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Diderot, Mathematics and the Idea of a Scientific Revolution: Retake of a Recurrent Theme

Luis Manuel A.V. Bernardo
NOVA University of Lisbon

Abstract

Diderot's relationship with mathematics is controversial, as he progressively denies their explanatory value without fully abandoning its practice. The main interpreters of his epistemology have considered that such a departure results from a formative fragility or a reorientation to the new fields of biology and chemistry. In this paper, differently, we seek to show that the reasons are of a philosophical kind, depending on how the notion of an ongoing scientific revolution determines the need to deactivate the henceforth outdated scientific paradigm and to seek for the epistemological conditions of the alternative that is already operating.

Keywords: Denis Diderot; Epistemology of mathematics; Scientific revolutions; Materialist paradigm; Enlightenment

1. Introduction

In an article titled "Diderot et le calcul des probabilités dans l'*Encyclopédie*", Jean Mayer summarized very precisely the complex relationship of Diderot with mathematics: "Despite the lasting fascination that mathematics have exerted on Diderot, we can say that they represent for him a disappointed ambition and that their role in his metaphysics remains precarious and circumscribed." (Mayer 1991, 375, our translation) Diderot was not the only one defending a different hierarchy of the knowledges. It suffices to think of the

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descriptive methodology followed by Buffon in his Natural History, based on the practice of observation and leaving for mathematics only the calculation of probable consequences of the facts. (Buffon 2007, 65-66) However, what is peculiar to him is the philosophical reach of that progressive distancing and an apparent indecision about the fitting place to attribute to them. That waiver of the *mathesis universalis*, in a time of consecration of the big mathematical models of modernity, by an author who, at the start of his journey, in *Mémoires sur différents sujets de mathématiques* (1748), seemed to be at ease with them, ended up converting it into an inevitable stopover for those who are dedicated to Diderot's epistemological perspective.

For most contemporary interpreters, willing participants in a scientific paradigm based on mathematics as ours, that surprising deviation has referred to the knowledges, the competencies and the interests of Diderot himself. That's precisely the way Mayer deals with it, stating that "the conclusion is not discussed: a conscientious personal effort to deepen his training was not enough to make Diderot an original mathematician and he did not even understand the transformation brought by his contemporaries in this field." (ibid. 376, our translation)

More recently, François Pépin starts from this same conclusion, but raises the hypothesis that "the epistemological contrast that allows this criticism of mathematics corresponds to a redeployment of Diderot's scientific culture." (Pépin 2012, 466-67, our translation) Such a perspective allows him to overcome an interpretation based on Diderot's effective competencies in the domain of mathematics to take on an important incursion into the big philosophical problems produced by such devaluing. Nevertheless, the intent to demonstrate the relevance of the inflection for the recent experimental sciences, particularly for chemistry, overdetermined the global scope.

Finding the full logic underlying the paradox requires, in our view, the complementary interpretive decision of handling the theme from a broader horizon. The idea of an on-going scientific revolution appears to us as the key notion for a sustained explanation of such dramatic detour. This results from the evidence that at the centre of Diderot's reflections lays the sketching of a new epistemology, consequent with the

declared feeling of participating "at the dawn of a great revolution in science". (Diderot 1999, 37) In a letter of February 19, 1758, addressed to Voltaire, he would confirm that appreciation for the sense of history: "the reign of mathematics is no more. Taste has changed. It is that of natural history and the letters that dominates". (Diderot 1997, 73, our translation) Seven years later, the memorial note on the dead of Alexis de Clairaut (1765) stresses once more that dynamics: "metaphysicians and poets had their time; systematic physicians succeeded them; experimental physics substituted systematic physics; geometry substituted experimental physics, natural history and chemistry, which are in vogue now and divide the spirits with politics, commerce and welfare matters, substituted geometry". (Diderot 1981, 403, our translation) This recurrence, even in circumstantial texts, confirms the prominence of the concept of scientific revolution in Diderot's epistemology and makes it necessary to consider the new role assigned to mathematics as a significant piece in such all-over transformation.

Therefore, we differ from the many interpreters that refer to the idea of a scientific revolution as the result of mere circumstantial judgement over what was fashionable at the time. Instead, we ascribe to the perspective of a scientific revolution the status of a conductive guideline that was mobilizing the ongoing methodological options in the *Letter on the Blind for the use of those who can see* (1749), consecrated in *Thoughts on the interpretation of Nature* (1753) and confirmed in subsequent texts. Moreover, we consider that the effects produced by the idea of a contemporary scientific revolution should make intelligible the crucial epistemological problems that the overcoming of the mathematical explanation entails, the sophisticated stratification of Diderot's critique aimed at them, and, no less important, the argumentative strategy followed by the philosopher. To achieve this hermeneutical perspective, we shall privilege what texts imply concerning Diderot's critique, rather than some biographical approach or the recurrent, but inconsistent, opposition between rationalist and empiricist partisanship.

2. The Baconian Reception

This reading of a radical and indisputable mutation, taking place in the present, but opening to a peculiar future, also limits the range of the successive historiographic attempts to redirect Diderot's proposal to a mere resume of the essential of Francis Bacon's philosophy of knowledge. In general, it becomes noticeable that the reception of Bacon's legacy follows a double intentionality indicating a sort of permanent translation exercise. (Adams 1999, 20) First, it figures as a learning process of the paths leading to the order of knowledge in construction, as far as "this extraordinary genius, unable to make the history of what we knew, did the one of what should be learn". (Diderot 1994, 215, our translation) Second, Bacon's project is like a disruptor of the Cartesian predominant, whilst it identifies with an alternate possibility at the core of Modernity, one for whom mathematics had only an ancillary role, in face of metaphysics and physics. In both cases, nevertheless, in no way does it exhausts the field of future epistemology, to deserve its straightforward reproduction.

Such strategy also reveals that, differently from Bacon whose "account is perfunctory, passing over the already substantial achievements made in the sixteenth century", (Bacon 2008, 583) as Brian Vickers puts it, his is self-conscious as well of the century realisations as of the main reason to consider that sense of a changeover to a "second Modernity".

In particular, the way he transforms Bacon's considerations on mathematics shows an active, but parodic and deviant reception of the British model. For instance, he eventually took on Bacon's suggestion in *The Advancement of Learning* that it would be "more agreeable to the nature of things and to the light of order to place it [Mathematics] as a branch of Metaphysics" (Bacon 2008, 199) to convert it in the idea of an idealistic metaphysical inner characteristic of mathematics. Such detour also involves the way he doesn't follow Bacon's ontological view of science based on inner natures, but nevertheless ascribes to mathematics such dependence of ontology or the way he converts Bacon's praise of "quantity determined or proportionable" as "one of the Essential Forms of things" (Bacon 2008, 199-200) into a critique

of mathematics' formality. Therefore, he returns to the Baconian idea that mathematics are subsidiary to the task of interpreting nature, but converts what, in the predecessor, constituted a generalist consideration into a circumstantiated critical exercise with two complementary purposes. On one side, he is committed to show why the epistemological model based in mathematics is exhausted. On the other side, he assumes the task of setting the guidelines for the recently arising one, including the structural conditions of the worldview that it requires.

3. Scientific Revolution and History of the Sciences

The argumentation follows, in *Thoughts*, two main lines. First, it is about showing that mathematics reached the limit of the possible knowledge for its sphere of research; second, it is concerned with establishing that the characteristic explanatory model of mathematics, even having reached a definitive degree of completion, is not valid for the interpretation of nature.

Diderot stands by the idea that the sciences and the arts are human activities, having, therefore, a history in relation with the history of humanity, understood as an alternation of periods of darkness and light, and with the history of the individuals that cultivate them, imposing their personal limits. That theory of history presupposes, for each science, a long interval between the moment of its birth and the culmination point, which, once reached, produces the justifying criterion of a revolution. The *Encyclopédie*'s article "Encyclopédie" states it: "revolutions are necessary; there have always been revolutions and always will be; the greatest interval from one revolution to another is known: this cause alone limits the extension of our work. There is a point in the sciences beyond which it is almost beyond their ability to go. When that point is reached, the achievements that remain of that advance are forever a marvel to the entire species." (Diderot & d'Alembert, 2007)

Therefore, the history of each science reproduces the universal game between obscurity and illumination: a period, in which a certain science reaches a maximum of evidence, after a period of ignorance, ends up followed by a progressive opacity until it becomes cryptic, with a degree of incomprehension that

Diderot links to the hieroglyph and the monument. "That, in brief, is the history of geometry and of every branch of science when it ceases to instruct or to delight", as he asserts. (Diderot 1999, 37) If it does not fall in disuse, it goes from the status of a universal language to that of a metalanguage, raising only a limited number of questions and answering a very specific set of problems. Therefore, just a restricted number of specialists will cultivate it. That means that it is confined to become an auxiliary science of the new dominant scientific conception.

4. A Metalanguage

Commentators tend usually to override the consideration of such passage from a knowledge seen as universal to the status of a particular metalanguage. Nevertheless, it constitutes a key for the referred ambiguous relation that Diderot maintains with mathematics, the critique of which is, simultaneously, demolishing and supportive of the respective appreciation in certain domains. Two theses on the status of mathematics with a different reach support that position, both functioning as a kind of mainstay for subsequent arguments.

The first assumes that mathematics are a type of formal language, more than a substantive knowledge of nature, hence they convert to metalanguage and not to *metaknowledge*, which entails immediate consequences about their importance. Moreover, as language, they remain attached to the function of translating a conception of reality built in the common interactions between subjects, mixing different factors, from the perceptive to the religious.

The second stresses its idealistic feature, as mathematics deal with a "world purely of the intellect" (Diderot 1999, 35) voided of rooting in the primary contact with materiality. The *Letter on the Blind* already suggested it, straight away on the sensorial basis. On the subject of Molyneux's problem, it set aside the existence of a direct intuition of ideas, namely of figure, to emphasize the centrality of reasoning by analogy in an experience that becomes constructed, as a complex process of constant learning. As he states, "during the first moments of sight we only receive a mass of confused sensations, which are only disentangled after

a time and by a process of reflection. It is by experience alone that we learn to compare our sensations with what occasions them; that sensations having no essential resemblance with their objects, it is from experience that we are to inform ourselves concerning analogies which seem to be merely positive". (Diderot 1999, 182)

Diderot also pointed to it when inverting the conventional relation at the heart of Cartesianism between geometry and physics. Whereas, for Cartesians, physics became scientific as an application of mathematics, Diderot refers to the transition "from physics to geometry" (Diderot 1999, 168), thus signalling the anteriority of the contact with beings in their materiality on the most generic considerations, viz, geometrical qualities. In turn, that formality reveals the abstractive aspect that limits them, when it comes to enunciating concrete dimensions of reality. This perspective is patent in the example of Saunderson, a blind mathematician that, as such, "would infallibly have supposed a geometrical relation between the object and its use" (Diderot 1999, 188-189), but would not be able to deal with its ornamental features.

5. A Science of Blind People?

One tends to see in the centrality of the role played by Saunderson in the *Letter*, as well as on the praise of his capacity of teaching those who see better than a seeing person, a sort of recognition of the value of mathematics. However, we thus overlook the irony of the opposition between a science considered clear and distinct, and its privileged apprehension by a person born blind, in which Diderot still insists in the *Addition to Letter on the Blind (1782)*. There, he writes that the blind Mélanie de Salignac "declared that geometry was the science of the blind, because it was of such universal application and no external aid was necessary to become proficient in it. "The geometrician", she added, "spends nearly all his life with his eyes shut"". (Diderot 1999, 197)

Now, that suggestion of a constitutive blindness of mathematics, despite the recreational nature of the purpose, in fact resumes one main conclusion of the *Letter*. It corresponds to the same idea of their circumscription to a formalist

intellectualism, as they do not depend on the referential relation that impends, in so many aspects, on the vision. Again, this transpires from the words of Mademoiselle de Salignac: "One day I said to her, "Mademoiselle, imagine a cube." – "I see it." – "Place a point in the centre of the cube." – "I have done so." – "From the point draw straight lines to the angles; into what have you divided the cube?" – "Into six pyramids," she replied without hesitation, "each having as its base one side of the cube, and a height equal to half its height." – "True, but tell me where you see this?" – "In my head, as you do."" (Diderot 1999, 197)

One could assume here an argument in favour of the common use of reason, if not for the distinction that appears in *Thoughts* as a decisive epistemological criterion to differentiate what constitutes an effective knowledge from a mere product of the thinking activity: "So long as something exists only in the mind, it remains there as an opinion, or a notion which may be either true or false, and which can be accepted or contradicted. It becomes meaningful only when linked to things which are external to it." (Diderot 1999, 39) This condition, in which one foresees the opposition fixed by Kant between analytical and synthetic judgements, does not imply that mathematics do not allow us to access a certain type of knowledge about specific objects. However, the suspicion is launched over the validity of the certainty to which they lead.

Whereas certainty raised, according to Descartes, from analytical purity, for Diderot the relation between mathematical reasoning and pure reason results mainly in language games pertaining both to the field of knowledge and to thought itself. Those need to submit to the proof of the real to acquire objectivity. Moreover, given that mathematical language games constitute a possible way to conceive and express the real, they lend themselves to comparison with other types of language, namely with the natural language. Concerning criteria such as expressiveness, translatability, representativeness, pertinence or universality, that the *Letter on the Deaf and the Dumb* (1751) introduce, Mathematics appear unsatisfactory, given the narrowness of their point of view, as well as the expected literality of their reasonings.

Mathematics is considered therefore as a way of talking about an aspect of the real without exhausting the possible enunciations in relation to the multiplicity of the other aspects. Practicing such reductionism makes mathematicians proficient, but to pretend that it stands for the totality of the reality is their biggest mistake, as Diderot reminds us when blurring the boundaries between scientific clairvoyance and metaphysical obscurity: "There is perhaps one certain method of falling into error in metaphysics, and that is, not sufficiently to simplify the subject under investigation; and an infallible secret for obtaining incorrect results in applied mathematics is to suppose objects less compounded than they usually are." (Diderot 1999, 160) The *Letter* ends, thus, with a dramatic sequence around the extension of our ignorance, despite the apogee of the cultivation of mathematics: "For what do we know? What of the nature of matter? Nothing. What of the nature of spirit and thought? Still less. What of the nature of movement, space and duration? Absolutely nothing. What of the truths of geometry? Ask any honest mathematicians, and they will own to you that all their propositions are identical, and that so many volumes upon the circle (for example) are nothing but repetitions by a hundred different methods that it is a figure where all the lines drawn from the centre to the circumference are equal." (Diderot 1999, 190)

6. An Exhausted Knowledge

This idea that mathematics reached a point of saturation, merely hinted here, is clearly enunciated in *Thoughts*: "To judge from the inclination men's minds would appear to have for ethics, literature, natural history and experimental physics, I would almost go so far as to assert that, within the next hundred years, there will hardly be three great geometricians in Europe. This branch of science will just cease at the point where Bernouilli, Euler, Maupertuis, Clairaut, Fontaine and d'Alembert have left it. It will stand like the Pillars of Hercules and no-one will pass beyond. Their works will endure in centuries to come, like the Egyptian pyramids, massive and laden with hieroglyphics, an awesome picture of the might and resources of the men who built them". (Diderot 1999, 37)

Such a limit is assessed in this work, based on internal and external criteria of the scientific domain in question, once more framed by the idea of the recent occurrence of a scientific revolution. The first are summed up in the consideration that all the explanatory potentialities of such a science, under the terms enunciated by that science itself, are fulfilled. The outcome is verifiable, according to Diderot, by the differential calculation, the Newtonian explanation of the system of the universe or the transcendent geometry of D'Alembert. Beyond those models, mathematics cannot advance without losing coherence or congruence. Thus, regardless of how we view their explanatory value - the object of the second series of arguments -, there remains the impossibility of progression, and therefore, if one decides to keep them as privileged language, or even as idealized conception of the world, one will be operating with a field already over determined, if not even definitively closed. Consequently, in case of the appearance of a new epistemological object, like the phenomenon of life, to which Diderot dedicated significantly *D'Alembert's Dream* (1769), one faces a dilemma: either mathematics can be applied to it, which means that we are before a pseudo-new object, or they cannot be applied to it, which forces us to find another explanatory model.

7. Conditions of Science

This understanding is a consequence of Diderot's reinstatement of the knowledges to certain conceptions of the world, according both to historic contexts and to specific interests that are not always, nor everywhere, the same. Hence, all knowledge is affirmed subject to certain conditions that validate it. These do not result from a transcendent truth but from an intersubjective intertwining, between the meaning that the wise find there and the meaning that they can share with other men, in order to institute as the most adequate the reading of the real originated from that conception. Therefore, one science cannot become the definitive or exclusive knowledge, holder of the absolute truth, nor aspire to timelessness.

The external criteria of validation are, consequently, as determinant as those designated as internal, since they are the ones deciding the pertinence of any knowledge for a society at a

certain period. That articulation between a process of epistemological saturation and a progressive disinterest from the community characterizes both sides of the scientific revolution. To understand the historical dialectic of the sciences in this way depends on two profound changes in perspective.

On one hand, the axiological criterion constituted by the idea of absolute, timeless and transcendent truth, assumed as the desire of knowledge, must see itself replaced by the one of utility, as is made explicit in *Thoughts* with the preview of a new scientific revolution: "It is also true that the idea of 'usefulness' sets boundaries on everything. The criterion of usefulness is about to place limits on geometry, and in a few centuries from now, it will do the same for experimental science. I estimate that this field of study will last for some centuries yet, because it has an infinitely broader spectrum of use than any abstract science, and because it is indisputably the basis of everything we know for certain". (Diderot 1999, 38) The *Notice sur Clairaut* insists in this social move: "It happens that taste turned towards useful things, and what is useful in geometry can be learned within six months, the remainder is mere curiosity". (Diderot 1981, 404)

This pragmatism replaces, thus, the image of scientific progress, as a cumulative line of successive approximations to a bigger truth, for one of a process animated by a functional logic, in which the evolution vector depends on the balance between theoretical developments, practical applications and social utility. No less meaningful is the fact that the emphasis placed on functionality guarantees both the reinstatement of science to the status of a product of men, thus limited by the constitutive elements of a pragmatic anthropology, and the effective historicity of the scheme of the revolutionary transits, that are not cyclical, nor related to any kind of providentialism.

On the other hand, the theory of scientific revolutions presupposes the intersection of the variants of history with an epistemological perspectivism, one that implies the mutual dependency between the dominant scientific matrix and world conception, and, in that way, converts the science of a period into a certain way of examining reality. Therefore, it can never

offer itself as the only one, nor the exclusive, even at an eminent stage of achievement.

8. Two Metaphysical Dimensions

This relativism means that each epistemological model constitutes a way of conceiving reality, so that the corresponding axiomatic is not mere theoretical axioms, but in it we find diverse theses, and principles that express the underlying vision. Thus, all science contains a complex metaphysics, with two major zones. First, a general metaphysics, which includes the broad defining lines of the cosmovision serving as general framework of meaning and determining the common places of the proposed analyses, like the spiritualist or materialist perspective. Second, a particular metaphysics corresponding to the specific axiological choices that identify and legitimize their own way of scrutinising, as "everything has its *metaphysic* and its practice". (Diderot 2007) An adequate reading of the scientific revolutions cannot but consider these two aspects, insofar as a revolution will differentiate itself from a simple reform given that both metaphysics must suffer a transformation together.

Consequently, Diderot insists on the progressive loss of reach of the general metaphysics that sustains the choice of the particular metaphysics, which leads to the privileging of the mathematical language as ideal expression of the real. That allows him to establish that mathematics institute a certain interpretation of reality that depends on the acceptance of the quantitative point of view as the one that better represents it, and they are dominant if that explanatory principle is admitted as justified. They constitute, therefore, a particular vision of the sense of reality, even when they establish universal statements. Such property, insofar, depends of the set of choices, principles, axioms that allow one to think in terms of quantities. As Saint-Amand reminds us, "it is also necessary to read all the debate on the qualitative and the quantitative in ideological terms. And, for that, we must go back to the very essence of mathematics. Because it is them that allow this desire for quantifiability that we find in physics". (Saint-Amand 1984, 27, our translation) To circumscribe the apparent universal reach of

mathematics, Diderot, then, presents the full argument by showing that their practice is reductive, their metaphysics is particular and, therefore, their utility becomes doubtful outside of those conditions and in face of the new interests, of the most recent research objects, and of the contemporary social patterns of well-being.

To grasp the full reach of this critique, it is necessary first to think of utility in a double sense: as contribution to the progress of the living conditions of humanity and as contribution to the progress of knowledge. Thought XIX establishes a difference between direct utility, required by the common, and utility that allows the clarification of knowledge, which must be put in the service of understanding what fails in mathematics. Consequently, even if Diderot recognizes the argument according to which a whole technology ensues from them, he does not consider it enough reason to establish its utility. As he endorses: "Think of all the effort, work and time wasted on measurement which could have been spent on discovery!" (Diderot 1999, 69) That means that, for him, in what truly concerns humanity, whether from the point of view of improving the everyday, whether of its self-understanding, mathematics have a very limited reach. This arises from the fact that they suppose a double scale in the constitution of their objects, ensuing from the double metaphysics that they convoke. On one hand, they work with an object reduced to quantifiable attributes to guarantee the greatest degree of certainty. On the other hand, they presuppose incommensurable notions like those of theological order or divine reason.

Therefore, they are not suited to account for nature, that is, for the reality that may interest the human race, "where what are taken for absolute truths cease entirely to be so when applied to the world we live in." (Diderot 1999, 35) It was, in fact, what the *Letter on the Blind* already led to believe, against Descartes, who conceived the opposition between spirit and body from the substantial duality between thought and extension: "units pure and simple are too vague and general symbols for us. Our senses bring us back to symbols more suited to our comprehension and the conformation of our organs". (Diderot 1999, 160)

9. A Third Metaphysical Dimension

But, in *Thoughts*, instead of returning to the argument about the limits of human reason, the author addresses the critique directly to the constitutive reductionism of mathematics that results from the epistemological choices of its fundamental metaphysics, according to which "bodies are stripped of their individual qualities". (Diderot 1999, 36) Therefore, reasoning become circular, for being always the product of conventions, to the extent that "mathematician's ideas have no greater reality in nature than those of the gambler." (Diderot 1999, 36)

This predominance of form over content, asserting the sign as such, without the mandatory referential correlation, makes manifest that, after all, "their entire discipline was nothing more than metaphysics." (Diderot 1999, 36) Hence, Diderot introduces a third connotation, now a pejorative one, for the term metaphysics, according to which a set of hypotheses unrelated to the reality of the experience is metaphysical, in the double meaning that it is beyond the experiential and, consequently, derives from an imaginative effort with which one replaces the experimented real with a fictional reality. To understand this properly, it is important to have in mind the distinction, generally verifiable, despite the terminological fluctuations of the authors' writing, between the hypothesis and the conjecture. In the first, echoing Newton, Diderot does not intend to trust, for being mere intellectual or opinionated exercise. By contrast, he considers conjectures vital to the interpretation of nature, for representing a theoretical possibility originated by experimental practice, which assumes the character of strong probability in the context of a proper experience of thought.

Consequently, even if in this "thought" Diderot seems to have his eye on D'Alembert's transcendent geometry, considering it affected, equally, by idealist generality, one should recognize that the central problem is of a broader kind, i.e. the epistemological object with which mathematics operate. Therefore, it is about a paradigmatic conflict between two conceptions of the real, separated by the discontinuity of an

ongoing scientific revolution. That why a more advanced knowledge of one of the branches of mathematics, like integral calculation, is no longer satisfactory, as it follow the same logic of an already dated worldview.

Thus, we understand better the reason why Diderot, refusing the solution of compromise between abstraction and experience, defended by D'Alembert, in "Discours Préliminaire", wrote: "This has led to the conclusion that it was the task of experimental philosophy to rectify geometrical calculations, and the logic of this view has been acknowledged by geometricians themselves. But what is the use of correcting geometrical calculations by experiment?". (Diderot 1999, 36) That means: what is the use, if it is not about the same object, nor the same method, nor the same metaphysics? Given that what is at stake know is the knowledge of nature, whose characteristics – life, self-production, variability of forms, multiplicity of causes and effects, temporality – are opposed to those of the objects of mechanical physics based on geometry, where can be the compromise?

It becomes once more noticeable that one of the keys to Diderot's radicalism in relation to mathematics is the amount of his epistemological concerns. This allows a better understanding of the dedication to young people, in which he declared the three fundamental theses that he intended to refuse: "Always bear in mind that *nature* is not *God*, that *man* is not a *machine*, that a *hypothesis* is not a *fact*." (Diderot 1999, 34) It consists in the difference between nature and universe, life and mechanism, as epistemological objects, and between hypothesis and fact, in what concerns methodology. These oppositions and the combinations that they admit must therefore figure as structural to the author's critique.

10. A Hypothetical Science

Summing up, Diderot accuses mathematical science of being completely dependent on a rational philosophy, with merely hypothetical content, due to three factors. First, its hypothetical-deductive progression forces it to proceed from an axiomatic basis that can only be formed by simple hypotheses, validated by reason, which, precisely, as hypotheses, are

neither facts, nor judgements founded or made upon facts. Second, its epistemological object is the result of a hypothetical reasoning over the adequation of the reduction of nature to geometry that never gets to happen in the effective experience of reality. Moreover, the presuppositions sustaining such narrowing, like that of the existence of a divine intelligence that would justify the universal order and knowledge in a macroscopic scale, are opposed to the very conditions of the scientific. Third, if we distance ourselves from their foundational idealism and we look for a knowledge of natural phenomena, we face unsurmountable anthropological and epistemological limits, which mathematical reasoning, in its internal activity, intends to bypass, but that it cannot expunge.

11. A General Metaphysics

The choice of Cartesianism as central interlocutor, seen as epitome of a vision of the world governed by the representation of mathematics, is obviously related to the critic of the general metaphysics in which they are supported. With said methodology, it is not a matter of reducing the modern to the cartesian mathematics, but of promoting the analogy between the justification scheme that the latter establishes and the one that is required by the very epistemological paradigm constituted by a mathematical apprehension of the real. To dismantle the model it becomes decisive to highlight that Cartesian science depends on the reinstatement of the model of the *mathesis universalis* to spiritualist metaphysics.

In fact, it appears to Diderot that everything relevant in such epistemological model is of strictly intellectual jurisdiction. The knowable thus stays enclosed in the interiority of the thinkable or of the adequacy of the ideas of men to the ideas of God, in such a way that mathematics becomes dependent of that stable and universal order foreseen by the divinity. Thus, they cannot discard the metaphysical hypothesis of the existence of a God to give objectivity to ideas and to establish the adequation between the figures and the movements attributed to the beings and the beings as such. At the limit, the *fable of the world* would end up being nothing more than the deductive development of the metaphysical hypothesis of the

universe as a plan of divine wisdom, despite Descartes' efforts to transform that hypothesis into scientific knowledge.

It is not his atheism what Diderot interposes, *prima facie*, to reject said metaphysics, but his refusal of a pure intellectualism that forces the introduction of a superior intelligence to assure the existence of beings. This strategic option, setting him apart from other atheists like D'Holbach, allows him to avoid all the issues around God's existence, even if these are manifestly implicated, or of being for or against such an order, while still providing enough indications on his position. God is thus turned into a metaphysical hypothesis ascribed to the options and the limits of mathematical reason, becoming dispensable for another scientific paradigm, namely, the one of an experimental physics with a programme that the *Thoughts* seek precisely to delineate.

By deeming it hypothetic, the author suggests also that, scientifically, we do not have the conditions necessary to transform it into a factual judgement, unless we illegitimately replace physics with metaphysics. In this case, we produce a confusion between the regulating idea of nature's unity, that must assist knowledge, as a whole, and the idea of a creator and legislator God, that can only belong to the domain of theology. If the first, i.e. the presumption of "the chain that links phenomena together", (Diderot 1999, 75) appears necessary for science to rise to the status of interpretation of nature, the second is a matter of faith, at the antipodes of the rational matrix of modern science.

Still, for Diderot, the confusion between the two spheres, generating the hypothesis of an *a priori* intelligible order, originates a misunderstanding that ignores the specific focus of modern science. The latter, contrary to the old science, intends to explain nature by secondary, material and effective causes. However, as the author shows in Thought LVI, the will "to explain nature's purposes" (Diderot 1999, 71) keeps pushing through most of the systems. It is the case of the idea that science is committed to the intellectual intuition of fixed and eternal ideal natures, as of the conviction over the existence of a perfect legality produced by divine reason. The same applies to the postulate of a universal order, even if this introduces a

subtler, but no less present, version of finality, by way of the idea of an intelligent intentionality.

Inspired by Buffon' distinction between "why ?", "how ?" and "how much? " questions (Buffon 2007, 151), Diderot defends that "the empirical scientist, whose profession is to instruct and not to edify, will therefore stop asking why, and concern himself only with the question of how. The question of how is based on actual beings, and the question of why is merely a product of our minds." (Diderot 1999, 72) The continuation, with the explicit mention of names such as Boërhave and Haller, clearly shows that he targets the fort of finalism that limits the scientific reach of mechanical explanations and does not prevent the permanent intrusion of the theological notion of a nature in a state of continuous miracle.

12. A Bad Interpretation of Nature

Thus, science, despite the efforts of its cultivators to follow objectivity patterns, assumes an inevitable dependency on the Apologetics that Diderot considers not only a false science but also a bad theology. As he asserts, "this way of interpreting nature is wrong, even in natural theology, as it substitutes human speculation for the workings of God, and binds the most important of truths to the fortunes of a hypothesis. But the most commonplace phenomenon will suffice to show how far the search for final causes is the opposite of true science". (Diderot 1999, 71-72)

The phenomenon chosen by Diderot – of the nature of milk – makes visible the multiplicity of reasons that turn the impasse of the finalist explanation into a central one. On one hand, by belonging to the life sciences, it allows reaching a triple objective: of contributing to the critique of science of the reasonable order; of evidencing that the emergent sciences are not sheltered by that fallacious procedure, but rather tend to perpetuate it; of introducing the difference between an explanation based on the issue of the destiny of a product that is kept in the sphere of finalism and one that addresses the process of formation by natural causation. On the other hand, because in being a metaphor of apologetics, that finds there the combination of utility and aesthetics manifesting the divine

providence in the most banal things, it becomes ideal to show the opposite. Diderot counters it with the contingency of relatively sparse effects, like the fact that "there have been men who have made milk spurt from their breasts" or "that milk is the cause of the swelling of the breasts which sometimes inconveniences young girls when their periods are due." (Diderot 1999, 72I)

The argument is reconstituted in two phases. First; if we know nothing and nothing can be known about a natural product as close to us as milk, what can be said of the more distant and complex finalities? Second: but if this ignorance is the epistemological and metaphysical condition of scientific practice, then science shall keep on being "ignorant", obviating any relation with apologetics concerns. Conclusion: in the equations of science there is no place for the introduction of the constant of God, neither for its conversion into a variable, because, instead of what the conception of mathematics supposes, it forms an epistemological obstacle to sensible scientific practice. It is, therefore, a science without the idea of God and others notions that derive from it – creation, absolute order, providence, finality, homology between divine reason and human reason – that must be built, unless, with the hat of science, one intends to do bad metaphysics or bad theology.

13. Some Variants

The virulence of the critique, however, does not imply the rejection, pure and simple, of the mathematical analysis, neither of the potentialities inherent in such language. Of course, for instance, physics cannot do without mathematics. Similarly, they are necessary for the formation of citizens tuned with the modern enlightened worldview.

The "Project for a University" send to the Russian Empress Catherine II in 1775, attributes to the elementary learning of arithmetic, algebra, calculation of probabilities and geometry the power of contributing to "rectify men's minds, by furnishing them with models of reasoning according to the strictest evidence and the most rigorous truth". (Diderot 1995, 436, our translation) Diderot claims that they help to enhance judgement according to logic principles, to cherish order, to

assume demonstration as the pattern of all reasoning, to lead to invention, and to reduce the vulnerability to superstition. (Diderot 1999, 436-437) They figure therefore at the very beginning of the curriculum, considered as a more available language for young children to learn, instead of the traditional reading and writing. The praise of their pedagogical virtues nevertheless does not interfere with the critique carried out, as it is mostly concerned with making the best of the evidence that "one counts everything, one measures everything. The use of our reason is often a rule of three". (Diderot 1999, 435) The perspective of an ongoing scientific revolution keeps intact for, as Diderot puts it, "if one thinks that the method of geometers cannot be applied to everything, one is mistaken, If one considers that it should not be applied to everything, one is right". (Diderot 1999, 436-437) That means that mathematics, being at the basis of modern science, became elementary, but no longer corresponds to a cutting-edge science. Consequently, this draft constitutes one good example of their assignment to specific uses and purposes, far from any late attempt to reassess the convictions of an early age.

Then, it is subject to the criterion of usefulness and free from spurious connexions, that mathematics assumes a specific place, with particular functions, in relation to concrete problems, that are of a mathematical nature.

In the *Letter on Blind People*, Diderot acknowledges the mathematical core of Molyneux's Problem. Therefore, even if he deals with it also in terms of sensitive representation, organic competence and education, he suggests that it is up to the geometer to lead the search of a proper solution. This is because the geometer "knows that what defines a square are its mathematical properties. That's why he is able to establish the relationship between sensitive data and mathematical idea and to operate the translation of one sense into another". (Duflo 2013, 148, our translation) Nevertheless, as we see it, this accuracy does not dispel the critical intent on the reach of mathematical explanation, but in a certain way reinforces it, by being assessed in the mastering of its own logic.

In *Thoughts*, for example, the philosopher follows a mathematical approach to speculate on the aggregation of the

elements into molecules that are composed of and coordinated in more complex systems, from the geometric theory of the resultant forces of the "*vibration of an elastic body under impact*." (Diderot 1999, 56) That explanation is the result of reasoning by abduction, as the conjecture transposes the most recent researches in the domain of mathematics on a specific problem originated in the natural sciences. It makes an oriented use that submits mathematics to the new epistemological paradigm.

The same occurs in the 1770 booklet, titled "*Principes philosophiques sur la matière et le mouvement*". There, Diderot discusses the concepts of body, movement, intrinsic and extrinsic force, inertia, weight, but subverts its conventional sense with the aim of introducing the general alternative of a universal driving force: "What is very certain is that all bodies gravitate upon each other, is that all particles of bodies gravitate upon each other, is that, in this universe, all is in translation or in effort [*in nisu*], or in translation and in effort [*in nisu*] at the same time." (Diderot 1975, 681, our translation) Hence, the possibility of a mathematical explanation appears after the modelling of the theme from other knowledges and not as first or exclusive explanation.

Despite the relevance conferred in this text to mathematical treatment, required by the analysis of the universal properties of matter, Diderot does not stop insisting on its subsidiary function. Presenting himself as a physician and a chemist, concerned with bodies in their materiality, he claims that geometry and metaphysics should be done by others. This means that, because of the scientific revolution, "it is required a global modification of the concepts, that accounts for the change of paradigm in the interpretation of nature". (Duflo 2013, 183, our translation) Henceforth, central terms like those of matter and movement correspond to other contents and functions, such as the explanation of complex body formation from elementary particles or the justification of the forms thus reached, despite the simplicity of the start-up process.

It remains what would have been, in 1761, a revaluing of mathematics, when controverting with D'Alembert, in *Sur deux mémoires de D'Alembert*, he defended the explanatory role of

the calculation of probabilities. Seeing it as a "mathematical physics of life" (Diderot 1975, 341, our translation), the author seemed to suggest a strong change of opinion on the role of mathematics, if not the abandonment of the idea of a scientific revolution. That is not so, as can be deduced from the concluding remarks to the *Mémoires*. There Diderot introduces a significant distinction that shows what he understands by the physical-mathematic approach: "the analysis of probabilities can be considered as an abstract science or as a physical-mathematic science. *Under the first aspect*, problems are solved in the geometer's mind, as they would be solved in divine understanding. […] *Under the second aspect*, it is a science limited to small means, to the experience of a moment, to a being that go like a lightning and that relates everything to its duration". (Diderot 1975) Adopting this second point of view implies, therefore, a completely different way of formulating the problems. Instead of considering in a generic perspective, "*men*, and an uninterrupted game and an endless life", one shall ask: "*Pierre and Jacques (two men) commit themselves to play throughout their lives, that game and under those conditions: which should be their bets?*" (Diderot 1975) Once more, it is not up to the science of nature to follow mathematical intellectual reasoning but the opposite. Four years later, in the article "Jouer" of *Encyclopaedia*, he will summarize the essay and drew a revealing conclusion: "I hear that, whatever affinity there may be between the functions of the geometer and those of the player, it is equally rare to see good geometers that are great players, and great players that are good geometers". (ibid., our translation)

Actually, Diderot uses the study of this branch of mathematics, beyond the multiple pragmatic applications, mainly to validate the materialist hypothesis, inspired by ancient Epicureanism, of the production of order as an effect of chance. Therefore, it is about an experience of thought that the calculation of probabilities helps to substantiate. Its contribution consists in showing that the analogy between the idea of a multiplicity of favourable conditions, in a minimum duration to the production of a chance interval, with the representation of the ontological opportunity of an event, like in

a game of dice, is viable. However, Diderot shows himself to be aware that this idea does not overcome moral certainty, that is, the degree of adequation regarding the level of calculation, in terms of hypothesis and not of factual description.

Being a question of analysing the variables, it does not allow us to form a metaphysical theory on the need, by associating this calculation with the differential calculation. On the contrary, its interest is proportional to the impossibility of converting it into a factual explanation and to the way in which it empowers a gnoseological and ontological perspectivism, giving us opportunity to think, from within mathematics themselves, of the prevalence of the contingent, the probable, the approximate, the phenomenal, the temporal, the unfinished, that is, of a set of values totally opposed to the ones of metaphysical mathematics.

In this sense, the probabilistic calculation does not reinforce or redeem the mathematical vision but ends up favouring its respective deconstruction. The calculation of probabilities accomplishes, accordingly, an epistemological function, by confirming the perspective of a nature in transformation, whose laws are not definitely fixed, but keep up with a continuous and exuberant process of morphogenesis. It is, therefore, from the new scientific paradigm that Diderot resumes the calculation of probabilities, taking advantage of the respective analytical functions to add to the consistency of the materialist hypothesis of a nature that operates on its own, without God or a superior intelligence. As summarized by Jean-Paul Jouary: "The interest, for Diderot, is to show that mathematics, far from leading to the thesis of an eternal order of nature, tend rather to show that *nature has a history* in the course of which there is a *real creativity, without us needing to request some finality, let alone a God geometer creator*." (Jouary 2011, 74, our translation) In the end, this leads necessarily to the idea that the scientific revolution is goes together with a philosophical revolution.

14. Present

The actuality of Diderot's claims is undeniable. From the multidimensional reading of the processes that lay at the origin

of the revolutionary impetus, which combines historical, social and epistemological aspects, the philosopher anticipates not only the contemporary ideation of scientific revolution as paradigm shift, but of some contents of that vision developed more recently by Thomas Kuhn, in *The Structure of Scientific Revolutions*. This is the case of the decisive role of history in scientific knowledge, the play between stability of the paradigmatic structure, in the stage of normal science, and the arbitrariness of the transition between paradigms, or the correlation between scientific practices and metaphysical orientations.

Such line of thought around the discontinuities of the history of sciences keeps on fulfilling an interpellator function concerning the rooted convictions on the singularity of the coeval scientific model, the inevitability of a dominance of mathematics and the obvious character of the relation that these hold with the truth. Given a generalised tendency to reconduct epistemology to a set of substantive questions, perspectivist pragmatism, ensuing from the idea of scientific revolution, forces the reflection over the concrete conditions of science, the way it relies on some narrative traits, as well as over the fundamental options that each of its versions depends on. This way, an unfoldment is introduced between what in scientific practice concerns the belief system over the truthful and what results from its cultural dimension. This duality does not represent a choice between two opposed possibilities, but a dialectics between two complementary orientations, that ends up caught by the perception of science as a cultural phenomenon.

In the case of mathematics, it leads, also, to the recognition of the possibility of conceiving alternative visions, in which their cultivation would be subsidiary, destined to make manifest the form of reductionism that, inevitably, constitutes them and makes them, simultaneously, extremely effective. Diderot's assertion of the three levels of metaphysics involved in mathematics also induces the need to ponder the correlation between the mathematised worldview of nature and the belief in a spiritualist order based on the government of a superior intelligence. Despite the diffused laicization, accelerated in the second half of the past century, with a justification that tends to go through the profanatory effects of science, it makes us

wonder whether the metaphysical conviction that mathematics is the writing of God is not always active.

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Luís Manuel A. V. Bernardo is Professor at NOVA University of Lisbon, Department of Philosophy and Researcher at CHAM – Center for the Humanities. He is also Co-Director of *Cultura – Revista de História e Teoria das Ideias*. His main teaching, researching and publishing fields are Philosophy of Knowledge, Hermeneutics, and Philosophy of Culture. Being particularly interested in the study of discourses of Modernity, he has published several books, papers and translations concerning the eighteenth and twentieth centuries.

Address:
Luís Manuel A. V. Bernardo
Faculty of Social Sciences and Humanities
Universidade NOVA de Lisboa
Avenida de Berna, 26-C / 1069-061 Lisbon, Portugal
Email: lm.bernardo@fcsh.unl.pt