# THE ROLE OF MATHEMATICS IN MAUPERTUIS'S EPISTEMOLOGY AND NATURAL PHILOSOPHY

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**Abstract.** The aim of this paper is to pinpoint the pervasive connections between Maupertuis's theory of knowledge and his particular way of unifying Newtonian science by means of a physico-metaphysical principle, i.e. the Principle of Least Action (PLA). It focuses on how epistemology fits into the discussion on the principle. Maupertuis's writings on this topic show a constant effort to balance between a purer form of empiricism and a mitigated ('rationalizing') one. On the one hand, the role of mathematics in the acquisition of knowledge is deeply connected with an empiricist viewpoint opposed to the mathematicism in the understanding of the natural world ascribed to Descartes and Wolff, but on the other hand, the applicability of mathematics in nature has to be considered an undeniable fact. The way to harmonize these seemingly divergent accounts is to set up a general principle that will allow mathematics to recommend itself as the most suitable cognitive instrument - namely, the metaphysical principle of simplicity. In the paper I will emphasize the rationale for the special status of this principle and why it acts like a bridge between epistemology and natural philosophy. Furthermore, I will try to offer a more precise understanding of the explanatory strategies employed by Maupertuis and examine why the PLA was chosen as a landmark case for their application.

**Keywords:** Maupertuis, epistemology, empiricism, laws, PLA, mathematics, simplicity

## Introduction

There is a general agreement that Maupertuis's principle of least action (PLA) is one of the most remarkable mechanical principles in the natural philosophy of the 18th century. Even if at the time of its development it was deemed controversial and marred by priority scandals, later it was appraised as a critical step in the evolution of mechanics.[1] However, although Maupertuis's scientific achievements have received wide acclaim and his merits concerning the elaboration of the PLA are clear, his philosophical output has been subjected to uncharitable criticism that often ignores the scope and the structure of the French author's argumentation. For example, in a paper of L. Gossman, it is argued that Maupertuis

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> […] was neither a systematic philosopher nor a notably rigorous thinker. His aim was not to construct a coherent philosophical system, but to attack a number of opinions to which he objected mainly on religious grounds. In doing so he was ready to adopt now one point of view, now another, to criticize an idea in one paper and to assume its validity in another.[2]

The detailed scholarship of G. Tonelli in the last decades of the previous century has done much to show that this critical outlook does not withstand careful scrutiny. Despite the fragmentary nature of Maupertuis's philosophical views, their coherence bears the mark of serious reflection and does not entirely lack systematic characteristics.[3] Moreover, it is impossible to correctly grasp the overall design of his achievement in mechanics without committing to a critical, architectonic estimation of his general philosophical views.

There are several reasons for the resistance on Maupertuis's part to go in for a more systematic endeavor. First and foremost, he professes an essential antagonism to system-building on the strength of interpreting this undertaking as a proliferation of metaphysical conceptualizations disconnected from the empirical inquiry of nature. In the most important sense, the word "system" refers specifically to metaphysical systems, that is, structured theoretical accounts founded on speculative principles, impervious to empirical refutation:

> Systems are real misfortunes for the progress of the sciences: a systematic author no longer sees nature, he sees only his own work. Everything which is not absolutely contrary to his system confirms it: the phenomena which are opposed to it to the greatest extent are nothing but a handful of exceptions. Those who read him, charmed by the acquisition of so much science at so little expense, join their interest to his. Such an edifice must remain standing, in order to bury the architect and all those who inhabit it under its ruins.[4]

Secondly, there is a constant evolution of Maupertuis's philosophical views and interests starting from his inquisitive explorations in the *Discours sur le différentes figures des astres* of 1732 and ending with the elegant and highly scrupulous tour-de-force in the *Examen philosophique de la prévue de l'existence de Dieu employée dans l'Essai de cosmologie* of 1756. In the first work the focus is almost exclusively on issues pertaining to the philosophy of science, to wit, the nature of gravity, physical forces and natural laws. In subsequent decades, he begins to develop and to supplement this account with a knowledge-theoretic foundation of a broadly empiricist background. An attempt to survey Maupertuis diachronically and contextually is bound to offer a vantage point for a more sympathetic assessment of his arguments.

More importantly, to evaluate Maupertuis's natural-philosophical endeavors is to understand how to situate him with respect to his predecessors in the wake of the grand methodological shifts at the turn of the 18th century. In this sense, the French author maintains an unshakable commitment to an empiricist worldview that gained ground due to the prestige and authority of Newton's *Principia* and at the same time he looks for a metaphysical foundation that would ensure the necessity of Newton's laws of motion.[5] Newton's overwhelming success in physics provided the incentive for philosophers to closely scrutinize the new methodological insights espoused therein and reconceptualize the ongoing debate on the structure of the natural sciences in empiricist terms. This marks a considerable rift with earlier 17th century attempts to provide a foundation for natural science starting from first principles.[6] The classical example that illustrates this development is Descartes. In a famous passage in the preface to his *Principles of Philosophy*, he states:

> Thus the whole of philosophy is like a tree. The roots are metaphysics, the trunk is physics, and the branches emerging from the trunk are all the other sciences, which may be reduced to three principal ones, namely medicine, mechanics and morals. By 'morals' I understand the highest and most perfect moral system, which presupposes a complete knowledge of the other sciences and is the ultimate level of wisdom.[7]

The Cartesian theoretical framework is established on two cornerstones: mathematics and mechanism. Descartes's account of scientific methodology hinges on a manifestly Euclidean penchant for starting from a foundation of firm, undeniable principles, drawn from reason as well as from empirical sources.[8] The decisive (and clearly, the most problematic) step is to link the more general metaphysical knowledge of substance and modes to specific physical phenomena. According to Descartes, the "glue" in this operation is mathematics, a science on the one hand grounded entirely a priori and confined to rational premises and on the other hand, suitable for the description and understanding of empirical facts. Once in the possession of a set of general principles, we can proceed therefrom mathematically to deduce all the special laws of nature and the structure of natural phenomena. Because the essential property of matter is extension (understood in a geometrical fashion), there is no clear distinction between geometry and empirical reality.[9] Therefore, in keeping with Descartes's conception of the scope of mathematics, all the knowledge concerning corporeal nature should be provided via mathematical methods.[10]

The mechanistic framework is generally grounded on the assumption that microscopic entities conform to a uniform and comprehensive set of laws that fully determine their behavior and hence, it follows, the behavior of more complex things they are constituents of; that is, it is strongly reductionist. Descartes had an epistemic bias towards seeking reductive accounts for phenomena by looking for explanatory factors exclusively at lower than higher levels. In his corpuscularian matter theory, we have a set of tightly causally connected parts having rigid spatial relations and behavior that is largely independent of their environment.[11] The parts compel themselves to adopt certain configurations due to their highly specific mode of reciprocal interaction and collective constraining. The web of natural laws is identified with the causal design that governs this "standard" mode of interaction – standard because the causal design imposes just one selected pattern to the disadvantage of many possible others. These laws operate in a typical bottom-up fashion, from the microscopic to the macroscopic.[12] In Cartesian physics, events and processes at the smallest scales are responsible for the changes that occur progressively at each level of complexity all the way up to planetary phenomena, in a strong deterministic manner.

It is not hard to see why this account is highly improper as a model of scientific investigation for Maupertuis. Because of its fundamentally deductive nature, all the results produced by means of the above-described methodology are absolutely certain and as such, there is no need to test them experimentally.[13] Descartes expresses that in the following way:

> […] I recognize no matter in corporeal things apart from that which the geometers call quantity, and take as the object of their demonstrations […] I will admit as true only what has been deduced from indubitable common notions so evidently that it is fit to be considered as a mathematical demonstration. And since all natural phenomena can be explained in this way, […], I do not think that any other principles are either admissible or desirable in physics.[14]

But according to Maupertuis and the Newtonians, if we proceed in this manner to deduce more specific and specialized phenomena, we will either reach at some point an outcome that conflicts with empirical reality, or, at best, an implausible construction marred by the permanent effort to preserve the main theoretical corpus by introducing ad-hoc hypotheses in order to keep the system in place.[15]

Furthermore, this paradigm staunchly diverges from the basic gist of the Newtonian worldview with its well-known investigative proviso "Hypotheses non fingo."[16] Although the extent to which Newton relies on the hypothetical-deductive method and the exact status of body in his system are a matter of scholarly debate and therefore, beside the scope of this paper, the empiricist proclivities of his work are undeniable.[17] For example, in the third of his *regulae philosophandi* he writes:

> Certainly idle fancies ought not to be fabricated recklessly against the evidence of experiments, nor should we depart from the analogy of nature, since nature is always simple and ever consonant with itself. The extension of bodies is known to us only through our senses, and yet there are bodies beyond the range of these senses; but because extension is found in all sensible bodies, it is ascribed to all bodies universally. We know by experience that some bodies are hard. Moreover, because the hardness of the whole arises from the hardness of its parts, we justly infer from this not only the hardness of the undivided particles of bodies that are accessible to our senses, but also of all other bodies. That all bodies are impenetrable we gather not by reason but by our senses. […] The extension, hardness, impenetrability, mobility, and force of inertia of the whole arise from the extension, hardness, impenetrability, mobility, and force of inertia of each of the parts; and thus we conclude that every one of the least parts of all bodies is extended, hard, impenetrable, movable, and endowed with a force of inertia. And this is the foundation of all natural philosophy.[18]

As we can see, Newton is certainly interested in finding the most general laws of nature but denies the possibility of identifying physics with geometry. In the preface to the first edition of the *Principia* he explicitly separates these two domains of inquiry, arguing that

> […] the whole subject of mechanics is distinguished from geometry by the attribution of exactness to geometry and of anything less than exactness to mechanics. […] geometry is founded on mechanical practice and is nothing other than that part of universal mechanics which reduces the art of measuring to exact propositions and demonstrations. But since the manual arts are applied especially to making bodies move, geometry is commonly used in reference to magnitude, and mechanics in reference to motion.[19]

The path of investigation is not arborescent, from axioms and principles to facts, but rather pyramidal: we begin with particular phenomena, as they are singled out, observed and measured (perhaps in experiments), and from there ascend to more general principles and laws that govern the empirical reality. Consequently, the attribution of certainty is turned upside down: whereas in the case of the antecedent paradigm, principles and axioms are assigned the greatest degree of certainty, after Newton this relationship is reversed: ascertained facts and phenomena are to be taken as a foundation for research, while more general principles and laws are only subsidiary to them; there cannot be any ontological commitment to them without acknowledging the foundational role of the layer of phenomena which ground them.[20]

With respect to the foundational role of metaphysical first principles, in the 18th century Christian Wolff argues in a manner similar to Descartes, even if a detailed survey of their philosophical methodologies reveals evident differences. But in what concerns the relation between metaphysics and physics, he also prescribes the subordinate status of the latter with respect to the former: according to Wolff, metaphysics and general cosmology demonstrate the first principles that are necessary to physics, while physics, in turn, draws its principles from ontology and cosmology:

> From what it has been said, it is clear that Metaphysics has to be placed ahead of Physics, if the latter is to be treated in a demonstrative way. Indeed, if Physics is to be treated demonstratively, its principles must be taken from Metaphysics. Thus, because the order of the parts of philosophy must be such as those which come first are those from which all the others borrow their principles, all the more Metaphysics should be placed before Physics.[21]

Thus it appears that for Wolff there is a strict methodological priority of metaphysics with respect to physical science.[22] However, the German philosopher disagrees with Descartes on the role mathematics ought to have in his framework. Specifically, he rejects the Cartesian geometric interpretation of physics, noting that the incursion of mathematical concepts in the sensory realm often leads to a confusion of what is imaginary with what is actual (real). This criticism also applies to Newton's conception of space.[23]

It must be noted that Wolff's general methodological approach is thoroughly axiomatic. The basic idea of this approach is that certain propositions are to be developed from other propositions of a more foundational level. Some of these propositions merely tell us what things are or define them, while others or axioms spell out some further characteristics of things. Wolff discriminates explicitly between mathematics and what he calls natural philosophy (*Naturlehre*), observing that it falls outside the scope of either to investigate what kind of reality objects have, if any at all. From a mathematical perspective, the correct approach is to single out the quantitative extension of the body (length, width, height), and purposely omit all the other qualities as extraneous. However, even if mathematics doesn't operate with real objects, but with concepts of imagination, these are "sufficient for finding the magnitudes" of things.[24] Mathematical science's purposes are such that imaginary concepts suffice for them. According to the German philosopher, even if mathematics cannot be used in the absolute, deductive manner championed by Descartes, "it by no means follows that Mathesis cannot be of service to metaphysics more generally."[25] More precisely, mathematics can be successfully employed to establish concepts in ontology, because the scope of mathematics' application is perceptual experience drawn from the natural world.

In the next section we will examine in what terms Maupertuis defines his philosophical framework and in what manner he critically evaluates the views of his predecessors, especially with respect to the role of mathematics as an epistemological instrument in natural philosophy.

**Maupertuis's theory of knowledge: mathematics and the search for certainty**

An examination of the French philosopher's writings quickly reveals a fundamental distrust concerning the cognitive capacity of the human intellect to achieve certainty in the sciences. An early exemplification of this epistemic pessimism is materialized in his early treatise on the shape of heavenly bodies, where, after considering Newton's rejection of attributing a cause to gravity, he concludes:

[…] I don't believe we are allowed to ascend to first causes, nor to understand how the bodies act one towards another.[26] Here Maupertuis follows the basic Newtonian insight that the investigation of effects is sufficient insofar these effects can be adequately subsumed under mathematical laws, and this is sufficient for the explanation of natural phenomena from a scientific point of view. In a later work from 1740, *Réflexions philosophiques*, we see Maupertuis vigorously extending his skepticism in the theory of knowledge and denying the capacity of human reason to move beyond our perceptual knowledge to reach its sources. This compels him to adopt a phenomenalistic position.[27]

Seeing thus that there is no similarity, no link between our perceptions and the external objects, it will be agreed that all these objects are nothing more than mere phenomena: extension, which we've taken as a foundation for all these objects, extension itself is nothing more than a phenomenon.[28]

After 1750, his earlier phenomenalistic views have undoubtedly been strengthened by the reading of Berkeley, whom he mentions approvingly.[29] Not unlike Berkeley, Maupertuis leans towards a certain kind of nominalism: if the "object" itself is nothing more than its perceptive reality, then this existence is justified by the accumulation of past perceptions of the object, present ones and also anticipations of future perceptions. Because the memory does not retain perfectly individual simple perceptions, the use of signs becomes necessary in order to ascertain the "there is" of an object. Pursuing further this presupposition of phenomenalism procures wider implications: the contingency of all knowledge, linguistic relativism, and uselessness of systematization.[30]

> But, if it is true that all our knowledge does not rely on anything else than first impressions, that the [external] objects have made upon our senses […] our science will not be anything anymore, it will be no different from a mere attribute that relates only to our species. […] Seeing how little agreement there is between the philosophers, it could be well worth thinking this last supposition to be the true one: [namely, that] our science is built upon principles which have nothing absolute.[31]

Thus Maupertuis, in a manner reminiscent of Berkeley and Newton before him, appears to confine and relegate all explanations of phenomena to the empirical level. It is perfectly acceptable to posit that connections between empirical phenomena can be grounded horizontally (effect-to-effect) instead of trying to bind them with a reality which lies beyond the appearances.[32] Consequently, the physical terminology employed by the natural philosopher which includes words like 'force', 'fall', 'attraction' and others have no ontological reference to something *beyond* the empirical.[33] In the *Essai de Cosmologie*, he extends that judgment to all the laws that are postulated by the scientist: they target exclusively perceptual experience and are "results of the phenomena":

> If a person who never touched a body and never saw it clashing with another, but has the experience of what happens when we mix colors, sees a blue body move towards a yellow body and is asked as to what will happen when these two bodies meet, probably he could say the blue body would become green as soon it hits the yellow body. But I do not think it's possible to foresee that the two bodies will unite to move with the same velocity, or that one will transfer to the other a portion of its velocity to move in the same direction with a different velocity, or that it will be deviated in the opposite direction.[34]

According to this assessment, there is nothing a priori in this case which would point to the relevant conclusions - experience is the sole witness that needs to be consulted in order to see what happens when two bodies clash.[35]

However, Maupertuis is skeptical to pursue the phenomenalistic premise to its logical conclusion, because it leads to a certain incompatibility with an alternative view which he partially rejects. According to this view, if God exists as an immutable and eternal being, then there is a whole gamut of necessary truths on which we can successfully base our reasoning, and thus establish certainty in the sciences. Maupertuis accepts the premise of this argument but rejects the conclusion. But then a curious conundrum arises: if we subscribe to the prospect that all our knowledge is based upon perceptions of particular, contingent phenomena alone, how can we be certain of the reality of God's existence? The necessity of finding an adequate proof for God's existence is a recurring theme all throughout his later philosophical output. The concern for an argument of this kind is manifested in an exemplary way in his *Essai de cosmologie*. According to Maupertuis, adequacy is to be equated with consistency and freedom from contradiction, as these are epistemic values that lead to certainty. In the *Essai* he argues at length against the argument from design and deems it plagued by inconsistencies, and countenances the need to prove the existence of the Supreme Being from the most general laws of nature.[36] Such laws need a mathematical form, because only mathematics can ensure the required certainty:

> Let us see whether we can find a suitable use for this science. Mathematical proofs for God's existence would have, above all others, the certainty which is characteristic of mathematical truths. Those who don't have enough trust in cosmology in their metaphysical reasoning would find more certitude in this kind of proofs, whereas those exposed to the popular proofs would find mathematical arguments more elevating and precise.[37]

But why is mathematics more certain and more precise than all the other sciences? Here, as it turns out, Maupertuis has an answer which resides in his particular understanding of the nature of mathematical objects. As we have seen, the French philosopher has noted the perennial disagreement in the sciences between the theoretical assessments of phenomena and the want of a methodology for gauging the truth and certainty of these assessments. This is true for all the sciences, saving mathematics. Only in mathematics there is agreement between all those who examine a given proposition.[38]

Maupertuis's approach concerning mathematics is robustly coherent with his general phenomenalistic approach. Mathematical concepts and ideas are, in essence, not different from all other concepts and ideas: they are perceptions that come from the senses. They are certainly not platonic archetypes of things, fallen from the skies; if that were true, as Maupertuis likes to stress, then we would be in the possession of the most secure foundation for the sciences. However, as he previously argued, this is clearly not the case. Thus, the French philosopher rejects explicitly to award mathematics such a massive central role, arguing instead for one greatly mitigated from the one present in the systems of Descartes, Wolff or even Newton. Furthermore, not only mathematical objects are not to be found out there a priori of all experience, they are not even creations of our own minds. Maupertuis is highly critical of the Wolffian stance concerning the origin of mathematical objects according to which they are created by the imagination ("figmenta imaginationis"):

> However, if the matter is looked upon more carefully, it is not so easy to pinpoint the true cause that gives mathematics advantages over all the other sciences, because […] saying that in mathematics the mind creates itself the object that it considers amounts to saying nothing or saying something

> entirely false: our mind creates nothing, it receives through the senses the impressions of objects. We may call *ideas* some of these perceptions while leaving the name *sensations* to the others [and the mind] can combine or separate them in thousands of ways, but it doesn't create a single new object, a single new perception.[39]

If all mathematical knowledge is drawn from empirical premises, one of the problems finds its solution: there is no need to posit a special framework to bridge mathematics and empirical reality, because mathematics comes *from* empirical reality; that is to say, the bulk of our perceptions is structured mathematically.

According to Maupertuis's mind, there is a reason why mathematics has a superior certainty with respect to the rest of the sciences and that is because mathematical objects possess a specific meta-property which he calls *replication* ("réplicabilité"). This quality belongs only to two properties of objects: number and extension. The idea of number is formed through the apprehension of the *form* of consecutive arrangement of perceptions, whose content is abstracted away. In the case of extension, it forms through considering the geometrical magnitudes of the body stripped of its sensible qualities; the end result is a Euclidean space. The nature of replication allows these two properties to be augmented and diminished at will.[40] This is possible because of the homogeneity of both number and extension: each 'unit' of these properties is identical and congruous to any such unit previously considered. Other qualities, like impenetrability, lack this propensity and cannot be manipulated in the same way:

> […] impenetrability, like extension itself, is a quality present in all bodies; [but] I don't know how to add an impenetrability to another impenetrability, nor to subtract one impenetrability from another in order to obtain a doubled or tripled, halved or cut-in-three impenetrability.[41]

Thus, mathematical objects, on the strength of their capacity to replicate, forge a systematic science that is internally coherent, consistent, and ultimately enclosed in experience.

**Dynamics, teleology and the structure of laws**

Once the configuration of the general epistemological framework is established, we can take a glance as to how it applies to mechanics and the movement of bodies. Concerning these, Maupertuis is much more cautious than in the case of pure mathematics: even if the application of mathematics renders mechanics more certain and truthful, not all the qualities of the bodies considered in mechanics possess replication, and as such, we must be careful in what way we interpret the results:

Dynamics will not always lead us to results as simple and clear as those of arithmetic and geometry; although there can be evidence and certainty if one discriminates in each object what is replicable from what is not; that one does not apply to an object in general what belongs only to some of its parts; finally if one is careful to explain and to understand.[42]

Hence, in dynamics we can only be certain insofar as the phenomena under consideration can be scrutinized by mathematical devices.[43] That is, as long as mathematics is considered in itself as a self-sufficient enclosed system, all mathematical results are *necessary*, that is, they do not require experimental proof. But as in natural science we have access only to the empirical phenomena (via perceptions), there is no way to conclude whether any of the prospective laws are necessary or contingent. Maupertuis's own engagement to phenomenalism precludes him to climb up the ladder to a causal supra-empirical layer that would ground the status of these laws. Clearly, a different approach is required.

Such an approach is revealed when we examine what place God ought to take in this system. Maupertuis acknowledges that is impossible to prove God's existence starting from phenomena or even theory-laden accounts of these phenomena; there is no certainty in such a procedure. Instead, he claims to reverse the order of proof in order to deduce mathematical laws from the attributes of the Supreme Being.[44] But to be sure, otherwise than declaratively, there is no trace of this kind of demonstration in his work. Instead, he works strenuously to integrate two divergent perspectives*:* a first empirical, bottom-up approach and a second teleological, top-down approach.[45]

The first type of approach was briefly sketched above. According to it, the world amounts to nothing more than an empirical matrix that supplies our cognitive apparatus with individual perceptions of the phenomena, which are in turn analyzed in order to identify their mathematical elements. The usual *modus operandi* is that of the natural scientist: to carry out measurements of a pool of effects and then try to establish mathematical connections between these effects. Whatever certainty is achieved in this process, evidently it will be only partial and mediated, as the perceptions in question also hold a plethora of properties unbefitting quantitative analysis.

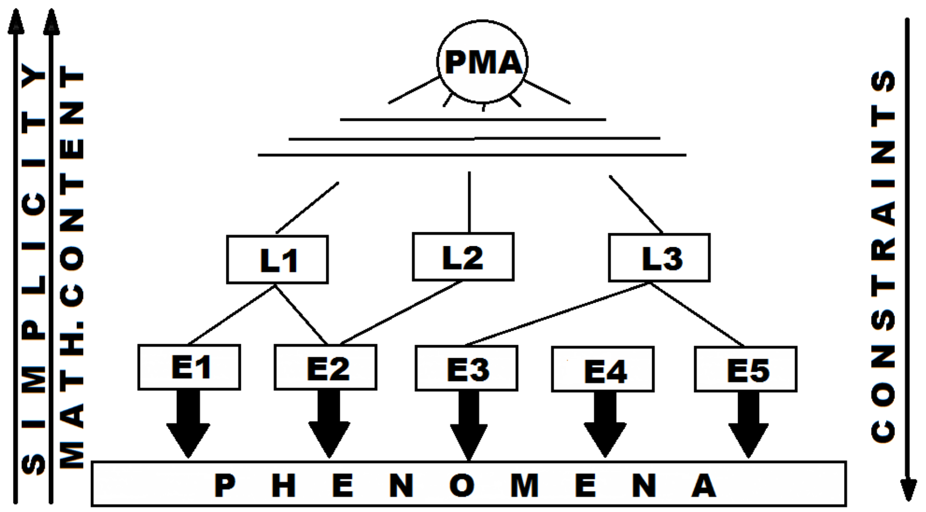
The second approach can be called teleological or structural. In one key passage, Maupertuis urges:

> The Supreme Being is everywhere; but He is not equally visible. We see Him better in the simplest objects: let us seek Him in the first laws that He imposed upon nature – in these rules according to which motion is preserved, distributed or destroyed – and not in phenomena which are but more complex consequences of these laws.[46]

The line of reasoning is framed as follows. Because God's existence can neither be validated empirically, nor asserted dogmatically in a priori fashion, the only way to prove it is to assume it hypothetically, and then to argue that nature is organized according to a structure that exhibits inherent causal order. If this causal order is grounded upon a metaphysical principle that concords with the divine attributes, then we can proceed to assume, by an inference to the best explanation, that the deployed metaphysical principle is not arbitrary but expresses intent.[47] In other words, if nature itself considered empirically expresses a subjacent immutable order in the laws that govern the phenomena, and this order may be purportedly accredited to a general non-empirical principle, it can be safely argued that this order is not arbitrary but hinges instead on the will and wisdom of a Designer.

Maupertuis is a determinist,[48] but unlike in the case of Descartes, his determinism does not rely on the causal, microstructural propensities of matter, but rather on a well-established hierarchy of laws. A better understanding of nature is achieved not by researching the mutual influence between a composite mix of corpuscles, but by inquiring into the laws that explain the regularities in the phenomena. The way the laws are connected, their reciprocal interaction and scope can reveal more about nature than we are able to gather by focusing on the causal powers, to which we may have at best only limited epistemic access. Therefore, it makes sense methodologically to shift the focus from innate causal powers that inhere in matter to laws and relations of dependence between laws. This strategy that could be deemed "law-constitutive" is of course reminiscent of Newton's similar attempts in the *Principia*. Because the concept of force cannot be suitably derived from corporeal microstructure, considering universal regularities as the starting point may serve as a more lucrative alternative which has the benefit of being explanatory powerful.[49]

This hierarchy of laws is rigorously organized according to their simplicity: the more particular empirical laws are situated at the bottom, while the wider-scope general laws are positioned at upper levels. At the topmost level, we should find the most general law, to which all the others are subordinate: on the grounds of its universality, says Maupertuis, sure it must count as a proof for God's existence, as opposed to other laws who are true only on certain conditions.[50] This general law is the Principle of Least Action (hereafter abbreviated PLA).[51] In the *Essai de Cosmologie*, Maupertuis gives PLA the following expression: "When there is a change in Nature, the quantity of action employed in this change is always the smallest possible." In his essays on the laws of optics and on the laws of motion and rest, he conjectures a mathematical formulation of the principle which is more in accordance to the subject-matter. Nevertheless, commentators have remarked that even with this caveat, the principle has the whiff of a metaphysical postulate rather than sound scientific thinking.[52]




*The hierarchy of laws according to Maupertuis*

Initially, in his essay on optics, the principle was stated in the following two forms: "the sum[53] is minimal" and "the quantity of action[54] is minimal". When a particle moves from point A to point B it does so at a specific velocity and follows a specific path. According to Maupertuis, the quantity of action is proportional "to the sum of the distances, each multiplied by the velocity at which the body passes through it".[55]

Later he put the principle in the metaphysical form quoted above. This development is indicative of Maupertuis's propensity for a more general methodology which focuses directly on structure of the laws (particularly the laws of motion). Furthermore, it marks an ontological commitment to the concept of law: empirical reality must obey laws. This assumes that laws possess a constitutive force that defines the structure of material reality.[56]

**Introducing simplicity as a bridge principle: from epistemology to teleology and beyond**

*Prima facie* the two perspectives seem too disconnected and divergent to even attempt to reconcile them. However, to my mind there is a principle that can function like metaphysical liaison that aggregates them in a coherent framework that does justice to both. That is, they both rely on a principle of simplicity. From ancient times up to modernity, philosophers such as Aristotle, Ockham, Leibniz and Newton have adhered to one or another version of the principle.[57] First let us examine how Maupertuis defines a principle in general. In mathematics he takes it to be a particular heuristic device to traverse the middle ground between axioms and empirical instances, and therefore is not prone to rigorous demonstration.[58] However, "[…] their certainty is so great that some mathematicians do not hesitate to make them the foundations of their theories, and use them every day to solve problems that would cost them much more trouble without these principles."[59] However, simplicity itself can be thematically restricted to two distinct meanings. The first sense of simplicity invoked here is the simplicity of mathematical objects:

> Until now, the goals of mathematics have rarely gone beyond coarse needs of the body and useless speculations of the spirit. The truths that it has uncovered are mostly those relating to dimensions and numbers. One should not be deceived by philosophical works that pretend to be mathematical, but are merely dubious and murky metaphysics. Just because a philosopher can recite the words lemma, theorem and corollary doesn't mean that his work has the certainty of mathematics. That certainty does not derive from big words, or even from the method used by geometers, but rather from the utter simplicity of the objects considered by mathematics.[60]

This particular flavor of simplicity is conspicuously epistemic, being inseparable from the certainty mathematics brings into natural philosophy. As we recall, the argument has been made along the following lines:

1. Mathematical objects have the property of replication, which disposes them as susceptible to quantitative analysis. These objects possess the utmost certainty because the lack of disagreement concerning their nature. Simplicity of mathematical objects in this sense is related to certainty and amounts to uninterpreted understanding free of contradiction.

2. In mechanics, certainty is directly proportional to the magnitude of replication detected in those objects. Mechanics is more certain insofar it can be mathematized. But because the objects of dynamics are, as we have seen above, laws, simplicity in this case amounts to nothing more than the possibility to focus on mathematical magnitudes while abstracting away empirical content that can't be appropriated via mathematical methods.

3. Thus, in mathematics and mechanics, simplicity appears as an epistemological device employed in the use of certainty: simplicity of understanding, of grasping, of apprehension.

But at the same time, Maupertuis is poised to assert that nature is organized (by God) in such a way that the laws of physics are hierarchically positioned from the most specific at the base (empirical laws) to the most generic at the top which is PLA. This hierarchy is also organized according to simplicity, as Maupertuis frequently mentions PLA being the simplest principle. But simplicity in this case has an entirely different meaning: that is, it refers to the *scope* or *domain of application* these laws have in empirical reality: more simpler laws cover more empirical ground that reunites different types of phenomena, while less simple laws are constrained to a specific domain of inquiry or type of phenomenon. The simplest law, the PLA, is granted by Maupertuis universal applicability:

> We may admire the applications of this principle in all phenomena: the movement of animals, the growth of plants, the revolutions of the planets, all are consequences of this principle. The spectacle of the universe seems all the

> more grand and beautiful and worthy of its Author, when one considers that it is all derived from a small number of laws laid down most wisely.[61]

Defined in this manner, simplicity is clearly metaphysical. Theologically, it can be interpreted in the sense that God desires order and designed reality as being homogenously amenable to structural laws: if the position in the hierarchy of laws is higher, so is the amount of order to be found.

But how can we relate the simplicity that structural laws impose, that is, understood as a measure of homogeneity ("uniformité"), with simplicity understood as the epistemic gauging of how much phenomena are mathematized? The answer lies in the unity between laws and mathematics. Connecting these two accounts of simplicity yields the following outcome: more particular laws in the hierarchy are less mathematized and are complemented by a bulk of unstructured empirical content, empirical testing or experimentation being required to discern the setting and the scope in which these laws operate. Concurrently, topmost generic laws are almost entirely mathematical and are much removed from the empirical content, thus requiring almost no empirical testing.[62] As an example we can emphasize the contrast between the laws of modern quantum mechanics and the laws of classical, Newtonian mechanics – the former are greatly mathematized, more general and their empirical content is harder to identify, while the latter have a narrower scope, less mathematical structure and more unstructured empirical content. It is important to note that for Maupertuis the symbolic formulation of the law, whether simple or complex, has no bearing whatsoever on the peculiar type of simplicity described above. This is unintuitive to some extent, because ordinarily we are used to tie the complexity of the symbolic formula to the complexity of its subject matter: thus understood, particular law-like correlations between measured magnitudes are simple, while more generic laws which carry a surplus of theoretical content are of increasing complexity. Not so for Maupertuis; for him, theoretical content is simple because it streamlines a set of well-connected, very general laws that cover a large swath of phenomena.

Essentially, what is revealed is that at any level of the hierarchy of laws, simplicity – in both its epistemic and metaphysical forms – is implicitly correlated with the measure of connectedness in the structure of the laws at that level. As argued previously, a more unified structure allows capturing more empirical content, while at the topmost level a structural principle like the PLA ultimately licenses the capture of all empirical content. Consequently, simplicity is deeply ingrained in the mathematical structure of reality.

**Conclusion**

Maupertuis's conception of the unifying power of simplicity in natural science provides the key mechanism for linking his eminently teleological principle of least action with the claims expressed in his theory of knowledge, more specifically, that mathematics is the primary vehicle for procuring certainty in mechanics. The need of integrating these two perspectives compels him to pivot around a dichotomic structure. On the one side there is the typical empiricist argument where individual laws emerge from phenomena, but a deeper understanding of the reasons of this development is inhibited by the limits of our own cognition; on the other side there is a hierarchy of necessary laws whose rigid organization exhibits operative design. A metaphysical principle of simplicity assumes the status of an interface between the complementary perspectives, effectively enabling their merging in a coherent way. This newly framed configuration employs a dynamic that is simultaneously bottom-up and top-down: the mathematical patterns and law-like regularities obtained from the phenomena mirror the patterns of homogeneity or order in the hierarchy of laws. Thus the link between epistemology and teleology in Maupertuis's natural philosophy is made manifest, allowing us a better understanding of his theoretical accomplishments.

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**References**

[1] On Maupertuis's controversies with Koenig and Voltaire, see Terrall, M., *The Man who flattened the Earth: Maupertuis and the Sciences in the Enlightenment* (Chicago: The University of Chicago Press, 2002), 293-309, and Beeson, D., *Maupertuis: An intellectual biography* (Oxford: Voltaire Foundation, 1992), 243ff. For the appraisals see Boudri, J. Chr., *What is Mechanical about Mechanics: the Concept of Force between Metaphysics and Mechanics between Newton and Lagrange* (Dordrecht: Springer, 2002), 137-138 and note 51 below for a quotation from Max Planck.

[2] Gossman, L., "Berkeley, Hume and Maupertuis", *French Studies* 14 (1960): 304-324.

[3] Tonelli, G., *La Pensée philosophique de Maupertuis: son milieu et ses sources* (Hildesheim: Georg Olms Verlag, 1987), 4.

[4] Maupertuis, P. L-M., *Oeuvres*, 4 vols. (Lyon, 1768, 2nd edition), vol. II, 257. Following this, Maupertuis criticizes Leibniz's metaphysical principles and mentions favorably Condillac's critique of those principles in the latter's *Traité de systèmes.* On Condillac's influence on Maupertuis and vice versa, see McNiven Hine, E., *A critical study of Condillac's Traité de systemes* (The Hague: Martinus Nijhoff Publishers, 1979), 139-142.

[5] On this point and the influence of Leibniz on the debate concerning the necessity of laws, see Charrak, A., *Contingence et nécessité des lois de la nature au XVIIIe siècle* (Paris: Vrin, 2006), 89-162 (chapters 3 and 4).

[6] This methodological shift has been thoroughly described in Cassirer's classic monography *Philosophy of Enlightenment.* See Cassirer, E., *The Philosophy of Enlightenment*, trans. J.P.A. Koelln and J. P. Pettegrove (Princeton: Princeton University Press, 1951), 50-54.

[7] Descartes, R., *Oeuvres de Descartes* (hereafter AT) eds. Ch. Adam and P. Tannery, 2nd ed. (Paris: Vrin, 1964–
1974), 11 vols. I will use the translations from *The Philosophical Writings of Descartes* (hereafter CSM) trans. J. Cottingham, R. Stoothoff, and D. Murdoch (Cambridge: Cambridge University Press, 1984–1985), 2 vols. and The Philosophical Writings of Descartes, vol. III (hereafter CSMK), trans. J. Cottingham, R. Stoothoff, D. Murdoch, and A. Kenny (Cambridge: Cambridge University Press, 1991). Descartes, R., CSM I, 186; AT IX-b, 14. A further analysis

and assessment of the problematic status of Descartes' peculiar ramification of the sciences is pursued in Ariew, R., "Descartes and the Tree of Knowledge", *Synthese* 92/1 (1992), 101-116.

[8] Garber, D., *Descartes' metaphysical physics* (Chicago: University of Chicago Press, 1992), 32. According to Garber's interpretation, epistemology underlies the entire system, in which metaphysics and physics, while separate domains of inquiry, are mutually interdependent. An alternative viewpoint that emphasizes the role of physical principles in Descartes' methodology is espoused in Gaukroger, S., *Descartes' system of natural philosophy* (Cambridge: Cambridge University Press, 2002), 67.

[9] "The nature of body consists not in weight, hardness, color, or the like, but simply in extension." CSM I, 224; AT IX-b, 65.

[10] There is a divergence between the role of mathematics thus defined by Descartes and how he actually employs mathematics in his physical works. On this issue see the discussion in Gaukroger, S., (2002), 67-69.

[11] Gaukroger, S., (2002), 68.

[12] Gabbey, A.,"Descartes' Physics and Descartes' Mechanics: Chicken and Egg?", in: *Essays in the philosophy and science of Rene Descartes,* ed. S. Voss (Oxford: Oxford University Press, 1993), 315.

[13] Gaukroger, S. "Descartes' project for a mathematical physics", in *Descartes: Philosophy, Mathematics and Physics*, ed. S. Gaukroger (Sussex: The Harvester Press, 1980), 134.

[14] CSM II, 247; AT IX-b, 102.

[15] Cotes' harsh critique of Cartesian vortices in his preface to Newton's *Principia* is illustrative on this matter. See Newton, I., *The Mathematical Principles of Natural Philosophy*, trans I. B. Cohen and A. Whitman (Berkeley: University of California Press, 1999), 385-399. On Maupertuis's take on the vortices, see the chapter "L'incompatibilité des lois de Kepler dans le système tourbillonnaire et la supériorité de l'explication newtonienne d'après Maupertuis" in Brunet, P., *L'introduction des théories de Newton en France au XVIIIe siècle* (Paris : Librairie Scientifique Albert Blanchard, 1931), 215-218.

[16] "I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy." Newton, I., (1999), 943. For a historical and textually-informed discussion on the meaning of *fingo*, consult Cohen's introductory study in this volume, § 9.1.

[17] The secondary literature on Newton's empiricism is substantial; for the purposes of this paper, especially relevant are Biener, Z. and Smeenk, C. "Cotes' Queries: Newton's Empiricism and Conceptions of Matter", in *Interpreting Newton. Critical essays,* ed. A. Janiak (Cambridge: Cambridge University Press, 2012), 105-138, Janiak's own *Newton as philosopher* (Cambridge: Cambridge University Press, 2008), 25-32, and chapter 2 of McGuire, J.E., *Tradition and Innovation: Newton's Metaphysics of Nature* (Dordrecht: Kluwer Academic Publishers, 1995), 52-102. A good introduction to Newton's labyrinthine natural-scientific methodology is Ducheyne, S., *The Main Business of Natural Philosophy: Isaac Newton's Natural-Philosophical Methodology* (Dordrecht: Springer, 2012).

[18] Newton, I., (1999), 795.

[19] Newton, I., (1999), 382.

[20] Cassirer, E., (1951), 52.

[21] Wolff, Chr., "Discursus praeliminaris de philosophia in genere", in *Philosophia rationalis sive Logica* (Frankfurt and Leipzig, 1740, 3rd edition), 1-104, §95. *Ex dictis patet, Metaphysicam Physicae praemittendam esse, si ea demonstrativa ratione pertractari debet. Si enim Physica demonstrativa ratione*

*pertractanda, principia petenda sunt ex Metaphysica. Quoniam itaque partium philosophiae ordo esse debet, ut eae praecedant, ex quibus aliae principia mutuantur; Metaphysica utique Physicae praemittenda.*

[22] Leduc, Chr., "La métaphysique de la nature à l'Académie de Berlin", *Philosophiques* 42/1 (2015) : 11-30.

[23] On the subject of mathematical cognition see the relevant paragraphs in Wolff's *Discursus praeliminaris,* namely §§14-19, §§33-34, §§93-97.

[24] Dunlop, K., "Mathematical method and Newtonian science in the philosophy of Christian Wolff", *Studies in the History and Philosophy of Science A* 44/3(2012), 1-13.

[25] Wolff, Chr., *Des weyland Reichs-Freyherrn von Wolff übrige theils noch gefundene kleine Schriften und einzele Betrachtungen zur Verbesserung der Wissenschaften* (Halle, 1755), 321-322.

[26] Maupertuis, *Oeuvres* I, 93. *Je ne crois pas qu'il nous soit permis de remonter au premières causes, ni de comprendre comment les corps agissent les uns sur les autres.*

[27] Tonelli, G., (1987), 8.

[28] Maupertuis, *Oeuvres* II, 233. *Réfléchissant donc sur ce qu'il n'y a aucune ressemblance, aucun rapport entre nos perceptions et les objets extérieurs, on conviendra que tous ces objets ne font que de simples phénomènes: l'étendue, que nous avons prise pour la base de tous ces objets, pour ce qui en concerne l'essence, l'étendue elle-même ne sera rien de plus qu'un phénomène.*

[29] "But if you want me to rely on a most straightforward and respectable authority, I will cite Mr. Berkeley, whose opinions on the matter are very close to ours." Maupertuis, *Oeuvres* I, 305.

[30] Ibrahim, A., "Matière inerte et matière vivante. La théorie de la perception chez Maupertuis", *Dix-huitième Siècle* 24 (1992) : 95-103.

[31] Maupertuis, P.-L.M., "Examen philosophique de la preuve de l'existence de Dieu employée dans L'essai de cosmologie", (Berlin Academy of Sciences, 1758), 389-424 (Hereafter *Examen*). *Mais, s'il étoit vrai que toutes nos connoissances ne dépendissent que des premières impressions que des objets ont faites sur nos sens, […] notre Science ne seroit plus rien d'absolu, elle ne seroit qu'une propriété apartenante a notre espèce. […] Le peu d'accord que nous voyons entre les Philosophes seroit bien capable de faire penser que c'est cette dernière supposition qui est la véritable : que notre science n'est fondée que sur des principes qui n'ont rien d'absolu.*

[32] For instance, concerning the laws of motion he points out: "As soon as the true mode of philosophizing was introduced, one was no longer satisfied with these vain disputes concerning the nature of motion, but rather wished to know by what laws it is distributed, preserved and destroyed: it was felt that these laws were the foundation of all natural philosophy." Maupertuis, *Oeuvres* I, 35-36.

[33] The similarity with Berkeley's views is striking: "'Force', 'gravity', 'attraction' and similar terms are useful for reasoning, and for calculations about motion and moving bodies, but not for understanding the simple nature of motion itself or for designating so many distinct qualities. It is certainly true that, in the case of attraction, it was used by Newton not as a genuine physical quality but merely as a mathematical hypothesis. And even Leibniz, when he distinguished elementary effort or striving from impetus, confesses that those entities are not really found in the natures of things but are constructed by abstraction." Berkeley, G., "On motion", in: *Philosophical Writings* (Cambridge: Cambridge University Press, 2008), 248 (§17).

[34] Maupertuis, *Oeuvres* I, 31. *Si quelqu'un qui n'eût jamais touché de corps, et qui n'en eût jamais vu se choquer, mais qui eût l'expérience de ce qui arrive lorsqu'on mêle ensemble différentes couleurs, voyoit un corps bleu se mouvoir vers un corps jaune, et qu'il fût interrogé fur ce qui arrivera lorsque les deux corps se rencontreront; peut-être que ce qu'il pourroit dire de plus vraisemblable seroit, que le corps bleu deviendra vert dès qu'il aura atteint le corps jaune. Mais qu'il prévît, ou que les deux corps s'uniroient pour de mouvoir d'une*

*vîtesse commune, ou que l'un communiqueroit à l'autre une partie de sa vîtesse pour se mouvoir dans le même sens avec une vîtesse différente, ou qu'il se réfléchiroit en sens contraîre, je ne crois pas cela possible.*

35 Gossman, S., (1960), 312-313.

36 Maupertuis, *Oeuvres* I, 21-22.

37 Maupertuis, *Oeuvres* I, 22-23. *Voyons si nous pourrons faire un usage plus heureux de cette science. Les preuves de l'existence de Dieu qu'elle fournira auront fur toutes les autres l'avantage de l'évidence, qui caractérise les vérités mathématiques: ceux qui font pas assez de confiance de Cosmologie dans les raisonnemens métaphysiques, trouveront plus de sûreté dans ce genre de preuves: et ceux qui ne font pas assez de cas des preuves populaires, trouveront dans celles-ci plus d'élévation et d'exactitude.*

38 Maupertuis, *Examen*: 392.

39 Maupertuis, *Examen*: 393. *Cependant si l'on considère la chose avec plus d'attention, on ne trouvera pas si facile de marquer la véritable cause de l'avantage de mathématiques sur les autres sciences, car […] dire que dans les mathématiques l'esprit s'est forme l'objet qu'il considère, c'est ne rien dire, ou dire quelque chose de très faux : notre Esprit ne crée rien, il reçoit par les sens l'impression des objets. Il peut appeler idées quelques-unes des perceptions et laisser le nom de sensations aux autres ; il les peut joindre et séparer de mille manières différentes, mais il ne crée pas un seul objet nouveau, il ne crée pas une seule perception nouvelle.*

40 Maupertuis, *Examen*: 394-395. This is an eminent anticipation of an idea which assumes a central role in L.E.J. Brouwer's intuitionistic philosophy of mathematics, namely, that a mathematical heap-object can be extended at will by the addition of extra members. This was so fundamentally important for Brouwer that he called it a core intuition (*Urintuition*) of his philosophy; on this see Black, M., *The Nature of Mathematics: A Critical Survey* (New York: The Humanities Press, 1950), 10-11. Maupertuis commitment to empiricism would prevent him, though, to accept Brouwer's constructivist tendencies of this methodology.

41 Maupertuis, *Examen*: 395. *[…] l'impénétrabilité, […] comme l'étendue, se trouve dans tous les corps, [mais] je ne saurois ajouter une impénétrabilité a une autre impénétrabilité ; retrancher une impénétrabilité d'une autre pour en former une impénétrabilité double ou triple, moitié ou tierce.*

42 Maupertuis, *Examen*: 400. *La dynamique ne nous conduira donc pas toujours à des résultats aussi simples et aussi clairs que ceux de l'arithmétique et de la géométrie ; quoiqu'on y puisse trouver l'évidence et la certitude, si l'on y distingue toujours bien dans chaque objet ce qui est replicable et ce qui ne l'est pas ;qu'on n'applique pas à un objet en général ce qui n'appartient qu'à quelques-unes de ses parties ; enfin si l'on a bien soin de s'expliquer et de s'entendre.*

43 This reflects in a remarkable way Einstein's views in the essay *Geometry and experience:* "At this point an enigma presents itself, which in all ages has agitated inquiring minds. How can it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality? Is human reason, then, without experience, merely by taking thought, able to fathom the properties of real things? In my opinion the answer to this question is, briefly, this: as far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality." Einstein, A., *The Collected Papers of Albert Einstein,* vol. 7, trans S. Bargmann (Princeton: Princeton University Press, 2002), 209.

44 Maupertuis, *Oeuvres* I, 23-34.

45 For an interpretation similar to my own, see Pulte, H., *Das Prinzip der kleinsten Wirkung und die Kraftkonzeptionen der rationalen Mechanik* (Stuttgart: Franz Steiner Verlag, 1989), 42-43. Unlike Pulte, however, I do not think that the teleological approach can be successfully relegated to a theological background.

46 Maupertuis, *Oeuvres* I, 23. *L'Être suprême est partout; mais il n'est pas partout également visible. Nous le verrons mieux dans les objets les plus simples: cherchons-le dans les premières loix qu'il a imposées à la Nature; dans ces règles universelles, selon lesquelles le mouvement se conferve, se distribue, ou se détruit; et non pas dans des phénomènes, qui ne font que des suites trop compliquées de ces loix.*

47 Tonelli, G. (1987), 18.

48 Maupertuis, *Oeuvres* IV, p. 21. *Une mécanique aveugle et nécessaire suit les desseins de l'Intelligence la plus éclairée et la plus libre [...]* The term "necessary mechanics" implies here, to my view, a deterministic outlook.

49 Brading, K., "On composite systems: Descartes, Newton and the Law-Constitutive approach", in *Vanishing Matter and the Laws of Motion: Descartes and Beyond* (London: Routledge, 2010), 130-152.

50 Panza, M., "De la nature épargnante aux forces généreuses : le principe de moindre action entre mathématiques et métaphysique. Maupertuis et Euler, 1740-1751", *Revue d'histoire des sciences* 48/4 (1995): 435-520, note 110.

51 The generality of PLA has been rightfully appraised by Max Planck: "In all the branches of science, to which it applies, it gives, not only an explanation of certain characteristics of phenomena at present encountered, but furnishes rules whereby their variations with time and space can be completely determined. It provides the answers to all questions relating to them, provided only that the necessary constants are known and the underlying external conditions appropriately chosen." Planck, M., *A Survey of Physical Theory,* trans R. Jones and D. H. Williams (New York: Dover Publications, 1960), 69. It is worth mentioning that Planck's (and other earlier authors like Helmholtz) historical outlook on the PLA is based on heavily outdated scholarship that effectively denigrates and plays down Maupertuis's role in elaborating the principle while exaggerating Leibniz's influence thereby. This bias might be due to the influence of Voltaire's early sarcastic account of Maupertuis's supposedly arrogant attitude. A more balanced, sensible account on Leibniz's conceptual legacy with respect to the PLA is provided in Pulte, H., (1989), 56-64.

52 Lyssy, A., "L'économie de la nature - Maupertuis et Euler sur le principe de moindre action", *Philosophiques* 42/1 (2015): 31-50.

53 In modern terminology this is the integral. For the mathematical details, see Boudri, J. Chr., (2002), 136, or Panza, M., "The Origins of Analytical Mechanics in 18th century", in *A History of Analysis*, ed. H. N. Jahnke (American Mathematical Society and London Mathematical Society, 2003), 137-153.

54 At this point, the quantity of action means whatever can move a body from one point to another and is measurable. See Maupertuis, *Oeuvres* IV, 17.

55 Maupertuis, *Oeuvres* IV, 17. *Elle est proportionnelle à la Somme des espaces multipliés chacun par la vîtesse avec laquelle le corps les parcourt.*

56 Boudri, J. Chr., (2002), 155.

57 For a short historical survey, consult Lyssy, A., (2015): 31-33.

58 Terrall, M., (2002), 175.

59 Maupertuis, *Oeuvres* IV, 46.

60 Maupertuis, *Oeuvres* I, 22. *Jusqu'ici la Mathématique n'a guère eu pour but que des besoins grossiers du corps, ou des spéculations inutiles de l'esprit: on n'a guère pensé à en faire usage pour démontrer ou découvrir d'autres vérités que celles qui regardent l'étendue et les nombres; car il ne faut pas s'y tromper dans quelques ouvrages, qui n'ont de Mathématique que l'air et la forme, et qui au fond ne font que de la Métaphysique la plus incertaine et la plus ténébreuse. L'exemple de quelques Philosophes doit avoir appris que les mots de lemme, de théorème et de corollaire, ne portent pas par -tout la certitude mathématique; que cette certitude ne dépend, ni de ces grands mots, ni même de la méthode que suivent les Géomètres, mais de la simplicité des objets qu'ils considèrent.*

61 Maupertuis, "Les loix du mouvement et du repos déduites d'un principe métaphysique", *Histoire de l'Académie Royale des Sciences et des Belles Lettres* (1746), 267-294. *Les loix du Mouvement et du Repos déduites de ce principe, se trouvant précisément les mêmes qui sont observées dans la Nature : nous pouvons en admirer l'application dans tous les Phénomènes. Le mouvement des Animaux, la végétation des*

*Plantes, la révolution des Astres, n'en sont que les suites : et le spectacle de l'Univers devient bien plus grand, bien plus beau, bien plus digne de son Auteur, lorsqu'on sait qu'un petit nombre de loix, le plus sagement établies, suffisent à tous ces mouvemens.* In the *Essai,* this paragraph is quoted almost verbatim (Maupertuis, *Oeuvres* I, 45) with last part of the phrase (after *Auteur)* omitted.

[62] With respect to the PLA, even if Maupertuis initially deduced it from optical experiences, in his late work (after 1750) he seems to endorse it explicitly as an universal principle that is not in need of empirical testing (perhaps on the ground that Newton's laws of motion derived from it are already found to be universal and certain). See the quote in note 61 above.