# Du Châtelet, “Pemberton’s Challenge”, and the justification of scientific knowledge

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**Abstract**

What is the best method for doing physics, and what is the epistemic status of the resulting theoretical claims? I read Du Châtelet’s account of scientific method as a response to “Pemberton’s Challenge,” which asks how we should navigate between, on the one hand, speculative systems whose claims about the natural world lack adequate justification to count as knowledge (which Pemberton attributed to the Cartesians), and on the other making such strict demands that little or nothing would pass muster as natural philosophical knowledge (the certainty of the mathematicians). What is at stake, I argue, is the search for alignment between the *method* for doing natural philosophy and the *epistemic status* of the resulting knowledge claims. I argue that Du Châtelet provided a richly-theorized account of uncertain knowledge, which may have taken Newton’s rules of reasoning as its starting point but soon transcended them. The upshot is a lasting transformation in our understanding of scientific knowledge.

## 1. Introduction

What is the best *method* for doing physics? And what is the *epistemic status* of the resulting knowledge claims? Emilie Du Châtelet was writing at a very interesting time for philosophy of science – after the publication of Newton’s *Principia* but while Cartesian physics was still dominant in France, and before Leibniz’s philosophy was very well known there – when a key issue was method for natural philosophy. What *is* the appropriate method? Does that method enable us to arrive at certainty? If not, what is the status of our knowledge claims, and how is that backed up by our method? This paper is about Du Châtelet’s answer. I will argue that she transformed our understanding of scientific knowledge.

At the time, Newtonian philosophers were rejecting Cartesian methods as too speculative – this is where Newton’s “hypotheses non fingo” comes in – but it wasn’t very clear what they were offering instead, and so what the epistemic status of claims in Newtonian physics was supposed to be. If they lack certainty, why aren’t they just as speculative as Cartesian claims? How, if at all, do they differ? This is a perfect place for philosophers of science to get involved, and that is exactly what Du Châtelet did.

Most famous is chapter 4 of her *Foundations of Physics*.[1] This is her chapter on hypotheses, which even to the modern reader looks strikingly familiar with its emphasis on falsification, avoiding ad hoc hypotheses, and so on. But we’ll come to that. First, I will provide some context, and this will help us see what’s important and interesting about what Du Châtelet had to say about method. I will argue that Du Châtelet is fruitfully read as responding to “Pemberton’s Challenge” (as I will call it). Her method plays two roles in this: it secures epistemic foundations such that scientific knowledge is possible, and it provides robust constraints on scientific theorizing (on a good hypothesis) to underwrite our particular knowledge claims. The upshot is a richly-theorized account of “uncertain knowledge” – an oxymoron at the time – as we will see.

The plan is as follows. In section 2, I explain “Pemberton’s Challenge,” arguing that the philosophical issue at stake was the search for alignment between the *method* for doing natural philosophy and the *epistemic status* of the resulting knowledge claims. In section 3, I present Du Châtelet’s initial response, as found in the manuscript version of the *Foundations*. I suggest that this may be understood as an attempt to better meet the methodological goals indicated in Newton’s rules of reasoning.[2] Then, in section 4, I investigate the revised account in the published version of the *Foundations*, which I argue addresses limitations in her initial response to “Pemberton’s Challenge.” These revisions also radically change the place of Newton’s rules in her philosophy, or so I claim. Section 5 explains the upshot: a lasting transformation in our conception of scientific knowledge. In Section 6, I summarize my conclusions.

## 2. Pemberton’s Challenge

Henry Pemberton was editor of the 1726 third edition of Newton’s *Principia* and author of his own book on Newton’s philosophy, published shortly thereafter.[3] Like other Newtonians, he responded to the perceived failings of the method for natural philosophy found in Descartes’s *Principles of Philosophy* and contributed to the methodological debates prompted by the publication of Newton’s *Principia*. This is the context for Du Châtelet’s intervention. In this section of my paper, I set out the most important features of this context, beginning with Descartes and then turning to Pemberton. As we will see, the central philosophical issue is the search for alignment between the method for doing natural philosophy and the epistemic status of the resulting knowledge claims.

### 2.1 Descartes’s method for natural philosophy

[1] Du Châtelet 1740, translated into English in Du Châtelet 2009 and 2019. See also the second edition, Du Châtelet 1742. Unless otherwise noted, I use the 1740 edition pending availability of an English translation of the 1742. I note any changes relevant to my argument.
[2] Newton 1999, 794-6, reproduced below in Appendix A.
[3] Pemberton 1728.

At the end of his *Principles*, Descartes claims that "there is nothing visible or perceptible in this world that I have not explained" (IV.199) with at least "moral certainty" (IV.205) and – in their general features – absolute certainty (IV.206).[4]

Our interest is in the relationship between his method and the epistemic status of his natural philosophical claims. In Decartes's case, our question becomes: What are the criteria of success for his explanations, and how do these criteria confer certainty (either moral or absolute) upon them?

We can determine the criteria for explanatory success by examining the many examples offered in Parts III and IV of the *Principles*, which encompass a wide range of observable phenomena from planetary motions to fire and magnetism. All the explanations Descartes offers appeal to the shapes, sizes and motions of unobservable micro-particles and follow the same pattern: so long as we are able to construct an account according to which *some* such shapes and motions plausibly yield the observable phenomena, in some qualitative sense, the explanation is successful. In short, our epistemic goal in physics is to demonstrate that natural phenomena are *consistent with* the prior matter theory.[5]

Descartes is aware of the limitation of this criterion of success, and is explicit about it. He writes:

> it suffices if I have explained what imperceptible things may be like, even if perhaps they are not so. …
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> For just as the same artisan can make two clocks which indicate the hours equally well and are exactly similar externally, but are internally composed of an entirely dissimilar combination of small wheels: so there is no doubt that the greatest Artificer of things could have made all those things which we see in many diverse ways. (1991, IV.204)

His criterion allows for – and even embraces – underdetermination in the microscopic explanations we provide for observable natural phenomena.[6]

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[4] Descartes 1991: 283 and 286-7, respectively.

[5] As is well known, Descarte's criterion of clear and distinct ideas is the cornerstone of his epistemology, and also of the methodology by which he sought to pursue his physics. This criterion yields the following resources out of which he seeks to build his physics. First, Cartesian matter is pure geometrical extension, indefinitely divisible and divided into parts by means of motion. Second, Cartesian bodies are parts of matter, with motion and rest as modes. And third, motion is local motion from place to place. This is the matter theory out of which Descartes seeks to explain all the rich variety and change found in the material world. His claim is that it is sufficient: "all the properties which we clearly perceive in [matter] are reducible to the sole fact that it is divisible and its parts movable ... all the variation of matter, or all the diversity of its forms, depends on motion" (*Principles*, II.23).

[6] For discussion of the extent to which Descartes sought to overcome these limitations, see Garber 2000, Hatfield 1988, Laudan 1981, 29-33, and references therein. In my view, ultimately the underdetermination isn't worrisome for Descartes because of the epistemic goal he sets himself for these explanations: they should render the natural world intelligible. Famously, Descartes was seeking to replace Aristotelian physics – with its allegedly *unintelligble* hylomorphism – with an intelligible physics of the "mechanical philosophy". We achieve this intelligibility when we provide an account of natural phenomena consistent with our criterion of clear and distinct ideas. We do this when

At first sight, this limitation might appear to be appropriate epistemic modesty, but in fact it is an epistemic catastrophe. The examples offered by Descartes show that the required consistency is qualitative, not quantitative, and that it is very loose: all that seems to be needed is that we can *imagine* how the phenomena *might* come about using only the resources given in Descartes's matter theory. Once we have done this, we have met the demand that the phenomena be rendered intelligible, and this completes our explanatory task. As a result, we can expect his method to yield multiple acceptable explanations for any and all phenomena. The method provides no resources for resolving this rampant underdetermination, nor even any motivation for doing so.

What, then, is the epistemic status of such explanations? Descartes claims they are "morally certain" by which he means that they "suffice for the needs of everyday life" (IV.205; Descartes 1991, 287). But this trades on an ambiguity between "good enough for everything we have done/observed so far" (because loosely compatible with our observations to date) versus "good enough for what we might do/observe in the future". Given we know that our explanations are wildly underdetermined, what justification do we have for believing that any one of them will be reliable, even for practical purposes, *going forward*? The answer is: none. Given any particular successful explanation, there will be innumberably many others that also meet Descartes's criterion of success, and so we can have no justification for associating any degree of certainty with that explanation. In Descartes's natural philosophy there is a gap between his method and the alleged epistemic status of his knowledge claims as "morally certain": the method does not support this view of their epistemic status. Indeed, it is unclear how these "knowledge claims" count as knowledge at all, given the underdetermination promoted by the method. The upshot is a lack of alignment between the method and the epistemic status Descartes claims for his explanations.

Here is the same point, expressed a little differently. Descartes's method enables us to render the phenomena intelligible. But, if knowledge of how the phenomena arise requires us to be able to determine *which* admissible explanation is true, then the method offers us no help for doing so. Once we have an explanation that meets Descartes's criteria for a successful explanation, the method provides no further resources for finding out whether we have gone wrong. For all we know, we may have committed ourselves to a fiction. The method for generating knowledge claims outstrips the justification for claiming that any particular explanation is true rather than a fiction compatible with some very loose constraints.

Regardless of whether one accepts this damning assessment of the Cartesian method for natural philosophy, what matters for our purposes is that the method was viewed in this way by others at the time. The above feature was criticized by Newtonian natural philosophers explicitly, as we will see below.[7] To the Newtonians, the epistemic permissiveness of the Cartesian method

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we show how the phenomena we experience may arise using only the resources of his matter theory. For the purposes of physics, we do not need to do more.

[7] A second feature was also criticized. The method encourages the development of comprehensive systems covering all phenomena – in line with Descartes's claim to have explained all the phenomena of nature – with the constraints

threatened the very possibility of knowledge in natural philosophy. To make this challenge more precise, I turn our attention to Pemberton.

**2.2 Pemberton on method**

Like other Newtonians, Pemberton objected to the Cartesian method. He describes it thus:

> The custom was to frame conjectures, and if upon comparing them with things, there appeared some kind of agreement, though very imperfect, it was held sufficient. Yet at the same time nothing less was undertaken than entire systems. (Pemberton 1728, p. 3)

Appealing to Bacon, Pemberton affirms "the great absurdity of proceeding in philosophy on conjectures" (1728, p. 10). According to his assessment, this way of proceeding befits only those who believe that "no degree of certainty was ever to be hoped for" (1728, p. 3). In other words, this method is unsuitable for natural philosophy because it cannot deliver claims for which we are justified in claiming any degree of certainty; it cannot deliver scientific knowledge.

To address this, we must adopt a more appropriate method:

> Therefore to decide what causes of things are rightly conceived into natural philosophy, requires only a distinct and clear conception of what kind of reasoning is to be allowed of as convincing, when we argue upon the works of nature." (Pemberton 1728, p. 19)

I reformulate Pemberton's point as a question: What is the method for arriving at claims sufficiently justified to count as scientific knowledge?

Here, Pemberton presents us with a dilemma. On the one hand, the Cartesian method doesn't provide justification for any degree of certainty. On the other hand, if we demand the level of certainty (and corresponding type of demonstration) found in mathematics, we ask for too much; for more than is possible in natural philosophy.[8] Experimental philosophers in the early 18$^{th}$ century were clear that the certainty they associated with mathematics is *not* the kind of knowledge that they were able to deliver in physics. Here is Pemberton again:

> The proofs in natural philosophy cannot be so absolutely conclusive, as in the mathematics… our method of arguing must fall a little short of absolute perfection. (Pemberton 1728, p. 19)

Similar statements are found in many of the self-proclaimed "Newtonian" philosophers of the time.

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on admissible systems being so weak that we again face the issue of having no way to determine which of the many equally admissible systems is true (if any).

[8] Walsh 2025, 243.

The issue being wrestled with is the alignment between the epistemic status of our knowledge claims in natural philosophy and the methods by which we are to arrive at those claims. The Newtonians worried that, on the one hand, the Cartesian methods are too epistemically permissive, while on the other hand the methods of the mathematician are too restrictive, and they sought a middle path. This way of framing the situation was widespread. Pemberton offered a clear and succinct statement of the problem, so I call it "Pemberton's Challenge":

> **"Pemberton's Challenge"**
> **It is only here required to steer a just course between the conjectural method of proceeding, against which I have so largely spoke, and demanding so rigorous a proof, as will reduce all philosophy to meer scepticism, and exclude all prospect of making any progress in the knowledge of nature. (Pemberton 1728, pp. 19–20)**

On the one extreme, we have speculative systems whose claims about the natural world lack adequate justification to count as knowledge. On the other, we place such strict demands that little or nothing would pass muster as natural philosophical knowledge. Either way, our methods are inadequate for the purposes of obtaining knowledge of the natural world. The challenge posed by Pemberton is: how do we steer a "just course" between the two? What is the method by which we are to proceed?

Pemberton offers us the following proposal:

> the only method, that can afford us any prospect of success in this difficult work, is to make our enquiries with the utmost caution… for in this spacious field of nature, if once we forsake the true path, we shall immediately lose ourselves, and must for ever wander with uncertainty. (Pemberton 1728, 5)

But proceeding with "utmost caution" is not a method. Pemberton elaborates by offering his readers Newton's four rules of reasoning.[9] The first three rules tell us about the *inductive method* that is to be used in order to find *causes* and to find the *universal qualities of bodies*. According to Pemberton, they provide the foundation of "that method of induction, without which no progress could be made in natural philosophy." With this method, "[t]he only caution here required is, that the observations and experiments we argue upon, be numerous enough, and that due regard be paid to all objections" (1728, 21). So, the method is "induction," and both the justification for this method and how it is to be implemented in practice are to be found in these first three rules of reasoning. Pemberton offers almost no further guidance or detail.

Nevertheless, if we follow this method then we are justified in admitting our claims as scientific knowledge, according to Pemberton:

[9] Newton, 1999, 794-6. I quote the rules in full in Appendix A, and discuss them in more detail in section 4.

> This is that method of induction, whereon all philosophy is founded, which our author farther inforces by this additional precept, that whatever is collected from this induction, ought to be received, notwithstanding any conjectural hypothesis to the contrary, till such times as it shall be contradicted or limited by farther observations on nature." (Pemberton, 1728, 22)

This is Pemberton's phrasing of Newton's fourth rule of reasoning, which Newton added in the 1726 third edition of the *Principia*. The fourth rule tells us about the epistemic status we should accord to the claims we arrive at by following the method. The method is to gather propositions from the phenomena by induction, and the epistemic status of these propositions is that they "ought to be received," says Pemberton, which means they should be "considered either exactly or very nearly true," according to Newton (1999, 796).

Neither Newton himself, nor his followers such as Pemberton, give us a great deal more to work with.[10] How exactly does this method work, and why should we believe that it yields propositions we are justified in accepting as "exactly or very nearly true"?

A satisfactory response to "Pemberton's Challenge" would provide a detailed account of both the *method* and the *epistemic status* of the resulting natural philosophical claims such that our method justifies our commitment to those claims as scientific knowledge. Though the issue was widely discussed, it remained unresolved among the natural philosophers of the time. This is the situation Du Châtelet encountered in the mid to late 1730s. I think she recognized it as the key methodological challenge concerning the epistemological foundations of physics and sought to respond to it in her *Foundations*.[11]

## 3. Du Châtelet responds

The most famous place where Du Châtelet talks about method is, of course, her chapter on hypotheses. In my view, this is profitably read as responding to "Pemberton's Challenge." Before proceeding, however, there is a *prima facie* puzzle to be addressed. If my proposal is correct then, since Du Châtelet read several Newtonian textbooks containing Newton's rules of reasoning, we might expect her to include them in her discussion. Yet the published version of the *Foundations* contains no reference to Newton's rules, seemingly undercutting the suggestion that the rules – and more generally "Pemberton's Challenge" – are important context for interpreting Du Châtelet on method. This impression is mistaken. The manuscript version of Chapter 1 of the *Foundations* contained Newton's third rule of reasoning, and so (we may infer)

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[10] For discussion of method amongst the Newtonians, see especially the work of Ducheyne (e.g. 2014, 2015, and with van Besouw 2021).

[11] Though Newton's rules of reasoning are found explicitly stated in his *Principia*, equally important for early 18th century discussions of method (and the epistemic status of resulting claims) is Newton's *Opticks*, in which respect see especially Walsh 2025. Indeed, Du Châtelet's deep engagement with Newton's work began with his *Opticks*.

at least the first three rules, and perhaps also the fourth.[12] It is true that, by the time of the published version, Newton's rules of reasoning had disappeared from Chapter 1 (which instead discusses the principles of sufficient reason and contradiction as the "principles of our knowledge," about which more later). Importantly, however, this change occurred *after* Chapter 4 was complete (modulo a change to be discussed below). In my opinion, Du Châtelet's response to "Pemberton's Challenge" begins with her attempt to elucidate and improve on the method gestured at in Newton's rules of reasoning.

We have seen that Newton's first three rules concern his inductive method and its justification, and the fourth rule articulates the epistemic status of the claims that result from following the method. Du Châtelet's chapter on hypotheses is an attempt to spell all of this out in more detail, as we will see: it not only provides a *method*, but also discusses the *epistemic status* of the resulting scientific claims, and shows how the method justifies that status. Indeed, this is the primary purpose of the chapter: to provide an account of how to use empirical resources as a constraint on admissible hypotheses such that we are justified in accepting them as scientific knowledge. In this way, Du Châtelet addresses "Pemberton's Challenge," as we will now see.

### 3.1 Articulating the challenge

In my opinion, "Pemberton's Challenge" provides appropriate context for reading Du Châtelet's *Foundations*. In the early paragraphs of chapter 4, Du Châtelet sets up her discussion of hypotheses accordingly.

First, she criticizes the "misuses of hypotheses" among Cartesians (2009, 4.55).[13] Having earlier stated that the goal of physics is to deliver the "true causes of natural effects and of the phenomena we observe" (2009, 4.53), she asserts that the Cartesian method delivers "fables and reveries" instead of truths (2009, 4.55). She rejects it for leading to explanations that are merely "fictions" (2009, 4.55). This is the first horn of Pemberton's dilemma, in which our conjectural method insufficiently constrains our knowledge claims.

Next, she turns her attention to the Newtonians, who famously denounced the use of hypotheses. Anything that isn't demonstrated is a hypothesis (2009, 4.56), Du Châtelet writes, so if we follow the Newtonians in rejecting hypotheses our only alternative is to provide demonstrations (2009, 4.55). But "we do not seem made for such knowledge." This is the second

[12] We have known this for a long time, at least since the work of Barber (1967) and Janik (1982). We can conclude that, in the original version of her text, Du Châtelet began the same way all the Newtonians began their books on physics: with a discussion of method that included Newton's first three rules of reasoning. Wells (2021) is the first paper to discuss Du Châtelet's use of Newton's rules of reasoning in detail. He argues for the continued presence of all four rules in the published version of the *Foundations*. The fourth rule was added only in the third edition of the *Principia*, and it isn't clear when Du Châtelet obtained a copy of this edition. However, it is likely that she was already highly familiar with Le Seur and Jacquier's Geneva 1739-40 edition of the *Principia* during its preparation, while she was writing (and then revising) her *Foundations* (Hutton, forthcoming), and this used the third edition of the *Principia*. So, we can be confident that Du Châtelet knew of the fourth rule at this time, even if we cannot prove she included it in the manuscript version of her *Foundations*.

[13] As noted above, I use the English translation of Du Châtelet 1740, and I indicate where there are relevant changes found in Du Châtelet 1742.

horn of Pemberton's dilemma, in which an overly strict demand for demonstrations is incompatible with our epistemic situation when it comes to natural philosophy.

Du Châtelet is pointing to an instability in the views espoused by the Newtonians, in both seeking a middle path between the two horns of Pemberton's dilemma and rejecting all use of hypotheses: the latter risks collapsing their position onto the second horn. Despite their best efforts, Du Châtelet does not believe that the Newtonians have successfully met the demands of "Pemberton's Challenge."

Having criticized the Cartesian and Newtonian views on hypotheses, Du Châtelet offers evidence from the history of physics for her opening point: hypotheses are both needed and useful in scientific theorizing (2009, 4.57-60). A middle way must be found between the over-speculative hypotheses of the Cartesians and the demand for proofs as secure as those in mathematics. How are we to proceed? How are we to successfully address "Pemberton's Challenge"?

### 3.2 Method and justification

The main concern of Du Châtelet's chapter is the method for using hypotheses and their resulting epistemic status. She begins the central portion of Chapter 4 as follows: "Without doubt there are rules to follow and pitfalls to avoid in hypotheses" (2009, 4.61). What follows is her detailed account of: how to use experiments and empirical evidence to constrain our theorizing; how this method puts us in a position to reject or accept hypotheses; and the extent to which we should give hypotheses our assent. She is telling us how to "steer a just course:" she is responding to "Pemberton's Challenge."

Her chapter on hypotheses has been widely discussed and is the subject of a growing secondary literature.[14] The main elements of her method can be summarized as follows. We are to proceed by constructing hypotheses and evaluating them in light of empirical evidence in non *ad hoc* ways (see especially 2009, 4.69). This includes using them to make novel predictions, pursuing empirical evidence for *all* the predictions of the hypothesis, and seeking as wide a range and variety as possible of observations falling under the hypothesis. Moreover, our method equips us to know when we have gone astray: "a single [experiment] suffices to reject [a hypothesis] when it is contrary to it" (2009, 4.64). We are to reject hypotheses or parts thereof that are falsified by empirical evidence. As is well known, Du Châtelet offers a detailed method for how to use experiments and empirical evidence in theorizing.

One of Du Châtelet's goals in this chapter, I believe, is to eludicate a method insufficiently spelled out in Newton's rules. We have already remarked that, while the official Newtonian method was "induction," what that meant in practice was under-theorized. Newton provided his first three rules of reasoning, and the Newtonian textbooks of the time typically offered these as a method but were of little more help. Du Châtelet's chapter on hypotheses presents something far more sophisticated: she explains in detail how to use empirical resources and inductive methods

[14] Recent work includes Paganini 2022, Rey 2023, and Wells 2024.

to arrive at knowledge in natural philosophy. She thereby fills a need left unmet by Newton’s first three rules of reasoning and existing Newtonian textbooks. I take this to have been her intent.

What about Newton’s fourth rule? What is the relationship between Du Châtelet’s proposed method and the epistemic status of the resulting knowledge claims? As we have seen, Newton tells us only that they are to be obtained by induction and then “taken as exactly, or very nearly, true.” Many at the time, especially Newtonians, argued for relaxing the criterion of certainty when it comes to knowledge in physics, but the epistemic status of propositions arrived at empirically, and how they obtain that status, was again under-theorized. This, too, is addressed by Du Châtelet in her chapter on hypotheses.

Throughout Chapter 4, Du Châtelet connects the state of the evidence, as arrived at by following her method, with the appropriate epistemic attitude for us to take towards the hypothesis in question. She goes into detail, writing that when novel predictions of a hypothesis are confirmed and “all the consequences drawn from it agree with observations,” then “its probability grows to such a point that we cannot refuse our assent to it, and that is almost equivalent to a demonstration” (2009, 149, 4.58). Similarly, later on she tells us that if “all the consequences” are “confirmed by experiment” then “the probability would be the greatest” (4.66) and such a hypothesis “deserves to be adopted” (4.71).

There are places where she suggests that the method can bring us close to certainty. One example she offers is the discovery of the rings of Saturn: “The correspondence between hypothesis and observation has finally converted this supposition of M. Huygens into a *certainty*” (2009, 150, 4.58, emphasis added). Later, she clarifies the type of certainty involved: “And, as a very great degree of probability gains our assent, and has on us almost the same effect as certainty, hypotheses finally become truths when their probability increases to such a point that one can morally present them as a certainty; this is what happened … with M. Huygens’s on the ring of Saturn” (2009, 4.67).[15] In short, she claims that her method offers a process “almost equivalent to a demonstration” so that we may (a) “morally present” the hypothesis as certain, and (b) take the hypothesis in question to be true.

Newton’s rule 4 is followed by this statement (Newton 1999, 796): “This rule should be followed so that arguments based on induction may not be nullified by hypotheses.” Famously, the rule is Newton’s attempt to distinguish between his theory of universal gravitation, which he believed had very strong empirical warrant, from Cartesian vortex theories that lacked anything like the same level of epistemic justification. His rhetorical move is to deny that his theory is a hypothesis, and to reject hypotheses (such as Cartesian vortices) as having any place in natural philosophy. Du Châtelet offers an alternative response. She provides an account of the degree of warrant that accrues to an hypothesis through experiment and empirical investigation, thereby enabling us to distinguish between those hypotheses that we are justified in accepting and those we are not, and to determine the degree of warrant, and therefore the degree of justification, we have for those hypotheses. She tells us that by following her method we will be able to (i) assess

[15] [Note to self: Translation checked for accuracy, passage unchanged in 1742 edition.]

hypotheses as more or less probable[16] (4.67) and (ii) arrive at scientific claims (hypotheses) for which we are justified in giving our assent (4.58, 4.67). In my view, this is her explication of what it means to take a proposition as "exactly or very nearly true," and her account of what justifies us in so doing.[17]

Du Châtelet's chapter on hypotheses is her detailed articulation of the conditions under which we are justified in taking a proposition to be "exactly or very nearly true notwithstanding contrary hypotheses".[18] But it also does more. Though we may hope to arrive at hypotheses with a high degree of warrant, much of our time will be spent reasoning with hypotheses that are less secure. Her method allows us to evaluate how much confidence we should have in a given hypothesis, and to use these hypotheses in proceeding with our enquiries without first demanding certainty. Her method concerns science as an *ongoing activity* in which we pursue scientific knowledge in the face of *un*certainty. Indeed, we might think of her method as being all about the relationship between uncertainty and knowledge in natural philosophy.

How can we achieve knowledge in physics, and what is the status of those knowledge claims? By the end of her chapter on hypotheses, Du Châtelet has put us in a position to answer this question. Her method provides rules to follow such that we reason well in our situation of uncertainty. As we progress in developing a hypothesis under the constraints of her method, the hypothesis becomes increasingly certain, and we are justified in increasing our commitment to that hypothesis. There is alignment between the method and the epistemic status of our knowledge claims: hypotheses have "a greater or lesser degree of certainty, depending on whether they satisfy a more or less great number of circumstances attendant upon the phenomenon that one wants to explain by their means" (2009, 4.67). Her method explains how to relate empirical evidence to our degree of justification, and also provides guidance on how to tell when we have gone wrong (and therefore when to reject a hypothesis). In my opinion, Du Châtelet's chapter on hypotheses offers a sophisticated response to "Pemberton's Challenge".

To sum up: In this section of the paper, we have seen that Chapter 4 of the *Foundations* is helpfully read as Du Châtelet's attempt to make good on the promise of the Newtonian method

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[16] I do not think this is a statistical notion of probability. Rather, I think that where certainty is the epistemic correlate of true propositions, so degree of uncertainty is the epistemic correlate of probable propositions. "Hypotheses, then, are only probable propositions that have a greater or lesser degree of certainty…" Du Châtelet 1740, 4.67. See section 5, below.

[17] Wells (2024) is the first to argue in detail for the importance of Newton's rules of reasoning in Du Châtelet's *Foundations*. He draws attention to the importance of Rule 4 for Du Châtelet's discussion of hypotheses, highlighting that, for Du Châtelet, "Hypotheses, once they meet certain criteria, may be assumed as true until some 'contrary experiment' or experience shows that they are wholly false" (Wells, 2024, 8). I completely agree with Wells that Rule 4 is crucial for our understanding of Du Châtelet's chapter on hypotheses. However, rather than seeing it as simply being present, as Wells suggests, I have a slightly different view. I think her chapter attempts to make good on the intent of Rule 4, but that when she revised her manuscript shortly before publication, she transformed it, as we will see below.

[18] As the work of George Smith has made clear, this phrase of Newton's has a highly specific and technical meaning not reflected in Du Châtelet's account. I don't think that she was in a position to see this and, as Smith's work shows, it was not until later in the 18th century that this aspect of Newton's method became apparent to leading practitioners in mathematical astronomy. Moreover, it is only with Smith's work that we see the method explicitly connected to Rule 4.

(as expressed in Newton's four rules of reasoning) as a response to "Pemberton's Challenge." I have claimed that the upshot is a new account of what we mean by scientific knowledge. Such knowledge is *justified hypothesis*, and Du Châtelet's method explains how hypotheses are justified. She provides us with a detailed account of the *uncertainty* of hypotheses and of their *justification* as knowledge.[19]

At the time when Du Châtelet first sent her *Foundations* for printing, this comprised the entirety of her response to "Pemberton's Challenge." It is the response we find in the manuscript version of 1738. By the time of the published version, her response had undergone a further evolution, as we will now see.

## 4. Du Châtelet's revised account of scientific knowledge

Chapter 4 of the *Foundations* underwent a small but significant addition shortly before publication, as part of wider changes between the manuscript and published version of Du Châtelet's *Foundations* impacting her account of scientific knowledge.[20] I think we can gain insight into these revisions by examining them in light of "Pemberton's Challenge".

The important change to Chapter 4 occurs in paragraph 4.61, where Du Châtelet says "Without doubt there are rules to follow and pitfalls to avoid in hypotheses". In the manuscript, Du Châtelet moves directly to the use of experiments and empirical evidence as constraints on a good hypothesis.[21] In the published version, this becomes the *second* prong of her method, and a new first prong is added: the appeal to the principle of sufficient reason (PSR), and to the principles of our knowledge more generally. She writes:

> Without doubt there are rules to follow and pitfalls to be avoided in hypotheses. **The first** is, that it not be in contradiction with the principle of sufficient reason, nor with any principles that are the foundations of our knowledge. **The second** rule 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. (2009, 4.61, emphasis added)

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[19] See section 5, below. See also Rey (2023, 37), who argues that in Du Châtelet's epistemology the fact that scientific knowledge is "probable" rather than "certain" is "less the mark of the failure of this knowledge than the sign of an ever-present precariousness that has a decisive significance for understanding the new conceptualization of knowledge in the middle of the 18th century." This precariousness arises from "the very instability of the world," due to its phenomenal character and the nature of our experience (as it arises from the underlying simples), and indeed our nature as knowers. Rey writes (2023, 38): "henceforth, knowing supposes integrating approximation as one of its fundamental dimensions." Rey (2023, 30-34) offers a discussion of Leibniz's epistemology as a way into thinking about Du Châtelet, whilst acknowledging that Du Châtelet did not have access to all the Leibniz texts that Rey relies on in her exposition. She argues that Du Châtelet transforms the relationship between certainty and probability, as we find it in Leibniz. (I thank Michael Veldman for drawing my attention to Rey's 2023 paper.)

[20] The complex revisions undergone by the Paris manuscript have been analyzed by Ruth Hagengruber and her colleagues, see Du Châtelet 2021-2025.

[21] See Paragraph LXI of the manuscript, available online via the Bibliothèque nationale de France, or the Hagengruber edition (Du Châtelet 2021-2025) Chapter 4, Version B (95v/12-90/96r/13).

This is her statement of her two-pronged methodology, as it appears in the book.[22]

Suppose I am right that the manuscript version of Chapter 4 was Du Châtelet's initial attempt to answer "Pemberton's Challenge." If that's so, then the addition she makes prior to publication suggests Du Châtelet came to believe her original single-pronged empirical method was insufficient. I think that's right. To understand why, and with what consequences, we need to situate this change to Chapter 4 in a broader context. The roadmap for this section of the paper is as follows.

We begin with the widespread changes that Du Châtelet made to the early chapters of the *Foundations* shortly before publication. The principle of contradiction (PC) and PSR lie at the heart of these revisions. One important precipatating factor was Du Châtelet's evolving views on the efficacy of the Newtonian method. In my opinion, she came to see it as inadequate for providing a secure epistemic foundation to underwrite knowledge claims in physics, albeit fallible knowledge. More specifically, she found it lacking in two distinct ways. First, the method leaves the foundations of knowledge *in general* unsecured, for reasons we will uncover (4.1). Addressing this has consequences for the place of Newton's first three rules of reasoning in her scientific method (4.2 and 4.3). We will see the philosophical reasons *why* Newton's first three rules disappear from the *Foundations*, and what this means for her account. Second, the constraints placed on *particular* scientific knowledge claims, even by the method set out in the manuscript version of Chapter 4, still left too much room for speculation and error, hence the addition of the new "first prong" to her method (4.4). I have argued that, in Chapter 4, Du Châtelet attempted to make good on the desideratum gestured to in Newton's rule 4 by showing how her method justifies the epistemic status of our knowledge claims in science. We will see what impact the addition of the first prong of her method has on this goal. The upshot is the final version of Du Châtelet's response to "Pemberton's Challenge." I end by summarizing the findings of this section (4.5).

### 4.1 Securing the epistemic foundations of physics

The earliest surviving manuscript version of Chapter 1 is entitled "The principles of our reasoning". Although this version already contains PC and PSR, presumably the title dates back to when it contained Newton's rules of reasoning. It was only in revising the manuscript that Du Châtelet changed the title to "The principles of our knowledge." In my view, this reflects an important shift in Du Châtelet's epistemology. Whereas her initial concern was to explain how Newton's rules of reasoning allow us to arrive at knowledge within physics, she later came to believe that PC and PSR must be presupposed in order for knowledge to be possible *at all*. This is why that chapter is re-named. Let's see how this plays out in her *Foundations*.

First, recall that Newton's rules of reasoning concern inductive methods for arriving at knowledge in physics. We have already noted that, at the time Du Châtelet was writing, the

[22] I discuss her two-pronged methodology in Brading 2019, chapter 2, and draw on that work here.

defense of induction in Newtonian texts was weak.[23] In the published version of the *Foundations*, Du Châtelet shows that PSR underwrites our inductive methods and, more generally, allows us to have knowledge of causes and effects. For her, PSR is presupposed in empirical knowledge because it is needed to tie events together from moment to moment: without it, we cannot make any inferences beyond the particular moment in which we find ourselves. One example Du Châtelet gives is of her room, which she has left in a particular state and which she is certain no-one else has entered: using PSR, she can be certain that it remains in this same state, but without PSR she could have no such certainty "since everything could have been thrown into confusion in my room" without any reason or cause. A more pertinent example from the perspective of Newtonian science concerns measurement. Without PSR, the outcome of a measurement at one moment would not allow us to infer anything about that quantity at a later moment: I might find that two balls weigh the same by placing them on a balance, but if "a change could happen in one and not the other for no reason at all" (2009, 1.8) then I would not be able to use this measurement result for any further reasoning about the balls and their behaviors. Since the argument for universal gravitation in Newton's *Principia* depends throughout on being able to weigh objects, both terrestrial and celestial, Du Châtelet is arguing that PSR provides the necessary foundation on which our claims to knowledge in physics – such as knowledge of gravity – rest. The justification for accepting claims arrived at by the Newtonian experimental methods depends on acceptance of PSR, as a *general* prerequisite. Without this, no reasoning about causes and effects, and therefore no inductive knowledge, is possible.[24]

Now, consider the argumentative structure of the opening chapters of the published version of the *Foundations*. In Chapter 1, Du Châtelet makes her case for PC and PSR as foundational for human knowledge. She writes that without PC there could be no knowledge because then "every thing could be, or not be, according to the fantasy of each person." We adopt PC as a principle of our knowledge and in doing so commit to it as a metaphysical principle, at least fallibly: for the universe to be knowable by us, it must satisfy PC.[25] Correspondingly, we commit to it as a methodological principle: when we assert that something is impossible (or possible), we are required to demonstrate a contradiction (or the absence of a contradiction). According to Du Châtelet, PC is a tool for arriving at necessary truths and PSR is a tool for arriving at contingent ones. When there are many possible states of a thing, to determine which of these is actual we must appeal to PSR.[26] As with PC, to adopt PSR as a principle of our knowledge is to commit to

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[23] See above, and for more details Brading, 2019, p. 35.

[24] Wells (2021, p. 4) discusses how PSR can be justified by grounding it on a prior principle (e.g. people who attempt to derive it as a consequence of PC), or by its utility: "If the application of the PSR could be shown to be indispensable for the success of physics or some other respected mode of inquiry, this could count as a regressive justification of the PSR." I agree that Du Châtelet doesn't ground PSR on a prior principle, but I think her position is slightly different from the "utility" justification. Her argument for PSR might go something like this: "If knowledge is possible for us, then these principles (PC and PSR) must be true. I am going to assume that knowledge is possible for us, so I am going to assume these principles are true." In this way, they are presupposed as conditions for the possibility of knowledge.

[25] For a detailed discussion of PC and the alignment between metaphysics and epistemology in Du Châtelet's philosophy, see Carus forthcoming.

[26] Du Châtelet elaborates on this in more detail in *Foundations* 3.50.

it as a metaphysical principle (albeit perhaps fallibly): the universe is intelligible (at least to some extent) because it operates in terms of causes and effects such that they satisfy PSR. Without it, human knowledge is not possible.

How, then, are we to deploy PC and PSR to achieve knowledge? In Chapter 2, Du Châtelet uses PC and PSR to get us from knowledge of our own existence to knowledge of the existence of God. More specifically, Du Châtelet uses PC and PSR to argue for the existence of a necessary being, which she calls God, and for His immutability.[27] Once we have knowledge of God's existence, we know that PC – and the truths we obtain from it – hold always and forever. This is because PC obtains in His understanding, which is unchanging.

From here, we arrive in Chapter 3 at knowledge of essences, and at our knowledge that these, too, are unchanging. For Du Châtelet, God's understanding contains all the possible "determinations" of things, and essences are non-contradictory collections of determinations. Thus, essences depend on PC, and they are "possibilia": not all essences are actualized.[28] Metaphysically, God's immutability (specifically, the immutability of His understanding) ensures the constancy of essences.[29] This, in turn, makes our knowledge of them possible. More on this later, in section 4.3.

To move from essences to attributes and modes (also in Chapter 3), we rely on PSR. Attributes are those determinations of a being for which the essence is the sufficient reason for their *actuality* (2019, 3.42).[30] Modes are the determinations for which the essence is the sufficient reason for their *possibility*, but which are not fully determined by the essence (or the dependent attributes).

Du Châtelet writes that since the reason for the actuality of the modes can be found in neither the essence nor the attributes of a being, it must be found in either the antecedent modes of the being itself, or exterior beings, or a combination of the two (2019, 3.44). This is where, in my opinion, Du Châtelet allows for *causation among beings*. She writes that when we consider a being placed in the order of things, linked with other beings, "one must show how a Being depends upon its neighbor, and which causes gave actuality to the modes that were simply possible when the Being was considered as isolated and outside the order of things" (2019, 3.50).

After Chapter 3 comes the chapter on hypotheses. This fact allows us to conclude the following: Du Châtelet believed that by the end of Chapter 3 she had secured the epistemic foundations of physics such that we are positioned to deploy empirical resources to obtain knowledge of causes in accordance with the method she will go on to describe in Chapter 4. Notice: she reaches this point without any mention of Newton's rules of reasoning. They have been eliminated. We will shortly be in a position to understand why.

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[27] Note that PSR is a *causal* principle in this context. See Lascano 2011.
[28] Whereas the possibility of things depends on God's understanding, their actuality depends on God's will (Du Châtelet 2019, 3.49).
[29] "[T]he possibiity of things has its source in the understanding of God, who necessarily conceived all that is possible from all eternity" (Du Châtelet 2019, 3.49). To add a new determination to an essence is not to change that essence, but simply to create a new one (2019, 3.46).
[30] i.e. given that the essence is actualized, this is sufficient for the attributes to be actualized.

So, by the end of Chapter 3, Du Châtelet has provided the resources needed prior to embarking on Chapter 4, her account of hypotheses and of empirical method. The justification for induction has already been put in place, and now, in Chapter 4, PSR gets deployed in a second role, as part of her method for arriving at *particular* contingent truths. As we will see in more detail below, the goal of physics at that time was to arrive at causes, and the whole purpose of Chapter 4 is to provide a method by which to do this. The addition of PSR as the first prong of her method contributes to this purpose, providing a stronger constraint on good hypotheses and an additional tool for discovering when we have gone wrong. Before turning to this in more detail, I first pause to emphasize that PSR plays a *dual* role in Du Châtelet's account of scientific knowledge, operating both generally – as a prerequisite for knowledge – and specifically – as a guide to particular contingent truths. Moreover, in both roles PSR operates as a causal principle, or so I have argued (Brading 2019, 34-8).[31] In the general role, it ties causes and effects together in sequences so that we may reason from our current experiences to knowledge of events beyond the here-and-now, including measurement comparisons. In its specific role, it takes its place in the first prong of her method.

In my opinion, the first four chapters of the *Foundations*, taken together, contain Du Châtelet's systematic account of human knowledge. As part of this, they complete Du Châtelet's response to "Pemberton's Challenge." They secure the foundations of scientific knowledge, showing how such knowledge is possible within the context of her general account of human knowledge, and (as argued above) Chapter 4 provides a detailed method by which to arrive at specific knowledge claims in physics such that the method justifies the epistemic status of those knowledge claims. One result of the revisions to these chapters is that Du Châtelet no longer needs Newton's first three rules of reasoning; we will next see why. Then, at the end of this section, we will at last return to that seemingly smallest of changes: the addition of PSR to Chapter 4.

### 4.2 Newton's Rules 1 and 2: the search for true causes

Physics in the early 18th century remained the search for and study of *causes*. More specifically, physics concerned itself with causal knowledge of the natural world in terms of the nature and properties of bodies.[32] Whereas Books 1 and 2 of Newton's *Principia* are "strictly mathematical," Book 3 is a book in *physics*.[33] Newton opens Book 3 with two rules of reasoning

[31] Wells (2021, pp. 6-7) nicely explains why we should not think of PSR as straightforwardly a causal principle, however. He writes that Du Châtelet's PSR "appeals to broader criteria of understanding that are not defined in terms of causality. Room is thus left for noncausal explanations. Conversely, … many causal proposition, on her view, fail to enable explanation or understanding." So, even though "there is considerable extensional overlap, on Du Châtelet's view, between causal truths and truths that make it possible to understand why something is the case," the two come apart. See also Janik 1982, 104. In my view, PSR is adopted as part of a method for finding causes.
[32] See Brading and Stan 2023, 99-103.
[33] Already in the first edition of the *Principia*, Newton's introductory paragraph to Book 3 reminds us that the first two books of the *Principia* are "strictly mathematical" (though illustrated in places with "philosophical scholia," i.e. applications in physics) whereas Book 3 is where the *physics* takes place: this is where Newton sets out to "exhibit

that tell us when and how we are justified in assigning *causes*.[34] I emphasize this because it is so important. Du Châtelet called her book *Foundations of Physics* deliberately: hers is a book about *physics*, and she is clear that this means the search for *causal knowledge* of the natural world. Recall the familiar opening sentence of Chapter 4 on hypotheses:

> The true causes of natural effects and of the phenomena we observe are often so far from the principles on which we can rely and the experiments we can make that one is obliged to be content with probable reasons to explain them. (2009 4.53)

This sentence expresses the *goal* of our enquiries in physics: we're looking for the "*true causes* of natural effects and of the phenomena we observe".[35] Newton's rules of reasoning purport to tell us how to go about this, and Du Châtelet included them in the original version of Chapter 1 of her *Foundations*, as we have seen.

Eric Schliesser has drawn attention to the explanatory sentences that follow Newton's statement of rule 1, and to the fact that they were added only in the second edition.[36] Newton writes:

> As the philosophers say: Nature does nothing in vain, and more causes are in vain when fewer suffice. For nature is simple and does not indulge in the luxury of superfluous causes. (1999, 794)

Here, Newton is offering "nature does nothing in vain" as a *justification* for rule 1. It is a metaphysical thesis, telling us something about how the world works. Having adopted it, we are then *epistemically justified* in assigning *causes* in accordance with the first and second rules of reasoning. It therefore has *methodological* force: seek and admit only those causes that are sufficient to explain the phenomena. Were we to admit additional causes beyond those that are sufficient, we would be attributing to nature a lack of parsimony ruled out by the metaphysical principle.

Now, on one way of understanding PSR, it can be used to articulate and make more precise the claim that "nature does nothing in vain." If the world is such that everything has a sufficient reason, then it cannot contain superfluous causes, for they themselves would lack sufficient reason. Thus understood, PSR is a metaphysical principle. Moreover, it also has *methodological* force: it tells us to seek sufficient reasons, and having found a sufficient reason, don't add more.

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the system of the world" (Newton 1999, 793). For more on this division between mathematics and physics in the *Principia*, see Brading 2023.

[34] These are hypotheses 1 and 2 in the first edition and become rules in the second (Newton, 1999, 198-200). See Domkski (2022, 29-30) for a clear and concise explanation of how rules 1 and 2 are to be understood, how they are to be deployed together, and how Newton does so in his *Principia*.

[35] For further discussion of this sentence and its import, see section 5.

[36] Talk given in Ambsterdam, March 2025. See also his https://digressionsimpressions.substack.com/p/newton-and-nature-does-nothing-in.

Finally, when we find the sufficient reason for a phenomenon, that reason will be *true* because nature itself operates in accordance with PSR. So, adopting PSR as a metaphysical principle underwrites its *epistemic* value as a methodological principle.

The upshot is that PSR provides everything we need to support Newton's first and second rules. We must seek and admit only sufficient reasons, where those reasons are – since this is physics – understood as causes. And, because we have adopted PSR as a metaphysical principle, we know that those causes will be true (as required by rule 1). In this way, PSR can be used to underwrite the full content of Newton's first and second rules of reasoning.

I suggest that Du Châtelet came to see PSR as a more precise articulation of the claim that "nature does nothing in vain," justifying Newton's first and second rules. In this role, it functions as a general metaphysical principle underwriting the rules. Then, with PSR adopted in this role, she reached a more radical conclusion. She realized that she no longer needed the first two rules of reasoning as formulated by Newton. This is because, as we have seen, PSR works not just *metaphysically* as a general foundational principle but also *methodologically* as a prescription for assigning *particular* causes, and *epistemically* to justify that assignment. And it provides the metaphysical grounds for the truth of these causes, justifying our claim to admit only true causes – a condition demanded by rule 1.

In short, we first notice that PSR can be used to provide a *justification* for adopting rules 1 and 2, thereby supplying the foundation for the method offered by Newton in those rules. Then, we notice that it can also be used to *replace* rules 1 and 2 as our method for admitting causes. Rules 1 and 2 are redundant and can be eliminated.

### 4.3 Newton's Rule 3: essential and universal qualities

What is the purpose of rule 3 in Newton's *Principia*? If we can answer this question, then we can address whether Du Châtelet needs it. We will see that she does not.

According to Newton, "Gravity exists in all bodies universally and is proportional to the quantity of matter in each" (*Principia*, Book 3, proposition 7. Newton 1999, 810). This is his conclusion asserting the existence of universal gravity. The primary role of rule 3, added to the second edition of the *Principia*, is to support this conclusion by telling us the basis on which certain qualities of bodies (such as extension, hardness, impenetrability, and so forth) "should be taken as qualities of all bodies universally" (Newton 1999, 795).[37] That is, rule 3 supports the claim of *universality* for certain qualities of bodies, including gravity.

[37] There is a large literature on Rule 3. See Domski 2022 and references therein. One reason Rule 3 has generated so much literature is that Newton (a) uses it to assign gravity to all bodies universally, (b) asserts that gravity varies with distance, and (c) asserts that a necessary condition for being a universal quality is that it "cannot be intended and remitted". These three claims have been thought to generate a contradiction, but this is so only if we fail to understand what "cannot be intended and remitted" means: it means that we cannot augment or diminish a quality by such processes as heating, cooling, smashing with a hammer etc. This we cannot do because gravity is in proportion to mass, and mass cannot be changed by such processes. So there is no contradiction. (In this aspect of interpretation, I disagree with Janiak 2021 and Domski 2022.)

Janiak (2021) highlights that in adding rule 3, Newton also addressed a second issue: he clarified the *meaning* of his claim, most importantly by denying that gravity is *essential* to matter. Having introduced a new concept into physics – gravity – Newton asked that it be accepted as a *universal* but *not essential* quality of bodies.[38] Unfortunately, Janiak argues, the attempted clarification only muddied the waters further.[39] Famously, Newton was highly reticient about the essential properties of bodies, admitting only inertia in this category and remaining silent on what it means for a property to be essential.[40] Hence the question Janiak stresses: What does it *mean* to deny that gravity is essential and assert that it is universal?

Janiak argues that clarifying the meaning of Book 3, proposition 7, was a pressing concern in the early 18th century. He argues that Du Châtelet recognized "the French Newtonians had failed to explain a central aspect of the new science of nature" (2021, 282), and that doing so required the elaboration and deployment of an explicit notion of essence. This is, he suggests, perhaps the most important reason for the introduction of an account of essence into the *Foundations*.

With her account in hand, Du Châtelet is able to address the question of the metaphysical status of gravity within the context of a systematic metaphysics. The theory of essences articulated in Chapter 3 allows us to say what it means for a quality to be essential, and in later chapters to determine which qualities belong to the essence of matter and body. This, in turn, enables us to resolve the question of whether gravity, as expressed in Newton's theory of universal gravitation, is an essential property of bodies, and to reject this.[41] She provides the resources to resolve a question that was both controversial and under-theorized at the time.[42]

Newton and Du Châtelet agree that gravity is not essential. In Newton's *Principia*, the purpose of rule 3 is to explain the evidential basis and inferential reasoning that underwrites its status as a quality of all bodies *universally*, as too for extension, hardness, impenetrability, and

[38] A new concept, albeit using an old word, "gravity", that had been used to cover many of the same phenomena that Newton now sought to theorize using his new concept.

[39] Janiak (2021) articulates the many strands of complexity left open by Newton's *Principia*, from whether gravity is essential, a primary quality, immutable, and so forth, to whether it is a property, force, action, tendency, etc.

[40] Newton's epistemic caution increased between the first and second editions of the *Principia*, and in the General Scholium – also added for the second edition – he argues that we cannot know the nature of substance. On this, and on the epistemic significance of the change of language from assertion to "taken as" in the rules, see Domski (2022, 10 and 15 n.21, respectively).

[41] See Janiak 2021 for more details of her argument. She developed this argument late and it represents a change of mind. Wells (2024, 4) discusses "an 11-page stretch dealing with Newton's argument for universal gravitation that, after several revision stages, was finally canceled out in its entirety. But these passages are not mere notes or unfinished drafts. They appear in two polished fair-copy versions, destined for an aborted 1738 printing of the Institutions. In 1739 or early 1740, Du Châtelet revised the chapter, which originally endorsed Newtonian attraction as a genuine cause and defended it against objections, to focus more narrowly on Newton's empirical discoveries. She then apparently added a new chapter that is close to the published version and denies that attraction is a genuine cause."

[42] Du Châtelet's uses PSR to argue against gravitational attraction and I agree with Janiak's observation that she deploys PSR in a novel way: "it is not that the PSR demands an *ultimate* explanation of how gravity operates (or of its 'cause'); it demands that we achieve clarity on the prior question of what *universal gravity means in the first place*" (Janiak 2021, 271). See also Wells (2021, 17) on how, unlike Wolff, Du Châtelet does not use PSR to pursue a foundationalist project when it comes to empirical science.

mobility (Newton 1999, 795). I do not believe Du Châtelet needs to make any such inferences, which means she has no need for rule 3.

In the case of extension, this is an essential quality of bodies, and so its universality is established that way. Mobility arises as a necessary consequence of another essential quality of bodies (active force), and so is universal. Insofar as hardness and impenetrability are also necessary consequences of the essential qualities, they will similarly be universal, but they need not have this status. They might, instead, turn out to be "physical qualities" and Du Châtelet has no need to establish that such qualities are universal.

In her account of scientific method, Du Châtelet distinguishes between mechanical and physical qualities.[43] Mechanical qualities are, or follow from, the essential qualities of matter (extension, active force, and passive force) and consist of shape, size, motion and situation. Du Châtelet argues that, while every phenomenon ultimately rests on the mechanical qualities of the smallest corpuscles, these corpuscles are so far from what is observable by us that we are often not in a position to arrive at mechanical explanations of phenomena. Instead, we can make use of physical qualities. The examples she gives are the *elasticity* of air, the *fluidity* of water, the *heat* of fire, and – in the 1740 edition – the *attraction* of the Sun.[44] Given our current state of knowledge, she argues, it is legitimate for us to explain why water rises in a pump by appeal to the elasticity of the air, and to explain the motions of the planets by appeal to the attraction of the Sun, without our yet being able to offer mechanical accounts of either elasticity or attraction. We can – and should – appeal to physical qualities in our explanations of the phenomena, without needing to explain them mechanically, so long as we don't make the mistake of taking physical qualities to represent the end point of explanation. There is always a mechanical explanation of any phenomenon, even if it is out of our epistemic reach.

So, physical qualities play an important role in our natural philosophical inquiries because of our epistemic situation and limitations. We are not in a position to arrive immediately (or perhaps ever) at mechanical explanations of all phenemona, and so we must make use of physical qualities meanwhile. Lin (2024, 1292) has argued that, among other criteria, these physical qualities must be "empirically trackable." By this, Lin seems to have in mind that an admissible physical quality must be quantitatively related to other measurable physical qualities. This is important because it means that such qualities can appear in hypotheses that are subject to

[43] See Brading (2019, 89-91); Lin (2024).

[44] See Du Châtelet 1740 8.162-4 and 9.184. In Du Châtelet 1742, the discussion of physical qualities is removed from chapter 8 and instead revised and developed in chapter 9, paragraphs 179-183. Interestingly, in the 1742 edition attraction no longer appears as an example of a physical quality, so far as I can tell. Lin (2024) has drawn attention to the importance of the 1742 edition for the topic of physical explanation. Lin claims that in this edition "Du Châtelet develops new theoretical resources that would allow her to admit attraction as an explanatory principle in physical theorizing" (1285) by introducing "a new category of explanation – *physical explanation*" (1790). While I disagree that this is new in the 1742 edition, Lin is right that Du Châtelet develops her view in much more detail in the 1742 edition, providing important elaborations and clarifications not present in the 1740 edition, and we should take the 1742 version as her considered view on this aspect of her methodology. I thank Lin for drawing my attention to the importance of the 1742 edition on this topic.

empirical investigation and testing by means of the method that Du Châtelet provides in her chapter on hypotheses. For our purposes, the crucial point is this: such physical qualities need not be universal. They need not be taken to be qualities of all bodies universally. We need only attribute them to the bodies falling under our investigation, and insofar as we have research problems that we are trying to solve. Thus, I can posit the elasticity of the air as a physical quality and use it in explanations, so long as I follow Du Châtelet's method, without needing to assert that it is a quality of all bodies universally or to provide justification for such a claim. That my hypothesis of the elasticity of the air holds good up to the limits of my empirical enquiries so far is sufficient for me to use it in explanations. Similarly with attraction, the constraints on a good hypothesis allow me to use attraction as a hypothesis in explaining the motions of the planets, without any need to make or justify a claim that gravitational attraction is a quality of bodies universally.

Where does this leave rule 3? On the one hand, Du Châtelet has an independent way of arriving at the essential (and therefore universal) qualities of bodies. On the other hand, gravitational attraction taken as a *physical* quality pertains only to those bodies under our investigation; it need not concern *all* bodies *universally* (though this is a hypothesis she could entertain, for further investigation). The crucial point is that Du Châtelet does not need a way of inferring *from* the bodies of our experience *to* bodies beyond our experimental reach when it comes to physical qualities. So, she has no need of rule 3.

Or at least, that's how it seems to me, but Wells (2024) has suggested that rule 3 may have a role to play in Du Châtelet's account of essences.

> Her account of our knowledge of essences itself involves an implicit inductive step. We begin with observed "constant determinations" in one particular, then generalize to properties that hold for all members of a kind (1742, pp. 62–65). To bridge the gap between particular observations and truths holding for a kind, she can be seen as relying on the induction principle, paralleling Newton's Rule 3, that she expounded in her chapter on hypotheses. (Wells 2024, 11)

I think this isn't right. Rule 3 tells us when we are justified in inferring *from* accumulated empirical evidence concerning the bodies that fall under our experimental reach *to* a claim about all bodies universally (or, in parallel, to a claim about the essence of all bodies, universally). I don't think this is Du Châtelet's concern in Chapter 8, in which she claims that the essence of bodies is extension, active force, and passive force. Rather, in beginning from the bodies of our experience she takes this to be a general category and assumes that her claims hold of bodies generally. She accepts without argument that these bodies are extended, and the purpose of Chapter 8 is to argue that active and passive force also belong to the essence of bodies. In these arguments, she appeals to our experience of bodies, but she takes this to be experience picking out a general category and does not see any need for an inductive step from the particular experiences to the general claim. Indeed, "bodies" that do not have extension, active force, and passive force as their essence are not bodies at all: for to change the essence is to switch the object of study to a different kind of being (1740, Ch 3).[45]

To sum up. First, Du Châtelet has a theory of essences that allows her to determine the essential qualities of bodies via her dual-pronged method. As a consequence of being essential, these qualities will also be universal. She has no need of rule 3 to determine these qualities. From these essential qualities follow necessarily the mechanical qualities of bodies, which are also therefore universal. Again, no need for rule 3. Second, Du Châtelet has her own theory of physical qualities that does not require they are universal. According to her account, we arrive at our knowledge of physical qualities experimentally, and we are permitted to use them in physical explanations, but Du Châtelet has no need of a rule that allows us to *universalize* them. That is, she does not need a method that allows us to move *from* the qualities we perceive in the observations and experiments we perform *to* a claim that these qualities are universal. The claim of universality is the claim that they are qualities of *all* bodies, even those on which we have not – *or indeed cannot* – perform experiments and observations to confirm that they have those qualities (see also Domski 2022, 16). Du Châtelet makes no such claim, and she doesn't need to. This is because physical qualities are of primarily practical utility, *for us*, as theorizers. If it helps us to move forward in theorizing, we may (fallibly) *hypothesize* that all bodies have a certain quality, but we do not need to infer or demonstrate that such a claim is true. Du Châtelet separates the task of identifying the essential properties of matter and/or bodies from that of identifying their physical qualities, and the latter has a much lower epistemic bar to meet. In short, the revisions Du Châtelet makes to the early chapter of the *Foundations*, shortly before publication, mean that she no longer has any use for Newton's third rule of reasoning.

**4.4 Rule 4 and the justification of scientific knowledge**

I argued above, in section 3, that Du Châtelet's chapter on hypotheses contains her detailed spelling out of the inductive methods to be followed such that we can take a proposition to be "exactly or very nearly true notwithstanding contrary hypotheses" (Newton, 1999, 796). I believe this is the case in both the manuscript and the published version of Chapter 4. Nevertheless, the revisions she made between the manuscript and published version change Du Châtelet's account in important ways.

Wells (2024, 6) has shown that, as Du Châtelet's confidence in the strength of the conclusions that one can draw using Newton's rules of reasoning gradually waned, she weakened the strength of her own conclusions (such as walking back her claim that gravity is an inherent quality of bodies) and the epistemic status she granted to those conclusions (no longer claiming that they have the status of demonstrations). In my opinion, we can go further: she discarded the first three rules entirely and offered a revised account of scientific knowledge in which the

[45] The justification for taking extension to be an essential property of body or matter became an increasingly pressing issue as the 18th century progressed, but it was not Du Châtelet's concern in her *Foundations*.

*uncertainty* of hypotheses and of their *justification* as knowledge are fully theorized. More specifically, her original account is strengthened in the published version in two important ways.

First, the manuscript leaves an underlying issue unaddressed. According to rule 4, the propositions we are to take as true are those "gathered from the phenomena by induction," but why think that *induction* provides justification for these propositions? What are our grounds for believing that induction provides a reliable route to knowledge of the natural world? The introduction of PSR addresses this shortcoming, as we have seen (section 4.1).

Second, Du Châtelet revised Chapter 4 to add a new "first prong" to her method: hypotheses must conform to PSR and to all the principles of our knowledge. So, PC and PSR play a second role in the *Foundations* as the first prong of Du Châtelet's method for the good use of hypotheses. In this role, they act as constraints on admissible hypotheses.

We do not need to get to Chapter 4 to see this. Already in Chapter 1, Du Châtelet offers examples of results she will return to later, including using the law of continuity (which she takes to be corollary of PSR) to rule out perfectly hard bodies, which is something her previous methodology does not do.[46] In Chapter 3, where Du Châtelet uses PC and PSR to argue for the immutability of essences (see above), she immediately connects this to the methodological role in constraining hypotheses (2019, 3.50):

> This single truth of the immutability of essences at a stroke banishes from Philosophy all precarious hypotheses, and all the monsters arising from the imagination of men, which have so held back the progress of the Sciences and of the human mind.

Among the "precarious hypotheses" Du Châtelet has in mind are Locke's thinking matter, and also Newtonian gravity understood as action-at-a-distance. Earlier in her thinking, prior to finalizing the *Foundations*, Du Châtelet had been willing to allow God's will as an explanation for natural effects. By 1740, she had decided that this is unsatisfactory: "one must not admit anything as true in Philosophy when one cannot give any reason for its possibility other than the will of God" (2019, 3.49). In her new account, a thing's being possible does not depend on God's will, but on his understanding. The application of PC is the only means by which we are allowed to admit a thing as possible.[47] In this way, PC is a tool for helping us in the avoidance of error, thereby strengthening her response to "Pemberton's Challenge".

As we have seen, PC gets us to knowledge of what's possible and impossible, but not to knowledge of what's actual. For that we need PSR, and we need it in two ways. One is to show that any given being is actual, rather than just possible, and the other is to explain its modes: to show "how a Being depends upon its neighbor, and which causes gave actuality to the modes that were simply possible when the Being was considered as isolated and outside the order of things" (2019, 3.50). In both cases, the role of PSR is to put much tighter constraints on

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[46] This is connected to a major topic of dispute at the time: the correct account of the force of bodies and of collisions, an issue Du Châtelet takes up in her final chapter on *vis viva*, and her famous dispute with Dortus de Mairan. See Brading and Stan 2023 for collisions as a pressing philosophical concern of the early 18th century.

[47] I think it is plausible that this feature of her method is at work in her rejection of atomism. See Brading 2019, 56.

admissible hypotheses than Du Châtelet allowed in her first attempt to meet "Pemberton's Challenge".[48] Later chapters of the *Foundations* offer numerous examples of PSR in this role. PSR is used to show how we go astray if we adopt the Cartesian conception of body as having extension only as its essence (Chapter 8), and whereas earlier Du Châtelet had believed in atoms (with their indivisibility explained by appeal to God), these are now ruled out (Chapter 7). She uses PSR to argue against gravitational attraction as an inherent quality of bodies (Chapter 16), and for *vis viva* as the measure of the motive force of bodies (Chapter 21). These are just some examples. The point is that the addition of the first prong of her methodology allows her to diagnose many more cases of where we have gone astray and resolve additional disputes between competing hypotheses: it significantly strengthens her method.

Notice that Du Châtelet is *not* using PSR to demand "ultimate explanations." As noted above, we are permitted to explain why water rises in a pump by appeal to the elasticity of the air, without also being required to also explain the elasticity of the air (even though we know it has a mechanical explanation, even if one currently beyond our ken). I agree with Janiak (2021, 271) and Wells (2021, 17) who emphasize this point and stress its novelty. It is connected to Du Châtelet's account of the epistemic status of hypotheses, in which explanations are not final and hypotheses are revisable as part of our ongoing scientific theorizing. Indeed, false hypotheses are indispensible for us, with the epistemic capacities that we have, as we move step by step, revision by revision, through increasingly justified hypotheses. Even in the best case scenario, scientific knowledge remains fallible. Wells (2021, 19) describes the situation thus:

> For Du Châtelet, our empirical knowledge is never absolutely certain. An empirical or 'physical' truth is equivalent to a very well-confirmed hypothesis: it is 'morally' certain but still defeasible in the face of new evidence. … As such, the reference to 'truths' in Du Châtelet's PSR is best understood as ranging not only over judgments that turn out to be exactly true, but also over those that are held to be true with good if not indefeasible evidence. The PSR does not endow empirical claims with absolute certainty…

The addition of the first prong of her method plays an important role in allowing us to find out when we have gone wrong, and in constraining what counts as a good hypothesis. It strengthens the criteria that must be satisfied in determining which hypotheses are candidates for scientific knowledge. By following Du Châtelet's method, we can arrive at well-confirmed hypotheses, and these we are epistemically justified in taking to be true "until yet other phenomena make such propositions either more exact or liable to exceptions," as Newton suggests (1999, 796).[49]

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[48] See Wells (2021, 3): "For Du Châtelet, empirical claims are merely probable. The PSR assists in reasoning under conditions of uncertainty."

[49] I have argued that Du Châtelet's Chapter 4 shows how and when we are justified in taking a hypothesis to be true. Wells (2021) emphasizes that, in accordance with Du Châtelet's method, a good hypothesis need not (and, in general, will not) be true. He has also argued that (2021, 17) "Du Châtelet's conception of what she calls a "good" explanation is not reducible to the question of how likely a hypothesis is to be true. Accordingly, I take the PSR's role in discriminating between good and bad explanations to be separable from its role in underwriting true belief."

The method aligns with the epistemic status claimed for the resulting propospitions. The challenge posed by Newton's rule 4 has been met.

**4.5 Upshot**

We began this section by noting the small revision that Du Châtelet made to her chapter on hypotheses, between the manuscript and the published version, when she added a new rule to her method in a single sentence. This is the introduction of PSR (and all the principles of our knowledge) as the first prong of her method for the good use of hypotheses. I have argued that this strengthens her resources for reasoning well in the face of uncertainty (not least by giving us another tool by which to find out when we have gone wrong), thereby allowing us to have greater confidence in the results of our reasoning. In this way, it strengthens Du Châtelet's articulation of how we can use empirical evidence to arrive at conclusions which, although not certain, we are justified in taking as scientific knowledge. There is alignment between the *method* and the *epistemic status* of the resulting knowledge claims.

This change to Chapter 4 is tied to deep and far-reaching changes in earlier chapters, as we have seen. Among other things, the adoption of PC and PSR as the principles of our knowledge allows Du Châtelet to provide a justification for the inductive reasoning of empirical science. With PSR adopted as a metaphysical principle, we are then *epistemically justified* in deploying causal reasoning (e.g. in our measurement practices, see section 4.1 above) and in admitting as true causes those that are sufficient to explain the phenomena. In this way, Du Châtelet secures the very possibility of our knowledge of causes (which was, as we have seen, the goal).

As a consequence of the changes, Du Châtelet no longer has any need for Newton's first three rules of reasoning, and the intended purpose of rule 4 is achieved in detail by her account of scientific knowledge and its justification – but in ways which take her far beyond anything indicated in Newton's formulation of that rule. Whereas the manuscript version of Chapter 4 might be read conservatively as a supplement to, or elaboration of, Newton's rules of reasoning, the published version makes it vividly clear that we are dealing with a great deal more. I seek to bring this point home in section 5, below.

To recap the conclusion of the present section: the published version of the *Foundations* doubly strengthens Du Châtelet's response to "Pemberton's Challenge," enhancing her method and securing the foundations of scientific knowledge.

**5. The transformation of scientific knowledge**

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I think Wells is right to emphasize that, for Du Châtelet, implementing PSR means demanding a sufficient reason that *enables us to understand* how the effect comes about (he calls this "determinacy") and why it is this rather than some other effect ("contrastivity"); that these conditions can be met to varying degrees; and that this is independent of the truth of the hypotheses in question.

To understand the significance of Du Châtelet's contribution, it will be helpful to situate "Pemberton's Challenge" more broadly within the history of epistemology.[50]

The early modern period inherited the ancient dichotomy between knowledge and opinion. *Knowledge,* or science, fell within the domain of philosophy, and was taken to be certain and infallible. This is in contrast to *opinion*, which fell within the domain of rhetoric, and made no such claims to certainty. To know something, according to this inherited picture, was to possess an idea that bears a discernible mark of truth.[51] The most familiar example of this from early modern philosophy is Descartes's criterion of clear and distinct ideas: when you examine your ideas and find one that is both clear and distinct, you thereby recognize it as true and certain; it is something you *know*. According to the traditional conception, systems of knowledge were to be built through the identification of self-evident first principles (principles that bear a discernible mark of truth) and demonstration (traditionally, logical demonstration). Moreover, such ideas and demonstrations *compel* your assent. As of the early 17th century, the traditional view of knowledge remained the dominant conception: it is demonstrable, certain, infallible, and bears a discernible mark of truth.

Given this account of knowledge, the two broad camps found in ancient philosophy are the *dogmatists*, who maintained that many of our ideas bear a discernible mark of truth, and the *skeptics*, who denied this. Notice, both positions share the same account of knowledge. Among the skeptics were those who, though asserting that we do not *know* much, nevertheless claimed that we are justified in accepting many things as "probable opinions" for the purposes of practical action, where "probability" was assessed largely on the basis of appeal to authority.

The above sketches the main theoretical backdrop inherited by early modern philosophers. There are two further components important for our purposes, both of which developed during the medieval and Renaissance periods. First, Christian scholars modified the above basic dichotomy between knowledge and opinion to add beliefs that are *true* but nevertheless (i) do not have a discernible mark of truth, (ii) are not acquired by logical demonstration, and (iii) do not compel assent, being adopted by choice (on faith). This introduced and made salient a category of "true belief" that is distinct from both knowledge and opinion as traditionally conceived. Second, scholars investigated moral choices under conditions of uncertainty, and non-demonstrative reasoning based on opinion. In both cases, a reasonable or justified basis for action in the absence of certainty was being theorized, and "probability" was assessed (though largely on the basis of authority once again). These developments enriched the epistemological landscape in ways that turned out to be destabilizing for the inherited strict dichotomy between knowledge and opinion.

During the course of the 17th century, especially during its latter half, the traditional dichotomy between certain knowledge and probable opinion dramatically eroded. It was replaced with a rather ill-defined continuum in which differing varieties of knowledge were deemed appropriate for different types of inquiry, and different degrees or kinds of certainty were

[50] I found Shapiro 1983 (ch 2) and Dutant 2015 most helpful in elucidating this background.
[51] Dutant 2015.

associated with each. This was especially the case in England among the members of the Royal Society.[52] Among these figures there was widespread agreement that the level of certainty and compelled assent associated with mathematical demonstration was not to be found in natural philosophy. This had two sources: they had little confidence that their inductive empirical methods of inquiry would or could lead to certain knowledge, and they shared an acceptance of the fallibility of the human senses and reason. In response, they offered different schemas setting out a continuum between certain knowledge and mere opinion. Such schemas frequently included “moral certainty” (borrowed from theology) and degrees of “probability,” now assessed not by appeal to authority but on the basis of experiments and community consensus.[53] The important point for our purposes is the lack of agreement on how to theorize this continuum. It was clear that a new theorization of *knowledge* was needed that would (i) allow for *degrees* of certainty or probablity, and (ii) take account of the *fallibility* of the human senses and reason. Some persisted with a traditional conception of knowledge (with its discernible mark of truth, its certainty, and its infallibility), but distinguished this from the “probable” products of natural philosophy, which did not count as knowledge.[54] The other – far more radical – option, suggestively present but under-theorized in the late 17th century, was to adapt our conception of knowledge to those products. This messy epistemological situation persisted into the early 18th century, as “Pemberton’s Challenge” makes clear.[55]

Within this context, the import of Du Châtelet’s contribution comes into stark relief.

First, she denied that our ideas carry a discernible mark of truth, thereby denying the core of the traditional conception of knowledge. She rejected Descartes’s criterion of clear and distinct ideas (2009, 1.II), but also the more general proposal that by inspecting our ideas we can discern which ones are true (2009, 1.II and 1.5). On the contrary, truths must be *confirmed* either “by experiment or by demonstration” (2009, 1.5).

Now, Du Châtelet does assert that human knowledge is founded on “certain principles whose truth is known without even reflecting on it, because they are self-evident” (2009, 1.I). We might be tempted to read this as saying that her principles of our knowledge (PC and PSR) carry a discernible mark of truth, and that she is therefore adopting a traditional conception of knowledge. However, I don’t think this is right. To see why, we need to look more carefully at

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[52] Shapiro 1983, ch2, draws our attention to the influence of Gassendi in France (and therefore possibly on Du Châtelet), and in England via Charleton. Gassendi tried to find a middle path between the dogmatists and the skeptics, arguing for natural knowledge as probable rather than certain (Shapiro 1983, 39).

[53] Looming large in the background here is Bacon’s influence on the members of the Royal Society. While they took many lessons from Bacon to heart (from the idols, to inductive methods, to natural philosophy as a communal undertaking), when it came to the detailed methods and the epistemic status of the resulting claims, disagreement persisted.

[54] A relevant example of this is Locke, who offered a new theorization of knowledge but persisted with the traditional requirement of certainty. See, for example, Osler 1970.

[55] Today, we do not take scientific knowledge to be certain and infallible. We have inherited a concept of science in which our knowledge claims are subject to revision. Yet the traditional conception of knowledge as true and therefore unchangeable also persists more broadly in our society, causing confusion and disaster in public discourse around science. This is the long tail of the epistemic crisis of the 17th century and the transformation in the conception of scientific knowledge that it precipitated, and we live with it today.

the status of PC and PSR. When Du Châtelet discusses PC, she offers two justifications. The first is compelled assent: "we cannot force our minds to admit that a thing simultaneously is and is not," and even the Pyrrhonian skeptics, who doubted everything else, did not deny it (2009, 1.4). But compelled assent is not offered as a mark of truth, it is offered as an inescapable feature of human reasoning. Whether PC is true or not, we cannot help but reason using it. The second justification is that, without it, we cannot have knowledge: if we are going to have a philosophy in which human knowledge is possible, then it must be presupposed (2009, 1.4, see also above). This doesn't guarantee the truth of PC. Similarly, when introducing PSR, Du Châtelet offers the same two justifications: we cannot help but reason using it ("All men naturally follow it") and without it, knowledge of contingent things would not be possible for us. So, in Du Châtelet's theory of knowledge, we do not begin with ideas or principles that carry a discernible mark of truth. Instead, we begin with principles that (i) human beings seem compelled to use in their reasoning, and (ii) we must presuppose in order for knowledge to be possible for us. This is *not* the traditional conception of knowledge.

Second, Du Châtelet accepted that most of our claims in physics do not have the epistemic status of being certain, as we have discussed in detail above, and as she makes clear in the chapter on hypotheses.[56] Nevertheless, the results achieved in physics when her method is followed are not merely "probable opinions": they are *knowledge* claims. She is clear that physics is a science (2009, 1.II), that she aims to cultivate "knowledge of the truth and the habit of looking for it and following it" in her son (2009, 1.IV) and to acquaint him with "what must be known" (the things one must know) (2009, 1.V). She asserts that experiments and reason are the path to new knowledge (2009, 1.IX). It seems to me that her goal is knowledge, so we should expect this to be what her method delivers, on pain of being uncharitable in our interpretation.

One might object that for Du Châtelet, hypotheses are merely probable, and hence her method does not yield knowledge, but I think this is not the right interpretation. I think Du Châtelet theorizes a continuum between mere probable opinion and propositions whose probability is sufficiently high as to justify their status as knowledge. [57] One role of PC is to distinguish knowledge from ideas that are "only more or less probable opinions, in which there is no certainty" (2009, 1.6). Yet, with her method for hypotheses, our propositions have degrees of certainty, so they are *not* merely the "probable opinions" of the rhetorician or sceptic (see above). Here is Du Châtelet's definition of hypotheses:

> {Definitin of Hypotheses} Hypotheses, then, are only probable propositions that have a greater or lesser degree of certainty, depending on whether they satisfy a more or less great number of circumstances attendant upon the phenomenon that one wants to explain by their means. {That which makes them probable} And, as a very great degree of probability gains are ascent, and has on us almost the same effect as certainty [compelled assent], hypotheses finally become truths when their probability increases to such a point

[56] Indeed, the limits of certainty in human knowledge seem quite narrow.
[57] See also Rey 2023 for Du Châtelet's place in the transformation from cerrtain to probable knowledge.

> that one can morally present them as a certainty…{That which makes them insecure} By contrast, a hypothesis becomes all the more improbable as it fails to explain more of its attendant circumstances… (Du Châtelet 2009 [1740], 4.67)

Hypotheses are probable propositions lying on a spectrum of increasing certainty, as their support increases in accordance with her method. A sufficiently high probability results in our being *justified* in presenting them as a certainty: that is, they have moral certainty. Such certainty is not the certainty of the traditional conception of knowledge: it does not compel assent, but almost does so. However, neither is it the moral certainty of "mere opinions" that suffice for the needs of every day life. For Du Châtelet, moral certainty is associated with a category of *knowledge*.

A hypothesis that has been subjected to the rigors of her two-pronged method will be a "probable reason" for the phenomena it purports to explain. Du Châtelet is explicit that one should not pass off a hypothesis as truth but should assess the "degree of probability" by means of her method (4.62). We are justified in associating a "degree of certainty" with the hypothesis in accordance with how probable it is; the more investigation it has been subjected to and survived, in accordance with her method, the more probable it becomes. At the far end of the continuum, when we arrive at morally certain propositions, we are justified in taking them as truths.

Du Châtelet has articulated a continuum of probability and a method by which we can move along that continuum such that the degree of certainty/probability we attach to our claims is *justified* by our method. With careful and successful application of her method, we can arrive at claims which, though not absolutely certain, are sufficiently probable that we are justified in taking them as truths.[58] However, it is not only these "truths" that fall within her account of knowledge. The continuum allows for knowledge claims with lower probability, so long as we do not pass them off as truths. Her account allows that knowledge is fallible.[59] This is a profound transformation in our conception of scientific knowledge, and her contribution represents the culmination of a century of epistemic struggle.

I am not suggesting that other people weren't writing on this topic and saying important things. They were. What makes Du Châtelet stand out is two things. (1) Her account is detailed and systematic in its connection between the *method* and the *epistemic status* of the associated

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[58] Also, and this is an important point, her account of scientific knowledge is situated in her account of knowledge more generally. So it's not like Locke, where we still have "Knowledge" traditionally understood, and then natural philosophical "knowledge" is this other category of thing, which is more like opinion. No! Her acccount of scientific knowledge is an account of human knowledge *generally*. What she offers us in her account of scientific knowledge is not some inferior form of knowledge, or something less than knowledge. The knowledge she offers us does not fall short: this is what it *is* for human beings to know things. See the change to the title of Chapter 1 of the *Foundations*, as discussed above (section 4.1).

[59] See also Rey 2023 for Du Châtelet's place in the transformation from cerrtain to probable knowledge.

knowledge claims, more so than any other account I have come across from that time. (2) Her *Foundations* was widely read[60] and therefore, we may surmise, influential.

To sum up, I return our attention to the familiar opening paragraph of Chapter 4:

> The true causes of natural effects and of the phenomena we observe are often so far from the principles on which we can rely and the experiments we can make that one is obliged to be content with probable reasons to explain them. Thus, probabilities are not to be rejected in the sciences, not only because they are often of great practical use, but also because they clear the path to truth. (B&Z 2009 4.53)

For our purposes, there are four important elements to notice.

(1) The *goal* of our enquiries: we're looking for the "*true causes* of natural effects and of the phenomena we observe". As we have seen, this was the goal of physics at the time, and Du Châtelet endorses it. We are looking for truths, and in particular true causes. We are looking for *knowledge* of true causes.

(2) There is an *epistemic gap* between the true causes (our goal) and what's readily accessible to us using the tools of enquiry we have available ("the principles on which we can rely and the experiments we can make"[61]). As a result, we need to make use of "probable reasons".[62]

(3) The *limitation* on what we can hope to achieve: the *epistemic status* of the claims we arrive at in our scientific enquiries will often be less than certainty. Du Châtelet is explicit that we will often need "to be content with probable reasons". This means that, in bridging the epistemic gap, we should not expect her method to deliver *certainty* about the true causes of things. Rather, we should expect an account of scientific knowledge that embraces and theorizes this uncertainty. This is indeed what she offers in Chapter 4.

(4) The *epistemic utility* of hypotheses: they clear the path to truth. Given the *epistemic gap*, and the *limitation* on what we can hope to achieve, hypotheses are a *necessary* part of the method by which we, as the kind of creatures that we are, should pursue our *goal* of finding true causes. Du Châtelet's account of hypotheses allows us to pursue our goal in the face of uncertainty by developing and making use of "probable reasons." The more probable a proposition becomes (through application of the method), the greater the degree of certainty (or the lower the degree of uncertainty) we are justified in attaching to it. There is alignment between the *method* and the *epistemic status* of the resulting claims.

Through her theorization of uncertainty in science, Du Châtelet is instrumental in transforming our conception of knowledge in physics (scientific knowledge) from certain truth to

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[60] Citations in support of this. Moreover, the hypotheses chapter was drawn on and referenced in the *Encyclopedia* entry on hypotheses, which – subject to work needed from the historians – we can surmise gave it an influence beyond those who came to it directly in the *Foundations* (notwithstanding (a) the shortness of the entry, and (b) the imposition of d'Alembert's epistemology into the entry, which she would not have agreed with – people would have had to use the reference to go to her Foundations to get the full picture of what she was doing).

[61] Du Châtelet spends considerable time in her opening chapters explaining these tools and how we are to use them, as we have seen.

[62] These include the non-mechanical "physical properties", such as elasticity, that we discussed above.

justified hypothesis (or justified theory, as we might say today), where justification is not all-or-nothing but comes in degrees. This was a transformation that was beginning, but my claim is that she is a critical figure in how it unfolded. It should not be under-estimated how profound a change in our conception of scientific knowledge is wrought by these developments, nor how important was Du Châtelet’s role.

## 6. Conclusions

In my opinion, Du Châtelet came to believe that the Newtonian method is inadequate for providing a secure epistemic foundation to underwrite claims to knowledge in physics, albeit fallible knowledge. As we have seen, Newton provided rules by which to arrive at causes, in line with the goal of physics as it was understood at the time, and one shared by Du Châtelet in her *Foundations*. However, as we have also seen, these methodological rules for how to reason in doing physics lacked adequate justification for securing the epistemic status of the resulting knowledge claims. What justifies us in claiming that the first and second rules are appropriate for arriving at true causes? Newton rests his first rule, and thereby his second, on the metaphysical principle that “nature does nothing in vain,” but says little to explain how this provides the appropriate justification. The third rule tells us how to identify “universal” qualities of bodies. How (or whether) to connect this result to essential, or even to causally-efficicious, properties remained under-theorized and controversial. Finally, the fourth rule asks that we take propositions gathered by induction to be “exactly true or very nearly true,” but the inductive methods that would justify this epistemic status for our scientific claims are not spelled out in any detail. Du Châtelet realized that a satisfactory response to “Pemberton’s Challenge” must include these justifications, or so I believe.

I have suggested that Du Châtelet intended the manuscript version of Chapter 4 to make good on the ambitions of Newon’s rules of reasoning as a response to “Pemberton’s Challenge” by spelling out a method for how to use induction in arriving at knowledge of causes (rules 1-3), and by providing a justification (in terms of this method) for taking the resulting claims to be “exactly of very nearly true” (rule 4). My suggestion is that Du Châtelet came to believe that her initial response to “Pemberton’s Challenge” was inadequate, and she re-wrote Chapter 1 at least in part to address this concern. She dropped her appeal to Newton’s rules of reasoning and turned instead to her version of Leibniz’s PSR and PC.[63] These enabled her to secure the epistemic foundations of scientific knowledge. For Du Châtelet, the PSR *must* be presupposed in order for knowledge of contingent truths to be possible *at all*. Without PSR, no reasoning from effects to causes is possible, which is fatal to the goal of determining the true causes. Without a commitment to PSR, the inductive reasoning suggested in Newton’s rules lacks justification. Having secured the epistemic foundations of physics, PSR and PC are then added to Chapter 4 as the first prong of her scientific methodology, and in that chapter their role is to assist in reining in

[63] Wells (2024) argues for the importance of Newton’s rules of reasoning in Du Châtelet’s methodology, including in the published version. See above.

the imagination so as to strengthen the alignment between the method and the justificatory status of the resulting hypotheses.

The opening four chapters of the *Foundations* put the following epistemic foundations in place. They explain what has to be the case for scientific knowledge to be possible. They explain what (sorts of things) can be known via the principles of our knowledge alone. They provide a method for using the principles of our knowledge combined with empirical resources to arrive at scientific knowledge. And they make clear what the epistemic status of these knowledge claims is, and how that status is justified. Importantly, they do not require certainty. Du Châtelet provides an account of how evidence accrues to propositions such that their degree of probability increases.

The way I read the *Foundations*, Du Châtelet's primary concern in the first four chapters is scientific method.[64] More specifically, these chapters are about the relationship between our epistemology, our methodology, and the corresponding metaphysical commitments that are pre-requisites such that scientific knowledge is possible. This is how I think about these four chapters and the philosophical work they're doing for Du Châtelet. I think Du Châtelet is exactly right that getting these three into alignment (the epistemology, the methodology, and the metaphysics) was one of the pressing challenges of the 17$^{th}$ and 18$^{th}$ centuries. So I also think that one way to evaluate her account of scientific methodology – one way to assess its strengths and shortcomings – is to look at how successfully it gets these three aligned. My view is that she is, overall, brilliantly successful.

I began this paper with "Pemberton's Challenge": how are we to "steer a just course" in scientific reasoning, between conjectures for which we have inadequate justification, and demanding mathematical certainty, which we cannot achieve in empirical science? My claim is that Du Châtelet set out to address this challenge by providing a method for arriving at scientific knowledge. In the process, she transformed our understanding of scientific knowledge and of the epistemic status of knowledge claims in physics. She provided a fully-theorized account of the *uncertainty* of hypotheses and of their *justification* as knowledge. Looking back from our present-day perspective, it seems to me that this is the upshot of her analysis and that, as in so much else, she was ahead of her time.

## Appendix A: Newton's rules of reasoning

*Newton's first rule*
"No more causes of natural things should be admitted than are both true and sufficient to explain their phenomena"

*Newton's second rule*

[64] Brading 2019.

“Therefore, the causes assigned to natural effects of the same kind must be, so far as possible, the same.”

*Newton’s third rule*
“Those qualities of bodies that cannot be intended and remitted and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally.”

*Newton’s fourth rule*
“In experimental philosophy, propositions gathered from the phenomena by induction should be considered either exactly or very nearly true notwithstanding contrary hypotheses, until yet other phenomena make such propositions either more exact or liable to exceptions.”

Newton, 1999, 794-6

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