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Abstract

This paper characterizes José Celestino Mutis' (1732-1808) appropriation of Newton in the Viceroyalty of New Granada. First, we examine critically traditional accounts of Mutis' works highlighting, on the one hand, their inadequacy for directing their claims towards the nineteenth-century independence from Spain and, on the other, for not differentiating between Newtonianism and Enlightenment. Next, we portray Mutis' complex Newtonianism from his own statements and from printed sources, including a variety of works and translations from British, Dutch and French authors, in addition to a wide range of Newton's writings, unusual for an eighteenth-century reader in America. Finally, we analyze a salient claim of Mutis' Newtonianism in order to depict his appropriation and transformation of Newton's ideas: the characterization of Newtonian experimental physics as a useful science. In so doing, Mutis further developed metaphysical and methodological positions not present in Newton's works.

Keywords

Newtonianism, Enlightenment, Colonial science, Jose Celestino Mutis, New Granada

Enlightenment, Newtonianism and independence in the historiography of Mutis

As early as 1923, the historian of mathematics Florian Cajori complained: “the early history of the mathematical sciences in America, especially in the Latin American colonies, has received little attention at the hands of scientific men.”[1] Cajori’s complaint still stands for important areas of scientific activities during colonial and subsequent times. Indeed, we are still far from having a somewhat complete panorama of the reception and integration of scientific activities into the colonial life in America, from the conquest to the emergence of the republics in the early and mid-nineteenth century. In fact, the common assertion that the introduction and reception of modern science played a role in the independence of these territories is another story to be told. However, it seems fair to say that historians have been too hasty in depicting scientific activities as an obvious and self-evident aspect of the colonial life, and therefore one to be included among the causes of the separatist sentiment leading to the colonial emancipation. This classical view has its roots in the apocryphal versions of the history of science emerging in the dawn of the independence, put forward by the pupils and acquaintances of the main intellectual figures of the revolutionary processes. During the nineteenth century, this view was incorporated into hagiographic stories of the national heroes, as part of the construction of national identity. In the 1980s and 1990s, Thomas Glick, John Lynch, Anthony McFarlane, and others moderated this view suggesting that modern science had a mere instrumental role for creole scientists that is, science provided the foundation for the development of a creole identity that assimilated the sovereignty over a territory with the first-hand knowledge of it. This revisionist version relies on the claim that the Bourbon reformism had several unexpected and counterproductive effects over the royal aspirations of deploying its enlightened despotism over the Atlantic World. In fact, this reformism supported the intellectualization and technical training of local creole elites that saw in the Spanish monarchy the cause of the retrograde state of the New World.

In the particular case of the northern territories of South America –the Viceroyalty of New Granada– the studies on the introduction of early modern science bear two salient characteristics. First, the scientific development in New Granada was noteworthy in the context of America because of the emergence of a recognizable enlightened movement at the end of the eighteenth century, despite the very late and slow social, commercial, and political development of New Granada when compared with the Viceroyalties of New Spain and Peru.[2] This development can be appreciated, for instance, in the growing scientific activities related to the Jesuits' establishment of the Xaverian University and in Mutis' pedagogical activities, such as the Botanical Expedition or the establishment in 1762 of the first chair of mathematics in New Granada that materialized institutions disseminating "new sciences."[3] Secondly, the classical view commonly portrays Mutis' scientific and pedagogical activities as a cause for the emergence of the separatist sentiment leading to the revolution of independence. By introducing enlightened ideas into the Viceroyalty of New Granada, it is said, Mutis would have planted the seeds of moral autonomy as an inseparable component of his teaching and scientific activities. Classical studies on Mutis heavily rely on this teleological view. It can be sharply illustrated, for example, by Diego Mendoza's foundational study of Mutis' Botanical Expedition: "it is clear that José Celestino Mutis is the true forerunner of Independence (…) The science Mutis disseminated in the Colony prepared it spiritually for its independence."[4]

Despite its efforts to nuance this apologetic presentation of Mutis' scientific activities and their impact on the intellectual figures conducting the revolution of independence, the revisionist version of this view presents similar and even more radical images of Mutis as a protagonist of New Granada's independence process.[5] Put briefly, this revised view claims that scientific endeavors led to a better understanding of natural resources and, in consequence, Spanish Americans realized, by accident, the potential of their territories as independent nations only in a medium-term process. For instance, Peset depicts Mutis as permanently playing a political role when performing his scientific activities. In his opinion, when Mutis arrived from Spain and during the time he planned to go back to Europe, his activities were oriented towards the dominion of locals; conversely, when he decided to settle in America, Peset describes Mutis on the edge of being a promoter of the independence in the minds of his pupils. In consequence, Peset concludes: "He [Mutis] will henceforth be considered the father of Colombian science and independence."[6] Likewise, Frías-Nuñez sets out the problem of understanding the figure of Mutis by considering the features a portrait of Mutis should include and, after mentioning his most celebrated scientific achievements, he adds: "we cannot forget his activities and contributions – and the influence through his contributors –in creating the platform of what shall be the independents' movement in Colombia."[7]

Nevertheless, the connections between Mutis' scientific activities –especially the Royal Botanical Expedition– and the political, economic, and historical events leading to the independence from Spain are far from being obvious. Silva has recently remarked the problems of this misleading view that holds that Mutis' natural researches are but patriotic actions leading to a growing consciousness of national identity among the creoles; this "has favored the convergence between the scientific pantheon and the republican one."[8] This approach has made of Mutis a Colombian national hero. Beyond the well-known problems of doing history of a national hero, these anachronistic and goal-oriented readings of Mutis' activities are deeply rooted in two basics misleading tenets.

Firstly, these readings depend on a now re-evaluated assessment of the role that education and science played in New Granada during the Bourbon Reforms, especially under the reign of Carlos III (1759-1788). It is commonly assumed that Bourbon Reforms led to the Enlightenment –or brought it from France– not only in metropolitan Spain but in the colonial territories as well. Bourbon rulers, in contrast with the Habsburgs, would have tried to modernize the administration of the colonies by promoting science and technical developments in order to improve the exploitation of natural resources and the production of goods for the commerce; thus changing the mining-based economy of the New World. Even those historians of science or ideas who are not centrally concerned with the political situation of the Spanish Empire causally connect the Bourbon's rule with the Spanish

Enlightenment.[9] However, historians such as Lynch, Mestre-Sanchis, and Pérez-García have shown how this rhetoric of modernization and enlightenment in Bourbon Spain is part of the propaganda that the new monarchy circulated when they ascended to the throne. For these historians, the introduction of early modern science in Spain came through the works of the so-called *novatores*, running back before the Bourbon House was enthroned in 1700. Mostly dedicated to chemical and medical problems, *novatores* such as Juan de Cabriada (1665-1714) or Diego Mateo Zapata (1664-1745) were committed to various forms of experimentalism and rationalization of nature encompassing different traditions; Baconian experimentalism, Gassendian atomism, and Cartesian mechanical philosophy were articulated in the aim of criticizing the scholastic character of the Spanish university.[10]

Secondly, studies on Mutis' conception of science has traditionally focused on the Botanical Expedition, reducing Mutis' activities and goals to the subsequent impact of his botany on the so-called enlightenment of New Granada. On this issue, Silva has indicated how Mutis' works are reduced to one of his achievements and his texts are read out of context, leaving aside the intentions, directions, and expectations of his author and audiences.[11] Indeed, the evident but complex links between the social institutions related to the Botanical Expedition and the process of independence have cast a shadow on Mutis' own views on the importance of Newtonian philosophy for the New Granada. Mutis' arguments do not have to coincide with those promoted by the Bourbon Reforms; but this does not mean that they have to conform to, or imply a creole identity around the ideals of freedom that became dominant among his students after 1808. In other words, we consider that it is problematic to read Mutis' conception of science either as part of a plot of the Spanish Empire to subdue Americans through knowledge, or as a pro-independent project consisting in a renewed moral attitude leading to nationalism wrapped up in the Newtonian experimental physics, misleadingly equated with the Enlightenment.

Central to these approaches is the problematic assumption that the Enlightenment is equivalent or necessarily connected with other historical categories such as Newtonianism. In the case of Mutis, his enthronement in the pantheon of national heroes, his pretended nationalist feelings, his alleged primacy in teaching the "New science" in America, the vindication of his scientific works by the nineteenth-century Colombian scholars as a source of moral autonomy and the emancipation of New Granada by his defense of the "New science," and the causal connection between the Bourbons' rule and the local enlightenment; all of these imprecise and teleological assumptions have in common a conception of enlightenment now deeply revaluated.[12] In most cases, categories used by the historical actors to represent their activities and works such as "Newtonian philosophy," "New science," and "Modern philosophy" are uncritically borrowed from them; more often than not these adjectives are simply equated with enlightenment, hiding the valuable clues to uncover the specific features of the intellectual atmospheres of the late eighteenth-century New Granada.

Our aim is to set out a characterization of Mutis' appropriation and defense of Newton's experimental physics in New Granada. This –not the "Enlightenment"– is arguably the most enduring Mutisian contribution to the establishment of a view of knowledge shared by the communities that emerged during the second half of the eighteenth century. From a different angle, this paper is a contribution to the recent and growing scholarship on Newtonianism, by considering its reception in the peripheral context of New Granada; this is an effort to document Mutis' most salient ideas about knowledge and natural research as an appropriation of Newton.[13] The introduction of Newton's *Principia* and *Opticks* through the visions that figures such as 'sGravesande and Musschenbroek made of these works seems not to have precedents in the young Viceroyalty. Therefore, our intention is to portray Mutis' rich appropriation of Newton as an illustrative case of the reception and development of scientific ideas in the colonial America. This is a first step into a larger project to pinpoint this local setting into a wider and revisionist reading now in course of "The Enlightenment" and its bonds with eighteenth-century Newtonianisms; or, to borrow Shank's wording, with delineating a new provincialized Newton in New Granada.[14]

This paper contains three sections. In the first, we analyze Mutis' interpretation of Newton's methodological pronouncements as presented in the lectures of mathematics at the *Colegio del Rosario*. In addition to Mutis' interpretation of Newton's analysis and synthesis methods, we present our discovery of his translation of 'sGravesande's *Physices elementa mathematica*, an unpublished translation that had not been correctly identified. In the second section, we track the consequences of Mutis' commitment to Newton for his project of the Botanical Expedition, including its theological foundations that includes a conception of the role of the king in administering God's creations in the New World. Lastly, we consider in detail Mutis' comments on the role of mathematics in the study of nature and how they reflect his commitment with Newton's natural philosophy. This includes some features of Mutis' translation of Wolff's *Elementa matheseos*, which we also discovered in the archives of the *Real Jardín Botánico* of Madrid.

Mutis as an eighteenth-century Newtonian

Before looking in detail at Mutis commitments to Newton's experimental physics, it is necessary to specify the elements implied in portraying Mutis' variety of Newtonianism. For this, we take up some elements from the recent scholarship on Newtonianism. These are (a) the adequacy of the label Newtonian as a historiographical category; (b) Mutis' own sense of the term Newtonian to represent himself and his own activities; and (c) the materialization of Mutis' Newtonianism, that is the specific means by which it was developed, characterized, and presented to specific audiences.

(a) The label Newtonianism is one of the most revised categories of the "Newton industry." Widely spread during the first half of the last century for describing, in a general way, the acceptance and diffusion of Newton's methodological and theoretical tenets and concepts throughout the eighteenth and nineteenth centuries, it helped to construct the image of these centuries as a period in which Newton's approach to natural-philosophical problems constituted the rationality of science *par excellence*. In the light of these considerations, several eighteenth-century authors from different fields –especially mathematics, natural philosophy, physics, medicine, and theology– from the Netherlands, France, Switzerland, Germany, and Italy were characterized as Newtonians, with little regard of the particular conditions under which they knew and used Newton's methodological and theoretical principles.

Nevertheless, since the 1970s, the classical image of Newtonianism as a single, uniform set of principles changed as the outcome of more detailed and specific researches about Newtonian authors. As historians like Schaffer, Ducheyne, and van Besouw argue, the general understanding of Newtonianism is problematic, because it does not account for the particularities of the appropriation of Newton's methodological and theoretical aspects in the different places where they were disseminated during the eighteenth and nineteenth centuries.[15] Thus, by using Newton's tenets and concepts, as well as his methodology for natural philosophy in diverse fields such as physics, medicine, chemistry, theology, geology, or zoology, these areas changed so much that it became impossible to distinguish the Newtonian features without considering them combined with the other traditions belonging to each discipline. Furthermore, Newton's theoretical and methodological principles were blended with local traditions, resulting in the emergence of different Newtonianisms in which authors and conceptions of nature apparently not compatible with Newton's own worldview were synthesized as the effect of the appropriation of Newton's methodology and theories in those different geographical and disciplinary contexts.

In this sense, we studied the specific ways in which Mutis appropriated Newton by analyzing his own definition of what it is to be a Newtonian, rather than assessing Mutis' ideas and including them in a general concept of Newtonianism. We will explore in some detail the ways in which Mutis' developed particular views on knowledge from his own reading of Newton. In this way, we will show that Mutis can be labeled as a Newtonian, not only because he presented an interpretation of Newton's experimental physics, but also because he self-defined as such. As we shall argue, by Newtonianism Mutis did not mean an inflexible commitment to Newton's claims nor a restriction to study the same topics that Newton did. Indeed, Mutis' conception of the Newtonian philosophy was framed within the idea that God had commanded the King of Spain to exploit the natural resources of America in order to fulfil a divine plane. This being so, Newtonian philosophy is reshaped as a "useful science" (*ciencia útil*), pre-eminently including natural history and mineralogy –areas not explored by Newton but widely valued in the New World, in addition to the teaching of Newton's physics and his mathematical approach to nature. The conception of the Newtonian philosophy emerging from this frame of divine commandment constitutes Mutis' expanded views on knowledge, mathematics and observation in Newtonian-inspired ways, but distancing from Newton himself.

It is important to specify that Mutis was not the only one concerned with the usefulness of science and the King's responsibility to promote natural research. Indeed, the utility of science, as part of the relationship between Spain and its colonies was a problem widely recognized in the eighteenth century, as scholars have documented it.[16] However, Mutis' formulation of the usefulness of science and its subsequent identification with Newton's philosophy is unique in his articulation of theological commitments, experimental approach, mathematical exigencies, and the moral duties of the philosopher responsible for the exploration of the "divine treasures." In other words, Mutis' solution to the then pressing problem of the utility of knowledge in the colony and in the Metropolitan Spain came from his appropriation of Newton, in which he saw a natural connection between utility, material progress, truth and religious concerns.

(b) In his lectures, textbooks and in all documents intended to present and defend his views to broad audiences –students, colleagues, local and imperial authorities, the Catholic Inquisition–, Mutis exposed the advantages of the "Newtonian experimental physics" and portrayed himself as a Newtonian. He differentiated "Newtonian philosophy" from others trends in natural research –mainly

Peripatetic and the "hypothetical philosophy" of Descartes– because of its anti-systemic spirit and its emphasis upon experiments and mathematics. In Mutis' opinion:

> Who would doubt that all progress in experimental physics is but a consequence of observations, experiments and the exact application of mathematics? The most illustrious mathematicians of the past, as well as those of the present century, have illuminated Physics with demonstrations and varied analytical calculations required to discover many truths that afterwards were found in line with experience. I should offer further proofs, more specific and determinate, if the entire corpus of Newtonian Physics were not but a continuous proof of what I have said.[17]

Following this path, the natural philosopher shall not build up an explanation of all phenomena –a system– but just of some of them. This would be, however, a long-lasting contribution to the true understanding of nature, because it was achieved with the greatest certainty and not by "framing hypotheses"– a typical Newtonian wording that Mutis constantly paraphrased. For him, this anti-systemic virtue of the Newtonian philosophy is present in two different contributions of Newton to the posterity: his method and his doctrine. Actually, Mutis sharply professed different degrees of commitment to each of them. On one hand, he embraced the "Newtonian method" without restriction, by considering both Newton's pronouncements on the method of analysis and synthesis and the rules for natural philosophy as they were interpreted by 'sGravesande in his *Physices Elementa Mathematica*. Mutis presented the former in his inaugural lecture of 1764, *Elements of natural philosophy, containing the principles of physics mathematically demonstrated and confirmed by observations and experiments: disposed for instructing the youth in the doctrine of the Newtonian philosophy in the Royal College of the Rosary of Santa Fe de Bogotá in the New Kingdom of Granada [Elementos de la filosofía natural, que contienen los principios de la física demostrados por las matemáticas y confirmados con observaciones y experiencias: dispuestos para instruir a la juventud en la doctrina de la filosofía newtoniana en el Real Colegio del Rosario de Santa fe de Bogotá en el*

Nuevo Reino de Granada]. Contrary to what the title suggests, Mutis did not deal with any of the physical principles of Newton's natural philosophy, but presented a historical panorama of its emergence and his interpretation of the method of analysis and synthesis as described by Newton in the "Query" 31 of the *Opticks*.[18] Mutis begins his *Elements* by explaining the importance of natural philosophy by its utility. According to him, the usefulness of natural philosophy consists in providing the conditions to know God through his providence. Thus, the main merit of natural philosophy "consists in that it is a solid foundation for natural religion and for moral philosophy, leading man in agreeable way to the high knowledge of the author of nature, creator of the universe."[19] This passage reveals that Mutis' conception of the utility of natural philosophy was not consistent with the enlightened ideal developed in Spain during mid-eighteenth century –especially during the reign of Carlos III. For Mutis the utility of natural philosophy was concerned with religious matters, as he argues that by knowing God's actions on the creation it is possible to find the principles of natural religion and moral philosophy, which arguably recalls the final paragraph of Newton's *Query* 31 of the *Opticks*. This theological emphasis is at odds with the common justification of science concerned with economic development and the improvement of the material conditions of Spanish territories.[20]

Afterwards, Mutis explains that the certainty of this theologically founded study of nature depends on the application of the geometrical method of analysis and synthesis to the study of natural phenomena, just as Newton had described it in the *Opticks*. In Mutis' words:

> In order to proceed with all certainty, and to get over disputes forever, [Newton] always relied on analytical and synthetic methods for the study of nature; so that, after beginning with phenomena or the effects, he moved to the discovery of powers or causes operating in nature. Similarly, he established that from particular causes it was necessary to move up to the more general ones and, from these latter to the most general cause. This is the analytical method. After discovering these causes, it should move down in an opposite order, considering [these causes] as principles already established

> to explain by mean of them the less general causes and next all phenomena, consequence of [the less general causes]; in this way, the soundness and firmness of explanations are clearly noticed. This is the synthetic method. It can be appreciated that in Physics, as in Mathematics, the investigation of difficult things should proceed with the analytical method, in order to apply the synthetic method afterwards.[21]

There are several elements in this passage concerning Mutis' presentation of Newton's methodology. We begin by the final statement. Mutis' presentation of the order in which the methods should be applied is remarkably similar to that of Newton in the "Query" 31 of the *Opticks:* "As in Mathematicks, so in Natural philosophy, the investigation of difficult things by the method of analysis, ought ever to precede the method of composition."[22] The difficult things that Newton –and by extension Mutis– was talking about were the causes producing natural phenomena which are their visible effects. The difficulty of the investigation relies on the fact that the discovery of causes cannot be achieved by the mere observation of natural phenomena. Conversely, Newton argues that in order to determine the causal connection between a particular phenomenon and its possible cause it is necessary to apply different mathematical procedures. Therefore, he concludes: "By this way of analysis we may proceed from Motions to the Forces producing them; and in general, from effects to their causes, and from particular causes to more general ones, till the argument end in the most general."[23] In this sense, following Newton, Mutis argues that it is necessary to proceed from particular causes to the most general ones, in order to determine the first principles of nature; such an investigation can be only conducted by articulating an experimental approach to nature with a mathematical analysis of the observed phenomena.

Another revealing aspect of the previous quotation is the particular concepts that Mutis used to characterize the results of the method of analysis and synthesis: powers (*potencias*) and phenomena (*fenómenos*). Both of them were representative of the main subject of physics as Mutis conceived it under the influence of 'sGravesande and of Mutis concerns regarding the very possibility of being understood by his students. In the manuscript containing Mutis' translation of 'sGravesande's *Physices elementa mathematica* –which we shall describe in the next section–, we can see that Mutis conceived natural phenomena in mechanical terms as he defined them as "all movements and all situations of natural bodies not depending immediately from an intelligent being and that are perceptible by our senses."[24] Based on this definition, we can assume that, in Mutis' opinion, the method of analysis allows to discover the causes of the motion of the bodies in nature: their powers, which he called *potencias*. For Mutis, physics is the study of powers causing the motion of bodies in nature. Thus, he proposed a reformed-mechanical physics, opposed to the Aristotelian physics taught in New Granada during the first half of the eighteenth century.[25]

For Mutis, the mathematical explanation of the principles discovered by analysis is one of the most important features of Newton's method for three reasons: (1) it illustrates the importance of mathematics for physics; (2) it allows to propose the particular causes discovered by observation and experiments as general causes and consequently to formulate them as universal laws. This is a central point for Mutis, because (3) it leads to know how God acts on his creation. According to Mutis, God interacts with his creation through a set of universal laws, established in order to rule and govern the motion of bodies. Hence, by adopting Newton's redefinition of the disciplinary boundaries between natural philosophy and theology, Mutis presented in his *Elements* one of the most intricate features of Newton's thought. We shall explain this particular point later when we consider the theological foundations of Mutis' formulation of the Botanical Expedition.

On the other hand, Mutis' interpretation of Newton's rules for philosophy is another revealing instance of his appropriation of Newtonianism as he used a translated version of 'sGravesande *Physices Elementa Mathematica* that he himself prepared for his students and that we discovered in the archives of the Real Jardín Botánico of Madrid. The translation, probably made in the 1760s, presents a conceptual description of the subject of physics as it is discussed in the first books of 'sGravesande work, emphasizing on the definition of concepts and the problems emerging from those definitions. It is consists of the first five chapters of Book I of the *Physices elementa mathematica*, where 'sGravesande discusses the basic constitution of bodies, the theological foundations of the laws of nature, and the role of Newton's rules for studying nature; partial as it is, this is still the only existing translation into Spanish of the *Physices elementa mathematica*.

'sGravesande introduced his reference to Newton's rules for philosophy with the intention of explaining how to proceed in order to find the regularities of the motions of the bodies and to generalize them as laws of motion: "It should be noted as well that in the enquiry of these laws the rules of Newtonian method shall be followed accurately; these rules are founded on the axiom we have already established."[26] It is worth noting that, in his translation, Mutis emphasized the need of applying Newton's rules accurately (*con toda exactitud*), because such an emphasis is not present in 'sGravesande's version. This shows that Mutis was convinced of the utility of Newton's rules in the study of nature and, in consequence, he promoted them as the only legitimate method to achieve a diligent study of any natural phenomena.

Mutis' use of 'sGravesande's theological foundation of Newton's rules for philosophy in his lectures on physics reveals that Mutis was interested in supporting his presentation of Newton's methodology on theological principles, more precisely, on the idea that, by discovering the laws of motion that God created, it is possible to discern his providence. After explaining the theological foundation of Newton's rules for philosophy, 'sGravesande presents the rules as Newton proposed them at the beginning of Book III of the *Principia*.[27] In the original version of the *Physices elementa mathematica*, 'sGravesande used the rules as a conclusion of Chapter I where he determines the subject and scope of physics. Then, he proceeded to explain the general properties of bodies and how they determine the qualities that we can perceive of them by postulating different experiments and mathematical demonstrations. Conversely, in Mutis' translated version, three scholia follow immediately after the rules; these scholia aimed to explain Newton's rules in detail. In Mutis' interpretation of them, it is possible to see a clear anti-Cartesian tone, expressed in the emphasis on the necessity of explaining natural phenomena by true and sufficient causes. This is intertwined with a limited interpretation of the logical and ontological consequences of Newton's rules as they were implied, for instance, in the fact that Mutis did not refer to the *ideoque* connecting Rule I and Rule II in Newton's version of the rules published in the second and third edition of the *Principia*.[28]

Newton's doctrine, on the other hand, is just partially accepted, apparently as an exercise in the same anti-systemic spirit that Mutis praised:

> Newton has been the only one who has described the nature, figure, workings, causes, movements and all the effects of all terrestrial and celestial objects and has brought the light with his experiments and meditations to the most recent philosophers, geometers and astronomers, especially to the English (…) In consequence, how cannot I be a Newtonian, dear listener, seeing the importance of the truths, the efficacy of demonstration, the weight of the experience and in short, the freedom to philosophize honoring the human mind? However, I am not a Newtonian similar to those that consider forbidden to recognize other Philosophers who have promoted aspects of Natural Philosophy with his observations, experiments, vigils and works. And even though I prefer to move away from the great Newton in some recent discoveries, I am no less Newtonian for this sake (…) Indeed, those Philosophers that, merely based on the effects and putting aside all hypotheses, try to deduce the arguments following the virtuous Newtonian method; these truly follow Newton's steps and are Newtonians in a sound way, contrary to those that only rest upon the master's authority.[29]

Mutis' Newtonianism is loyal to Newton's "way of philosophizing" and, as we shall see, to the metaphysical and epistemological claims implied in it. In fact, Mutis is less attached to Newton's doctrines, even though he exhibits a great enthusiasm and reasonable knowledge of them. In other words, Mutis was less interested in following the technical problems laid out by Newton's mechanics, mathematics or astronomy than other continental Newtonians such as Euler or Maupertuis; contrary to the German reception of Newton, just to mention one example, Mutis valued in Newton's legacy not only technical developments on mathematics and astronomy but above all, a new metaphysical conception of nature and the resultant approach to knowledge.[30] However, it does not mean that Mutis had a superficial engagement with the technical problems of Newton's experimental physics. The manuscript evidence suggests that he was particularly interested in the analysis of the motion of bodies in conic sections via Newton's calculus of fluxions. Amongst the set of Mutis' manuscripts containing his lectures in New Granada, four deal with different matters of physics, mechanics, and natural philosophy: his translations of 'sGravesande's *Physices elementa mathematica* and of Newton's *Principia*; the manuscript entitled *Elements of mechanics [Elementos de mecánica]*; and the manuscript entitled *Knowledge required for understanding phenomena* [*Conocimientos para la inteligencia de los fenómenos*]. These manuscripts, probably written between 1764 and 1777, encompass several matters of Newton's physics and mechanics. In addition, they reveal multiple traditions converging in Mutis' lectures on physics. These traditions are reflected in the topics he studied: the considerations of the body based on Newton's matter theory as it was developed in the Netherlands –and especially at Leiden– during the early-eighteenth century, a conception of natural philosophy and physics openly based on Mutis' interpretation of Newton's *Principia,* and a nuanced Wolffian mechanics. In general, these manuscripts reveal that Mutis was deeply interested in teaching on natural laws and Newton's characterization of attractive forces as they were applied to study the corpuscular constitution of bodies and to the motion of bodies in conic sections. Likewise, these manuscripts present forces framed in the theological foundation of the laws of nature and the application of mathematics to the natural philosophy that, as we mentioned in the previous section, underlies Mutis' argumentative structure. In particular, in *Knowledge required…*, Mutis explains the motion of a body in an ellipse as the result of the application of both a projective force (*fuerza de proyección*) –inertial– and a centripetal force. In this manuscript, Mutis (1) argues that the centripetal force accelerating a body traversing an ellipse should be drawn towards one focus of the ellipse; (2) he considers the fact that, in elliptical motions, centripetal and inertial forces should be in equilibrium;

and (3) he applies the mathematical analysis directly to the planetary motion. In so doing, he treated the subject with geometrical demonstrations, applying it to planetary motion. Similarly, the manuscript resembles different passages of Newton's *Principia* –especially Section VI of Book I and Propositions I through VIII of Book III–, in which Newton discusses the motions of bodies in conic sections, the forces required for their production, and the application of mathematical models to the phenomena of motion of heavenly bodies.[31]

Certainly, that characterization reveals that the interpretation of Mutis as an advocate of Newton's methodology, and his lectures in New Granada as a defense of it, only describe a partial aspect of Mutis' lectures and that further research on the unpublished manuscripts shall provide more evidence to characterize in detail the scope of them. Nevertheless, it is possible to conclude at this point that, for Mutis, Newton was a not only a natural philosopher but also a metaphysician. This is why Mutis' sight is directed to what we could see as a Newtonian foundation for natural history – consisting of zoology, botany and mineralogy, embodied in his project of the Botanical Expedition, as a true and useful knowledge of the world.

Also, it is important to stress Mutis' first-hand knowledge of Newton's and Newtonians' works, which can explain why he did not exclusively embraced Newton's claims –an expected attitude of a natural philosopher relatively isolated of the cultural life of European *lettres*– but saw them as the starting point of a new and authentic way to research the natural phenomena, spreading across the world: "All kingdoms are now Newtonian," wrote Mutis to the Viceroy in 1801.[32] Mutis had the largest personal library in the Viceroyalty and probably one of the largest collections in private hands of natural history in the world. It is well-known that Alexander von Humboldt was deeply impressed by Mutis' library and claimed that it was surpassed, at least in botany, only by Joseph Bank's library at London.[33] Bearing in mind the material difficulties for getting European-printed books in the eighteenth century in South America, Mutis' library of around 8,588 volumes is a material testimony of his professed love to knowledge and interest of persistent communication with the world. (Indeed, Santa Fé was located on top of the Andes and its access was considered to be so dangerous that travelers from Cartagena used to dictate their testaments before undertaking the journey).[34] This library contained some of the most important works by Newton available to an eighteenth-century reader and, among the Newtonians' works, it is not surprising that the often referred works by the Dutch Newtonians (Boerhaave, Muschenbroek and 'sGravesande) are represented even in different editions and translations.

Mutis owned a 1687 edition of the *Principia*, the commented edition by Le Seur and Jacquier published between 1739-1742 in three volumes, and the French translation of Du Châtelet prefaced by Voltaire (1759). Mutis made a partial translation of the *Principia* into Spanish around 1770 –the first translation into that language ever made–, based on both the first edition and the Geneva edition.[35] Mutis also owned two translations of the *Opticks*: the 1740 Latin translation, following the original made by Samuel Clarke, and the 1720 French translation by Pierre Coste. Also, Mutis had a copy of Newton's optical lectures in Latin (*Isaaci Newton in Academia Cantabrigiensi lectiones opticae: annis MDCLXIX, MDCLXX et MDCLXXI in scholis publicis habitae et nunc primum ex Mss. in lucem edite*) (1729); a copy of *The doctrine of fluxions founded on sir Isaac Newton's method: published by himself in his tract upon the quadrature of curves* (1758); and the three-volume set of the *Opuscula mathematica, philosophica et philologica* (1744). This is an unusual approach to Newton, if we bear in mind that the majority of eighteenth-century readers ignored Newton's works outside mathematics and natural philosophy, as Schliesser has recently stressed.[36]

For the sake of brevity, it is impossible to detail all the Newtonian works existing in Mutis' library (not to mention those in the libraries of the *Colegio Mayor de San Bartolomé* and the *Colegio Mayor del Rosario*, to which he certainly had access); however, we will mention the most relevant to our point in Mutis' library: the revision of Rohault's *Physica* by Samuel Clarke (1718); a French translation of Colin MacLaurin's *Account* of Newton (1749); John Keill's *Introduction to physics and astronomy* in Latin (1725); a French edition of the works of Maupertuis (1768), his *Discourse sur le* *parallaxe de la lune* (1741) and his *La figure de la Terre* (1738); also, Boerhaave's *Institutiones Medicae* (1796), a Spanish translation of the *Aphorisms* (1786), his Medical *Opera omnia* (1766), a French translation of the *Traité de la matière medicale* (1739), among others; of his favorite Dutch, Musschenbroek, Mutis had a 1761 Latin edition of his *Elementa Physica*, a 1756 Latin edition of his *Physica experimentales, et geometricae de magnete*, and the 1739 French edition of his *Essai de Physique*. To complete the Dutch authors, Mutis owned 'sGravesande's *Physices Elementa Mathematica* (1742) and a French translation (1746), his *Introductio ad philosophiam, metaphysicam et logicam* (1737) and the English version *Mathematical elements of natural philosophy* (1731). It is also possible to find works by Jean-Antoine Nollet, D'Alambert, Desaguliers, Boscovich, Paulian, Jorge Juan, just to mention a few more. Mutis' library was well stocked with Newtonian works.

(c) Contrary to some continental Newtonianisms, in which the technical development of problems pushed natural philosophers and mathematicians to accept, reject or reinterpret Newton's claims –for example, the *vis viva* controversy or the technical limitations of Newtonian tools to solve the three-body problem,[37] Mutis' appropriation of Newton's experimental physics appears in his lectures directed to wide social audiences; it is not derived from efforts to struggle with Newton's own claims in technical issues. Being a physician interested in drawing up a Botanical Expedition, Mutis' interest in technical problems of astronomy or natural philosophy were mainly related to his teaching during the 1760s-1770s. However, all the public statements from his arrival in New Granada until his death, his textbooks and notes intended for education defended the "Newtonian or experimental" philosophy, its foundations, its historical development and the benefits that the Kingdom will derive from its implementation as a collective and royal-supported effort.

In order to detail these elements of Mutis' Newtonianism, we will provide an analysis of his conception of Newtonian philosophy as a useful knowledge. However, it is necessary, to introduce Mutis' specific claim that knowledge is useful by Divine commandment; in this, Newtonian philosophy appears on the stage.

The commandment of God as a royal duty: science as useful knowledge

Mutis traveled to New Granada as a physician and a surgeon of the newly elected Viceroy Pedro Messía de la Cerda. However, in his *Diary of Observations* [*Diario de Observaciones*], Mutis reveals the real reasons motivating his journey to New Granada as he bitterly complained about the impossibility of fulfilling the purpose of drawing up a botanical expedition to the "southern regions" of America: "In Spain, I thought that by this time I would be heading to Loja, with the purpose of researching the quina."[38] Since his arrival in Santa Fé, center of New Granada, Mutis was constantly looking for appropriate conditions to explore the flora. In May 1763, supported by Viceroy Messía de la Cerda, he wrote from Cartagena de Indias to King Carlos III asking for authorization and funding to establish a Royal Botanical Expedition. The first request was ignored. One year later, in June 1764, Mutis tried once more to get the Royal consent sending the same request with minor additions to the King, but he again received no answer. As is well known, the Expedition was not fully launched until 1783, when the Archbishop and Viceroy Antonio Caballero y Góngora first authorized it on his authority, and only later wrote to the King requesting his support. By then, Mutis had started with his own researches in natural history, and he was widely known in Santa Fé for exploiting natural resources, particularly minerals.[39] The documents requesting Royal support present in subtle but straight manner Mutis thoughts about the aims of science, the connection with national interests and –the most revealing point– the King's divine duty to share with the whole of humanity the benefits of the natural goods entrusted to him. For Mutis, a botanical expedition established upon Newtonian principles would be the adequate mean to fulfil this commandment. In an attempt to persuade the King of granting his approval and funding for the expedition, Mutis put forward two arguments. These arguments also appear in other writings and it would be a mistake to treat them as rhetorical strategies limited to convince the King of his support for the Botanical Expedition. On the contrary, they are intertwined with Mutis' own conception of the problem of the utility of knowledge, widely discussed in Spain, and with the divine rights of the King to which he turned a lot of times in public and private writings; for example, they appear in his correspondence to European friends to explain details of the ordinary life in the colony, to justify the compulsory character of the inoculation, or to relate his own version of the 1781 “revolt of the comuneros.”[40]

Mutis begins his requests of 1763/64 with a brief account of the relationship between the development of scientific knowledge and the improvement of the welfare of nations. In his opinion, Spain was behind in the development of sciences until the middle of the century, when Fernando VI and the regent King began to support the creation of National Academies and encouraged for example, the first Expedition of Limits, led by Carl Löfling –one of Linnaeus’ followers. Although this Expedition had the only goal of drawing the boundaries between Spanish and Portuguese domains in the Orinoco after the *Tratado de Madrid* (1750), it was also used for botanical and zoological explorations; Linnaeus himself had instructed his student on these matters. However, Mutis chose to emphasize the resemblance of his project with Francisco Hernández’s expedition to New Spain –an early exploration launched at the end of the seventeenth century. In so doing, Mutis was recognizing that the king had previously supported a project partially concerned with botany –the Expedition of Limits; and at the same time, he was trying to connect his own project with an earlier expedition with explicitly botanical and medical concerns launched during the most powerful days of the Spanish Empire.

> The Natural history of America, for which Europa yearns, is a work of a Monarch such as your Majesty. This [history] has its beginnings in the liberality of the principles of Philip II who, looking forward to admiring the valuable natural goods of New Spain and no less concerned with promoting the Good for humanity resulting therefrom thanks to the abundant discoveries of some medicinal and mineral goods, sent the wise Dr. Hernández, his Physician, with adequate resources for the Real Project.[41]

From the previous quotation it is also evident that Mutis was not only trying to align his project with Hernández's; he was also trying to align Carlos III's new reign with Felipe II's –a reign then remembered as the time when the Spanish Empire reached its highest level of power and influence all over the world. Mutis suggested that an integral part of a successful and adequate ruling includes the promotion of science and in particular of botanical expeditions to find "medicinal and mineral goods." However, Mutis goes on, these early attempts to consolidate expeditions to Spanish dominions in America were frustrated by the "Spanish lethargy" which put its scientific development behind in comparison with other nations.[42] In spite of this, Mutis considered that Spain was then experiencing a rebirth after the war with Portugal and Great Britain, not only because the sovereign had time to improve his Kingdom, but also because he was an experienced King, having reigned for many years in Sicily:

> Now that your Majesty has seen the fruit of your fatigue in the solid peace that has been recently established, the sages shall consider your Majesty diligently dedicated to the complete reestablishment of Sciences, Arts and Trade; in this your Majesty will achieve the same happiness and skill that he has achieved in making happy, wise and respectable his other Kingdom.[43]

For Mutis, the King's dedication to promote natural knowledge was an obvious consequence of the duties all the rulers of civilized nations should observe. If Spain had no significant reputation for promoting natural knowledge it was because of the wars, but it was the obvious intention of a generous ruler to make of his Kingdom a "wise and respectable" one. Despite that all rulers of the "civilized nations" realized the importance of this endeavor, Mutis stressed that in the Spanish case the situation was more important and pressing, because of the extension of the realm and the richness, variety, and utility of the "treasures" therein.

> Nobody knows better than your Majesty about the immortal glory for yourself which shall come of this glorious endeavor skillfully performed, because no other nation than

> Spain is concerned with the knowledge and recognition of the admirable productions with which the Divine Providence has enriched the extensive domains of those who are fortunate to live under the rule of your Majesty in this New World.[44]

This promotion of science shall place Spain among the civilized nations and, in consequence, shall improve the glory of the sovereign. This passage also highlights a connection between the New World and the right to exploit its natural resources. Though Mutis was persistent in the first argument, it relies heavily upon the King's personal attitudes and ultimately depends on his will. If he wanted to be considered a wise and generous King, he was called upon to promote arts and sciences, including the exploration of the rich flora of New Granada. Arts and sciences, after all, are related to trade and commerce. However, for Mutis himself, the promotion of arts and sciences and the connected exploitation of the natural resources, was more than a choice of the sovereign: it was a duty imposed by God's design of the world and, in this sense, it was unavoidable. It is God's design to have entrusted America to the King of Spain as the last quotation suggests. In fact, Mutis usually refers to natural resources as "God's treasures contained in the dominions of His Majesty." According to this view, the project of the flora of Bogotá was part of a divine plan in which the King had to distribute God's gifts to humankind.

Mutis' mention of this duty appears abundantly in his expositions of the healing benefits derived from the application of herbs and particularly in his defenses of the inoculation. In the representations of 1763/1764 this topic appears when mentioning the Quina (*cinchona officinalis*), a bark very well known at the court of Madrid thanks to the trade and use of it during the seventeenth and eighteenth centuries from the Viceroyalty of Peru. Sebastian Bado, a Spanish seventeenth-century physician who first published a work about the medical properties of Quina *c.*1650, claimed that it was more precious than all the gold and silver that the Spaniards had obtained from the New World.[45] Despite the bark of Quina's tree had proved to be exceptionally effective as a febrifuge,[46] Quina had been discredited in Spain at Mutis' times, because bark of bad quality or other barks confused with

Quina had circulated in Europe. However, it was still somewhat valued in Europe, and Mutis pinned his hopes on the discovery of new sources of it since his arrival in New Granada. Because of the proximity to Peru and the oral reports of locals that they had caught sight of similar trees near to the hillsides of Bogotá, Mutis felt confident that he was going to discover the bark. This happened in 1772, according to Mutis himself.[47] Bearing this in mind, he wrote to the King in his 1763/64 requests:

> [The Quina] A medicine so admirable that competes for being greater than the others, among the few known antidotes, entrusted by the Divine Providence to the hands of your Majesty for the universal Good of mankind (…) will be scarce at the third century of its happy discovery if your Majesty does not rule about it in due course.[48]

For Mutis, natural resources had a theological meaning. Following this thread, Quina was then considered one of the highest manifestations of God's power and generosity, because of its admirable properties. In a similar way in which for Newton celestial movements explicitly exhibited the wisdom and power of God, plants and trees –and Quina in particular– had a theological meaning for Mutis:

> The Divine Providence had conceded us generously four very different varieties of medicinal Quina and every one of them has different virtues in its own way. His generosity dispensed them to us with positive signs of their abundance in relation to their virtues against the diseases to which every one must be applied, balancing the production and distribution of the medicine with the need of it, in order to reveal in this inestimable benefit that seal of number, weight, and measure which uncovers an omnipotent hand in all his works.[49]

Not only were the properties of Quina a natural resource that humans should use for their own benefit. Natural resources have a purpose in the Divine plan in which humans are meant to reveal God's generosity from the "positive signs" he had left spread over nature. These "positive signs," as we shall see, can be only discerned by experiments. The reference to God's intervention in terms of "that seal of number, weight, and measure" is recurrent in Mutis' writings as an equivalent to the Galilean motto that nature is written in mathematical characters.[50] Accordingly, botanical explorations are not only desirable but also necessary in order to reach the equilibrium between disease and medicine, revealing God's plan. In other words, the botanical researches are not only wanted in order to heal but, on the contrary, because healing by using medicinal plants is part of God's plan. In consequence, humans should not only use plants, and by extension nature, for their own benefits: they must. Science, then, cannot be but useful and usable knowledge by divine decree. This sense of duty and the usefulness of science displayed in Mutis' arguments are not present in Newton's writings.

If natural resources are part of a divine plan, then humans are expected to have responsibility in finding the proper way to establish the balance between disease and health using medicines or, in general terms, to use rightly the goods through which God exerts his power to fulfil his commandment. Humans have a central role in the divine plan; they have to explore nature to find medicines and the causes, connections, and properties of natural phenomena. In the case of medicine, the perfect match between a disease and a medicine is to be uncovered through botanical and chemical researches by he who manages God's resources: the King and his subjects. The subtle but clear demand that Mutis put forward to the King in his representation of 1763/64 and to which he referred to in other writings has a theological root.

In addition, the fact that God entrusted this resource only to the King of Spain by spreading the Quina exclusively in America, reinforces his unavoidable and direct responsibility. Mutis offers himself to help the King with such a heavy burden: "The useful Quina, a treasure only conceded to the domains of your Majesty, in whose hand is entrusted to distribute it to the other nations in the same way that the Dutch distributed Ceylon's cinnamon (…) will be confidently, easily and rightly handled when my observations reach the public."[51] In the following section, it will be clearer how Mutis came to consider himself as playing a central role in this endeavor.

The Quina is just the most obvious example of the required intervention of the King as administrator of divine resources. However, further unknown resources that God may have deposited in the lands of the New World were waiting to be discovered and used for the benefit and welfare of humanity but also to accomplish the divine plan:

> America, in whose fortunate land the Creator deposited infinite goods worthy of admiration, has reached its name not only for its gold, silver, precious stones and other treasures hidden in its womb; also produces on its surface, for trade and utility, exquisite dyes which industry will find in the plants; the *cochinilla*, abundant in this Kingdom, though not farmed because of the indifference of the natives of this land; the precious wax of a bush named *laurelito* and that coming from the Palm tree; many glues, that can be used in the Arts; very valued woods for instruments and furniture; finally produces, for the Good of mankind, many other trees, herbs, resin and balsams. We have a long way until we know all of this; and what is most valued, we have a long way until we know how to use what we already have discovered.[52]

If the King was responsible for supporting the exploration and distribution of natural resources, because God entrusted them to him science is but usable knowledge to fulfil this plan; in Mutis version, useful science is his Newtonian philosophy –and he, himself– a proper instrument to achieve this end.

Mathematics and observation: the virtues of the Newtonian philosopher

Mutis' conception of "Newtonian" or "experimental physics" rests on a particular reading of methodological and epistemological topics displayed in the *Principia* and the *Opticks*. This reading is largely shaped by the theological views previously explained, resulting in a conception of science as useful knowledge both in theological and material senses. Accordingly, knowledge is understood as a way to transform materially the creation. The resultant emphasis on usefulness and material intervention is not present at all in Newton's works. However, Mutis' attentive reading of Newton allows him to grasp central features of Newton's empiricism, mathematics, and their relationship blended in his idea of useful science.

Mutis' systematic explanation of his conception of science, mathematics, and experimentation is first exposed on the inauguration of the chair of mathematics at the *Colegio del Rosario* in 1762. Expanded versions of the main topics here presented appear in his *Elements* and in the prefatory comments to his translation of Wolff's *Elementa matheseos*.[53] The antecedents to the foundation of the first chair of mathematics in New Granada are well known and have been widely discussed. Mutis offered his own version of this fact. According to him, it goes back to the time when he was traveling to America:

> I had promised in the ship that I would give a course of mathematics at home to the young people travelling with H.E [His Excellency, the Viceroy Messía de la Cerda]. Yet a lot of time has passed since our arrival in Santa Fe, the officers and pages of the Viceroy make me keep my word; I prepared myself to do it, wishing to begin this course after the Epiphany day. Everything was set while I made up a preliminary speech. But after the Rector of the University was informed about my new determination, since he never could persuade me to lecture on Medicine for reasons that I have set down elsewhere, he could demand from me the consent to lecture in public on Mathematics, if the Viceroy stipulated it so. The 29 February he went to talk to HE about this point and he got what he wished. The same day, H. E. gave me in La Mesa his consent and pleasure in this new ruling.[54]

For the inauguration, Mutis wrote and read the "Preliminary speech pronounced in the opening of the Course of Mathematics, 13 March 1762, in the Colegio Mayor of Our Lady of the Rosary in Santafé de Bogotá,"[55] as he wrote in his diary. The highest religious and political authorities of the Viceroyalty were in the audience, as well as members of the local elite of creoles and students, according to his own account.[56] The "Speech" is an abridgement of philosophical and methodological issues that Mutis developed elsewhere. However, it is a crucial piece because it is a general exposition and defense of the philosophical and methodological issues rooted in Newton's work, intended for a non-specialist public and directed against the Peripatetic teachings widely spread in Santa Fé's educational atmosphere. The "Speech" relates sciences –and foremost, mathematics– with the education of young people and with the development of the colony.

In Mutis' use, both in the "Speech" and in the *Elements*, mathematics refer to: (1) the proper language to understand nature, because it was used by God when creating the world, establishing the order and harmony grasped by the human mind in the regularity of the laws of nature; this meaning has ontological and theological consequences; (2) a way to conduct reasoning (*more geometrico*) that can be applied outside the domain of quantitative studies, improving the process of enquiry in any area and preventing the mind from making mistakes; (3) the specific study of quantity, discrete and continuous, by means of comparing "all that can be augmented or reduced." The way to proceed in the specific domain of quantity can be extended to "other matters," giving rise then to "mixed Mathematics" or "Physico-Mathematical sciences."[57] Though the third and the second senses may appear quite similar, they actually refer to different nuances of the term. In the second sense, mathematics is conceived in terms of analytic and synthetic ways to proceed from experience and observations to general laws of nature that can be extended, for example, to medicine or botany; in the third, the specific methods and procedures of mathematics are applied not only to discrete and continual magnitudes, such as numbers and figures, but also to letters and signs, as it is done in specious arithmetic (algebra) or in calculus. In other words in the *more geometrico* sense, mathematics provides an order for reasoning, while in the third one it is a way to compute ("measure") things by their signs, giving rise to mixed mathematics. In this third sense, Mutis advanced his ideas regarding mathematics in the preface for his translation of Wolff's *Elementa matheseos*. Mutis' translation is made out of different excerpts of Wolff's textbook, which are nowadays found in two separated manuscripts; both of them entitled *Elements of arithmetic* [*Elementos de arismetica* [sic.]] which complement each other. In general, both of them contain Wolff's arithmetical definitions and the basic concepts and tenets of arithmetic, only varying in the extension and detail with which Mutis explained different topics.[58] Thus, for instance, in the shortest manuscript Mutis exclusively translated Chapter I of Wolff's *Elementa*, treating in detail the definitions of arithmetic, and including Wolff's scholia and problems. Conversely, although more concise regarding the definitions –it only presents them without including scholia and problems– the largest manuscript includes chapters I up to VIII of Wolff's *Elementa*, being particularly focused on the operations with fractions. The shortest manuscript is also important because Mutis included a preface in it, describing the historical approaches of mathematicians to the relation between physics and mathematics as it was related to the definition of quantity. In it, he argues that mathematics deals with quantities and that they can be considered either as intelligible or sensible. In describing sensible quantities, Mutis claims:

> [Sensible quantities] include not only what has number, sensible extension and weight but also what has time, motion, the light, the sounds, the qualities, the perfections, the relationships, chance, in general, anything having parts, modifications, comparisons, greater, less and greater in itself, and by comparison with other quantities of the same species (…) Because of this, the mathematician deals with numbers, considers bodies, forms figures, measures the earth, determines the depth of the sky, gets right the motion of celestial bodies, decomposes light, follows the sound, builds machines, adds up or limits their energy, raises buildings, commands armies, fortifies cities, move ships all around the world.[59]

In this sense, Mutis concludes that although ancient mathematicians divided mathematics into arithmetic, geometry, music, and astronomy, modern mathematicians have reconsidered such classification, thus establishing a simpler division between pure and mixed mathematics; being the latter the field of application of mathematics to the study of nature. In Mutis' words,

> Pure mathematics considers quantity in itself, not including the consideration of any accident or sensible affection. These are arithmetic and geometry, both universal (…) Mixed-mathematics, or non-pure, considers dressed quantity and in company with some accident or affection [illeg.]; and because sensible affections belong to natural philosophy or physics, they are called physico-mathematical parts. [60]

Mutis related mathematics and physics by claiming that the latter provides its subject of study to the mixed mathematics as it studies natural bodies and natural phenomena known by observations and experiments. Arguably, this idea is founded on his conception that nature has been created in a mathematical manner, which, as we suggested in the previous section, is inherited from diverse traditions of the seventeenth century which Mutis regardless identified as Newton's experimental physics. This point is particularly important because it reveals that, in the lectures following his *Speech* and *Elements*, Mutis presented mathematics as a theoretical and practical field, narrowly related to physics.

Nevertheless, Mutis argued that in order to study nature from a mathematical point of view, the natural philosopher needed to know the theoretical principles underlying pure mathematics: "Before going deeper into the doctrine of the physico-mathematics it is required to be perfectly instructed in pure mathematics."[61] Such a characterization of the process required to study mixed mathematics reveals that Mutis conceived his lectures on mathematics with an instrumental purpose as a foundation to teach the theoretical elements to his students, for them to be capable of studying nature under the precepts of Newton. This is particularly important as it reveals that Mutis' ultimate purpose with his lectures was connected with the enterprise that motivated him to travel to New Granada in the first place, the botanical expedition, and with its theological foundation.

On the other hand, mathematics, in the first sense, is the cornerstone of sciences. The logical outcome of this foundational sense is that from cultivating it in the third sense, it can provide a way to account for natural phenomena. On the other hand, by extending its methods to other domains – as described in the second and third senses – more utilities are revealed: the improvement of the ability to reason rightly, the preservation of life, the improvement of navigation and exploration of unknown seas and lands, for example. For Mutis, the foundation of mathematics and the cause of its capability to account for natural phenomena are ultimately based on theological considerations:

> When God created the world –this so wonderful machine that we shall never live enough to admire sufficiently– seems to have formed the high design to implement mathematical laws. Everything was created by number, weight and measure with an order so constant that they shall remain until some day (…) Not in vain a wise man said that the World is a large book and, though open to all, just a few can read it, because it is written with ciphers and mathematical characters.[62]

In the language of the mechanical philosophy current in seventeenth-century Europe and well known to Mutis, the world was conceived as a machine, whose processes can be explained in terms of mathematical laws, because God seems to have turned to numbers during the creation; in other words, the world is an exercise of God's knowledge of mathematics. In consequence, it constitutes the proper way to understand "this so wonderful machine." Interestingly, Mutis encompassed this theologically-based conception of the relationship between mathematics and physics with some religious considerations that can be identified with the theological purposes underpinning the Botanical Expedition. These considerations are reflected in the fact that the knowledge of God's actions allowed humans to determine the best manner to adore him; a relationship that resembles Mutis' presentation of the method of analysis and synthesis as we described it.

Here, it is important to stress that for Mutis the mathematical structure of the creation includes natural history and medicine, as they were related to both chemical and physiological phenomena that can be explained in mathematical terms. In addition, Mutis also stressed his Newtonianism in these disciplines by extending to them the implications of Newton's treatment of attractive forces –which he knew through 'sGravesande's interpretation. In so doing, Mutis connected his Newtonianism with the tradition of the Newtonian medicine developed in the early eighteenth century in the works of physicians such as Albercht von Haller, Archibald Pitcairne, James Keill, and Boerhaave; Actually, as a training surgeon in Cadiz, Mutis reproduced von Haller's experiments and vivisections and in New Granada he relied on Boerhaave's *Aphorisms* and *Institutiones Medicae* as textbooks for the curriculum of medicine that he prepared in 1804 for the *Colegio del Rosario*.[63] The conditional character of this knowledge –that God seems to have turned to mathematics in the creation– will be clarified with the exposition of the virtues of the philosopher. This conception of mathematics explains, as we have seen, why Mutis believed that mathematics could account for natural phenomena; and, on the other hand, it reveals that mathematics is an antidote against atheism:

> But if the world is designed following such wise and manifest laws, how important is it for the man looking for knowledge to set aside a short time to the contemplation of things entering through senses, as the most adequate means to properly praise the Creator? Atheism had not progressed and the spirit of so many barbarous nations had not degraded to such terms that would have embarrassed the lofty status of human nature in all ages.[64]

Indeed, Mutis considered that the main business of natural philosophy, and of knowledge in general, is to serve as solid foundation for natural religion and moral philosophy, leading humans in a "very agreeable way to the high knowledge of the Author of Nature and Creator of the Universe"; because studying nature amounts to leading to the knowledge of the wonderful works of that Sovereign Creator, who allows himself to be known, in part, from the visible things.[65]

As ambiguous as the expression "Newtonian methodology" can be –Newton's methodological guidelines and procedures in the *Principia* and the *Opticks* are not a coherent and unified set of rules or strategies; we can note differences between what Newton calls "deduction from phenomena" in the *Principia* and the demonstrative parts of the *Opticks*, on the one hand; and the exploration and speculation about hypothetical statements in the Queries, on the other. According to the "Speech" and the *Elements*, Mutis firmly identified "the method of Newton" with the former, supporting Newton's famous statement "hypotheses non fingo." For Mutis, Newton "never decided to suppose not even one of his favorite principles: he never made a supposition, because he was not concerned with the establishment of a system."[66] The result is that Mutis aligned Newton's methodology and his own with the analytical and synthetic style which he also reads in the *Opticks* –except for the analogical reasoning we have explained before, justified by the nature of the subject, but Newtonian for his deduction from the rules for philosophizing.

In the introduction to *Elements*, Mutis claims that "the Book of nature is only studied now by means of observation and experience establishing reasoning in the safer way of mathematical demonstration." Observation and experience or "the contemplation of things entering through senses" is the starting point of any enquiry. In Mutis' view, mathematics constitutes a way to infer causes from the given phenomena and to demonstrate these conclusions, but it cannot postulate the existence of the entities; these must be uncovered by experience. On the contrary, mathematics is the way by means of which, starting from observation and experiments, we can "rise to the discovery of the causes by their effects, and to explain the effects by their causes. For this he [Newton] used a sublime Geometry which was always his guide in his delicate and prickly enquiries." Mutis introduced Newton's method of analysis and synthesis in *Elements* in order to explain how it allows the study of nature without the problems of the speculative-deductive systems, by establishing a relationship between mathematics and natural philosophy. He established such a relationship in both methodological and conceptual levels, arguing that the principles of the geometrical method of analysis and synthesis should guide the study of nature to discover the laws ruling the motion of bodies.

In Mutis' view, the most important of Newton's teachings was that "it was necessary to consult nature itself, to follow all its steps in all its manifest operations and to extract from it womb the mysteries it hides from us." The uncovering of the causes of phenomena must start from their attentive observation by applying the analytical method, not from principles supposed or deduced from other principles. However, experimental findings are not only the departure point for launching researches but also, following Newton's Rule IV, a permanent referent for the philosopher during the enquiry. For Mutis, this is crystal-clear in Newton's work: "He never wanted to hear any objection against an evident experience, even though it were deduced from the subtlest reflection of metaphysics." Accordingly, experience is the link between the findings of knowledge and the actual structure of phenomena to be explained. In this sense, experience is the touchstone of the mind.

This is so because our knowledge of the world ultimately rests on the way God decided to arrange nature; in this sense, our knowledge is always limited.[67] For Mutis, empiricism is based on a particular conception of God's relation with his works. In translating 'sGravesande's interpretation of Newton's arguments in the "Scholium Generale" to the *Principia*, Mutis considers that experience and observation is the only way to the true study of nature. In his view, a God acting through constant laws in nature supports the relation between knowledge and experience. In order to justify this, Mutis included in his translation a set of definitions found in Book I of the *Physices Elementa Mathematica* in which 'sGravesande describes Newton's methodology in the *Principia*: natural things are bodies (Def. 1) and the sum of all bodies is the universe (Def. 2). Natural phenomena are "the movements and all situation of natural bodies not depending immediately upon the action of an intelligent being,"[68] that is, their movement is not caused by the immediate action of God (3). Voluntary movements are part of natural phenomena, but it is necessary to distinguish between those movements depending on our own will and those depending on other causes (4). All these movements follow specific and determinate laws (5). Even those phenomena that we consider arising from chance, such as the growth of plants, could be explained in terms of laws if we had at hand sufficient observations to discover regularities and uncover causal bonds. When we discover that the entire world is subject to laws, we find the foundation of all reasoning of physics (Def. 7) in this supreme principle: "Axiom. The Creator of the universe rules all things with specific and constant laws, appropriate to his wisdom, arising spontaneously from the very nature of things" (Def. 8). Physics then is the enquiry into, and explanation of, natural phenomena, that is, it uncovers and exposes the causes of phenomena (Def. 9). In examining these causes, the body in general must be examined and, after this, it should be asked "what rules God wanted to be executed in these motions. These rules are called laws of nature" (Def. 10). This is why "a law of nature is that rule or constant norm, according to which God wanted these movements to be performed" (Def. 11). In consequence, a law of nature is, from the human point of view, a simple effect that appears in all occasions as one and the same and whose cause is unknown to us, whenever we cannot discover that it arises from a law already known; because they can arise as well from any other law simpler, but concealed from us (Def. 12). However, in what concerns to us, we do not care that one thing depends immediately on God's will or that it will be known to us by any other mediate cause that we ignore (Def. 13). The conclusion of all these 13 definitions is that "it is then evident that we cannot know the laws of nature but by examining natural phenomena" (Def. 14).[69]

Hitherto we have shown how Mutis appropriates and defends "the method of Newton," developing some methodological conclusions and theological foundations not present in Newton's works. This appropriation, as we argued, conceives Newtonian philosophy as a useful science. This conception also imposes a moral exigency for the philosopher sketched in Newton's theological and historical studies known to Mutis. He subsumes these moral virtues of the philosopher under his own understanding of him as an executioner of God's plan. In other words, because knowing the world amounts to being a servant of God's plan, a material executor of divine designs –a kind of demiurge–, the philosopher must be the bearer of moral virtues required by his role in the theological ordering of the world: "[To the knowledge of the Creator] are to be oriented the sight of the philosopher (…)

because it is certain that it is not possible to contemplate and admire the order of such an excellent system without at the same time being part of the general harmony of nature in order to arise to the Creator."[70] Mutis connects a set of virtues with the experimental or Newtonian philosopher: diligence, patience, humility; in so doing, he reinterprets Newton's methodological and epistemological statements as implying a moral condition required to follow the adequate path that shall led to fulfilling the divine designs: "In order to reach such high ends, the Philosopher may not be precipitated in his discoveries; rather he must follow his path with due humility and the highest precaution in these matters." The history of philosophy contains plenty of examples of the natural inclination of humans to fall into superstition; this happened when they "applied themselves to penetrate the hidden mysteries of nature without the due precautions."[71] In this way, experimental or Newtonian philosophy is restricted to those who do not expect to build by themselves a complete system of the world, but to those who are willing to contribute, even to a small measure, to the hard task of understanding natural effects by their causes. In so doing, they shed light on and complete divine designs, despite the limitations of the human mind.

> The knowledge we have of nature, though imperfect, is always useful to represent to us that Sovereign Power, which dominates all things and though never weakens. This is the main end of a philosopher; and in order to reach it, he must not hasten our discoveries creating systems to waste the time, leading to impiety and atheism, or to form dangerous opinions on the divinity and the universe.[72]

This moral exigency should not to be confused with the moral consequences of natural philosophy to which Newton referred at the end of the *Opticks* and in other works on historical studies and natural religion known to Mutis.[73] On one hand, the philosopher ought to be humble to reach knowledge; on the other, the complete system of natural philosophy would provide or at least indicate a moral philosophy by indicating our duties towards each other. Bearing in mind the limits of knowledge and the difficulties in establishing firm conclusions from experiences, the philosopher has to be patient and dedicated; his sight should be directed to a divine end, not to his own glory. The immensity and complexity of the world cannot be grasped all at once, but by the experimental work without any individual interests. In opposition to this attitude, Mutis links the attitudes of those who pursue the fame and look to immortalize their names with the construction of complete systems and ambitious explanations without appealing to experience and mathematics. The result of this attitude is the construction of systems leading to atheism; if natural philosophy is the foundation of religion, then a false natural philosophy would lead to a false religion or even to atheism, a formula present in Newton's works and widely spread among supporters of experimental philosophy in other latitudes, mainly in Britain.[74] Through these religious and moral derivations of his Newtonianism, inherited and reinterpreted from Newton's own works, Mutis reinforces his arguments in favor of the Newtonian philosophy for having pious implications supporting the true religion and, in this sense, responsive to the challenges of a useful science for the Spanish America.

Mutis considered himself as fulfilling the requirements of the natural philosopher. However, how can a bearer of these moral virtues claim that he is such? Mutis' strategy for so doing was to point to his actions. In his Representations to the King of 1763/64, when Mutis asked for support and funding for the Botanical Expedition, he claims:

> When considering the happy outcomes of my enterprise, I do not know if you, my Lord, say [that they are done] to perpetrate among the wise men an eternal gratitude to the immortal glory of H. M, or that for not a little confusion of myself Providence had reserved in your Court a young adventurous and full of life, vassal of H.M. (designated a few years ago to go to London under the Royal protection of the August Brother Predecessor of H.M. by the reports of your Excellent Minister. D. Ricardo Wall) who deprived of orders, help and royal protection (…), only guided and inspired by the glory of the Nation, would have by himself determined by his hand to continue the works of those Great Monarchs, Predecessors of H.M. All this has been verified in myself; and

> it is publicly known in this Kingdom (…) that I wanted to throw myself into such an arduous task.[75]

He, in his view, was concerned solely with “the glory and Universal Good of the Nation,” leaving aside his “particular interests.” Mutis himself was an adequate bearer of the moral virtues and the Newtonian way required to advance in God’s plan for America.

Conclusion

The traditional historiographies on the eighteenth-century New Granada have uncritically subsumed all the intellectual and cultural phenomena occurring in this corner of the Spanish Empire under the general label of “Enlightenment,” concealing historical process such as the appropriation of Newtonian philosophy –introduced by Mutis and inherited in different ways by his enlightened students. A general revision of this understanding of the Enlightenment, supported by recent studies, has opened an adequate space to advance in our understanding of Mutis’ engagement with Newton in the light of the recent debates on eighteenth-century Newtonianism and natural philosophy.

As we expect to have shown, Mutis’ “Newtonianism” is not a mere appeal to authority, but an original appropriation of Newton’s doctrine and method to provide a foundation and to derive consequences for areas non-traditionally considered as Newtonian: natural history and medicine. In so doing, Mutis unfolds a critical examination of Newton’s methodological precepts and the order of sciences. This examination leads to the development of epistemological and metaphysical positions not present in Newton’s works but sharply derived from his own understanding of them, mediated by his reading and translations of European eighteenth-century Newtonians such as 'sGravesande and Musschenbroek. In this sense, we claim that Mutis was a committed and creative Newtonian.

This examination of Mutis' conception of Newtonian experimental physics is also a starting point to more detailed studies on Mutis' appropriation of Newton's in the context of the eighteenth-century Newtonianism. Indeed, Mutis takes sides on interesting topics familiar to others Newtonians of the period such as the cause of universal gravitation, the nature of bodies and forces, the nature and properties of light and the theological underpinnings of laws of nature; all these deserve separate studies. Mutis reconciliation of Newtonian philosophy with Catholic challenges through his useful science can open new questions and routes on the relationship between science, religion, and society in Catholic contexts. In addition, it is necessary to revisit Mutis' works on natural history, medicine and hygiene to make visible the underlying Newtonian principles not recognized by the existing accounts –in most cases, the references to Newton are just ignored. This new perspective will contribute to a better understanding of his achievements and of the resources he used in solving the educational and medical problems he found in New Granada. However, this does not lead to a reduction of all his contributions to a successful application of Newton's method. Conversely, it brings to light a structural element present in Mutis' works widely ignored or minimized that needs to be placed in context to improve our understanding of the specifics of his achievements in every field, of the spreading of Newtonianism in New Granada through his disciples and, in general terms, as a contribution to the reexamination of the abused idea of Enlightenment. If our reading of Mutis' Newtonianism is right, it can also provide elements to contribute to the on-going debates on topics such as the botanical expeditions and the creation of a visual culture unknown to Europeans. Indeed, Mutis' Botanical Expedition is unique in being conceived and executed as an exercise in the experimental teachings of Newton, the "Prince of Philosophers."[76]

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[1] Florian Cajori, "The Mathematical Sciences in the Latin Colonies of American," *The Scientific Monthly* 16 (1923): 194-204, 194.

[2] The New Granada was erected Viceroyalty for the first time in 1719, but definitively acquired this status in 1739 as part of Bourbon reforms until the independence war in 1810. On the development of New Granada in comparison to the Viceroyalties of New Spain and Peru see Peter Lynch, *Bourbon Spain, 1700-1808* (Oxford: Blackwell, 1989); David Bushnell, *The making of modern Colombia: A nation in spite of itself* (Berkeley: California University Press, 1993); Anthony McFarlane, *Colombia before independence: Economy, society, and politics under Bourbon rule* (Cambridge: Cambridge University Press, 1993), pp.23–28.

[3] On the Jesuits in New Granada see José del Rey, *Los jesuitas en Cartagena de Indias, 1604-1767* (Bogotá: CEJA, 2004); José del Rey, *La respuesta de la provincia del Nuevo Reino de Granada al reto legado por Ignacio de Loyola a sus seguidores* (Bogotá: Pontificia Universidad Javeriana, 2011); *Guillermo Hernández, Documentos para la historia de la educación en Colombia* (Bogotá: Patronato Colombiano de Artes y Ciencias, 1969); Juan M. Pacheco, *Los jesuitas en Colombia* (Bogotá: San Juan Eudes, 1959), is the most comprehensive and still useful study on the topic. About the chair of mathematics see Diana Soto et al., *Estudios sobre la universidad latinoamericana* (Tunja: RUDECOLOMBIA, 2004); Renán Silva, *Los ilustrados de Nueva Granada, 1760-1808* (Medellín: Banco de la República, 2002); Renán Silva, *Universidad y sociedad en el Nuevo Reino de Granada* (Medellín: La Carreta, 2009); Guillermo Hernández, *Crónica del muy ilustre Colegio real mayor de Nuestra Señora del Rosario* (Bogotá: Editorial Centro, 1938). About the Astronomical Observatory, see Alfredo Bateman, *El observatorio astronómico de Bogotá* (Bogotá: Imprenta Nacional, 1954); also Caldas' own description of 1810 in Francisco José de Caldas, *Obras completas de Francisco José de Caldas*, (Bogotá: Imprenta Nacional, 1966), pp.45–54.

[4] Diego Mendoza, *Expedición botánica de José Celestino Mutis al Nuevo Reino de Granada y Memorias inéditas de Francisco José de Caldas* (Madrid: Librería de V. Suarez, 1909), p.146. See also Florentino Vezga, *Memoria sobre la historia del estudio de la botánica en la Nueva Granada* (Bogotá: Sociedad de Naturalistas Neo-Granadinos, 1860); José M. Vergara y Vergara, *Historia de la literatura en Nueva Granada* (Bogotá: Imprenta de La Luz, 1867); José M. Groot, *Historia eclesiástica y civil de la Nueva Granada* (Bogotá: M. Rivas & C, 1869); Federico Gredilla, *Biografía de José Celestino Mutis y sus observaciones sobre las vigilias y sueños de algunas plantas* (Bogotá: Plaza & Janés, 1982) and Francisco De Las Barras de Aragón, *Documentos referentes a Mutis y su tiempo. Recolectados en el archivo de Indias de Sevilla* (Madrid: Librería de V. Suárez, 1933).

[5] The most representative works are Enrique Pérez-Arbeláez, *José Celestino Mutis y la Real Expedición Botánica del Nuevo Reino de Granada* (Bogotá: Antares), 1967; Luis Carlos Arboleda, “Acerca del problema de la difusión científica en la periferia: El caso de la física newtoniana en la Nueva Granada (1740-1820)” *Quipu* 4 (1987), pp. 7–32; Germán Marquínez-Argote, “Filosofía de la ilustración,” in Germán Marquínez-Argote *et al*. (eds.) *La filosofía en Colombia. Historia de las ideas* (Bogotá: El Búho, 1988) pp.133–162; José Luis Peset, *Ciencia y libertad: El papel del científico ante la independencia americana*, Madrid: CSIC, 1987; Marcelo Frías, *Tras El Dorado vegetal: José Celestino Mutis y la Real Expedición Botánica del Nuevo Reino de Granada (1783-1808)* (Sevilla: Diputación Provincial, 1994); Emilio Quevedo *et al., Historia social de la ciencia en* Colombia, vol. 2: Matemáticas, astronomía y geología, 10 vols., (Bogotá: Colciencias, 1993-1996); Luis Carlos Arboleda and Diana Soto, “Modern Scientific Thought in Santa Fe, Quito, and Caracas 1736-1803” in Juan José Saldaña (ed.) *Science in Latin America: a history,* (Austin: University of Texas, 2006), pp.93–122; Santiago Castro-Gómez, *La hybris del punto cero: Ciencia, raza e ilustración en la Nueva Granada (1750-1816)* (Bogotá: Pontificia Universidad Javeriana, 2005).
[6] Peset, *Ciencia y libertad*, p.346 (note 5).
[7] Frías, *Tras el Dorado,* p.38 (note 5). Were we to follow this argument, we would have to claim that Isaac Newton had a central role in the independence of New Granada through his influence on Mutis. This way of reasoning is obviously misleading and barely can explain actual historical problems.
[8] Renán Silva, *La Ilustración en el virreinato de Nueva Granada: Estudios de historia cultural* (Medellín: La Carreta, 2005), p.50.
[9] See, for example, the use of this category in Mauricio Nieto, *Remedios para el imperio: Historia natural y la apropiación del Nuevo Mundo* (Bogotá, Universidad de los Andes, 1996), pp.9–10; Arboleda, “Acerca del problema” (note 5); Soto *et al*., *Estudios sobre la universidad* (note 3); Frías, *Tras el Dorado* (note 5); Peset, *Ciencia y libertad* (note 5).
[10] John Lynch, *Latin America between colony and nation: Selected essays* (Hampshire: Palgrave, 2001), pp.91–92; Antonio Mestre-Sanchis and Pablo Pérez-García, “La cultura en el siglo XVIII español” in Luis Gil Fernández (ed.) *La cultura española en la edad moderna* (Madrid: Akal, 2004), pp.387-538, 410.
[11] Silva, *La Ilustración,* p.51 (note 8).
[12] On recent reexaminations of the Enlightenment we have followed, among others: G. S. Rousseau and Roy Porter (eds.), *The ferment of knowledge. Studies in the historiography of eighteenth-century science* (Cambridge: Cambridge University Press, 1980); Roy Porter, *Enlightenment: Britain and the Creation of the Modern World* (London: Penguin, 2000); Thomas Ahnert, *Religion and the Origins of the German Enlightenment: Faith and the Reform of Learning in the thought of Christian Thomasius* (Rochester, NY: University of Rochester Press, 2006); J. B. Shank, *The Newton Wars and the Beginning of the French Enlightenment* (Chicago: University of Chicago Press, 2008); H. M. Scott, *Enlightened absolutism: reform and reformers in later eighteenth-century Europe* (Basingstoke: Macmillan, 1990); Nicholas Dew and James Delbourgo, *Science and Empire in the Atlantic World* (London: Routledge, 2008); Antonio Barrera-Osorio, *Experiencing nature. The Spanish American Empire and the Early Scientific Revolution* (Austin: University of Texas Press, 1990).
[13] See, for example, Simon Schaffer, “Newtonianism,” in R. C. Olby et al. (eds.) *Companion to the History of Modern Science* (New York and London: Routledge, 1990), pp.610–262; John Gascoigne, “Ideas of nature: Natural Philosophy,” in Roy Porter (ed.) in *The Cambridge History of Science, vol. 4: Eighteenth-century Science* (Cambridge: Cambridge University Press, 2003), pp.285–304; Eric Schliesser, “Newton and Newtonianism” in Aaron Garrett (ed.), *The Routledge Companion to Eighteenth-century Philosophy* (New York and London: Routledge, 2014), pp.62–90; Thomas Ahnert, “Newtonianism in Early Enlightenment Germany, c.1720 to 1750: Metaphysics and the Critique of Dogmatic Philosophy,” *Studies in History and Philosophy of Science* 35 (2004), pp.71–91; Eric Schliesser, “Newton’s challenge to philosophy: a programmatic essay,” *HOPOS* 1 (2011), 1 pp.101–128; J. B. Shank, *The Newton Wars,* (note 12); recently, a complete issue of *The Southern Journal of Philosophy* was dedicated to “Newton and Newtonianism,” Mary Domsky, “Newton and Newtonianism,” *The Southern Journal of Philosophy* 50 (2012), 50, pp. 363-369; Stephen Ducheyne, “'sGravesande's appropriation of Newton's Natural Philosophy, Part I: Epistemological and theological issues,” *Centaurus* 56 (2014), pp.31–55; Stephen Ducheyne, “'sGravesande's appropriation of Newton's Natural Philosophy, Part II: Methodological issues,” *Centaurus* 56 (2014) 56, pp.97–120; Vicenzo Ferrone, *The intellectual roots of the Italian Enlightenment: Newtonian Science, Religion and Politics in the Early Eighteenth Century* (New York: Prometheus, 1995); Massimo Mazzotti, “Newton for ladies: gentility, gender and radical culture,” *British Journal for the History of Science* 37 (2004), pp. 119-146.
[14] J. B. Shank, *The Newton Wars*. (note 12).
[15] *Cf*. Simon Schaffer, “Newton on the Beach: The Information Order of Principia Mathematica,” *History of Science* 47(2009), pp.243–276; Steffen Ducheyne and Jip van Besouw, “Newton and the Dutch ‘Newtonians’: 1713–1750.” In Eric Schliesser & Chris Smeenk (eds.) *The Oxford Handbook of Newton* (Oxford: Oxford University Press, 2017). A good compendium of studies on the historical reception of Newton’s physics in different European contexts is in Elizabethanne Boran & Mordechai Feingold (Eds.), *Reading Newton in early modern Europe* (Leiden: Brill, 2017).
[16] Jonathan I. Israel, *Democratic Enlightenment. Philosophy, Revolution, and Human Rights, 1750-1790* (Oxford: Oxford University Press, 2011), pp.504–534; Juan Manuel Dávila, *Ciencias útiles y planes de estudio en la Nueva Granada. Método racional y canon wolffiano en la Filosofía escolar neogranadina (1726-1826)*, M.A thesis in History, (Bogotá:

Pontificia Universidad Javeriana, 2011), pp.77–120; Silva, *La Ilustración*, pp.15–45 (note 9); Silva, *Los ilustrados*, pp.525–539 (note 3).

[17] Guillermo Hernandez (ed) *Pensamiento científico y filosófico de José Celestino Mutis* (Bogotá: Fondo Cultural Cafetero, 1982), p.38.

[18] One version of the lecture is in Hernandez, *Pensamiento científico*, pp.43–68 (note 17). The manuscript version of the lecture is Real Jardín Botánico de Madrid (RJB) III, 2, 4, 11, ff. 2r-19v.

[19] RJB III, 2, 4, 11, f.5r.

[20] *Cf*. Isacc Newton, *Opticks: Or a Treatise of the Reflections, Refractions, Inflections & Colours of Light* (New York: Dover Publications, 1952), pp.405–406.

[21] RJB III, 2, 4, 11, f.9r.

[22] Newton, *Opticks*, p.404 (note 20)

[23] Newton, *Opticks*, p.404 (note 20)

[24] RJB III, 7, 1, 5, f.282r.

[25] For the history of the teaching of physics in New Granada during the colonial times, see Regino Martínez Chavanz, "La física en Colombia: su historia y su filosofía." In E. Quevedo (Ed.), *Historia social de la ciencia*, Vol. 4, pp.31–183 (note 5). Juan David García Bacca and José Manuel Rivas Sacconi provide transcriptions and translations of a good deal of manuscripts regarding the teaching of physics in New Granada. *Cf*. Juan David García Bacca, *Antología del pensamiento filosófico en Colombia (1647-1761)* (Bogotá: Imprenta Nacional, 1955); José Manuel Rivas Sacconi, *El latín en Colombia: bosquejo histórico del humanismo colombiano* (Bogotá: Instituto Colombiano de Cultura, 1993).

[26] RJB III, 7, 1, 5, f.283r.

[27] RJB III, 7, 1, 5, f.283r.

[28] RJB III, 7, 1, 5, f.282r–302r.

[29] Hernandez, *Pensamiento científico*, p.140 (note 17).

[30] See Ahnert, "Newtonianism in Early Enlightenment Germany" (note 13); J. B. Shank, *The Newton Wars* (note 12).

[31] This point is particularly visible in RJB III, 7, 1, 5, f. 325r-328r.

[32] José Celestino Mutis, "Informe redactado a solicitud del Virrey del Nuevo Reino de Granada, don Pedro de Mendinueta, con ocasión de unas conclusiones propuestas por los Padres Agustinos de Santafé de Bogotá. Año de 1801," in José Celestino Mutis, *Escritos científicos de don José Celestino Mutis* (ed. Guillermo Hernández de Alba), (Bogotá: Editorial Kelly, 1983), vol. 2, p.148.

[33] According to the fund "José Celestino Mutis" in the Biblioteca Nacional de Colombia where Mutis' books are preserved, he had more than a decent collection of Newton's and Newtonian. For details on Mutis' library and the now extant books see Luis Carlos Arboleda, "Sobre una traducción inédita de los *Principia* al castellano hecha por Mutis en la Nueva Granada *circa* 1770," *Ideas y valores* 74–75 (1987), pp.119–142. Nora Cañón-Vega, "El catálogo de la biblioteca de José Celestino Mutis," *Senderos* 5 (2011), pp.638–648; Julio Ovalle-Mora, "El fondo José Celestino Mutis de la Biblioteca Nacional de Colombia," *Boletín de historia y antigüedades* 93 (2006), pp.359–374.

[34] Pablo Rodríguez, "Testamento y vida familiar en el Nuevo Reino de Granada (siglo XVIII),"*Boletín Cultural y Biográfico* 31(37) (1994), pp.3–20.

[35] For details on this translation and Mutis' copies of Newton's *Principia* see Arboleda, "Sobre una traducción" (note 33).

[36] Schliesser, "Newton and Newtonianism," p. 64 (note 13).

[37] For example, in the German case. See Ahnert, "Newtonianism in Early Enlightenment Germany" (note 13).

[38] José Celestino Mutis, *Diario de observaciones* (Bogotá: Minerva, 1957), p.104.

[39] In a letter to the Archbishop Antonio Caballero y Góngora –the most enthusiastic towards science of the Viceroys of New Granada–, dated 27 March 1783, Mutis wrote a story of his frustrations related to the Botanical Expedition, including how the King ignored his two representations of 1763/1764. This is an invaluable indication of Mutis' own activities before the official start of the Botanical Expedition in 1783: "Later, disenchanted with the little or no acceptance those thoughts or their author deserved, my tasks ran with the slowness provided at my expense (...) Although the tasks of practical medicine, where I took out the aid for the continuation of my Natural History, I sought to allocate a few hours for public lessons in Mathematics and Newtonian Philosophy." Guillermo Hernández de Alba, *Archivo epistolar del sabio naturalista José Celestino Mutis*, 4 vols., (Bogotá: Ministerio de Educación Nacional, 1947), vol.1, pp.57 and Gredilla, *Biografía*, pp.140–145, 142 (note 4).

[40] See Silva, *La Ilustración*, p.210-243. These arguments are emphasized in Mutis' "Plan general de estudios médicos, 1804" and in "Sobre las precauciones que deben observarse en la práctica de la inoculación, 1782," in Mutis, *Escritos científicos*, vol. 1, pp. 63-95 and 189–194 (note 32).

[41] Gredilla, *Biografía*, p. 41 (note 4).

[42] The idea that Spain was in lethargy is usual in Mutis' writings and is common in the Spanish Enlightenment. As early as 1687, Juan de Cabriada wrote in the letter of dedication of his Carta: "The regrettable and even shameful thing is, that like Indians, we shall be the last to receive the news and public lights already spread throughout Europe" Juan de Cabriada, *Carta filosófica médico-chymica. En que se desmuestra, que de los tiempos, y experiencias se han aprendido los Mejores Remedios contra las Enfermedades. Por La Nova-Antigua Medicina* (Madrid: Oficina de Lucas Antonio de Bedmar y Baldivia, 1687), p.1. Benito Feijoó's popular *Theatre* attempts to challenge several common views held by "uneducated masses." The most illustrative of this is his letter "Causes of the backwardness suffered in Spain in relation to Natural

Sciences" recorded as letter 16 of the second volume II of his Letters. See Benito Feijoó, *Cartas eruditas, y curiosas: En que, por la mayor parte se continúa el designio del Theatro critico universal, impugnando, o reduciendo a dudosas varias opiniones comunes* (Madrid: B. Roman, 1781).
[43] Gredilla, *Biografía*, p.41 (note 4).
[44] Gredilla, *Biografía*, p.43 (note 4).
[45] Bado's book contains in his chapter II the almost mythical story that the bark was known for the first time when it was used to heal a Jesuit in the 1620's and after that he recommended it to the Countess of Chinchon, wife of the Viceroy of Peru (from which Linnaeus would take the name, probably mistaking the pronunciation of the Spanish "ch") when she was taken ill at his arrival in Lima. She brought the bark in the 1640's to Spain. See Sebastián Bado, *Anastasis corticis peruviae, seu chinae chinae defensio, Sebastiani Badi Genuensis patrij veriusque Nosochomij olim Medici, et Publicae Sanitatis in Civitate Consultioris,* (Genuae: Typis Petri Ioannis Calenzani, 1653); Hipólito Ruiz, *Quinologia* (Madrid: La viuda é hijo de Marin, 1792), also refers this story and quotes Bado as his source.
[46] The Quina (*cinchona officinalis*) is the natural source of quinine, an alkaloid having antipyretic, antimalarial, analgesic and anti-inflammatory properties. Now it can be synthesized in the laboratory and it is still used for treating some diseases. On the history of the discovery of quinine see N. Taylor, "Quinine: the story of Cinchona," *The Scientific Monthly* 57 (1943), pp.17–32; J. H. Kirkbride, "The Cinchona Species of José Celestino Mutis" *Taxon* 31 (1982), pp.693–697; Patricia Barton and James Mills, *Drugs and Empires: Essays in Modern Imperialism and Intoxication 1500-1930* (New York: Macmillan, 2007).
[47] On the importance of the Quina for Europe during the colonial times and its relationship with Mutis' career, it is useful to see Ruiz, *Quinologia* (note 42), the most important and systematic work on the Peruvian discoveries. Mutis' own findings on Quina were published during his lifetime in José Celestino Mutis, *Instrucción formada por un facultativo existente por muchos años en el Perú, relativa de las especies y virtudes de la Quina* (Cadiz: Don Manuel Ximenez Carreño, 1792). The posthumous work José Celestino Mutis, *El arcano de la quina: Discurso que contiene la parte médica de las cuatro especies de quinas oficinales, sus virtudes eminentes y su legítima preparación* (Madrid: Ibara, 1828), comprises the partial results he had already published in *El papel periódico de la ciudad de Santa Fe de Bogotá*, edited by Manuel del Socorro, between 1793 and 1794. On the Quina and its impact on European medicine and trade in the eighteenth century see Matthew Crawford, *Empire's experts: The politics of knowledge in Spain's royal monopoly of Quina (1751-1808)*, La Jolla: University of California, 2009; Nieto, *Remedios para el imperio* (note 9); Gonzálo Hernández, *Quinas amargas. El sabio Mutis y la discusión naturalista del siglo XVIII* (Bogotá: Luis Ángel Arango, 2010).
[48] Gredilla, *Biografía*, p.44 (note 4).
[49] Mutis, *Instrucción*, p.8 (note 47).
[50] More often than not, Mutis aligns Galileo's famous phrase occurring in *The Assayer* with the Biblical and Augustinian triad of "number, weight, and measure," to show that Galileo's thought was compatible with Catholic teachings. Mutis stresses this equivalence in his defense of the Copernican system during the inquisitorial trial, made by the Dominicans of the Thomistic University of Santa Fe. Mutis, *Escritos científicos*, vol. 2, pp.93–149 (note 32).
[51] Gredilla, *Biografía*, p.44 (note 4).
[52] Gredilla, *Biografía*, p.44 (note 4).
[53] Mutis, *Escritos científicos*, vol. 2, pp.48–71 (note 32).
[54] Mutis, *Diario*, p. 145 (note 38).
[55] Mutis, *Escritos científicos*, vol. 2, pp. 39–47 (note 32).
[56] Mutis, *Escritos científicos*, vol. 1, pp. 145-146 (note 32).
[57] This is explained in "Elements of Arithmetic. On the fundamental principles of Arithmetic" partially printed in Mutis, *Escritos científicos*, vol. 2, pp. 85–86 (note 32).
[58] The two versions of the *Elements of artihmetic* [*Elementos de Arismetica*], as Mutis entitled them, are found in RJB III, 7, 1, 5, ff.436r–522r.
[59] RJB, III, 7, 1, 5, f.436r.
[60] RJB III, 7, 1, 5, f.436v.
[61] RJB III, 7, 1, 5, f.436v.
[62] Hernandez, *Pensamiento científico*, p.41 (note 17).
[63] The emergence and development of the so-called Newtonian medicine has been explained in Anita Guerrini, *Newtonian Matter Theory, Chemistry, and Medicine, 1690-1713*, (Ph.D. Dissertation) (Indiana: Indiana University, 1983); Theodore M. Brown, "From Mechanism to Vitalism in Eighteenth-Century English Physiology," *Journal of the History of Biology*, 7(2) (1974), pp.179–216. A transcription of Mutis' curriculum on medicine is in Mutis, *Escritos científicos*, vol. 2, pp.33–62.
[64] Mutis, *Escritos científicos*, vol.1, p.51 (note 32).
[65] Mutis, *Escritos científicos*, vol.1, p.51 (note 32).
[66] Mutis, *Escritos científicos*, vol.2, p.55 (note 32).
[67] Mutis explains this limitation of knowledge in contrast with the infinitely small or large: "In all quantities, be they either small or large, there is a certain degree of them offered to our senses and from whose knowledge we can take immense utilities for the human genre. This same degree is the foundation of philosophy; this is so because, though all kinds and all degrees be subjects worthy of study by philosophical enquiry, that only from that part given to us is to be

considered by the philosopher as the beginning of his safe and certain procedures towards his discoveries, going up or down in the examination of things with the adequate order of the subject in question" Mutis, *Escritos científicos,* vol.2, p.65 (note 32).

[68] This is the contact point between natural philosophy and religion: only he who knows God's natural laws can appreciate what is actually extraordinary, that is. the consequence of God's direct action "breaking" or avoiding the laws of nature; in other words, only someone trained in the true natural philosophy can recognize miracles and, in consequence God's extraordinary action.

[69] Mutis, *Escritos científicos,* vol.1, pp. 89–91 (note 32).

[70] Mutis, *Escritos científicos,* vol.1, p.51 (note 32).

[71] Mutis, *Escritos científicos,* vol.1, pp.51–52 (note 32).

[72] Mutis, *Escritos científicos,* vol.2, p.95 (note 32).

[73] See John Henry, "Enlarging the bounds of moral philosophy: Why did Isaac Newton conclude the *Opticks* the way he did?," *Notes and Records* 71 (2017): 21-39; Newton, *Opticks,* p. 404 (note 20). These virtues of the philosopher and the history of knowledge as a "general decay" are topics presents in Newton's "Chronology of Ancient Kingdoms" and "Observations upon the prophecies of Daniel and the Apocalypse of St. John," both contained in Isaac Newton, *Opuscula mathematica philosophica et philologica*, 3 vols., (Lausannae and Genevae: Apud Marcum-Michaelm Bousquet, 1744).

[74] This is a prominent topic in the seventeenth- and early eighteenth-century natural philosophy and is manifest in Newton's concluding words of the *Opticks* and the "Scholium Generale" to the *Principia*. We can find it, in a recognizable form since Francis Bacon's *Novum Organum* –which Mutis owned and quoted to this end. See Amos Funkenstein, *Theology and the Scientific Imagination* (Princeton: Princeton University Press, 1986); John Henry, "Voluntarist theology at the Origins of Modern Science" *History of Science* xlvii (2009), pp.79–113; John Henry, "Religion and the Scientific Revolution," in Peter Harrison (ed.) *The Cambridge Companion to Science and Religion*, (Cambridge: Cambridge University Press, 2010), pp.39–58; Peter Harrison, *The Bible, Protestantism and the rise of natural science* (Cambridge: Cambridge University Press, 1998).

[75] Mutis, *Escritos científicos,* vol.1, p.46 (note 32).

[76] Mutis, *Escritos científicos,* vol.1, p.148 (note 32).