conditions which help establish the truth of hypotheses, thus making their use as first principles in systems acceptable. First, the investigator must develop an exhaustive catalog of all possible explanations, and second, the investigator must have some way of eliminating false hypotheses and 'for confirming our choice or that makes us recognize our error' (*ibid.*, p. 123). As long as these two conditions are met, hypotheses are exceedingly useful; indeed 'they are even absolutely necessary' (*ibid.*, p. 124). Condillac goes on to argue that systems based upon hypotheses are most useful in pure mathematics because we are less likely to take false hypotheses as true in that field. This is because we have clear and distinct ideas of numbers and have methods by which we can check our conclusions. Being conceptually dependent upon mathematical methods, astronomy also makes good use of hypotheses. Conversely, it is much more difficult to use hypotheses well in physics, and his arguments here seem to rely upon criticizing the way his near predecessors have misused hypotheses in physics. For example, mechanists hypothesized about the subvisible mechanisms by which visible change supposedly comes about without any way open to them to test those hypotheses (*ibid.*, p. 125), and they assume without warrant that the subvisible world will be constituted by materials and mechanisms like those we observe at the visible level (*ibid.*, p. 126). While Condillac primarily faults Descartes as an abstract systematizer, he also notes that Descartes makes use of hypotheses as foundational principles, but that Descartes uses hypotheses in physics which are mere hints and therefore can not be taken as true. Thus, according to Condillac, Descartes is guilty also for invoking systems based upon the wrong – and not the useful – kind of hypothesis (*ibid.*, pp. 126-7).

The third, and for physics, only valid, systems are those whose principles are verified by experience, and 'we can construct true systems only in cases where we have enough observations

to grasp the interconnection of phenomena' (*ibid.*, p. 139). Since we cannot observe 'the elements of things' or original causes, we must rely upon systems whose principles are the 'remote effects' of those causes. 'Consequently the best principles that we can have in physics are phenomena that explain others but which themselves depend upon unknown causes' (*ibid.*, p. 139). These third, valid systems are employed profitably across a wide range of fields of study, from politics, to physics, to the fine arts. In physics, the two fundamental principles are the phenomena of extension and movement, phenomena on which several others depend. We take these two principles as fundamental because we cannot go back any further *through experience* to any other principle which explains them (*ibid.*, p. 144). Some so-called principles should be dismissed from systems in physics because they are based on abstraction and not direct experience. Force, for example, 'is the name of a thing about which we have no idea' because we cannot observe it; we merely observe its supposed effects, namely, motion (*ibid.*, p. 144). In the practice of physics, we may have to proliferate principles in order to explain some phenomena if our science has not progressed to the point of explaining complex phenomena through a small number of principles. Condillac takes principles established through observation to be *facts*. From fundamental principles, or facts, the physicist must explain through a clear relation – e.g., clearly demonstrated and/or observed – how other phenomena derive from those principles, and how various phenomena interrelate. 'If as we collect phenomena we arrange them in an order in which the first ones explain the last ones, we shall see them shed light upon each other' (*ibid.*, p. 145). Building such an interrelated system of phenomena will also suggest to the physicist experiments that need to be done in order to elucidate further, unknown relations among phenomena, and the physicist will often have to rely upon hypotheses in the framing of these experiments (*ibid.*, p. 145). In such cases, the aim is for these hypotheses to be confirmed by experience, by which Condillac seems to mean that hypotheses which can be used to explain multiple effects are more likely to be true than those that cannot be so used.

> Hypotheses and facts that serve as principles differ in that a hypothesis becomes more uncertain as we discover more effects that it cannot explain whereas a fact always has the same certainty and cannot cease to be the principle of phenomena that it has once explained. If there are effects that it does not explain, it should not be rejected. We should work to discover phenomena connected with the principle, such that the principle makes all of them into a single system (*ibid.*, p. 146).

So here, too, is an example of a mixed system in which both systems of the second type (based on hypothetical principles) and systems of the third type (based on principles verified by experience) are found together.

With Condillac's framework on three types of systems, and the principles on which they are based, before me, I can now return to my discussion of Descartes and Du Châtelet on hypotheses in order to draw important contrasts between them, and thus in order to locate Du Châtelet in the early modern quarrel over systems theory as captured by Condillac's scheme.

3.3 Descartes and Du Châtelet on hypotheses II: divergences

In the broad strokes (and, I think, generally true) picture often offered of Du Châtelet's merging of Newtonian physics with *some* kind of metaphysical underpinning, one of Du Châtelet's primary concerns with Newton is his refusal to speculate at an early stage in scientific investigation on the possible metaphysical causes for the phenomena that he so powerfully describes in mathematical terms (e.g. Janik 1982, pp. 93 and 102). An adequate investigation of Newton's complex account of the role of hypothesis in physics, and Du Châtelet's understanding of that account, will need to be dealt with elsewhere, but let me here note her reaction to Voltaire's interpretation of Newton, an interpretation that was extremely common in Du Châtelet's intellectual circle. Du Châtelet rejects Voltaire's adherence to an extreme interpretation of the 'hypotheses non fingo' doctrine combined with the primacy he places on God's will over his intellect. Faced with naturally inexplicable phenomena, Voltaire does not suggest the search for, in his words, 'sufficient causes' in nature for those phenomena; rather we should bear in mind that the first cause of nature's activities is to be referred to God's will and power.[34] It is enough to appeal to this as the source of phenomena, and then leave it at that. This, protests Du Châtelet, is an appeal we ought not to make as scientists (IP §162), for it is an utterly unscientific approach to a natural problem, putting the cause of the phenomena wholly beyond our ability to investigate it.[35]

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[34]Voltaire to Maupertuis, 1 October 1738 in Voltaire, *Correspondence and related documents*, ed. Theodore Besterman (Genève: Institut et Musee Voltaire, 1968-77), letter #1622. See Barber, 'Mme Du Châtelet', p. 220 for a detailed account of her rejection of Voltaire's extreme reaction against metaphysics.

[35] Janik notes this as one of Du Châtelet's central physico-theological interests with her opinion solidifying in favor of intellectualism by 1740. See Janik, 'Search for the metaphysics of physics', pp. 101 and 104. See also Robert Locqueneux, 'Les *Institutions de physique* de Madame Du Châtelet, ou un traite de paix entre Descartes, Leibniz et Newton' *Revue du Nord* 77.312 (1995): 866. For her disagreement with Voltaire's approach because of its disadvantage in science, see Hagengruber, 'Émilie Du Châtelet between Leibniz and Newton: The Transformation

Descartes' brand of voluntarism (if I might even call it that)[36] is significantly more subtle than what we find in Voltaire. But it is nonetheless at the root of one of two critical points of divergence, which I wish to highlight between Du Châtelet's and Descartes' use of hypotheses in science. This first point of divergence is that Descartes' first principles include robust claims about metaphysical truths that we supposedly know innately, while Du Châtelet's first principles are simply rules of reasoning that deliver much less robust truth claims about metaphysics. Their second major divergence is that when it comes to testing hypotheses, experience ends up playing very different roles for these two thinkers. The first point of departure shows that Descartes belongs squarely in Condillac's first sort of systematizes (as noted in the previous section), while Du Châtelet does not fit in that category at all. The second point of departure shows that, to the degree that Descartes fits into Condillac's second sort of systematizer, he does so by relying on hypotheses that remain mere hints. Du Châtelet, by contrast, fits squarely into that second group, but by relying upon hypotheses that are well established. I deal with each of these two divergences in turn.

It is true that Descartes believes that God freely created, for example, the eternal truths of math and logic, rather than merely recognizing these with his intellect, and being bound to create them (AT I, 145 & 152/CSMK 23 & 25). And it is true that God freely willed the laws of nature and the essence of matter that he did, and that he could just as well have done otherwise. But unlike some of his more extreme voluntarist contemporaries (Gassendi, for example) this does not translate into the necessity that we must rely only upon observations of the natural world in order to know what God did, in fact, choose to create. For unlike Gassendi,[37] Descartes posits two further constraints on the doctrine of the primacy of God's will, constraints that greatly impacts his methodology. First, God will never change what he has chosen at creation – once they are created, the eternal truths and the laws of nature, are immutable, and God's unitary and immutable nature would not allow him to capriciously will that things now be different (AT I,

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of Metaphysics' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012), 1-60.

[36] Descartes himself refuses to privilege God's will over his intellect, or indeed any 'part' of God over another since God is a perfect unity and does not, therefore, have parts. It is a mark of our epistemic limitation that we have to think of him as having parts with one (e.g. will) taking precedence over another (e.g. intellect). See AT I, 152-3; CSMK 25-6.

[37] Pierre Gassendi, *Disquisitio metaphysica seu dubitationes et instantiae adversus Renati Cartesii metaphysicam et responsa*, edited and translated into French by Bernard Rochot (Paris: Vrin, 1962). In Pierre Gassendi, *Opera omnia*, 6 volumes (Lyon: 1658), vol. III.

145-6/CSMK 23; AT IV, 315-16/CSMK 273). Second, God 'implanted' knowledge of the eternal truths and the essence of matter, into the minds of his rational creatures, so that these truths 'are all *inborn in our minds*' (AT I, 145/CSMK 23). This is the doctrine of innate ideas which both characterizes Descartes' metaphysics of the knowing subject, and lands him squarely in Condillac's first, disparaged, category of abstract systematizers.

These two constraints on Descartes' belief in the primacy of God's will over his intellect explain why we can proceed in science as we do, and they explain exactly how hypothetical thinking enters into this project. It also shows the points of friction between Descartes and Du Châtelet on that front. I will underscore three points. First, Descartes' particular views on the creation of eternal truths lend support to his truth criterion of clear and distinct ideas. However he might have arrived at the criterion, Descartes claims in the *Principles*, for example, that whatever we clearly and distinctly perceive must be true because of the fit between our ideas of the world and the world itself, ensured by a benevolent God in his creation of both that world and of rational creatures with innate ideas of it (AT VIIIa16-17/CSM I, 207). Importantly, and this leads to the second point, this truth criterion applies equally to truths of math and logic on the one hand, and truths about the essence of matter, the role of God in nature, and perhaps even the laws of nature (AT VI, 41/CSM I 131; see also AT VIIIa, 33/CSM I, 217) on the other hand. And so, second, the rationally intuited first principles noted in the first part of the paper that must constrain any hypothesis the scientist might posit to explain our observations of nature include absolutely *inviolable* metaphysical claims about the nature of the created world. A fairly robust, and in principle untouchable, systematic metaphysics is worked into Descartes' theory of scientific practice before the activities of positing hypotheses even begin. Third, Descartes' beliefs regarding the relation between God's will and intellect make meaningful the search for metaphysical causes that actually do give rise to the phenomena of nature. While God is not necessitated to choose as he did, as Descartes tells Mesland (AT IV, 118-19/CSMK 234-5), God did will that his choices be necessary once instituted. We can therefore depend upon the immutability of nature's laws to help us find the most likely causal chains that give rise to observed effects, and we can rest assured that the rational structure of the world will match our intuition of it.

Du Châtelet has no quarrel with the basic spirit of this third point. Indeed, it is her own search for a rational underlying structure of nature – a systematic explanation for the kind of

systematic description given by Newton – that separates her from Newton (and Voltaire) whom, she believes, cannot provide this precisely because of what she sees as the capriciousness of God's will as they conceive it. But she does have serious quarrels with the first two points. Right at the outset of her *Institutions*, she dissents from Descartes' appeal to clear and distinct ideas, asserting that these are really just clear and distinct internal sentiments that give us no knowledge at all of the truths of the world (IP §2). Because of his mistake on this point, Descartes is led, Du Châtelet believes, to the wrong set of first metaphysical principles. Paramount here are Du Châtelet's beliefs that Descartes is committed to a conception of matter as extension that is wholly passive (IP §2)[38] and extended everywhere with no empty space, and that Descartes is therefore committed to the ancillary beliefs that God as the proximate source of all motion in the world, and that matter must move in vortices (IP §138-141).

And so it would seem that Du Châtelet's dissent from Descartes is not in his general approach of positing hypothetical metaphysical causes to fill the gap between *a priori* first principles and empirical facts of the matter. Rather, her dispute is with the very nature of the first metaphysical principles themselves, a fact that can be traced back to Descartes' belief in the primacy of God's will, and the consequent need to ensure the veracity of our knowledge of the metaphysics of the world by appeal to our innate ideas of those first principles. Contrasting these two thinkers on their first principles *of knowledge* shows a stunning departure between them on the nature of the *metaphysical* first principles, which set constraints on hypothesizing. Du Châtelet's two primary first principles of knowledge are the principle of contradiction – 'the basic axiom upon which all truths are founded', which is consequently the foundation of all certainty (§4) – and the principle of sufficient reason (§8). The principle of contradiction is foundational in all our thinking. These two principles operate *not* by opening up a category of metaphysical truths that are innate to our minds. Rather, they operate by giving universal (perhaps one would want to call these innate)[39] *procedures* for delineating what is possible from

[38] Importantly, while Du Châtelet may believe Descartes is committed to the passivity of matter, this may not be Descartes' own view. Indeed, Descartes' Sixth Meditation argument for the existence of body relies upon there being an active principle within material substance as the cause of my ideas of bodies. I am grateful to Eileen O'Neill for bringing this point to my attention.

[39] Hagengruber thinks Du Châtelet is committed to 'innate ideas' in opposition to Locke, and while I agree that she departs from Locke on this point, I do not think she is thus thrust directly into Descartes' camp on the issue of nativism (see below). See Ruth Hagengruber, 'Émilie Du Châtelet between Leibniz and Newton: The Transformation of Metaphysics' in *Émilie Du Châtelet: Between Leibniz and Newton*, edited by Ruth Hagengruber (London: Springer, 2012), 1-60.

what is impossible, and then for determining what is necessary and what is actual (as opposed to non-actual) from among the range of possibilities.

While I cannot here do full justice to Du Châtelet's account of the first principles of knowledge, I provide some essential background to these principles in order to elucidate her departure from Descartes on the role of hypotheses in natural philosophy. At its most basic, Du Châtelet's principle of contradiction seems to be the principle that for any proposition *p*, if *p* implies a contradiction, then *p* is false: 'For, if one once granted that something may exist and not exist at the same time, there would no longer be any truth…' (IP §4). According to Du Châtelet once this principle as stated is acknowledged, one can divide claims into the impossible and the possible: 'It follows from this [principle] that the impossible is that which implies contradiction, and the possible does not imply it at all' (IP §5). The possibles include the possibilities from among which God created the world.

But the principle of contradiction does more work for Du Châtelet than just separating out the possible from the impossible. It secondarily divides the category of the possible into truths that are necessary from those that are contingent. At this second stage, she seems to be employing a new conception of the principle of contradiction. To show this, I examine her way of distinguishing between necessary and contingent truths. Necessary truths are 'truths which can only be determined in a single way, for this is what is meant by the term *necessary*' (IP §7). Immediately after this (admittedly odd) definition she contrasts necessary truths with contingent truths, 'that is to say, when a thing can exist in various ways' (IP §7), indicating that necessary truths are claims about things that can exist in only one way. To use her own examples to further clarify (IP §8), geometrical truths are necessary because a triangle (generally conceived) can exist in only one way, i.e., it is a figure whose three angles added together are equal to the sum of two right angles. Conversely, truths about the posture Du Châtelet finds herself in are contingent because she can exist in many ways, i.e., standing, sitting, lying down and so forth. Implicit here is a version of the principle of contradiction which states that for any proposition, *p*, if *p* is or is reducible to an identical proposition, then *p* is a necessary truth. For 'triangle' and 'a figure whose three angles added together are equal to the sum of two right angles' can be reduced to an

identity statement (triangles can exist only in that one way) while 'Du Châtelet' and 'sitting down' cannot be reduced to an identity statement (Du Châtelet can exist in many other ways).[40]

According to Du Châtelet, the principle of sufficient reason is '[t]he principle on which all contingent truths depend…' (IP §8). Given what follows, the most consistent way to interpret Du Châtelet's claim here is *not* to assume that the PSR picks out all contingent truths, for this is clearly the work of the PC (when that latter principle separates out necessary from contingent truths). Rather, Du Châtelet seems quite clearly to mean that the PSR explains why the contingent truths *that actually obtain in the world* do obtain. So, immediately after her definition of the PSR given above, she writes that:

> When asking someone to account for his actions, we persist with our own question until we obtain a reason that satisfies us, and in all cases we feel that we cannot force our mind to accept something without a sufficient reason, that is to say, without a reason that makes us understand *why the thing is what it is*, rather than something completely different (IP§8, emphasis added).

According to this interpretation of the PSR, it is the principle that explains why some contingent truths actually obtain while others do not (there is no sufficient reason for these other to obtain). The PSR is also the reason that led God to actualize this world from among the various possibilities (IP §9); that is, to reiterate the interpretation offered here, it is the principle that explains why our contingent universe exists rather than any number of other such possible, but not necessary, universes.

Du Châtelet puts the principle of sufficient reason to a number of different uses. In one example, in the closing sections of her chapter on the nature of body (§162-4), she makes clear that since full knowledge of contingent truths is too complex for humans to grasp through rational intuition (IP §9), we need to turn to some other way of learning them. But because God is bound by the principle of sufficient reason, we cannot appeal directly to his will as the 'explanation' of these truths, and so we must turn to proximate causes rather than the ultimate cause for explanation. We must investigate nature. Empirical observations that we have of how bodies actually do operate in the actual world will lead the investigator to beliefs about features

[40] Many thanks to Eileen O'Neill for suggesting various ways of interpreting the principle of contradiction, suggestions that helped clarify my thinking on this aspect of Du Châtelet's philosophy.

of bodies, but these features are not taken to be certainly true as a result of their being supposedly known by introspection into our innate ideas (as they are for Descartes).

Still, sometimes Du Châtelet wants more; indeed, she sometimes wants the kind of certainty Descartes believes he has secured for his first metaphysical principles. In the preface to the *Institutions*, she writes: 'It is certain that there are a number of points in metaphysics which lend themselves to demonstrations just as rigorous as the demonstrations of geometry, even if they are different in kind' (*Avant-propos*, XII). So while Du Châtelet's first principles of knowledge do not lead her to posit innate ideas of the essence of matter, for example, they do help to *indirectly* establish what she believes is certainty with respect to some metaphysical claims. As one example, in her chapter 'On the Elements of Matter', she reaches the conclusion that the simple beings out of which matter is composed have no extension and are therefore indivisible (IP §122). Showing how she derives this conclusion from her first principles of knowledge is informative in what it further tells us about those principles. I demonstrate that here by focusing on one strand of her argument – of which there are a few, admittedly none of them without difficulty. Du Châtelet relies on the premise that 'it is finally necessary to arrive at necessary things when explaining the origin of beings' (IP §121). Her argument makes most sense if we take the beings whose origin is in need of explanation to be contingent, material beings. And the context of her argument establishes that the necessary things that will explain the origin of contingent material beings are those things that must exist because without them, there would be no continent, material beings (*pace* our experience of the world). These necessary things need a reason showing why they are necessary, 'and this reason cannot but be the contradiction to be found in what is opposed to it' (IP §121). Atoms cannot be these necessary things that are the explanatory foundation of contingent, material beings; that is atoms cannot be the necessary things out of which contingent, material beings are composed. For atoms, defined as *indivisible*, extended particles of matter are actually *divisible*, and thus their very definition, taken together with the fact of their divisibility, implies a contradiction. So atoms cannot be the necessary beings out of which matter is composed; indeed, they are by definition impossible. How does Du Châtelet justify the claim to atoms' divisibility? She justifies this claim based upon the principle of contradiction: 'there is no contradiction in the divisibility of extended things,' and atoms are extended thing (IP §121). Notice here, she must be relying upon a conceptual divisibility rather than a physical divisibility (for atoms are conceived of as *physically*

indivisible), though one could bolster this argument by claiming that if an atom is conceptually divisible by us, then it is physically divisible by an omnipotence God, and therefore is in neither way indivisible. Indeed, the divisibility of *anything* – atoms or something else – that is extended indicates that extension is *composed* and not simple; it is composed out of the parts into which it can be divided (IP §120). So nothing extended – neither atoms nor any other piece of extension – can serve as the simple beings out of which composed beings are made. Only something unextended can serve as those simple beings (IP §122). Since this conclusion follows from the principle of contradiction, it is a conclusion about the *necessary* constitution of the simple beings of our universe.

One further feature of Du Châtelet's first principles of knowledge emerges from this discussion. The principle of contradiction, in the case of simple beings, establishes both the necessary *existence* and *nature* of simple beings. That is, simple beings are necessarily unextended (their nature), and they necessarily must exist so as to explain the fact of existing composed, extended beings – a fact established by our experience that such composed beings do indeed exist. But this is what we might call a *hypothetical* necessity (as opposed to what we might call an *absolute* necessity). That is, these necessary facts about the simple beings of our world obtain only on the hypothesis that our world actually does exist. God could have created another world from among the possible worlds, and had he done so, then simple beings with the nature of being unextended need not have existed at all.

The above example is just one of many by which Du Châtelet uses her first principles of knowledge (the PC and PSR) to reach metaphysical conclusions about the constitution of the created world. There are other examples. Here, I will simply state some of her metaphysical conclusions, leaving an exposition and analysis of her arguments to those conclusions for another occasion. This current work will allow me to evaluate her theory of hypotheses and scientific method in comparison and contrast with Descartes'. She concludes, for example, that the simple substances (monads) are active due to the force that is parts of their nature (IP §139). This helps to explain the brute fact of motion in the phenomenal world. At that same time, precisely because things do not always move in the natural world, this force must be of two kinds: active force – the source of motion – and passive force, or inertia – the source of rest (IP §142). From her letter to Maupertuis of 30 April 1738 (#122), we know that she was familiar with Leibniz's work on dynamics and metaphysics, having sought out his articles on the topics – articles such as 'The

Brief Demonstration of the Error of Descartes' and 'A Specimen of Dynamics'. So again, phenomena of our actual world that Leibniz details in those papers leads Du Châtelet to the same conclusions regarding the metaphysics of substance that Leibniz reaches – that the necessarily unextended simple substances are also internally active through their possession of force, as this claim helps explain the phenomena of the natural world.[41]

These conclusions, and most especially the fact that Du Châtelet believes she can legitimately reach these conclusions by reasoning from her first principles of knowledge, place Du Châtelet in an interesting position with respect to Condillac's first system – abstract systems based upon innate principles. Both she and Descartes start with first principles of knowledge, but the nature of those principles lead to different forms of nativism. Descartes' clear and distinct ideas, and the truth rule (whatever is clearly and distinctly perceived is true), lead him to the conclusion that humans have access within their minds to a rich store of ideas that inform us of metaphysical truths about the essence of the external, created world. Further, he argues that the truth of these ideas cannot be denied precisely because they are clear and distinct innate ideas placed without our minds by God to inform us of the world's nature. As an example, the claim that matter is extension is a clear and distinct innate idea about the nature of matter itself, and this *metaphysical* first principle that emerges from his first principle of knowledge simply cannot be challenged. Du Châtelet's first principles of knowledge are the PC and the PSR, in the various forms in which she conceives of these principles, some of which are detailed above. For Du Châtelet, these principles cannot be rejected – all humans employ these principles in their reasoning (§4 and §8) – and as such, they represent a sort of nativism at the core of her philosophy as well. For, unlike Locke for example,[42] she does think there are some universally held principles such as the belief that something cannot be and not be at the same time (one possible rendition of the principle of contradiction). Moreover, her claim that extended matter is *necessarily* composed of unextended monads which possess force in Leibniz's sense, seems surely to be an abstract metaphysical principle about the constitution of the created world if ever there were one. On this score, then, she may seem to be committed to a nativism as strong as that

[41] For a careful account of Du Châtelet's metaphysics and relation to mechanics, including difficulties with Du Châtelet's own characterization of the nature of matter, see Carolyn Iltis, 'Madame Du Châtelet's Metaphysics and Mechanics'*Studies in the History of Philosophy of Science* 8.1 (1977), 29-48.

[42] John Locke, *An Essay Concerning Human Understanding*, fourth edition, edited by Peter H. Nidditch (Oxford: Oxford University Press, [1695] 1975, I, ii, §4, p. 49.

of Descartes. Still, a crucial fact separates her from Descartes on this point. Her claim that matter is ultimately composed of monads is not *in principle* beyond discussion and dispute, in the way that Descartes' appeal to clear and distinct perceptions of the innate idea of matter's nature *does* put his metaphysical claims regarding the essence of matter in principle beyond dispute. Du Châtelet's first principles of knowledge have a public, demonstrable nature – one can *demonstrate* when a contradiction occurs, and one can publicly articulate sufficient reasons for choosing X over Y, in a way that one cannot publicly share the clarity and distinctness one feels when perceiving an idea. As a result, it is entirely legitimate for someone to argue against her supposedly *necessary* conclusions about matter by employing those very rules of reasoning (PC and PSR) which she herself uses to reach those conclusions. In brief, her nativism is of a different and weaker form than Descartes' nativism. Hers prescribes innate rules of reasoning that can then be used to develop a metaphysics, while Descartes' nativism directly delivers robust metaphysical information about the world. For this reason, I think it plausible that her metaphysical systems do not belong – as do Descartes' – to Condillac's first and most disparaged category.

Du Châtelet's first principles of knowledge in fact do more to set her clearly apart from Descartes on the role played by metaphysical systems in their science. For precisely because the elements of matter are simple, unextended active monads, what we see around us as extended must be merely phenomenal, and she does endorse this Leibnizian-Wolffian[43] conclusion. Throughout her seventh chapter 'On the Elements of Body', she follows the Leibnizian tradition in concluding that since reason tells us that metaphysical reality must consist in unextended monads, then what we see in nature as extended must be mere phenomena and not real in the fullest metaphysical sense. She concludes, for example, that phenomena, known best through sense, result from the confusion of simple beings (IP §152-5), and that just as monads are characterized by active and passive force (now termed primitive force), so too are phenomenal bodies to be thought of as possessing force – both derivative active and passive force (IP §158-9). Thus, suppositions such as Newton's that the natural world can be described with reference to inelastic, invisible, extended atoms must be suppositions not about ground floor metaphysics but

[43] For an account of the role of Leibniz's, Wolff's, and 's Gravesande's philosophies on Du Châtelet's own thought in the *Institutions*, see Anne-Lise Rey, 'La figure du leibnizianisme dans les *Institutions de physique*' in *Émilie Du Châtalet: éclairages & documents nouveaux*, edited by Ulla Kölving and Olivier Courcelle (Ferney-Voltaire: Centre International d'Étude du XVIIIe Siècle, 2008), 231-42.

about the derivative physical world *which is merely phenomenal* in a broadly Leibnizian sense. This has led Janik to helpfully characterize Du Châtelet's account of the created world as a three-tier account (Janik 1982, 106): the basic metaphysical tier of unextended monads, the subvisible physical tier of (for Du Châtelet) extended matter which is also imbued with derivative force, and the visible physical tier of bodies in motion and at rest.

Without working through the details of her picture, including the coherence or difficulties with it, what this three-tier account permits is greater separation between the metaphysics and the physics, for while we can know *that* there is a systematic interconnection among all elements of the created world – the principle of sufficient reason, together with what we can derive of God's nature seem to establish this for Du Châtelet – we cannot always know the details of that systematicity, and Du Châtelet does not spell out in detail how exactly the metaphysical tier and physical tiers are related to each other (Iltis 1977, 36-7). While it is certainly true that there is some connection between the metaphysics and physics – for example, the force, which belongs to monads explains the brute phenomena of motion and rest in the physical world – physics does enjoy significant autonomy from metaphysics (Janik 1982, 106; Barber 1967, 209).[44] This is in stark contrast with Descartes, for whom the physics grows out of and is sharply constrained by the *known* metaphysical truths in the roots of his "tree of philosophy" (AT IXb, 14; CSM I, 186).

Du Châtelet also uses her principle of sufficient reason to caution the scientist against being *too* systematic, this time within the realm of the physical (as opposed to metaphysical). This becomes clear in her Chapter XVI, 'Of Newtonian Attraction', when she argues against some of Newton's followers who aimed to universalize Newton's attraction. While Du Châtelet argues that Newton's theory of attraction is better than Descartes' vortices at explaining the effects of gravity, and that Newton's theory of attraction can satisfactorily explain a wide range of other phenomena such as tidal movements, the rotation of the earth, and irregularities in the movement of the moon, she criticizes Newton's disciples for extending Newton's theory of attraction too far. Specifically, John Freind and John Keill claim that attraction is a property of matter, which therefore can account for the cohesion of bodies (IP §389-92).[45] According to Du

[44] For a detailed analysis of the seventh and eighth chapters of the *Institutions* in order to make sense of the relation between Leibnizian and Newtonian ideas therein, see Annie Gireau-Geneaux, 'Mme Du Châtelet entre Leibniz et Newton: matière, force et substance' in *Cirey dans la vie intellectualle: La réception de Newton en France*, edited by François de Gandt, in the series *Studies on Voltaire and the Eighteenth Century* (2001): 11, 173-186.

[45] See Hutton, 'Émilie Du Châtelet's *Institutions de physique*', 521ff for a discussion of this point.

Châtelet, the principle of sufficient reason positively rules out extending attraction to account for this phenomenon. How so? The argument seems to be that if attraction (as some sort of *active* principle or force) were to be inherent in bodies, then bodies would always move, contrary to our experience of the physical world. There is no sufficient reason – an inherent *passive* principle within bodies, for example, to counteract the active force – to account for the brute fact that bodies are at rest. [46] So attraction cannot be an inherent property of matter (c.f. IP *Avant-propos* VII). Yet for attraction to explain the cohesion of bodies, it would need to be an inherent property. So attraction cannot be employed as the cause of the cohesion of bodies.

Three crucial points for a consideration of Du Châtelet's scientific method as opposed to Descartes' emerges from this use of one of her first principles of knowledge. First, the role played by our experience of the world is crucial. If our experiences (in this case, bodies at rest) falsify an hypothesis (attraction belongs to matter), then the hypothesis must be rejected. I return to this point below. Second, while Du Châtelet accepts the systematic interconnection of the created world as a feature of it, and as a sort of heuristic in our scientific practice, she puts strict limits on the scientist's appeal to a systematic account of phenomena, especially in light of falsifying experience. So, while the universalizing of Newton's theory of attraction to account for a plethora of phenomena would represent a more interconnected physical system, this systematicity must be rejected in light of our experiences of nature. Finally, while it is true that Du Châtelet thinks a full scientific account must try to give the causes of phenomena we experience – whether those be causes in the basic metaphysical tier or causes in the derivative, subvisible physical tier – when scientists are unable to give a causal account without violating the empirical facts of nature, then they ought *not* to give such an account. One significant addition to her 1742 version of the *Institutions*, in this sixteenth chapter, is a criticism of some of Newton's followers for going too far with causal explanation when they do not yet have the knowledge required to give such explanations. As Hutton points out, in her emphasis on this, Du Châtelet shows a significant affinity with an approach that favors accurate description of phenomena over casual explanations when the latter cannot be given (Hutton 2004a, 229). And I would underscore that it is her use of one of her grounding principles of knowledge, the PSR,

[46] While I have alluded to different ways in which Du Châtelet uses the principle of sufficient reason throughout this paper, I do not offer a systematic account of her employment of that principle. For one such account, see Paul Veatch Moriarty, 'The principle of sufficient reason in Du Châtelet's *Institutions*' in *Émilie Du Châtelet: rewriting Enlightenment philosophy and science*, edited by Judith P. Zinsser and Julie Candler Hayes, in the series *Studies on Voltaire and the Eighteenth Century* 2006:01, 203-225.

which pulls her back from decisively positing causes for physical phenomena, quite unlike Descartes' first principles of knowledge, specifically the truth rule and the association of clear and distinct perceptions with innate ideas, which gives him warrant to make robust (metaphysical) claims.

The points of departure between Descartes and Du Châtelet thus far discussed indicate another way in which surface similarities on method hide deep divergences. Judith Zinsser notes, (Zinsser 2006, 173) and Marcy Lascano expands upon, the similarities in overall method exhibited by Descartes' *Principles* and Du Châtelet's *Institutions*. As Lascano notes, both texts start with indubitable principles of knowledge, which then lead to conclusions about the metaphysics of God. These conclusions allow one to gain knowledge of the structure of the world, which in turn grounds physical laws, which allow the observer to make scientific sense of the world (Lascano 2011, 742-3). As with the two thinkers' approach to hypotheses, the broad moves in their overall method are similar. But just as they diverged on details with their use of hypothesis, so too do they diverge on details here, for right from the start, with their different principles of knowledge, Descartes and Du Châtelet part ways. This becomes very clear when we turn to the second divergence on the issue of hypotheses, which I want to underscore, for it shows how radically our two thinkers depart on how they each weighs the importance of experience, on the one hand, and commitment to systematicity on the other – a point just underscored in Du Châtelet's rejection of universalizing the theory of attraction.

So the first crucial divergence between Descartes and Du Châtelet is that they have very different first principles of knowledge, which lead to very different metaphysical first principles. This divergence leads to the conclusion that Descartes, but not Du Châtelet, belongs in Condillac's first kind of systematizer. The second crucial divergence between Du Châtelet and Descartes comes when we consider where we ought to locate each within Condillac's second category of systems – the category based upon hypotheses taken as principles, and this depends upon seeing the very different role played by experience in each of their natural philosophies.

Recall that Condillac notes that there are two different types of hypotheses, those which are mere hints (bad hypotheses to serve as principles for a system) and hypotheses well-confirmed by new observations (good hypotheses to serve as principles for a system). Recall, too, that he believes that Descartes' hypotheses are mere hints. Yet, given the notable overlap in our thinkers, detailed in section I above, and given that each thinker seems to require hypotheses

to account for more and more observed effects to be taken as increasingly probable, both Descartes and Du Châtelet would seem to both be hypothesizers of the good type. But Condillac's distinction is very helpful for seeing how differently Descartes and Du Châtelet approach the use of empirical data, and why it does make sense to place Du Châtelet, but not Descartes, among those who make use of 'good' hypotheses *as Condillac defines them*. To make this claim, I turn to two features of Du Châtelet's theory of hypotheses, which separate her from Descartes. These are the fact that Du Châtelet believes that hypotheses are useful for suggesting innovative experiments by which to test them, and the fact that one falsifying piece of data is enough to reject a hypothesis or part of it.

McMullin points out that for Descartes it is very difficult to 'devise experiments or observations that would discriminate between the alternatives' that one might entertain as hypothetical causes given the nature of those causes – for example, the precise size, shape and so forth of *subvisible* bits of matter (McMullin 2008, 97). As a result, Descartes' suggestion that we turn to experience to see by which possible means our world came to be is tantamount to his 'issuing a promissory note' (*ibid*. 98). But even when it is possible to test hypotheses, Descartes is not particularly open to such tests and nor is he swayed by their conclusions. We see an example of this in Descartes' exchange with Beeckman (mediated through Mersenne) on Descartes' hypothesis of the fall of the pendulum. This is a hypothesis open to empirical testing for Descartes posits a relation between the vertical and circular speeds of the pendulum which could be subject to experiments, and Beeckman does just this, apparently providing falsifying evidence for the relation Descartes hypothesizes. Descartes famously declares that he can ignore this evidence (AT I, 100). He appeals to the interference of innumerable and uncontrollable factors such as the resistance of air and the material of the pendulum as reason for his being justified in dismissing the falsifying data.[47] Spyros Sakellariadis develops a compelling account of why Descartes believes he is justified in treating falsifying data thus, despite his own insistence on amassing empirical data as part of his scientific endeavor. According to this account, Descartes aims to develop a thoroughgoing general theory of the world, with hypotheses contributing to this theory and holding *in ideal conditions* as described by that theory (1982, *passim*). In laying out his first principles and positing hypotheses of the phenomena he

[47] For discussion of Descartes' rejection of falsifying data, see both McMullin (1990) and Spyros Sakellariadis, 'Descartes's use of Empirical Data to Test Hypotheses' *Isis* 73.1 (1982), 68-76.

observes, Descartes indeed does begin to develop this general, ideal theory. Data that seems to falsify a specific hypothesis cannot be taken as falsifying precisely because it cannot control for innumerable factors, factors which do not expunge the general theory, complete with hypotheses, since the latter are meant to hold in ideal conditions. In an earlier letter on this controversy, when addressing the resistance of air (which he acknowledges may well result in a different relation than the one he hypothesizes holding between the vertical and circular speeds of the pendulum) Descartes writes '[a]s for the cause of the air resistance which you ask me about, in my view it is impossible to answer this question since it does not come under the heading of knowledge…,' for it depends upon too many unknown facts about the air and the pendulum (AT I, 73; CSMK 9-10). He simply dismisses the falsifying data as relying on unknowable factors, which impact real but not ideal conditions; such data does not, therefore, call his general ideal system of the whole world into question.

If Sakellariadis' interpretation is correct (and it is certainly more charitable than simply accusing Descartes of bull-headed dogmatism in his refusal to admit falsifying data), then Descartes clearly favors a systematic, whole account of the world – which is necessarily ideal in the initial development of that holistic account – over empirical data that might seem to falsify a small part of that whole ideal account. This is McMullin's evaluation too. One may assess hypotheses by looking at a number of factors, including their compatibility with first principles, with empirical evidence and with other perceived virtues. According to McMullin, for Descartes 'hypotheses are assessed mainly by their coherence and simplicity… and by their compatibility with the basic laws' (McMullin 1990, 43). Systematicity and simplicity are the prime virtues for a theory and its hypotheses for Descartes.[48]

Du Châtelet clearly departs from Descartes, both on the role of empirical data and consequently on the primacy of empirical data over a systematic theory of the whole world, even while she does believe the world is a systematically, rationally ordered and interconnected whole. As the outline of her theoretical approach to hypotheses in the first section of this paper indicates, she is in theory open to looking for experiments to test hypothesis, and should such an experiment show a hypothesis or part of a hypothesis to be wrong, one must reject the hypothesis. Moreover, the examples she calls upon in that chapter indicate that she is in practice

[48] Vartanian notes that Diderot at least picks up this feature of Cartesian science in the eighteenth century. Vartanian, *Diderot and Descartes*, pp. 154-5.

quite willing to dismiss a theory should falsifying evidence require it. Ptolemy's theory of planetary motion and Descartes' vortical theory of gravity both fall afoul of falsifying data, and so they must be dismissed.

This is easier for her to do because she is not committed, as is Descartes, to *first* working out a general theory of the whole of the world, with hypotheses fitting into that theory. For one, the clear split between metaphysics and the realm of phenomena, and our inability to understand their relation, allows the latter – the realm of physics – to be relatively autonomous from the former. Still, she expects that the realm of phenomena will be a systematically ordered interconnected whole too. Yet her acknowledgment that we cannot know the truth about the systematic whole of the world because contingent truths are too complex for humans to grasp through rational intuition (IP §9), and that we need to turn to proximate causes and investigate nature in order to slowly uncover these truths, indicates a much more empirical approach to discovering, as best we can, the systematic, interconnected nature of the phenomenal world. Her acknowledgment of how little humans know about nature and of how communal and long the scientific process is (*Avant-propos*, XI) is testament to her willingness to acknowledge that we must build slowly from empirical interaction with the world whatever knowledge we might gain of its underlying physical systematicity. This relates directly to her openness to empirical testing of hypotheses and her willingness to dismiss them should falsifying data require this of us. It also places her squarely in Condillac's category of those systematizers who use hypotheses, but *good* hypotheses.

Descartes, despite his apparent openness to such testing is not, in practice, always open to falsifying data, and so cannot be included with Du Châtelet in Condillac's class of good hypothesizers. Nonetheless, I do not think he makes use of 'bad' hypotheses on Condillac's account of what counts as a bad hypothesis. For Descartes' insistence that we wait until all the data is in before we can *know* which data is truly falsifying indicates a significantly different project than Du Châtelet's. For I think Du Châtelet's reticence to believe we can get a thoroughgoing account of the underlying metaphysical account of the world, as well as a thoroughgoing account of the relation between metaphysics and physics, urges her to accept the conclusion that apparently falsifying data is exactly that – falsifying – at least until further data requires we revise that conclusion. Descartes, conversely, sometimes remains agnostic on the true nature of apparently falsifying data, for his concern is with giving the thoroughgoing and

systematic account of the whole of the world. In this way, I qualify my claim made in section I above that both Du Châtelet and Descartes are after the truth of the natural world in their positing of hypotheses. While, in the long run, I do think they share this aim, I also believe that Du Châtelet is willing to embrace a theory of hypotheses that says they aim to save the phenomena, at least in the immediate term as science continues to progress toward the ultimate end of providing a true account of the causal nature of the world. Descartes, at least in the pendulum example, is much more firmly in the camp of providing a true causal account of nature.[49]

There is astonishing general overlap in Du Châtelet's and Descartes' general approach to hypotheses, but as I have argued in this section, there are notable disagreements as well, disagreements which make a significant difference in the kind and role of metaphysical (and for Du Châtelet, physical) systems found in each of their natural philosophies. Undoubtedly, Du Châtelet belongs to the pre-contemporary world of natural philosophers. The role that God plays in her philosophy, according to which he creates a simple, yet rich in detail, systematic and interconnected world, which serves as a premise guiding her in her general theory of the role of hypotheses in physics, ensures that. But just as undoubtedly, she has taken significant steps away from Descartes in her scientific epistemology, which moves her closer to a mindset that see a role for hypotheses to 'save the phenomena' than that which we find in Descartes. Just as Descartes cannot be counted as an early advocate of the hypothetico-deductive method due to the difficulty of his devising testing experiments and due to his approach to falsifying data (McMullin 1990, 44; McMullin 2008, 98), for her very friendliness to this sort of engagement with the empirical, we might well see Du Châtelet as an early advocate of that very modern method. At the same time, her commitment to a role for hypotheses in scientific investigation, and everything that that commitment can tell us about her as a philosopher, makes clear that her thought is not to be assimilated to that of Voltaire's. She was a true original, should there remain any doubt of that point.

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